Hydraulic Fracturing and its relationship to seismicity levels in in Oklahoma, USA

Robert W. Schupp, J.D.

Associate Professor of Business and Employment Law
University of North Florida
1 UNF Drive
Jacksonville, Florida 32224

ABSTRACT

As the demand for clean low-cost energy increases in our world, new sources of energy and new methods of extracting energy from older sources expands every day. Hydraulic fracturing (fracking) is a technique designed to improve the production of oil and natural gas from wells by increasing the number of fluid pathways in a rock formations through which oil and gas flow to the surface. Problems associated with fracking include wastewater disposal and increased seismicity levels (earthquakes). The relationship between earthquakes and fracking is discussed in this paper by focusing on Oklahoma, USA, an area where fracking is prevalent. Regulation, legislation and litigation are reviewed as effective methods of balancing the need for oil and natural gas with the dangers to the ecology and associated with its extraction. Insurance and other alternatives are also discussed.

KEY WORDS

Hydraulic fracturing, fracking, seismic activity, Oklahoma, subsurface geology, natural gas, Safe Water Drinking Act, Oklahoma Corporation Commission. U.S. Geological Service, property insurance, earthquakes

I. Introduction

The impact of human activity on Earth is a relatively new phenomenon that intensifies with each passing day. In the two centuries that have passed since the beginning of the industrial revolution, humanity's need for energy has fundamentally altered the planet's natural landscape and geology. To put the extent of this change in perspective, imagine the Earth's history on a human time scale. The Earth is 4.6 billion years old. If 4.6 billion were scaled down to 46years, the first traces of human life would have appeared 4 years ago. That would mean the industrial revolution began one minute ago. In that infinitesimal fraction of time, humans have destroyedover 50% of the world's forests and exterminated more than 40% of its species.Despitethe apparent dangers of unsustainable consumption, humans continue to exhaust the planet's natural resources at an accelerated rate. The consequences of this unconstrained development are difficult to predict, and even more difficult to control. In many instances, people only become aware of the consequences after witnessinglarge-scale devastation and disaster. This was the case with the infamous Chernobyl nuclear meltdown and the more recent BP Oil Spill in the Gulf of Mexico. However, as the accuracy of scientific predictions increases and the public grows more aware of the potentially dangerous consequences of human activity, there are more opportunities to prevent disaster by acting proactively. For the past century it has been known that pumping fluids into the Earth's subsurface has the potential to cause earthquakes. (NRC,vii). The problem is that it is nearly impossible to determine between man-made earthquakes and those caused by natural tectonic forces.

(Ellsworth). Today an opportunity exists to study the relationship of man's activities, specifically, waste water injection in the state of Oklahoma, where the current rate of earthquakes is approximately 600 times the historical average.

The Oklahoma Corporation Commission, the state regulatory agency responsible for the administration of all class II injection wells, published this finding in their 2016 annual report. Although not absolute, there is a widespread consensus in the scientific community that these injection wells, which play an important role in oil and gas operations in the region, are responsible for Oklahoma's increased seismicity. As was the case with the Chernobyl and BP Oil disasters, unconstrained and insufficiently regulated energy development has put the citizens of Oklahoma at risk. Fortunately for those citizens, there is one major difference between their current situation and the horrors of the past. In Oklahoma, the warning signs are clear. In November 2011, a magnitude 5.7 earthquake that injured two people, destroyed 14 homes, and caused nearly $1 million in damage (Zeits, 4).It was the largest earthquake in state history until just 6 months ago, when a magnitude 5.8 earthquake ravaged the state. The 2016 earthquake inspired a massive class action lawsuit, and was felt all the way from North Dakota to Houston, Texas: a 1,300 mile stretch (Yeck, 711).In order to prevent future destruction, something in Oklahoma will clearly have to change. The question that remains is what it will be.

Rising seismicity levelsin Oklahoma havecreated controversybetween the state's citizenry and business communities. Pro-business, energy industry sympathizers in the region are threatened by the concerned citizenry's demand for change. Because oil and gas production comprise a substantial portion of the state's economy, many business interests perceive the movement to combat rising seismicity levels as an attack on energy. This belief is unfounded. Induced seismicity is the result of unsustainable wastewater disposal methods, not hydraulic fracturing or the more general processes of oil and gas production. Thus, the concerned citizenry's problem is not with the oil or gas industries, it is with a singular, isolated aspect of the energy development process that can be changed without majorly injuring business interests in Oklahoma. Abundant evidence supports this point:

In terms of the overall impact on U.S. production volumes and commodity prices, the concerns related to human induced seismicity in Oklahoma are unlikely to make much of a difference. The several operations in central and north-central Oklahoma produce a relatively small amount of crude oil. Most importantly, production there is typically characterized by very rapid declines… The contraction in capital investment due to seismicity concerns will have minimal impact on future production volumes (Zeits, 8).

Economic losses the energy industry will incur by switching to more sustainable wastewater disposal methods will be minimal. In the long term, the economic impact of switching to more sustainable disposal methods will actually be positive, because it will prevent the energy industry from incurring billions of dollars in future liability resulting from earthquake damage.

Hydraulic Fracturing, also known as fracking, is a technique designed to improve the production of oil and natural gas wells by increasing the number of fluid pathways in a rock formation through which oil and gas can flow to the surface. Oil and natural gas are hydrocarbons that reside in pore spaces between grains of subsurface rock. If geological conditions are favorable, hydrocarbons naturally flow from rock formations to oil and gas wells. In many instances, however, hydrocarbons are trapped between microscopic pore spaces. This is especially common in fine-grained rocks with low permeability. Low permeability rock formations are frequently referred to as "tight formations" because their pore spaces are small and poorly connected. Hydraulic fracturing enables extraction from tight formations, which would otherwise be uneconomical to produce, by enhancing their permeability to a point where oil and gas flow freely to wells. A combination of high-pressure water, chemicals, and minerals are injected into the rock. In many cases, sand is used as a proppant to hold the newly formed fractures open so that fluids can efficiently flow through. Some of the fracturing fluids remain below the surface. Some return to the surface along with oil, natural gas, and water that was already present in the rock formation. This liquid is either called flow back or produced water and is generally highly saline. At

the surface, oil and gas are separated from flowback water, which is collected in tanks or lined pits and prepared for disposal. At this point, the processes of fracking, and of oil and gas production more generally, are over.

The second stage in the energy development process is wastewater disposal. In this stage, flowback wastewater is collected for disposal, treatment, or reuse.Wastewater does not exclusivelyor even primarily contain fracking fluid. Fracking fluid is a byproduct of fracking operations, but all oil and natural gas production operations produce saline and mineral wastewaters. Two types of companies are responsible for disposing wastewater. Commercial injection well disposal operators are independent contractors that charge fracking and drilling operators a fee to dispose their wastewater. "Non-commercial" injection well disposal operators are oil and gas production companies that dispose of their own wastewater. Many states treat the two kinds of well operators differently under the law.

In the past decade, a massive increase in unconventional oil and gas production has caused frequent earthquakes to occur in areas in the central and eastern United States that are not naturally prone to seismic activity. In the 30 year period from 1970-2000, the central and eastern U.S. experienced an average rate of 21 earthquakes with a magnitude greater than 3.0 per year. The number of oil and gas production operations in the region increased rapidly starting in 2006. In the 3 year period from 2010 to 2013, the same area experienced more than 300 M3+ earthquakes. In 2014, alone, there were 659 (Oklahoma Corporation Commission). A class action lawsuit against the operators of Arkansas wells that contributed to a 4.7 magnitude earthquake in 2011 settled in favor of the plaintiffs and two defendant well operators went bankrupt (Richards, 27). A similar class action suit is pending in Oklahoma.

It is believed that the disposal of wastewater by injection into deep wellsis responsible for induced seismicity in the central and eastern United States.This is because injected fluids change subsurface pressure and friction dynamics, causing shifts in the rock that would not have occurred naturally. Injected fluids reduce the frictional resistance that stops faults from slipping. Even the most miniscule of movements can cause the energy stored in brittle rock to be released in the form of earthquakes. Fluid pore pressure increases on stressed faults appear to be the primary cause of injection-induced earthquakes Oklahoma and the surrounding states. In many instances, fluid pressure increases have also been linked to groundwater contamination. There are several reasons disposal operations generate pressure increases even though fracking and most oil and gasproduction operations do not. Because disposal wells typically operate for longer than production wells, they inject higher volumes of fluid than fracking or drilling operations. In addition, disposal operations typically injectwastewater below the production zone. Unlike fracking operations, which almost exclusively occur in rock formations that have previously been used for oil and gas production, disposal operations generally inject into pristine rock: rock formations that have never been drilled or disrupted by human activity.

The relationship between wastewater disposal and earthquakes is not new, but the threat it poses to Oklahoma is.In locations all over the world, it is common for wastewater disposal by deep-well injection to produce earthquakes of magnitude 2.0 or less. These "micro-quakes" occur consistently and are too small to be felt. In fact, most of the world's injection wells are not associated with felt earthquakes or human induced increases in seismicity. Geological Survey data from 10,000 wells in the Bakken and the Marcellus support this finding. These wells have produced more gas than Oklahoma and Kansas combined and not experienced any earthquakes strong enough to be felt or an increase in seismicity (Conca, 7). A combination of several factors is necessary to induce seismicity. Among these are: injection rate and total volume injected, presence of sufficiently large faults close enough the injection point, large enough stresses, and the presence of pathways for the fluid pressure to travel from the injection points to faults. Of these factors, injection rate and total volume have the greatest impact.The Geological Society of America recently reported dramatic increases in earthquakes magnitude 3.0 or greater in areas associated with high volumes and rates of injection. The greater volume of water injected, the more massive the earthquakes are likely to be. This is because the injected water reactivates pre-existing faults in the area by upsetting the subsurface pressure regimes that otherwise would have kept the fault closed ("GSA: Critical Issue").

Oklahoma

There is a scientific belief that wastewater disposal by deep well injections responsible for the recent increase in earthquakes in the central and eastern United States. There is also a general agreement that Oklahoma is one of the regions' most at risk. There is much more debate regarding the implications of what induced seismicity will mean for the future, especially in terms of potential liability. However, there is consensus that, the potential for damages due to more frequent and stronger earthquakes in Oklahoma cannot be ruled out.

Oklahoma Geological Survey research confirmed that the body of scientific research on the topic of induced seismicity in Oklahoma is "quite abundant and is growing rapidly. Seismologists and geo-scientists concur that the recent rise in earthquakes cannot be attributed to natural causes and is most likely "triggered" by human activity" (Zeits, 6). Another report citing Oklahoma Geological Survey research concluded that, "the majority of recent earthquakes in central and north-central Oklahoma are very likely triggered by the injection of produced water by disposal wells" (Mills). These findings were corroborated during an interview with Jim Flis: a senior staff geophysicist who worked in the energy industry for 38 years. Flies spent most of his career serving as a senior advisor at Chevron: a gas mega-corporation and energy industry titan. During the interview, he admitted, "It's now widely acknowledged that the rapid increase in the number of wastewater injection wells in Oklahoma has contributed to a surge of earthquakes in the region."

In three areas that encompass the vast majority of the recent seismicity increase in Oklahoma followed 5 to 10-fold increases in the rates of saltwater disposal. The formations used for water disposal were usually hydraulically connected to active faults in the crystalline basement, where nearly all of Oklahoma's recent earthquakes have occurred (Walsh). A separate study published in the *Science* was one of the first to analyze the connection between injection wells and earthquakes on a broad, national scale. This study concluded that disposal wells injecting at a rate greater than 300,000 barrels per month were much more likely to trigger earthquakes than lower-rate wells (Rosen).

There is far less agreement on the degree of risk, and thus the potential future liability, injection well operators might incur. However, there is still a consensus that potential future liability resulting from damaging earthquakes cannot be ruled out. According to Oklahoma Geological Survey research, there is no way of dismissing the possibility of damaging earthquakes that may originate from active basement faults (Zeits, 7). Similarly stated "The possibility of triggering damaging earthquakes on potentially active faults in Oklahoma cannot be discounted." (Walsh).

Subsurface Geology

Although there are several regions in the central and eastern United States that have recently experienced a drastic increase in induced seismicity, the danger is greatest in Oklahoma. In large part, this is due to the state's subsurface geology. The combination of nearly 11,000 active disposal wells and 5 different fault lines cutting through the state predispose Oklahoma to future earthquakes. Additional subsurface conditions increase the likelihood that these future earthquakes will be more frequent and more damaging.

According to geologist Richard Zeits, the types of bedrock most likely to be impacted by the increased seismicity in Oklahoma and Kansas are Missippian limeand Shallow Woodford Shale, which is abundant inCentral Oklahoma.Fracking and drilling operations in the Missippian-Woodford bedrock trend are prone to induced seismicity because they inevitably produce very high water volumes alongside oil and natural gas (Zeits, 8). The Oklahoma Corporation Commission's findings support this point. Last year, the OCC reported that thestate's induced seismicity zone is expanding further south from the most active oil and natural gas development areas, which contain Missippian Lime and shallow Woodford Shale bedrock, all the way to Oklahoma City: the most populous city in the state (5). The United States Geological Survey's 2016 seismic

hazard forecast predicted a 5-17% chance of significant damages to homes and structures in the area (Conca, 3).With a population of well over half a million people, the future liability posed by the potential of a damaging earthquake near Oklahoma City is astronomical. This potential liability puts oil and gas operators' production volumes and asset valuations at risk. The risk is so great that it may pose a threat to these operations' financial survival.

In addition to bedrock trends, the most common type of rock formation in Oklahoma also predisposes the state to earthquakes. According to Oklahoma Geological Survey research, the vast majority of the state's recent earthquakes originated in the shallow crystalline basement that lies underneath the Arbuckle rock formation. The Arbuckle formation is the deepest rock formation in the state. It is also the formation most frequently used for wastewater injection. "There is broad agreement among seismologists that injecting below the Arbuckle rock formation and into the crystalline basement poses the highest potential risk of triggering earthquakes in Oklahoma*"*(Zeits, 6). Another study, which was conducted by Oklahoma Geological Survey and published in *Geophysical Research Letters*, concluded that the majority of recent earthquakes occurred on "near-vertical, optimally oriented (NE-SW and NW-SE), strike slip faults in the shallow crystalline basement." The team also concluded that this "increased the probability for a damaging earthquake in Oklahoma*"* (McNamara).

Regulatory Climate

The regulatory environment is split between the states and the federal government. In recent years the federal government has been reluctant to pass legislation regulating fracking and/or wastewater disposal. Today on the federal side the Environmental Protection Agency is the principal agency involved with wastewater disposal and derives its authority over subsurface injection fluids from the Safe Water Drinking Act.(SWDA). (Folger i) The Act enacted in 1974 gave the EPA the primary responsibility to ensure that our resources of safe drinking water were protected from contamination of injected fluids(Richards,7). While federal legislation has been introduced as late as the 114th Congress (The Fracturing Responsibility and Awareness of Chemicals Act of 2015), it has gained little traction as it was referred to the House Energy and Commerce Subcommittee on Environment and the Economy.(H.R. 1482-114th Congress) Even had the legislation been enacted with its expanded definition of "underground injection", it is not clear whether or not it would have given the EPA authority regarding induced seismicity unless the seismic activity endangered underground drinking water supplies. (Folger,4) With the dearth of legislation from Congress, the Obama administration attempted to issue regulations on fracking on federal and Indian lands in May of 2016, only to see a Federal judge, U.S. District Judge Scott Skavdahl rule that Congress had not granted the Bureau of Land Management authority to establish rules over fracking on those lands. The judge stated "The issue before this Court is not whether hydraulic fracturing is good or bad for the environment or the citizens of the United States," The question is "whether Congress has delegated to the Department of Interior legal authority to regulate hydraulic fracturing. It has not." The judge was appointed by President Obama.

Pursuant to the SWDA the EPA established the Underground Injection Control (UIC) program. The purpose of the program is to ensure the protection of underground drinking water sources. The EPA in enforcing the provisions of the Act, has promulgated regulations for six classes of injection wells, including Class II wells which are used for the disposal of wastewater from oil and gas operations. (Folger, i) The act permitted the EPA through the UIC to promulgate rules and regulations governing the construction, operation, permitting, plugging (closing), and abandoning of thousands of Class II waste water disposal wells. (Richards, 7)

Although the SWDA does not address earthquake risk directly, the EPA rules and regulations for certain classes of wells require evaluations of seismic risk. Ironically the seismic risk evaluation requirement does not

apply to the Class II wells. While in states where the EPA administers the program, it has developed an evaluation matrix for seismic risk, Oklahoma is not one of those states. (Folger, i)

States, such as Oklahoma, also play an important role in the oversight of the activities surrounding operation and closure of such wells. The EPA may delegate the responsibility to ensure safe drinking water to the states. A state may gain primary authority (primacy) over the regulation of such activities by showing that it has at least as strong/stringent program as the federal one in meeting the requirements of inspecting and monitoring (including record keeping and inspecting) the operations of the industry. (Richards,7)

Another provision of the SDWA permits states who wish to take control of the oil and gas production in their state may exercise control over Class II wells by demonstrating their programs also protect the safety of drinking water resources. States comply by promulgating rules which comply with the criteria set out by the EPA. Approximately 25 states have gained control of the monitoring of Class II wells through this program. If the EPA does not approve of the state's program, it retains jurisdiction over the wells and implements its own program. Oklahoma is one the states whose plan was approved by the EPA and has gained control of the UIC program. The program in Oklahoma is administered through The Oklahoma Corporation Commission. (Richards,8)

The EPA requires states and regions promulgate regulations over permitting, construction, types of fluids injected into the ground, and pressure at which the fluids are injected. Some of the more important reporting requirements include the disclosure of factors which might induce seismicity such as fluid injection pressure and the geology of the area (see 40 C.F.R.146.22 (b)(1). The EPA overall responsibility is reviewing the contamination risk, not necessarily earthquake risk.

Oklahoma has promulgated a number of requirements for permitting Class II wells. Operators must publish information in local newspapers, in one case which led to protests from area residents concerned about environmental damage including water contamination. The matter came before an administrative law judge of the Oklahoma Corporation Commission and the operator withdrew its application. Whether or not Class II well permits will be denied on the basis of induced seismic activity is not known. At present Oklahoma currently has no Class II well permit regulations related to induced seismicity risk. An interesting note about Oklahoma is that it distinguishes between non-commercial and commercial Class II disposal well permits, requiring more information of commercial permits. (Oklahoma Corporation Commission).

Litigation

The rapid rise in both the number and magnitude of earthquakes in Oklahoma has not unexpectedly brought on a flurry of litigation. Plaintiffs' attorneys are attempting to link the increase in fracking and more importantly the increase in injection wells which dispose of the wastewater which is a byproduct of fracking, to the increase in earthquakes and the subsequent damage caused by the quakes and aftershocks. As we have seen everyone from homeowners to insurance companies and oil companies are taking note of the problems. The legal arena is a different animal in the sense that what may appear to be a cause and effect relationship may not satisfy the legal requirement for liability. Insurance companies can raise rates on assumptions of future events, but courts of law need a causal connection sometimes referred to as proximate cause in order to place liability on a party.

Government agencies such as the U.S. Geological Service have warned of increased seismic activity in Oklahoma, but cannot pinpoint the cause of the activity with certainty. One of the problems for homeowners' attorneys is that earthquakes have been around for a long time before fracking and determining that an earthquake was caused by fracking or injection of waste water is a difficult. Even more difficult is tying a specific earthquake to the actions of a given well or injection operation. As we have already seen the geology of an area can play an important role in what happens underground and Oklahoma has some unique geology which may make it more susceptible to injection operations. Problems of causation aside attorneys are busy filing cases based on several legal theories.

The principal culprit appears to be the disposal wells which are used to appropriately enough dispose of the byproducts of the fracking. When the fracking well are drilled much of what comes out of the ground is not oil, but brine or salt water often mixed with sand and other fluids used to help extract the oil. While any number of options are available to dispose of the "wastewater," the least expensive and up until now one the most environmentally friendly was to simply send the water back down into the ground. The problem is the both the quantity of wastewater and the pressure needed to force it back into the ground. Oklahoma has unfortunately a great deal of oil and some unusual and possibly unstable geological underground formations. Adding to the legal problem of liability is the need to identify particular actions which cause the earthquakes. (Sellers,2)

Since the beginning of 2016 Oklahoma has suffered from an earthquake of a magnitude of 5.1 (the third largest recorded) and several others of 4.0 or higher. (McClure, Earthquake Litigation,1). This comes at a time when over one billion barrels of wastewater were scheduled for disposal in injection wells. .

Several theories of liability have been proposed in recent cases, including *Felts, et al v. Devon Energy No. CJ-2016-137 (Oklahoma County District Court)* in which the plaintiffs claim damage such as cracks in walls, bricks and fascia and movement of the foundations of structures as a result of seismic activity in late 2015 and early 2016 was caused by the pumping of wastewater into to the injection wells for disposal. The plaintiffs claim both negligence and strict liability arguing the oil companies were the proximate cause of the earthquakes. The suit also alleges damages for pain and suffering and for "worry" about earth quakes in the future. Although they have not cited any scientific evidence which links the specific activities of the defendants to the earthquakes, plaintiffs are seeking punitive damages as well as a permanent injunction against the operators. Causation appears to be tenuous and a continuing problem

In *Griggs, et al. v. Chesapeake Operating LLC* No. CJ-2016-6 (Logan County District Court (2016), a class action suit, allegations of property damage from earthquakes which occurred in 2014 and 2015 were made. The legal theories include private nuisance and ultra-hazardous activities on the part of the oil companies, as well as trespass.

The *Sierra Club v. Chesapeake Operating LLC No.* CIV-16-134-F, (W.D. Okla. 2016),is a federal action filed under the Resource and Conservation and Recovery Act (42 USC section 6972 (a)(1)(B) which was filed on behalf of Sierra Club members who suffered property damage from earthquakes. It seeks injunctive relief claiming that the disposal of waste water and other production wastes violate the RCRA. It alleges the waste water may present "imminent and substantial endangerment to health and the environment". The complaint alleges that "if a large earthquake struck the massive oil storage area in Cushing Oklahoma, huge amounts of oil could be released causing massive environmental damage". The Plaintiffs must prove that the owner or operator handled, stored, treated, transported, or disposed "of any solid or hazardous waste which may present an imminent and substantial endangerment to health or the environment" (42 U.S.C. section 6972(a)(1)(B) (L-E-1) Cases files in federal court such as this may encounter jurisdictional problems based in the decision of the U.S. Supreme Court in *Burford, et al. v Sun Oil Company, et al*, 319 U.S. 315 (1943) which appears to limit federal courts in cases where state courts have a greater expertise in complex matters of special significance to the state and a state regulatory policy is in place.

Occasionally, the threat of litigation is sufficient to gain results. The Oklahoma Corporation Commission entered into settlement discussions after threatening litigation. In one such instance the Oklahoma Corporation Commission (media Advisory January 20, 2016) permitted the Oklahoma Geological Survey to monitor four wells to provide data in real-time as to seismicity. Additionally, the Commission is investigating the result of bring injection wells back on line simultaneously such as after an electric outage.

In a case filed in November of 2016 in *James Adams et al. v Eagle Road Oil LLC* (2016)Plaintiffs alleged that waste water pumped into the ground in Oklahoma helped trigger and earthquake and numerous aftershocks lasting several weeks. It claims that on September 3, 2016 that a 5.8 magnitude earthquake hit

Pawnee County the strongest earthquake to ever hit Oklahoma. The suit argues liability based upon absolute liability, trespass, private nuisance and negligence.

Insurance

What role does insurance play in the Oklahoma situation? Is insurance a viable alternative for citizens to protect themselves from the dangers of earthquakes? First it is important to note that a standard homeowner's policy does not cover earthquake damage and until recent years was not often purchased by Oklahoma homeowners. Since 2011 the percent of Oklahomans purchasing the insurance has risen dramatically from approximately 2% to 15%. Oklahoma now has the dubious distinction of leading the nation in earthquake insurance leaving California far behind California with 10% coverage. (Wilmoth)

Earthquake insurance is available in many packages and coverages designed to meet the needs of the consumers. It is available as an endorsement (added provision) to a homeowner's policy or in some instances may be purchased as a stand-alone policy independent of the homeowner's policy. Normally it can be purchased at any time, but immediately after an earthquake insurance companies normally require a waiting period after the initial shock to defend against aftershocks. The waiting period can vary from 3-60 days. (Oklahoma)

The coverage possibilities are varied and may cover the basic structure like a home, but not a garage. Alternatively, it can cover virtually all of the premises including fences, pools, and other out buildings. Personal property may or not be covered as well as living expenses. While exclusions vary, the most common are masonry veneer (brick), vehicles and pre-existing damage. Most polices also have a deductible which is a percentage of the insured value of the home. A 10% or higher deductible is not unusual, meaning the first $10,000.00 of damage is born by the homeowner. If the home were valued at $200,000.00 the deductible would be $20,000.00. Unlike common homeowners' policies which may have $500.00-$1,000.00 deductibles. (Oklahoma)

The cost of the policy depends on the coverage and the deductible with the cost decreasing as the deductible increases. Basic polices in Oklahoma may be found for a low as several hundred dollars with limited coverage up to several thousand dollars. As with any property insurance the size of the structure, location, age and construction type, and replacement cost all factor into the determination of the premium.

Whether or not the insurance would cover damages of earthquakes shown to be caused by waste water injection depends on the insurance company. Many polices do not cover "man-made" earthquakes. Homeowners' should consult with their agents.

One insurance company, Swiss Re, recently reported that an updated risk assessment model has been developed to reflect changes in the model used in Oklahoma due to the increased seismic activity. "Prior to 2009, a damaging earthquake in Oklahoma was expected once in roughly 100 years, with the updated model reflecting the increased rate of activity, the expectation is now roughly 1 in 7 years." (1) "In other words, financially preparing for the worst-case tornado scenario wouldn't leave adequate protection for a severe earthquake loss that is now much more likely." The report went on to state "Specific portfolios with high exposure in Oklahoma could now see more risk due to an earthquake than for tornado." Swiss Re noted that while tornados remain the dominant risk for the Oklahoma insurance market in the short term that earthquake losses could be more costly for long term periods of more than 100 years.

According to a Reuters story in May, 2016, six insurers has raised premiums as much as 260% and while several others raised deductibles and some did both. Others left the market all together. (Reuters) Travelers insurance Company stopped permitting existing policy holders to add earthquake insurance, The Hartford stopped writing it completely, and The Oklahoma State Farm made a "business decision" to remove coverage several years ago. The overriding fear seems to be of the "big one" happening. (Reuters) Several large insurance companies which cover man-made quakes indicated that they would consider suing the oil and gas companies if a large scale quake occurs. (Reuters) Swiss Re has suggested that new products may be useful

such as one which incorporates an aggregate coverage for customers with multiple small losses. Premiums still are very important and the new policies for multiple small damages might in fact carry a higher premium that a catastrophic policy noted the Oklahoma Insurance Commissioner.

The history of insurance coverage leaves something to be desired when reviewing earthquake policies. In 2014, about 100 earthquake claims were filed, but only 8 were paid. Many polices carry an exclusion for "man-made" damage. Since the law is not clear on the cause, many companies deny coverage based on the belief that these earthquakes were a result of injection well activity. Until clarification of "man-made" earthquakes is determined, it appears many Oklahomans are skeptical of purchasing the insurance, even if available. At this time the Insurance Commissioner's position seems to be clear-"In light of unsettled science, I am concerned that insurers could be denying claims based on the unsupported belief that these earthquakes were the result of fracking or injections well activity." (Wilmoth)

Other Alternatives

Other possible alternatives to litigation and direct purchase of insurance by the homeowners include the possibility of a state mandated fund to subsidize earthquake insurance costs. Owners and operators of wells whether fracking or disposal wells might be charged a royalty/tax on doing business. The fund then would be used to lower/subsidize the costs of homeowners' insurance premiums. The state of Oklahoma might simply decide that earthquakes are a fact of life in Oklahoma and therefore a state problem without regard to the causation. The state could consider the costs of lowering insurance premiums a state obligation. If and when causation is proven the state could get out of the insurance subsidy business.

While determining sources of revenue to carry out state programs is outside the scope of this paper, a novel and oft used idea is a state lottery. The Florida legislature passed a state lottery, as have many states, with the stated purpose of promoting and improving higher education. The anticipated objections to spending state funds often disappears when no additional taxes are imposed. A state lottery has that advantage.

References

Conca, James. "Thanks To Fracking, Earthquake Hazards In Parts Of Oklahoma Now Comparable To California." *Forbes*. Forbes Magazine, 8 September, 2016. Web. 17 March, 2017. <www.forbes.com/sites/jamesconca/2016/09/07/the-connection-between-earthquakes-and-fracking/#10ba822d6d68>.

Ellsworth, William L., "Injection-Induced Earthquakes," *Science*, vol. 341, July 12, 2013.

Flis, Jim. "Senior Staff Geophycisist, worked at Chevron for 38 years." Personal Interview. 28 February, 2016.

Folger, Peter, and Mary Tiemann. "Human-Induced Earthquakes from Deep-Well Injection: A Brief Overview" *Congressional Research Service*, 7-5700 found at www.crs.gov R43836.

"Induced Earthquakes." *U.S. Geological Survey*. N.p., n.d. Web. 17 March, 2017. <https://earthquake.usgs.gov/research/induced/modeling.php>,

International, Inc. Advanced Solutions. "GSA Critical Issue: Hydraulic Fracturing." *GSA Critical Issues - Hydraulic Fracturing*. Geological Society of America, n.d. Web. 17 March, 2017.<www.geosociety.org/GSA/Science_Policy/Critical_Issues/hf/GSA/Policy/issues/hf/seismicity.aspx>.

McClure, Daniel, Lauren Brogdon, and Barclay Richardson. "Oklahoma Quakes Trigger Increasing Earthquake Legal Concerns." *Norton Rose Fulbright*. N.p., 15 February, 2016. Web. 20 March, 2017. <http://www.nortonrosefulbright.com/knowledge/publications/136769/oklahoma-quakes-trigger-increasing-earthquake-legal-concerns>.

McClure, Daniel M., Barclay Nicholson, Lauren Brogdon, and Emery Richards. "Earthquake

Litigation Spikes Following Recent Oklahoma Quakes" *Norton Rose Fulbright US LLP*

McNamara, D. E., and H. M. Benz. "Earthquake hypocenters and focal mechanisms in central Oklahoma reveal a complex system of reactivated subsurface strike-slip faulting." *Geophysical Research Letters* 42.8 (2015): 2742-749. *Web Of Science*. Web. 20 March, 2017. <http://onlinelibrary.wiley.com/doi/10.1002/2014GL062730/abstract>.

Mills, Chellie. "Oklahoma Geological Survey: Earthquakes linked to oil and gas activity." New Channel 4, 23 Apr. 2015. Web. 20 March, 2017. <http://kfor.com/2015/04/21/oklahoma-geological-survey-earthquakes-linked-to-oil-and-gas-activity/>.

National Research Council (NRC) "Induced Seismicity Potential in Energy Technologies," 2013,

Oklahoma Corporation Commission. "Earthquakes in Oklahoma." N.p., n.d. Web. 20 March, 2017. <https://earthquakes.ok.gov/what-we-are-doing/oklahoma-corporation-commission/>.

Oklahoma Insurance Department. " Earthquakes." https://www.ok.gov/oid/Consumers/Prepare_Yourself/Earthquakes. Html

Reuters. "Fracking-related quakes have made earthquake insurance almost impossible to buy in Oklahoma", http://www.rawstory.com/2016/05/fracking-related-quakes-have-made-earthquake-insurance…

Richards, Emery. "Finding Fault: Induced Earthquake Liability and Regulation." *Columbia Journal of Environmental Law* (2015): 1-33. Web. 17 March, 2017.<http://www.columbiaenvironmentallaw.org/wp-content/uploads/sites/14/2016/04/Richards_Macro_WEB_final.pdf_>

Rorke, Catrina. "Should Oil Firms Be Held Liable in Earthquake Lawsuits?" *The Wall Street Journal*. Dow Jones & Company, 15 November, 2015. Web. 17 March, 2017. <www.wsj.com/articles/should-oil-firms-be-held-liable-in-earthquake-lawsuits-1447643517>.

Rosen, Julia. "Huge study links wastewater injection wells to earthquakes." *Science* (2015): n. pag. *ProQuest*. Web. 20 March, 2017. <http://www.sciencemag.org/news/2015/06/huge-study-links-wastewater-injection-wells-earthquakes>.

Sellers, Steven M. "Earthquakes, Fracking, Disposal Wells… and Litigation." Bloomberg BNA, *Toxic Law Reporter*, April 26, 2016.

Walsh, F. Rall, and Mark Zoback. "Oklahoma's recent earthquakes and saltwater disposal." *Science Advances* 1.5 (2015): n. pag. *JSTOR Arts & Sciences*. Web. 17 March, 2017. <http://advances.sciencemag.org/content/1/5/e1500195>.

Wilmoth, Adam. "Insurance Commissioner Clarifies "Man-made" Earthquake Policies." *The Oklahoman,* March 3-4, 2015.

Yeck, W. L., and G. P. Hayes. "Oklahoma experiences largest earthquake during ongoing regional wastewater injection hazard mitigation efforts." *Geophysical Research Letters* 44.2 (2017): 711-17. *ProQuest*. Web. 20 March, 2017. <http://search.proquest.com.dax.lib.unf.edu/agricenvironm/docview/1870044800/34C355506F08404BPQ/1?accountid=14690>.

Zeits, Richard. "Oklahoma Earthquakes: Is There A Liability And What Companies Are Impacted?" *Seeking Alpha*. N.p., 26 June, 2015. Web. 17 March, 2017. <http://seekingalpha.com/article/3286625-oklahoma-earthquakes-is-there-a-liability-and-what-companies-are-impacted>.