SALTY PLAINTIFFS AND INDUSTRY DEFENSES: A TEXAS LAWYER'S GUIDE TO INDUCED SEISMICITY AND SALTWATER DISPOSAL WELLS

Comment*

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I. INTRODUCTION

"But the wrath of Poseidon visited them without delay; an earthquake promptly struck their land and swallowed up, without leaving a trace for posterity to see, both the buildings and the very site on which the city stood."[1]

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1. *Greek Texts and Translations*, PERSEUS UNDER PHILOLOGIC, http://perseus.uchicago.edu/perseus-cgi/citequery3.pl?dbname=GreekFeb2011&getid=1&query=Paus.%207.24.8 (last visited Apr. 5, 2016).

On November 5, 2011, Sandra Ladra was at ease in her living room watching television with her family when her world literally began to shake.[2] A powerful earthquake sent shockwaves through her home, shaking her chimney apart and sending its falling pieces cratering into her living room, crushing her knees and legs.[3] In all, she suffered over $75,000 in personal injury damages and $100,000 in damages to her home, and a doctor indicated that she would need surgery to repair her legs.[4] But Ms. Ladra did not blame the record-setting 5.6 magnitude earthquake on natural forces.[5] Instead, she sued two oil and gas companies, alleging that their saltwater disposal operations caused the massive earthquake.[6] In 2013, a group of homeowners in Alvarado, Texas, sued EOG Resources and other oil and gas companies, alleging that the companies' waste disposal operations were also causing earthquakes, which resulted in widespread property damage.[7] Currently, plaintiffs in Arkansas, Oklahoma, and Texas have sued energy companies, theorizing that saltwater disposal operations have induced earthquake activity.[8]

Oil and gas exploration and production commonly produces large volumes of saltwater that comingles with underground hydrocarbons.[9] The Texas Railroad Commission (RRC or Commission), the regulatory agency responsible for overseeing the Texas oil and gas industry, has indicated that "approximately 10 barrels of salt water are produced with every barrel of crude oil."[10] Given that Texas oil and gas companies produced over 975 million barrels of oil in 2014, it is easy to appreciate the difficulty of dealing

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2. *See* Ladra v. New Dominion, LLC, 353 P.3d 529, 530 (Okla. 2015); Miguel Bustillo & Daniel Gilbert, *Energy's New Legal Threat: Earthquake Suits*, WALL ST. J. (Mar. 30, 2015, 1:22 PM), http://www.wsj.com/articles/frackings-new-legal-threat-earthquake-suits-1427736148.

3. *See Ladra*, 353 P.3d at 530; Bustillo & Gilbert, *supra* note 2.

4. *See Ladra*, 353 P.3d at 530; Bustillo & Gilbert, *supra* note 2.

5. Bustillo & Gilbert, *supra* note 2.

6. *Id.*

7. *See* Jeremy Heallen, *Fracking by EOG, Shell Caused Damaging Tremors, Suit Says*, LAW360 (Aug. 2, 2013, 5:21 PM), http://www.law360.com/articles/462214/fracking-by-eog-shell-caused-damaging-tremors-suit-says (quoting the plaintiffs' attorney, who said, "While the oil and gas companies have rights to drill and inject waste into their disposal wells, they do not have the right to destroy their neighbor's surface property rights in the process."). Alvarado is a town about thirty miles south of Fort Worth, Texas, with a 2010 population of 3,785. *Alvarado, TX*, TEX. ST. HIST. ASS'N, https://tshaonline.org/handbook/online/articles/hga03 (last modified Dec. 17, 2014).

8. *Ladra*, 353 P.3d at 529; Hearn v. BHP Billiton Petroleum (Ark.), Inc., No. 11-CV-0474 (E.D. Ark., filed June 9, 2011); Original Petition, Cooper v. New Dominion, LLC, No. CJ-2015-24 (Lincoln Cty. Dist. Ct., Okla. Feb. 10, 2015); Original Petition, Finn v. EOG Res., Inc., No. C2013-00343 (18th Dist. Ct., Johnson County, Tex. July 30, 2013). Most of these and other cases alleging damage from induced seismicity were dismissed. *See* ROCKY MOUNTAIN MINERAL LAW FOUND., LITIGATION INVOLVING ALLEGED INDUCED SEISMICITY OR RISKS OF INDUCED SEISMICITY (2015), https://www.rmmlf.org/proceedings/AI61,%20Ch.%205,%20Litigation.pdf.

9. *Oil and Gas Waste Disposal*, RAILROAD COMMISSION TEX., http://www.rrc.state.tx.us/oil-gas/applications-and-permits/injection-permit-types-and-information/oil-and-gas-waste-disposal/ (last updated July 20, 2015, 9:27 PM).

10. *Id.* One barrel is equal to forty-two gallons. PATRICK H. MARTIN & BRUCE M. KRAMER, WILLIAMS & MEYERS MANUAL OF OIL AND GAS TERMS 82 (15th ed. 2012).

with the approximately 9.7 billion barrels of associated brine.[11] To cope with this geological reality, operators of oil and gas wells typically apply to the RRC for permits to drill saltwater disposal wells (SWDs) to re-introduce produced brine back into subsurface rock formations, or contract with SWD operators to dispose of the waste.[12] There is a growing consensus in the scientific community that if certain geologic conditions exist in a given subsurface formation, this practice can potentially cause seismic activity strong enough to be felt at the surface.[13] Indeed, the correlation between rising disposal rates and the dramatic spike of localized earthquakes is curious, if not alarming.[14] In Oklahoma for instance, saltwater disposal volumes have roughly doubled since 1997, from 80 million barrels disposed per month to over 160 million barrels per month in 2013.[15] The state's earthquake numbers have seen an even sharper uptick.[16] From 1978 to 2008, Oklahoma experienced 2.2 earthquakes annually with a magnitude of 3.0 or greater.[17] In 2009, twenty such earthquakes occurred.[18] 2013 saw 109, and 2014 saw 585.[19] And in 2015, while outpacing every state in the country combined (except Alaska), Oklahoma experienced 890 earthquakes with a magnitude of 3.0 or greater.[20] That is an increase from about two each year

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11. *Texas Monthly Oil & Gas Production*, RAILROAD COMMISSION TEX., http://www.rrc.state.tx.us/oil-gas/research-and-statistics/production-data/texas-monthly-oil-gas-production/ (last updated Mar. 24, 2016). That is well over 600,000 Olympic swimming pools worth of saltwater.

12. *See Oil and Gas Waste Disposal*, *supra* note 9. Operators also have the option of trucking saltwater off site, but at least one energy service company president estimates that this option is largely cost-prohibitive at $5,000–$6,000 per truckload and a typical carrying capacity of 190 barrels per truck. *See* CITY OF FORT WORTH, SALT WATER DISPOSAL TERMS AND DATA 4, http://fortworthtexas.gov/uploadedFiles/Gas_Wells/SWD_questions.pdf; Keith Schaefer, *The 'Holy Grail' Business Model For Water*, OIL & GAS INV. BULL. (Feb. 11, 2012), http://oilandgas-investments.com/2012/energy-services/the-holy-grail-business-model-for-water/.

13. *See* GROUND WATER PROT. COUNCIL & INTERSTATE OIL & GAS COMPACT COMM'N, POTENTIAL INJECTION-INDUCED SEISMICITY ASSOCIATED WITH OIL AND GAS DEVELOPMENT: A PRIMER ON TECHNICAL AND REGULATORY CONSIDERATIONS INFORMING RISK MANAGEMENT AND MITIGATION 14 (2015), http://www.gwpc.org/sites/default/files/finalprimerweb.pdf. *See generally* Matthew J. Hornbach et al., *Causal Factors for Seismicity Near Azle, Texas*, 6 NATURE COMMC'NS, no. 6728, Apr. 21, 2015, http://www.nature.com/ncomms/2015/150421/ncomms7728/pdf/ncomms7728.pdf; F. Rall Walsh III & Mark D. Zoback, *Oklahoma's Recent Earthquakes and Saltwater Disposal*, SCI. ADVANCES, June 18, 2015, at 1–2, http://advances.sciencemag.org/content/advances/1/5/e1500195.full.pdf (explaining in detail the seismological and geophysical causal mechanisms).

14. *See* Walsh III & Zoback, *supra* note 13; *Oklahoma Earthquakes Magnitude 3.0 and Greater*, U.S. GEOLOGICAL SURV., http://www.earthquake.usgs.gov/earthquakes/states/oklahoma/images/OklahomaEQsBarGraph.png (last visited Apr. 6, 2016).

15. Walsh III & Zoback, *supra* note 13, at 1.

16. *Oklahoma Earthquakes Magnitude 3.0 and Greater*, *supra* note 14.

17. *Id.*

18. *Id.*

19. *Id.*

20. Brad Sowder, *Oklahoma Has More Earthquakes in 2015 than All of Continental U.S. Combined*, KOCO OKLA. CITY (Dec. 31, 2015, 11:58 AM), http://www.koco.com/weather/oklahoma-ha-more-earthquakes-in-2015-than-all-of-continental-us-combined/37209902.

to over two *each day*.[21] While this issue currently lacks the urgency in Texas that it carries in Oklahoma, some Texas lawyers surmise this is only because scientists currently lack data to demonstrate causation.[22] As scientists continue to study the issue though, the RRC itself has suggested that this could change.[23] And as homeowners like Ms. Ladra can attest, Texas SWD operators may soon find themselves increasingly the targets of lawsuits on this basis.[24] Part II of this Comment lays the scientific groundwork for a basic understanding of this issue. Part III looks at the most comprehensive scientific examination of induced seismicity in Texas to date and its legal implications. Part IV analyzes various common law and statutory theories of operator liability, accompanied by a discussion of defenses available to the industry, primarily in the context of current Texas tort law. Part V discusses rulemaking initiatives designed to enhance seismologists' understanding of this issue. Finally, this Comment concludes with legislative recommendations designed to incentivize alternatives to SWDs in a bid to bypass this hot potato.

II. UNDERGROUND BACKGROUND

A. Geology: A Hard Science

Any analysis of the legal aspects of induced seismicity requires at least a basic understanding of geologic principles and earthquake mechanics. To begin with, among the rock properties geologists use to describe rocks in the earth's crust, two are important for this discussion: porosity and permeability.[25] Porosity describes the percentage of a rock's volume that is occupied by void spaces.[26] The earth's crust is not solid like a block of poured concrete—there are small cavities within the rock layers. Some of the larger cavities—known as vugs—are even the size of your fist.[27] Porosity is important because it measures a rock formation's fluid storage capacity.[28]

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21. *See* Keith B. Hall, *Induced Seismicity: An Energy Lawyer's Guide to Legal Issues and the Causes of Man-Made Earthquakes*, 61 ROCKY MTN. MIN. L. INST. 5-1, 5-3 (2015).

22. *See* Jess Davis, *Texas Quake Findings Likely to Deter Civil Suits*, LAW360 (Nov. 3, 2015, 9:10 PM), http://www.law360.com/articles/722616/texas-quake-findings-likely-to-deter-civil-suits.

23. *See* R.R. COMM'N OF TEX., *Hearing to Consider Whether Operation of the Enervest Operating LLC, Briar Lease, Well No. 1, in the Coughlin (Strawn) Field, is Causing or Contributing to Seismic Activity*, Docket No. 09-0296410 (Oil & Gas Div. Sept. 10, 2015) (proposal for decision) [hereinafter *EnerVest Hearing*], http://www.rrc.state.tx.us/media/31022/09-96410-sho-pfd.pdf.

24. *See* Bustillo & Gilbert, *supra* note 2.

25. *See* COMM. ON INDUCED SEISMICITY POTENTIAL IN ENERGY TECHS. ET AL., INDUCED SEISMICITY POTENTIAL IN ENERGY TECHNOLOGIES 13 (2013).

26. ROGER G. WOLFF, U.S. DEP'T OF THE INTERIOR, PHYSICAL PROPERTIES OF ROCKS—POROSITY, PERMEABILITY, DISTRIBUTION COEFFICIENTS, AND DISPERSIVITY 3 (1982), http://pubs.usgs.gov/of/1982/0166/report.pdf.

27. NORMAN J. HYNE, NONTECHNICAL GUIDE TO PETROLEUM GEOLOGY, EXPLORATION, DRILLING & PRODUCTION 150 (Stephen Hill ed., 3d ed. 2012).

28. *Id.* at 120.

A rock's porosity might range anywhere from 0.2% by volume for a granite formation to around 40% by volume for some sandstones.[29] Oil, gas, and saltwater exist in these pore spaces, and when SWD operators dump oilfield brine into the underground rock, the brine is stored in these pore spaces.[30] To qualify as a viable reservoir for oil and gas development, a rock formation will generally need at least 10% porosity.[31] Most disposal wells permitted in Texas dispose into formations of at least 25% porosity.[32]

Another property geologists use to characterize rocks is permeability.[33] Rock formations have varying degrees of porosity, and permeability describes the degree to which those pore systems are interconnected, thereby allowing liquid or gaseous substances to move throughout the rock layer.[34] Permeability describes the ease with which a fluid can travel through porous rock and is measured in units called darcys, or millidarcys.[35] One darcy describes "the permeability that will allow a flow of 1 cubic centimeter per second of a fluid with 1 centipoise viscosity (resistance to flow) through a distance of 1 centimeter through an area of 1 square centimeter under a differential pressure of 1 atmosphere."[36] To be a viable reservoir for hydrocarbon production, rock formations must be sufficiently permeable to allow oil or gas to flow from the rock formation into the wellbore.[37] The same holds true for saltwater disposal wells: the disposal formation must be sufficiently porous and permeable to accommodate the injection of possibly tens of thousands of barrels of saltwater per day.[38] For this reason,

29. *See* G. EDWARD MANGER, U.S. DEP'T OF THE INTERIOR, POROSITY AND BULK DENSITY OF SEDIMENTARY ROCKS E-12, E-42 (1963), http://pubs.usgs.gov/bul/1144e/report.pdf.

30. TEX. DEP'T OF WATER RES., NO. 274, UNDERGROUND INJECTION CONTROL TECHNICAL ASSISTANCE MANUAL: SUBSURFACE DISPOSAL AND SOLUTION MINING 4 (1983), http://www.twdb.texas.gov/publications/reports/numbered_reports/doc/R274/R274.pdf; *see also* HYNE, *supra* note 27, at 124 (describing how oil and gas exist commingled with saltwater in the reservoir formation's pore spaces).

31. *See* HYNE, *supra* note 27, at 120–21. For the purposes of oil production, porosity from 0%–5% by volume is insignificant. *Id.* A poor reservoir ranges from 5%–10%, a fair reservoir ranges from 10%–15%, a good reservoir ranges from 15%–20%, and an excellent reservoir is 20% and up. *Id.*

32. TEX. DEP'T OF WATER RES., *supra* note 30, at 18.

33. *See* HYNE, *supra* note 27, at 120.

34. *See id.* at 121–24.

35. *See id.* at 120–22.

36. *Id.* at 121. For reference, water has a viscosity of 1 centipoise. *Viscosity Tables*, VP SCI., INC., http://www.vp-scientific.com/Viscosity_Tables.htm (last visited Apr. 6, 2016). Honey has a viscosity of roughly 10,000 centipoise. *Id.*

37. HYNE, *supra* note 27, at 122. An oil reservoir with poor permeability ranges from 1–10 millidarcys, a good reservoir ranges from 10–1000 millidarcys, and an excellent reservoir ranges from 100–1000 millidarcys. *Id.*

38. TEX. DEP'T OF WATER RES., *supra* note 30. For instance, one North Texas SWD was permitted to dispose up to 25,000 barrels of water per day, equal to 1,050,000 gallons, and actually disposed of an estimated daily average of 15,000 barrels per day. R.R. COMM'N OF TEX., *Permit to Dispose of Non-Hazardous Oil and Gas Waste by Injection Into a Porous Formation Not Productive of Oil and Gas*, Permit No. 12872 (Oil & Gas Div. Feb. 19, 2009).

"[p]orosity and permeability are principal factors used to determine the suitability of a potential disposal reservoir."[39]

While micro-geologic features play a key role in understanding induced seismicity, a brief description of larger scale geologic principles is also necessary to complete the picture. To begin with, the earth is composed of three general layers: the core, the mantle, and the crust.[40] The outermost layer, the crust, is the solid layer overlying the mostly solid mantle and ranges anywhere from ten to seventy kilometers thick, depending on location.[41] The crust is composed of many smaller blocks of rock that exist along both sides of fault lines.[42] A geologic "fault is a fracture along which the blocks of crust . . . have moved relative to one another parallel to the fracture."[43]

Three basic physical forces exist along geologic fault lines: friction, normal force, and shear force.[44] We all intuitively understand friction—it (or, more properly, the lack of it) is what can cause us to slip and fall on an icy patch or a banana peel. Scientists describe the level of friction a given surface generates as the "coefficient of friction," with a larger coefficient indicating a tendency to create greater friction resistance. The coefficient of friction is often represented by the Greek letter mu, μ.[45] Another force that exists along a fault line, normal force, describes the force tending to push the two opposing crustal blocks together.[46] For example, there is a greater normal force between brake pads and a tire's discs when the brake pedal is more firmly depressed. Or, there is a greater normal force between the plates of a vice grip and the object it secures, the tighter you ratchet the vice. Scientists use the lower case Greek letter sigma, σ, to refer to normal force.[47] Thus, the total frictional forces along any fault line are described as the coefficient of friction times the normal force: $\mu\sigma$.[48] In addition, huge levels of shear stress (described as tau, τ) can exist along fault lines between crustal blocks.[49] This shear force tends to move opposing crustal blocks laterally past each other.[50] However, a fault will remain stable so long as the frictional forces existing along the fault are greater than the tensional (i.e. shear) forces

39. TEX. DEP'T OF WATER RES., *supra* note 30.

40. Eugene C. Robertson, *The Interior of the Earth*, U.S. GEOLOGICAL SURV., http://pubs.usgs.gov/gip/interior/ (last modified Jan. 14, 2011).

41. *How Thick is the Earth's Crust?*, U.S. GEOLOGICAL SURV., http://earthquake.usgs.gov/data/crust/ (last modified June 25, 2014, 3:25 PM).

42. *See How Earthquakes Happen*, U.S. GEOLOGICAL SURV., http://pubs.usgs.gov/gip/earthq1/how.html (last modified Jan. 11, 2013, 11:12 AM).

43. *Earthquake Glossary—Fault*, U.S. GEOLOGICAL SURV., http://earthquake.usgs.gov/learn/glossary/?term=fault (last modified July 18, 2012, 6:52 PM).

44. Hall, *supra* note 21, at 5-15.

45. *Id.* at 5-10.

46. *Id.* at 5-11.

47. *Id.*

48. *Id.*

49. COMM. ON INDUCED SEISMICITY POTENTIAL IN ENERGY TECHS. ET AL., *supra* note 25, at 37–38.

50. *Id.*

tending to cause the two blocks to move laterally past one another.[51] Or, in scientific terms, a fault will remain stable as long as the following is true: $\mu\sigma > \tau$.[52] Slippage will occur when a fault experiences a critical level of stress and the shear forces tending to push the two slabs of rock past one another becomes greater than the frictional forces along the fault line that keep the fault stabilized.[53] When that slippage occurs suddenly, the result is an earthquake.[54]

Scientists measure earthquakes using a variety of scales, but the most common of these is the Richter Scale, popularized by Charles Richter in the 1930s, which measures the magnitude of an earthquake, defined as the amplitude of the shockwaves.[55] The Richter Scale is a logarithmic scale, meaning that for every +/- 1.0, an earthquake has increased or decreased in magnitude by a power of ten, and a corresponding "release of about 31 times more energy than the amount associated with the preceding whole number value."[56]

Table 1. Frequency and Effects of Seismic Events of Different Magnitudes[57]

Magnitude on Richter Scale	Typical Effects	Description and Detection	Average Number of Events Annually Worldwide
-3.0 to 0.5	Not felt. Hydraulic fracturing typically causes numerous microseismic events in the -3.0 to -2.0 range.	Microseismic events.	Many millions (estimated)

51. *Id.* at 40.

52. *Id.* For reasons discussed below, a new variable describing the pore pressure (if any) acting along a fault line will slightly alter this inequality. *See infra* notes 87–91 and accompanying text.

53. COMM. ON INDUCED SEISMICITY POTENTIAL IN ENERGY TECHS. ET AL., *supra* note 25, at 37–38.

54. *The Science of Earthquakes*, U.S. GEOLOGICAL SURV., http://earthquake.usgs.gov/learn/kids/eqscience.php (last modified July 18, 2012, 6:51 PM).

55. *The Severity of an Earthquake*, U.S. GEOLOGICAL SURV., http://pubs.usgs.gov/gip/earthq4/severitygip.html (last modified Jan. 11, 2013, 12:51 PM).

56. *Id.*

57. Hall, *supra* note 21, at 5-8–5-10; *Earthquake Facts and Statistics*, U.S. GEOLOGICAL SURV., http://earthquake.usgs.gov/earthquakes/eqarchives/year/eqstats.php (last modified Jan. 13, 2015, 11:51 PM).

0.5 to 2.0	Not felt.	Micro earthquakes. Ability to detect these earthquakes varies considerably.	Many millions (estimated)
2.0 to 2.9	Generally not felt. May be felt under favorable conditions.	Minor earthquakes.	1,300,000 (estimated)
3.0 to 3.9	Often felt, but rarely cause damage.	Minor earthquakes.	130,000 (estimated)
4 to 4.9	Generally will be felt. Noticeable shaking of indoor items but rarely cause significant damage.	Light earthquakes.	13,000 (estimated)
5 to 5.9	Often cause damage, but generally do not cause structural damage in well-built structures.	Strong earthquakes.	1,319
6 to 6.9	Even well-built structures may incur some damage.	Very strong earthquakes.	134
7 to 7.9	Damages generally slight in specially built structures, but otherwise is significant even in well-built structures, and is great in poorly built structures.	Severe earthquakes.	15
8 and higher	Some well-built structures and most poorly built structures are completely destroyed.	Extreme earthquakes.	1

B. Salt of the Earth: The Basics of Saltwater Disposal Wells

On a national average, for every barrel of oil produced from a well, a corresponding ten barrels of saltwater are also produced.[58] To deal with this issue, many operators rely on SWDs to re-inject this produced brine back into the subsurface.[59] Under the Federal Safe Drinking Water Act (SDWA), the U.S. Environmental Protection Agency (EPA) regulates the lifecycle of these injection and disposal wells under its Underground Injection Control (UIC) program.[60] Many states, however, have achieved primary enforcement responsibility of the EPA's UIC program by attaining EPA approval of programs designed to achieve the SDWA's goals and enforce its standards.[61] Texas gained full primacy in 1982 for all disposal and injection wells relating to oil and gas production under a plan designating the RRC as the administering agency.[62] Pursuant to the UIC program as adopted by Texas, the EPA established six different well classes.[63] Class II includes both saltwater disposal wells and wells that inject fluids for enhanced recovery operations of oil and gas companies.[64] There are over 34,200 active Class II wells in Texas.[65] Of these, approximately 8,100 are used for disposal purposes, and the rest are used for injection purposes.[66]

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58. *Oil and Gas Waste Disposal*, *supra* note 9.

59. *Injection and Disposal Wells*, RAILROAD COMMISSION TEX., http://www.rrc.state.tx.us/about-us/resource-center/faqs/oil-gas-faqs/faq-injection-and-disposal-wells/ (last visited Apr. 6, 2016).

60. COMM. ON INDUCED SEISMICITY POTENTIAL IN ENERGY TECHS. ET AL., *supra* note 25, at 118; *see also* Underground Injection Control Programs, 40 C.F.R. § 144 (2011) (detailing the regulatory framework of the EPA's UIC program).

61. *Primary Enforcement Authority for the Underground Injection Control Program*, EPA, https://www.epa.gov/uic/primary-enforcement-authority-underground-injection-control-program #how_apply (last updated Feb. 12, 2016); *see also* GROUND WATER PROT. COUNCIL & INTERSTATE OIL & GAS COMPACT COMM'N, *supra* note 13, at 56 (noting that states' primacy and their UIC regulatory programs are subject to approval by the EPA).

62. R.R. COMM'N OF TEX., SELF-EVALUATION REPORT 27 (2015), http://www.rrc.state.tx.us/media /30156/final-self-evaluation-report-2015.pdf.

63. *See* 40 C.F.R. § 144.6.

64. *Id.* § 144.6(b). Injection wells, as distinguished from disposal wells, are drilled to inject water into an oil or gas bearing rock formation to optimize reservoir pressures in a nearby well producing oil or gas from the same formation, thereby enhancing hydrocarbon recovery from that well. *See Enhanced Recovery*, RAILROAD COMMISSION TEX., http://www.rrc.texas.gov/oil-gas/applications-and-permits/ injection-permit-types-and-information/enhanced-recovery/ (last updated Mar. 8, 2016, 8:22 AM). This process is known as "waterflooding." *Id.* Class I wells dispose of radioactive and other hazardous materials. 40 C.F.R. § 144.6(a). Class III wells are drilled for the extraction or mining of sulfur, various metal ores, salts, or potash. *Id.* § 144.6(c). Class IV includes wells that dispose of radioactive or hazardous materials in rock formations within a quarter of a mile of an underground source of drinking water. *Id.* § 144.6(d). Class V is a general catch-all category that describes wells not included in Classes I, II, III, IV, or VI. *Id.* § 144.6(e). And Class VI wells are drilled only for carbon sequestration. *Id.* § 144.6(f).

65. *Injection and Disposal Wells*, *supra* note 59.

66. *Id.*

1. How to Dig a Hole: Permitting and Drilling

Acquiring a permit to operate a saltwater disposal well in Texas involves the well operator's submission of the following information: (1) a well log identifying the proposed injection zone and surrounding formations; (2) a "groundwater depth letter . . . to evaluate the depth of groundwater protection needed in the proposed injection well;" (3) a disclosure of any wells within a quarter-mile radius of the proposed disposal well; and (4) a disclosure of any recent seismic activity in the area.[67] Likely in response to the growing awareness that disposal wells might trigger seismic activity, the RRC adopted the current version of the fourth requirement in August 2014, and the requirement became effective November 21, 2014.[68] Under this rule, operators proposing to complete a SWD or amend a permit to an existing well must disclose any seismic events that have occurred within a circular area of 100 square miles of the proposed disposal well site, as recorded by the U.S. Geological Survey.[69] In addition, the new rule "clarif[ies] the [RRC's] staff authority to modify or suspend or terminate a disposal well permit," and authorizes the RRC to require more frequent disclosures of disposal well volumes and pressures, and any additional information the Commission finds necessary.[70] Along with these disclosures, applicants for SWD permits must demonstrate that the proposed disposal formation is "separated from freshwater formations by impervious beds which will give adequate protection to such freshwater formations."[71] Applicants must also notify the surface owner and each of the adjacent landowners where the well is to be drilled.[72] If an interested party protests a permit application, the RRC sets a hearing to determine whether the permit should issue.[73] Once approved, the RRC has authority to modify, suspend, or terminate a disposal well permit for just cause if it determines that the SWD is the likely cause of local seismic activity, if freshwater pollution is likely to result from the SWD operation, or if a range of other problems occur.[74] The drilling and completion of the SWD is subject to a number of design specifications.[75] Once completed, the operator must submit periodic reports to the RRC to

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67. *Attachments for New Injection/Disposal Wells*, RAILROAD COMMISSION TEX., http://www.rrc.texas.gov/oil-gas/publications-and-notices/manuals/injectiondisposal-well-manual/summary-of-standards-and-procedures/attachments-for-new-wells/ (last updated Mar. 23, 2016, 10:54 AM); *see* 16 TEX. ADMIN. CODE § 3.9 (2015).

68. *Railroad Commission Adopts Disposal Well Rule Amendments Today*, RAILROAD COMMISSION TEX. (Oct. 28, 2014), http://www.rrc.state.tx.us/all-news/102814b/.

69. *Attachments for New Injection/Disposal Wells*, *supra* note 67; *see* 16 TEX. ADMIN. CODE § 3.9.

70. *Railroad Commission Adopts Disposal Well Rule Amendments Today*, *supra* note 68.

71. 16 TEX. ADMIN. CODE § 3.9(2).

72. *Id.* § 3.9(5).

73. *Id.*

74. *Id.* § 3.9(6)(a).

75. *Id.* § 3.9(8)–(9).

ensure the integrity of the wellbore and the safe, proper operation of the SWD.[76]

Once permitted, drilling and completing a disposal well involves drilling into a nonproductive rock formation suitable for wastewater storage.[77] The "wells are designed and constructed to adequately confine injected fluids to the authorized injection zone and prevent the migration of fluids into underground sources of drinking water (USDW)."[78] SWDs feature multiple layers of steel pipe and cement that the driller installs into the well to protect USDWs.[79] First, the operator drills a hole "to a depth below the base of usable-quality water . . . and [steel pipe] is set to this depth and cemented."[80] This steel pipe, known as surface casing, protects any freshwater sources by sealing off groundwater formations from the wellbore and is run from the surface to a depth below any fresh groundwater.[81] After the driller cements the surface casing in place, "the well is drilled to total depth and the long-string casing is set and cemented."[82] Long-string casing is another layer of steel pipe set from the surface casing all the way to the target formation.[83] "Finally, the well is completed with the injection tubing and packer installation," which provides the actual conduit through which injected brine will flow and seals off the gap between the injection tubing and the long-string casing.[84] When disposal operations begin, the wastewater is injected thousands of feet below the surface into a formation with sufficient porosity and permeability to accommodate the disposal of potentially millions of barrels of water.[85]

2. *The Grand Hypothesis: A Different Kind of "Salt Shaker"*

In attempting to identify a causal nexus between saltwater disposal wells and induced seismicity, geologists and geophysicists suggest that a disposal

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76. *Id.* § 3.9(11)–(12).

77. *Injection and Disposal Wells*, *supra* note 59.

78. GROUND WATER PROT. COUNCIL & INTERSTATE OIL & GAS COMPACT COMM'N, *supra* note 13, at 56.

79. *See id.*; TEX. DEP'T OF WATER RES., *supra* note 30, at 28–29.

80. TEX. DEP'T OF WATER RES., *supra* note 30, at 29.

81. GROUND WATER PROT. COUNCIL & INTERSTATE OIL & GAS COMPACT COMM'N, *supra* note 13, at 56; *see also* MARTIN & KRAMER, *supra* note 10, at 130–31 (describing the various layers of casing built into a well).

82. TEX. DEP'T OF WATER RES., *supra* note 30, at 29.

83. *See id.* at 29–30.

84. *Id.* at 29; *see also* GROUND WATER PROT. COUNCIL & INTERSTATE OIL & GAS COMPACT COMM'N, *supra* note 13, at 56 (describing the operation of a packer and providing a helpful illustration).

85. TEX. DEP'T OF WATER RES., *supra* note 30; *see also EnerVest Hearing*, *supra* note 23 (noting one formation in North Texas receiving 28 million barrels of disposed saltwater from two SWDs). For a helpful video illustrating the mechanics of a saltwater disposal well and the basic geology involved, see Power Service, Inc., *Salt Water Disposal Unit - Animated Example*, YOUTUBE (Aug. 11, 2014), https://www.you tube.com/watch?v=nHOGAHadp98.

well might increase subsurface pore pressures and reduce the forces tending to keep the fault stabilized.[86]

A helpful way to think of this mechanism is to imagine an air hockey table. Before the air jets are turned on, the friction between the puck and the table makes it difficult to play.[87] But once the jets are turned on, there is some pressure exerted against the puck, which decreases the frictional forces between the puck and the table and allows the puck to glide with ease.[88] This air pressure that exists between the puck and table is roughly analogous to the way scientists theorize injected saltwater acts along a fault between two opposing, critically stressed blocks of the earth's crust.[89]

In more scientific terms, seismologists theorize that, like turning on the air jets, if communication exists between the disposal formation and a critically stressed fault line, saltwater migrating downward into the fault system could increase the pore pressure along the fault, effectively decreasing the frictional forces stabilizing the fault system.[90] To modify the inequality discussed earlier, if P represents the pressure increase along the fault, the fault will slip if $\mu(\sigma - P) < \tau$.[91] As an important aside, however, scientists suggest that saltwater-induced seismicity requires the alignment of a number of operational and geologic conditions.[92]

C. Alternatives, Costs, and Financial Considerations of Saltwater Management

Currently, SWDs represent one in a range of options available to operators to deal with produced salt water.[93] For instance, an operator could employ various recycling technologies designed to reduce or eliminate the volumes of produced water that must be disposed of underground.[94] Many oilfield service companies have designed mobile units to treat produced water

86. GROUND WATER PROT. COUNCIL & INTERSTATE OIL & GAS COMPACT COMM'N, *supra* note 13, at 15; Hall, *supra* note 21, at 7-8; Ernest L. Majer et al., *Induced Seismicity Associated with Enhanced Geothermal Systems*, 36 GEOTHERMICS 185, 187–89 (2007).

87. Hall, *supra* note 21, at 5-11.

88. *Id.*

89. *Id.* at 5-16.

90. *Id.* at 5-15; COMM. ON INDUCED SEISMICITY POTENTIAL IN ENERGY TECHS. ET AL., *supra* note 25, at 46–50 ("Injection of fluid in rocks causes an increase of the pore pressure and also modifies the state of the stress. The stress change is associated with a volume expansion of the rock due to the increase of the pore pressure . . . ." (citation omitted)).

91. *See* Hall, *supra* note 21, at 5-15. As a reminder, μ represents the coefficient of friction of a given surface, σ represents the normal force tending to push the opposing blocks together, and τ represents the shear forces that tend to push the crustal blocks laterally past each other. COMM. ON INDUCED SEISMICITY POTENTIAL IN ENERGY TECHS. ET AL., *supra* note 25, at 37–38.

92. Hall, *supra* note 21, at 5-16 (including proximity to a critically stressed fault, pathway for the saltwater to migrate to the fault, sufficient increase in pore pressure, and sufficient depth of the fault).

93. *See What Are Salt Water Disposal Wells?*, BARNETT SHALE ENERGY EDUC. COUNCIL, http://www.bseec.org/what_are_saltwater_disposal_wells (last visited Apr. 6, 2016).

94. *See id.*

on-site through reverse osmosis and other processes.[95] Other companies have developed distillation techniques to separate impurities from the produced water.[96] These technologies promise to transform produced brine into pure water—available for any number of environmentally beneficial applications.[97] This would be especially helpful in drought-prone Texas, and some in the drilling industry even posit that oilfield brine could eventually be turned into drinking water.[98]

Recycling represents perhaps the ideal solution to an operator's disposal needs from an environmental standpoint, but current technology makes this alternative cost-prohibitive.[99] Testifying before the Texas House Natural Resources and House Energy Resources Committees, a representative of Devon Energy estimated that "[r]ecycling for us—it varies from area to area, again—is 50 to 75 percent more expensive than the alternatives."[100] This is because "water that comes out of the oilfields needs a good cleaning before it is reused" and can contain boron, sulfates, or even naturally occurring radioactive materials.[101] By contrast, disposing of brine in a company-operated SWD commonly results in disposal costs under $0.25 per barrel.[102] Commercial SWD operators often charge customers $0.50 to $2.50 per barrel of disposed fluid.[103] These prices depend on the local economics, geology, and disposal infrastructure, and whether SWD operators are operating at capacity.[104] Transportation costs also represent a considerable proportion of the cost of underground disposal.[105] On average, brine transportation "will cost an operator $1.00 per barrel of brine per hour of transportation time."[106] This figure depends on the number of SWDs available in an area, which can vary dramatically.[107] In the Barnett Shale for instance, "where [SWDs] are plentiful, brine transportation may only add

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95. *See* JEAN-PHILIPPE NICOT ET AL., BUREAU OF ECON. GEOLOGY, CURRENT AND PROJECTED WATER USE IN THE TEXAS MINING AND OIL AND GAS INDUSTRY 185 (2011), http://www.beg.utexas.edu/water-energy/docs/Report_TWDB-MiningWaterUse_9.pdf.

96. *Id.*

97. *See id.* at 185–86. Agricultural applications and the provision of drinking water both readily come to mind.

98. Kate Galbraith, *In Texas, Recycling Oilfield Water Has Far to Go*, TEX. TRIBUNE (Mar. 19, 2013), http://www.texastribune.org/2013/03/19/texas-recycling-oilfield-water-has-far-go/.

99. *See id.*

100. *Id.*

101. *Id.* An entire segment of the oilfield service industry has developed in recent years to help operators address saltwater disposal problems and promises to make recycling a more viable alternative. *See* NICOT ET AL., *supra* note 95. Many companies have also developed mobile, on-site water-purification systems designed to return produced water to potable quality. *See id.*

102. RICK MCCURDY, UNDERGROUND INJECTION WELLS FOR PRODUCED WATER DISPOSAL 17, http://www2.epa.gov/sites/production/files/documents/21_McCurdy_-_UIC_Disposal_508.pdf (last visited Apr. 6, 2016).

103. *Id.*

104. *Id.*

105. *Id.*

106. *Id.*

107. *Id.*

$0.50 per barrel to the cost of brine disposal."[108] But "in northern Pennsylvania, where the nearest commercial disposal well may be in Ohio or West Virginia, the cost of transportation can easily add $4.00 to $6.00 per barrel to the cost of disposal."[109]

Another alternative to subsurface disposal of produced saltwater is mixing it into a solution and using it to hydraulically fracture another well.[110] In that scenario, instead of sending the produced brine into a disposal well —which could be miles away, thus increasing trucking costs and traffic—an operator treats the saltwater for immediate reuse in another well, possibly even on site.[111]

Evaporation technologies represent another alternative.[112] Low-tech evaporating ponds are one possibility.[113] The high cost of land in an urban environment renders this option particularly unattractive in many places, such as the Barnett Shale, where the demand for brine disposal is centered in an urban area.[114] An estimated eleven square miles of land would be required to evaporate 30 million gallons of saltwater per day (roughly 715,000 barrels).[115] And while this technology is relatively simple, it also deprives anybody of the immediate beneficial use of the purified water.[116] Other evaporation-based alternatives involve the use of condensers or mobile thermal processors.[117] These technologies involve running produced water through either a mobile unit or a centralized processing facility that heats the water and promotes evaporation.[118] Once evaporated, the water can either simply "escape as vapor or be piped through a condenser and converted into

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108. *Id.*

109. *Id.*

110. *See* Jennifer Hiller, *Water Recycling Costs Coming Down in South Texas*, FUEL FIX (June 1, 2015), http://fuelfix.com/blog/2015/06/01/water-recycling-costs-coming-down-in-south-texas/.

111. *See News9's "Hot Seat"—Evaporation Technology Offers Alternative to Wastewater Injection*, CAPITOLBEATOK (June 8, 2015), http://www.capitolbeatok.com/reports/news9s-hot-seat-evaporation-technology-offers-alternative-to-wastewater-injection.

112. *See id.*

113. *See* THOMAS K. POULSON, CENTRAL ARIZONA SALINITY STUDY: STRATEGIC ALTERNATIVES FOR BRINE MANAGEMENT IN THE VALLEY OF THE SUN 5–6 (2010), http://www.usbr.gov/lc/phoenix/programs/cass/pdf/SABD.pdf.

114. *See id.* at 1.

115. *See id.* at 11. For a comparison, XTO Energy and EnerVest Operating each operate a disposal well near Azle, Texas, and are permitted to dispose of 25,000 barrels and 10,000 barrels per day, respectively. R.R. COMM'N OF TEX., *Permit to Dispose of Non-Hazardous Oil and Gas Waste by Injection Into a Porous Formation Not Productive of Oil and Gas*, Permit No. 12872 (Oil & Gas Div. Feb. 19, 2009); R.R. COMM'N OF TEX., *Permit to Dispose of Non-Hazardous Oil and Gas Waste by Injection Into a Porous Formation Not Productive of Oil and Gas*, Permit No. 12112 (Oil & Gas Div. Apr. 11, 2006).

116. POULSON, *supra* note 113, at 11. Evaporation ponds also carry heightened environmental risks of seepage into nearby groundwater resources. *See* F.G. Baker & C.M. Brendecke, *Seepage from Oilfield Brine Disposal Ponds in Utah*, 21 GROUND WATER 317 (1983), http://info.ngwa.org/gwol/pdf/831522908.PDF.

117. *See* POULSON, *supra* note 113, at 11; *News9's "Hot Seat"—Evaporation Technology Offers Alternative to Wastewater Injection*, *supra* note 111.

118. *See News9's "Hot Seat"—Evaporation Technology Offers Alternative to Wastewater Injection*, *supra* note 111.

purified water," and then be captured for further beneficial application.[119] These technologies, however, require "specialized and highly trained personnel to operate and maintain them," and consume large amounts of energy, thereby driving up costs.[120] Condensers consume from 60 to 100 kilowatts per hour for every 1,000 gallons of brine.[121] At "$0.077 per kW/hr, the cost ranges from $4,600 to $7,700 per day to process" approximately 24,000 barrels of brine.[122]

As is clear, a range of treatment and disposal technologies is available to the industry. Some options are more cost-prohibitive than others, and the appropriate solution for an operator in any given situation depends on a variety of local factors.[123] On balance, however, subsurface disposal of oilfield brine with SWDs remains the cheapest alternative for producers.[124] Until other technologies become more competitive or are otherwise incentivized by favorable tax treatment, Texas can expect to see the volumes of injected saltwater keep pace with the prolific levels of oil and gas production brought on by the Barnett Shale, the Eagle Ford Shale, and other shale plays throughout the state. This is a problem if, as some scientists suggest, these injection volumes can induce earthquakes in nearby fault systems.

III. PONYING UP FOR PLAINTIFFS EVERYWHERE: THE SMU STUDY

In April 2015, a team of researchers led by Dr. Matthew Hornbach at Southern Methodist University in Dallas published a study (SMU study) examining the causal factors behind the swarm of earthquakes beginning in November 2013 near Azle, Texas.[125] The SMU study concluded that "brine production combined with wastewater disposal represent the most likely cause of recent seismicity near Azle."[126] Responding to the study three days after its publication, the RRC summoned the operators of two SWDs to a show-cause hearing to demonstrate that their SWDs had not caused the earthquakes.[127] After examining the operators' evidence alongside the study,

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119. *See id.*

120. POULSON, *supra* note 113, at 11.

121. *Id.* at 12.

122. *Id.*

123. *See* Galbraith, *supra* note 98.

124. *See* MCCURDY, *supra* note 102.

125. Hornbach et al., *supra* note 13, at 2. Azle is a community about fourteen miles northwest of Fort Worth with a population of roughly 11,000. *History*, CITY OF AZLE, http://www.cityofazle.org/index.aspx?NID=394 (last visited Apr. 6, 2016).

126. Hornbach et al., *supra* note 13, at 1.

127. *EnerVest Hearing*, *supra* note 23; R.R. COMM'N OF TEX., *Hearing to Consider Whether Operation of the XTO Energy, Inc., West Lake SWD, Well No. 1, in the Newark East (Barnett Shale) Field, is Causing or Contributing to Seismic Activity*, Docket No. 09-0296411 (Oil & Gas Div. Aug. 31, 2015) (proposal for decision) [hereinafter *XTO Hearing*], http://www.rrc.state.tx.us/media/31023/09-96411-sho-pfd.pdf.

the RRC determined that the SWDs did not contribute to the Azle-area seismicity.[128] What follows is a discussion of the pertinent details of the SMU study and the RRC's decisions.

In addition to brine production and subsurface saltwater disposal, the SMU study considered the possibility that the natural shift of Earth's tectonic plates and stress changes brought on by water table fluctuations were responsible for the Azle-area seismicity.[129] Recalling the earlier discussion, when the tensional forces along a fault suddenly exceed the frictional forces tending to keep the fault stabilized, an earthquake occurs.[130] Stress changes may occur in at least three different ways: the natural shifting of Earth's tectonic plates, the fluctuation of the water table, or the removal and injection of subsurface fluids.[131] The study considered each of these regional phenomena to understand the role each might have played in the earthquakes that occurred in the Azle area beginning in November 2013.[132]

Considering the natural shift of tectonic plates, the study noted that the surface overlying the geologic zone where the Azle earthquakes occurred—the Fort Worth basin—has been permanently settled for roughly 150 years.[133] Over that entire period of time, prior to 2010, not a single earthquake had been recorded or felt in the Azle area, and only one earthquake had ever been recorded in the entire Fort Worth Basin.[134] The study cited a lack of evidence of any significant faulting in the region and concluded that natural tectonic stress changes were an unlikely cause of seismicity in the area.[135]

The study examined water level variations as a potential causal factor in the Azle earthquake swarm.[136] Eagle Mountain Lake is a large reservoir roughly three miles east of the earthquakes' epicenters.[137] Between April 2012 and November 2013, drought conditions caused the lake level to drop by 2.1 meters.[138] This drop reduced the stress on the Ellenburger formation—the injection formation of the two subject SWDs—by roughly 0.09 psi.[139] After noting that this pressure change is "one to three orders of magnitude smaller than typical stress changes associated with triggered seismicity," the study concluded, "It is therefore difficult to attribute recent seismicity in Azle to lake level change."[140] The study also noted that the freshwater aquifer

128. *EnerVest Hearing*, *supra* note 23, at 32; *XTO Hearing*, *supra* note 127, at 30.

129. Hornbach et al., *supra* note 13, at 2.

130. COMM. ON INDUCED SEISMICITY POTENTIAL IN ENERGY TECHS. ET AL., *supra* note 25, at 37–38.

131. Hornbach et al., *supra* note 13, at 2.

132. *Id.*

133. *Id.* at 5.

134. *Id.*

135. *Id.*

136. *Id.* at 1.

137. *Id.* at 5.

138. *Id.* The earthquakes began occurring in November 2013. *Id.* at 1.

139. *Id.* at 3. The Ellenburger is a highly permeable limestone formation. *Id.*

140. *Id.* at 5.

overlying the epicenters—the Trinity Aquifer—has remained relatively unchanged over the last six to eight years.[141] Accordingly, water table fluctuations were also unlikely causal candidates.[142]

However, in its analysis of oil and gas activity, the study concluded that local brine removal and injection was the most likely causal candidate for the Azle earthquakes.[143] To make this assessment, the study utilized completion, production, and disposal records of the two SWDs and seventy gas-producing wells—all within 6.2 miles of the earthquake sequence and a fault line traversing the SWD disposal formation, the Ellenburger limestone.[144] With this information, the study modeled the pressure change along the fault resulting from oil and gas activity.[145] The study explained that the modeled pressure increases along the fault were "consistent with values that are known to trigger earthquakes on critically stressed faults."[146] Recalling the earlier analogy to an air hockey table, the injected brine appeared to exert pressure between the opposing faults—like the air pressure between the puck and the table—promoting slippage.[147]

Of course, this is unhelpful if the pressure increases do not correlate in time with the November 2013 earthquakes.[148] Based on permeability values, the study noted a three-month delay between an increase in injection volumes and a rise in modeled fault pressure.[149] In other words, it took one to three months for injected fluids to permeate the disposal formation and cause the formation pressure to rise—the hypothesized cause of the earthquakes.[150] Injection activity accelerated at one SWD in the summer and fall of 2013.[151] The earthquakes began in November 2013.[152]

For all of its modeling, the study noted a host of uncertainties.[153] The authors conceded that the points of rupture for many of the initial earthquakes were unknown.[154] Of those that were known, the study explained that some

141. *Id.* at 3.

142. *Id.*

143. *Id.* at 1.

144. *Id.* at 5. The gas producing wells were relevant to understanding pressure changes along the fault because of the large volume of saltwater produced as a waste byproduct of the gas production—sometimes approaching 5,000 barrels of saltwater per month. *Id.* As fluids are removed from a rock formation, the pressure in the formation decreases. *See* HYNE, *supra* note 27, at 432, 435. The study also notes that the earthquake swarms "occur almost directly below the estimated subsurface location of two large brine production wells [(i.e., gas wells)] in the region." Hornbach et al., *supra* note 13, at 7.

145. Hornbach et al., *supra* note 13, at 5.

146. *Id.* at 6.

147. *See supra* notes 87–89 and accompanying text.

148. *See* Hornbach et al., *supra* note 13, at 4, 6 (graphing injection volumes along with fault pressure changes and earthquake activity).

149. *Id.* at 4.

150. *Id.* at 6.

151. *Id.* at 4.

152. *Id.* at 6.

153. *Id.* at 7–10.

154. *Id.* at 7.

were located in the granite basement formation—well over 10,000 feet beneath the Ellenburger disposal formation.[155] There were also uncertainties about the permeability of the granite basement, which would need to be explored to establish a mechanical link between the initial ruptures and the shallower injection zone nearly two miles closer to the surface.[156] The study also indicated uncertainties regarding other modeling issues, permeability values, brine production data, pressure readings, regional geology, and stress magnitudes.[157]

Nonetheless, in direct response to the study, the RRC summoned the operators of the two subject SWDs, EnerVest Operating, LLC and XTO Energy, Inc., to show-cause hearings to determine whether the operators' injection was causing or contributing to seismic activity.[158] At the EnerVest hearing, the examiners noted the parties' agreement that the initial November 2013 earthquakes occurred in the basement granite formation—below the Ellenburger formation where the SWDs were completed.[159] To demonstrate a causal link between injection activity and an earthquake originating in the basement granite, a mechanical link must exist between the injection activity and the earthquake's hypocenter.[160] Crucially, the study only modeled pressure changes in the disposal formation—not the basement granite where initial earthquakes occurred.[161] The hearings examiners noted the SMU study's conjecture that the deeper earthquakes were due to a downward pressure transfer in the fault system.[162] But according to the hearing examiners, "this hypothesis was not explored."[163] Accordingly, the examiners found that there was "no evidence in the record establishing the operation of a mechanical system capable of transferring energy from the injection well . . . to the location of initial rupture."[164]

The examiners did note that the evidence, "albeit thin," supported a temporal link between increased injection activity and seismic events.[165] They observed that, based on estimated permeability values, while

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155. *Id.* at 3.

156. *Id.* at 7.

157. *Id.* at 7–11.

158. *EnerVest Hearing*, *supra* note 23, at 2; *XTO Hearing*, *supra* note 127, at 2. Under Texas administrative law, an affirmative answer permits the RRC to modify, suspend, or terminate a SWD operator's well permit. 16 TEX. ADMIN. CODE § 3.9(6)(a)(vi) (2015).

159. *EnerVest Hearing*, *supra* note 23, at 24.

160. *Id.* at 25. An earthquake's hypocenter is the subsurface location where the rupture starts. *Earthquake Glossary—Hypocenter*, U.S. GEOLOGICAL SURV., http://earthquake.usgs.gov/learn/glossary/?term=hypocenter (last modified July 18, 2012, 6:52 PM). The epicenter, by contrast, "is the point directly above it at the surface." *Id.*

161. *XTO Hearing*, *supra* note 127, at 26; *see also* Hornbach et al., *supra* note 13, at 7 ("For simplicity, the model assesses pressure only in the Ellenburger formation where several earthquakes were recorded.").

162. Hornbach et al., *supra* note 13, at 7.

163. *XTO Hearing*, *supra* note 127, at 26.

164. *Id.*

165. *EnerVest Hearing*, *supra* note 23, at 27.

the initial hypocenters were 10,000 feet below the Ellenburger fault, the one- to three-month gap between injection increases and seismic activity was consistent with the possibility that a mechanical link existed between the injection zone and the initial hypocenters.[166]

On balance, the examiners concluded that the SMU study was a useful initial look at the possible link between SWDs and induced seismicity.[167] However, the paucity of seismic and geologic data prevented the examiners from reaching the conclusion that either of the SWDs were likely contributing to seismic activity.[168]

IV. THEORIES OF LIABILITY AND DEFENSES

Because the induced seismicity issue is relatively new to the public consciousness, courts will have to flesh out the cases through imperfect analogies to dissimilar fact patterns. Texas plaintiffs seeking judgments against SWD operators do so in a context of a historically extensive body of common law causes of action against the oil and gas industry.[169] This Part seeks analogues between current tort cases and the facts likely to develop in a case alleging induced seismicity.

A. Nuisance

Few causes of action seem as broadly applicable to any number of fact patterns as nuisance.[170] Nuisance is best understood as an invasion of a certain kind of legally protected interest, rather than as a specific sort of conduct.[171] In Texas, "nuisance is a condition that substantially interferes with the use and enjoyment of land by causing unreasonable discomfort or annoyance to persons of ordinary sensibilities."[172] Broadly speaking, there are two types of nuisance.[173] Private nuisance refers to an invasion of a protected interest held by an individual or a small number of people, while

166. *Id.*

167. *Id.* at 30.

168. *Id.*

169. *See* Coastal Oil & Gas Corp. v. Garza Energy Tr., 268 S.W.3d 1, 4 (Tex. 2008) (trespass); Cerny v. Marathon Oil Corp., No. 04-14-00650-CV, 2015 WL 5852596, at *1 (Tex. App.—San Antonio Oct. 7, 2015, pet. filed) (private nuisance and negligence); *In re* Apache Corp., 61 S.W.3d 432, 433 (Tex. App.—Amarillo 2001, no pet.) (strict liability, negligence per se, and intentional infliction of emotional distress).

170. *See* William L. Prosser, *Nuisance Without Fault*, 20 TEX. L. REV. 399, 410–12 (1942) (describing nuisance claims involving alarming advertisements; cockroaches baked into pies; hogpens; lotteries; the pollution of waterways; houses of prostitution; cases of dust, smoke, or vibration; and obstruction of highways or waterways).

171. *See* City of Tyler v. Likes, 962 S.W.2d 489, 503 (Tex. 1997) ("Courts have broken actionable nuisance into three classifications: negligent invasion of another's interests; intentional invasion of another's interests; or other conduct, culpable because abnormal and out of place in its surroundings, that invades another's interests.").

172. Barnes v. Mathis, 353 S.W.3d 760, 763 (Tex. 2011).

173. *See* Walker v. Tex. Elec. Serv. Co., 499 S.W.2d 20, 27 (Tex. App.—Fort Worth 1973, no writ).

public nuisance refers generally to an invasion of rights held by the public at large.[174] "The difference does not consist in any difference in the nature or quality of the thing itself, but in the parties affected."[175] Texas courts have long applied the law of nuisance to oilfield fact patterns.[176] In fact, nuisance is commonly a preferred theory because it is an intentional tort, meaning that a plaintiff need not demonstrate the defendant's negligence.[177] A nuisance may occur despite the tortfeasor's utmost care.[178] This subsection focuses on private nuisance, however, because in general, private citizens lack standing to sue on a public nuisance claim.[179]

Texas courts have identified four broad elements of private nuisance.[180] First, a plaintiff must demonstrate a private interest in land.[181] Past owners, current owners, and lawful occupants all enjoy qualifying interests in this regard.[182] Their ownership might be legal or equitable title, and could include either an owner or an occupant.[183] In the context of an induced seismicity lawsuit, any person with an interest in the property where the earthquake causes damage will easily show the first element.[184]

Second, the plaintiff must demonstrate the defendant's interference with that interest.[185] This interference must be either (1) intentional and unreasonable, (2) negligent, or (3) the result of abnormally dangerous or

174. *Id.*

175. *Id.*

176. *See, e.g.*, Cerny v. Marathon Oil Corp., No. 04-014-00650-CV, 2015 WL 5852596, at *1, *8 (Tex. App.—San Antonio Oct. 7, 2015, pet. filed) (denying nuisance claim when legally insufficient evidence existed to support the claim that the oil company's facilities were causing noxious odors); Cook v. Exxon Corp., 145 S.W.3d 776, 778, 785–86 (Tex. App.—Texarkana 2004, no pet.) (denying nuisance claim when oilfield equipment was abandoned on a lease before plaintiff acquired the surface); Hicks v. Humble Oil & Ref. Co., 970 S.W.2d 90, 92, 97 (Tex. App.—Houston [14th Dist.] 1998, pet. denied) (denying nuisance claim against oil company that stored oil in unlined earthen pits); Domengeaux v. Kirkwood & Co., 297 S.W.2d 748, 749–50 (Tex. Civ. App.—San Antonio 1956, no writ) (denying nuisance claim against operator drilling a well sixty feet from the plaintiff's property line).

177. *See* Manchester Terminal Corp. v. Tex. TX Marine Transp., Inc., 781 S.W.2d 646, 651 (Tex. App.—Houston [1st Dist.] 1989, writ denied).

178. *Id.*

179. Garland Grain Co. v. D-C Home Owners Improvement Ass'n, 393 S.W.2d 635, 640 (Tex. Civ. App.—Tyler 1965, writ ref'd n.r.e.).

180. *See* City of Tyler v. Likes, 962 S.W.2d 489, 503–04 (Tex. 1997); Salazar v. Sanders, 440 S.W.3d 863 (Tex. App.—El Paso 2013, pet. denied); Mathis v. Barnes, 316 S.W.3d 795, 801 (Tex. App.—Tyler 2010), *rev'd in part on other grounds*, 353 S.W.3d 760 (Tex. 2011); Hot Rod Hill Motor Park v. Triolo, 293 S.W.3d 788, 790 (Tex. App.—Waco 2009, pet. denied).

181. *Likes*, 962 S.W.2d at 503 ("Courts have broken actionable nuisance into three classifications . . . ."); *Hot Rod Hill Motor Park*, 293 S.W.3d at 790 ("Actionable nuisance involves an invasion of another's interests.").

182. *See* Schneider Nat'l Carriers, Inc. v. Bates, 147 S.W.3d 264, 268 n.2 (Tex. 2004) (holding that tenants may sue for private nuisance); Vann v. Bowie Sewerage Co., 90 S.W.2d 561, 562–63 (Tex. 1936) (past owners); Ft. Worth & Rio Grande Ry. Co. v. Glenn, 80 S.W. 992, 993–94 (Tex. 1904) (holding that a plaintiff may sue for private nuisance if the plaintiff owned the land when the nuisance occurred); Lay v. Aetna Ins. Co., 599 S.W.2d 684, 686 (Tex. Civ. App.—Austin 1980, writ ref'd n.r.e.) (current owner).

183. *See Glenn*, 80 S.W. at 993–94.

184. *See Hot Rod Hill Motor Park*, 293 S.W.3d at 790.

185. *Likes*, 962 S.W.2d at 503–04.

out-of-place conduct.[186] Whether the interference is intentional and unreasonable will involve a fact-intensive inquiry.[187] An intentional interference occurs when either (1) the defendant acts with the object or purpose of causing the interference, or (2) the defendant knows with substantial certainty that the interference is or will result from his or her conduct.[188] On this point, while it seems clear that no SWD operator trying to make a living would set out to induce earthquakes in the community it works in, scientific evidence demonstrating an increased chance of earthquakes surrounding a critically stressed fault, coupled with a SWD, would tend to show knowledge with substantial certainty. The problem, however, is the current lack of seismic data surrounding SWD operations.[189] To that end, in 2015, Governor Abbott approved legislation authorizing $4.47 million to create an enhanced statewide seismic monitoring network, known as the TexNet Seismic Monitoring Program.[190] The program will increase the number of state seismometers from the sixteen currently in place to seventy-four.[191] In turn, this will permit seismologists working with the Bureau of Economic Geology at The University of Texas at Austin to better understand Texas earthquakes, their causes, and the potential impact of human activity on seismic events.[192] This enhanced understanding of the causal forces behind Texas earthquakes could bear directly on whether an SWD operator knows that seismic activity is "resulting or substantially certain to result from his conduct."[193]

As an alternative to showing that the SWD operator's conduct was intentional and unreasonable, the plaintiff could demonstrate that the conduct was negligent.[194] The obvious downside to this track, however, is having to demonstrate the elements of negligence—duty, breach, and proximate cause—as only a component of the plaintiff's broader nuisance claim.[195] Recent rule amendments by the RRC require SWD operators to disclose the locations of any historical earthquake activity surrounding a proposed

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186. *Id.*

187. RESTATEMENT (SECOND) OF TORTS § 822(a) cmt. c (AM. LAW INST. 1979) ("A person is subject to liability for an intentional invasion when his conduct is unreasonable under the circumstances of the particular case . . . .").

188. City of Princeton v. Abbott, 792 S.W.2d 161, 166 (Tex. App.—Dallas 1990, writ denied).

189. *See Seeking Earthquake Answers, TexNet Seismic Monitoring Program Authorized by the State of Texas*, UT NEWS (June 22, 2015), http://news.utexas.edu/2015/06/22/texnet-seismic-monitoring-program-authorized-by-state.

190. *Id.*

191. *Id.*

192. *Id.*

193. *Abbott*, 792 S.W.2d at 166.

194. *See* Sage v. Wong, 720 S.W.2d 882, 885 (Tex. App.—Fort Worth 1986, writ ref'd n.r.e.) ("Although not all nuisances are grounded on negligence, where negligence has created or contributed to the creation of a nuisance, such negligence should be alleged.").

195. *See id.*

SWD.[196] Evidence that an operator failed to make such a disclosure might constitute negligence, although because this is a permit condition, this scenario is relatively unlikely. Fitting an induced seismicity case into a negligence claim is discussed below.[197]

As a final alternative for demonstrating the culpable nature of the SWD operator's conduct, a plaintiff could attempt to show that the SWD operation itself is "abnormal and out of place in its surroundings."[198] Far from the earth-shattering consequences of a violent earthquake, Texas courts have held many (seemingly less onerous) interferences as "abnormal or out of place."[199] But especially in areas with a high number of SWDs, a plaintiff will probably have difficulty demonstrating that a SWD operator's activity is abnormal and out of place.[200] For instance, in Texas alone there are over 8,100 SWDs.[201] Many of these are concentrated in North Texas, where the recent spate of earthquakes occurred.[202] In fact, the swarm occurring near Azle, Texas, was the subject of the recent study conducted by the team of SMU seismologists.[203] Because of the proliferation of SWDs, especially in urban areas, rural plaintiffs would have difficulty demonstrating that a particular SWD is out of place.[204]

Third, the defendant's conduct must result in a substantial interference with the plaintiff's use or enjoyment of the land.[205] An injury characterized more accurately as a minor annoyance or speculative possibility will not amount to a nuisance.[206] The interference must be one that causes "unreasonable discomfort or annoyance to persons of ordinary

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196. *Attachments for New Injection/Disposal Wells*, *supra* note 67; *see* 16 TEX. ADMIN. CODE § 3.9 (2015).

197. *Infra* Part IV.B.

198. Salazar v. Sanders, 440 S.W.3d 863, 870 (Tex. App.—El Paso 2013, pet. denied).

199. *See* City of Tyler v. Likes, 962 S.W.2d 489, 493 (Tex. 1997); *see, e.g.*, Hill v. Villarreal, 362 S.W.2d 348, 349 (Tex. Civ. App.—Waco 1962, writ ref'd n.r.e.) (offensive odors emanating from a rendering plant surrounded by homes and located within the San Antonio city limits); Econ. Furniture, Inc. v. Jirasek, 345 S.W.2d 951, 957 (Tex. Civ. App.—Austin 1961, writ ref'd n.r.e.) (sawdust, ash, and fumes emitted by an industrial incinerator located 1,600 feet from plaintiff's home); Columbian Carbon Co. v. Tholen, 199 S.W.2d 825, 828 (Tex. Civ. App.—Galveston 1947, writ ref'd) (carbon soot); City of Temple v. Mitchell, 180 S.W.2d 959, 961–62 (Tex. Civ. App.—Austin 1944, no writ) (sewage odors emanating from a treatment plant located 2,700 feet from plaintiff's farm home).

200. *See Likes*, 962 S.W.2d at 503–04.

201. *Injection and Disposal Wells*, *supra* note 59.

202. *See generally* Hornbach et al., *supra* note 13, at 1.

203. *Id.*

204. *See* Vill. of Euclid v. Ambler Realty Co., 272 U.S. 365, 388 (1926) (describing a nuisance as the "right thing in the wrong place, like a pig in the parlor instead of the barnyard").

205. Barnes v. Mathis, 353 S.W.3d 760, 763 (Tex. 2011).

206. *See, e.g.*, Aguilar v. Trujillo, 162 S.W.3d 839, 854 (Tex. App.—El Paso 2005, pet. denied) (explaining that the mere possibility that defendant's manure-based fertilizer might percolate into plaintiff's groundwater did not substantially interfere with plaintiff's use and enjoyment); *see also* RESTATEMENT (SECOND) OF TORTS § 821F cmt. c (AM. LAW INST. 1979) ("The law does not concern itself with trifles, and therefore there must be a real and appreciable invasion of the plaintiff's interests before he can have an action for either a public or a private nuisance.").

sensibilities."[207] Much of what occurs in the SWD business—and indeed the oil and gas business in general—necessarily *requires* subsurface disturbances and pressure changes.[208] Intentionally creating thousands of micro-seismic events is the very purpose of hydraulic fracturing.[209] These events are not typically felt at the surface and would not rise to the level of a substantial interference.[210] Further, the U.S. Geological Survey estimates that millions of earthquakes with a magnitude of less than 3.0 occur naturally each year, almost none of which are felt at the surface.[211] Assuming a plaintiff can overcome what probably will become his heaviest burden—causation—any resulting seismic activity must substantially interfere with the plaintiff's use and enjoyment of his or her property to justify a nuisance claim.[212] But the story of Sandra Ladra, coupled with the research at SMU, at least suggests the possibility that SWD operations can cause potentially devastating harm.[213]

Finally, and perhaps most crucially in the induced seismicity context, the plaintiff must demonstrate causation.[214] The plaintiff must show that the defendant's conduct has caused some injury, either to the plaintiff personally or to the plaintiff's property.[215] Texas courts have recognized nuisances resulting from harm to the property in a number of contexts.[216] Alternatively, if the injury is to the plaintiff personally, it may result from either physical harm or "emotional harm to a person from the deprivation of the enjoyment of his property through fear, apprehension, or loss of peace of mind."[217]

Of these four elements—private interest in land, culpable interference with that interest, substantial interference, and causation—causation will

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207. *Barnes*, 353 S.W.3d at 763.

208. TEX. DEP'T OF WATER RES., *supra* note 30, at 18 (describing a subsurface pressure change analysis for SWD operations).

209. *See* HYNE, *supra* note 27, at 471–72 (describing the process of hydraulic fracturing).

210. *See* RESTATEMENT (SECOND) OF TORTS § 821F cmt. c.

211. *Earthquake Facts and Statistics*, *supra* note 57.

212. *See generally* City of Tyler v. Likes, 962 S.W.2d 489, 503–04 (Tex. 1997).

213. *See* Ladra v. New Dominion, LLC, 353 P.3d 529, 530 (Okla. 2015); Hornbach et al., *supra* note 13, at 1–7; Walsh III & Zoback, *supra* note 13 (explaining in detail the seismological and geophysical causal mechanisms); Bustillo & Gilbert, *supra* note 2.

214. *See* Holubec v. Brandenberger, 111 S.W.3d 32, 37 (Tex. 2003); *see also* Walton v. Phillips Petroleum Co., 65 S.W.3d 262, 270 (Tex. App.—El Paso 2001, pet. denied) (noting that a nuisance may result from harm caused to the property or to the person), *abrogated by In re* Estate of Swanson, 130 S.W.3d 144 (Tex. App.—El Paso 2003, no pet.).

215. *Holubec*, 111 S.W.3d at 37.

216. *See, e.g.*, Baker v. City of Fort Worth, 210 S.W.2d 564, 565 (Tex. 1948) (discussing the damage to plaintiff's equipment and merchandise resulting from the city's diversion of floodwater); Manchester Terminal Corp. v. Tex. TX TX Marine Transp., Inc., 781 S.W.2d 646, 648 (Tex. App.—Houston [1st Dist.] 1989, writ denied) (explaining that large amounts of petroleum coke dust from defendant's business settled on the plaintiff's business, severely hampering the desirability of plaintiff's land).

217. Aguilar v. Trujillo, 162 S.W.3d 839, 850 (Tex. App.—El Paso 2005, pet. denied); *see, e.g.*, Bay Petroleum Corp. v. Crumpler, 372 S.W.2d 318, 318 (Tex. 1963) (explaining that noxious fumes escaping from a subsurface natural gas storage formation caused discomfort and injury to plaintiffs).

almost certainly be the heaviest burden for a plaintiff.[218] In what appears to be the most comprehensive look to date at the seismic effects of SWDs on Texas earthquakes, the researchers at SMU came up short.[219] Having to demonstrate which one of a range of SWDs caused a particular earthquake only further obfuscates the plaintiff's mission.[220] If six SWD operators, for instance, all maintain wells within a short distance of an earthquake's epicenter, a plaintiff will be hard-pressed to show by a preponderance of the evidence which operator caused the earthquake.[221]

Assuming, however, that a plaintiff makes all these showings, the issue of damages remains. In Texas, the measure of damages to real property in a nuisance action depends on whether the nuisance is permanent or temporary.[222] Plaintiffs may collect special damages flowing from a temporary nuisance (e.g., repair costs); diminution in market value is available against permanent nuisances.[223] A nuisance is permanent if a party can evaluate its impact on the market value of the real property in question.[224] If the nature of the interference is repeated, continual, and regular, the damage is probably permanent.[225] Likewise, the likelihood that the interference will continue in the future also tends to show a permanent nuisance.[226] Interferences that are only occasional, irregular, or intermittent amount to temporary nuisances.[227]

While earthquakes do tend to occur in swarms, their unpredictable nature seems to cut in favor of a temporary nuisance.[228] The largest earthquakes started and stopped within a period of about ninety days between November 2013 and January 2014.[229] Without an accurate way to forecast the continued occurrence of seismic activity, a plaintiff will be limited to collecting damages proximately caused by the nuisance.[230] In the induced

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218. Interview with Professor William Keffer, Oil and Gas Law Professor, Tex. Tech Univ. Sch. of Law, in Lubbock, Tex. (Sept. 17, 2015); *see also infra* notes 265–92 and accompanying text (expanding on the intricacies behind proving causation and discussing the courts' development of joint and several liability and joint enterprise liability).

219. *See* Hornbach et al., *supra* note 13, at 7–11.

220. *See* ZYGMUNT J.B. PLATER ET AL., ENVIRONMENTAL LAW AND POLICY: NATURE, LAW, AND SOCIETY 102 (Vicki Been et al. eds., 4th ed. 2010) (discussing the common problem of demonstrating causation in environmental cases involving multiple defendants).

221. *Id.*

222. Nat. Gas Pipeline Co. of Am. v. Justiss, 397 S.W.3d 150, 155 (Tex. 2012).

223. *Id.*; Schneider Nat'l Carriers, Inc. v. Bates, 147 S.W.3d 264, 276 (Tex. 2004).

224. *See* Gilbert Wheeler, Inc. v. Enbridge Pipelines (E. Tex.), L.P., 449 S.W.3d 474, 480 (Tex. 2014).

225. *Id.*

226. *Bates*, 147 S.W.3d at 276–77.

227. *Gilbert Wheeler, Inc.*, 449 S.W.3d at 480.

228. Robert J. Geller, *Earthquake Prediction: Is This Debate Necessary?*, NATURE.COM (Feb. 25, 1999), http://www.nature.com/nature/debates/earthquake/equake_1.html.

229. *See* Hornbach et al., *supra* note 13, at 6.

230. *See Bates*, 147 S.W.3d at 276.

seismicity context, that would include the cost of repairing any structural damage to buildings or lost rent.[231]

B. Negligence

For well over 150 years, Texas courts have dealt with negligence cases.[232] And, as recently expressed by the Supreme Court of Texas, there are three elements of negligence.[233] First, the plaintiff must demonstrate a legal duty owed by the defendant to the plaintiff.[234] Without a legally recognized duty, there is no negligence.[235] This duty can arise by operation of a statute or common law.[236] If the plaintiff establishes a statutory basis for the duty, negligence per se is the appropriate theory, discussed *infra*.[237] Alternatively, common law duties involve a variation of the risk–utility test.[238] Courts weigh the "risk, foreseeability, and likelihood of injury . . . against the social utility of the actor's conduct, the magnitude of the burden of guarding against the injury, and the consequences of placing the burden on the defendant."[239] In balancing these interrelated factors, the Texas Supreme Court has emphasized that "[w]hile foreseeability of the risk 'is the foremost and dominant consideration,' . . . 'foreseeability alone is not sufficient to justify the imposition of a duty.'"[240]

In the induced seismicity context, the growing body of research and the headlines of many newspapers at least suggest the possibility that SWDs pose a risk of seismic activity.[241] And, as an understanding of a given SWD's local

231. *See* C.C. Carlton Indus., Ltd. v. Blanchard, 311 S.W.3d 654, 663 (Tex. App.—Austin 2010, no pet.). Personal injury damages are also recoverable. Vann v. Bowie Sewerage Co., 90 S.W.2d 561, 563 (Tex. 1936).

232. *See* Walker v. Herron, 22 Tex. 55, 55 (1858) (involving alleged negligence when defendant let his diseased horses into the range where plaintiff kept his own healthy herd—infecting the plaintiff's herd). This case also appears to be the oldest case in the Texas Reports directly involving negligence. *But see* Fowler V. Harper, *Malicious Prosecution, False Imprisonment and Defamation*, 15 TEX. L. REV. 157, 157 n.3 (1937) (noting the "tardy ripening of the idea of negligence as a source of liability" as compared to contract law and suggesting that negligence, as a cause of action, only coalesced in American courts in the mid to late 19th century).

233. D. Houst., Inc. v. Love, 92 S.W.3d 450, 454 (Tex. 2002).

234. *Id.*

235. Sw. Elec. Power Co. v. Grant, 73 S.W.3d 211, 224 (Tex. 2002) (Enoch, J., concurring).

236. *See, e.g.*, Nabors Drilling, U.S.A., Inc. v. Escoto, 288 S.W.3d 401, 410 (Tex. 2009) (common law duty); Parrott v. Garcia, 436 S.W.2d 897, 899 (Tex. 1969) (statutory basis of duty); *see also* United States v. Carroll Towing Co., 159 F.2d 169, 173 (2d Cir. 1947) (discussing Judge Learned Hand's classic formulation of the negligence balancing test, in which a duty exists if the seriousness of the perceived harm and the probability of it occurring outweigh the burden of taking adequate precautions).

237. *See* E. Tex. Motor Freight Lines v. Loftis, 223 S.W.2d 613, 615 (Tex. 1949); *infra* Part IV.C.

238. Greater Houst. Transp. Co. v. Phillips, 801 S.W.2d 523, 525 (Tex. 1990).

239. *Id.*; *see Nabors Drilling*, 288 S.W.3d at 405.

240. City of Waco v. Kirwan, 298 S.W.3d 618, 624 (Tex. 2009) (quoting *Greater Houst. Transp. Co.*, 801 S.W.2d at 525 and Golden Spread Council, Inc. v. Akins, 926 S.W.2d 287, 290–91 (Tex. 1996)).

241. *See, e.g.*, COMM. ON INDUCED SEISMICITY POTENTIAL IN ENERGY TECHS. ET AL., *supra* note 25, at 1 ("Injection for disposal of wastewater derived from energy technologies into the subsurface does pose some risk for induced seismicity, but very few events have been documented over the past several decades

geology increases, the foreseeable risk that an SWD will trigger seismic activity will also increase—assuming a causal mechanism.[242] An earthquake is a function of the various forces involved along a fault line.[243] Assuming all else is equal, as the number of faults in and under disposal formations increases, the likelihood or foreseeability of an induced earthquake should rise correspondingly.[244] Oil and gas companies can create detailed maps of the subsurface using 3D and 4D imaging technology, and developing an understanding of regional fault systems often drives the exploration process of oil and gas reservoirs.[245]

On the other hand, although oil and gas companies are adept at mapping faults, little is known about the forces that exist along those faults until a company actually drills a well.[246] This is key because although Earth's subsurface is riddled with fault systems, it is the forces involved in those systems that drive earthquake activity.[247] One fault may be critically stressed, while another might be relatively stable—a low earthquake risk.[248] But this measurement is difficult to make with any accuracy before drilling.[249] Therefore, foreseeability and likelihood of risk will involve a high degree of uncertainty in these cases.

On the other side of the risk–utility balance, the importance of SWDs to the Texas economy, and especially to Texas's oil and gas industry, is high. Currently, SWDs represent the cheapest alternative available for the disposal of billions of barrels of subterranean saltwater, which is produced concurrently as a waste by-product with oil and gas.[250] With nowhere to economically dispose of the estimated ten barrels of salt water for every produced barrel of crude, the Texas oil and gas industry would quickly face major problems.[251] The increased costs of saltwater management would

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relative to the large number of disposal wells in operation."); Hornbach et al., *supra* note 13, at 2; Bustillo & Gilbert, *supra* note 2; Jim Fuquay, *Injection Wells Seen as Possible Cause of Earthquakes*, FORT WORTH STAR-TELEGRAM (Jan. 10, 2014, 4:01 PM), http://www.star-telegram.com/news/business/article3842249.html.

242. *See* Hornback et al., *supra* note 13, at 7 (describing the need for additional geologic data to create more reliable seismic models).

243. COMM. ON INDUCED SEISMICITY POTENTIAL IN ENERGY TECHS. ET AL., *supra* note 25, at 40.

244. *See supra* Part III.

245. *See* HYNE, *supra* note 27, at 232–34.

246. *See* COMM. ON INDUCED SEISMICITY POTENTIAL IN ENERGY TECHS. ET AL., *supra* note 25, at 38–39 ("Although the conditions for initiating slip on a preexisting fault are well understood, the difficulty remains to make reliable estimates of the various quantities in the Coulomb criterion [$(\mu(\sigma - P))$]. Lacking these estimates, predicting how close or how far the fault system is from instability remains difficult, even if the orientation of the fault is known.").

247. *See supra* notes 90–92 and accompanying text.

248. *See* COMM. ON INDUCED SEISMICITY POTENTIAL IN ENERGY TECHS. ET AL., *supra* note 25, at 38–39.

249. *See id.*

250. *See* MCCURDY, *supra* note 102.

251. *See Oil and Gas Waste Disposal*, *supra* note 9; *Texas Monthly Oil & Gas Production*, *supra* note 11.

punish oil and gas companies at the margins.[252] Operators might cut back on production, which would lead to lower royalty checks for lessors and less tax revenue for state and local governments.

Given the high degree of uncertainty involved with individual SWDs and their relationship to local earthquakes, along with the importance of easy access to cheap saltwater management systems, it does not seem likely that a court would recognize any radically new duty for SWD operators over and above acting as a reasonable prudent operator.[253] However, as our geological and geophysical understanding of Texas earthquakes develops further, this analysis may change.[254]

In addition to showing a legally recognized duty, a plaintiff must show a breach of that duty.[255] This issue is ordinarily a question for the jury.[256] It involves an inquiry into the appropriate standard of care.[257] For instance, the standard of ordinary care "is generally defined as that which an ordinarily prudent person, exercising ordinary care would have done under the same circumstances."[258] In other scenarios, courts hold a defendant to a higher degree of care depending on the facts and circumstances of the case. Common carriers, handlers of explosive or dangerous materials, and pharmacists, for instance, have all been held to a higher standard of care.[259] The rationale for these higher standards has to do with consumer expectations, safety concerns, and the nature of the particular defendant's line of work.[260] In the case of pharmacists, it is not difficult to imagine the "danger flowing from the substitution of deadly poisons for harmless medicines."[261] And with regard to handlers of dangerous or explosive "commodities, the law exacts a duty to protect the public which is proportionate to and commensurate with the dangers involved."[262]

Plaintiffs will argue that, like handlers of explosives, SWD operators—whose activities are believed to trigger earthquake activity—should similarly

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252. *See* CITY OF FORT WORTH, *supra* note 12.

253. *See XTO Hearing*, *supra* note 127, at 27–28.

254. *See id.* at 27.

255. D. Houst., Inc. v. Love, 92 S.W.3d 450, 454 (Tex. 2002).

256. Caldwell v. Curioni, 125 S.W.3d 784, 793 (Tex. App.—Dallas 2004, pet. denied).

257. *See* Harris v. Ebby Halliday Real Estate, Inc., 345 S.W.3d 756, 759 (Tex. App.—El Paso 2011, no pet.) ("Whether or not a breach has occurred is determined by comparison to the applicable standard of care.").

258. *Id.*

259. Speed Boat Leasing, Inc. v. Elmer, 124 S.W.3d 210, 212 (Tex. 2003) (common carriers); Robert R. Walker, Inc. v. Burgdorf, 244 S.W.2d 506, 509–10 (Tex. 1951) (gasoline handlers); Morgan v. Wal-Mart Stores, Inc., 30 S.W.3d 455, 462 (Tex. App.—Austin 2000, pet. denied) (pharmacists).

260. *See Speed Boat Leasing, Inc.*, 124 S.W.3d at 212; *Burgdorf*, 244 S.W.2d at 509–10. Noting the higher standard for common carriers, one court considered the business of carriage and explained that "passengers should feel safe when traveling." *Speed Boat Leasing, Inc.*, 124 S.W.3d at 212.

261. *Morgan*, 30 S.W.3d at 462 (quoting Dunlap v. Oak Cliff Pharmacy Co., 288 S.W. 236, 237 (Tex. Civ. App.—Austin 1926, writ ref'd)); *see Burgdorf*, 244 S.W.2d at 509–10.

262. *Burgdorf*, 244 S.W.2d at 509.

be held to a higher standard of care.[263] However, the causal relationship between an improperly handled gasoline truck and a highway disaster is obvious.[264] What is currently less clear is the relationship between SWDs and earthquakes.[265] Indeed, the causal relationship between the two will be the very crux of any lawsuit alleging induced seismicity.[266] So, to urge a court to exact a higher standard based on heightened risk might be putting the cart before the horse.

On the other hand, a plaintiff might argue that although the causal relationship between a *particular* SWD and a local earthquake might be the squarely presented issue to the jury, a growing body of research supports the idea that SWDs are generally capable of triggering earthquakes.[267] On notice of this possibility, a plaintiff might argue that a court would be remiss to hold SWD operators to the standard of mere ordinary care.[268]

Finally, a plaintiff must demonstrate that the defendant's breach proximately caused the plaintiff's injury.[269] This element involves a two-step showing of both causation in fact and foreseeability.[270] Causation in fact exists when the defendant's act or omission was a substantial factor in causing the injury.[271] Put another way, but for the defendant's conduct, the injury would not have occurred.[272] Further, if the defendant's negligence merely furnished a condition that made the injury possible, there is no causation in fact.[273] Neither conjecture, speculation, nor mere guessing can support causation in fact.[274] In general, when the plaintiff's injury results from one of many possible causes, "and the jury can do no more than guess or speculate as to which was, in fact, the efficient cause, the submission of" causation in fact to a jury is improper.[275]

Almost certainly, causation will be the biggest hurdle for any plaintiff alleging induced seismicity.[276] Indeed, after what was perhaps the most comprehensive look to date at whether a particular SWD was causing a

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263. *See Morgan*, 30 S.W.3d at 462.

264. *See id.*

265. *See* Hornbach et al., *supra* note 13, at 5, 7.

266. *See id.*

267. *See, e.g.*, COMM. ON INDUCED SEISMICITY POTENTIAL IN ENERGY TECHS. ET AL., *supra* note 25, at 1.

268. *Id.*

269. Nabors Drilling, U.S.A., Inc. v. Escoto, 288 S.W.3d 401, 404 (Tex. 2009); D. Houst., Inc. v. Love, 92 S.W.3d 450, 454 (Tex. 2002).

270. W. Invs., Inc. v. Urena, 162 S.W.3d 547, 551 (Tex. 2005).

271. *Id.*

272. *Id.*

273. *Id.*

274. Marathon Corp. v. Pitzner, 106 S.W.3d 724, 727 (Tex. 2003).

275. Lenger v. Physician's Gen. Hosp., Inc., 455 S.W.2d 703, 706 (Tex. 1970) (quoting Ramberg v. Morgan, 218 N.W. 492, 492 (Iowa 1928)).

276. *See EnerVest Hearing*, *supra* note 23, at 1 (judgment adopted as proposed); Interview with Professor William Keffer, *supra* note 218 (answering in the affirmative when asked whether causation will be the plaintiff's biggest hurdle at trial).

particular swarm of earthquakes, the RRC concluded that the SMU study, while "a commendable first-order investigation," did not imply a causal relationship.[277] In a win for the industry, the RRC's standard of review was even identical to a plaintiff's burden of proof at trial: preponderance of the evidence.[278] Without an enhanced understanding of the geological conditions surrounding a given SWD, it seems unlikely that a plaintiff could demonstrate causation in fact.[279]

Cases involving multiple SWDs would only compound a plaintiff's problem. Faced with the burden of demonstrating which defendant, by a preponderance of the evidence, caused the earthquake in question would obfuscate things further. However, courts faced with these issues have developed the theory of joint and several liability when a plaintiff can show that each defendant has been negligent.[280] The classic case of *Summers v. Tice* illustrates the principle.[281] The case involved two defendants, each of whom negligently fired a shotgun in the plaintiff's direction.[282] One of the shotgun pellets struck the plaintiff's eye, though it could not be said with certainty which gun the blinding pellet came from.[283] Rather than require the plaintiff to make this showing, the court shifted the burden of production onto the defendants to show that the other shooter blinded the plaintiff.[284] Absent this showing, the defendants were both liable to the plaintiff.[285] A plaintiff can avail himself of joint and several liability only if he has already shown the first two elements of negligence, which, as discussed, appears doubtful.[286] If a plaintiff can resolve the duty–breach issue in his favor, however, the principle of *Summers v. Tice* could help a plaintiff around the multiple defendant problem.

Joint enterprise liability may be available against multiple parties who each own operating interests in one operation—here, a SWD.[287] However, a plaintiff would be hard-pressed to establish enterprise liability against a group of operators that each separately operates its own SWD.[288] In Texas, a plaintiff must establish: "(1) an agreement among the members of the

277. *XTO Hearing*, *supra* note 127, at 21.

278. *Id.* at 4.

279. *See* Hornbach et al., *supra* note 13, at 5, 7 (noting, among other informational deficiencies, the need for more data on the following: permeability values in the disposal formation and the underlying basement rock, gas volumes and production values near the SWDs, and brine production volumes from producing oil and gas wells). Article III of the U.S. Constitution would represent an additional challenge for plaintiffs in federal court because causation is one of the three traditional elements of standing—the other two being injury and redressability. Lujan v. Defs. of Wildlife, 504 U.S. 555, 560 (1992).

280. *See, e.g.*, Summers v. Tice, 199 P.2d 1, 2 (Cal. 1948) (en banc).

281. *See id.*

282. *Id.*

283. *Id.*

284. *Id.* at 4.

285. *Id.*

286. *See supra* notes 228–57 and accompanying text.

287. *See* Blount v. Bordens, Inc., 910 S.W.2d 931, 933 (Tex. 1995).

288. *See id.*

group; (2) a common purpose; (3) a community of pecuniary interest; and (4) an equal right to control the enterprise."[289] Assuming a causal link exists, companies that each own an interest in the responsible well would probably have at the very least an oral arrangement as to the operation of the well.[290] Likewise, a common purpose and a community of pecuniary interest in the joint operation of a commercial saltwater disposal well would presumably be easy to show.[291] Depending on the circumstances of the business arrangement, each party involved may enjoy the right to control the SWD operation. Trying to impose enterprise liability against a group of operators of separate SWDs, however, would prove more difficult. Far from sharing in an enterprise, commercial SWD operators compete with each other for contracts with brine-producing oil and gas companies. And oil and gas companies that operate their own SWDs do so only out of necessity—the brine needs a place to be disposed of. Enterprise liability would only have limited applicability in cases involving multiple interest owners in the same SWD.[292] And this theory makes the (currently tenuous) assumption that a causal link exists between the well(s) in question and local seismic activity.

Foreseeability is the second aspect of proximate cause in Texas.[293] It exists when "a person of ordinary intelligence should have anticipated the danger created by a negligent act or omission."[294] Further, foreseeability "does not require that a person anticipate the precise manner in which injury will occur once he has created a dangerous situation through his negligence."[295] It requires only "that the injury be of such a general character as might reasonably have been anticipated; and that the injured party should be so situated with relation to the wrongful act that injury to him or to one similarly situated might reasonably have been foreseen."[296]

Foreseeability will also pose a major problem for plaintiffs. While a growing body of research suggests that SWDs in general may be capable of triggering seismic activity, a host of geologic conditions must hold true before any *particular* SWD will induce an earthquake.[297] These include the existence of a fault within the crystalline basement rock, the fault must be critically stressed, the SWD must be drilled deep enough and close enough to the fault for a mechanical link (communication) to exist between the

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289. *Id.*

290. *Cf.* MARTIN & KRAMER, *supra* note 10, at 525–26 (describing the detailed contractual arrangement among owners of interests in oil and gas wells—the joint operating agreement).

291. *See id.*

292. *See Blount*, 910 S.W.2d at 933.

293. W. Invs., Inc. v. Urena, 162 S.W.3d 547, 551 (Tex. 2005).

294. Doe v. Boys Clubs of Greater Dall., Inc., 907 S.W.2d 472, 478 (Tex. 1995).

295. Travis v. City of Mesquite, 830 S.W.2d 94, 98 (Tex. 1992).

296. Nixon v. Mr. Prop. Mgmt. Co., 690 S.W.2d 546, 551 (Tex. 1985) (emphasis omitted) (quoting Carey v. Pure Distrib. Corp., 124 S.W.2d 847, 849 (Tex. 1939)).

297. Keith B. Hall, *Recent Developments in Hydraulic Fracturing Regulation and Litigation*, 29 J. LAND USE & ENVTL. L. 29, 50–51 (2013).

injection zone and the fault, and the disposal volumes and pressures must be high enough and for a sufficient amount of time to trigger slippage along that fault.[298] Moreover, throughout the United States, only a tiny fraction of SWDs have been linked to seismic activity, adding gravity to the point that any seismic inducement would not be foreseeable. Disposal companies have drilled over 144,000 SWDs.[299] One recent article, though, suggests that less than ten of those SWDs have been linked to seismic activity.[300] Even if a SWD operator learned everything that current science can tell us about the rock layers, the scientific reality remains that earthquakes are unpredictable.[301] Why is this? One seismologist explains:

> This question cannot be answered conclusively, as we do not yet have a definitive theory of the seismic source. The Earth's crust (where almost all earthquakes occur) is highly heterogeneous, as is the distribution of strength and stored elastic strain energy. The earthquake source process seems to be extremely sensitive to small variations in the initial conditions (as are fracture and failure processes in general). There is complex and highly nonlinear interaction between faults in the crust, making prediction yet more difficult. In short, there is no good reason to think that earthquakes ought to be predictable in the first place.[302]

In other words, the highly complex interplay of heterogeneous stresses that exist in all directions throughout Earth's crust is impossible to measure with current technology.[303] Seismologists and other earth scientists lament the impossibility of quantifying the initial geophysical conditions that drive seismicity, to say nothing of whether an oilfield service company can reasonably foresee an earthquake.[304]

C. Negligence per se

Negligence per se, while ultimately prone to the same causation weaknesses as nuisance and negligence, permits a plaintiff to prove the first two elements of negligence—duty and breach—simply by showing that the defendant, without excuse, violated some relevant statute, ordinance, or

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298. *Id.* at 52.

299. *Id.* at 50–51.

300. *Id.*

301. *See* Geller, *supra* note 228 (comparing the science of earthquake prediction to alchemy, the pseudoscientific study of turning lead into gold); *Earthquake Myths FAQs*, U.S. GEOLOGICAL SURV., http://www.usgs.gov/faq/categories/9830/3278 (last modified Feb. 24, 2016) (explaining that earthquakes are not predictable, and that seismologists do not expect them to become predictable in the foreseeable future).

302. Geller, *supra* note 228.

303. *See* COMM. ON INDUCED SEISMICITY POTENTIAL IN ENERGY TECHS. ET AL., *supra* note 25, at 38–39.

304. *See id.*

regulation.[305] The plaintiff, however, must belong to the class of persons the pertinent rule was designed to protect, and he or she must have suffered the sort of injury that the rule was designed to prevent.[306]

The RRC recently adopted rules requiring the disclosure of seismic activity that might provide a regulatory basis for negligence per se.[307] In August 2014, the RRC adopted an amendment to disposal well permit applications, requiring operators to disclose historic seismicity near the site of the proposed SWD.[308] As adopted, the rule provides:

> The applicant for a disposal well permit under this section shall include with the permit application a printed copy or screenshot showing the results of a survey of information from the United States Geological Survey (USGS) regarding the locations of any historical seismic events within a circular area of 100 square miles (a circle with a radius of 9.08 kilometers) centered around the proposed disposal well location.[309]

A reasonable interpretation of this new rule is that it was designed to prevent or mitigate the potential devastation that an earthquake can cause.[310] If that is so, a plaintiff injured by an earthquake occurring near a SWD has at least a colorable argument that she is both a member of the class the rule is designed to protect and that she suffered an injury the rule is meant to prevent.[311] Indeed, the legislature enacted the amendment in November 2014, a time when the induced seismicity issue was coming to the forefront of the public consciousness.[312]

Even if both of these conditions exist, the plaintiff must further show that "it is appropriate to impose tort liability for violations of the statute."[313] Not all legislative or administrative rules serve as a basis for negligence per

305. *See* Perry v. S.N., 973 S.W.2d 301, 306 (Tex. 1998); *see also* Nixon v. Mr. Prop. Mgmt. Co., 690 S.W.2d 546, 549 (Tex. 1985) (city ordinance); Moughon v. Wolf, 576 S.W.2d 603, 604 (Tex. 1978) (holding that violation of a civil statute constituted negligence per se); Parrott v. Garcia, 436 S.W.2d 897, 899 (Tex. 1969) (imposing contributory negligence per se in a civil suit based on violation of a criminal statute); Cont'l Oil Co. v. Simpson, 604 S.W.2d 530, 534 (Tex. Civ. App.—Amarillo 1980, writ ref'd n.r.e.) (administrative regulation).

306. *Perry*, 973 S.W.2d at 305.

307. 16 TEX. ADMIN. CODE § 3.9(3) (2015).

308. *Id.*

309. *Id.* § 3.9(3)(B).

310. *See Railroad Commission Adopts Disposal Well Rule Amendments Today*, *supra* note 68 ("[A]mendments . . . are designed to address disposal well operations in areas of historical or future seismic activity."); *see also* 39 Tex. Reg. 8988, 8988–9005 (2014) (codified at 16 TEX. ADMIN. CODE §§ 3.9, 3.46) (suggesting the purpose of the amendments was to mitigate the risk of seismic activity in and around Texas disposal wells).

311. *Cf.* Osti v. Saylors, 991 S.W.2d 322, 327–28 (Tex. App.—Houston [1st Dist.] 1999, pet. denied) (explaining that the individuals trapped in a burning building were within the protected class and suffered injury that a building code requiring multiple exits was designed to prevent).

312. *See, e.g.*, COMM. ON INDUCED SEISMICITY POTENTIAL IN ENERGY TECHS. ET AL., *supra* note 25, at 1; Bustillo & Gilbert, *supra* note 2.

313. Perry v. S.N., 973 S.W.2d 301, 305 (Tex. 1998).

se, and the matter is within the court's discretion.[314] A primary factor driving this inquiry is whether a common law duty exists independent of the statute at issue.[315] Courts are hesitant to make radical changes to the law of negligence by permitting statutory violations to stand in for the traditional duty–breach inquiry when no corresponding common law duty existed in the first place.[316] But when a statute merely defines the precise contours of a previously recognized common law duty, a court is more willing to apply negligence per se.[317]

While courts have indicated that regulatory violations may ground negligence per se claims, convincing a court that civil liability is appropriate for violations of Texas Administrative Code § 3.9(3) may be difficult.[318] First, it is not a penal statute.[319] At least two courts of appeals have considered that reason enough to reject a plaintiff's negligence per se claim.[320] The RRC rule merely outlines the requirements of a permit application to drill a SWD.[321] While the RRC was understandably concerned with the prospect that SWDs might contribute to earthquake activity, the industry should argue that permit denial—not civil tort liability—should be the only consequence of failing to comply with a rule that outlines permit application requirements.

Second, before the enactment of this rule, operators were under no common law duty to disclose historic seismicity to the RRC or anybody else.[322] When a statute or regulation prescribes conduct over and above what

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314. *See id.* at 304 n.4; Cont'l Oil Co. v. Simpson, 604 S.W.2d 530, 534 (Tex. Civ. App.—Amarillo 1980, writ ref'd n.r.e.) ("The availability of the negligence per se rule does not mean that it is applied obdurately to the violation of every administrative rule or regulation. Neither does the mere fact that an administrative agency promulgates a rule or regulation mean that the courts must accept it as a standard for civil liability.").

315. *Perry*, 973 S.W.2d at 305–07.

316. *Id.* at 306–07.

317. *See id.* at 306 ("In contrast, the defendant in most negligence per se cases already owes the plaintiff a pre-existing common law duty to act as a reasonably prudent person, so that the statute's role is merely to define more precisely what conduct breaches that duty.").

318. *See Cont'l Oil Co.*, 604 S.W.2d at 534; *see also* RESTATEMENT (SECOND) OF TORTS § 288B (AM. LAW INST. 1965) ("The unexcused violation of a legislative enactment or an administrative regulation which is adopted by the court as defining the standard of conduct of a reasonable man, is negligence in itself."). *But see* Pack v. Crossroads, Inc., 53 S.W.3d 492, 510 (Tex. App.—Fort Worth 2001, pet. denied) (holding the trial court properly dismissed a negligence per se claim when the underlying regulation was not penal in nature).

319. *See* Ridgecrest Ret. & Healthcare v. Urban, 135 S.W.3d 757, 762 (Tex. App.—Houston [1st Dist.] 2004, pet. denied) ("A violation of a non-penal administrative code statute does not establish a negligence per-se claim."). *But see* Nixon v. Mr. Prop. Mgmt. Co., 690 S.W.2d 546, 549 (Tex. 1985) (explaining that a civil ordinance requiring building owners to lock vacant buildings is a proper basis for negligence per se).

320. *Ridgecrest Ret. & Healthcare*, 135 S.W.3d at 762; *Pack*, 53 S.W.3d at 510.

321. 16 TEX. ADMIN. CODE § 3.9(3) (2015) ("The applicant . . . shall include with the permit application a printed copy . . . of a survey . . . regarding the locations of any historical seismic events . . . .").

322. *See Railroad Commission Adopts Disposal Well Rule Amendments Today*, *supra* note 68. In a statement about the new seismicity disclosure requirements, Commissioner Christi Craddick even noted that the RRC was "taking the lead" by adopting the new rules. *Id.*

the common law would, courts are hesitant to permit the pertinent rule to ground a negligence per se claim.[323] Cautious of recognizing a new duty and effectuating a major change in negligence law, a court would be hard-pressed to apply Texas Administrative Code § 3.9(3) to a negligence per se claim.

D. Citizen Suits: The Resource Conservation and Recovery Act of 1976

Enacted in 1976, the federal Resource Conservation and Recovery Act (RCRA) imposes a cradle-to-grave regulatory framework for solid or hazardous waste products.[324] By governing the generation, transportation, treatment, and ultimate disposal of these products, the Act's basic idea is straightforward: if we know where hazardous material is, and we know that that location is secure, we know the material is not causing problems in the environment.[325]

The policy impetus of RCRA was to mitigate the risk of hazardous waste contamination.[326] Leaking barrels of toxic sludge in a chemical dump, faulty underground storage tanks for gasoline and other petroleum products, and illegal dumping of industrial waste are scenarios that all come to mind.[327] In RCRA's findings section, Congress noted that "most solid waste is disposed of on land in open dumps and sanitary landfills; . . . [and] as a result of [various state and federal environmental laws], greater amounts of solid waste (in the form of sludge and other pollution treatment residues) have been created."[328] Congress cited "inadequate and environmentally unsound practices for the disposal" of these wastes as a further impetus driving the new law.[329] In a House Report that preceded RCRA's passage, the Committee noted concerns about groundwater leachate, contaminated runoff, air pollution, animal poisoning, and chemical fires.[330]

At first blush, these types of environmental wrongs at which RCRA is aimed do not seem akin to the idea that disposed saltwater is causing seismic activity. That is, invoking a pollution law seems like a strange way to try and halt an earthquake. RCRA was built to address releases of hazardous wastes whose dangers stem from their toxicity—not their alleged connection to

323. Perry v. S.N., 973 S.W.2d 301, 305–07 (Tex. 1998).

324. 42 U.S.C. §§ 6901–92 (2012); *see* PLATER ET AL., *supra* note 220, at 192.

325. *See* PLATER ET AL., *supra* note 220, at 744.

326. *See id.* at 743.

327. *See id.*

328. 42 U.S.C. § 6901(b)(1)–(3).

329. *Id.* § 6901(b)(3); *see also* H.R. REP. No. 94-1491, at 2 (1976), *as reprinted in* 1976 U.S.C.C.A.N. 6238, 6240 (noting that "liquid and contained gaseous wastes, semi-solid wastes and sludges are the subjects of this legislation.").

330. H.R. REP. NO. 94-1491.

earthquakes.[331] But RCRA contains a citizen suit provision that might bring SWD companies within its ambit.[332] The relevant language provides:

> [A]ny person may commence a civil action on his own behalf . . . against any person . . . who has contributed or who is contributing to the past or present handling, storage, treatment, transportation, *or disposal* of any solid or hazardous waste *which may present an imminent and substantial endangerment to health or the environment* . . . .[333]

The EPA, charged with administering RCRA, defined "disposal" as "the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water . . . including ground waters."[334] Further, by its own terms the citizen suit provision applies only to "solid or hazardous" wastes.[335] In fact, much depends on whether the material at issue is a solid or hazardous waste.[336] Many of RCRA's critics point out that while the goal of RCRA is commendable, it "makes a great deal turn on the division" between "solid," "hazardous," and "nonhazardous" waste—"and then draws that line in a fiendishly complicated way."[337] Congress defined "solid waste" as

> any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but does not include solid or dissolved material in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under [§] 1342 of Title 33, or source, special nuclear, or byproduct material as defined by the Atomic Energy Act of 1954, as amended.[338]

Simplifying this analysis, for saltwater disposal purposes at least, is an EPA exclusion: "The following *solid wastes* are not hazardous wastes: . . . [d]rilling fluids, produced waters, and other wastes associated with the exploration, development, or production of crude oil, natural gas or geothermal energy."[339] So, at least according to the EPA, saltwater produced

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331. *Id.*
332. 42 U.S.C. § 6972(a)(1)(B) .
333. *Id.* (emphasis added).
334. 40 C.F.R. § 260.10 (2015).
335. 42 U.S.C. § 6972(a)(1)(B).
336. *See id.*
337. *See* PLATER ET AL., *supra* note 220, at 757–58.
338. 42 U.S.C. § 6903(27).
339. 40 C.F.R. § 261.4(b)(4) (emphasis added).

from an SWD appears to qualify at least as a solid waste subject to RCRA citizen suit provisions.[340]

Congress primarily designed RCRA's citizen suit provision for plaintiffs to obtain injunctive relief in the form of abatements—the Supreme Court has held that it does not authorize private recovery of past cleanup costs.[341] When a defendant's activity poses "an imminent and substantial endangerment to health or the environment," the citizen suit becomes an option.[342]

To this end, in February 2016 the Sierra Club filed a complaint in the Western District of Oklahoma against four Oklahoma oil and gas companies, alleging that the companies' saltwater disposal operations "have contributed and continue to contribute to the increased seismicity" in Oklahoma.[343] Citing RCRA's citizen suit provision, along with a host of studies, earthquake data, production volumes, and conclusions from the Oklahoma Geological Survey, the U.S. Geological Survey, and the EPA, the Sierra Club demanded that the defendants immediately and substantially reduce their saltwater disposal rates, establish an Oklahoma earthquake prediction center, and reinforce weak buildings throughout the state.[344] While no answers have yet been filed with the court, this novel application of RCRA is a case of first impression and appears subject to the same causation difficulties as any other theory.

In court, the private RCRA plaintiff must make three showings based on the same standards a court would apply if the government were bringing the lawsuit.[345] The plaintiff must show: "(1) that the conditions at the site present an imminent and substantial endangerment; (2) that the endangerment stems from the handling, storage, treatment, transportation, or disposal of any solid or hazardous waste; and (3) that the defendant has contributed or is contributing to such handling, storage, treatment,

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340. *See id.*; *see also* H.R. REP. No. 94-1491, at 2 (1976), *as reprinted in* 1976 U.S.C.C.A.N. 6238, 6240 ("[T]he Committee recognizes that Solid Waste, the traditional term for trash or refuse is inappropriate. The words solid waste are laden with false connotations. They are more narrow in meaning than the Committee's concern. The words discarded materials more accurately reflect the Committee's interest.").

341. Meghrig v. KFC W., Inc., 516 U.S. 479, 479 (1996); *see also* 42 U.S.C. § 6972(a) ("The district court shall have jurisdiction . . . *to restrain* any person who has contributed or who is contributing to the past or present handling, storage, treatment, transportation, or disposal of any solid or hazardous waste referred to in paragraph (1)(B), *to order such person to take such other action as may be necessary*, or both . . . ." (emphasis added)).

342. 42 U.S.C. § 6972(a)(1)(B).

343. Complaint at 2, Sierra Club v. Chesapeake Operating LLC, No. CIV-17-134-F (W.D. Okla. Feb. 16, 2016); *see also supra* notes 15–21 and accompanying text (noting the dramatic increase of both saltwater disposal rates and earthquake numbers throughout Oklahoma).

344. First Amended Complaint at 3, 10–21, *Sierra Club*, No. CIV-17-134-F (W.D. Okla. Feb. 16, 2016).

345. *See* Eileen Gauna, *Federal Environmental Citizen Provisions: Obstacles and Incentives on the Road to Environmental Justices*, 22 ECOLOGY L.Q. no. 1, 64, 66 (1995).

transportation, or disposal."[346] The standard of "imminent and substantial endangerment" is subject to judicial interpretation and involves a fact-intensive inquiry.[347] One court noted a link between RCRA and the common law cause of public nuisance:

> [The citizen suit provision] is essentially a codification of the common law public nuisance. . . .
>
> However, [it] should not be construed solely with respect to the common law. Some terms and concepts, such as persons "contributing to" disposal resulting in a substantial endangerment, are meant to be more liberal than their common law counterparts.[348]

If that is so, the citizen RCRA suit may be susceptible to the same causation weaknesses that characterize the nuisance issue.[349] But if a plaintiff overcomes these weaknesses, the EPA's (and by extension the § 6972 plaintiff's) "authority to abate waste hazards is expansive."[350] This is so because the only tool that RCRA "has to remedy the effects of past disposal practices which are not sound is its imminent hazard authority" in § 6973.[351] Nevertheless, if the same proof problems appear in a RCRA suit as will inevitably arise in the nuisance context, plaintiffs will have a steep uphill climb.

Along with causation difficulties, plaintiffs in RCRA cases face the possibility of federal court abstention under *Burford v. Sun Oil Co.*[352] In *Burford*, the U.S. Supreme Court held that federal courts should refrain from exercising jurisdiction to avoid needless conflict with a state's administration of its own affairs.[353] Sun Oil made a due process challenge to an order from the RRC permitting Burford to drill wells near Sun Oil leases.[354] The Court discussed the RRC's comprehensive regulatory framework of the Texas oil and gas industry, along with the state's immense interest in the industry's economic impact.[355] Given the RRC's specialized knowledge and expertise in regulating the oil and gas business, the court concluded that principles of federalism and "a sound respect for the independence of state action"

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346. United States v. Bliss, 667 F. Supp. 1298, 1313 (E.D. Mo. 1987) (citing 42 U.S.C.A. § 6973 (1987)).

347. *See* Gauna, *supra* note 345, at 64.

348. United States v. Waste Indus., Inc., 734 F.2d 159, 167 (4th Cir. 1984) (first alteration in original) (quoting SUBCOMM. ON OVERSIGHT AND INVESTIGATIONS OF THE COMM. ON INTERSTATE AND FOREIGN COMMERCE, H.R. DOC. NO. 96–IFC 31, 96TH CONG., 1ST SESS., REPORT ON HAZARDOUS WASTE DISPOSAL 32 (Comm. Print 1979)).

349. *See* discussion *supra* notes 218–21.

350. *Waste Indus.*, 734 F.2d at 167.

351. *Id.* at 166.

352. *See* RICHARD L. MARCUS ET AL., COMPLEX LITIGATION: CASES AND MATERIALS ON ADVANCED CIVIL PROCEDURE 178–79 (6th ed. 2015); *see also* Burford v. Sun Oil Co., 319 U.S. 315 (1943).

353. *Burford*, 319 U.S. at 334.

354. *Id.* at 316–17.

355. *Id.* at 319–20.

necessitated a dismissal.[356] Accordingly, the RRC's historic, comprehensive regulation of the oil and gas business, coupled with the RRC's recent sensitivity to this issue, may result in prompt application of *Burford* abstention in a federal RCRA suit against SWD operators.[357]

V. RECOMMENDATIONS

Regardless of the legal theory, a plaintiff will have to show a causal link between SWDs and induced seismicity. But even the most comprehensive analysis of a particular Texas SWD to date failed to demonstrate, by a preponderance of the evidence, any such causal relationship.[358] The scarcity of geophysical data fundamentally undercuts seismologists' understanding of any link between SWDs and induced seismicity.[359] The authors of the SMU study cited informational deficiencies ranging from crude estimates of brine production, uncertainty about hypocenter locations and permeability data, and a basic need for more comprehensive seismic monitoring.[360] In June 2015, Governor Abbott took a definitive step toward enhancing our understanding of this issue when he signed legislation authorizing $4.47 million to fund an increased statewide network of seismometers.[361] The TexNet Seismic Monitoring Program will add at least fifty-eight new seismometers throughout Texas that will better permit researchers to understand the dynamics of earthquakes in our state.[362]

But more can be done. The scarcity of public brine production and disposal well data is also a driver of scientific uncertainty. Heightened reporting requirements would help remedy this deficiency. For instance, the only brine production information typically available to researchers is found in reports of annual well test results required by the RRC.[363] The RRC does require *monthly* oil and gas production reports from operators, but these reports do not include brine production data.[364] If the RRC amended its monthly production report form to include a field for brine production,

356. *Id.* at 334.

357. *See supra* notes 307–12 and accompanying text (discussing recent RRC rules amendments designed to detect SWD-related seismicity).

358. *XTO Hearing*, *supra* note 127, at 28.

359. *See* Hornbach et al., *supra* note 13, at 7.

360. *Id.* at 5, 7.

361. *Seeking Earthquake Answers, TexNet Seismic Monitoring Program Authorized by the State of Texas*, *supra* note 189.

362. *Id.*

363. Hornbach et al., *supra* note 13, at 5, 7; *see* 16 TEX. ADMIN. CODE §§ 3.53, 3.28 (2015); R.R. COMM'N OF TEX., FORM G-10, GAS WELL STATUS REPORT, www.rrc.state.tx.us /media/2864/g-10p.pdf (last visited Apr. 6, 2016). Brine production volumes should be distinguished from brine disposal volumes. *See* R.R. COMM'N OF TEX., *supra.* Brine production refers to the volume of saltwater produced by oil and gas wells as a waste byproduct. *See* MARTIN & KRAMER, *supra* note 10, at 106. Brine disposal refers to the disposal volumes accommodated by SWDs. *See id.*

364. *See* R.R. COMM'N OF TEX., FORM PR, MONTHLY PRODUCTION REPORT, www.rrc.state.tx.us /media/2644/formpr-02-2005.pdf (last visited Apr. 6, 2016).

researchers could develop pore-pressure models that more accurately reflect subsurface dynamics.[365] In turn, this would aid the RRC in determining whether "injection is likely to be . . . contributing to seismic activity."[366]

Moreover, for SWDs, brine disposal volumes are recorded monthly but only reported annually.[367] The additional burden of requiring monthly brine disposal reporting does not appear heavy. There are over 275,000 active oil and gas wells in Texas, each subject to monthly reporting requirements.[368] By contrast, there are only about 8,100 SWDs in the state.[369] Collecting monthly disposal data would lend much needed accuracy to the pore-pressure models seismologists build to examine any hypothesized effect of SWDs on seismic activity.[370] Any case involving highly technical or specialized factual issues requires expert testimony, and equipping researchers with the data to evaluate these claims is crucial.[371]

While scientists work to enhance our understanding of this issue, bypassing it altogether could be a better answer. In general, SWDs currently represent the cheapest system of saltwater management.[372] Incentivizing alternatives to SWDs such that oil and gas companies voluntarily opt for other technologies would help alleviate the induced seismicity concern. In addition to promoting goodwill within concerned communities, some oilfield service companies that provide these alternate technologies even contend that oilfield brine could eventually be transformed into potable water.[373] Devising a federal tax credit for these companies would permit them to lower costs to the end users—oil and gas companies. Permitting oil and gas companies to deduct a portion of their expenses allocated to alternative saltwater management systems is another option.

From a policy standpoint, favorable tax treatment toward alternative saltwater management systems is preferable to taxing the use of SWDs for at least two reasons. First, taxing a particular practice—as a way of discouraging it—makes the most sense only if it is conclusively linked with some undesirable outcome. But that is the very issue that seismologists are

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365. *See* Hornbach et al., *supra* note 13, at 7.

366. 16 TEX. ADMIN. CODE § 3.9 (IV)(A)(vi); *see also XTO Hearing*, *supra* note 127, at 27 ("Monthly average data of injection rates and pressures may not be discrete enough to model formation pressure responses in time and space. Modeling daily injection rate and pressure data, if available, will likely yield more accurate results.").

367. *See* 16 TEX. ADMIN. CODE § 3.9(11) ("The operator shall monitor the . . . injection rate of each disposal well on at least a monthly basis . . . . The results of the monitoring shall be reported annually . . . ."); R.R. COMM'N OF TEX., FORM H-10, ANNUAL DISPOSAL/INJECTION WELL MONITORING REPORT, www.rrc.state.tx.us/media/30265/blank-h10p.pdf (last visited Apr. 6, 2016).

368. R.R. COMM'N OF TEX., DISTRIBUTION OF WELLS MONITORED BY THE RAILROAD COMMISSION (2015), http://www.rrc.texas.gov/media/31890/welldistribution1215.pdf.

369. *Injection and Disposal Wells*, *supra* note 59.

370. *See* Hornbach et al., *supra* note 13, at 5.

371. *See* Mack Trucks, Inc. v. Tamez, 206 S.W.3d 572, 583 (Tex. 2006).

372. *See* MCCURDY, *supra* note 102.

373. *See* NICOT ET AL., *supra* note 95.

still grappling with. The "sin tax" levied against cigarettes makes sense because, plainly, cigarettes cause cancer.[374] But until the science is more certain, taxing SWD operators or their clients may just be punishing innocent behavior.

Second, favorable tax treatment for alternative saltwater management systems is more politically realistic than penalizing saltwater disposal companies. On the one hand, environmental groups are concerned about induced seismicity and an industry-wide practice that might lead to it. On the other hand, economic factors loom largest in any decision-making process an industry faces, especially in the current climate of cheap oil and gas. Industry backlash against SWD taxes might choke any such scheme before it gets off the ground. Subsidizing preferred alternatives would align the goals of both sides. Altering industry practice does not have to be a zero-sum game.

Many of these technologies already enjoy certain cost-saving advantages over SWD systems. First, on-site treatment plants (permanent or mobile), while requiring trained personnel to operate them, permit operators to save on transportation costs.[375] Instead of trucking thousands of barrels of saltwater each day to a remote disposal facility, on-site treatment would leave companies with reusable water for hydraulic fracturing stimulation at another well, possibly even on site. Or if a potable quality is achieved, profitable arrangements with adjacent agricultural operations would also create synergies.[376] Especially in drought-prone Texas, environmental groups, the oil and gas industry, and both sides of the political aisle have every incentive to maximize opportunities for abundant freshwater. The primary obstacle to all this, of course, is cost.[377] But by providing favorable tax treatment for alternative saltwater management systems, the federal government has the opportunity to begin working around the induced seismicity issue.

In rural parts of the state, low-tech evaporation technologies represent a low-cost alternative to saltwater management.[378] While the high cost of land makes this option unattractive in many urban parts of Texas, some of our most prolific oil and gas regions run through wide swaths of rural countryside.[379] The Permian Basin, in West Texas, covers roughly 75,000

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374. James Sadowsky, *The Economics of Sin Taxes*, ACTON INST., http://www.acton.org/pub/religion-liberty/volume-4-number-2/economics-sin-taxes (last visited Apr. 6, 2016).

375. *See* POULSON, *supra* note 113.

376. *See supra* notes 93–98 and accompanying text (examining various saltwater disposal recycling technologies available in the industry).

377. *See supra* notes 99–101 and accompanying text (discussing the cost-prohibitive nature of and need to clean recycled water).

378. *See* POULSON, *supra* note 113.

379. *See Oil and Gas Map of Texas 2005*, U. TEX. LIBR., https://www.lib.utexas.edu/geo/pics/oilandgasmapfront.jpg (last visited Apr. 6, 2016).

square miles.[380] Midland, the largest city in the Permian Basin, takes up about 0.1% of that sparsely populated region.[381] Yet the Permian Basin produced over 70% of our state's oil in 2011.[382] If the Texas Legislature would allocate money to lease or purchase land in the Permian Basin or South Texas, where land is relatively cheap, the need in those places for developed SWD infrastructure would decline. For instance, one eleven-square-mile evaporation complex would accommodate an estimated 715,000 barrels of saltwater per day.[383] By comparison, the RRC permitted the two SWDs that were the subject of the SMU study to dispose of 35,000 barrels per day.[384] Just one low-tech evaporation complex can replace forty SWDs. Promoting alternative saltwater management programs should be a key energy policy priority for our legislators. Doing so will help bypass the assuredly contentious causation issue in any lawsuit and only reinforce our state's reputation as a global leader in energy technology.

VI. CONCLUSION

If nothing else, stories like Sandra Ladra's grab headlines.[385] Cowering helplessly as a record-setting earthquake breaks your house apart would not be a good day. Texas plaintiffs hoping to pin responsibility for these earthquakes on SWD operators, however, do not have an easy road. Whether the theory of liability is nuisance, negligence, negligence per se, or a citizen suit under RCRA, causation represents the chief hurdle. Seismologists in Texas have taken a close look at two wells suspected of inducing earthquakes in the Azle area—as close a look as the available data currently allow.[386] The result, however, is inconclusive.[387] Until we enhance our understanding of the interplay between SWDs and seismic activity, the jury will remain out—if it ever even gets to trial.

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380. Charles D. Vertrees, *The Handbook of Texas: Permian Basin*, TEX. ST. HIST. ASS'N, https://tshaonline.org/handbook/online/articles/ryp02 (last visited Apr. 6, 2016).

381. *Quick Facts: Midland County, Tex.*, U.S. CENSUS BUREAU, http://www.census.gov/quickfacts/table/PST045215/48329 (last visited Apr. 6, 2016). The city of Midland covers approximately 900.3 square miles. *Id.*

382. *Permian Basin Information*, RAILROAD COMMISSION TEX., http://www.rrc.state.tx.us/oil-gas/major-oil-gas-formations/permian-basin/ (last visited Apr. 6, 2016).

383. *See* POULSON, *supra* note 113, at 11.

384. *See* R.R. COMM'N OF TEX., *Permit to Dispose of Non-Hazardous Oil and Gas Waste by Injection Into a Porous Formation Not Productive of Oil and Gas*, Permit No. 12872 (Oil & Gas Div. Feb. 19, 2009); R.R. COMM'N OF TEX., *Permit to Dispose of Non-Hazardous Oil and Gas Waste by Injection Into a Porous Formation Not Productive of Oil and Gas*, Permit No. 12112 (Oil & Gas Div. Apr. 11, 2006).

385. *See* Bustillo & Gilbert, *supra* note 2.

386. *See* Hornbach et al., *supra* note 13.

387. *See XTO Hearing*, *supra* note 127, at 28.