# 2019 DISCLOSING THE FACTS:

## TRANSPARENCY AND RISK IN WATER & CHEMICALS MANAGEMENT FOR HYDRAULIC FRACTURING OPERATIONS

A COLLABORATIVE PROJECT OF:

AS YOU SOW®

BOSTON COMMON ASSET MANAGEMENT

# AUTHORS

Richard Liroff, Senior Advisor
Danielle Fugere, *As You Sow*
Steven Heim, Boston Common Asset Management, LLC
Lila Holzman, *As You Sow*
Benjamin Davis, *As You Sow* Consultant


# COLLABORATING ORGANIZATIONS

***AS YOU SOW*** promotes environmental and social corporate responsibility through shareholder advocacy, coalition building, and innovative legal strategies. Our efforts create large-scale systemic change by establishing sustainable and equitable corporate practices.

**BOSTON COMMON ASSET MANAGEMENT, LLC** is a sustainable investment firm dedicated to generating competitive financial returns and meaningful improvements in corporate performance on environmental, social, and governance (ESG) issues. We are long-term investors. We believe that markets typically misvalue the timing and magnitude of risks and opportunities presented by ESG factors. Therefore, our investment strategy is to build and grow diversified portfolios using the high-quality but undervalued sustainable stocks that our integrated investment research identifies. As part of this, we look to add value through targeted company and industry engagement efforts.

# ACKNOWLEDGEMENTS


This report was made possible by the generous support of the Marisla Foundation, New Belgium Family Foundation, Park Foundation, Shugar Magic Foundation, and Tides Foundation. Additional support was provided by the Arkay Foundation, Arntz Family Foundation, Firedoll Foundation, Hanley Foundation, The Libra Foundation, The Roddenberry Foundation, Roy and Patricia Disney Family Foundation, Singing Field Foundation, and the Wallace Global Fund.

This report has benefited from the suggestions of outside reviewers. They include (in alphabetical order by last name with affiliations for identification purposes only): Monika Freyman (Ceres), Roy Hartstein (Responsible Energy Solutions, LLC), George E. King (GEK Engineering), Andrew Kondash (Duke University School of Earth and Ocean Science), Kate Konschnik (Duke University Nicholas Institute for Environmental Policy Solutions), Amy Mall (Natural Resources Defense Council), Sara Murphy (Sustainable Investments Institute), Samantha Rubright, Lucas Schoeppner (Sustainalytics), and Aaron Ziulkowski (Boston Trust/Walden Asset Management). Thanks also go to the additional professionals from industry and other sectors who provided reviews. Any errors or omissions are solely the responsibility of the authors.

We would like to thank Sanford Lewis for legal review, Tami Holzman for copy-editing, and Jill Courtenay (*As You Sow*) for communications support.


# DISCLAIMER




COVER CREDIT: Daniel Azocar

# TABLE OF CONTENTS



## TABLES & FIGURES

# EXECUTIVE SUMMARY

*Disclosing the Facts 2019: Transparency and Risk in Water & Chemicals Management for Hydraulic Fracturing Operations (DTF 2019)* is an investor report designed to promote improved water and chemical management and reporting practices among oil and gas producers engaged in horizontal drilling and hydraulic fracturing in the United States and Canada.

Investors are focused on water, because it is a vital resource whose availability has extensive impacts across the economy. Investors' attention to water reflects their increasing focus on the role this resource has on companies' ability to operate as well as the impact companies have on water availability and quality in areas where they are located. As climate change affects the scarcity of water in different regions, investors need assurance that companies are responsibly managing the quantity of water used. The process of hydraulic fracturing uses a range of chemicals, raising the risk of unintended releases that could result in water contamination, and increases the risk of induced seismic activity, among others. Given the oil and gas sector has a relatively low response rate to the CDP water questionnaire,[1] *DTF 2019* seeks to highlight the importance of comprehensive water management.

*Disclosing the Facts 2019* ranks companies on disclosures of key elements of their water management processes, seeking not only quantitative information about the impacts of company operations on water but also qualitative information about corporate policies and practices. Sound corporate management of water and chemicals requires thorough, systematic planning — from site development through production and wastewater disposal, advanced equipment design, and practices that efficiently use water and minimize impacts on the surrounding environment and local communities.

*Disclosing the Facts 2019* also addresses the very real problem of regulatory inconsistency. Since most regulation of oil and gas production operations is done by states, and state regulation of known risks is uneven, companies must go beyond issuing boiler-plate statements to investors that they comply with regulations. Investors are seeking greater information on risk management practices, especially where they differ from one play[2] to another, and where practices may go beyond compliance requirements or not.

*Disclosing the Facts 2019* poses 25 questions reflecting a systematic approach to water management. The actions of 30 top producing companies are assessed against these criteria, which range from design and operating practices to monitoring and reporting.[3]

## 2019 COMPANY SCORES

| COMPANY | TOTAL |
|---|---|
| Southwestern Energy Co. (SWN) | 23 |
| Apache Corp. (APA) | 22 |
| Anadarko Petroleum Corp. (APC) | 20 |
| Range Resources Corp. (RRC) | 20 |
| Occidental Petroleum Corp. (OXY) | 19 |
| Antero Resources Inc. (AR) | 17 |
| Royal Dutch Shell plc. (RDS) | 17 |
| ConocoPhillips Co. (COP) | 16 |
| Hess Corp. (HES) | 15 |
| Devon Energy Corp. (DVN) | 12 |
| Chesapeake Energy Corp. (CHK) | 11 |
| Newfield Exploration Co. (NFX) | 11 |
| EQT Corp. (EQT) | 8 |
| Noble Energy, Inc. (NBL) | 6 |
| BP plc. (BP) | 5 |
| Chevron Corp. (CVX) | 5 |
| Cimarex Energy Co. (XEC) | 5 |
| Marathon Oil Corp. (MRO) | 5 |
| Cabot Oil and Gas Corp. (COG) | 4 |
| Encana Corp. (ECA) | 4 |
| Equinor ASA (EQNR) | 4 |
| Exxon Mobil Corp. (XOM) | 4 |
| Ultra Petroleum Corp. (UPL) | 3 |
| CNX Resources Corp. (CNX) | 2 |
| Concho Resources Inc. (CXO) | 2 |
| Pioneer Natural Resources (PXD) | 2 |
| EOG Resources, Inc. (EOG) | 1 |
| Total S.A. (FP) | 1 |
| Continental Resources, Inc. (CLR) | 0 |
| Gulfport Energy Corp. (GPOR) | 0 |

1. CDP provides a voluntary framework for companies to report on water management data and practices.
2. A play is a geological formation that contains a significant amount of oil and/or natural gas.
3. *See* Appendix B for a description of how companies were selected, which plays they were asked to report on, and other methodological issues.

**Disclosure Leaders and Laggards:** Of the 30 companies scored on 25 indicators, the top scorers were: *Southwestern Energy* (23 points), *Apache Corporation* (22), *Anadarko Petroleum* (20), *Range Resources* (20), and *Occidental Petroleum* (19). The next five were *Antero Resources* (17), *Royal Dutch Shell* (17), *ConocoPhillips* (16), *Hess Corporation* (15), and *Devon Energy* (12). At the bottom of the rankings, *Gulfport Energy* and *Continental Resources* tallied zero, *Total* and *EOG Resources* scored one (1), and *CNX Resources*, *Pioneer Natural Resources* and *Concho Resources* scored two (2). Of the three largest oil and gas companies, *Shell* (17) has offered the greatest disclosures while *Exxon Mobil* (4) and *Chevron* (5) continue to lag.

**Most and Least Disclosed Indicators:**[4] Twenty-one of the 30 companies disclosed that they collect reports of "near misses" or close calls that did not result in leaks, spills, injuries, or environmental harms. These companies used such information to proactively identify problems with the goal of preventing or reducing future equipment failures and human errors. Seventeen companies state clearly that their public disclosures of chemicals used for hydraulic fracturing do not include chemicals protected by claims of trade secrecy. Sixteen companies discuss their practices for assuring the operational integrity of their wells. Fifteen companies report, on a play-by-play basis, the percentages of their wastewater recycled and reused for fracturing additional wells. On the other hand, only one company earns credit for disclosing its post-drilling monitoring practices, including chemicals monitored and frequency of monitoring, on a play-by-play basis. A few additional companies disclose such practices but are silent on the frequency of such testing. Three companies earn credit for disclosing their pre-drilling monitoring practices, including the type of chemicals monitored and frequency of monitoring, on a play-by-play basis. As with post-drilling monitoring, a few additional companies disclose that such testing occurs without stating frequency or types of test. Only three companies earn credit for disclosing, in percentage terms (from a base year), quantitative reductions in the toxicity of the chemicals they use for fracturing. Other questions have more evenly dispersed responses.

# INTRODUCTION: INVESTOR CONCERNS ABOUT WATER AND CHEMICAL RISKS FROM HORIZONTAL DRILLING AND HYDRAULIC FRACTURING

In recent years, horizontally drilled and hydraulically fractured horizontal wells have accounted for the majority of all new oil and natural gas wells drilled in the United States. In 2016, such wells accounted for 69% of new wells drilled, according to the latest figures published by the U.S. Energy Information Administration (EIA).[5] EIA reports that in December 2018, U.S. shale and "tight" plays contributed 70% of U.S. dry natural gas production and 60% of U.S. oil production.[6] Between 2011 and 2019 alone, nearly 128,000 wells were horizontally drilled and hydraulically fractured.[7] Horizontal drilling and hydraulic fracturing have been controversial because of concerns arising from their environmental risks (including water risks and methane leaks that contribute to climate change) and, due to the closer proximity these wells often have to communities, negative impacts on people living near drilling and fracturing operations.

4. Table 1 provides complete scoring results for all 25 questions.
5. U.S. Energy Information Administration, "Hydraulically fractured horizontal wells account for most new oil and natural gas wells," *eia.gov*, 30 Jan. 2018, https://www.eia.gov/todayinenergy/detail.php?id=34732.
6. U.S. Energy Information Administration, "EIA adds new play production data to shale gas and tight oil reports," *eia.gov*, 15 Feb. 2019, https://www.eia.gov/todayinenergy/detail.php?id=38372.
7. "FracFocus," *fracfocus.org*, Ground Water Protection Council and Interstate Oil and Gas Compact Commission, 11 April 2011, https://fracfocus.org/.

Since 2009, broad coalitions of investors, including public pension funds, large institutional investors, banks, and faith-based and sustainability-focused investors have been pressing oil and gas producing companies to be more transparent about how they manage and mitigate the environmental risks and community impacts of horizontal drilling and hydraulic fracturing.[8] Investors require rigorous, relevant, timely and comparable data to make informed investment decisions. Such data also help provide assurance to investors that companies have appropriate oversight and accountability practices in place to track—and therefore to mitigate—impacts of their operations. Companies implementing current best practices in operations, and providing transparent information about their effects, will reduce regulatory and reputational risks, enhance the likelihood of securing and maintaining their social license to operate, and reduce liabilities associated with poor performance, spills, contamination, and litigation.[9]

Figure 1 below sets forth the major U.S. “shale plays” (geologically-defined regions) where horizontal drilling and hydraulic fracturing are conducted.[10] Additional major North American shale plays are located in the Canadian provinces of Alberta and British Columbia.

For many indicators,[11] *DTF 2019* requests “play-by-play” reporting by companies (reporting of data and practices by individual plays). Play-by-play reporting is critical, because water concerns are primarily regional or local in nature. Accountability at this level serves as an important indicator to investors of a company’s ability to effectively manage regional and local operating challenges.[12]

8. Similarly, there is growing interest by large industrial suppliers of natural gas, most notably public utilities, in ensuring that safe and responsible practices were used in producing the natural gas they supply. In 2017, the Natural Gas Supply Collaborative published a list of environmental and social performance indicators, drawing on several published sets of suggested indicators, including *Disclosing the Facts*. *See* “Natural gas supply collaborative,” https://www.mjbradley.com/content/natural-gas-supply-collaborative. The movement toward “responsible gas” is growing. In 2018, the Edison Electric Institute (EEI) and the American Gas Association similarly released an updated compilation of environmental, social, and governance (ESG) metrics for their ESG/Sustainability reporting template. *See also* “EEI and AGA update ESG/sustainability reporting template to include natural gas metrics,” http://www.eei.org/resourcesandmedia/newsroom/Pages/Press%20Releases/EEI%20and%20AGA%20Update%20ESGSustainability%20Reporting%20Template%20to%20Include%20Natural%20Gas%20Metrics.aspx.

   Independent Energy Standards Corporation, founded in 2013, has developed a proprietary tool for assessing companies’ risk management practices. The tool is intended to serve oil and gas companies, insurance, and investor clients. In 2018, the company certified its first “responsible gas” transaction, a sale by *Southwestern Energy* to *New Jersey Natural Gas*, from a group of certified West Virginia wells. *See* “Company overview of Independent Energy Standards Corporation,” https://www.bloomberg.com/research/stocks/private/snapshot.asp?privcapId=412957982; https://www.globenewswire.com/news-release/2018/09/06/1566697/0/en/IES-Makes-History-in-Oil-Gas-Industry-and-Establishes-Market-for-Differentiated-Gas-by-Completing-First-TrustWell-Responsible-Gas-Transaction.html; and https://www.naturalgasintel.com/articles/115862-southwestern-earning-higher-prices-for-responsibly-produced-natural-gas.

9. Some investors also view horizontal drilling and fracturing operations through a human rights lens, citing the United Nations definition of the human right to water and sanitation as the “right of everyone to sufficient, safe, acceptable and physically accessible and affordable water for personal and domestic uses.” *See* United Nations Committee on Economic, Social and Cultural Rights, “Human right to water and sanitation/international decade for action ‘water for life’ 2005-2015,” *un.org*, United Nations, 28 July 2010, http://www.un.org/waterforlifedecade/human_right_to_water.shtml.

   *See also* “Human right to water,” *iccr.org*, Interfaith Center on Corporate Responsibility, https://www.iccr.org/our-issues/water-stewardship-and-sustainability/human-right-water.

   For a compendium of activist analyses of human rights and hydraulic fracturing operations, see “Works on human rights, fracking and climate change,” *tribunalonfracking.org*, The Permanent Peoples’ Tribunal on Human Rights, Fracking and Climate Change, https://www.tribunalonfracking.org/preliminary-human-rights-work-on-fracking/.

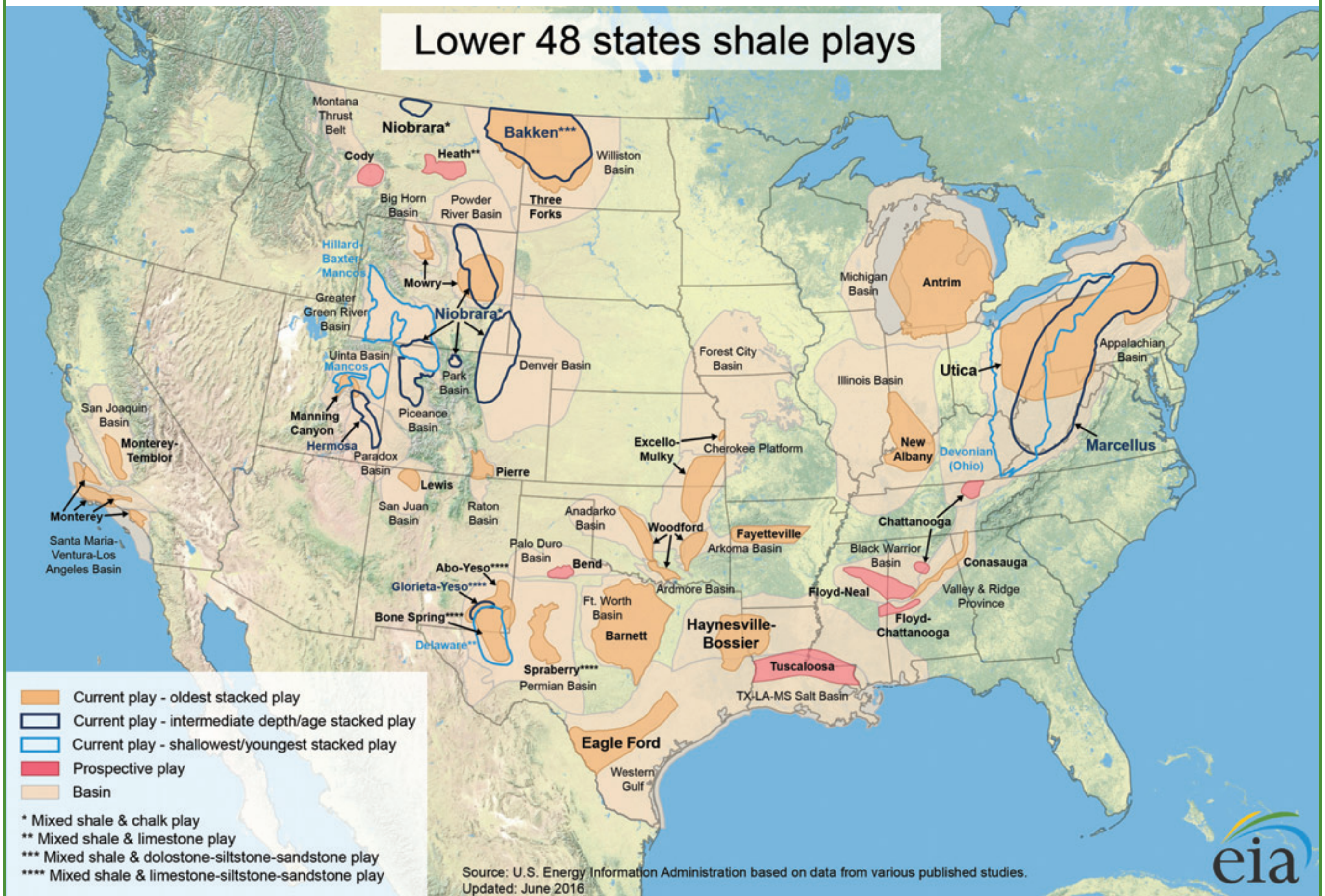
10. The U.S. Geological Survey defines a play as a “set of known or postulated oil and/or gas accumulations sharing similar geologic, geographic, and temporal properties.” See Klett, T.R., et al., “World Petroleum Assessment 2000,” *usgs.gov*, U.S. Geological Survey, 2000, https://certmapper.cr.usgs.gov/data/PubArchives/WEcont/chaps/GL.pdf. p. GL-6.

    Figure 1 is captioned “shale plays,” although it notes that hydraulic fracturing is used to economically recover marketable hydrocarbons from mixtures of rock formations.

11. *See* Appendix A for a complete list of questions.

12. In some cases, water risk can vary even within plays where the plays are several hundred square miles and cut across diverse hydrologic systems. In other cases, geologic plays are stacked on top of one another, so it may be appropriate to aggregate reporting for such plays. Regional reporting is critical to understanding water risk, although selection of the most appropriate reporting scale remains a challenge.

FIGURE 1: LOWER 48 STATES SHALE PLAYS




SOURCE: U.S. Energy Information Administration, 2016

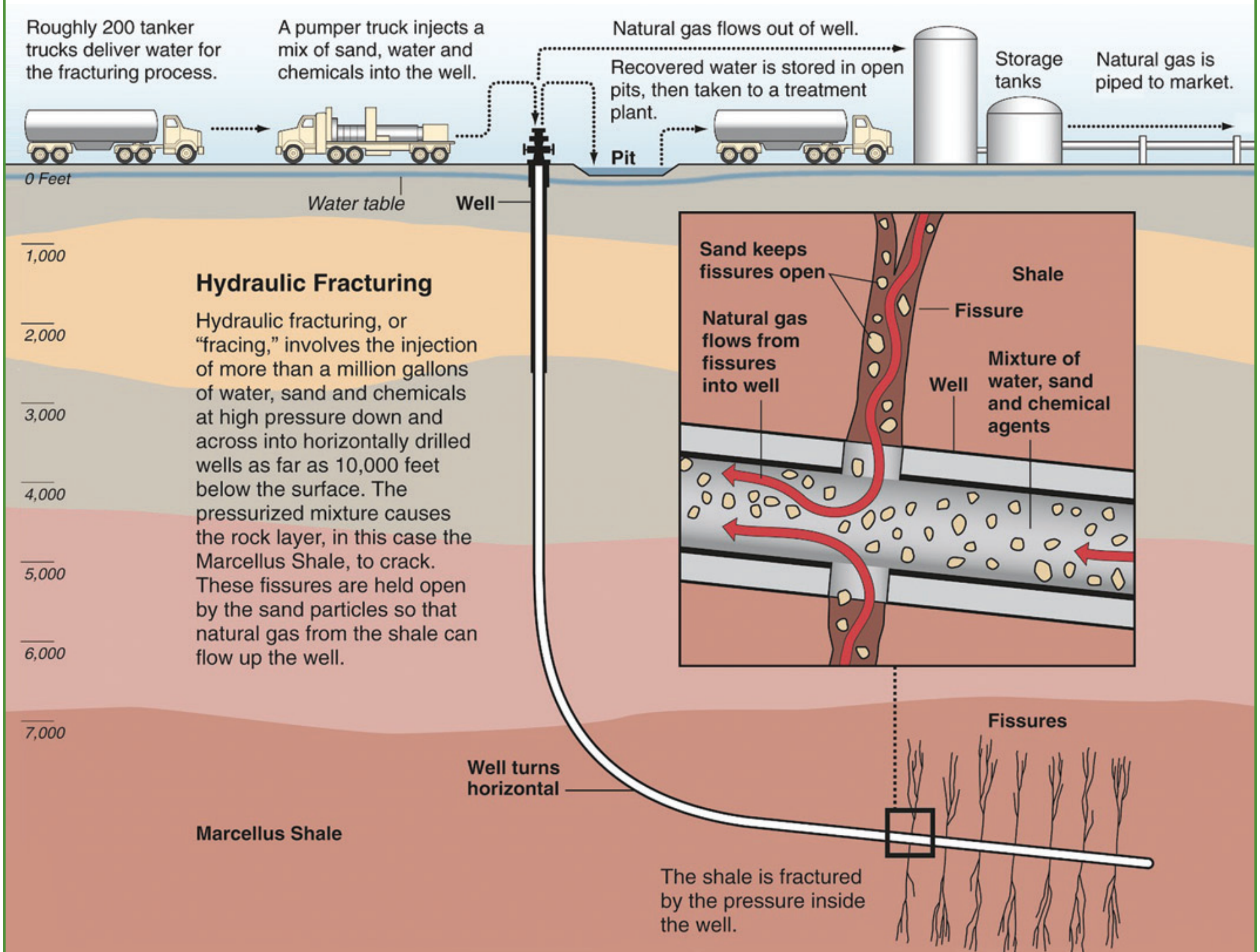
In technical terms, hydraulic fracturing is the injection under pressure of a combination of water, chemicals, and sand or similar synthetic particles into a geological formation. This injection creates a microscopic fracture network in the target rock that facilitates the flow of oil, gas, and related liquids up the well for capture and sale. Horizontally drilled wells begin with a vertical well most commonly bored many thousands of feet downward from the surface. The wellbore curves as it approaches the targeted production formation, through which it moves horizontally. (See Figure 2).

Figure 3 displays the general timeline and summary of activities at a hydraulically fractured oil or gas production well.

The risks associated with hydraulic fracturing encompass the larger array of activities accompanying horizontally drilling and fracturing wells, including the life-cycle of the water used for fracturing and its eventual recycling or disposal. *DTF 2019* labels this larger scope of actions “hydraulic fracturing operations.”

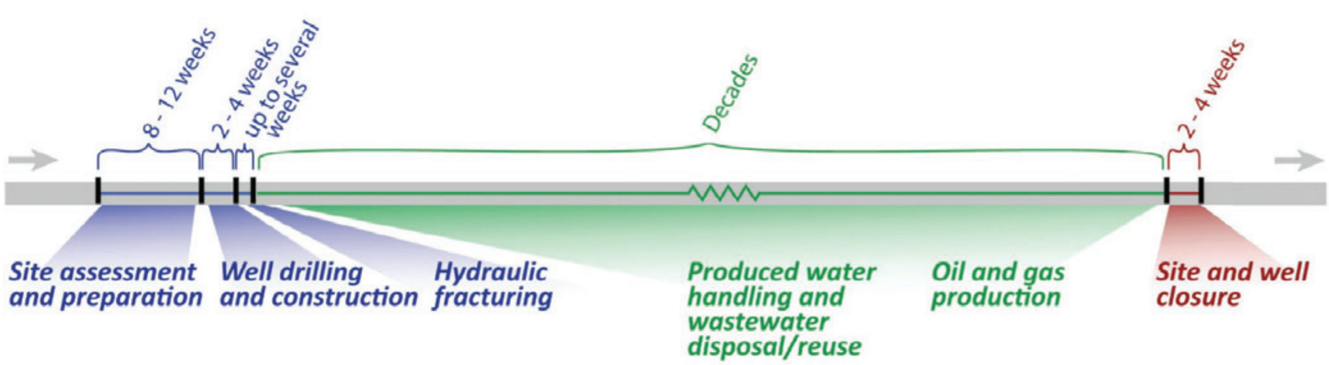
When a well is ready to be fractured (“completed”), millions of gallons of water, tens of thousands of gallons of chemicals, and tons of sand are typically brought to the site. Companies often drill and complete multiple wells from a single pad to access the formation in multiple horizontal directions or to access several productive formations stacked atop one another. As shown in Figure 3, these ‘completion’ activities are concentrated in the first months of the life of a well that will produce for many years.

## FIGURE 2: HYDRAULIC FRACTURING PROCESS




SOURCE: Al Granberg / ProPublica.org

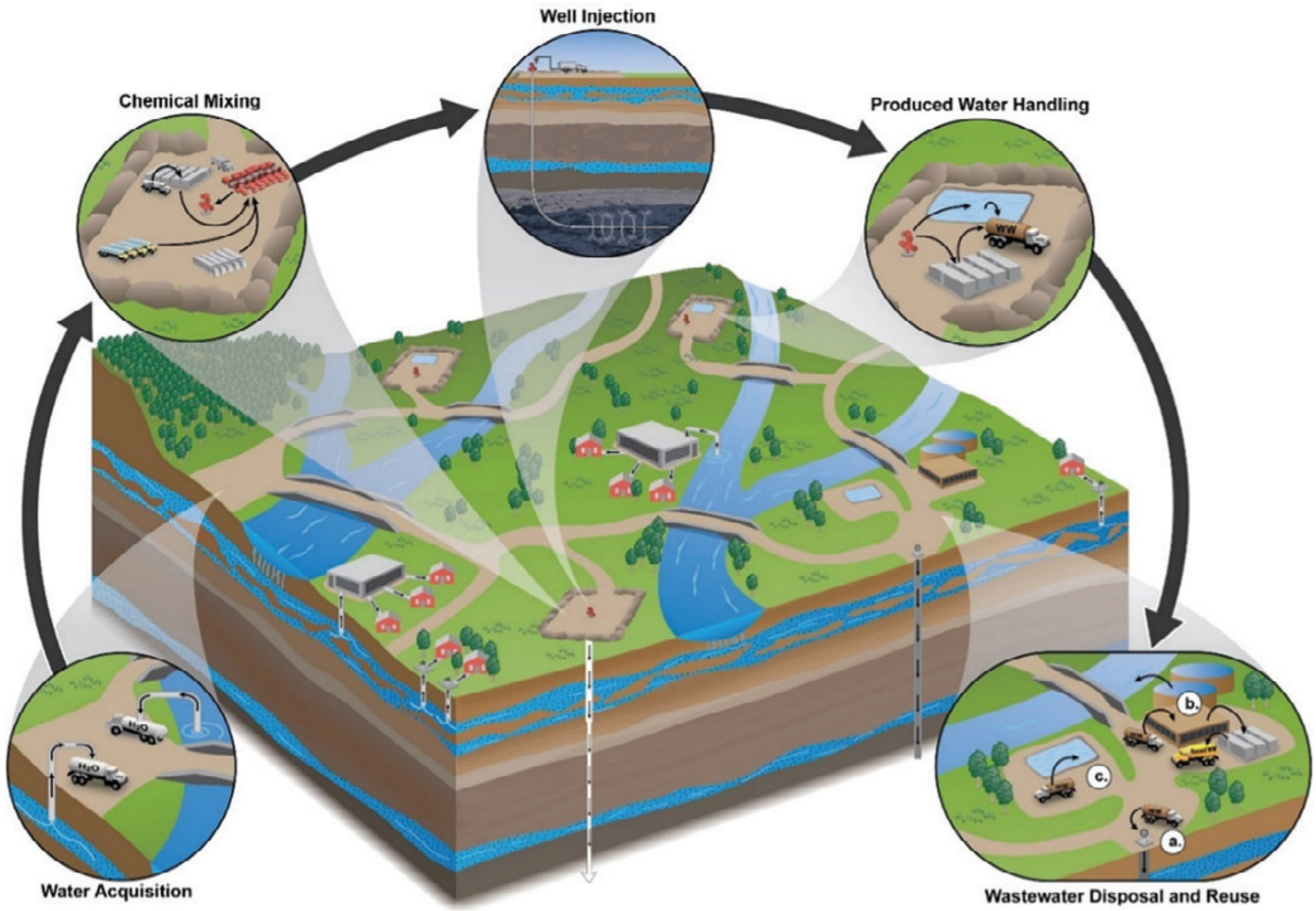
## FIGURE 3: LIFECYCLE OF A TYPICAL HYDRAULICALLY FRACTURED WELL




SOURCE: U.S. Environmental Protection Agency, *Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States.* Hereafter cited as "EPA Drinking Water Study," page ES-4.

Figure 4 presents the life cycle of water use for hydraulic fracturing:

FIGURE 4: THE FIVE STAGES OF THE HYDRAULIC FRACTURING WATER CYCLE




**The five stages of the hydraulic fracturing water cycle. The stages (shown in the inserts) identify activities involving water that support hydraulic fracturing for oil and gas. Activities may take place in the same watershed or different watersheds and close to or far from drinking water resources. Thin arrows in the inserts depict the movement of water and chemicals. Specific activities in the "Wastewater Disposal and Reuse" inset include (a) disposal of wastewater through underground injection, (b) wastewater treatment followed by reuse in other hydraulic fracturing operations or discharge to surface waters, and (c) disposal through evaporation or percolation pits.**

SOURCE: EPA Drinking Water Study, page 1-5.

Risks related to water quality are a significant concern for companies, their investors, and the public due to the chemicals used during hydraulic fracturing and the large volumes of contaminated water produced from wells. One pathway for contaminants to enter the environment is via wellbore leaks that allow pollutants to move out from and travel along the outside of the well casing into ground water. A second pathway can be created by contaminants moving via newly created fractures in the production zone, through intersecting neighboring wells, abandoned wells, or existing faults and fractures. Risks from "induced seismicity" (earthquakes resulting from operations) have also risen to prominence in recent years. While most induced earthquakes are related to disposal of wastewater ("deep well injection"), in some areas increased seismic activity has been associated with hydraulic fracturing itself.[13]

13. *See* additional sources cited in "Minimizing Induced Seismicity" section.

Securing sufficient water supplies poses another risk management challenge to companies. Hydraulic fracturing of horizontally drilled wells typically requires millions of gallons of water per well, which can be a significant issue in water-scarce areas. Companies using saline groundwater, treated municipal water, or industrial discharges for their operations, or recycling and reusing their wastewater from previously fractured wells, can reduce their demand for fresh water.

The fluids injected down the wellbore during completions are primarily a mix of water and sand or synthetic sand-like particles. Chemicals, typically comprising between 0.5 to 2% of the water/sand mix, are added for, among other purposes, reducing clogging, protecting metal components, and reducing friction. Some are highly hazardous and others more benign.[14,15]

After the fracturing process is complete, a portion of the water and chemicals injected into the well will flow back out of the well. This water is commonly referred to as “flowback water.” “Produced water” already present in the geological formation also comes to the surface as oil and gas are produced.[16] These wastewaters can contain fracturing fluid chemicals, chemicals naturally present in the formation being fractured, and new compounds created when the fracturing fluid interacts with the formation. Surface spills and leaks, especially from wastewaters stored onsite in tanks or open pits, can also contaminate surface and ground waters.

Wastewaters and solid waste from drilling operations can contain naturally-occurring radioactive materials (NORM), bringing risks that companies must manage. If allowed by regulation, wastewater may be used for road deicing, dust suppression, or irrigation purposes, potentially creating contamination risks to nearby waters, soils, and crops. Waste material from the initial drilling process must also be disposed of or reprocessed. When wells are no longer economically productive, companies must close and seal them effectively to mitigate risks to the environment in the future.

In 2016, at the request of Congress, the U.S. Environmental Protection Agency (EPA) published a wide-ranging study on the impact of hydraulic fracturing on drinking water resources.[17] The report provides a review and synthesis of available scientific information concerning the relationship between hydraulic fracturing activities and drinking water resources in the United States. Its goals “were to assess the potential for activities in the hydraulic fracturing water cycle to impact the quality or quantity of drinking water resources and to identify factors that affect the frequency or severity of those impacts.”[18] EPA commented that “significant data gaps and

14. “Chemical use in hydraulic fracturing,” *fracfocus.org*, Ground Water Protection Council and Interstate Oil and Gas Compact Commission, 11 April 2011, http://fracfocus.org/water-protection/drilling-usage.

15. *See* additional sources cited in “Reducing Chemical Hazards” section.

16. “Flowback" and "produced water" are sometimes referred to together as produced water. *DTF 2019* uses "wastewater" to refer to both.

17. *Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States*, Washington, U.S. Environmental Protection Agency, 2016 (hereafter cited as EPA Drinking Water Study), http://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=332990.

    For the executive summary alone, see *Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States Executive Summary*, Washington, U.S. Environmental Protection Agency, 2016 (hereafter cited as EPA Drinking Water Study Executive Summary), https://www.epa.gov/sites/production/files/2016-12/documents/hfdwa_executive_summary.pdf.

18. EPA Drinking Water Study Executive Summary, p. 1, https://www.epa.gov/sites/production/files/2016-12/documents/hfdwa_executive_summary.pdf.

uncertainties in available data prevented [it] from calculating or estimating the national frequency of impacts on drinking water resources."[19,20]

Drawing on "cases of identified impacts and other data, information, and analyses," EPA stated that "the following combinations of activities and factors are more likely than others to result in more frequent or more severe impacts:"[21]

- Water withdrawals at times or in areas where water is relatively scarce;
- Spills from managing fluids that result in large volumes or high concentrations of chemicals reaching groundwater;
- Injection of fluids into wells "with inadequate mechanical integrity;"
- Injection of hydraulic fracturing fluids directly into groundwater;
- Discharge of inadequately treated wastewater to surface water; and
- Disposal or storage of wastewater in unlined pits.

*DTF 2019* encourages companies to disclose, on a play-by-play basis, the measures they take to lessen or prevent environmental impacts from these and other issues related to water use, water quality, and chemical use. Such disclosures can help investors understand how well a company is evaluating and managing the broad set of water-related risks associated with hydraulic fracturing operations for oil and gas production.

19. Id., p. 2.

20. *See also* Carroll, Matthew, "Ground and stream water clues reveal shale drilling impacts," *news.psu.edu*, Pennsylvania State University Media Release, 19 Nov. 2018, https://news.psu.edu/story/548378/2018/11/19/research/ground-and-stream-water-clues-reveal-shale-drilling-impacts; Woda, Josh, et al., "Detecting and explaining why aquifers occasionally become degraded near hydraulically fractured shale gas wells," *pnas.org*, Proceedings of the National Academy of Sciences, 4 Dec. 2018, https://www.pnas.org/content/115/49/12349; Legere, Laura, "DEP releases updated details on water contamination near drilling sites," *Pittsburgh Post-Gazette*, 8 Sept. 2014, https://www.post-gazette.com/business/powersource/2014/09/09/DEP-releases-details-on-water-contamination/stories/201409090010; Wen, Tao, et al., "Big groundwater data sets reveal possible rare contamination amid otherwise improved water quality for some analytes in a region of Marcellus Shale development," *Environmental Science & Technology*, vol. 52, issue 12, (2018), pp. 7149-7159, https://www.ncbi.nlm.nih.gov/pubmed/29783843; Rubinkam, Michael, "Studies show groundwater holding own against drilling boom," *Associated Press*, 18 July 2018, https://www.apnews.com/b3cecd15c46d4feb88974b17a033f892; Larson, Toti E., et al., "Monitoring stray natural gas in groundwater with dissolved nitrogen. An example from Parker County, Texas," *Water Resources Research*, (2018): 6024-6041, https://doi.org/10.1029/2018WR022612; "No link between Barnett Shale natural gas production and methane in groundwater, studies conclude," *news.utexas.com*, University of Texas at Austin, 24 Sept. 2018, https://news.utexas.edu/2018/09/24/methane-in-barnett-area-groundwater-naturally-occurring; Botner, E. Claire, et al., "Monitoring concentration and isotopic composition of methane in groundwater in the Utica Shale hydraulic fracturing region of Ohio," 190 *Environmental Monitoring and Assessment*, 190, p. 322 (2018), https://link.springer.com/article/10.1007/s10661-018-6696-1; Barth-Naftilan, E., et al., "Methane in groundwater before, during and after hydraulic fracturing of the Marcellus Shale," *pnas.org*, Proceedings of the Natural Academy of Sciences, 12 June 2018, https://www.pnas.org/content/pnas/early/2018/06/12/1720898115.full.pdf; Peter B. McMahon, et al., "Methane and benzene in drinking-water wells overlying the eagle ford, Fayetteville, and Haynesville shale hydrocarbon production areas," *Environmental Science and Technology*, 2017, https://pubs.acs.org/doi/abs/10.1021/acs.est.7b00746.

21. EPA Drinking Water Study Executive Summary, pp. 1-2, https://www.epa.gov/sites/production/files/2016-12/documents/hfdwa_executive_summary.pdf.

# ISSUES AND QUESTIONS

## TABLE 1: *DISCLOSING THE FACTS 2019* SCORECARD

| COMPANY | Anadarko | Antero | Apache | BP | Cabot | Chesapeake | Chevron | Cimarex | CNX | Concho | ConocoPhillips | Continental | Devon | Encana | EOG | EQT | Equinor | Exxon Mobil | Gulfport | Hess | Marathon Oil | Newfield | Noble | Occidental | Pioneer | Range | Shell | Southwestern | Total | Ultra Petroleum | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) Well Evaluation | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | | | ✓ | | ✓ | | ✓ | | | ✓ | | ✓ | | | ✓ | ✓ | | ✓ | ✓ | ✓ | | | 16 |
| 2) Well Integrity | | ✓ | | | | | | | | | | | | | | | | | | ✓ | | ✓ | | | | ✓ | | ✓ | | | 5 |
| 3) Near Misses | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | | ✓ | ✓ | | ✓ | | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | * | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | 21 |
| 4) Offset Well Management | ✓ | ✓ | ✓ | | | ✓ | | | | | ✓ | | | | | ✓ | ✓ | | | ✓ | ✓ | | * | ✓ | | | ✓ | ✓ | | | 12 |
| 5) Avoiding Induced Seismic Activity | ✓ | ✓ | ✓ | ✓ | | | | ✓ | | | ✓ | | | ✓ | | | | ✓ | | ✓ | | ✓ | | ✓ | | ✓ | ✓ | ✓ | | | 14 |
| 6) Pre-drill H20 Monitoring | ✓ | | | | ✓ | * | | | | | | | | | | | | | | * | | | * | | | | | ✓ | | | 3 |
| 7) Post-drill H20 Monitoring | ✓ | | | | | * | | | | | | | | | | | | | | * | | | * | | | | | | | | 1 |
| 8) Evaluating Water Scarcity | ✓ | ✓ | ✓ | | | ✓ | | | | ✓ | ✓ | | | | | | ✓ | | | ✓ | | | | ✓ | | ✓ | ✓ | ✓ | | | 12 |
| 9) Total Water Use | ✓ | ✓ | ✓ | | | | | | | | ✓ | | ✓ | | | ✓ | | | | * | | | ✓ | ✓ | | ✓ | | ✓ | | | 10 |
| 10) Freshwater & Non-freshwater Use | ✓ | ✓ | ✓ | | | | | | | | ✓ | | | | | | | | | ✓ | | | | ✓ | | ✓ | ✓ | ✓ | | | 9 |
| 11) Water Source Types | ✓ | | ✓ | | | | | | | | | | | | | ✓ | | | | * | | | | | | ✓ | ✓ | ✓ | | | 6 |
| 12) Wastewater Use | ✓ | ✓ | ✓ | | ✓ | | | ✓ | ✓ | | | | | | | ✓ | | | | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | 15 |
| 13) Reducing Freshwater | ✓ | | ✓ | | | | ✓ | | | | | | ✓ | | | | | | | ✓ | | | | ✓ | | ✓ | ✓ | ✓ | | | 9 |
| 14) Wastewater Volume | ✓ | ✓ | ✓ | | | | | | ✓ | | ✓ | | | | | ✓ | | | | | | ✓ | * | ✓ | | ✓ | | ✓ | | | 10 |
| 15) Wastewater Storage Methods | | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | ✓ | | ✓ | ✓ | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | 16 |
| 16) Wastewater Storage Safeguards | | ✓ | ✓ | | | ✓ | | ✓ | | | | | ✓ | ✓ | | | | | | ✓ | ✓ | | * | ✓ | | ✓ | ✓ | ✓ | | | 12 |
| 17) Drilling Residuals | ✓ | ✓ | ✓ | | | ✓ | | | | | ✓ | | ✓ | | | ✓ | | | | ✓ | | | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | 14 |
| 18) NORM | ✓ | ✓ | ✓ | | | ✓ | | | | | ✓ | | ✓ | | | | | | | * | | ✓ | | ✓ | | ✓ | ✓ | ✓ | | | 11 |
| 19) Managing Inactive Wells | ✓ | | ✓ | | | ✓ | | | | | ✓ | | | | | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | | ✓ | | ✓ | | ✓ | 14 |
| 20) Use of Waste Products | ✓ | ✓ | ✓ | | | | | | | | ✓ | | ✓ | | | | | | | | | | * | ✓ | | ✓ | ✓ | ✓ | | | 9 |
| 21) Toxicity Reduction | | | ✓ | | | | | | | | | | | | | | | | | | | | | | | | ✓ | ✓ | | | 3 |
| 22) Dry Chemical Use | ✓ | | ✓ | ✓ | | ✓ | | | | | ✓ | | ✓ | | | | | | | | | ✓ | * | ✓ | | ✓ | | ✓ | | | 10 |
| 23) Eliminating BTEX | | | ✓ | | ✓ | | ✓ | ✓ | | | ✓ | | | | | | | | | ✓ | | | * | ✓ | | ✓ | ✓ | ✓ | | | 10 |
| 24) CBI Disclaimer | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | | | ✓ | | ✓ | ✓ | | | | | | ✓ | ✓ | ✓ | * | ✓ | ✓ | ✓ | ✓ | ✓ | | | 17 |
| 25) Reducing CBI Claims | ✓ | ✓ | ✓ | | | | | | | | | | ✓ | * | | | | | | | | ✓ | | | | | | | | | 5 |
| TOTAL SCORE | 20 | 17 | 22 | 5 | 4 | 11 | 5 | 5 | 2 | 2 | 16 | 0 | 12 | 4 | 1 | 8 | 4 | 4 | 0 | 15 | 5 | 11 | 6 | 19 | 2 | 20 | 17 | 23 | 1 | 3 | |

* Asterisks indicate where disclosures met criteria but were provided after scoring

## PREVENTING WELL INTEGRITY FAILURES

*DTF 2019* asks whether companies disclose practices to maintain integrity and to detect and prevent leaks during subsequent oil and gas production, including ongoing pressure tests; continuous monitoring; and temperature, acoustic, or ultrasonic assessments. To determine the effectiveness of companies' measures to assure well integrity, *DTF 2019* also asks for companies to report the percentage of wells that experience integrity failures leading to releases to the environment. It also asks companies to disclose if they track "near misses" and how they use such data to improve practices.[22]

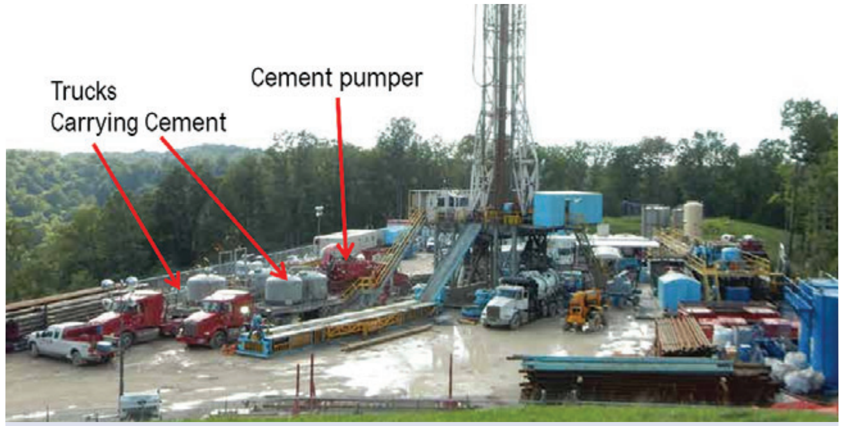
### Background

Proper well construction and monitoring are widely viewed by experts as key factors in reducing risk to groundwater from hydraulic fracturing operations. The methods for constructing wells and monitoring integrity

22. For text of the questions on which scores are based, see questions 1-3 in Appendix A.

have been improving continually over time;[23,24] on the other hand, pumping pressures have been increasing, which can raise problems with well integrity.

During completion and production, wells can experience breaches in their cement or casing structures, creating risks to groundwater.[25] These well integrity failures are caused by a number of factors such as human error, flaws in well design and construction, corrosive substances[26] in the fracturing fluid and wastewater, formation stresses, and changes in well temperature and pressure during production.[27]




SOURCE: Bill Hughes, OVEC/ohvec.org

Cementing casing on drill pad in Wetzel County, WV

Well design and construction flaws include failure to cement along key segments of the well.[28] Additionally, if companies use cement that is inappropriate for subsurface conditions, fail to clear the wellbore of drilling fluids, or install the casing to one side of the wellbore, channels may be left in the cement that can serve as conduits for unwanted flows of contaminants from the well.[29]

Wells typically include multiple protective layers of pipes and cement to reduce the risk that fluids and gas will be released to the environment when a single protective layer fails. Poor cementing jobs in regions where methane exists close to the surface may allow methane to move upward through the outermost portion of the wellbore into drinking water aquifers or may allow it to escape into the atmosphere.

Published estimates of well integrity failures vary due to differing definitions, types of data sources reviewed, and time periods assessed. One study in the Marcellus region of Pennsylvania estimated that 2.6% of wells had "barrier or integrity failure;" a second estimated 3.4% had "well-barrier leakage;" a third estimated 6.3% of wells had "a well-barrier or integrity failure;" and a fourth found that 1.9% of wells showed "loss of structural integrity."[30] A much broader analysis, based on a review of global data sets covering over 600,000 wells,

23. King, George E. and King, Daniel E., "Environmental risk arising from well-construction failure--differences between barrier and well failure, and estimates of failure frequency across common well types, locations, and well age," *SPE Production & Operations*, 28.04 (2013), *One Petro* (hereafter cited as King and King), https://www.onepetro.org/journal-paper/SPE-166142-PA.

24. Elements of this study can be found at King, George E. "Facts on environmental risk in fracturing & well construction: What do the numbers say?" *spe.org*, Society of Petroleum Engineers, 18 Dec.2013, https://connect.spe.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=926cbc80-f76d-4d4c-b82c-ba15fc7a7760.

25. Jackson, Robert, "The integrity of oil and gas wells," *Proceedings of the National Academy of Sciences*, 111.30 (2014): 10902-10903, *U.S. National Library of Medicine, National Institutes of Health* (hereafter cited as Jackson), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4121783/.

26. Corrosive substances include hydrogen sulfide, a naturally-occurring compound in oil and natural gas, and brine. *See* Wilson, Elizabeth "Fracking wells can cut their toxic chemical use," *Scientific American*, 8 April 2016, https://www.scientificamerican.com/article/fracking-wells-can-cut-their-toxic-chemical-use/; see also, "Hydrogen sulfide," *earthworks.org*, Earthworks, https://earthworks.org/issues/hydrogen_sulfide; and EPA Drinking Water Study, pp. 6-18 https://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=332990.

27. Corrosion is most often a problem at collars, which join two sections of casing, in un-cemented zones. Formation stresses can contribute to breaches when changes in underground pressure, brought on by hydraulic fracturing, cause the rock in an unstable layer to shear and damage the casing. Injecting cool fracturing fluid in a warm well can cause casing temperatures to fall from 212 °F to 64 °F. Fracturing fluid injection can also generate between 2,000 and 12,000 psi of pressure on the casings and cement. Wells fractured in multiple stages or refractured can undergo multiple fluctuations in pressure and temperature, causing stress or failure. For an overview of well construction issues, including casing, cementing, and factors that can affect movement of gas and fluids from the well to drinking water sources, see EPA Drinking Water Study, section 6.2, https://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=332990; EPA Drinking Water Study, Executive Summary, p. 23, https://www.epa.gov/sites/production/files/2016-12/documents/hfdwa_executive_summary.pdf.

28. EPA Drinking Water Study, pp. 6-27, https://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=332990.

29. Ibid.

30. Jackson, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4121783/.

concludes that actual well integrity failures, where all barriers fail and a leak can occur, is very rare."[31] Some studies have found that as the distance between the production layer and groundwater decreases, the likelihood of fracturing fluid and wastewater migrating to groundwater from an integrity failure increases.[32,33] It is generally believed that earlier generations of wells are riskier than more recently constructed wells because of substantial improvements in well construction practices. Additionally, as wells age, their risks of failure increase.[34] These improved practices include better cementing, methods for connecting pipes, and well integrity assessment tools.

Many companies describe the measures they take during well construction and completion to avoid leaks and detect well failures associated with construction. The measures described typically include diagrams of multiple protective pipe and cement layers and descriptions of cementing practices. Companies also describe their monitoring practices during drilling, completion, and production.

Companies seeking to prevent accidents, leaks, regulatory violations, and the like can benefit from requiring and tracking reports of "near misses"— close calls that did not result in leaks, spills, injuries, or environmental harms. By requiring tracking and reporting of near misses, companies can learn from events and work to prevent accidents and reduce environmental impacts. They can learn where and how processes, activities, and/or equipment are problematic and alert staff and contractors to take precautionary preventive actions. Such actions can include additional staff training to reduce human error, addressing equipment inadequacies, and installing upgraded technology. Companies can also use the findings to drive research on innovative equipment and work practices.

States have been tightening regulations governing well integrity; however, regulations still vary in their stringency.[35]

## Scores

Sixteen companies earned credit for their disclosures of well integrity practices and five earned credit for disclosing percentages of well integrity failures. Twenty-one disclosed their tracking and use of "near miss" data.

## Notable Disclosures[36]

The most detailed, informative disclosures on well integrity provide details on how a well is constructed, including descriptions of cementing practices. They also provide information on monitoring of well integrity during drilling,

31. King and King, https://www.onepetro.org/journal-paper/SPE-166142-PA.
32. Birdsell, Daniel T. et. al., "Hydraulic fracturing fluid migration in the subsurface: A review and expanded modeling results," *Water Resources Research*, vol. 51, issue 9, (2015): 7159-7188, *AGU Publications*, https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1002/2015WR017810.
33. *See also* EPA Drinking Water Study Executive Summary, p. 27, https://www.epa.gov/sites/production/files/2016-12/documents/hfdwa_executive_summary.pdf.

    The distance between the producing formation and groundwater varies among plays although it is also the case that fractures from operations less than 2,000 feet from the surface tend to move horizontally while those from operations conducted deeper than 2,000 feet tend to move vertically.

    *See* "Hydraulic Fracturing: The Process," *fracfocus.org*, Ground Water Protection Council and Interstate Oil and Gas Compact Commission, 20 July 2010, http://fracfocus.org/hydraulic-fracturing-how-it-works/hydraulic-fracturing-process.
34. King and King, https://www.onepetro.org/journal-paper/SPE-166142-PA.
35. *DTF 2019's* description of state regulations addressing specific practices relies on a November 2017 overview of regulations in 27 states by the Groundwater Protection Council (GWPC), a not-for profit multi-state organization of officials responsible for groundwater protection. The report tallies the numbers of states addressing specific practices, though it does not systematically associate specific states with particular regulations. Like the EPA Drinking Water Study, the report is a rich source of basic information about drilling, completion, and production operations but in more compact form. Paque, Mike, *State Oil and Natural Gas Regulations Designed to Protect Water Resources: Third Edition*, Oklahoma City: Ground Water Protection Council, 2017 (hereafter cited as GWPC State Regulation Study), http://www.gwpc.org/sites/default/files/State%20Regulations%20Report%202017%20Final.pdf.

    *See* "Well integrity regulatory elements for consideration," *gwpc.org*, Ground Water Protection Council, Aug 2016, http://www.gwpc.org/sites/default/files/Well%20Integrity%20-%20Full%20Publication%202016.pdf. The council drew upon a model regulatory framework developed by a collaboration of the Environmental Defense Fund and Southwestern Energy, which Texas and other states had drawn on previously in updating their regulations.
36. For this section and all the following, 'notable disclosures" describe both relatively robust and informative disclosures as well as noteworthy practices and accomplishments. However, not all notable disclosures, practices, and accomplishments have been awarded credit when assessed against the specific criteria required in the scorecard questions.

completion, and production. *Southwestern Energy* provides one of the best such disclosures. Uniquely within the industry, it discloses the results of its investigations of public complaints about water contamination.[37,38] *Chesapeake Energy* provides details on its remote well monitoring system and its proprietary "Welltender" mobile application for prioritizing and entering operating data for field visits.[39]

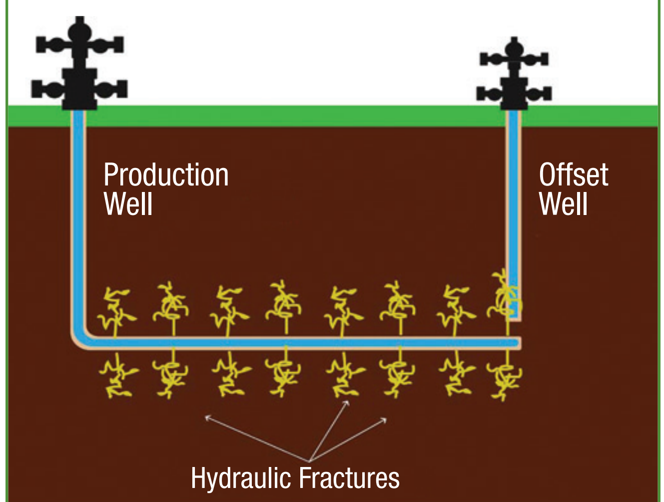
## MANAGING RISKS FROM NEARBY WELLS, FAULTS, AND FRACTURES

*DTF 2019* asks if companies disclose the steps they take to minimize the risk that nearby wells will provide a pathway for release of contaminants to the environment from drilling and completion of new wells.[40]

### Background

During the hydraulic fracturing process, companies can experience "frac hits," where "fracturing at one well affects a nearby oil and gas well or fracture network, resulting in unexpected pressure increases at the nearby well, damage to the nearby well, or spills at the surface of the nearby well."[41] According to the EPA, while frac hits are capable of reaching wells more than 8,400 feet away, more commonly they reach wells that are within 1,100 feet of one another.[42]

FIGURE 5: 'FRAC HIT' OF OFFSET WELL (NOT TO SCALE)




SOURCE: Elizabeth Hoffman / Adapted from graph by OleumTech

Fractures that intersect an existing operating well can lower productivity.[43] Frac hits also pose environmental risks. When a frac hit causes fracturing fluid to enter an abandoned well, the combination of the high pressure of the fracturing fluids and low pressure in the depleted reservoir creates a vacuum that draws the fluids into the older well.[44] If that well has integrity problems – such as deteriorated cement or worn, insufficient or improperly installed plugs – the fracturing fluids can travel into nearby water sources.[45] In Tioga County, Pennsylvania, a fracture that hit a nearby abandoned well caused brine and methane to shoot 30 feet into the air for more than a week.[46]

37. "The steps we take to assure well integrity," *swn.com*, Southwestern Energy, https://www.swn.com/operations/pages/wellintegrity.aspx.
38. For the results of the company's investigation of 209 complaints (170 in Arkansas) concerning the 5,550 horizontally drilled and hydraulically fractured wells it has completed since 2005, see the well water impairment claim findings section at "Water," *swncr.com*, Southwestern Energy, https://www.swncr.com/responsibility/environment/water/.
39. "Operations and Environmental Protection," *chk.com*, Chesapeake Energy, http://www.chk.com/responsibility/environment/operations.
40. *See* Question 4 in Appendix A for the text of the question on which scores are based.
41. EPA Drinking Water Study Executive Summary, p. 28, https://www.epa.gov/sites/production/files/2016-12/documents/hfdwa_executive_summary.pdf.
42. Ibid.
43. Productivity can be lowered in three ways. First, sand from the fracturing fluid can travel into the producing well and block the natural gas' pathway to the surface, which is referred to as being "sanded in." Second, the fracturing fluid can flush proppants (the term used for the sand or sand-like particles injected into a well to prop frac fissures open, allowing gas and oil to flow from the formation) from the producing well, shutting off the flow of gas from the fissure. Third, frac hits can undercut the productivity of the new well by diverting the fracturing fluid's pressure into the fractures of an already producing well, leaving the targeted areas of high concentrations of natural gas not fully fractured. Frac hits have lowered the productivity of new wells by 30% in some areas of the Permian Basin. Jacobs, Trent, "Oil and gas producers find frac hits in shale wells a major challenge," *Journal of Petroleum Technology*, (2017), (Hereafter cited as Jacobs, 2017), https://www.spe.org/en/jpt/jpt-article-detail/?art=2819.
44. Ibid.
45. EPA Drinking Water Study Executive Summary, p. 28, https://www.epa.gov/sites/production/files/2016-12/documents/hfdwa_executive_summary.pdf.
46. Ibid., p. 28.

Frac hits are becoming more common as companies increasingly drill new wells close to existing wells. For example, in 2010, most companies' new hydraulically fractured wells were located more than 1,000 feet from existing wells. By 2017, many companies were completing new wells within 250 to 550 feet of existing wells.[47] Additionally, in 2017, companies hydraulically fractured new wells using two to three times more water and sand than for previous wells. The increased water volumes can create long fractures that penetrate previously fractured areas.[48]

Twenty-one frac hit incidents were reported in Alberta between 2010 and 2012, some leading to spills and others leading to nearby well damage. These incidents prompted Alberta regulators to direct companies to better assess and reduce risks related to nearby wells.[49,50]

Between 2013 and 2016, six states adopted rules toward development of area of review requirements, mandating analyses of existing wells near proposed new wells, but such regulations remain uneven in their impact and requirements.[51,52] Model drilling regulations developed by *Southwestern Energy* and the Environmental Defense Fund (EDF) call for states to establish databases of existing and abandoned wells and for drilling permit applicants to identify them during the permit process.[53] Where states do not provide such service, companies should consider doing so.

### Scores

Twelve companies earned credit for their disclosures of risk reduction measures to avoid hitting nearby wells.

### Notable Disclosure

In Colorado, *Anadarko Petroleum* goes beyond state requirements for examining nearby wells.[54] Colorado requires companies to look out 1,500 feet from a proposed new well; *Anadarko* assesses out to 2,000 feet and remediates or plugs wells that do not meet current integrity standards. It also performs an "anti-collision" analysis when planning wells to decrease the likelihood that their fractures intersect live or abandoned wells. The company discloses similar measures it takes across all its plays.

## MINIMIZING INDUCED SEISMICITY

*DTF 2019* asks if companies disclose the steps they take, or require of their contractors, to identify and avoid inducing seismic activity that can be felt on the earth's surface.[55]

### Background

EPA's Drinking Water Study finds that wastewater is injected into deep wells for disposal in most states conducting hydraulic fracturing, except in California, Oklahoma, Colorado, and Texas, where wastewater is

47. Jacobs, 2017, https://www.spe.org/en/jpt/jpt-article-detail/?art=2819.
48. Ibid.
49. Vaidyanathan, Gayathri, "As 'frack hits' grew in Alberta, regulators stepped in," *EnergyWire*, 7 Jan. 2014, http://www.eenews.net/stories/1059992459.
50. *See also*, DTF 2015, p. 18 and note 29, http://disclosingthefacts.org/2015/.
51. GWPC State Regulation Review, pp. 95-96, http://www.gwpc.org/sites/default/files/State%20Regulations%20Report%202017%20Final.pdf.
52. For guidance on implementation of Pennsylvania's area of review regulations, see "Guidelines for implementing area of review (AOR) regulatory requirements for unconventional wells," *dep.pa.gov*, Pennsylvania Department of Environmental Protection, Oil of Oil and Gas Management, 8 Oct. 2016, http://www.depgreenport.state.pa.us/elibrary/GetDocument?docId=3582&DocName=800-0810-001.pdf.
53. "Model regulatory framework for hydraulically fractured hydrocarbon production wells," *edf.org*, Environmental Defense Fund, 2014, sections 2.2 and 2.5, https://www.edf.org/sites/default/files/content/Model_Regulatory_Framework_For_Hydraulically_Fractured_Hydrocarbon_Production_Wells_2014.pdf.
54. "Water Management," *anadarko.com*, Anadarko Petroleum Corporation, https://www.anadarko.com/Corporate-Responsibility/HSE/Environment/Water-Management/.
55. *See* question 5 in Appendix A for the text of the question on which scores in this section are based.

SOURCE: Brian Sherrod, USGC

Building damage from Oklahoma earthquake

generally injected into conventionally-drilled, oil-producing formations to increase production.[56,57,58] Discharges of wastewater to surface waters in most states are relatively low, ranging from a high of 10% in Colorado to a low of 2.3% in Pennsylvania, with five states estimated as 0%, and two having no or uncertain data.[59]

As the volume of wastewater generated by the boom in horizontal drilling and hydraulic fracturing has increased, regulators and the public have grown increasingly more concerned about seismic events (i.e., earthquakes) induced by deep well injection of this waste. In the United States, earthquakes associated with hydraulic fracturing operations are related primarily to deep injection wells;[60,61] although in some vulnerable geographies, regulators are increasingly tying seismic events to hydraulic fracturing itself.[62]

In a 2018 study, researchers from the University of Texas and the Oklahoma Geological Survey reviewed data from several oil and gas production areas—Bakken, Eagle Ford, Permian Basin, and Oklahoma.[63] They statistically associated seismicity in Oklahoma to injection rates, cumulative wastewater volumes, and proximity to "basement rocks." Basement rocks are deep formations that are often connected to faults that can trigger earthquakes when stressed.[64] The study observes that "the major difference between intensive seismicity in Oklahoma versus low seismicity levels in the Bakken, Eagle Ford, and Permian Basin plays" is attributable to the proximity of deep injection wells to basement rock in Oklahoma compared to shallower injections farther from basement rocks in the other plays.

56. EPA Drinking Water Study, Table 8-2, pp. 8-16, https://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=332990.

57. "Conventional" oil producing formations are reservoirs in which hydrocarbons flow readily into vertical wellbores from concentrated pools and thus hydraulic fracturing is not necessary. This is in contrast to shales and other "unconventional" reservoirs in which hydrocarbons are more broadly distributed within the formation rock and can only be economically recovered through use of hydraulic fracturing or other approaches. To increase production from conventional oil reservoirs, water is injected in a process known as "secondary recovery" to maintain reservoir pressure and facilitate movement of oil toward the wellbore. See definitions of "conventional reservoir" and "secondary recovery" at "Oilfield Glossary," *glossary.oilfield.slb.com*, Schlumberger, https://www.glossary.oilfield.slb.com/en/Terms/c/conventional_reservoir.aspx; and https://www.glossary.oilfield.slb.com/en/Terms/s/secondary_recovery.aspx.

58. EPA Drinking Water Study, Table 8-2, pp. 8-16, https://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=332990. Pennsylvania's subsurface formations are generally not suitable for waste injection wells, so companies not recycling and reusing wastewater in Pennsylvania's Marcellus Shale ship it to Ohio for disposal wells there.

59. EPA Drinking Water Study, Table 8-2, pp. 8-16, https://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=332990.

60. Folger, Peter and Tiemann, Mary, "Human-Induced earthquakes from deep-well injection: a brief overview," *fas.org*, Congressional Research Service, 30 Sept. 2016, https://www.fas.org/sgp/crs/misc/R43836.pdf.

61. When companies inject wastewater into disposal wells, it becomes a lubricant, reducing the friction between the fault blocks and causing them to slip. *See* "How oil and gas disposal wells can cause earthquakes," *stateimpact.npr.org*, State Impact, https://stateimpact.npr.org/texas/tag/earthquake. *See also*, Witman, Sarah "More earthquakes may be the result of fracking than we thought," *Journal of Geophysical Research*: Solid Earth, 2018, https://eos.org/research-spotlights/more-earthquakes-may-be-the-result-of-fracking-than-we-thought.

62. Wethe, David, "A new breed of fracking quake emerges," *Bloomberg* 9 Feb. 2018, https://www.bloomberg.com/news/articles/2018-02-09/new-breed-of-fracking-earthquakes-sends-warning-to-oil-drillers.

63. Scanlon, Bridget, et al., "Managing basin-scale fluid budgets to reduce injection-induced seismicity from the recent U.S. shale oil revolution," *Seismological Research Letters*, vol. 90, no. 1,(2019), *Geoscience World*, https://pubs.geoscienceworld.org/ssa/srl/article-abstract/90/1/171/566121/managing-basin-scale-fluid-budgets-to-reduce?redirectedFrom=fulltext.

64. "Where water goes after fracking is tied to earthquake risk," *Jsg.utexas.edu*, University of Texas at Austin Jackson School of Geosciences, 1 Nov. 2018, http://www.jsg.utexas.edu/news/2018/11/where-water-goes-after-fracking-is-tied-to-earthquake-risk/.

Earthquake activity in Oklahoma, Kansas, and Texas has increased considerably in recent years. Oklahoma averaged fewer than two earthquakes of magnitude 3.0 or greater prior to 2008.[65,66] But as wastewater disposal has increased, the number of earthquakes has increased dramatically. By 2014, the state had experienced 579 earthquakes of magnitude 3.0 or greater, and the number rose to 903 in 2015.[67] In 2016, Oklahoma experienced its most severe recorded earthquake (magnitude 5.8) and subsequently experienced a magnitude 5.0 earthquake that reportedly damaged 40 to 50 homes in the vicinity of Cushing, an enormous oil storage and transfer hub.[68,69]

Kansas, which experienced 15 earthquakes of a magnitude 3.0 or greater between 1973 and 2012, experienced 127 earthquakes magnitude 3.0 or greater between 2013 and 2016.[70] (Deep well disposal increased approximately ten-fold between 2011 and 2014 in south-central Kansas.)[71] One hundred and fifteen of these Kansas earthquakes were in Harper and Sumner counties, which are home to intensive fossil fuel production.[72,73]

In Texas, since 2008, the rate of earthquakes with magnitudes greater than 3.0 has increased from about two per year to 12 per year. Much of this change is attributed to earthquakes occurring within a short distance of wastewater disposal wells where injection rates are high.[74]

Following this sharp increase in earthquakes, state regulators have tightened regulations for permitting and operation of disposal wells. In early 2016, Oklahoma's Corporation Commission, which regulates oil and gas production in the state, issued restrictions on wastewater disposal for a 5,281 square mile area of Oklahoma, encompassing 245 disposal wells. The plan called for reducing the amount of wastewater disposed by more than 40% daily.[75] Following the regulations, the number of earthquakes greater than 3.0 fell steadily from 623 in 2016, to 302 in 2017, and 196 in 2018.[76]

65. Allison, Edith and Mandler, Ben, *Petroleum and the Environment*, Alexandria: American Geosciences Institute, 2018 (hereafter cited as AGI Petroleum and the Environment Report, p. 3-1), https://www.americangeosciences.org/sites/default/files/AGI_PetroleumEnvironment_web.pdf.

66. *See also*, Wines, Michael, "Drilling is making Oklahoma as quake prone as California," *The New York Times*, 29 March 2016, https://www.nytimes.com/2016/03/29/us/earthquake-risk-in-oklahoma-and-kansas-comparable-to-california.html.

67. "Earthquakes in Oklahoma," *ok.gov*, Office of The Oklahoma Secretary of Energy and Environment, https://earthquakes.ok.gov/.

68. Bustillo, Miguel, "Oklahoma earthquake's magnitude raised to 5.8," *Wall Street Journal*, 7 Sept. 2016, http://www.wsj.com/articles/oklahoma-earthquakes-magnitude-raised-to-5-8-1473288994.

69. *See also*, Juozapavicius, Justin, "Oklahoma 5.0 earthquake damages 40-50 buildings," *Associated Press* (printed in *Las Vegas Review-Journal*), 7 Nov. 2016, http://www.reviewjournal.com/news/nation-and-world/oklahoma-50-earthquake-damages-40-50-buildings. *See also*, "How large are the earthquakes induced by fluid injection?" *usgs.gov*, U.S. Geological Survey, https://www.usgs.gov/faqs/how-large-are-earthquakes-induced-fluid-injection?qt-news_science_products=0#qt-news_science_products.

70. Rubinstein, Justin L., et al., "The 2013-2016 induced earthquakes in Harper and Sumner Counties, southern Kansas," *Bulletin of the Seismological Society of America*, vol. 108, no. 2, (2018), pp. 674-689, *Geoscience World*, (hereafter cited as Rubinstein, et al.), https://pubs.er.usgs.gov/publication/70195671.

71. AGI Petroleum and the Environment Report, p. 3-2 https://www.americangeosciences.org/sites/default/files/AGI_PetroleumEnvironment_web.pdf.

72. Rubenstein, et al.

73. *See also*, Seismological Society of America, "Earthquakes follow wastewater disposal patterns in southern Kansas," *sciencedaily.com*, Science Daily, 20 Feb. 2018, https://www.sciencedaily.com/releases/2018/02/180219124758.htm.

74. Frohlich, Cliff, et al., "A historical review of induced earthquakes in Texas," *Seismological Research Letters*, vol. 87, no. 4, (2016), pp. 1022-1038, https://pubs.geoscienceworld.org/ssa/srl/article-abstract/87/4/1022/314110/a-historical-review-of-induced-earthquakes-in?redirectedFrom=fulltext. The authors note that earthquakes have also occurred in association with water injection operations intended to increase conventional well production.

75. Baker, Tim, "Media advisory—regional earthquake response plan for western Oklahoma," *occeweb.com*, Oklahoma Corporation Commission, 16 Feb. 2016, http://www.occeweb.com/News/2016/02-16-16WesternRegionalPlan.pdf; *see* Wine, Michael, "Oklahoma puts limits on oil and gas wells to fight quakes," *New York Times*, 7 March 2016, http://www.nytimes.com/2016/03/08/us/oklahoma-earthquakes-oil-gas-wells.html?_r=0. The restrictions were further tightened in September 2016, closing additional wastewater injection wells in a 500 square-mile area. The regulations addressed not only wastewater volumes, but disposal at deeper depths more prone to induced seismicity.

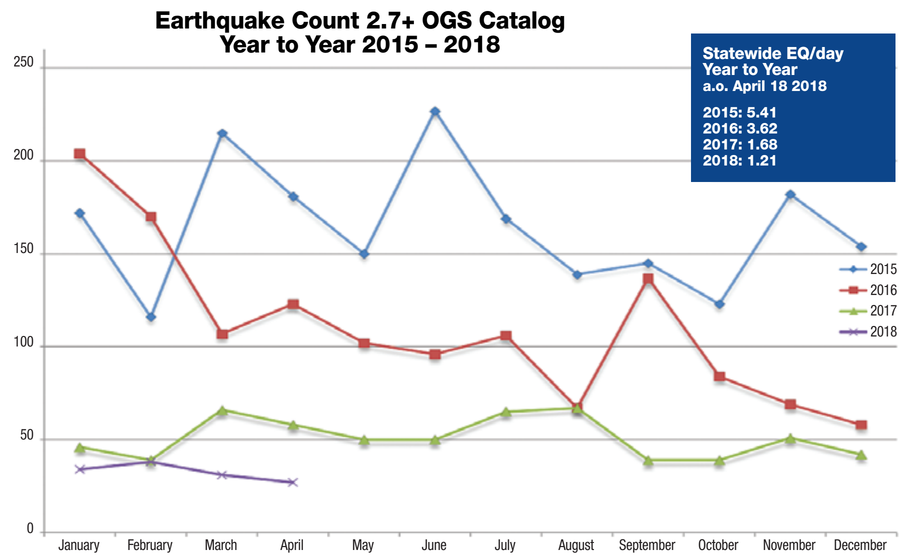
76. "Oklahoma earthquakes decrease for 3rd straight year," *Associated Press*, 1 Jan. 2019, https://www.apnews.com/216ddc7f8391467c90bd526696beb4f3.

Figure 6 traces the drop in earthquakes in Oklahoma between 2015 (top line) and early 2018 (bottom line), as regulators restricted the volume of wastewater disposal.

Similarly, the number of earthquakes in Kansas decreased by 50% after Kansas' Corporation Commission enacted restrictions on injection wells.[77,78]

Texas enhanced its seismic monitoring system in 2017, driven by increases in induced seismicity in the Permian Basin. As of 2019, the state is developing regulations to govern deep well injection to ensure that well operators stay within strict disposal volumes and pressures.[79]

## FIGURE 6: EARTHQUAKE COUNT 2.7 MAGNITUDE OR HIGHER




SOURCE: Oklahoma Corporation Commission data

While the majority of hydraulic fracturing-related earthquakes result from disposal wells, in recent years scientists have uncovered new evidence showing connections between hydraulic fracturing itself and earthquakes.[80] Oklahoma regulators have responded to growing reports of earthquakes associated with hydraulic fracturing in the South Central Oklahoma Oil Province (SCOOP) and Sooner Trend (oil field), Anadarko (basin), Canadian and Kingfisher (counties) (STACK) formations of the Anadarko Basin. Oklahoma now requires operators in a 15,000 square mile area to have access to real-time seismicity readings and halt fracturing for at least six hours after an earthquake of 2.5 or greater magnitude.[81,82] Regulators in both Ohio and Pennsylvania have issued protocols requiring companies operating in seismic hazard areas to monitor for earthquakes and adjust or stop operations

77. "Earthquakes follow wastewater disposal patterns in southern Kansas," *Science Daily*, 20 Feb. 2018, https://www.sciencedaily.com/releases/2018/02/180219124758.htm.

78. *See also* Rubenstein, et al., https://pubs.er.usgs.gov/publication/70195671. The drop in 2016 Kansas earthquakes has been attributed to a combination of the new restrictions *and* declines in oil and gas development. *See* Fifield, Jen, "States' efforts to curb fracking-related earthquakes seem to be working," *Washington Post*, 15 Aug. 2016, https://www.washingtonpost.com/national/health-science/states-effort-to-curb-fracking-related-earthquakes-appear-to-be-paying-off/2016/08/15/d0a71108-49ce-11e6-90a8-fb84201e0645_story.html?utm_term=.72b5117b7680.

79. "More Texas earthquakes have regulators cracking down on oilfield water disposal," *energymakerag.com*, EnergyMakers Advisory Group, 7 Dec. 2018, https://energymakersag.com/more-texas-earthquakes-have-regulators-cracking-down-on-oilfield-water-disposal/.

80. For examples of new evidence showing the connections between hydraulic fracturing and earthquakes, see Schultz R., et al., "Hydraulic fracturing volume is associated with induced earthquake productivity in the Duvernay play," *Science*, 359.6373 (2018): pp. 304-308, http://science.sciencemag.org/content/359/6373/304/tab-pdf. *See also* Babaie, Alireza, et al., "Fluid Injection and seismic activity in the Northern Montney play, British Columbia, Canada, with special reference to the 17 August 2015 Mw 4.6 induced earthquake," *Bulletin of the Seismological Society of America*, vol. 107, issue 2, (2017), pp. 542-552, https://pubs.geoscienceworld.org/ssa/bssa/article-abstract/107/2/542/354161/fluid-injection-and-seismic-activity-in-the?redirectedFrom=fulltext. *See also*, Wang, Ruijia, et al., "Source analysis of a potentially hydraulic-fracturing-induced earthquake near Fox Creek, Alberta," *AGU Publications*, vol. 43, issue 2, (2015), pp. 564-572, https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2015GL066917.

81. Skinner, Matt, "Moving forward: New protocol to further address seismicity in state's largest oil and gas play," *occeweb.com*, Oklahoma Corporation Commission, 27 Feb. 2019, http://www.occeweb.com/OG/02-27-18PROTOCOL.pdf.

82. Ohio has been tightening its regulations pertaining to seismicity concerns at disposal wells since 2012 and, as noted in the text, has begun to address seismicity issues around production wells. See Konschnik, Kate, "Regulating stability: State compensation funds for induced seismicity," *Georgetown Environmental Law Review*, Winter (2017), pp. 227-300, footnotes 112, 114-116, 118-119,123-124, http://go.galegroup.com/ps/anonymous?id=GALE%7CA506676499&sid=googleScholar&v=2.1&it=r&linkaccess=abs&issn=23801905&p=AONE&sw=w.

beyond certain thresholds. This action was based on emerging evidence of induced seismicity associated with fracturing in the Utica Shale, which lies several thousand feet below the Marcellus Shale.[83,84]

SOURCE: Provided by FracTracker Alliance, fractracker.org/photos

Deep disposal wells for wastewater have been linked to earthquakes. Warren, OH

The seismic activity induced by hydraulic fracturing-related activities has created liability risks for oil and gas companies and citizens in the vicinity of such operations. In Oklahoma, increased earthquake frequency and consequent damage have raised earthquake insurance costs and prompted litigation. From 2014 to 2016, six insurers raised earthquake insurance premiums for homeowners by as much as 260 percent, three increased deductibles, and three more stopped writing new earthquake insurance policies completely.[85,86] In August 2018, Steadfast Insurance Co., which paid claims to homeowners whose houses were damaged by the aforementioned 5.8 magnitude earthquake, sued seven oil and gas companies for damages.[87] Many homeowners have also filed lawsuits, including in tribal court, for damages caused by the earthquakes.[88] In September 2018, a state judge lifted a stay on two class action lawsuits in which homeowners are suing seven oil and gas companies for earthquake damage.[89]

Induced seismicity from hydraulic fracturing has also been reported in Canada, but it occurs in only a small proportion of Canadian hydraulic fracturing operations. In an area near the border between Alberta and British Columbia, between 1985 and 2015, researchers found 39 hydraulically fractured wells (representing 0.3% of

83. Legere, Laura, "Researchers find fracking spurs bigger quakes at different depths," *Pittsburgh Post-Gazette*, 12 Feb. 2018, https://www.post-gazette.com/business/powersource/2018/02/12/Utica-Shale-oil-gas-fracking-spurs-bigger-earthquakes-deeper-depths-Ohio-Pennsylvania/stories/201802120008; *see also* King, Hobart M., "Utica Shale—The gas giant below the Marcellus," *geology.com*, https://geology.com/articles/utica-shale/.

84. Cohen, Luc, "Fracking-related quakes have made earthquake insurance almost impossible to buy in Oklahoma," *Reuters*, 12 May 2016.

85. Cohen, Luc, "Fracking-related quakes have made earthquake insurance almost impossible to buy in Oklahoma," *Reuters*, 12 May 2016, http://www.rawstory.com/2016/05/fracking-related-quakes-have-made-earthquake-insurance-almost-impossible-to-buy-in-oklahoma/; *see also* Russell, Josh "Fracking earthquakes not covered, insurers say," *Courthouse News Service*, 2016, https://www.courthousenews.com/fracking-earthquakes-not-covered-insurers-say/.

86. For discussion of the limitations of earthquake insurance and a recommendation that states consider establishing compensation funds for induced seismicity, see Konschnik, Kate "Regulating stability: State compensation funds for induced seismicity," *Georgetown Environmental Law Review*, Winter (2017): 227-300, footnotes 112, 114-116, 118-119,123-124. http://go.galegroup.com/ps/anonymous?id=GALE%7CA506676499&sid=googleScholar&v=2.1&it=r&linkaccess=abs&issn=23801905&p=AONE&sw=w.

87. Wilmouth, Adam, "Earthquake-related lawsuits advance," *The Oklahoman*, 11 Sept. 2018, https://newsok.com/article/5607800/earthquake-related-lawsuits-advance. *See also*, Turn, G., "Steadfast Insurance files lawsuit against oil and gas companies for causing earthquakes," *Live Insurance News*, 2018, http://www.liveinsurancenews.com/steadfast-insurance-files-lawsuit-against-oil-and-gas-companies-for-causing-earthquakes/8545847/.

88. Wertz, Joe, "Cushing residents seek class-action lawsuit against oil companies over earthquakes," *StateImpact Oklahoma*, 6 Dec. 2016, https://stateimpact.npr.org/oklahoma/2016/12/06/cushing-residents-seek-class-action-lawsuit-against-oil-companies-over-earthquakes; *see also* Wertz, Joe, "Pawnee Nation first to use tribal courts to sue oil companies over quake damage," *StateImpact Oklahoma*, 3 March 2017, https://stateimpact.npr.org/oklahoma/2017/03/03/pawnee-nation-first-to-use-tribal-courts-to-sue-oil-companies-over-quake-damage; Wertz, Joe, "Landmark earthquake lawsuit settled, former state scientist testifies about industry pressure in another," *StateImpact Oklahoma*, 20 Oct. 2017, https://stateimpact.npr.org/oklahoma/2017/10/20/landmark-earthquake-lawsuit-settled-former-state-scientist-testifies-about-industry-pressure-in-another; Wertz, Joe, "Judge dismisses Sierra Club lawsuit against oil companies over Oklahoma quakes," *StateImpact Oklahoma*, 5 April 2017, https://stateimpact.npr.org/oklahoma/2017/04/05/judge-dismisses-sierra-club-lawsuit-against-oil-companies-over-oklahoma-quakes; Monies, Paul, "Edmond residents file earthquake lawsuit against 12 oil companies," *The Oklahoman*, 12 Jan. 2016, http://newsok.com/article/5471984.

89. Wilmouth, Adam, "Earthquake-related lawsuits advance," *The Oklahoman*, 11 Sept. 2018, https://newsok.com/article/5607800/earthquake-related-lawsuits-advance.

those studied) and 17 wastewater disposal wells (representing 1% of those studied) that could be linked to earthquakes of magnitude 3.0 or larger. Although the responsible wells were a very small portion of the wells studied, the researchers estimated that more than 60% of earthquakes in the area of greater than magnitude 3.0 in recent years could be associated with fracturing activities, 30 to 35% to wastewater disposal, and only 5 to 10% to natural origins.[90]

## Scores

Fourteen companies earned credit for their disclosures about induced seismicity management measures. These companies address their own injection wells, those of third-party waste disposal contractors, and induced seismicity risks from drilling and completing new production wells.

## Notable Disclosures

- *Apache Corporation* provides one of the most detailed play-by-play descriptions of its actions.[91] For example, in Oklahoma, the company has managed to avoid seismic events that would have required it to cease or suspend operations. The company states it "routinely exceeds regulatory minimums by wide margins," deploying an extensive array of seismicity monitors and implementing contingency plans to prevent seismic events above specific levels. In West Texas, the site of *Apache's* Alpine High production operations, the Delaware Basin is the most seismically active region of the state. To minimize risks of groundwater contamination and seismic activity, *Apache* has worked to keep commercial disposal wells out of the Alpine High area.[92]

- *Cimarex Energy* similarly provides detailed play-by-play disclosure of its induced seismicity management efforts.[93] The company began monitoring seismicity in Oklahoma in 2012. Any seismicity detected above magnitude 2.0 triggers the company's seismicity protocol, "which causes operations to be minimized or stopped." It extended use of this monitoring and action protocol to its Permian Basin operations in 2016.

- *CNX Resources'* mid-stream water management subsidiary, Convey, provides a detailed description of its screening process for using third-party disposal wells.[94] This includes avoiding injection wells having a high potential to induce seismicity, by avoiding wells located in buffer zones around areas of known faults or increased seismic activity, and reviewing well logs to ensure that wells are not injecting into or above a formation with increased seismicity risk.

- As part of its "seismicity mitigation plan," *Encana* monitors both completion and waste disposal operations, including injection rates, pressures, and cumulative volumes.[95] It uses a "traffic light" approach to guide its response: any detected or felt seismicity is grounds for stopping work. *Encana* also audits, inspects, and/or confirms management of seismicity risks at third-party disposal facilities.

90. Atkinson, Gail, et al., "Hydraulic fracturing and seismicity in the Western Canada Sedimentary Basin," *Seismological Research Letters*, vol. 87, issue 3, (2016), pp 1-17, https://scits.stanford.edu/sites/default/files/atkinson_canada_eq_study_clean.pdf. Additionally, in December 2018, the BC Oil and Gas Commission determined that hydraulic fracturing caused three earthquakes, of magnitudes 3.4, 4.0, and 4.5 the previous month. The Commission subsequently suspended hydraulic fracturing operations in the lower Montney. See also "B.C. regulator says fracking caused earthquakes near Fort St. John," *Canadian Press*, 22 Dec. 2018, https://www.cbc.ca/news/canada/british-columbia/fracking-earthquakes-bc-1.4957379.

91. "2018 Sustainability Report," *Apachecorp.com*, Apache Corporation, 2018, p. 63, http://www.apachecorp.com/Resources/Upload/file/sustainability/APACHE-Sustainability_Report_2018.pdf.

92. Hunn, David, "Apache cribs activist tactic and protests wastewater well at Alpine High," *Houston Chronicle*, 8 Aug. 2017, https://www.chron.com/business/energy/article/Apache-cribs-activist-tactic-and-protests-11955462.php.

93. "Seismicity," *cimarex.com*, Cimarex, https://www.cimarex.com/corporate-responsibility/environment/seismicity/default.aspx.

94. "2017 Corporate Responsibility Report," *cnx.com*, CNX Resources, 2017, p. 23, https://www.cnx.com/cnx/media/Pdf/2017_Consol_CRR_Report.pdf. Note: the company operates in the Marcellus and Utica Shale plays.

95. "Environment," *encana.com*, Encana Corporation, https://www.encana.com/sustainability/environment/.

# REDUCING CHEMICAL HAZARDS

*DTF 2019* asks whether a company provides quantitative reporting regarding its progress in reducing the toxicity of hydraulic fracturing additives. Additionally, the scorecard asks whether companies report on ways to mitigate risks from chemicals, specifically by using dry chemicals instead of liquid ones and eliminating the use of benzene, toluene, ethylbenzene, and xylene (BTEX).

*DTF 2019* also asks whether companies disclose what steps they are taking to reduce their own and their contractors' confidential business information (CBI) claims, and whether they clearly state that FracFocus, a voluntary chemical disclosure website created in 2011, may not include specific chemicals due to such claims. This question is intended to avoid a company claiming on its website or sustainability report that FracFocus provides information on all its chemical use for fracturing where such information is actually shielded from public review by CBI claims. Companies that disclose their chemical use publicly can enhance credibility if they are clear about when those disclosures are limited by trade secret constraints.[96]

SOURCE: Bill Hughes, OVEC/ohvec.org

Truck hauling chemicals to well pad

## Background

The chemicals added to hydraulic fracturing fluids pose a risk principally because of their potential impact on water quality. Chemicals in hydraulic fracturing fluid have generated significant public concern and become a flashpoint for public controversy, drawing investor attention. Chemicals typically constitute between 0.5% and 2.0% of fracturing fluid by volume according to FracFocus.[97,98] While these chemicals comprise a low percentage of total fracturing fluids, large volumes of chemicals are used. A company that fractures a well with 5 million gallons of fluid requires approximately 50,000 gallons of chemicals.[99]

Table 2 describes the functions of chemicals commonly used for hydraulic fracturing. The EPA's drinking water study reports that 1,084 chemicals were used for hydraulic fracturing between 2005 and 2013.[100] Some chemicals are used quite often while many others are not. FracFocus' website profiles 59 of the most commonly used.[101] Portions of some of the chemicals injected into the well return to the surface in wastewater. Other injected chemicals are transformed below the surface and their byproducts can remain below ground or return to the surface.[102] For example, an iron control additive reacts with minerals in the formation to create simple

96. *See* Questions 21-25 for the texts of the questions on which scores in this section are based.

97. "Chemical use in hydraulic fracturing," *fracfocus.org*, Ground Water Protection Council and Interstate Oil and Gas Compact Commission, http://fracfocus.org/water-protection/drilling-usage.

98. FracFocus (www.fracfocus.org) is the principal vehicle by which companies report chemical use on a well-by-well basis. FracFocus is managed by the Ground Water Protection Council (GWPC) and Interstate Oil and Gas Compact Commission. *See also* http://www.gwpc.org/about-us and http://iogcc.ok.gov/about-us. For chemical disclosures in Canada, see http://fracfocus.ca/.

99. "What is fracking fluid?" *fracktracker.org*, FracTracker Alliance, https://www.fractracker.org/resources/oil-and-gas-101/fracking-fluid.

100. EPA Drinking Water Study Executive Summary, p. 16, https://www.epa.gov/sites/production/files/2016-12/documents/hfdwa_executive_summary.pdf.

101. "What chemicals are used," *fracfocus.org*, Ground Water Protection Council and Interstate Oil and Gas Commission, http://fracfocus.org/chemical-use/what-chemicals-are-used.

102. "Why chemicals are used," *fracfocus.org*, Ground Water Protection Council and Interstate Oil and Gas Commission, http://fracfocus.org/chemical-use/why-chemicals-are-used.

## TABLE 2: THE FUNCTIONS OF COMMON CHEMICALS IN HYDRAULIC FRACTURING FLUID

| Additives | Function | Chemicals reported in 20% or more of disclosures in the EPA FracFocus 1.0 project database for given additive.[a,b] |
|---|---|---|
| Acid | Dissolves cement, minerals, and clays to reduce clogging of the pore space | Hydrochloric acid |
| Biocide | Controls or eliminates bacterial growth, which can be present in the base fluid and may have detrimental effects on the long term well productivity | Glutaraldehyde; 2,2-dibromo-3-nitrilopropionamide |
| Breaker | Reduces the designed increase in viscosity of specialized treatment fluids such as gels and foams after the proppant has been placed and flowback commences to clean up the well | Peroxydisulfuric acid diammonium salt |
| Clay control | Prevents the swelling and migration of formation clays that otherwise react to water-based fluids | Choline chloride |
| Corrosion inhibitor | Protects the iron and steel components in the wellbore and treating equipment from corrosive fluids | Methanol; propargyl alcohol; isopropanol |
| Crosslinker | Increases the viscosity of base gel fluids by connecting polymer molecules | Ethylene glycol; potassium hydroxide; sodium hydroxide |
| Emulsifier | Facilitates the dispersion of one immiscible fluid into another by reducing the interfacial tension between the two liquids to achieve stability | 2-Butoxyethanol; polyoxyethylene(10)nonylphenyl ether; methanol; nonyl phenol ethoxylate |
| Foaming agent | Generates and stabilizes foam fracturing fluids | 2-Butoxyethanol; nitrogen, liquid; isopropanol; methanol; ethanol |
| Friction reducer | Reduces the friction pressures experienced when pumping fluids through tools and tubulars in the wellbore | Hydrotreated light petroleum distillates |
| Gelling agent | Increases fracturing fluid viscosity allowing the fluid to carry more proppant into the fractures and to reduce fluid loss to the reservoir | Guar gum; hydrotreated light petroleum distillates |
| Iron control agent | Controls the precipitation of iron compounds (e.g., $Fe_2O_3$) from solution | Citric acid |
| Nonemulsifier | Separates problematic emulsions generated within the formation | Methanol; isopropanol; nonyl phenol ethoxylate |
| pH control | Affects the pH of a solution by either inducing a change (pH adjuster) or stabilizing and resisting change (buffer) to achieve desired qualities and optimize performance | Carbonic acid, dipotassium salt; potassium hydroxide; sodium hydroxide; acetic acid |
| Resin curing agents | Lowers the curable resin coated proppant activation temperature when bottom hole temperatures are too low to thermally activate bonding | Methanol; nonyl phenol ethoxylate; isopropanol; alcohols, C12-14-secondary, ethoxylated |
| Scale inhibitor | Controls or prevents scale deposition in the production conduit or completion system | Ethylene glycol; methanol |
| Solvent | Controls the wettability of contact surfaces or prevents or breaks emulsions | Hydrochloric acid |

a Chemicals (excluding water and quartz) listed in the EPA FracFocus 1.0 project database in more than 20% of disclosures for a given purpose when that purpose was listed as used on a disclosure (U.S. EPA, 2015c). These are not necessarily the active ingredients for the purpose, but rather are listed as being commonly present for the given purpose. Chemicals may be disclosed for more than a single purpose (e.g., 2-butoxyethanol is listed as being used as an emulsifier and a foaming agent).

b. Analysis considered 32,885 disclosures and 615,436 ingredient records that met selected quality assurance criteria, including: completely parsed (parsing is the process of analyzing a string of symbols to identify and separate various components); unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; valid CASRN; valid concentrations; and valid purpose. Disclosures that did not meet quality assurance criteria (5,645) or other, query-specific criteria were excluded from analysis.

SOURCE: EPA Drinking Water Study, pp. 5-11 and 5-12 salts, carbon dioxide and water that return to the surface. Most of an injected scale inhibitor returns to the surface but some remains in the formation where it reacts with microorganisms that consume it.[103]

Public concern about chemical use has two principal components. The first is a fear of the hazardous chemicals known to be part of chemical additives in fracturing fluid. This fear is exacerbated by high-profile incidents where adverse human health effects, harm to domestic and farm animals, and property and environmental damage have occurred.[104] The second is a fear of the unknown. Chemical identities can be masked in FracFocus by chemical suppliers' or oil and gas companies' claims that chemical identities are protected as trade secrets, CBI, or proprietary information. These claims foster a lack of trust in companies and their operations.[105]

Chemicals used or created through hydraulic fracturing operations, if released into the environment, can have a range of harmful impacts based on their volume, toxicity, mobility, solubility, volatility, and persistence.[106] The chemicals can range from relatively benign, such as the guar gum used in food products, to more hazardous chemicals. EPA's drinking water study found potential human health hazards including cancer, immune system effects, changes in body weight, changes in blood chemistry, cardiotoxicity, neurotoxicity, liver and kidney toxicity, and reproductive and developmental toxicity associated with 98 chemicals used in hydraulic fracturing

103. Ibid.

104. In 2014, the Pennsylvania Department of Environmental Protection released records related to approximately 240 private water supplies where damage appeared to be linked to oil and gas operations. According to a *Pittsburgh Post-Gazette* analysis, either contaminants were newly introduced into the water supplies or their levels were raised above applicable standards. The most common pollutant was methane, reported in 115 of the water supplies, followed by iron (79 supplies), and manganese (76 supplies). Two markers of salinity, total dissolved solids and chlorides, were found in 29 and 25 wells, respectively. In general, the methane was associated with flawed wellbores, abandoned wells, or displacement from shallow gas pockets during drilling, while the other contaminants were associated with sediment from construction activities and leakage of briny fluids and rock waste from spills or damaged pits. See Legere, Laura, "DEP releases updated details on water contamination near drilling sites," *Pittsburgh Post-Gazette*, 8 Sept. 2014, https://www.post-gazette.com/business/powersource/2014/09/09/DEP-releases-details-on-water-contamination/stories/201409090010. For a detailed report of one incident of water supply, health, and property damage linked to a nearby oil and gas operation that describes the actions of landowners, Pennsylvania regulators, and a natural gas producer, see Griswold, Eliza, "Amity and Prosperity: One Family and the Fracturing of America," New York, Farrar, Straus and Giroux, 2018. Much scientific research remains to be done to refine knowledge about the human health effects of drilling and completion operations, not only from exposures to water pollution but also from air pollution. A journalist's review in 2018 of existing science, which included interviews with scientists and pro- and anti-oil and gas industry advocates, concluded with respect to water contamination, "While scientists have not found large-scale groundwater contamination from fracking, the process has at times polluted ground and surface water." Regarding human health studies more generally, the writer concluded that "Studies of health outcomes in shale regions are largely preliminary and do not conclusively show that unconventional oil and gas development has caused specific ailments, illnesses or disease." A scientist at the Health Effects Institute observed that while studies correlating drilling and completion activities with health impacts over large areas have been conducted, because existing studies generally lack data about "the nature and concentration of pollutants to which the local population is exposed, it's hard to conclude much about human health risks." *See* King, Pamela, "A decade of fracking research: What have we learned?" *Energy and Environmental News*, 11 July 2018, https://www.eenews.net/stories/1060087955. Organizations critical of hydraulic fracturing operations have compiled incident reports and published science emphasizing the adverse effects of these operations. *See*, for example, Concerned Health Professionals of New York and Physicians for Social Responsibility, "Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction) fifth edition," 2018, https://www.psr.org/wp-content/uploads/2018/04/Fracking_Science_Compendium_5.pdf. *See also* "List of the harmed," *pennsylvaniaallianceforcleanwaterandair.wordpress.com*, The Pennsylvania Alliance for Clean Water and Air, Updated 22 Aug. 2018, https://pennsylvaniaallianceforcleanwaterandair.wordpress.com/the-list/.

105. For discussion of public fears of new or unknown chemical risks, see Gorman, Sara, "How do we perceive risk?: Paul Slovic's landmark analysis," *The Pumphandle*, 16 Jan. 2013, http://www.thepumphandle.org/2013/01/16/how-do-we-perceive-risk-paul-slovics-landmark-analysis-2/#.XHAc-KJKgnQ. For discussion of the legal distinctions among trade secrets, confidential and proprietary information, see Konschnik, Katherine and Dayalu, Archana, "Hydraulic fracturing chemicals reporting: analysis of available data and recommendations for policymakers," *Energy Policy* 88 (2016), pp 504-514, (hereafter cited as Harvard Chemical Disclosure Study), https://doi.org/10.1016/j.enpol.2015.11.002. (The authors reviewed data for more than four years beginning in March 2011.)

106. The California Council on Science and Technology, in a report requested by California's state legislature, recommended, "use of chemicals with unknown environmental profiles should be disallowed. The overall number of different chemicals should be reduced, and the use of more hazardous chemicals and chemicals with poor environmental profiles should be reduced, avoided, or disallowed." The council further suggested that operators should apply green chemistry principles (which include reducing innate chemical hazard) in formulating hydraulic fracturing fluids. See Long, Jane C.S., et al., *An independent scientific assessment of well stimulation in California—summary report—an examination of hydraulic fracturing and acid stimulations in the oil and gas industry*, Sacramento: California Council on Science and Technology, 2015, p. 36, https://ccst.us/publications/2015/2015SB4summary.pdf. For a robust summary of chemical hazards and risk assessment, see "Chemical risk assessment and regulatory decision making," *acs.org*, American Chemical Society, https://www.acs.org/content/acs/en/policy/publicpolicies/sustainability/chemicalsmanagement.html. This ACS position statement relies on detailed analyses from the National Academies of Science, Engineering, and Medicine.

fluids.[107] Benzene, toluene, ethylbenzene, and xylene (BTEX) is a family of toxic chemicals associated with leukemia, neurological damage, and other health effects. BTEX chemicals naturally occur in crude oil and can also be added to fracturing fluids. Companies reducing the toxicity of their chemicals in their operations mitigate associated environmental, legal, and social license to operate risks.


SOURCE: Bill Hughes, OVEC/ohvec.org

Chemicals (surfactants) being trucked to well sites

Companies transporting dry (powdered) chemicals to well pads to mix with liquids on-site can also lower risks of environmental contamination. Dry forms of chemicals are regarded as easier to clean up in the event of spills. For example, a release of dry chemicals is not as likely to require excavation of massive amounts of contaminated soil that a wet spill would. Companies also save on energy and transportation expenses, because dry chemicals are lighter and more compact than liquid chemicals. However, some companies may decide against their use based on concern about workers' inhalation exposure to dry chemicals during on-site mixing and handling processes. While inhalation risks can be minimized by mixing chemicals in enclosed systems, companies may also be wary of having workers experienced with using liquid formulations begin to use novel dry chemicals and their associated mixing processes.

Companies that fail to disclose chemicals used open themselves to increased social license to operate risks. Published analyses of the rate of nondisclosed chemicals by EPA, the Harvard Environmental Policy Initiative, and the Groundwater Protection Council (GWPC), conducted over different time periods, report rates of withheld chemical identities. EPA calculated an 11% withholding rate, GWPC calculated a 16.7% rate for a slightly later period, and the Harvard project calculated 16.5 percent.[108] The Harvard study also reported that an average of 92% of FracFocus forms completed for individual wells had at least one ingredient withheld.[109] The Partnership for Policy Integrity reported in 2018 that, between 2013 and 2017, companies injected non-disclosed chemicals into 55% of the hydraulically fractured wells drilled in Pennsylvania.[110] An average of more than five chemicals per well were not disclosed.[111]

Chemical companies and service contractors to oil and gas producers can be loath to disclose chemical identities. This hesitance is due to the fact that, when associated with specific products listed on FracFocus,

107. EPA Drinking Water Study Executive Summary, p. 38, https://www.epa.gov/sites/production/files/2016-12/documents/hfdwa_executive_summary.pdf. A Yale University study in 2017 identified and analyzed 925 chemicals in hydraulic fracturing fluid and wastewater. Of the 194 chemicals with available toxicity data, researchers identified 119 as potentially having reproductive and/or developmental toxicity. Elliot, Elise G., et al., "A systematic evaluation of chemicals in hydraulic-fracturing fluids and wastewater for reproductive and developmental toxicity," *Journal of Exposure Science and Environmental Epidemiology* 27 (2017), pp 90-99, https://www.nature.com/articles/jes201581. Similarly, a study by The Endocrine Disruption Exchange analyzed 353 of the chemicals in hydraulic fracturing fluid and found 40-50% can impact the brain or nervous system and 25% can cause cancer and mutations. Colborn, Theo, et al., "Natural gas operations from a public health perspective," *Human and Ecological Risk Assessment: An International Journal* 17.5 (2011): 1039-1056, https://www.tandfonline.com/doi/abs/10.1080/10807039.2011.605662.

108. Figures from the studies are summarized in the Harvard Chemical Disclosure Study, p. 508 https://doi.org/10.1016/j.enpol.2015.11.002. These calculations exclude a category of unidentified chemicals labeled as "n.a.," whose inclusion would increase the nondisclosure percentages. The Harvard Chemical Disclosure Study, p. 510, discusses the several reasons why chemicals may fall in the "n.a." category.

109. Id., p. 509.

110. Horwitt, Dusty, *Keystone Secrets: Records Show Widespread Use of Secret Fracking Chemicals Is a Looming Risk for Delaware River Basin, Pennsylvania Communities*, Pelham: Partnership for Policy Integrity, 2018, http://www.pfpi.net/wp-content/uploads/2018/09/PASecretFrackingChemicalsReportPFPI9.10.2018.pdf. See p. 11.

111. Id., p. 13.

competitor companies can more readily learn proprietary product formulas. One method of reducing undisclosed chemicals is for companies reporting on FracFocus to use a "systems approach" in which a company discloses both product names and chemicals but does not associate the chemicals with specific products. Schlumberger, Baker Hughes, and, to a much smaller degree, Halliburton—the major service companies providing well completion services to oil and gas companies—began using this approach in 2014.[112] The Harvard study found that when companies and their suppliers used the systems approach, confidentiality claims dropped four-fold, from 14.4% to 3.3 percent.[113]

Of the twenty-four states that require some form of chemical disclosure, 20 allow or require the use of FracFocus.[114]

## Scores

Three companies earned credit for quantitatively reporting their progress in toxicity reduction, ten reported on use of dry chemicals, ten disclosed their policies to eliminate BTEX, seventeen reported that the identity of some chemicals is not disclosed on FracFocus, and five described efforts to reduce trade secrecy claims.

## Notable Disclosures

- *Chesapeake Energy's* GreenFrac® program, which assesses whether use of individual chemicals is necessary, employs a scorecard system to evaluate the safety of each chemical based on U.S. and international regulations and information about chemical hazards.[115] *Chesapeake's* vendors are required to evaluate their chemicals against the scorecard criteria with "environmentally friendly" chemicals yielding a better score. The process encourages use of dry additives and extremely low-aromatic solvents in place of chemicals that incorporate aromatic or BTEX-containing solvents.

- *Southwestern Energy's* Right Products Program assesses each fracturing fluid chemical for key environmental and health hazards (chemical additives comprise 0.01% of the company's fracturing fluid; the other 99.9% is water and sand).[116] Based on the results of the assessment, each product is approved, recommended for further evaluation, or denied for use. The company provides numerous details on this process. By 2017, the company had evaluated more than 97% of the products used for hydraulic fracturing. Of the 292 products reviewed, 64% were approved upon initial evaluation, 17% were approved after additional evaluation, and 19% were denied approval.

- *Apache Corporation* has been a leader in lowering the hazards of chemicals used for drilling and completions, relying on its own staff rather than on drilling and completion service companies to develop safer product formulas. The company declares "it is on the forefront of incorporating recently developed 'dry' hydraulic fracturing technologies."[117] Apache is replacing liquid guar slurry, friction reducers, and scale inhibitors with powdered materials where feasible. The chemical substitution process yields reductions in emissions and transportation safety and spill containment benefits.

112. Harvard Chemical Disclosure Study, p. 511, https://doi.org/10.1016/j.enpol.2015.11.002. For more information on the systems approach, see "Hydraulic fracturing disclosure: Frequently asked questions," *slb.com*, Schlumberger, revised 25 April 2014, https://www.slb.com/~/media/Files/industry_challenges/unconventional_gas/other/hydraulic_fracturing_disclosure_faq.pdf.

113. Harvard Chemical Disclosure Study, p. 511, https://doi.org/10.1016/j.enpol.2015.11.002.

114. GWPC State Regulation Review, p. 39, http://www.gwpc.org/sites/default/files/State%20Regulations%20Report%202017%20Final.pdf.

115. "Operations and Environmental Protection," *chk.com*, Chesapeake Energy Corporation, http://www.chk.com/responsibility/environment/operations.

116. "Water," *swncr.com*, Southwestern Energy, https://www.swncr.com/responsibility/environment/water/. Southwestern has published a detailed description of its program's operations and results, including statistics for its individual service contractors. Available at a website for industry professionals, the paper provides a model adoptable by other companies. It describes hazard assessment and product scoring, workflow, lessons learned, and provides examples of assessed products. *See* Boothie, M., et al., "Choosing the 'right products,' *onepetro.org*, Society of Petroleum Engineers, 2018, https://www.onepetro.org/conference-paper/SPE-189891-MS.

117. "Building for the Future 2018 Sustainability Report," *apachecorp.com*, Apache Corporation, 2018, p. 58, http://www.apachecorp.com/Resources/Upload/file/sustainability/APACHE-Sustainability_Report_2018.pdf.

- *Anadarko Petroleum's* Chemical Assessment Rating Evaluator (CARE) tool scores chemicals for their safety[118] as does *Encana's* Responsible Products Program.[119]

## MONITORING WATER QUALITY BEFORE AND AFTER DRILLING AND COMPLETIONS

*DTF 2019* asks companies to disclose their pre- and post-drilling water quality monitoring practices on a play-by-play basis, including information on the frequency and types of tests conducted.[120] Tests should be for substances known to be associated with hydraulic fracturing, including methane and hazardous chemicals associated with both fracturing fluids and wastewater from the formation. As the chemical composition of groundwater can change over time, multiple samples at a location are superior to a single sample for determining the quality of the groundwater measured both for pre- and post-drilling samplings.

SOURCE: Kozorog/Adobe Stock

Local water sampling is important before and after drilling activities

### Background

Monitoring water quality prior to drilling can help determine the state of subsurface groundwater aquifers and drinking water wells prior to horizontal drilling and hydraulic fracturing, providing a baseline of water quality data from which to make future assessments.[121] Post-completion monitoring can provide information about whether subsequent contamination related to drilling has occurred and whether it may be associated with drilling and completion operations.

Pre- and post-drilling water quality testing can also help companies protect themselves from being held liable for pre-existing contamination. Groundwater can be contaminated from a range of activities including commercial activities on the surface that predate horizontal drilling and hydraulic fracturing or by naturally occurring substances. This is especially the case in Pennsylvania, where studies by the U.S. Geological Survey have reported the widespread presence of naturally-occurring methane in groundwater.[122] More than 3 million residents rely on private wells for their drinking water in Pennsylvania. Unlike most states, Pennsylvania has no state-wide regulations governing private water wells.[123] Pennsylvania regulations do, however, presume companies are responsible for contamination of a water well, if the water well is within 2,500 feet of a new horizontally drilled well, and the contamination occurs within 12 months of drilling or completion.[124]

118. "Hydraulic Fracturing," *anadarko.com*, Anadarko Petroleum Corporation, https://www.anadarko.com/Corporate-Responsibility/HSE/Environment/Hydraulic-Fracturing/.

119. "Responsible Products Program," *encana.com*, Encana Corporation, https://www.encana.com/sustainability/environment/water/fracturing/products.html.

120. *See* Questions 6 and 7 in Appendix A for the text of the questions on which scores in this section are based.

121. Groundwater quality can vary daily and seasonally. *See* "General facts and concepts about ground water," *pubs.usgs.gov*, U.S. Geological Survey, https://pubs.usgs.gov/circ/circ1186/html/gen_facts.html and "Trends in nitrate concentrations in UK ground water," *bgs.ac.uk*, British Geological Survey, 2007, https://www.bgs.ac.uk/research/groundwater/quality/nitrate/trends.html.

122. "Baseline groundwater quality studies find naturally occurring methane in northeastern Pennsylvania," *usgs.gov*, U.S. Geological Survey, 13 Nov. 2014, https://www.usgs.gov/news/baseline-groundwater-quality-studies-find-naturally-occurring-methane-northeastern-pennsylvania.

123. Swistock, Brian R., et al., *Drinking water quality in rural Pennsylvania and the effect of management practices*, Harrisburg: Center for Rural Pennsylvania, 2009, http://www.rural.palegislature.us/drinking_water_quality.pdf.

124. 58 Pennsylvania Consolidated Statutes §3218, https://www.legis.state.pa.us/WU01/LI/LI/CT/HTM/58/00.032.018.000..HTM.

In the absence of baseline sampling revealing that the contamination existed prior to drilling, companies may lack the needed evidence to overcome the presumption of responsibility.

Controversy over drinking water contamination in the Pavillion, Wyoming area further underscores the potential importance of pre-drill water quality monitoring to identify the impacts of new wells. EPA's Drinking Water Study describes the lengthy debate over contamination in the area, noting that the absence of pre-drill water quality monitoring, the unique geological setting, and the difficulty of identifying specific pathways make "identifying the precise source(s) of contamination…challenging."[125]

Between 2013 and 2016, state regulations requiring pre-drill testing jumped from four to nine.[126]

### Scores

Three companies earned credit for disclosing their pre-drill monitoring practices, and one company earned credit for disclosing post-drill monitoring practices.

### Notable Disclosures

Some companies provide considerable detail on their water quality monitoring practices, though most disclosures lack sufficient discussion of monitoring frequency, preventing investors from understanding if sampling occurs more than once. These disclosures indicate, for example, whether monitoring exceeds regulatory requirements, occurs in all plays or just some, the types of water sources monitored and their distances from the wellbore, and the chemicals measured. *Cabot Oil & Gas*[127] provides the most detailed disclosure. Other noteworthy disclosures include those of *Chesapeake Energy*,[128] *Range Resources*,[129] and *Shell*.[130]

## SOURCING WATER

*DTF 2019* asks whether companies disclose, on a play-by-play basis, quantifiable metrics regarding water use: total quantity of water used; quantity of water sourced from potable and non-potable resources; quantity of water sourced from specific location types (e.g., ground and surface water); and percentage of wastewater reused for hydraulic fracturing. *DTF 2019* also asks companies to disclose whether they operate in fresh water scarce areas (and how they determine that) and their practices for reducing use of fresh water.[131]

125. EPA Drinking Water Study, p. 6-49. https://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=332990. *See also*, See Richards, Heather, "Pavillion couple reach settlement with Encana on polluted water," *Casper Star Tribune*, 24 Jan. 2018, http://trib.com/business/energy/pavillion-couple-reach-settlement-with-encana-on-polluted-water/article_42c6121f-5156-5e70-84f0-d0de2c07b340.html.

126. GWPC State Regulation Review, p. 10. http://www.gwpc.org/sites/default/files/State%20Regulations%20Report%202017%20Final.pdf. The American Petroleum Institute's hydraulic fracturing guidelines recommend baseline testing of private water wells and groundwater on a site-specific basis before fracturing operations begin. See American Petroleum Institute, "Water management associated with hydraulic fracturing, upstream segment, API guidance document HF2 first edition," 2010, http://gost-snip.su/download/api_hf22010_water_management_associated_with_hydraulic_fract. For a detailed summary of mandatory baseline water quality requirements in five states, see Cranch, William, et al., *Responding to landowner complaints of water contamination from oil and gas activities: Best practices*, Cambridge: Emmet Environmental Law & Policy Clinic and the Environmental Policy Initiative, Harvard Law School, 2014, http://eelp.law.harvard.edu/wp-content/uploads/responding-landowner-complaints-water-contamination-best-practices.pdf.

127. "Steps Cabot Oil & Gas Corporation is taking to ensure that its operations protect Pennsylvania's water and air resources," *cabotog.com*, Cabot Oil & Gas Corporation, http://www.cabotog.com/pdfs/WaterQAclean_final.pdf.

128. "Responsible Water Management," *chk.com*, Chesapeake Energy, http://www.chk.com/responsibility/environment/water.

129. "Water Protection," *rangeresources.com*, Range Resources, http://www.rangeresources.com/corp-responsibility/environment-health-and-safety/water-protection.

130. "Shell onshore operating principles in action: water fact sheet," *Shell.com*, Royal Dutch Shell, 2016, pp. 8-9, https://www.shell.com/energy-and-innovation/natural-gas/tight-and-shale-gas/shells-principles-for-producing-tight-shale-oil-and-gas/_jcr_content/par/textimage.stream/1550525675115/207ce5238d5231530a30892bc74eb3b38a1fe528f337a7344775422c28e2d0ea/shell-onshore-operating-principles-in-action-water-fact-sheet.pdf.

131. *See* Questions 8-14 in Appendix A for text of questions on which scoring in this section is based.

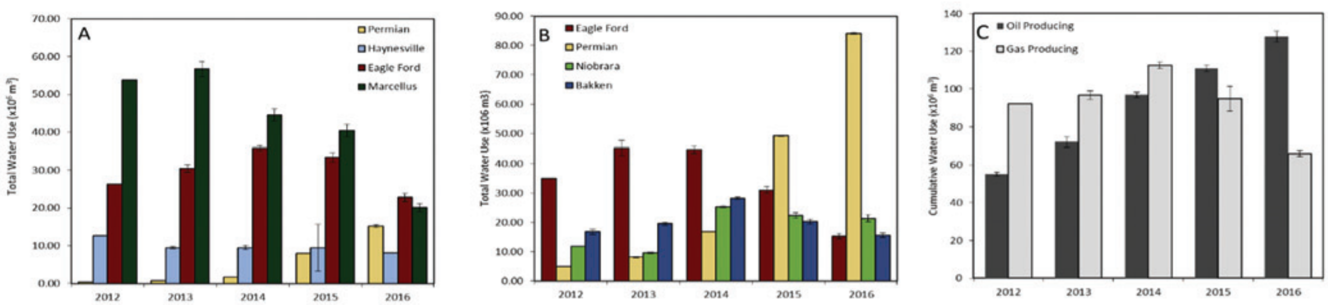
## Background

Hydraulic fracturing requires large volumes of water. In the eastern United States, surface water supplies most of the water for fracturing, while a combination of surface and groundwater supplies more arid western states.[132] EPA's drinking water study concluded that "water withdrawals for hydraulic fracturing in times or areas of low water availability" can lead to severe impacts.[133] Twenty-three states require companies to report their volume of water use.[134]

In a 2016 update to its 2014 report on hydraulic fracturing and water stress, investor organization Ceres noted that 57% of the nearly 110,000 wells fractured between January 2011 and January 2016 were located in regions with high or extremely high water stress, including basins in Texas, Colorado, Oklahoma, and California.[135] The updated report also found that nine of the top 10 companies it analyzed operated 70% or more of their wells in regions with medium or higher water stress. Ceres further observed that when analyzed on a county-by-county basis, water stress can be especially apparent. For example, annual water use for hydraulic fracturing in Weld County, Colorado represents 50% of all domestic water use. Water stress could intensify as the effects of climate variability grow.[136]

In 2018, Duke University researchers published a study of "the intensification of the water footprint of hydraulic fracturing," examining water use and wastewater generation in multiple plays.[137] Figure 7 below shows cumulative water use for hydraulic fracturing used in shale gas and tight oil producing formations.

### FIGURE 7: TOTAL WATER USE FOR OIL AND GAS PRODUCTION, BY PLAY AND BY YEAR, 2012-2016




SOURCE: Kondash, et al., Supplementary Materials

Total water use for oil and gas production, by play and by year for (A) shale gas and (B) tight oil, and cumulative water use (C) for shale gas (grey) and tight oil (black), 2012-2016

132. EPA Drinking Water Study, pp. 4-5, https://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=332990.

133. Id., p. ES-3.

134. GWPC State Regulation Review, p. 42, http://www.gwpc.org/sites/default/files/State%20Regulations%20Report%202017%20Final.pdf.

135. *Hydraulic Fracturing & Water Stress: Water Demand by the Numbers*, Boston, Ceres, 2016, https://www.ceres.org/resources/reports/hydraulic-fracturing-water-stress-water-demand-numbers?report=view. *See also*, *An Investor Guide to Hydraulic Fracturing and Water Stress*, Boston: Ceres, 2017, https://eplanning.blm.gov/epl-front-office/projects/nepa/68426/102904/125791/CERES_2016_An_Investor_Guide_to_Hydraulic_Fracturing_and_Water_Stress.pdf. Ceres judged water stress based on "competition between cities, agriculture and industry for renewable water supplies." Personal communication, Ceres Project Director Monika Freyman, February 2019.

136. Schwartz, John, "More floods and more droughts: Climate change delivers both," *The New York Times*, 12 Dec. 2018, https://www.nytimes.com/2018/12/12/climate/climate-change-floods-droughts.html?login=email&auth=login-email.

137. Kondash, Andrew, et al., "The intensification of the water footprint of hydraulic fracturing," *Environmental Studies* 4.8, (2018) (hereafter cited as Kondash, et al.), http://advances.sciencemag.org/content/advances/4/8/eaar5982.full.pdf. *See also* Kondash, Andrew, et al., "Supplementary materials for the intensification of the water footprint of hydraulic fracturing," *Environmental Studies* 4.8 (2018), p. 7 (hereafter cited as "Kondash, et al., Supplementary Materials"), http://advances.sciencemag.org/content/advances/suppl/2018/08/13/4.8.eaar5982.DC1/aar5982_SM.pdf.

Figure 7, Chart C combines results from individual plays by oil and gas production. It shows a cumulative rise in water use for oil production, evidently impacted by sharp increases in the Permian Basin, and a rise and then decline in cumulative water use for gas production. Increases in water use per well ranged from 20% in the Marcellus play to 770% in the Permian Basin.[138] The study found that the amount of water used per meter of lateral for all plays except two increased. This is especially true for the Permian Basin where water use increased nearly seven times for gas wells and nearly five times for oil wells.

The Duke study highlights that, with regard to the amount of water used per unit of energy produced, "despite lower water intensity compared to other energy sources, the permanent loss of water used for hydraulic fracturing from the hydrosphere [due to frac fluids injected in formations remaining there and deep well injection of most wastewater] could outweigh its relatively lower water intensity."

The amount of wastewater generated is another concern. This is particularly true in the Permian Basin.[139] According to the Environmental Defense Fund (EDF), in some areas "opportunities to inject produced water into disposal wells [are] shrinking and costs are growing."[140] EDF further contends that the "massive influx [of oil and gas wastewater] is forcing states, companies and other stakeholders to seriously think about whether our current methods for handling this wastewater are the best methods for the future based on a number of shifting dynamics."[141]

A 2017 University of Texas study of the Permian Basin notes that companies using wastewater from fractured wells, rather than disposing of it in injection wells, can help address seismicity concerns while reducing demand for fresh water.[142]

Historically, companies used freshwater in hydraulic fracturing activities because it was most compatible with the cocktail of fracturing fluid chemicals available.[143] More recently, companies have begun to prioritize use of brackish water and wastewater in fracturing fluid.[144] Chemical suppliers as well as drilling and completions service contractors developing new formulas for fracturing chemicals that can be effective with non-freshwater have enabled this change.[145] Barclays, citing the Railroad Commission of Texas data, reports that companies operating in the Permian have increased their use of brackish water. For example, on the Delaware side of the Permian Basin, almost 80% of water is sourced from brackish water; while on the Midland side, that value is 30 percent.[146]

Researchers at the University of Texas examining demand for fresh water for fracturing note the increasing use of non-fresh water, including brackish water, from deep groundwater formations, water from municipal and industrial

138. Increased water use per well can be a consequence of drilling longer laterals for newer wells, but the strength of this association varies among plays.

139. Kondash, et al., p. 4, http://advances.sciencemag.org/content/advances/4/8/eaar5982.full.pdf.

140. Saunders, Nichole, "Three things to know ahead of EPA's oil and gas wastewater meeting," *edf.org*, Environmental Defense Fund, 8 Oct. 2018, http://blogs.edf.org/energyexchange/2018/10/08/three-things-to-know-ahead-of-epas-oil-and-gas-wastewater-hearing/?utm_source=mailchimp&utm_campaign=energyex_none_upd_dmt&utm_medium=email&utm_id=1535389929.

141. Ibid.

142. The researchers also noted also that horizontally drilled and hydraulically fractured wells use more water than conventional wells while yielding less wastewater. *See* Scanlon, B.R., et al., "Water issues related to transitioning from conventional to unconventional oil production in the Permian Basin," *Environmental Science and Technology*, (2017), https://pubs.acs.org/doi/pdf/10.1021/acs.est.7b02185.

143. EPA Drinking Water Study, p. 4-8 https://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=332990.

144. For examples, see Notable Disclosures section

145. For example, Halliburton developed salt-tolerant friction-reducer for the Marcellus Shale. *See* "New salt-tolerant friction-reducer system enables 100% reuse of produced water," *Journal of Petroleum Technology*, 69.12 (2017), https://www.spe.org/en/jpt/jpt-article-detail/?art=3630. Similarly, Schlumberger developed a salt-tolerant friction reducer that can be used in 100% produced water from the Bakken Shale. *See* McMahon, Blake, et al., "First 100% reuse of Bakken produced water in hybrid treatments using inexpensive polysaccharide gelling agents," *onepetro.org*, Society of Petroleum Engineers, 2015, https://www.onepetro.org/conference-paper/SPE-173783-MS.

146. "The water challenge: preserving a global resource," *investmentbank.barclay.com*, Barclays Bank and Columbia Water Center, 2017 (hereafter cited as Barclays), p. 21, https://www.investmentbank.barclays.com/content/dam/barclaysmicrosites/ibpublic/documents/our-insights/water-report/ImpactSeries_WaterReport_Final.pdf. For conclusions similar to Barclay's, from Wood Mackenzie, see "Permian produced water: slowly extinguishing a roaring basin?" *woodmac.com*, Wood Mackenzie, 2018, Link contains summaries of two reports: "Permian produced water: slowly extinguishing a roaring basin?" and "Permian produced water: injecting simple solutions into complex situations." https://www.woodmac.com/press-releases/permian-produced-water/.

discharges, and reuse of wastewater from fractured wells.[147] This can replace sourcing of fresh water for operations. In a 2014 study, University of Texas researchers concluded that because of the availability of brackish groundwater "with appropriate management, water availability should not physically limit future shale energy production" in the Eagle Ford play.[148] The study also noted that use of brackish groundwater and recycling of wastewater was increasing in the Permian Basin, where large volumes of produced water accompany production of oil from nearby conventional wells. Conventional oil production in the Permian Basin can yield substantial amounts of produced water, which can be reused for hydraulic fracturing.

The economics of reusing brackish water can be compelling, although costs will vary based on the availability of fresh water, competing uses, produced water quality, distance from water sources and disposal sites, and other factors. Approximately 10 to 30% of a well's capital expenses are linked to water, while 40 to 55% of operating costs are linked to produced water management and disposal.[149,150] In the Permian, fresh water for completions costs $0.50 per barrel, brackish water $0.45, and water reused from a well $0.27.[151] Barclays estimates that companies reusing produced water could lower their water costs by about 45% and save over 300,000 barrels of freshwater per well.[152]

Barclays states that "[t]he companies that will be best positioned for an uncertain water future will be those that engage in sustainable water management practices by cutting down or eliminating freshwater usage, and treating wastewater as a resource."[153] This view is reflected in the growing interest of private investors in water management companies serving the oil and gas industry. As the *Wall Street Journal* reports, "[s]ome investors see fortunes to be made in the U.S.' hottest oil field—by speculating in water, not crude."[154] Consultancy IHS Markit expects spending on water management in the Permian Basin to nearly double to more than $22 billion in five years, driven by existing disposal capacity beginning to fill up.[155]

As companies in the Permian and elsewhere consolidate contiguous operating parcels, they are able to cost-effectively develop coordinated water sourcing and wastewater reuse pipeline systems to service their well pads. Other companies are sourcing treated wastewater from municipalities in exchange for company investment in

147. The United States Geological Survey defines "brackish water" as follows: "All water naturally contains dissolved solids that, if present in sufficient concentration, can make a surface-water or groundwater resource 'brackish', typically defined as distastefully salty. Although quantitative definitions of this term vary, it is generally understood that brackish groundwater is water that has a greater dissolved-solids content than occurs in fresh water, but not as much as seawater (35,000 milligrams per liter*)." *See* "What is 'brackish'?" *water.usgs.gov*, U.S. Geological Survey, https://water.usgs.gov/ogw/gwrp/brackishgw/brackish.html.

148. Scanlon, B.R., et al., "Will water scarcity in semiarid regions limit hydraulic fracturing of shale plays?" *Environmental Research Letters* 9.12 (2014), http://iopscience.iop.org/article/10.1088/1748-9326/9/12/124011/pdf.

149. Barclays, p. 20, https://www.investmentbank.barclays.com/content/dam/barclaysmicrosites/ibpublic/documents/our-insights/water-report/ImpactSeries_WaterReport_Final.pdf.

150. On large volumes of wastewater in the Permian Basin possibly constraining future production growth, see Rassenfoss, Stephen, "Rising tide of produced water could pinch Permian growth," *Journal of Petroleum Technology*, (2018), https://www.spe.org/en/jpt/jpt-article-detail/?art=4273. The article is based on a 2018 report by energy consultancy Wood Mackenzie. *See also* "Permian Basin water disposal volumes expected to double by 2022," *Houston Chronicle*, 15 Aug. 2019, https://www.houstonchronicle.com/business/energy/article/Permian-Basin-water-disposal-volumes-expected-to-13765666.php. This article is based on further analysis by Wood Mackenzie finding that, "even with 100% water reuse for completions, which is unlikely, the current salt water disposal infrastructure is expected to hit capacity in the near future," https://www.woodmac.com/news/feature/hell-or-high-water/.

151. Barclays, p. 24 https://www.investmentbank.barclays.com/content/dam/barclaysmicrosites/ibpublic/documents/our-insights/water-report/ImpactSeries_WaterReport_Final.pdf.

152. Id., p. 20.

153. Ibid.

154. Matthews, Christopher M, "The next big bet in fracking: water," *Wall Street Journal*, 22 Aug. 2018, https://www.wsj.com/articles/the-next-big-bet-in-fracking-water-1534930200.

155. For example, WaterBridge is one of multiple water management companies in which private equity investors have invested more than $500 million, according to *The Wall Street Journal* Wethe, David and Crowley, Kevin, "Drowning in dirty water, Permian seeks $22 billion lifeline," *Bloomberg*, 16 Sept. 2018, https://www.news-journal.com/news/business/drowning-in-dirty-water-permian-seeks-billion-lifeline/article_05d30c86-b6f8-11e8-bbe8-d7e8e7fe2621.html. *See also* Chapa, Sergio, "Solaris Water Midstream begins water recycling operations in the Permian Basin," *Houston Chronicle*, 12 Feb. 2019, (reprinted in San Francisco Chronicle), https://www.sfchronicle.com/business/energy/article/Solaris-Water-Midstream-begins-water-recycling-13610075.php.

upgrades of the municipal treatment plants, while others are constructing water treatment plants.[156] These types of projects can serve not only a company's own needs but the needs of other oil and gas companies, creating revenue streams or reducing costs. Companies' growing interest in using recycled water, which saves them money, can conversely reduce revenues for landowners, municipal governments, and other traditional sellers of freshwater.[157]

SOURCE: Lea Harper, Provided by FracTracker Alliance, fractracker.org/photos

Shale gas water withdrawal. Seneca Lake, OH, 2014

## Scores

Eight companies earned credit for disclosing their practices for reducing their use of fresh water in each play; ten disclosed their total water use per play; nine disclosed the percentage of water sourced from fresh versus non-fresh water sources, per play; six disclosed the percentage of water sourced from specific location types, per play; and fifteen disclosed the percentage of wastewater reused for well completions.

## Notable Disclosures

- *Southwestern Energy* created a unique "water neutral" program, striving to offset or replace every gallon of fresh water in the same operating region where it was used. The company has achieved its water neutrality goal in each of its plays. The company also provides the most detailed and comprehensive data on water sourcing of any company, displaying play-by-play data for three years in an extensive data appendix to its corporate responsibility report.[158]

- *ConocoPhillips*[159] and *Shell*[160] provide detailed disclosures of their water planning, sourcing, and management practices. *Shell* also reports wastewater recycling percentages of 100% in Appalachia, 76% in the Groundbirch play in Canada, and 21% in the Permian Basin. It reports that brackish water provides 99% of its water needs in the Permian Basin. Of this 99%, 16% is recycled produced water, and 84% from sub-surface sources. In the Groundbirch play, 97% of water needs are satisfied from non-fresh water sources. Produced water comprises 96% of these non-fresh water sources and municipal wastewater comprises 4%.[161]

- *Devon Energy*, in disclosing its water management practices, emphasizes reuse of wastewater. *Devon* was the first company to recycle wastewater from natural gas wells in North Texas and has become the largest user of treated wastewater in New Mexico, where it led efforts to establish state rules to encourage recycling.[162]

156. For examples, see Dunkel, Michael, "Water management and infrastructure--a multi-basin prospective," *Shale Play Water Management*, November-December 2018, pp. 20-25, https://rm-media-group-llc.dcatalog.com/v/SPWM-NovDec-2018/?page=22.

157. "Recycling water produced during development of Texas oil fields threatens landowners' profits," *Rice.edu*, Rice University, 20 Oct. 2017, http://news.rice.edu/2017/10/20/recycling-water-produced-during-development-of-texas-oil-fields-threatens-landowners-profits/. *See also* Collins, Gabriel, "Frac ranching vs. cattle ranching: Exploring the economic motivations behind operator-surface owner conflicts over produced water recycling projects," *bakerinstitute.org*, Rice University's Baker Institute for Public Policy, 17 Oct, 2017, https://www.bakerinstitute.org/media/files/files/448a93b3/BI-Brief-101717-CES_Ranching.pdf.

158. "Corporate Responsibility Report Appendix 2017-18," *swncr.com*, Southwestern Energy, 2018, pp. 13-16 https://www.swncr.com/assets/uploads/2018/11/2017-18-CR-Report-Appendix.pdf.

159. "Focus on Hydraulic Fracturing," *conocophillips.com*, ConocoPhillips, pp. 12-19. http://static.conocophillips.com/files/resources/focus-on-hydraulic-fracturing.pdf.

160. "Shell onshore operating principles in action: water fact sheet," *Shell.com*, Royal Dutch Shell, 2016, https://www.shell.com/energy-and-innovation/natural-gas/tight-and-shale-gas/shells-principles-for-producing-tight-shale-oil-and-gas/_jcr_content/par/textimage.stream/1550525675115/9b026e74e2c5a3854f30ec520e8da9afae6c8c08/shell-onshore-operating-principles-in-action-water-fact-sheet.pdf.

161. Id., p. 4.

162. "Water Management," *devonenergy.com*, Devon Energy, https://www.devonenergy.com/sustainability/environment/water-management.

- *CNX Resources* provides data on wastewater use not only on a play-by-play basis but for sub-areas of the Marcellus Shale in Pennsylvania.[163]
- *Pioneer Natural Resources* created a dedicated water management subsidiary, Pioneer Water Management, LLC. The subsidiary focuses on reducing use of fresh water, promoting recycling, and minimizing trucking of water on public roads. Pioneer created a partnership with the Permian Basin cities of Odessa and Midland, investing in treatment facilities and sourcing municipal effluent water, reducing its use of fresh water by 27 percent.[164]
- *CNX Resources* created its CONVEY Water Systems subsidiary to manage its entire water cycle from sourcing to disposal. CONVEY promotes water reuse, including by third-party customers, which reduces demand for fresh water.[165]
- *Antero Resources* partnered with Veolia, a major international water treatment company, to create the *Antero* Clearwater Facility, which it characterizes as "the largest wastewater treatment facility in the world designed for oil and gas operations." Veolia provides long-term fresh water and wastewater services to *Antero* at the facility.[166]
- *Encana* reports that saline water provides 65% of its water for fracturing in British Columbia and 50% of its water in the Eagle Ford play.[167]
- *Apache Corporation* discloses that 90% of the water used for drilling and completions in its Alpine High play in the Permian Basin was recycled or non-potable water.[168]
- *Range Resources* recycles nearly 100% of its wastewater in the Marcellus Shale. The company reports it "pioneered large-scale recycling for shale gas development in Pennsylvania in 2009."[169]

## STORING WASTEWATER AND DRILLING WASTES

*DTF 2019* asks companies the quantity of wastewater generated, whether they report their practices for storing wastewater (i.e. tanks or open impoundments), and their processes to protect the environment for each practice. Similarly, it asks whether companies report their practices for managing drilling wastes.[170]

### Background

As the amount of wastewater increases, the risk of contamination from mishandling it can increase.[171]

163. "2017 Corporate Responsibility Report," *cnx.com*, CNX Resources, 2017, p. 14, https://www.cnx.com/cnx/media/Pdf/2017_Consol_CRR_Report.pdf.
164. "2018 Sustainability Report," *Pxd.com*, Pioneer Natural Resources, 2018, pp. 30-31, https://pxd.com/sites/default/files/reports/2018%20Sustainability%20Report.pdf.
165. "2017 Corporate Responsibility Report," *cnx.com*, CNX Resources, 2017, p. 22, https://www.cnx.com/cnx/media/Pdf/2017_Consol_CRR_Report.pdf.
166. "Operations," *anteromidstream.com*, Antero Resources (Antero Midstream), https://www.anteromidstream.com/operations/water-handling-and-treatment.
167. "Environment," *encana.com*, Encana, https://www.encana.com/sustainability/environment/.
168. "2018 Sustainability Report," *Apachecorp.com*, Apache Corporation, 2018, p. 42, http://www.apachecorp.com/Resources/Upload/file/sustainability/APACHE-Sustainability_Report_2018.pdf.
169. "Water Sourcing," *rangeresouces.com*, Range Resources, http://www.rangeresources.com/corp-responsibility/environment-health-and-safety/water-sourcing.
170. *See* questions 15-17 in Appendix A for the text of the questions on which scores in this section are based.
171. Mueller, Dan, "Recycling wastewater from oil and gas wells poses challenges," *blogs.edf.org*. Environmental Defense Fund, 11 Nov. 2015, http://blogs.edf.org/energyexchange/2015/11/11/recycling-wastewater-from-oil-and-gas-wells-poses-challenges-2. *See also* "Pretreatment standards for the oil and gas extraction point source category," *epa.gov*, U.S. Environmental Protection Agency, 2016, Web, https://www.epa.gov/sites/production/files/2016-06/documents/uog-final-rule_fact-sheet_06-14-2016.pdf.

SOURCE: WV Host Farms Program (www.wvhostfarms.org), Provided by FracTracker Alliance, fractracker.org/photos

Post-drilling pit prior to site remediation, WV

Companies can spill wastewater into soil and waterways when they are collecting it from the wellbore and storing it at the well pad.[172] Wastewater spills are caused by different factors (e.g., blowout, pipeline leak, equipment failure). Pits, tanks, and other equipment can develop leaks, leading to environmental releases. Pits can overflow during storm conditions if not properly designed to accommodate storm flows, and tanks can overflow when being filled if they lack monitors to detect the level of their contents. Transporting wastewater for disposal or for recycling and reuse can expose companies to vehicle and road hazards or leaks from pipelines. Treatment of wastewater for recycling can also increase the concentration of residual wastes requiring management and disposal.

Spills can pollute surface and ground water.[173] Spill rates in different states are not comparable, as states vary in their reporting requirements including the thresholds for reportable spills. From 2005 to 2014, over 31,400 hydraulically fractured well sites in Colorado, New Mexico, North Dakota, and Pennsylvania logged 6,648 spills.[174] On average, 55 spills were reported annually per 1,000 wells. The average spill rate ranged between 2% (Colorado) to 15% (North Dakota) of wells during the first three years of well life, with rates decreasing as wells matured. Declining spill rates are consistent with drilling, fracturing, and high initial production rates in a well's early years, which are accompanied by handling larger amounts of wastewater and then decrease over time.

Most spills are small. The median spill volume ranged from 1,302 gallons in New Mexico to 120 gallons in Pennsylvania.[175] EPA reported that median spill volumes in North Dakota in 2015 ranged between 340 and 1,000 gallons.[176] Of the 609 spills analyzed, few were very large: 12 were greater than 21,000 gallons, five were greater than 42,000 gallons, and one was 2.9 million gallons.[177]

Open surface pits for storing wastewater materials have been identified as a potential source for leaks or spills, contributing to water pollution.[178] To protect water resources from open pits, oil and gas companies must

172. EPA Drinking Water Study Executive Summary, p. 31, https://www.epa.gov/sites/production/files/2016-12/documents/hfdwa_executive_summary.pdf.

173. A Yale University study in 2017, cited previously in the Reducing Toxic Hazards section, identified and analyzed 132 chemicals in wastewater. Of the 73 chemicals with available toxicity data, researchers identified 62 as potentially having reproductive and/or developmental toxicity. *See* Elliot, Elise, et al., "A systematic evaluation of chemicals in hydraulic-fracturing fluids and wastewater for reproductive and developmental toxicity," 27 *Journal of Exposure Science and Environmental Epidemiology* (2017), pp 90-99, https://www.nature.com/articles/jes201581. In a University of Alberta study researchers exposed trout to low concentrations of fracturing fluid; the fish experienced endocrine disruption, biotransformation, and oxidative stress. The study concluded that wastewater "could cause significant adverse effects on fish." See He, Yuhe, et al., "Effects of biotransformation, oxidative stress, and endocrine disruption in Rainbow Trout (*Oncorhynchus mykiss*) exposed to hydraulic fracturing flowback and produced water," 51 *Environmental Science & Technology* (2017):940-947. *See also* Petch, Thomas, "Proof that chemical fracking harm fish," *Anglers Mail*, 24 Feb. 2017, https://www.anglersmail.co.uk/news/proof-chemical-fracking-harms-fish-72535.

174. Patterson, Lauren, et al., "Unconventional oil and gas spills: Risks, mitigation priorities, and state reporting requirements," 51 *Environmental Science & Technology* (2017), pp 2563-2573, (Hereafter cited as Patterson, et al.) https://pubs.acs.org/doi/pdf/10.1021/acs.est.6b05749. *See also*, Pierre-Louis, Kendra, "Fracking fluid is leaking more often than we thought," *Popular Science*, 24 Feb. 2017, https://www.popsci.com/fracking-fluid-hydraulic-fracturing-spill.

175. Patterson, et al. The differences in median spill volumes could be in part a result of different reporting thresholds. Not all volumes of the 6,648 spills were reported.

176. EPA Drinking Water Study, pp. 7-34–7-35 https://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=332990 and EPA Drinking Water Study Executive Summary, p. 31, https://www.epa.gov/sites/production/files/2016-12/documents/hfdwa_executive_summary.pdf.

177. The 2.9 million gallon spill was from a broken pipeline. *Id*. EPA Executive Summary, p. 31 & EPA Water Study, pp. 7-34 and 7-35.

178. EPA Drinking Water Study Executive Summary, pp. 1-2, https://www.epa.gov/sites/production/files/2016-12/documents/hfdwa_executive_summary.pdf.

appropriately design, construct, and maintain liners, berms, and leak detection equipment. Open pits also can be an air quality concern, because wastewater contains volatile chemicals. To lower air pollution risks from volatile chemicals, companies can separate out these chemicals before the wastewater is stored in open pits.[179] Oil and gas companies can further lower the risk of water contamination and air pollution by storing wastewater in above-ground storage tanks equipped with anti-corrosion and vapor control monitors to detect potential overflows placed above impermeable liners and surrounded by berms.[180]

SOURCE: Bill Hughes, OVEC/ohvec.org

Storage tanks on well pad

In addition to managing the wastewater generated by hydraulic fracturing, oil and gas companies must manage waste generated from drilling. These drilling residuals include cuttings (the rock fragments created by the drill bit) and drilling mud (the material used to cool the drill bit and hold the cuttings). The residuals can contain an array of toxic metals, such as arsenic, lead, and mercury, as well as salts, hydrocarbons, and radioactive materials.[181] The best management practices for post-drilling residuals that protect the environment include using a closed-loop system at the well pad and disposing of the cuttings at landfills and other sites that have been designed to hold the waste.[182]


SOURCE: Bill Hughes

Drill cuttings

179. Hirji, Zahra, et al., "Small study may have big answers on health risks of fracking's open waste ponds," *Inside Climate News*, 10 Oct. 2014, http://insideclimatenews.org/news/20141010/small-study-may-have-big-answers-health-risks-frackings-open-waste-ponds.

180. In 2017, the Groundwater Protection Council published a non-quantitative comparison of risk factors from pits and tanks indicating that some risks were higher for pits than tanks and some were lower. *See* Paque, Mike, *State oil and natural gas regulations designed to protect water resources*, Oklahoma City, Groundwater Protection Council, U.S. Department of Energy, Office of Fossil Energy, and National Energy Technology Laboratory, 2014, Appendix 6, pp. 124-127, http://www.gwpc.org/sites/default/files/state_oil_and_gas_regulations_designed_to_protect_water_resources_0.pdf.

181. Scott, J. Blake, Scott Energy Technologies, "Recycling drilled cuttings – current rules and approaches," *iogcc.ok.gov*, Interstate Oil & Gas Compact Commission, 7 May 2018, Slide 3, http://iogcc.ok.gov/Websites/iogcc/images/Blake%20Scott%20-%20Enviornment%20and%20Safety%20Presentation.pdf.

182. In a closed-loop system, open reserve pits for capturing drilling muds are replaced by a series of storage tanks. Solids and liquids are separated, minimizing the amount of drilling waste muds and cuttings that require disposal and maximizing the amount of drilling fluid recycled and reused in the drilling process. *See* "Alternatives to pits," *earthworks.com*, Earthworks, https://earthworks.org/issues/alternatives_to_pits.

Regulations for storage and transport of wastewater vary significantly among the states.[183]

## Scores

Ten companies earned credit for disclosing the total volume of wastewater generated per play. Sixteen companies disclosed their wastewater storage methods and twelve disclosed their methods to protect the environment for each practice. Fourteen companies disclosed their drilling waste management practices.

SOURCE: Brook Lenker, Provided by FracTracker Alliance, fractracker.org/photos

Impoundment and rig. WV, 2013

## Notable Disclosures

- *Chesapeake Energy* provides considerable detail about its safeguards for preventing leaks from tanks that store wastewater. The tanks comply with API standards, are coated with internal corrosion inhibitors, painted outside, and use replaceable pieces of metal that corrode first, are monitored, and are replaced periodically as a preventive measure.[184]

- *ConocoPhillips* manages oil-based drilling waste using a closed-loop system. Waste is contained in a steel tank and either hauled to a regulated disposal facility or treated and recycled. In the Eagle Ford play, the company launched a pilot program to recycle 100% of its oil-based cutting waste. The waste is taken to a nearby reclamation company, reducing distances traveled by trucks up to 60 percent. Cuttings are processed to reclaim oil and dry ash. The reclaimed oil is used to power drilling rigs, saving $6,000 to $10,000 per drilling rig.[185]

183. **Leaks:** Four states require companies to inspect piping, valves, and flowlines for leaks during production. Three states require such inspections for tank, oil/water separators and similar equipment during production. **Pits:** Twenty-four states have specific requirements concerning pits for drilling residuals and 18 regulate wastewater storage pits. Four states ban the use of such pits. Fifteen states require a liner for wastewater storage pits and 13 provide specifications for such liners. Ten states require pits to be inspected by state personnel before they begin operation. **Tanks:** Nineteen agencies require a secondary containment system for tanks, 15 of which require continuing inspections of the containment area. Specific regulation of the tanks themselves, however, is much more limited; only six states have design and construction standards for tanks, and one uses a standard developed by an external standard-setting organization. **Transportation of wastewater** can be divided among different state agencies, so the tally of state oil and gas agency regulations provides an incomplete picture of state regulations. Nine agencies require prior authorization to move wastewater, three require pipeline use, and eight regulate movement by truck. Regardless of whether pipes or trucks are used, 10 agencies require companies to track the movement of the wastewater, and 13 require reporting its final disposition. GWPC State Regulation Review, pp. 12-13, 56, 64 (states are not identified in this report), http://www.gwpc.org/sites/default/files/State%20Regulations%20Report%202017%20Final.pdf.

184. "Preventing Spills," *chk.com*, Chesapeake Energy, http://www.chk.com/responsibility/environment/spill-prevention.

185. "Focus on Hydraulic Fracturing," *conocophillips.com*, ConocoPhillips, p. 20 http://static.conocophillips.com/files/resources/focus-on-hydraulic-fracturing.pdf.

## APPLYING TREATED WASTEWATER TO ROADS AND CROPS

As this is an emerging issue with potential for significant public health implications and liability, *DTF 2019* asks companies to disclose whether their waste products are reused for purposes beyond onsite recycling. If so, *DTF 2019* seeks to understand how are they used, and what measures are taken to ensure they do not cause human or environmental harm.[186]

### Background

Growing amounts of wastewater pose an increasing management challenge. Some state and federal agencies and companies are beginning to explore alternatives for wastewater reuse. Many think this emerging field lacks the research needed to determine whether such practices are safe or might negatively impact the environment. One researcher studying the issue at the Colorado School of Mines said, "If you're worried about introducing this water to places where it could interact with the environment or human health, it's impossible to say if it's dangerous or not dangerous because we simply don't know."[187]

In July 2018, the EPA and the state of New Mexico launched a working group to identify "potential opportunities for treated produced water beneficial use."[188] In 2016 and 2017, the Produced Water Working Group of the Oklahoma Water Resources Board conducted a 66-county study to assess the feasibility of alternatives for disposing of produced water, such as "desalination for surface discharge."[189] Finding alternatives could lower demand for deep well injection, which must be closely controlled to limit earthquake risks.

The Environmental Defense Fund has urged EPA and New Mexico to be very cautious when considering wider dispersal of wastewater into the environment, noting that policy makers lack adequate data on the toxicity of chemicals found in produced water. For example, water quality standards — or even approved ways of detecting harmful chemicals — "do not exist" for most of the chemicals of concern in produced water.[190]

Recent controversies in Pennsylvania, which had permitted oil and gas wastewater from conventional wells to be used for road deicing and dust suppression, and in California, which allows oil and gas wastewater from conventional wells to be used on food crops, underscore the need to proceed with caution before allowing water from fractured wells to be used for such purposes. State regulations vary on application of wastewater to roads and land.[191]

Wastewater discharged onto roads can run off into surface water, leach into adjacent soil, and percolate into groundwater. Contaminants in the wastewater can also be become airborne, dispersing into areas far from

186. *See* Question 20 in Appendix A for the text of the question on which scoring in this section is based.

187. Work, Nikki, "Energy pipeline: Mines study shows testing methods necessary to study reuse of drilling wastewater," *Greeley Tribune*, 4 Oct. 2017, https://www.greeleytribune.com/news/energy-pipeline-mines-study-shows-testing-methods-necessary-to-study-reuse-of-drilling-wastewater/.

188. "News Release: EPA signs MOU with New Mexico to explore wastewater reuse options in oil and natural gas industry," *epa.gov*, U.S. Environmental Protection Agency, 19 July 2018, https://www.epa.gov/newsreleases/epa-signs-mou-new-mexico-explore-wastewater-reuse-options-oil-and-natural-gas-industry.

189. "Water for 2060 Produced Water Reuse and Recycling," *owrb.ok.gov*, Oklahoma Water Resources Board, p. 1, https://www.owrb.ok.gov/2060/PWWG/Study_2_Page_Handout.pdf.

190. Anderson, Scott, "Why New Mexico shouldn't rush toward repurposing oilfield wastewater," *blogs.edf.org*, Environmental Defense Fund, 27 Sept. 2018, http://blogs.edf.org/energyexchange/2018/09/27/why-new-mexico-shouldnt-rush-toward-repurposing-oilfield-wastewater/. *See also*, Leyden, Colin and Saunders, Nichole, "EPA-New Mexico wastewater report is a conversation starter, not the final word," *blogs.edf.org*, Environmental Defense Fund, 20 Dec. 2018, http://blogs.edf.org/energyexchange/2018/12/20/epa-new-mexico-wastewater-report-is-a-conversation-starter-not-the-final-word/.

191. At least 13 states allow oil and gas wastewater to be used on roads for dust suppression, deicing, and maintenance. Five of these states limit the oil and gas wastewater that can be used on roads to waste that is not the product of high-volume hydraulic fracturing. Nine states prohibit application of wastewater to land, seven require a permit for application to land, and six require a permit for applications to roads. Tasker, Travis L., et al, "Environmental and Human Health Impacts of Spreading Oil and Gas Wastewater on Roads," *Environmental Science & Technology*, vol. 52, issue 12 (2018), pp. 7081-7091 (hereafter cited as Tasker, et al.), https://pubs.acs.org/doi/10.1021/acs.est.8b00716 and GWPC State Regulation Review, p. 75, http://www.gwpc.org/sites/default/files/State%20Regulations%20Report%202017%20Final.pdf.

roads.[192] In the past, Pennsylvania has allowed use of wastewater from conventional oil and gas wells for deicing and dust suppression, while prohibiting its use from hydraulically fractured wells. But it has halted approvals statewide apparently in response to public concerns.[193]

In 2016, Pennsylvania municipalities spread more than 11 million gallons of brine on roads, 96% of it in the northwestern part of the state; this represented 6% of the wastewater from Pennsylvania's conventional wells.[194] Penn State researchers expressed concern about Pennsylvania's use of wastewater on roads, estimating from laboratory simulations that the amounts of radium dispersed to the environment were far above the amounts discharged from oil and gas wastewater treatment facilities and from spills.[195] They further noted that, more generally, states' regulations of such use do not require radium analyses prior to road treatment. In Farmington Township, Pennsylvania, after residents voiced concerns about health problems from the brine that was spread on roads,[196] the state Department of Environmental Protection admitted it made a mistake in allowing the practice, because the waste should have been reclassified under state law to a category that would not have allowed its reuse.[197]

For more than 30 years, California has allowed wastewater from conventional wells to be used to irrigate crops in the areas east and north of Bakersfield in Kern County. Management of conventional oil field wastes in Kern County has been controversial. In 2012, in a review of California's regulation of the types of wells in which such waste is disposed when not reused, the EPA found that California regulators were permitting disposal of wastewater into aquifers where it should not have been allowed, prompting a reassessment of these decisions.[198] In 2013, California's state legislature enacted Senate Bill 4, strengthening regulations governing hydraulic fracturing and other well stimulation treatments.[199] The bill, declaring that "providing transparency and accountability to the public…is of paramount concern," required greater disclosure of the chemicals in both hydraulic fracturing fluids and wastewater.[200] SB-4, declaring that insufficient information was available to fully

192. See Tasker, et al., https://pubs.acs.org/doi/10.1021/acs.est.8b00716.

193. Pennsylvania is not allowing reuse of any oil and gas wastewater state-wide. Personal communication with staff of Office of Oil and Gas Management, Pennsylvania Department of Environmental Protection, February 22, 2019. The public worries are not cited in the personal communication, but in media reporting such as in Hopey, Don, "Amish oppose use of drilling 'brine' wastewater on roads," *Pittsburgh Post-Gazette*, 29, Oct. 2016, https://www.post-gazette.com/news/environment/2016/10/30/Amish/stories/201610300078 and Hopey, Don "DEP revokes permission to dump wastewater brine from drilling on dirt roads," *Pittsburgh Post-Gazette*, 22 May 2018, https://www.post-gazette.com/news/environment/2018/05/22/DEP-brine-prohibited-roadways-pennsylvania-warren-county-gas-oil-drilling/stories/201805220114.

194. Frazier, Reid, "Study finds health threats from oil and gas wastewater spread on roads," *StateImpact* 31 May 2018, https://stateimpact.npr.org/pennsylvania/2018/05/31/study-finds-health-threats-from-oil-and-gas-wastewater-spread-on-roads/.

195. Tasker, et al., https://pubs.acs.org/doi/10.1021/acs.est.8b00716.

196. Hopey, Don, "Amish oppose use of drilling 'brine' wastewater on roads," *Pittsburgh Post-Gazette*, 30 Oct. 2016, https://www.post-gazette.com/news/environment/2016/10/30/Amish/stories/201610300078.

197. Hopey, Don, "DEP revokes permission to dump wastewater brine from drilling on dirt roads," *Pittsburgh Post-Gazette*, 22 May 2018, https://www.post-gazette.com/news/environment/2018/05/22/DEP-brine-prohibited-roadways-pennsylvania-warren-county-gas-oil-drilling/stories/201805220114. In 2015, the Pennsylvania Department of Environmental Protection published a study of radioactivity associated with oil and natural gas development in Pennsylvania. The study recommended additional analyses but overall concluded "there is little potential for harm to workers or the public from radiation exposure due to oil and gas development." Pennsylvania Department of Environmental Protection, "DEP study shows there is little potential for radiation exposure from oil and gas development," 2015, http://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/RadiationProtection/rls-DEP-TENORM-01xx15AW.pdf. *See* "Technologically enhanced naturally occurring radioactive materials (TENORM) study," dep.pa.gov, Pennsylvania Department of Environmental Protection, revised 18 May 2016, https://www.dep.pa.gov/Business/Energy/OilandGasPrograms/OilandGasMgmt/Oil-and-Gas-Related-Topics/Pages/Radiation-Protection.aspx.

198. "EPA oversight of California's underground injection control (UIC) program," *epa.gov*, U.S. Environmental Protection Agency, https://www.epa.gov/uic/epa-oversight-californias-underground-injection-control-uic-program.

199. California State Senate, "An act to amend Sections 3213, 3215, 3236.5, and 3401 of, and to add Article 3 (commencing with Section 3150) to Chapter 1 of Division 3 of, the Public Resources Code, and to add Section 10783 to the Water Code, relating to oil and gas," *Leginfo.legislature.ca.gov*, California State Legislature, 20 Sept. 2013 (hereafter cited as "SB-4"), https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB4. (Other stimulation activities include "matrix acidizing" and "acid fracturing," which are beyond the scope of *DTF 2019*.)

200. SB-4, Section 1(c).

assess well stimulation practices and their risks, directed the California Natural Resources Agency to commission an "independent scientific analysis."[201] The California Council on Science and Technology (CCST) reported its findings, conclusions, and recommendations in 2015.[202] CCST expressed considerable uncertainty about chemical impacts, partly due to the absence of information. CCST did not find recorded negative impacts from hydraulic fracturing chemical use but also observed that no state agency had systematically investigated possible impacts.[203] A few classes of chemicals presented larger hazards, but the use of many chemicals remained unknown: "We lack information to determine if these chemicals would present a threat to human health or the environment if released to groundwater or other environmental media."[204] CCST suggested that reuse of produced water from hydraulic fracturing for crop irrigation was "unknown but likely."[205] In contrast, California's Water Resources Control Board stated that it "has *never* [emphasis in the original] authorized the use of produced water from fractured wells on food crops."[206] In view of the pervasive data uncertainties, it is reasonable to conclude that the statements of both the water board and CCST regarding use of fracturing wastewater on crops could be true.

CCST further underscored data paucity when noting that operators dispose of produced water from stimulated wells in unlined percolation pits, but the effluent had not been tested for measurable concentrations of hydraulic fracturing chemical constituents. Even if testing was to be conducted, the environmental health impacts would be extremely difficult to predict, because "there are so many possible chemicals, and the environmental profiles of many of them are unmeasured."[207] CCST recommended that regulators "clarify that produced water from hydraulically fractured wells cannot be reused for purposes such as irrigation that could negatively impact the environment [and this] should continue until or unless testing the produced water specifically for…fracturing chemicals and breakdown products shows non-hazardous concentrations…or required water treatment reduces concentrations to non-hazardous levels."[208]

Following SB-4's enactment and release of the CCST report, California regulators have been working to implement strengthened regulations and collect additional data. For example, the Central Valley Water Board, the local regulatory authority, established an expert advisory panel on food safety, including representatives from multiple agencies, a firm that conducts risk assessments for companies, and a representative of an

201. Id., Section 1(b) and Article 3, section 3160(a).

202. Long, Jane C.S., et al., *An independent scientific assessment of well stimulation in California: executive summary an examination of hydraulic fracturing and acid stimulations in the oil and gas industry*, Sacramento: California Council on Science and Technology, 2015 (hereafter cited as "CCST Report Executive Summary"), https://ccst.us/wp-content/uploads/2015SB4-v2ES.pdf. Long, Jane C.S., et al., *An independent scientific assessment of well stimulation in California Volume II potential environmental impacts of hydraulic fracturing and acid stimulations*, Sacramento: California Council on Science and Technology, 2015 (hereafter cited as CCST Summary Report), https://ccst.us/wp-content/uploads/2015SB4summary.pdf. Long, Jane C.S., et al., *An independent scientific assessment of well stimulation in California Volume II potential environmental impacts of hydraulic fracturing and acid stimulations Volume II*, Sacramento: California Council on Science and Technology, 2015 (hereafter cited as "CCST Report Volume II"), https://ccst.us/wp-content/uploads/160708-sb4-vol-II-7.pdf. CCST began by noting that hydraulic fracturing practice and geologic conditions in California differ from those in other states. The average fracturing operation in California is conducted in relatively shallow vertical wells, less than 2,000 feet deep. The average fracturing operation uses 140,000 gallons of water. See CCST Report Executive Summary, p. 2 and Long, Jane C.S., et al., *An independent scientific assessment of well stimulation in California, Volume 1*, Sacramento: California Council on Science and Technology, 2015 (hereafter cited as "CCST Report, Volume 1"), p. 87, https://ccst.us/wp-content/uploads/160708-sb4-vol-I.pdf.

203. CCST Report Executive Summary, p. 5, https://ccst.us/wp-content/uploads/2015SB4-v2ES.pdf.

204. Ibid.

205. CCST Report, Volume II, p. 107, https://ccst.us/wp-content/uploads/160708-sb4-vol-II-7.pdf.

206. "Frequently asked questions about recycled oilfield water for crop irrigation," *waterboards.ca.gov*, California Environmental Protection Agency, State Water Resources Control Board, 2019, https://www.waterboards.ca.gov/rwqcb5/water_issues/oil_fields/food_safety/data/fact_sheet/of_foodsafety_fact_sheet.pdf.

207. CCST Report Executive Summary, p. 7 https://ccst.us/wp-content/uploads/2015SB4-v2ES.pdf.

208. Id., p. 9.

environmental advocacy organization.[209] With advice from and review by the advisory panel, the Central Valley Water Board has been requiring sampling of crops in irrigation districts that accept produced water for irrigation. Thus far "'*no evidence*' [has been found] that consuming crops irrigated with produced water poses any threat to human health."[210] (Emphasis in original).

### Scores

Nine companies earned credit for disclosing their practices for reusing wastewater for road or other such uses, or disclosing they do not reuse wastewater for such purposes.

## MANAGING RADIATION RISKS

SOURCE: Photo courtesy of The Allegheny Front

Truck passing through radiation monitors (white tubes) to enter Casella landfill in Chemung County, NY

*DTF 2019* asks whether companies disclose practices for identifying and managing hazards associated with radioactive waste.[211]

### Background

Waste management and surface disposal practices from hydraulic fracturing operations must be sufficient to protect against contaminating people and the environment with naturally occurring radioactive materials (NORM). NORM in the shale formation can be brought to the surface in produced water and drilling waste.[212] The radioactive chemicals and chemical byproducts dissolved in brine can separate and settle out, forming several types of wastes including mineral scales inside pipes and sludge and sediments that accumulate in tanks and pits. NORM can pose an occupational health hazard to workers. If not disposed of properly, they may pose further environmental hazards. For example, if

209. *See* "Oil Fields – Food Safety," *waterboards.ca.gov*, California Water Boards – Central Valley, updated 8 Feb. 2019, https://www.waterboards.ca.gov/centralvalley/water_issues/oil_fields/food_safety/. The environmental advocate, Dr. Seth Shonkoff, coauthored with university and national laboratory researchers an analysis of hazards related to produced water. *See* Shonkoff, Seth B.C., et al., *Hazard assessment of chemical additives used in oil fields that reuse produced water for agricultural irrigation, livestock watering, and groundwater recharge in the San Joaquin Valley of California: Preliminary results*, Oakland: PSE Energy Inc., 2016, https://www.psehealthyenergy.org/wp-content/uploads/2017/04/Preliminary_Results_13267_Disclosures_FINAL-1.pdf. The California Resources Corporation, an oil and gas company, commissioned a consultancy study of risks from processed wastewater used for agricultural irrigation: Navarro, Luis, et al., *Development of risk-based comparison levels for chemicals in agricultural irrigation water*, Bakersfield: ERM, 2016, https://www.waterboards.ca.gov/rwqcb5/water_issues/oil_fields/food_safety/data/studies/erm_riskassrpt.pdf.

210. Through early 2019, citrus, almonds, carrots, garlic, pistachios, grapes, tomatoes, and apples have been sampled for constituents associated with oil fields, including some chemical additives. *See* "Frequently Asked Questions about Recycled Oilfield Water for Crop Irrigation," *waterboards.ca.gov*, California Water Boards, updated 15 Feb. 2019, https://www.waterboards.ca.gov/rwqcb5/water_issues/oil_fields/food_safety/data/fact_sheet/of_foodsafety_fact_sheet.pdf.

211. *See* question 18 in Appendix A for the text of the question on which scoring in this section is based.

212. NORM can include uranium, thorium, radium, potassium-40, and lead-210/polonium-210. Drilling, completion, and production concentrate naturally-occurring radiation and associated wastes that can become classified as Technologically Enhanced Naturally Occurring Radioactive Materials. These have the acronym TENORM, but for simplicity, *DTF 2019* applies the acronym NORM to both. *See* "TENORM: Oil and gas production wastes," *epa.gov*, U.S. Environmental Protection Agency, https://www.epa.gov/radiation/tenorm-oil-and-gas-production-wastes. *See also*, "Naturally occurring radioactive materials (NORM) in produced water and oil-field equipment—An issue for the energy industry (USGS Fact Sheet FS-142-99)," *pubs.usgs.gov*, U.S. Geological Survey, Sept. 1999, http://pubs.usgs.gov/fs/fs-0142-99/fs-0142-99.pdf.

discharged into streams, NORM can accumulate in sediments.[213] As noted above, they can be dispersed into the environment if used to treat roads.

To minimize risks to health and the environment from NORM, companies should implement measures to protect their workers and the environment. Contaminated waste should be tracked and disposed of at sites licensed to manage such radioactive waste appropriately.

### Scores

Eleven companies earned credit for disclosing their practices for managing NORM.

### Notable Disclosures

Companies providing considerable detail on their NORM management procedures include *Anadarko Petroleum*,[214] *ConocoPhillips*,[215] *Occidental Petroleum*,[216] and *Southwestern Energy*.[217]

## MANAGING INACTIVE WELLS

*DTF 2019* asks if companies disclose their processes for managing inactive wells, emphasizing disclosures regarding decommissioning.[218]

### Background

In the United States, according to a study of "inactive well policy" by Resources for the Future, approximately 3 million oil and gas wells are inactive, meaning the operators have ceased production, either temporarily or permanently.[219] A portion of the inactive wells have been temporarily abandoned, allowing the company to easily restart production. Companies have either decommissioned the rest – which entails plugging the wells, taking away the equipment, and restoring the land – or abandoned them without first taking decommissioning steps.[220]

---

213. On the accumulation in sediment of radioactivity from conventional well water waste (not from horizontally drilled and fractured wells), see Lucas, Tim, "Radioactivity from oil and gas wastewater persists in Pennsylvania stream sediments," *Phys.org*, 19 Jan. 2018, https://phys.org/news/2018-01-radioactivity-oil-gas-wastewater-persists.html. Radionucleides may also accumulate in wildlife. *See* "Radionucleides in fracking wastewater: Managing a toxic blend," *Environmental Health Perspectives*, vol. 122, no. 2, (2014), https://ehp.niehs.nih.gov/doi/pdf/10.1289/ehp.122-A50.

214. "Health, Safety and Environment," *Anadarko.com*, Anadarko Petroleum, https://www.anadarko.com/Corporate-Responsibility/HSE/.

215. "Focus on Hydraulic Fracturing," *conocophillips.com*, ConocoPhillips, p. 20 http://static.conocophillips.com/files/resources/focus-on-hydraulic-fracturing.pdf.

216. "Supplemental Information Drilling Completions Hydraulic Fracturing," *Oxy.com*, Occidental Petroleum, p. 7, https://www.oxy.com/SocialResponsibility/overview/SiteAssets/Pages/Social-Responsibility-at-Oxy/Assets/Supplemental-information-Occidentals-drilling-completions-hydraulic-fracturing-practices-water-mgmt_2019.pdf.

217. "Land," *swncr.com*, Southwestern Energy. https://www.swncr.com/responsibility/environment/land/#solid-waste; and "HSE Programs and Training," *swncr.com*, Southwestern Energy, https://www.swncr.com/responsibility/health-safety/hse-programs-and-training/#industrial-hygiene.

218. *See* Question 19 in Appendix A for the text of the question on which scoring in this section is based.

219. Ho, Jacqueline, et al., *Plugging the gaps in inactive well policy*, Washington, Resources for the Future, 2016 (hereafter referred to as "RFF Inactive Wells Study"), p. 5, https://www.rff.org/publications/reports/plugging-the-gaps-in-inactive-well-policy/. RFF's selection of this term reflected variations in regulatory definitions. Common terms for wells "with no recent production and no responsible operator" might include "orphaned, deserted, long-term idle, abandoned." The term "abandoned wells" might include wells "that have been plugged to prevent migration of gas or fluids. *See* "Greenhouse gas emissions and sinks 1990-2016: Abandoned oil and gas wells," *epa.gov*, U.S. Environmental Protection Agency, 2018, https://www.epa.gov/sites/production/files/2018-04/documents/ghgemissions_abandoned_wells.pdf.
The American Petroleum Institute defines an inactive well as a well where "production, injection, disposal or workover operations have ceased, but permanent abandonment has not taken place." *See* API definition at "Drilling Lexicon," *iadclexicon.org*, International Association of Drilling Contractors, http://www.iadclexicon.org/inactive-well/.

220. In 2018, the Pennsylvania Department of Environmental Protection (DEP) issued administrative orders requiring three companies to plug 1,058 "abandoned wells" across Pennsylvania. When doing so, DEP noted that the agency has an inventory of thousands of abandoned oil and gas wells. Pennsylvania deems a well as abandoned if it has not been used "to produce, extract, or inject any gas, petroleum or other liquid within the preceding 12 months." *See*, "DEP orders well operators to plug 1,058 abandoned wells statewide," *media.pa.gov*,

Inactive wells can pose an array of environmental risks. Inactive wells that have not been plugged have comparatively high rates of leakage. Leaks allow methane, brine, heavy metals, and NORM to enter groundwater, surface water, soil, and, in the case of methane, the atmosphere. According to a 2015 study of 138 inactive wells in the Powder River, Denver-Julesburg (DJ), Uintah, and Appalachian basins, unplugged wells leaked 10.02 grams of methane per hour while plugged wells leaked 0.002 grams of methane per hour.[221] Other studies comparing methane leakage rates have reached similar findings.[222]

While well plugs can reduce leakage, many plugged wells still leak. According to a 2015 study from Alberta's Abandoned Well Integrity Assessment Project, 11.6% of wells plugged in 2008 or later have leaked.[223]

SOURCE: Ecoflight

Abandoned wells are an issue in Wyoming

State regulations on closure of inactive wells vary considerably.[224] Companies can mitigate environmental risks from inactive wells by employing plugging methods that include using cement to isolate the completion interval from which oil and gas are extracted, any intermediate oil and gas-bearing zones, and freshwater aquifers and filling the non-cemented portions of the wellbore with mud.[225] Additionally, research shows that the likelihood of wells leaking depends on the type of plug technologies used.[226] In general, however, further research is needed to identify the magnitude of risk reductions associated with different types of technologies deployed at diverse types of wells.[227]

Pennsylvania Department of Environmental Protection, 25 July 2018, https://www.media.pa.gov/pages/DEP_details.aspx?newsid=1039.

221. Townsend-Small, Amy, et al., "Emissions of coalbed and natural gas methane from abandoned wells in the United States," *Geophysical Research Letters*, vol. 43, issue 5, (2016), https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1002/2015GL067623.

222. For a discussion of some studies, see "Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2016: Abandoned Oil and Gas Wells," *epa.gov*, U.S. Environmental Protection Agency, April 2018, https://www.epa.gov/sites/production/files/2018-04/documents/ghgemissions_abandoned_wells.pdf.

223. RFF Inactive Wells Study, p. 10, https://www.rff.org/publications/reports/plugging-the-gaps-in-inactive-well-policy/ (citing Gerry Boyer, Alberta Energy Regulator, "Vent flow/gas Migration data trends in the western provinces," 2015, https://www.geoconvention.com/archives/2016/283_GC2016_Vent_Flow_Gas_Migration_Data_Trends_Western_Provinces.pdf.

224. Most states require companies to notify them in advance of temporarily abandoning a well. Eighteen require a company to obtain prior authorization, and 18 require a company to either pressure test the well or meet specific well construction standards before permitting such abandonment. Twenty-two agencies specify when a well must be plugged. States usually establish a time limit following drilling or after a well becomes inactive. Twenty-seven require advance notice of intent to plug a well to allow regulators to witness the plugging. Six agencies require such witnessing. Twenty-three agencies specify the location, thickness, and types of plugs that must be placed in a well. Eighteen states require placement of cement across all protected groundwater zones, while twenty-seven require placement across at least the deepest protected groundwater zone. GWPC State Regulation Review, pp. 52, 57. http://www.gwpc.org/sites/default/files/State%20Regulations%20Report%202017%20Final.pdf.

225. RFF Inactive Wells Study, p. 10, https://www.rff.org/publications/reports/plugging-the-gaps-in-inactive-well-policy/.

226. Id., p. 10, citing Theresa Watson and Bachu, Stefan, "Evaluation of the potential for gas and CO2 leakage along wellbores," *onepetro.org*, Society of Petroleum Engineers, 2007, https://www.onepetro.org/conference-paper/SPE-106817-MS).

## Scores

Fourteen companies received credit for their disclosures on closing wells.

## Notable Disclosures

*Anadarko Petroleum*[228] provides considerable detail on its well closing procedures in Colorado, and *Noble Energy*[229] highlights the hundreds of wells it has plugged in Colorado, plugging more older ones than drilling new ones.

# CONCLUSION

The first *Disclosing the Facts* report was issued in 2013 in response to immense public pressure on hydraulic fracturing companies to reduce environmental and community risks from this exponentially growing means of producing oil and gas. As a result of this pressure, and the risk it posed to companies' social license to operate, investors sought increased company disclosures to better understand these risks and how companies are managing them.

Company disclosures have improved substantially since the release of *DTF 2013*, with increased reporting across a greater range of factors—from how companies address water quality and quantity impacts, to practices designed to reduce earthquakes, and a whole range of issues in between. A growing number of companies has shifted from broad generalizations to more detailed, quantitative reporting on regional impacts. During this time, several outstanding leaders in reporting have emerged and, overall, many more companies have adopted improved reporting practices.

Through this process, investors and companies have learned much from one another; companies better understand why investors care about these issues, and investors know more about the industry, why and how companies are addressing risk, and areas where more action is needed.

Given water's importance as a critical global resource and the historic lack of oil and gas company disclosure on water management issues, investors have begun to seek greater transparency on this topic. In turn, companies are responding in disclosing their water and chemical management practices. Companies have focused on minimizing water use and increasing use of recycled water. Development of a new generation of fracturing chemicals that work cost-effectively with non-potable water has facilitated an increased sourcing of non-potable water. In tandem with this technological innovation, companies have been scaling up waste treatment operations and increasing collaboration with other companies on waste treatment.

Increasing on-site wastewater recycling has lowered demand for fresh water withdrawals while reducing air emissions, road damage, and community disruption from water trucks, particularly when recycling is done on multi-well pads. Wastewater recycling and reuse also has the beneficial effect of lowering the need for deep wastewater injection wells whose growing use has been associated with increased earthquake activity in some areas. When storing and moving wastewater, it is important for companies to assure they take appropriate precautionary measures to reduce risk, including robust spill prevention and control programs.

Companies' disclosures attest to the increasing uptake of cost-effective innovations to decrease fresh water use and handle waste more effectively. Such disclosures provide investors with insight into the quality of corporate management, particularly regarding the extent to which companies have developed data on, and planning processes to enable, the adoption of improved measures. While certain companies have improved corporate

227. Id., pp. 48-49.

228. "The Plug and Restore Process," *anadarko.com*, Anadarko Petroleum, https://www.anadarko.com/content/documents/apc/Operations/United_States/Colorado/2018_APC_Plug_Restore_Process.pdf.

disclosures, the industry as a whole still has a long way to go to present a complete picture of the effectiveness of management practices to decrease water and waste impacts. Currently, a significant portion of the industry is leaving investors substantially in the dark in this regard.

Well integrity remains a core issue in avoiding water contamination. Companies must assure investors and other concerned stakeholders that they have adopted current best practices for well integrity and, more importantly, that those practices have been effectively implemented. Well integrity requires not only the sound construction of production wells, but also taking into account nearby wells in fracturing operations, the siting and operation of disposal wells to minimize induced seismicity, and effective monitoring of wells to ensure integrity. Effective pre- and post- drilling water testing can provide a means by which well integrity can be monitored.

On all such issues ranging from water consumption in water-stressed areas, to water quality impacts on communities from nearby operations, to wastewater disposal and induced seismic activity, companies that practice hydraulic fracturing must inform investors and the public at large about whether they are implementing best practices and tracking appropriate performance metrics. We hope that the newly evolved questions in *DTF 2019* will give industry a clear disclosure framework to help it meet this important challenge.

# APPENDIX A: SCORECARD QUESTIONS

1. Does the company describe its practices, above and beyond regulatory requirements, to maintain and monitor for well integrity post completion, including use of pressure tests, continuous monitoring, or temperature, acoustic, or ultrasonic measures?
2. Does the company disclose the percentage of its wells that experienced well integrity failures that resulted in a release to the environment?
3. Does the company have a data system for tracking near misses with respect to leaks, spills, accidents, etc. that it uses to improve safety practices at the company?
4. Does the company report steps it takes, when planning to drill and complete new wells, to minimize the risk that nearby offset oil and gas wells (both active and inactive) will provide pathways for fracturing fluids, hydrocarbons, and other contaminants to enter the environment, including the atmosphere or surface or groundwater?
5. Does the company state the practices it uses when planning completion of new production wells, and when drilling and operating injection wells, to avoid seismic activity that can be felt at the surface? If the company uses third party contractors, does it require its contractors to take the same or equivalent actions to avoid seismic events?
6. For each play, does the company disclose whether it assesses groundwater quality before it drills, including the frequency and type of tests conducted?
7. For each play does the company disclose whether it routinely assesses groundwater quality after it drills, including the frequency and type of tests conducted?
8. For each play, does the company report whether or not the play is located in a water scarce area and the objective criteria it uses to assess whether an area is 'water scarce'?
9. For each play does the company report the aggregate quantity of water used for operations?
10. For each play, for the quantity of water reported in response to Q9, does the company report the percentage of water sourced from freshwater vs. non-freshwater resources?

11. For each play, for the quantity of water reported in Q9 does the company report the percentage of water sourced from specific location types (e.g., groundwater, surface water, municipal, water recycled from operations or other forms of recycled water, or other such categories)?
12. For each play does the company disclose the percentage of produced and/or flowback water from wells that is reused for subsequent well completions?
13. For each play, does the company state its practices for reducing use of fresh water in operations?
14. For each play, does the company report the total volume of wastewater generated at its well-heads?
15. Does the company state the methods it uses for all plays to store produced water (i.e., tanks, open impoundments)?
16. For each storage method in the question above, does the company state the measures it takes to reduce spills, leaks, volatile emissions, and/or hazards to wildlife?
17. For each play, does the company describe its management practices for post-drilling residuals, including residuals that contain oily wastes or other toxic or hazardous materials?
18. Does the company report its practices for identifying and managing the hazards from naturally occurring radioactive materials (NORM), including both contaminated equipment and contaminated wastewater, and for tracking its own and its contractors' management of such wastes?
19. Does the company explain its process for managing inactive wells, including whether the practice differs from play to play?
20. If the waste products from a company's operations are reused for purposes other than hydraulic fracturing operations, does the company disclose how such waste products are used (e.g., wastewater for dust suppression or agricultural irrigation or road de-icing) and methods for assuring such measures do not cause human or environmental harm?
21. Does the company report quantitatively on toxic chemical use reduction, including indicating a baseline year?
22. Does the company state a practice to use dry hydraulic fracturing chemicals instead of liquid ones, and in what circumstances?
23. Does the company state a practice to not use benzene, toluene, ethylbenzene and xylene (BTEX) in hydraulic fracturing fluids?
24. If a company excludes reporting of chemicals due to claims of confidential business information (CBI), does the company clearly state on its website that FracFocus and/or its reporting may exclude chemicals protected by claims of CBI?
25. Does the company state measures it and/or its third-party contractors take to reduce CBI claims for chemicals used in its hydraulic fracturing operations?

# APPENDIX B: METHODOLOGY

## Scorecard Goals

*Disclosing the Facts 2019* has three goals: (1) assess the overall state of industry disclosure; (2) identify those issues about which most disclosures are made; and (3) distinguish industry leaders from laggards with regard to disclosure.

## Company Selection

To determine the list of 30 companies assessed in the scorecard, this report's authors used the following determinants.

Companies needed to appear on at least one of the National Gas Supply Association's (NGSA) lists of top 40 natural gas producers for the second, third, and fourth quarter of 2017 and the first quarter of 2018.[230]

Of the companies on NGSA's lists, companies were included in the scorecard if they also met one of the following criteria:

- One of the top five fossil fuel producers in the Permian Basin or Appalachian Basin.[231]
- One of the top three fossil fuel producers in the Williston Basin (Bakken formation), Eagle Ford shale, Cotton/Bossier Basin (Haynesville shale), Niobrara/DJ Basin, or Cana/Anadarko/Woodford Basin[232] and produce an annual amount of 30,000 MBOE (i.e. 30 million barrels) in that basin.
- The largest oil and gas producer in the San Juan Basin, Green River Basin, Barnett shale, or Fayetteville shale.[233,234]

If a company was not one of the largest producers in the plays listed above, that company was included in the scorecard if its average natural gas production from the four quarters (from the second quarter of 2017 through the first quarter of 2018) was greater than 500 million cubic feet per day (MMCFD),[235] and the company was listed on the Russell 3000 Index.[236]

229. "Land Use," *nblenergy.com*, Noble Energy, https://www.nblenergy.com/sustainability/2017/land-use.

230. The lists, produced by the Natural Gas Supply Association are titled, "U.S. Natural Gas Production – MMcf/day – Year to Year Comparison." The quarter is printed in the bottom left corner of each list. The list for the second quarter of 2017 is available at https://www.ngsa.org/download/Second-Q-2017-production_2.pdf. The list for the third quarter of 2017 is available at https://www.ngsa.org/download/analysis_studies/Third-Q-2017-production_2.pdf. The list for the fourth quarter of 2017 is available at https://www.ngsa.org/download/Fourth-Q-2017-production.pdf. The list for the first quarter of 2018 is available at https://www.ngsa.org/wp-content/uploads/2018/07/First-Q-2018-production.pdf.

231. The 30,000 MBOE threshold in the next bullet does not apply to the top five producers in these basins, because they all produce more than 30,000 MBOE in these basins.

232. Because companies can calculate MBOE in different ways, companies that were the fourth largest producers were included if the difference between their production figures and the production figures of the third largest producers might be a result of different MBOE calculation methods.

233. The 30,000 MBOE threshold in the above bullet does not apply to the top producers in these basins, because they all produce more than 30,000 MBOE in these basins.

234. Production figures for each play for each company were determined using information disclosed on companies' websites and SEC filings. The production figures used to make comparisons between companies were the summation of oil, natural gas, and natural gas liquids production figures. To be able to make comparisons, all production figures provided by companies were converted into thousand barrels of oil equivalent (MBOE) for companies that did not provide the figures in those units. For some figures, this report's researchers made inferences and estimations due to a lack of data. If companies did not disclose production data for some basins/plays, those data were not included in this analysis. For this reason, this report's determination of the largest players in each basin/play might not be the actual largest players.

235. Average natural gas production was determined from the Natural Gas Supply Association's lists in footnote 230 above.

236. For a list of companies on the Russell 3000 Index, see *Membership list*, (FTSE Russell, 25 June 2018), https://www.ftserussell.com/files/support-documents/2018-membership-list-russell-3000.

While *Encana Corporation*, which was included on NGSA's lists, did not meet the other criteria (it was not one of the largest producers in a play, and average production was not more than 500 MMCFD), *Encana* was included in the scorecard because it recently purchased *Newfield Exploration Inc.*,[237] which did meet the other criteria.

## Geographic Coverage & Play-by-Play Considerations

The scorecard addresses onshore operations in the United States and Canada. To determine the plays for which companies must provide play-specific information to receive credit, *DTF 2019*'s researchers used the complete FracFocus dataset available at https://fracfocus.org/data-download. Researchers filtered to the companies in the scorecard and the wells completed in 2017, grouped by company and state, and counted the number of wells. Researchers then used the production information on companies' websites and SEC filings to match the states to specific basins/plays. When necessary, researchers used the county data in the FracFocus dataset to determine the basins/plays. If a comparatively small number of a company's completed wells are in a certain play, researchers used discretion to determine whether that company needed to include information on that play to receive credit for the play-specific questions.

## Chronological Coverage

The scorecard addresses reporting on specific, identified metrics for 2017 as publicly disclosed on websites or otherwise by Feb. 19, 2019.

## Indicator Selection

Indicators are both qualitative and quantitative. The goal was to select indicators that would enable clear "yes/no" answers, with minimal interpretation required by participating companies. This edition of the scorecard contains 25 indicators, representing both new indicators about water and chemical management and indicators adapted from prior editions of *Disclosing the Facts*.

## Company Scoring

Each company was scored based solely on documents and information available through its public website, including SEC proxy and annual report filings, water reports submitted to CDP and posted directly on the company website, and sustainability/corporate social responsibility reports. Companies were scored independently by two or more project staff. Companies received a copy of the questions on which they were scored, the corporate disclosures found pertinent to the questions, and their draft scores. Companies were given an opportunity to provide feedback on the accuracy of the scorecard information compiled and to update their public disclosures with all additional information provided to the authors by Feb. 4, 2019. Final scoring was based on staff confirmation that updated disclosure information provided by Feb. 4, 2019 was published on company websites by Feb. 19, 2019.

237. Blas, Javier and Orland, Kevin, "Encana forges shale energy giant with $5.5 billion deal for Newfield Exploration," *Financial Post* (byline is Bloomberg News), 1 Nov. 2018, https://business.financialpost.com/commodities/energy/update-1-canadas-encana-to-buy-newfield-exploration-in-5-5-bln-deal.

**A COLLABORATIVE PROJECT OF:**

AS YOU SOW®

1611 Telegraph Ave., Ste. 1450 • Oakland, CA 94612 • 510.735.8158
www.asyousow.org

BOSTON COMMON
ASSET MANAGEMENT

200 State Street, 7th Floor • Boston, MA 02109 • 617.720.5557
www.bostoncommonasset.com