William & Mary Environmental Law and Policy Review

Volume 42 (2017-2018)
Issue 1

Article 4

November 2017

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Abstract

The U.S. has recently experienced a domestic energy renaissance, made possible by technological advances, enabling the development of unconventional oil and gas resources. Vital to this development is hydraulic fracturing ("fracking"), whereby fluid is injected underground at high pressure to fracture the rock, thereby enabling the flow of oil and gas. Fracking has recently faced growing opposition with many concerned about its environmental impacts, particularly its potential to adversely affect water resources, because fracking uses vast amounts of fresh water that ends up as contaminated wastewater. Most of this wastewater is disposed of through underground injection, resulting in its permanent removal from the hydrological cycle. As an alternative, however, the wastewater could be recycled for use in future fracking treatments. This would lead to a decline in fresh water withdrawals for fracking, reducing the potential for water shortages, which are already becoming a problem in arid and semi-arid areas, where many fracking sites are located. In view of these benefits, policymakers in some states have recently sought to encourage greater recycling, but with limited success. This Paper outlines additional policy options for encouraging recycling. It argues that the current low rates of recycling are due, in large part, to the ease with which oil and gas producers can acquire fresh water and dispose of wastewater. After reviewing the existing legal framework for fresh water

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acquisition and wastewater disposal, the Paper identifies various reforms aimed at making these activities more difficult for oil and gas producers, and thereby encouraging them to invest in recycling.

INTRODUCTION

The United States is well on its way to becoming an energy superpower, producing over thirteen percent of global oil supplies and nearly twenty-two percent of global gas supplies in 2015.[1] This followed a decade of rapid growth in domestic production of oil and gas, which rose by eighty-four percent and fifty percent respectively from 2005 to 2015.[2] The increase in production is attributable to technological advances, including the combination of horizontal drilling with hydraulic fracturing ("fracking"), enabling development of unconventional hydrocarbon resources, such as shale oil and gas.[3] Shale development has expanded significantly in recent years and now accounts for almost half of domestic oil and gas production.[4] This is a remarkable outcome given that, until fairly recently, extracting oil and gas from shale was widely considered uneconomical.[5]

Shale is a fine grained sedimentary rock formed through the compaction of silt and other clay-sized mineral particles.[6] As a result of

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[1] BP ST. REVIEW OF WORLD ENERGY at 8, 22 (June 2016), *available at* http://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2016/bp-statistical-review-of-world-energy-2016-full-report.pdf [https://perma.cc/HCR9-JZTL] (indicating that global oil production in 2015 was 91.7 million barrels ("MMbbl"), of which the U.S. produced 12.7 MMbbl. In the same year, global natural gas production was 3,538.6 billion cubic meters ("bcm"), of which the U.S. produced 767.3 bcm).

[2] *Id.* (indicating that, between 2005 and 2015, U.S. oil production increased from 6.9 MMbbl to 12.7 MMbbl and U.S. natural gas production increased from 511.1 bcm to 767.3 bcm).

[3] "Shale oil" and "shale gas" are used in this Paper to refer to oil and gas deposits found in shale reservoirs. Shale oil is a subset of tight oil, which is oil produced from reservoirs with low permeability. *See* definition of "tight oil," U.S. ENERGY INFO. ADMIN., *Glossary*, http://www.eia.gov/tools/glossary/ [https://perma.cc/N56V-98WM] (last visited Oct. 23, 2017).

[4] U.S. ENERGY INFO. ADMIN., *Frequently Asked Questions: Does EIA have data on shale (or tight oil) production?*, https://www.eia.gov/tools/faqs/faq.cfm?id=847&t=6 [https://perma.cc/KNG2-Q9Y8] (last visited Oct. 23, 2017) (indicating that tight oil (also known as shale oil) accounted for 49% of total U.S. production in 2014); U.S. ENERGY INFO. ADMIN., *supra* (indicating that 47% of total natural gas production was from shale and tight oil resources in 2013).

[5] Qiang Wang et al., *Natural gas from shale formation—The evolution, evidences and challenges of shale gas revolution in United States*, 30 RENEWABLE & SUSTAINABLE ENERGY REV. 1, 2 (2014).

[6] U.S. ENERGY INFO. ADMIN., *Natural Gas Explained: Where Our Natural Gas Comes*

the compaction process, the rock has low permeability, which constrains the movement of oil and gas through the shale. To increase shales' permeability, producers inject fluid underground at high pressure to fracture the rock, thereby enabling the flow of oil and gas.[7] Fracking was first developed in the 1940s and has been used in conventional (vertical) wells since that time.[8] Over the last two decades, fracking has been combined with horizontal drilling to develop shale and other unconventional resources.[9] This has led to increased development in traditional oil and gas producing regions, such as the Permian Basin in west Texas, as well as expansion into new areas, including the Bakken Formation in North Dakota.[10]

The recent growth in fracking has been met with strong opposition, particularly from environmental groups, concerned about its impacts on water resources.[11] Much of the concern has focused on the potential for chemicals used during fracking to contaminate surface and ground water.[12] Responding to these concerns, state and federal regulators have adopted various measures aimed at minimizing the water quality impacts of fracking. Notably however, comparatively little attention has been given to fracking's potential water quantity impacts. These impacts are difficult to assess as many oil and gas producers do not report their water use. The water use figures that are reported vary significantly between and within shale plays, likely due to differences in the nature of the rock and the hydrocarbon resources found there.[13] Although this makes generalizations difficult, most commentators agree that

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From, http://www.eia.gov/energyexplained/index.cfm?page=natural_gas_where [https://perma.cc/Z8VH-G9TX] (last updated Jan. 10, 2017).

[7] N.Y. DEP'T OF ENVTL. CONSERV., FINAL SUPPLEMENTAL GENERIC ENVIRONMENTAL IMPACT STATEMENT ON THE OIL, GAS, AND SOLUTION MINING REGULATORY PROGRAM 5-1 (2015), http://www.dec.ny.gov/docs/materials_minerals_pdf/fsgeis2015.pdf [https://perma.cc/TR5T-RNTC].

[8] EPA, HYDRAULIC FRACTURING FOR OIL AND GAS: IMPACTS FROM THE HYDRAULIC FRACTURING WATER CYCLE ON DRINKING WATER RESOURCES IN THE U.S. ES-5 & 1-3 (2016), http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=530159 [https://perma.cc/HSM6-WU9T].

[9] *Id.*

[10] *Id.* at 3-37, 4-22.

[11] For a discussion of the potential environmental impacts associated with fracking, *see* N.Y. DEP'T OF ENVTL. CONSERV., *supra* note 7, at Ch. 6.

[12] *Id.*

[13] Andrew Kondash & Avner Vengosh, *Water Footprint of Hydraulic Fracturing*, 2 ENVTL. SCI. & TECH. LETTERS 276, 277 (2015) (stating that analysis of reporting figures "reveals large variations in water use" from 3.6 million to 6.3 million gallons per well).

fracking is highly water intensive, typically requiring millions of gallons per well.[14] Much of this water is permanently removed from the hydrological cycle and therefore unavailable for use in other applications.[15]

The Environmental Protection Agency ("EPA") estimates that up to forty-five billion gallons of water are used in fracking each year in the U.S.[16] Although this represents a small fraction (less than one percent) of national water use,[17] when considered at the local level, fracking operations may be major water users in some areas.[18] Most fracking operators use fresh water withdrawn from surface streams and/or underground aquifers in close proximity to the well-site.[19] These withdrawals may

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[14] *Id. See also* U.S. DEP'T OF ENERGY, MODERN SHALE GAS DEVELOPMENT IN THE UNITED STATES: A PRIMER (2009), http://energy.gov/sites/prod/files/2013/03/f0/ShaleGasPrimer_Online_4-2009.pdf [https://perma.cc/CYA9-BGQK] (reporting that "[t]he amount of water needed to drill and fracture a horizontal shale gas well generally ranges from about 2 million to 4 million gallons, depending on the basin and formation characteristics"); EPA, *supra* note 8, at 4-7 (stating that "the median volume of water used [in fracking] per well, based on 37,796 disclosures nationally, was 1.5 million gallons"); Steven Goodwin, *Water Intensity Assessment of Shale Gas Resources in the Wattenberg Field in Northeastern Colorado*, 48 ENVTL. SCI. & TECH. 5991, 5991, 5993 (2014) (estimating that 1.4 to 7.5 million gallons of water is required per well in the Wattenberg Field in Colorado); Kyle E. Murray, *State-Scale Perspective on Water Use and Production Associated with Oil and Gas Operations, Oklahoma, U.S*, 47 ENVTL. SCI. & TECH. 4918, 4923 (2013) (estimating that, in Oklahoma, approximately 3 million gallons of water are required per well); Jean-Philippe Nicot & Bridget Scanlon, *Water Use for Shale-Gas Production in Texas, U.S.*, 46 ENVTL. SCI. & TECH. 3580, 3583 (2012) (estimating that, in parts of Texas, over nine million gallons of water are required per well).

[15] Robin Kundis Craig, *Hydraulic Fracturing (Fracking), Federalism, and the Water-Energy Nexus*, 49 IDAHO L. REV. 241, 253 (2013) (noting that "under current norms for dealing with fracking produced water—namely, injection of the water into underground injection wells—use of water in fracking is one hundred percent consumptive" (internal citations omitted)).

[16] EPA, *supra* note 8, at 4-13.

[17] Total nationwide water usage is approximately 129,575 billion gallons. *See Water Use in the United States*, U.S. GEOLOGICAL SURV., http://water.usgs.gov/watuse/wuto.html [https://perma.cc/L3MB-J457] (last updated Dec. 9, 2016) [hereinafter *Water Use*] (estimating that, in 2010, total fresh and saline water withdrawals were approximately 355 billion gallons per day).

[18] MONIKA FREYMAN, CERES, HYDRAULIC FRACTURING & WATER STRESS: WATER DEMAND BY THE NUMBERS 29 (2014), http://www.ceres.org/resources/reports/hydraulic-fracturing-water-stress-water-demand-by-the-numbers/view (finding that, in many counties, the amount of "[w]ater used . . . for hydraulic fracturing is often many times higher than water used for domestic residential water use" and arguing that "[w]ater use in certain counties can be very high because shale development tends to concentrate in 'sweet spots' where wells may be particularly productive"). *See also* EPA, *supra* note 8, at 10-4 (finding that, in forty five counties, water use in fracking exceeds ten percent of available water. Of those counties, thirty-five exceeded thirty percent, and seventeen exceeded 100 percent).

[19] EPA, *supra* note 8, at ES-12 (indicating that "[w]ater used for hydraulic fracturing is

have adverse environmental impacts, leading to changes in the hydrological regime of streams and threatening water-dependent species. They could also lead to increased competition for water, particularly in areas prone to drought and/or with high rates of water use in other sectors, such as agricultural production.

An estimated twenty-seven percent of shale resources nationwide are in areas of high or extremely high water stress and a further ten percent are in arid regions.[20] These include the Monterey shale in California, the Niobrara formation in Colorado, and the Eagle Ford basin in Texas.[21] In many of these areas, water supplies have come under increasing pressure in recent years, due to rising withdrawals. This trend is expected to continue in the future, with population growth likely to lead to greater demand for water. At the same time, water supplies may decline as a result of climate change, which is predicted to lead to more frequent and severe droughts in arid states. Recognizing this, state policymakers have emphasized the importance of limiting fresh water use, particularly in oil and gas production.[22] In Texas, for example, Railroad Commissioner Christi Craddick has urged large producers to eliminate all fresh water use in their operations in the next five years.[23]

Various alternative water sources, such as brackish water and/or municipal effluent, may be used in oil and gas production. One of the most promising alternatives, which is already being used by some producers, is wastewater from past fracking treatments. A portion of the fluid injected during fracking returns to the surface, along with water occurring naturally in the rock formation (together "wastewater").[24] The amount of these return flows varies between geological formations, but may exceed 100 percent of injected volumes.[25] After treatment to remove salts, metals, and other contaminants, the wastewater may be reused in

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typically fresh water taken from available groundwater and/or surface water resources located near [fracked] oil and gas production wells").

[20] Paul Reig et al., World Resources Institute, Global Shale Gas Development: Water Availability and Business Risks, WORLD RES. INST., 67 (2014), *available at* http://www.wri.org/sites/default/files/wri14_report_shalegas.pdf [https://perma.cc/64MQ-L5U2].

[21] *Id.* at 69, 71.

[22] Joint Hearing Before the H. Comm. on Energy Resources and H. Comm. on Natural Resources, 2015 Leg., 84th Sess. (Tx. 2015) (statement of David Porter, Chairman, Railroad Commission of Texas).

[23] Editorial, *For frackers, waste not, want not*, DALLAS MORNING NEWS (Aug. 13, 2014), http://www.dallasnews.com/opinion/editorials/20140813-editorial-waste-not-want-not.ece [https://perma.cc/EE95-BE3A].

[24] EPA, *supra* note 8, at 7-3.

[25] *Id.* at 7-5 to 7-9.

future fracking operations, reducing the quantity of fresh water that is needed. Reuse also has the added benefit of eliminating the need for wastewater disposal. Most wastewater is currently disposed of (without treatment) through underground injection, which results in its permanent removal from the hydrological cycle.[26]

Despite the potential benefits of wastewater recycling, use of the practice remains limited, likely due to the costs involved.[27] For many oil and gas producers, the cost of recycling exceeds the expenses that would otherwise be incurred in disposing of the wastewater, and sourcing fresh water for future fracking treatments. Producers are, therefore, unlikely to recycle wastewater absent regulatory mandates or incentives. Recognizing this, some states have recently adopted regulations aimed at encouraging recycling by producers. In Texas, for example, the permitting process for new recycling facilities has been streamlined and producers have been offered tax incentives to recycle. This Paper explores other measures states could take to support recycling.

The remainder of this Paper is structured as follows: Part I of this Paper discusses current fresh water use in fracking. Part II then identifies alternative water sources for fracking and, after exploring their pros and cons, concludes that recycled wastewater is the best option. Policies for encouraging wastewater recycling, including restrictions on the use of fresh water in, and disposal of wastewater from, fracking are outlined in Part III. The current regulation of those activities is analyzed in Parts IV and V to determine their impact on recycling. Based on that analysis, Part VI identifies regulatory changes that may encourage recycling.

I. FRACKING 101

The process of developing shale and other unconventional hydrocarbons tends to be more resource intensive than conventional hydrocarbon development.[28] This is due to shale's low permeability, which constrains the movement of hydrocarbons through the rock.[29] Extracting hydrocarbons

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[26] For a discussion of the risks associated with underground injection, *see* MICHAEL KIPARSKY & JAYNI FOLEY HEIN, REGULATION OF HYDRAULIC FRACTURING IN CALIFORNIA: A WASTEWATER AND WATER QUALITY PERSPECTIVE 19–20 (2013), https://www.law.berkeley.edu/files/ccelp/Wheeler_HydraulicFracturing_April2013.pdf [https://perma.cc/X3G7-B4XD].

[27] Xochitl Torres Small, *Water Use and Recycling in Hydraulic Fracturing: Creating a Regulatory Pilot for Smarter Water Use in the West*, 55 NAT. RESOURCES J. 409, 413 (2015). *See also* Fakhru'l-Razi Ahmadun et al., *Review of Technologies for Oil and Gas Produced Water Treatment*, 170 J. HAZARDOUS MATERIALS 530, 531 (2009).

[28] U.S. DEP'T OF ENERGY, *supra* note 14, at 14.

[29] *Id.* at 56.

from shale therefore requires use of advanced drilling techniques to increase the rocks' permeability.

Most shale hydrocarbon resources are accessed using directional drilling, whereby the drill bit is initially placed vertically and continues down, until it is just above the layer of rock containing oil and gas.[30] The drill bit is then gradually angled such that drilling can continue horizontally along the rock layer.[31] After the completion of drilling, the well is then stimulated to aid the flow of oil and gas.[32] One common well stimulation technique is fracking, a process the Texas Supreme Court has described as:

> pumping fluid down a well at high pressure so that it is forced out into the formation. The pressure creates cracks in the rock that propagate along the azimuth of natural fault lines in an elongated elliptical pattern in opposite directions from the well. Behind the fluid comes a slurry containing small granules called proppants—sand, ceramic beads, or bauxite are used—that lodge themselves in the cracks, propping them open . . . The fluid is then drained, leaving the cracks open for gas or oil to flow to the wellbore.[33]

A. *The Essential Role of Water in Fracking*

Water is a key input in oil and gas production, used in the initial drilling of a well to cool and lubricate the drill bit, as well as to clean the wellbore.[34] Water also plays a role in many well completion processes, including fracking, although some waterless techniques are available.[35] Data on current rates of water use in fracking are currently only available in some areas.[36] The amount of water used can vary significantly between, and even within, geological formations depending on the nature of the rock and the drilling method used.[37] This variation makes relying

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[30] N.Y. DEP'T ENVTL. CONSERV., *supra* note 7, at 5-20.
[31] *Id.*
[32] *Id.*
[33] Coastal Oil & Gas Corp. v. Garza Energy Tr., 268 S.W.3d 1, 6–7 (Tex. 2008).
[34] N.Y. DEP'T OF ENVTL. CONSERV., *supra* note 7, at 5-20.
[35] Anthony Brino, *New Waterless Methods Avoid Pollution Problems, But Drillers Slow to Embrace it*, INSIDE CLIMATE NEWS (Aug. 2017), http://insideclimatenews.org/print/12241?page=3 [https://perma.cc/PM92-2GTB].
[36] EPA, *supra* note 8, at 4-20.
[37] B. R. Scanlon et al., *Comparison of Water Use for Hydraulic Fracturing for Unconventional Oil and Gas versus Conventional Oil*, 48 ENVTL. SCI. & TECH. 12386, 12386–87 (2014). *See also* Tanya J. Gallegos et al., *Hydraulic Fracturing Water Use Variability in the United States and Potential Environmental Implications*, 51 WATER RESOURCES RES. 5839, 5841

on average water use figures problematic and creates difficulties in extrapolating from use in any one area. Seeking to avoid these issues, this section discusses water use in primarily qualitative terms and includes only limited quantitative data.

Recent studies indicate that both conventional and unconventional oil and gas production use similar amounts of water per unit of energy produced.[38] When assessed on a per well basis, however, water use in unconventional production is often significantly higher than conventional production.[39] This is because unconventional production typically requires the use of horizontal wells, which have longer laterals, and therefore require more water to drill and frack.[40] Many horizontal wells have to be fracked multiple times as adequate pressure cannot be obtained from a single fluid injection.[41] To overcome this problem, producers divide the wellbore into a dozen or more segments and frack each separately, increasing the total amount of water required.[42]

Fracking may be performed using water-based liquids, gels, or foams (together "fracking fluids").[43] The composition of fracking fluids varies between geological formations.[44] In shale formations, oil and gas producers often use slick water fracturing, wherein the fracking fluid is comprised principally (over ninety percent) of water, mixed with a proppant and various chemical additives.[45] Common additives include biocides, clay stabilizers, friction reducers, gelling agents, oxygen scavengers, pH buffers, and scale inhibitors.[46]

(2015) (indicating that "the amount of water used for hydraulic fracturing is . . . directly or indirectly influenced by local or regional oil-reservoir and gas-reservoir characteristics. The reservoir extent, depth, and thickness of oil-bearing or gas-bearing strata influences the perforated interval of the well and the amount of water needed to induce fractures while the porosity, permeability, temperature, pressure and other intrinsic properties impact water saturation, fracture geometry, and hydraulic fracturing treatment fluid design").

[38] Scanlon et al., *supra* note 37, at 12392 (finding that "water use to oil production ratios . . . for unconventional oil production are within the lower range of those for conventional oil production").

[39] Gallegos et al., *supra* note 37, at 5841 (finding that, in 2014, median national annual water volumes used to hydraulically fracture horizontal wells were 15,275 m^3 and 19,425 m^3 per oil and gas well respectively, while median water use in vertical wells was less than 2600m^3).

[40] *Id.*

[41] N.Y. DEP'T ENVTL. CONSERV., *supra* note 7, at 5-87.

[42] *Id.* at 5-89.

[43] *Id.* at 5-34.

[44] *Id.*

[45] *Id.* at 5-35.

[46] *Id.* at 5-34, 5-37 to 5-43. *See also* Gallegos et al., *supra* note 37, at 5842 (stating that

The EPA estimates that, on average, fracking operations use more than one million gallons of water per well.[47] There is, however, significant geographic variation in fracking water use.[48] Table 1 below shows median water use in fracking in select areas as estimated by the EPA.

TABLE 1: VOLUME OF WATER USED DURING FRACKING[49]

Formation	**Median Water Use (Per Well)**
Texas	
Fort Worth Basin (including the Barnett shale play)	3.9 million gallons[50]
Permian Basin (including the Wolfcamp/ Cline shale play)	840,000 million gallons[51]
Western Gulf (including the Eagle Ford shale play)	3.8 million gallons[52]
Oklahoma	
Ardmore Basin (including the Woodford shale play)	8.0 million gallons[53]
Arkoma Basin (including the Fayetteville shale play)	6.7 million gallons[54]

"shale-gas reservoirs are often hydraulically fractured using slick water, a formulation containing a large proportion of water").

[47] EPA, *supra* note 8, at 4-11.

[48] *Id.* at 4-18.

[49] The EPA estimated median water use per well based on disclosures made by oil and gas producers in the FracFocus database managed by the Ground Water Protection Council and Interstate Oil and Gas Compact Commission. The EPA analyzed disclosures for over 38,000 wells that underwent fracking between January 1, 2011 and February 28, 2013. *See id.* at ES-13.

[50] *Id.* at 4-23.

[51] *Id.* Note that the Permian Basin extends from Texas into New Mexico. The EPA attributes the relatively low level of water use in the Permian Basin to an abundance of vertical wells in the area. *See id.* at 4-24.

[52] EPA, *supra* note 8, at 4-23.

[53] *Id.* at B-54.

[54] *Id.* Note that the Arkoma Basin extends from Oklahoma into Arkansas.

Formation	Median Water Use (Per Well)
Anadarko basin (including the Woodford shale play)	3.3 million gallons[55]
Louisiana	
TX-LA-MS Salt Basin (including the Haynesville shale play)	5.1 million gallons[56]
North Dakota	
Willison Basin (including the Bakken shale play)	2.0 million gallons[57]
Colorado	
Denver Basin (including the Niobrara shale play)	400,000 gallons[58]
Raton Basin (including the Cretaceous Pierre shale play)	96,000 gallons[59]
Uinta-Piceance Basin	1.8 million gallons[60]
Pennsylvania	
Appalachian Basin (including the Marcellus, Devonian, and Utica plays)	4.2 million gallons[61]

[55] *Id.* Note that the Anadarko Basin extends from Oklahoma into Texas.
[56] *Id.* at 4-44. Note that the TX-LA-MS Salt Basin extends from Louisiana west into Texas and east into Mississippi. The EPA estimates water use in the Texas portion of the TX-LA-MS Salt Basin at 3.1 million gallons per well. *See id.* at 4-23.
[57] EPA, *supra* note 8, at 4-41. Note that the Willison Basin extends from North Dakota into Montana. The EPA estimates water use in the Montana portion of the basin at 1.6 million gallons per well. *See id.*
[58] *Id.* at 4-32. Note that the Denver Basin extends from Colorado into Wyoming.
[59] *Id.* Note that the Raton Basin extends from Colorado into New Mexico. The EPA attributes the low level of water use in the Raton Basin to the prevalence of coalbed methane extraction in the area. *See id.*
[60] *Id.* Note that the Appalachian Basin extends from Pennsylvania into Ohio and West Virginia.
[61] EPA, *supra* note 8, at 4-36. Note that the Appalachian Basin extends from Pennsylvania into Ohio and West Virginia. The EPA estimates water use per well in the Ohio portion of the basin at 3.9 million gallons and in the West Virginia portion at 5.0 million gallons. *See id.*

Most oil and gas producers use fresh water for fracking.[62] Identifying the precise source of the water used in a particular fracking treatment is difficult because producers often do not publicly report this information.[63] It is believed that, due to the high cost of transportation, most producers source water close to the well site.[64] Surface water is more likely to be used in temperate eastern states, while in the more arid west, producers may be forced to use ground water.[65] In the Marcellus shale in Pennsylvania, for example, over ninety percent of water used in fracking is sourced from surface water bodies and less than ten percent from underground aquifers.[66] The percentages are reversed in Texas's Eagle Ford shale.[67]

B. *Wastewater Generation in Fracking*

A portion of the fluid injected during fracking remains underground permanently.[68] Some, however, returns to the surface when the pressure used during injection is released ("flowback fluid").[69] These return flows, which occur within the first ten to fourteen days after injection (the "flowback period"), consist primarily of fracking fluid.[70] The flows may contain chemicals added to the fracking mixture, new compounds formed by reactions between additives, and substances occurring naturally in the rock formation.[71] Materials typically present include dissolved solids (e.g., chlorides and sulfates), metals (e.g., magnesium and strontium), mineral scales (e.g., calcium carbonate), acid gases (e.g., carbon dioxide), and suspended materials (e.g., clay and silt).[72]

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[62] *Id.* at ES-12 (indicating that "[w]ater used for hydraulic fracturing is typically fresh water taken from available groundwater and/or surface water resources located near [fracked] oil and gas production wells").
[63] Jean-Philippe Nicot et al., *Current and Projected Water Use in the Texas Mining and Oil and Gas Industry,* JACKSON SCHOOL OF GEOSCIENCES at 35 (2011), http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/0904830939_MiningWaterUse.pdf [https://perma.cc/9Z7Y-BYEP] [hereinafter *Current and Projected Water Use*].
[64] EPA, *supra* note 8, at 4-5.
[65] *Id.* at 4-6.
[66] *Id.*
[67] *Id.*
[68] Gallegos et al., *supra* note 37, at 5844.
[69] *Id.*
[70] Benjamin K. Sovacool, *Cornucopia or curse? Reviewing the costs and benefits of shale gas hydraulic fracturing (fracking),* RENEWABLE AND SUSTAINABLE ENERGY REVS. 250, 251 (2014).
[71] N.Y. DEP'T ENVTL. CONSERV., *supra* note 7, at 5-94.
[72] *Id.* at 5-94 to 5-95.

After the initial flowback period, as oil and/or gas are produced from the well, additional fluid returns to the surface ("produced water").[73] This produced water is comprised primarily of fluid occurring naturally in the rock and may also include small amounts of fluid injected during fracking.[74] It typically has a high mineral content, often containing barium, calcium, iron, and/or other salts and metals that have leached from the rock over time.[75] Additionally, it may also contain dissolved hydrocarbons, such as methane and naturally occurring radioactive materials, including radium isotopes.[76]

The total amount of wastewater (i.e., both flowback fluid and produced water) generated during fracking is dependent on several factors, including the type of hydrocarbon being produced and the method of production.[77] Gas wells typically generate larger volumes of wastewater than oil wells; across both categories, wastewater generation tends to be highest in wells that have undergone fracking.[78] On average, in the Marcellus shale, ten to thirty percent of the water injected during fracking returns to the surface.[79] Return flows tend to be higher in the Bakken shale, and may reach forty percent of injected volumes.[80] In the Barnett shale, return flows can exceed 100 percent of injected volumes.[81]

In recent years, as oil and gas production has risen due to the expansion of fracking, increasing volumes of wastewater have been generated.[82] In the Marcellus shale, for example, wastewater volumes increased sixfold between 2004 and 2011.[83] By 2012, in the Pennsylvania portion of the Marcellus shale alone, 1.2 billion gallons of wastewater were produced.[84] In other areas, wastewater volumes were even higher.

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[73] Sovacool, *supra* note 70, at 251.
[74] N.Y. DEP'T ENVTL. CONSERV., *supra* note 7, at 5-94.
[75] Sovacool, *supra* note 70, at 251.
[76] N.Y. DEP'T ENVTL. CONSERV., *supra* note 7, at 5-94.
[77] ENERGY-WATER NEXUS: INFORMATION ON THE QUANTITY, QUALITY, AND MANAGEMENT OF WATER PRODUCED DURING OIL AND GAS PRODUCTION, GAO at 10–11 (2012), http://www.gao.gov/assets/590/587522.pdf [https://perma.cc/FV9S-TN5X] [hereinafter ENERGY-WATER NEXUS].
[78] *Id.* at 11.
[79] EPA, *supra* note 8, at 7-8.
[80] Pam Boschee, *Produced and Flowback Water Recycling and Reuse: Economics, Limitations, and Technology*, 3 OIL & GAS FACILITIES 1, 2 (2014).
[81] EPA, *supra* note 8, at 7-8.
[82] *Id.* at 8-19.
[83] Charles Schmidt, *Estimating Wastewater Impacts from Fracking*, 121 ENVTL. HEALTH PERSP. 4, A117 (2013).
[84] Elizabeth Ridlington & John Rumpler, *Fracking by the Numbers: Key Impacts of Dirty Drilling at the State and National Level,* ENV'T AM. at 21 (Oct. 2013), http://www.environ

Approximately 12 billion gallons of wastewater were produced in North Dakota in 2012,[85] while in Texas, wastewater volumes were 260 billion gallons.[86] Nationwide, fracking is estimated to produce over 280 billion gallons of wastewater each year.[87]

II. ALTERNATIVES TO FRESH WATER FOR FRACKING

The EPA estimates that, each year in the U.S., up to forty-five billion gallons of water are used in fracking.[88] This represents a small portion (less than one percent) of national water withdrawals.[89] Water use in fracking is unevenly distributed, however, being concentrated in active shale plays.[90] In these areas, shale oil and gas development may account for a significantly larger share of water use.[91] As an example, a 2012 study found that in Johnson County, in the heart of Texas's Barnett shale, twenty-nine percent of water use is in gas development.[92] In several Texas counties, water use for gas development is projected to exceed all other uses in coming decades.[93]

Most of the water used in fracking is withdrawn from nearby surface streams and/or underground aquifers.[94] These withdrawals may contribute to local water shortages, particularly in arid regions, where many water bodies are already under stress.[95] Almost half of all wells fracked in the U.S. between January 2011 and May 2013 were in areas of high or extremely high water stress (i.e., where over forty percent of available water is already allocated to municipal, industrial, and agricultural

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mentamerica.org/sites/environment/files/reports/EA_FrackingNumbers_scrn.pdf [https://perma.cc/F864-DWVX].

[85] *Id.*

[86] *Id.*

[87] *Id. See also* Kondash & Vengosh, *supra* note 13, at 278 (finding that, between 2000 and 2015, "[s]hale gas plays in sum produced slightly less water (472 X 10^9 L, 125 X 10^9 gal) than was used for hydraulic fracturing (708 X 10^9 L, 187 X 10^9 gal), while unconventional oil wells (331 X 10^9 L, 87 X 10^9 gal) produced more FP water than was used to fracture them (232 X 10^9 L, 61 X 10^9 gal)").

[88] EPA, *supra* note 8, at 4-13.

[89] *Water Use*, *supra* note 17 (estimating that total, nationwide water use was 355 billion gallons per day in 2010).

[90] Nicot & Scanlon, *supra* note 14.

[91] *Id.*

[92] *Id.* at 3583.

[93] *Id.*

[94] EPA, *supra* note 8, at 4-6 to 4-7.

[95] *Id.* at 4-29.

use).[96] The figure was higher in Texas, where fifty-two percent of wells were in high or extremely high water stress areas.[97] In Colorado and California, over ninety percent of wells were in high or extremely high water stress areas.[98] The percentages could rise over the next decade as water resources come under increasing pressure.[99] Population growth is likely to lead to greater demand for water in coming years.[100] At the same time, climate change is expected to cause more frequent and severe droughts, particularly in arid areas.[101] In those areas, withdrawals for fracking could lead to water shortages.

Water shortages could also become a problem in less arid areas such as the Marcellus shale play. To date, in the Marcellus, there has been little competition for water between oil and gas producers and other users. Just two percent of oil and gas wells in the region are in high or extremely high water stress areas.[102] Most wells are in areas of medium water stress, meaning that less than forty percent of water supplies have been allocated to municipal, industrial, and agricultural use, with sixty percent available for fracking and/or other uses.[103] Nevertheless, over time, increasing withdrawals for fracking may lead to greater competition between water users. There are signs this may be already occurring. In August 2011, eleven permits granted to gas operations withdrawing water from the Susquehanna River Basin in Pennsylvania were suspended due to low stream levels. According to a report on the incident, "[w]hile parts of

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[96] FREYMAN, *supra* note 18, at 6.
[97] *Id.*
[98] *Id.*
[99] *Id.* at 12.
[100] *See, e.g.*, TEXAS WATER DEV. BOARD, WATER FOR TEXAS: 2017 STATE WATER PLAN at 49 (2016), http://www.twdb.texas.gov/waterplanning/swp/2017/doc/SWP17-Water-for-Texas.pdf [https://perma.cc/BZ6B-AU8B] (noting that "Texas's population is expected to increase more than 70 percent between 2020 and 2070," leading to increased demand for water. "Water demand is projected to increase by 17 percent, from 18.4 million acre-feet per year in 2020 to 21.6 million acre-feet per year in 2020"); CAL. DEP'T OF WATER RES., CALIFORNIA WATER PLAN: UPDATE 2013 at 2-11 (2014), http://www.waterplan.water.ca.gov/docs/cwpu2013/Final/0a-Vol1-full2.pdf [https://perma.cc/3CB6-PWUM] (stating that "[f]rom 1990 to 2010, California's population increased from about 30 million to about 37.3 million. The California Department of Finance projects that this trend means a state population of roughly 51 million by 2050 . . . [As a result,] future urban water demands . . . could increase by several million acre-feet").
[101] *See, e.g.*, CAL. DEP'T OF WATER RES., *supra* note 100, at 2-12 (noting that climate change is expected to cause droughts to "become more frequent and persistent" resulting in declining water supplies).
[102] FREYMAN, *supra* note 18, at 68.
[103] *Id.* at 68–70.

the state were abnormally dry, the basin was not experiencing a drought at the time, suggesting that natural gas operations are already creating conflicts with other uses under normal conditions."[104]

Avoiding future water shortages will require a reduction in fresh water use in oil and gas production. Recognizing this, a number of producers have been exploring waterless fracking techniques, which use propane, mineral oil, liquid carbon dioxide, liquid nitrogen, and/or other fluids in place of water.[105] To date, however, such techniques have proved less effective in stimulating the flow of oil and gas than water-based fracking.[106] Any shift to waterless fracking is, therefore, likely many years away. In the interim, producers should reduce their use of fresh water and instead use alternatives, such as brackish or recycled water.

A. Brackish Water

Oil and gas producers have, in the past, insisted that fracking requires use of fresh water with salinity less than 1,000 milligrams per liter ("mg/l") total dissolved solids ("TDS").[107] Many producers have expressed concern that using water with a higher salt content, commonly referred to as brackish water, may interfere with the performance of some fracking chemicals. For example, friction reducers added to the fracking fluid (i.e., to enable those fluids to be pumped down the well at a higher rate and reduced pressure than if water alone were used) may not work properly in water with high TDS.[108] Using high TDS water can also cause scale to build up in the wellbore, which impedes the flow of oil and gas to the surface.[109]

The risks associated with using brackish water have been significantly reduced through advances in fracking techniques, including

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[104] Heather Cooley & Kristina Donnelly, *Hydraulic Fracturing and Water Resources: Separating the Frack from the Fiction,* PACIFIC INST. at 16 (2012), http://www.velaw.com/uploadedfiles/vesite/e-comms/full_report.pdf [https://perma.cc/XER7-ZFP2].

[105] Andrew Topf, *Water-less Fracking Could Be Industry Game Changer*, Oilprice.com (Nov. 6, 2014, 5:41 PM), http://oilprice.com/Energy/Energy-General/Water-less-Fracking-Could-Be-Industry-Game-Changer.html [https://perma.cc/X2QS-QN9R].

[106] Danielle Wente, *Waterless fracking test well isn't doing so hot*, BAKKEN.COM (May 13, 2015), http://bakken.com/news/id/238762/waterless-fracking-test-well-isnt-doing-so-hot/ [https://perma.cc/QBE4-Q8Q7] (reporting that, during a test in Ohio, a well using waterless fracking produced half the amount of oil than its neighboring well fractured with water).

[107] Margaret A. Cook et al., *Who Regulates It? Water Policy and Hydraulic Fracturing in Texas*, 6 TEX. WATER J. 45, 54 (2015).

[108] *Id.*

[109] Paul D. Lord & Renee LeBas, *Treatment Enables High-TDS Water Use as Base Fluid for Hydraulic Fracturing*, J. OF PETROLEUM TECH., 30, 32 (2013).

improvements in the efficiency of chemicals added to the fracking fluid and the development of salt tolerant fracking chemicals. Despite this, however, brackish water use in fracking remains limited.[110] Using brackish water can be costly, particularly where it has high TDS (exceeding 10,000 mg/L) as such water may require treatment prior to use.[111] While less saline water can often be used without treatment, additional chemicals may be needed, which represent an added cost for the producer. The costs of handling brackish water might also be higher than those for fresh water.[112]

Even if the costs issues can be addressed brackish water is arguably not an ideal substitute for fresh water from an environmental perspective.[113] Substituting brackish water for fresh water in fracking may adversely affect the environment, increasing the risk of soil contamination as a result of spills.[114] It could also lead to pollution of fresh water supplies, with spilled brackish water seeping into underground aquifers and/or flowing into surface streams, making them uninhabitable by fish and other aquatic organisms.[115] Birds are also at risk as saline water used in fracking may be stored in open pits, which birds can land in and drink from.[116] This risk could, of course, be reduced by storing the brackish water in sealed tanks. Tanks may be costly, however.

Using brackish water in fracking could also lead to future resource shortages. As water scarcity increases in coming decades, brackish water will likely become an important source of supply for various uses. In some arid areas, including parts of Texas, brackish water is already used in agriculture.[117] Municipalities have also begun augmenting their water supplies with desalinated brackish water.[118] Although desalination supplied

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[110] *See, e.g.*, Jean-Philippe Nicot et al., *Source and Fate of Hydraulic Fracturing Water in the Barnett Shale: A Historical Perspective*, 48 ENVTL. SCI. & TECH. 2464, 2467 (2014) (estimating that just three percent of the water used in fracking in the Barnett shale is brackish water).

[111] Cook et al., *supra* note 107, at 54 (noting that, despite recent improvements in the efficiency of chemical additives, some chemicals added to fracking fluid may not work properly in water with high TDS).

[112] Strict requirements apply to the transport and storage of brackish water, due to the potential for fresh water contamination, and other environmental harms (e.g., to birds landing in, and drinking from, a pit of brackish water). For a discussion of these issues, *see* Cook et al., *supra* note 107.

[113] *Id.*

[114] *Id.*

[115] *Id.*

[116] *Id.*

[117] *Id.* at 45, 54.

[118] Cook et al., *supra* note 107.

less than one percent of all municipal water in the U.S. in 2000,[119] its use has grown significantly in recent years[120] and now accounts for as much as ten percent of water supplies in some regions.[121] This trend is expected to continue in the future, with desalination of brackish water likely to become a key source of supply for many municipalities, particularly in Texas and other arid areas.[122] Substituting brackish water for fresh water in fracking may, therefore, do little to alleviate competition between water users.

B. *Municipal Effluent*

Instead of using fresh or brackish water in fracking, oil and gas producers could make use of municipal effluent, including household sewage and industrial wastewater that has been treated at publicly owned treatment works ("POTWs"). Treated effluent is already commonly used by oil and gas producers in some areas. In Texas's Eagle Ford basin, for example, Apache Corporation has entered into a two year contract to purchase three million gallons of treated effluent per day from the city of College Station.[123] Apache Corporation pumps the effluent from the city's treatment plant into central ponds and it is then piped to production areas for use in well drilling and fracking.[124]

Municipal effluent has, in the past, been a cost effective alternative to fresh water for use in oil and gas production.[125] Producers are, however,

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[119] NAT'L GROUND WATER ASS'N, NGWA INFORMATION BRIEF: BRACKISH GROUNDWATER at 1 (2010), http://www.ngwa.org/media-center/briefs/documents/brackish_water_info_brief_2010.pdf [https://perma.cc/FMX5-NZKL].
[120] *Id.* (finding that "desalination grew about 40 percent between 2000 and 2005").
[121] *See, e.g.*, TAMPA BAY WATER, *Tampa Bay Seawater Desalination Plan*t, http://www.tampabaywater.org/tampa-bay-seawater-desalination-plant.aspx [https://perma.cc/V2HK-CAZE] (last visited Oct. 23, 2017).
[122] Richard L. Stover, *Water Treatment Markets in North America*, DESALITECH, INC. (Keynote Presentation, May 6, 2014), *available at* http://www.siww.com.sg/sites/default/files/DES_Dr-Rick-Stover.pdf [https://perma.cc/N3UC-G2QM].
[123] *See* Press Release, Apache Corporation, Apache Recognized for Innovative Water Conservation Efforts in College Station (Dec. 19, 2014), http://investor.apachecorp.com/releasedetail.cfm?ReleaseID=888463 [https://perma.cc/K5G5-C38W]; *see also Effluent Sales Contract for the City Council*, COLLEGE STATION UTILITIES (June 12, 2014), *available at* https://blog.cstx.gov/2014/06/12/live blog thursdays city council meetings June 12/ [https://perma.cc/5MLC-4S6X]; *see also* Patrina Adger, *College Station City Council Votes Unanimously for Apache Corp. Treated Water Deal*, KBTX (June 12, 2014), http://www.kbtx.com/home/headlines/College-Station-city-council-votes-unanimously-for--262980441.html [https://perma.cc/SG8B-D62G].
[124] Adger, *supra* note 123.
[125] Cook et al., *supra* note 107, at 56.

likely to face greater competition for municipal effluent in future years as fresh water resources come under increasing stress from climate change, population growth, and other factors. Already, in some water stressed regions, municipalities have begun treating and reusing effluent for landscape irrigation, fire protection, and other non-potable uses.[126] In the future, treated effluent could also be used to augment potable water supplies, used for drinking and bathing.[127] It will likely also become an increasingly important source of water for agriculture and may be used to irrigate food crops and/or livestock pasture.[128]

Currently, treated effluent that is not reused is generally discharged to surface streams.[129] These discharges are often vital to maintain in-stream flows, which support fish and wildlife populations and enable various recreational activities.[130] They may also be relied upon by municipalities and other users wishing to extract water downstream from the treatment plant.[131] These downstream users may be adversely affected if larger amounts of treated effluent are used in fracking as this would reduce discharges to surface streams.[132] Reduced discharges could also have negative environmental impacts and lead to a decline in water for instream uses.[133]

C. *Oil and Gas Wastewater*

A third alternative water source, which may be used in oil and gas production, is recycled fracking wastewater.[134] As explained above, a portion of the fluid injected during fracking returns to the surface, along with water occurring naturally in the rock formation.[135] This so-called 'waste-water' is often contaminated with chemicals used during fracking and materials leached from the rock. As a result, most fracking wastewater

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[126] For a discussion of non-potable reuse of municipal wastewater, *see* Nat'l Res. Council, *Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater*, NAT'L ACAD. PRESS 26–29 (2012), http://www.nap.edu/catalog/13303/water-reuse-potential-for-expanding-the-nations-water-supply-through [https://perma.cc/U7ZW-YYHK].
[127] For a discussion of the potable reuse of municipal wastewater, *see id.* at 36–37, 39, 41.
[128] For a discussion of the reuse of municipal wastewater in agriculture, *see id.* at 29.
[129] Nat'l Res. Council, *supra* note 126, at 44–46.
[130] *Id.*
[131] *Id.*
[132] *Id.* at 47.
[133] *Id.*
[134] Nat'l Res. Council, *supra* note 126, at 47.
[135] *Id.*

is not reused, but rather disposed of, typically through underground injection.[136] The injected wastewater is permanently removed from the hydrological cycle and is therefore not available for other uses.

Rather than simply disposing of wastewater, oil and gas producers could recycle it for future use, either in later stages of the same frack job, or at another well undergoing fracking. Recycling has dual benefits for producers, reducing their need for fresh water, as well as the requirement to dispose of wastewater.[137] Despite this, however, use of recycling technologies is currently limited. This is likely due to the costs involved.

The costs of recycling depend on, among other things, the amount of wastewater returning to the surface after fracking and the time period over which those return flows occur.[138] Return flows vary between shale plays, ranging from a small fraction of the volume injected during fracking, to double or even triple that amount.[139] The rate of return is typically highest shortly after fracking and declines exponentially over the life of the well.[140] At some wells, even the initial flow may be small, making it difficult for oil and gas producers to collect sufficient wastewater to support cost-effective recycling.[141] Even if sufficient wastewater can be collected, recycling may be prohibitively costly, due to the need for treatment.[142] Although some wastewater is not treated, such as where it is blended with fresh water or used with specially developed chemicals, most requires

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[136] *Id.*

[137] *See* Cook et al., *supra* note 107, at 56 (recycling process may generate solid waste requiring disposal).

[138] Michael Chimowitz et al., *Addressing Air and Water Concerns: State Policy Opportunities in Unconventional Oil and Gas,* PRINCETON U. WOODROW WILSON SCH. OF PUB. & INT'L AFF. 18 (2015), https://www.princeton.edu/~mauzeral/teaching/Princeton.OilGas.report.F2014.final.pdf [https://perma.cc/C88P-PLHP] (noting that "[k]ey variables that operators consider when determining their water management practices include: (1) the number of wells, (2) volumes of flowback and produced water, and (3) the proximity of these sources to be able to aggregate sufficient waste water to make recycling cost effective").

[139] *Current and Projected Water Use*, *supra* note 63, at 185 (noting that wastewater production "can vary from three times the volume injected in the Barnett Shale . . . to a small fraction, as in the Marcellus in Pennsylvania").

[140] Kondash & Vengosh, *supra* note 13, at 278 (noting that "the production rates [of wastewater] gradually decrease parallel to the oil and gas production").

[141] *Id.* (indicating that "[i]n some unconventional shale gas and oil formations, the volume of [waste]water after 1 to 2 years exceeds the volume of water injected for hydraulic fracturing (Bakken, Eagle Ford, Niobrara, and Monterey-Temblor), while in other formations (Barnett, Haynesville, and Marcellus), the volume of [waste]water, even after 8 to 9 years of operation, is typically lower").

[142] EPA, *supra* note 8, at 8-35 (noting that, in determining whether to reuse fracking wastewater, "quality is a consideration").

some treatment. The treatment required will depend on the starting quality of the wastewater and the level of purity needed for reuse. It may include, among other things:

- de-oiling to remove oil and grease from the wastewater;
- removal of dissolved organic material, such as acids;
- removal of dissolved salts, metals, and other inorganics;
- removal of sand, clay, and other suspended solids;
- disinfection to remove bacteria and other microorganisms;
- removal of dissolved carbon dioxide and other gases; and
- removal of naturally occurring radioactive materials.[143]

One or more physical, chemical, and/or biological processes may be used to treat wastewater. Physical treatment processes include filtration, in which wastewater is passed through a membrane to remove suspended particles.[144] Chemical processes, such as coagulation and flocculation, use chemicals that cause solid particles in the wastewater to aggregate into larger masses, which are then removed.[145] Biological processes use microorganisms to decompose organic materials in the wastewater.[146]

A combination of physiochemical and/or biological processes is often required to treat fracking wastewater due to its high level of contaminants.[147] Conventional treatment processes, such as filtration and coagulation, may be used to de-oil fracking wastewater and can also remove suspended solids. They may not, however, remove other substances often present in fracking wastewater such as chloride, bromide, and sodium. Removing these substances may require secondary treatment, using more

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[143] J. Daniel Arthur et al., *Technical Summary of Oil and Gas Produced Water Treatment Technologies*, ALL CONSULTING, LLC 1, 3 (2005), http://www.all-llc.com/publicdownloads/ALLConsulting-WaterTreatmentOptionsReport.pdf [https://perma.cc/2GFH-YGHC].
[144] N.Y. DEP'T ENVTL. CONSERV., *supra* note 7, at 5-115 & 5-119 to 5-120.
[145] *Id.* at 5-115.
[146] H.K. Shon et al., *Effluent Organic Matter (EfOM) in Wastewater; Constituents, Effects, and Treatments*, 36 CRITICAL REVS. IN ENVTL. SC. & TECH. 327, 341 (2006), *available at* https://search.proquest.com/docview/219214640/fulltextPDF/27E87D467F294908PQ/1?accountid=15053 [https://perma.cc/XA3Y-ZG64].
[147] Ahmadun et al., *supra* note 27, at 542.

advanced processes, such as membrane distillation (i.e., evaporating the wastewater to separate out dissolved solids) or reverse osmosis (i.e., passing the wastewater through a semi-permeable barrier). Such advanced treatment may not be economical, however. Reverse osmosis, for example, is driven by mechanical pressure and therefore requires large amounts of energy. Even with the current low energy prices, the process is extremely costly, particularly for wastewater with high TDS.[148]

Treatment is further complicated when wastewater contains naturally occurring radioactive materials. Uranium and other radioactive elements are widely distributed in the Earth's crust and, over time, may leach into ground water.[149] This is particularly common where ground water is colocated with oil and/or gas, as such water is often rich in chloride, which enhances the solubility of radioactive elements.[150] As an example, water in the Marcellus shale often contains high levels of radium-226, a decay product of uranium.[151] The radium must be removed before the water is reused to avoid the build-up of radioactive scale in pipes and other equipment.[152] This may necessitate chemical treatment of the water, as radium is not removed by reverse osmosis and other physical processes alone.[153]

Treating water contaminated with radium and/or other substances may give rise to environmental and other risks. As an example, recycling may lead to soil and/or water contamination if wastewater is spilled as a result of human error in waste handling and/or leaks from pipelines. Contamination may also result from the improper disposal of waste substrate produced during the treatment process. Wastewater treatment results in the production of sludge, composed of suspended particles, radioactive materials, and other substances removed from the water.[154]

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[148] Reverse osmosis is only considered cost effective for treating wastewater with TDS below 40,000 mg/L. Pei Xu et al., NOVEL AND EMERGING TECHNOLOGIES FOR PRODUCED WATER TREATMENT at 13 (2011), https://www.epa.gov/sites/production/files/documents/18_Xu_-_Treatment_Technologies_508.pdf [https://perma.cc/RJR3-34LK].

[149] U.S. GEOLOGICAL SURV., *Naturally Occurring Radioactive Materials (NORM) in Produced Water and Oil-Field Equipment—An Issue for the Energy Industry* (1999), https://pubs.usgs.gov/fs/fs-0142-99/fs-0142-99.pdf [https://perma.cc/2P88-3PA7].

[150] *Id.*

[151] Valerie J. Brown, *Radionuclides in Fracking Wastewater: Managing a Toxic Blend*, 122 ENVTL. HEALTH PERSP. A50, A51 (2014).

[152] *Id.*

[153] Michael Havener, *Radium Removal Technologies for Portable Groundwater Systems*, WATERWORLD, http://www.waterworld.com/articles/print/volume-23/issue-5/awwa-exhibitors/radium-removal-technologies-for-potable-groundwater-systems.html.

[154] For a discussion of radioactive materials in sludge, *see* Avner Vengosh et al., *A Critical Review of the Risks to Water Resources from Unconventional Shale Gas Development and Hydraulic Fracturing in the United States*, 48 ENVTL. SCI. & TECH. 8334, 8342 (2014).

It must, therefore, be handled carefully to ensure public safety and minimize risks to the environment.

III. ENCOURAGING USE OF ALTERNATIVE WATER SOURCES BY OIL AND GAS PRODUCERS

Recognizing the growing threat to fresh water supplies, policymakers in a number of states have emphasized the need to develop alternatives for use in oil and gas production. Much of the focus to date has been on the recycling of oil and gas wastewater. Of the three alternatives discussed above, wastewater recycling arguably has the greatest potential to reduce competition between water users, while also minimizing environmental impacts. Whereas brackish water and municipal effluent have other uses outside the oil and gas sector, this is often not the case for fracking wastewater, which is simply disposed of.[155] Disposal typically occurs via underground injection, which can have serious environmental impacts.[156] Underground disposal would likely continue if producers switch to using brackish water or municipal effluent, but would not be required if they began recycling their wastewater. Recycling therefore provides dual benefits, reducing fresh water withdrawals for fracking, while also improving wastewater management.

In view of these benefits, some oil and gas producers have begun recycling wastewater for use in fracking. In the Marcellus shale in Pennsylvania, for example, nearly seventy percent of wastewater is recycled.[157] Rates are lower in other areas, however, likely due to the costs of recycling.[158] In determining whether to recycle, producers compare the costs thereof against the expenses likely to be incurred in disposing of wastewater from existing wells and sourcing fresh water for new wells. The costs of wastewater disposal and fresh water sourcing, although varying across the U.S., are generally low.[159] Throughout much of the

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[155] Nat'l Res. Council, *supra* note 126, at 38–42.
[156] EPA, *supra* note 8, at 8-36.
[157] *Id.* at 8-36.
[158] *Id.* (noting that, in the Barnett Shale in Texas, just five percent of wastewater is recycled). *See also* ENERGY-WATER NEXUS, *supra* note 77, at 23 (indicating that while a variety of factors may influence producers' recycling decisions, cost is the most important consideration).
[159] One exception is Pennsylvania, where underground disposal of wastewater tends to be costly, as geological conditions are poorly suited for disposal wells. *See* William E. Hefley et al., *The Economic Impact of the Value Chain of a Marcellus Shale Well* 49 (Pitt Business Working Papers, 2011), http://www.business.pitt.edu/faculty/papers/PittMarcellus

U.S., the combined cost of these activities is significantly less than that of recycling, making the practice uneconomic.[160] Producers are, therefore, unlikely to recycle wastewater absent regulatory mandates or incentives.

A. *Policy Support for Recycling*

To the author's knowledge, no state has adopted regulatory mandates with respect to the recycling of fracking wastewater. In fact, most states do not have any regulations dealing with wastewater recycling.[161] Those that do, such as Texas, Oklahoma, and Pennsylvania, typically require producers to obtain a permit before recycling.[162] The permitting requirements are intended to enhance state oversight of recycling to ensure that it is conducted safely and does not endanger public health or the environment. They may, however, have the unintended consequence of discouraging recycling by leading to burdensome and/or time-consuming reviews.

Recognizing this, a number of states have recently taken steps to streamline the permitting process. One example is Pennsylvania, wherein regulations require all recycling operations to be permitted by the Department of Environmental Protection ("PDEP").[163] In 2012, the PDEP

ShaleEconomics2011.pdf [https://perma.cc/XJJ9-DSY9] (finding that, in the Marcellus, wastewater disposal costs $10 to $14 per barrel). *But compare* ENERGY-WATER NEXUS, *supra* note 77, at 23 (indicating that "costs for underground injection range from $0.07 to $1.60 per barrel of produced water"). *See also* Ahmadun et al., *supra* note 27, at 548 (estimating the cost of wastewater disposal at $0.05–$2.65 per barrel); Cook et al., *supra* note 107, at 49 & 57 (reporting that "[f]resh water costs approximately $0.35–$1.50" per barrel and "[d]isposal costs approximately $0.60 to several dollars per barrel").

[160] Ahmadun et al., *supra* note 27, at 548 (estimating that treating wastewater for reuse may cost up to $5 per barrel). *See also* David Biello, *How Can We Cope with the Dirty Water from Fracking?*, SCI. AM. (May 25, 2012), http://www.scientificamerican.com/article/how-can-we-cope-with-the-dirty-water-from-fracking-for-natural-gas-and-oil/ [https://perma.cc/LSD9-YX7R] (indicating that treating wastewater for reuse using membranes can cost $8.50 per barrel).

[161] Nathan Richardson et al., *The State of State Shale Gas Regulation* at 52, RESOURCES FOR THE FUTURE (2013), http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-Rpt-StateofStateRegs_Report.pdf [https://perma.cc/3M8W-VGQQ].

[162] *See, e.g.*, 16 TEX. ADMIN. CODE § 3.8(d)(7)(A)–(B) (2016) (setting out permitting requirements for recycling facilities in Texas); OKLA. ADMIN. CODE § 165:10-7-32 (2016) (setting out permitting requirements for recycling facilities in Oklahoma); 25 PA. CODE § 287.101(a) (2016) (setting out permitting requirements for recycling facilities in Pennsylvania); N.M. CODE R. §§ 19.15.34.8–19.15.34.9 (2016) (setting out permitting requirements for recycling facilities in New Mexico); N.D. ADMIN. CODE § 43-02-03-51 (setting out permitting requirements for recycling facilities in North Dakota).

[163] The PDEP is authorized to issue general permits under 25 PA. CODE § 287.612.

issued a general permit authorizing the recycling of oil and gas liquid waste for reuse in developing or fracturing a well.[164] Where the general permit applies, recycling operations do not have to be permitted on an individual basis, and need only register with the PDEP.[165]

Other states have gone even further. In New Mexico, for example, regulations require all stationary and mobile facilities "used exclusively for the treatment, reuse or recycling of produced water intended for disposition by use" ("recycling facilities")[166] to be permitted by the New Mexico Oil Conservation Division ("NMOCD").[167] This requirement was historically applied to facilities recycling wastewater for reuse in oil and gas production.[168] However, in March 2015, the NMOCD adopted new rules providing that a permit is not required to recycle wastewater for reuse in the drilling, completion, producing, secondary recovery, pressure maintenance, or plugging of a well.[169] The NMOCD indicated that the new rules were intended to "promote the recycling or reuse of produced water."[170]

Citing similar reasons the Texas RRC also recently amended its regulations to simplify the permitting of recycling facilities.[171] Until 2013, Texas regulations required all recycling facilities to be permitted.[172] Although this requirement continues to apply to commercial facilities, in March 2013, state regulations were amended to allow certain non-commercial recycling without a permit.[173] Under the amended regulations,

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[164] Oil and gas liquid waste is defined to include "liquid wastes from the drilling, development and operation of oil and gas wells and transmission facilities." *See*, GENERAL PERMIT WMGR123 PROCESSING AND BENEFICIAL USE OF OIL AND GAS WASTE at 2, DEP'T OF ENVTL. PROTECTION (2012), http://files.dep.state.pa.us/Waste/Bureau%20of%20Waste%20Management/WasteMgtPortalFiles/SolidWaste/Residual_Waste/GP/WMGR123.pdf [https://perma.cc/2B8M-QJDG].
[165] *Id.* at 2. *See also* 25 PA. CODE § 287.612(a) (2016).
[166] N.M. CODE R. § 19.15.34.7(A) (LexisNexis 2015). *See also id.* § 19.15.2.7(P)(10) (LexisNexis 2015) (defining "produced water" to mean "water that is an incidental byproduct from drilling for or the production of oil and gas").
[167] *Id.* § 19.15.34.9(A) (LexisNexis 2015).
[168] *Id.*
[169] *Id.* § 19.15.34.8(A)(1) (LexisNexis 2015). Note, however, that recycling facilities must be registered in certain circumstances, including where the facility is an addition to the secondary recovery of oil and gas, enhanced oil recovery of oil and gas, or pressure maintenance projects. *See id.* § 19.15.34.9(B) (LexisNexis 2015).
[170] N.M. CODE R. § 19.15.34.6 (LexisNexis 2015).
[171] *Recycling*, R.R. COMM'N OF TEX., http://www.rrc.state.tx.us/oil-gas/applications-and-permits/environmental-permit-types-information/recycling/ [https://perma.cc/CD6W-XS5J] (last visited Oct. 23, 2017).
[172] *Id.*
[173] *Id.*

a permit is not required for the recycling of flowback fluid at a drilling site if the recycled fluid will be used "as make-up water for a hydraulic fracturing fluid treatment(s), or as another type of oilfield fluid to be used in the wellbore of an oil, gas, geothermal, or service well."[174]

Texas has also provided tax incentives to encourage recycling. Legislation enacted in 2007 exempts "tangible personal property specifically used to process, reuse, or recycle wastewater that will be used in fracturing work performed at an oil and gas well" from state sales, excise, and use taxes.[175] The Legislature has considered providing tax credits to oil and gas producers who use recycled wastewater and/or other alternatives to fresh water in their operations.[176]

These and other similar policies should, in theory, encourage increased wastewater recycling by lowering the costs faced by oil and gas producers. Their practical effect is, however, difficult to determine as most producers do not report the extent to which they recycle wastewater. Nevertheless, there is some anecdotal evidence that recycling is increasing. Apache Corporation, for example, has doubled the use of recycled water in its operations in Irion County in central Texas.[177] Similar increases in recycling have also been achieved by Fasken Oil and Ranch Ltd ("Fasken"), allowing it to eliminate fresh water use in its operations in west Texas.[178] Fasken asserts that recent policy changes, particularly the streamlining of RRC's permitting regime, have played a "key" role in supporting increased recycling.[179]

Although some progress has clearly been made, use of recycled wastewater remains fairly limited. The EPA estimates that, on average throughout the U.S., just eight percent of the water used in fracking is recycled.[180] The use of recycled water is even lower in some areas.[181] Many of those areas are semi-arid or arid and, as such, are at high risk of water shortages.[182] Examples include Texas's Barnett Shale, where five percent

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[174] 16 TEX. ADMIN. CODE § 3.8(d)(7)(B).
[175] TEX. TAX CODE ANN. § 151.355(7) (West 2001).
[176] H.B. 4021, 84th Leg., Reg. Sess. (Tex. 2015).
[177] Joint Hearing Before the H. Comm. on Energy Resources and H. Comm. on Natural Resources, 2015 Leg., 84th Sess. (Tx. 2015) (statement of Cal Cooper, Manager of Special Projects, Apache Corporation).
[178] Joint Hearing Before the H. Comm. on Energy Resources and H. Comm. on Natural Resources, 2015 Leg., 84th Sess. (Tx. 2015) (statement of Jimmy Carlile, Fasken Oil and Ranch).
[179] *Id.*
[180] EPA, *supra* note 8, at 4-7.
[181] *Id.*
[182] *Id.*

of the water used in fracking is recycled, and the Permian Basin, where recycled wastewater accounts for just two percent of the water used in fracking.[183] In these and other areas, additional policy changes may be needed to support recycling.

B. Restricting Fresh Water Use to Encourage Recycling

Policymakers could encourage greater recycling of fracking wastewater by restricting oil and gas producers' access to fresh water. Past studies have identified the availability of fresh water as a key factor affecting the extent of recycling by producers.[184] Some producers purchase fresh water from landowners, municipalities, and/or other suppliers, but most self-supply water, via direct withdrawals from surface and/or ground water bodies.[185] These withdrawals are regulated primarily at the state level and are subject to the same general rules as apply to all other water users.[186] There are, however, important differences between water use in oil and gas production and other sectors which arguably justify differential treatment. Most significantly, the water used in fracking to produce oil and gas is often permanently removed from the hydrological cycle.[187] This leads to higher rates of water consumption in oil and gas production, compared to other sectors, warranting the imposition of additional restrictions thereon.

Oil and gas producers' access to water could be restricted in various ways, including through:

- *Bans on fresh water use in fracking:* States could, for example, prohibit new water withdrawals by oil and gas producers for fracking or other activities. This would force producers to use alternatives, such as recycled wastewater, in fracking or develop waterless fracking techniques.

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[183] *Id.*
[184] *See, e.g.*, Steve Jester et al., *Evaluation of Produced Water Reuse for Hydraulic Fracturing in Eagle Ford*, ATL. COUNCIL (2013), http://www.slideshare.net/atlanticcouncil/produced-water-session-x-steve-jester [https://perma.cc/5D8J-T4UZ] (finding that recycling is more likely where there is limited availability of high quality source water).
[185] EPA, *supra* note 8, at 4-45 (indicating that oil and gas producers "usually self-supply surface or ground water directly, but may also obtain water from public water systems or other suppliers").
[186] *Id.*
[187] Craig, *supra* note 15, at 49.

- *Caps on fresh water use:* States could impose a cap on fresh water use, expressed in absolute terms (e.g., barrels per well) or as a percentage of total water use. The cap could take the form of a static limit which must be met by all oil and gas producers or a trading system could be established, under which producers who do not reduce their water use to the capped level could purchase credits from others whose use is below the cap.[188]
- *Rebuttable presumption against fresh water use:* States could create a presumption against fresh water use in fracking, but allow oil and gas producers to use such water, if they meet specified conditions. Producers may, for example, be allowed to use fresh water if they demonstrate that recycling is infeasible because sufficient wastewater cannot be collected.
- *Fees for fresh water use:* Imposing fees for fresh water use would increase the costs faced by producers, making wastewater recycling a more attractive option. It would be up to individual producers to decide whether to switch to using recycled wastewater or pay the fee to continue using fresh water. Provided the amount of the fee exceeds the cost of recycling, producers can be expected to change their behavior.

These policies should lead to a reduction in fresh water use in fracking. Under each policy, it would be up to oil and gas producers to decide whether to continue engaging in fracking, perhaps using waterless techniques and/or alternative water sources, such as recycled wastewater.

C. Restricting Wastewater Disposal to Encourage Recycling

An alternative means of encouraging oil and gas producers to recycle wastewater would be to impose restrictions on its disposal. As noted above, most wastewater is currently disposed of via underground injection into sealed disposal wells.[189] The widespread availability of such

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[188] For an example of a trading system, *see* Small, *supra* note 27, at 435.
[189] EPA, *supra* note 8, at 8-75.

wells[190] and the low fees charged for use[191] are thought to have discouraged recycling.[192] Indeed, many commentators have emphasized that recycling rates are highest in areas where few disposal wells exist.[193] This has led to calls for limits on wastewater disposal.[194]

Significant prior research has been conducted into policy options for limiting wastewater disposal. Commonly discussed options include:

- *Restrictions on underground injection:* States could prohibit all underground injection of wastewater. Alternatively, underground injection could be prohibited unless the wastewater is incapable of recycling.[195] This would make disposal more difficult and costly, thereby encouraging producers to look at other options, such as wastewater recycling.
- *Fees for underground injection:* Cost is the primary factor producers consider when assessing wastewater management options. Underground injection is often the cheapest option, typically costing less than $2 per barrel of wastewater.[196] Levying a fee

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190 *Underground Injection Control (UIC): Class II Oil and Gas Related Injection Wells*, EPA, https://www.epa.gov/uic/class-ii-oil-and-gas-related-injection-wells [https://perma.cc/CT3A-WBDA] (last updated Sep. 6, 2016) (indicating that there are approximately 180,000 Class II wells, that may be used to inject fluids associated with oil and gas production, of which twenty percent are disposal wells).

191 FREYMAN, *supra* note 18, at 41 (stating that "[f]ees charged for disposing of this [waste]water [through underground injection] are low or non-existent").

192 *Id.* at 41 (finding that "[m]ost operators, especially in drier regions, don't recycle water because of the availability of deep well injection sites where . . . wastewater can be disposed of at almost no cost").

193 *Id.* (noting that "one of the more water abundant shale plays in the country, the Marcellus, has the highest recycling rates (estimated at 66 percent) because geological conditions are poorly suited for deep disposal wells"). *See also* EPA, *supra* note 8, at 4-8 (finding "increased reuse as a percent of injected volume over time in both Pennsylvania and West Virginia, likely due to the lack of nearby disposal options").

194 *See, e.g.*, Cook et al., *supra* note 107, at 59; Small, *supra* note 27, at 436.

195 *See, e.g.*, H.R. 2992, 83d Leg., Reg. Sess. (Tex. 2013), which would have prohibited wastewater being

> disposed of in an oil and gas waste disposal well unless the fluid is incapable of being treated to a degree that would allow the fluid to be: (1) used to perform a hydraulic fracturing treatment on another oil or gas well; (2) used for another beneficial purpose; or (3) discharged into or adjacent to water in the state.

196 ENERGY-WATER NEXUS, *supra* note 77, at 23 (stating that "costs for underground injection range from $0.07 to $1.60 per barrel [of wastewater]"); Cook et al., *supra* note

> for injection would increase disposal costs, making recycling more attractive in comparison.[197]

These policies are intended to encourage oil and gas producers to recycle wastewater by increasing the cost of disposal. The policies may not always achieve this goal, however. Faced with restrictions on underground injection, producers may begin disposing of wastewater in other ways, such as by discharging it to surface water. Where this occurs, there may be no increase in wastewater recycling, nor reduction in fresh water use.

IV. CURRENT LEGAL FRAMEWORK FOR WATER USE IN FRACKING

Despite the adoption of policies supporting wastewater recycling, many oil and gas producers continue to use fresh water in fracking and other activities.[198] Further policy changes are, therefore, required to maximize producers' use of recycled wastewater. These changes could be directed at restricting producers' access to fresh water and/or increasing the costs they face in disposing of wastewater. To assess the desirability of such changes, it is important to understand the current regulation of these practices. To that end, this section explores how the current regulatory framework governing water withdrawals for fracking affects producers' incentives to recycle.[199]

107, at 57 (indicating that costs for underground injection start at approximately $0.60 per barrel); Ahmadun et al., *supra* note 27, at 548 (estimating the cost of wastewater disposal at $0.05–$2.65 per barrel); R. LeBas et al., *Development and Use of High-TDS Recycling Produced Water for Crosslinked-Gel-Based Hydraulic Fracturing*, SOC'Y OF PETROLEUM ENG'RS, SPE 163824 (2013), http://www.ftwatersolutions.com/pdfs/ProducedWaterPaper.pdf [https://perma.cc/W8S2-YDZ4] (estimating that the average cost of underground injection is $0.75 to $1 per barrel).

[197] *See, e.g.*, H.R. 379, 83d Leg., Reg. Sess. (Tex. 2013), which would have imposed a fee "on oil and gas waste disposed of by injection in a commercial well . . . in the amount of 1 cent for each barrel of 42 standard gallons."

[198] EPA, *supra* note 8, at ES-12 (finding that "[w]ater used for hydraulic fracturing is typically fresh water taken from available groundwater and/or surface water resources"). *See also* N.Y. DEP'T OF ENVTL. CONSERV., *supra* note 7, at 6-2 (reporting that "surface water bodies are still the primary source of water supplies for the drilling of Marcellus wells in Pennsylvania"); Trey Nesloney, *Fracking Dry: Issues in Obtaining Water for Hydraulic Fracturing Operations in Texas*, 45 TEX. ENVTL. L.J. 197, 202–03 (2015) (indicating that "80% of all the water used in the Barnett Shale play is fresh surface water" and that, in the Haynesville Shale, "70% of the new water used . . . is groundwater. Use of brackish water or reuse of wastewater is rare" (internal citations omitted)).

[199] This section focuses on the regulation of water withdrawals by producers. It does not address the situation in which producers obtain water from a third-party supplier.

Water withdrawals are regulated primarily at the state level. In most states, there are no specific regulations governing withdrawals for oil and gas production. Rather, producers withdraw water under the same general rules as apply to all other users. These rules were initially developed through the common law and later supplemented by legislation. The states' legislative power in this area is limited by the Dormant Commerce Clause,[200] as water resources have been held to be articles of commerce, subject to federal jurisdiction under the Commerce Clause of the U.S. Constitution.[201] The federal government regulates withdrawals from certain water resources, including those on federal lands.[202] Some other resources (e.g., those crossing state boundaries) are managed regionally under interstate compacts. Beyond this, however, most resources are managed by the states under a patchwork of old common law and newer statutory rules.

Most states apply different rules to the use of water, depending on its characteristics, including whether it is found above or below ground. State rules governing surface water can be divided into two broad categories, with eastern states generally using some form of riparian doctrine, which bases rights to water on land ownership, while western states typically use a prior appropriation system, wherein rights are based on the beneficial use of water.[203] Some states also use the prior appropriation system to allocate rights to ground water. In other states, ground water rights are dependent on ownership of the overlying land.

A. Common Law Framework Governing Surface Water Use

Many oil and gas producers use surface water, extracted from rivers, streams, lakes, and reservoirs, for fracking and other activities. Surface water use is particularly common in temperate areas, such as Pennsylvania's Marcellus shale play, where ninety-two percent of the water used

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[200] The Dormant Commerce Clause prevents states interfering with instate commerce. It arises from the Commerce Clause in the U.S. Constitution, which grants the federal government exclusive power to regulate interstate commerce. As exclusive power has been granted to the federal government, the states cannot legislate in a manner which interferes with interstate commerce. For a discussion of the application of the Dormant Commerce Clause to state water law, *see* Mark S. Davis & Michael Pappas, *Escaping the Sporhase Maze: Protecting State Waters Within the Commerce Clause*, 73 LA. L. REV. 175 (2012).

[201] Sporhase v. Neb, 458 U.S. 941 (1982).

[202] Federally regulated water withdrawals are not addressed in this Paper.

[203] A. DAN TARLOCK ET AL., WATER RESOURCE MANAGEMENT: A CASEBOOK IN LAW AND PUBLIC POLICY 124 (6th ed.) (2009).

in fracking comes from surface bodies.[204] Even in more arid regions, surface water is an important source for fracking. In Texas's Barnett shale, for example, surface water bodies supply approximately fifty percent of the water used in fracking.[205]

1. Riparian Water Rights

Historically, states east of the 100th meridian[206] generally applied the common law doctrine of riparian rights to surface water use. The riparian rights doctrine is essentially a torts regime, which is premised on the notion that the right to use water is an inherent characteristic of land, "dependent on the natural availability of water to the land."[207] Under the doctrine, the owner of land abutting a water body ("riparian land") has limited rights to use the water therein. These so-called "riparian rights" are correlative, meaning that no one riparian owner's rights are absolute, but rather subject to the equal rights of all other owners.[208] The exercise of riparian rights was initially governed by the natural flow theory, which gave all riparian owners an absolute entitlement to have water flow through their property and prevented any one owner diverting or obstructing that flow, except to use the water for essential domestic purposes.[209]

The natural flow theory, if construed literally, would prevent riparian landowners making any consumptive use of water (save for minor domestic uses). In *Tyler v. Wilkinson*, 24 F. Cas. 472 (C.C.D.R.I. 1827), Supreme Court Justice Story acknowledged that each riparian has "a right to the use of water flowing over [riparian land] in its natural current without diminution or obstruction."[210] However, Justice Story went on to hold that this does not mean "there can be no diminution . . . and no obstruction or impediment whatsoever, by a riparian proprietor, in the use of the water as' [sic] it flows; for that would be to deny any valuable use of it. There may be, and there must be allowed of that, a reasonable use."[211]

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[204] EPA, *supra* note 8, at 4-6.
[205] *Id.* at 4-19.
[206] CHARLES F. WILKINSON, CROSSING THE NEXT MERIDIAN: LAND, WATER, AND THE FUTURE OF THE WEST 219 (1992).
[207] Joseph W. Dellapenna, *Adapting Riparian Rights to the Twenty-First Century*, 106 W. VA. L. REV. 539, 555 (2004). *See also* Tyler v. Wilkinson, 24 F. Cas. 472, 474 (C.C.D.R.I. 1827) (No. 14,312) (holding that "[t]he natural stream . . . is an incident annexed, by operation of law, to the land itself").
[208] TARLOCK ET AL., *supra* note 203, at 124.
[209] *Id.* at 128.
[210] Tyler v. Wilkinson, 24 F. Cas. 472, 474 (C.C.D.R.I. 1827).
[211] *Id.*

Justice Story's so-called "reasonable use" doctrine allowed "some diminution of flow as to both quantity and quality, so long as the challenged use was reasonable."[212] Under the doctrine, preference is given to the domestic use of water by riparian landowners.[213] Riparian owners may always take water for drinking, bathing, and similar domestic purposes necessary to preserve life and health.[214] Water may also be taken for other uses, provided such use does not cause material injury to other riparians.[215] Subject to this limitation, the courts have upheld the right of riparians to take and use water for agricultural, manufacturing, and industrial purposes.[216]

The amount of water used by a riparian landowner must be reasonable. The *Restatement (Second) of Torts* identifies nine factors to be considered in assessing reasonableness, namely:

> (a) the purpose of the use, (b) the suitability of the use to the watercourse or lake, (c) the economic value of the use, (d) the social value of the use, (e) the extent and amount of the harm it causes, (f) the practicality of avoiding the harm by adjusting the use or method of use of one [riparian] proprietor or the other, (g) the practicality of adjusting the quantity of water used by each proprietor, (h) the protection for existing values of water uses, land, investments and enterprises, and (i) the justice of requiring the user causing harm to bear the loss.[217]

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[212] JOSEPH L. SAX ET AL., LEGAL CONTROL OF WATER RESOURCES: CASES AND MATERIALS 24 (3d ed. 2000).

[213] Harris v. Brooks, 283 S.W.2d 129, 134 (Ark. 1955) (stating "[t]he right to use water for domestic purposes—such as household use—is superior to many other uses of water—such as for fishing, recreation and irrigation").

[214] *Id. See also* Kundel Farms v. Vir-Jo Farms, Inc., 467 N.W.2d 291, 294 (1991) (holding that a riparian owner "may use the water for his natural and ordinary wants, regardless of the effect upon other proprietors on the stream").

[215] *Kundel Farms,* 467 N.W.2d at 294 (holding that, where a riparian owner "puts the water to an extraordinary or artificial use, he must do so in such a manner as not to interfere with its lawful use by others above or below him upon the same stream").

[216] Laura Springer, *Waterproofing the New Fracking Regulation: The Necessity of Defining Riparian Rights in Louisiana's Water Law*, 72 LA. L. REV. 225, 246 (2011).

[217] RESTATEMENT (SECOND) OF TORTS: THE REASONABLENESS OF USE OF WATER § 850 (AM. LAW. INSTIT. 1979). *See also* Harris v. Brooks, 283 S.W.2d 129, 136 (Ark. 1955) (holding that riparian owners may exercise water rights to the extent not detrimental to rights of other riparian owners); Mason v. Hoyle, 14 A. 786, 791 (Conn. 1888) (holding that water use by one riparian owner may not render downstream owners' rights useless or unproductive);

The use of water on non-riparian land was historically considered to be per se unreasonable and therefore all uses had to occur on, or be for the benefit of, riparian land.[218] This requirement has, however, been relaxed over time. A number of states now allow reasonable use of water on non-riparian land, provided that such use does not injure other riparian owners.[219] Some states allow water use on non-riparian land regardless of effects.[220]

Under the common law doctrine of riparian rights, then, there are few restrictions on water use in oil and gas production. This is particularly true where the producer owns riparian land. In such cases, the producer may take water from the abutting water source for use on the riparian land and, provided others are not injured, on non-riparian land. Other producers, who do not own riparian land, may acquire rights to take and use water from riparian owners. As a general rule, riparian rights can be severed from the land, and transferred separately.[221] In such cases, the transferee's use of water is subject to the same reasonableness test as applies to water use by riparian landowners.[222]

The courts have upheld, as reasonable, water use in the drilling of oil and gas wells.[223] While there are no court decisions specifically

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Hoover v. Crane, 106 N.W.2d 563, 565 (Mich. 1960) (holding that, when evaluating reasonable use, courts should consider use, extent and duration).

[218] TARLOCK ET AL., *supra* note 203, at 145.

[219] *Id. See, e.g.*, Stratton v. Mt. Hermon Boys' Sch., 103 N.E. 87, 87 (Mass. 1913) (holding that non-riparian uses will only be restricted if "there is actual injury" to other riparians). Note that, in the western third of Pennsylvania, where the common law of riparian rights still applies, the courts have held that water cannot be diverted to non-riparian land, regardless of effects. *See, e.g.*, Scranton Gas & Water Co. v. Del. Lackawanna & W. R.R. Co., 88 A. 24 (Pa. 1913) (holding that it is "unlawful" to divert a stream "for purposes other than those incident to the proper enjoyment of the riparian land"). In at least some situations, however, the courts have required a showing of actual injury to a riparian owner before enjoining such diversions. *See* Belin v. Dep't of Envtl. Res., 291 A.2d 553, 555–56 (Pa. Commw. Ct. 1972)(holding that diversion can only be enjoined if it causes actual injury to a riparian owner). For a discussion of the position in Pennsylvania, *see* Michael Dillon, *Water Scarcity and Hydraulic Fracturing in Pennsylvania: Examining Pennsylvania Water Law and Water Shortage Issues Presented by Natural Gas Operations in the Marcellus Shale*, 84 TEMP. L. REV. 201, 216 (2011).

[220] *See, e.g.*, Ralph W. Aigler, *The Right to Divert Water to Non-Riparian Land*, 12 MICH. L. REV. 304, 306 (1914).

[221] TARLOCK ET AL., *supra* note 203, at 142.

[222] *See, e.g.*, Humphreys-Mexia Oil Co. v. Arseneaux, 297 S.W. 225 (Tex. 1927) (holding that a riparian may confer on another rights to use water on non-riparian land, provided there is no perceptible injury to others).

[223] *Id.* (holding that the lessee of riparian property may, in exercise of his riparian rights, take water for use in drilling oil wells); Smith v. Stanolind Oil & Gas Co., 172 P.2d 1002 (Okla. 1946) (upholding the taking of water by an oil company for use in drilling).

addressing water use in fracking, such use is also likely to be considered reasonable. It is well established that reasonableness is a question of fact, which must be assessed on a case-by-case basis, taking into account the circumstances of use.[224] In the context of fracking, the significant amount of water used and the fact that such use is generally consumptive are relevant considerations, tending to suggest that the use is unreasonable.[225] These considerations are, however, arguably outweighed by the importance of the use.[226] Given the economic value generated by fracking, water use therein is likely to be considered reasonable.

Given the above, in states applying the common law doctrine of riparian rights, oil and gas producers may take and use water for fracking. Such use is limited only by the rights of other riparian landowners. Provided those landowners are not harmed, producers may take large amounts of water for fracking, even if doing so results in unsustainable rates of water withdrawal. While producers may have to reduce their water use in times of drought or other shortage, they could continue to take some water for use in their operations. Because of the correlative nature of riparian rights, in times of shortage, all riparian owners must share the available water.[227] Each riparian is, therefore, guaranteed some water. As we shall in the next section, this is not the case in states using the prior appropriation system of water rights.

2. Prior Appropriation Water Rights

Whereas eastern states generally apply the riparian doctrine, most western states use the prior appropriation system, which is grounded in property rather than tort law.[228] Under the prior appropriation system,

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[224] *See, e.g.*, Lux v. Haggin 10 P. 674, 755 (Cal. 1886) (recognizing that "riparian proprietors are entitled to a reasonable use of the waters of the stream . . . What is such reasonable use is a question of fact, and depends upon the circumstances"); McDonough v. Russell-Miller Milling Co., 16 N.W. 504, 504 (N.D. 1917) (holding that "[t]he question whether a reasonable . . . use of the water is being made . . . is to be determined by the circumstances of each particular case"); Franco-American Charolaise, Ltd. v. Okla. Water Res. Bd., 855 P.2d 568, 575 (Okla. 1990) (declaring that "[r]easonableness is a question of fact to be determined on a case-by-case basis").

[225] *Franco-American Charolaise*, 855 P.2d at 575(stating "[f]actors courts consider in determining reasonableness include the . . . size of the diversion").

[226] *Id.* (stating that, in assessing reasonableness, the courts will consider the "type of use and its importance").

[227] RESTATEMENT (SECOND) OF TORTS § 859 (1979) (indicating that, in times of drought or other shortage, reasonableness requires the available water to be shared between riparian landowners).

[228] TARLOCK ET AL., *supra* note 203, at 112.

rights to water arise from beneficial use.[229] Simply put, the first person to apply water to a beneficial use obtains a right that is superior to the rights of all later users.[230] In times of scarcity, junior (i.e., later) water rights must yield to senior (i.e., earlier) rights.[231] As a result, while the senior right holder may continue to receive his/her full water allocation, junior rights holders may receive only part or, in some cases, none of their allocations.[232]

Like the riparian rights doctrine, the prior appropriation system developed separately in each state, resulting in some geographic variation. Generally speaking, however, a water right can only be obtained in prior appropriation states if unappropriated water is available. This is because, if such water is not available, the grant of new rights may interfere with the taking of water by existing (senior) rights holders, which have priority.[233] Assuming water is available for appropriation, persons seeking rights to that water must comply with three basic requirements. First, the person must demonstrate an intent to appropriate water;[234] this was historically done by posting a notice and/or undertaking other preparatory work in the area of the proposed appropriation,[235] but now typically only requires the filing an application with a state agency.[236] Second, once the application is approved, the person must then divert water.[237] Finally, after diversion, the water must be put to beneficial use.[238]

For the purposes of defining water rights, beneficial use encompasses two related principles. As the Washington Supreme Court has observed:

> First, it refers to the purposes, or type of activities, for which water may be used . . . Second, beneficial use determines

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[229] *Id.* at 58.
[230] *Id.*
[231] *State ex rel.* Cary v. Cochran, 292 N.W. 239, 245 (Neb. 1940)
[232] There are some exceptions to this rule. *See, e.g.*, *State ex rel. Cary*, 292 N.W. at 239 (stating that a senior right holder cannot make a call on a junior right holder if it would be futile).
[233] The courts have held that the holder of a junior water right may appropriate water provided such appropriation does not injure senior right holder. A senior right holder is considered to be injured by a junior's appropriation if it deprives him/her/it of some or all of his/her/its allocated water. *See id.* at 246.
[234] TARLOCK ET AL., *supra* note 203, at 158.
[235] *Id.* at 170.
[236] *Id.* at 171.
[237] *Id.* at 158. The requirement for physical diversion of water has been relaxed over time. *See id.* at 158–68.
[238] *Id.*

> the measure of the water right. The owner of a water right is entitled to the amount of water necessary for the purpose to which it has been put, provided that purpose constitutes a beneficial use.[239]

Activities commonly recognized as beneficial uses of water include, but are not limited to, stock watering, irrigation, municipal water supply, power generation, industrial production, and recreation.[240] The quantity of water used in these activities must be no more than is reasonably necessary and there must be no waste of water.[241] Reasonableness is determined on a case-by-case basis, taking into account the particular circumstances of use.[242] In contrast to the position under the riparian rights doctrine, under the prior appropriation system, rights to water are not dependent on land ownership.[243] Compared to the riparian rights doctrine, then, the prior appropriation system arguably makes it easier for oil and gas producers to obtain water rights. The key requirement for obtaining water rights, under the prior appropriation system, is the application of water to a beneficial use.

Since the 19th century, the courts have consistently held that the use of water for mining is a beneficial use.[244] The earliest case law focused on the use of water by gold miners,[245] while later cases have considered water use in the development of other minerals.[246] No cases have examined the use of water in fracking to develop oil and gas. Notably however, the Colorado Supreme Court recently examined water use in coalbed methane production. During production, water is removed from

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[239] State Dep't of Ecology v. Grimes, 852 P.2d 1044, 1049 (Wash. 1993).
[240] *See, e.g.*, Okla. Water Res. Bd. v. Tex. County Irrigation & Water Res. Ass'n, 711 P.2d 38, 44 (Okla. 1984).
[241] *See, e.g.*, *Grimes*, 852 P.2d 1044 (noting that "[f]rom an early date, courts announced the rule that no appropriation of water was valid where the water simply went to waste." There must "be a reasonable and economical use of the water in view of other present and future demands").
[242] Tulare Irrigation Dist. v. Lindsay-Strathmore Irrigation Dist., 45 P.2d 972, 1007 (Cal. 1935) (declaring that "[w]hat is a reasonable use, of course, depends upon the facts and circumstances of each case").
[243] TARLOCK ET AL., *supra* note 203, at 58.
[244] Cal. Or. Power Co. v. Beaver Portland Cement Co., 295 U.S. 142, 152 (1935) (holding that "[t]he rule generally recognized . . . was that the acquisition of water . . . for a beneficial use was entitled to protection; and the rule applied whether the water was diverted for manufacturing, irrigation, or mining purposes").
[245] *See, e.g.*, Irwin v. Phillips, 5 Cal. 140, 146–47 (Cal. 1855).
[246] *See, e.g.*, Kaiser Steel Corp. v. W.S. Ranch Co., 81 N.M. 414 (1970).

the natural fractures in deep coalbed formations, to enable the flow of gas. In *Vance v. Wolfe*, 205 P.3d 1165 (Colo. 2009) ("*Vance*"), the court held that the removed water is put to beneficial use, stating:

> The [Water Right Determination and Administration Act of 1969] defines "beneficial use" as "the use of that amount of water that is reasonable and appropriate under reasonably efficient practices to accomplish without waste the purpose for which the appropriation is lawfully made." . . . Under the language of the 1969 Act, the [coalbed methane process] "uses" water—by extracting it from the ground and storing it in tanks—to "accomplish" a particular "purpose"—the release of methane gas. The extraction of water to facilitate [coalbed methane] production is therefore a "beneficial use."[247]

As this quote indicates, in *Vance*, the court was applying the statutory definition of beneficial use in Colorado's Water Right Determination and Administration Act.[248] That statute retains the essence of the common law, with both emphasizing that beneficial use involves use of a reasonable amount of water for a specified purpose, without waste. The decision in *Vance* is, therefore, of general applicability. Following the court's reasoning, fracking is arguably a beneficial use as it involves the use of water (i.e., by pumping it underground) to achieve a specified purpose (i.e., the extraction of oil and/or gas).

Given the above, the common law doctrine of prior appropriation arguably imposes few restrictions on water use in oil and gas production. Under the doctrine, producers' may appropriate water for use in their operations and such use will be limited only by the rights of prior appropriators. When there is insufficient water to satisfy prior rights, producers may see their allocations curtailed. A producer can, however, reduce the risk of curtailment by purchasing existing (senior) water rights. Under the prior appropriation system, water rights can generally be transferred and retain their original priority date following transfer.[249]

One possible restriction on water use in oil and gas production is the requirement, under the prior appropriation system, that there be no wastage of water. The courts have long held that the use of water in a

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[247] Vance v. Wolfe, 205 P.3d 1165, 1167 (Colo. 2009).
[248] COLO. REV. STAT. § 37-92-101 et seq.
[249] TARLOCK ET AL., *supra* note 203, at 230.

wasteful manner is not "beneficial" for the purposes of the prior appropriation system.[250] As beneficial use is the basis of water rights under the prior appropriation system, wasteful use is not permitted.[251] In this context, waste has been defined as "the amount of flow diverted in excess of reasonable needs under customary . . . practices."[252] To avoid waste, water must be used in a reasonably efficient manner, taking into account prevailing conditions, including local custom.[253] The user is not, however, required to adopt the best or most efficient practices. In this regard, the California Supreme Court has noted that "an appropriator cannot be compelled to divert according to the most scientific method known. He is entitled to make a reasonable use of the water according to the general custom of the locality, so long as the custom does not involve unnecessary waste."[254]

The prohibition on waste is, therefore, not a technology forcing standard. The courts have allowed continuation of suboptimal methods of use provided they are customary. As one commentator has observed, "[w]ater use had to be completely out of line with local custom or blatantly inefficient to merit an actual finding of waste from a court."[255] Given this, water use in fracking to produce oil and gas is unlikely to be found to be wasteful, as it is customary across all shale plays. The previous cases, in which the courts found uses to be wasteful, generally involved significant loss of water (e.g., the transport of water for irrigation in open earthen ditches resulting in loss of almost the entire flow through absorption and evaporation).[256] It could be argued that, as the water used in fracking is often permanently removed from the hydrological cycle, it is lost and therefore wasted. It seems unlikely, however, that the courts would restrict water use in fracking on this basis.

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[250] *Grimes*, 852 P.2d at 1051 (noting that the courts have long held that "the appropriator who diverted more [water] than was needed for the appropriators actual requirements and allowed the excess to go to waste acquired no right to the excess). *See also* Janet C. Neuman, *Beneficial Use, Waste, and Forfeiture: The Inefficient Search for Efficiency in Western Water Use*, 28 ENVTL. L. 919, 928 (1998) (noting that beneficial use "includes the requirement of nonwasteful use").

[251] Neuman, *supra* note 250, at 928 (stating that "[w]ater that is legally wasted . . . is not a legitimate part of the water right and can be deleted from the entitlement upon challenge").

[252] Steven J. Shupe, *Waste in Western Water Law: A Blueprint for Change*, 61 OR. L. REV. 483, 491 (1982).

[253] *Grimes*, 852 P.2d 1044 (holding that "an appropriator's use of water must be reasonably efficient").

[254] Tulare Irrigation Dist. v. Lindsay-Strathmore Irrigation Dist., 45 P.2d 972, 997 (Cal. 1935).

[255] Neuman, *supra* note 250, at 937.

[256] For a discussion of this issue, see *id.* at 928, 933–46.

B. MODERN STATUTORY REGIMES GOVERNING SURFACE WATER USE

No western state continues to apply to common law doctrine of prior appropriation. Rather, each state has adopted a statutory permit system.[257] The statutes generally require persons wishing to take and use water to apply for an interim permit from the state.[258] Once an interim permit has been obtained, the person may take water and apply it to a beneficial use. After the person demonstrates that water has been beneficially used, the state may then issue him/her with a perfected water right, specifying the quantity of water that can be taken in the future.[259] Each water right has a priority date—typically the date on which the interim permit application was filed—which determines the security of his/her entitlement.[260]

Similar statutory permitting regimes have also been adopted in a number of eastern states. These regimes are often labelled "regulated riparianism" as they codify many of the principles of common law riparian rights, while providing for greater regulatory oversight of the exercise of those rights. Iowa is generally regarded as having adopted the first comprehensive regulated riparian regime in 1957.[261] In subsequent years, nearly two dozen other states have adopted similar regimes.[262] The regimes generally declare all water to be owned by the state in trust for its citizens and provide that water may only be used with state approval.[263] In most states, approval takes the form of a permit granted by a regulatory body, pursuant to statute.

Although each state statute differs, the grant of water rights generally depends on mostly the same factors, regardless of whether the statutory regime is grounded in the common law doctrine of riparian rights or prior appropriation system. Virtually all state statutes require applicants for new water rights to establish that appropriation of water will not harm existing rights holders[264] and several also require proof that

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[257] A Dan. Tarlock, *Prior Appropriation: Rule, Principle, or Rhetoric?*, 76 N.D. LAW REV. 881, 881–882 (2001).
[258] *Id.*
[259] *Id.*
[260] *Id.*
[261] Joseph W. Dellapenna, *Issues Arising Under Riparian Rights: Replacing Common Law Riparian Rights with Regulated Riparianism*, *in* WATER RIGHTS OF THE EASTERN U.S. 35, 41 (Kenneth W. Wright ed., 1998).
[262] Debra L. Freeman, *Introduction*, *in* WATER RIGHTS OF THE EASTERN UNITED STATES 1, 3 (Kenneth W. Wright ed., 1998) (listing regulated riparian states).
[263] TARLOCK ET AL., *supra* note 203, at 281.
[264] *Id.* at 308.

appropriation will benefit the public interest.[265] There may be additional restrictions on the grant of water rights in some states. Many western states, for example, prohibit the grant of new water rights in respect of sources that are over-appropriated (i.e., where the average supply of water from the source is less than the aggregate of all existing water rights).[266] This prohibition may create difficulties for oil and gas producers operating in the west as many surface water sources there are over-appropriated.

Some oil and gas producers have sought to overcome the above difficulties by purchasing existing water rights. Most western states allow water rights to be transferred. Notably however, the transferee generally requires state approval if he/she/it wishes to use the water for a purpose other than that specified in the transferred right. A change will typically only be approved if it does not injure other rights holders.[267] In Wyoming, for example, the State Board of Control must not approve any change that would increase the amount or rate of diversion, increase the amount of water consumptively used, decrease return flows, or otherwise injure appropriators.[268] This has created difficulties for oil and gas producers wishing to use water previously devoted to irrigation. Such water is often not consumed, but rather returns to its source, where it may be used by others.[269] In such cases, only the water actually consumed in irrigation can be repurposed for use in oil and gas production.[270]

Given the above, the statutory permitting regimes in western states may restrict oil and gas producers' ability to withdraw surface water for use in fracking, particularly where the water source is already over-appropriated. Beyond this, however, state statutes impose few restrictions on water withdrawals by producers. Compared to the common law, the statutes may make it easier for producers to secure water in some circumstances. For example, in most regulated riparian states, water rights have now been separated from land ownership. State permitting agencies now decide who gets water and under what conditions. Permits may authorize water use by non-riparians on non-riparian land.

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[265] *Id.* at 319–20.
[266] *See, e.g.*, OR. ADMIN. R. 690-400-010(11)(a), 609-410-0070 (2016) (preventing the grant of new water rights in over-appropriate streams, defined as streams in which "[t]he quantity of surface water available during a specified period is not sufficient to meet the expected demands from all water rights at least 80 percent of the time during that period").
[267] TARLOCK ET AL., *supra* note 203, at 237.
[268] WYO. STAT. ANN. § 41-3-104(a) (2016).
[269] TARLOCK ET AL., *supra* note 203, at 237.
[270] *See, e.g.*, Green v. Chaffee Ditch Co., 371 P.2d 775, 781–83 (Colo. 1962).

The requirement to obtain a permit prior to using water could, in theory, act as a barrier to such use by oil and gas producers. In practice, however, this barrier is unlikely to be significant. Many water permitting statutes, particularly those adopted in eastern states, provide exemptions for water uses below a certain threshold.[271] One example is Ohio, which requires registration of any new water withdrawal exceeding 100,000 gallons per day, but does not require the withdrawal to be permitted, unless it could result in consumptive use of more than two million gallons of water per day.[272] A number of other eastern states, including New York[273] and Virginia,[274] have similar provisions exempting water withdrawals below a certain threshold from permitting. Such thresholds are less common in western states and, where they do exist, tend to be lower than those in the east.[275]

C. Legal Framework for Ground Water Use

Underground aquifers are an important source of supply for oil and gas production, particularly in arid areas where surface water supplies are limited. In Texas's Eagle Ford basin, for example, producers source up to ninety percent of their water from underground aquifers.[276] In the Texas portion of the Permian basin, aquifers supply all of the water used in production.[277] With the recent growth in fracking in these areas, ground water withdrawals for production have increased, placing added pressure on resources. Withdrawals for fracking have led to increased competition for water, as many agricultural producers and other users also rely heavily on ground water, due to the limited availability of surface

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[271] Richardson et al., *supra* note 161, at 42 (finding that, of twenty-six states with permitting requirements, fourteen only require permits for water withdrawals over a specified threshold).
[272] OHIO REV. CODE ANN. §§ 1521.16, 1501.33 (LexisNexis 2016). But note § 1501.32 (requiring a permit for any division exceeding 100,000 gallons of water per day out of the Ohio River watershed).
[273] N.Y. COMP. CODE R. & REGS. tit. 6, §§ 601.2(p), 601.6 (2016) (providing that a permit is required for water withdrawals equal to or greater than the threshold volume, defined as 100,000 gallons per day).
[274] 9 VA. ADMIN. CODE § 25-210-60(B)(4)–(5) (2016) (exempting, from permitting, surface water withdrawals from nontidal waters for agriculture that total less than one million gallons in a single month and surface water withdrawals from nontidal water for all other purposes that total less than 10,000 gallons per day).
[275] Richardson et al., *supra* note 161, at 42.
[276] EPA, *supra* note 8, at 4-6.
[277] *Id.* at 4-19.

supplies. As a result, in the Eagle Ford basin, ground water is currently being withdrawn at 2.5 times the natural recharge rate.[278]

Overextraction of ground water can lead to the depletion of surface water supplies as the two are interdependent.[279] Despite this, however, most states historically treated ground and surface water as separate resources.[280] The states typically distinguished between two categories of ground water, namely: (1) water in an underground stream, and (2) percolating ground water.[281] Underground streams were generally subject to the same regulatory framework as surface streams (outlined above), while percolating ground water was regulated separately.[282] Because of the difficulty of determining whether an underground stream exists, ground water is presumed to be percolating, absent a showing to the contrary.[283] The rules for allocating percolating ground water are highly complex and differ considerably between states.[284]

Some states have recently taken steps to integrate the management of surface and ground water.[285] The extent of integration varies, however.[286] At one end of the spectrum are states such as Alaska[287] and North Dakota,[288] which make no legal distinction between surface and ground water. Other states treat ground water as legally distinct from

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[278] Benton Arnett et al., *Water Use in the Eagle Ford Shale: An Economic and Policy Analysis of Water Supply and Demand* at 6, THE BUSH SCHOOL OF GOV. & PUB. SERV. (2014), http://bush.tamu.edu/research/capstones/mpsa/projects/2014/Hydraulic%20Fracturing%20in%20the%20Eagle%20Ford%20Shale.pdf [https://perma.cc/VQ2K-KA43].

[279] *Water Interaction*, CAL. DEP'T OF WATER RES., http://www.water.ca.gov/groundwater/groundwater_basics/gw_sw_interaction.cfm [https://perma.cc/Z7XM-UPKM] (last updated Jan. 15, 2015).

[280] *Id.*

[281] *See* Hayes v. Adams, 218 P. 933, 993 (Or. 1923) (An "underground stream" has been defined to mean water flowing underground within "reasonably ascertainable boundaries."); *see also* TARLOCK ET AL., *supra* note 203, at 556 (Any ground water not forming an underground stream is considered percolating water).

[282] *See Hayes,* 218 P. at 933.

[283] *See, e.g.*, Tex. Co. v. Burkett, 296 S.W. 273, 278 (Tex. 1927) (noting that ground water is presumed to be percolating water).

[284] *See, e.g.*, ALASKA STAT. ANN. § 46.15.260 (West 2017); COLO. REV. STAT. ANN. § 37-92-102 (West 2013); N.D. CENT. CODE ANN. § 61-01-01 (West 2017).

[285] *Id.*

[286] *Id.*

[287] ALASKA STAT. ANN § 46.15.260(9) (defining "water" to mean "all water of the state, surface and subsurface, occurring in a natural state"). *See also id.* § 46.15.040 (governing the appropriation of water).

[288] N.D. CENT. CODE ANN. § 61-01-01 (2016) (providing that all waters within the limit of the state, including waters on and under the surface of the earth, belong to the public). *See also id.* Ch. 61-04 (governing the appropriation of water).

surface water, but manage the two conjunctively, meaning that the state may restrict a ground water right when withdrawals harm surface water users.[289] Such conjunctive management systems are used in many western states.[290] In Colorado, for example, ground water is presumed to be hydrologically connected with surface water and both resources are allocated under the same prior appropriation system.[291] Ground water rights have been integrated into the system of surface water priorities, under which earlier rights take precedence over later ones.[292] Out-of-priority diversions are, however, permitted in some circumstances.[293] For example, the holder of a junior ground water right may divert water if he/she/it provides a substitute source of supply to avoid any decline in the amount of surface water available to other, more senior rights holders.[294]

Not all states have integrated the management of surface and ground water.[295] Some states continue to manage ground water as a separate resource.[296] In those states, four key doctrines are used to allocate ground water, namely:

- The rule of capture (also known as the absolute ownership or English rule), which gives the owner of land overlying an aquifer the right to take water from beneath his/her/its property for any purpose.[297] In its purest form, the rule allowed each landowner to withdraw an unlimited amount of water, provided only that the withdrawal did not result in waste.[298] Over time, additional restrictions have been imposed on withdrawals, including that they not be made with malicious intent, trespass on neighboring

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[289] *See, e.g.*, COLO. REV. STAT. § 37-92-102(2)(West 2013).
[290] *Id.*
[291] Safranek v. Limon, 228 P.2d 975, 977 (1951) (noting that, in Colorado, ground water has consistently been presumed to be tributary to a natural stream).
[292] § 37-92-102(1)(a) (declaring that "it is the policy of this state to integrate the appropriation, use, and administration of underground water tributary to a stream with the use of surface water in such a way as to maximize the beneficial use of all of the waters of this state"). *See also* § 37-90-107 (governing the appropriation of underground water).
[293] Williams v. Midway Ranches Property Owners Ass'n, Inc., 938 P.2d 515, 522 (Colo. 1997).
[294] *Id.*
[295] *See* Houston & Tex. Cent. Ry. Co. v. W.A. East, 81 S.W. 279, 281 (Tex. 1904).
[296] *Id.*
[297] *See id.* at 280 (holding that a landowner may apply any ground water he finds "to his own purposes"); *see also* TARLOCK ET AL., *supra* note 203, at 561–62.
[298] TARLOCK ET AL., *supra* note 203, at 562.

property, or cause land subsidence.[299] Provided these requirements are met, the landowner may withdraw as much water as he/she wishes, even if doing so deprives others of water.[300] Once withdrawn, the water becomes the property of the landowner and may be sold to third parties.[301]

- The reasonable use rule (also known as the American rule), under which the owner of land overlying an aquifer may withdraw an unlimited amount of water from below his/her property, provided he/she uses that water for purposes reasonably related to the natural use of the land.[302] What constitutes a natural and reasonable use must be assessed on a case-by-case basis, taking into account all relevant circumstances, including the persons involved, their relative positions, the nature and value of their uses, and local climatic conditions.[303] The use of water on overlying land for agricultural, domestic, mining, or manufacturing purposes is generally permitted.[304] Water cannot, however, be used on non-overlying land if this would injure other landowners.[305] This no injury rule applies to the sale of water for use

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[299] Sipriano v. Great Spring Waters of Am., Inc., 1 S.W.3d 75, 76 (Tex. 1999) (holding that "the rule [of capture] provides that, absent malice or willful waste, landowners have the right to take all the water they can capture under their land and do with it what they please, and they will not be liable to neighbors even if in doing so they deprive their neighbors of the water's use"). Some states have placed additional restrictions on ground water withdrawals.

[300] *Id.*

[301] Corpus Christi v. Pleasanton, 276 S.W.2d 798, 802 (Tex. 1955) (holding that the owner of land overlying water "could capture [that water] from wells on his land for whatever beneficial purposes he needed it, on or off of the land, and could likewise sell it to others for use off of the land").

[302] Higday v. Nickolaus, 469 S.W.2d 859, 866 (Mo. Ct. App. 1971) (holding that "[u]nder the rule of reasonable use, the overlying owner may use the subjacent groundwater freely, and without liability to an adjoining owner, but only if his use is for purposes incident to the beneficial enjoyment of the land from which the water was taken").

[303] *Id.*

[304] *Id.* (holding that groundwater may be used "for agriculture, manufacturing, irrigation, mining, or any other purpose by which a landowner might legitimately use and enjoy his land").

[305] *Id.* (holding that a landowner "may not withdraw percolating water and transport it for sale or other use away from the land from which it was taken if the result is to impair the supply of an adjoining landowner to his injury").

on non-overlying land (i.e., sales are prohibited if they would injure overlying landowners).[306]

- The correlative rights doctrine, gives each owner of land overlying a common source of ground water equal or correlative rights to that water.[307] Under the doctrine, overlying owners have no proprietary interest in the water beneath their property.[308] Each owner is, however, entitled to a reasonable share of the water, typically determined by reference to the size of his/her land holding.[309] The water must generally be put to reasonable beneficial use on the overlying land.[310] Any surplus water may be used on non-overlying lands.[311] During times of shortage, non-overlying uses must be suspended and the available water shared among all landowners.[312]

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[306] Schenk v. City of Ann Arbor, 163 N.W. 109, 112 (Mich. 1917) (stating that the reasonable use rule "prevent[s] the withdrawal of underground waters for distribution or sale for uses not connected with any beneficial ownership or enjoyment of the land whence they are taken, if it results therefrom that the owner of adjacent or neighboring land is interfered with in his right to the reasonable user of subsurface water upon his land").

[307] San Bernardino v. Riverside, 198 P. 784, 787 (Cal. 1921) (holding that "the respective rights of owners of land in the waters percolating or lying beneath the surface are reciprocal and correlative as to each other"); Katz v. Walkinshaw, 74 P. 766, 767 (Cal. 1903) (stating that the correlative rights doctrine "require[s] an equitable distribution [of percolating ground water] among the different land owners").

[308] Higday v. Nickolaus, 469 S.W.2d 859, 866.

[309] *Id.*

[310] Los Angeles v. San Fernando, 537 P.2d 1250, 1291 (Cal. 1975) (holding that landowners may withdraw "ground water for reasonable beneficial uses on their overlying land"); Pasadena v. Alhambra, 207 P.2d 17, 28 (Cal. 1949) (holding that the owner of land has a right "to take water from the ground underneath for use on his land" but that the owner "may take only such amount as he reasonably needs for beneficial purposes"); *San Bernardino*, 198 P. at 788 (holding that "each owner of land overlying the same general underground supply of water may take such water on his own land for any beneficial use thereon, so long as such taking works no unreasonable injury to other land overlying such waters").

[311] *San Fernando*, 537 P.2d at 307 (holding that ground water may be withdrawn "for non-overlying beneficial uses during periods of basin surplus"); *Pasadena*, 207 P.2d at 28 (holding that "[a]ny water not needed for the reasonably beneficial uses of those having prior rights is excess or surplus water . . . [S]urplus water may rightfully be appropriated . . . for nonoverlying uses").

[312] *Pasadena*, 207 P.2d at 28 (holding that, when there is surplus ground water, the excess may be appropriated for use on non-overlying land, but "[p]roper overlying use . . . is paramount, and the right of an appropriator . . . must yield to that of the overlying owner in the event of a shortage"); *Katz*, 74 P. at 772 (holding that "[d]isputes between

- The prior appropriation doctrine, which holds that the first person to put water to beneficial use has a right to continue doing so.[313] Others who make use of water at a later time acquire more junior rights and must not interfere with the rights of earlier (senior) users.[314] Most states do not, however, protect holders of senior rights to ground water from any interference whatsoever (as is generally the case for surface water).[315] Because virtually any extraction of ground water reduces the level of the aquifer, and therefore affects every other pumper, most states allow some interference with the exercise of senior rights by junior rights holders.[316] In such cases, the junior's exercise of his/her rights is subject to a reasonableness test.[317]

The rule of capture was historically widely used, but has now been replaced in most states.[318] One notable exception is Texas, which continues to apply the rule of capture to ground water, except where that water is regulated by a ground water conservation district.[319] Where the rule of capture applies, oil and gas producers are likely to encounter few barriers in obtaining water for fracking and other activities.[320] Under the rule of capture, producers owning land overlying an aquifer may take (virtually) unlimited amounts of water for use in oil and gas production on that land and at other sites.[321] The rule of capture also allows producers who do not own overlying land to use water obtained from landowners.[322]

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overlying landowners, concerning water for use on the land, to which they have an equal right, in cases where the supply is insufficient for all, are to be settled by giving each a fair and just proportion").

[313] NEB. REV. STAT. ANN. § 46-203 (West 2017).

[314] Upper Big Blue Nat. Res. Dist. v. Fremont, 495 N.W.2d 23, 31 (Neb. 1993).

[315] NEB. REV. STAT. ANN. § 46-204 (West 2017).

[316] *Id.*

[317] *See id.*

[318] Gary Bryner & Elizabeth Purcell, *Groundwater Law Sourcebook of the Western United States*, NAT. RES. LAW. CTR., UNIV. OF COLO. SCH. OF LAW EDS. 63 (2003), *available at* http://www.informedcynic.com/water-fire/Water-legal-and%20technical-docs/groundwater-law-sourcebook-of-the-western-united-states.pdf [https://perma.cc/AAN3-N7M8].

[319] *Sipriano,* 1 S.W.3d at 75.

[320] *See id.*

[321] *Id.*

[322] *Id.*

With so few restrictions on their use of fresh water, producers have little incentive to recycle wastewater for reuse.[323] That may explain the current low levels of recycling in Texas. The EPA estimates that no more than five percent of the water used in fracking in the Texas portions of the Barnett shale and Permian basin is recycled.[324]

Compared to the rule of capture, the reasonable use and correlative rights doctrines impose greater restrictions on water use by oil and gas producers, thereby providing a stronger incentive for recycling.[325] Under the reasonable use doctrine, for example, producers can only use ground water on land overlying an aquifer and such use is limited to a reasonable amount.[326] Producers' use of water would also be limited under the correlative rights doctrine which, as explained above, defines water rights in relation to landholdings.[327] Where the correlative rights doctrine applies, then, producers owning small tracts of land could only withdraw correspondingly small amounts of water.[328] This may be insufficient to meet the producers' water needs, forcing them to look at other sources of supply.

D. Special Rules for Water Use in Oil and Gas Production

In all states, water use in oil and gas production is regulated under the same general framework as applies to other uses, including agriculture and municipal supply. To supplement this general framework, a small number of states have adopted additional rules, which apply only to water use by oil and gas producers, subjecting them to planning requirements not imposed on other users.[329] In Pennsylvania, for example, legislation enacted in 2012 requires any producer wishing to use water in the drilling and fracking of an unconventional gas well to develop a water management plan.[330] The plan must include, among other things, details

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323 Kate Galbraith, *Recycling Oilfield Water Has Far To Go in Texas*, TEX. TRIBUNE (Mar. 19, 2013, 6:00 AM), http://www.texastribune.org/2013/03/19/texas-recycling-oilfield-water-has-far-go/ [https://perma.cc/W6NS-L4VS].
324 U.S. EPA, *supra* note 8, at 4-7.
325 BRIAN E. GRAY, THE REASONABLE USE DOCTRINE IN CALIFORNIA WATER LAW AND POLICY 93–94 (Allison Lassiter ed., 2015).
326 *Id.* at 100.
327 Theresa D. Poindexter, *Correlative Rights Doctrine, Not the Rule of Capture, Provides Correct Analysis for Resolving Hydraulic Fracturing Cases*, 48 WASHBURN L.J. 755, 767 (2009) (explaining the doctrine of correlative rights).
328 *Id.*
329 *See, e.g.*, 58 PA. CONS. STAT. § 3211(m)(1) (2016).
330 *Id.*

of the source(s) from which water will be withdrawn, an estimate of the average quantity of water to be withdrawn and the maximum rate of withdrawal from each source, and an analysis of the potential impacts of the withdrawal.[331] It is subject to review and approval by the PDEP.[332]

Similar planning requirements have also been adopted in neighboring West Virginia, which requires oil and gas producers seeking a permit for a horizontal well to provide "an estimation of the volume of water that will be used in conjunction with drilling, fracturing or stimulating the well for which the permit is sought."[333] If these activities will require the withdrawal of more than 210,000 gallons of water during any thirty day period, the producer must prepare a water management plan providing details of the withdrawal, including the type and location of water source to be used, the location at which the withdrawal will occur, the anticipated volume of the withdrawal, and the month(s) when it will be made.[334] The plan is subject to review and approval by the West Virginia Department of Environmental Protection Office of Oil and Gas.[335] The Office may, as part of its approval of a plan, specify minimum flow requirements which must be maintained at all times.[336]

Like West Virginia, Michigan also requires applications for drilling permits to include information about certain, large water withdrawals. The requirements apply to withdrawals "intended to produce a cumulative total of over 100,000 gallons of water per day" (averaged over 30 days) for use in fracking.[337] Information on the volume of water to be withdrawn, the proposed number of water withdrawal wells, and the well depth, pumping rate, and pumping frequency must be provided to the Department of Environmental Quality's Office of Geological Survey.[338] The Office must also be provided with a water withdrawal evaluation, assessing the likely impact of the withdrawals on nearby streams and rivers.[339]

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[331] *See id.*; *see also* COMMONWEALTH OF PA. DEP'T OF ENVTL. PROTECTION OFFICE OF OIL AND GAS MGMT., WATER MANAGEMENT PLAN FOR UNCONVENTIONAL GAS WELL DEVELOPMENT (2016), http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-95180/8000-PM-OOGM0087%20Instructions.docx [https://perma.cc/7J52-ZDJ6].
[332] 58 PA. CONS. STAT. § 3211(m)(2) (2016).
[333] W. VA. CODE R. § 35-8-5.6.a (2016).
[334] *Id.* §§ 35-8-5.6.a, 35-8-5.6.b.
[335] *Id.* § 35-8-5.6.d.
[336] *Id.*
[337] MICH. DEP'T OF ENV'T QUALITY, SUPERVISOR OF WELLS INSTRUCTION 1-2011: HIGH VOLUME HYDRAULIC FRACTURING WELL COMPLETIONS (2011), https://www.michigan.gov/documents/deq/SI_1-2011_353936_7.pdf [https://perma.cc/M5DL-3QKQ].
[338] *Id.*
[339] *See id.* (The water withdrawal evaluation must be conducted using Michigan's Water

E. Conclusion

Adoption of regulations mandating water use planning by oil and gas producers are a welcome development. Such planning forces producers to consider the effects of their fresh water use and, as such, may encourage them to investigate alternative water sources, including recycled wastewater. Producers will, however, only engage in wastewater recycling if doing so is economical. In assessing the economics, producers compare the expenses likely to be incurred in recycling against the combined costs of fresh water sourcing, plus wastewater disposal. A key factor affecting this trade-off is the ease of obtaining fresh water for use in production.

State law generally imposes few restrictions on fresh water use in oil and gas production. In all states, to use fresh water in fracking and/or other activities, producers must hold a valid water right. The states have adopted different systems for granting water rights. Regardless of which system is used, however, producers are likely to find it relatively easy to obtain water for fracking. Compare, for example, the common law doctrine of riparian rights and the newer statutorily regulated riparian systems applied to surface water in eastern states. Where the common law doctrine applies, any producer who owns riparian land may withdraw water from the adjacent watercourse. Such withdrawals are limited only by the rights of other riparian landowners and there is no requirement for state approval. State approval is required under statutorily regulated riparian systems. Notably however, in determining whether to approve water withdrawals, state agencies generally apply common law principles relating to reasonable use. This typically only requires a showing that the use of water will not harm other users and, as such, may not prevent the unsustainable overextraction of water.

Oil and gas producers are also unlikely to encounter significant difficulties in obtaining surface water in western states. In those states, producers may withdraw water under statutory permitting regimes, which generally codify the common law system of prior appropriation, under which rights to water arise from its beneficial use. Many of the statutory regimes prevent the grant of new rights where the water system is already fully appropriated. Even where this is the case, however, producers will generally be able to obtain water by purchasing existing rights from

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Withdrawal Assessment Tool); *see also* MICH. DEP'T OF ENV'T QUALITY, WELCOME, MICHIGAN'S WATER WITHDRAWAL ASSESSMENT TOOL, http://www.michigan.gov/deq/0,4561,7-135-3313_3684_45331-201102--,00.html [https://perma.cc/22XN-BQXX].

other users. With fresh water so easily accessible, producers have little reason to pursue alternatives, such as wastewater recycling.

V. CURRENT LEGAL FRAMEWORK FOR WASTEWATER DISPOSAL

A number of commentators have argued that, in order to encourage greater recycling by oil and gas producers, states should restrict disposal of fracking wastewater. The most common method of wastewater disposal is through underground injection into hydrologically sealed wells. This type of deep well injection was first used in the 1930s to dispose of brackish water from conventional oil and gas production.[340] Since this time, as production has expanded and wastewater volumes increased, disposal wells have become more prevalent.[341] The EPA estimates that there are 36,000 disposal wells capable of receiving oil and gas wastewater throughout the U.S.[342] Wells have been constructed in most key oil and gas producing regions. Texas, for example, had 8,100 active disposal wells as of July 2015.[343] The widespread availability of wells makes it easy for producers to dispose of their wastewater and may thereby undermine incentives for recycling.

A. Underground Injection of Wastewater

Underground injection poses a number of risks, including to ground water, as contaminated waste may migrate into aquifers, through natural fractures or abandoned wells. Ground water contamination can, however, be avoided through careful construction of disposal wells. Well construction is regulated by the EPA, through its Underground Injection Control ("UIC") Program, established under the Safe Drinking Water Act (42 U.S.C. § 300f et seq.).[344] The UIC Program classifies injection wells into six classes based on the type of waste they accept. Federal regulations, adopted by the EPA, establish minimum standards for the construction

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[340] J. E. Clark, D. K. Bonura & R. F. Van Voorhees, *An Overview of Injection Well History In the United States of America*, 52 DEV. WATER SCI. 3 (2005).
[341] *Id.*
[342] *See* EPA, *Class II Oil and Gas Related Injection Wells*, UNDERGROUND INJECTION CONTROL, https://www.epa.gov/uic/class-ii-oil-and-gas-related-injection-wells [https://perma.cc/YLL2-K86Q] (last updated Sep. 6, 2016).
[343] *Injection and Disposal Wells*, R.R. COMM'N OF TEX., http://www.rrc.state.tx.us/about-us/resource-center/faqs/oil-gas-faqs/faq-injection-and-disposal-wells/ [https://perma.cc/2DBR-XANC] (last visited Oct. 23, 2017).
[344] 42 U.S.C. § 300h (2017).

and operation of each class of well.[345] Those standards are ordinarily enforced by the EPA; however, with EPA approval, a state may take on enforcement responsibility.[346]

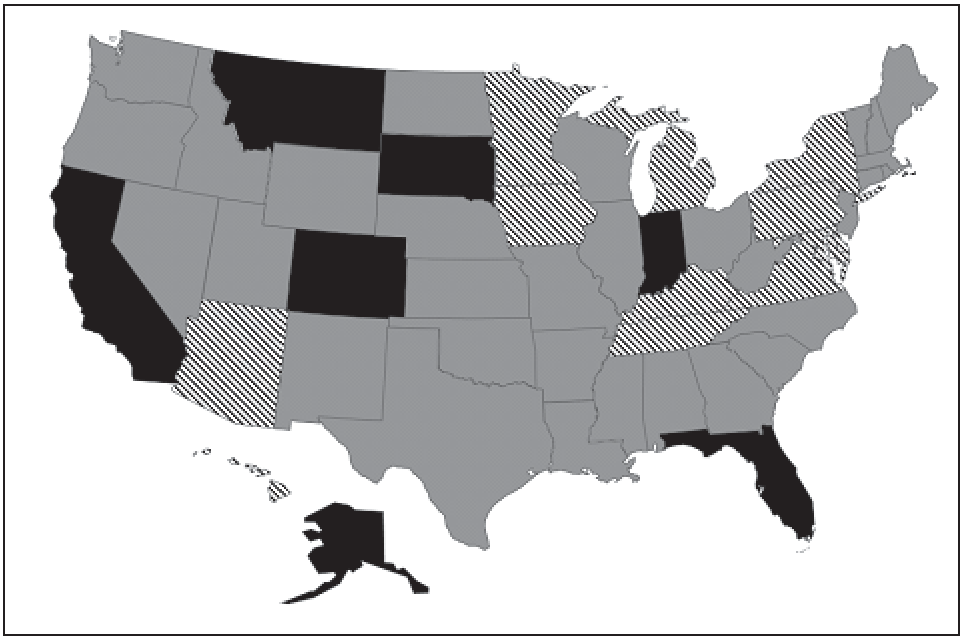

Figure 1: State Responsibility for Underground Injection

(States shaded in gray have been authorized by the EPA to take on enforcement responsibility for all classes of injection wells. States shaded in black have partial responsibility for some classes of wells, with the remaining wells regulated by the EPA. In other states, striped black and white, the EPA retains responsibility over underground injection.)

All injection wells accepting oil and gas wastewater ("Class II wells") must be permitted under the UIC Program.[347] Existing Class II wells are permitted by rule, meaning that the operator generally does not have to obtain an individual permit, unless specifically required to do so by the EPA Director.[348] An individual permit must be obtained for any

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[345] 40 C.F.R. § 144.1(a)(2017).
[346] *Id.* § 144.1(b).
[347] *Id.* § 144.11 (2015).
[348] *Id.* § 144.21(a), (c)(2015).

new Class II well.[349] Permits are issued by the EPA or, in states that have assumed primary responsibility for underground injection, the relevant state agency.[350] The permit holder must comply with minimum standards relating to well construction and operation,[351] including ensuring that the well is sited outside any formation containing underground sources of drinking water[352] and cased and cemented to prevent the movement of waste into drinking water.[353]

These permitting requirements may affect the pace at which new disposal wells are constructed. Limited availability of new wells could make disposal more difficult and/or expensive which may, in turn, encourage greater wastewater recycling. To date, however, this has not been the case. In most states, particularly in the west and south, there are numerous disposal wells.[354] Due to the widespread availability of such wells, disposing of wastewater via underground injection is typically inexpensive, averaging just $1 to $2 per barrel in most areas.[355] One notable exception is Pennsylvania which, as of December 2016, had just nine active disposal wells, only three of which were commercially operated.[356] Those wells are unable to handle all wastewater produced in Pennsylvania, forcing oil and gas producers to look for alternatives. Some producers have elected to truck wastewater to neighboring states, such as Ohio, which has over 200 disposal wells clustered mostly in the eastern half of the state.[357] Interstate trucking is costly, however.[358] Seeking to minimize costs, many producers have begun recycling, with nearly seventy percent of fracking wastewater recycled in Pennsylvania, well above other states.[359]

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[349] *See id.* § 144.31(a) (2015) (note that the Director may issue a permit on an area basis, rather than for each well individually, in certain circumstances); *See also id.* § 144.33 (2015).
[350] 40 C.F.R. § 145.1, 145.11 (2015).
[351] *Id.* §§ 144.52(a), 146.22, 146.23 (2015).
[352] *Id.* § 146.22(a) (2015).
[353] *Id.* §§ 146.22(b)–(e) (2015).
[354] EPA, *supra* note 8, at 8-23 to 8-24 (finding that "there are about 26,400 active Class IID [i.e., disposal] wells in the United States," with over 7,800 wells located in Texas, 5,500 in Kansas, 3,800 in Oklahoma, 2,400 in Louisiana, and 1,000 in Illinois).
[355] ENERGY-WATER NEXUS, *supra* note 77, at 23; Cook et al., *supra* note 107, at 57; Ahmadun et al., *supra* note 27, at 548; LeBas et al., *supra* note 196, at 1.
[356] EPA, *supra* note 8, at 8-23.
[357] OHIO DEP'T NAT. RES., *Underground Injection Control (UIC)* (2017), http://oilandgas.ohiodnr.gov/regulatory-sections/underground-injection-control [https://perma.cc/TSN2-64A7] (click the PDF map below the YouTube video).
[358] FREYMAN, *supra* note 18, at 41.
[359] EPA, *supra* note 8, at 8-36.

B. *Other Wastewater Disposal Methods*

Oil and gas producers also have other options for disposing of wastewater, including discharging it to surface waters and/or applying it to land. While less common than underground injection, these disposal methods are used in some states, particularly for wastewater with low contaminant levels.[360] The following sections outline the regulatory framework governing their use.

1. Discharge to Surface Waters

The Federal Water Pollution Control Act (33 U.S.C. § 1251 et seq.), commonly known as the Clean Water Act, prohibits the "discharge of any pollutant from any point source" without a permit.[361] For the purposes of the Act, a "point source" means any discernible, confined, and discrete conveyance from which pollutants are discharged.[362] The Act applies to oil and gas producers discharging wastewater, from fracking and/or other operations, into surface water bodies.[363] Such discharges are subject to the National Pollution Discharge Elimination System ("NPDES") Program, under which the EPA or an authorized state agency may issue permits, authorizing discharges to surface water.[364] These permits include limits on the maximum concentration of pollutants in the discharge, which are set based on the available treatment technology,[365] as well as the desired quality of the receiving water.[366]

Under the NPDES Program, certain classes of oil and gas wastewater may be discharged to surface waters, without prior treatment. These include produced water generated from onshore facilities located west of the 98th meridian[367] with a use in agriculture or wildlife propagation[368] and wastewater from facilities producing ten barrels of crude oil

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[360] *Id.* at 8-75.
[361] 33 U.S.C. § 1311(a)(2017).
[362] 40 C.F.R. § 122.2(b)(3)(d)(b)(2017).
[363] Craig, *supra* note 15, at 249 (Uncontaminated storm water discharges associated with oil and gas construction and field operation activities are exempt from the permitting requirements in the Clean Water Act. For a discussion of this exemption).
[364] 33 U.S.C.S. §§ 1311(a), 1342(a).
[365] *Id.* § 1311(b)(1)(A); 40 C.F.R. § 125.
[366] 33 U.S.C.S. § 1311(b)(1)(C); 40 C.F.R. § 131.
[367] The 98th meridian runs through North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas.
[368] 40 C.F.R. §§ 435.50, 435.52.

or less per day.[369] Except in those circumstances, oil and gas wastewater must be treated prior to discharge.[370] Treatment generally occurs at private facilities, known as centralized waste treatment facilities ("CWTs"), which are specially designed to handle industrial waste. CWTs may be authorized, by permit, to discharge treated wastewater to surface waters. The discharge must comply with pollutant concentration limits set out in federal regulations and/or included in the CWT's discharge permit.[371]

Oil and gas wastewater was, in the past, also treated at POTWs. However, POTWs are typically designed to treat municipal (domestic) wastewater and are, therefore, often poorly suited to treating oil and gas wastewater with higher pollutant concentrations. Inadequately treated oil and gas wastewater, discharged by POTWs, was recently blamed for contamination of the Monongahela River in Pennsylvania.[372] Following these contamination incidents, in 2016, EPA updated its regulations with respect to the treatment of wastewater at POTWs.[373] The updated regulations establish a "zero discharge" standard, which prevents POTWs accepting wastewater from onshore facilities[374] used in "production, field exploration, drilling, well completion, or well treatment for unconventional oil and gas extraction."[375] POTWs can accept waste from conventional oil and gas and coal-bed methane extraction facilities, provided it does not contain pollutants that "pass-through"[376] or cause "interference"[377] with the operations of the POTW.[378] A POTW receiving such wastewater must specify pollutant limits, which translate the general prohibition on pass-through

[369] *Id.* § 435.60.
[370] *Id.* § 435.32 (prohibiting the "discharge of waste water pollutants into navigable waters from any source associated with production, field exploration, drilling, well completion, or well treatment (i.e., produced water, drilling muds, drill cuttings, and produced sand)" into waters of the U.S.).
[371] *Id.* § 437 (2016).
[372] For a discussion of this incident, *see* Joaquin Sapien, *With Natural Gas Drilling Boom, Pennsylvania Faces an Onslaught of Wastewater*, PROPUBLICA (Oct. 3, 2009), https://www.propublica.org/article/wastewater-from-gas-drilling-boom-may-threaten-monongahela-river [https://perma.cc/MEE4-5YE2].
[373] 40 C.F.R. § 435, Subpt. C.
[374] "Onshore facilities" are those located landward of the inner boundary of the territorial sea. *See id.* § 435.30.
[375] *Id.* § 435.33.
[376] For the purposes of the standards, "pass-through" occurs where a pollutant is not removed through treatment at the POTW. *See id.* § 403.3(p) (2016).
[377] "Interference" occurs where a pollutant inhibits or disrupts the POTW, its treatment processes or operations, or its sludge processes, use, or disposal, resulting in a violation of the POTW's NPDES permit, or certain statutory provisions. *See id.* § 403.3(k) (2015).
[378] *Id.* § 403.5(a)(1) (2015).

and interference into site-specific limitations, based on the POTW's capabilities.[379] These limits must be met by all persons introducing wastewater into the POTW.

2. Application to Land

While less frequent, wastewater from oil and gas production may also be disposed of on land, subject to state regulation.[380] Regulations in a number of states permit wastewater to be disposed of through land-farming, whereby the wastewater is mixed with or applied to soil in such a manner that it will not migrate to other areas.[381] Some states also permit wastewater to be spread on roads. This is particularly common in states experiencing freezing winter temperatures, where brines are used for roadway pre-wetting, anti-icing, and deicing purposes. In Colorado for example, oil and gas producers may dispose of produced water through road-spreading, provided that the water meets specified pollutant concentration limits.[382]

In addition to land-farming and road-spreading, Colorado and other states also permit the disposal of wastewater in earthen impoundments, commonly known as pits. Oil and gas producers in Colorado may dispose of produced water through evaporation or percolation in pits, provided that the water is first treated to remove oil and condensate.[383] Similarly, in New Mexico, wastewater meeting specified pollutant concentration limits may be disposed of in pits.[384] Other large oil and gas producing states, such as Oklahoma and Wyoming, also allow wastewater disposal in pits in certain circumstances.[385] In each state, pits used for disposal must generally be permitted. Most states have adopted regulations limiting the areas in which pits may be constructed and setting minimum requirements for pit construction.

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[379] 40 C.F.R. §§ 403.5(c), 403.8(f)(4) (2015).

[380] Due to the exemption of oil and gas wastewater from the Resource Conservation and Recovery Act, land disposal practices are not subject to federal regulation. *See generally* Resource Conservation and Recovery Act, 94 Pub. L. No. 580, 90 Stat. 2795.

[381] In Texas, for example, low-chloride water-based drilling fluids used in oil and gas production may be disposed of through landfarming. *See* 16 TEX. ADMIN. CODE § 3.8(d) (2016).

[382] 2 COLO. CODE REGS. § 404-1 (2016).

[383] *Id.* § 404-1 (2015).

[384] N.M. CODE R. §§ 19.15.17.13, 19.15.34.8(B)(1), 19.15.34.20 (LexisNexis 2016).

[385] OKLA. ADMIN. CODE §§ 165:10-7-16, 165:10-9-1 (2016); 055-000-004 WYO. CODE. R. §§ 1, 13(a) (LexisNexis 2016).

3. Conclusion

As the foregoing discussion indicates, there are currently few limits on wastewater disposal, which can generally occur through underground injection. Most oil and gas producing regions have numerous injection sites at which oil and gas producers can dispose of wastewater at little cost. One exception is the Marcellus shale in Pennsylvania, where geologic conditions are poorly suited to underground injection, and there are few disposal wells. This has made it difficult for Marcellus producers to dispose of wastewater through underground injection. Producers have limited other wastewater disposal options, with state regulations preventing wastewater being disposed of at a POTW, unless it is first treated at a CWT.

Restrictions on wastewater disposal may encourage oil and gas producers to invest in recycling and thereby help to reduce fresh water use in production. This appears to have been the case in Pennsylvania, which has a significantly higher rate of recycling than other states such as Texas, where producers have a range of disposal options. While it is difficult to establish a causal connection, some commentators have attributed the high recycling rate in Pennsylvania to the lack of wastewater disposal facilities there, and suggested that other states should limit disposal to encourage recycling.[386] States should, however, exercise caution when adopting such limits as they may have unintended consequences.

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[386] *See, e.g.*, EPA, *supra* note 8, at 8-75 (noting that "the majority of hydraulic fracturing wastewater is injected into Class IID [disposal] wells regulated under the UIC Program. In the Marcellus Shale region in Pennsylvania, this option is limited, and the majority of wastewater is reused"); FREYMAN, *supra* note 18, at 41 (stating that "the Marcellus has the highest recycling rates (estimated at 66 percent) because geologic conditions are poorly suited for deep disposal wells"); Brian G. Rahm, *Wastewater Management and Marcellus Shale Gas Development: Trends, Drivers, and Planning Implications*, 120 J. ENVTL. MGMT. 105, 111 (2013) (indicating that "regional infrastructure and geography . . . can play a significant role in . . . wastewater management" and that "[t]he presence and capacity of injection disposal wells should be recognized as an important driver of wastewater management behaviors"); REBECCA HAMMER & JEANNE VAN BRIESEN, NATURAL RESOURCES DEFENSE COUNCIL, IN FRACKING'S WAKE: NEW RULES ARE NEEDED TO PROTECT OUR HEALTH AND ENVIRONMENT FROM CONTAMINATED WASTEWATER 66 (2012), *available at* http://www.nrdc.org/energy/files/fracking-wastewater-fullreport.pdf [https://perma.cc/6ZX8-DEVQ] (noting that "extensive development of these options [i.e., wastewater recycling and reuse] has been undertaken in the Marcellus gas field due to the low availability of traditional off-site disposal methods in close proximity to well development"). *See also* ENERGY-WATER NEXUS, *supra* note 77, at 20 (stating that "[i]n the last couple of years, reusing produced water for hydraulic fracturing has become more common among shale gas producers in Pennsylvania . . . . The shift was motivated, in part, by a change in the state's surface discharge standards that ultimately made treatment and discharge a comparatively more expensive practice").

By way of example, restrictions on underground injection of wastewater could lead to an increase in illegal dumping, resulting in environmental damage. Even if this does not occur, the restrictions may do little to encourage recycling, and simply lead producers to switch from one disposal method to another.

VI. WHERE TO FROM HERE? POLICY CHANGES THAT MAY ENCOURAGE GREATER WASTEWATER RECYCLING

A number of states have recently sought to encourage greater wastewater recycling by oil and gas producers by removing regulatory barriers and/or providing financial incentives. Despite this, however, many producers are yet to embrace recycling. The costs of wastewater recycling often exceed the combined expense of disposing of that wastewater and sourcing fresh water for future use. Recognizing this, several commentators have argued that states may encourage recycling by restricting wastewater disposal or otherwise increasing its cost. Recycling could also be encouraged through state action targeting water sourcing. Such action could take various forms, including banning fresh water use in fracking, establishing a rebuttable presumption against such water use, imposing a cap on the amount of water used, and/or levying fees for water use.

The appropriateness of these and/or other policies must be assessed on a state-by-state basis taking into account local conditions, including differences in the water resource landscape. As noted above, policies restricting oil and gas producers' access to fresh water are likely to have a greater impact on recycling than limits on wastewater disposal. Even if states were to adopt a complete ban on underground injection of wastewater, as proposed by many commentators, producers could switch to using other disposal methods and not invest in recycling. Such a ban may, therefore, have little impact on fresh water use in fracking. As a result, in states facing severe water shortages, due to prolonged drought and/or other factors, restrictions on fresh water use may be necessary.

A complete ban on fresh water use in fracking is unlikely to be politically feasible in any state. Some oil and gas producers may find it difficult to comply with a ban on fresh water use because, for example, they are unable to collect sufficient wastewater for recycling and/or find wastewater recycling uneconomical. As a result, banning all fresh water use in fracking could lead to a decline in oil and gas production, which may have adverse economic effects, particularly in states with large oil and gas sectors. States may be more willing to impose a cap on, or levy fees for, fresh water use in fracking. Which of these policies is most appropriate will, again, depend on local conditions. Differences in institutional capacity, for example, may affect a states' ability to use each policy. As an illustration, for a fee on fresh water use to encourage wastewater recycling, it must exceed the cost thereof. Some state regulators may not have accurate information about the costs faced by producers, creating a risk that the fee will be set too low to encourage wastewater recycling. In those states, regulators may prefer to encourage recycling by capping fresh water use.

CONCLUSION

Increased shale oil and gas production has led to a dramatic rise in water use by producers. Due to the low permeability of shale, extracting oil and gas therefrom typically requires the use of fracking, whereby a water-based fluid is injected underground to fracture the rock, enabling the flow of oil and gas. The amount of water required for fracking varies between shale plays, ranging from less than 100,000 gallons to over 6 million gallons per well.[387] A portion of this water returns to the surface after injection, along with water occurring naturally in the shale formation. The returning wastewater may be contaminated with various organic substances, heavy metals, and even radioactive materials. As a result, most fracking wastewater is not reused, but simply disposed of. The most common method of disposal is through underground injection, which results in the wastewater being permanently removed from the hydrological cycle.

After disposing of their wastewater, oil and gas producers may then withdraw fresh water, for use in future frack jobs. These withdrawals may contribute to local water shortages, particularly in areas prone to drought and/or with high rates of use in other sectors. Almost half of all wells fracked in the U.S. between January 2011 and May 2013 were in areas or high or extremely high water stress, meaning that over forty percent of available water is already allocated for municipal, industrial, and agricultural use.[388] Water demand for these uses is likely to increase due to future population growth, while supplies may decline as a result of climate change, which is expected to cause more frequent and severe droughts in arid areas. The stage is, therefore, set for increasing competition over water in future years. This competition will be intensified by water consumption in fracking.

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[387] EPA, *supra* note 8, at ES-12 (noting that there is "wide variation in the water volumes reported per well, with 10th and 90th percentiles of 74,000 gallons (280,000 liters) and 6 million gallons (23 million liters) per well, respectively").
[388] FREYMAN, *supra* note 18, at 28.

Recognizing this, policymakers in a number of states have called for a reduction in fresh water use in oil and gas production. In response to these calls, producers have explored various alternative water sources, including brackish water and municipal effluent. Most attention has, however, been devoted to the possibility of recycling wastewater collected during past fracking treatments. This approach has dual benefits for producers, reducing their need for fresh water, as well as their disposal of wastewater. Recycling can, however, be expensive due to the need to treat wastewater prior to reuse. In many areas, the expense of recycling exceeds the combined costs of fresh water sourcing and wastewater disposal, making the practice uneconomic.

Oil and gas producers are more likely to recycle their wastewater if unable to obtain fresh water and/or dispose of wastewater. In most areas, however, producers are likely to encounter few difficulties in performing these activities. One exception is Pennsylvania, where wastewater disposal options are extremely limited, and recycling fairly common. This has led some commentators to assert that, to encourage recycling, states should restrict wastewater disposal. Restrictions on fresh water use may also have the same effect. The restrictions could involve:

- *A ban or cap on fresh water use in fracking:* States could prohibit new water withdrawals by oil and gas producers or require producers to ensure that their withdrawals do not exceed a specified cap.
- *A presumption against fresh water use:* States could prohibit water use in oil and gas production, unless the producer demonstrates that recycling is infeasible or meets other specified conditions.
- *A fee for fresh water use and / or wastewater disposal:* States could require oil and gas producers to pay a set fee for each barrel of fresh water used and/or wastewater disposed of.
- *A limit on wastewater disposal:* States could prohibit underground injection of wastewater, either absolutely or if the wastewater cannot be recycled.

Adoption of these policies would increase the costs faced by oil and gas producers in sourcing fresh water for, and disposing of wastewater from, fracking. Producers would, therefore, be more likely to invest in recycling which should help to mitigate the impacts of fracking on water supplies throughout the U.S.