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Risk and Response in Fracturing Policy

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RISK AND RESPONSE IN FRACTURING POLICY

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An oil and gas extraction technique called hydraulic fracturing (also called fracing, fracking, or hydrofracking) has swept the country and has raised the stakes of the energy policy debate. As operators drill thousands of new wells and inject water and chemicals down these wells in order to fracture underground shale and tight sandstone formations, concerned citizens' groups and the media have pointed to flaming tap water and have worried about chemical contamination; at the same time, industry representatives and many state regulators have sworn that the practice has never contaminated groundwater. The outpouring of attention to injection—just one stage of a complex well development process—threatens to distract from the core issues of "tight" oil and gas development and to leave the most pressing concerns unaddressed. Through a comparison of regulation and alleged violations of environmental and oil and gas laws at hydraulically fractured well sites, this Article illuminates the factors that must inform policy and regulatory changes that guide modern oil and gas development. The examples of violations so far suggest that the most pressing risks may predominantly arise not from the injection of chemicals and water but from other stages of the well development process introduced by fracturing and from the higher rate of well drilling spurred by fracturing. This does not suggest that fracturing itself poses no risks.

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Rather, we must recognize the new risks introduced by several non-injection stages essential to the fracturing process, as well as by the drilling enabled by fracturing, and shift our attention to the most problematic stages. Chemicals may spill when transported to well sites, and new types of wastes must be stored and disposed of. Furthermore, methane may contaminate underground water sources during the drilling process preceding fracturing. If policymakers and regulators allow drilling and fracturing to continue at their current frenzied pace, it is imperative that they change course to recognize and respond to these core risks. The analysis in this Article offers an initial path forward.

INTRODUCTION

A once obscure oil and gas extraction technique has transformed the American economy[1] and introduced one of the greatest policy and regulatory challenges of recent times. Hydraulic fracturing (or fracing, fracking, or hydrofracking) has triggered fossil fuel production from areas once thought inaccessible or economically inefficient to utilize,[2] and it has led the United States toward the status of fuel exporter.[3] In particular, the practice of "slickwater" or "slick water" fracturing,[4] developed in the late 1990s,[5] has recently spurred the development of thousands of new wells[6] in shales, tight

1. The United States may soon be a net exporter of oil and gas. *See* INTL. ENERGY AGENCY, WORLD ENERGY OUTLOOK 2012 at 74 (2012) (not accessible by the public without payment; on file with author).

2. *See, e.g.*, HALLIBURTON, U.S. SHALE GAS 1 (2008), http://www.halliburton.com/public/solutions/contents/shale/related_docs/H063771.pdf (noting that "one of the first recognized major shale gas plays, the Barnett Shale of Texas, was under investigation as early as 1981, but not until 1995 was the hydraulic fracturing technology available that successfully brought in the gas at commercial rates").

3. *See* INTL. ENERGY AGENCY, *supra* note 1; *see also* Fred Hagemeyer, *Production and Marketing of Hydrocarbons in the U.S.—A Survey of Recent Trends and Development*, *in* OIL & GAS AGREEMENTS: MIDSTREAM AND MARKETING, at 1-1, (Rocky Mtn. Min. L. Found, Min. L. Series, Vol. 2011 No. 1) (observing that "[f]ive years ago, conventional wisdom suggested that the U.S. hydrocarbon resource base was peaking and poised for a long-term decline" but that this wisdom has changed due largely to the production of unconventional oil from the Bakken Shale and to a boom in natural gas production from shales in several regions).

4. *Water Use in the Barnett Shale*, R.R. COMM'N OF TEX. (Jan. 24, 2011), http://www.rrc.state.tx.us/barnettshale/wateruse_barnettshale.php (describing fracturing of shale—the pumping of large volumes of water and some chemicals down the well—as slick water fracturing).

5. *See* David F. Martineau, *Expansion of the Barnett Shale Play Fort Worth Basin—Texas*, *in* DEVELOPMENT ISSUES & CONFLICTS IN MODERN GAS & OIL PLAYS, at 5-13 (Rocky Mountain. Min. L. Found., Min. L. Series, Vol. 2004 No. 4) ("In 1997, Mitchell [Energy] changed the frac method to a 'slick water frac' or 'light sand frac.'").

6. *See What Is Shale Gas and Why Is It Important?*, U.S. ENERGY INFO. ADMIN. (July 12, 2012), http://www.eia.gov/energy_in_brief/about_shale_gas.cfm (explaining that without horizontal drilling and hydraulic fracturing, "natural gas does not flow to the well rapidly, and commercial quantities cannot be produced from shale"); *see also* Penn. Dep't of Envtl. Prot., Bureau of Oil & Gas Mgmt., *2010 Total Wells Drilled* (last updated Jan. 5, 2011), http://www.dep.state.pa.us/dep/deputate/minres/oilgas/photogallery/photo13295/2010%20%20Wells%20Drilled.gif (showing 1,386 Marcellus wells drilled in 2010) [hereinafter *Pennsylvania 2010 Total Wells Drilled*]; R.R. COMM'N OF TEX., NEWARK, EAST (BARNETT SHALE) FIELD [hereinafter NEWARK, EAST (BARNETT SHALE) FIELD], http://www.rrc.state.tx.us/data/fielddata/barnettshale.pdf ("As of October 09, 2012 there are 16,346 total gas wells entered on RRC records" and an additional 2,532

sandstones ("tight sands"), and coalbeds—called "tight" formations because of their low permeability.[7] International energy companies have rushed to the United States to better understand the technique and transport it to their own fossil fuel reserves,[8] and once-sleepy communities have benefited from suddenly-valuable mineral rights and an infusion of new jobs.[9] At the same time, these communities have struggled to address road damage,[10] social and economic change,[11] and

"permitted locations.").

7. Stephen A. Holditch, *Tight Gas Sands*, 58 J. PETROL. TECH. 86 (2006), http://www.spe.org/jpt/print/archives/2006/06/JPT2006_06_DA_series.pdf (describing tight gas formations as "low-permeability reservoirs that produce mainly dry natural gas," including "carbonates, shales, and coal seams"); *see also* Hong Sun et al., *A Nondamaging Friction Reducer for Slickwater Frac Applications*, SOC'Y OF PETROL. ENG'RS, no. 139480, 2011 at 1 (article purchased by and on file with author) (describing slickwater fracturing jobs in shales and tight sandstone formations). This Article does not address coalbed methane development.

8. *See, e.g.*, Ed Crooks et al., *China and France Chase U.S. Shale Assets*, FINANCIAL TIMES (Jan. 3, 2012, 7:30 PM), *available at* http://www.ft.com/intl/cms/s/0/30c4c46e-35e2-11e1-9f9800144feabdc0.html#axzz2D5RjYdg0 (describing foreign investment in U.S. shale gas and oil and China's "hopes that techniques pioneered in the U.S. could be used to develop China's own resources").

9. *See* TIMOTHY J. CONSIDINE, THE ECONOMIC IMPACTS OF THE MARCELLUS SHALE: IMPLICATIONS FOR NEW YORK, PENNSYLVANIA, AND WEST VIRGINIA 19, (July 14, 2010), http://www.api.org/~/media/Files/Policy/Exploration/APIEconomic-Impacts-Marcellus-Shale.ashx (concluding in a report prepared for the American Petroleum Institute that "[t]he Marcellus gas industry in Pennsylvania provides a direct economic stimulus of $3.77 billion gross sales to the local economy" and encourages spending that "adds another $1.56 billion to total state gross output" and that the total economic impact in West Virginia in 2009 was $939 million).

10. *See* MARK MURAWSKI, TRANSPORTATION PATTERNS AND IMPACTS FROM MARCELLUS DEVELOPMENT (May 24, 2012), http://planningpa.org/wp-content/uploads/ Marcellus_Transpo_Impacts_5-24-12.pdf (showing pictures of road damage, and noting that "[f]or the most part, gas companies are doing a good job making necessary repairs to local roads" but that "[f]uture road maintenance may be a concern," as well as "[a]ccelerated deterioration to life cycle pavements."); SOC'Y OF PETROL. ENG'RS, WHITE PAPER ON SPE SUMMIT ON HYDRAULIC FRACTURING 1, 5–6 (2011) (noting that "[h]eavy truck traffic on local roadways contributes to noise, congestion, and the potential for vehicle accidents").

11. *See, e.g.*, JONATHAN WILLIAMSON & BONITA KOLB, CTR. FOR THE STUDY OF CMTY. & THE ECON., LYCOMING COLLEGE, MARCELLUS NATURAL GAS DEVELOPMENT'S EFFECT ON HOUSING IN PENNSYLVANIA 4–5 (Oct. 2011), http://www.marcellus.psu.edu/resources/PDFs/housingreport.pdf (concluding that "[s]ignificant variation exists in each community's ability to absorb demand for additional housing" but that some areas are experiencing shortages, and that impacts fall most heavily on residents "on the economic margins"); SOC'Y OF PETROL. ENG'RS, *supra* note 10, at 5 ("Numerous industry out-of-town workers contribute to the local economy, but may drive prices higher and change the sociological dynamics of small communities.").

environmental effects.[12]

This rapid energy transition, which has created both powerful benefits and challenges, has deeply divided the country. Industry representatives and many state regulators argue that oil and gas operators[13] have used hydraulic fracturing for more than half a century without any notable damage to the environment or human health,[14] while the media has broadcast images of homeowners lighting their tap water on fire.[15] Environmental groups have split, with some tepidly supporting the development of a cleaner fossil fuel (natural gas) through fracturing[16] and others expressing deep concerns about extraction effects.[17] New York temporarily halted most fracturing that uses large volumes of water and sued the federal government in search of stricter controls.[18]

12. *See infra* Part II for a discussion of state enforcement of environmental regulations at well sites, which shows some of the environmental effects that have occurred.

13. In the oil and gas context, the entity that drills the well is typically referred to as the operator. *See* JOHN S. LOWE ET AL., CASES AND MATERIALS ON OIL AND GAS LAW 31 n.12 (5th ed. 2008).

14. *See, e.g.*, Joseph H. Frantz, Jr., *Natural Gas, Range Resources, and the Marcellus Shale, in* DEVELOPMENT ISSUES IN THE MAJOR SHALE PLAYS, at 2-24, (Rocky Mountain. Min. L. Found., Min. L. Series, Vol. 2010 No. 5) (describing fracturing as "safe and proven . . . in its 60-year history"); Kevin Fisher, Halliburton, *Frac Facts: Data Confirm Safety of Well Fracturing*, AM. OIL & GAS REPORTER, June 14, 2011, http://www.aogr.com/index.php/magazine/frac-facts ("In the more than [sixty] years following . . . [the] first treatments, more than [two] million frac treatments have been pumped with no documented case of any treatment polluting an aquifer."); *infra* text accompanying notes 40–48 (describing statements by many state regulators).

15. Davidmholmes, *My Water's on Fire Tonight (The Fracking Song)*, YOUTUBE (May 10, 2011), http://www.youtube.com/watch?v= timfvNgr_Q4&noredirect=1; GASLAND (Joshua Fox 2010) (showing flaming tapwater).

16. ENVTL. DEF. FUND, THREE KEY ENVIRONMENTAL RISKS OF NATURAL GAS DEVELOPMENT 1 (Jan. 18, 2011), http://www.edf.org/sites/default/files/environmental-risks-of-natural-gas-development_0.pdf (noting that "[n]atural gas is a resurgent part of the energy mix" but identifying risks in well construction, air emissions, and wastewater disposal).

17. *See generally, e.g.*, LISA SUMI, OIL AND GAS ACCOUNTABILITY PROJECT, OUR DRINKING WATER AT RISK (Apr. 2005), http://www.earthworksaction.org/files/publications/DrinkingWaterAtRisk.pdf (arguing that fracturing contaminates water and has a range of other negative impacts); Amy Mall, *Incidents Where Hydraulic Fracturing Is a Suspected Cause of Drinking Water Contamination*, SWITCHBOARD: NAT. RES. DEF. COUNCIL STAFF BLOG (Nov. 11, 2011), http://switchboard.nrdc.org/blogs/amall/ incidents_where_hydraulic_frac.html.

18. *SGEIS on the Oil, Gas, and Solution Mining Regulatory Program*, N.Y. STATE DEP'T OF ENVTL. CONSERV., http://www.dec.ny.gov/energy/47554.html (explaining that when the Department completes the environmental impact statement, it "will then process and, as appropriate, issue well permits for gas well development using high-volume hydraulic fracturing") (last visited Nov. 23,

Neighboring Pennsylvania, in contrast, allowed the number of fractured wells to increase more than 300 percent between 2008 and 2009,[19] and again by 180 percent from 2009 to 2010.[20] The state began to update its environmental regulations as well development rushed forward.[21] Energy companies in Arkansas,[22] Colorado,[23] Louisiana,[24] Michigan,[25] North

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2012); New York v. U.S. Army Corps of Engineers, 2012 WL 4336701 at *1, *10–13 (E.D.N.Y. 2012) (describing the lawsuit against the Corps and other federal parties that allegedly should have conducted a full environmental review of proposed regulations of the Delaware River Basin Commission before finalizing the regulations, and dismissing the suit on standing grounds, but stating that New York could likely sue when the challenged regulations had been finalized).

19. Ford Turner, *State-Issued Marcellus Shale Gas Well Drilling Permits Increase 300% in 2009*, PATRIOT-NEWS (Nov. 4, 2009, 11:28 AM), *available at* http://www.pennlive.com/midstate/index.ssf/2009/11/stateissued_marcellus_shale_g.html; *see also* Penn. Dep't of Envtl. Prot., Bureau of Oil and Gas Mgmt., *2008 Total Wells Drilled* (Dec. 31, 2008) [hereinafter *Pennsylvania 2008 Total Wells Drilled*], http://www.dep.state.pa.us/dep/deputate/minres/oilgas/BOGM%20Website%20Pictures/2008/2008%20Wells%20Drilled.jpg (showing 195 Marcellus Shale wells drilled in 2008); Penn. Dep't of Envtl. Prot., Bureau of Oil and Gas Mgmt., *2009 Total Wells Drilled* (Jan. 25, 2010) [hereinafter *Pennsylvania 2009 Total Wells Drilled*], http://www.dep.state.pa.us/dep/deputate/minres/oilgas/BOGM%20Website%20Pictures/2009/2009%20%20Wells%20Drilled.jpg (showing 768 Marcellus Shale wells drilled in 2009).

20. *See Pennsylvania 2009 Total Wells Drilled*, *supra* note 19 (showing 768 Marcellus Shale wells drilled in 2009); *Pennsylvania 2010 Total Wells Drilled*, *supra* note 6 (showing 1,386 Marcellus Shale wells drilled in 2010).

21. H.RB. 1950, 2011–2012 Gen. Assemb., Reg. Sess. (Pa. 2011) Pa. Gen. Assembly (2011) (signed); Dep't of Envtl. Prot., *Bureau of Water Standards and Facility Regulation, Doc. 385-2100-002*, Nov. 12, 2011, http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-85967/385-2100-002%20tech%20guidance.pdf (describing new wastewater treatment requirements); 25 Pa. Bull. 78 (Feb. 5, 2011), *available at* http://www.pabulletin.com/secure/data/vol41/41-6/239.html (showing updates to casing and cementing requirements).

22. *See* Ark. Geological Survey, *General Information*, http://www.geology.ar.gov/energy/natural_gas.htm (noting that "[a]pproximately 2.5 million acres have been leased in the Fayetteville Shale gas play" and providing production numbers).

23. *Natural Gas Drilling: Public Health and Environmental Impacts: Hearing Before the S. Comm. on Envtl. and Pub. Works*, 112th Cong. 1 (2011) [hereinafter *Neslin Testimony*] (testimony of David Neslin, Dir., Colo, Oil and Gas Conserv. Comm'n), http://cogcc.state.co.us/Announcements/Hot_Topics/Hydraulic_Fracturing/Director_Neslin_Senate_Testimony_041211.pdf (explaining that most of Colorado's 44,000 active gas wells are hydraulically fractured).

24. La. Dep't of Nat. Res., *Haynesville Shale Gas Play Well Activity Map*, http://dnr.louisiana.gov/assets/OC/haynesville_shale/haynesville_20111027.pdf (last visited Nov. 23, 2011) (showing 1,591 producing wells in the Haynesville Shale).

25. Mich. Pub. Serv. Comm'n, Dep't of Licensing and Regulatory Affairs, *About Michigan's Natural Gas Industry: Exploration and Production*, *http://www.dleg.state.mi.us/mpsc/gas/about1.htm* (last visited Nov. 12, 2011) (describing approximately 9,700 wells producing gas in the Antrim Shale in 2010, but explaining that production peaked in 1993).

Dakota,[26] Texas,[27] and many other states have similarly forged ahead with drilling and fracturing.

While this rush of activity continues, the debate has tended to focus on whether or not the injection of water and chemicals underground—the only stage of the process that is technically described as "fracturing"[28]—pollutes groundwater.[29] Yet injection represents only a small part of a multi-stage well development process,[30] and this narrow focus is unproductive. Fracking would not occur without many other essential well development steps, including constructing a well pad and access road, drilling and casing (lining) a well, and storing and disposing of drilling and fracturing wastes, among many other steps.[31] Investigating the more complete life cycle of a drilled and fractured well reveals certain risks that have received insufficient attention, such as potential surface or underground water contamination from chemical spills and improper waste storage and disposal, methane contamination of underground water supplies from drilling that precedes fracturing, and higher quantities of water use.[32]

26. AM. PETROL. INST., STRATEGIC ENERGY RESOURCES: BAKKEN SHALE, NORTH DAKOTA (Winter 2008), http://www.api.org/~/media/Files/Policy/Exploration/Energy-Resources/StrategicEnergyResources-BakkenShale.pdf (describing how hydraulic fracturing has enabled production from the Bakken and noting that there are "nearly 4,000 active oil wells in North Dakota").

27. *See* NEWARK, EAST (BARNETT SHALE) FIELD, *supra* note 6.

28. *See* Jennifer L. Miskimins, Jeff Johnson & Mark Turner, *The Technical Aspects of Hydraulic Fracturing*, ROCKY MTN. MIN. L. FOUND, no. 5, 2011, at 1-2 (describing fracturing as including injection of a fluid "pad," followed by slurry injection of water and proppants (such as sand) to prop open fractures and allow gas to flow, a stage that allows the fractures to close back around the proppant, and flow back of the fracturing fluids).

29. *See infra* notes 35–39 and accompanying text (describing congressionally-mandated EPA studies and nonprofit documents addressing potential groundwater contamination).

30. For sources describing the many stages of the well development and fracturing process, see N.Y. STATE DEP'T OF ENVTL. CONSERV., REVISED DRAFT: SUPPLEMENTAL GENERIC ENVIRONMENTAL IMPACT STATEMENT ON THE OIL, GAS, AND SOLUTION MINING REGULATORY PROGRAM 5-6 to -143 (Sept. 7, 2011), http://www.dec.ny.gov/data/dmn/ rdsgeisfull0911.pdf (describing stages from land disturbance to build access roads and well pads through well plugging); HANNAH WISEMAN & FRANCIS GRADIJAN, REGULATION OF SHALE GAS DEVELOPMENT, INCLUDING HYDRAULIC FRACTURING 9–14 (Jan. 2012), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1953547 (research funded by the University of Texas Energy Institute).

31. *See* N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 30, at 5-6 to -14, 5-24 to -37, 5-118 to -134.

32. As explained, *infra*, Part I.A., describing the risks of tight oil and gas well development with slickwater fracturing is difficult in terms of defining the baselines from which comparison should occur and in defining "risk" itself.

This Article proposes to reframe the debate. In light of the states' core regulatory responsibility for controlling risk in this area, it reviews state agency enforcement activity at well sites to suggest an alternative understanding of the core risks of the well development process—which include fracturing and many other stages—and to provide a framework for effective dialogue moving forward. In investigating each potential risk, it describes how local, state, regional, and federal regulations and enforcement of these regulations have, in some cases, failed to adequately respond to the risks. Although the degree and geographic reach of the risks remains an open question requiring further, detailed study,[33] the focus in regulation and policy must immediately shift to these areas. Reviewing the environmental violations to date, existing regulatory structures, and the nascent scientific literature enables an important early understanding of how this focus must shift.

Part I describes the tendency of policymakers and regulators to focus on injection of water and chemicals down wells, which distracts from other potential risks. Part II introduces the methodology underlying this Article's preliminary identification of broader risks—beyond injection—and the adequacy of regulatory response. Part III then explores the potential risks of fracturing from a regulatory perspective and describes the regulatory responses to date, briefly suggesting how they may need to change. It looks to the new activities that fracturing introduces to the well-development process, the increase in oil and gas drilling enabled by fracturing, the violations of state environmental and oil and gas laws that have accompanied these activities, and preliminary analyses of risk by scientists and state agencies. After each core potential risk is identified, Part III also describes the regulatory responses to these risks thus far. Finally, Part IV begins to explore how these responses may

33. *See, e.g.*, U.S. GOV'T. ACCOUNTABILITY OFFICE, GAO-12-732, INFORMATION ON SHALE RESOURCES, DEVELOPMENT, AND ENVIRONMENTAL AND PUBLIC HEALTH RISKS 4 (2012), http://www.gao.gov/assets/650/647791.pdf (concluding that "[t]he risks identified in the studies and publications we reviewed cannot, at present, be quantified"); Stephen G. Osborn et al., *Methane Contamination of Drinking Water Accompanying Gas-Well Drilling and Hydraulic Fracturing*, PROCEEDINGS OF THE NATL. ACAD. OF SCI. (May 9, 2011), *available at* http://www.pnas.org/content/early/2011/05/02/1100682108.full.pdf+html (describing potential causes of methane contamination in groundwater wells in Pennsylvania near Marcellus wells but concluding that further research is needed to fully identify the pathways).

need to change and, very briefly, at what level of governance the changes may need to occur.

Drilling and hydraulic fracturing of unconventional wells will likely continue to be a common technique within oil and gas development through the foreseeable future. Regulatory agencies cannot afford to ignore the risks of fracturing and the many well-development stages that both precede and follow it. The practice is so economically important in part because it can be profitably employed across large swaths of the United States, including highly populated areas.[34] For the same reason, the potential for environmental harm is not limited to a few isolated regions of the country. Crafting regulations that will allow industry, states, and communities to reap the benefits of enhanced natural gas extraction while minimizing the potential for environmental damage is, therefore, crucially important.

I. THE NARROW FOCUS ON FRACTURING (INJECTION) AND GROUNDWATER

As policymakers, agencies, scientists, industrial actors, and citizens' groups spar over the risks of tight oil and gas development and needed regulatory change, the focus on the injection portion of the development process is pervasive. Questions of whether fracturing will pollute underground water sources dominate the only complete Environmental Protection Agency ("EPA") study that has addressed fracturing—a controversial 2004 report that concluded that contamination was not a concern and that further study was unnecessary.[35] A second, in-progress study of fracturing in shales also prioritizes concerns about drinking water contamination from fracturing because a House of Representatives Committee proposed this focus,[36] although the

34. *See, e.g.*, City of Fort Worth, *Gas Wells, Applications and Permits*, http://fortworthtexas.gov/gaswells/default.aspx?id=50608 (showing 1,483 gas wells in Fort Worth, Texas, which include "pre-existing" wells, and showing an additional 526 permitted wells in the city).

35. U.S. ENVTL. PROT. AGENCY, EPA 816-R-04-003, EVALUATION OF IMPACTS TO UNDERGROUND SOURCES OF DRINKING WATER BY HYDRAULIC FRACTURING OF COALBED METHANE RESERVOIRS 7–5 (2004), *available at* water.epa.gov/type/groundwater/ uic/upload/completestudy.zip.

36. U.S. ENVTL. PROT. AGENCY, SCOPING MATERIALS FOR INITIAL DESIGN OF EPA RESEARCH STUDY ON POTENTIAL RELATIONSHIPS BETWEEN HYDRAULIC FRACTURING AND DRINKING WATER RESOURCES 2 (2010), http://yosemite.epa.gov/sab/sabproduct.nsf/0/3B745430D624ED3B852576D400514B76/$File/Hydrauli

EPA has promised to address broader questions, such as surface water use and the risks of surface spills.[37] The Oil and Gas Accountability Project of Earthworks similarly highlights water contamination concerns,[38] and the Natural Resources Defense Council maintains a running list of potential groundwater contamination incidents linked to drilling and fracturing.[39]

Responding to these concerns, many state officials, too, have focused their efforts on proving that injection (fracturing) is safe and has not polluted groundwater. On May 11, 2011, the Chairman of Texas's oil and gas regulatory agency testified before Congress that "not once has Texas experienced a case of groundwater contamination caused by hydraulic fracturing" and asserted that she did "not know of a single reported case of contamination nationwide."[40] The Colorado Oil and Gas Commissioner similarly noted that most of Colorado's wells are hydraulically fractured and that the agency has "found no verified instance of hydraulic fracturing harming groundwater."[41] State regulators also have split hairs over allegations of groundwater contamination in written statements prepared for the Ground Water Protection Council (a nonprofit association of state regulators that opposes certain federal regulation of fracturing[42]), admitting that some water had been

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c+Frac+Scoping+Doc+for+SAB-3-22-10+Final.pdf (describing the budget report of the U.S. House of Representatives Appropriation Conference Committee that urged "the Agency to carry out a study on the relationship between hydraulic fracturing and drinking water"); U.S. ENVTL. PROT. AGENCY, EPA/600/R-11/122, PLAN TO STUDY THE POTENTIAL IMPACTS OF HYDRAULIC FRACTURING ON DRINKING WATER RESOURCES, at ix (2011), http://www.epa.gov/hfstudy/HF_Study__Plan_110211_FINAL_508.pdf; U.S. ENVTL. PROT. AGENCY, EPA 601/R-12/011, STUDY OF THE POTENTIAL IMPACTS OF HYDRAULIC FRACTURING ON DRINKING WATER RESOURCES: PROGRESS REPORT (2012), http://www.epa.gov/hfstudy/pdfs/hf-report20121214.pdf (showing initial results of the study in a progress report).

37. *See supra* note 36.

38. *See, e.g.*, SUMI, *supra* note 17.

39. Mall*, supra* note 17.

40. *Review of Hydraulic Fracturing Technology: Hearing Before the H. Comm. on Sci., Space, and Tech.*, 112th Cong. 1 (May 11, 2011) (testimony of Elizabeth Ames Jones, Chairman, R.R. Comm'n of Tex.), http://science.house.gov/sites/republicans.science.house.gov/files/documents/hearings/Hydraulic%20Fracturing%20Written%20Testimony-Final-5-9-2011%20jones.pdf.

41. *Neslin Testimony*, *supra* note 23.

42. *Hearing Before H. Comm. on Natural Res. & Subcomm. on Energy and Mineral Res.*, 110th Cong. 2–3 (June 4, 2009) (statement of Scott Kell, President, Ground Water Prot. Council), http://www.dec.ny.gov/docs/materials_minerals_pdf/ogsgeisapp2.pdf (arguing that "state regulations are designed to provide the level of water protection needed to assure water resources remain both viable and

polluted and some homes had exploded[43] but that these were the result of poor well casing or cementing jobs, "operator negligence,"[44] the use of pits to store wastes,[45] or other events unrelated to hydraulic fracturing. These regulators concluded that "no groundwater pollution or disruption of underground sources of drinking water has been attributed to hydraulic fracturing of deep gas formations,"[46] that they had "not documented a single incident involving contamination of groundwater attributed to hydraulic fracturing,"[47] that they had "found no example of contamination of usable water where the cause was claimed to be hydraulic fracturing,"[48] and that not one water contamination case "was caused by hydraulic fracturing activity."[49] Environmental groups, in turn, have argued that these regulators too thinly parse the definition of hydraulic fracturing and that the practice has in fact caused water contamination.[50]

available" and that "[a] one-size-fits-all federal program is not the most effective way to regulate in this area").

43. Letter from Scott R. Kell, Deputy Chief, Div. of Mineral Res. Mgmt. (Ohio), to Mike Paque, Exec. Dir., Ground Water Prot. Council (May 27, 2009) [hereinafter Kell Letter], http://www.dec.ny.gov/docs/materials_minerals_pdf/ogsgeisapp2.pdf (noting that natural gas migration into aquifers and a resulting home explosion, which "significantly damaged one house," were caused by ineffective well casing, not fracturing).

44. Letter from Joseph J. Lee, Jr., Chief, Source Prot. Section, Div. of Water Use Planning, Penn. Dep't of Envtl. Prot., to Michael Paque, Exec. Dir., Ground Water Prot. Council (June 1, 2009) [hereinafter Lee Letter], http://www.dec.ny.gov/docs/materials_minerals_pdf/ogsgeisapp2.pdf.

45. Letter from Mark E. Fesmire, PE, Dir., N.M. Oil Conserv. Div., to Michael Paque, Exec. Dir., Ground Water Prot. Council (May 29, 2009) [hereinafter Fesmire Letter], http://www.dec.ny.gov/docs/materials_minerals_pdf/ogsgeisapp2.pdf ("While we do currently list approximately 421 ground water contamination cases caused by pits and approximately an equal number caused by other contamination mechanisms, we have found no example of contamination of usable water where the cause was claimed to be hydraulic fracturing.").

46. Lee Letter, *supra* note 44.

47. Kell Letter, *supra* note 43.

48. Fesmire Letter, *supra* note 45.

49. Letter from Victor G. Carillo, Chairman, R.R. Comm'n. of Tex., to Michael Paque, Exec. Dir., Ground Water Prot. Council (May 29, 2009), http://www.dec.ny.gov/docs/materials_minerals_pdf/ogsgeisapp2.pdf.

50. *See, e.g.*, Mall, *supra* note 17 (arguing that "incidents of drinking water contamination where hydraulic fracturing is considered as a suspected cause have not been sufficiently investigated"); Mike Soraghan, *Baffled About Fracking? You're Not Alone*, N.Y. TIMES, May 13, 2011, *available at* http://www.nytimes.com/gwire/2011/05/13/13greenwire-baffled-about-fracking-youre-not-alone-44383.html?pagewanted=all (quoting Josh Fox, director of the *Gasland* documentary: "When they [industry officials] confine their definition to the single moment of the underground fracturing—a part of the process that has never been investigated—they can legally deny the obvious," but noting that methane contamination likely

Despite regulators' assurances that fracturing is safe, groundwater contamination concerns associated with injection are important issues that must not be ignored as fracturing rapidly expands. Indeed, one incident in Wyoming in a relatively shallow shale[51] suggests that injection may potentially have contributed to water contamination, although investigations of the cause of contamination continue and are hotly debated.[52] Despite the need to continue to study the risk of underground contamination from injection, the short history of widespread shale gas development suggests that other risks may be far more important. The following Part discusses my attempts to identify the risks to be prioritized and various governments' efforts to respond to these risks.

II. METHODS OF IDENTIFYING RISK AND RESPONSE

Any effort to identify the core environmental risks of shale gas development and to measure the adequacy of regulatory response is itself fraught with risk. Oil and gas drilling is a highly technical field that employs sophisticated technologies, and the industry has the most extensive and accurate knowledge of the field's intricacies. Further, the business is not comprised of one cohesive group, thus complicating the picture even more: certain firms have detailed knowledge about formulating fracturing chemicals, others conduct well drilling, and still others employ experienced engineers to guide the several stages of well perforation and injection for fracturing.[53] These knowledgeable industry actors likely have incentives to reveal only a fraction of this information, both to protect individual firm competitiveness and, in some cases, perhaps to downplay the risks.[54] Indeed, the EPA has, in some cases, had

has been caused by drilling, not fracturing).

51. *See* U.S. ENVTL. PROT. AGENCY, EPA 600/R-00/000, DRAFT, INVESTIGATION OF GROUND WATER CONTAMINATION NEAR PAVILLION, WYOMING (2011), http://www.epa.gov/region8/superfund/wy/pavillion/EPA_ReportOnPavillion_Dec-8-2011.pdf.

52. *See, e.g.*, Susan Phillips, *Chesapeake Disputes EPA's Report on Pavilion, Wyo.*, NATL. PUB. RADIO, Dec. 12, 2011, *available at* http://stateimpact.npr.org/pennsylvania/2011/12/12/chesapeake-official-disputes-epas-report-on-pavilion-wyo/.

53. *See, e.g.*, *Production Enhancement*, HALLIBURTON, http://www.halliburton.com/careers/ default.aspx?pageid=4312&navid=2013 (last visited Dec. 4, 2012) ("Production Enhancement Field Engineers oversee and execute stimulation designs and techniques . . . .").

54. *See, e.g.*, Katie Howell, *More Oversight Sought for Hydraulic Fracturing*,

to use formal requests—even subpoenas—to collect information about the chemicals used in fracturing and wastewater disposal practices associated with fractured wells.[55]

Risks also are not stagnant. As technologies and practices evolve, so too do the associated environmental concerns. Technologies associated with fracturing change quickly, with new experimental technologies for on-site waste treatment and wastewater recycling emerging daily.[56] Finally, because slickwater fracturing has only recently become a dominant practice in oil and gas, the available literature on fracturing risk is sparse.

This Part takes one step toward identifying risks through a methodology based in state administrative law: it proposes that we can paint an initial picture of risk and thus frame a policy debate by looking both to the existing literature and to violations of state oil and gas and environmental laws at oil and gas sites—particularly those with fracturing operations. This provides a concrete, albeit incomplete, view of the likely effects of drilling and fracturing, and thus, the areas that state agencies should prioritize. Section A below describes how this Article employs the term "risk" and the types of data collected to begin to identify this risk, including the limitations of these data. Section B introduces the literature and regulatory sources that show how governments have begun to respond to the effects of shale gas development.

N.Y. TIMES, Nov. 4, 2009, *available at* http://www.nytimes.com/gwire/2009/11/04/04greenwire-more-oversight-sought-for-hydraulic-fracturing-35961.html?pagewanted=all (noting that "[i]n the past, companies have been loath to disclose the components of fracturing fluids," although more companies now support disclosure). *Cf.*, Bradley C. Karkkainen, *Bottlenecks and Baselines: Tackling Information Deficits in Environmental Regulation*, 86 TEX. L. REV. 1409, 1412 (2008) ("Industries generally hold an advantage over regulators with respect to their understanding of the production processes and pollution-control technologies available to them, but arguably have a disincentive to share that information with regulatory agencies that might use it as a basis for regulation.").

55. U.S. ENVTL. PROT. AGENCY, SUBPOENA AND INFORMATION REQUEST (HALLIBURTON) (Nov. 9, 2010), http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/hydrofrac_halliburton_subpoena_11-9-2010.pdf; Press Release, U.S. Envtl. Prot. Agency, EPA Seeks More Information from Natural Gas Drilling Operations to Ensure Safety of Wastewater Disposal, (May 12, 2011), *available at* http://yosemite.epa.gov/opa/admpress.nsf/0/4816775AD0E881AB8525788E006A91ED.

56. *See, e.g.*, *CleanSuite™ Technologies*, HALLIBURTON, http://www.halliburton.com/public/projects/pubsdata/hydraulic_fracturing/CleanSuite_Technologies.html (last visited Dec. 4, 2012) (describing treatment technologies).

A. *Understanding the Risks: Definitions and Methodology*

This Article employs a broad definition of risk, describing the potential for an activity to introduce pollutants to any environmental medium, including air, water (surface or underground), or soil, as an environmental risk.[57] Other methodologies define risk more narrowly. To use contamination of environmental resources as one example, a recent study of groundwater contamination risks posed by fracturing defines contamination only as including "anything that could potentially exceed the limits of the U.S. Clean Water Act or Safe Drinking Water Act."[58] In contrast, this Article describes many incidents of pollutant releases from wells or disposal sites and associated contamination of soil, surface water, or groundwater, as posing potential risks; it does so even when information about the incident does not show whether or not the contamination exceeded environmental standards. This Article uses this broader definition only to demonstrate the *potential* for serious incidents that cause exceedances of standards to occur.

In defining risk, questions about baselines also emerge: Do we define risks as compared to a baseline of zero pollution, or simply to previous practices? This Article sets a baseline in the mid-1990s—a time before which slickwater fracturing of horizontal wells in shales and tight sands became common.[59] The Article therefore somewhat artificially draws a line separating new oil and gas practices from old ones. Broadly

57. This follows definitions from the literature and cases. *See* Talbot R. Page, *A Generic View of Toxic Chemicals and Similar Risks,* 7 ECOLOGY L.Q. 207, 207 n.1 (1978) ("'Risk' has several distinct meanings depending on its usage. In 'environmental risk,' the term draws attention to the potential adverse consequences, for which the underlying probability may be highly uncertain."); California v. Watt, 668 F.2d 1290, 1308 (D.C. Cir. 1981) (defining a risk as "exposure to the chance of injury or loss," including, for example, in the oil spill context, "both the likelihood of a spill and the amount of damage the spill would inflict").

58. Daniel J. Rozell & Sheldon J. Reaven, *Water Pollution Risk Associated with Natural Gas Extraction from the Marcellus Shale*, 32 RISK ANALYSIS 1382, 1384 (2011), http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2011.01757.x/pdf.

59. *See Water Use in the Barnett Shale*, *supra* note 6 ("In 1997, the first slick water frac (or light sand frac) was performed and found to be very successful in stimulating the Barnett Shale."); Penn. Dep't of Envtl. Prot., *Drilling For Natural Gas in the Marcellus Shale Formation: Frequently Asked Questions*, http://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/MarcellusShale/MarcellusFAQ.pdf (noting the use of horizontal drilling) [hereinafter *Marcellus Shale Formation FAQ*].

speaking, "old" oil and gas practices often involved conventional oil and gas wells and vertical unconventional wells (drilled straight down into a formation) that were fractured with gels.[60] To fracture a well with gels, an operator, after drilling a well, would inject large quantities of gel-like substances down wells. These substances fractured the formation around the well and released oil or gas; the gels then carried large quantities of proppants (sand) into the formations to prop open fractures and allow the released oil or gas to flow.[61]

The Article assumes that new oil and gas practices involve more horizontal wells (drilled straight down and then laterally underground)[62] and slickwater fracturing in shales and tight sandstone formations; it ignores production from coalbeds, which uses somewhat different technologies and presents different risks.[63] The slickwater fracturing technique applied to shales and tight sands uses different chemicals than did gel fracturing, and it uses far more water.[64] In slickwater fracturing, operators inject millions of gallons of water down a

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60. D.V. Satya Gupta & Baker Hughes, *Unconventional Fracturing Fluids* 22, 23, *in* ENVTL. PROT. AGENCY, PROC. OF THE TECHNICAL WORKSHOPS FOR THE HYDRAULIC FRACTURING STUDY: CHEMICAL & ANALYTICAL METHODS (2011), http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/proceedingsofhfchemanalmethodsfinalmay2011.pdf (comparing conventional fracturing fluids with unconventional ones, including "non-polymer-containing fluids," and noting that "[a]s the industry moves to extracting gas from tighter and tighter formations, particularly formations such as shales or coalbeds . . ., fluids that are non-damaging to the proppant pack and formation are becoming increasingly important"); Jay A. Rushing & Richard B. Sullivan, *Improved Water-Frac Increases Production*, EXPLORATION & PROD. MAG. (Oct. 12, 2007), http://www.epmag.com/archives/ features/661.htm (describing "large conventional gel treatments commonly employed during the 1980s"); Sun et al., *supra* note 7, at 1–2 (describing old treatments in which cross-linked polymer solutions were needed to carry large quantities of proppant into the formation).

61. Rushing & Sullivan, *supra* note 60.

62. *See, e.g.*, *Marcellus Shale Formation FAQ*, *supra* note 59, at 1 ("Extracting natural gas from the Marcellus Shale formation requires horizontal drilling.").

63. *See infra* note 118 (describing coalbed methane technologies and chemicals).

64. *See* Rushing & Sullivan, *supra* note 60 (describing the larger quantities of water used); Gupta & Hughes, *supra* note 60, at 22–23 (2011) (describing the new chemicals needed for fracturing, particularly slickwater fracturing in shales and coalbeds); Bill Chase et al., *Clear Fracturing Fluids for Increased Well Productivity*, OILFIELD REV., Autumn 1997, at 20–21, http://www.slb.com/~/media/Files/resources/oilfield_review/ors97/aut97/clearfluids.pdf (describing new "polymer-free fracturing fluids"); N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 6-15 ("The total amount of fracturing additives and water used in hydraulic fracturing of horizontal wells is considerably larger than for traditional vertical wells.").

well at high pressure.[65] When forced out of the wellbore far underground, the water fractures the shale. The water contains some chemicals to reduce the friction caused by water flowing down the wellbore and also to carry proppants into the shale.[66]

These assumptions regarding new and old practices in oil and gas production and the associated current risks, as compared to old ones, are gross generalizations. In many shales and tight sands, fracturing treatments employ a hybrid of old fracturing technologies, which used large quantities of gel, and new fracturing technologies, which use more water.[67] In other shales and tight sands, operators use more traditional gel or hybrid gel and water treatments.[68] And not all wells in shales and tight sands are drilled horizontally.[69]

Despite these gross generalizations, the combination of horizontal drilling and slickwater fracturing has enabled the development of thousands of new wells that otherwise would not have been drilled—thus substantially expanding the scale of oil and gas development in the United States and the associated cumulative environmental effects. Both horizontal drilling and slickwater fracturing, however, do reduce certain environmental effects, at least on an individual well basis. Horizontal drilling allows operators to avoid sensitive surface areas because they can drill a well thousands of feet from the target underground formation and then drill laterally, underground, to the target.[70] For any given quantity of oil or gas produced, this drilling practice also generates less waste[71] than would have been generated by the large number of vertical wells required to produce that quantity of oil or gas. And although slickwater fracturing greatly increases the

65. Miskimins et al., *supra* note 28.

66. Sun et al., *supra* note 7, at 1–2.

67. *See* Rushing & Sullivan, *supra* note 60 ("Hybrid water fracs still use water to generate fracture width and length while keeping net pressures low. Following creation of fracture geometry, gels with relatively low guar concentrations are used to transport proppant down the fracture.").

68. *See, e.g.*, HALLIBURTON, U.S. SHALE GAS, *supra* note 2, at 4 (noting a hybrid gelled water frac used in the Bakken because of "more traditional frac geometries").

69. *See* J. DANIEL ARTHUR ET AL., HYDRAULIC FRACTURING CONSIDERATIONS FOR NATURAL GAS WELLS OF THE MARCELLUS SHALE (2008), http://www.dec.ny.gov/docs/materials_minerals_pdf/GWPCMarcellus.pdf.

70. U.S. DEP'T OF ENERGY, OFFICE OF FOSSIL ENERGY, DOE-FE-0385, ENVIRONMENTAL BENEFITS OF ADVANCED OIL AND GAS EXPLORATION AND PRODUCTION TECHNOLOGY 36 (1999), http://www.fe.doe.gov/programs/oilgas/publications/environ_benefits/env_benefits.pdf.

71. *Id.*

amount of water used at each well—as compared to drilling of conventional wells and earlier fracturing techniques[72]—in some cases, it uses less toxic chemicals than did earlier types of fracturing.[73] It is not clear whether, on net, the negative environmental effects of the massive increase in well numbers enabled by horizontal drilling and slickwater fracturing outweigh the efficiencies and benefits that these technologies have introduced on an individual well basis. This is an important question to be further explored.[74]

One way of identifying potential environmental effects—with the above definitional limitations in mind—is to explore recent violations of environmental regulations and oil and gas, which are primarily aimed at limiting environmental risk. Understanding violations of these regulations can highlight the problems caused by drilling and fracturing so far and thus, potentially, the most prevalent risks. As described in more detail below, with the valuable help of research assistants, I collected information on recent violations of state environmental regulations at oil and gas sites—most of which also hosted fracturing activity—to paint a more concrete picture of risk. Air emissions from drilling and fracturing;[75] soil erosion from well sites;[76] soil compaction and road damage;[77] surface spills of chemicals and wastes;[78] leaking disposal wells[79] and discharge of improperly-treated wastes;[80] methane that migrates from wells into soil, water, and basements; and improper well casing (which could contribute to future underground methane leakage)[81] all count as risks within this

72. *See supra* sources cited in note 64 and accompanying text.

73. Ricky McCurdy, *High Rate Hydraulic Fracturing Additives in Non-Marcellus Unconventional Shales*, *in* U.S. ENVTL. PROT. AGENCY, EPA 600/R-11/066, PROCEEDINGS OF THE TECHNICAL WORKSHOPS FOR THE HYDRAULIC FRACTURING STUDY: CHEMICAL & ANALYTICAL METHODS 17, 21 (2011), http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/proceedingsofhfchemanalmethodsfinalmay2011.pdf.

74. One of my forthcoming pieces will explore this phenomenon, which itself may be a new risk. The simple expansion of well numbers could cause threshold effects, linear expansions of harms that are not adequately enforced, and unevenly distributed effects. *See* Hannah J. Wiseman, *Regulating Regulatory Diseconomies of Scale in Administrative Law* (draft on file with author).

75. *See infra* notes 462–464 and accompanying text.

76. *See infra* notes 402–406 and accompanying text.

77. *See supra* note 10.

78. *See infra* note 443 and accompanying text.

79. *See infra* note 384 and accompanying text.

80. *See infra* notes 230–232 and accompanying text.

81. *See infra* notes 308–314 and accompanying text.

framework. These risks vary substantially in magnitude, however. A spill of thousands of gallons of an undiluted toxic substance that migrates to a stream tributary will pose a much higher risk than, say, a small amount of soil erosion from a well site. I attempted to account for this variance by categorizing the data along a spectrum of incidents that appeared to have no environmental effects to those that may have caused major impacts.

I collected much of the regulatory data analyzed in this Article through a project funded by the Energy Institute at the University of Texas. Using public records requests and reviews of state regulatory databases, my research assistants and I located regulations, violations, and alleged violations of environmental and oil and gas regulations in several states with a recent uptick in fracturing activity or with impending fracturing development. The violations that we collected included both notices of violation issued by inspectors—which are only "alleged" or "informal" violations[82]—as well as confirmed violations that led to various formal enforcement actions, including, for example, settlements, administrative orders, penalties and fines, and orders to remediate sites or take other action. The violation data that we obtained had several limitations, as discussed below.

My research assistants and I requested violation and enforcement data from fifteen states but received only eight responses that allowed for meaningful review.[83] Information

82. We collected this broad range of violation data because states have a variety of approaches to violations and enforcements. *See, e.g.*, 2 COLO. CODE REGS. § 404-1:522(a) (2012) (explaining how potential enforcement actions are initiated, how inspectors may either "cause the operator to voluntarily remedy the violation" or "issue an NOAV [Notice of Alleged Violation] to the operator," which triggers the enforcement process, and that operators can halt the NOAV process by showing that no violation has occurred or by entering into a written agreement with the Director of the Colorado Oil and Gas Conservation Commission); *Oil and Gas Regulatory Enforcement*, OHIO DEP'T. OF NAT. RES. (July 9, 2012), http://ohiodnr.com/mineral/enforcement/tabid/17872/Default.aspx ("The division generally maintains a standard operating procedure of escalating enforcement measures from informal to formal, depending upon the nature of the violation."); *Oil & Gas Industry: Compliance & Enforcement Policies and Procedures*, MICH. DEP'T. OF ENVTL. QUALITY, http://www.michigan.gov/documents/deq/ogs-compliance-factsheet_262981_7.pdf (noting that voluntary compliance with a notice of violation allows an operator to avoid a formal Opportunity to Show Compliance (OPTSC) meeting).

83. My research assistants and I sent inquiries to Arkansas, Colorado, Louisiana, Maryland, Michigan, Montana, New Mexico, North Dakota, Ohio, Oklahoma, Pennsylvania, Texas, West Virginia, and Wyoming. The eight states for which we obtained usable data were Colorado, Louisiana, Michigan, New

from four of these states is described in detail in this Article,[84] with several additional states providing anecdotal evidence. Of the states described here, the records of violations and enforcement actions taken—such as agreed compliance orders, issuance of penalties, or mandatory remediation—provide varying degrees of detail. Some include the type of substance involved and the environmental resource affected, while others only offer a cursory account of the activity leading to a violation, such as a failure to plug a well.

The violation data that we identified was not comprehensive, and in some cases may have included a small number of wells that were not fractured. Many states do not directly track whether wells are fractured; as a proxy, in response to our data requests, these states identified violations from wells in counties overlying shale gas and tight sands formations or wells identified as producing from these formations, which require fracturing for economic production.[85]

Mexico, Ohio, Pennsylvania, Texas, and Wyoming. Of the eight states for which we have usable data, I am continuing to characterize and sort the voluminous violation data from Colorado, Ohio, and Pennsylvania, and therefore only use violations from these states as examples of incidents that can occur at shale gas and tight sands sites. At the time of data collection, Wyoming had experienced a very limited number of incidents at its twenty-five unconventional wells in the Niobrara shale and the tight oil sands of the Sussex, Parkman, Turner, and Frontier formations, and none resulted in fines or penalties. One involved an oil spill that was "contained, remediated, and reclaimed," and others involved complaints about ground disturbance from seismic testing and the flaring of gas, which were addressed on site without rule violations. E-mail from Thomas E. Doll, P.E., State Oil and Gas Supervisor, Wyoming Oil and Gas Conservation Commission, to Jeremy Schepers (June 21, 2011) (on file with author). Of the remaining seven states, Maryland and New York have no meaningful violation data because no high-volume (slickwater) fracturing has yet occurred there. *See Marcellus Shale*, N.Y. ST. DEP'T OF ENVTL. CONSERV., http://www.dec.ny.gov/energy/46288.html (last visited Nov. 26, 2012) (explaining that while the Department completes its environmental review of high-volume fracturing, applications to drill and fracture may only be approved after case-specific review); Telephone Interview by Matthew Pena with Wes McBride, Engineer, Md. Dep't of Env't, Mining Program (July 15, 2011) (explaining that no wells have yet been permitted). We did not successfully obtain data from Montana, North Dakota, or Oklahoma. Finally, the summary data of West Virginia violations that I received from a research assistant requires further review and verification.

84. The data from Colorado, Ohio, and Pennsylvania are extensive and require further analysis; enforcements from these states are discussed only anecdotally in this paper. Data from West Virginia and Wyoming are excluded because of the small size of the data sets obtained. Data from Louisiana, Michigan, New Mexico (fractured tight sands), and Texas form the bulk of this paper.

85. Miskimins et al., *supra* note 28 (noting that fracturing is "[r]equired for unconventional reservoirs").

It is likely that a small number of the violations identified occurred at wells that were not fractured.[86] Further, we did not locate all of the violations at shale and tight sands well sites in each state. Some states, such as Texas, only provided violations that led to administrative orders and/or penalties, which may omit violations that were noted but resulted in less formal (or no) enforcement action. Although the chief geologist at Texas's Railroad Commission describes the data that she provided to me as a comprehensive set,[87] inspectors there sometimes also note minor issues at fractured sites, and this information was unavailable.[88] Further, for New Mexico, we were unable to identify all violations—even those that resulted in formal enforcement action. Because we located many of the New Mexico violations from that state's spills database, the violation data there tend to be skewed toward spills. Table 1 summarizes the types of wells for which we obtained violation data in each of the states.

Table 1. Violation data: Types of wells studied

State	Well Types
Louisiana	Haynesville Shale wells[89]
Michigan	Antrim Shale wells
New Mexico	Shale and tight sands wells (not comprehensive)
Pennsylvania[90]	Marcellus Shale wells
Texas	Barnett Shale wells ("formal" enforcements only)

86. For the states for which I have not yet analyzed comprehensive violations, I use violations as anecdotal evidence. Pennsylvania and Ohio incidents described in this paper are incidents at shale wells that were fractured, unless otherwise indicated. Wyoming incidents described also include incidents at shale sites only. *See* E-mail from Jeremy Schepers to Hannah Wiseman (Sept. 12, 2011, 8:07 PM) (on file with author). Michigan data include only Antrim shale wells—most of which likely were fractured—and New Mexico data include only shale and tight sand wells. *See id*. Texas data include only fractured shale wells. *See* E-mail from Leslie Savage, Chief Geologist, R.R. Comm'n of Tex., to Hannah Wiseman (Feb. 27, 2012, 9:01 AM) (on file with author).

87. E-mail from Leslie Savage to Hannah Wiseman (Feb. 27, 2012, 9:01 AM) (on file with author) (noting that "[t]he information should be comprehensive" for 2008–2011).

88. *See id*.

89. E-mail from John Adams, Louisiana Dep't of Nat. Res., to Molly Wurzer (Sept. 28, 2011, 8:14 AM) (on file with author) (noting that "shale gas wells" is not a field in Louisiana's enforcement database and therefore tallying the inspections that occurred at Haynesville Shale wells).

90. Violations used for anecdotal purposes only; not fully categorized for this Article.

Just as some of the violation data described in Part II is from an incomplete set of violations, the time periods for which we collected violations vary.[91] Some states were willing to provide violation data over a longer period than were others, and some states have experienced substantial hydraulic fracturing activity for a longer time period than have others. In certain cases, violation data were therefore only available for three to four years, regardless of a state agency's willingness to provide data. The time periods of the data collected are summarized in Table 2.

Table 2. Violation data: Time periods studied

State	Time period
Louisiana	2008–2011[92]
Michigan	1999–2011
New Mexico	2000–2011
Pennsylvania[93]	2008–2011
Texas	2007–2011

Due to the varied time periods and the lack of comprehensive enforcement data in some states, the examples of violations described in this Article should be viewed as examples only—not as full accounts of incidents at shale and tight sands well sites.

From the data that my research assistants and I obtained, I roughly characterized each type of violation by the magnitude of risk that likely attached to it, relying on the type of substance causing a violation, the quantity of substance, the environmental resource affected, and the seriousness of the violation's remedy, such as a requirement that the operator pay a large penalty or remediate the site. I used five categories of violations of state environmental laws, ranging from procedural to major violations, as described in Table 3.[94] These

91. Note that some time periods were for fiscal years rather than calendar years. *See, e.g.*, *id.*

92. Through July 14, 2011. E-mail from Molly Wurzer to Hannah Wiseman (Apr. 8, 2012, 7:55 PM) (on file with author).

93. Violations used for anecdotal purposes only; not fully categorized for this Article.

94. For additional description of the categories and the types of incidents that I placed within these categories, see HANNAH WISEMAN, STATE ENFORCEMENT OF SHALE GAS DEVELOPMENT REGULATIONS 25 (funded by Univ. of Tex. at Austin

categorizations do not fully capture the seriousness of violations; the impact of substances spilled, for example, likely varied depending on the exact type of soil or water affected. Accurately judging the magnitude of various incidents would require careful scientific and economic analysis. Further, the examples of violations described in Part III of this Article tend to be those that were categorized as "substantial" or "major." I use the most serious violations to highlight the worst-case scenarios, but this threatens to skew the impression of risk. The reader should be aware that a large percentage of the total violations identified in each state studied were minor under my rough characterizations of the magnitude of risk, as described in Table 3.

Table 3. Likely magnitude of violations identified[95]

State	Procedural[96]	Minor–no effect:[97]	Minor[98]	Substantial[99]	Major[100]
Louisiana	46%	31%	5%	18%	1%
Michigan	33%	28%	24%	15%	0%
New Mexico	26%	1%	20%	42%	12%
Texas	36%	0%	23%	37%	5%

Finally, the violations that we identified tended to be from shales and tight sands only and tended to involve natural gas. This Article therefore does not fully address the risks of shale oil development, which tend to be similar due to the similar slickwater fracturing process used, and it entirely omits the risks of other types of unconventional development that uses fracturing, including coalbed methane development. When this Article uses the term "shale gas," it refers generally to development in both shales and tight sands. More work is needed in order to collect additional data from comparable time periods; better understand the importance of each risk;

Energy Inst., Fla. St. U. C. of L., Pub. Law Research Paper No. 581, 2011), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1992064.

95. *See id*. at 25.

96. For example, failure to post a sign or obtain permit; environmental effects unknown.

97. Meaning no environmental resource apparently affected.

98. Meaning apparently minor effects on environmental resource.

99. Meaning possibly had relatively large effects (e.g., spills of a medium size on site).

100. Meaning possibly had substantial effects (e.g., spills that migrated off site)

measure the magnitude of environmental harm, if any, caused by various violations; and identify other risks that may be omitted here. Despite these many limitations, this Article aims to redirect the policy and regulatory focus on tight gas by providing an initial account of likely risks based on the existing, albeit limited, data.

B. *Response Sources: Legislation, Regulation, Environmental Review, and Industry Practices*

The "responses" to risk explored in Part III include both existing laws and regulations—written before slickwater fracturing was common—and recent modifications and additions that recognize and respond to the rise of drilling and fracturing. In many cases, agencies have attempted to fit fracturing within old statutes and regulations (described generally as "regulations" throughout the article), which do not address many of the well development changes introduced by fracturing.[101] Existing regulations, therefore, frequently apply only marginally to these practices, but they nonetheless count as responses to fracturing risk, even if these responses force square pegs into round holes. In other cases, the federal government, states, regional compact commissions, and municipalities have developed new controls for oil and gas development and fracturing or have extensively changed existing ones, thus engaging in a more direct response.[102]

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101. *See, e.g.*, 16 TEX. ADMIN. CODE § 3.8(d)(4) (2012) (in its regulations with respect to pits for waste and drilling materials, failing to describe which regulations apply to pits with fracturing materials and wastes); OKLA. ADMIN. CODE § 165:10-3-10(c) (2012) (only describing portions of the existing code that apply to fracturing). *But see* OKLA. ADMIN. CODE 165:10-3-10(a) (2012) (generally prohibiting the pollution of water during fracturing); OKLA. ADMIN. CODE § 165:10-3-10 (Westlaw 2012) (effective July 2012), http://www.occeweb.com/rules/Web%20Ready%20Ch10%20FY13%2007-01-12%20searchable.pdf (requiring disclosure of chemicals); ST. REV. OF OIL & NAT. GAS ENVTL. REGS. (STRONGER), OKLAHOMA HYDRAULIC FRACTURING STATE REVIEW 4 (2011), http://www.strongerinc.org/documents/Final%20Report%20of%20OK%20HF%20Review%201-19-2011.pdf (noting that Oklahoma includes hydraulic fracturing in a five-year "strategic review" of its regulatory program); Memorandum from Cristina Self, R.R. Comm'n. of Tex., Off. General Counsel, Att'y to Barry T. Smitherman, R.R. Comm'n. of Tex., Off. General Counsel, Chairman (July 17, 2012), http://www.rrc.state.tx.us/rules/prop-amend-3-13-Aug21-2012.PDF (proposing amendments to 16 Tex. Admin. Code § 3.13 regarding new casing and blowout prevention requirements).

102. *See, e.g.*, COLO. DEP'T OF NAT. RESOURCES, OIL & GAS CONSERV. COMM'N, http://cogcc.state.co.us/ (last visited Nov. 26, 2012) (follow "Rules" hyperlink in blue menu to the left of the page, then follow "2008 Rulemaking" hyperlink, then

The descriptions of regulatory responses in this Article rely in part on regulatory information from an earlier study,[103] which the University of Texas Energy Institute also funded. In that study, I identified laws and regulations governing all stages of the shale gas or tight sands fracturing process through a comprehensive Lexis and Westlaw review of state administrative codes and oil and gas statutes, searches of state oil and gas and environmental agency websites, and a literature review. Part III discusses regulations that have emerged since that study, agency directives, voluntary industry responses such as disclosure of fracturing chemicals, and other less formal efforts to respond to the risks identified.

III. UNDERSTANDING RISK AND RESPONSE

As described in Part II, although fracturing is an old practice,[104] it is distinctly new in two important ways. First, the specific practice of slickwater hydraulic fracturing has introduced new processes to old fracturing techniques.[105] Higher water use in fracturing requires, for example, larger water withdrawals[106] and more truck trips carrying water (if water is not piped in) and chemicals to the site.[107] Second, slickwater fracturing has enabled the development of

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follow "COGCC Amended Rules Redline") (showing revisions to most portions of Colorado's oil and gas regulations); H.B. 1950 2011 Gen. Assemb., Reg. Sess. (Pa. 2011), *available at* http://www.legis.state.pa.us/cfdocs/billInfo/billInfo.cfm?sYear=2011&sInd=0&body=H&type=B&bn=1950 (updating many regulations and adding more stringent requirements for many unconventional (Marcellus) wells, but further preempting local regulation (note that this Act is commonly referred to as Act 13)); H.B. 401, 2011 Leg., 4th Spec. Sess. (W. Va. 2011), *available at* http://www.legis.state.wv.us/Bill_Text_HTML/2011_SESSIONS/4X/Bills/hb401%20enr.htm (adding W. VA. CODE 22-6-2a).

103. *See* WISEMAN & GRADIJAN, *supra* note 31.

104. *See, e.g.*, Coastal Oil & Gas Corp. v. Garza Energy Trust, 268 S.W.3d. 1, 7 (Tex. 2008) (noting that fracking was "[f]irst used commercially in 1949"); Miskimins et al., *supra* note 28, (noting that "[i]n 1947, the first intentional fracture treatment took place in the Hugoton gas field of western Kansas" and "was called . . . a 'hydrofrac'").

105. *See supra* notes 64–66 and accompanying text.

106. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 5-93 to -94 (estimating that between 2.4 and 7.8 million gallons are required for each hydraulic fracturing treatment of a 4,000-foot horizontal well).

107. U.S. DEP'T OF INTERIOR, NAT'L PARK SERVICE, POTENTIAL DEVELOPMENT OF THE NATURAL GAS RESOURCES IN THE MARCELLUS SHALE 9 (2008), http://www.eesi.psu.edu/news_events/EarthTalks/2009Spring/materials2009spr/NatParkService-GRD-M-Shale_12-11-2008_view.pdf (estimating that "100 to 1,000 truckloads" are required for "Fracture Stimulation Fluids and Materials" and "100 to 150 truckloads" are required for "Fracture Stimulation Equipment").

thousands of new oil and gas wells in the United States.[108] This expands the magnitude of the long-known risks of drilling, such as soil erosion and improper casing (lining) of wells to prevent leakage of substances from wells into underground resources.[109]

This Part proposes that these two core concerns, including new stages of well development introduced by fracturing and a rise in well drilling activity, should command the most regulatory attention, and it details the specific risks underlying these concerns. Part III.A. describes the relatively new risks introduced by a higher rate of slickwater fracturing in several regions of the country, and Part III.B. focuses on the risks associated with higher drilling rates enabled by fracturing.

After describing each risk, Parts III.A. and B. discuss the responses to risks that have emerged as shale gas and tight sands development has boomed. City officials have entered into contracts with oil and gas operators to protect local roads,[110]

108. *See* R.R. COMM'N OF TEX., NEWARK EAST (BARNETT SHALE) DRILLING PERMITS ISSUED (1993–2010) (on file with author) (showing 3,643 drilling permits issued in 2007, 4,145 in 2008, 1,755 in 2009, and 2,157 in 2010 in the Barnett Shale of Texas—a formation that requires fracturing to be economically developed); U.S. ENVTL. PROT. AGENCY, PROPOSED AMENDMENTS TO AIR REGULATIONS FOR THE OIL AND NATURAL GAS INDUSTRY: FACT SHEET 2, http://epa.gov/airquality/oilandgas/pdfs/20110728factsheet.pdf (last visited Nov. 26, 2012) ("11,400 new wells are fractured each year; another 14,000 are refractured . . . ."). This appears to refer only to shale wells, as in some areas, 95 percent of all wells are fractured, and each of these areas has thousands of wells. Miskimins et al., *supra* note 28; Penn. Dep't of Envtl. Prot., Bureau of Oil and Gas Mgmt., *2011 Wells Drilled January–November*, http://www.dep.state.pa.us/dep/deputate/minres/oilgas/2011%20Wells%20Drilled.gif (last updated Dec. 5, 2011) (showing 1,751 Marcellus Shale wells drilled in Pennsylvania); NEWARK, EAST (BARNETT SHALE) FIELD*, supra* note 6 (although not all permits issued result in drilling and fracturing, 1,231 permits were issued for Barnett Shale wells from January 2011 through December 2011).

109. *See, e.g*., Regulatory Determination for Oil and Gas and Geothermal Exploration, Development and Production Rates, 53 Fed. Reg. 25446, 25446 (July 6, 1988), http://epa.gov/osw/nonhaz/industrial/special/oil/og88wp.pdf (summarizing damage associated with the handling and disposal of oil and gas wastes and state regulatory gaps); Tribal Energy and Envtl. Info. Clearinghouse, *Oil and Gas Drilling/Development Impacts*, http://teeic.anl.gov/er/oilgas/impact/drilldev/index.cfm (last visited Dec. 22, 2012) (noting that "[v]egetation and topsoil would be removed" for access roads and describing other access road impacts); *id*. (noting the "potential for increased erosion" as a result of well pad development); *id*. (noting the risk of improper handling and releases "to the environment"). *Cf.* Rozell & Reaven, *supra* note 58, at 1386–87 (describing methods of estimating well casing failure rates).

110. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-142 to -143 (noting that "[m]unicipalities may require trucks transporting hazardous materials to travel on designated routes, in accordance with a road use agreement"); GROUND WATER PROT. COUNCIL, MODERN SHALE GAS

and state legislatures have required disclosure of the chemicals used in fracturing.[111] State oil and gas and environmental agencies have applied existing regulations at well sites or have updated regulations and written new ones, and regional water basin commissions have proposed more controls on fracturing.[112] In addition to initiating a study of the water quality impacts of shale gas development[113] and demanding information about wastewater management from operators,[114] the EPA has finalized new regulations under the Clean Air Act[115] and has begun to propose limited regulations in other areas.[116] As this Part discusses, although several levels of government have made progress toward addressing the risks identified here, much more effort will be required to fully address the impacts of shale gas development.

A. *New Stages of Well Development Introduced by Slickwater Fracturing*

Hydraulic fracturing of an oil or gas well has one core purpose: cracking the formation around a drilled well to

DEVELOPMENT IN THE UNITED STATES: A PRIMER 50 (Apr. 2009), http://www.netl.doe.gov/technologies/oilgas/publications/epreports/shale_gas_primer_2009.pdf (describing road use agreements).

111. 16 TEX. ADMIN. CODE § 3.29 (2012) (Hydraulic Fracturing Chemical Disclosure Requirements, adoption approved at conference, Dec. 13, 2011).

112. DEL. RIVER BASIN COMM'N, NATURAL GAS DEVELOPMENT REGULATIONS (Nov. 8, 2011), http://www.state.nj.us/drbc/library/documents/naturalgas-REVISEDdraftregs110811.pdf.

113. *See supra* note 36.

114. *See* Press Release, U.S. Envtl. Prot. Agency, EPA Seeks More Information from Natural Gas Drilling Operations to Ensure Safety of Wastewater Disposal (May 12, 2011), *available at* http://yosemite.epa.gov/opa/admpress.nsf/0/4816775AD0E881AB8525788E006A91ED.

115. Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants Reviews, 77 Fed. Reg. 49490 (Aug. 16, 2012) (to be codified at 40 C.F.R. pts. 60 & 63).

116. U.S. ENVTL. PROT. AGENCY, EPA INITIATES RULEMAKING TO SET DISCHARGE STANDARDS FOR WASTEWATER FROM SHALE GAS EXTRACTION 1 (Oct. 2011), http://water.epa.gov/scitech/wastetech/guide/upload/shalereporterfactsheet.pdf (explaining that "EPA plans to propose new standards for public comment in 2014" for wastewater from shale gas extraction); U.S. ENVTL. PROT. AGENCY, EPA 816-R-12-004, PERMITTING GUIDANCE FOR OIL AND GAS HYDRAULIC FRACTURING ACTIVITIES USING DIESEL FUELS—DRAFT: UNDERGROUND INJECTION PROGRAM GUIDANCE #84 (2012), http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/hfdieselfuelsguidance508.pdf (proposing guidelines for fracturing with diesel fuels, including information to be submitted by operators applying for Safe Drinking Water Act permits, which are required in order to fracture with diesel; definitions of the substances that include diesel; and improved casing and reporting requirements, among other protections).

increase the exposed surface area and allow fossil fuels to flow from the formation and into the well.[117] The techniques followed to achieve this goal are complex and vary substantially among wells and the formations into which wells are drilled.[118] Fracturing of coalbeds for methane has been common for several decades, inspiring a federal lawsuit,[119] a criticized EPA review,[120] and some modified state regulations.[121] But it is the more recent technique of slickwater fracturing in shales and tight sand formations[122] that has triggered a fundamental change in domestic energy, enlivening this country's economy and, in some cases, shaking its trust in domestic oil and gas development. Although experts dispute estimates of gas reserves,[123] initial production numbers suggest

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117. *See* U.S. ENVTL. PROT. AGENCY, EPA 816-R-04-003, EVALUATION OF IMPACTS TO UNDERGROUND SOURCES OF DRINKING WATER BY HYDRAULIC FRACTURING OF COALBED METHANE RESERVOIRS 3–4 (2004), *available at* http://www.water.epa.gov/type/groundwater/uic/upload/completestudy.zip.

118. *See, e.g.*, *id.* at 3–6 (describing some coalbed methane fractures that occur at depths less of less than 1,000 feet); *id.* at 3-11 (indicating that typical water volumes used in coalbed methane wells involve a "maximum average injection volume of 150,000 gal/well and a median average injection volume of 57,500 gal/well"); ALL CONSULTING & MONT. BD. OF OIL AND GAS CONSERV., COAL BED METHANE PRIMER: NEW SOURCE OF NATURAL GAS: ENVIRONMENTAL IMPLICATIONS 10 (Feb. 2004), http://www.all-llc.com/publicdownloads/CBMPRIMERFINAL.pdf ("CBM wells are typically no more than 5000 feet in depth, although some deeper wells have been drilled."); GROUND WATER PROT. COUNCIL, *supra* note 110, at 18–21 (noting that the Barnett Shale occurs at a "depth of 6,500 feet to 8,500 feet," that the Fayetteville is between 1,000 and 7,000 feet deep, the Haynesville is between 10,500 and 13,500 feet deep, and that the Marcellus occurs between 4,000 and 8,500 feet below ground).

119. Legal Envtl. Assist. Found. v. EPA, 118 F.3d 1467 (11th Cir. 1997).

120. Members of Congress and a whistleblower argued that EPA had failed to explain why it changed certain data in the report and that report peer reviewers had conflicts of interest. *See* Hannah Wiseman, *Untested Waters: The Rise of Hydraulic Fracturing in Oil and Gas Production and the Need to Revisit Regulation*, 20 FORDHAM ENVTL. L. REV. 115, 134 n.106 (2009).

121. *See, e.g.*, MONTANA DEP'T OF NAT. RESOURCES, BD. OF OIL AND GAS, FINAL COALBED METHANE ORDER FOR POWDER RIVER BASIN CONTROLLED GROUNDWATER AREA, Order No. 99-99 (Dec. 9, 1999), *available at* http://bogc.dnrc.mt.gov/CBMOrder.asp (requiring operators to "offer water mitigation agreements to owners of water wells or natural springs within one-half mile of a CBM field proposed for approval"); WYO. OIL & GAS CONSERV. COMM'N RULE 3-23(a)(i)(B) (2010), http://soswy.state.wy.us/Rules/RULES/7928.pdf ("The Supervisor, on a site specific basis, may require the use of blowout preventers or other methods of controlling shallow coalbed methane wells.").

122. *See infra* note 124.

123. *See, e.g.*, PENN. DEP'T OF ENVTL. PROT., *Marcellus Shale*, http://www.dcnr.state.pa.us/topogeo/econresource/oilandgas/marcellus/marcellus_faq/marcellus_shale/index.htm (last visited Dec. 15, 2012) (explaining that for projections of recoverable gas reserves in the Marcellus Shale, "[i]ndustrial and academic assessments vary from 50 to 500 trillion cubic feet (Tcf)"); PENN. STATE

that natural gas from shales will be the dominant source of domestic natural gas by 2035 if slickwater fracturing continues unabated.[124] Slickwater fracturing in shales, in particular, will continue to challenge U.S. environmental policy as it expands.

1. Using Some New Chemicals

Drilling a traditional oil or gas well involves several stages. An oil or gas operator constructs a well pad and a road to the pad; brings drilling rigs and other equipment to the site; pumps or trucks in water and chemicals to the site to use in drilling fluid and drilling mud (which cools the drill bit as it moves through the formation[125]); drills a vertical well and cements casing (metal tubes) into the well; stores drilling wastes on site in earthen surface pits or metal tanks; and disposes of these wastes.[126] Once the well begins producing, the operator restores most of the site and leaves small amounts of equipment at the wellhead and small oil or gas collector lines on site.[127] When gas or oil eventually stops flowing in economic quantities from the well, the operator plugs it and removes the remaining equipment.[128] Hydraulically fractured wells all require these drilling steps—which are similar to the steps that always have been required for drilling conventional wells.[129] (Hydraulically fractured wells often are deeper,[130] however,

EXTENSION, *How Much Natural Gas Can the Marcellus Shale Produce?* (Feb. 5, 2012), http://extension.psu.edu/naturalgas/news/2012/how-much-natural-gas-can-the-marcellus-shale-produce (summarizing various estimates for the Marcellus).

124. ENERGY INFO. ADMIN., *What Is Shale Gas and Why is it Important?* (Dec. 5, 2012), http://www.eia.gov/energy_in_brief/about_shale_gas.cfm (follow "Download Figure Data" under "U.S. dry natural gas production trillion cubic feet"; percentage calculations on file with author) (projecting that by 2035, 50 percent of the U.S. dry natural gas supply will come from shales, followed by tight gas at 22 percent, non-associated offshore gas (gas not tightly attached to a formation such as a coalbed or shale) at 6 percent, non-associated onshore gas at 6 percent, gas associated with oil at 5 percent, and coalbed methane at 6 percent).

125. CHESAPEAKE ENERGY, *Water Use in Deep Shale Gas Exploration* 1 (May 2012), http://www.chk.com/media/educational-library/fact-sheets/corporate/water_use_fact_sheet.pdf.

126. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 5-25 to -39.

127. *Id*. at 5-139 to -140.

128. *Id*. at 5-143 to -144.

129. *See id*. at 1-3 to -4 (describing how high-volume (slickwater) fracturing involves stages of oil and gas development already studied in a previous generic environmental impact statement but also introduces new concerns).

130. NATURAL GAS SUPPLY ASSOC., *Unconventional Natural Gas Resources*, http://www.naturalgas.org/overview/unconvent_ng_resource.asp (last visited Dec. 15, 2012).

and often use a horizontal wellbore in addition to a vertical one.[131]) The addition of slickwater fracturing to the well development process introduces several new stages: On an individual well basis—as compared to conventional wells and older fracturing techniques—slickwater fracturing requires more water and uses new chemicals.[132]

a. Risks: Chemical Spills During Transport and Transfer on Site

Slickwater hydraulic fracturing relies primarily on water[133] that is injected at high pressure down a well to fracture a formation and to carry proppant into the fractures to hold them open.[134] Chemicals, although used in much smaller quantities,[135] are also an integral part of the process. The operator trucks chemicals to a site and stores them on site in preparation for fracturing.[136] Many of the chemicals sit in large plastic tanks on the beds of trucks, and others are surrounded by thick metal "boxes."[137] After the operator drills and cases a well, she punches holes in or "perforates" small portions of the well and casing.[138] Following well perforation, she pumps acid (often hydrochloric acid) out of a storage tank and down the well.[139] This acid moves beyond the perforated portions of the well, cleaning the perforations and the shale around them and preparing the formation for fracturing.[140] The acid also can help to induce fractures.[141]

Following the acid treatment, the operator begins the

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131. *See Marcellus Shale Formation FAQ*, *supra* note 59.

132. *See supra* note 60. As noted *supra* note 73, at 21, these chemicals are sometimes less toxic than those previously used in fracturing.

133. *See* CHESAPEAKE ENERGY, *supra* note 125 (explaining that the company uses water both for drilling and fracturing and that it is "an essential component" of deep shale gas development).

134. *See* Miskimins et al., *supra* note 28 (explaining that sand is used to "[p]rop fractures open to enable gas production").

135. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 5-53 to -54; *see also* Joseph H. Frantz, Jr., *Natural Gas, Range Resources, and the Marcellus Shale*, ROCKY MTN. MIN. L. FOUND., Dec. 6-7, 2010, at 3 (estimating that chemicals comprise 0.1 percent of the mixture).

136. *See* N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 5-80.

137. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 5-80 to -82.

138. BRAD HANSEN, DEVON ENERGY CORP., CASING PERFORATING OVERVIEW, http://www.epa.gov/hfstudy/casingperforatedoverview.pdf.

139. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 5-50.

140. *Id.*

141. Author visit to Woodford Shale fracturing site, Oct. 28, 2011 (operator explained that acids can help to induce fractures).

fracture treatment, injecting water and chemicals into the well. The chemicals, which represent about 0.5 percent of the fracture solution by weight (approximately twenty-five thousand gallons if five million gallons of water are used for a fracture treatment),[142] can contain a variety of substances. Some, as industry emphasizes, are common chemicals found in cosmetics and foods.[143] Others are highly toxic.[144] A report prepared by the minority staff of the House Committee on Energy and Commerce, which surveyed fourteen hydraulic fracturing companies in the United States, noted that in a five-year period (2005–2009), these companies "used more than 2,500 hydraulic fracturing products containing 750 chemicals and other components"—a total of 780 million gallons.[145] By volume, methanol was the most common chemical used in fracturing.[146]

The effects of these many chemicals vary depending on their properties (whether they are toxic or not and, if toxic, their level of toxicity[147]), the ways that they change when introduced to environmental media (they may break down into other substances, for example, or be diluted[148]), and the routes by which humans and wildlife may be exposed to them,[149] among many other factors.[150]

Indeed, the quantity of chemicals used per fractured well appears to have declined, thus reducing certain chemical risks.[151] As more wells are fractured, however, this could introduce chemicals to new areas. As illustrated by the environmental violations that have occurred so far at unconventional wells, this poses several risks—particularly at

142. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 5-51 to -54.

143. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 5-76.

144. STAFF OF H. COMM. ON ENERGY AND COMMERCE, 112TH CONG., CHEMICALS USED IN HYDRAULIC FRACTURING 1 (Apr. 19, 2011) (describing some of the chemicals used in hydraulic fracturing as "extremely toxic").

145. *Id.* at 5.

146. *Id.* at 1.

147. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 5-75.

148. U.S. ENVTL. PROTECTION AGENCY, *supra* note 35, at 7-5.

149. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 5-75.

150. *See, e.g.*, *id.* at 5-75 (noting that fully understanding the effects of various spills would require "information specific to the event such as the specific additives being used and site-specific information about exposure pathways and environmental contaminant levels").

151. *Id.* at 5-39 (noting that a consulting company "states that the development of water fracturing technologies has reduced the quantity of chemicals required to hydraulically fracture target reservoirs").

the surface.[152]

Chemicals used in fracturing may be spilled while being transported to the site, stored on site, or transferred to water for fracturing, and these spills can have significant impacts. One university study, which explored potential water contamination from spills combined with other incidents, such as leaking wells, concluded that in the Marcellus Shale alone, these combined incidents could potentially contaminate water volumes equal to "a few thousand Olympic-sized swimming pools;"[153] the study concluded that this was a "potential substantial risk."[154] Indeed, spills—one of the potential contributors to water contamination—have been a somewhat common incident at shale gas and tight sands sites so far. In Pennsylvania in 2010 an unknown quantity of fracturing fluid was released from a trailer into a ditch,[155] and about ten barrels of fracturing fluid escaped from a surface pit that had a tear in its liner.[156] A tank with an improperly shut valve at a Marcellus site in Pennsylvania also released about five barrels of fracturing fluids onto the ground,[157] and an unnamed quantity of fracturing fluid, antifreeze, and other substances spilled at another site.[158] Another tank with a valve open released nearly 13,000 gallons (nearly 309 barrels) of frac fluid, some of which entered surface water.[159]

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152. As noted in Part I, because I was unable to obtain comprehensive information on violations in certain states, such as New Mexico, the violations involving risks posed by chemicals, such as surface spills, may represent only a portion of the actual number of incidents. The actual risks posed by the spills also differ in ways that cannot be fully identified by the information available about environmental violations. In some cases, for example, spills may have been fully recovered and cleaned up by an operator without this information being included in an agency report, thus suggesting that the spill, although sounding problematic, resulted in limited or no environmental harm. In other cases, spills of unidentified substances may be more problematic than they sound—if, for example, they entered surface waters or involved highly toxic substances.

153. Rozell & Reaven, *supra* note 58, at 1391.

154. *Id*.

155. Sullivan, violation no. 601902, 601903 (Dec. 2010), Penn. Dep't. of Envtl. Protection Prot. (no permit number noted).

156. Permit no. 015-20613, violation no. 596121, Armenia (Sept. 2010), Penn. Dep't. of Envtl. Prot.

157. Permit no. 129-28075, violation no. 588239, Fairfield (May 2010), Penn. Dep't. of Envtl. Prot.

158. Permit no. 081-20128 (Mar. 2010), Penn. Dep't. of Envtl. Prot, Lycoming (notice of violation).

159. Press Release, Penn. Dep't. of Envtl. Prot, DEP Investigating Lycoming County Fracking Fluid Spill at XTO Energy Marcellus Well (Nov. 22, 2010), *available at*, http://www.portal.state.pa.us/portal/server.pt/community/newsroom/14287?id=15315&typeid=1.

Chemicals that are transferred and stored in a relatively undiluted state likely pose the highest risk when spilled at the surface,[160] but diluted chemicals in the water that flows back up out of the well after fracturing—"flowback" water—also can pose risks when stored, transferred, and disposed of, as discussed in Part III.A.2.a, below. Governments at several levels have only responded in limited ways to the types of chemicals used in fracturing, thus shifting most of the work of limiting risk to regulations that address chemical transportation, spill prevention and response, and containment.

b. Responses: Identifying Fracturing Chemicals Used, and Employing Some New Spill Prevention and Containment Practices

Much of the policy response to fracturing has focused on obtaining information about the chemicals used. As introduced above, the House Democratic minority on the Energy Commerce Committee demanded information on chemicals used from fourteen companies,[161] and states, too, have jumped on the chemical disclosure bandwagon.[162] In further efforts to identify the chemicals used and their potential impacts, Congressman Waxman[163] has held hearings about fracturing chemicals and their toxicity,[164] several Cornell professors have expressed concerns about the toxicity of chemicals used in fracturing,[165] and a number of comments on recently proposed

160. *Cf.* N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-74 (explaining that the use of setbacks is important because it "prevents direct flow of the full, undiluted volume of a spilled contaminant into a surface water body").

161. STAFF OF H. COMM. ON ENERGY AND COMMERCE, 112TH CONG., CHEMICALS USED IN HYDRAULIC FRACTURING 1 (Apr. 19, 2011).

162. For a summary of disclosure requirements, see WISEMAN & GRADIJAN, *supra* note 31, at 86–91.

163. Congressman Henry A. Waxman, 30th Congressional District of California.

164. STAFF OF H. COMM. ON OVERSIGHT AND GOV'T REFORM, 110TH CONG., HR'G SUMMARY: HR'G ON OIL AND GAS EXEMPTIONS IN FED. ENVTL. PROTS., *available at* http://democrats.oversight.house.gov/images/stories/documents/20080602114913.pdf (last visited Dec. 28, 2012) (prepared by Committee Chairman Rep. Henry A. Waxman).

165. SUSAN RIHA ET AL., N.Y. STATE DEP'T ENVTL. CONSERV., COMMENTS ON DRAFT SGEIS ON THE OIL, GAS AND SOLUTION MINING REGULATORY PROGRAM 4, http://blogs.cornell.edu/nyswri/files/2010/01/Comments-on-draft-sGEIS-for-Marcellus-Shale.pdf (last visited Dec. 15, 2012) ("Ensuring proper well bore casing is critical to reducing exposure of fresh groundwater resources to chemicals used in drilling and fracking, as well as migration of contaminants from deeper

regulations similarly focus on the alleged potential for a toxic soup to emerge at fracturing sites.[166]

The use of chemicals in the fracturing process itself—the injection of water and chemicals at high pressure down a well—remains largely unregulated due to historic interpretations of the Safe Drinking Water Act ("SDWA") and an explicit exemption in 2005.[167] Fracturing with diesel fuel, however, is not exempt from the SDWA,[168] and the EPA has produced draft guidance directing states how to review and issue permits for fracturing that uses diesel fuel.[169] For the many wells for which diesel is not used in fracturing, states have typically not supplemented the SDWA exemption with their own limits on the types of chemicals that may be injected in order to fracture a well.[170]

The handling of chemicals is, however, regulated to varying degrees. A number of state regulations that existed prior to fracturing already require spill control and response plans and likely will cover new types of spills that occur.[171]

formations to formations containing potable groundwater."). *But see generally id.* (expressing a number of concerns beyond chemical contamination of groundwater).

166. *See, e.g.*, Mont. Dep't. of Nat. Resources, *Hydraulic Fracturing Rulemaking, Written & E-mailed Comments* (2011), http://bogc.dnrc.mt.gov/PDF/CombinedComments.pdf (showing comments such as, "I want to know what is in the chemicals as they will end up in my food and water."; "How would you like to have someone inject a variety of unknown but certain-to-be-hazardous substances into your water supply?"; "Wells have already been seriously contaminated elsewhere"; and "Please assure us that the fracking chemicals will be SAFE if they drift into the water table . . . ."); Comment submitted by Anthony Romano regarding the N.Y. State Dep't. of Envtl. Conservation Supplemental Generic Envtironmental Impact Statement for the Oil and & Gas Solution Mining Program, Oct. 28, 2009 Hearing, http://catskillcitizens.org/learnmore/romanocomments.pdf (arguing that "[s]ince the shale sits below the aquifer which provides Sullivan county residents, (who mainly rely on wells for their water) it leaves too much room for errors and contamination of our fresh water supply," but also noting other potential effects) (last visited Dec. 12, 2012).

167. 42 U.S.C. § 300h (d)(1) (2012) (exempting hydraulic fracturing from the definition of "underground injection" under the Safe Drinking Water Act, with the exception of hydraulic fracturing with diesel).

168. *Id.*

169. U.S. ENVTL. PROT. AGENCY, EPA 816-R-12-004, PERMITTING GUIDANCE FOR OIL AND GAS HYDRAULIC FRACTURING ACTIVITIES USING DIESEL FUELS—DRAFT: UNDERGROUND INJECTION PROGRAM GUIDANCE #84 (2012), http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/hfdieselfuelsguidance508.pdf.

170. *But see* IDAHO ADMIN. CODE. r. 20.07.02.056 (2012) (prohibiting certain volatile organic compound use).

171. *See* WISEMAN & GRADIJAN, *supra* note 31, at 95–96 (describing states' spill control and response plans, which require, for example, that pits must have

These apply to the handling of both fracturing and oil and gas wastes, requiring, for example, staff training, reporting procedures if spills occur, and other safety measures.[172] Transporters of chemicals also already must comply with the Department of Transportation's hazardous transport regulations, which require labeling of trucks, driver training, and minimum designs for containers and trucks that help to prevent spills during traffic accidents, among other protections.[173] Some states, however, have implemented updated transport and handling rules. New York has suggested that towns could more stringently regulate the transportation of hazardous fracturing chemicals[174] and has proposed secondary containment, such as drip pans, beneath chemical transfer operations.[175] Colorado also requires that containers storing fracturing chemicals contain safety information.[176] Several other states have updated secondary containment requirements to ensure that if tanks with chemicals spill, the chemicals will not contaminate the site or run off site.[177]

Although few regulations limit the type of chemical used, and a limited set of requirements guides the handling of chemicals, informational mandates abound. Operators under the Occupational Safety and Health Act must maintain material safety data sheets for all of the chemicals stored on site in certain threshold quantities,[178] although they may claim trade secret status for the chemicals.[179] The Emergency Planning and Community Right-to-Know Act gives the public

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containment dikes to catch spills, *see, e.g.*, MICH. ADMIN. CODE r. 324.2006 (2012), and that all materials leaked or spilled as a result of *drilling* operations be confined, *see, e.g.*, W. VA. CODE R. § 35-4-16 (2011). However, as shown by the West Virginia regulation, not all of these regulations apply directly to fracturing.).

172. *See* WISEMAN & GRADIJAN, *supra* note 31, at 95–96.

173. 49 C.F.R. §§ 17–80 (2011).

174. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-143 (noting that "[m]unicipalities may require trucks transporting hazardous materials to travel on designated routes, in accordance with a road use agreement").

175. N.Y. STATE DEP'T OF ENVTL. CONSERV., REVISED DRAFT: SUPPLEMENTAL GENERIC ENVIRONMENTAL IMPACT STATEMENT ON THE OIL, GAS, AND SOLUTION MINING REGULATORY PROGRAM 1337 app. 10 at 9 (Sept. 7, 2011), http://www.dec.ny.gov/data/dmn/rdsgeisfull0911.pdf.

176. COLO. OIL & GAS CONSERV. COMM'N RULE 210(d) (2011).

177. *See, e.g.*, COLO. OIL & GAS CONSERV. COMM'N RULE 603(e)(12) (implementing secondary containment requirements for high-density areas); 58 PA. CODE 3218.2(d) (2012), *available at* http://www.legis.state.pa.us/WU01/LI/LI/US/HTM/2012/0/0013.HTM (expanding secondary containment requirements).

178. 42 U.S.C. 11005, 11021–22 (2011).

179. 29 C.F.R. § 1910.1200(i) (2010).

only limited access to these data sheets,[180] and some states have responded to demands for better public information in a surprisingly quick fashion. Arkansas,[181] Colorado,[182] Louisiana,[183] Montana,[184] New York,[185] New Mexico,[186] North Dakota,[187] Oklahoma,[188] Pennsylvania,[189] Texas,[190] West Virginia,[191] and Wyoming,[192] among others, all require or have proposed to mandate that operators disclose to state agencies all chemicals used, and several of these states allow public access to this information.[193] All of these states allow operators to claim trade secret status for their chemicals, with limited exceptions.[194] Thus, operators can sometimes avoid granting public access to certain chemical information.

Requiring disclosure of fracturing chemicals appears to be far more palatable to legislators and agencies than imposing substantive limits on the chemicals used—particularly because the industry has partnered with state regulators to create a voluntary chemical disclosure website.[195] Disclosure is an

180. 42 U.S.C. § 11021(c)(2).

181. ARK. OIL & GAS COMM'N RULE 19(k) (2012).

182. 2 COLO. CODE REGS. § 404-1:205A (2012).

183. LA. ADMIN. CODE tit. 43:XIX.118 (2011).

184. MONT. ADMIN. R. 36.22.1015(2) (2011).

185. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-32.

186. N.M. CODE R. § 19.15.3.11 (2011).

187. N.D. ADMIN. CODE 43-02-03-27.1 (2)(i) (2012).

188. OKLA. ADMIN. CODE § 165:10-3-10(b) (2012).

189. 58 PA. STAT. ANN. § 3222(b.1)(1)(i) (2012).

190. 16 TEX. ADMIN. CODE § 3.29 (c)(2)(A)(ix),(x),(xi) (2012).

191. W. VA. CODE R. § 22-6-22 (2012).

192. WYO. OIL & GAS CONSERV. COMM'N RULE 3-45(d) (2010), http://soswy.state.wy.us/Rules/RULES/7928.pdf.

193. *See* LA. ADMIN. CODE tit. 43:XIX.118 (2011) (proposing disclosure to the Department of Natural Resources or on FracFocus); MONT. ADMIN. R. 36.22.1015(2) (2011) (requiring disclosure to the agency or on FracFocus); N.M. CODE R. § 19.15.3.11 (2011) (requiring disclosure to the agency or on the public FracFocus website); *SGEIS on the Oil, Gas, and Solution Mining Regulatory Program*, *supra* note 18 (noting that the information will be publicly available); 16 TEX. ADMIN. CODE § 3.29(c)(2) (2012) (requiring public access); Rebecca Torrellas, *Wyoming Forces Frac Fluid Disclosure*, EXPLORATION & PRODUCTION MAG. (Sept. 2, 2010), http://www.epmag.com/2010/September/item66859.php (suggesting that there will be public access in Wyoming even though only disclosure to agency is required).

194. *See* WISEMAN & GRADIJAN, *supra* note 31, at 90 (describing and citing to trade secret protections within state regulations and describing exceptions, such as requirements that health care professionals have access to chemical data); *see also* 16 TEX. ADMIN. CODE § 3.29(c)(4), (f)(1) (2012) (allowing certain parties to appeal trade secret status).

195. FRAC FOCUS CHEMICAL DISCLOSURE REGISTRY, http://fracfocus.org/ (last visited Dec. 9, 2012).

essential step. It allows the public to participate in the fracturing policy dialogue with a better understanding of the chemicals that are being transported to and stored on sites and injected into wells. It also allows agencies to formulate laws about chemical handling with better knowledge of the toxicity and quantity of the chemicals involved. Disclosure laws fail to directly address, however, whether certain fracturing chemicals should be banned or allowed only in limited quantities, and thus leave substantial holes.

2. Fracturing: Producing, Storing, and Disposing of New Waste

The use of new fracturing chemicals at well sites, in addition to raising the potential for spills and improper storage, introduces new wastes to the oil and gas production process. Traditional oil and gas wells generate a number of wastes, including drill cuttings (soil and rocks) and produced water, which comes up naturally out of a formation.[196] Depending on the nature of the formation drilled, both of these types of wastes can be "salty"[197] and sometimes have low levels of naturally occurring radioactive materials.[198] Fracturing adds a new waste to this mix. After an operator injects water and chemicals down the well and ends the fracturing treatment, some of the water-chemical mixture flows back up to the surface.[199] The operator must transfer this flowback water to a pit or a tank on the surface and then to a site for disposal.[200] Disposal of flowback water occurs in an underground injection

196. Joseph Dancy, *Solid Waste Management and Environmental Regulation of Commonly Encountered Oil Field Wastes*, 35 ROCKY MTN. MIN. L. FOUND. SPECIAL INST. 3, 13 (1994).

197. *Id.* at 5–6 ("[T]he average TDS [(total dissolved solids)] level of produced water (50,000 ppm) exceeds the solids content of seawater (approx. 34,500 ppm).").

198. R. Timothy Weston, *Water and Wastewater Issues in Conducting Operations in a Shale Play—The Appalachian Basin Experience*, *in* DEVELOPMENT ISSUES IN THE MAJOR SHALE PLAYS 34 (2010), *available at* http://www.klgates.com/publications/weston_article.

199. BARCLAY R. NICHOLSON, FRACKING: ARE THE REGULATORS COMING OR NOT? A REVIEW OF THE STATE OF THE INDUSTRY 10 (2011), http://www.fulbright.com/images/publications/20110928FrackingAretheRegulatorsComingorNot.pdf (noting that fracturing "[p]roduces large volumes of fluids called 'flowback'").

200. AM. PETROL. INST., WATER MANAGEMENT ASSOCIATED WITH HYDRAULIC FRACTURING 17–18 (2010), http://www.shalegas.energy.gov/resources/HF2_e1.pdf (noting that fluids from fracturing and other processes typically are stored in "tanks or lined surface impoundments").

control well or wastewater treatment plant, or the operator reuses the water to fracture another well.[201] The management and disposal of flowback poses several risks that regulators have not adequately addressed, as discussed in this Section. Flowback can spill on the surface while being transferred to storage. When improperly disposed of in underground injection control wells, it also can, in rare instances, create localized earthquakes and potentially contaminate underground water sources. Finally, if inadequately treated and discharged, it can contribute to surface water pollution.

a. *Risks: Surface Spills From Pits and Tanks, Inadequate Wastewater Treatment, Leaking Disposal Wells, and Earthquakes*

Flowback water, which sometimes contains benzene, toluene, xylene, and other toxic chemicals,[202] emits volatile organic compounds ("VOCs"), which have a variety of health effects.[203] Flowback water may also spill when transferred, thus potentially contaminating soils with salty water with low levels of chemicals.[204] A number of flowback spills have occurred at well sites. In Pennsylvania, an operator moving flowback from a water holding tank to a reserve pit allowed the hose to fall out of the pit, thus discharging flowback onto the site's surface.[205] Other inspections noted general releases of flowback to the ground,[206] one of which was associated with a "large area of dead" vegetation.[207] A number of violations of state environmental and oil and gas laws have also occurred as a result of storing flowback on site in pits or tanks prior to

201. *See* Dianne Rahm, *Regulating Hydraulic Fracturing in Shale Gas Plays: The Case of Texas*, 39 ENERGY POLICY 2974, 2976 (2011) (discussing disposal); WISEMAN & GRADIJAN, *supra* note 31, at 111–14, 123 (describing state requirements for flowback disposal).

202. U.S. ENVTL. PROT. AGENCY, *supra* note 108, at 2.

203. *Id.*

204. *Cf.* MARY BETH ADAMS ET AL., U.S. FOREST SERVICE, EFFECTS OF DEVELOPMENT OF A NATURAL GAS WELL AND ASSOCIATED PIPELINE ON THE NATURAL AND SCIENTIFIC RESOURCES OF THE FERNOW EXPERIMENTAL FOREST 12 (2011), http://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs76.pdf (discussing a controlled application of salty flowback to national forest, showing vegetation die-off).

205. Permit no. 027-21505, violation no. 598916, Burnside, Penn. Dep't. of Envtl. Prot., Oct. 2010.

206. Permit no. 081-20196, violation no. 588780, Shrewsbury, Penn. Dep't. of Envtl. Prot., May 2010.

207. Permit no. 015-20326, violation no. 586721, West Burlington, Penn. Dep't. of Envtl. Prot. (notice of violation).

disposal and allowing spills. In Ohio, an inspector noted leaking frac tanks and "fill spots" south of the tanks[208] and flowback "dumping down the hill"; at this latter site, the inspector observed that the "[g]round still is not growing grass and several big trees have been killed."[209] Another site had "a couple of valves leaking on the frac tanks" and an oil spill and brine near the tanks.[210] One operator drilling and fracturing in the Marcellus Shale that underlies Pennsylvania allowed "ongoing flowback leaks from tanks," which caused "several spills,"[211] and an impoundment that was not "structurally sound" caused a flowback spill that extended "roughly 800 to 1,000 feet" from the well site and, like another flowback spill, was associated with a "[l]arge swath of dead vegetation."[212] In another case involving potential off-site migration of flowback, the Pennsylvania Department of Environmental Protection noted that surface water from a leaking flowback pit "surfaced" in a pasture "adjacent to" the well pad.[213] The flowback had apparently migrated about one hundred feet.[214] A frac tank in Pennsylvania similarly spilled flowback that "migrated off [a] well pad" toward surface water,[215] and another flowback spill entered a drainage ditch.[216]

At tight sand wells in New Mexico, the Oil Conservation Division also noted several surface spills of flowback from storage units.[217] In one case, a valve left open during fracturing of a well released 245 gallons of "frac water" that contained 2 percent potassium chloride, all of which was recovered.[218] In

208. 34111227680000, 818583295, Monroe, Franklin, Ohio Dep't. of Envtl. Conserv., May 14, 2008, (violation, follow-up to notice of violation 1380926203).

209. 34167296270000, 1246335529, Washington, Independence, Ohio Dep't. of Envtl. Conserv., June 3–4, 2008 inspection (violation).

210. 34019203250000, 964324099, Carol, Rose, Ohio Dep't. of Envtl. Conserv., June 18, 2008 inspection (violation).

211. Permit no. 015-20209, violation no. 586310, Burlington, Penn. Dep't. of Envtl. Prot., May 2010 (notice of violation).

212. Permit no. 015-20016, Burlington, violation no. 588163, Penn. Dep't. of Envtl. Prot., May 2010.

213. Permit no. 117-20368, violation no. 586294, Tioga, Shippen, May 3, 2010 inspection, Penn. Dep't. of Envtl. Prot., (notice of violation).

214. Permit no. 117-20368, Shippen, violation nos. 586293, 587064, Penn. Dep't. of Envtl. Prot., May 2010.

215. Permit no. 117-20409, violation no. 590077, Jackson , Penn. Dep't. of Envtl. Prot., Dec. 2010.

216. Permit no. 035-21179, Noyes, Penn. Dep't. of Envtl. Prot., Jan. 2011 (notice of violation).

217. The documents refer to the substance as "frac water."

218. Permit no. 30-045-34625, incident nRMD 0928649711 (December 2008), Oil Conservation Div. (violation noted).

others, corroded bottoms of tanks caused five[219] to fifty[220] barrels of frac water (also 2 percent potassium chloride) to be released on site, some of which the operator recovered. An operator who mistakenly poured fluids into a leaky tank released fifteen barrels of frac water.[221] And, in a final incident attributed to vandalism, someone opened two tanks that held fluids, releasing 800 gallons, which were not recovered.[222]

When an operator moves flowback water off site to dispose of it, additional risks emerge. In many states, flowback and produced water is disposed of in Class II underground injection control ("UIC") wells, which are deep wells constructed for the disposal of oil and gas wastes.[223] Although these wells are regulated under the federal SDWA,[224] which is typically administered through a state permitting program, wells can, in rare situations, fail and pollute underground waters.[225] They also have caused localized earthquakes.[226] Both of these effects are discussed in Part II.B. below, which addresses produced water disposal.

If UIC well space is limited, as it is in Pennsylvania,[227] flowback water is sometimes shipped to wastewater treatment plants.[228] As Marcellus Shale operators trucked thousands of

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219. Permit no. 30-045-34507, incident no. nRMD0928247679 (Sept. 2009), Oil Conservation Div. (violation noted).

220. Permit no. 30-045-34705, incident no. nRMD0928239664 (Oct. 2009), Oil Conservation Div. (violation noted). Another incident released seven barrels of frac water. *See* Permit no. 30-045-34709, incident no. nBP0918952242 (Mar. 2009), Oil Conservation Div. (violation noted).

221. Permit no. 30-039-30603, incident no. nRMD0924752168 (May 2009), Oil Conservation Div. (violation noted).

222. Permit no. 30-045-34815, violation no. KGR0910634065 (Mar. 2009), Oil Conservation Div.

223. *See* R.R. Comm'n of Tex. v. Tex. Citizens for a Safe Future and Clean Water, 336 S.W.3d 619, 621–22 (Tex. 2011) ("A company fracking a well must dispose of the resulting waste. Most companies do so by injecting the waste into subsurface zones which are naturally saline environments, usually in old wells converted to injection wells.").

224. Bruce M. Kramer, *A Short History of Federal Statutory and Regulatory Concerns Relating to Hydraulic Fracturing*, ROCKY MTN. MIN. L. FOUND.: HYDRAULIC FRACTURING CORE ISSUES AND TRENDS, no. 5, 2011 2-5 to -11 (describing the regulation of Class II wells under the Act and the cooperative federalist approach to this regulation, which involves both the EPA and the states).

225. *See infra* note 384.

226. *See infra* note 385.

227. *See* PENN. DEP'T OF ENVTL. PROT., PENNSYLVANIA HYDRAULIC FRACTURING STATE REVIEW 11 (2010), http://www.shalegas.energy.gov/resources/ only one commercial class II UIC well in Pennsylvania).

228. AM. PETROL. INST., *supra* note 200, at 20 (noting that "[w]ater used in the

gallons of flowback and produced water to old wastewater treatment plants in Pennsylvania in 2011, *The New York Times* expressed concerns that these plants were not equipped to handle these large quantities of wastes—some of them containing substances not previously encountered by the treatment plants—and were discharging waste with low levels of radioactivity into rivers.[229] The EPA subsequently expressed alarm that plants operating under old permits might be accepting new waste that they could not adequately treat,[230] leading the Pennsylvania Department of Environmental Protection to respond that testing near these plants' discharge points showed safe water quality levels.[231] The EPA was not satisfied with this response, however, and demanded more testing;[232] it also used the investigative portion of the Clean Water Act to request records from several large fracturing companies, demanding to know how they had been handling their wastewater from drilling and fracturing.[233] The Pennsylvania Department of Environmental Protection, in the meantime—with the permission of Governor Corbett—"requested" that operators stop sending their drilling and fracturing waste to grandfathered plants.[234] The challenges associated with flowback disposal, water scarcity concerns, and, in some cases, regulatory sticks[235] have led more

hydraulic fracturing process is usually managed and disposed of in one of three ways," including underground injection, delivery to water treatment facilities (or treatment followed by surface discharge), and reuse and recycling).

229. Ian Urbina, *Regulation Lax as Gas Wells' Tainted Water Hits Rivers*, N.Y. TIMES, Feb. 26, 2011, at A1, *available at* http://www.nytimes.com/2011/02/27/us/27gas.html?_r=1&pagewanted=all.

230. Letter from Shawn M. Garvin, EPA Region 3 Adm'r, to Michael Krancer, Acting Sec'y, Penn. Dep't of Envtl. Prot. (Mar. 7, 2011), *available at* http://www.epa.gov/region3/marcellus_shale/PADEP_Marcellus_Shale_030711.pdf.

231. Letter from Michael Krancer, Acting Sec'y, Penn. Dep't of Envtl. Prot., to Shawn M. Garvin, EPA Region 3 Adm'r (Apr. 6, 2011), *available at* http://www.epa.gov/region03/marcellus_shale/Shawn_Garvin_Letter-April_6_2011.pdf.

232. Letter from Shawn M. Garvin, EPA Region 3 Adm'r, to Michael Krancer, Acting Sec'y, Penn. Dep't of Envtl. Prot. (May 12, 2011), *available at* http://www.epa.gov/region03/marcellus_shale/pdf/letter/krancer-letter5-12-11.pdf.

233. Press Release, U.S. Envtl. Prot. Agency, EPA Seeks More Information from Natural Gas Drilling Operations to Ensure Safety of Wastewater Disposal (May 12, 2011), *available at* http://yosemite.epa.gov/opa/admpress.nsf/0/4816775AD0E881AB8525788E006A91ED.

234. *See* Commnwlth. of Penn., DEP Calls on Natural Gas Drillers to Stop Giving Treatment Facilities Wastewater, Apr. 19, 2011, http://www.portal.state.pa.us/portal/server.pt/community/newsroom/14287?id=%2017071%20&typeid=1.

235. *See* 25 PA. CODE § 95.10 (2011) (requiring that a wastewater source

operators to move toward flowback reuse and recycling—a promising but not yet fully developed technique.[236] Recycling appears to be most common in Pennsylvania,[237] where the state has strongly encouraged it, but several pilot projects also have emerged in Texas.[238] Until recycling is perfected and becomes more affordable, the risks associated with flowback disposal will continue.

b. *Responses: Minor Revisions of On-Site Storage Requirements and Encouraging Flowback Recycling*

Depending on the chemicals used in fracturing, flowback water may contain low concentrations of toxic chemicals and, as described above, may also have naturally occurring levels of chlorides and radioactive substances.[239] For most industries, the handling, transport, and disposal of hazardous wastes is regulated under Subtitle C of the federal Resource Conservation and Recovery Act ("RCRA").[240] Most high-volume wastes from oil and gas drilling and fracturing, called "exploration and production" or E&P wastes,[241] are exempted

reduction strategy "identify the methods and procedures the operator shall use to maximize the recycling and reuse of flow back or production fluid either to fracture other natural gas wells, or for other beneficial uses").

236. AM. PETROL. INST., *supra* note 200, at 22 (explaining that many other treatment and recycling approaches "are being developed and modified to address the specific treatment of needs of flow back water in different operating regions").

237. Stephen Rassenfoss, *From Flowback to Fracturing: Water Recycling Grows in the Marcellus Shale*, 63 J. PETROL. TECH. 48, 48 (July 2011), www.spe.org/jpt/print/archives/2011/07/12Marcellus.pdf (noting that "[i]n Pennsylvania, recycling wastewater from wells in the Marcellus Shale has been transformed from a trend to an essential skill" and that in April 2011, "two-thirds of the water from fracturing was recycled in Pennsylvania").

238. *Water Use in the Barnett Shale*, *supra* note 6 (describing Railroad Commission authorizations of recycling pilot projects in the Barnett Shale).

239. *See* AM. PETROL. INST., *supra* note 200, at 17 (noting that "[g]as wells can bring NORM [natrually occuring radioactive materials] to the surface in the cuttings, flow back fluid, and production brine" and that flow back can range from brackish to saline to "supersaturated brine").

240. 42 U.S.C. § 6922(a) (2010) (requiring standards for hazardous waste generators); 42 U.S.C. § 6922(b) (2011) (requiring standards for hazardous waste transporters); 42 U.S.C. § 6922(c) (2010) (requiring standards for operators of treatment, storage, and disposal facilities).

241. For examples of the exempt E&P wastes, see STATE REV. OF OIL & NAT. GAS ENVTL. REGS., STATE REVIEW GUIDELINES 12–14, *available at* http://67.20.79.30/sites/all/themes/stronger02/downloads/Revised%20guidelines.pdf (including drill cuttings, rig wash, drilling fluids, and well completion, treatment, and stimulation fluids, among others) (last visited Dec. 8, 2012).

from this provision[242] despite sometimes having hazardous characteristics.[243]

When the EPA omitted most oil and gas E&P wastes from RCRA Subtitle C regulation, it noted that in some cases, state controls were inadequate.[244] It therefore required the development of a voluntary state review, which has since morphed into a program called the State Review of Oil & Natural Gas Environmental Regulations ("STRONGER").[245] STRONGER is a partnership between industry, environmental groups, and state regulators, which has developed guidelines for better management and disposal of oil and gas wastes.[246] It asks states to voluntarily agree to reviews of their oil and gas regulations, in which STRONGER suggests how state programs could better comport with the guidelines.[247] The process is wholly voluntary; if states choose to be reviewed, they may accept or reject the suggestions as they wish.[248]

As fracturing has introduced new chemicals to the oil and gas development process, STRONGER has developed hydraulic fracturing guidelines and has completed several reviews of state hydraulic fracturing regulations,[249] some of which are

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242. Regulatory Determination for Oil and Gas and Geothermal Exploration, Development and Production Wastes, 53 Fed. Reg. 25,446–47 (July 6, 1988).

243. *Id.* at 25,454–56. For an in-depth description of the exemption, see James R. Cox, *Revisiting RCRA's Oilfield Waste Exemption as to Certain Hazardous Oilfield Exploration and Production Wastes*, 14 VILL. ENVTL. L.J. 1, 2 (2003); Hannah Wiseman, *Regulatory Adaptation in Fractured Appalachia*, 21 VILL. ENVTL. L.J. 229, 243–47 (2010).

244. Regulatory Determination for Oil and Gas and Geothermal Exploration, Development and Production Wastes, 53 Fed. Reg. at 25,455–56.

245. *Id.* at 25,456.

246. STATE REV. OF OIL AND NAT. GAS ENVTL. REGS., GUIDELINES FOR THE REVIEW OF STATE OIL & NATURAL GAS ENVIRONMENTAL REGULATORY PROGRAMS § 2.6 (June 2000) *available at* http://67.20.79.30/sites/all/themes/stronger02/downloads/Revised%20guidelines.pdf; Memorandum from the State Rev. of Oil and Nat. Gas Envtl. Regs. Bd. to Persons Interested in the Hydraulic Fracturing Guidelines, Update on the Development of Hydraulic Fracturing Guidelines (Feb. 8, 2010), http://www.strongerinc.org/documents/HF%20Guideline%20Web%20posting.pdf.

247. *See What Is the State Review Process?*, STATE REV. OF OIL & NAT. GAS ENVTL. REGS., http://www.strongerinc.org/ (Oct. 27, 2012) (explaining that team members "review state oil and gas waste management programs against a set of guidelines").

248. Mike Soraghan, *Protecting Oil From Water—The History of State Regulation*, ENVTL. & ENERGY PUBL'G, http://www.eenews.net/public/Greenwire/2011/12/14/1 (last visited Oct. 28, 2012) (noting that the review process is voluntary and that "STRONGER hasn't conducted a full review of a state regulatory program since 2007").

249. *See Past Reviews*, STATE REV. OF OIL & NAT. GAS ENVTL. REGS., http://www.strongerinc.org/past-reviews (last visited Oct. 27, 2012) (showing

more thorough than others.[250] The reviews are therefore valuable but fail to comprehensively address gaps in state regulation. Further, the STRONGER guidelines are suggestions only,[251] and they do not cover all phases of the tight oil or gas development process.[252] Some of the guidelines focus on procedure, not substance, encouraging state agencies to require that operators notify them prior to fracturing and to disclose chemicals to them.[253] While ensuring that agencies have opportunities to monitor shale gas and oil development is important, the guidelines may not sufficiently address the many substantive risks at all stages of well development.

Some states—with or without STRONGER's prodding—have begun to update regulations addressing the transfer, storage, and disposal of fracturing wastes. Arkansas, for example, requires transporters of flowback water to obtain a permit (renewed annually), carry a visible permit sticker, and provide emergency telephone numbers, among other

where hydraulic fracturing reviews have been completed).

250. *See* STATE REV. OF OIL & NAT. GAS ENVTL. REGS., ARKANSAS HYDRAULIC FRACTURING STATE REVIEW (2012), http://67.20.79.30/sites/all/themes/stronger02/downloads/Arkansas%20HF%20Review%202-2012.pdf; STATE REV. OF OIL & NAT. GAS ENVTL. REGS., COLORADO HYDRAULIC FRACTURING STATE REVIEW (2011), http://www.strongerinc.org/documents/Colorado%20HF%20Review%202011.pdf; STATE REV. OF OIL & NAT. GAS ENVTL. REGS., LOUISIANA HYDRAULIC FRACTURING STATE REVIEW (2011), http://www.strongerinc.org/documents/Final%20Louisiana%20HF%20Review%203-2011.pdf; STATE REV. OF OIL & NAT. GAS ENVTL. REGS., OHIO HYDRAULIC FRACTURING STATE REVIEW (2011), http://www.strongerinc.org/documents/Final%20Report%20of%202011%20OH%20HF%20Review.pdf; STATE REV. OF OIL & NAT. GAS ENVTL. REGS., OKLAHOMA HYDRAULIC FRACTURING STATE REVIEW (2011), http://www.strongerinc.org/documents/Final%20Report%20of%20OK%20HF%20Review%201-19-2011.pdf; STATE REV. OF OIL & NAT. GAS ENVTL. REGS., PENNSYLVANIA HYDRAULIC FRACTURING STATE REVIEW (2010), http://www.shalegas.energy.gov/resources/071311_stronger_pa_hf_review.pdf (showing reports of varying length and detail, which conclude, for example, in the case of Oklahoma, that regulations are comprehensive even though they do not address issues such as whether casing may be reused).

251. Memorandum from the State Rev. of Oil & Nat. Gas Envtl. Regs Board, *supra* note 246 (explaining that the guidelines do not set "prescriptive regulatory standards for states").

252. *See id*. (pointing operators to existing STRONGER guidelines for surface control of waste and waste and wastewater management, and proposing sufficient staffing, dissemination of educational information—particularly in areas where high-volume fracturing has not occurred in the past—notification of agency staff prior to fracturing, and "standards for casing and cementing" that will "meet anticipated pressures" on the well).

253. STATE REV. OF OIL & NATURAL GAS ENVTL. REGS., HYDRAULIC FRACTURING GUIDELINES § X.2.2 (Jan. 10, 2010), http://67.20.79.30/sites/all/themes/stronger02/downloads/HF%20Guideline%20Web%20posting.pdf.

requirements for safe transport.[254] New York has proposed to require that flowback water be stored in steel tanks with secondary containment and that it be disposed of through wastewater treatment plants.[255] Also at the disposal stage, Pennsylvania is aggressively pushing for wastewater recycling[256] and requires each operator to develop a "wastewater source reduction strategy."[257] Operators in West Virginia similarly must indicate on their well permit application how they plan to dispose of fracturing wastes,[258] and operators must take steps to prohibit disposal of their flowback waste through a publicly owned treatment works unless the Department of Environmental Protection approves this disposal method.[259] Oklahoma, on the other hand, has updated its regulations only to tell operators which existing oil and gas regulations apply to fracturing and fracturing wastes, with the exception of required chemical disclosure.[260] Many states have, surprisingly, failed even to do this.[261] In some cases it is therefore not clear whether flowback water may be stored in an unlined pit or not and how it must be disposed of.[262]

254. ARK. OIL & GAS COMM'N RULE B-17(g) (2012); ARK. OIL & GAS COMM'N RULE E-3(d) (2012).

255. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-39, 7-63.

256. *See* 25 PA. CODE § 95.10 (Westlaw 2012) (requiring a wastewater source reduction strategy that identifies "the methods and procedures the operator shall use to maximize the recycling and reuse of flow back or production fluid").

257. *Id.*

258. *See, e.g.*, GENE C. SMITH, W. VA. DEP'T ENVTL. PROT., OFF. OF OIL & GAS, PERMITTING OVERVIEW 4 (Feb. 2012), http://www.dep.wv.gov/oil-and-gas/Horizontal-Permits/Horizontal%20Well%20Permit%20Packet/Documents/Workshop%20Presentations/Permitting.pdf (requiring an operator, in an application for horizontal drilling, to describe the "[m]ethod of management and disposal of produced and flow-back water").

259. W. Va. Exec. Order No. 4-11 (July 12, 2011), *available at* http://anr.ext.wvu.edu/r/download/98484.

260. OKLA. ADMIN. CODE § 165:10-7-24(b)(3) (2011).

261. *See, e.g.*, MONT. ADMIN. R. 36.22.1001 (2011) (requiring only "suitable and safe" surface casing); OHIO REV. CODE ANN. § 1509.17 (2012) (in casing requirements, failing to account for increased pressure that may be placed on casing as a result of fracturing); 16 TEX. ADMIN. CODE § 3.8(d)(4) (2012) (in the regulatory definition of regulated pits, failing to specify which pits are used to store flowback water and how these pits must be lined, if at all, although including a definition of "disposal pit," which likely collects flowback).

262. *See, e.g.*, 16 TEX. ADMIN. CODE § 3.8(d)(4) (2012) (stating that pits for flowback likely fall within the "[c]ollecting pit" category, which is a "[p]it used for storage of saltwater or other oil and gas wastes prior to disposal at a disposal well or fluid injection well," and for which permits are required. This could be clarified, however, by directly referring to flowback); MICH. ADMIN. CODE r. 324.407 (2012) (in a regulation that appears to require tanks for flowback, providing that "only

As briefly introduced in Part I.A.3 above, the disposal of flowback water has not only caught the attention of state regulators, but also of the federal EPA.[263] After *The New York Times* expressed concerns about wastewater treatment,[264] the EPA took note and has since become more involved in wastewater disposal. It has requested that the Pennsylvania Department of Environmental Protection ensure that wastewater treatment plants are not violating their existing CWA permits,[265] and it has announced that it will impose Clean Water Act treatment standards on wastewater from coalbed methane wells in 2013 and shale gas wells in 2014.[266] Regional regulatory bodies also have taken note. The Delaware River Basin Commission has proposed that flowback water must be disposed of through wastewater treatment plants either within or outside the basin; the Commission proposes that the plants must certify that they are able to accept the water and adequately treat it.[267] Texas, in turn, has approved several wastewater treatment plants to accept produced water (but not flowback) and has encouraged pilot projects to test flowback treatment and recycling.[268]

The large quantities of new wastewater produced by fracturing continue to pose substantial environmental challenges. EPA draft standards for treating wastewater from fractured shale gas wells will not be implemented until 2014.[269] In the meantime, there is a risk that in regions with limited underground injection capacity, wastewater treatment plants operating under old CWA permits might accept, and inadequately treat, millions of gallons of flowback water before discharging it into surface waters.[270]

the following materials may be placed in a lined pit" and does not include flowback water or completion fluids in the list of acceptable materials).

263. *See* Letter from Shawn M. Garvin (Mar. 7, 2011), *supra* note 230, at 1 (expressing concerns about wastewater that may contain materials damaging to human health and the environment); Press Release, U.S. Envtl. Prot. Agency, *supra* note 233 (describing EPA requests for disposal information from fracturing companies).

264. *See* Urbina, *supra* note 229 (expressing concerns that wastewaters with low levels of radiation were being released into rivers).

265. Letter from Shawn M. Garvin (Mar. 7, 2011), *supra* note 230, at 2.

266. U.S. ENVTL. PROT. AGENCY, *supra* note 116, at 1.

267. DEL. RIVER BASIN COMM'N, *supra* note 112, at 61–62.

268. *Water Use in the Barnett Shale*, *supra* note 6.

269. U.S. ENVTL. PROT. AGENCY, *supra* note 116, at 1.

270. *See, e.g.*, Complaint at 4, Clean Water Action and Three Rivers Waterkeeper v. Municipal Authority of the City of Mckeesport, No. 11CV00940, 2011 WL 2883571 (W.D. Pa. July 19, 2011) (alleging that a wastewater treatment

Finally, disposal of flowback in underground injection wells could cause small earthquakes[271] or pollute aquifers.[272] These potential disposal risks have not been sufficiently addressed in some states, as discussed in Part III.B.2 below.

3. Withdrawing More Water

Perhaps the most dramatic change introduced by slickwater fracturing is the quantity of water used for well development. Operators have long used water as a component of drilling fluid and mud, but this consumption pales in comparison to the millions of gallons of water withdrawn for each fracture job, or "treatment," as it is often called.[273] Many operators drive tanker trucks to surface waters, insert a large hose into the water, pump water into the truck, and drive it to the well site or centralized impoundment.[274] Alternatively, operators build a new water pipeline from a stream or aquifer[275] to the site or tap into an existing one—or drill a water well at the well site.[276] The risks associated with heightened water use, and certain responses, are briefly described in this Section.

a. Risks: Water Quantity and Quality Impacts

More water withdrawals of larger quantities of water

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plant accepted "oil and gas drilling wastewater without the capacity to treat it before discharging the wastewater into the Monongahela River"); Urbina, *supra* note 229; Letter from Shawm M. Garvin (May 12, 2011), *supra* note 232; Press Release, U.S. Envtl. Prot. Agency, *supra* note 233.

271. *See infra* note 385.

272. *See infra* note 384.

273. *See Marcellus Shale Formation FAQ*, *supra* note 59 (explaining that "[e]xtracting natural gas from the Marcellus Shale formation requires . . . a process known as 'hydraulic fracturing' that uses far greater amounts of water than traditional natural gas exploration").

274. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 6-2.

275. *Id.* ("Water for hydraulic fracturing may be obtained by withdrawing it from surface water bodies or new or existing water-supply wells drilled into aquifers"). A website developed and maintained by industry and the Ground Water Protection Council suggests that "[m]ost water used in hydraulic fracturing comes from surface water sources such as lakes, rivers and municipal supplies" but notes some groundwater use. *Hydraulic Fracturing Water Usage*, FRACFOCUS CHEMICAL DISCLOSURE REGISTRY (Nov. 13, 2011) http://fracfocus.org/water-protection/hydraulic-fracturing-usage.

276. Site visit by the author to an Oklahoma well site (Oct. 28, 2011) (The operator showed the author and students a water well that he had drilled for the fracturing operation, with permission of the surface owner).

introduce several environmental risks. Hoses used to pump water out of surface supplies can transfer invasive species between water sources.[277] Withdrawing larger quantities of water can cause surface water temperatures and pollutant concentrations to increase (when new pollutants are added to smaller water volumes), thus impacting aquatic plants and wildlife and reducing water quality for all water users—not just oil and gas companies.[278] Lower flow conditions in surface waters can also lower the oxygen content of water, which negatively affects certain species.[279] Finally, water withdrawals for fracturing can, of course, reduce the amount of water available from underground sources. The Railroad Commission of Texas, for example, estimates that 7 to 13 percent of groundwater withdrawals in the Barnett Shale area will be for fracturing by 2025, which could disproportionately impact rural areas that tend to rely on groundwater for their water supply.[280] Because fractured wells often are concentrated in highly productive or easily accessible portions of the shale,[281] water withdrawals can be similarly concentrated, thus having potentially powerful collective impacts.[282] Unfortunately, as described in the following Section, states have not fully addressed these impacts.

b. *Responses: Monitoring Water Withdrawals and Implementing Some Substantive Limits*

States have historically controlled water use, and their primary reaction to oil and gas operators' consumption[283] of

277. COLO. CODE REGS. § 404-1:1204 (2012) (requiring disinfection of hoses and water transportation tanks in cutthroat trout habitat).

278. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 6-2 (summarizing the "[p]otential effects of reduced stream flow," including "insufficient supplies for downstream uses," "adverse impacts to quantity and quality of" habitats, "unsuitable water temperature and dissolved oxygen concentrations," and "degraded" water quality).

279. *See id.*

280. *Water Use in the Barnett Shale*, *supra* note 6.

281. *See, e.g.*, *Pennsylvania 2010 Total Wells Drilled*, *supra* note 6 (showing Marcellus Shale wells as being concentrated in portions of the state); *Barnett Shale Information*, R.R. COMM'N OF TEX. (Feb. 17, 2012), http://www.rrc.state.tx.us/barnettshale/index.php (describing the "core" counties for Barnett drilling).

282. *See* DEL. RIVER BASIN COMM'N, *supra* note 112, at 20 (noting "potential streamflow and assimilative capacity impacts affected by the quantity, location, timing and manner" of withdrawals for fracturing).

283. Thomas W. Beauduy, *"Shale" We Drill? The Legal and Environmental*

millions of gallons of water to drill and fracture new wells has been to monitor this use. West Virginia, for example, requires that operators applying for a permit report the volume of water that they anticipate using and its source,[284] although it recently added substantive limitations on withdrawals.[285] Texas's Railroad Commission similarly mandates reporting of actual quantities of water used at each well.[286]

Other states and regional bodies have already moved beyond monitoring, recognizing that withdrawals of water from surface and underground sources could lower available water supply and affect water quality.[287] New York requires permitting for surface water withdrawals and has proposed to prevent operators from degrading water quality as a result of water withdrawal.[288] Maryland requires a water appropriation and use permit for all surface and groundwater withdrawals.[289] Operators in Pennsylvania must submit a detailed water management plan to the state.[290] Michigan prohibits the use of surface water for drilling fluid unless there is an emergency but does not appear to similarly bar the use of surface water in fracturing.[291] The Delaware and Susquehanna River Basin Commissions—two regional bodies operating under interstate compacts—have implemented some of the most stringent provisions for water withdrawals for fracturing. The DRBC would prohibit any alteration of flow that would impair a fresh surface water body's best designated use (such as use for drinking water) and would bar all withdrawals that caused surface waters to dip below certain "pass-by flow" quantities,

Impacts of Extracting Natural Gas from Marcellus Shale, 22 VILL. ENVTL. L.J. 189, 217 (2011) (noting that "one hundred percent of the water that goes down the bore hole is considered lost to the basin").

284. W. VA. CODE §§ 22-26-2 to -3 (2012).

285. *Id.* § 22-6A-7(e) (2012) (requiring a water management plan if more than 210,000 gallons will be used in any thirty-day period, including, among other provisions, a demonstration that sufficient instream flow will be available immediately downstream of the water withdrawal point).

286. *Water Use in the Barnett Shale*, *supra* note 6 (explaining that the Commission requires reporting).

287. For a more in-depth discussion of substantive limits, see WISEMAN & GRADIJAN, *supra* note 31, at 71–82.

288. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-2 to -5.

289. MD. DEP'T OF THE ENV'T., APPLICATION FOR GAS EXPLORATION AND PRODUCTION 7 (2008), http://www.mde.state.md.us/assets/document/permit/MDE-LMA-PER045.pdf.

290. PA. DEP'T OF ENVTL. PROT., *supra* note 256, at 1; 58 PA. CONS. STAT. § 3211 (2012).

291. MICH. ADMIN. CODE r. 324.404 (2011).

defined by the volume of water flowing by a point in a stream over a certain period of time.[292] The SRBC similarly requires permits for water withdrawals for fracturing and well development and the maintenance of certain stream flows when surface waters are withdrawn.[293]

Although some regulatory bodies have begun to address increased water withdrawals through monitoring and/or controlling use—and the EPA has promised to study the issue[294]—more attention is needed in some regions, particularly as droughts plague areas experiencing a fracturing boom.[295]

In sum, slickwater hydraulic fracturing, in consuming vast quantities of water, requiring new chemicals, and producing more wastes, has introduced a range of new risks to the oil and gas development process. As well numbers have risen, long-known impacts of oil and gas development also have grown. These familiar risks (now expanded) often are ignored in policy and regulatory debates. Part III.B. describes these risks and the limited attention that they have received in political and regulatory circles.

B. *The Expansion of Oil and Gas Development in Certain Regions*

Many of the core risks of fracturing appear to arise not from the technology itself but from the enhanced oil and gas *drilling* activity that it inspires in certain areas—activity that has long occurred but has changed in scale. Some regulators and policymakers have, at least sporadically, responded to the new stages of well development introduced by fracturing; some of these responses have at least indirectly recognized that more fracturing leads to more well development and thus higher risks.[296] Some states have made or proposed comprehensive

292. DEL. RIVER BASIN COMM'N, *supra* note 112, at 54.

293. Review and Approval of Projects, Susquehanna River Basin Commission, 73 Fed. Reg. 78618, 78620 (Dec. 23, 2008) (codified at 18 C.F.R. § 806.23).

294. U.S. ENVTL. PROT. AGENCY., EPA/600/R-11/122, *supra* note 36, at xi.

295. *Water Use in the Barnett Shale*, *supra* note 6; *see also* NAT'L DROUGHT MITIGATION CTR., *U.S. Drought Monitor: Texas*, http://droughtmonitor.unl.edu/DM_state.htm?TX,S (last visited Nov. 2, 2012) (showing relatively severe drought in the Barnett Shale area).

296. *See, e.g.*, H.B. 401, § 22-6A-2, 2011 Leg. (W. Va. 2011), *available at* http://www.legis.state.wv.us/Bill_Text_HTML/2011_SESSIONS/4X/Bills/hb401%20enr.htm (noting that both new and old practices, including hydraulic fracturing, have "resulted in a new type and scale of natural gas development" and that

revisions of their oil and gas codes as fracturing and drilling have increased—thus recognizing both fracturing and the uptick in traditional well development. Colorado,[297] New York,[298] Pennsylvania,[299] and West Virginia[300] have been leaders in this area. For the most part, though, states have failed to make several needed changes.

This Part describes the stages of well development that are necessary for both conventional and fractured wells and explores how the familiar risks of these development stages expand as fracturing enables well numbers to grow. After identifying the potential risks associated with methane leakage during drilling, handling and disposal of more wastes, increased soil erosion, and spills from drilling equipment on site, it explores how, if at all, states have responded to these problems associated with enhanced drilling activity.

1. Drilling, Casing, and Cementing More Wells

One of the most important stages of well development involves the casing or "lining" of a well to prevent fossil fuels flowing through the well from mixing with underground water and other underground resources.[301] Operators cement this casing in place to secure it within the well.[302] If casing and cementing fail, methane—or potentially sediment—can escape and pollute nearby resources. As this Section discusses, some states have updated gas well casing requirements and mandates for blowout equipment, which can help control and prevent pressure build-up in the well. Others, however, have not addressed the risks posed by higher drilling rates.

"[e]xisting laws and regulations developed for conventional oil and gas operations do not adequately address these new technologies and practices").

297. COLO. DEP'T OF NAT. RES., OIL & GAS CONSERV. COMM'N, COGCC AMENDED RULES REDLINE, http://cogcc.state.co.us/ (follow "Rules" hyperlink in blue menu to the left of the page, then follow "2008 Rulemaking" hyperlink, then follow "COGCC Amended Rules Redline") (showing revisions to portions of Colorado's oil and gas regulations).

298. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31 (comprehensively examining risks and, in chapter 7, proposing many conditions to address these risks at each stage of the development process).

299. H.R. 1950, 2012 Sess. (Pa. 2012); *infra* notes 326–327 (showing additional Pennsylvania rulemakings).

300. H.R. 401, § 22-6A-2, 2011 Leg. (W. Va. 2011).

301. GROUND WATER PROT. COUNCIL, *supra* note 110, at 51–52.

302. *Id*. at 52.

a. Risks: Methane Migration from Improperly Cased Wells, Well Blowouts, and Future Well Failure

As operators drill thousands of new wells prior to fracturing them, each new well threatens to pollute underground soil and water resources if not properly lined and cased. Fracturing further heightens the need for proper well casing because fracturing places more pressure on the wellbore.[303] Well casing can fail while the well is being drilled or fractured as a result of the installation of used, weak casing or insufficient cementing or, in some cases, when an underground blowout occurs, which is an "uncontrolled flow of formation fluids from a high pressure zone into a lower pressure zone."[304] Casing and well integrity also can be compromised long after the well has stopped producing and has been plugged—again as a result of weak or insufficient casing or cementing.[305] When casing fails, gas or other substances can pollute drinking water wells and other underground and surface resources.[306] Methane also occurs naturally underground and may pollute improperly constructed water wells in the absence of any oil or gas drilling activity.[307] Enhanced drilling activity, accompanied by the improper

303. *See* COLO. OIL & GAS CONSERV. COMM'N, FREQUENTLY ASKED QUESTIONS ABOUT HYDRAULIC FRACTURING, http://cogcc.state.co.us/Announcements/Hot_Topics/Hydraulic_Fracturing/Frequent_Questions_about_Hydraulic%20Fracturing.pdf (last visited Nov. 3, 2012) (noting that "[h]ydraulic fracturing involves injection pressures that exceed those of the geologic formation").

304. *Special Kick Problems and Procedures*, SERENE ENERGY, http://www.sereneenergy.org/Special-Kicks-Problems--and--Procedure.php (last visited Nov. 3, 2012).

305. *See* Richard J. Davies, *Methane Contamination of Drinking Water Caused by Hydraulic Fracturing Remains Unproven*, 108 PROCEEDINGS OF THE NAT'L ACAD. OF SCI. (Oct. 25, 2011), www.pnas.org/content/108/43/E871.full.pdf (noting the many improperly plugged, old wells in Pennsylvania that could be leaking methane).

306. *See, e.g.*, *infra* note 307 (describing the East Resources casing failure that contributed to a methane release, which entered the subsurface and sent methane to nearby springs and a well).

307. *See, e.g.*, EAST RESOURCES, INC., DELCIOTTO NO. 2, SUBSURFACE NATURAL GAS RELEASE REPORT ROARING BRANCH, MCNETT TWP., LYCOMING CNTY., PA. 10-11 (Sept. 18, 2009) (on file with author). This report was obtained in an October 7, 2011, response to Right-to-Know request 4400-11-170 submitted by the author. In an incident where a water well and several other water sources were contaminated with methane, the report noted that "[c]oncentrations of gas in several receptors identified during the investigation" were from historical stray gas." *Id.*; Davies, *supra* note 305 (noting that "natural seepage of methane in Pennsylvania is common").

plugging and casing of wells, however, might increase the risk of water contamination with methane.[308]

A number of well, spring, and stream contamination incidents in Pennsylvania—which may be linked to gas drilling—illuminate the potential for underground gas to migrate to water sources from improperly cased wells,[309] suggesting that drilling, not fracturing, may be one of the core culprits. A draft report of methane contamination in Pennsylvania preliminarily concludes that both newly drilled and old wells that were improperly cased have caused methane contamination of water, as has naturally occurring stray gas that migrated underground and into poorly constructed water wells.[310] In McNett Township, for example, the state Department of Environmental Protection believes that an improperly cased new gas well caused gas to leak from the well,[311] thus forcing "one resident to evacuate her home" and contaminating "multiple private drinking water wells and two tributaries of Lycoming Creek."[312] Several sources support the conclusion that improper casing of a drilled (not fractured) well at least partially caused a release of gas into nearby water in McNett.[313] A report conducted by the well operator concluded that the gas release "resulted in sediment and gas migration into streams, groundwater wells, springs, culverts, and a

308. *See infra* notes 310–317.

309. *See* WISEMAN & GRADIJAN, *supra* note 31, at 52–53 n.230 (listing gas migration incidents and "Section 208" letters from the Department of Environmental Protection to landowners, which concluded that the Department believed that methane contamination was associated with natural gas activity. Note, however, that the rebuttable presumption of contamination in Pennsylvania may have influenced these DEP conclusions).

310. *See* PENN DEP'T OF ENVTL. PROT., STRAY NATURAL GAS MIGRATION ASSOCIATED WITH OIL AND GAS WELLS (Oct. 28, 2009), http://www.dep.state.pa.us/dep/subject/advcoun/oil_gas/2009/Stray%20Gas%20Migration%20Cases.pdf (describing a number of pre-2008 cases, which preceded the Marcellus boom beginning in 2008); *Pennsylvania 2008 Total Wells Drilled*, *supra* note 19 (showing that drilling in the Marcellus began to expand in 2008); *see also* EAST RESOURCES, INC., *supra* note 307 (describing both naturally occurring gas and gas from a drilled well as contributing to the gas located in wells and creeks).

311. It is not clear whether this well was actually drilled in the Marcellus Shale, where fracturing is consistently used, and it is important to note that the incident likely occurred during drilling, not fracturing. PENN DEP'T OF ENVTL. PROT., STRAY NATURAL GAS MIGRATION ASSOCIATED WITH OIL AND GAS WELLS, *supra* note 310.

312. PENN DEP'T OF ENVTL. PROT., STRAY NATURAL GAS MIGRATION ASSOCIATED WITH OIL AND GAS WELLS, *supra* note 310.

313. *See* EAST RESOURCES, INC., *supra* note 307, at 10; Letter from Caleb Woolever, Geologic Trainee, Oil & Gas Mgmt., Pa. Dep't of Envtl. Prot., to Matthew Carpenter (Dec. 4, 2009) (on file with author).

residential structure."[314] The report further concluded that improper casing of one well caused the gas release,[315] although "historical stray gas" from "existing subsurface conditions" also caused some of the contamination of water.[316] The DEP notified several nearby property owners that stream and water well contamination was "caused by failure in a nearby natural gas well" and recommended that the residents not drink the water.[317] A settlement between DEP and the well operator also noted that the operator allowed natural gas to enter a freshwater spring and creek tributaries.[318]

A recent draft article, forthcoming in the *Proceedings of the National Academy of Sciences*, suggests that fracturing, not just drilling, may be connected to methane contamination of water wells in Pennsylvania[319]—thus fueling[320] the fire of the existing nationwide policy debate over contamination. The authors conclude that thermogenic gas, which is typically found in deep formations, such as shales, has migrated to underground sources of drinking water and that a higher percentage of water wells in active drilling and fracturing areas contain methane than do wells in inactive areas.[321] Although the authors implicate fracturing, not just well drilling, they conclude that more research is needed to confirm this alleged connection.[322] Other authors have disputed the findings presented in the article.[323]

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314. EAST RESOURCES, INC., *supra* note 307, at 1.

315. *Id.* at 10 (reporting that "ERI believes the source of the natural gas released to the subsurface was from the Delciotto No. 2 (well) annular space between the 7-inch production casing and the open hole").

316. *Id.* at 10–11.

317. Letter from Caleb Woolever (Dec. 4, 2009), *supra* note 313; Letter from Caleb Woolever, Geologic Trainee, Oil & Gas Mgmt., Pa. Dep't of Envtl. Prot., to Allyn Leonard (Dec. 4, 2009) (obtained from Right-to-Know request 4400-11-170 and on file with author).

318. Pa. Dep't of Envtl. Prot., In the Matter of: East Resources, Inc., Permit 081-20130 Delciotto 2 McNett, Consent Assessment of Civil Penalty at 6 (Apr. 19, 2011) (obtained from Right-to-Know request 4400-11-170 and on file with author).

319. *Supra* note 309.

320. Osborn et al., *supra* note 33, at 8173–76.

321. *Id.* at 2.

322. *Id.* at 4–5.

323. *See, e.g.*, Samuel C. Schon, *Hydraulic Fracturing Not Responsible for Methane Migration*, 108 PROCEEDINGS OF THE NAT'L ACAD. OF SCI., Sept. 13, 2011, *available at* http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3174578/; Davies, *supra* note 305.

b. Responses: Requiring Better Casing and Cementing, and Preventing Blowouts

While drilling with improper casing has been proven to cause stray gas migration, the media, environmental groups, and members of Congress have continued to investigate potential connections between fracturing and methane contamination. On one side of the debate, a steady stream of testimony from state regulators has certified that fracturing has never caused contamination,[324] while environmental groups list dozens of likely contamination events.[325]

As the fracturing-methane migration debate has continued to unfold, states have implemented and enforced existing casing and cementing regulations that apply to the drilling process and, in some cases, updated these regulations as more wells are drilled and fractured.[326] In limited cases, states have also updated some regulations to avoid blowouts (pressure or fluid build-ups in the well that cause it to "explode") and to require that wells be more thoroughly plugged after production ends.[327]

Typical state casing regulations require that casing be of a certain strength (either a narrative standard, such as "suitable"[328] casing or a technical requirement, such as "new steel casing" of a certain grade[329]); that the cement used to

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324. *See supra* notes 40–48 and accompanying text.

325. *See supra* note 17 and accompanying text. In many cases, investigations did not occur sufficiently soon after fracturing to prove or deny these claims. U.S. ENVTL. PROT. AGENCY, *supra* note 35, at 6–11.

326. *See, e.g.*, ARK. OIL & GAS . COMM'N RULE B-19(g) (2012) (showing updated casing requirements); 2 COLO. CODE REGS. § 404-1:317(o) (2012) (showing updated cement bond log requirement); N.D. ADMIN. CODE 43-02-03-21 (2012) (showing updated cementing requirements); N.D. ADMIN. CODE 43-02-03-27.1 (2012) (showing updated casing test requirements); PA. BULLETIN, PROPOSED RULEMAKING, 25 PA. CODE § 78.83 (c) (July 10, 2010), http://www.pabulletin.com/secure/data/vol40/40-28/1248.html (showing updated requirements for setting of casing).

327. *See, e.g.*, PA. BULLETIN, PROPOSED RULEMAKING, 25 PA. CODE § 78.93 (July 10, 2012), http://www.pabulletin.com/secure/data/vol40/40-28/1248.html.

328. *E.g.*, MONT. ADMIN. R. 36.22.1106(1) (2011).

329. *See, e.g.*, ARK. OIL & GAS COMM'N RULE B-19(d) (2012) (requiring steel alloy casing that will withstand a certain pressure); N.D. ADMIN. CODE 43-02-03-21 (2012) (requiring new or reconditioned pipe tested to withstand a certain pressure); N.Y. STATE DEP'T OF ENVTL. CONSERVATION, *supra* note 18, at 7-50 (2011) (requiring new casing); OHIO REV. CODE ANN. § 1509.17(A) (2011) (requiring steel production casing); 16 TEX. ADMIN. CODE § 3.13(b)(1)(A) (2010) (requiring used steel casing to be tested to a certain pressure).

secure the casing in the well be of a certain strength;[330] that the cement be allowed to set for a certain amount of time and up to a certain compressive strength before being disturbed by drilling or testing;[331] that the casing extend a certain number of feet below the lowest fresh groundwater;[332] and that operators submit cementing logs to show how they have cased and cemented a well.[333]

330. *See, e.g.*, 2 COLO. CODE REGS. § 404-1:317(h) (2011) (requiring casing to meet a certain pressure test after a certain number of hours at a designated temperature); MD. CODE REGS. 26.19.01.10(P) (2011) (requiring cement to meet an American Petroleum institute standard (meaning that it may not contain more than three percent calcium chloride) and minimum cement setting time); MONT. ADMIN. R. 36.22.1001(2) (2011) (requiring cement to set until it has reached a minimum pounds per square inch (PSI) level); N.M. CODE R. § 19.156.16.10(G)(2) (LexisNexis 2011) (requiring cement to set until it has a compressive strength of 500 psi); N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-53 (also proposing to require 500 psi); 25 PA. CODE § 78.85 (2011) (requiring "cement that meets or exceeds the ASTM International C 150, Type I, II or III Standard or API Specification 10").

331. *See supra* note 330 (describing both cement strength and set times in certain state regulations).

332. See Ark. Oil & Gas Comm'n, Order No. 146-2005-09, Cove Creek Field, at 7 (Sept. 27, 2005), http://www.aogc.state.ar.us/Field%20Rules/Fayetteville%20Shale/146-2005-09.pdf; Ark. Oil & Gas Comm'n, Griffin Mountain Field, Amendment 7 (July 26, 2005), http://www.aogc.state.ar.us/Field%20Rules/Fayetteville%20Shale/114-2005-07.pdf; Ark. Oil & Gas Comm'n, Gravel Hill Field, Order No. 97-2005-06, 7 (June 28, 2005), http://www.aogc.state.ar.us/Field%20Rules/Fayetteville%20Shale/97-2005-06.pdf; Ark. Oil & Gas Comm'n, Scotland Field, Order No. 96-2005-06, 7 (June 28, 20062005), http://www.aogc.state.ar.us/Field%20Rules/Fayetteville%20Shale/96-2005-06.pdf (requiring at least 500 feet of surface casing in all Fayetteville Shale fields); MD. CODE REGS. 26.19.01.10(O)(4) (requiring casing 100 feet deep or below the deepest known workable coal, whichever is deeper); MICH. ADMIN. CODE R. 324.408(1) (2011) (requiring casing 100 feet below all freshwater strata); N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-50 (proposing to require casing seventy five-feet deep or into bedrock, whichever is deeper); STATE REV. OF OIL & NAT. GAS ENVTL. REGS., OHIO HYDRAULIC FRACTURING STATE REVIEW 11 (Jan. 2011), *available at* http://www.dnr.state.oh.us/Portals/11/oil/pdf/stronger_review11.pdf (indicating that Ohio has a fifty-foot depth requirement); OHIO REV. CODE ANN. § 1509.17(D) (LexisNexis 2011) (providing that agency-specific review of casing is not required if casing is at least 500 feet deep); OKLA. ADMIN. CODE § 165:10-3-4(c)(1) (requiring fifty-foot casing or casing that is ninety feet below the surface, whichever is deeper); 25 PA. CODE § 78.83(c) (2011) (requiring casing that is fifty feet deep or into consolidated rock, whichever is deeper); W. VA. DEP'T ENVTL. PROT., CASING AND CEMENTING STANDARDS 2, http://www.dep.wv.gov/oil-and-gas/Documents/Casing%20and%20Cementing%20Standards.pdf (last visited Oct. 28, 2012) (requiring casing to be between fifty and one hundred feet below the lowest fresh groundwater).

333. *See, e.g.*, ARK. OIL & GAS COMM'N RULE B-19(f) (2012) (if cementing fails to isolate hydraulic fracturing zone, bond log or "other cement evaluation tool" required); MICH. ADMIN. CODE r. 324.418(a) (2011) (requiring log); N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-54 (proposing to require log); OHIO REV. CODE ANN. § 1509.17(D) (LexisNexis 2012) (requiring log for "each cemented

Protections against well blowouts typically either broadly require the use of blowout preventers ("BOPs")[334] or specify the types of BOP equipment that must be used,[335] including, for example, BOPs with certain types of equipment[336] and a remote control capability.[337] Plugging regulations—which follow drilling, casing, and production of oil or gas—require operators to post bonds, which are forfeited and used by the state to plug a well if the operator fails to do so herself.[338] They also require that operators use a certain type of cement and cement-application method to ensure proper plugging.[339]

The states that have updated their regulations in recognition of the rise of oil and gas development and fracturing have largely focused on casing—requiring that casing be extended farther below groundwater, be pressure tested to ensure that it will withstand fracturing, and use stronger cement.[340] Several states have also modified blowout

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string of casing"); 3 WYO. CODE §§ 12, 21(a) (LexisNexis 20121) (requiring well log and report on well completion).

334. *But see* 805 KY. ADMIN. REGS. 1:020 (2011) (only requiring BOPs "[i]n areas where abnormal pressures are expected or encountered").

335. *See, e.g.*, ARK. OIL & GAS COMM'N RULE B-41(V) (2012), http://www.aogc.state.ar.us/onlinedata/forms/rules%20and%20regulations.pdf (requiring BOPs and regular BOP testing); COLO. CODE REGS. § 404-1:317(a) (2011) (requiring BOP equipment to exceed the maximum surface pressure to which it will be subjected); LA. ADMIN. CODE tit. 42, Pt. XIX § 111(C) (2011) (requiring installation of BOP); MD. CODE REGS. 26.19.01.10(Q) (2011) (requiring installation of BOP); MONTANA ADMIN. R. § 36.22.1014 (2011) (requiring installation of BOP with specific parameters); N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-38 (requiring BOP to be maintained and in working order); OHIO REV. CODE ANN. § 1509.17(A) (LexisNexis 2011) (requiring casing to provide base for BOP and other equipment necessary to control well); OKLA. ADMIN. CODE § 165:10-29-1(a) (2011) (requiring installation of BOP with specific parameters); 25 PA. CODE § 78.72 (2011) (requiring BOP for all wells in the Marcellus Shale).

336. *See, e.g.*, 2 COLO. CODE REGS. § 404-1:603(e)(4) (requiring blind ram) (2011); MICH. ADMIN. CODE r. 324.406(1)(a) (2011) (same).

337. *See, e.g.*, MICH. ADMIN. CODE r. 324.406(1)(b) (2011) (requiring "[a]ccessible controls on rig floor and at a safe remote location"); MONT. ADMIN. R. 36.22.1014(7)(c) (2011) (requiring remote controls of BOP equipment).

338. *See, e.g.*, 16 TEX. ADMIN. CODE § 3.14(d)(1) ("Wells shall be plugged to insure that all formations bearing usable quality water, oil, gas, or geothermal resources are protected."); 16 TEX. ADMIN. CODE § 3.78(f) ("Operators shall submit required financial security or well-specific plugging insurance policies at the time of filing an initial organization report, as a condition of the issuance of a permit to drill, recomplete or reenter, upon yearly renewal, or as otherwise required under this section.").

339. *See, e.g.*, 16 TEX. ADMIN. CODE § 3.14(d) (2012) ("All cementing operations during plugging shall be performed under the direct supervision of the operator or his authorized representative . . . . Cement plugs shall be set to isolate each productive horizon and usable quality water strata.").

340. PA. BULLETIN, PROPOSED RULEMAKING, 25 PA. CODE § 78 (July 10, 2010),

prevention requirements to ensure that BOPs are installed and used during drilling and fracturing.[341] Casing and BOP requirements still vary substantially, however. Arkansas, Maryland, and Michigan appear to require the deepest surface casing,[342] while Kentucky only requires that the casing extend thirty feet below groundwater.[343] Others simply require "sufficient"[344] casing, with individual requirements for well casing varying by well. Texas has proposed, but not yet finalized, new rules that would include more stringent casing and cementing requirements.[345]

Even in those states that have expanded casing and blowout prevention regulations, legislatures and agencies have generally omitted a key regulatory component that will be essential in an updated policy dialogue. States need information on the quality of water near well sites prior to drilling and fracturing—the baseline quality.[346] If states know existing concentrations of pollutants in waters near proposed wells, they can attempt to trace any additional pollutants post-drilling and fracturing either to oil and gas wells or to natural sources.[347] Isotopic analysis of gas within the well annulus (the space between the well bore and the casing), for example, may show that the gas that escaped from the well is similar to the gas that entered the water.[348] Alternatively, the gas in

http://www.pabulletin.com/secure/data/vol40/40-28/1248.html (regulations codified at 25 PA. CODE § 78.83 (2011)); 25 PA. CODE § 78.72(k) (2012) (updating cementing requirements).

341. *See, e.g.*, N.D. DEP'T OF MINERAL RES., PROPOSED 2012 RULE CHANGES, GENERAL RULES AND REGULATIONS, 43-02-03-27.1, (Nov. 9, 2011), *available at* https://www.dmr.nd.gov/oilgas/rules2012changes.pdf (showing updates for pressure release valves and blowout equipment required); PA. BULLETIN, PROPOSED RULEMAKING, 25 PA. CODE § 78.72, 78.84 (July 10, 2010), http://www.pabulletin.com/secure/data/vol40/40-28/1248.html (showing new blowout prevention requirements for Marcellus Shale (unconventional) wells).

342. *See supra* note 332.

343. 805 KY. ADMIN. REGS. 1:020.3(1) (2011).

344. 16 TEX. ADMIN. CODE § 3.13(b)(2)(A)(i) (2010) ("sufficient surface casing to protect water"); 2 COLO. CODE REGS. § 404-1:317(f) (2011) ("manner sufficient to protect all fresh water").

345. R.R. Comm'n. of Tex., *supra* note 101, at 1-11 (proposing improved casing and cementing requirements, including mechanical integrity tests, better quality of cement, and avoiding disturbing the well within eight hours after cement is in place, among other protections).

346. *See, e.g.*, Osborn et al., *supra* note 33, at 4 (noting chemical comparisons in water wells with "baseline historical data").

347. *See id*.

348. *See, e.g.*, EAST RESOURCES, INC., *supra* note 307, at 10–11 (describing an isotopic analysis).

underground water may exhibit the qualities of historic gas that has long been in the formation, suggesting that drilling may not be the culprit.[349] Despite the importance of these types of baseline analyses in determining the sources of water pollution, many states do not require baseline testing.

A number of states, and at least one regional regulatory body, have started to address this problem. Colorado requires baseline surface water testing near certain public water systems and aquifers.[350] Louisiana mandates groundwater monitoring if a pit is likely to contaminate groundwater.[351] Michigan,[352] New York,[353] Ohio,[354] and West Virginia (at the water well owner's request)[355] all require testing of water wells within a certain number of feet of a proposed gas well. Oklahoma, in contrast, appears to only require baseline water testing around certain underground injection disposal wells.[356]

Through somewhat more comprehensive rules for ascertaining water quality problems and their causes, Pennsylvania strongly encourages[357] baseline testing around all wells by applying a rebuttable presumption that gas operators have caused water contamination if it occurs within one year of drilling and within a certain distance of the site.[358] West Virginia has a similar rebuttable presumption.[359] Finally, the Delaware River Basin Commission has proposed to require groundwater and surface water studies prior to the construction of well sites in the basin watershed.[360]

Policy efforts to require better water quality information have been some of the most successful so far, likely because they do not require difficult substantive changes in industry practice, aside from potentially expensive monitoring and reporting. Industry and state legislators alike have similarly supported chemical disclosure requirements. The many states

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349. *See id*.
350. 2 COLO. CODE REGS. 404-1:317(b) (Westlaw 2012).
351. LA. ADMIN. CODE tit; 43, pt. XIX, § 309(A) (2011).
352. MICH. ADMIN. CODE r. 324.1002 (2011).
353. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 1-10.
354. OHIO ADMIN. CODE § 1501:9-1-02(F) (2011) (testing for water wells within 300 feet of the oil and gas well, in urbanized areas); OHIO REV. CODE § 1509.06 (2012) (testing for water wells within 1,500 feet of proposed horizontal wells).
355. W. VA. CODE R. § 35-4-19.1 (2011).
356. OKLA. ADMIN. CODE § 165:10-5-5(b)(5)(C) (2011).
357. 58 PA. CONS. STAT. § 3218 (2012).
358. 58 PA. CONS. STAT. ANN. § 3218(c) (Westlaw 2012).
359. W. VA. CODE § 22-6A-18(b) (2012).
360. DEL. RIVER BASIN COMM'N, *supra* note 112, at § 7.4(e)(4) (2011).

that support expanded information about chemicals but do not require baseline testing of underground and surface water supplies near proposed wells should not overlook the importance of baseline testing—they should demand baseline testing along with chemical information. Only with better data on the pre- and post-drill content of waters can we understand the causes of alleged contamination, both at and below the surface.

2. Producing, Storing, and Disposing of Drilling Wastes

Heightened drilling activity enabled by fracturing does not only use more drilling fluids and muds and increase the risk of casing and cement failures; higher drilling rates also could generate more waste,[361] and thus increase the risks of improper handling and disposal of these wastes, as discussed in this Section. Following discussion of these risks, this Section describes the existing state spill prevention and control laws that apply to drilling, state efforts to expand requirements to setback wells and well pads from protected resources and increase spill containment on well sites, and limited efforts to address the risks of underground and surface waste disposal.

a. Risks: Spills and Contamination of Soil and Surface or Underground Water

The potentially larger volume of drilling wastes generated by higher rates of drilling[362] include used drilling fluids and muds, drill cuttings (the soil and rock from the drilled formation), and produced water that comes up naturally out of the formation.[363] Drill cuttings can be contaminated with drilling fluids and may contain salts and naturally low levels of radioactive material.[364] Produced water, too, tends to have high salt levels[365] and may be slightly radioactive.[366] Used drilling

361. Note, however, that horizontal drilling decreases the amount of waste that otherwise would have been required to produce the same amount of gas from vertical wells. *See supra* note 70.

362. *But see id*.

363. *Cf.* Dancy, *supra* note 196 (describing naturally-occurring levels of total dissolved solids in the water).

364. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 6-205 (2011).

365. *See supra* note 197.

366. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 6-205 (2011).

fluids and muds (mixed with drill cuttings) are often stored on site in a reserve pit, and produced water is stored in a pit or tank.[367] Storage pits can leak due to a torn liner, and pits or tanks may overflow if improperly constructed or maintained, thus causing spills onto or beyond the well pad.[368] In total, about 64 percent of violations identified at sites with fractured wells in Louisiana, Michigan, New Mexico, and Texas were caused by storage or disposal of oil and gas wastes, although spills represented a small percentage of total violations in many states.[369]

In Ohio, Department of Natural Resources inspectors noted that the "backside wall" of a drill pit had given way, "causing the contents to spill down into woods and down to a creek."[370] In New Mexico, several spills occurred during transfers of produced water. Twelve barrels of produced water spilled when a flowline ruptured (ten of which were recovered),[371] and improperly installed piping at a site spilled twenty-five barrels of produced water.[372] Additionally, several pit or tank overflows, due either to the malfunctioning of a tank, weather, or improper construction, have caused spills of as much as 5,964 gallons of produced water, which was only partially recovered.[373] Similarly, produced water in a tank in Louisiana flowed out of the tank and over a surrounding retaining wall into a "ditch and swampy area."[374]

In addition to overflows and spills during transfers to tanks or pits, pits can leak into soil or water if they are

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367. *See, e.g.*, 2 COLO. CODE REGS. 404-1:904 (Westlaw 2012) (requiring tank storage (closed loop systems) when drilling near water supply); LA. ADMIN. CODE tit. 43, pt. XIX, § .307(A) (2011) (regulating produced water pits); MD. CODE REGS. 26.19.01.10 (J)(4-5) (Westlaw 2012) (regulating pits); MICH. ADMIN. CODE r. 324.407 (2011) (regulating pits for drilling wastes); N.D. ADMIN. CODE 43-02- 03-19.3 (2011) (regulating pits); OHIO ADMIN. CODE 1501: 9-3-08 (2011) (regulating pits); 25 PA. CODE § 78.56 (2011) (regulating pits); 16 TEX. ADMIN. CODE § 3.8(d)(4) (regulating pits).

368. *See infra* notes 369–374.

369. Wiseman, *State Enforcement of Shale Gas Development Regulations*, *supra* note 94, at 19.

370. API well no., 34111241810000, violation spreadsheet reference no. 2016754140, Ohio Dep't of Nat. Resources, May 16, 2008 inspection (violation).

371. Permit no. 30-045-31190, incident no. nBP0719742443, New Mexico Oil Conservation Div., June 2007 (referred to environmental inspector).

372. Permit no. 30-045-29954, incident no. nBP0625440443, New Mexico Oil Conservation Div., Aug. 2006.

373. Permit no. 30-039-25947, incident no. nDGF0100955815, New Mexico Oil Conservation Div., Jan. 8, 2001 (142 barrels (5,964 gallons) of produced water spilled, seventy barrels were recovered; violation noted, no known enforcement).

374. La. Permit no. 238585, Bossier Parish, Mar. 18, 2009.

improperly lined or constructed, or if the clay or synthetic liner is damaged. In New Mexico, a partially-melted liner caused a leak of five barrels of produced water,[375] and several tears in pit liners have been noted in Pennsylvania—some of which caused pit contents to leak.[376] Louisiana violations similarly showed that reserve pits, which contain drilling wastes, contained selenium and other pollutants above acceptable levels; these led to several orders for remedial action.[377] Further, if well sites and pits are not fenced or covered, animals and humans can come into contact with waste and chemicals stored in pits or spilled on the surface.[378]

Several additional risks emerge when the wastes stored in pits or tanks on site are eventually removed from pits or tanks and disposed of. Produced water is sometimes disposed of on roads for dust control,[379] while used drilling fluids may be spread on the surface of the well site (particularly if they are water, not oil-based),[380] and drill cuttings often are reinserted

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375. No.Permit no. 30-045-34475, incident no. nRMD1010257007, New Mexico Oil Conservation Div., June 11 and 18, 2009.

376. Well Permit no. 115-20250, Springville, Susquehanna, Penn. Dep't of Envtl. Protection (Jan. 5, 2011) ("Tears in the liner were observed on the well pad behind baker tanks and heating system. Black fluid was impacting the surface of the ground due to breached containment."); Well Permit no. 115-20150, Dimock, Susquehanna, Pa. Dep't of Envtl. Protection (Feb. 18, 2011) (noting improperly lined pit and tears in the liner); Well Permit no. 021-21166, Inspection no. 1941745, Adams Twp., Cambria Pa. Dep't of Envtl. Prot. (Jan. 5, 2011) (noting drill cuttings on a "torn, structurally unsound liner").

377. Permit no. 238448, Caddo Parish, La. Dep't Nat. Res., Oct. 26, 2010, Nov. 8, 2010 (selenium); Permit no. 240637, Caddo Parish, La. Dep't Nat. Res., May 13, 2010 (arsenic); Permit no. 240662, Caddo Parish, La. Dep't Nat. Res., May 3, 2010 (arsenic); Permit no. 239603, De Soto Parish, La. Dep't Nat. Res., June 2, 2009, Aug. 28, 2009 (selenium); Permit no. 241394, Caddo Parish, La. Dep't Nat. Res., Aug. 5, 2010 (pH).

378. *See, e.g.*, Vickie Wellborn, *Chesapeake, Schlumberger Fined $22,000 Each in Cows' Deaths*, SHREVEPORT TIMES, Mar. 25, 2010, *available at* http://un-naturalgas.org/weblog/2010/04/chesapeake-schlumberger-fined-22000-each-in-hydraulic-fracturing-related-deaths-of-cattle (describing cattle deaths after cattle allegedly came into contact with fracturing fluid spilled on a well site surface).

379. *See, e.g.*, OHIO REV. CODE ANN. § 1509.226 (West 2011) (allowing roadspreading if approved by municipality); 2 COLO. CODE REGS. § 404-1:907 (2011) (allowing roadspreading outside of sensitive areas); MICH. ADMIN. CODE r. 324.703 (2011); MICH. ADMIN. CODE r. 324.705 (2011) (allowing roadspreading for ice or dust control); WY ADC OIL GEN Ch. 4 s 1 (mm) (2011) (allowing roadspreading); N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-60 to -61 (proposing to allow roadspreading after beneficial use determination); OHIO REV. CODE ANN. § 1509.226 (West 2011) (allowing roadspreading if approved by municipality); WY ADC OIL GEN Ch. 4 s 1 (mm) (2011) (allowing roadspreading).

380. *See, e.g.*, 2 COLO. CODE REGS. § 404-1:907(e)(1)(B) (2011) (allowing land treatment onsite even for oil-based fluids); OKLA. ADMIN. CODE § 165:10-7-19 (allowing land application of water-based fluids from earthen tanks); 16 TEX.

into the well bore or buried at the well site.[381] Extensive application of produced water and other wastes to roads or other surface locations can also cause surface pollution if not done properly.[382]

As an alternative to surface application, operators often dispose of produced water in an underground injection control well or through a wastewater treatment plant. Both of these methods pose risks.[383] In Texas, an improperly constructed underground injection control well with salty oil and gas wastes leaked into and contaminated Midland's drinking water aquifer,[384] while several UIC wells have caused small, localized earthquakes.[385]

ADMIN. CODE § 3.8(d)(3) (allowing land farming of low-chloride fluids, burial for those with higher chloride concentrations); WY ADC OIL GEN Ch. 4 s 1 (mm) (2011) (allowing land farming or land spreading with approval). *But see* MICH. ADMIN. CODE r. 324.703 (2011) (requiring disposal in an injection well).

381. *See, e.g.*, LA. ADMIN. CODE tit. 43, § XIX.313 (2011); LA. ADMIN. CODE tit. 33, § IX.708 (2011) (allowing surface discharge or water-based cuttings); MD. CODE REGS. 26.19.01.06, 26.19.01.10 (2011) (allowing land farming in areas of disturbance); 25 PA. CODE § 78.61 (2011) (allowing land application); N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-66 to -67 (proposing to allow burial on site; consultation with Division of Minerals Mgt. required if certain pollutants present).

382. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 8-53 (noting the possibility that produced waters discharged on the surface could enter surface waters); No.Permit no. 30-045-34475, incident no. nRMD1010257007, New Mexico Oil Conservation Div., June 11 and 18, 2009 (violation for discharge to a swampy area).

383. Dancy, *supra* note 197, at 15 (noting that "[m]ost produced water is disposed of in underground injection control wells"); Press Release, U.S. Envtl. Prot. Agency, *supra* note 233 (describing the need for information about disposal methods due to concerns about wastewater treatment); Weston, *supra* note 198, at 35 (describing disposal through publicly-owned treatment works).

384. *See* City of Midland's Motion for Estimation of Claims for Purpose of Allowance, Voting, and Determining Plan Feasibility, and Request for Determination that Remediation Claim is Entitled to Administrative Expense Priority at 2, *In re* Heritage Consolidated LLC, et al., Case. No. 10-36484-hdh-11 (D. Tex. Nov. 15, 2010) (on file with author) (describing how leaking UIC wells caused a "release of a tremendous amount of water contaminated with chloride (and other harmful elements) into the Cenozoic Pecos Alluvium Aquifer").

385. AUSTIN HOLLAND, OKLA. GEOLOGICAL SURVEY, EXAMINATION OF POSSIBLY INDUCED SEISMICITY FROM HYDRAULIC FRACTURING IN THE EOLA FIELD, GARVIN COUNTY, OKLAHOMA 18 (2011), http://www.ogs.ou.edu/pubsscanned/openfile/OF1_2011.pdf ("Cases of clear anthropogenically-triggered seismicity from fluid injection are well documented with correlations between the number of earthquakes in an area and injection, specifically injection pressures, with earthquakes occurring very close to the well"); OHIO DEP'T OF NAT. RESOURCES, PRELIMINARY REPORT ON THE NORTHSTAR 1 CLASS II INJECTION WELL AND THE SEISMIC EVENTS IN THE YOUNGSTOWN, OHIO, AREA 17 (2012), http://media.cleveland.com/business_impact/other/UICReport.pdf (concluding that there is a "compelling argument" that an injection well induced an earthquake

In Pennsylvania, as introduced above, the EPA began investigating discharges from wastewater treatment plants that accept produced water and fracturing waste, worrying that the plants may not be equipped to adequately treat these large volumes of waste before discharging into rivers.[386]

b. Responses: Some Setback and Secondary Containment Requirements, and Limited Disposal Well Protections

Despite the risks posed by the generation of more drilling wastes, the federal government and many states have not adequately modified policies and regulations to address the risks. As introduced in Part III.A.3. above, which discusses the handling and disposal of flowback water from fracturing, this may represent a significant gap. At the waste storage stage, most drilling wastes are temporarily stored on site in pits; states have a range of requirements for these pits.[387] Some states require that pits be lined, while others do not.[388] Some state and local governments require fences and/or netting around pits to keep out birds, other wildlife, livestock, and humans, while others fail to prevent these potential exposures.[389] Some go further, requiring steel tanks for all waste in areas close to surface drinking water supplies.[390] Still others have modified setback requirements for wells or well pads,[391] which can prevent contamination of protected resources if waste spills, and have updated requirements for

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because, in addition to other factors, seismic events began three months after injection operations began and "subsequent seismic events were clustered around the vicinity of the wellbore").

386. *See supra* note 230 and accompanying text.

387. *See* WISEMAN & GRADIJAN, *supra* note 31, at 108–09 (showing liner requirements for pits that contain flowback, some of which apply to all waste pits); *id.* at 110 (showing freeboard requirements for various waste pits).

388. *See id.*

389. *See, e.g.*, N.D. ADMIN. CODE 43-02-03-19.1 (2011) (requiring fencing of all "open pits and ponds which contain saltwater" and fencing, netting, and screening of all pits and ponds with oil); CITY OF ARLINGTON, TEX. ORDINANCE NO. 07-074 § 7.01(C)(12) (2007), *available at* http://www.marcellus-shale.us/pdf/Gas-Drill-Ord_Arlington-TX.pdf (requiring complete enclosure of operations sites with masonry walls); CITY OF FORT WORTH, TEX., ORDINANCE NO. 18449-02-2009 § 15-42(A)(26)(f) (2009), *available at* http://www.fortworthgov.org/uploadedFiles/Gas_Wells/090120_gas_drilling_final.pdf (requiring all drill pits to be fenced on all open sides).

390. 2 COLO. CODE REGS. § 404-1:317B (2012).

391. *See infra* note 409.

secondary containment beneath waste and chemical storage areas.[392]

For the waste disposal stage, only Ohio, which issues UIC permits under delegated federal Safe Drinking Water Act Authority ("SDWA"), appears to have updated its UIC requirements to address potential earthquake problems.[393] The EPA therefore may need to exert its federal SDWA authority to ensure that state permitting programs are adequate. Although these programs already have bonding and other requirements[394] to avoid leakage of wastes into underground aquifers, the adequacy of these programs must be reconsidered as millions of gallons of additional waste are pumped into UIC wells.[395]

At the surface, in response to concerns about contamination from disposal, Pennsylvania has discouraged disposal of oil and gas wastes through wastewater treatment plants—in some cases causing these wastes to be shipped to out-of-state plants, which may also be ill-equipped to handle large volumes of new wastes.[396] Finally, some operators continue to send solid drilling wastes to centralized landfills for exploration and production wastes,[397] which could become overwhelmed as thousands of new operators search for disposal

392. *See supra* note 177.

393. OHIO DEP'T OF NAT. RESOURCES, CLASS II DISPOSAL WELL REFORMS/YOUNGSTOWN SEISMIC ACTIVITY QUESTIONS AND ANSWERS 2, http://ohiodnr.com/downloads/northstar/YoungstownFAQ.pdf (last visited Nov. 29, 2012) (preventing construction of wells in certain formations and requiring monitoring).

394. *See* U.S. ENVTL. PROT. AGENCY, EPA 570/9-90-003, FEDERAL FINANCIAL RESPONSIBILITY DEMONSTRATIONS FOR OWNERS AND OPERATORS OF CLASS II OIL AND GAS-RELATED INJECTIONS WELLS 8 (1990), *available at* http://www.epa.gov/r5water/uic/forms/ffrdooc2.pdf (explaining bonding requirements).

395. *See, e.g.*, W. VA. DEP'T EVNTL. PROT., INDUSTRY GUIDANCE: GAS WELL DRILLING/COMPLETION, LARGE WATER VOLUME FRACTURE TREATMENTS 4 (2010), http://www.dep.wv.gov/oil-and-gas/GI/Documents/Marcellus%20Guidance%201-8-10%20Final.pdf (noting that "to handle the expected amount of water, many additional UIC wells will need to be permitted, drilled or converted").

396. Julie Carr Smyth, *Ohio Quakes Could Incite Fracking Policy Shift*, ASSOCIATED PRESS, Jan. 4, 2012, *available at* http://www.nola.com/science/index.ssf/2012/01/ohio_quakes_could_incite_frack.html (noting that some of Pennsylvania's "waste is trucked into Ohio, where the geology allows for more injection wells").

397. *See, e.g.*, 2 COLO. CODE REGS. § 404-1:907 (2011) (allowing disposal of oily wastes at centralized E&P facility); LA. ADMIN. CODE tit. 43, § XIX.313 (2011), LA. ADMIN. CODE tit. 33, § IX.708 (2011) (allowing disposal of water-based drill cuttings at an approved disposal facility, among other options); MD. CODE REGS. 26.19.01.06, 26.19.01.10 (2011) (same).

space.[398] Additionally, many oil and gas wastes are disposed of at well sites,[399] or, in some cases, on roads.[400]

If drilling rates increase sufficiently, the wastes produced could require revisiting these typical methods of disposal. While it may previously have been acceptable for a few operators to bury drill cuttings on the surface of well sites, for example, thousands of new operators following the same disposal procedures could raise the risk of contamination.

3. Constructing Well Pads and Access Roads, and Expanding Road Use

Fracturing, by enabling more wells to be drilled, does not only increase drilling waste and the risk of improper casing, it also, of course, requires the construction of more well pads—surface facilities that support the well drilling operation. Operators construct access roads to the pads if they cannot use existing roads, thus fragmenting habitat and disturbing more soil, and they typically use existing local roads to transport a host of heavy equipment.[401] Predictably, this also increases certain environmental risks—particularly soil erosion and sedimentation. This Section explores this risk and states' limited modifications of stormwater permitting requirements in response. It also describes the positive regulatory trend toward mandated setbacks of wells and well pads from natural resources that could be polluted as a result of soil erosion or spills.

398. *See, e.g.*, W. VA. DEP'T OF ENVTL. PROT., INDUSTRY GUIDANCE, *supra* note 394, at 4 (noting that the state only has two UIC wells and strongly encouraging reuse of wastes).

399. *See, e.g.*, N.D. ADMIN. CODE § 43-02-03-19.2 (2011) (allowing disposal of drill cuttings on site); 25 PA. CODE § 78.61 (2011) (allowing disposal of drill cuttings in a pit on site or land application, with varying requirements depending on the origin of the cuttings); *see also Fact Sheet: Onsite Burial (Pits, Landfills)*, WASTE MGMT. INFO. SYSTEM, http://web.ead.anl.gov/dwm/techdesc/burial/index.cfm (last visited Dec. 18, 2012) ("Burial is the most common onshore disposal technique used for disposing of drilling wastes (mud and cuttings).").

400. *See supra* note 379.

401. *See* 2 COLO. CODE. REGS. § 404-1:1002(e)(4) (2011) ("Existing roads shall be used to the greatest extent practicable to avoid erosion and minimize the land area devoted to oil and gas operations.").

a. Risks: Soil Erosion and Migration of Other Contaminants

Any type of construction—including construction of well pads and access roads—can cause soil erosion, which can pollute surface water and may introduce invasive plants as construction equipment travels from site to site.[402] In Michigan, state officials recently noted a "badly eroded" access road leading to a well site.[403] Approximately 22 percent of violations at well sites in the Fayetteville Shale in Arkansas between 2006 and 2010 allegedly involved eroded well sites or access roads.[404] Pennsylvania has similarly noted a "failure to minimize accelerated erosion" or potential erosion at a number of Marcellus Shale sites since drilling and fracturing began.[405]

402. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 6-14 to -68.

403. Permit no. 49851, Antrim County, Mich. Dep't of Envtl. Quality (May 2, 2011) (violation noted; no known enforcement).

404. ARK. PUB. POL'Y PANEL, VIOLATIONS OF WATER QUALITY STANDARDS FROM GAS PRODUCTION IN ARKANSAS 4 (2011), arpanel.org/policy/reports/natural-gas/violations/at_download/file.http://arpanel.org/content/Violations%20of%20Water%20Standards.pdf.

405. Permit no. 051-24411, German, Pa. Dep't of Envtl. Prot. (May 4, 2011) (violations noted and resolved); *See also* Permit no. 115-20019, Dimock, Pa. Dep't of Envtl. Prot. (Mar. 22, 2011) (violations noted and resolved); Permit no. 115-20036, Dimock, Pa. Dep't of Envtl. Prot. (Mar. 22, 2011) (violations noted and resolved); Permit no. 115-20043, Dimock, Pa. Dep't of Envtl. Prot. (Mar. 22, 2011) (violations noted and resolved); Permit no. 115-20087, Springville, Pa. Dep't of Envtl. Prot. (Mar. 5, 2011) (violations noted and resolved); Permit no. 115-20091, Dimock, Pa. Dep't of Envtl. Prot. (Mar. 22, 2011) (violations noted and resolved); Permit no. 115-20171, Dimock, Pa. Dep't of Envtl. Prot. (Mar. 14, 2011) (violations noted and resolved); Permit no. 115-20178, Dimock, Pa. Dep't of Envtl. Prot. (Apr. 6, 2011) (violations noted and resolved); Permit no. 115-20201, Dimock, Pa. Dep't of Envtl. Prot. (Mar. 22, 2011) (violations noted and resolved); Permit no. 115-20252, Dimock, Pa. Dep't of Envtl. Prot. (May 31, 2011) (violations noted and resolved); Permit no. 115-20307, Springville, Pa. Dep't of Envtl. Prot. (May 2, 2011) (violations noted and resolved); Permit no. 115-20334, Dimock, Pa. Dep't of Envtl. Prot. (Feb. 24, 2011) (violations noted and resolved); Permit no. 115-20363, Rush, Pa. Dep't of Envtl. Prot. (May 17, 2011) (violations noted); Permit no. 115-20481, Springville, Pa. Dep't of Envtl. Prot. (May 27, 2011) (violations noted and resolved); Permit no. 115-20499, Auburn, Pa. Dep't of Envtl. Prot. (May 10, 2011) (violations noted); Permit no. 115-20279, Auburn, Pa. Dep't of Envtl. Prot. (Feb. 28, 2011) (violations noted and resolved); Permit no. 015-21208, Albany, Pa. Dep't of Envtl. Prot. (Apr. 28, 2011) (violations noted and resolved); Permit no. 015-21589, Rome, Pa. Dep't of Envtl. Prot. (May 4, 2011) (violations noted); Permit no. 0115-20255, Troy, Pa. Dep't of Envtl. Prot. (May 17, 2011) (violations noted); Permit no. 015-20943, Troy, Pa. Dep't of Envtl. Prot. (Apr. 5, 2011) (violations noted); Permit no. 015-20945, Albany, Pa. Dep't of Envtl. Prot. (May 4, 2011) (violations noted and resolved); Permit no. 015-21209, Albany, Pa. Dep't of Envtl. Prot. (May 4, 2011) (violations noted); Permit no. 015-21392, Orwell, Pa. Dep't of Envtl. Prot. (Apr. 12, 2011) (violations noted and resolved); Permit no. 015-21463,

Increased truck traffic, both for construction of the well pad and the development of the well itself, can also strain small roads,[406] while more diesel engines contribute to higher air emissions. A Texas citizens' group recently challenged an oil and gas disposal well on the basis of this concern, unsuccessfully arguing that the determination of whether the well was in the "public interest"—a necessary factor for its approval—must include considerations about traffic safety and damage to local roads.[407]

As discussed below, governments have taken measures to address road use concerns. However, they have largely failed to directly address expanded erosion impacts, with the exception of requirements for well site setbacks from water.

b. *Responses: Controlling Well Pad Location and Implementing Stormwater Permitting*

The construction of well pads and access roads has long been regulated at the local, state, and federal levels. Many local governments control the location of well pads through zoning (prohibiting oil and gas wells in residential areas, for example), and states increasingly require that a well or well pad be set back a minimum distance from various natural resources.[408] Indeed, several recent regulatory modifications have focused on adding or expanding setback requirements.[409] These types of

Wyalusing, Pa. Dep't of Envtl. Prot. (Jan. 4, 2011) (violations noted and resolved); Permit no. 113-20055, Elkland, Pa. Dep't of Envtl. Prot. (May 4, 2011) (violations noted and resolved); Permit no. 113-20078, Elkland, Pa. Dep't of Envtl. Prot. (May 10, 2011) (violations noted and resolved); Permit no. 113-20094, Elkland, Pa. Dep't of Envtl. Prot. (Mar. 1, 2011) (violations noted and resolved); Permit no. 115-20317, Auburn, Pa. Dep't of Envtl. Prot. (Apr. 20, 2011) (violations noted and resolved); Permit no. 131-20115, Meshoppen, Pa. Dep't of Envtl. Prot. (Apr. 28, 2011) (violations noted and resolved); Permit no. 113-20005, Elkland, Pa. Dep't of Envtl. Prot. (Mar. 1, 2011) (violations noted and resolved); Permit no. 015-21426, Albany, Pa. Dep't of Envtl. Prot. (Apr. 5, 2011) (violations noted and resolved).

406. *See* MICHELE ROGERS, PENN. ST. COLL. OF AGRIC. SCI., MARCELLUS SHALE: WHAT LOCAL GOVERNMENT OFFICIALS NEED TO KNOW 11 (2008), http://www.coshoctoncounty.net/cpa/images/marcellusshalewhatlocalgovernmentofficialsneedtoknow.pdf ("The process of drilling, fracturing, and maintaining natural gas wells can create significant heavy truck traffic on rural roads, many of which were not designed for carrying vehicles of this size.").

407. R.R. Comm'n of Tex. v. Tex. Citizens for a Safe Future & Clean Water, 336 S.W.3d 619, 622–23, 633 (Tex. 2011).

408. *See infra* notes 412–418.

409. PA. GENERAL ASSEMBLY, *Bill Information, Regular Session 2011-2012, House Bill 1950,* http://www.legis.state.pa.us/cfdocs/billinfo/bill_history.cfm?syear=2011&sind=0&body=H&type=B&bn=1950 (updating setbacks to include

regulations can prevent erosion and spilled substances from entering surface waters and other protected resources.[410]

Some states, such as Texas, have few, if any, setback requirements—mandating only that wells be two-hundred feet from houses.[411] Others (including Colorado,[412] New York,[413] New Mexico,[414] Pennsylvania,[415] and West Virginia[416]) have minimum setbacks between well pads, wells, or tanks and surface waters, such as streams, public water supplies, and wetlands.[417] Additionally, New York officials have engaged in a lengthy discussion as to whether they will permit any fracturing within the watershed of New York City's unfiltered water supply—a network of surface reservoirs in the Catskills area.[418]

States have not been as proactive in limiting erosion from

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minimum distances from edge of disturbed sites and increasing some setbacks); H.B. 401, 2011 Leg., 4th Special Sess. (W. Va. 2011), *available at* http://www.legis.state.wv.us/Bill_Status/bills_history.cfm?year=2011&sessiontype=4X&input=401 (showing legislative changes, which require, among other actions, setbacks of wells from streams, wetlands, and other natural resources).

410. *See, e.g*, N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 6-39 (noting that secondary containment requirements and "setbacks proposed for high-volume hydraulic fracturing are likely to effectively contain most surface spills at and in the vicinity of the well pads" but that there remains a risk of release to nearby resources, including aquifers).

411. TEX. LOC. GOV. CODE § 253.005(c) (2012).

412. 2 COLO. CODE REGS. § 404-1:603 (2011) (providing a three-hundred-foot buffer for public water supplies and limitations on drilling within intermediate and external buffers).

413. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-34 (proposing 500-foot setback between well pad and stream); *id*. at 1-17 (proposing a 2,000-foot setback from public water supplies).

414. N.M. CODE R. § 19.15.17.10 (LexisNexis 2012) (requiring a 500-foot setback of pits or tanks from wetlands); N.M. CODE R. § 19.15.17.10 (LexisNexis 2012) (requiring a 300-foot setback of pits or tanks from streams).

415. 58 PA. CONS. STAT. § 3215(b)(3) (2012) (requiring unconventional wells to be set back 300 feet from wetlands greater than one-acre and the edge of the disturbed site to be set back 100 feet); *Id.* § 3215(b)(1) (requiring the vertical unconventional well bore to be set back 300 feet or the edge of the disturbed area to be set back 100 feet from a stream—whichever is greater).

416. W. VA. CODE § 22-6A-12 (2012) (requiring a 100-foot setback for wells or well pads from wetlands); *Id.* § 22-6A-12(b) (requiring a 100-foot setback from streams and 300-foot setback from naturally-producing trout streams).

417. 58. PA. CONS. STAT. § 3215(b)(4) (2012) (100-foot setback of well or well site from stream or wetland greater than one acre); N.M. CODE R. § 19.15.17.10 (LexisNexis 2011) (300-foot setback of pits from streams); 2 COLO. CODE REGS. § 404-1:603 (2011) (300-foot buffer for public water supplies); N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-34 (500-foot setback between well pad and stream).

418. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-55 to -56.

sites. The federal CWA[419] controls erosion from well pads and access roads[420] through stormwater permitting for sites one acre and larger. Operating under a cooperative federalist scheme, states typically implement these permitting programs,[421] but few states have updated their permitting requirements to recognize potential impacts of larger well numbers, including more soil disturbances at well sites and access roads.[422] Arkansas,[423] New York,[424] Ohio,[425] and Pennsylvania[426] have been more proactive by requiring specific erosion and sediment control practices for certain wells.

The lack of a comprehensive response to erosion may result from the relative ease of ignoring nonpoint source runoff from diverse sites. But states and municipalities have not been able to ignore the direct road damage caused by thousands of new trucks traveling to and from sites. Accordingly, some municipalities have entered into road use agreements with operators—requiring them, for example, to repair, build, or expand roads and to limit municipal liability for road damage.[427]

Despite progress in addressing road use, requiring setbacks of oil and gas wells and sites from protected resources, and modifying some erosion controls, much remains to be done. Particularly with the increased use of horizontal drilling—

419. 33 U.S.C. § 1251(l) (2011).

420. *See* U.S. ENVTL. PROT. AGENCY, *Regulation of Oil and Gas Construction Activities*, http://cfpub.epa.gov/npdes/stormwater/oilgas.cfm (last updated Mar. 9, 2009).

421. *See* U.S. ENVTL. PROT. AGENCY, *Authorization Status for EPA's Stormwater Construction and Industrial Programs*, http://cfpub.epa.gov/npdes stormwater/authorizationstatus.cfm (last updated Apr. 16, 2012).

422. *See* WISEMAN & GRADIJAN, *supra* note 31, at 33–34, 38.

423. ARK. OIL & GAS COMM'N RULE B-17(h)(6) (2012) (requiring a "stormwater erosion and sediment control plan" for each well site).

424. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-26 to -29 (requiring a new general permit for oil and gas operations and a special permit for stormwater discharges within 500 feet of principal aquifers).

425. OHIO ADMIN. CODE 1501:9-1-07(B) (2012) (requiring best management practices at sites in urbanized areas).

426. *See* PA. DEP'T OF ENVTL. PROT., 5500-PM-OG0005, INSTRUCTIONS FOR A NOTICE OF INTENT (NOI) FOR COVERAGE UNDER THE EROSION AND SEDIMENT CONTROL GENERAL PERMIT (ESCGP-1) FOR EARTH DISTURBANCE ASSOCIATED WITH OIL AND GAS EXPLORATION, PRODUCTION, PROCESSING OR TREATMENT OPERATIONS OR TRANSMISSION FACILITIES (2011), http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-83401/Modified%205500-PM-OG0005%20NOI%20Instructions%202.pdf.

427. *See* Martin E. Garza, *Local Regulation of Gas Development in an Urban Setting: The Texas Experience*, *in* 60 CTR. FOR AM. & INTL. LAW, OIL & GAS LAW 273, 285 (2009).

which increases the flexibility of drilling locations[428]—states should consistently focus on requiring minimum distances between well pads (not just the well itself) and protected surface and underground resources. They also must modify current stormwater permitting requirements to address higher levels of erosion and associated water quality impacts.

4. Using Diesel, Drilling Fluids, and Drilling Muds, and Storing Produced Oil and Gas on Site

Constructing well pads and access roads and drilling oil and gas wells requires diesel equipment, grease, and hydraulic fluids for drilling rigs and other equipment, as well as drilling fluids and muds.[429] A higher drilling rate, therefore, once again expands certain risks, yet it has generated few specific regulatory responses. As with the handling of fracturing chemicals and drilling and fracturing wastes, the use of equipment on site can cause spills of certain chemicals—often diesel. Most states have not changed their regulations to specifically address equipment spills, although existing spill prevention and response plans, as well as the setbacks and secondary containment requirements introduced above,[430] can help to control the impact of these spills.

a. Risks: Spills and Contamination of Surface or Underground Water and Soil

When equipment is used to construct well pads, roads, and drill wells, diesel fuel can leak from engines or can spill when poured into tanks.[431] Drilling fluids and muds, which lubricate the drill bit and otherwise aid the drilling process, sometimes also contain petroleum.[432] Both new and spent drilling fluids and muds can spill when transferred between pits or tanks and

428. U.S. DEP'T OF ENERGY, OFFICE OF FOSSIL ENERGY, DOE-FE-0385, ENVTL. BENEFITS OF ADVANCED OIL AND GAS EXPLORATION AND PRODUCTION TECHNOLOGY 36–37 (1999), http://www.fe.doe.gov/programs/oilgas/publications/environ_benefits/env_benefits.pdf.

429. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 6-99.

430. *See supra* notes 410, 412–416 (setbacks); *supra* note 177 (containment).

431. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 6-98 to -99; *infra* notes 438–439.

432. *Cf.* MONT. ADMIN. R. 36.22.1005 (2011) (requiring off-site disposal of waste from petroleum-based drilling in a floodplain); N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at § 7-66 to -67 (requiring disposal of cuttings from petroleum-based drilling in a landfill).

the well.[433] Further, oil- or gas-containing substances produced from the well may spill from the wellhead or storage tanks and pollute the site or nearby areas.[434] These familiar well production risks increase with each new well drilled.

A number of violations noted by state regulators in counties with shale or tight sands production illustrate these risks. In one incident in Louisiana, an operator released oil-based drilling mud near a well. The mud migrated to a natural drainage, leading to an administrative settlement that required the operator to document clean-up and submit lab results or pay civil penalties.[435] In Pennsylvania's Marcellus Shale, the DEP also noted violations of state environmental laws caused by surface releases of drilling mud,[436] including one 1,500-gallon spill.[437] And in a complaint filed in federal district court, sixty-three plaintiffs from Montrose and Dimock, Pennsylvania, alleged that an operator caused "[d]iesel fuel . . . to be spilled onto the ground near Plaintiffs' homes and water wells" and discharged drilling mud "into diversion ditches near Plaintiffs' homes and water wells."[438] Further, a confirmed diesel fuel spill of less than five gallons occurred at a Pennsylvania site outside of a containment area; the operator cleaned it up with absorbent materials and excavated the soil.[439] In Michigan, one "equipment collapse" spilled oil on the surface at a well site,[440] and a citizen complaint alleged that oil leaked from equipment into a nearby lake, although no environmental violation was found.[441] In New Mexico, a drain

433. *See, e.g.*, *infra* text accompanying notes 436–437.

434. *See supra* notes 372–376.

435. Permit no. 239818, Red River Parish, La. Dep't Nat. Resources, Sept. 6, 2009 (settled Nov. 12, 2009).

436. *See, e.g.*, Permit no. 115-20357, Springville, Pa. Dep't of Envtl. Protection (Apr. 15, 2011); Permit no. 115-20339, Jessup, Pa. Dep't of Envtl. Protection (Mar. 31, 2011) ("[d]rilling mud observed on ground surface near plastic"; violation noted, no known enforcement); Permit no. 115-20473, Forest Lake, Pa. Dep't of Envt. Protection (Mar. 16, 2011) (noting "residual mud" at the site; violation noted, no known enforcement).

437. Permit no. 131-20047, Washington, Pa. Dep't of Envtl. Protection (Feb. 14, 2011) (spill on "surface of the ground outside of the containment area"; violation noted, no known enforcement).

438. Amended Complaint at 14, Fiorentino v. Cabot Oil & Gas Corp., Civil Action No. 3:09-cv-02294-TIV (M.D. Pa., Mar. 5, 2010).

439. Permit no. 115-20453, Rush, Pa. Dep't of Envtl. Prot., Mar. 2011 (violation noted).

440. Permit no. 51006, Antrim County, Mich. Dep't of Envtl. Quality (Sept. 2003) (violation noted, no known enforcement).

441. Permit no. 35926, Kalkaska County, Mich. Dep't of Envtl. Quality (July 2001) (no violation or enforcement).

valve on a tank containing produced oil froze and released eight barrels of oil, two of which were recovered.[442] Other equipment or human-based errors in New Mexico have led to surface spills of six to eighteen barrels of oil, some of which was recovered.[443]

Considering the thousands of wells drilled, these types of incidents may not cause much concern. Indeed, initial review of select environmental violations at unconventional oil and gas sites suggests that in some states the majority of violations are minor or involved no environmental effects.[444] More research is needed to determine the percentage of wells drilled that lead to these types of spills and the number of spills that are significant. This, in turn, requires further analysis of the percentage of wells that are inspected—and how often—as well as whether officials provide notice prior to entering sites for investigation. From the data currently available, it appears that surface spills in some states are much more common than other types of violations, such as improper casing of wells, but that they occur at a small percentage of the wells investigated.[445] While perhaps not posing a large risk, surface spills may be more important in the aggregate than, say, concerns about underground contamination from fracturing. One underground contamination incident, on the other hand, could dwarf the effects of multiple small spills due to the difficulties of detecting and cleaning up underground releases. Although continued study of the likelihood of underground contamination is important, it should not occur at the expense of attention to surface incidents.

442. Permit no. 30-045-24395, incident no. nBP0800952968, N.M. Oil Conserv. Div. (Dec. 2007) (violation noted, no known enforcement).

443. *See* Permit no. 30-045-29710, incident no. nBP0918933399, N.M. Oil Conserv. Div., (Feb. 2009) (six barrels spilled when valve on wellhead froze, four were recovered); Permit no. 30-045-29095, incident no. nBP0711033468, N.M. Oil Conserv. Div., (Dec. 2006) (ten barrels spilled due to human error, all were recovered); Permit no. 30-045-26706, incident no. nBP1026448466, N.M. Oil Conserv. Div., (July 2010) (separator malfunction spilled eighteen barrels, nine were recovered; violations noted).

444. *See* Wiseman, *State Enforcement of Shale Gas Development Regulations*, *supra* note 94, at 25.

445. *Id.* at 17 (showing a generally low percentage of surface spills, with the exception of New Mexico, for which much of the enforcement data came from a spill database).

b. Responses: Use of Existing Spill Prevention Plans, Expanded Setbacks, and Secondary Containment Requirements

As introduced above in the context of chemical and waste spills, few efforts have directly responded to concerns about surface spills from drilling equipment and other drilling activities. This is likely in part due to existing regulations that address some of these concerns. Some federal regulations potentially apply to certain violations, including large oil spills,[446] but many problems fall under state jurisdiction. Most states require some form of spill prevention plan, in which operators show how they will avoid spills by, for example, using secondary containment underneath drilling equipment and responding when spills occur.[447] Most states also require reporting of spills of many substances involved in drilling, although some only require reporting of oil spills, and others only require reporting spills of hazardous chemicals of a certain quantity.[448] The time and method of reporting also varies, ranging from within twenty-four hours of the spill to seven days, via hotline or written notification.[449] Nearly all of these regulations, with the exception of New York's proposed spill prevention and containment regulations[450] and Colorado's

446. *See, e.g.*, 33 U.S.C. § 1321 (2012) (creating liability for certain spills of oil into or onto U.S. navigable waters).

447. *See, e.g.*, LA. ADMIN. CODE tit. 33:, pt. IX, § 905 (2011); MD. DEP'T OF THE ENV'T, *supra* note 289, at 12; MICH. ADMIN. CODE r. 324.2006 (2011) (pollution incident prevention plan if certain threshold of chemicals is at site); PA. DEP'T. OF ENVTL. PROT., OIL & GAS MGMT. PRACTICES 4, (2001), http://www.elibrary.dep.state.pa.us/dsweb/Get/Version-48243/chap4.pdf (requiring Preparedness, Prevention, and Contingency Plan).

448. *See* WISEMAN & GRADIJAN, *supra* note 30, at 95–96 (describing states' requirements for spill prevention and response plans).

449. *See, e.g.*, 2 COLO. CODE REGS. § 404-1:337, 906(b) (2011) (requiring 240-hour notification); COLO. REV. STAT. § 25-8-601(2) (2012) (requiring reporting to the Oil and Gas Conservation Commission of all spills and releases of more than five barrels or of any size that could threaten waters); MD. CODE REGS. 26.19.01.02 (2011) (requiring reporting of spills two state agency within two hours of detection); MICH. ADMIN. CODE r. 324.1008 (2011) (requiring operators to "[p]romptly report" all spills; report within eight hours spills of "42 gallons or more of brine, crude oil, or oil and gas field waste"); N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-57 (requiring verbal notification of state agency within two hours of discovering spill); N.D. ADMIN. CODE 43-02-03-30 (2011) (requiring verbal notification of any release within twenty-four hours of release).

450. *See* N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-28 (requiring secondary containment and drip pans).

revised regulations,[451] were on the books prior to the rise of fracturing and the accompanying expansion of oil and gas development.

In addition to existing spill prevention and response plans, some states' requirements for the setbacks of well pads from protected resources will help to prevent equipment spills from affecting nearby environmental resources. Few states have adequately focused on the potentially broad impacts of surface spills, including from equipment and drilling activities, although some have comprehensively addressed this issue.

5. Emitting Gas Condensate and Air Pollution from Drilling and Fracturing Equipment

An oil and gas drilling site is, although only temporarily, host to a range of diesel engines running constantly and emitting a range of air pollutants.[452] Operators use bulldozers and excavators to construct the well pad, which hosts the well and its associated pits and tanks, and the access road to the pad.[453] Rigs, trucks, and other equipment run during the drilling process (and later during fracturing), and after drilling, the gas from the well is "flared" to test the well before converting it to the production stage.[454] In some regions, gas, which is not pure, contains condensate that is stored in tanks and may emit volatile organic compounds into the air.[455] Some gas flowing through pipelines also leaks, emitting a potent greenhouse gas.[456] All of these emissions can, in certain

451. COLO. OIL & GAS CONSERV. COMM'N RULE 604(a)(4) (requiring secondary containment around all produced water, crude oil, and condensate tanks); COLO. OIL & GAS CONSERV. COMM'N RULE 317B (requiring emergency spill response programs in three-hundred foot buffer areas around public water supplies).

452. PA. DEP'T OF ENVTL. PROT., NORTHEASTERN PENNSYLVANIA MARCELLUS SHALE SHORT-TERM AMBIENT AIR SAMPLING REPORT 2 (May 6, 2011), http://www.dep.state.pa.us/dep/deputate/airwaste/aq/aqm/docs/Marcellus_NC_05-06-11.pdf (noting that "pollutants are emitted from diesel engines" at the well construction, drilling and fracturing stages).

453. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 5-135.

454. PA. DEP'T OF ENVTL. PROT., NORTHEASTERN PENNSYLVANIA MARCELLUS SHALE SHORT-TERM AMBIENT AIR SAMPLING REPORT, *supra* note 452, at 1.

455. *Cf.* Oil and Gas in the Natural Sector: New Source Performance Standards and National Emissions Standards for Hazardous Air Pollutants Reviews, 76 Fed. Reg. 52738 (proposed Aug. 23, 2011) (codified at 40 C.F.R. pt. 63) (proposing controls on VOC emissions from condensate tanks).

456. *See* ROBERT W. HOWARTH ET AL., METHANE AND THE GREENHOUSE GAS FOOTPRINT OF NATURAL GAS FROM SHALE CLIMATIC CHANGE 6 (Climatic Change 2011), http://www.sustainablefuture.cornell.edu/news/attachments/Howarth-EtAl-2011.pdf (discussing estimates of pipeline leakage).

quantities, affect human health and welfare, and the federal government and states have only begun to address the many air quality issues that enhanced drilling and fracturing may generate.[457] The following Subsections describe the risks associated with these emissions and the state and the federal government initial efforts to address them.

a. *Risks: Adding to Existing Air Quality Problems*

Particularly on well sites in urban and suburban areas—as are common in Texas's Barnett Shale[458]—drilling and fracturing activities can exacerbate existing air quality problems.[459] In pristine areas, they may cause new visibility and odor problems.[460] Both Texas and Pennsylvania have increased some air emissions monitoring near shale gas wells to measure the magnitude of this problem.[461] Pennsylvania's initial results show "[e]levated methane levels" at two compressor stations and well sites; "methyl mercaptan," which produced odors; and "[c]oncentrations of certain natural gas constituents" near drilling operations.[462] The Texas Commission on Environmental Quality collected air quality samples downwind of natural gas compressor stations in Lake

457. *See infra* text accompanying note 461 (describing how some states are just beginning to monitor air emissions from natural gas well sites).

458. *See, e.g.*, Martineau, *supra* note 5, at 5–10 (noting that "there is gas under Fort Worth and wells have been drilled in the mid-cities area and near DFW airport"); *Applications and Permits*, CITY OF FORT WORTH, http://fortworthtexas.gov/gaswells/default.aspx?id=50608 (last visited Nov. 29, 2012) (showing 1,483 producing gas wells within the city).

459. *Cf.* COLO. DEP'T OF PUB. HEALTH & ENV'T, AIR POLLUTION CONTROL DIV., OIL & GAS EXPLORATION & PRODUCTION REGULATION NO. 7 REQUIREMENTS 1 (2011), http://www.cdphe.state.co.us/ap/sbap/SBAPoilgastankguidance.pdf (explaining Colorado air quality regulations that apply to oil and gas condensate tank owners and operators in nonattainment areas).

460. *See, e.g.*, *Air Emissions Requirements for Oil and Gas Industry*, COLO. DEP'T OF PUB. HEALTH & ENV'T, http://www.colorado.gov/cs/Satellite/CDPHE-AP/CBON/1251597643322 (noting stricter controls on oil and gas air pollutant emissions statewide and in the "Front-Range ozone nonattainment area," where air quality already fails to comply with federal requirements).

461. *See Barnett Shale Geological Area*, TEX. COMM'N ON ENVTL. QUALITY, http://www.tceq.texas.gov/airquality/barnettshale (last visited Dec. 1, 2012) (describing air sampling, inventories, and other air-quality-related activities in the Barnett Shale); PA. DEP'T OF ENVTL. PROT., NORTHEASTERN PENNSYLVANIA MARCELLUS SHALE SHORT-TERM AMBIENT AIR SAMPLING REPORT, *supra* note 452.

462. PA. DEP'T OF ENVTL. PROT., NORTHEASTERN PENNSYLVANIA MARCELLUS SHALE SHORT-TERM AMBIENT AIR SAMPLING REPORT, *supra* note 452, at ii–iii.

Arlington and Dish, Texas, concluding that with the possible exception of one pollutant, which was not detected at levels for which the TCEQ could measure health effects, concentrations of carbonyls in the air were "not of any short-term health or welfare concern."[463] Staff members at the site noticed "exhaust" and "natural gas" odors, which they concluded were likely air pollutants not measured by their analysis.[464]

Each new site drilled raises the quantity of air pollutants released and suggests that, at least, we must continue to monitor emissions. Several state and national studies agree with, for example, the Department of Energy's Shale Gas Production Subcommittee's call for more attention to air emissions,[465] and the New York Department of Environmental Conservation's observation regarding potentially strong air impacts from drilling and fracturing.[466]

b. Responses: Monitoring or Capping Certain Emissions

The EPA has addressed certain air quality concerns through its recent finalization of rules that control VOCs from fracturing and refractured wells.[467] The Clean Air Act may also limit emissions from oil and gas sites in limited circumstances. Particularly in areas that have not achieved Clean Air Act standards, states regulate even minor sources of air pollution—including oil and gas sites—through their Clean Air Act State Implementation Plans.[468]

The less aggressive response by states has been to monitor emissions. As introduced above, Pennsylvania and Texas have

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463. Interoffice Memorandum from Shannon Ethridge, Tex. Comm'n on Envt'l Quality, Toxicology Div., Chief Eng'r's Off., to John Sadler, Dep. Dir., Off. of Compliance & Enforcement 1 (Feb. 24, 2011), http://www.tceq.state.tx.us/assets/public/implementation/barnett_shale/healthEffects/2011.02.24-CarbonylMonitoringProject.pdf.

464. *Id*. at 2.

465. SEC'Y OF ENERGY ADVISORY BD., SHALE GAS PRODUCTION SUBCOMMITTEE SECOND NINETY-DAY REPORT 4 (Nov. 18, 2011), http://www.shalegas.energy.gov/resources/111811_final_report.pdf.

466. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 6-132 to -140.

467. 40 C.F.R. § 63 (2012), http://www.epa.gov/airquality/oilandgas/pdfs/20120417finalrule.pdf (Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants Reviews).

468. *See, e.g.*, COLO. DEP'T OF PUBLIC HEALTH & ENV'T, AIR POLLUTION CONTROL DIV., *supra* note 459 (describing air emissions regulations for all oil and gas condensate tanks in nonattainment areas).

conducted air monitoring in areas with heavy drilling and fracturing.[469] Some states, however, have gone further by substantively limiting emissions. New York has proposed a range of controls, including limitations on the length of time for which drilling may occur,[470] a greenhouse gas mitigation requirement,[471] and a mandate that the vapor from condensate tanks be minimized.[472] Colorado requires that condensate and produced water tanks with the potential to emit a certain quantity of volatile organic compounds ("VOCs") per year must reduce emissions of VOCs by at least 95 percent in certain counties and must be placed more than a quarter mile from buildings.[473] Throughout the state, condensate tanks with particularly high annual VOC emissions also must capture 95 percent of these emissions.[474]

In addition, several states control the venting and flaring of gas, which occurs either during oil production (when gas that comes up along with oil is not captured for sale), drilling, flowback, or just before production—when the first produced gas is burned off.[475] Louisiana, for example, provides that operators must "minimize gas releases into the open air" and may flare (burn off) gas but may not have an open flame within 200 feet of a building.[476] New York limits the amount of gas venting permitted during flowback within a consecutive twelve-month period,[477] and Oklahoma allows flaring of a certain amount of gas per day without a permit.[478] If operating without a permit, the operator must use a "suitable" stack for flaring "to prevent a hazard to people or property."[479]

In a number of states, regulations do not control the total

469. *See supra* notes 462–464.

470. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-131.

471. *Id.* at 7-116 to -117.

472. *Id.* at 7-108.

473. 2 COLO. CODE REGS. § 404-1:805 (Westlaw 2012).

474. *Air Emissions Requirements for Oil and Gas Industry*, COLO. DEP'T OF PUBLIC HEALTH AND ENVIR., AIR POLLUTION CONTROL DIV., http://www.cdphe.state.co.us/ap/oilgas.html (last visited Dec. 8, 2012).

475. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-108 (limiting gas venting).

476. LA. OFF. OF CONSERV. ORDER No U-HS, at 4 (2009), http://dnr.louisiana.gov/assets/docs/news/2009/U-HS.pdf.

477. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31, at 7-108 (providing maximum venting in a 12-month period).

478. OKLA. ADMIN. CODE § 165:10-3-15 (2011) (allowing venting without a permit if it is "not economically feasible to market the gas" and if other conditions are met).

479. *Id.*

quantity of air emissions from oil and gas sites, but they do aim to ensure that emissions do not build up in one area. Employing the old trick of midwestern power plants (which, prior to the implementation of stricter Clean Air Act controls, built tall smokestacks and sent air emissions to the East Coast)[480], Montana requires minimum stack heights on drilling equipment in certain areas,[481] and Farmington, New Mexico requires exhaust to be vented away from well sites.[482]

State regulations that solely monitor or displace air emissions from gas well sites may not go far enough. Some oil and gas operators faced no federal (or, in some cases, state) controls on air emissions until the recent implementation of certain federal air regulations,[483] and progress beyond the VOC controls already implemented by the EPA remains to be made.

The risks of shale gas development pose a daunting hurdle to local, regional, state, and federal regulators and policymakers. Those responsible for protecting public health and the environment have paid insufficient attention to the risks that emerge from two core changes: the new stages of gas development introduced by slickwater fracturing and, just as importantly, the sheer rise in the number of wells drilled as a result of fracturing. Although all levels of government have begun to respond, it appears that this effort is not enough. Much more will be required to make shale gas development a safe practice that benefits communities and the national economy while adequately controlling environmental risk.

The argument that regulation is currently inadequate assumes, of course, that the current externalities of shale gas and tight sands development are problematic simply because they exist. This broad assumption requires review in future study; it is not based on a cost-benefit analysis comparing the expense of externality reduction to the benefits in terms of improved health and environmental protection; rather, it assumes that many of the risks, such as contamination from

480. *See Acid Rain Questions and Answers,* N.Y. STATE DEP'T OF ENVTL. CONSERV., http://www.dec.ny.gov/chemical/8418.html (last visited Dec. 3, 2012).

481. *See* MONT. ADMIN. R. 17.8.402 (2011) (requiring "good engineering" stack heights in some areas).

482. CODE OF CITY OF FARMINGTON, N.M. § 19-2-74(f)(6) (2011), *available at* http://library.municode.com/index.aspx?clientId=10760.

483. *See Oil and Natural Gas Air Pollution Standards: Regulatory Actions*, U.S. ENVTL. PROT. AGENCY, http://www.epa.gov/airquality/oilandgas/actions.html (last visited Dec. 19, 2012) (noting that in April 2012 the EPA issued the "first federal air standards for natural gas wells that are hydraulically fractured").

spills, could be reduced at a relatively low expense to industry and that improved regulatory efforts are merited. Others, however, note that industry has already made efforts to reduce risks and is continuing to implement best management practices;[484] some also argue that state regulation is adequate[485] and that oil and gas extraction has far fewer effects than other industries[486] and, thus, does not merit what may be viewed as over-regulation. The risks of shale and tight sands oil and gas extraction should indeed be viewed in a larger context—one that recognizes the benefits of this extraction and the comparative effects of other industries, including other types of mineral extraction. This does not justify, however, fully ignoring the impacts or efforts to limit them—particularly when efforts to reduce known risks do not impose a high cost on industry, and would meaningfully improve human health or the environment.

The following Part briefly suggests the risks that governments should prioritize and the considerations that should inform the level of government at which these risks will best be addressed.

IV. PRELIMINARY PROPOSALS FOR A MODIFIED FOCUS

From introducing new stages to the well development process to enabling more well construction, fracturing has expanded certain environmental risks of oil and gas development. The introduction of fracturing chemicals to the well development process raises the risks of chemical spills and improper disposal of wastewater, and fracturing increases the

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484. *Cf.*, AM. PETROL. INST., OVERVIEW OF INDUSTRY GUIDANCE/BEST PRACTICES ON HYDRAULIC FRACTURING (HF) (Oct. 21, 2011), http://www.api.org/~/media/Files/Policy/Exploration/Hydraulic_Fracturing_InfoSheet.ash (showing detailed industry guidance on best practices for fracturing but not estimating how many operators implement this guidance).

485. *See, e.g.*, GROUND WATER PROT. COUNCIL, STATE OIL AND NATURAL GAS REGULATIONS DESIGNED TO PROTECT WATER RESOURCES 7 (May 2009), http://fracfocus.org/sites/default/files/publications/state_oil_and_gas_regulations_designed_to_protect_water_resources_0.pdf (noting regulatory improvements in Pennsylvania and arguing that "[s]tate oil and gas regulations are adequately designed to directly protect water resources").

486. *See, e.g.*, Mike Krancer, Sec'y., Pa. Dep't of Envtl. Prot., Hydraulic Fracturing: Facts, History, Context and Perspective, Presentation Before the American Bar Assn., Section on Environment, Energy, and Resources, 20th Section Fall Meeting (Oct. 13, 2012) (arguing that "[u]nfortunately, this incredible opportunity to secure and develop a clean, reliable, domestic and affordable energy source has been attacked") (on file with author).

amount of water consumed for each well.[487] Additionally, drilling more wells appears to increase the chance of methane escaping into water, expands the quantities of wastes typically associated with oil and gas drilling, increases the chance of spills from equipment and of drilling materials, and creates more well pads and access roads that cause erosion.[488] The policy debate and regulatory processes, however, have not yet shifted to adequately address these problems, as discussed in Part III. While the debate should include questions about groundwater contamination from fracturing, as well as institutional competence and federalism, we must know the risks at all stages of well development and identify the areas that need the most attention. The following Sections identify these priority areas and suggest initial steps toward locating the most effective levels of governance for improved regulatory and policy responses.

A. *Needed Responses*

At the broadest level, institutions with authority over drilling and fracturing must comprehensively revisit their policies and regulations, noting the most important risks and determining whether existing regimes adequately address these risks. To do this, they should follow the lead of New York, which has conducted a detailed environmental analysis.[489] Because risks are not fully known, they also must implement regulations that help to generate more information on the impacts of drilling and fracturing, thus forming a clearer picture of risks. Requiring the testing of water near oil and gas sites prior to and after well development and reporting of quantities of waters used, wastes produced, and pollutants emitted would help to produce this type of needed information.

Next, state agencies must focus on updating regulations in the core areas of risk and requiring more than disclosure and reporting. Informational mandates that states have tended to implement, such as chemical disclosure and water use reporting, are important first steps toward better understanding risks, yet informational requirements will not, for example, ensure adequate instream flow as millions of gallons of water are withdrawn from streams, nor will they

487. *See supra* Part III.A.
488. *See supra* Part III.B.
489. *See* N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31.

prevent chemical spills from improperly maintained tanks or pits.

To assist states in identifying the best regulatory options, the federal government should provide a comprehensive database of state, local, and regional oil, gas, and fracturing regulations and should separately document regulatory modifications as they occur. This would remind the laggards of areas where improvement is needed and demonstrate the many variations in risk response. Ideally, this database would also include industry guidelines, such as those published by the American Petroleum Institute,[490] as well as industry best practices and the locations in which those practices have been implemented.

From the preliminary risks identified here and the regulatory innovations that have already occurred in some states, as discussed above, the following are examples of substantive regulations that states should consider:

1) Require detailed spill prevention and response plans beyond those already followed at oil and gas sites and new substantive provisions within those plans, such as the use of drip pans beneath the filling ports for chemical tanks;
2) Following the lead of states like Pennsylvania and West Virginia and the River Basin Commissions in the Marcellus region,[491] ensure that surface water withdrawals will not reduce instream flow below levels needed to support aquatic life and identify maximum daily levels of water that may be withdrawn from various sources;
3) Require the use of closed-loop systems for the storage of drilling and fracturing wastes, particularly in sensitive environmental areas;
4) Increase required setbacks between well pads (not just wells) and natural resources;
5) Require all wastewater treatment plants accepting flowback water to provide evidence that they will be able to treat flowback and

490. *See, e.g.*, AM. PETROL. INST., WATER MANAGEMENT ASSOCIATED WITH HYDRAULIC FRACTURING, *supra* note 200.

491. *See supra* text accompanying notes 290, 292; W. VA. CODE R. § 22-6A-7(e) (Westlaw 2012) (placing conditions on water withdrawals).

produced water, and require operators to receive approval before disposing of wastes at wastewater treatment plants;

6) Update underground injection control well casing requirements to prevent well leakage. Additionally, like Ohio,[492] require that operators proposing new UIC wells prove that the proposed location is not likely to cause localized earthquakes and continuously monitor the wells for seismicity issues;
7) Encourage or require reuse of flowback and produced water;
8) Update well casing requirements to prohibit the use of used casing (or require that used casing meet certain pressure tests) and increase the distance that casing must extend below underground water resources;
9) Require operators to pressure test the well before fracturing, up to the maximum pressure to which the well will be subjected, and require blowout equipment with remote control capabilities;
10) Following the lead of Pennsylvania and West Virginia,[493] implement a rebuttable presumption that methane contamination within a certain distance from the drilling operation that occurs within a certain time after drilling was caused by the operator or implement a similar regime that allows landowners to investigate contamination without having to litigate the issue; and
11) Require air emissions monitoring and reporting at all wells and consider needed minor source regulation.

This list only includes a small sample of likely needed responses that have not yet been consistently implemented by states. In addition to writing these and a number of other needed regulations, states must ensure that they have adequate capacity to enforce their updated regulations, even in

492. *See supra* note 398 and accompanying text.
493. *See supra* notes 358–359 and accompanying text.

difficult financial times, and that their enforcement staff are adequately educated and trained. West Virginia has been a recent leader in this area, requiring minimum education and experience levels as well as minimum salaries for agency staff.[494]

This Article provides a preliminary framework for this improved response, suggesting the likely areas of focus. Some of the potential risks identified here may not, in the end, be as serious as this Article has suggested, while others may be more important than anticipated. Indeed, scientific research and further study of violations is essential in order to better define risks. But the recent violations at oil and gas sites, combined with the existing literature, provide an important, concrete starting point and suggest how the policy response should proceed.

B. Federalism Considerations

In any proposal for improved regulation, preliminary questions of ideal levels of governance often arise. My previous articles have partially addressed governance level concerns, describing the many federal exemptions for oil and gas and suggesting that in some cases, states are not adequately filling in the gaps.[495] But this fails to explain whether local, regional, state, or federal actors would best fill these gaps or whether a new regulatory scheme that combines several levels is necessary.

Several considerations are relevant in normative federalism considerations, including the scope of the externalities generated by shale gas development, the expertise of the governing actors and the resources available to them, the closeness of these actors to regulated entities, and the extent to which the governance choice will allow for continued innovative experimentation—both in terms of the institutions that regulate shale gas activity and the substance of regulation, among many others.

For effects that cross state lines, such as air emissions and river pollution from wastewater treatment discharges, a federal cooperative governance scheme may be the best

494. W. VA. CODE R. § 22-6-2a (2011).

495. *See* Wiseman, *Regulatory Adaptation in Fractured Appalachia*, *supra* note 243, at 276–82.

approach[496] and in some cases already is being implemented under federal environmental statutes.[497] For any interstate effects not yet being addressed at the federal level, a regime with a federal floor would provide a guaranteed minimal level of environmental protection while allowing states to experiment above this floor.[498] A federal information clearinghouse containing state laws would improve state implementation and enable effective, tailored responses. Regional schemes also offer promising models for interstate effects, particularly where environmental factors—such as the level of radioactivity in wastewater—are unique to the formation shared by several states.

However, many of the effects of shale gas development are intrastate and raise more complicated questions about the best level of governance. Although these effects do not cross state lines, races to the bottom among states competing to attract development can cause collective environmental degradation. Races to the top may also be occurring, as evidenced by New York's relatively precautionary approach.

Even if races one way or another are emerging, there are other reasons to question whether purely local effects should be governed only by municipalities or states. Local actors, although closer to the development and more aware of its location-specific benefits and harms, may lack the resources or expertise needed to protect populations from substantial risks. While a federal clearinghouse could help here—as with regulation above a federal floor for interstate effects—states lacking the resources to implement suggested regulatory

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496. *Cf.* David Spence, *Federalism, Regulatory Lags, and the Political Economy of Energy Production*, 161 U. PENN. L. REV. 431 (2012) ("Consistent with the public economics literature on federalism, the first rationale for federal regulation focuses on the geographic scope of the externalities in question, and argues for regulation at the lowest level of government that encompasses (geographically) the costs and benefits of the regulated activity").

497. *See* U.S. ENVTL. PROT. AGENCY, EPA 816-R-04-003, *supra* note 116 (discussing the commencement of writing wastewater treatment standards for flowback); 40 C.F.R. § 63 (2012), http://www.epa.gov/airquality/oilandgas/pdfs/20120417finalrule.pdf (discussing air quality standards).

498. *See, e.g.*, William W. Buzbee, *Asymmetrical Regulation: Risk, Preemption, and the Floor/Ceiling Distinction*, 82 N.Y.U. L. REV. 1547, 1585, 1587 (2007) (noting the institutional diversity enabled by a floor and comparing its benefits to biodiversity, noting that if one institution fails, another is available to address risks, thus reducing the vulnerability of the entire system); *id.* at 1592 (defining the experimentalist regulation that occurs above a floor as a system in which "regulators reexamine their choices, measure results, and improve regulatory choices in an ongoing way").

programs would not benefit from simple suggestions for improvement. States also could be inefficiently captured by industry, which benefits from revolving-door connections to state regulatory bodies and has lobbied heavily against federal fracturing regulation.[499]

On the other hand, states have a long history of regulation and thus a deep body of expertise. They have also indicated a willingness to respond to the concerns of the scattered populous,[500] suggesting that public choice predictions don't always hold true—or that environmental and citizen groups have managed to overcome free-rider obstacles and have, in limited cases, organized into an effective lobbying group that counters industry's influence.

Professor David Spence, who has thoroughly analyzed federalism rationales in the shale gas context, concludes that "[i]f most of fracking's effects are local, the state should be in the best position to balance costs and benefits, and ought to build its regulatory capacity and regulatory infrastructure accordingly."[501] He notes, however, that even within one state, there are risks of over- and under-regulation: the costs and benefits of the development will never occur within just one political jurisdiction, and particularly where populous jurisdictions do not bear the brunt of the costs, state politicians may favor their voice over affected dissenters.[502] Professor Spence concludes that these problems can be addressed—through compensation or the option of local vetoes, for example[503]—and suggests that federal regulation be limited to interstate effects of shale gas development.[504] In contrast, Professor Jody Freeman proposes a cooperative federalist scheme with minimum performance standards, arguing that "[t]he uneven approach is bad not only for the environment but also for industry, because under the current system, mistakes by a few bad apples could lead to overregulation or even

499. *Cf. supra* notes 40–49 (describing assertions by industry and other entities that state regulation is effective).

500. *See, e.g.*, N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31 (showing that New York has conducted an extensive risk analysis while placing a temporary moratorium on development); COLO. DEP'T OF NAT. RESOURCES, OIL & GAS CONSERV. COMM'N, *supra* note 102 (showing comprehensive revisions to Colorado's oil and gas code).

501. Spence, *supra* note 496, at 43.

502. *Id*. at 44–45.

503. *Id*. at 46.

504. *Id*. at 54.

outright bans on drilling."[505]

Whether one favors a primary regime of federal, regional, state, or local governance of shale gas development—or some combination of those—in the short term it appears that states will continue to bear the brunt of regulatory responsibility. This Article leaves for future work a full analysis of where the regulatory improvements need to occur. In the meantime, however, states—the governments that currently have the primary responsibility for mitigating risk—must act now.

CONCLUSION

A careful scientific analysis of fracturing will be necessary to accurately identify, quantify, and rank the environmental risks of oil and gas development from shales and tight sands, and this Article does not purport to conduct this full analysis. Indeed, with the information currently available, we can only guess at the exact nature and magnitude of the risks, and the preliminary nature of the reports and violations discussed here cannot be overemphasized: even the Department of Energy—a core repository of information about oil and gas development and its risks—has noted that "uncertainties about impacts need to be quantified and clarified" in the context of fracturing.[506]

Despite these knowledge limitations, an initial investigation of the existing literature and potential environmental violations noted by states suggests several important conclusions. The core areas of concern introduced by new fracturing technologies appear to encompass issues that policymakers and administrators have not yet adequately considered or addressed, including more water withdrawals, the use of new chemicals, and the production of new and more wastes. The higher rate of oil and gas development enabled by fracturing, in turn, expands many traditional risks tied to this development, including surface spills of drilling fluids and produced substances, improper storage and disposal of drilling wastes, inadequate casing and cementing of wells, higher

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505. Jody Freeman, *The Wise Way to Regulate Gas Drilling*, N.Y. TIMES, July 5, 2012, http://www.nytimes.com/2012/07/06/opinion/the-wise-way-to-regulate-hydraulic-fracturing.html?_r=1&hp.

506. SEC'Y OF ENERGY ADVISORY BD., SHALE GAS PRODUCTION SUBCOMM. 90-DAY REPORT 33 (Aug. 18, 2011), http://www.shalegas.energy.gov/resources/081811_90_day_report_final.pdf.

emissions of air pollutants, and more land disturbances from well pads and access roads, among other potential effects. Instead of addressing these risks, however, much of the policy debate so far has centered around one concern: that injection of water and chemicals underground in the fracturing process could contaminate groundwater.

This tendency toward tunnel vision is beginning to change, at least in some areas. The New York Department of Environmental Conservation has completed an extensive analysis of the effects of shale gas development that uses large quantities of water, although its assessment largely relies on an existing and incomplete set of data.[507] The Department of Energy's Shale Gas Production Subcommittee, in turn, has published two reports emphasizing the need for a more comprehensive consideration of risks and immediate policy action in some areas.[508] The Pennsylvania Governor's Marcellus Shale Advisory Commission has released a similar, region-specific paper.[509] Members of Congress, on the other hand, have continued to call in state regulators to testify to the lack of any groundwater contamination from fracturing and to assert that no federal regulation of fracturing is needed—arguing that states have the situation under control.[510]

In order to understand who *should* be regulating, and whether and where more regulatory attention is needed, we must know the true risks. Focusing on states' past approaches to oil and gas development, the lack of proven groundwater contamination from fracturing, and rare yet alarming incidents creates an unproductive stalemate while well development continues to march forward at an astounding rate. The policy dialogue and regulatory response, as currently framed, have taken important steps toward identifying key risks but fail to move us toward a much-needed comprehensive assessment of the risks of this new boom. We must modify our approach in favor of a careful discussion that moves beyond tired sound bites, and this Article proposes a new, more productive framework.

The issues raised here are by no means the only ones that

507. N.Y. STATE DEP'T OF ENVTL. CONSERV., *supra* note 31.

508. *See* SEC'Y OF ENERGY ADVISORY BD., *supra* note 465; SEC'Y OF ENERGY ADVISORY BD., *supra* note 499.

509. PA. GOVERNOR'S MARCELLUS SHALE ADVISORY COMMISSION REPORT (July 22, 2011), http://files.dep.state.pa.us/PublicParticipation/MarcellusShaleAdvisoryCommission/MarcellusShaleAdvisoryPortalFiles/MSAC_Final_Report.pdf.

510. *See supra* notes 40–48.

should be considered in this new dialogue. Indeed, some of the risks suggested may prove to be low, while other, larger, concerns may have been omitted. We cannot know this until we frame the debate more broadly to consider and address risks comprehensively and produce regulations that will both generate new information on risks and address known risks. Without this, America's energy policy—already notoriously haphazard and reactionary—will continue down a winding and potentially damaging road.