Hoffman, Stephen F. 3042

From:	RegComments@pa.gov
Sent:	Thursday, May 21, 2015 11:01 AM
To:	Environment-Committee@pasenate.com; apankake@pasen.gov; IRRC; RegComments@pa.gov; eregop@pahousegop.com; environmentalcommittee@pahouse.net; gvitali@pahouse.net
Cc:	ra-epmsdevelopment@pa.gov
Subject:	Comment notice for - Advanced Notice of Final Rulemaking - Environmental Protection Performance Standards at Oil and Gas Well Sites (7-484)

Re: Advanced Notice of Final Rulemaking - Environmental Protection Performance Standards at Oil and Gas Well Sites (7-484)

The following comments have been received regarding the above-referenced advanced notice of final rulemaking.

Commentator Information:

Adam Kron
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1000 Vermont Avenue NW, Suite 1100
Washington, DC 20005 US

Comments entered:

Dear DEP Policy Office:

EIP hereby submits the attached comments on PA DEP's Final Revisions to 25 Pa. Code Chapter 78 (Conventional Oil and Gas Wells) and Chapter 78a (Unconventional Wells) on behalf of EIP, Clean Air Council, and Citizens for Pennsylvania's Future (PennFuture). Our comments additionally include as attachments our previous comment letter on the proposed regulations and a recent study on direct measurements of emissions from abandoned oil and gas wells in Pennsylvania.

If you have any questions regarding our comments or technical issues concerning the attached file, please do not hesitate to get in touch with me at 202-263-4451 or akron@environmentalintegrity.org.

Thanks you for your time and consideration of these important issues,

Adam Kron
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May 19, 2015

DEP Policy Office
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Harrisburg, PA 17105-2063

Via Electronic Mail (RegComments@pa.gov)

Re: Final Revisions to 25 Pa. Code Chapter 78 (Conventional Oil and Gas Wells) and Chapter 78a (Unconventional Wells)

Dear DEP Policy Office:

The Environmental Integrity Project (EIP) hereby submits the following comments on the final revised regulations under Chapter 78 and Chapter 78a of Title 25 of the Pennsylvania Code, relating to conventional oil and natural gas wells and unconventional wells. We appreciate the opportunity to provide these comments, which we submit on behalf of EIP, Clean Air Council, and Citizens for Pennsylvania's Future ("PennFuture").

As we stated in our attached March 14, 2014 comments on the proposed revisions to Chapter 78, these revisions are a needed update to Pennsylvania's requirements for oil and gas development and are particularly necessary in light of the industry's vast growth and expansion in Pennsylvania over the last decade. However, the regulations do not go far enough, exempt certain practices and operations too broadly, and in that way, run counter to the overall goal of the rules.

In our comments on the proposed regulations, we focused on two areas in particular: (1) the proposed regulations for abandoned wells, and (2) requirements for seismic testing, which the proposed regulations fail to include. First, for the requirements relating to abandoned wells, we raised three main shortcomings:

- The provisions for identifying abandoned wells only required operators to reference limited sources of information rather than conducting fuller or on-the-ground surveys;
- The requirements for plugging abandoned wells only applied after an operator "alters" the abandoned well, thereby failing to take needed preventive measures, and also without defining the term "alter," which triggers the requirement; and
- The requirements only applied to wells that are hydraulically fractured, even though communication with abandoned wells is a problem that has long existed in Pennsylvania.

The final regulations offer improvements over the proposed regulations with respect to abandoned wells, for which we commend the Pennsylvania Department of Environmental Protection (PA DEP). However, the regulations still fail to address these three shortcomings

sufficiently. Specifically, the final regulations still do not require a physical, on-the-ground survey for abandoned wells; only require an operator to plug an abandoned well after the operator "alters" the well; and only apply the abandoned well requirements to operations using hydraulic fracturing. These are significant shortcomings, and PA DEP should not issue the final regulations unless they are fully addressed.

The second issue we raised in our comments on the proposed regulations was that the proposed regulations included no requirements that apply to seismic exploration for oil and gas (i.e., seismic testing). The only applicable requirements to seismic testing are PA DEP's generic regulations for explosives, and PA DEP has no regulations or permitting for other types of seismic testing operations, such as vibroseis trucks. We offered several important elements to include in seismic testing regulations, drawn from other states' regulations and municipal ordinances. In the final regulations, however, PA DEP has not addressed this issue at all. The regulations continue to lack any requirements for seismic testing, and the generic explosives regulations do not provide adequate protection for the public and the environment. PA DEP should not issue the final regulations without filling this important gap.

These are by no means our only concerns with the final regulations, and we endorse comments written by other groups and individuals addressing other needed improvements to the proposed regulations' protections for Pennsylvanians and the environment. In particular, we hereby endorse the comments filed by the Clean Air Council and the comments filed by Earthjustice.

I. PA DEP MUST IMPROVE THE CHAPTER 78 AND CHAPTER 78A REQUIREMENTS FOR ABANDONED AND ORPHANED WELLS

A. The Final Regulations Still Do Not Require a Physical Survey for Abandoned Wells

In our comments on the proposed regulations, we raised the issue that the requirements for the pre-drilling survey were limited to certain "paper" sources and did not require an actual, on-the-ground survey for unplugged abandoned wells in the vicinity of the new operation.[1] The final regulations include some improvements to the survey requirements, which are a step in the right direction. Not included in these improved requirements, however, is any provision that the new operator must conduct a physical survey. Additionally, some improvements should go further.

The final regulations have made certain positive changes to the pre-drilling survey requirements:

[1] *See* Letter from EIP et al. to Environmental Quality Board, Re: Proposed Revisions to 25 Pa. Code Chapter 78 (Oil and Gas Wells) 6-7 (March 14, 2014) [hereafter Proposed Regulations Comments].

- Sections 78.52a and 78a.52a now require that the survey also include active and inactive wells, in addition to orphaned and abandoned wells;[2]
- Sections 78.52a and 78a.52a broaden the information sources from which the survey is drawn, now stating "historical sources of information, such as applicable farm line maps" instead of just "applicable farm line maps";[3]
- Sections 78.52a and 78a.52a now require that the operator submit a full report to PA DEP at least thirty days prior to drilling, including a monitoring plan for wells within a certain vertical depth of the new well, the depth of all identified wells, the source of information on the identified wells, and any surface evidence of the identified wells' failed integrity;[4] and
- Sections 78.73 and 78a.73 include an improved notification and monitoring provision, under which the operator will notify owners of identified wells within seventy-two hours of commencing hydraulic fracturing and must specifically notify PA DEP "of any treatment pressure changes indicative of abnormal fracture propagation at the well being stimulated" and cease stimulation until further approval.[5]

Each of these new requirements is a positive change and a step in the right direction. We support PA DEP's additions of these requirements and urge the department to make further revisions in this same spirit, in order to ensure that operators take key preventive steps prior to drilling and hydraulic fracturing. Specifically, we suggest the following additional revisions:

- First, as we raised in our comments on the proposed regulations, the operator should conduct a physical, on-the-ground survey for unplugged abandoned and orphaned wells. While it is positive that the final regulations broaden the sources of information for the survey, there is a daunting number of abandoned and orphaned wells in Pennsylvania (anywhere from 200,000 to 500,000, depending on the estimate), and a survey only of paper sources will inevitably result in wells being missed. There is simply no substitute for an on-the-ground survey. Not only is it safer and more accurate, but also it will add needed information to Pennsylvania's Abandoned and Orphaned Well Plugging Program.

- Second, the operator should notify the owners of identified wells sooner than seventy-two hours prior to commencing hydraulic fracturing. Ideally, the regulations should require the operator to notify the owners at the same time the operator transmits the report to PA DEP: at least thirty days prior to commencing drilling. While the operator also should be required to notify the well owners prior to hydraulic fracturing, earlier advance notice is a cheap and easy preventive measure and allows all parties to plan accordingly.

We appreciate the efforts PA DEP has taken to improve the pre-drilling survey requirements and we urge PA DEP to make these two additional revisions to ensure that oil and gas development is safe, well-informed, and not harmful to Pennsylvanians or the environment.

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[2] *See* PA DEP, Advanced Notice of Final Rulemaking, Chapters 78 & 78a at 22, 150 (April 4, 2015) [hereafter Final Regulations].
[3] *Id.*
[4] *Id.* at 23, 151.
[5] *Id.* at 105, 236.

B. The Final Regulations Still Do Not Require an Operator to Plug Abandoned Wells Prior to Hydraulic Fracturing

One of the central shortcomings we raised in our comments on the proposed regulations is that they only required an operator to plug an abandoned or orphaned well if the operator "alters" the well by hydraulic fracturing. Otherwise, the operator could leave the abandoned well unplugged, no matter the vicinity to the new well, the depth of the abandoned well, or any other consideration. Unfortunately, the only change the final regulations have made to this key gap is that they now allow the operator the choice to put the abandoned well back into service rather than plugging it.[6] Clearly, this does not address the issue.

The problem with this provision is that it is not preventive. Instead of requiring the operator to make an up-front investment toward ensuring the safety of the new well and surrounding community, the regulations allow the operator to wait until disaster occurs. As we raised in our previous comments, there are several major instances in recent Pennsylvania history in which an abandoned well's "communication" with new hydraulic fracturing can result in explosions, air pollution, contamination of groundwater, and evacuation of nearby residents. At this point, it is too late to plug the abandoned well in an easy manner. Instead, gas must be vented or flared for hours or days to reduce pressure and ensure safety.[7] In other words, a requirement that the operator plug the well once it is "altered" is only slightly better than no requirement at all.

This is not a new issue for PA DEP. In 2010, the "non-profit, multi-stakeholder organization" State Review of Oil and Natural Gas Environmental Regulations, Inc. (STRONGER) conducted an independent review of Pennsylvania's oil and gas regulations and found this specific gap to be an issue, particularly as it related to groundwater contamination.[8] STRONGER urged that Pennsylvania "require operators to identify and eliminate the potential pathways" prior to fracking.[9] Nearly five years have passed since STRONGER's review, and a number of dangerous abandoned well incidents have occurred since then. It is time for PA DEP to address this issue in a meaningful way.

In connection with this provision, we also previously raised the issue that the proposed regulations failed to define "alter."[10] Even though the final regulations added and updated other definitions, they still do not include an entry for "alter."[11] Aside from the safety and environmental implications, this is bad for regulatory certainty. The entire plugging requirement hinges on an undefined term, which may mean that even the most scrupulous oil and gas operators may be unsure of their responsibilities and that more delinquent operators could use the

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[6] *See* Final Regulations, *supra*, at 106, 236.
[7] *See* Proposed Regulations Comments, *supra*, at 8-9.
[8] *See* STRONGER, *Pennsylvania Hydraulic Fracturing State Review* 16 (2010), http://67.20.79.30/sites/all/themes/stronger02/downloads/PA%20HF%20Review%20Print%20Version.pdf (last visited May 18, 2015).
[9] *Id.*
[10] *Id.* at 9.
[11] *See* Final Regulations, *supra*, at 1, 121-22.

ambiguity to avoid full compliance. The most direct course is to require plugging of all nearby abandoned wells prior to hydraulic fracturing. But even if PA DEP opts to retain the requirement that wells only be plugged after alteration, it must include a clear definition of the triggering event.

C. The Survey, Monitoring, and Plugging Requirements Should Apply to All New Wells, Not Just Hydraulically Fractured Wells

A final issue we raised in our previous comments with respect to abandoned wells is that the proposed regulations only applied the surveying, monitoring, and plugging requirements of Sections 78.52a and 78.73 to hydraulically fractured wells.[12] Given that the final regulations appear to have kept this exemption in place, we again urge PA DEP to apply the requirements to all new wells.[13]

While it is true that hydraulic fracturing is a standard practice for most wells currently, even wells that do not use hydraulic fracturing can cause problems, and the preventive measures to avoid these problems are fairly simple.[14] As we stated in our previous comments, the Environmental Quality Board estimated that the cost to identify and monitor abandoned and orphaned wells is $2,000 per operator.[15] If the exemption of non-hydraulically fractured wells is in consideration of regulatory and cost burdens on smaller operators, PA DEP can easily impose reduced requirements. For example, such reduced requirements could follow on the regulations' differing identification and monitoring distance for vertical wells and horizontal wells.[16] A smaller identification and monitoring distance could easily be required for non-hydraulically fractured wells.

D. New Data and Events over the Last Year Demonstrate the Need for Improved Regulations for Abandoned and Orphaned Wells

Our previous comments on the proposed regulations documented a number of studies, articles, and events to demonstrate the safety, human health, and environmental concerns caused by unplugged abandoned and orphaned wells.[17] Given that over a year has passed since we submitted those comments, we include here certain events and studies that have occurred or been released since then:

- A summer 2014 article in the National Academy of Engineering's publication The Bridge discussed the extent to which older wells poser higher risks of leakage and pollution.

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[12] *See* Proposed Regulations Comments, *supra*, at 9.
[13] *See* Final Regulations, *supra*, at 22-23, 105-06, 150-51, 236.
[14] *See* Proposed Regulations Comments, *supra*, at 9.
[15] *See id.* (citing PA DEP, *Regulatory Analysis Form: Environmental Protection Performance Standards at Oil & Gas Sites* 14 (2013)).
[16] *See* Final Regulations, *supra*, at 22, 150.
[17] *See* Proposed Regulations Comments, *supra*, at 3-6.

Cement plugs help to impede the flow of leaking gas, though older cement plugs can degrade over time and should meet certain criteria to serve as an effective barrier.[18]

- On December 23, 2014 the Proceedings of the National Academy of Sciences published a study by Princeton researcher Mary Kang that directly measured emissions of methane and other fluids to the atmosphere from nineteen abandoned oil and gas wells in Potter and McKean Counties, Pennsylvania. The study found that every measured well emitted methane, with a mean flow rate of 0.27 kilograms per day per well (or 216.81 pounds of methane per year per well). Three of the measured wells were especially high emitters—emitting thousands of times more methane than the lower-emitting wells. Based on these direct measurements, the study estimated that methane emissions from abandoned wells represent four to seven percent of total statewide methane emissions from human activity. The study also found, based on a review of supporting information, that the actual number of abandoned wells in Pennsylvania may be as high as 500,000.[19]

- A February 25, 2015 article in the Wall Street Journal examined the problem of abandoned wells in Pennsylvania, Wyoming, and other states. The article noted that, while certain state regulators have estimated that the cost of plugging wells is high, the actual cost for plugging certain shallow wells in Wyoming was $7,500 per well. The article also interviewed an economics professor and Pennsylvania's former state geologist, both of whom found the current required bonding to be "unreasonably low" and insufficient to fund the state's efforts to plug abandoned wells. In fact, Pennsylvania was only able to plug 48 wells from its overall list of over 8,000 orphaned wells. According to an audit of Louisiana's program, insufficient bonding "may provide an incentive for operators to abandon their wells since forfeiting the financial security may be more economical than paying plugging costs."[20]

Based on these articles and studies, one can see that the problem of abandoned and orphaned wells is not going away and is likely only to increase with more drilling and hydraulic fracturing of new wells. With its first major revision of oil and gas rules in years, PA DEP has a unique opportunity to address this problem in a direct way by requiring new operators to survey, monitor, and remedy abandoned wells. Unless PA DEP addresses the significant shortcomings we have identified in these comments and our previous comments, it should not issue the final regulations.

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[18] *See* Stefan Bachu & Randy L. Valencia, Well Integrity: Challenges and Risk Mitigation Measures, The Bridge, Summer 2014, at 28-33.

[19] *See* Mary Kang et al., *Direct measurements of methane emissions from abandoned oil and gas wells in Pennsylvania*, 111 Proc. Nat'l Acad. Sci. 18,173 (2014) (attached); *see also* John Sullivan, *Abandoned wells can be 'super-emitters' of greenhouse gas*, News at Princeton, Dec. 9, 2014, http://www.princeton.edu/main/news/archive/S41/80/71G06/index.xml?section=topstories (last visited May 18, 2015).

[20] *See* Dan Frosch & Russell Gold, *How 'Orphan' Wells Leave States Holding the Cleanup Bag: Wyoming has to deal with abandoned wells seized from would-be mogul and his Gazmo device*, Wall St. J., Feb. 25, 2015, *available at* http://www.wsj.com/articles/how-orphan-wells-leave-states-holding-the-cleanup-bag-1424921403?mod=WSJ_hp_RightTopStories.

II. PA DEP MUST REVISE THE CHAPTER 78 AND CHAPTER 78A REGULATIONS TO INCLUDE APPROPRIATE REQUIREMENTS FOR SEISMIC TESTING

The second major area we raised in our comments on the proposed regulations was that the regulations contained no requirements with respect to seismic testing, whether via blasting, vibroseis trucks, or other practices.[21] We noted that the only applicable requirements to seismic testing were PA DEP's generic regulations for explosives, which are implemented by PA DEP's Bureau of Mining and Reclamation rather than the Office of Oil and Gas Management.[22] And these regulations fail to cover other types of seismic testing operations, such as vibroseis trucks. We offered several important elements to include in seismic testing regulations, drawn from other states' regulations and municipal ordinances, including required notice to landowners and municipalities, location restrictions (e.g., setbacks), and a requirement that all seismic companies obtain full local approval.[23] In the final regulations, however, PA DEP has not addressed this issue at all.

Because there have been no developments since the proposed regulations, we reiterate our comments on the proposed regulations and incorporate them in their entirety. In particular, we again raise the need for baseline seismic testing requirements due to the regulatory vacuum that currently exists; the increasing number of conflicts between municipalities and companies and between landowners and companies; and the important issues with respect to safety, the environment, and human health.[24]

To highlight these issues, we call to PA DEP's attention the following events and developments that have occurred in the year since we submitted our comments on the proposed regulations:

- On March 31, 2014, seismic testing company ION Geophysical Corp. of Houston, Texas, sued Hempfield Township, Westmoreland County, in federal court to "forbid Hempfield from interfering with Ion's survey and exempt the company for one year from any ordinance regulating seismic activity in Hempfield, should the township decide to pass one."[25] On April 23, 2014, the township settled with after the company successfully obtained a

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[21] *See* Proposed Regulations Comments, *supra*, at 10-17.
[22] *Id.* at 11.
[23] *Id.* at 15-17.
[24] *Id.* at 10-12, 12-15.
[25] *See* Anya Litvak, *Ion Geophysical sues Westmoreland County town in seismic mapping case*, Pittsburgh Post-Gazette, March 31, 2014, http://powersource.post-gazette.com/powersource/policy-powersource/2014/03/31/Ion-Geophysical-lawsuit-Westmoreland-County-Hempfield-seismic-gas/stories/201403310002 (last visited May 18, 2015).

preliminary injunction preventing the township from prohibiting seismic testing on public roads.[26]

- On April 25, 2014, Rep. Rob Matzie announced legislation that would make it easier for landowners to obtain compensation for damage caused by seismic testing. The representative noted complaints from his constituents regarding property damage from the practice and stated that "as policy makers we should expect those who are conducting business in our commonwealth to be fair and adhere to good business practices, up to and including repair of property that was damaged that was no fault to a property owner."[27] The bill was referred to the Judiciary Committee, where it appears to have died.[28]

- On July 23, 2014, seismic testing company Geokinetics filed a lawsuit against Center Township, Greene County, challenging a seismic testing ordinance the township passed in May 2014. This suit follows on the previous lawsuits filed by another seismic testing company, Seitel Data Ltd., against Hopewell and Potter Townships, which we discussed in our previous comments.[29]

- On October 8, 2014, PublicSource published an article on Leigh Shields, a resident of Spraggs, Greene County. The article recounts Mr. Shields' encounters with the seismic testing company Geokinetics and the landmen from Cougar Land Services working on behalf of Geokinetics. Over the course of 2013, landmen visited his house on three or four occasions, requesting permission to conduct seismic testing on Mr. Shields' eighty-eight acres. After repeated refusals from Mr. Shields, Geokinetics trespassed onto Mr. Shields' land in June 2014 to mark testing sites, dig holes, and drop a bag of testing equipment by helicopter. When Mr. Shields seized the bag of testing equipment, Geokinetics sent a Pennsylvania state trooper to retrieve it. The trooper stated that "such situations happen frequently in Greene County, with helicopters dropping equipment on people's land." The article also discusses the lawsuit filed by Geokinetics against Center Township's seismic testing ordinance, noting in particular affidavits on how Geokinetics "threatened landowners who wouldn't sign permits, harassed them to enter their land and entered from other points when they were denied."[30]

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[26] *See Pa. township, firm settle over seismic tests*, Associated Press, http://wkbn.com/2014/04/23/pa-township-firm-settle-suit-over-seismic-tests/ (last visited May 18, 2015).

[27] *See* Dan Packel, *Pa. Rep. Aims to Protect Landowners from Pre-Fracking Tests*, Law360, http://www.law360.com/articles/531853/pa-rep-aims-to-protect-landowners-from-pre-fracking-tests (last visited May 18, 2015).

[28] *See* LegiScan, Bill Text: PA HB2254 | 2013-2014 | Regular Session | Introduced, https://legiscan.com/PA/text/HB2254/id/1022162 (last visited May 18, 2015).

[29] *See* Dan Packel, *Pa. Municipality Sued over Seismic Testing Ordinance*, Law360, July 23, 2014, http://www.law360.com/articles/559903/pa-municipality-sued-over-seismic-testing-ordinance (last visited May 18, 2015).

[30] *See* Natasha Khan, *Marcellus Life: One Greene County man's encounter with a landman*, PublicSource, Oct. 8, 2014, http://publicsource.org/investigations/marcellus-life-one-greene-county-man-s-encounter-with-landman#.VVnx4flVhBc (last visited May 18, 2015).

These events demonstrate the conflict and confusion caused by PA DEP's failure to establish clear regulations on seismic testing for oil and gas. Out-of-state seismic companies are capitalizing on this regulatory vacuum to the detriment of landowners, public infrastructure, and the environment. And municipalities are seeking to fill this gap and protect their residents through the adoption local controls, only to encounter threats and lawsuits. By promulgating simple, straightforward baseline regulations for seismic testing, PA DEP could add order to this "wild west" environment; give clarity to landowners, municipalities, and companies; and ensure that all Pennsylvanians and communities have adequate protections from this expanding practice.

III. CONCLUSION

We appreciate the opportunity to comment on PA DEP's final regulations under Chapters 78 and 78a of Title 25 of the Pennsylvania Code. While we note the improvements PA DEP has made over the proposed regulations, there are still key gaps and shortcomings that exempt certain oil and gas industry practices and in some cases ignore important subsets of the industry.

As we stated in our attached comments on the proposed regulations, oil and gas development in Pennsylvania is booming, increasing its technological advances, and expanding to areas of the Commonwealth that are almost entirely new to the industry. It is important that PA DEP promulgate appropriate and protective regulations to keep up with the industry, fully address its impacts, and better protect Pennsylvanians and the Commonwealth's resources.

If you have any questions, please do not hesitate to contact me at (202) 263-4451 or akron@environmentalintegrity.org. Thank you for your attention to these important issues.

Sincerely,

Adam Kron
Attorney
Environmental Integrity Project
1000 Vermont Ave. N.W., Suite 1100
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On behalf of EIP, Clean Air Council, and PennFuture

Attachments

ATTACHMENTS

ENVIRONMENTAL INTEGRITY PROJECT

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March 14, 2014

Environmental Quality Board
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*Via U.S. Mail and Electronic Mail (*RegComments@pa.gov*)*

Re: Proposed Revisions to 25 Pa. Code Chapter 78 (Oil and Gas Wells)

Dear Environmental Quality Board:

The Environmental Integrity Project (EIP) hereby submits the following comments on the Environmental Quality Board's (EQB) proposed regulations to Chapter 78 of Title 25 of the Pennsylvania Code, relating to oil and natural gas wells. We appreciate the opportunity to provide these comments, which we submit on behalf of EIP and the following groups and Pennsylvania residents: Clean Air Council, Lower Susquehanna Riverkeeper, PennFuture, Responsible Drilling Alliance, SWPA Environmental Health Project, Robert M. Donnan, Cathy Lodge, Robert Schmetzer, and William and Angela Smith.

In submitting these comments, we first note the Pennsylvania Supreme Court's decision of December 19, 2013, which occurred after these proposed regulations were published.[1] The Pennsylvania Supreme Court's decision invalidated parts of Act 13, codified as the 2012 Oil and Gas Act, on which these proposed regulations are based in part.[2] Should it become necessary to further revise these regulations in compliance with the Court's ruling, the EQB is under a duty to provide opportunities for notice and comment on those revisions, and we hereby reserve the right to provide such comments.

The proposed revisions to Chapter 78 are a needed update to Pennsylvania's requirements for oil and gas development, and are particularly necessary in light of the industry's vast growth and expansion in Pennsylvania over the last decade. However, the proposed regulations also contain serious shortcomings that exempt practices too broadly, run counter to the overall goal of the rules, and ignore certain operations of the oil and gas industry.

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[1] *See Robinson Twp. et al. v. Commonwealth*, 83 A.3d 901 (Pa. 2013); Marie Cusick, *Pennsylvania Supreme Court strikes down controversial portions of Act 13*, StateImpact Pennsylvania, Dec. 19, 2013, http://stateimpact.npr.org/pennsylvania/2013/12/19/state-supreme-court-strikes-down-act-13-local-zoning-restrictions/.

[2] *See* EQB, Notice of Proposed Rulemaking, Department of Environmental Protection, Environmental Quality Board , 25 Pa. Code Chapter 78 (Oil and Gas Wells) 2 (2013).

In these comments, we focus on two areas in particular: (1) the proposed regulations for abandoned wells, and (2) requirements for seismic testing, which the proposed regulations fail to include. First, for the requirements relating to abandoned wells, we raise three main concerns:

- The provisions for identifying abandoned wells only require operators to reference limited sources of information rather than conducting fuller or on-the-ground surveys;
- The requirements for plugging abandoned wells only apply after an operator "alters" the abandoned well, thereby failing to take needed preventive measures, and also without defining the term "alter," which triggers the requirement; and
- The requirements only apply to wells that are hydraulically fractured, even though communication with abandoned wells is a problem that has long existed in Pennsylvania.

Second, we raise the issue that the proposed regulations include no requirements that apply to seismic testing. As it stands, blasting used for seismic testing is covered in part under the Pennsylvania Department of Environmental Protection's (PA DEP) generic regulations for explosives, and PA DEP has no regulations or permitting for other types of seismic testing operations, such as vibroseis trucks. We provide several important elements that the EQB should include in the needed seismic testing regulations, drawn from other states' regulations and municipal ordinances in Pennsylvania.

These are by no means our only concerns with the proposed regulations, and we endorse comments written by other groups and individuals addressing other needed improvements to the proposed regulations' protections for Pennsylvanians and the environment. In particular, we hereby endorse the comments filed by the Clean Air Council and the comments filed by Earthjustice, Earthworks and, the Delaware Riverkeeper Network.

I. REQUIREMENTS FOR ABANDONED AND ORPHANED WELLS

The EQB's proposed regulations with respect to identification and plugging of abandoned oil and natural gas wells add several important requirements that are needed to address the Commonwealth's growing legacy of abandoned wells. Specifically, the proposed regulations require certain measures prior to the commencement of hydraulic fracturing, including identification of abandoned wells, the submittal of questionnaires to surrounding landowners regarding abandoned wells on their property, and the submittal of a plat of the identified abandoned wells to PA DEP.[3] During and after hydraulic fracturing, the proposed regulations also require operators to monitor certain abandoned wells, notify PA DEP of any changes, take action to prevent water pollution, and in certain cases plug abandoned wells.[4]

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[3] EQB, Chapter 78 Proposed Regulations 15 (2013) [hereafter Proposed Regulations], *available at* http://files.dep.state.pa.us/PublicParticipation/Public%20Participation%20Center/PubPartCenterPortalFiles/Environmental%20Quality%20Board/2013/August%2027%20EQB/Proposed%20Rulemaking%20-%20Ch%2078/Annex.pdf.

[4] *Id.* at 63.

While these proposed requirements are important steps toward addressing Pennsylvania's abandoned wells and represent improvements over the previous regulations, they need to go further in order to fully protect human health and safety, stay on par with other oil and gas states, and keep up with the growing industry.

A. Background

The issue of abandoned wells in Pennsylvania dates to 1859, with the drilling of the world's first commercial oil well.[5] Since then, operators have drilled an estimated 325,000 oil and gas wells.[6] The vast majority, however, were drilled prior to state permitting or registration requirements and are therefore unaccounted for.[7] Most recently, PA DEP has estimated that there are approximately 300,000 abandoned wells in the Commonwealth.[8] Under the Oil and Gas Act of 1984, Pennsylvania began to address the problem with the establishment of the Abandoned and Orphaned Well Plugging Program and the permit surcharges to fund the Program's search for and plugging of abandoned wells.[9] But the Program's work has been slow-going, due to limited funding and a lack of records of older wells. In addition, the recent Marcellus shale and fracking boom has meant the development of many more wells, a greater potential for harmful interactions with abandoned wells, and more pressure to address the problem as soon as possible.

1. Human Health and Safety Issues

Unless identified and plugged, abandoned wells can lead to serious safety and human health issues when they "communicate"—that is, intersect or otherwise interact—with new oil

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[5] EQB, Summary: Proposed Regulations for Oil and Gas Surface Activities (2013), *available at* http://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/PublicResources/RegulationSummary-PreCommentPeriod.pdf.

[6] PA DEP, *Fact Sheet: Abandoned and Orphaned Oil and Gas Wells and the Well Plugging Program 1*(2012) [hereafter *Abandoned Well Program Fact Sheet*], *available at* http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-91715/8000-FS-DEP1670.pdf; Scott Detrow, *Perilous Pathways: Behind the Staggering Number of Abandoned Wells in Pennsylvania*, StateImpact Pennsylvania, Oct. 10, 2012 [hereafter *Perilous Pathways: Part 2*], http://stateimpact.npr.org/pennsylvania/2012/10/10/perilous-pathways-behind-the-staggering-number-of-abandoned-wells-in-pennsylvania/.

[7] *Id.*

[8] PA DEP, Regulatory Analysis Form: Environmental Protection Performance Standards at Oil & Gas Sites 4 (2013) [hereafter Regulatory Analysis Form].

[9] *Perilous Pathways: Part 2*, *supra*; *Abandoned Well Program Fact Sheet*, *supra*, at 1.

and gas development.[10] Additionally, leaks and explosions have occurred even without the involvement of new development activity.[11]

For example, in 2012, communication between new development by Shell and an eighty-year-old abandoned well led to a thirty-foot "geyser" of water and gas.[12] In that instance, Shell began to drill a new Marcellus well that apparently "displaced shallow pockets of natural gas," leading to a "chain reaction" in which the gas migrated until it found a conduit to the surface—through a nearby abandoned well drilled in 1932.[13] The resulting geyser continued for a week. In addition, a cabin flooded, gas bubbled out of a nearby creek, and homes in the vicinity were evacuated due to the threat of explosion.[14] Although Shell knew of the abandoned well, it assumed it had been properly plugged and continued with its own drilling.[15] In the aftermath, Shell had to burn off "months' worth" of gas at its other nearby well sites in order to reduce pressure enough to allow for plugging of the abandoned well.[16]

Another example of this problem occurred in Armstrong County in 2008. A vertical gas rig "hit a pocket of gas linked to an undocumented abandoned well," displacing and mobilizing the gas and leading to the evacuation of an elementary school and several houses.[17] Ultimately, the situation required "operators to vent off nearby wells in order to lower underground gas pressure" and the installation of vents on homes to prevent the dangerous accumulation of methane.[18] Likewise, in 2010 and 2011, two homes in McKean County exploded, leading PA DEP to require the plugging of three abandoned wells dating from the turn of the century.[19]

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[10] Scott Detrow, *Perilous Pathways: How Drilling Near an Abandoned Well Produced a Methane Geyser*, StateImpact Pennsylvania, Oct. 9, 2012 [hereafter *Perilous Pathways: Part 1*], http://stateimpact.npr.org/pennsylvania/2012/10/09/perilous-pathways-how-drilling-near-an-abandoned-well-produced-a-methane-geyser/.
[11] *Id.*; *see also Gas Wells Cause For Concern In Versailles Boro*, WPXI, May 29, 2008, http://www.wpxi.com/news/news/gas-wells-cause-for-concern-in-versailles-boro/nGgFf/.
[12] *Id.*
[13] *Id.*
[14] *Id.*
[15] Scott Detrow, *Perilous Pathways: Abandoned Wells Don't Factor into Pennsylvania's Permitting Process*, StateImpact Pennsylvania, Oct. 12, 2012, http://stateimpact.npr.org/pennsylvania/2012/10/12/perilous-pathways-abandoned-wells-dont-factor-into-pennsylvanias-permitting-process/.
[16] *Id.*
[17] *Perilous Pathways: Part 1*, *supra*; Mitch Fryer, *Gas leak forces evacuation in Dayton*, Kittanning Leader-Times, March 11, 2008, *available at* http://triblive.com/x/leadertimes/news/s_556633.html#axzz2j3CD1wwH.
[18] *Perilous Pathways: Part 1*, *supra.*
[19] Scott Detrow, *Perilous Pathways: Hunting for Hidden Wells*, StateImpact Pennsylvania, Oct. 11, 2012 [hereafter *Perilous Pathways: Part 3*], http://stateimpact.npr.org/pennsylvania/2012/10/11/perilous-pathways-hunting-for-hidden-wells/; Press Release, PA DEP, *DEP Orders McKean County Resident to Plug Three Abandoned Wells near Recent House Explosion Site*, April 18, 2011, *available at* http://www.prnewswire.com/news-releases/dep-orders-mckean-county-resident-to-plug-three-

2. Air Pollution

In addition to these issues for safety and human health, abandoned wells also cause substantial environmental impacts. One of the most apparent of these is air pollution. Left unplugged, a well will continue to emit whatever gases were previously locked in formations underground. There is no single perfect estimate of emissions from abandoned wells, simply because oil and gas formations from different regions have different production rates and lifespans and the abandoned wells may be in varying conditions, ranging from modern wellheads with functioning equipment to open holes in the ground.[20] In Pennsylvania, where oil and gas production has spanned over 150 years, this is especially relevant.

Although there is not yet a definitive study of exactly how much gas will leak from an average abandoned well, we have been able to use existing emissions data in two ways to make some estimates. First, assuming an abandoned wellhead has some basic equipment in place, we can use datasets that estimate leaks from various points in the natural gas extraction process. Second, assuming an abandoned wellhead has no control equipment on site—i.e., "open holes in the ground"—we can refer to datasets that look specifically at production rates from low-producing wells, known as "marginal" or "stripper" wells.[21] That is, without control equipment in place, a well's production rate would be equal to its emissions rate. Both approaches give a wide range of potential emissions.

First, for abandoned wells with some equipment in place, the most conservative emissions factor, from EPA's most recent greenhouse gas inventory,[22] estimates that an abandoned wellhead will annually emit 114 pounds of methane, 31.8 pounds of volatile organic compounds, and 1.2 pounds of hazardous air pollutants, such as benzene and toluene.[23] The least conservative estimate, from a recently released study by the University of Texas, estimates that an abandoned wellhead will annually emit 1.774 tons of methane, 0.4931 tons of volatile organic compounds, and 37.2 pounds of hazardous air pollutants.[24]

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abandoned-wells-near-recent-house-explosion-site-119498684.html; *see also Sen. Bob Casey wants feds to help investigate Pennsylvania house explosions*, Associated Press, March 29, 2011, http://www.pennlive.com/midstate/index.ssf/2011/03/sen_bob_casey_wants_feds_to_he.html.

[20] *See Perilous Pathways: Part 2.*

[21] *See* Don Hopey, *Decades-old oil and gas wells dot the state, sometimes causing controversy*, Pittsburgh Post-Gazette, June 14, 2009, *available at* http://www.post-gazette.com/neighborhoods-south/2009/06/14/Decades-old-oil-and-gas-wells-dot-the-state-sometimes-causing-controversy/stories/200906140148.

[22] EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011* (2013).

[23] *Id.* To reach the figures for VOC and HAP emissions from the estimated methane emissions, we applied EPA's estimate that the gas stream in "production" phases (i.e., during production and processing) will have a ratio of 0.278 VOC:Methane and 0.0105:1 HAP:Methane. *See* Memorandum from Heather P. Brown, P.E., EC/R Incorporated, to Bruce Moore, EPA, *Re: Composition of Natural Gas for use in the Oil and Natural Gas Sector Rulemaking* 10 Tbl. 6 (July 28, 2011) (on file with EIP).

[24] *See* David T. Allen et al., *Measurement of methane emissions at natural gas production sites in the United States*, 110 Proc. Nat'l Acad. of Sciences 17,768 (2013).

Second, for abandoned wells with no equipment in place, the estimates come from two datasets of production rates for low-producing wells: PA DEP's 2011 production data for conventional (non-Marcellus) wells and a 2010 study by the Interstate Oil and Gas Compact Commission (IOGCC) of state-by-state production from marginal wells in 2009.[25] The most conservative emissions factor—using the first quantile production rate of the PA DEP 2011 production data—estimated that an abandoned wellhead with no equipment would annually 10.1 tons of methane, 2.8 tons of volatile organic compounds, and 0.11 tons of hazardous air pollutants.[26] The least conservative factor—the IOGCC Marginal Wells Report's estimate of the average marginal well in Pennsylvania—estimated that an abandoned wellhead with no equipment would annually 375.4 tons of methane, 104.3 tons of volatile organic compounds, and 3.9 tons of hazardous air pollutants.[27]

Although the ranges of emissions are wide, they provide an examination of wholly different potential scenarios—as well as a demonstration of how little we know for sure about emissions from abandoned wells and how bad the problem could be. Overall, these figures show that the air pollution from Pennsylvania's abandoned wells is a significant environmental and human health issue that must be taken seriously.

B. The EQB's Proposed Regulations for Abandoned Wells Contain Shortcomings and Exemptions that Require Revision

The proposed revisions to the Chapter 78 regulations take steps in the right direction. As discussed above, the revisions would add several requirements, including that an operator identify any abandoned wells within 1,000 feet of the new well bore prior to hydraulic fracturing, report the location of those wells to PA DEP, visually monitor any such abandoned wells during hydraulic fracturing activities, and plug any abandoned wells that the hydraulic fracturing activities alter.[28] But the proposed revisions fall short in several important ways.

1. The Proposed Regulations Should Include More Stringent Requirements for Identifying Abandoned Wells

First, 25 Pa. Code § 78.52a of the proposed regulations provides requirements for the identification of abandoned wells prior to the commencement of hydraulic fracturing.[29] However, under these new requirements, an operator need not physically survey the surrounding

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[25] *See* PA DEP, Production Report Jan. - Dec. 2011: Annual O&G, without Marcellus [hereafter PA DEP 2011 Production Report], https://www.paoilandgasreporting.state.pa.us/publicreports/Modules/DataExports/ExportProductionData.aspx?PERIOD_ID=2011-0 (last visited March 13, 2014); IOGCC, *Marginal Wells: Fuel for Economic Growth* (2010), *available at* http://iogcc.publishpath.com/Websites/iogcc/images/2010marginalwell.pdf.
[26] *See* PA DEP 2011 Production Report, *supra*.
[27] *See* IOGCC, *Marginal Wells: Fuel for Economic Growth*, *supra*.
[28] Proposed Regulations, *supra*, at 15, 63.
[29] Proposed Regulations, *supra*, at 15.

land for the abandoned wells. Rather, the proposed regulations only require that the operator conduct the survey by:

(1) A review of the Department's orphaned and abandoned well database;

(2) A review of applicable farm line maps, where accessible; and

(3) Submitting a questionnaire on forms provided by the Department to landowners . . . regarding the precise location of orphaned and abandoned wells on their property.[30]

By limiting the identification requirements to just these "paper" surveys, the proposed regulations do not go far enough and inevitably will result in abandoned wells being missed. For example, by PA DEP's own admission, its orphaned and abandoned well database covers only a small fraction of abandoned wells—less than 9,000 wells, compared to the 300,000 estimated to exist statewide—and plat maps are often inaccurate.[31]

In fact, even PA DEP takes a more comprehensive approach when conducting its own searches for abandoned wells: for example, using databases of aerial photographs.[32] And other states' regulations do not let applicants off the hook by limiting the identification requirements to certain sources of data, like the proposed regulations. For example, Colorado, North Dakota, Ohio, and West Virginia all require the applicant to submit a plat that shows all wells within a certain area, including abandoned wells, with no limitations to the sources of data from which the applicant draws.[33]

Specifically, Colorado requires a "plat showing the area involved, together with the well or wells, including drilling wells, dry and abandoned wells located thereon, all properly designated."[34] North Dakota requires a "plat depicting the area of review, (one-quarter-mile [402.34-meter] radius) and detailing the location, well name, and operator of all wells in the area of review. The plat should include all injection wells, producing wells, plugged wells, abandoned wells, drilling wells, dry holes, and water wells."[35] Ohio requires "a map or maps showing and containing the following information: . . . [t]he geographic location of all wells penetrating the formation proposed for injection, regardless of status, within the area of review."[36] And West Virginia requires "[a]ll wells within the scope of the plat, whether active, drilling, or abandoned."[37] In each case, the state regulations do not provide the minimum sources the applicant must consult; it is simply the applicant's duty that the plat be accurate.

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[30] *Id.*
[31] *See Perilous Pathways: Part 2*, *supra*; *Perilous Pathways: Part 3*, *supra*; Regulatory Analysis Form, *supra*, at 4.
[32] *Perilous Pathways: Part 3*, *supra*.
[33] *See* 2 Colo. Code Regs. § 404-401(b)(1); N.D. Admin. Code 43-02-05-04(1)(i); Ohio Admin. Code 1501:9-5-05(D); W. Va. Code R. § 35-4-9.2.j.
[34] 2 Colo. Code Regs. § 404-401(b)(1).
[35] N.D. Admin. Code 43-02-05-04(1)(i).
[36] Ohio Admin. Code 1501:9-5-05(D).
[37] W. Va. Code R. § 35-4-9.2.j.

Given the vastness of the problem, the EQB should require drillers to conduct physical, on-the-ground surveys for abandoned wells prior to hydraulic fracturing and/or otherwise require that the applicant gather full and accurate information without limits on sources. Not only would this better ensure safety and protect against pollution, but it would accomplish two additional goals: (1) protecting the investments of the new wells' owners and operators, since communication with abandoned wells often requires expensive remediation and flaring of marketable gas; and (2) bolstering PA DEP's underfunded Abandoned and Orphaned Well Plugging Program with needed manpower and information.

2. The Proposed Regulations Should Require Operators to Plug Abandoned Wells, and Not Just Those That the Operator "Alters"

Second, 25 Pa. Code § 78.73(d) of the proposed regulations require new operators to plug nearby orphaned and abandoned wells, but only if the operator "alters an orphaned or abandoned well by hydraulic fracturing."[38] Otherwise, the proposed regulations provide no plugging requirement. This is a shortcoming for several reasons.

For one, and most significantly, the requirement is not preventive; rather, it waits until after a problem occurs before requiring a solution. This is more or less the same dysfunctional system that exists in Pennsylvania today. As discussed above, recent history has shown that plugging abandoned wells after communication occurs is not a safe or effective solution. Before the affected abandoned well can be plugged, gas must be flared or vented from nearby active wells to reduce pressure, sometimes for days or longer. And during that time, the incident may cause water and air pollution, contaminate groundwater supplies, fill buildings with explosive and poisonous gases, and require evacuations of nearby residents.

Indeed, an independent review by the "non-profit, multi-stakeholder organization" State Review of Oil and Natural Gas Environmental Regulations, Inc. (STRONGER) found this gap to be an issue, particularly as it related to groundwater contamination.[39] STRONGER urged that Pennsylvania "require operators to identify and eliminate the potential pathways" prior to fracking.[40] Similarly, Colorado's oil and gas regulations require that the applicant "include information regarding the need for remedial action on wells penetrating the injection zone within one-quarter (1/4) mile of each injection well and a plan for the performance of any such remedial work."[41] The EQB should amend the proposed regulations to include such preventive measures.

In addition to this broader issue, the plugging requirement is premised on a term—"alters"—that the proposed regulations do not define.[42] Given that this term is the trigger for the

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[38] Proposed Regulations, *supra*, at 63.
[39] STRONGER, *Pennsylvania Hydraulic Fracturing State Review* 16 (2010), http://67.20.79.30/sites/all/themes/stronger02/downloads/PA%20HF%20Review%20Print%20Version.pdf.
[40] *Id.*
[41] 2 Colo. Code Regs. § 404-401(b)(1).
[42] Proposed Regulations, *supra*, at 15, 63.

important plugging requirement, the EQB should ensure that the term is clearly defined. Without such a clear definition, even the best oil and gas operators may be unsure of their responsibilities, and more delinquent operators may use the ambiguity to avoid full compliance. While the far superior course is for the EQB to require plugging of all nearby abandoned wells prior to fracking, in the event that the EQB retains the current provision, it must include a clear definition of the triggering event.

3. The Proposed Regulations' Abandoned Well Requirements Should Apply to All New Wells, Not Just Those That are Hydraulically Fractured

Third, the proposed regulations under 25 Pa. Code § 78.52a and 25 Pa. Code § 78.73(c)-(d) only apply to operators of wells that use hydraulic fracturing.[43] While wells completed with hydraulic fracturing do have a higher chance of communicating with abandoned wells, history has shown that even non-hydraulically fractured wells can cause problems.[44] And the costs of the abandoned well requirements are fairly low; the EQB has estimated that identification and monitoring of abandoned wells will cost a well operator $2,000 total.[45] Compared to other costs estimated by the EQB, such as $7,000 to $50,000 for freshwater impoundment fencing, $3,500 for determining the seasonal high groundwater table, and $7,000 for installing tank valves and access lids, the identification and monitoring cost is on the low end.[46] And it is a particularly reasonable cost when compared against the long and intensive remediation measures needed when an abandoned well is not properly identified or monitored.

In the alternative, if the EQB's proposed exemption of non-hydraulically fractured wells from these requirements is an attempt to lower regulatory and cost burdens on smaller operators, this can easily be done by imposing reduced requirements. For example, the proposed regulations already require less of an identification and monitoring distance for vertical wells (within 500 feet of the well bore) than for horizontal wells (within 1,000 feet of the entire length of the horizontal well bore).[47] A smaller identification and monitoring distance could easily be required for non-hydraulically fractured wells.

Overall, the EQB's proposed regulations for abandoned wells represent a first step in the right direction. Pennsylvania has a long and continuing legacy of abandoned wells, and it will not be solved overnight. With the addition of regulations such as these and the necessary corrections to their gaps discussed above, the EQB can make substantial progress to ending this legacy, ensuring the health and safety of Pennsylvanians, and protecting their air and water.

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[43] *Id.* at 15.
[44] *See* PA DEP, Stray Gas Migration Cases (2009), *available at* http://www.dep.state.pa.us/dep/subject/advcoun/oil_gas/2009/Stray%20Gas%20Migration%20Cases.doc.
[45] *See* Regulatory Analysis Form, *supra*, at 14.
[46] *Id.* at 15.
[47] Proposed Regulations, *supra*, at 15.

II. REQUIREMENTS FOR SEISMIC TESTING OPERATIONS FOR OIL AND GAS

PA DEP currently has specific permitting requirements and regulations for an operator to develop oil and gas deposits, including for well drilling, erosion and sedimentation, and excavation in a wetland, stream, or other waterbody. Yet there are no specific requirements for seismic testing of these same gas and oil deposits, despite the potential threats that such exploration poses to safety, infrastructure, and natural resources of the Commonwealth. Instead, PA DEP permits seismic exploration of shale gas and oil under its generic and outdated blasting regulations and with no apparent regulations to address the use of other equipment, such as vibroseis—or "thumper"—trucks.

The proposed revisions to Chapter 78 are an ideal opportunity for the EQB to remedy this situation and finally promulgate specific regulations for seismic blasting, vibroseis trucks, and other seismic testing practices. Without regulatory action, the EQB has left the burden to act on the townships and municipalities that are facing seismic testing companies for the first time. And where these local governments have made attempts to set reasonable ordinances, the seismic companies have sued to overturn the ordinances and otherwise have taken advantage of the resulting confusion. The EQB needs to step in and set the baseline.

A. Background

Oil and gas exploration companies use explosive charges and vibroseis trucks to locate, survey, and map deposits. Each mapping project typically spans several counties and uses tens of thousands of explosive shots, each containing three to five pounds of explosive, and each placed in holes thirty feet deep or more.[48] The vibrations travel from the shot point or truck through the ground, reflect off the strata, and return to be measured by geophones on the surface. The geophones record the "seismic echo," and create maps of the physical qualities of the underlying formation.[49]

When using explosives is not possible—due to location, geography, or landowner permission—or in conjunction with explosives, companies use vibroseis trucks positioned on roadways. The trucks use a large plate positioned on the ground to send a vibration into the formations below, which then reflects back upward and delivers mapping information.[50] The

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[48] *See, e.g.*, Rachel Morgan, *The ins, outs and reverberations of seismic testing*, Shale Reporter, March 7, 2013, http://www.shalereporter.com/industry/article_fa61c9de-8730-11e2-88f3-0019bb30f31a.html.

[49] James D. Decker, *Selected Technical and Legal Issues Arising From Seismic Exploration*, 8th Annual Advanced Oil, Gas and Mineral Law Course C-1; Howard R. Williams & Charles J. Meyers, *Manual of Oil and Gas Terms* 457-458 (10th ed. 1997).

[50] Rachel Morgan, *Seismic testing company sues W.Pa. towns*, Shale Reporter, Aug. 20, 2013, http://www.shalereporter.com/industry/article_d8a08e6a-0995-11e3-98fb-001a4bcf6878.html; Rachel Morgan, *The ins, outs and reverberations of seismic testing*, *supra*; Timothy Puko, *Movers, shakers of shale: Seismic testing adapts to Western Pa.*, Pittsburgh Tribune-Review, Nov. 23, 2013, *available at* http://triblive.com/business/headlines/5063407-74/seismic-gas-testing#axzz2vgwlZv6yvir.

companies either conduct these surveys on behalf of oil and gas production companies or sell this information to such companies, who then use the maps and information to determine location for oil and gas development.[51]

Despite modern advances in seismic testing, Pennsylvania's regulations and permits have not kept pace. Current state regulations governing the use of explosives are not specific to seismic testing for oil and gas and fail to account for the environmental consequences of repeated testing on unstable lands or older infrastructure.

Specifically, PA DEP currently regulates seismic blasting under the Chapter 211 of Title 25, which governs the storage, handling, and use of explosives.[52] By design, the Chapter 211 regulations are meant to apply generally, and do not have specific provisions for blasting that is conducted for oil and gas seismic testing or any provisions for the use of vibroseis trucks. In fact, the regulatory and permitting authority under Chapter 211 is PA DEP's Bureau of Mining and Reclamation, not the Office of Oil and Gas Management. PA DEP recently confirmed that currently there is no PA DEP permit required for seismic testing using vibroseis trucks. [53]

For this reason, a number of townships have attempted to fill this regulatory gap by adopting their own ordinances to regulate and permit seismic testing within their boundaries.[54] As discussed below, these ordinances contain substantive requirements for permitting of seismic operations, location and minimum setbacks, notice to surrounding landowners, and surety bonds.[55] And PA DEP has seemingly been comfortable with this regulatory landscape, given that it has not opted to include any updated seismic testing requirements—particularly for vibroseis trucks—in its revisions and has advised in the meantime that operators "may be subject to local municipal ordinances."[56]

While this might have been a workable arrangement for those municipalities that have seismic testing ordinances in place, the seismic operators have hit back hard with a series of lawsuits to enjoin and prevent the enactment of such ordinances. For example, in August 2013, a seismic operator sued Hopewell and Potter Townships to block their ordinances that regulated seismic testing on local roads.[57] The court granted the order in September 2013 and followed up in January of this year with an order preventing Hopewell from communicating with or giving

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[51] Timothy Puko, *Movers, shakers of shale: Seismic testing adapts to Western Pa.*, *supra*.
[52] *See* 25 Pa. Code § 211.102(a).
[53] Rachel Morgan, *Court order blocks Pa. town from interfering in seismic testing*, Shale Reporter, Feb. 12, 2014, http://www.shalereporter.com/government/article_76cc2208-93f6-11e3-ba6e-0017a43b2370.html.
[54] *See, e.g.*, Robinson Twp., Pa., Ordinance No. 63-10 (2010) [hereafter Robinson Twp. Seismic Ordinance].
[55] *See* Part II.C, *infra*.
[56] Rachel Morgan, *Court order blocks Pa. town from interfering in seismic testing*, *supra*.
[57] *Id.*

instructions to residents regarding the seismic testing.[58] Hopewell has appealed the latter order to the Pennsylvania Supreme Court.[59]

In additional cases, the same seismic testing company sued three other municipalities that had rescinded or never properly adopted seismic testing ordinances and won a preliminary order prohibiting them "from enforcing and applying seismic regulations either by resolution or agreement to petitioner's survey operations and from arbitrarily and unreasonably prohibiting petitioner's use of the municipality's respective roads."[60] And just this week, those three municipalities won a procedural victory when the Pennsylvania Commonwealth Court found it did not have jurisdiction over the municipalities' actions.[61]

Week by week and locality by locality, the regulation of seismic testing in Pennsylvania is in flux, and operators are taking advantage of this confusion to complete their testing as quickly and with as few controls as possible. It is vital that the EQB step in and provide clear, baseline regulation in order that the rules and permits governing seismic testing are straightforward statewide.

B. Issues for Safety, Human Health, and the Environment

Seismic testing via blasting and vibroseis trucks can have major safety issues and cause damages to buildings, infrastructure, and drinking water wells. For example, there are a number of recorded instances in Pennsylvania and other oil and gas states in which landowners have discovered cracks in walls and foundations of their residences in the aftermath of seismic testing operations.[62] Just last month, a resident of Hopewell Township discovered cracks in the wall and

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[58] *Id.*

[59] Hopewell Township, Commonwealth Court Order RE: Seitel Data, Ltd. v. Hopewell Township, Feb. 10, 2014, http://www.hopewelltwp.com/news/view-commonwealth-court-order-re-seitel-data-ltd-v-hopewell-township/ (last visited March 14, 2014); Kelly Knaub, *Pa. Town In High Court Fight To Warn Locals Of Seismic Test*, Law360, March 10, 2014, http://www.law360.com/energy/articles/516755/pa-town-in-high-court-fight-to-warn-locals-of-seismic-test

[60] Rachel Morgan, *Court order blocks Pa. town from interfering in seismic testing*, *supra*.

[61] Zack Needles, *Act 13 Narrows Commonwealth Ct. Jurisdiction*, The Legal Intelligencer, March 13, 2014, http://www.thelegalintelligencer.com/home/id=1202646613687/Act%2013%20Narrows%20Commonwealth%20Ct%20Jurisdiction?mcode=1202615324169&curindex=0&slreturn=20140213091000

[62] *See* Rachel Morgan, *Pa. resident says seismic testing damaged his home*, Shale Reporter, Feb. 14, 2014, http://www.shalereporter.com/industry/article_7e54f0d6-9586-11e3-be9b-0017a43b2370.html; David Singer, *Seismic Testing for Marcellus Shale Drilling Worries Residents*, Canon-McMillan Patch, May 9, 2012, http://canon-mcmillan.patch.com/groups/politics-and-elections/p/seismic-testing-for-marcellus-shale-drilling-worries-residents; Bruce Finley, *Seismic surveying rattles Colorado homeowners*, Denver Post, March 16, 2013, *available at* http://www.denverpost.com/ci_22803371/seismic-surveying-rattles-colorado-homeowners.

floor of his home and garage, as well as leaks from a broken water line, after a seismic operator conducted vibroseis testing on a road forty feet from his residence.[63]

Damage to public infrastructure such as roads, water lines, and sewer lines is also a serious issue, particularly given that many of Pennsylvania's municipalities rely on historic and aging infrastructure that was not designed to withstand blasting or vibroseis.[64] For example, sewer infrastructure in an Ohio courthouse ruptured, flooding a document storage room with sewage, after five vibroseis trucks conducted testing activity on the adjacent street.[65] And in October 2013, two municipal water authorities in Pennsylvania sued to prevent local seismic testing operations on the basis that the testing could damage water infrastructure beneath certain roads.[66]

Seismic testing may also damage or destroy private drinking water wells. This is a serious issue for Pennsylvania, as over three million Pennsylvanians rely on well water in rural areas, including many of the areas that have been selected for seismic testing.[67] For example, in Colorado, which also has extensive seismic operations, landowners found that their sixty-foot-deep water well collapsed in the aftermath of seismic testing and stopped giving water.[68]

Other safety issues have arisen with the intersection of seismic testing and certain high-hazard areas. For example, in 2013, residents of LaBelle, Pennsylvania, discovered that a seismic testing company had illegally set over one hundred explosive charges at a mine reclamation and coal ash disposal site adjacent to the town.[69] PA DEP and the Mine Safety and Health Administration ordered the operator to remove the explosives, but the operator appealed the order, claiming that its PA DEP blasting permit had not specifically prohibited testing in the high-hazard area.[70]

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[63] *See* Rachel Morgan, *Pa. resident says seismic testing damaged his home, supra.*
[64] *See* Rachel Morgan, *The ins, outs and reverberations of seismic testing, supra.*
[65] *See* Sam Shawver, *Vibrations blamed for court sewer leak*, Marietta (Ohio) Times, July 12, 2012, *available at* https://www.mariettatimes.com/page/content.detail/id/545346/Vibrations-blamed-for-court-sewe---.html.
[66] Rachel Morgan, *Court order blocks Pa. town from interfering in seismic testing, supra.*
[67] *See* Bryan R. Swistock et al., *Water quality and management of private drinking water wells in Pennsylvania*, 75 J. Envtl. Health 60 (2013); *see also* Elizabeth W. Boyer, Ph.D. et al., Ctr. for Rural Pa., *The Impact of Marcellus Gas Drilling on Rural Drinking Water Supplies* 5 (2011) (on file with EIP).
[68] *See* Bruce Finley, *Seismic surveying rattles Colorado homeowners, supra.*
[69] *See* Don Hopey, *Firm appeals restraint on seismic testing in Pittsburgh region*, Pittsburgh Post-Gazette, June 4, 2013, *available at* http://www.post-gazette.com/local/marcellusshale/2013/06/04/Firm-appeals-restraint-on-seismic-testing-in-Pittsburgh-region/stories/201306040142.
[70] *Id.*

In addition to these significant issues for health and safety, seismic testing can also result in a variety of environmental impacts.[71] The major environmental risks associated with seismic exploration stem from the physical process of seismic testing itself, which includes vibrations from explosions, dust, degradation of water supplies, landslides, and sinkholes.[72] Physical blasts can release rocks and debris, causing damage to nearby land, people, or property.[73] The blasts may also release gases trapped in the type of rock commonly found in Pennsylvania or in the more than 3,800 abandoned mines throughout the state.[74]

In 1997, the Pennsylvania Office of Mineral Resource Management (OMRM) released a Public Advisory warning residents about the health threats of carbon monoxide, released during seismic exploration.[75] While the surveying companies denied causation, the OMRM advised that the blast had forced the gas outwards through utility lines and existing fractures in the rock and into homes.[76]

In addition, the unique issues stemming from Pennsylvania's geographic instability make the state particularly vulnerable to repeated explosions. The sheer number of explosions—tens of thousands per seismic testing project—may affect structurally vulnerable areas near abandoned or active coal mines or quarries, causing landslides or sinkholes. Landslides and sinkholes are common in Pennsylvania because of the ubiquity of shale, limestone, and dolomite, the proliferation of surface mining, and the number of heavily excavated underground mines.[77] Repeated vibrations from blasting affect plant growth, cause soil compaction and surface erosion, and disturb soil layers, ultimately creating instability and resulting in these geological hazards.[78]

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[71] Yousif K. Kharaka et al., *The energy-water nexus: potential groundwater-quality degradation associated with production of shale gas*, 7 Procedia Earth & Planetary Sci. 420 (2013).
[72] PA DEP, Bureau of District Mining Operations, http://www.portal.state.pa.us/portal/server.pt/community/bureau_of_district_mining_operations/20764 (last visited March 14, 2014).
[73] Nancy Saint-Paul, 1 *Summers Oil and Gas* § 45:3 (3d ed. 2012).
[74] Jeff Skousen, W. Va. Univ., *Remining In Pennsylvania and West Virginia Costs and Water Quality Changes*, Green Lands, Summer 1997, *available at* http://www.wvu.edu/~agexten/landrec/remining.htm; *see also* E. Pa. Coal. for Abandoned Mine Reclamation, Abandoned Mine Land Program Fact Sheet, http://epcamr.org/storage/Abandoned_Mine_Land_Pgm_Fact_Sheet.pdf.
[75] PA DEP, Office of Mineral Res. Mgmt., Public Advisory: Carbon Monoxide Poisoning from Blasting Activities, Office of Mineral Resource Management (1997), *available at* http://www.portal.state.pa.us/portal/server.pt/community/blasting_and_explosives/20881/public_advisory/1150248.
[76] *Id.*
[77] Pa. Dep't of Conservation and Natural Res., Geologic Hazards in Pennsylvania, http://www.dcnr.state.pa.us/topogeo/hazards/index.htm (last visited March 14, 2014).
[78] PA DEP, What causes a sink hole?, http://www.portal.state.pa.us/portal/server.pt/community/sinkholes/10637/what_causes_a_sinkhole_/554362 (last visited March 14, 2014).

Overall, Pennsylvania is particularly vulnerable to the ill-effects of unregulated seismic exploration, both in terms of the impacts to human health and safety—such as buildings, drinking water wells, and infrastructure—and environmental impacts to the land, air, and water.

C. The EQB Must Promulgate Specific Regulations to Cover and Permit Oil and Gas Seismic Testing Operations

In order to fully and specifically address these issues, the EQB should promulgate regulations for seismic testing operations under Chapter 78. Based on a review of other states' regulations and local ordinances, Pennsylvania's new regulations and permitting scheme should cover at least three basic areas: pre-testing notice to landowners, municipalities and other relevant parties; limits and setbacks for seismic testing locations; and surety bonding. Additionally, the regulations and permitting scheme should make clear that approval under applicable local ordinances is necessary before testing commences.

First, it is important that the new regulations contain requirements that the company notify surrounding landowners and relevant state and local governments before the commencement of testing. Under the current regime, there is often no notice provided to landowners before testing commences or even before seismic operators' employees enter and leave equipment on private property.[79]

For example, Robinson Township's seismic testing ordinance requires that a company provide written notice by U.S. Mail or in-person delivery to landowners within 250 feet of testing at least ten working days before commencing operations. The notice must provide the start date of operations, the type of operations (i.e., blasting or vibroseis), and an offer to provide proof of the company's insurance information to the landowner.[80] For landowners within 400 feet of blasting or 125 feet of vibroseis, the company must also provide ten working days' notice, in which it offers to provide free pre- and post-operations testing of water wells.[81] Additionally, the company must publish an ad in the local newspaper for at least two weeks and provide notice to the relevant township official at least three working days prior to the commencement of operations.[82]

Other states with seismic testing regulations have similar requirements. For example:

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[79] *See* John Paul, *Seismic Mapping: Devices Left In People's Yards Causing Alarm In Aliquippa & Hopewell*, Beaver Countian, Feb. 11, 2014, http://beavercountian.com/content/daily/seismic-testing-begins-devices-peoples-yards-causing-alarm-aliquippa-hopewell; Amanda Gilloly, *Cecil: Seismic Testing Company 'Willfully Violated' Ordinance*, Canon-McMillan Patch, July 10, 2012, http://canon-mcmillan.patch.com/groups/politics-and-elections/p/cecil-seismic-testing-company-willfully-violated-ordinance.

[80] Robinson Twp. Seismic Ordinance, *supra*, § 6(a).

[81] *Id.* § 6(b).

[82] *Id.* §§ 4, 6(c).

- Colorado requires operators to notify the local government at the same time it applies to the state regulatory authority and consult all surface owners of lands in the area;[83]
- North Dakota requires operators to apply for a seismic exploration permit at least three days before commencing operations and inform the state commission twenty-four hours before actually commencing operations;[84] and
- West Virginia requires operators to provide notice to "Miss Utility of West Virginia Inc." and to "all surface owners, coal owners and lessees, and natural gas storage field operators" on whose property the testing will occur at least three days prior to commencing operations. The notice also must contain a reclamation plan.[85]

Second, the new regulations should contain location provisions, including setback distances, prohibitions, and other special considerations for certain areas. For example, the Robinson Township seismic testing ordinance contains a minimum setback for vibroseis operations of 150 feet from any building and a minimum setback for blasting operations of 300 feet from any building, water well, or underground hazardous waste storage site.[86] For seismic blasting occurring within 600 feet of any occupied building, the operator must also provide monitoring.[87]

Similarly, Colorado requires that blasting "be kept a safe distance from a building unit, water well or spring, unless by special written permission of the surface owner or lessee," according to minimum setback distances set by the weight of the explosive charge. For charges between two and five pounds, for example, the setback distance is 300 feet, with distances increasing to as much as one quarter-mile for charges exceeding 20 pounds.[88] North Dakota prohibits seismic blasting operations within 600 feet of water wells, buildings, cisterns, pipelines, and flowing springs, and prohibits non-explosive operations such as vibroseis within 300 feet of such structures and resources.[89]

Additionally, certain state regulations contain restrictions for seismic testing in environmentally fragile areas. For example, Maryland specifically restricts permitting of seismic testing in areas where it "poses a substantial risk of causing environmental damage."[90] Alaska does not grant exploration permits on land with an active permit for coal exploration.[91] And Louisiana does not grant seismic testing permits for exploration of "unsuitable" lands, including fragile or historic lands, lands where exploration could result in a substantial loss or reduction of productivity of water supply, or natural hazard lands, such as areas subject to frequent flooding or of unstable geology.[92]

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[83] 2 Colo. Code Regs. § 404-333(a), (b).
[84] N.D. Admin. Code 43-02-12-04(1), (2).
[85] W. Va. Code R. § §22-6A-10(j).
[86] Robinson Twp. Seismic Ordinance, *supra*, § 10(b).
[87] *Id.*
[88] 2 Colo. Code Regs. § 404-333(c)(2).
[89] N.D. Admin. Code 43-02-12-05.
[90] Md. Code Regs. § 26.19.01.03(3)(b).
[91] Alaska Stat. § 38.05.132.
[92] La. Rev. Stat. Ann. § 30:922(A)(3).

Third, bonding requirements are critical to insuring that all seismic operations are conducted safely and that any necessary remediation efforts are at least partially funded. Robinson Township requires a bond of $100,000, which must be valid for a period of two years from the date of permit issuance.[93] Additionally, the Township requires that the operator possess liability insurance with minimum coverage of $1 million per person, $3 million per occurrence, and $1 million for property damage.[94]

Colorado requires a bond of $25,000, provided however that the operator will be responsible for plugging seismic exploration holes whether or not the cost exceeds the bond.[95] And North Dakota requires a bond of $50,000 for blasting operations and $25,000 for any other type of seismic operations.[96] Any subcontractor must also obtain a bond of $10,000.[97]

Finally, the regulations or permitting scheme should make clear that approval under applicable local ordinances is also necessary before testing commences. As discussed above, certain municipalities in Pennsylvania have made great strides in enacting detailed, substantive ordinances to govern seismic testing within their borders.[98] And while PA DEP has attempted to instruct operators that local requirements are necessary, certain operators have been hostile to such ordinances. In light of these important requirements and the recent Pennsylvania Supreme Court ruling reaffirming municipalities' ability to enact such ordinances,[99] the EQB should make clear in the regulations and permitting scheme that seismic operators must also be sure to obtain local approval before commencing operations and abide by such requirements throughout.

While it is unfortunate that the EQB has not included requirements for seismic testing in its proposed revisions to Chapter 78, it still has the opportunity to do so. As with the other practices and effects of Pennsylvania's shale boom, seismic testing in the Commonwealth is expanding rapidly, moving into areas that have never seen the practice and causing major impacts to residences, infrastructure, and the environment. Fortunately, certain of Pennsylvania's townships and other states have laid much of the groundwork for such regulations, and the EQB should build on these sources to promulgate substantive seismic testing regulations for the benefit of Pennsylvanians and their environment.

III. CONCLUSION

We appreciate the opportunity to comment on the EQB's proposed regulations under Chapter 78 and commend the EQB for taking this important step to modernize and update these necessary requirements. At the same time, the proposed regulations contain important gaps and

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[93] Robinson Twp. Seismic Ordinance, *supra*, § 11(a).
[94] *Id.* § 11(b).
[95] 2 Colo. Code Regs. §§ 404-705, 404-320.
[96] N.D. Admin. Code 43-02-12-03(2).
[97] *Id.*
[98] *See* Part II.A, C, *supra*.
[99] *See Robinson Twp. et al. v. Commonwealth*, 83 A.3d 901 (Pa. 2013).

shortcomings that exempt certain oil and gas industry practices and in some cases ignore important subsets of the industry.

Oil and gas development in Pennsylvania is booming, increasing its technological advances, and expanding to areas of the Commonwealth that are almost entirely new to the industry. It is important that the EQB properly revise its regulations to keep up with the industry, fully address its impacts, and better protect Pennsylvanians and the Commonwealth's resources.

If you have any questions in regard to these comments, please do not hesitate to contact me at (202) 263-4451 or akron@environmentalintegrity.org. Thank you for your attention to these important issues.

Sincerely,

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Direct measurements of methane emissions from abandoned oil and gas wells in Pennsylvania

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Abandoned oil and gas wells provide a potential pathway for subsurface migration and emissions of methane and other fluids to the atmosphere. Little is known about methane fluxes from the millions of abandoned wells that exist in the United States. Here, we report direct measurements of methane fluxes from abandoned oil and gas wells in Pennsylvania, using static flux chambers. A total of 42 and 52 direct measurements were made at wells and at locations near the wells ("controls") in forested, wetland, grassland, and river areas in July, August, October 2013 and January 2014, respectively. The mean methane flow rates at these well locations were 0.27 kg/d/well, and the mean methane flow rate at the control locations was 4.5×10^{-6} kg/d/location. Three out of the 19 measured wells were high emitters that had methane flow rates that were three orders of magnitude larger than the median flow rate of 1.3×10^{-3} kg/d/well. Assuming the mean flow rate found here is representative of all abandoned wells in Pennsylvania, we scaled the methane emissions to be 4–7% of estimated total anthropogenic methane emissions in Pennsylvania. The presence of ethane, propane, and n-butane, along with the methane isotopic composition, indicate that the emitted methane is predominantly of thermogenic origin. These measurements show that methane emissions from abandoned oil and gas wells can be significant. The research required to quantify these emissions nationally should be undertaken so they can be accurately described and included in greenhouse gas emissions inventories.

methane emissions | oil and gas | abandoned wells | hydrocarbons | isotopes

Abandoned oil and gas wells provide a potential pathway for subsurface migration and emissions to the atmosphere of methane and other fluids (1). According to one recent study, there are an estimated 3 million abandoned oil and gas wells throughout the United States (2). Methane emissions from these wells are assumed to be the second largest potential contribution to total US methane emissions above US Environmental Protection Agency estimates and are not included in any emissions inventory (2). There is a lack of empirical studies that can be used to estimate the methane emission potential of these wells (2).

Methane is a greenhouse gas (GHG) and its oxidation produces ozone (O_3) that degrades air quality and adversely impacts human health, agricultural yields, and ecosystem productivity (3). Therefore, it is important to understand methane emission sources so that appropriate mitigation strategies can be developed and implemented.

Efforts to improve estimates of methane emissions to the atmosphere from oil and gas production in the United States are being driven, in part, by growth in unconventional production. Estimates of methane emissions from activities on producing oil and gas sites, including well completion, routine maintenance, and equipment leaks, are used to develop bottom–up estimates (4, 5). Overall, a comparison of bottom–up and top–down estimates indicate that there may be missing sources in bottom–up estimates (2, 6–8, 9). Here, we focus on one missing source: abandoned oil and gas wells.

There is no regulatory requirement to monitor or account for methane emissions from abandoned wells in the United States. Methane leakage through abandoned wells linked to recent growth in unconventional oil and gas production is being studied as a groundwater contamination issue (10–14), but no direct evidence for leakage through abandoned wells to groundwater aquifers currently exists. Abandoned wells have been connected to subsurface methane accumulations that have caused explosions, which are major concerns in urban areas with oil and gas development or natural gas storage reservoirs, as well as in coal mines (15, 16). Therefore, existing monitoring is focused on detecting large concentrations. The result is a lack of information to quantify methane emissions from abandoned oil and gas wells.

To characterize abandoned oil and gas wells' potential as a significant methane source, we made first-of-a-kind direct measurements of methane flow rates from 19 wells in various locations across McKean and Potter counties in Pennsylvania (PA) (Fig. 1). The measured wells were selected mainly based on logistical and legal access (*Supporting Information*). As of January 17, 2014, only 1 of the 19 wells was on the PA Department of Environmental Protection's (DEP's) list of abandoned and orphaned wells. (Orphaned wells can be defined as abandoned wells with no

Significance

Recent studies indicate that greenhouse gas emission inventories are likely missing methane emission sources. We conducted the first methane emission measurements from abandoned oil and gas wells and found substantial emissions, particularly from high-emitting abandoned wells. These emissions are not currently considered in any emissions inventory. We scaled methane emissions from our direct measurements of abandoned wells in Pennsylvania and calculate that they represent 4–7% of current total anthropogenic methane emissions in Pennsylvania. Millions of abandoned wells exist across the country and some are likely to be high emitters. Additional measurements of methane emissions from abandoned wells and their inclusion in greenhouse gas inventories will aid in developing and implementing appropriate greenhouse gas emission reduction strategies.

Author contributions: M.K., C.M.K., M.C.R., X.Z., and Y.C. designed research; M.K., C.M.K., M.C.R., X.Z., D.L.M., M.A.C., Y.C., and T.C.O. performed research; M.K. analyzed data; and M.K., D.L.M., and M.A.C. wrote the paper.

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ENVIRONMENTAL SCIENCES

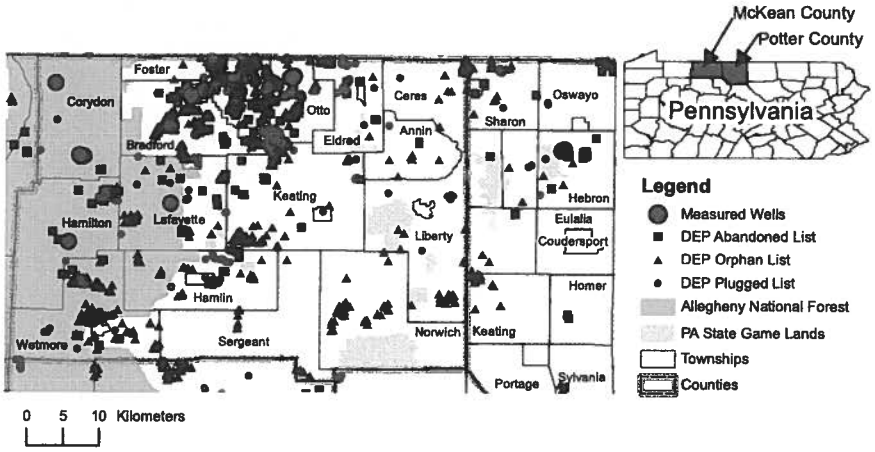

Fig. 1. The 19 measured wells are located in McKean County and Potter County in Pennsylvania. There are 12,127 abandoned, orphaned, and plugged wells on the Pennsylvania DEP's website (as of January 17, 2014), with 4,273 in McKean County and 188 in Potter County. The map shows the DEP wells that are in the region of our field study. Note that only the western portion of Potter County is shown in the detailed map.

responsible party available, other than the state.) The DEP database provides information on the well status (abandoned, plugged, or orphan) and well type (gas, oil, combined oil and gas, or undetermined) but does not provide other information such as well age and depth. No additional information on the measured wells is available. This is indicative of the general scarcity of available information on this class of old wells in PA. Given the lack of records on the wells we measured, no distinction was made between oil and gas wells; the wells were simply categorized as plugged or unplugged, based on surface evidence of cementing and/or presence of a marker. With this criterion, 5 of the 19 measured wells (26%) were classified as plugged.

In addition to methane, we also analyzed the collected samples for ethane, propane, n-butane, and carbon isotopes of methane, to provide insight on the potential sources of the emitted methane. This work provides previously unavailable data on methane leakage rates and other emissions from abandoned oil and gas wells.

Results

Methane Flow Rates. Mass flow rates, in units of mass per time per well, were measured using a static chamber methodology (17, 18) (*Materials and Methods* and *Supporting Information*). Methane flow rates from wells and controls were measured at various sites over five sampling campaigns that took place in July, August, and October 2013, and January 2014. At each well site, measurements of one to six controls located 0.1–62 m from the measured well were taken. (Flow rates at each control were scaled to reflect the same areal footprint as that of the nearest well to ensure that measurements for wells and controls were consistent.)

Methane flow rates from abandoned wells were found to be significantly higher than methane flow rates observed at controls (Fig. 2). The mean flow rate at well locations was 11,000 mg/h/well (0.27 kg/d/well), and the mean flow rate at control locations was 0.19 mg/h/location (4.5×10^{-6} kg/d/location). The median flow rate at well locations was 56 mg/h/well (1.3×10^{-3} kg/d/well), which is still higher than both the mean and median flow rate at control locations. The median flow rate at controls was 0 mg/h/location (or 0 kg/d/location) considering all values, and 6.7×10^{-3} mg/h/location (1.6×10^{-7} kg/d/location) considering nonzero values only. Positive methane flow rates were observed at all 19 wells with values, averaged over multiple sampling events, ranging from 6.3×10^{-1} to 8.6×10^{4} mg/h/well. Average methane flow rates over multiple sampling events at control locations ranged from -1.2×10^{-1} to 4.2 mg/h/location. Methane flow rates at wells were based on good linear fits with 88% of the flow rates having R^2 values greater than 0.8 (*Supporting Information*). Sources of uncertainty included flux chamber design, deployment, sampling, laboratory analysis of samples, and data selection for regression analysis (*Supporting Information*). We estimate that the combined effect of the various sources of uncertainties in flow rate estimates will lead to errors within a factor of 2 of our estimate. This error is small relative to the seven orders of magnitude variation in measured flow rates. Furthermore, most of the sources of measurement uncertainty would bias the measured flow rates to be lower than their actual value.

Methane flow rates at well locations appeared to be unaffected by land cover, which included forest, grassland, river, and wetland. In contrast, we found that methane fluxes at control locations were dependent on land cover. A large proportion of flow rates from controls in forests and grasslands were negative (i.e., methane sinks) and ranged from -1.2×10^{-1} to 1.8 mg/h/location, and the flow rates from controls in wetlands were consistently positive and relatively high, ranging from 1.6×10^{-2} to 4.2×10^{1} mg/h/location. We found seasonal effects were present in controls, with lower methane fluxes observed in the January 2014 sampling round. Although there is no evidence of significant seasonal effects in the methane flow rates from wells, additional measurements are needed to reach a firm conclusion.

According to regulations on well abandonment, wells are plugged to limit vertical migration from subsurface source

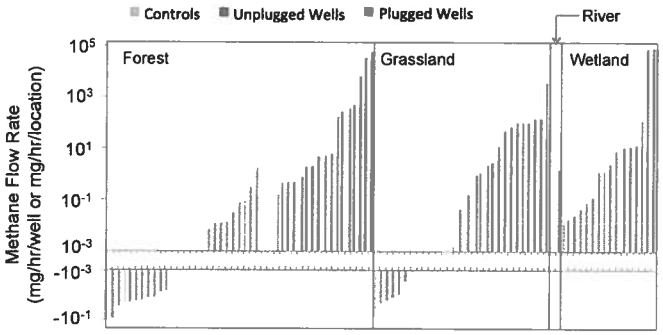

Fig. 2. A total of 42 and 52 measurements were made at wells and at locations near the wells (controls), respectively, in forested, wetland, grassland, and river areas in July, August, October 2013 and January 2014.

formations (oil and gas reservoirs and coal beds), which includes minimizing impacts on groundwater. We found that methane flow rates from plugged wells were not necessarily lower than methane flow rates at unplugged wells. For example, in the grassland area, both the largest and the second lowest methane fluxes originated from plugged wells. Evaluation of plugging status and wellbore integrity was difficult using only visual inspection at the surface and lack of additional information.

Presence of Ethane, Propane, and n-Butane. The presence and concentration of ethane, propane, and n-butane are useful for identifying the methane source as thermogenic or microbial. Because ethane is not coproduced during microbial methanogenesis, the presence of ethane-to-methane ratios greater than 0.01 indicates gas of largely thermogenic origin (14, 19). A similar threshold is not readily available in literature for propane-to-methane and n-butane-to-methane ratios, but we expect this threshold value to be less than 0.01. Ratios of ethane, propane, and n-butane relative to methane were more frequently greater than 0.01, and at higher values, for wells than for controls (Fig. 3). Nonetheless, the presence of these nonmethane hydrocarbons in controls indicates that there may be subsurface horizontal gas flow away from the well and subsequent emissions to the atmosphere. We also did not find a consistent ratio for wells or controls and obtained alkane ratios ranging from 1×10^{-5} to 0.8. The high variability in alkane ratios may be a result of mixing between various microbial and thermogenic (deeper) sources.

Carbon Isotopes of Methane. Carbon isotope information provides additional evidence suggesting that the source of methane from the wells is likely to represent a mixture of microbial and thermogenic sources. In general, methane originating from thermogenic sources is more enriched in ^{13}C; whereas, methane originating from microbial sources is relatively depleted in ^{13}C. We found that the samples collected at wells were likely to be more enriched in ^{13}C than those collected at controls (Fig. 4). A comparison of the methane $\delta^{13}C$ values to that of known thermogenic and microbial sources (20) indicates that most of the methane flow rates from wells are thermogenic or a mixture of microbial and thermogenic sources. Only 3 of the 26 measurements at wells had methane $\delta^{13}C$ values in the microbial range. The methane $\delta^{13}C$ values of the measured wells ranged from −71‰ to −21‰. This range is broader than published methane $\delta^{13}C$ values of thermogenic methane in natural gas in the northern Appalachian basin, which range from −47.9‰ to −30.7‰ (21). The methane $\delta^{13}C$ values at controls ranged from −85‰ to 756‰, indicating control sources were more likely to be of primarily microbial origin.

Fig. 4 also shows that locations with larger methane flow rates emitted methane that was more enriched in ^{13}C. Wells with methane flow rates that were greater than 10^3 mg/h/well were likely to be emitting methane of thermogenic origin; and wells

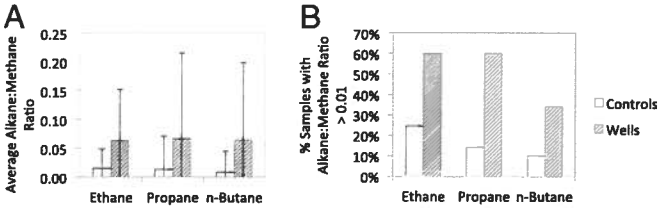

Fig. 3. Average alkane ratios ($[C_2H_6]/[CH_4]$, $[C_3H_8]/[CH_4]$, and $[n\text{-}C_4H_{10}]/[CH_4]$) (*A*) and proportions of samples with alkane ratios greater than 0.01 (*B*) at control and well location with detectable ethane, propane, and n-butane concentrations are calculated for samples collected in July, August, and October 2013 and January 2014. The error bars in *A* represent the SDs of the dataset.

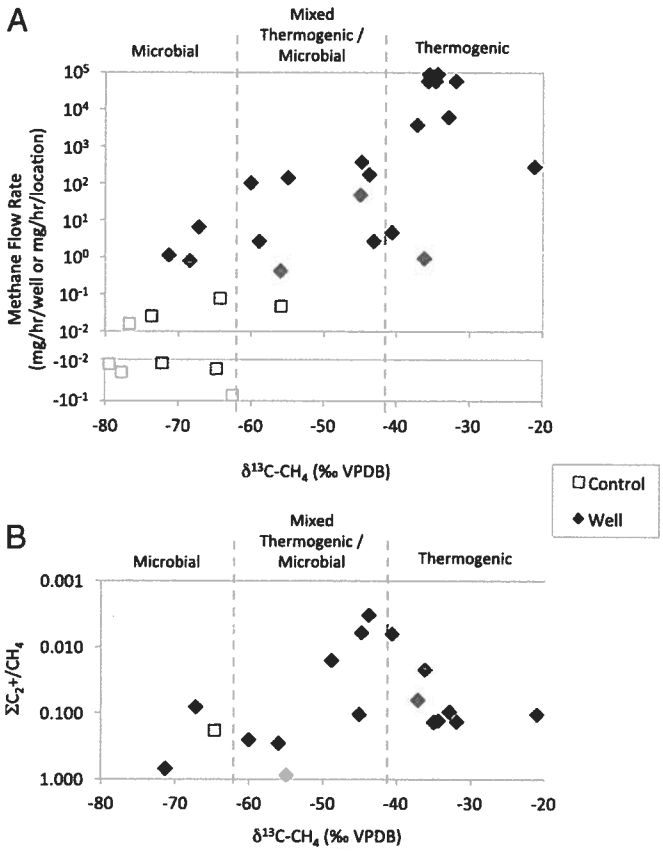

Fig. 4. Composition of carbon isotopes of methane for select samples collected at well and control locations in July, August, and October 2013 and January 2014 are compared with the methane flow rate (*A*) and the sum of ethane, propane, and n-butane concentrations divided by methane concentrations (*B*).

with flow rates in the order of 10^0 to 10^1 mg/h/well emitted methane of microbial, thermogenic, or mixed thermogenic/microbial origin. Methane emitted from most control locations is in the microbial range; however, one measurement reveals that methane emitted from control sources can contain thermogenic sources of methane as well. If we consider the integrated fluxes from all these wells, the methane emitted is primarily of thermogenic origin because the high-emitting wells would represent a large fraction of the total methane emitted from abandoned wells.

We expected the ratio of the sum of ethane, propane, and n-butane concentrations divided by methane concentrations ($\sum C_2+/CH_4$) to be higher for samples more enriched in methane $\delta^{13}C$ (19). Instead, we observed the opposite with quite a few of the samples depleted in methane $\delta^{13}C$ with large values of $\sum C_2+/CH_4$ (Fig. 4). This trend may indicate that there may be complex microbial cycling occurring in and around the wells.

Methane Emissions from Abandoned Wells in PA

Total methane emissions from all abandoned oil and gas wells in PA can be estimated from the number of wells and the emissions per well. If we assume the 19 measured wells are representative of wells across the state, we can use the mean of measured methane flow rates from the wells (0.27 kg/d/well) as a gross estimate of the statewide emission rate per well. As shown in Fig. 5, the mean is ~3 orders of magnitude larger than the median, indicating that the mean value is controlled by a few high emitters. We note that site selection was not based on knowledge about a well's emission potential (*Supporting Information*). It is difficult to quantitatively assess the ability of our measurements

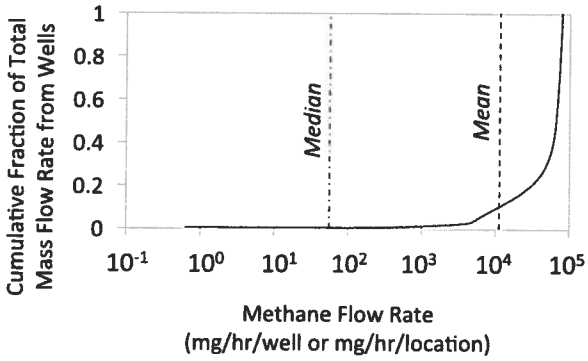

Fig. 5. Cumulative fraction of total measured methane mass flow rate from wells with respect to mass flow rate order of magnitude.

to capture the distribution from all abandoned wells in PA and the representativeness of the mean flow rate for all wells in PA remains uncertain.

The number of abandoned oil and gas wells in the United States and abroad is also highly uncertain. The numbers are complicated by the fact that many of the abandoned wells are "lost" with no evidence of their existence at the surface and/or via public records. Based on the history of oil and gas production in PA, 300,000–500,000 abandoned and orphaned wells have been estimated to exist in PA (*Supporting Information*).

Using these numbers, we estimate methane emissions from abandoned oil and gas wells in PA to be 0.03–0.05 Mt CH_4 per year, which corresponds to 4–7% of estimated total anthropogenic methane emissions in PA for 2010 (22) (*Supporting Information*). We also calculate methane emissions from abandoned wells to be ~0.3–0.5% in 2010 and 0.1–0.2% in 2011 of gross gas withdrawal in PA. These percentages are relatively close to methane leakage from US natural gas production estimated at 0.53–0.59% of gross US gas production in 2011 (5). We provide the scaled estimates to give some context for the relative significance of methane emissions from abandoned wells. We acknowledge that the sample may not be representative of all wells in PA and the denominator used to determine the percentage in terms of total anthropogenic methane emissions is uncertain (*Supporting Information*). (Also, recall that the measurement error in flow rates is estimated to be up to a factor of 2.) We also note that the millions of abandoned oil and gas wells across the country will increase the current contribution to methane emissions from natural gas and petroleum systems, which are 23% and 5% of total methane emissions, respectively, for 2010 (23).

Conclusions

Methane emissions from abandoned oil and gas wells appear to be a significant source of methane emissions to the atmosphere. An improved understanding of abandoned oil and gas wells as a methane emission source may help bridge the current gap in local, regional, and global methane budgets. Additional measurements are required to characterize and determine the distribution of methane flow rates from these wells. Also, lost wells must be identified, located, and recorded to improve estimates of the number of abandoned oil and gas wells.

The measured wells presented in this paper are likely to be half a century old or older, and the positive flow rates measured at these wells indicate that the methane emissions from these wells may have been occurring for many decades and possibly more than a century. Therefore, the cumulative emissions from abandoned wells may be significantly larger than the cumulative leakage associated with oil and gas production, which has a shorter lifetime of operation.

As oil and gas development continues to grow in the United States and abroad, the number of abandoned oil and gas wells will continue to grow. Inclusion of abandoned wells in methane emissions accounting (e.g., GHG emissions inventories) will facilitate an improved understanding of their impact on the environment and the development and implementation of effective mitigation strategies and policies. In addition, the measurements provided here may be useful for characterizing groundwater contamination sources and estimating subsurface accumulations of methane and other fluids.

Materials and Methods

We selected the abandoned wells to be measured based on location information, access (legal and logistical), wellhead configuration/geometry above ground, land cover, and plugging status (*Supporting Information*). A static chamber methodology was adapted from techniques to measure trace gas fluxes from soil–plant systems (17, 18). The chambers were designed to enclose the wellhead and measure the methane and other trace gas fluxes from the well and surrounding areas. This is discussed further in the *Supporting Information*. Air samples were analyzed for CH_4, C_2H_6, C_3H_8, and n-C_4H_{10} using flame ionization gas chromatography on a Shimadzu GC-2014 instrument (*Supporting Information*). To measure the C isotopic composition of CH_4, a near-IR continuous wave-cavity ring-down spectrometer (CW-CRDS) was used (24) (*Supporting Information*).

Mass flow rates, in units of mass per time per well, beginning from the moment of chamber deployment, were calculated using linear regression in *MATLAB* on the concentration data, c [mass/volume], over time.

$$F = \frac{dc}{dt} \cdot V_e, \qquad [1]$$

where dc/dt is the slope of the fitted line for $c(t)$ and V_e is the effective chamber volume. For control locations, F is scaled based on the land area covered by the chamber for the control and the nearest well location.

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