EXHIBIT 1

Bakken Wells Require a 1320' Setback Rule

Robert "Pat" Wilson
Bainville, MT

Our family cattle ranch is located seven miles southeast of Bainville, adjacent to the North Dakota state line. It is a very active area within the Montana Bakken. Within a one mile radius of our ranch , there are eighteen producing Bakken/Three Forks wells; the nearest one is/ about 900 feet from our house, our barns, and our corrals. Since 2009, I have learned a little about living near large numbers of oil and gas wells, and my personal experience causes me to agree emphatically with the Oil and Gas Task Force of NPRC (of which I am a member): Montana needs a rule mandating that oil and gas development stay at least a quarter mile from inhabited structures.

My reasons for requesting such a setback rule are as follows, in an ascending order of importance -like Letterman's Top Ten list:

5. Noise and Dust. Do any of you live within 900 feet of a producing Bakken well? Have any of you ever observed and heard a frack job taking place? First, hundreds of trucks deliver frack tanks, propant and millions of gallons of water. In dry Northeastern Montana the dust alone can be a problem, and attempts at dust mitigation never seem to be enough. There is blessed relief after the frack job is over, but in the case of the well 900 feet from our house, the horsehead pump often emits a screeching sound audible inside the house. "The screeching is repetitive," my long-suffering daughter-in-law states. You learn to live with it." With the flexibility offered by directional drilling, should she and her family have to? Once the belts began squealing for a long time and eventually caught fire—a little disconcerting when I saw it at first light.

4. Trash. Trash along the road is undesireable anywhere, but it seems especially annoying a few hundred feet from the house. And by trash I do not mean the occasional pop can. The most memorable item was a Chevy Lumina abandoned alongside the ROW. The worst things to pick up are milk jugs full of trucker's urine. Time is money to a trucker. But there are three kids at the ranch, and we do not want them to pick up those milks jugs. After heated exchanges between my son and an oil company representative, dumpsters have been provided and things have improved.

3. Spills, pipeline leaks, and casing failures. Spills and leaks of oil, drilling mud, and especially produced water are among the "vulnerabilities" mentioned in the EPA's recent study of fracking and drinking water contamination They are more common than generally acknowledged. At our place, we have had the follow events:
   a) a salt water truck tip over on a road that also serves as a dam embankment.
   b) an oil spill briefly overtop the berm on one location.
   c)a frack crew, when they were done, deliberately open the valve on one of those huge Poseidon tanks, and run the water across and off the location-a clear violation of MCA 75-5-605 (2) (c). We informed the DEQ but nothing happened.

Admittedly, most spills and leaks are rather small and usually contained. But when they are uncontained, they can be devastating, and we have had at least three million plus gallon spills and leaks on the North Dakota side of the Bakken. Significant spills and leaks certainly are capable of contaminating acquifers. Why tempt Fate? Directional drilling gives producers options. They can move drilling away from habitation and water sources, or if they feel they need every foot of lateral, they can often move to the other end of the spacing unit.

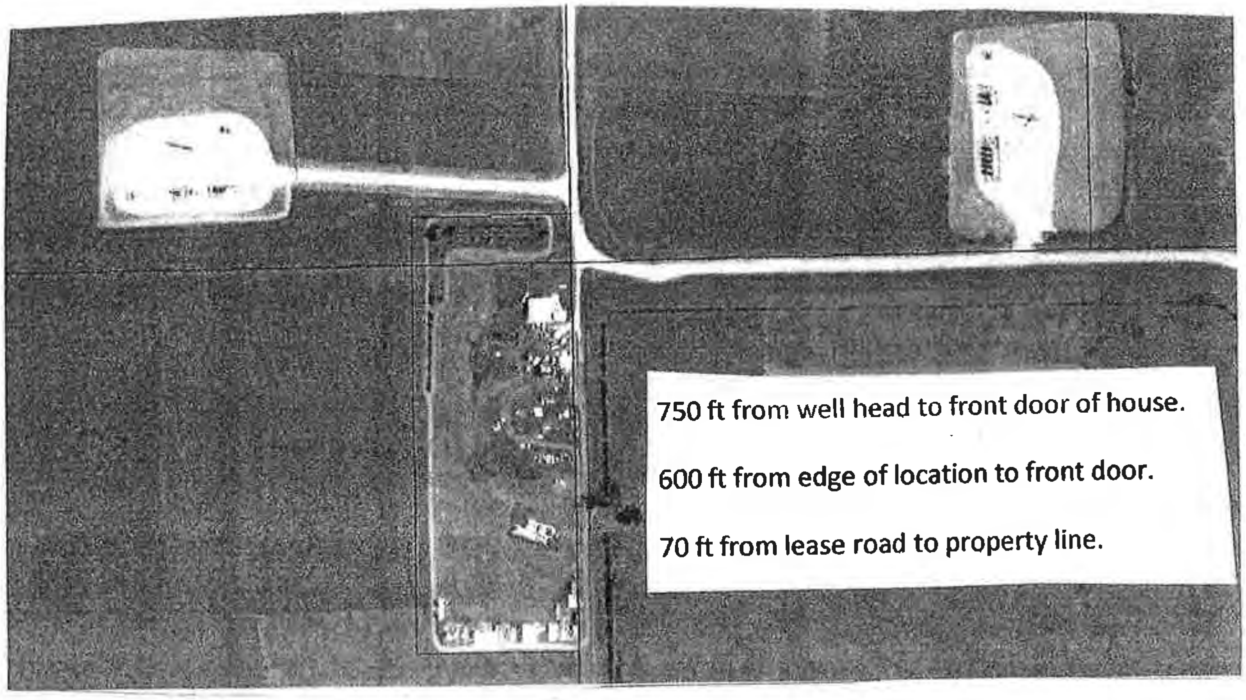
2. VOCs. Volatile Organic Compounds are "higher end " hydrocarbons such as propane, methane, benzene, toluene, and a host of others. Light Bakken crude is loaded with VOCs, which not only makes it highly explosive (a trainload of Bakken crude blew a small Quebec town off the face of the earth, killing fifty residents), but VOCs outgassing from well tanks have pretty much proven to be hazardous to human health for quite a distance around the locations. There is a wonderful book (Uddameri, Morse, & Tindle, Hydraulic Fracturing Impacts and Technologies Boca Raton: CRC Press, 2015) published by a group of scientists and engineers from Texas Tech University that provides some disturbing data regarding VOCs and human health. Here are two eye-opening excerpts gleaned from many in this book:

    > *Elevated hazard index in proximity to well sites.* McKenzie and her colleagues in 2012 calculated the risk of human illness resulting from the elevated level of air toxins that they measured within 152 m(500 ft) of drilling sites in Colorado compared to the much lower levels that were present 762 m (2500 ft) away, in the study mentioned earlier. They determined that people living 152m (500 ft) or closer to well sites in an area of intense oil and gas activity had a **FIVE TIMES INCREASED RISK OF NONCANCER ILLNESS COMPARED TO THOSE LIVING 2500 FT AWAY (P.104) {caps mine}.**

    > *Children are at greater risk.* Paulson has pointed out that air contamination standards are determined by a standard for healthy adults; however, developing fetuses, babies, and children will have a greater risk of illness and cancer from the same level of exposure. Also, the elderly and those with underlying medical illnesses will be at a greater risk of noncancer illness (p. 105).

    Surely health risks such as these warrant setbacks of **at least** 1320 ft.!

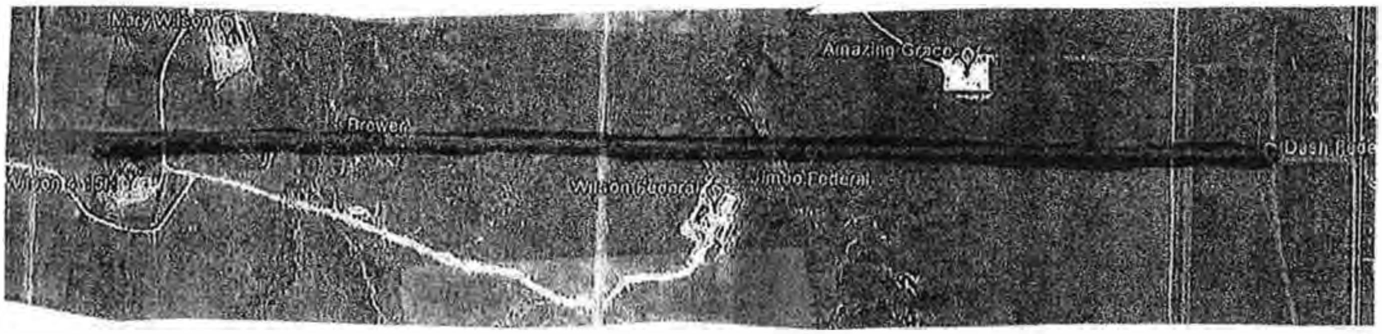
1. Many, if not most citizens in the Bakken region have little or no say concerning well siting, or for that matter any other aspect of oil and gas development. That is a tragedy, especially in a state that prides itself on respect for both individual rights and property rights.
   Let me try to demonstrate with two illustrations. The first is an aerial view of a residence sitting on a five acre tract. I don't think the landowner has the minerals. There are two oil wells very close to his home. All parties involved are very nice.



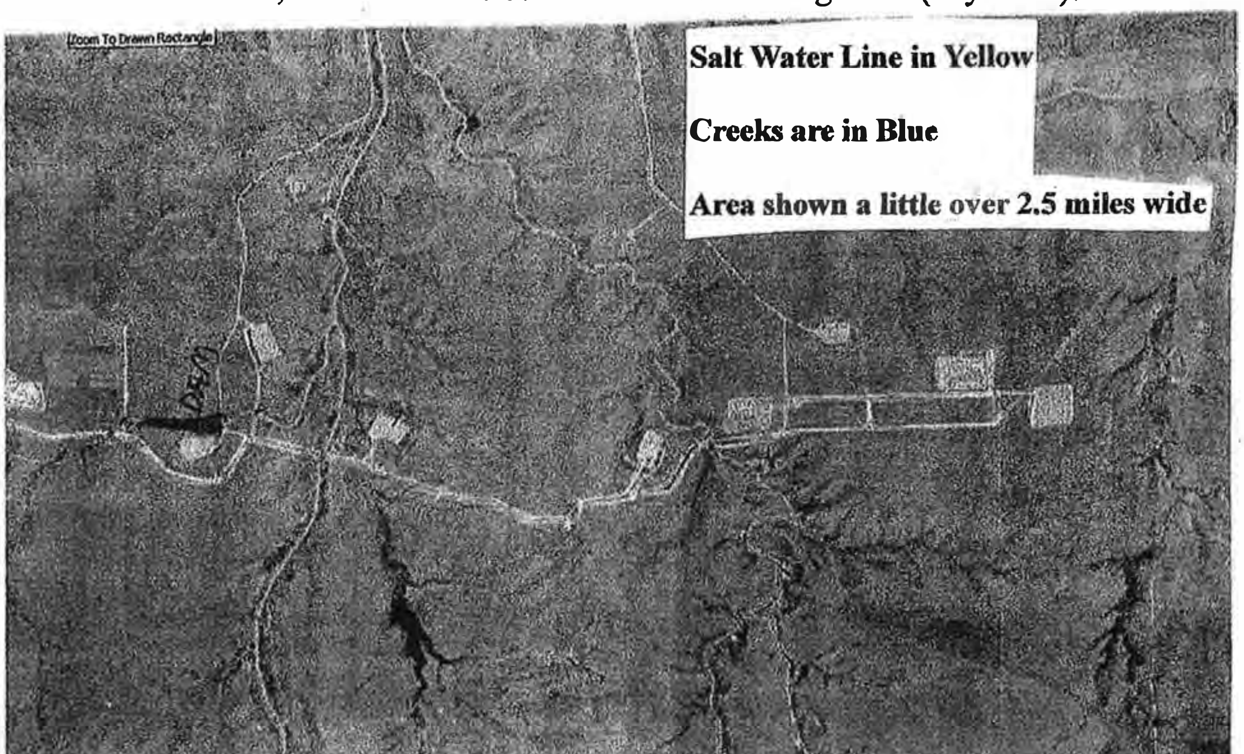
But I'll wager the company who drilled did not include this person in the conversation about well siting—they would not have to. Who listens to surface owners without minerals? I hear the argument that "We do not need a setback rule. Let that be negotiated as part of the lease." Surface owners have no lease, and unless something is actually sited on their property, they do not even have a Surface Use Agreement. They have no rights in the matter, and that's just wrong. Even if the landowner includes setback language in the lease, there is no guarantee the lessor will honor it. Here is an excerpt from one of our current leases:

5. LIMITS AND LIABILITIES FOR SEISMIC OPERATIONS: Lessee may not conduct seismic operations within 990 feet and other operations within 600 feet of a building, structure, water well, spring, dam or creek without obtaining prior consent from, and paying appropriate compensation to the surface owner. Lessee shall negotiate with the surface owner for the use of any water from the leased premises. If operations by Lessee on the leased land premises under the provisions of this lease cause damage to any water well or the surface owner or its tenants for domestic livestock or agricultural purposes, or would do injury to any ground water supply, Lessee shall pay for all damages, including the cost of a new water well if deemed necessary.

The oil company knew we feared saltwater pipelines, so rather than negotiate, they preemptively "20 dayed" us. As part of the 20 day letter, they sent map" as follows:



The straight blue line was the closest thing we got to a route until after the line was built, and the line **as built** took the following route (in yellow):



The line as built crosses three creeks and skirts a dam so close that when the dam is full the pipeline is actually under the west end. So much for the letter of the lease protecting the owner. Oil companies will sometimes beg forgiveness rather than ask permission.

Members of the Board, I believe the only way to insure an modicum of fairness is to have a rule regarding setbacks from areas of habitation, with a sensible and safer distance of 1320 feet. Again,thank you for hearing me.

EXHIBIT 2

NORTHERN PLAINS
RESOURCE COUNCIL

June 23rd, 2015

Montana Board of Oil and Gas Conservation
Linda Nelson, Chairperson
Board members
Attn: Jim Halvorson, Administrator
Montana Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102

Re: Setbacks special session

Dear Members of the Montana Board of Oil and Gas Conservation,

Northern Plains Resource Council (Northern Plains) is excited to see the Montana Board of Oil and Gas Conservation (BOGC) initiate the rulemaking process for establishing setbacks for oil and gas wells in Montana. For more than 42 years Northern Plains and its affiliates have advocated for responsible energy development that does not harm the land, air, water, and social and economic fabric of Montana. As such, Northern Plains appreciates the opportunity to serve as a working partner with the Montana Board of Oil and Gas Conservation (BOGC) as the Board negotiates the balance between landowner protections and the extraction of Montana's oil and gas reserves.

Northern Plains heartily supports setback requirements as a good common sense policy to create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. That setbacks can work is clear from the presence of setbacks in other oil and gas producing states, notably Montana's neighbors of Wyoming and North Dakota. That setbacks are needed to preserve the public welfare is becoming clear through studies of oil and gas producing regions across the country, as well as the experiences of Montanans living in close proximity to wells today.

Due to these considerations, Northern Plains urges the Board to establish a setback rule for Montana that places protective and reasonable buffers between oil and gas wells and inhabited buildings either through the drafting of a new rule in Subchapters 7 "Well Spacing Units" or Subchapter 11 "Safety;" or a revision to rule 36.22.702 "Spacing of Wells" to include a buffer from inhabited buildings.

While Northern Plains supports a dynamic rule that establishes different setbacks for various categories of inhabited buildings, public spaces, and well types, Northern Plains supports a 1,320 ft. setback from inhabited homes.

Setbacks are Common Practice in other oil and gas producing states

Rather than being in line with other oil and gas producing states regarding setback requirements, Montana is in the minority by not having statewide setback requirements for oil and gas wells[1]. Setbacks are a regular part of doing business in other states, notably our neighboring states of Wyoming and North Dakota. North Dakota[2], and more recently Wyoming[3], both uphold setbacks of 500 feet from occupied dwellings or structures. Additionally, in North Dakota, the Industrial Commission may impose conditions on any permits within 1,000 feet of an occupied dwelling. Colorado, on the other hand, has implemented a more pragmatic rule with setbacks that range from 500 feet from building units to 1,000 feet from high occupancy building units such as schools, nursing facilities, life care institutions, correctional facilities, and child care centers[4].

As evidenced by the general prevalence of oil and gas setbacks, setbacks do not prevent the continuation of oil and gas extraction, but rather provide clarity and consistency on the appropriate distance of wells from inhabited buildings. Montana's lack of setback regulations, complex or otherwise, leaves surface owners in undue risk.

Setbacks appropriately assign the burden of proof

At the Board's April meeting, Administrator Jim Halvorson reported that historically the Board has dealt with concerns over well distance from homes and other structures on a case by case basis through the protest process. While Northern Plains appreciates the attention the Board and Staff have paid to this issue in the past, this kind of ad hoc approach is inadequate to ensure all surface owners, rather than just some, receive reasonable protections from the impacts of an oil and gas operation.

While the protest process can be effective in dealing with individual issues, the process places the burden of ensuring reasonability completely on the shoulders of the most impacted populations: landowners. The practices and procedures of this Board are not necessarily common knowledge among citizens with little or no previous experience with oil and gas operations. Oil and gas companies, mineral owners, and the Board are all well versed in oil and gas activity and more likely to know the procedures of working with this Board. Surface owners, on the other hand, may not even know what regulatory body regulates oil and gas and may not have the resources to go through the protest process. The website of this Board continues to lack easily accessible information on citizens' rights and options and therefore does little to help the typical citizen.

Additionally, the protest process is not simple. Anyone wishing to protest a setback would have to present before the Board during a hearing in Billings, often hundreds of miles away from the

---

[1] According to the Interstate Oil & Gas Compact Commission's "Complete Summary of State Statutes" as of 2014 Arkansas, Indiana, Kentucky, Louisiana, Maryland, Michigan, Ohio, Oklahoma, Tennessee, Virginia, and West Virginia also have implemented general setbacks. Retrieved from http://iogcc.publishpath.com/Websites/iogcc/images/2014SOS/Summary_of_State_Statutes_2014.pdf.

[2] NDCC 38-08-05

[3] WOGCC regulations Chapter 3, Section 47 (a)

[4] COGCC Rule 604.a.

well and residence in question. Therefore, in order to request a greater setback a surface owner could have to pay to travel potentially hundreds of miles and take off or delay work in order to appear , implying a substantial amount of time and financial resources be invested on the part of a surface owner for a simple protection that landowners in other states already enjoy.

In comparison, establishing clear, statewide setback requirements will provide all surface owners with reasonable protections without having to go through the protest process, while still allowing mineral owners to develop their mineral interests. If exceptional circumstances justify an exception to a setback, then the burden of proving these circumstances lies, instead, with the operators whose business it is to stay in communication with the BOGC.

Setback requirements take no authority from the BOGC

Establishing a statewide setback requirement would not exclude the Board from granting exceptions from the rule when the Board deems such an action is appropriate. Setback requirements in other states and municipalities typically contain provisions allowing established setbacks to be waived through approved requests from an operator or consent of a surface owner. As the body writing the rule, it is up to the Board's discretion to maintain its authority to grant exemptions when reasonable.

Setbacks protect the public welfare

According to ARM 36.1.101 (2) (g) (ii), one responsibility of the BOGC is preventing "contamination" as well as "damage to land."[5] Setbacks are a clear and effective way to protect the public welfare by mitigating contamination by fugitive air emissions as well as maintaining the property value of surface estates.

While there are still gaps in the data, the majority of studies researching air quality near oil and gas wells indicate potentially unsafe levels of air contamination near oil and gas wells.[6] For instance, a 2012 study by researchers at the University of Colorado found that people living less than a half mile from a well are at greater risk of suffering skin, eye, and lung health impacts than those living a mile away from natural gas wells.[7] Similarly, a Yale study published in January of this year found the number of reported symptoms in people living less than 1 km from a gas well was greater than people living 2 km from a gas well. In this study, 13% of people living less than 1 km (0.62 miles) from a gas well reported suffering skin conditions versus 3% of people living 2 km (1.24 miles) away. Similarly, 39% of people living less than 1 km from a gas well reported having upper respiratory symptoms as opposed to 18% of people living 2 km away[8]. In the face of such potential negative impacts of direct and fugitive air emissions to skin,

---

[5] ARM 36.1.101 (2) (g) (ii)

[6] *Toward an understanding of the environmental and public health impacts of shale gas development: an analysis of the peer-reviewed scientific literature, 2009-2014,* PSE Healthy Energy, 10 December, 2014.

[7] McKenzie, Lisa M., et al., *Human health risk assessment of air emissions from development of unconventional natural gas resources,* Science of the Total Environment, 22 March, 2012.

[8] Rabinowitz, et al., *Proximity to Natural Gas Wells and Reported Health Status: Results of a Household Survey in Washington County*, Pennsylvania, Environmental Health Perspectives, Sept. 10, 2014

eye, and lung irritation, setback requirements would protect surface owners and land from air emission impacts and are an appropriate action against promoting contamination by the BOGC.

Additionally, setback requirements promote the public welfare by protecting the housing market in oil and gas regions. Studies show a substantial property value decrease for properties near oil and gas development. A 2014 study of the housing market in Pennsylvania and New York state concluded that groundwater-fed homes in areas of shale gas development are so negatively impacted by the perceived risk to groundwater that their property values decrease between 10 and 22.4% within a 1 to 1.5 km range (or 3,280.84 to 4,921.26 feet) from a well. This study's findings that visible wells reduced property values, regardless of water source, contributed to the authors' conclusion that there would be gains to the housing market by establishing policy that reduce the risk of decreasing property values.[9] Furthermore, the perceived risk of oil and gas development in some cases has prevented surface owners from receiving or renewing homeowners insurance. Some banks are denying new residential mortgage loans to homeowners in the Marcellus Shale region (or requiring significant buffer zones) under concerns that oil and gas activity will impair the property's marketability.[10] These trends leave homeowners near oil and gas wells, and their communities, at serious financial risk.

Opportunity for Montana to be a National Leader

Establishing a protective setback requirement in Montana would establish Montana as a national leader in proactive and adaptive oil and gas development that takes seriously public health and welfare concerns.

In past public comment periods Northern Plains has urged the Board to consider the merits of a 1,320 ft. setback from inhabited buildings. A review of the above mentioned studies showing correlations between proximity to a well and respiratory and dermatological ailments would justify an even greater distance than 1,320 ft. to minimize negative impacts to public health. Studies that demonstrate the negative impacts to the value of surface estates up to 4,921.26 feet away from oil and gas wells support a similar conclusion.

However, perhaps the most telling support for a 1,320 ft. setback can be seen in the experience of other states. Until the recent adoption of HB 40 in Texas last month, many municipalities in Texas imposed setbacks between 1,000 feet and 1,500 feet from homes. Many of these communities had debated appropriate setback levels more than once, and in all cases opted to increase setback distances rather than decrease them[11]. These ordinances sought to achieve a reasonable balance between public concerns and mineral development as evidenced by this language from Fort Worth's Ordinance 14880 from December 2001:

---

[9] Muehlenbachs, et al., *The Housing Market Impacts of Shale Gas Development*, RFF Discussion Paper 13-39-REV, December 2013.
[10] Elisabeth Radow, *Homeowners and Gas Drilling Leases: Boon or Bust?*, NEW YORK STATE BAR ASSOCIATION JOURNAL, Vo. 89 No. 9, November/December 2011
[11] Fry, Matthew. "Urban Gas Drilling and Distance Ordinances" Elsevier July 2013.

> It is hereby declared to be the purpose of this Ordinance to establish reasonable and uniform limitations, safeguards and regulations for present and future operations related to the exploring, drilling, developing, producing, transporting and storing of gas and other substances produced in association with gas within the City to protect the health, safety and general welfare of the public, minimize the potential impact to property and mineral rights owners, protect the quality of the environment and encourage the orderly production of available mineral resources. [12]

Similarly, in our neighboring state of Wyoming citizens have repeatedly petitioned their Oil and Gas Conservation Commission to increase setbacks also due to public health and property value concerns. During the most recent rulemaking process in Wyoming the citizens group Powder River Basin Resource Council strongly advocated for a setback of 1,320 feet as a base protective minimum to preserve human health. The ability for oil and gas wells to impact a quarter mile area was re-established earlier this month when a well blowout in Texas contaminated a ¼ mile of surrounding vegetation and land.[13]

By establishing a setback of 1,320 feet for wells in Montana, the Board would establish itself as a proactive regulator promoting development within a responsible framework that takes into consideration public health, safety, and welfare.

In Conclusion

Northern Plains appreciates the opportunity to provide comment to the Board of Oil and Gas Conservation members on the merits of oil and gas setback requirements in Montana. As Northern Plains strongly supports a comprehensive and reasonable rule, Northern Plains is not opposed to the Board developing a complex rule establishing different setback distances for different building, public space, and well situations. We greatly appreciate the Board Members and Staff's time and attention on this matter, and we look forward to working with you to ensure oil and gas development is done right across the state.

Sincerely,

Cindy Webber

Chair, Northern Plains Resource Council Oil and Gas Task Force
220 South 27th Street, Suite A
Billings, MT 59101

---

[12] Fry, Matthew. "Urban Gas Drilling and Distance Ordinances" Elsevier July 2013.
[13] Coleman, Jesse. "Fracking Blowout in Texas Causes Huge Dead Zone." *Huff Post Green.* June 17, 2015.

Toward an understanding of the environmental and public health impacts of shale gas development: an analysis of the peer-reviewed scientific literature, 2009-2014

Introduction

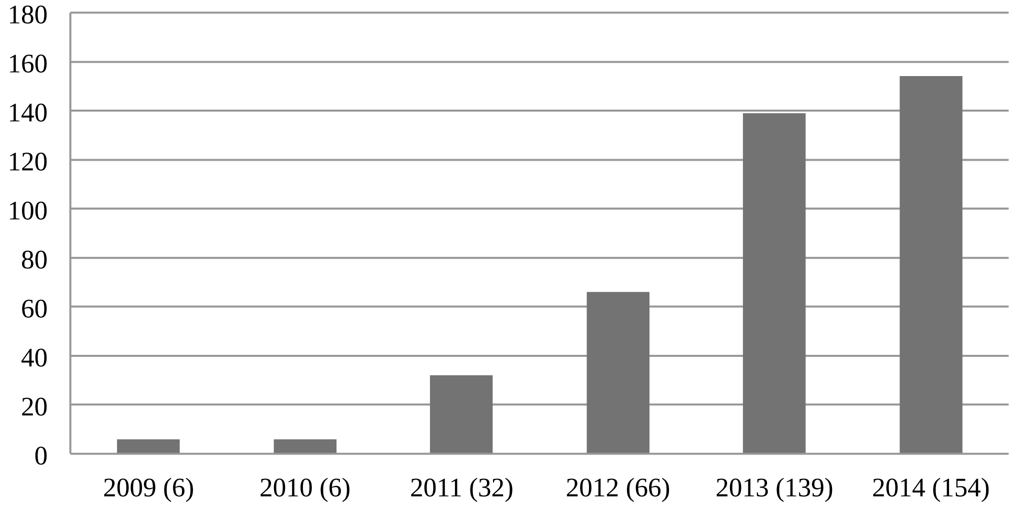
Conversations on the negative environmental and public health impacts of shale gas development continue to play out in the media, in policy discussions, and among the general public. But what does the science actually say? While research continues to lag behind the rapid scaling of shale gas development, there has been a surge of peer-reviewed scientific papers published in recent years. In fact, of all the available scientific peer-reviewed literature on the impacts of shale gas development approximately 73% has been published since January 1, 2013. What this tells us is that the scientific community is only now beginning to understand the impacts of this industry on the environment and human populations. Hazards and risks have been identified, but many data gaps still persist. Importantly, there remains a dearth of quantitative epidemiology that assesses associations between risk factors and human health outcomes among populations.

Still, there is now a lot more known about the impacts of shale gas development than when New York's de facto moratorium went into effect. This analysis is intended to provide a cursory overview of what is currently known about the potential impacts of shale gas development on human health and the environment. We include only the published peer-reviewed literature available on the subject. Specifically, this analysis uses studies relevant to near-term and long-term population health in communities experiencing shale gas development.

As the industry continues to expand in other parts of the country, New York has been in a unique position to learn from experiences and research in places like Pennsylvania, Texas, and Colorado. Clearly, this is a complex, polarizing issue and one that likely requires more than simply empirical evidence to create sound policy decisions. Yet, New York should pay close attention to the actual experiences and evidence arising out of other parts of the country that have opened their borders to shale gas development.

There are limitations to this analysis and it provides just a snapshot of what we know scientifically about the public health hazards, risks, and impacts associated with shale gas development. Furthermore, this document is preliminary and has not yet been subjected to external peer review. Nonetheless, it should provide readers with a general sense of the existing body of scientific literature on shale gas development.

Number of peer-reviewed publications on the impacts of shale or tight gas development by year, 2009-2014



Methods

Database assemblage and review

This analysis was conducted using the PSE Study Citation Database (available at: http://psehealthyenergy.org/site/view/1180). This near exhaustive collection of peer-reviewed literature on shale gas development was broken into 12 topics that attempt to organize the studies in a useful and coherent fashion. These topics include air quality, climate, community, ecology, economics, general (comment/review), health, regulation, seismicity, waste/fluids, water quality, and water usage. This collection was assembled over several years using a number of different search strategies, including the following:

- Systematic searches in scientific databases across multiple disciplines: PubMed (http://www.ncbi.nlm.nih.gov/pubmed/), Web of Science (http://www.webofknowledge.com), and ScienceDirect (http://www.sciencedirect.com)
- Searches in existing collections of scientific literature on shale gas development, such as the Marcellus Shale Initiative Publications Database at Bucknell University (http://www.bucknell.edu/script/environmentalcenter/marcellus), complemented by Google (http://www.google.com) and Google Scholar (http://scholar.google.com)
- Manual searches (hand-searches) of references included in all peer-reviewed studies that pertained directly to shale gas development.

For bibliographic databases, we used a combination of Medical Subject Headings

(MeSH)-based and keyword strategies, which included the following terms, as well as relevant combinations:

> shale gas, shale, hydraulic fracturing, fracking, drilling, natural gas, air pollution, methane, water pollution, public health, water contamination, fugitive emissions, air quality, climate, seismicity, waste, fluids, economics, ecology, water usage, regulation, community, epidemiology, Marcellus, Barnett, Denver-Julesberg Basin, unconventional gas development, and environmental pathways.

This database and subsequent analysis excluded technical papers on shale gas development not applicable to determining potential environmental and public health impacts. Examples include papers on optimal drilling strategies, reservoir evaluations, estimation algorithms of absorption capacity, patent analyses, and fracture models designed to inform stimulation techniques. Because this collection is limited to papers subjected to external peer-review in the scientific community, it does not include government reports, environmental impact statements, policy briefs, white papers, law review articles, or other grey literature. This database also does not include studies on coalbed methane, coal seam gas, tar sands or other forms of fossil fuel extraction (offshore drilling, etc.).

We have tried to include all literature that meets our criteria in our collection of the peer-reviewed science; however, it is possible that some papers may have gone undetected. Thus, we refer to the collection as *near* exhaustive. We are sure, however, that the most seminal studies on the public health dimensions of shale gas development in leading scientific journals are included. The PSE Healthy Energy database has been used and reviewed by academics and experts throughout the U.S. and internationally and has been subjected to public and professional scrutiny before and after this analysis. It represents the most comprehensive public collection of peer-reviewed scientific literature on shale gas development in the world and has been accessed by thousands of people. Many of the publications in this database can be found in a review paper, published in the peer-reviewed journal, *Environmental Health Perspectives*, authored by Shonkoff et al. (2014) (http://ehp.niehs.nih.gov/wp-content/uploads/advpub/2014/4/ehp.1307866.pdf).

Scope of analysis & inclusion/exclusion criteria

There has been great confusion about environmental dimensions of shale gas development or “fracking” because of the lack of uniform, well-defined terminology and boundaries of analysis. The public and the media use the term fracking as an umbrella term to refer to the entirety of shale gas development, including processes ranging from land clearing to well stimulation, to waste disposal. On the other hand, the oil and gas industry and many in the scientific community generally use the term as shorthand for one particular type of well stimulation method used to enhance the production of oil and natural gas – hydraulic fracturing.

The PSE Healthy Energy database and this analysis are both concerned with shale gas development in its entirety, enabled by hydraulic fracturing, and not just the moment of hydraulic fracturing well stimulation, which should have a limited role in policy discussions. If we are to understand the social, environmental, and public health dimensions of shale gas development we must look beyond only the moment of well stimulation, especially when the scientific literature indicates other aspects of the overall process warrant concern. Thus, this project can be viewed as an analysis of the scientific literature on hydraulic fracturing *and* its associated operations and ancillary infrastructure.

The focus of this analysis is, first and foremost, on the primary research on shale gas development published to date. To that extent we have only included papers that evaluate the association between shale gas development and environmental and public health impacts. As such, not all publications in the PSE Healthy Energy database were used in this analysis. We have not included the following topics in this analysis: climate, community, ecology, economics, general, regulation, seismicity, waste/fluids, and water usage. We have also not included all of the papers that fit within the three topics used in this report (health, water quality, and air quality). For instance, with the exception of public health papers, for which there has been very little primary research, we have excluded commentaries and review articles. Further, we have excluded those papers that provide baseline data or address research methods that do not assess impacts. We have also excluded letters to the editor of scientific journals that critique a particular study or the subsequent response of the author(s).

We have restricted the studies included in this analysis to those published between 2009 and 2014. The main reason for doing so is that scientific literature on shale gas development did not appear until around that time. There are some studies in the database on conventional forms of oil and natural gas development that are relevant to shale gas, but to maintain greater consistency we have decided to exclude those prior to 2009 from the analysis. For instance, we excluded a study published in *The Lancet* that examined the association between testicular cancer and employment in agriculture and oil and gas development published in 1986 (Sewell et al. 1986). Relatedly, some of the studies included in this analysis may be broader than shale gas development and could potentially include other forms of both conventional and unconventional oil and gas development. This is true for some of the top-down, field based air pollutant emissions studies that gauge leakage rates and emission factors in Western oil and gas fields. Where studies are not specifically related to shale gas development we included them only when the findings are recent and substantially relevant.

Again, it is important to note that scientists are only beginning to understand the environmental and public health impacts of these rapidly expanding industrial practices. Our analysis represents a survey of the existing science to date in an attempt to determine the direction in which consensus is headed and to achieve a deeper understanding of the environmental and public health impacts of this form of energy development. What we know at this time is based on modeling and field-based studies on unconventional oil and gas development (primarily from shale) in parts of the United States, such as Texas, Colorado, and Pennsylvania, where the extraction of natural gas from shale formations has only been scaled relatively recently.

Categorical framework

We have created categories for each topic in an attempt to identify and group studies in ways that are both useful and intuitive. Clearly, there are limitations to this approach and many studies are nuanced or incommensurable in ways that may be inappropriate for this type of analysis. This is especially true for some topics, such as air and water quality. Further, some studies may properly belong in multiple topics and in a few cases we have done so. For instance, some studies may contain data that are relevant to both air quality and public health (Bunch et al. 2014; Colborn et al. 2014; Macey et al. 2014).

Nonetheless, in order to glean some kind of scientific overview or growing scientific consensus on the environmental public health dimensions of shale gas development that may be useful to policy determinations we strived to create the most simple and accurate approach possible. Please refer to the tables included in the appendix for the citations and categorization of the studies.

Topics	**Categories**
Health	• Indication of potential risks of or actual adverse health outcomes • No indication of significant risks of or actual adverse health outcomes
Water Quality	• Indication of potential, positive association, or actual incidence of water contamination • Indication of minimal potential, negative association, or rare incidence of water contamination
Air Quality	• Indication of elevated air pollutant emissions and/or atmospheric concentrations • No indication of significantly elevated air pollutant emissions and/or atmospheric concentrations

Health

Health outcome studies and epidemiologic investigations continue to be particularly limited and most of the peer-reviewed papers to date are commentaries and reviews. We have also separately analyzed peer-reviewed scientific commentaries (“all papers”) because original research is still so limited for public health. Although commentaries should essentially be acknowledged as opinions, they are the opinions of experts formed from the available literature and have also been subjected to peer-review.

We have included in this topic papers that consider the question of public health in the context of shale gas development. Of course, research findings in other categories such as air quality and water quality are relevant to public health, but here we only include those studies that *directly* consider the health of individuals and human populations. We considered this topic and its related categories in both the context of original research and commentaries and reviews. We only consider research to be original if it measures health outcomes or complaints (i.e., not health research that only attempts to determine opinion or methods for future research agendas). The vast majority of these papers indicate the need for additional study, particularly large-scale, quantitative epidemiologic research.

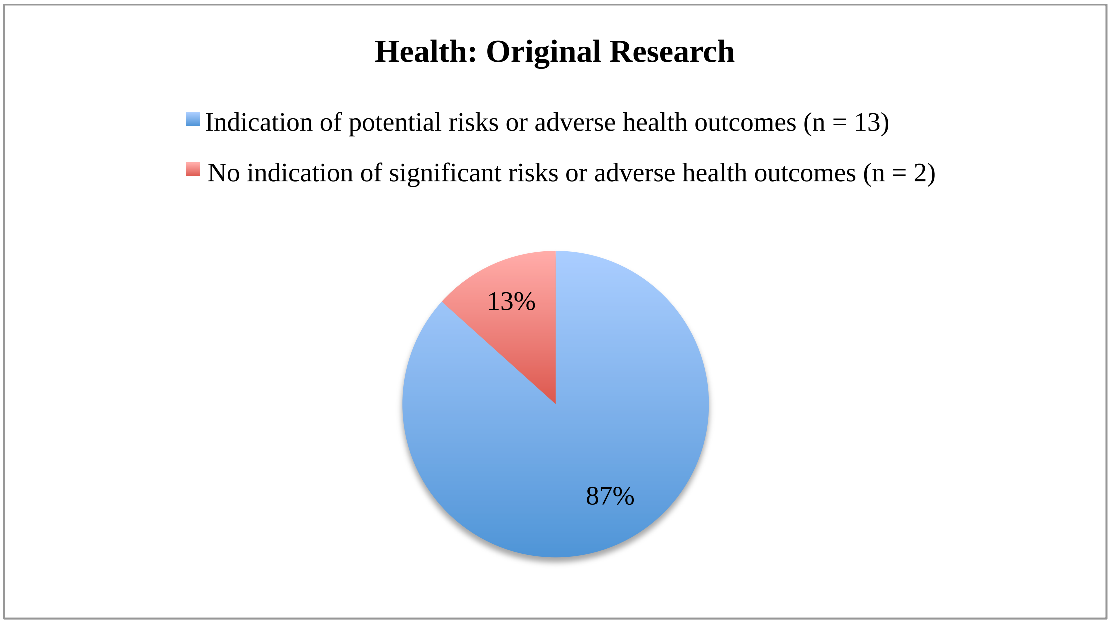
Water Quality

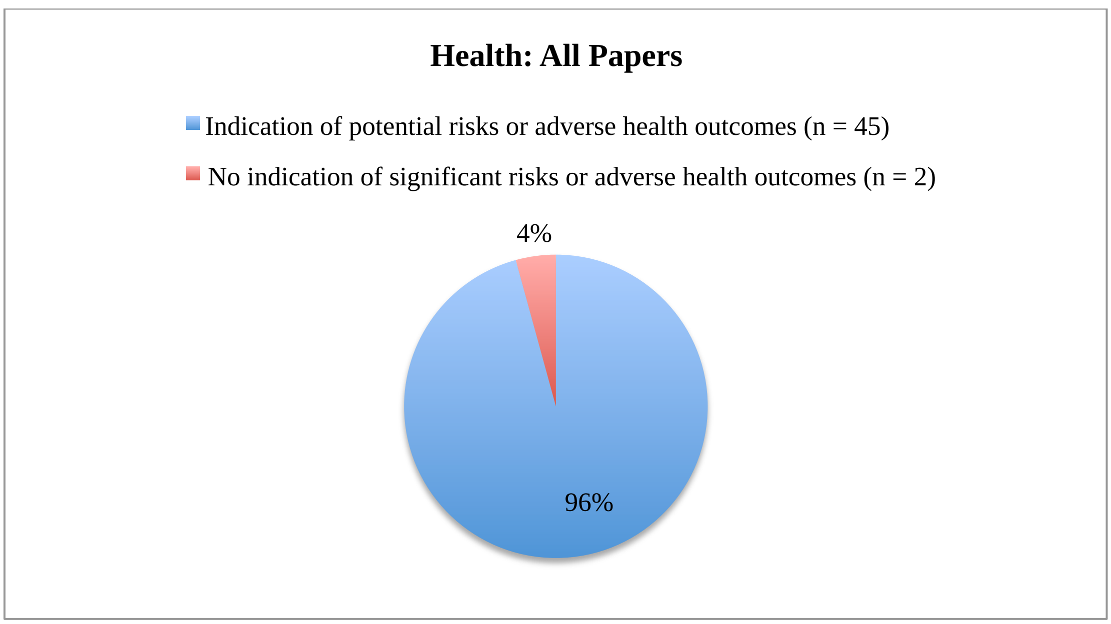
Papers on water quality are more nuanced in that some rely on empirical field measurements, while others explore mechanisms for contamination or use modeled data to determine water quality risks. Further, some of these studies explore only one aspect of shale gas development, such as the well stimulation process enabled by hydraulic fracturing. Thus, these studies do not indicate whether or not shale gas development as a whole is associated with water contamination and are therefore limited in their utility for gauging water quality impacts. Nonetheless, we have included all original research, including modeling studies. We have excluded studies that explore only evaluative methodology or baseline assessments as well papers that simply comment on or review previous studies. Here we are only concerned with actual findings in the field or modeling studies that specifically address the risk or occurrence of water contamination.

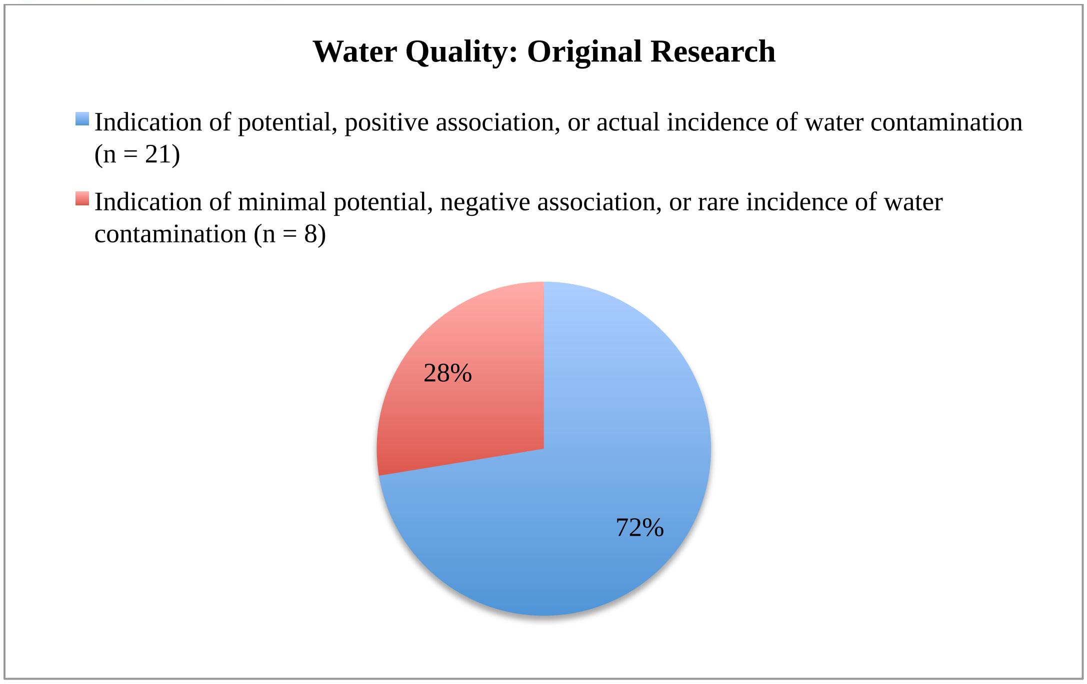
Air Quality

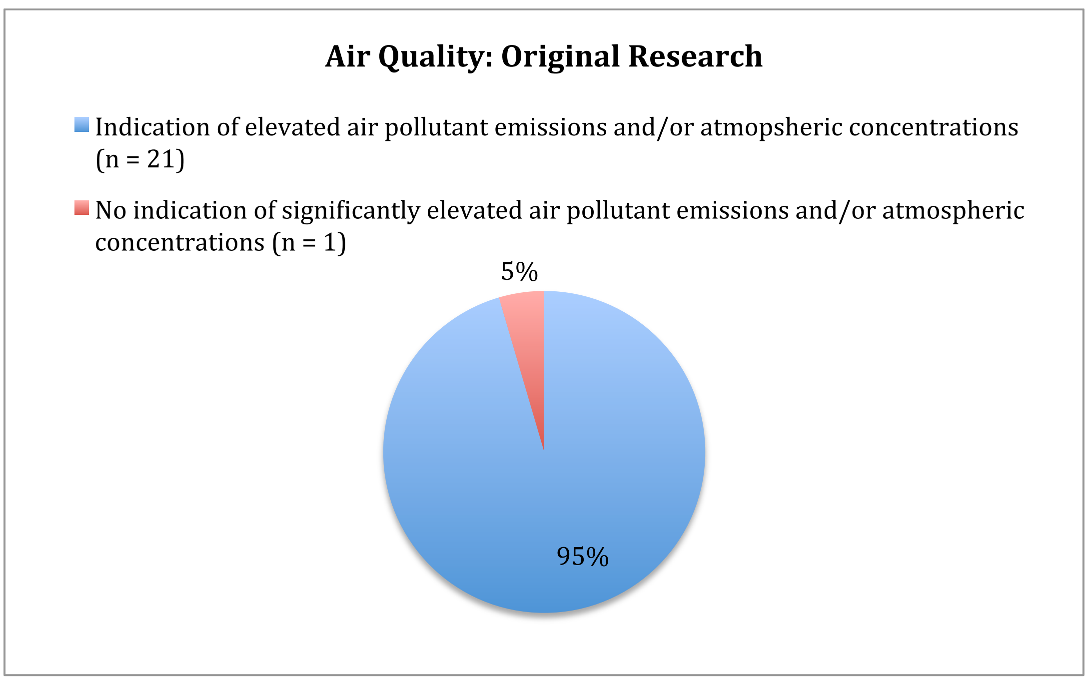
Air quality is a more complex, subjective measure that beckons comparison to other forms of energy development or industrial processes. Yet, a review and analysis of the air quality data is still useful and certainly relevant to health outcomes. Although methane is a precursor to tropospheric ozone we have excluded studies that focus exclusively on methane emissions from this topic. However, studies that address methane *and* non-methane volatile organic compound (VOC) emissions have been included, given the health-damaging dimensions of a number of VOCs (i.e., benzene, toluene, ethylbenzene, xylene, etc.) and the role of VOCs in the production of tropospheric ozone, a strong respiratory irritant. Studies that have explored the health implications of air pollution emissions, atmospheric concentrations, and exposure levels are included in both this category and the public health category. The papers in this topic are those that specifically address air emissions and air quality from well stimulation-enabled oil and gas development (i.e., unconventional oil and gas development) at either a local or regional scale. These include local and regional measurements of non-methane volatile organic compounds and tropospheric ozone.

Results


Health: Original Research
Indication of potential risks or adverse health outcomes (n = 13)
No indication of significant risks or adverse health outcomes (n = 2)
13%
87%


Health: All Papers
Indication of potential risks or adverse health outcomes (n = 45)
No indication of significant risks or adverse health outcomes (n = 2)
4%
96%


Water Quality: Original Research
Indication of potential, positive association, or actual incidence of water contamination (n = 21)
Indication of minimal potential, negative association, or rare incidence of water contamination (n = 8)
28%
72%


Air Quality: Original Research
Indication of elevated air pollutant emissions and/or atmopsheric concentrations (n = 21)
No indication of significantly elevated air pollutant emissions and/or atmospheric concentrations (n = 1)
5%
95%

Limitations

This project aims to provide an overview of existing scientific studies and findings based on the world's experience with shale gas development. While our database is to our best estimation exhaustive, our literature search may not have captured all relevant scientific literature. Additionally, differences in geography may render some studies less relevant when interpreted across geographic and geological space. While the majority of the studies included in this analysis are directly relevant to shale gas development, some may include data from other types of well stimulation-enabled oil and gas reservoirs (e.g., tight sands). However, because many of the processes are for practical purposes sufficiently similar (e.g., drilling, hydraulic fracturing, generation and disposal of waste), we have included them in this analysis.

Despite the inherent limitations in this type of analysis, our literature review provides a general idea of the weight of the scientific evidence of possible impacts that could ensue in New York State should it open its borders to shale gas development. It is important to note that this analysis only concerns itself with current empirical evidence and does not take into account developments that could potentially influence environmental and public health outcomes in positive or negative ways under different regulatory regimes. For instance, technological improvements may mitigate some existing problems, but as development continues, well pad intensities increase, and novel geologies and practices are encountered, impacts may increase.

Finally, all forms of energy production and industrial processing have environmental impacts. This report is only focused on reviewing and presenting the available science on some of the most salient environmental and public health concerns associated with shale gas development. We make no claims about the level of impacts that should be tolerated by society – these are ultimately questions of value.

Science of the Total Environment 424 (2012) 79–87

Contents lists available at SciVerse ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Human health risk assessment of air emissions from development of unconventional natural gas resources☆,☆☆

Lisa M. McKenzie *, Roxana Z. Witter, Lee S. Newman, John L. Adgate

Colorado School of Public Health, University of Colorado, Anschutz Medical Campus, Aurora, Colorado, USA

ARTICLE INFO

Article history:
Received 15 September 2011
Received in revised form 10 February 2012
Accepted 10 February 2012
Available online 22 March 2012

Keywords:
Natural gas development
Risk assessment
Air pollution
Hydrocarbon emissions

ABSTRACT

Background: Technological advances (e.g. directional drilling, hydraulic fracturing), have led to increases in unconventional natural gas development (NGD), raising questions about health impacts.
Objectives: We estimated health risks for exposures to air emissions from a NGD project in Garfield County, Colorado with the objective of supporting risk prevention recommendations in a health impact assessment (HIA).
Methods: We used EPA guidance to estimate chronic and subchronic non-cancer hazard indices and cancer risks from exposure to hydrocarbons for two populations: (1) residents living >½ mile from wells and (2) residents living ≤½ mile from wells.
Results: Residents living ≤½ mile from wells are at greater risk for health effects from NGD than are residents living >½ mile from wells. Subchronic exposures to air pollutants during well completion activities present the greatest potential for health effects. The subchronic non-cancer hazard index (HI) of 5 for residents ≤½ mile from wells was driven primarily by exposure to trimethylbenzenes, xylenes, and aliphatic hydrocarbons. Chronic HIs were 1 and 0.4. for residents ≤½ mile from wells and >½ mile from wells, respectively. Cumulative cancer risks were 10 in a million and 6 in a million for residents living ≤½ mile and >½ mile from wells, respectively, with benzene as the major contributor to the risk.
Conclusions: Risk assessment can be used in HIAs to direct health risk prevention strategies. Risk management approaches should focus on reducing exposures to emissions during well completions. These preliminary results indicate that health effects resulting from air emissions during unconventional NGD warrant further study. Prospective studies should focus on health effects associated with air pollution.

© 2012 Elsevier B.V. All rights reserved.

1. Introduction

The United States (US) holds large reserves of unconventional natural gas resources in coalbeds, shale, and tight sands. Technological advances, such as directional drilling and hydraulic fracturing, have led to a rapid increase in the development of these resources. For example, shale gas production had an average annual growth rate of 48% over the 2006 to 2010 period and is projected to grow almost fourfold from 2009 to 2035 (US EIA, 2011). The number of unconventional natural gas wells in the US rose from 18,485 in 2004 to 25,145 in 2007 and is expected to continue increasing through at least 2020 (Vidas and Hugman, 2008). With this expansion, it is becoming increasingly common for unconventional natural gas development (NGD) to occur near where people live, work, and play. People living near these development sites are raising public health concerns, as rapid NGD exposes more people to various potential stressors (COGCC, 2009a).

The process of unconventional NGD is typically divided into two phases: well development and production (US EPA, 2010a; US DOE, 2009). Well development involves pad preparation, well drilling, and well completion. The well completion process has three primary stages: 1) completion transitions (concrete well plugs are installed in wells to separate fracturing stages and then drilled out to release gas for production); 2) hydraulic fracturing ("fracking": the high pressure injection of water, chemicals, and propants into the drilled well to release the natural gas); and 3) flowback, the return of fracking and geologic fluids, liquid hydrocarbons ("condensate") and natural gas to the surface (US EPA, 2010a; US DOE, 2009). Once development is

Abbreviations: BTEX, benzene, toluene, ethylbenzene, and xylenes; COGCC, Colorardo Oil and Gas Conservation Commission; HAP, hazardous air pollutant; HI, hazard index; HIA, health impact assessment; HQ, hazard quotient; NATA, National Air Toxics Assessment; NGD, natural gas development.

☆ This study was supported by the Garfield County Board of County Commissioners and the Colorado School of Public Health.

☆☆ The authors declare they have no competing financial interests.

* Corresponding author at: Colorado School of Public Health, 13001 East 17th Place, Mail Stop B119, Aurora, CO 80045, USA. Tel.: +1 303 724 5557; fax: +1 303 724 4617.
E-mail address: lisa.mckenzie@ucdenver.edu (L.M. McKenzie).

0048-9697/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.scitotenv.2012.02.018

complete, the "salable" gas is collected, processed, and distributed. While methane is the primary constituent of natural gas, it contains many other chemicals, including alkanes, benzene, and other aromatic hydrocarbons (TERC, 2009).

As shown by ambient air studies in Colorado, Texas, and Wyoming, the NGD process results in direct and fugitive air emissions of a complex mixture of pollutants from the natural gas resource itself as well as diesel engines, tanks containing produced water, and on site materials used in production, such as drilling muds and fracking fluids (CDPHE, 2009; Frazier, 2009; Walther, 2011; Zielinska et al., 2011). The specific contribution of each of these potential NGD sources has yet to be ascertained and pollutants such as petroleum hydrocarbons are likely to be emitted from several of these NGD sources. This complex mixture of chemicals and resultant secondary air pollutants, such as ozone, can be transported to nearby residences and population centers (Walther, 2011; GCPH, 2010).

Multiple studies on inhalation exposure to petroleum hydrocarbons in occupational settings as well as residences near refineries, oil spills and petrol stations indicate an increased risk of eye irritation and headaches, asthma symptoms, acute childhood leukemia, acute myelogenous leukemia, and multiple myeloma (Glass et al., 2003; Kirkeleit et al., 2008; Brosselin et al., 2009; Kim et al., 2009; White et al., 2009). Many of the petroleum hydrocarbons observed in these studies are present in and around NGD sites (TERC, 2009). Some, such as benzene, ethylbenzene, toluene, and xylene (BTEX) have robust exposure and toxicity knowledge bases, while toxicity information for others, such as heptane, octane, and diethylbenzene, is more limited. Assessments in Colorado have concluded that ambient benzene levels demonstrate an increased potential risk of developing cancer as well as chronic and acute non-cancer health effects in areas of Garfield County Colorado where NGD is the only major industry other than agriculture (CDPHE, 2007; Coons and Walker, 2008; CDPHE, 2010). Health effects associated with benzene include acute and chronic nonlymphocytic leukemia, acute myeloid leukemia, chronic lymphocytic leukemia, anemia, and other blood disorders and immunological effects. (ATSDR, 2007a, IRIS, 2011). In addition, maternal exposure to ambient levels of benzene recently has been associated with an increase in birth prevalence of neural tube defects (Lupo et al., 2011). Health effects of xylene exposure include eye, nose, and throat irritation, difficulty in breathing, impaired lung function, and nervous system impairment (ATSDR, 2007b). In addition, inhalation of xylenes, benzene, and alkanes can adversely affect the nervous system (Carpenter et al., 1978; Nilsen et al., 1988; Galvin and Marashi, 1999; ATSDR, 2007a; ATSDR, 2007b).

Previous assessments are limited in that they were not able to distinguish between risks from ambient air pollution and specific NGD stages, such as well completions or risks between residents living near wells and residents living further from wells. We were able to isolate risks to residents living near wells during the flowback stage of well completions by using air quality data collected at the perimeter of the wells while flowback was occurring.

Battlement Mesa (population ~5000) located in rural Garfield County, Colorado is one community experiencing the rapid expansion of NGD in an unconventional tight sand resource. A NGD operator has proposed developing 200 gas wells on 9 well pads located as close as 500 ft from residences. Colorado Oil and Gas Commission (COGCC) rules allow natural gas wells to be placed as close as 150 ft from residences (COGCC, 2009b). Because of community concerns, as described elsewhere, we conducted a health impact assessment (HIA) to assess how the project may impact public health (Witter et al., 2011), working with a range of stakeholders to identify the potential public health risks and benefits.

In this article, we illustrate how a risk assessment was used to support elements of the HIA process and inform risk prevention recommendations by estimating chronic and subchronic non-cancer hazard indices (HIs) and lifetime excess cancer risks due to NGD air emissions.

2. Methods

We used standard United States Environmental Protection Agency (EPA) methodology to estimate non-cancer HIs and excess lifetime cancer risks for exposures to hydrocarbons (US EPA, 1989; US EPA, 2004) using residential exposure scenarios developed for the NGD project. We used air toxics data collected in Garfield County from January 2008 to November 2010 as part of a special study of short term exposures as well as on-going ambient air monitoring program data to estimate subchronic and chronic exposures and health risks (Frazier, 2009; GCPH, 2009; GCPH, 2010; GCPH, 2011; Antero, 2010).

2.1. Sample collection and analysis

All samples were collected and analyzed according to published EPA methods. Analyses were conducted by EPA certified laboratories. The Garfield County Department of Public Health (GCPH) and Olsson Associates, Inc. (Olsson) collected ambient air samples into evacuated SUMMA® passivated stainless-steel canisters over 24-hour intervals. The GCPH collected the samples from a fixed monitoring station and along the perimeters of four well pads and shipped samples to Eastern Research Group for analysis of 78 hydrocarbons using EPA's compendium method TO-12, Method for the Determination of Non-Methane Organic Compounds in Ambient Air Using Cyrogenic Pre-concentration and Direct Flame Ionization Detection (US EPA, 1999). Olsson collected samples along the perimeter of one well pad and shipped samples to Atmospheric Analysis and Consulting, Inc. for analysis of 56 hydrocarbons (a subset of the 78 hydrocarbons determined by Eastern Research Group) using method TO-12. Per method TO-12, a fixed volume of sample was cryogenically concentrated and then desorbed onto a gas chromatography column equipped with a flame ionization detector. Chemicals were identified by retention time and reported in a concentration of parts per billion carbon (ppbC). The ppbC values were converted to micrograms per cubic meter ($\mu g/m^3$) at 01.325 kPa and 298.15 K.

Two different sets of samples were collected from rural (population < 50,000) areas in western Garfield County over varying time periods. The main economy, aside from the NGD industry, of western Garfield County is agricultural. There is no other major industry.

2.1.1. NGD area samples

The GCPH collected ambient air samples every six days between January 2008 and November 2010 (163 samples) from a fixed monitoring station located in the midst of rural home sites and ranches and NGD, during both well development and production. The site is located on top of a small hill and 4 miles upwind of other potential emission sources, such as a major highway (Interstate-70) and the town of Silt, CO (GCPH, 2009; GCPH, 2010; GCPH, 2011).

2.1.2. Well completion samples

The GCPH collected 16 ambient air samples at each cardinal direction along 4 well pad perimeters (130 to 500 ft from the well pad center) in rural Garfield County during well completion activities. The samples were collected on the perimeter of 4 well pads being developed by 4 different natural gas operators in summer 2008 (Frazier, 2009). The GCPH worked closely with the NGD operators to ensure these air samples were collected during the period while at least one well was on uncontrolled (emissions not controlled) flowback into collection tanks vented directly to the air. The number of wells on each pad and other activities occurring on the pad were not documented. Samples were collected over 24 to 27-hour intervals, and samples included emissions from both uncontrolled flowback and diesel engines (i.e., from. trucks and generators supporting completion activities). In addition, the GCPH collected a background sample 0.33 to 1 mile from each well pad (Frazier, 2009). The highest hydrocarbon levels corresponded to samples collected directly downwind of the tanks (Frazier, 2009; Antero, 2010). The lowest hydrocarbon levels corresponded either to background samples or samples collected upwind of the flowback tanks (Frazier, 2009; Antero, 2010).

Antero Resources Inc., a natural gas operator, contracted Olsson to collect eight 24-hour integrated ambient air samples at each cardinal direction at 350 and 500 ft from the well pad center during well completion activities conducted on one of their well pads in summer 2010 (Antero, 2010). Of the 12 wells on this pad, 8 were producing salable natural gas; 1 had been drilled but not completed; 2 were being hydraulically fractured during daytime hours, with ensuing uncontrolled flowback during nighttime hours; and 1 was on uncontrolled flowback during nighttime hours.

All five well pads are located in areas with active gas production, approximately 1 mile from Interstate-70.

2.2. Data assessment

We evaluated outliers and compared distributions of chemical concentrations from NGD area and well completion samples using Q–Q plots and the Mann–Whitney *U* test, respectively, in EPA's ProUCL version 4.00.05 software (US EPA, 2010b). The Mann–Whitney *U* test was used because the measurement data were not normally distributed. Distributions were considered as significantly different at an alpha of 0.05. Per EPA guidance, we assigned the exposure concentration as either the 95% upper confidence limit (UCL) of the mean concentration for compounds found in 10 or more samples or the maximum detected concentration for compounds found in more than 1 but fewer than 10 samples. This latter category included three compounds: 1,3-butadiene, 2,2,4-trimethylpentane, and styrene in the well completion samples. EPA's ProUCL software was used to select appropriate methods based on sample distributions and detection frequency for computing 95% UCLs of the mean concentration (US EPA, 2010b).

2.3. Exposure assessment

Risks were estimated for two populations: (1) residents >½ mile from wells; and (2) residents ≤½ mile from wells. We defined residents ≤½ mile from wells as living near wells, based on residents reporting odor complaints attributed to gas wells in the summer of 2010 (COGCC, 2011).

Exposure scenarios were developed for chronic non-cancer HIs and cancer risks. For both populations, we assumed a 30-year project duration based on an estimated 5-year well development period for all well pads, followed by 20 to 30 years of production. We assumed a resident lives, works, and otherwise remains within the town 24 h/day, 350 days/year and that lifetime of a resident is 70 years, based on standard EPA reasonable maximum exposure (RME) defaults (US EPA, 1989).

2.3.1. Residents >½ mile from well pads

As illustrated in Fig. 1, data from the NGD area samples were used to estimate chronic and subchronic risks for residents >½ mile from well development and production throughout the project. The exposure concentrations for this population were the 95% UCL on the mean concentration and median concentration from the 163 NGD samples.

2.3.2. Residents ≤½ mile from well pads

To evaluate subchronic non-cancer HIs from well completion emissions, we estimated that a resident lives ≤½ mile from two well pads resulting a 20-month exposure duration based on 2 weeks per well for completion and 20 wells per pad, assuming some overlap in between activities. The subchronic exposure concentrations for this population were the 95% UCL on the mean concentration and the median concentration from the 24 well completion samples. To evaluate chronic risks to residents ≤½ mile from wells throughout the NGD project, we calculated a time-weighted exposure concentration (C_{S+c}) to account for exposure to emissions from well completions for 20-months followed by 340 months of exposure to emissions from the NGD area using the following formula:

$$C_{S+c} = (C_c \times ED_c/ED) + (C_S \times ED_S/ED)$$

where:

C_c Chronic exposure point concentration (μg/m^3) based on the 95% UCL of the mean concentration or median concentration from the 163 NGD area samples

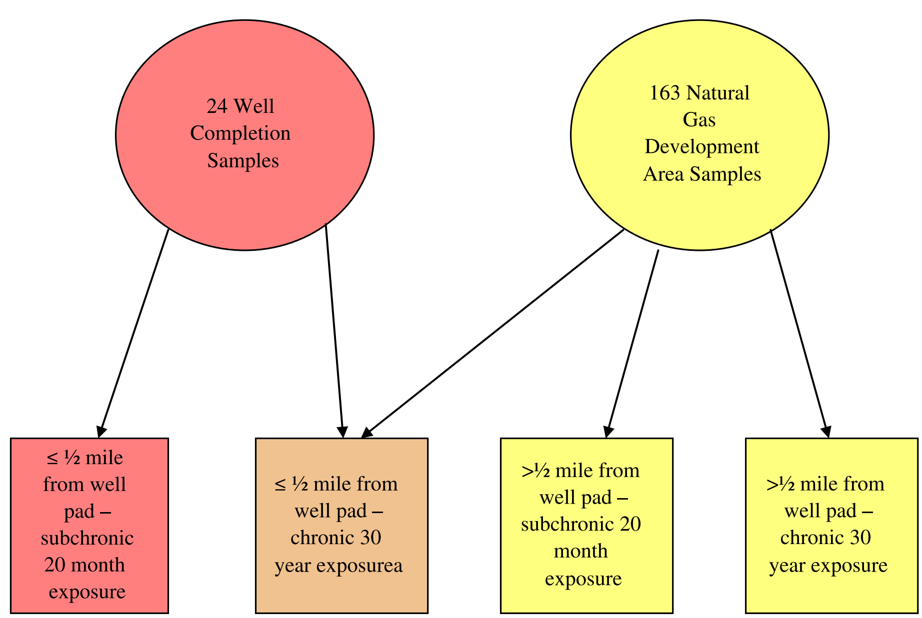


Fig. 1. Relationship between completion samples and natural gas development area samples and residents living ≤½ mile and >½ mile from wells. [a]Time weighted average based on 20-month contribution from well completion samples and 340-month contribution from natural gas development samples.

ED_c Chronic exposure duration
C_S Subchronic exposure point concentration (μg/m^3) based on the 95% UCL of the mean concentration or median concentration from the 24 well completion samples
ED_S Subchronic exposure duration
ED Total exposure duration

2.4. Toxicity assessment and risk characterization

For non-carcinogens, we expressed inhalation toxicity measurements as a reference concentration (RfC in units of μg/m^3 air). We used chronic RfCs to evaluate long-term exposures of 30 years and subchronic RfCs to evaluate subchronic exposures of 20-months. If a subchronic RfC was not available, we used the chronic RfC. We obtained RfCs from (in order of preference) EPA's Integrated Risk Information System (IRIS) (US EPA, 2011), California Environmental Protection Agency (CalEPA) (CalEPA, 2003), EPA's Provisional Peer-Reviewed Toxicity Values (ORNL, 2009), and Health Effects Assessment Summary Tables (US EPA, 1997). We used surrogate RfCs according to EPA guidance for C_5 to C_{18} aliphatic and C_6 to C_{18} aromatic hydrocarbons which did not have a chemical-specific toxicity value (US EPA, 2009a). We derived semi-quantitative hazards, in terms of the hazard quotient (HQ), defined as the ratio between an estimated exposure concentration and RfC. We summed HQs for individual compounds to estimate the total cumulative HI. We then separated HQs specific to neurological, respiratory, hematological, and developmental effects and calculated a cumulative HI for each of these specific effects.

For carcinogens, we expressed inhalation toxicity measurements as inhalation unit risk (IUR) in units of risk per μg/m^3. We used IURs from EPA's IRIS (US EPA, 2011) when available or the CalEPA (CalEPA, 2003). The lifetime cancer risk for each compound was derived by multiplying estimated exposure concentration by the IUR. We summed cancer risks for individual compounds to estimate the cumulative cancer risk. Risks are expressed as excess cancers per 1 million population based on exposure over 30 years.

Toxicity values (i.e., RfCs or IURs) or a surrogate toxicity value were available for 45 out of 78 hydrocarbons measured. We performed a quantitative risk assessment for these hydrocarbons. The remaining 33 hydrocarbons were considered qualitatively in the risk assessment.

3. Results

3.1. Data assessment

Evaluation of potential outliers revealed no sampling, analytical, or other anomalies were associated with the outliers. In addition, removal of potential outliers from the NGD area samples did not change the final HIs and cancer risks. Potential outliers in the well completion samples were associated with samples collected downwind from flowback tanks and are representative of emissions during flowback. Therefore, no data was removed from either data set.

Descriptive statistics for concentrations of the hydrocarbons used in the quantitative risk assessment are presented in Table 1. A list of the hydrocarbons detected in the samples that were considered qualitatively in the risk assessment because toxicity values were not available is presented in Table 2. Descriptive statistics for all hydrocarbons are available in Supplemental Table 1. Two thirds more hydrocarbons were detected at a frequency of 100% in the well completion samples (38 hydrocarbons) than in the NGD area samples (23 hydrocarbons). Generally, the highest alkane and aromatic hydrocarbon median concentrations were observed in the well completion samples, while the highest median concentrations of several alkenes were observed in the NGD area samples. Median concentrations of benzene, ethylbenzene, toluene, and m-xylene/p-xlyene were 2.7, 4.5, 4.3, and 9 times higher in the well completion samples than in the NGD area samples, respectively. Wilcoxon–Mann–Whitney test results indicate that

Table 1
Descriptive statistics for hydrocarbon concentrations with toxicity values in 24-hour integrated samples collected in NGD area and samples collected during well completions.

Hydrocarbon (μg/m^3)	NGD area sample results[a]							Well completion sample results[b]						
	No.	% > MDL	Med	SD	95% UCL[c]	Min	Max	No.	% > MDL	Med	SD	95% UCL[c]	Min	Max
1,2,3-Trimethylbenzene	163	39	0.11	0.095	0.099	0.022	0.85	24	83	0.84	2.3	3.2	0.055	12
1,2,4-Trimethylbenzene	163	96	0.18	0.34	0.31	0.063	3.1	24	100	1.7	17	21	0.44	83
1,3,5-Trimethylbenzene	163	83	0.12	0.13	0.175	0.024	1.2	24	100	1.3	16	19.5	0.33	78
1,3-Butadiene	163	7	0.11	0.020	0.0465	0.025	0.15	16	56	0.11	0.021	NC	0.068	0.17
Benzene	163	100	0.95	1.3	1.7	0.096	14	24	100	2.6	14	20	0.94	69
Cyclohexane	163	100	2.1	8.3	6.2	0.11	105	24	100	5.3	43	58	2.21	200
Ethylbenzene	163	95	0.17	0.73	0.415	0.056	8.1	24	100	0.77	47	54	0.25	230
Isopropylbenzene	163	38	0.15	0.053	0.074	0.020	0.33	24	67	0.33	1.0	1.0	0.0	4.8
Methylcyclohexane	163	100	3.7	4.0	6.3	0.15	24	24	100	14	149	190	3.1	720
m-Xylene/p-Xylene	163	100	0.87	1.2	1.3	0.16	9.9	24	100	7.8	194	240	2.0	880
n-Hexane	163	100	4.0	4.2	6.7	0.13	25	24	100	7.7	57	80	1.7	255
n-Nonane	163	99	0.44	0.49	0.66	0.064	3.1	24	100	3.6	61	76	1.2	300
n-Pentane	163	100	9.1	9.8	14	0.23	62	24	100	11	156	210	3.9	550
n-Propylbenzene	163	66	0.10	0.068	0.10	0.032	0.71	24	88	0.64	2.4	3.3	0.098	12
o-Xylene	163	97	0.22	0.33	0.33	0.064	3.6	24	100	1.2	40	48.5	0.38	190
Propylene	163	100	0.34	0.23	0.40	0.11	2.5	24	100	0.41	0.34	0.60	0.16	1.9
Styrene	163	15	0.15	0.26	0.13	0.017	3.4	24	21	0.13	1.2	NC	0.23	5.9
Toluene	163	100	1.8	6.2	4.8	0.11	79	24	100	7.8	67	92	2.7	320
Aliphatic hydrocarbons C_5–C_8[d]	163	NC	29	NA	44	1.7	220	24	NC	56	NA	780	24	2700
Aliphatic hydrocarbons C_9–C_{18}[e]	163	NC	1.3	NA	14	0.18	400	24	NC	7.9	NA	100	1.4	390
Aromatic hydrocarbons C_9–C_{18}[f]	163	NC	0.57	NA	0.695	0.17	5.6	24	NC	3.7	NA	27	0.71	120

Abbreviations: Max, maximum detected concentration; Med, median; Min, minimum detected concentration; NGD, natural gas development; NC, not calculated; No., number of samples; SD, standard deviation; % > MDL, percent greater than method detection limit; μg/m^3 micrograms per cubic meter; 95% UCL 95% upper confidence limit on the mean.
[a] Samples collected at one site every 6 six days between 2008 and 2010.
[b] Samples collected at four separate sites in summer 2008 and one site in summer 2010.
[c] Calculated using EPA's ProUCL version 4.00.05 software (US EPA, 2010b).
[d] Sum of 2,2,2-trimethylpentane, 2,2,4-trimethylpentane, 2,2-dimethylbutane, 2,3,4-trimethylpentane, 2,3-dimethylbutane, 2,3-dimethylpentane, 2,4-dimethylpentane, 2-methylheptane, 2-methylhexane, 2-methylpentane, 3-methylheptane, 3-methylhexane, 3-methylpentane, cyclopentane, isopentane, methylcyclopentane, n-heptane, n-octane.
[e] Sum of n-decane, n-dodecane, n-tridecane, n-undecane.
[f] Sum of m-diethylbenzene, m-ethyltoluene, o-ethyltoluene, p-diethylbenzene, p-ethyltoluene.

Table 2
Detection frequencies of hydrocarbons without toxicity values detected in NGD area or well completion samples.

Hydrocarbon	NGD area sample[a] detection frequency (%)	Well completion sample[b] detection frequency (%)
1-Dodecene	36	81
1-Heptene	94	100
1-Hexene	63	79
1-Nonene	52	94
1-Octene	29	75
1-Pentene	98	79
1-Tridecene	7	38
1-Undecene	28	81
2-Ethyl-1-butene	1	0
2-Methyl-1-butene	29	44
2-Methyl-1-pentene	1	6
2-Methyl-2-butene	36	69
3-Methyl-1-butene	6	6
4-Methyl-1-pentene	16	69
Acetylene	100	92
a-Pinene	63	100
b-Pinene	10	44
cis-2-Butene	58	75
cis-2-Hexene	13	81
cis-2-Pentene	38	54
Cyclopentene	44	94
Ethane	100	100
Ethylene	100	100
Isobutane	100	100
Isobutene/1-Butene	73	44
Isoprene	71	96
n-Butane	98	100
Propane	100	100
Propyne	1	0
trans-2-Butene	80	75
trans-2-Hexene	1	6
trans-2-Pentene	55	83

Abbreviations: NGD, natural gas development.
[a] Samples collected at one site every 6 six days between 2008 and 2010.
[b] Samples collected at four separate sites in summer 2008 and one site in summer 2010.

concentrations of hydrocarbons from well completion samples were significantly higher than concentrations from NGD area samples ($p<0.05$) with the exception of 1,2,3-trimethylbenzene, n-pentane, 1,3-butadiene, isopropylbenzene, n-propylbenzene, propylene, and styrene (Supplemental Table 2).

3.2. Non-cancer hazard indices

Table 3 presents chronic and subchronic RfCs used in calculating non-cancer HIs, as well critical effects and other effects. Chronic non-cancer HQ and HI estimates based on ambient air concentrations are presented in Table 4. The total chronic HIs based on the 95% UCL of the mean concentration were 0.4 for residents >½ mile from wells and 1 for residents ≤½ mile from wells. Most of the chronic non-cancer hazard is attributed to neurological effects with neurological HIs of 0.3 for residents >½ mile from wells and 0.9 for residents ≤½ mile from wells.

Total subchronic non-cancer HQs and HI estimates are presented in Table 5. The total subchronic HIs based on the 95% UCL of the mean concentration were 0.2 for residents >½ mile from wells and 5 for residents ≤½ mile from wells. The subchronic non-cancer hazard for residents >½ mile from wells is attributed mostly to respiratory effects (HI = 0.2), while the subchronic hazard for residents ≤½ mile from wells is attributed to neurological (HI = 4), respiratory (HI = 2), hematologic (HI = 3), and developmental (HI = 1) effects.

For residents >½ mile from wells, aliphatic hydrocarbons (51%), trimethylbenzenes (22%), and benzene (14%) are primary contributors to the chronic non-cancer HI. For residents ≤½ mile from wells, trimethylbenzenes (45%), aliphatic hydrocarbons (32%), and xylenes (17%) are primary contributors to the chronic non-cancer HI, and trimethylbenzenes (46%), aliphatic hydrocarbons (21%) and xylenes (15%) also are primary contributors to the subchronic HI.

3.3. Cancer risks

Cancer risk estimates calculated based on measured ambient air concentrations are presented in Table 6. The cumulative cancer risks based on the 95% UCL of the mean concentration were 6 in a million for residents >½ from wells and 10 in a million for residents ≤½ mile from wells. Benzene (84%) and 1,3-butadiene (9%) were the primary contributors to cumulative cancer risk for residents >½ mile from wells. Benzene (67%) and ethylbenzene (27%) were the primary contributors to cumulative cancer risk for residents ≤½ mile from wells.

4. Discussion

Our results show that the non-cancer HI from air emissions due to natural gas development is greater for residents living closer to wells. Our greatest HI corresponds to the relatively short-term (i.e., subchronic), but high emission, well completion period. This HI is driven principally by exposure to trimethylbenzenes, aliphatic hydrocarbons, and xylenes, all of which have neurological and/or respiratory effects. We also calculated higher cancer risks for residents living nearer to wells as compared to residents residing further from wells. Benzene is the major contributor to lifetime excess cancer risk for both scenarios. It also is notable that these increased risk metrics are seen in an air shed that has elevated ambient levels of several measured air toxics, such as benzene (CDPHE, 2009; GCPH, 2010).

4.1. Representation of exposures from NGD

It is likely that NGD is the major source of the hydrocarbons observed in the NGD area samples used in this risk assessment. The NGD area monitoring site is located in the midst of multi-acre rural home sites and ranches. Natural gas is the only industry in the area other than agriculture. Furthermore, the site is at least 4 miles upwind from any other major emission source, including Interstate 70 and the town of Silt, Colorado. Interestingly, levels of benzene, m,p-xylene, and 1,3,5-trimethylbenzene measured at this rural monitoring site in 2009 were higher than levels measured at 27 out of 37 EPA air toxics monitoring sites where SNMOCs were measured, including urban sites such as Elizabeth, NJ, Dearborn, MI, and Tulsa, OK (GCPH, 2010; US EPA, 2009b). In addition, the 2007 Garfield County emission inventory attributes the bulk of benzene, xylene, toluene, and ethylbenzene emissions in the county to NGD, with NGD point and non-point sources contributing five times more benzene than any other emission source, including on-road vehicles, wildfires, and wood burning. The emission inventory also indicates that NGD sources (e.g. condensate tanks, drill rigs, venting during completions, fugitive emissions from wells and pipes, and compressor engines) contributed ten times more VOC emissions than any source, other than biogenic sources (e.g. plants, animals, marshes, and the earth) (CDPHE, 2009).

Emissions from flowback operations, which may include emissions from various sources on the pads such as wells and diesel engines, are likely the major source of the hydrocarbons observed in the well completion samples. These samples were collected very near (130 to 500 ft from the center) well pads during uncontrolled flowback into tanks venting directly to the air. As for the NGD area samples, no sources other than those associated with NGD were in the vicinity of the sampling locations.

Subchronic health effects, such as headaches and throat and eye irritation reported by residents during well completion activities

Table 3
Chronic and subchronic reference concentrations, critical effects, and major effects for hydrocarbons in quantitative risk assessment.

Hydrocarbon	Chronic		Subchronic		Critical effect/ target organ	Other effects
	RfC (μg/m^3)	Source	RfC (μg/m^3)	Source		
1,2,3-Trimethylbenzene	5.00E+00	PPTRV	5.00E+01	PPTRV	Neurological	Respiratory, hematological
1,3,5-Trimethylbenzene	6.00E+00	PPTRV	1.00E+01	PPTRV	Neurological	Hematological
Isopropylbenzene	4.00E+02	IRIS	9.00E+01	HEAST	Renal	Neurological, respiratory
n-Hexane	7.00E+02	IRIS	2.00E+03	PPTRV	Neurological	–
n-Nonane	2.00E+02	PPTRV	2.00E+03	PPTRV	Neurological	Respiratory
n-Pentane	1.00E+03	PPTRV	1.00E+04	PPTRV	Neurological	–
Styrene	1.00E+03	IRIS	3.00E+03	HEAST	Neurological	–
Toluene	5.00E+03	IRIS	5.00E+03	PPTRV	Neurological	Developmental, respiratory
Xylenes, total	1.00E+02	IRIS	4.00E+02	PPTRV	Neurological	Developmental, respiratory
n-propylbenzene	1.00E+03	PPTRV	1.00E+03	Chronic RfC PPTRV	Developmental	Neurological
1,2,4-Trimethylbenzene	7.00E+00	PPTRV	7.00E+01	PPTRV	Decrease in blood clotting time	Neurological, respiratory
1,3-Butadiene	2.00E+00	IRIS	2.00E+00	Chronic RfC IRIS	Reproductive	Neurological, respiratory
Propylene	3.00E+03	CalEPA	1.00E+03	Chronic RfC CalEPA	Respiratory	–
Benzene	3.00E+01	ATSDR	8.00E+01	PPTRV	Decreased lymphocyte count	Neurological, developmental, reproductive
Ethylbenzene	1.00E+03	ATSDR	9.00E+03	PPTRV	Auditory	Neurological, respiratory, renal
Cyclohexane	6.00E+03	IRIS	1.80E+04	PPTRV	Developmental	Neurological
Methylcyclohexane	3.00E+03	HEAST	3.00E+03	HEAST	Renal	–
Aliphatic hydrocarbons C_5–C_8[a]	6E+02	PPTRV	2.7E+04	PPTRV	Neurological	–
Aliphatic hydrocarbons C_9–C_{18}	1E+02	PPTRV	1E+02	PPTRV	Respiratory	–
Aromatic hydrocarbons C_9–C_{18}[b]	1E+02	PPTRV	1E+03	PPRTV	Decreased maternal body weight	Respiratory

Abbreviations: 95%UCL, 95% upper confidence limit; CalEPA, California Environmental Protection Agency; HEAST, EPA Health Effects Assessment Summary Tables 1997; HQ, hazard quotient; IRIS, Integrated Risk Information System; Max, maximum; PPTRV, EPA Provisional Peer-Reviewed Toxicity Value; RfC, reference concentration; μg/m^3, micrograms per cubic meter. Data from CalEPA 2011; IRIS (US EPA, 2011); ORNL 2011.

[a] Based on PPTRV for commercial hexane.

[b] Based on PPTRV for high flash naphtha.

occurring in Garfield County, are consistent with known health effects of many of the hydrocarbons evaluated in this analysis (COGCC, 2011; Witter et al., 2011). Inhalation of trimethylbenzenes and xylenes can irritate the respiratory system and mucous membranes with effects ranging from eye, nose, and throat irritation to difficulty in breathing and impaired lung function (ATSDR, 2007a;

Table 4
Chronic hazard quotients and hazard indices for residents living >½ mile from wells and residents living ≤½ mile from wells.

Hydrocarbon	>½ mile		≤½ mile	
	Chronic HQ based on median concentration	Chronic HQ based on 95% UCL of mean concentration	Chronic HQ based on median concentration	Chronic HQ based on 95% UCL of mean concentration
1,2,3-Trimethylbenzene	2.09E−02	1.90E−02	2.87E−02	5.21E−02
1,2,4-Trimethylbenzene	2.51E−02	4.22E−02	3.64E−02	2.01E−01
1,3,5-Trimethylbenzene	1.96E−02	2.80E−02	3.00E−02	1.99E−01
1,3-Butadiene	5.05E−02	2.23E−02	5.05E−02	2.25E−02
Benzene	3.03E−02	5.40E−02	3.32E−02	8.70E−02
Cyclohexane	3.40E−04	9.98E−04	3.67E−04	1.46E−03
Ethylbenzene	1.63E−04	3.98E−04	1.95E−04	3.23E−03
Isopropylbenzene	3.68E−04	1.78E−04	3.90E−04	3.05E−04
Methylcyclohexane	1.18E−03	2.00E−03	1.36E−03	5.32E−03
n-Hexane	5.49E−03	9.23E−03	5.76E−03	1.47E−02
n-Nonane	2.11E−03	3.14E−03	2.95E−03	2.31E−02
n-Pentane	8.71E−03	1.32E−02	8.79E−03	2.39E−02
n-propylbenzene	9.95E−05	9.59E−05	1.28E−04	2.64E−04
Propylene	1.09E−04	1.27E−04	1.10E−04	1.30E−04
Styrene	1.43E−04	1.25E−04	1.42E−04	4.32E−04
Toluene	3.40E−04	9.28E−04	4.06E−04	1.86E−03
Xylenes, total	1.16E−02	1.57E−02	1.54E−02	1.71E−01
Aliphatic hydrocarbons C_5–C_8	4.63E−02	7.02E−02	4.87E−02	1.36E−01
Aliphatic hydrocarbons C_9–C_{18}	1.22E−02	1.35E−01	1.58E−02	1.83E−01
Aromatic hydrocarbons C_9–C_{18}	5.44E−03	6.67E−03	7.12E−03	2.04E−02
Total Hazard Index	2E−01	4E−01	3E−01	1E+00
Neuorological Effects Hazard Index[a]	2E−01	3E−01	3E−01	9E−01
Respiratory Effects Hazard Index[b]	1E−01	2E−02	2E−02	7E−01
Hematogical Effects Hazard Index[c]	1E−01	1E−01	1E−01	5E−01
Developmental Effects Hazard Index[d]	4E−02	7E−02	5E−02	3E−01

Abbreviations: 95%UCL, 95% upper confidence limit; HQ, hazard quotient.

[a] Sum of HQs for hydrocarbons with neurological effects: 1,2,3-Trimethylbenzene, 1,2,4-Trimethylbenzene, 1,3,5-Trimethylbenzene, 1,3-butadiene, benzene, cyclohexane, ethylbenzene, isopropylbenzene, n-hexane, n-nonane, n-pentane, n-propylbenzene, styrene, toluene, xylenes, aliphatic C_5–C_8 hydrocarbons.

[b] Sum of HQs for hydrocarbons with respiratory effects: 1,2,3-Trimethylbenzene, 1,2,4-Trimethylbenzene, 1,3-butadiene, ethylbenzene, isopropylbenzene, n-nonane, propylene, toluene, xylenes, aliphatic C_9–C_{18} hydrocarbons, aromatic C_9–C_{18} hydrocarbons.

[c] Sum of HQs for hydrocarbons with hematological effects: 1,2,3-trimethylbenzene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, benzene.

[d] Sum of HQs for hydrocarbons with developmental effects: benzene, cyclohexane, toluene, and xylenes.

Table 5
Subchronic hazard quotients and hazard indices residents living >½ mile from wells and residents living ≤½ mile from wells.

Hydrocarbon (μg/m^3)	>½ mile		≤½ mile	
	Subchronic HQ based on median concentration	Subchronic HQ based on 95% UCL of mean concentration	Subchronic HQ based on median concentration	Subchronic HQ based on 95% UCL of mean concentration
1,2,3-Trimethylbenzene	2.09E−03	1.90E−03	1.67E−02	6.40E−02
1,2,4-Trimethylbenzene	2.51E−03	4.22E−03	2.38E−02	3.02E−01
1,3,5-Trimethylbenzene	1.18E−02	1.68E−02	1.29E−01	1.95E+00
1,3-Butadiene	5.04E−02	2.23E−02	5.25E−02	8.30E−02
Benzene	1.14E−02	2.02E−02	3.25E−02	2.55E−01
Cyclohexane	1.13E−04	3.33E−04	2.93E−04	3.24E−03
Ethylbenzene	1.81E−05	4.42E−05	8.56E−05	5.96E−03
Isopropylbenzene	1.63E−03	7.92E−04	3.62E−03	1.14E−02
Methylcyclohexane	1.18E−03	2.01E−03	4.67E−03	6.47E−02
n-Hexane	1.92E−03	3.23E−03	3.86E−03	3.98E−02
n-Nonane	2.11E−04	3.14E−04	1.80E−03	3.78E−02
n-Pentane	8.71E−04	1.32E−03	1.05E−03	2.13E−02
n-propylbenzene	9.95E−05	9.57E−05	6.36E−04	3.26E−03
Propylene	1.43E−04	3.80E−04	4.12E−04	6.02E−04
Styrene	5.68E−04	4.16E−05	4.00E−06	1.97E−03
Toluene	4.18E−05	9.28E−04	2.46E−04	1.84E−02
Xylenes, total	2.91E−03	3.93E−03	2.05E−02	7.21E−01
Aliphatic hydrocarbons C_5–C_8	1.07E−03	1.63E−03	2.07E−03	2.89E−02
Aliphatic hydrocarbons C_9–C_{18}	1.3E−02	1.41E−01	7.9E−02	1.03E−00
Aromatic hydrocarbons C_9–C_{18}	6.00E−04	6.95E−04	3.7E−03	2.64E−02
Total Hazard Index	1E−01	2E−01	4E−01	5E+00
Neurological Effects Hazard Index[a]	9E−02	8E−02	3E−01	4E+00
Respiratory Effects Hazard Index[b]	7E−02	2E−01	2E−01	2E+00
Hematogical Effects Hazard Index[c]	3E−02	4E−02	2E−01	3E+00
Developmental Effects Hazard Index[d]	1E−02	3E−02	5E−02	1E+00

Abbreviations: 95%UCL, 95% upper confidence limit; HQ, hazard quotient.
[a] Sum of HQs for hydrocarbons with neurological effects: 1,2,3-Trimethylbenzene, 1,2,4-Trimethylbenzene, 1,3,5-Trimethylbenzene, 1,3-butadiene, benzene, cyclohexane, ethylbenzene, isopropylbenzene, n-hexane, n-nonane, n-pentane, n-propylbenzene, styrene, toluene, xylenes, aliphatic C_5–C_8 hydrocarbons.
[b] Sum of HQs for hydrocarbons with respiratory effects: 1,2,3-Trimethylbenzene, 1,2,4-Trimethylbenzene, 1,3-butadiene, ethylbenzene, isopropylbenzene, n-nonane, propylene, toluene, xylenes, aliphatic C_9–C_{18} hydrocarbons, aromatic C_9–C_{18} hydrocarbons.
[c] Sum of HQs for hydrocarbons with hematological effects: 1,2,3-trimethylbenzene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, benzene.
[d] Sum of HQs for hydrocarbons with developmental effects: benzene, cyclohexane, toluene, and xylenes.

ATSDR, 2007b; US EPA, 1994). Inhalation of trimethylbenzenes, xylenes, benzene, and alkanes can adversely affect the nervous system with effects ranging from dizziness, headaches, fatigue at lower exposures to numbness in the limbs, incoordination, tremors, temporary limb paralysis, and unconsciousness at higher exposures (Carpenter et al., 1978; Nilsen et al., 1988; US EPA, 1994; Galvin and Marashi, 1999; ATSDR, 2007a; ATSDR, 2007b).

4.2. Risk assessment as a tool for health impact assessment

HIA is a policy tool used internationally that is being increasingly used in the United States to assess multiple complex hazards and exposures in communities. Comparison of risks between residents based on proximity to wells illustrates how the risk assessment process can be used to support the HIA process. An important component of the HIA process is to identify where and when public health is most likely to be impacted and to recommend mitigations to reduce or eliminate the potential impact (Collins and Koplan, 2009). This risk assessment indicates that public health most likely would be impacted by well completion activities, particularly for residents living nearest the wells. Based on this information, suggested risk prevention strategies in the HIA are directed at minimizing exposures for those living closet to the well pads, especially during well completion activities when emissions are the highest. The HIA includes recommendations to (1) control and monitor emissions during completion transitions and flowback; (2) capture and reduce emissions through use of low or no emission flowback tanks; and (3) establish and maintain communications regarding well pad activities with the community (Witter et al., 2011).

4.3. Comparisons to other risk estimates

This risk assessment is one of the first studies in the peer-reviewed literature to provide a scientific perspective to the potential health risks associated with development of unconventional natural

Table 6
Excess cancer risks for residents living >½ mile from wells and residents living ≤½ mile from wells.

Hydrocarbon	WOE		Unit Risk (μg/m^3)	Source	>½ mile		≤½ mile	
	IRIS	IARC			Cancer risk based on median concentration	Cancer risk based on 95% UCL of mean concentration	Cancer risk based on median concentration	Cancer risk based on 95% UCL of mean concentration
1,3-Butadiene	B2	1	3.00E−05	IRIS	1.30E−06	5.73E−07	1.30E−06	6.54E−07
Benzene	A	1	7.80E−06	IRIS	3.03E−06	5.40E−06	3.33E−06	8.74E−06
Ethylbenzene	NC	2B	2.50E−06	CalEPA	1.75E−07	4.26E−07	2.09E−07	3.48E−06
Styrene	NC	2B	5.00E−07	CEP	3.10E−08	2.70E−08	3.00E−08	9.30E−08
Cumulative cancer risk					5E−06	6E−06	5E−06	1E−05

Abbreviations: 95%UCL, 95% upper confidence limit; CalEPA, California Environmental Protection Agency; CEP, (Caldwell et al., 1998); IARC, International Agency for Research on Cancer; IRIS, Integrated Risk Information System; Max, maximum; NC, not calculated; WOE, weight of evidence; μg/m^3, micrograms per cubic meter. Data from CalEPA 2011; IRIS (US EPA, 2011).

gas resources. Our results for chronic non-cancer HIs and cancer risks for residents > than ½ mile from wells are similar to those reported for NGD areas in the relatively few previous risk assessments in the non-peer reviewed literature that have addressed this issue (CDPHE, 2010; Coons and Walker, 2008; CDPHE, 2007; Walther, 2011). Our risk assessment differs from these previous risk assessments in that it is the first to separately examine residential populations nearer versus further from wells and to report health impact of emissions resulting from well completions. It also adds information on exposure to air emissions from development of these resources. These data show that it is important to include air pollution in the national dialogue on unconventional NGD that, to date, has largely focused on water exposures to hydraulic fracturing chemicals.

4.4. Limitations

As with all risk assessments, scientific limitations may lead to an over- or underestimation of the actual risks. Factors that may lead to overestimation of risk include use of: 1) 95% UCL on the mean exposure concentrations; 2) maximum detected values for 1,3-butadiene, 2,2,4-trimethylpentane, and styrene because of a low number of detectable measurements; 3) default RME exposure assumptions, such as an exposure time of 24 h per day and exposure frequency of 350 days per year; and 4) upper bound cancer risk and non-cancer toxicity values for some of our major risk drivers. The benzene IUR, for example, is based on the high end of a range of maximum likelihood values and includes uncertainty factors to account for limitations in the epidemiological studies for the dose–response and exposure data (US EPA, 2011). Similiarly, the xylene chronic RfC is adjusted by a factor of 300 to account for uncertainties in extrapolating from animal studies, variability of sensitivity in humans, and extrapolating from subchronic studies (US EPA, 2011). Our use of chronic RfCs values when subchronic RfCs were not available may also have overestimated 1,3-butadiene, n-propylbenzene, and propylene subchronic HQs. None of these three chemicals, however, were primary contributors to the subchronic HI, so their overall effect on the HI is relatively small.

Several factors may have lead to an underestimation of risk in our study results. We were not able to completely characterize exposures because several criteria or hazardous air pollutants directly associated with the NGD process via emissions from wells or equipment used to develop wells, including formaldehyde, acetaldehyde, crotonaldehyde, naphthalene, particulate matter, and polycyclic aromatic hydrocarbons, were not measured. No toxicity values appropriate for quantitative risk assessment were available for assessing the risk to several alkenes and low molecular weight alkanes (particularly $< C_5$ aliphatic hydrocarbons). While at low concentrations the toxicity of alkanes and alkenes is generally considered to be minimal (Sandmeyer, 1981), the maximum concentrations of several low molecular weight alkanes measured in the well completion samples exceeded the 200–1000 $\mu g/m^3$ range of the RfCs for the three alkanes with toxicity values: n-hexane, n-pentane, and n-nonane (US EPA, 2011; ORNL, 2009). We did not consider health effects from acute (i.e., less than 1 h) exposures to peak hydrocarbon emissions because there were no appropriate measurements. Previous risk assessments have estimated an acute HQ of 6 from benzene in grab samples collected when residents noticed odors they attributed to NGD (CDPHE, 2007). We did not include ozone or other potentially relevant exposure pathways such as ingestion of water and inhalation of dust in this risk assessment because of a lack of available data. Elevated concentrations of ozone precursors (specifically, VOCs and nitrogen oxides) have been observed in Garfield County's NGD area and the 8-h average ozone concentration has periodically approached the 75 ppb National Ambient Air Quality Standard (NAAQS) (CDPHE, 2009; GCPH, 2010).

This risk assessment also was limited by the spatial and temporal scope of available monitoring data. For the estimated chronic exposure, we used 3 years of monitoring data to estimate exposures over a 30 year exposure period and a relatively small database of 24 samples collected at varying distances up to 500 ft from a well head (which also were used to estimate shorter-term non-cancer hazard index). Our estimated 20-month subchronic exposure was limited to samples collected in the summer, which may have not have captured temporal variation in well completion emissions. Our ½ mile cut point for defining the two different exposed populations in our exposure scenarios was based on complaint reports from residents living within ½ mile of existing NGD, which were the only data available. The actual distance at which residents may experience greater exposures from air emissions may be less than or greater than a ½ mile, depending on dispersion and local topography and meteorology. This lack of spatially and temporally appropriate data increases the uncertainty associated with the results.

Lastly, this risk assessment was limited in that appropriate data were not available for apportionment to specific sources within NGD (e.g. diesel emissions, the natural gas resource itself, emissions from tanks, etc.). This increases the uncertainty in the potential effectiveness of risk mitigation options.

These limitations and uncertainties in our risk assessment highlight the preliminary nature of our results. However, there is more certainty in the comparison of the risks between the populations and in the comparison of subchronic to chronic exposures because the limitations and uncertainties similarly affected the risk estimates.

4.5. Next steps

Further studies are warranted, in order to reduce the uncertainties in the health effects of exposures to NGD air emissions, to better direct efforts to prevent exposures, and thus address the limitations of this risk assessment. Next steps should include the modeling of short- and longer-term exposures as well as collection of area, residential, and personal exposure data, particularly for peak short-term emissions. Furthermore, studies should examine the toxicity of hydrocarbons, such as alkanes, including health effects of mixtures of HAPs and other air pollutants associated with NGD. Emissions from specific emission sources should be characterized and include development of dispersion profiles of HAPs. This emissions data, when coupled with information on local meteorological conditions and topography, can help provide guidance on minimum distances needed to protect occupant health in nearby homes, schools, and businesses. Studies that incorporate all relevant pathways and exposure scenarios, including occupational exposures, are needed to better understand the impacts of NGD of unconventional resources, such as tight sands and shale, on public health. Prospective medical monitoring and surveillance for potential air pollution-related health effects is needed for populations living in areas near the development of unconventional natural gas resources.

5. Conclusions

Risk assessment can be used as a tool in HIAs to identify where and when public health is most likely to be impacted and to inform risk prevention strategies directed towards efficient reduction of negative health impacts. These preliminary results indicate that health effects resulting from air emissions during development of unconventional natural gas resources are most likely to occur in residents living nearest to the well pads and warrant further study. Risk prevention efforts should be directed towards reducing air emission exposures for persons living and working near wells during well completions.

Supplementary materials related to this article can be found online at doi:10.1016/j.scitotenv.2012.02.018.

Acknowledgements

We extend special thanks to J. Rada, P. Reaser, C. Archuleta, K. Stinson, and K. Scott. We are very grateful to the Garfield County Department of Public Health.

References

Antero. Air Quality Sampling Summary Report Well Completion and Flowback Development Scenario Watson Ranch Pad Garfield County Colorado December 22, 2010. Denver, CO: Antero Resources; 2010.

ATSDR. Toxicological Profile for Benzene. Atlanta, GA: Agency for Toxic Substances and Disease Registry, US Deparment of Health and Human Services; 2007a.

ATSDR. Toxicological Profile for Xylenes. Atlanta, GA: Agency for Toxic Substances and Disease Registry, US Deparment of Health and Human Services; 2007b.

Brosselin P, Rudant J, Orsi L, Leverger G, Baruchel A, Bertrand Y, et al. Acute Childhood Leukaemia and Residence Next to Petrol Stations and Automotive Repair Garages: the ESCALE study (SFCE). Occup Environ Med 2009;66(9):598–606.

Caldwell JC, Woodruff TJ, Morello-Frosch R, Axelrad DA. Application of health information to hazardous air pollutants modeled in EPA's Cumulative Exposure Project. Toxicol Ind Health 1998;14(3):429–54.

CalEPA. Toxicity Criteria Database. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment; 2003. Available: http://oehha.ca.gov/risk/chemicalDB/index.asp [Accessed May 2011].

Carpenter CP, Geary DL, Myers RC, Nachreiner DJ, Sullivan LJ, King JM. Petroleum Hydrocarbons Toxicity Studies XVII. Animal Responses to n-Nonane Vapor. Toxicol Appl Pharmacol 1978;44:53–61.

CDPHE. Garfield County Air Toxics Inhalation: Screening Level Human Health Risk Assessment: Inhalation of Volatile organic Compounds Measured in Rural, Urban, and Oil &Gas Areas in Ambient Air Study (June 2005–May 2007). Denver, CO: Environmental Epidemiology Division, Colorado Department of Public Health and Environment; 2007. Available: http://www.garfieldcountyaq.net/default_new.aspx.

CDPHE. Garfield County Emissions Inventory. Denver, CO: Air Pollution Control Division, Colorado Department of Public Health and Environment; 2009. Available: http://www.garfieldcountyaq.net/default_new.aspx.

CDPHE. Garfield County Air Toxics Inhalation: Screening Level Human Health Risk Assessment: Inhalation of Volatile Organic Compounds Measured In 2008 Air Quality Monitoring Study. Denver, CO: Environmental Epidemiology Division, Colorado Department of Public Health and Environment; 2010. Available: http://www.garfieldcountyaq.net/default_new.aspx.

COGCC. Statement of Basis, Specific Statutory Authority, and Purpose: New Rules and Amendments to Current Rules of the Colorado Oil and Gas Conservation Commission, 2 CCR 404–1. Colorado Oil and Gas Conservation Commission; 2009a. Available: http://cogcc.state.co.us/.

COGCC. Rules and Regulations, 2 CCR 404–1. Colorado Oil and Gas Conservation Commission; 2009b. Available: http://cogcc.state.co.us/.

COGCC. Inspection/Incident Database. Denver, CO: Colorado Oil and Gas Information System, Colorado Oil and Gas Conservation Commission; 2011. Available: http://cogcc.state.co.us/.

Collins J, Koplan JP. Health impact assessment: a step toward health in all policies. JAMA 2009;302(3):315–7.

Coons T, Walker R. Community Health Risk Analysis of Oil and Gas Industry in Garfield County. Grand Junction, CO: Saccommano Research Institute; 2008. Available: http://www.garfieldcountyaq.net/default_new.aspx.

Frazier A. Analysis of Data Obtained for the Garfield County Air Toxics Study Summer 2008. Rifle Denver, CO: Air Pollution Control Division, Colorado Department of Public Health and Environment; 2009. Available: http://www.garfieldcountyaq.net/default_new.aspx.

Galvin JB, Marashi F. n-Pentane. J Toxicol Environ Health 1999;1(58):35–56.

GCPH. Garfield County 2008 Air Quality Monitoring Summary Report. Rifle CO: Garfield County Public Health Department; 2009. Available: http://www.garfieldcountyaq.net/default_new.aspx.

GCPH. Garfield County 2009 Air Quality Monitoring Summary Report. Rifle CO: Garfield County Public Health Department; 2010. Available: http://www.garfieldcountyaq.net/default_new.aspx.

GCPH. Garfield County Quarterly Monitoring Report. Fourth Quarter October 1 through December 31, 2010. Rifle CO: Garfield County Public Health Department; 2011. Available: http://www.garfieldcountyaq.net/default_new.aspx.

Glass DC, Gray CN, Jolley DJ, Gibbons C, Sim MR, Fritschi L, et al. Leukemia Risk Associated with Low-Level Benzene Exposure. Epidemiology 2003;14(5):569–77.

Kim BM, Park EK, LeeAn SY, Ha M, Kim EJ, Kwon H, et al. BTEX exposure and its health effects in pregnant women following the Hebei spirit oil spill. J Prev Med Public Health Yebang Uihakhoe Chi 2009;42(2):96-103.

Kirkeleit J, Riise T, Bråtveit M, Moen B. Increased risk of acute myelogenous leukemia and multiple myeloma in a historical cohort of upstream petroleum workers exposed to crude oil. Cancer Causes Control 2008;19(1):13–23.

Lupo P, Symanski E, Waller D, Chan W, Langlosi P, Canfield M, et al. Maternal Exposure to Ambient Levels of Benzene and Neural Tube Defects among Offspring, Texas 1999–2004. Environ Health Perspect 2011;119(3):397–402.

Nilsen OG, Haugen OA, Zahisen K, Halgunset J, Helseth A, Aarset A, et al. Toxicity of n-C9 to n-C13 alkanes in the rat on short term inhalation. Pharmacol Toxicol 1988;62:259–66.

ORNL. The Risk Assessment Information System. Oak Ridge National Laboratory, TN: US Department of Energy; 2009. Available: http://rais.ornl.gov/ [Accessed May 2011].

Sandmeyer EE. Aliphatic Hydrocarbons. Patty's Industrial Hygeine and Toxicology, Third Edition, Volume IIB. New York: John Wiley; 1981. p. 3175–220.

TERC. VOC Emissions from Oil and Condensate Storage Tanks. Texas Environmental Research Consortium; 2009. p. 1-34. Available online at: http://files.harc.edu/Projects/AirQuality/Projects/H051C/H051CFinalReport.pdf. The Woodlands, TX.

US DOE. "Modern Shale Gas Development in the United States: A Primer," Office of Fossil Energy and National Energy Technology Laboratory, United States Department of Energy; 2009. http://www.netl.doe.gov/technologies/oil-gas/publications/EPreports/Shale_Gas_Primer_2009.pdf (accessed January 2012).

US EIA. Annual Energy Outlook 2011 with Projections to 2035. Washington DC: Energy Information Administration, United States Department of Energy; 2011.

US EPA. Risk Assessment Guidance for Superfund (Part A). Washington, DC: Office of Emergency and Remedial Response, US Environmental Protection Agency; 1989.

US EPA. Chemicals in the Environment: 1,2,4-trimethylbenzene (C.A.S. No. 95-63-6). Washington, DC: Office of Pollution Prevention and Toxics, US Environmental Protection Agency; 1994.

US EPA. Health Effects Assessment Summary Tables. Washington, DC: US Environmental Protection Agency; 1997.

US EPA. Method for the Determination of Non-Methane Organic Compounds (NMOC) in Ambient Air Using Cryogenic Preconcentrations and Direct Flame Ionization Detection (PDFID). Cincinnati OH: Office of Research and Development, US Environmental Protection Agency; 1999.

US EPA. The OAQPS Air Toxic Risk Assessment Library. US Environmental Protection Agency; 2004. Available: http://www.epa.gov/ttn/fera/risk_atra_main.html.

US EPA. Provisional Peer Reviewed Toxicity Values for Complex Mixtures of Aliphatic and Aromatic Hydrocarbons. Cinninati Ohio: Superfund Health Risk Technical Support Center National Center for Environmental Assessment: Office of Reasearch and Development., US Environmental Protection Agency; 2009a.

US EPA. Technology Transfer Network Air Quality System. Washington DC: Office of Air and Radiation, US Environmental Protection Agency; 2009b. Available: http://www.epa.gov/ttn/airs/airsaqs/.

US EPA. Greenhouse Gas Emissions Reporting from the Petroleum and Natural Gas Industry Background Technical Support Documtent. Washington DC: Climate Change Division, US Environmental Protection Agency; 2010a.

US EPA. ProUCL Version 4.00.05 Technical Guide Statistical Software for Environmental Applications for Data Sets With and Without Nondetect Observations(Draft). Washington DC: Office of Research and Development, US Environmental Protection Agency; 2010b.

US EPA. Integrated Risk Information System (IRIS). Washington DC: US Environmental Protection Agency; 2011. Available: http://www.epa.gov/IRIS/ [Accessed May 2011].

Vidas H, Hugman B. ICF International. Availability, Economics, and Production Potential of North American Unconventional Natural Gas SuppliesPrepared for The INGAA Foundation, Inc. by: ICF International; 2008.

Walther E. Screening Health Risk Assessment Sublette County, Wyoming. Pinedale WY: Sierra Research, Inc.; 2011. Available: http://www.sublettewyo.com/DocumentView.aspx?DID=438.

White N, teWaterNaude J, van der Walt A, Ravenscroft G, Roberts W, Ehrlich R. Meteorologically estimated exposure but not distance predicts asthma symptoms in school children in the environs of a petrochemical refinery: a cross-sectional study. Environ Health 2009;8(1):45.

Witter R, McKenzie L, Towle M, Stinson K, Scott K, Newman L, et al. Draft Health Impact Assessment for Battlement Mesa, Garfield County, Colorado. Colorado School of Public Health; 2011. Available: http://www.garfield-county.com/index.aspx?page=1408.

Zielinska B, Fujita E, Campbell D. Monitoring of Emissions from Barnett Shale Natural Gas Production Facilities for Population Exposure Assessment. Houston TX: Desert Research Institute; 2011. Available: http://www.sph.uth.tmc.edu/mleland/attachments/Barnett%20Shale%20Study%20Final%20Report.pdf.

ehp ENVIRONMENTAL HEALTH PERSPECTIVES
http://www.ehponline.org

Exhibit 13

Proximity to Natural Gas Wells and Reported Health Status: Results of a Household Survey in Washington County, Pennsylvania

Peter M. Rabinowitz, Ilya B. Slizovskiy, Vanessa Lamers, Sally J. Trufan, Theodore R. Holford, James D. Dziura, Peter N. Peduzzi, Michael J. Kane, John S. Reif, Theresa R. Weiss, and Meredith H. Stowe

http://dx.doi.org/10.1289/ehp.1307732
Received: 17 October 2013
Accepted: 20 August 2014
Advance Publication: 10 September 2014

NIH National Institute of Environmental Health Sciences

Proximity to Natural Gas Wells and Reported Health Status: Results of a Household Survey in Washington County, Pennsylvania

Peter M. Rabinowitz,[1,2] Ilya B. Slizovskiy,[1,3] Vanessa Lamers,[3,4] Sally J. Trufan,[1] Theodore R. Holford,[3] James D. Dziura,[3] Peter N. Peduzzi,[3] Michael J. Kane,[3] John S. Reif,[5] Theresa R. Weiss,[1] and Meredith H. Stowe[1]

[1]Yale University School of Medicine, New Haven, Connecticut, USA; [2]University of Washington, Seattle, Washington, USA; [3]Yale School of Public Health, New Haven, Connecticut, USA; [4]Yale School of Forestry & Environmental Sciences, New Haven, Connecticut, USA; [5]Colorado State University College of Veterinary Medicine & Biomedical Sciences, Fort Collins, Colorado, USA

Address correspondence to Peter M. Rabinowitz, University of Washington School of Public Health, Department of Environmental and Occupational Health, 1959 NE Pacific Street, F551 Health Sciences Center, Box 357234, Seattle, WA 98195 USA. Telephone: (206) 685-2654.

Running title: Proximity to Gas Wells and Reported Health Status

Acknowledgments: This study was supported by grants from The Heinz Endowments, as well as the Schmidt Family Foundation and the Claneil Foundation. Additional support was received from the Jan Stolwijk Fellowship fund and by Yale University Clinical and Translational Science Award (CTSA) Grant Number UL1 RR024139 from the National Center for Research Resources (NCRR) and the National Center for Advancing Translational Science (NCATS), components of the National Institutes of Health (NIH), and NIH roadmap for Medical Research. Its contents are solely the responsibility of the authors and do not necessarily represent the official view of NIH.

The authors would like to thank the Southwest Pennsylvania Environmental Health Project for assistance with the community survey, Lisa Conti DVM MPH for assistance with study design, Deron Galusha and Fangyong Li with data analysis, and Jessica Bonthius for assistance with data entry and management. Authors Peter M. Rabinowitz and James D. Dziura had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Competing financial interests: The authors declare no conflicts of interest.

Abstract

Background: Little is known about the environmental and public health impact of unconventional natural gas extraction activities including hydraulic fracturing that occur near residential areas.

Objectives: To assess the relationship between household proximity to natural gas wells and reported health symptoms.

Methods: We conducted a hypothesis generating health symptom survey of 492 persons in 180 randomly selected households with ground-fed wells in an area of active natural gas drilling. Gas well proximity for each household was compared to the prevalence and frequency of reported dermal, respiratory, gastrointestinal, cardiovascular, and neurological symptoms.

Results: The number of reported health symptoms per person was higher among residents living <1 km (mean 3.27 ± 3.72) compared with >2 km from the nearest gas well (mean 1.60 ± 2.14, p=0.02). In a model that adjusted for age, gender, household education, smoking, awareness of environmental risk, work type, and animals in house, reported skin conditions were more common in households <1 km compared with >2 km from the nearest gas well (OR= 4.1; 95% CI: 1.4, 12.3; p=0.01). Upper respiratory symptoms were also more frequently reported in persons living in households less than 1 km from gas wells (39%) compared to households 1-2 km or >2 km from the nearest well (31 and 18%, respectively) (p=0.004). No equivalent correlation was found between well proximity and other reported groups of respiratory, neurological, cardiovascular, or gastrointestinal conditions.

Conclusion: While these results should be viewed as hypothesis generating, and the population studied was limited to households with a ground fed water supply, proximity of natural gas wells may be associated with the prevalence of health symptoms including dermal and respiratory

conditions in residents living near natural gas extraction activities. Further study of these associations, including the role of specific air and water exposures, is warranted.

Introduction

Unconventional methods of natural gas extraction, including directional drilling and hydraulic fracturing (also known as "fracking"), have made it possible to reach natural gas reserves in shale deposits thousands of feet underground (Myers 2012). Increased drilling activity in a number of locations in the U.S. has led to growing concern that natural gas extraction activities could lead to contamination of water supplies and ambient air, resulting in unforeseen adverse public health effects (Goldstein et al. 2012). At the same time, there is little peer-reviewed evidence regarding the public health risks of natural gas drilling activities (Kovats et al. 2014; McDermott-Levy and Kaktins 2012; Mitka 2012) including a lack of systematic surveys of human health effects.

The process of natural gas extraction

Natural gas extraction of shale gas reserves may involve multiple activities occurring over a period of months. These include drilling and casing of deep wells that contain both vertical and horizontal components and placement of underground explosives, transport and injection of millions of gallons of water containing sand and a number of chemical additives into the wells at high pressures to extract gas from the shale deposits (hydraulic fracturing) (Jackson et al. 2013a). Chemicals used in the hydraulic fracturing process can include inorganic acids, polymers, petroleum distillates, anti-scaling compounds, microbicides, and surfactants (Vidic et al. 2013). While some of these fluids are recovered during the fracking process as "flow back" or "produced" water, a significant amount (as much as 90%) (Vidic et al. 2013) may remain underground. The recovered flow back water, which may contain both chemicals added to the fracking fluid as well as naturally occurring chemicals such as salts, arsenic and barium as well as naturally occurring radioactive material originating in the geological formations, may be stored in holding ponds or transported offsite for disposal and/or wastewater treatment elsewhere.

Potential water exposures

While much of the hydraulic fracturing process takes place deep underground, there are a number of potential mechanisms for chemicals used in the fracturing process as well as naturally occurring minerals, petroleum compounds (including volatile organic compounds or VOCs), and other substances of flow back water (Chapman et al. 2012) to enter drinking water supplies. These include spills during transport of chemicals and flow back water, leaks of a well casing, (Kovats et al. 2014), leaks through underground fissures in rock formations, runoff from drilling sites, and disposal of fracking flow back water (Rozell and Reaven 2012). Studies have reported increased levels of methane in drinking water wells located less than 1 km from natural gas drilling, suggesting contamination of water wells from hydraulic fracturing activities (Jackson et al. 2013b; Osborn et al. 2011), although natural movement of methane and brine from shale deposits into aquifers has also been suggested (Warner et al. 2012). If contaminants from hydraulic fracturing activities were able to enter drinking water supplies or surface water bodies, humans could be exposed to such contaminants through drinking, cooking, showering, and swimming.

Potential air exposures

The drilling and completion of natural gas wells, as well as the storage of waste fluids in containment ponds, may release chemicals into the atmosphere through evaporation and off-gassing. In Pennsylvania, flow back fluids are not usually disposed of in deep injection wells, and therefore surface ponds containing flow back fluids are relatively common and could be sources of air contamination through evaporation. Flaring of gas wells, operation of diesel equipment and vehicles and other point sources for air quality contamination around drilling activities may also pose a risk of respiratory exposures to nitrogen oxides, volatile organic compounds, and particulate matter. Release of ozone precursors into the environment by natural gas production activities may lead to increases in local ozone levels (Olaguer 2012). Well completion and gas transport may cause leakage of methane and other greenhouse gases into the environment (Allen 2014). Studies in Colorado have reported elevated air levels of volatile organic compounds including trimethylbenzenes, xylenes, and aliphatic hydrocarbons related to well drilling activities (McKenzie et al. 2012).

Human health impact

Concerns about the impact of natural gas extraction on the health of nearby communities have included exposures to contaminants in water and air described above as well as noise and social disruption (Witter et al. 2013). A published case series cited the occurrence of respiratory, skin, neurological and gastrointestinal symptoms in humans living near gas wells (Bamberger and Oswald 2012). A convenience sample survey of 108 individuals in 55 households across 14 counties in Pennsylvania who were concerned about health effects from natural gas facilities found that a number of self-reported symptoms were more common in individuals living near gas facilities, including throat and nasal irritation, eye burning, sinus problems, headaches, skin problems, loss of smell, cough, nosebleeds, and painful joints (Steinzor et al. 2013). Similarly, a convenience sample survey of 53 community members living near Marcellus Shale development found that respondents attributed a number of health impacts and stressors to the development. Stress was the symptom reported most frequently (Ferrar et al. 2013).

We report on the analysis of a cross sectional, random sample survey of the health of residents having ground-fed water wells in the vicinity of natural gas extraction wells to determine whether proximity to gas wells was associated with reported respiratory, dermal, neurological, or gastrointestinal symptoms

Methods

Selection of study area

The Marcellus formation, a principal source of shale-based natural gas in the United States, is a Middle Devonian-age black, low density, organically rich shale which has been predominantly horizontally drilled for gas extraction in the southwestern portion of the State of Pennsylvania since 2003 (PADEP 2013). As a result, this study focused on Washington County in southwestern Pennsylvania, an area of active natural gas drilling (Carter et al. 2011). At the time of the administration of the household survey during summer, 2012, there were, according to the Pennsylvania Department of Environmental Protection, 624 active natural gas wells in Washington County. Of these natural gas wells, 95% were horizontally drilled (PADEP 2012). The county has a highly rural classification with nearly 40% of the land devoted to agriculture (National Agriculture Statistics Service 2007). Washington County has a population of approximately 200,000 persons with 94% self-identified as white, 90% having at least a high school diploma, and a 2012 median household income of $53,545 (Center for Rural Pennsylvania 2014). We selected a contiguous set of 38 rural townships within the center of Washington County as our study site in order to avoid urban areas bordering Pittsburgh, which would be unlikely to have ground-fed water wells, and areas near the Pennsylvania border which might be influenced by gas wells in other states (Figure 1).

Survey instrument

We designed a community environmental health assessment of reported health symptoms and health status based on questions drawn from publicly available surveys. Symptom questions, covering a range of organ systems which had been mentioned in published reports (Bamberger and Oswald 2012; Steinzor et al. 2013), asked respondents whether they or any household members had experienced each condition during the past year (see Supplemental Material, Questionnaire and Table 2). The health assessment also asked a number of general yes/no questions about concerns of environmental hazards in the community, such as whether respondents were satisfied with air quality, water quality, soil quality, and environmental noise and odors and traffic, but did not specifically mention natural gas wells or hydraulic fracturing or other natural gas extraction activities. The survey was pre-tested with focus groups in the study area in collaboration with a community based group and revised to ensure comprehensibility of questions.

Selection and recruitment of households

Using ArcGIS Desktop 10.0 software (ESRI, Inc., Redlands, CA, USA), we randomly selected 20 geographic points from each of 38 contiguous townships in the study county (Figure 1). We identified an eligible home nearest to each randomly generated sampling point, and visited each home to determine which households were occupied and had ground-fed water wells. We selected households with ground-fed water wells in order to assess possible health effects related to water contamination. From the original 760 points identified (i.e. 20 points in each of the 38 townships), we excluded 12 duplicate points and 64 points found not to correspond to a house structure (see Supplemental Material, Figure S1). After site visits by the study team who spoke to residents or neighbors, we excluded house locations determined not to have a ground-fed well or spring. Additional points were excluded if the structure was not occupied (5) or inaccessible from the road (4). During visits to eligible households, a study member invited a responding adult at least 18 years of age to participate in the survey, described as a survey of community environmental health that considered a number of environmental health factors. Three households were excluded when the respondent was unable to answer the questionnaire due to language or health problems. Eligible households were offered a small cash stipend for participation. The Yale University School of Medicine Human Research Protection Program determined the study to be exempt from Human Subjects review. Respondents provided verbal consent but were not asked to sign consent forms; their names were not recorded.

Of the 255 eligible households, respondents refused to complete the survey in 47 households and we were not able to contact residents in another 26 households. Reasons for refusal included “not interested (8), “no time/too busy” (3), “afraid” (1), while 35 gave no reason. The rate of refusal varied by distance category, with 12/74 (16%) of households <1km from a gas well, 10/67 (15%) of households 1-2 km from wells, and 25/86 (25%) of eligible households > 2km from a gas well refusing to participate, but the differences were not statistically significant. At the consenting 180 households (71% of eligible households), an adult respondent completed the survey covering the health status of the 492 individuals living in these households.

Administration of survey at residence

Trained study personnel administered the survey in English. The responding adult at the participating household reported on the health status of all persons in the household over the past year. A study team member recorded the Global Positioning System (GPS) coordinates of the household using a Garmin GPSMAP® 62S Series handheld GPS device (Garmin International, Inc., Olathe, KS, USA). Survey personnel were not aware of the mapping results for gas well proximity to the households being surveyed.

Household proximity to nearest active gas well and age of wells

A map of 624 active natural gas wells in the study area, and their age and type, was created by utilizing gas well permit data publicly available at the Pennsylvania Department of Environmental Protection (PADEP 2013). Ninety five percent of the gas wells had “spud dates” (first date of drilling) between 2008 and 2012, with more than half of spud dates occurring in 2010 and 2011. We used ArcGIS to calculate the distance between each household location (as defined by the GPS reading taken during the site visit) and each natural gas well in the study area. We then classified households according to their distance from the nearest gas well with distance categories of less than 1 km, 1-2 km or greater than 2 km. We used 1 km as the initial cutpoint for distance to a nearest gas well because of the reported association of higher methane levels in drinking water wells located less than 1 km from natural gas wells (Osborn et al. 2011), and 2 km as the second cutpoint since it was close to the mean of the distances between households and nearest gas wells. The mean and median distance between a household and the nearest natural gas well was 2.0 km and 1.4 km respectively. We classified the age of each gas well as the time interval between spud date and the date that the household survey was conducted during summer, 2012.

Statistical analysis

Demographic variables were analyzed for differences among individuals between distance categories using Chi-Square, ANOVA or generalized linear mixed model statistics as appropriate. Reported occupation was classified as either blue collar, office sales and service, management/ professional, or not working, using US Census classifications (Census 2013).

The prevalence of each outcome and the number of symptoms reported for each household member included in the study were calculated according to the distance of each household (<1, 1–2, or >2km) from the nearest gas well. The association between household distance from a well and the overall number of symptoms as well as the presence or absence of each of six groups of health conditions (dermal, upper respiratory, lower respiratory, gastrointestinal, neurological and cardiovascular) was tested using SAS 9.3 in a generalized linear mixed model (GLMM) analysis using maximum likelihood estimation with adaptive quadrature methods (Schabenberger 2007) with a random effect for household to account for the clustering of individuals within a household. The model was adjusted for age of individual (continuous), gender (binary), average adult household education (continuous), smoker present in household (yes/no), awareness of environmental hazard nearby (yes/no), employment type (4 categories), and if animals were present in the home or backyard (yes/no). Given the exploratory nature of this study, no adjustments were made for multiple comparisons and significance was established at the two-sided 0.05 level. Statistical analyses were conducted using SAS 9.3 (SAS Institute, Cary, NC, USA).

Results

Demographics

Individuals living in households <1 km from gas wells were older (mean 46.9 ± 21.9) compared to individuals in households greater than 2 km from a gas well (mean 40.0 ± 23.5 years, p=0.03) (Table 1). There was a higher proportion of children in the households > 2 km from a gas well compared to those <1 km from a gas well (27% vs 14%, p=0.008). Families had lived in their homes an average of 22.8 (± 17.2) years at the time of the interview. Thirty four percent of individuals had blue-collar jobs and 38% of the subjects were non-workers (unemployed, students, etc.). Sixty-six percent reported using their ground-fed water (well or natural spring) for drinking water and 84% reported using it for other activities such as bathing. The age of the nearest gas well was significantly greater for households <1 km from a gas well (mean 2.3 ± 1.6) compared to those 1-2 km or >2km from a well (1.5 ± 1.3, 1.1 ± 0.9, respectively, p <0.05). Reported smoking was less common in households near gas wells, while reported respondent awareness regarding environmental health risks was higher, although these differences were not statistically significant.

Reported health symptoms

The average number of reported symptoms per person in residents of households <1 km from a gas well (3.27 ± 3.72) was greater compared to those living >2 km from gas wells (1.60 ± 2.14, p = 0.001).

Individuals living in households less than 1 km or 1-2 km from natural gas wells were more likely to report having any of the queried skin conditions over the past year (13%) than residents of households > 2 km from a well (3%, χ^2=13.8, p=0.001) (Table 2). Reported upper respiratory symptoms were also more frequent among households <1km (39%) compared to household > 2 km from gas wells (18%, χ^2=17.9, p=0.0001).

In a hierarchical model that adjusted for age, gender, household education level, smokers in household, job type, animals in household, and awareness of environmental risk (Table 3), household proximity to natural gas wells remained associated with number of symptoms reported per person <1 km (p=0.002) and 1-2 km (p=0.05) as compared to >2 km from gas wells, respectively. In similar models, living in a household <1 km from the nearest gas well remained associated with increased reporting of skin conditions (OR= 4.13; 95% CI: 1.38, 12.3) and upper respiratory symptoms (OR= 3.10; 95% CI: 1.45, 6.65) compared to households > 2 km from the nearest gas well.

For the other grouped symptom complexes examined, there was not a significant relationship in our adjusted model between the prevalence of symptom reports and proximity to nearest gas well. In the multivariate model, environmental risk awareness was, however, significantly associated with report of all groups of symptoms.

Age of the nearest gas well was found to be negatively correlated with distance (r=-0.325, p<0.0001), meaning that gas wells less than 1 km from households tended to be older than the nearest wells in other distance categories. When age of wells was added to the multivariate model, proximity to gas wells remained significantly associated with respiratory symptoms but the association between proximity and dermal symptoms lost statistical significance.

Discussion

This spatially random health survey of households with ground-fed water supply in a region with a large number of active natural gas wells, to our knowledge the largest study to date of the association of reported symptoms and natural gas drilling activities, found an increased frequency of reported symptoms over the past year in households in closer proximity to active gas wells compared to households farther from gas wells. This association was also seen for certain categories of symptoms, including skin conditions and upper respiratory symptoms. This association persisted even after adjusting for age, gender, smokers in household, presence of animals in the household, education level, work type, and awareness of environmental risks. Other groups of reported symptoms, including cardiac, neurological, or gastrointestinal symptoms, did not show a similar association with gas well proximity. These results support the need for further investigation of whether natural gas extraction activities are associated with community health impacts.

These findings are consistent with earlier reports of respiratory and dermal conditions in persons living near natural gas wells (Bamberger and Oswald 2012; Steinzor et al. 2013). Strengths of the study included the larger sample size compared to previously published surveys, and the random method of selecting households using GIS methodology which reduces the possibility of selection bias (although only a subset of households, those with ground-fed water supply, were sampled).

A limitation of the study was the reliance on self-report of health symptoms. On the one hand, symptoms in other household members may have been under-reported by the household respondent; on the other hand, awareness bias in individuals concerned about the presence of an environmental health hazard would be more likely to increase reporting of illness symptoms, leading to recall bias of the results. We did not collect data on whether individuals were receiving financial compensation for gas well drilling on their property, which could have affected their willingness to report symptoms. It is possible that differential refusal to participate could have introduced potential for selection bias, such as individuals who were receiving compensation for gas drilling on their property potentially being less willing to participate in the survey. We found instead that the refusal rate, while less than 25% overall, was higher among households farther from gas wells, suggesting that such households may have been less interested in participating due to lesser awareness of hazards. The study questionnaire did not include questions about natural gas extraction activities, in order to reduce awareness bias. At the same time, it is likely that household residents were aware of gas drilling activities in the vicinity of households, and the fact that reported environmental awareness by respondents was associated with the prevalence of all groups of reported health symptoms suggests a correlation between heightened awareness of health risks and reported health conditions. Nevertheless, the observed association between gas well proximity and reported dermal and upper respiratory symptoms persisted in the multivariate model even after adjusting for environmental awareness. Future studies should attempt to medically confirm particular diagnoses and further assess and control for the effect of awareness on reported health status.

A further study limitation was the fact that our analysis includes multiple comparisons between groups of households, and the consequent possibility that random error could account for some of our findings. We limited such comparisons by grouping individual symptoms into organ system clusters. However, we acknowledge that the multiple comparisons used in the methodology mean that any such particular findings should be viewed as preliminary and hypothesis generating.

Our use of gas well proximity as a measure of exposure was an indirect measure of potential water or airborne exposures. More precise data could come from direct monitoring and modeling of air and water contaminants, and correlating such measured exposures with confirmed health effects should be a focus of future study. Biomonitoring of individuals living near natural gas wells could provide additional information about the role and extent of particular chemical exposures.

There are several potential explanations for the finding of increased skin conditions among inhabitants living near gas wells. One is that natural gas extraction wells could have caused contamination of well water through breaks in the gas well casing or other underground communication between ground water supplies and fracking activities. The geographic area studied has experienced petroleum and coal exploration and extraction activities in the past century, and such activities may increase the risk of chemicals in fracking fluid or flow back water entering ground water and contaminating wells. If such contamination did occur, a number of types of chemicals in fracking fluid have irritant properties and could potentially cause skin rashes or burning sensation through exposure during showers or baths. There are published reports of associations between the prevalence of eczema and other skin conditions with exposure to drinking water polluted with chemicals including volatile organic compounds (Chaumont et al. 2012; Lampi et al. 2000; Yorifuji et al. 2012), as well as changes in water hardness (Chaumont et al. 2012; McNally et al. 1998).

A second possible explanation for the skin symptoms could be exposure to air pollutants including volatile organic compounds, particulates, and ozone from upwind sources, such as flaring of gas wells (McKenzie et al. 2012) and exhaust from vehicles and heavy machinery.

A third possibility to explain the clustering of skin and other symptoms would be that they could be related to stress or anxiety that was greater for households living near gas wells. In this study, awareness of environmental risk was independently associated with overall reporting of symptoms as well as reporting of skin problems. However, in multivariate models, proximity to gas wells remained a significant predictor of symptoms even when adjusting for such awareness. These results argue for possible air or water contaminant exposures, in addition to stress, contributing to the observed patterns of increased health symptoms in households near gas wells.

A fourth possibility would be the role of allergens or irritant chemicals not related to natural gas drilling activities, such as exposure to agricultural chemicals or household animals. We did not see a correlation between skin conditions and either the presence of an animal in the household or agricultural occupation, making this association less likely. At the same time, it is possible that other confounding could be present but not accounted for in our models.

Our findings of increased reporting of upper respiratory symptoms among persons living <1 km from a natural gas well suggests that airborne irritant exposures related to natural gas extraction activities could be playing a role. Such irritant exposures could result from a number of activities related to natural gas drilling, including flaring of gas wells and exhaust from diesel equipment. Since other studies have suggested that airborne exposures could be a significant consequence of natural gas drilling activity, further investigation of the impact of such activities on respiratory health of nearby communities should be investigated. Future studies should collect such data.

Since the majority of the gas wells in the study area had been drilled in the past 5-6 years, one would not yet expect to see associations with diseases with long latency, such as cancer. Furthermore, if some of the impact of natural gas extraction on ground water happens over a number of years, this initial survey could have failed to detect health consequences of delayed contamination. However, if the finding of skin and respiratory conditions near gas wells indicates significant exposure to either fracking fluids and chemicals or airborne contaminants from natural gas wells, studies looking at such long term health effects in chronically exposed populations would be indicated.

Conclusions

The results of this study suggest that natural gas drilling activities could be associated with increased reports of dermal and upper respiratory symptoms in nearby communities and support the need for further research into health effects of natural gas extraction activities. Such research could include longitudinal assessment of the health of individuals living in proximity to natural gas drilling activities, medical confirmation of health conditions, and more precise assessment of contaminant exposures.

References

Allen DT. 2014. Atmospheric emissions and air quality impacts from natural gas production and use. Annual review of chemical and biomolecular engineering: Annu Rev Chem Biomol Eng. Available: http://www.annualreviews.org/doi/abs/10.1146/annurev-chembioeng-060713-035938 [accessed 3/12/2014].

Bamberger M, Oswald RE. 2012. Impacts of gas drilling on human and animal health. New solutions : a journal of environmental and occupational health policy : NS 22:51-77.

Carter KM, Harper JA, Schmid KW, Kostelnik J. 2011. Unconventional natural gas resources in Pennsylvania: The backstory of the modern marcellus shale play. Environmental Geosciences 18:217-257.

Chapman EC, Capo RC, Stewart BW, Kirby CS, Hammack RW, Schroeder KT, et al. 2012. Geochemical and strontium isotope characterization of produced waters from marcellus shale natural gas extraction. Environmental Science & Technology 46:3545-3553.

Chaumont A, Voisin C, Sardella A, Bernard A. 2012. Interactions between domestic water hardness, infant swimming and atopy in the development of childhood eczema. Environmental Research 116:52-57.

Center for Rural Pennsylvania. 2014. Demographics for Washington county. Available: http://www.ruralpa2.org/county_profiles.cfm [accessed 07/29/2014].

Ferrar KJ, Kriesky J, Christen CL, Marshall LP, Malone SL, Sharma RK, et al. 2013. Assessment and longitudinal analysis of health impacts and stressors perceived to result from unconventional shale gas development in the Marcellus shale region. International Journal of Occupational and Environmental Health 19:104-112.

Goldstein BD, Kriesky J, Pavliakova B. 2012. Missing from the table: Role of the environmental public health community in governmental advisory commissions related to marcellus shale drilling. Environ Health Perspect 120:483-486.

Jackson RE, Gorody AW, Mayer B, Roy JW, Ryan MC, Van Stempvoort DR. 2013a. Groundwater protection and unconventional gas extraction: The critical need for field-based hydrogeological research. Ground Water 51:488-510.

Jackson RB, Vengosh A, Darrah TH, Warner NR, Down A, Poreda RJ, et al. 2013b. Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction. Proceedings of the National Academy of Science USA 110: 11250-11255.

Kovats S, Depledge M, Haines A, Fleming LE, Wilkinson P, Shonkoff SB, et al. 2014. The health implications of fracking. The Lancet 383:757-758.

Lampi P, Vohlonen I, Tuomisto J, Heinonen OP. 2000. Increase of specific symptoms after long-term use of chlorophenol polluted drinking water in a community. Eur J Epidemiol 16:245-251.

McDermott-Levy R, Kaktins N. 2012. Preserving health in the Marcellus region. The PA Nurse 67:4-10; quiz 11-12.

McKenzie LM, Witter RZ, Newman LS, Adgate JL. 2012. Human health risk assessment of air emissions from development of unconventional natural gas resources. Science of the Total Environment 424:79-87.

McNally NJ, Williams HC, Phillips DR, Smallman-Raynor M, Lewis S, Venn A, et al. 1998. Atopic eczema and domestic water hardness. The Lancet 352:527-531.

Mitka M. 2012. Rigorous evidence slim for determining health risks from natural gas fracking. JAMA 307:2135-2136.

Myers T. 2012. Potential contaminant pathways from hydraulically fractured shale to aquifers. Ground Water 50:872-882.

National Agriculture Statistics Service. 2007. Census of agriculture. Available: http://www.agcensus.usda.gov/index.php [accessed 01/10/2014].

National Resources Conservations Service. 2013. Web soil survey. Available: http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm [accessed 01/07/2014].

Olaguer EP. 2012. The potential near-source ozone impacts of upstream oil and gas industry emissions. Journal of the Air & Waste Management Association 62:966-977.

Osborn SG, Vengosh A, Warner NR, Jackson RB. 2011. Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. Proceedings of the National Academy of Sciences 108:8172-8176.

PADEP (Pennsylvania Department of Environmental Protection), 2012. PA Department of Environmental Protection oil & gas reporting website. Available: https://www.paoilandgasreporting.state.pa.us/publicreports/Modules/DataExports/DataExports.aspx [accessed Jan 12, 2012].

PADEP. 2013. Coal mining operations. Available: http://www.pasda.psu.edu/ [accessed 10/12/2012].

Rozell DJ, Reaven SJ. 2012. Water pollution risk associated with natural gas extraction from the marcellus shale. Risk analysis : an official publication of the Society for Risk Analysis 32:1382-1393.

Schabenberger, O. 2007. Growing Up Fast: SAS 9.2 Enhancements to the GLIMMIX Procedure. Paper 177-2007, SAS Global Forum 2007, SAS Institute, Cary, NC.

Steinzor N, Subra W, Sumi L. 2013. Investigating links between shale gas development and health impacts through a community survey project in pennsylvania. New Solutions 23:55-83.

US Census (United States Census), 2014. 2010 Census Occupational Classification. Available: http://www.bls.gov/cps/cenocc2010.htm [accessed 31 July 2014].

Vidic RD, Brantley SL, Vandenbossche JM, Yoxtheimer D, Abad JD. 2013. Impact of shale gas development on regional water quality. Science 340:1235009.

Warner NR, Jackson RB, Darrah TH, Osborn SG, Down A, Zhao K, et al. 2012. Geochemical evidence for possible natural migration of marcellus formation brine to shallow aquifers in pennsylvania. Proceedings of the National Academy of Sciences of the United States of America 109:11961-11966.

Witter RZ, McKenzie L, Stinson KE, Scott K, Newman LS, Adgate J. 2013. The use of health impact assessment for a community undergoing natural gas development. American Journal of Public Health 103:1002-1010.

Yorifuji T, Noguchi M, Tsuda T, Suzuki E, Takao S, Kashima S, et al. 2012. Does open-air exposure to volatile organic compounds near a plastic recycling factory cause health effects? Journal of Occupational Health 54:79-87.

Table 1. Demographics and Household Characteristics by Proximity to the Nearest Natural Gas Well.

Characteristics	< 1 Km	1-2 Km	> 2 Km	All
Individuals				
Number	150	150	192	492
Gender [n(%)]				
Male	80 (53)	78 (52)	92 (48)	250 (51)
Female	70 (47)	72 (48)	100 (52)	242 (49)
Children [n (%)]	21 (14) *	27 (18)	52 (27)	100 (20)
Education (mean years ± SD)	13.4 ± 2.0	13.5 ± 1.9	13.3 ± 2.0	13.4 ± 1.9
Age (mean years ± SD)	46.9 ± 21.9**	45.5 ± 22.7	40.0 ± 23.5	43.8 ± 23.0
Occupation [n (%)][a]				
M/P	29 (19)	34 (23)	33 (17)	96 (19)
O/S	17 (11)	11 (7)	14 (7)	42(9)
BC	60 (40)	51 (34)	56 (29)	167 (34)
NW	44 (29)	54 (36)	89 (46)	187 (38)
Households				
Number	62	57	61	180
Smoking [n (%)][b]	7 (11)	12 (21)	14 (23)	33 (18)
Years in household	23.7 ± 16.6	23.5 ± 16.4	21.2 ± 18.6	22.8 ± 17.2
Body mass index (mean Kg/m^2 ± SD)	27.9 ± 5.1	27.5 ± 5.4	27.9 ± 6.1	27.8 ± 5.5
Use ground-fed water [n (%)]				
Drinking	39 (63)	41 (72)	38 (62)	118 (66)
Other	54 (87)	51 (89)	46 (75)	151 (84)
Water has unnatural appearance [n (%)]	13 (21)	7 (12)	6 (10)	26 (14)
Taste/odor prevents water use [n (%)]	14 (23)	10 (23)	19 (31)	43 (24)
Dissatisfied w/ odor in environment [n (%)]	7 (11)	1 (2)	1 (2)	9 (5)
Environmental risk awareness [n (%)][c]	16 (25)	16 (28)	9 (15)	41 (23)
Years since spud date of closest well (mean years ± SD)	2.3 ± 1.6 ***	1.5 ± 1.3	1.1 ± 0.9	1.6 ± 1.4

[a]Participant occupation was categorized into six main industries according to the U.S. Census system, and presented here in four main groups: M/P—management or professional; O/S—office, sales, or service; BC—blue collar (fishing, farming, and forestry; construction, extraction, maintenance, production, transportation, and material moving); NW—non worker (student, disabled, retired, or unemployed). [b]Household smoking was determined when respondents were asked if they or at least one member of their household smoked cigarettes in the house at the time of the survey. [c]Household respondents were asked if they were aware of any environmental health risks near their residence (yes / no), to approximate potential sources of expectation or awareness bias.

*p=0.008 compared to Over 2 km households.

**p=0.03 compared to Over 2 km households.

***p < 0.05 compared to 1-2 KM and Over 2 KM households.

Table 2. Prevalence of Selected Health Conditions Reported by Individuals by Proximity to the Nearest Gas Well (2011-2012).[a]

Symptoms	< 1 Km (N = 150)	1-2 Km (N = 150)	> 2 Km (N = 192)
Total number of symptoms per individual	3.27 ± 3.72	2.56 ± 3.26	1.60 ± 2.14
Dermal [n (%)]	19 (13)	7 (5)	6 (3)
Rashes/skin problems	10 (7)	7 (5)	6 (3)
Dermatitis	6 (4)	5 (3)	2 (1)
Irritation	6 (4)	2 (1)	1 (1)
Burning	8 (5)	4 (3)	1 (1)
Itching	9 (6)	5 (3)	2 (1)
Hair loss	2 (1)	0 (0)	1 (1)
Upper respiratory [n (%)]	58 (39)	46 (31)	35 (18)
Allergies/sinus problems	35 (23)	27 (18)	27 (14)
Cough/sore throat	10 (7)	3 (2)	2 (1)
Itchy eyes	19 (13)	22 (15)	10 (5)
Nose bleeds	13 (9)	8 (5)	4 (2)
Stuffy nose	16 (11)	8 (5)	4 (2)
Lower respiratory [n (%)]	29 (19)	29 (19)	27 (14)
Asthma/COPD	16 (11)	21 (14)	15 (8)
Chronic bronchitis	8 (5)	2 (1)	2 (1)
Chest wheeze/whistling	6 (4)	9 (6)	7 (4)
Shortness of breath	8 (5)	7 (5)	8 (4)
Chest tightness	4 (3)	6 (4)	5 (3)
Cardiac [n (%)]	46 (31)	39 (26)	37 (19)
High blood pressure	38 (25)	33 (22)	29 (15)
Chest pain	8 (5)	5 (3)	6 (3)
Heart palpitations	10 (7)	7 (5)	4 (2)
Ankle swelling	11 (7)	5 (3)	5 (3)
Gastrointestinal [n (%)]	15 (10)	13 (9)	11 (6)
Ulcers/stomach problems	11 (7)	7 (5)	8 (4)
Liver problems	4 (3)	0 (0)	1 (0.5)
Nausea/vomiting	1 (1)	3 (2)	1 (0.5)
Abdominal pain	4 (3)	2 (1)	2 (1)
Diarrhea	5 (3)	2 (1)	2 (1)
Bleeding	4 (3)	4 (3)	0 (0)
Neurologic [n (%)]	48 (32)	37 (25)	39 (20)
Neurologic problems	1 (0.7)	5 (3)	0 (0)
Severe headache/migraine	24 (16)	14 (9)	18 (9)
Dizziness/balance problems	11 (7)	12 (8)	11 (6)
Depression	4 (3)	3 (2)	2 (1)
Difficulty concentrating/remembering	9 (6)	9 (6)	6 (3)
Difficulty sleeping/insomnia	18 (12)	19 (13)	10 (5)
Anxiety/nervousness	11 (7)	4 (3)	11 (6)
Seizures	2 (1)	2 (1)	1 (0.5)

[a]Six categories representing major health conditions of *a priori* interest chosen to ascertain symptom prevalence amongst individuals living in proximity to the nearest gas well in 2011-2012.

Table 3. Associations of nearest gas well proximity and symptoms.[a]

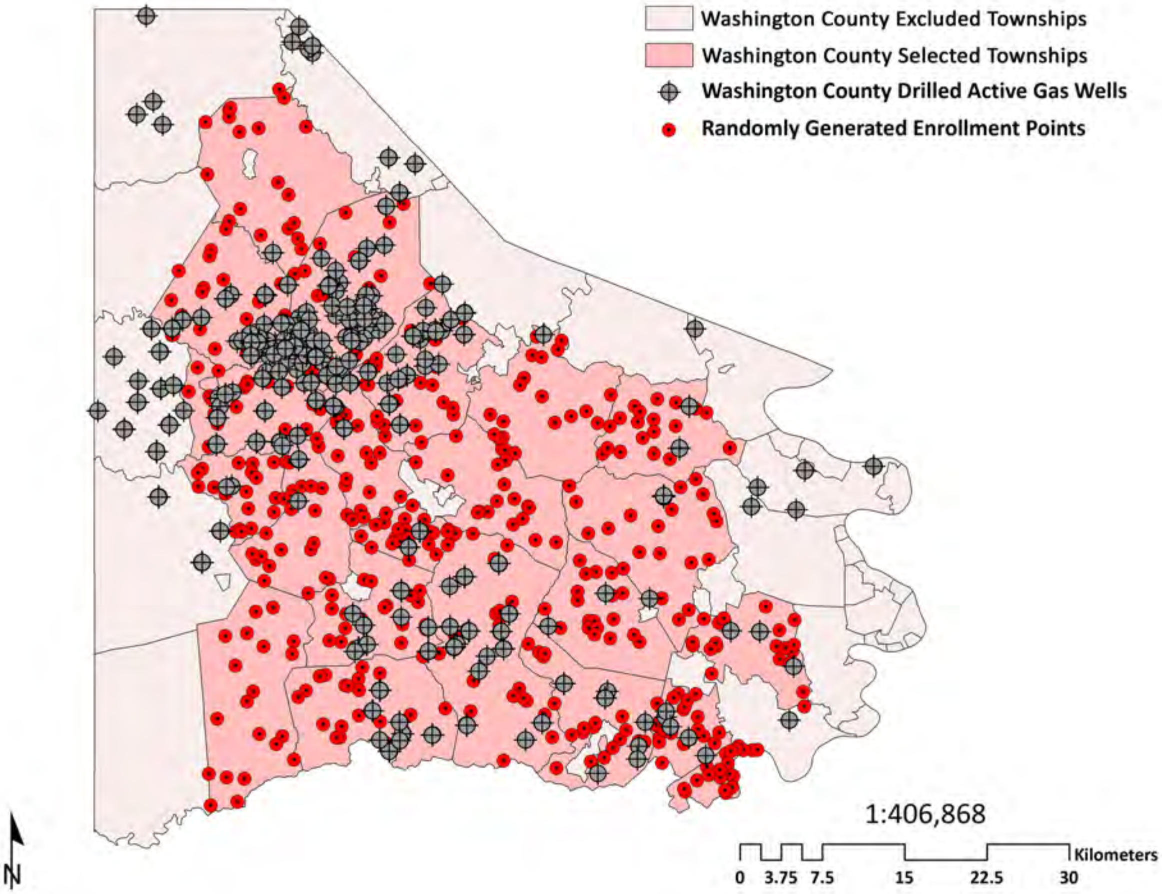
Outcome	< 1 Km OR (95% CI)	*P*-value	1–2 Km OR (95% CI)	*P*-value	> 2 Km
Dermal	4.13 (1.38, 12.3)	0.011	1.44 (0.42, 4.9)	0.563	Ref
Upper respiratory	3.10 (1.45, 6.65)	0.004	1.76 (0.81, 3.76)	0.148	Ref
Lower respiratory	1.45 (0.67, 3.14)	0.339	1.40 (0.65, 3.03)	0.387	Ref
Cardiac	1.67 (0.85, 3.26)	0.135	1.28 (0.65, 2.52)	0.473	Ref
Gastrointestinal	2.01 (0.49, 8.18)	0.328	1.79 (0.43, 7.41)	0.417	Ref
Neurological	1.53 (0.89, 2.63)	0.123	1.04 (0.59, 1.82)	0.885	Ref

[a]Results from hierarchical logistic regression that adjusted for age, household education level, gender, smokers in household, job type, animals in household, and awareness of environmental risk

Figure Legend

Figure 1. Distribution of Drilled Active Marcellus Shale Natural Gas Wells (N=624) and Randomly Generated Sampling Sites (N=760) for Eligible Municipalities of Washington County, Pennsylvania, USA.

Figure 1.



Washington County Excluded Townships
Washington County Selected Townships
Washington County Drilled Active Gas Wells
Randomly Generated Enrollment Points
1:406,868
0
3.75
7.5
15
22.5
30
Kilometers
N

Exhibit 22

POINT OF VIEW

Gas drilling in Dimock, PA

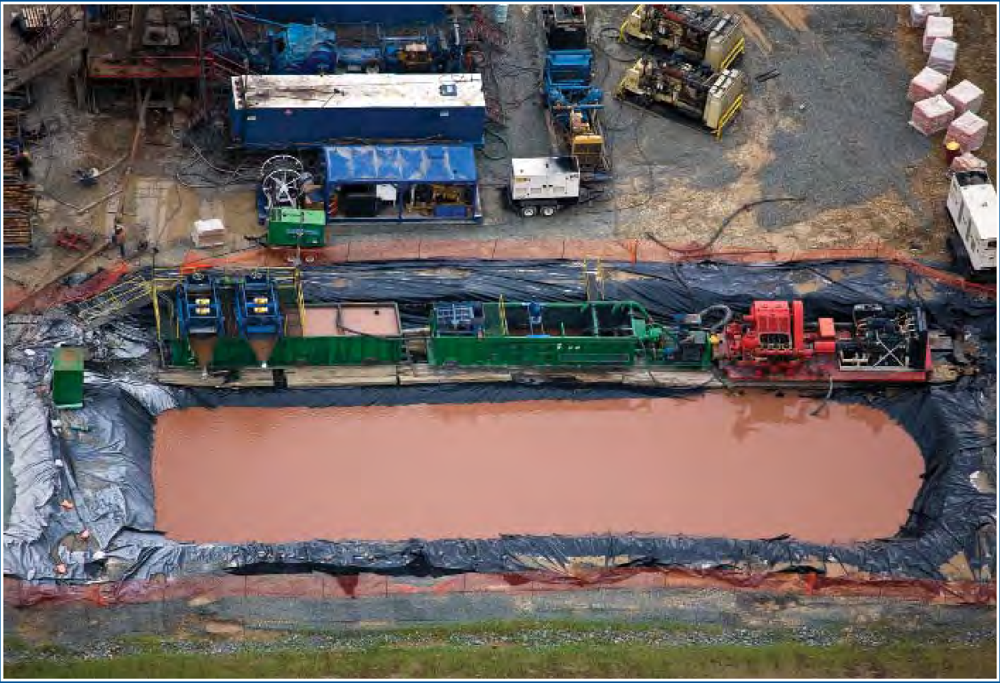
Homeowners and Gas Drilling Leases: Boon or Bust?

By Elisabeth N. Radow

The Conundrum

Gas companies covet the shale gas deposits lying under homes and farms in New York's Marcellus Shale region and are pursuing leasing agreements with area property owners. Many homeowners and farmers in need of cash are inclined to say yes. In making their argument, gas companies reassure property owners that the drilling processes and chemicals used are safe. Yet aside from arguments about the relative safety of the extraction process are issues not often discussed, such as the owner's potential liability and the continued viability of the mortgage. The property owner can be particularly vulnerable when the drilling process involves high-volume, horizontal hydraulic fracturing, or "fracking."

For example, when Ellen Harrison signed a gas lease agreement in 2008, the company representative made no mention of fracking. Harrison received no details, only the chance for a "win-win" with "clean" gas for the locals and royalties for her. Like most Americans, Harrison has a mortgage loan secured by her home. All mortgages, Harrison's included, prohibit hazardous activity and hazardous substances on the property.

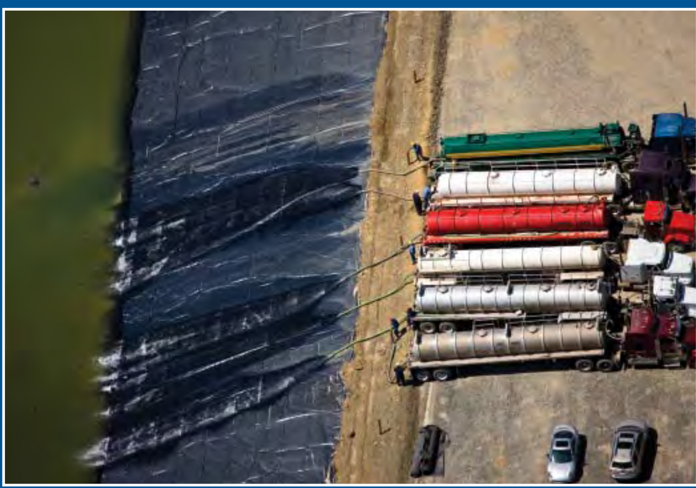


Waste pond at hydro-fracking drill site, Dimock, PA

Elisabeth N. Radow (eradow@cuddyfeder.com) is Special Counsel to the White Plains law firm of Cuddy & Feder LLP. Ms. Radow chairs the Hydraulic Fracturing Committee for the League of Women Voters of New York State. Ms. Radow's Law Note, *Citizen David Tames Gas Goliaths on the Marcellus Shale Stage*, was published in the 2010 Spring issue of the *Cardozo Journal of Conflict Resolution*. This analysis and the assertions made in this article are attributable to the author alone.

Photographs courtesy of J Henry Fair. Mr. Fair's work has appeared in the *New York Times, Vanity Fair, Time and National Geographic*. His new book, *The Day After Tomorrow: Images of Our Earth In Crisis* is a series of essays and startling images. www.industrialscars.com.

Flight services provided by LightHawk http://www.lighthawk.org.



Tanker trucks filling water reservoir at hydo-fracking gas drilling operations near Sopertown, Columbia Township, PA

Overspray of drilling slurry at hydro-fracking drill site, Dimock, PA

Residential fracking carries heavy industrial risks, and the ripple effects could be tremendous. Homeowners can be confronted with uninsurable property damage for activities that they cannot control. And now a growing number of banks won't give new mortgage loans on homes with gas leases because they don't meet secondary mortgage market guidelines. New construction starts, the bellwether of economic recovery, won't budge where residential fracking occurs since construction loans depend on risk-free property and a purchaser. This shift of drilling risks from the gas companies to the housing sector, homeowners and taxpayers creates a perfect storm begging for immediate attention.

> A home represents a family's most valuable asset, financially and otherwise.

The introduction of fracking in homeowners' backyards presents a divergence from typical current land use practice, which separates residential living from heavy industrial activity, and the gas leases allocate rights and risks between the homeowner and gas company-lessee in uncharacteristic ways. Also, New York's compulsory integration law can force neighbors who do not want to lease their land into a drilling pool, which can affect their liability and mortgages as well.

The Marcellus Shale Region

The Marcellus Shale region, located across New York's Southern Tier, represents a portion of one of America's largest underground shale formations, with accessibility to gas deposits ranging from ground surface to more than a mile deep. The decade-old combined use of horizontal drilling and high-volume hydraulic fracturing is the current proposed means of extracting the trapped shale gas. Horizontal drilling, which dates back to 1929, became widely used in the 1980s, with the current technology providing lateral access to mile-deep shale in multiple directions from a single well pad.

To envision what this looks like, imagine one well pad that accommodates eight or more vertical wells with each well engineered to extend a mile or more in depth then turn and drill horizontally in its own direction, up to a mile through shale across residential properties and farms owned by a cluster of neighboring residents. High-volume hydraulic fracturing, first introduced by Halliburton in 1949, mixes millions of gallons of water with sand, brine and any of a number of undisclosed chemicals, which are injected into the well bore at pressure sufficient to rupture open the formation, prop open the mile-deep shale fractures with sand and release the trapped gas back into the well. Fracking-produced wastewater, with concentrated levels of these toxic chemicals, drilling mud, bore clippings and naturally occurring radioactive material, such as uranium, radium 226 and radon, is released from the well into mud pits and holding tanks, then trucked out for waste treatment or reused. Reuse of frack fluid, currently the favored practice because it spares the finite water supply, concentrates the waste toxicity. The Environmental Protection Agency estimates that 20%–40% of the fracking wastewater stays underground. The Marcellus Shale sits amid an intricate network of underground aquifers that supply drinking water in New York and surrounding states via municipal water supplies, private wells and springs. Shallow private wells constitute the primary source of drinking water for the upstate New York residences and farms where fracking for shale gas would take place, posing a cumulative threat to the state's complex matrix of aquifers that source our groundwater.

The Risks

The use of fracking expanded in 2005 when Congress exempted it through statutory amendments from complying with decades-old federal environmental laws governing safe drinking water and clean air. (This exemption is now commonly known as the Halliburton loophole.) Also in 2005, New York changed its compulsory integration law to pave the way for fracking.

According to the 2010 Form 10-Ks of Chesapeake Energy and Range Resources (both doing business in the Marcellus Shale region), natural gas operations are subject to many risks, including well blow-outs, craterings, explosions, pipe failures, fires, uncontrollable flows of natural gas or well fluids, formations with abnormal pressures and other environmental hazards and risks. Drilling operations, according to Chesapeake, involve risks from high pressure and mechanical difficulties such as stuck pipes, collapsed casings and separated cables. If any of these hazards occur it can result in injury or loss of life, severe damage or destruction of property, natural resources and equipment, pollution or other environmental damage and clean-up responsibilities,[1] all in the homeowner's backyard.

American culture traditionally favors land use that keeps heavy industrial activity out of residential neighborhoods. The reasons range from safety to aesthetics. A home represents a family's most valuable asset, financially and otherwise. In legal terms, homeownership or "fee simple absolute title" means a bundle of rights encompassing the air space above and the ground below the land surface. It entitles homeowners to build up and out, pledge the house and land as collateral for a mortgage loan, and lease or sell the property. Part of a home's purchase price pays for this bundle of rights. Another bundle of rights attributable to homeownership

Continued on Page 14

Do you want to have a baby?

We can help.

You've worked long and hard to get to the top of your profession. You've put your career first. Now, you want to start a family. The doctors and staff at the Center for Reproductive Medicine offer the most advanced and effective treatments to help you achieve that dream. With multiple offices located conveniently for patients in the tri-state area, we offer comprehensive and compassionate care. For more than two decades we've made your desire to build a family our main priority. If you or someone you know has been struggling to have a baby, contact us at **(646) 962-CRMI** or visit us on the web at **www.ivf.org**.

We accept **UnitedHealthcare** and **Oxford Health** plans for most fertility treatments.

The Ronald O. Perelman and Claudia Cohen
CENTER FOR REPRODUCTIVE MEDICINE
of Weill Cornell Medical College

New York 646·962·2764 | **Garden City** 516·742·4100 | **Westchester** 914·242·3700 | **Flushing** 646·962·5626

Turning Patients into Parents

Weill Cornell Medical College

NewYork-Presbyterian
Weill Cornell Medical Center

www.ivf.org

Continued from Page 12

consists of the actual roof over one's head; clean, running water; and access to utilities. A third bundle of rights is attributable to the intangibles that make a house a home, such as peaceful sanctuary, fresh air, and a safe, secure haven for budding children. Residential fracking challenges all of these attributes of home ownership.

Shifting Risk

Gas leases provide the bundle of rights from which gas companies generate financing and operate gas wells. Profitable gas *extraction* benefits from broad rights to access, extract, store and transport the gas, on the company's timetable. Gas leases contain these rights. Profitable gas *investment* benefits from latitude on timing of gas extraction and the latitude not to extract gas at all. Gas leases contain these rights too. The gas company has the sole discretion to drill, or not to drill. Leases provide the currency in trade. The longer the lease term, the more latitude a leaseholder has to manage market fluctuations. With its broad gas storage rights, a leaseholder can store gas from other sources, on-site and wait for the demand curve to peak before executing the most favorable transactions. In August 2011, the U.S. Geologic Survey estimated reserves of "technically recoverable" shale in the Marcellus Shale play at 84 trillion cubic feet, reflecting a significant reduction from DEC's long-standing website estimate of between 168 trillion and 516 trillion cubic feet. Shale gas projections have an inherent value, separate and apart from the extracted gas. People invest capital based on the anticipated reserves. Time will tell how the new estimates change if and where gas companies actually drill in New York. Some regions may be too difficult or expensive to access; others will be off-limits by law. The terms of the gas leases nevertheless entitle the gas lessee to maintain the leasehold, which can facilitate investor activity. The Form 10-K appended to the 2010 Chesapeake Energy Annual Report states,

> Recognizing that better horizontal drilling and completion technologies, when applied to new unconventional plays, would likely create a unique opportunity to capture decades worth of drilling opportunities, we embarked on an aggressive lease acquisition program, which we have referred to as the "gas shale land grab" of 2006 through 2008 and the "unconventional oil land grab" of 2009 and 2010. We believed that the winner of these land grabs would enjoy competitive advantages for decades to come as other companies would be locked out of the best new unconventional resource plays in the U.S. We

Hydro-fracking drill sites, feeder pipelines, and access roads and gravel banks for road building (Dimock, PA)

> believe that we have executed our land acquisition strategy with particular distinction. At December 31, 2010, we held approximately 13.2 million net acres of onshore leasehold in the U.S. and have identified approximately 38,000 drilling opportunities on this leasehold. We believe this extensive backlog of drilling, more than ten years worth at current drilling levels, provides unmistakable evidence of our future growth capabilities.[2]

The broad bundle of rights granted by gas leases enables gas companies to raise capital in the millions or billions of dollars once the up-front per-acre signing bonus is paid to the homeowner. This is beneficial for the drilling investment itself and for maintaining the company's competitive advantage. On the other hand, the effect of the lease encumbering the homeowner's residence can have repercussions for mortgage financing, as will be discussed below.

Getting the Gas

Drilling companies derive the right to drill underneath residential (and non-residential) property in three ways:

- deed to the subsurface rights below the fee estate (a practice not typically used in New York);
- lease agreement with the fee owner; and
- compulsory integration, which involves government action that forces a property owner who wishes no drilling activity below its property into a drilling pool if the lessee otherwise has control of a statutorily prescribed percentage of land (in New York it is 60%).

A drilling application submitted to DEC must show the area (up to 640 aces), known as a spacing unit, assigned to the well. The spacing unit becomes officially established when DEC issues the well permit.

Deed to Subsurface Rights

A deed to the subsurface or mineral rights splits the fee estate between the surface property and the subsurface property, with separate deeds for each estate. Subsurface deeds are common in Western states where drilling is an established practice; it gives the deed holder the full range of rights to the subsurface. As with the surface deed, it is considered a real property interest and is also recorded in the land records against the section, block and lot for the surface property. The rights do not extend above the subsurface and should not, as a legal matter, interfere with the rights of the surface owner. As a practical matter, because of drilling lifecycle hazards, the surface owner may sacrifice some of the attributes of home ownership discussed in this article.

Standard Lease Agreement With Fee Owner

The standard space lease, between a building owner (landlord or lessor) and a tenant (or lessee) grants the right to occupy a specified space in the building for a finite time, in exchange for an agreed upon rent payable in regular installments. If the lease contains a percentage rent (a commercial lease concept based upon tenant revenue), it includes a formula for calculating the percentage rent and gives the landlord the right to inspect the tenant's books to verify that the landlord receives the agreed upon percentage. Except for the space leased to the tenant, the landlord retains all rights of ownership. When the lease expires, the tenant moves out, or the tenancy converts to a month-to-month tenancy. No duration of month-to-month holding over on the tenant's part converts the month-to-month arrangement into a lease for years. To end the relationship, either the landlord or tenant can give 30 days' written notice to the other.[3] To extend beyond the month-to-month relationship, the parties must enter into a new written lease.

In contrast, gas leases function more like a deed with a homeowner indemnity than a space lease – revealed by an assessment of the cumulative impact of the broad bundle of rights granted to the gas company-lessee and the corresponding bundle of rights relinquished by the homeowner. Standard pre-printed gas leases presented to New York homeowners by landmen and signed, *without negotiation*, represent the typical practice (until recently) in our state, and will be used here to illustrate the impact this has on the of rights and responsibilities of the homeowner. Depending upon the DEC's ultimate regulatory framework, homeowners who negotiate gas leases can expect similar impacts given the industrial sized risks involved.

The Use

A gas lease grants the right to extract the gas and a litany of related gas-constituents; it also grants the right to explore, develop, produce, measure and market for production from the leasehold and adjoining lands using methods and techniques which are not restricted to current technology.

The Space

In a standard gas lease, the physical leased space consists of the subsurface area within the property boundaries and undesignated portions of the surface lands

> to set up and store drilling equipment; create a surface right of way to use or install roads, electric power and telephone facilities, construct underground pipelines and so-called "appurtenant facilities," including data acquisition, compression and collection facilities for use in the production and transportation of gas products to, from and across the leased property; and store any kind of gas underground, regardless of the source, including the injecting of gas, protecting and removing gas, among other things.

The lessee's expansive, undesignated, reserved surface rights can result in acres going to support the operation, jeopardize a home mortgage and eliminate the homeowner's ability to build on the surface in areas the lessee determines would interfere with drilling operations. Without limiting the location, size and type of pipeline, the homeowner leaves open the chance of a high-pressure gas line running under the property.

The Term

The lease runs for a five-year primary term (a portion contain a five-year renewal term), which in a standard lease the lessee can unilaterally transform into an indefinite, extended term, without signing a new lease, for any of the following reasons:

> exploration anywhere in the spacing unit, or a well in the spacing unit is deemed "capable of production," or gas from the spacing unit is produced, or the spacing unit is used for underground gas storage, or the prescribed payments are made.

The term "capable of production" is defined broadly enough to include off-site preparatory work. Regardless of the stated lease term, once a well is "capable of production," the rights continue for as long as operations continue, possibly decades.

The Rent

Homeowners receive a signing bonus ranging from dollars to thousands of dollars per acre of leased land. This single payment can potentially tie up the property, indefinitely. References in so-called "paid-up" leases (common in New York) to other potential additional payments (except for the royalty payment) are deemed satisfied by the signing bonus. Absent negotiation, royalties consist of a percentage (typically 1/8 or 12.5%), net of production-related expenses and any loss in gas volume that reduces the revenue received. Late payments or failure to make a royalty payment can "never" result in an automatic lease termination. Homeowners share the royalty with other members of the drilling pool on a pro-rated basis. This is known as correlative rights. The larger the drilling pool, the smaller the royalty. Unlike the percentage rent provision in a commercial lease, a gas lease contains no detailed formula for calculating the net royalty payment, no pro-rata share corollary to calculate the relative percent the homeowner bears to the pool of all other property owners entitled to divide the royalty pie and no right to review the lessee's books and records.

Assignment

Space leases require a tenant to obtain landlord consent for a third-party lease assignment. In contrast, a gas lessee can sell and assign to or finance the gas lease (or any interest) with any party it selects, without providing notice to the homeowner. This continuing right deprives homeowners of control over confirming consistency between the initial lease and the terms of the assigned document – who ends up with the lease, who gets hired and allowed onto the family's private property and the quality of the drilling activity performed in their backyard. As the record title holder, homeowners remain potentially liable for the activity that occurs on their property, if it is not effectively delegated.

Hazardous Activity/Hazardous Substances

Space leases expressly prohibit hazardous activity and the presence or storage of hazardous substances on the property, such as chemicals and flammable or toxic petroleum products. Gas leases permit both the drilling activity and the use of hazardous substances and flammable products, such as the methane gas itself. Gas leases reserve the right to store gas of any kind, indefinitely, underground, regardless of the source, which can create additional risk to the homeowner's personal safety and adversely impact, as will be discussed, a homeowner's responsibility to its lender.

Easements

Gas leases contain grants of easements, which is not typical for a lease. This grant includes the lessee's right, even after surrendering the leasehold, to "reasonable and convenient easements" for the existing wells, pipelines, pole-lines, roadways and other facilities on the surrendered lands. Assuming its enforceability, a driller can surrender a lease and still assert a range of potentially perpetual surface and subsurface rights as superior to those of the fee owner without any further payment and without the obligation for repair, maintenance or resulting damage. However, unless the actual lease containing the easement grant gets recorded against the residential property in the public records, which, apparently is often not the case, the lessee has no assurance the easements will be protected. Even so, leases reserving potentially perpetual, undesignated easements for roads and pipelines raise expensive, long-term liability concerns for homeowners, their lenders and, potentially, fellow taxpayers.

Insurance/Indemnification-Risk Allocation to Homeowner

Space leases typically require the tenant to post a security deposit to cover late rent or property damage. Gas leases do not contain a similar provision. Space leases also require tenants to purchase general liability insurance naming the landlord as an additional named insured with an indemnity covering costs for uninsured damage and other costs occasioned by the tenant and its invitees. Risks associated with typical leasehold property damage belong to tenants since they control the space. Drilling leases typically omit these points. Absent negotiation, gas leases contain no insurance and no indemnification. Even assuming the existence of an indemnification, federal protection via the Halliburton loophole can provide cover. Unless anticipated DEC rules change, New York intends to require disclosure only of fracking chemicals by gas companies. While this represents a step in the right direction, it also gives companies an "out" by merely requiring them to disclose which chemicals they use. It does not necessarily make companies liable for the damage those chemicals cause. Eliminating the right to frack with toxic and carcinogenic chemicals by reinstating the laws amended by the Halliburton loophole would eliminate the shift of financial responsibility away from the gas company as it relates to this aspect of the gas drilling lifecycle. Regulating use of benign fracking additives that can boost risk would be useful as well. For example, radioactivity, a known danger at elevated levels, poses greater risks when it interacts with frack-fluid additives that contain calcium.[4] By not restoring liability to the companies that control drilling operations and coupling it with economic reasons to prevent casualties, a homeowner will have to first experience the property damage or personal injury, then successfully arbitrate or litigate against the gas lessee for reimbursement and remediation, a burden most homeowners can't afford or mentally handle. Even assuming a homeowner's fortitude to sue, focus on damages and remediation misses the fact that residential fracking introduces irreparable risks to homes and the families that live there.

Assuming its enforceability, a driller can surrender a lease and still assert a range of potentially perpetual surface and subsurface rights as superior to those of the fee owner.

Gas Lease Mortgages

New York law[5] recognizes minerals (before extraction) as real property. In May 2011, a Chesapeake Energy subsidiary, Chesapeake Appalachia, pledged mineral rights on over 1,000 Bradford County, Pennsylvania, mineral leases as collateral for a $5 billion line of credit mortgage loan with Union Bank of California, while in July, 2011, another Chesapeake Energy subsidiary, Appalachia Midstream Services, pledged pipeline rights-of-way on over 2,000 Bradford County properties to access an unspecified line of credit mortgage loan with Wells Fargo. Although the mortgage was properly recorded in the county recorder's office against the section, block and lot of the fee/surface property, the news of a $5 billion loan linked to their property surprised mortgage-seeking homeowners. Legally, Chesapeake's mortgaged interests are distinguishable from the surface owner's, so that shouldn't interfere with a home loan, but residential fracking might. It is worth noting that Wells Fargo, one of Chesapeake's lenders, stands among national lenders that do not grant mortgage loans to homeowners with gas leases.

Homeowner Predicament

Despite DEC website warnings about the potential adverse impacts of gas leases,[6] the government plays no role in the lease process. Contract law favors the rights of private parties to enter into arm's-length transactions without government intervention. Yet, when large numbers of complaining upstate homeowners recount consistent practices employed by the landmen that resulted in pre-printed standard gas leases signed without negotiation, it would be appropriate to involve the New York Attorney General, to examine the facts. In consumer protection contexts, the government (on its own or as a result of litigation) has seen fit to offer protection. Homeowners who signed gas leases do not constitute consumers *per se*, but the analogy supports Attorney General involvement to restore to the landowner the bulk of rights attributable to fee ownership and, by extension, the property's value. Paradoxically, for example, gas leases reciting "good faith negotiations" between the parties lock in homeowners with lessee-favored termination clauses. Unlike space leases that terminate on a stated expiration date, gas leases give lessees latitude to extend a stated lease term, indefinitely, by asserting it is "capable of production" or "paid up" or otherwise, subject to "force majeure," asserting New York's de facto drilling moratorium as the event beyond their control. "Force majeure" litigation is now on the dockets across New York's Southern Tier.

Municipal Backlash; Indefinite Leases

Municipalities within the 28 counties sitting on top of New York's Marcellus Shale differ on the benefits of fracking. Municipalities in favor of fracking focus on local economic growth.[7] Municipalities opposing fracking take into consideration competing established economies, such as agriculture and tourism. By asserting home rule, municipalities have enacted moratoria, amended master plans or codes to prohibit heavy industry, including gas drilling, and banned drilling on public land or altogether.[8] In September 2011, Anschutz Exploration Corp. filed a lawsuit against the Town of Dryden asserting the supremacy of the state to issue a drilling permit over the right of the municipality to amend its zoning law to prohibit drilling or storage of natural gas.[9] The outcome of this case will have significant ripple effects throughout the state.

When municipalities favor fracking, homeowners with questions or concerns are on their own. Residents who do not wish to renew and residents who are committed to leasing but want to renegotiate terms when their lease expires, as with an expired space lease, are meeting some resistance from the gas companies, who are using General Obligations Law § 15-304 (GOL) to reinstate expired leases. That statute states that after a recorded drilling lease expires by its own terms, the owner "may" serve a cancellation notice to the lessee triggering a lessee right to file an affidavit affirming that the lease is in full force and effect. Then, more papers get filed to confirm and preserve that right. Unlike the space lease which terminates on a certain date, GOL § 15-304 gives drillers a second chance which (so long as the driller has recorded the full lease) can tie an unwilling homeowner indefinitely to a gas lease the homeowner no longer wants. Homeowners electing not to give the statutory notice live in limbo, uncertain as to where they stand.

If a lessee decides to drill for gas but lacks the total acreage it needs, the lease provides the statutorily required leverage to form a so-called "spacing unit" by forcing unwilling property owners surrounding the voluntarily leased property into a drilling pool, a process called compulsory integration.

Compulsory Integration

Involuntary compulsory integration represents the most controversial method drilling companies use to access gas. Compulsory integration (or forced pooling) exists by statute in 39 states.[10] It replaced the common law rule of "capture" which allowed Person A to legitimately collect and own gas from Person B's supply if it flowed into Person A's well. To capture gas before a neighbor did, surface wells proliferated in close proximity to one another, causing the overall gas pressure to drop and making gas extraction inefficient for all involved. It also blighted the surface lands. Today, Environmental Conservation Law § 23-0901 (ECL) deputizes a driller, subject to a DEC hearing, to force an unwilling property owner into a spacing unit if the drilling company otherwise controls 60% or more of the acreage in the spacing unit either by lease, deed or voluntary integration,[11] which itself involves lease swaps among leaseholders to form the spacing unit.

Proponents assert that forced pooling makes the drilling infrastructure investment more cost efficient by maximizing access to gas while also maintaining the surface landscape and fairly compensating the noncontributing "integrated" homeowner with a shared net 12.5% royalty. Opponents consider it a form of eminent domain. The constitutionality of forced pooling under a predecessor statute was confirmed in dicta by the New York Court of Appeals in *Sylvania v. Kilborne*, itself citing the United States Supreme Court, which held that "a state has constitutional power to regulate production of oil and gas so as to prevent waste and to secure equitable apportionment among landholders of migratory gas and oil underlying their land fairly distributing among them the costs of production and the apportionment."[12]

Yet, the updated statute's effect eliminates the homeowner's right to control the homestead, creates financial risk for the driller's acts by not expressly holding the driller responsible, and jeopardizes access to a mortgage or the ability to sell the property. The ECL permits objection by a homeowner to the forced pooling within prescribed guidelines (having a scientific basis) none of which includes asserting a conflict with other (existing or intended) contract obligations, such as a mortgage. ECL § 23-0503, empowers DEC to schedule an adjudicatory hearing if it determines that "substantial and significant issues have been raised in a timely manner." Whether a driller's rights of involuntary compulsory integration come after, or trump, sanctity of contract between a homeowner and its mortgage lender needs clarification.

$6.7 Trillion Secondary Mortgage Market

The Federal Housing Finance Agency (FHFA) was created in July 2008 on the heels of the mortgage crisis, to provide supervision, regulation and housing mission oversight of Fannie Mae and Freddie Mac and the Federal Home Loan Banks (FHLB) and to support a stable and liquid mortgage market. As of September 2010, according to FHFA, the combined debt obligations of these government-sponsored entities totaled $6.7 trillion, with Fannie Mae and Freddie Mac purchasing or guarantying 65% of new mortgage originations. FHFA, as conservator of the secondary mortgage market, has a fiduciary responsibility to promote the soundness and safety of the secondary mortgage market. It is in FHFA's interest to limit mortgage defaults.

Most American homeowners hold a mortgage loan and 90% of all residential mortgage loans are sold into the secondary mortgage market (exceptions exist for million dollar homes which do not get sold by the lending bank). It is assumed that most upstate New Yorkers who signed gas leases have a mortgage, will want one in the future or want that right for a future purchaser. Mortgage lending favors low-risk activity on its mortgaged properties. Fannie Mae, Freddie Mac and the FHLB establish lending guidelines for appraisers and underwriters that dictate whether a home is a worthy investment. This helps to facilitate their combined mission to attract investors, such as pension funds, who provide liquidity in the secondary mortgage market. Primary lenders, in turn, rely on their borrowers' compliance with mortgage covenants mirroring these lending guidelines for the life of the loan.

Assuming 10% of the existing secondary mortgage market portfolio includes residential properties subject to drilling activity, this amounts to $670 billion of secondary mortgage market debt; assuming the number is only 1%, this amounts to $67 billion. Eventually, gas drilling may span up to 34 of the lower 48 states, including densely populated cities such as Fort Worth, Texas. If so, a substantial portion of the secondary residential mortgage market portfolio may be at risk from residential fracking.

Loan Underwriting Reveals Collateral Flaws With Residential Fracking

Home Appraisal

All mortgage loans require a property appraisal, title insurance covering the lender or its assignees and homeowner's insurance. Home and land appraisals are based upon like-properties, similarly situated, and are used to determine market value, the loan-to-value ratio and the maximum loan amount. Reliable appraisals of properties subject to gas leases are difficult to obtain and potentially prohibitively expensive; it would require a comprehensive title search of area properties encumbered by gas leases. Often a memorandum of the gas lease and not the lease itself is recorded, and a read-through of the entire gas lease is required to make a fair comparison between lease-encumbered properties. Underwriters need to evaluate the risks and know who pays for them; without the full lease in hand, they can't make such an evaluation.[13]

Evaluating the driller's identity can be another underwriting challenge; with unrecorded lease assignments, lenders don't know who is performing the heavy industrial activity on their residential collateral. Federal Housing Authority guidelines for federally insured mortgage loans, which make up a portion of the secondary mortgage market debt, require that a site be rejected "if property is subject to hazards, environmental contaminants, noxious odors, offensive sights or excessive noise to the point of endangering the physical improvements or affecting the livability of the property, its marketability or the health and safety of its occupants,"[14] all of which are potential characteristics of residential fracking.

Flare at hydro-fracking gas drilling operations near Sopertown, Columbia Township, PA

Lender's Title Insurance

A lender's title policy insures the mortgage lien, as of the date of the policy (up to the loan amount), against loss or damage if title is vested in someone other than the homeowner. Gas leases signed after the policy date are not covered by the policy. Gas leases in effect when the policy is issued will be listed as a title exception. Coverage won't include the gas lease or any claims arising out of it. Title endorsements don't eliminate this exception to coverage. Underwriters consider these exceptions a red flag, sufficient to jeopardize the loan. Lenders financing properties subject to compulsory integration won't discover the title encumbrance from a title search because ECL § 23-0901 makes no apparent reference to recording the DEC determination of compulsory integration in the land records. New York title policies expressly exclude from coverage loss or claims relating to any permit regulating land use. It remains unclear whether a gas drilling permit which includes forced pooled property would fall within this exclusion. Either the Legislature will clarify the statute or the ambiguity will be a source of future litigation. Rating agencies and secondary mortgage market investors should be apprised if a loan portfolio which they have rated or in which they have invested, as the case may be, contains gas leases or forced pooled properties, since both add new risk.

Homeowner's Insurance

All residential mortgage lenders require homeowner's insurance from their borrowers. Even the most comprehensive homeowner's coverage, known as "broad risk form" or "special form" insurance excludes the types of property damage associated with the drilling lifecycle, such as air pollution, well-water contamination, earth movement and other risky commercial activity performed on residential property.

The Mortgage: No Hazardous Activity/Substances, No Gas/Gas Storage, No Radioactive Material

Residential mortgages prohibit borrowers from committing waste, damage or destruction or causing substantial change to the mortgaged property or allowing a third party to do so. This includes operations for gas drilling. Standard residential mortgages prohibit borrowers from causing or permitting the presence, use, disposal, storage, or release of any "hazardous substances" on, under or about the mortgaged property. In mortgages, "hazardous substances" include gasoline, kerosene, other flammable or toxic petroleum products, volatile solvents, toxic pesticides and herbicides, materials containing asbestos or formaldehyde and radioactive materials. Borrowers are also prohibited from allowing anyone to do anything affecting the mortgaged property that violates any "environmental law." "Environmental law" means federal, state and local law that relates to health, safety and environmental protection. Mortgages obligate borrowers to give lenders written notice of any release, or threat of release, of any hazardous substances and any condition involving a hazardous substance which adversely affects the value of the mortgaged property.

Mortgages prohibit the activities gas leases permit to preserve the property's marketability. For example, shallow water wells and springs, typical in the northeast, represent the home's drinking water source; they become susceptible to contamination from drill site spills and leaks or flooding from frack wastewater. Frack fluid chemicals, pollutants and naturally occurring radioactivity in the waste have been reported to far exceed levels considered safe for drinking water. A contaminated well cannot be easily remediated, if at all. A home or a farm without on-site potable water may not sell. Migrating methane gas from the drilling process risks explosions both inside and outside of the home.

Because water and migrating methane gas each defy boundaries, following minimal underwriting setback requirements between the home and the drill site may prove inadequate to protect a water well from irreparable contamination or a home from explosion. A bank can consider these factors when approving a mortgage loan, and once financed, when declaring a mortgage loan in default.

Homeowner and Lender Vulnerability

The 2010 Form 10-K issued by Chesapeake states:

> There is inherent risk of incurring significant environmental costs and liabilities in our operation due to our generation, handling and disposal of materials, including waste and petroleum hydrocarbons. We may incur joint and several liability, strict liability under applicable U.S. federal and state environmental laws in connection with releases of petroleum hydrocarbons and other hazardous substances at, on, under or from our leasehold or owned properties, some of which have been used for natural gas and oil exploration and production activities for a number of years, often by third parties not under our control. For our non-operated properties, we are dependent upon the operator for operational and regulatory compliance. While we maintain insurance against some, but not all risks described above, our insurance may not be adequate to cover casualty losses or liabilities, and our insurance does not cover penalties or fines that may be assessed by a governmental authority. Also, in the future we may not be able to obtain insurance at premium levels that justify the purchase.[15]

In the Form 10-K appended to its 2010 Annual Report, Range Resources adds:

> We have experienced substantial increases in premiums, especially in areas affected by hurricanes and tropical storms. Insurers have imposed revised limits affecting how much the insurer will pay on actual storm claims plus the cost to re-drill wells where substantial damage has been incurred. Insurers are also requiring us to retain larger deductibles and reducing the scope of what insurable losses will include.[16]

Signing a gas lease without lender consent is likely to constitute a mortgage default. At any time before or after the drilling begins, a lender can demand the borrower to either terminate the lease or pay off the loan. Since the gas companies have pledged the gas leases as collateral for loans or brought in investors based upon the potential income the gas lease can produce, facilitating a lease termination may require protracted litigation. Further, it is not likely that most homeowner-borrowers will have the ready cash to repay the loan. This places the lender in an untenable position.

Residential fracking, perpetual unfunded easements and long-term gas storage beneath mortgaged homes create a cumulative threat to the repayment of mortgage loans tranched in secondary mortgage market portfolios. Homeowners suffering irreparable property damage, such as well water contamination, structural damage or casualty from a gas explosion, won't have coverage from homeowner's insurance and may have no recourse against the gas company holding the lease. This is so even if homeowners sue and succeed in court since the gas companies' own disclosure statements state they are underinsured. New York State Comptroller Thomas Di Napoli has proposed an up-front gas company–funded emergency fund to remediate those emergencies that can be fixed. As of yet, the gas industry, the Governor, the state Senate and the Assembly have not offered support for such a fund. The Form 10-K for Chesapeake Energy and Range Resources, for example, cite the risks attendant to gas drilling. They do not indicate the source of funding to support the numerous risks from the drilling activity. Unless this source of funding can be identified, the secondary mortgage market, as holder of 90% of the nation's home mortgages, may be left with the clean-up bill. Ultimately, financial responsibility could fall on the taxpayers.

New York homeowners who signed gas leases without the facts about this unconventional drilling claim they did not know the risks involved. These homeowners did not know that they violated their mortgage by entering into the gas lease or have potentially no insurance coverage in case of a drilling loss. Impacted homeowners can write to New York's Attorney General to (1) document their experience; (2) request a reprieve from a mortgage loan default; and (3) institute a "no gas drilling" policy until it is determined that the mortgaged collateral won't be at risk from the driller's plans. To achieve this, gas leases should be revised to modify or omit the risky clauses, such as gas storage, surface rights and undesignated, unfunded easements. In the alternative, the gas leases can be terminated. Homeowners need help before gas permitting begins, in order to spare the homestead and the home mortgage market too.

New Mortgages for Homeowners With Gas Leases and New Construction[18]

Even before the drilling commences, many upstate New York homeowners with gas leases cannot obtain mortgages. Bank of America, Wells Fargo, Provident Funding, GMAC, FNCB, Fidelity and First Liberty, First Place Bank, Solvay Bank, Tompkins Trust Company, CFCU Community Credit Union and others[17] are either imposing large buffer zones (too large for many borrowers) around the home as a condition to the loan or not granting a mortgage at all.

Once lenders connect the "no hazardous activity" clause in the mortgage with the mounting uptick in uninsurable events from residential fracking, this policy can be expected to expand. Originating lenders with gas industry business relationships may decide to assume the risk, make mortgage loans to homeowners with gas leases and keep the non-conforming loans in their own loan portfolio. However, there is a limit to what an originating bank can keep in its own loan portfolio. Eventually, cash infusions from the secondary mortgage market will become a necessity; and secondary mortgage market lending guidelines will be a reality. If homeowners with gas leases can't mortgage their property, they probably can't sell their property either (this assumes the purchaser will need mortgage financing to fund the purchase). The inability to sell one's home may represent the most pervasive adverse impact of residential fracking.

Real estate developers and contractors rely on construction financing and financeable homeowners to stimulate construction starts. New York's upstate construction future depends upon the ability to sell what one builds. Washington County, Pennsylvania, for example, reported improved home sales servicing the gas industry in 2010, but apparently not of properties built on drill sites.

The Conundrum Revisited

The energy and housing sectors both rely on investor dollars to fund their future. Pension funds and other money sources that still invest in housing but now consider natural gas the preferred investment raise a potential paradox: Will individuals' retirement funds expand as their homeownership rights fade away? The conundrum to consider: how can a nation with $6.7 trillion in residential secondary mortgage market debt that measures economic recovery by construction starts and new mortgage loans also accommodate risky and underinsured residential fracking involving a still-unknown quantity of this residential mortgage collateral? Before New York embraces fracking as a new frontier, it would be wise for our corporate and government leaders focused on the vitality of our housing and energy sectors to address and resolve this conundrum. ■

1. Chesapeake Energy Corp., *10-K: Annual Report Pursuant to Section 13 and 15(d)* 27 (2011) (Chesapeake Energy 10-K: Annual Report); Range Resources, Uncovering Tomorrow's Energy: 2010 Annual Report 13 (2010) (Range Resources 2010 Annual Report).

2. Chesapeake Energy 10-K: Annual Report 4.

3. N.Y. Real Property Law § 232-b.

4. Mark Greenblatt, *Texas drinking water makes pipes and plumbing radioactive*, KHOU.com (May 18, 2011) at http://www.khou.com/home/-I-Team-Texas-drinking-water-makes-pipes-and-plumbing-radioactive-1221408194.html.

5. N.Y. Jurisprudence, Mines § 7; *see* N.Y. Uniform Commercial Code § 9-102.

6. Div. of Mineral Res., A Landowner's Guide to Oil & Gas Leasing, Dep't of Envtl. Conservation (2008), http://www.dec.gov/docs/materials_minerals_pdf/brochure.pdf.

7. Cornell University Professor Susan Christopherson cautions against boom-bust impacts. *See* Susan Christopherson, *Marcellus Gas Drilling*, Cornell Univ. 2011, http://www.greenchoices.cornell.edu/development/marcellus.

8. Joe Hoff, *Moratoria, Bans, Resolutions Opposed to Hydrofracking: A Local and Global Sampling*, R-Cause (Sept. 20, 2011) www.r-cause.net/bans-moratoria.

9. *Anschutz Exploration Corp. v. Town of Dryden & Town of Dryden Town Bd.*, Supreme Court, Tompkins County; N.Y. Environmental Conservation Law § 23-0303(2) (ECL).

10. ECL § 23-0901; Marie C. Baca, *State Law Can Compel Landowners to Accept Gas and Oil Drilling*, Pro Publica (May 19, 2011), http://projects.propublica.org/tables/forced-pooling.

11. ECL § 23-0901.

12. *Sylvania Corp. v. Kilborne*, 28 N.Y.2d 427 (1971) (quoting *Hunter Co. v. McHugh*, 320 U.S. 222 (1943)).

13. *See* Greg May, VP, residential lending, *Gas and Oil Leases Impact on Residential Lending*,Tompkins Trust Co., White Paper,(Mar. 24, 2011), http://www.tompkins-co.org/tccog/Gas_Drilling/Focus_Groups/Assessment%20Documents/White%20Paper.pdf

14. Dep't of Hous. & Urban Dev., *Valuation Analysis for Single Family One-to-Four Unit Dwellings* (4150.2) (2011).

15. Chesapeake Energy 10-K: Annual Report 29, *supra* note 1.

16. Range Resources 2010 Annual Report 13, *supra* note 1.

17. Greg May, VP, residential lending Tompkins County Trust, telephonic update of white paper, *supra* note 13, and Joseph Heath, Esq.

18. *See* Ian Urbina, *Rush to Drill for Natural Gas Creates Conflicts With Mortgages*, N.Y. Times, Oct. 20, 2011, p. 1. Mr. Urbina's article used Elisabeth Radow's August 11, 2011, letter to Freddie Mac and the federal agency that oversees Freddie Mac, warning the agencies about potential conflicts in the mortgage market, as a documentary source for his piece. The letter may be viewed at http://www.nytimes.com/interactive/us/drilling-down-documents-8.html#document/p12/a33448.

DISCUSSION PAPER

December 2013, revised January 2014 ■ RFF DP 13-39-REV

The Housing Market Impacts of Shale Gas Development

Lucija Muehlenbachs, Elisheba Spiller, and Christopher Timmins

1616 P St. NW
Washington, DC 20036
202-328-5000 www.rff.org

RESOURCES FOR THE FUTURE

The Housing Market Impacts of Shale Gas Development

Lucija Muehlenbachs
Elisheba Spiller
Christopher Timmins*

January 10, 2014

Abstract

Using data from Pennsylvania and New York and an array of empirical techniques to control for confounding factors, we recover hedonic estimates of property value impacts from shale gas development that vary with geographic scale, water source, well productivity, and visibility. Results indicate large negative impacts on nearby groundwater-dependent homes, while piped-water-dependent homes exhibit smaller positive impacts, suggesting benefits from lease payments. At a broader geographic scale, we find that new wellbores increase property values, but these effects diminish over time. Undrilled permits cause property values to decrease. Results have implications for the debate over regulation of shale gas development.

JEL Classification Numbers: Q32, Q33, Q50, Q53

Keywords: shale gas, groundwater, property values, hedonic models, nearest neighbor matching, differences-in-differences, triple differences

*Muehlenbachs: University of Calgary and Resources for the Future, *muehlenbachs@rff.org.* Spiller: Environmental Defense Fund, New York, *espiller@edf.org.* Timmins: Department of Economics, Duke University, *christopher.timmins@duke.edu.* Acknowledgements: We thank Kelly Bishop, Yanyou Chen, Jessica Chu, Elaine Hill, Mark Fleming, Carolyn Kousky, Alan Krupnick, Nicolai Kuminoff, Corey Lang, Lala Ma, Jan Mares, Ralph Mastromonaco, Klaus Moeltner, Jaren Pope, Stefan Staubli, Randy Walsh, and Jackie Willwerth for their support. We thank seminar participants at Carnegie-Mellon University, Tinbergen Institute/Free University of Amsterdam, Toulouse School of Economics, University of Massachusetts Amherst, University of Michigan, University of Pittsburgh, and University of Stirling for their helpful comments. All remaining errors and omissions are our own. We are grateful to CoreLogic for the data on property transactions. We thank the Bureau of Topographic and Geologic Survey in the PA Department of Conservation and Natural Resources for data on well completions and Nicholas Berry from NYS Department of Taxation and Finance for data on NY water service.

1 Introduction

Technological improvements in the extraction of oil and natural gas from unconventional sources have transformed communities and landscapes and brought debate and controversy in the policy arena. Shale gas plays underlying the populated northeastern United States were thought to be uneconomical less than 10 years ago, but now contribute a major share of US gas supply.[1] Natural gas has been hailed as a bridge to energy independence and a clean future because of its domestic sourcing and, compared with coal and petroleum derivatives, its smaller carbon footprint and reduced emissions of other pollutants (e.g., particulates, sulfur dioxide, carbon monoxide, and nitrous oxides). Furthermore, proponents note that jobs associated with shale gas development will boost local economic growth.[2] Yet opposition to unconventional methods of natural gas extraction has emerged, citing the potential for damages from methane leakage (Howarth et al., 2011; Hultman et al., 2011; Burnham et al., 2011), water contamination (Osborn et al., 2011; US Environmental Protection Agency, 2011; Olmstead et al., 2013), local air pollution (Kargbo et al., 2010; Schmidt, 2011; Howarth et al., 2011), and increased congestion from truck traffic (Bailey, 2010; Considine et al., 2011).

Economic and environmental impacts may also arise from the "boom town" phenomenon, where local areas facing shale development see increases in population, employment, business activity, and government revenues (Lillydahl et al., 1982; Wynveen, 2011). However, boom towns may also suffer from negative social, economic, and environmental consequences such as increased crime rates, housing rental costs, and air pollution (Lovejoy, 1977; Albrecht, 1978; Freudenburg, 1982). Furthermore, the "boom" may be followed by a "bust" if benefits from shale gas development are only temporary. Local public goods might be expanded during boom times at considerable cost only to be left underutilized when wells are capped or abandoned.

Properties within a boom town may experience growth or decline in value depending on whether the benefits of the boom outweigh the costs. Moreover, benefits and costs may be heterogeneous across housing types. For example, properties that rely on

[1] In 2000, shale gas accounted for 1.6 percent of total US natural gas production; this rose to 4.1 percent in 2005, and by 2010, it had reached 23.1 percent (Wang and Krupnick, 2013). Natural gas from the Marcellus formation currently accounts for the majority of this production (Rahm et al., 2013) and can be attributed to advances in hydraulic fracturing, horizontal drilling, and 3-D seismic imaging.

[2] Weber (2012) estimates an increase of 2.35 jobs per each million dollars in gas production, and Weinstein and Partridge (2011) find that 20,000 jobs were created in Pennsylvania from 2004 to 2010 due to the shale gas industry expansion (though they argue that this number is much lower than the industry's claims of job increases).

private water may suffer greater reductions in value when confronted with shale gas development if there is a risk of losing their water source. Access to a safe, reliable source of drinking water is an important determinant of a property's value. Even a perceived threat to that access can have detrimental effects on housing prices. This is very important, as the potential for shale gas development to contaminate groundwater has been hotly debated.[3] Perceptions of the risks and benefits from drilling can vary with a variety of factors, including the density of drilling activity, environmental activism, economic activity, unemployment levels, and urban density (Theodori, 2009; Wynveen, 2011; Brasier et al., 2011). While there are valid arguments on both sides of the debate surrounding shale gas development, the question of whether the benefits outweigh the costs has not yet been answered. This paper is a first step in understanding these costs and benefits.

Hedonic analysis describes how a home buyer chooses a house based on the characteristics of the property and its location (see Section 2 for a deeper discussion of the hedonic method as it applies to this paper). Measuring the impacts of shale gas activity on property values is therefore one way to quantify its effects (either real or perceived). There has been limited prior research into how local gas drilling affects property values. A few notable exceptions include Boxall et al. (2005), who focused on sour gas wells in Alberta, and Klaiber and Gopalakrishnan (2012), who measured the temporal impact of shale gas wells in Washington County, Pennsylvania. Most closely related to the present paper is our earlier work (Muehlenbachs et al., 2013), which also used data from Washington County to measure the impact of shale gas proximity on groundwater homes.

This paper extends our earlier analysis to include areas comprising most of the shale gas development in Pennsylvania as well as areas not experiencing development in Pennsylvania and New York. Looking beyond a single county, we are also able to control for more potential sources of estimation bias, and to explore the broader economic impacts of shale gas development. In particular, we measure several impact categories. We label these as *adjacency effects*, *groundwater contamination risk*, and *vicinity effects*. The first refers to the combined impacts (both positive and negative) from being in close proximity to shale gas development aside from groundwater contamination risk (e.g., air, noise, and light pollution; landscape alteration; and the receipt

[3] An example from Dimock, Pennsylvania, can be seen in these headlines: "Water Test Results Prove Fracking Contamination in Dimock," Riverkeeper.org, March 22, 2012, and on the other hand, "Just Like We've Been Saying—Clean Water in Dimock," eidmarcellus.org, August 3, 2012. Under ambiguity aversion, such a debate would decrease the value of groundwater-dependent properties.

of lease payments), the second refers to the *additional* effect of adjacency specific *only* to groundwater-dependent households, and the third refers to impacts associated with the boom town phenomenon along with negative externalities that occur on a broad geographic scale (e.g., air pollution, increased truck traffic, and wastewater disposal).

A major obstacle to accurately estimating the impact of shale gas development on surrounding homes is the presence of correlated unobservables that may confound identification. For example, shale gas wells are not located randomly but are placed in areas that facilitate the drilling process, such as near a road; unobservable property and neighborhood attributes may therefore be correlated both with proximity and with the property value. Methodologically, we utilize a combination of fixed effects along with difference-in-differences nearest-neighbor matching (DDNNM), triple-difference (DDD), and treatment boundary techniques in order to eliminate unobservables that may be correlated with adjacency or vicinity to shale gas wells or water source and thus lead to biased estimates.

Using data from Pennsylvania, both off and on the Marcellus shale, along with bordering counties in New York (where a moratorium has prevented hydraulic fracturing to this point), we are able to identify vicinity effects, as well as control for macroeconomic effects due to the Great Recession and other economic factors that affected the region more broadly. Furthermore, our panel of properties sold in Pennsylvania and New York between January 1995 and April 2012 creates a solid baseline prior to shale gas wells being drilled, more accurately captures time trends, and includes properties that were sold several years after drilling began in the state.

Our results demonstrate that groundwater-dependent homes are, in fact, negatively affected by nearby shale gas development. Similarly proximate homes dependent on piped water, on the other hand, appear to receive small benefits from that development. At a broader geographic scale, we find that drilling increases property values, likely through the boost to the local economy of increased activity. However, undrilled well permits, particularly those that have been permitted for more than a year, can offset these benefits. This is likely due to undrilled permits creating an aesthetic disamenity (e.g., through the clearing of land), but could also be from the loss of the option value of signing a more favorable mineral lease in the future.

Our paper proceeds as follows. Section 2 discusses the hedonic method, which provides the backdrop for our analysis. Section 3 describes our methodology, Section 4 details our data, and Section 5 reports our empirical models and main results, with a summary of different property value impacts in Section 6. Section 7 concludes.

Finally, We provide an appendix for online publication analyzing the impact of shale gas development on community sociodemographics, the frequency of sales, and new construction.

2 Hedonic Method

Rosen (1974) established the connection between individual preferences and the hedonic price function, allowing the researcher to interpret the hedonic gradient as the marginal willingness to pay for an incremental change in a non-marketed house or neighborhood attribute. In the context of our application, $P(W)$ represents the hedonic price relationship describing how prices vary with exposure to increasing numbers of wells, *ceteris paribus*. Rosen describes how the hedonic price function is formed by the equilibrium of buyers and sellers sorting to one another in the marketplace. In Figure 1, buyers A and B are represented by indifference curves (U_1^A, U_1^B, U_2^A, U_2^B); each represents combinations of price and shale gas well exposure that yield a constant level of utility. Sellers X and Y are described by offer curves (O_0^X, O_1^X, O_0^Y, O_1^Y), each of which represents combinations of price and well exposure that yield a constant level of profit. The hedonic price function is formed by the envelope of these indifference and offer curves.

Individuals choose a house that maximizes utility. For individual A, who neither likes paying a lot for a house nor (for the purposes of this discussion) wants exposure to shale gas wells, this is accomplished by reaching the indifference curve lying farthest to the southwest. Considering the constraint formed by the hedonic price function, utility is maximized at point A^*, where that individual achieves utility U_1^A. Individual B similarly maximizes utility at B^*. The fundamental insight of the hedonic method is that, at A^* and B^*, the slope of the price function is equal to the slope of each individual's indifference curve at that point. That slope describes the individual's willingness to give up consumption of other goods in exchange for a marginal reduction in exposure to nearby wells. This is how the literature typically defines marginal willingness to pay (MWTP); we will do the same.[4]

Of course, the value of MWTP defined by the slope of the price function at the level

[4]Other measures of value used in the literature include compensating and equivalent variations in income. CV or EV can be calculated both in a partial equilibrium context, where individuals' housing choices and equilibrium prices are not updated, and in a general equilibrium context, where they are updated to reflect re-optimization and subsequent market re-equilibration.

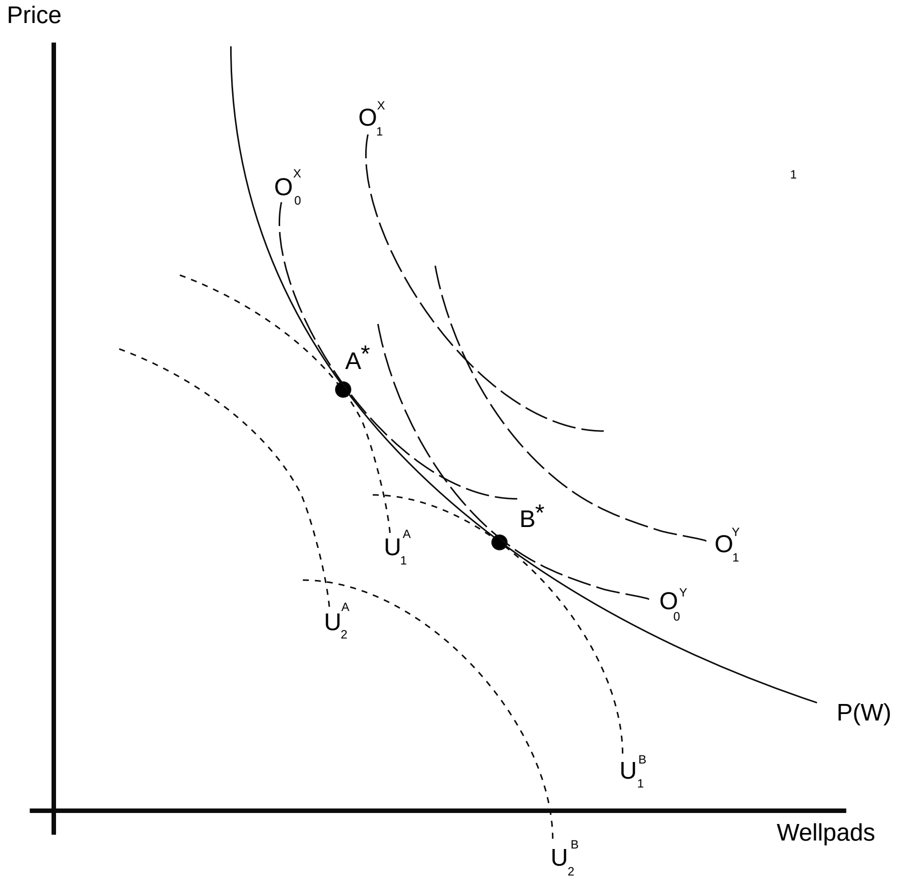


Figure 1: Formation of the Hedonic Price Function

of well exposure chosen by the individual represents just one point on the individual's indifference curve. If we were to trace out each individual's MWTP at each point on a particular indifference curve, we would end up with functions for each individual like those shown in Figure 2.

With cross-sectional data, the hedonic gradient (i.e., the slope of the hedonic price function) therefore only identifies one point on each MWTP function. This is the crux of the identification problems detailed by Brown and Rosen (1982) and Mendelsohn (1985). Endogeneity problems also arise in the effort to econometrically recover these functions; for a discussion, see Bartik (1987) and Epple (1987). More recent literature dealing with the recovery of MWTP functions includes Ekeland et al. (2004), Bajari

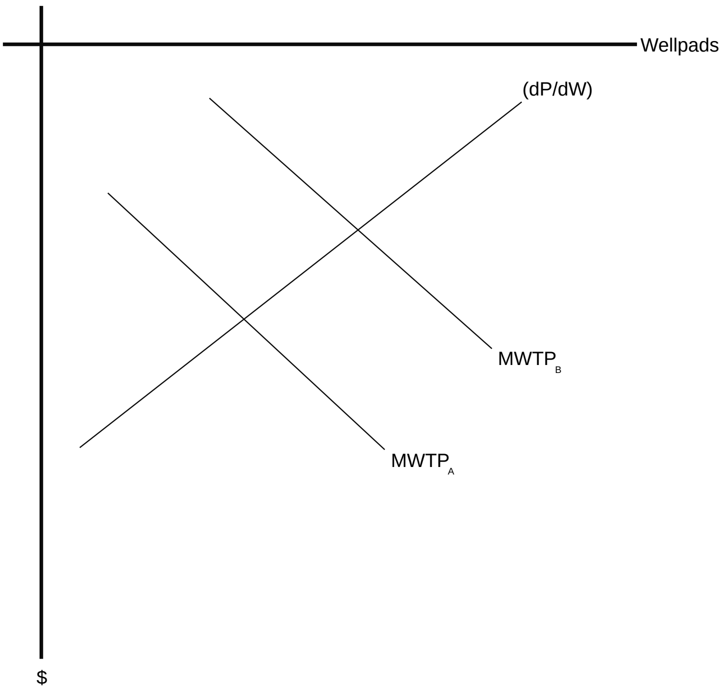


Figure 2: Marginal Willingness to Pay

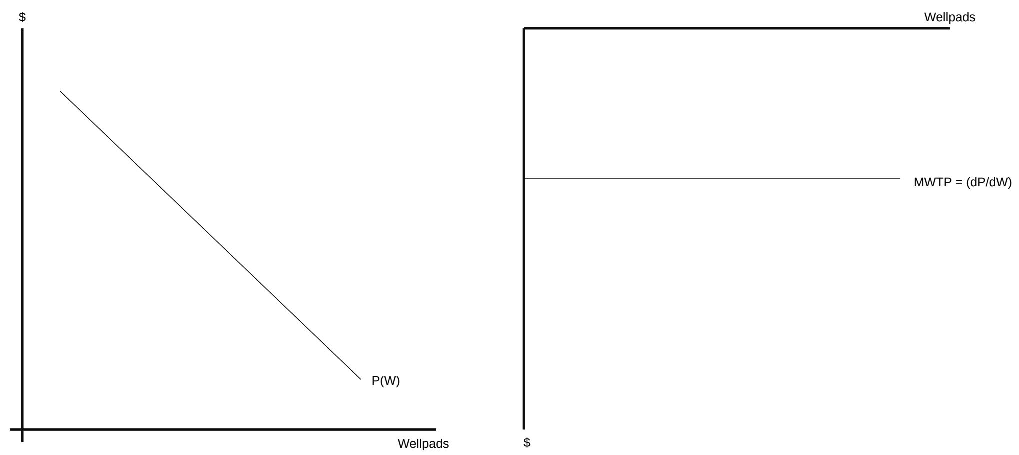


Figure 3: Marginal Willingness to Pay—Simplification

and Benkard (2005), Heckman et al. (2010), and Bishop and Timmins (2012).

With few exceptions, the applied hedonic literature has not estimated heterogeneous MWTP functions, but has instead relied on a strong assumption to simplify the problem—in particular, that the hedonic price function is linear and that preferences are homogenous (so that the hedonic gradient is a horizontal line that represents the MWTP function for all individuals).

This avoids the difficulties associated with recovering estimates of MWTP discussed above, and allows attention to be focused instead on recovering unbiased estimates of the hedonic price function. This literature is vast and includes applications dealing with air quality (Chay and Greenstone, 2005; Bajari et al., 2010; Bui and Mayer, 2003; Smith and Huang, 1995; Harrison Jr and Rubinfeld, 1978; Ridker and Henning, 1967), water quality (Walsh et al., 2011; Poor et al., 2007; Leggett and Bockstael, 2000), school quality (Black, 1999), crime (Linden and Rockoff, 2008; Pope, 2008b), and airport noise (Andersson et al., 2010; Pope, 2008a). Our application is most similar in spirit to papers that have examined locally undesirable land uses (LULUs): Superfund sites (Greenberg and Hughes, 1992; Kiel and Williams, 2007; Greenstone and Gallagher, 2008; Gamper-Rabindran and Timmins, 2011), brownfield redevelopment (Haninger et al., 2012; Linn, 2013), commercial hog farms (Palmquist et al., 1997), underground storage tanks (Zabel and Guignet, 2012), cancer clusters (Davis, 2004), and electric power plants (Davis, 2011). Our estimation strategy described below will draw upon insights from many of these papers.

Of particular importance for our analysis is the discussion in Kuminoff and Pope (forthcoming). They highlight the fact that the change in price over time (which allows for the use of differencing strategies to control for time-invariant unobservables) will only yield a measure of the willingness to pay for the corresponding change in the attribute being considered under a strong set of assumptions. These assumptions include those described above (i.e., linear hedonic price function, common MWTP function). In addition, the hedonic price function must not move over the time period accompanying the change in the attribute. If it does, as in Figure 4, the change in the price accompanying the change in the attribute may provide a poor approximation of the slope of the hedonic price function.

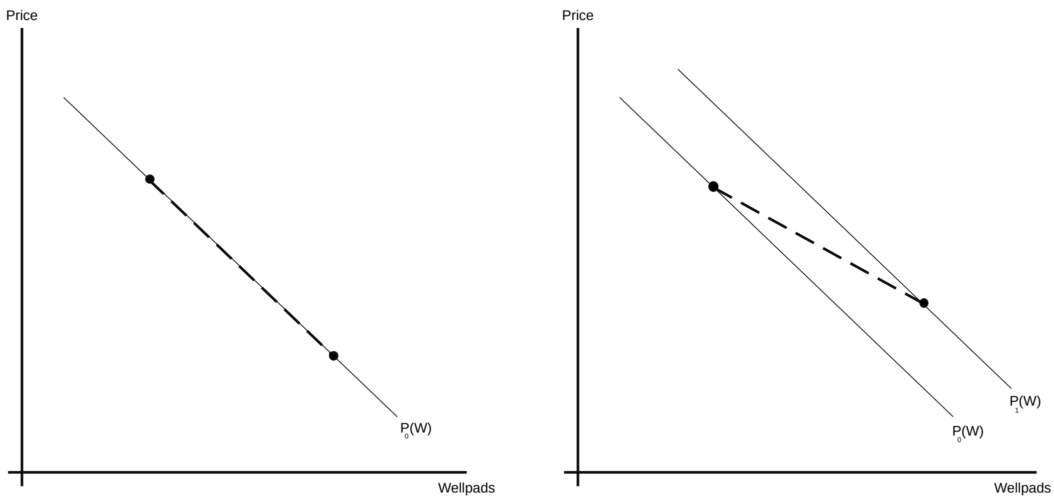


Figure 4: Time-Varying $P(W)$

Determining whether or not the hedonic price function has moved over time is difficult; in particular, it requires having some way of recovering an unbiased estimate of the hedonic price function without exploiting time variation. We provide one strategy for recovering the impact of groundwater contamination risk (double-difference nearest neighbor matching) that avoids using time variation. In the appendix, we also provide an indication of how much of a problem shifting gradients present for our double- and triple-difference strategies by looking at the extent to which neighborhood sociodemographics change because of fracking. If they change a lot, preferences of the local population will likely be altered as well, and caution would be advised when interpreting our results as measures of welfare rather than simple capitalization effects. We note here, however, that the changes we find attributable to shale gas development are quite small.

3 Methodology

Our goal is to recover estimates of the non-marketed costs and benefits of shale gas wells by measuring their capitalization into housing prices. Housing market impacts occur at different levels defined by proximity to wells and by water source—i.e., houses dependent upon private groundwater wells as a source of drinking water (GW) and houses in public water service areas with access to piped water (PWSA). This paper works to identify these impacts and understand how they differ by drinking water source.

3.1 Impact Categories

We categorize the impacts of shale gas exploration and development on housing values as follows. (1) *Adjacency Effects*; this category refers to all of the costs and benefits associated with close proximity to a shale gas well that are incurred regardless of water source. Costs in this category may include noise and light pollution, local air pollution (including methane, hydrogen sulfide, VOCs, and other conventional pollutants), alteration of the local landscape, and visual disamenities associated with drilling equipment and cleared land.[5] The most obvious benefit would be royalties and lease payments

[5]Given that property values could be negatively affected by proximity to a shale gas well, one might wonder why a homeowner would be willing to lease their mineral rights to the gas company. In many cases refusing to lease out the mineral rights under one's property might not prevent a company from drilling on a neighbor's land, which would still expose the holdout-homeowner to development nearby. Therefore, since the signing of the lease can be very lucrative in the short run for the homeowner, leasing out the mineral rights will result in higher payoffs than holding out and still being exposed to the impacts of shale development. Furthermore, horizontal drilling requires having the rights to drill under a large contiguous area, which implies that a critical mass of homeowners need to lease their mineral rights before drilling occurs. In this case, if all homeowners in a neighborhood refuse to sign and thus prevent development, a single homeowner can reap the benefits of the bonus payment without being exposed to nearby shale gas wells. Unless there is a binding agreement between neighbors, each homeowner has a private incentive to lease their mineral rights to the gas companies.

paid to the property owner for the extraction of the natural gas beneath their land.[6] (2) *Groundwater Contamination Risk* (GWCR); this category represents the additional cost capitalized into adjacent properties that are dependent upon groundwater. Our identification strategy assumes that this is the only additional impact of adjacency associated with reliance on groundwater.[7] (3) *Vicinity Effects*; this category refers to impacts on houses within a broadly defined area (e.g., 20km) surrounding wells. These impacts may include increased traffic congestion and road damage from trucks delivering fresh water to wells and hauling away wastewater, wastewater disposal (to the extent that is done locally), and increased local employment and demand for goods and services.

In addition to these three direct impacts of shale gas activities on housing prices, there is a fourth category of housing market impacts that are common to areas with and without shale gas extraction—(4) *Macro Effects.* Given the time period that we study, this impact category includes the housing bubble, the subsequent housing bust and national recession, impacts of globalization and jobs moving overseas, and other regional economic impacts.

[6] Upon signing their mineral rights to a gas company, landowners may receive two dollars to thousands of dollars per acre as an upfront "bonus" payment, and then a 12.5 percent to 21 percent royalty per unit of gas extracted. Natural Gas Forum for Landowners: Natural Gas Lease Offer Tracker, available at
http://www.naturalgasforums.com/natgasSubs/naturalGasLeaseOfferTracker.php.

[7] As noted earlier, we emphasize that data on groundwater contamination resulting from shale gas activities in Pennsylvania are not generally available to researchers or homeowners because there was no widespread testing of groundwater prior to the start of drilling. What we are measuring is therefore the cost associated with the *risk* of contamination *perceived* by homeowners.

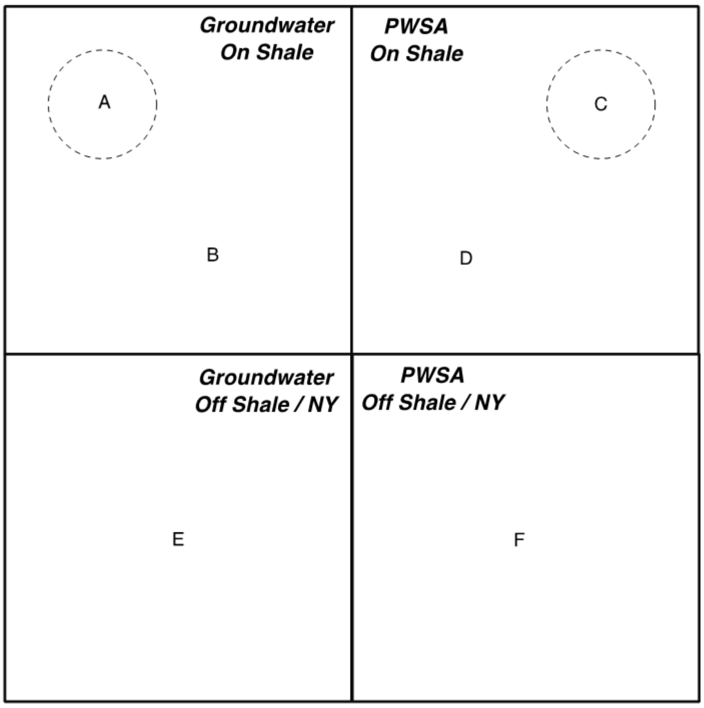


Figure 5: Types of Areas Examined

Figure 5 is useful in describing our identification strategy, and we will refer to it in more detail in Section 5.1.1. Area A represents a buffer drawn around a well pad that defines adjacency; we discuss the difference between wellbores and well pads in Section 4, and provide more information on how the size of the buffer is determined below. That buffer is located in an area dependent upon groundwater (GW)—i.e., outside the public water service area (PWSA). The remainder of that area, which is not adjacent to a well pad but is in the vicinity of one, and which is located in Pennsylvania where drilling is allowed and can occur due to the presence of the Marcellus shale formation, is labeled as area B.[8] Similarly defined regions of the PWSA area are labeled by C and D, respectively. Areas E and F represent regions (GW and PWSA, respectively) that are not exposed to hydraulic fracturing, either because they do not lie on the shale in Pennsylvania, or because they are in New York where a moratorium prohibits the

[8]Area B could also include homes in NY or in PA but off the shale that are within 20km.

practice.[9]

3.2 Defining the Adjacency Buffer

Our analysis focuses on how proximity to shale gas wells affects property values; we focus first on houses in close proximity to shale gas wells—an effect we refer to as *adjacency*. In order to define an adjacency "buffer" (i.e., what is "close" in terms of proximity), we draw on an empirical strategy similar to that employed by Linden and Rockoff (2008), which determines the point where a localized (dis)amenity no longer has localized impacts. In particular, this method compares the prices of properties sold after the drilling of a well to the prices of properties sold prior to drilling, and identifies the distance beyond which that well no longer has an effect that is different from that experienced elsewhere in the area. We then define our adjacency treatment group as properties having a well pad within this distance.

In order to conduct this test, we create a subsample of properties that have, at some point in time (either before the property is sold or after), only one well pad located within 10km.[10] We begin by estimating two price functions based on distance to a well pad—one for property sales that occurred prior to a well pad being drilled and one for property sales after drilling began, controlling for property characteristics (X), census tract characteristics (Z), and county $\times$ year fixed effects, ν_{it}:[11]

$$\ln P_{it} = X_{it}'\alpha_1 + Z_{it}'\alpha_2 + \sum_{j=1}^{7}(\beta_j D_{ij}) + \nu_{it} + \epsilon_{it} \quad (1)$$

[9]We include homes located in areas E and F in our vicinity regressions to test the robustness of the baseline for estimating our vicinity treatment effect. We find that including or excluding these properties does not significantly affect our coefficients (See Section 5.2). For adjacency impacts, comparing across homes in areas A and B (and areas C and D) allows us to eliminate the common macro impacts without having to rely on homes in areas E and F.

[10]For this exercise, we choose to only look at homes that have one well pad within 10km, as the impact of multiple well pads on a home's value may be multiplicative instead of additive, which could confound this threshold test. Furthermore, it would be difficult to separate the impact of the nearest well pad before and after the well pad is drilled if the home was already being impacted by another well pad drilled nearby. Restricting the sample to properties with only one well within a larger distance than 10km would reduce our sample size but we think it is a reasonable assumption that vicinity impacts that are felt at more than 10km will likely be felt in the same way as at 10km.

[11]Property characteristics are square feet, lot size, lot size squared, year built, and distance to nearest MSA. Other characteristics such as number of rooms, number of bathrooms, and number of stories were not reported for all properties and therefore to increase our sample size we did not include these characteristics. Census tract characteristics include percent of 25-year-olds with high school, percent black, percent Hispanic, percent unemployed, and mean income.

$\ln P_{it}$ is the natural logarithm of the transaction price for house i in year t. D_{ij} are indicators for whether a home is within a certain distance to a well as defined by 1.5km bins: (0, 1.5km], (1.5, 3km], and so on. Excluding an indicator for a home more than 9km from a well as our reference category, we have seven indicators. Equation (1) is estimated for each water source two times: once using the sample of properties that are eventually within 10km of a well pad (but not at the time of sale), and once using the sample of properties that are within 10km of a well pad at the time of sale. We plot the β_j's for each of the different distance intervals. We also plot the 95^{th} percentile confidence bands for the coefficients. The point at which the confidence intervals of the coefficients before and after a well pad is drilled intersect is the distance at which property values are no longer affected by adjacency. For groundwater homes, we see a sharp decline in property values after wells are drilled nearby; however, the difference between the before and after graphs goes away outside 1.5km. For PWSA houses, the distance functions are statistically indistinguishable before and after drilling. These figures demonstrate that adjacency impacts differ by drinking water source within 1.5km of a well.

Although the relative effect on groundwater houses (as demonstrated by the difference in the impact before and after a shale gas well is drilled at 1.5km) is statistically significant and negative, it does have a large confidence interval, ranging from just below zero to roughly -5. We don't rely on these numbers to identify our estimate of adjacency because it is a special sample (specifically, homes within 10km of only one shale gas well), and this technique does not control for many unobservable attributes associated with location. Instead we use this figure to motivate our selection of buffer distances below.

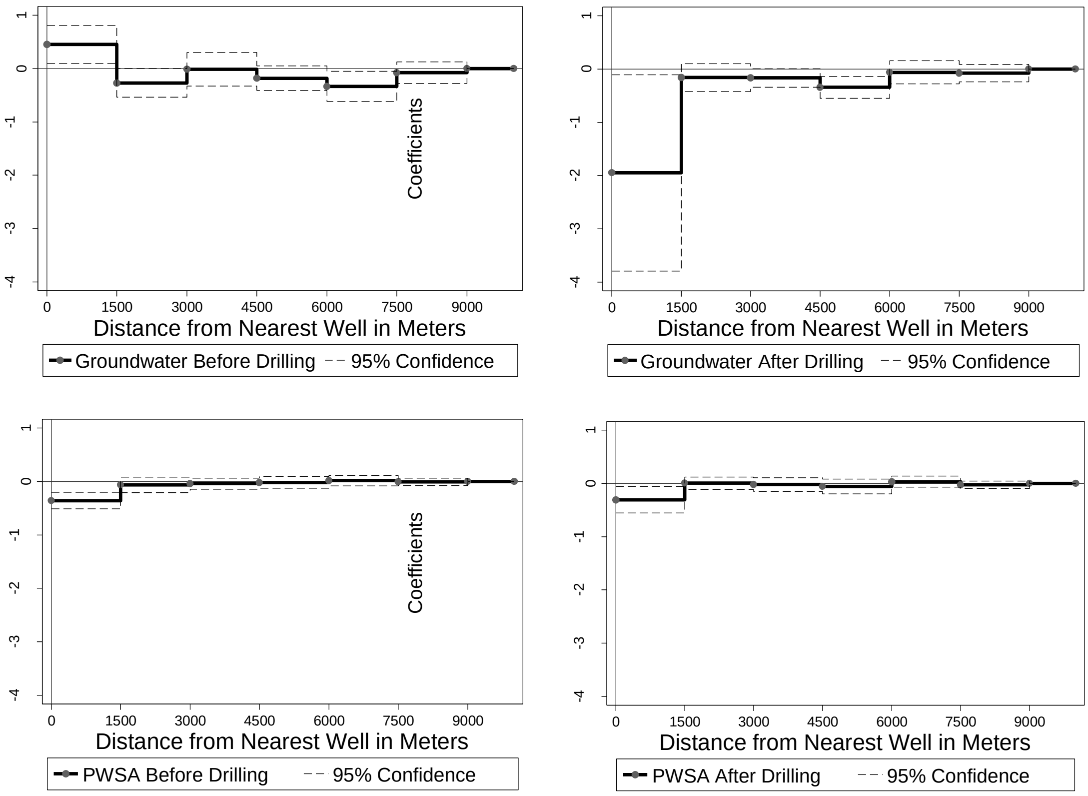


Figure 6: Coefficients from Equation (1) by Drinking Water Source and Timing of Drilling

4 Data

We obtained transaction records of all properties sold in 36 counties in Pennsylvania and seven border counties in New York between January 1995 and April 2012 from CoreLogic, a national real estate data provider. The data contain information on the transaction price, exact street address, parcel boundaries, square footage, year built, lot size, number of rooms, number of bathrooms, and number of stories. We start with 1.38 million unique observations of sales that have information on the location of the property. After excluding properties without a listed price, a price in the top or bottom 1% of all prices, and properties sold more than once in a single year, we are left with 1.20 million sales observations. Of these, there are 1.12 million sales of properties designated as a single family residence, rural home site, duplex, or townhouse; our main specifications only include these properties in order to estimate the impact on (likely) owner-occupied homes, rather than properties that are more likely transient or rented.[12] Furthermore, we want to include in our main specification only homes that were sold from one person to another (i.e., excluding made-to-order homes), thus we drop approximately 8,000 properties that were sold in the year built.[13] After eliminating new homes, of the remaining 1.04 million sales, 473,605 are repeat sales—a necessary condition for including property fixed effects. For specifications that instead rely on observed housing attributes, not all properties report a full slate of housing characteristics; out of our 1.04 million sale sample, only 799,767 have information on all property characteristics.

Figure 7 depicts the location of the Marcellus shale formation as well as the properties sold in Pennsylvania and bordering counties in New York (where hydraulic fracturing has been prohibited throughout our sample period). We also calculate the distance of each property's exact location to the population-weighted centroid of the nearest Metropolitan Statistical Area (MSA) in order to measure the property's rural character.

To determine the date that wells are drilled, we use the Pennsylvania Department of Environmental Protection (PADEP) Spud Data as well as the Department of Conservation and Natural Resources (DCNR) Well Information System (the Pennsylvania

[12]Though CoreLogic provides an indicator for whether the property is owner-occupied, this variable is not consistently reported by all counties. We exclude properties listed as a hotel, motel, residence hall, or transient lodging.

[13]Results are similar if these homes are included. We return to the question of new home construction in response to shale gas development in Appendix Section A.3.

Internet Record Imaging System/Wells Information System [PA*IRIS/WIS]). Combining these two datasets provides us with the most comprehensive dataset on wells drilled in Pennsylvania that is available (for example, no other data distributors, such as IHS, would provide more comprehensive data than this).The final dataset includes both vertical and horizontal wells, both of which produce similar disamenities, including risks of groundwater contamination.[14]

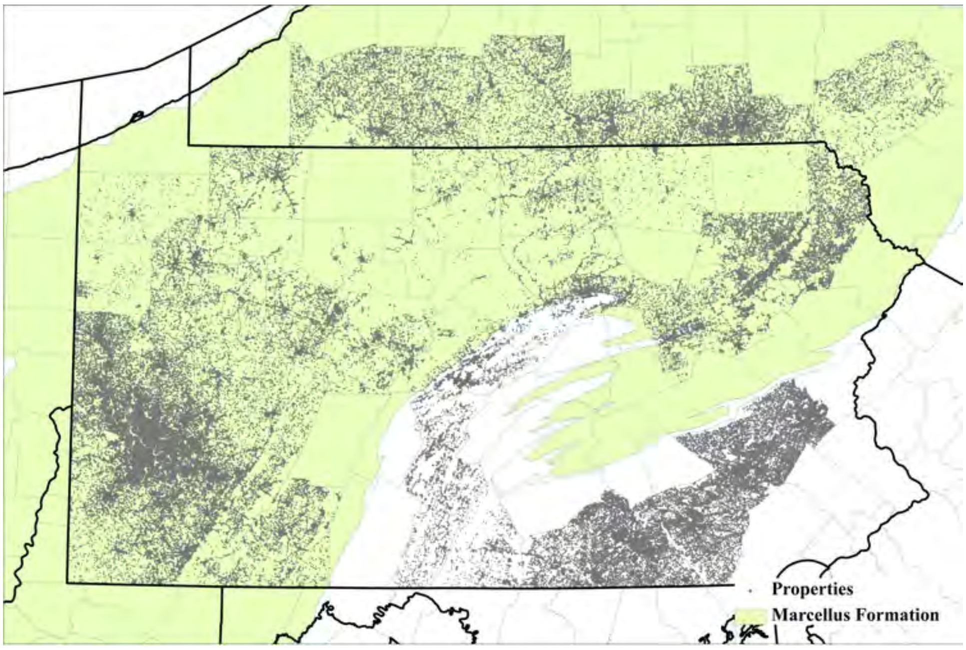


Figure 7: The Marcellus Shale Formation and Property Sales in Pennsylvania and New York

Because operators are able to drill horizontally underground, they can locate the tops of several wellbores close together at the surface, and radiate out the horizontal portion of the wellbore beneath the surface. Therefore, multiple wellbores can be drilled within meters of one another on the same "well pad," concentrating the surface disruption to a smaller space. Though the data do not group wells into well pads, we believe this is important to consider when estimating the effect of shale gas wells on nearby properties, as the impact from an additional wellbore is likely different than the impact of an additional well pad. We therefore assume that any wellbore within a

[14]Risk of improper well casing or cementing would be present in both vertical and horizontal wells.

short distance of another wellbore is located on the same pad (specifically, any wellbore that is closer than 63m, or the length of an acre, to any other wellbore in a well pad).[15] We start with 6,260 wellbores, which we group into 3,167 well pads (with an average of 2 wellbores per pad and a maximum of 12). Using the geographic information system (GIS) location of the wells and the properties, we calculate counts of the number of well pads that have been drilled, within certain distances, at the time of the property sale. The PADEP also provides information on the GIS location of all permitted wells, which we use to count the number of wells that have been permitted but have not yet been drilled (only about 60% of the wells that have been permitted have been drilled). We can also use the date that the well was permitted to determine how long a permit has remained undrilled. And finally, we obtain the volume of natural gas produced for each wellbore from the PADEP's Oil & Gas Reporting Website.[16]

Pennsylvania has many hilly and mountainous areas as well as plateaus. Therefore, depending on where the property is located, a homeowner may or may not be able to see all the wells within a 2km distance. Following the methodology in Walls et al. (2013), who examine the property value of natural landscape views, we count the number of wells that are in view and not in view at the time of sale. To do so we use ArcGIS's Viewshed tool and an elevation map from the National Elevation Dataset (at a 30 meter resolution) to predict how far a 5-foot tall observer can see from all directions around the property centroid. From this we make a count of the visible wells within different radii (1, 1.5, and 2km).

To identify properties that do not have access to piped drinking water, we utilize data on public water service areas. We obtained the GIS boundaries of the public water supplier's service area in Pennsylvania from the PADEP, and the GIS locations of parcel centroids that have access to public water in New York from the New York State Department of Taxation and Finance (NYDTF).[17] In the case of Pennsylvania,

[15]During completion, a multi-well pad, access road, and infrastructure are estimated to encompass 7.4 acres in size; after completion and partial reclamation, a multi-well pad averages 4.5 acres in size (New York State Department of Environmental Conservation, 2011).

[16]The data are reported as annual quantities until 2009 and then biannual from 2010 to 2012.

[17]In order to designate a PWSA/GW indication for New York properties, we utilize GIS to determine whether each CoreLogic parcel boundary intersects one of the NYDTF parcels. However, not all property locations geocoded in the NYDTF data fall within the parcel boundaries of the CoreLogic properties. For these unmatched CoreLogic properties, we create 250m buffer areas around each NYDTF parcel indicated as having access to public water. The unmatched CoreLogic properties that fall within this buffer are designated as having public water. If these properties fall outside the buffer, we assume they are groundwater dependent.

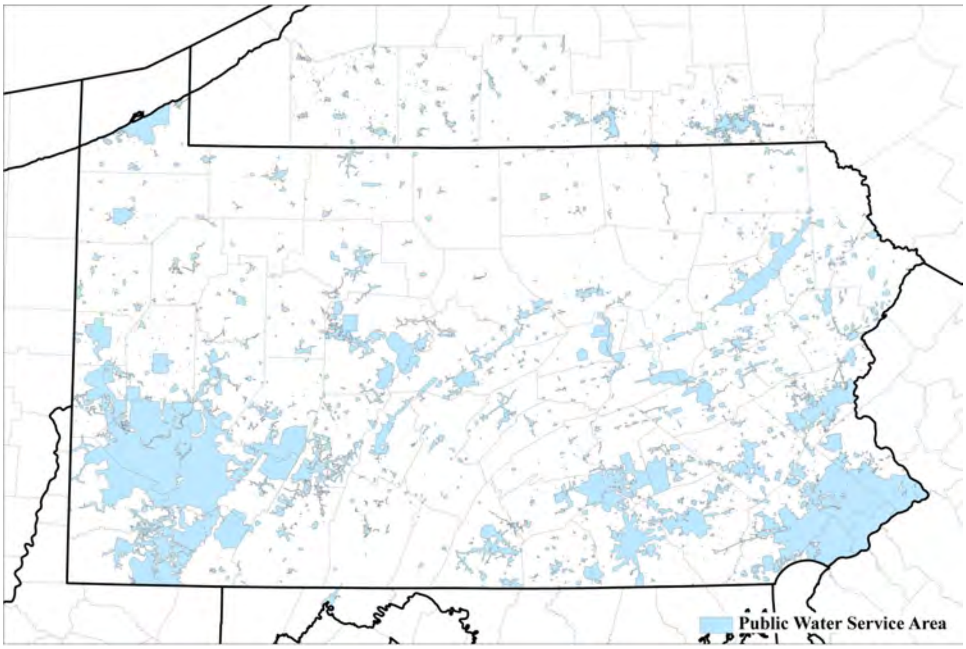


Figure 8: Public Water Service Areas in Pennsylvania and Bordering Counties in New York

any property that was outside the PWSA was assumed to be groundwater dependent.[18]

Table 1 shows that there exist observable differences between PWSA and GW homes, in terms of lot size, property values, age, ruralness, and well proximity, demonstrating the importance of controlling for property-level unobservables with property fixed effects. Furthermore, differences in observables across the two types of water sources suggest there may be unobservable, time-varying differences across PWSA and GW homes that could confound the estimates of impacts of proximity to shale gas wells on property values. We deal with this issue by focusing on GW homes that are near PWSA homes, in order to minimize the unobservable differences in location across the two water source homes; see Section 5.1.2 for a more in depth discussion of how we utilize the GW boundary to minimize these unobservables. Figure 8 shows the PWSA areas for Pennsylvania and New York, where the unshaded areas are assumed to depend on private groundwater wells as a drinking water source. This figure demonstrates that the PWSAs are scattered throughout both states, further illustrating the

[18]There is not much financial assistance to households that wish to extend the piped water area to their location, and this is a costly endeavor according to personal communication with the development manager at the Washington County Planning Commission, April 24, 2012.

importance of estimating the impacts of shale development on groundwater homes. Figure 9 demonstrates the PWSA boundary sample for an example county, Armstrong County, Pennsylvania.

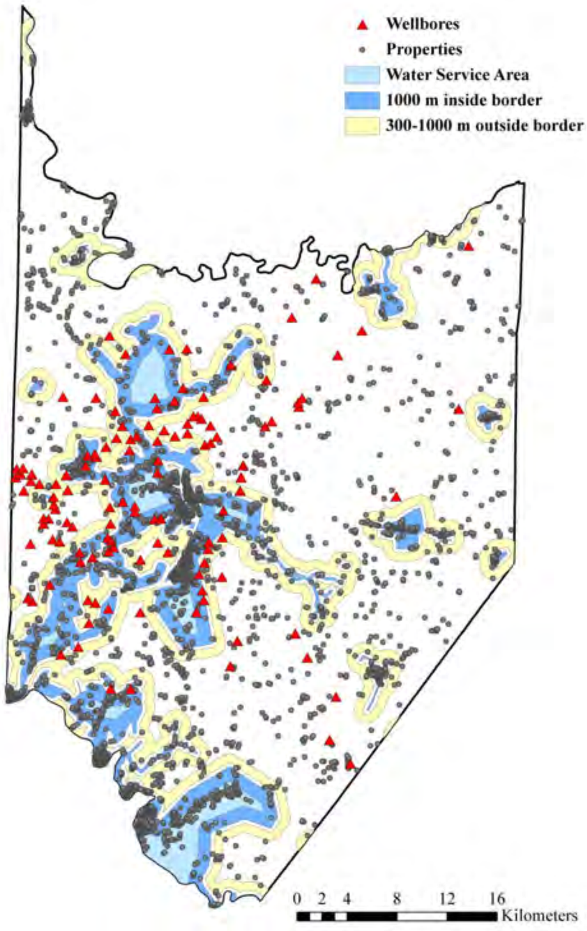


Figure 9: Example Indicating the 1000m Boundary Inside and 300-1000m Boundary Outside of Public Water Service Areas in Armstrong County, Pennsylvania

To obtain information on neighborhood attributes, we merge in census tract data compiled by SimplyMap, a national data mapping software tool.[19] SimplyMap combines information from decennial censuses, the American Community Survey Public Use Microdata Samples, the Annual Demographic Survey, Current Population Reports, numerous special Census reports, and information from the US Postal Service to create estimates for key sociodemographic variables at the census tract level. Data are available in 2010 census tract geographies for 2000, 2010, 2011, and 2012.

[19]http://geographicresearch.com/simplymap/

Table 1: Summary Statistics by Sample

	GW	**PWSA**	**PA/On**	**PA/Off**	**NY**
	Means(SD)	Means(SD)	Means(SD)	Means(SD)	Means(SD)
Transaction Price (k 2012 Dollars)	174	147	128	165	100
	(106)	(95.4)	(98.4)	(95.7)	(77.7)
GW	1	0	.116	.212	.378
	(0)	(0)	(.321)	(.409)	(.485)
Age	41.5	52.2	56.8	50.5	63.5
	(38.7)	(33.9)	(32.3)	(39.5)	(37.1)
Total Living Area (1000 sqft)	1.77	1.65	1.59	1.7	1.66
	(.739)	(.66)	(.82)	(.666)	(.665)
No. Bathrooms	1.92	1.88	1.79	1.9	1.75
	(.851)	(.857)	(.877)	(.857)	(.761)
No. Bedrooms	3.09	3.08	2.97	3.2	3.17
	(.818)	(.843)	(.961)	(.889)	(1.01)
Lot Size (acres)	3.47	1.52	.87	3.23	4.07
	(11.5)	(233)	(5.97)	(352)	(16.7)
Distance to nearest MSA (km)	22.3	18.1	22.8	15.4	19.8
	(11.1)	(10.5)	(12.6)	(7.84)	(13.5)
% Age 25 w/High School	42.3	36	37.5	39.3	35.2
	(7.92)	(10.5)	(11.5)	(8.42)	(8.65)
% Black	1.16	5.83	6.56	5.17	2.15
	(1.94)	(10.8)	(13.7)	(7.17)	(2.22)
% Hispanic	.457	1.5	.59	3.16	.699
	(.697)	(3.77)	(2.04)	(5.74)	(1.16)
% Unemployed	3.69	4.26	4.1	4.78	4.5
	(1.34)	(2.37)	(2.07)	(3.03)	(2.11)
Mean Income (k Dollars)	68.7	66.3	64.5	63.7	59.3
	(15.7)	(26)	(27.4)	(19.2)	(14.9)
Marcellus Indicator	.466	.634	1	0	1
	(.499)	(.482)	(0)	(0)	(0)
Distance to Closest Well Pad (km)	10.3	12.3	11.2	16.1	15.3
	(5.62)	(5.12)	(5.4)	(2.49)	(3)
Pads in 1km	.00224	.000701	.004	0	0
	(.0618)	(.0366)	(.0928)	(0)	(0)
Pads in 1.5km	.00575	.00205	.0107	0	0
	(.123)	(.0738)	(.19)	(0)	(0)
Pads in 2km	.0115	.00462	.0219	0	.000032
	(.2)	(.127)	(.328)	(0)	(.0073)
Pads in View in 1km	.00042	.000116	.00063	0	0
	(.0249)	(.0132)	(.0298)	(0)	(0)
Pads in View in 1.5km	.000709	.000306	.00145	0	0
	(.0327)	(.0218)	(.0498)	(0)	(0)
Pads in View in 2km	.00106	.0005	.00232	0	0
	(.0415)	(.0304)	(.0721)	(0)	(0)
Annual Prod. in 1.5km (MMcf)	.655	.176	.891	0	0
	(41)	(25)	(57.6)	(0)	(0)
Annual Prod. in 1km (MMcf)	1.55	.533	2.3	0	0
	(79.7)	(48.2)	(102)	(0)	(0)
Annual Prod. in 2km (MMcf)	3.44	1.18	4.79	0	0
	(137)	(80.5)	(163)	(0)	(0)
Wellbores in 20km	2.55	3.77	7.25	.0313	1.2
	(21.3)	(21.8)	(32.5)	(.868)	(7.73)
Undrilled Permits in 20km	1.62	2.68	4.85	.00753	.777
	(13.5)	(15.7)	(21.9)	(.222)	(5.23)
Annual Prod. in 20km (MMcf)	482	670	1,359	3.04	144
	(6,071)	(5,396)	(9,407)	(184)	(1,249)
Observations	121,352	656,010	581,198	397,275	93,845

Notes: GW refers to properties without access to piped water. PWSA refers to properties in a public water service area. PA/On refers to properties on the Marcellus shale in PA. PA/Off refers to properties off the Marcellus shale in PA. NY refers to properties in New York (all of which are on the Marcellus shale).

5 Empirical Strategy and Results

5.1 Adjacency Effects and Groundwater Contamination Risk

In this section, we estimate the impacts of close proximity (adjacency) to shale gas wells on property values. These effects can be positive, such as in the case that the property owner receives royalty or other lease payments from the gas company for the natural gas extracted under their property, or negative, given perceived impacts of groundwater contamination or the alteration of the local landscape. As the siting of shale gas wells can be strategic on the part of gas companies, it is important to account for a wide range of unobservable attributes that may be correlated with proximity to both the property and the shale well. Thus, we employ two different empirical approaches—a difference-in-differences technique combined with a nearest-neighbor matching algorithm and a triple-difference technique that makes use of a PWSA boundary sample (described in more detail in Section 5.1.2) in order to eliminate unobservables and thus more accurately capture the impact of adjacency.

5.1.1 Difference-in-Differences Nearest Neighbor Matching (DDNNM)

To begin, we are interested in measuring the GWCR—i.e., the effect of well pad adjacency on groundwater-dependent homes. The standard problem in recovering a treatment effect is that we are unable to observe the counterfactual for a treated observation; in the current setting, we fail to observe the price of a house located in close proximity to a well pad if that same house were instead located farther away ("same," in this context, is in terms of both house and neighborhood attributes, both time invariant and those that vary over time). Parametric hedonic regression functions are used to address this problem by specifying a functional relationship with which the counterfactual value can be imputed. This assumes that unobserved determinants of house value are not correlated with observed determinants.[20]

Matching estimators impute counterfactual observations by pairing treated houses with similar houses from a control group.[21] The effect of treatment is then found by averaging across the price differences for matched pairs. More detail on the techniques

[20]A number of quasi-experimental approaches have been developed to deal with the case when this assumption does not hold (Parmeter and Pope, 2009); we utilize several of these ideas in subsequent sections.

[21]For more background on the advantages of matching compared to parametric hedonic methods, see Cochran and Rubin (1973), Rubin (1974), Rosenbaum and Rubin (1983), Rubin and Thomas (1992), and Heckman et al. (1998).

involved in matching estimators can be found in Abadie and Imbens (2002), Abadie and Imbens (2006), Abadie and Imbens (2011), and Abbott and Klaiber (2011); our main specification uses the nearest neighbor matching technique.

The key to the success of this type of matching estimator is to structure the problem so that unobservable house and neighborhood attributes are not correlated with treatment status. We do so here by limiting the control sample in certain dimensions and by requiring exact matches in other dimensions.[22] In particular, the nearest neighbor matching estimator allows us to require exact matches in the geographic dimension (i.e., census tract) to control for neighborhood unobservables, and in the temporal dimension (i.e., transaction year) to control for time-varying unobservables. We require exact matches in these dimensions to help control for various forms of unobservables that might otherwise bias our results. Moreover, we limit the sample to include only houses that we expect to be in a relatively homogenous neighborhood within each census tract. Thus, we (1) limit our analysis to only houses that are within 6km of a well pad (defining the treatment buffer to be 1, 1.5, or 2km given evidence of a small adjacency buffer found in Section 3.2, (2) require exact matches by census tract, (3) require exact matches by year of sale, and (4) perform the analysis separately for groundwater and PWSA houses. The idea behind these restrictions is that houses within 6km of a well pad in the same census tract that rely on the same water source will be located in similar neighborhoods, thereby reducing both the time-varying and time-invariant unobservables that may be correlated with the location of the property. Requiring exact matching by year of sale will further eliminate differences in unobservables that vary from year to year at this level of the neighborhood.

The nearest neighbor matching algorithm is used to recover an estimate of the average treatment effect on the treated (ATT), or the impact on price from moving a non-adjacent house inside the adjacency buffer. In Figure 5, this corresponds to a move from B to A for groundwater houses, and from D to C for PWSA houses. We now show that, by differencing these ATT estimates, we are able to recover an estimate

[22]It is important to note that there may exist residual impacts of shale gas development for homes that are not immediately adjacent to a shale gas well. For example, homes that depend on piped water may face some level of drinking water contamination, or some exposure to other types of drilling externalities. Key to our identification is that outside of a clearly defined adjacency buffer, the homes are not only less likely to be affected by shale gas development but also that these homes will be equally affected by development regardless of location (i.e., the contamination of drinking water is not correlated with adjacency). However, although there is evidence that shale gas development has affected surface water (see Olmstead et al. (2013)), there have been no studies of shale gas development on piped drinking water.

of GWCR. Using the areas defined in Figure 5, we can refer to the price of housing in each area as being composed of a number of constituent parts:

$$
\begin{aligned}
P_A &= \text{GWCR} + \text{Adjacency} + \text{Vicinity} + \text{Macro} \\
P_B &= \text{Vicinity} + \text{Macro} \\
P_C &= \text{Adjacency} + \text{Vicinity} + \text{Macro} \\
P_D &= \text{Vicinity} + \text{Macro} \\
P_E &= \text{Macro} \\
P_F &= \text{Macro}
\end{aligned}
$$

Our nearest neighbor matching algorithm applied to groundwater houses yields an estimate of the GWCR combined with the adjacency effect: $P_A - P_B = GWCR + Adjacency$. Applied to PWSA houses, it yields an estimate of the adjacency effect alone: $P_C - P_D = Adjacency$. Differencing these two estimates leaves us with an estimate of the GWCR:

$$\text{GWCR}_{\text{DDNNM}} = (P_A - P_B) - (P_C - P_D)$$

The results of the nearest neighbor matching procedure are reported in Table 2. The first two rows report the point estimates and 90% confidence intervals for PWSA houses using 1, 1.5, and 2km treatment buffers. The next two rows report comparable figures for groundwater houses.

In all cases, the difference-in-differences estimate of the GWCR effect based on these estimates is negative. In the case of the 1.5km treatment buffer, the DD estimate is large (-16.7%) and significant at the 10% level.

An advantage of the DDNNM estimator is that, unlike the DDD estimator that we describe below, it does not rely on variation in exposure to shale gas development over time; the concerns about shifting hedonic price gradients raised by Kuminoff and Pope (forthcoming), as discussed in Section 2, are therefore not relevant.

Table 2: Log Sale Price on Groundwater Contamination Risk of Well Pads from a Matching Estimator

	Treatment Buffer		
Sample	1km	1.5km	2km
PWSA (*n=9,517*)	-0.0064	0.039	0.006
	(-0.080, 0.073)	(-0.014, 0.092)	(-0.036, 0.047)
GW (*n=1,980*)	-0.0834	-0.128	-0.088
	(-0.187, 0.020)	(-0.211, -0.044)	(-0.163, -0.013)
DD Estimate	-0.077	-0.167	-0.094
Bias Adjustment Variables			
-House Attributes	Yes	Yes	Yes
-Year Fixed Effects	Yes	Yes	Yes
-County Fixed Effects	Yes	Yes	Yes

Notes: Sample comprising all houses within 6km of a well pad. Each house in the treatment buffer is matched with 4 houses in the control sample. Exact match required on year of sale and census tract. Matching also based on house attributes (lot size, square footage, number of bedrooms, number of bathrooms, and year built). Treatment buffer size varies between 1 and 2km. Bias adjustment equation contains all matching variables and census tract fixed effects. 90% confidence intervals reported in parentheses.

5.1.2 Triple-Difference Estimator (DDD)

A second approach is used to identify *both* adjacency and vicinity effects jointly. Unlike the previous approach, however, it does exploit variation in house prices over time. Considering the impact categories defined above, we begin with the change in a *particular* property's value over time (ΔP) in each area:

$$\begin{aligned}
\Delta P_A &= \Delta\text{GWCR} + \Delta\text{Adjacency} + \Delta\text{Vicinity} \ + \Delta\text{Macro} \\
\Delta P_B &= \Delta\text{Vicinity} + \Delta\text{Macro} \\
\Delta P_C &= \Delta\text{Adjacency} + \Delta\text{Vicinity} + \Delta\text{Macro} \\
\Delta P_D &= \Delta\text{Vicinity} + \Delta\text{Macro} \\
\Delta P_E &= \Delta \text{ Macro} \\
\Delta P_F &= \Delta\text{Macro}
\end{aligned}$$

Our strategy for identifying adjacency effects uses a difference-in-differences (DD) estimator:

$$\Delta\text{Adjacency}_{\text{DD}} = [\Delta P_C - \Delta P_D]$$

$$\Delta\text{Adjacency}_{\text{DD}} + \Delta\text{GWCR}_{\text{DD}} = [\Delta P_A - \Delta P_B]$$

where the first difference, "Δ," reflects the change in price of a particular house (e.g., accompanying the addition of a new well pad). The second difference compares the change in prices for PWSA properties adjacent to shale gas development to the change in prices of PWSA properties not adjacent to development. For the PWSA homes, this differences away vicinity and macro effects that are common across C and D; the corresponding equation for GW homes results in both adjacency and groundwater contamination risk. Finally, to estimate the effect of perceived groundwater contamination risk, we take the third difference, between the effects in PWSA and GW areas in a triple-difference (DDD) estimator defined by:

$$\Delta \text{GWCR}_{\text{DDD}} = [\Delta P_A - \Delta P_B] - [\Delta P_C - \Delta P_D]$$

In this expression, the first difference, Δ reflects the change in the price of a particular house accompanying the addition of a new well pad. The second difference (i.e., $[\Delta P_A - \Delta P_B]$ and $[\Delta P_C - \Delta P_D]$) compares the change in prices inside each adjacency buffer to the change in prices in the area outside of that buffer. This differences away relevant vicinity and macro effects, which should be the same on both sides of the adjacency buffer boundary, leaving only GWCR and adjacency effects. The third (and final) difference differences those double-differences, eliminating adjacency effects and leaving only GWCR.

In order to conduct this test in an empirical framework, we define our impact variable given the results of our adjacency test in Section 3.2. Specifically, we look at well pads rather than wellbores for adjacency effects. We choose to look at pads in order to identify GWCR because we are capturing perceptions of contamination risk. When the pad is cleared and drilling begins, it is unlikely that the second bore will have the same impact on property values as the initial pad. Essentially, here we assume that the perception that groundwater will be contaminated will be the same regardless of the number of wellbores.[23] Therefore, we run separate regressions for the impact of different counts of well pads within 1, 1.5, or 2km of property i at time t of sale (i.e., $pads_{it}$ in Equation 2). Our first regression specification takes the following form:

$$\ln P_{it} = \theta pads_{it} + \lambda (GW \times pads)_{it} + \nu_{it} + \mu_i + \epsilon_{it} \tag{2}$$

[23]We test this by running the regressions on bores rather than pads and find that bores do not significantly affect GWCR.

We include controls for county × year,[24] ν_{it}, and property, μ_i, fixed effects. Importantly, we restrict the sample to only houses that are at some point in time inside a treatment buffer (i.e., area A or C). θ therefore measures ΔP_C and $\lambda+\theta$ measures ΔP_A; $\Delta P_A - \Delta P_C$ is thus defined by λ, the coefficient on the interaction term between *pads* and GW. Assuming $\Delta P_B = \Delta P_D$, λ will provide an estimate of the capitalization effect of groundwater contamination risk. Of course, there is no reason to expect *a priori* that $\Delta P_B = \Delta P_D$; however, a simple F-test demonstrates that this is indeed the case.[25] Therefore, only using properties that are at some point in time within an adjacency buffer (areas A and C), allows us to conduct an implicit triple difference, where the macro and vicinity effects are canceled out; i.e., $\lambda = [\Delta P_A - \Delta P_B] - [\Delta P_C - \Delta P_D]$. This allows us to estimate the GWCR and adjacency effects without having to control explicitly for vicinity impacts.

As mentioned earlier, unobservables can affect the estimated impact of proximity to shale gas wells on property values. We utilize several strategies including difference-in-differences and triple differences to control for many of these unobservables. We also use property fixed effects to control for any time invariant unobservables at the house level and county × year fixed effects to control for time-varying unobservables at the county level.

In addition to these controls, we implement a sample restriction designed to minimize differences in time-varying unobservables across the GW and PWSA subsamples. In particular, we limit our sample to only properties located in a narrow band around the PWSA boundary—1000m on either side, ignoring houses on the GW side within 300m (to avoid potential miscodes of PWSA houses as GW houses).[26] GW and PWSA houses can be very different on average (see Table 1 for summary statistics); these

[24] In an alternate specification, we instead attempted to use census tract fixed effects × year to capture more local time varying unobservable attributes of the neighborhood. However, while the results were statistically significant and qualitatively similar for GWCR, the adjacency effects were insignificant (although they were comparable in sign and magnitude). We believe this may be due to the fact that census tract fixed effects × year jointly with property fixed effects soaks up too much variation in order to accurately capture adjacency impacts.

[25] Vicinity effects, estimated using wellbores, are described below. We re-estimate those vicinity regressions using well pads, adding interactions between all variables and the groundwater dummy. We then conduct an F-test of the joint significance of the interactions between groundwater and the well pad count variables. That F-test reveals that these interactions are not jointly statistically significant ($Prob > F = 0.4805$), demonstrating that the vicinity effects do not differ across drinking water sources.

[26] Our final results are robust to removing 300m on the PWSA side as well; doing so, we find an even larger decrease in values of GW-dependent homes and a statistically significant increase in PWSA homes.

structural differences are, however, captured by property fixed effects. Time-varying unobservable differences in GW and PWSA houses are, conversely, more likely to result from changing neighborhood attributes. In particular, we would expect neighborhood attributes to be very different across GW and PWSA houses located far from the boundary—some of the GW houses are in very rural areas while some of the PWSA houses are in urban areas. By limiting our DDD analysis to houses along the PWSA boundary, we still allow for variation in water source while geographically restricting neighborhoods to be more homogenous.[27]

We provide simple evidence that restricting our sample to the band surrounding the PWSA boundary functions as intended. In particular, using data from years prior to the onset of hydraulic fracturing, we estimate the following regression equation:

$$\ln P_{it} = year'_{it}\gamma + (GW \times year)'_{it}\delta + \mu_i + \epsilon_{it}$$

$\ln P_{it}$ is the log of the transaction price of the property in year t, $year'_{it}$ are indicators for the year the property was sold, GW is an indicator for whether the property is groundwater dependent, μ_i are property fixed effects, and ϵ_{it} is a time-varying error term.

We estimate this regression equation first using the full sample and then using only properties in the band surrounding the PWSA boundary. If the band is able to successfully control for time-varying differences between GW and PWSA houses, we would expect to see δ become insignificant using the boundary sample.

Figure 10 describes the 95% confidence interval for estimates of δ derived from the full sample and the PWSA band for each year of our data prior to the onset of hydraulic fracturing (i.e., 1996 to 2005). While δ derived from the full sample is significant in every year except 1998 and 2003, δ derived from the PWSA band is insignificant in every year except 2004. This demonstrates that utilizing only the sample within 1000m of the PWSA band eliminates (most) time-varying unobservables that may confound our estimates of shale gas impacts on property values.

As we have now defined the PWSA boundary, we restrict our attention to those homes located within this region in order to clearly identify the GWCR in our triple-difference estimation. Using this sample, results show that the GWCR effect is negative, large, and statistically significant.

[27]In our matching technique described in Section 5.1.1 the definition of our control group and requirement of exact matching on year and census tract do this job.

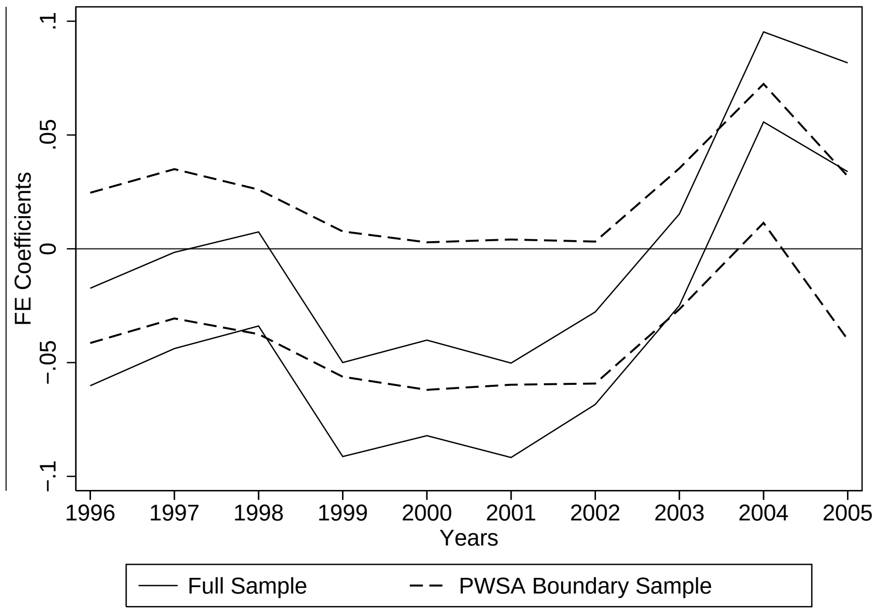


Figure 10: 95% Confidence Bands on Groundwater × Year Fixed Effect Interaction—Full Sample vs. PWSA Boundary Band

Table 3: Groundwater Contamination Risk

	Using $K \leq 1$km		Using $K \leq 1.5$km		Using $K \leq 2$km	
	Full	Boundary	Full	Boundary	Full	Boundary
	(1)	(2)	(3)	(4)	(5)	(6)
	ln(price)	ln(price)	ln(price)	ln(price)	ln(price)	ln(price)
Pads in Kkm	.046	.057	.047**	.066**	.016*	.031***
	(.040)	(.042)	(.020)	(.030)	(.010)	(.010)
(Pads in Kkm)*GW	-.003	-.224***	-.005	-.100**	.021	.031
	(.062)	(.051)	(.028)	(.046)	(.018)	(.069)
County-Year Effects	Yes	Yes	Yes	Yes	Yes	Yes
Property Effects	Yes	Yes	Yes	Yes	Yes	Yes
n	1,961	942	3,885	1,835	6,608	3,090

Notes: Dependent variable is log sale price in 2012 dollars. Sample includes only properties that at some point in time (future or present) are within Kkm of a well pad. *Boundary* restricts sample to a buffer around the border of the public water service area. Regressors include counts of well pads drilled within Kkm before the sale date. Robust standard errors are clustered by census tract. *** Statistically significant at the 1% level; ** 5% level; * 10% level.

One thing to note is that the *overall* impact of adding a well pad within 1km is not just the GWCR, but must also take into account the positive (although sometimes statistically insignificant) adjacency effect. The results from Table 3 imply that adding an extra well within 1.5km causes groundwater homes to depreciate by 3.4%, (although an F-test reveals that the summation of these two effects has a t-stat of -0.7 and thus is not statistically significant at 1.5km) with -10% being due to the risk of groundwater contamination, and +6.6% due to the positive impact of lease payments and other adjacency impacts. However, it is interesting to see how the effects differ as we change the size of the adjacency buffer. Very near the well (within 1km), we see much larger negative impacts and insignificant positive impacts, where the summation of the two coefficients implies a statistically significant drop of 16.7% (t-stat of -4.19) for groundwater-dependent homes. This may be due jointly to the increased perception of groundwater contamination along with increased negative impacts (such as noise and light pollution associated with drilling) that dampen the positive impacts of lease payments. Moving farther from the well (from 1km to 1.5km) reduces the negative impact on PWSA homes (perhaps by decreasing the localized pollution impacts) and allows for a positive impact to emerge; the negative impact on GW homes also diminishes. Finally, farthest from the shale gas well, at 2km, there are no longer significant negative impacts of proximity for GW homes; this is intuitive, as we would expect that being located farther from a well would decrease the perception of groundwater contamination risk. For PWSA homes, on the other hand, the *net* positive benefits decrease at 2km relative to 1.5km; this is likely the result of fewer homes at this distance receiving lease payments.[28]

To examine the effect of adjacency to shale gas wells in more detail, we next focus only on properties that have access to piped water (i.e., any property located in areas C and D). This allows us to identify the adjacency effect in the absence of any concerns over GWCR, via a difference-in-difference estimation. Table 4 displays how the impacts of shale gas development depend on characteristics of that development, using different distances (1km, 1.5km, and 2km) as adjacency buffers.

[28]Although electronic records of the location of the horizontal segment of the wellbores are not available, anecdotal evidence suggests that wellbores are typically between 3,000 (.9km) and 5,000 feet (1.5km) (US Energy Information Administration, 2013), but could be up to 9,000 feet (2.7km) (Horizontal Well Drillers, 2012).

Table 4: Adjacency Effects

	K=1km	K=1.5km	K=2km
	(1)	(2)	(3)
	ln(price)	ln(price)	ln(price)
A. Log Sale Price on Well Pads in View			
Not-Visible Well Pads in Kkm	.023	.012*	.032**
	(.028)	(.006)	(.013)
Visible Well Pads in Kkm	-.006	.014	-.027
	(.071)	(.037)	(.059)
B. Log Sale Price on Production			
Annual Production in Kkm (MMcf)	2.1e-05	2.2e-05**	9.0e-06*
	(1.9e-05)	(8.8e-06)	(5.2e-06)
C. Log Sale Price on Timing of Wellbores			
New Bores (drilled $\leq$ 365 days)	.015	.020**	.009**
	(.018)	(.010)	(.004)
Old Bores (drilled > 365 days)	-.008	-.012	-.003
	(.029)	(.013)	(.008)
New Undrilled Permits	.052**	.020	.010
	(.025)	(.014)	(.011)
Old Undrilled Permits	.040*	.006	.006
	(.023)	(.013)	(.008)
County-Year Effects	Yes	Yes	Yes
Property Effects	Yes	Yes	Yes
n	507,023	507,023	507,023

Notes: Dependent variable is log sale price in 2012 dollars and each panel and column represents a separate regression. Regressors are the count of wells (or annual natural gas production) within Kkm, depending on the column. Sample includes only properties that are in piped water service areas, in Pennsylvania, on the Marcellus Shale. Robust standard errors are clustered by census tract. *** Statistically significant at the 1% level; ** 5% level; * 10% level.

First, since the topography of Pennsylvania varies across the state, we have variation in the number of wells that are visible to a 5ft individual looking 360 degrees around a property. Panel A of Table 4 shows that that the positive impact of being adjacent to a well is driven by those wells that are not in view of the property. The positive effects from lease payments appear to be offset when the wells are in view, as the coefficient on wells in view is statistically insignificant.

We next examine whether the positive results are indeed driven by royalties from the gas production by including as a regressor total production from nearby wells. We do find evidence to support this; in Panel B we find that the amount of natural gas produced by the wells (as measured as total natural gas production in the year of sale) increases property values. This result is intuitive, as the level of production would result in higher royalty payments to the homeowner.[29]

Our final specification in Panel C explores the timing of the well drilling: in particular, we estimate whether newly drilled bores (i.e., bores drilled within a year prior to the sale of the home) affect property values more than older bores. Results show that newly drilled bores positively impact property values for homes within 1.5km and 2km, while old bores have an insignificant, negative impact. At a very close distance, 1km, there is no positive effect felt from newly drilled wells, however there is a positive effect from permits implying that expectations for drilling have positive implications for property values in close proximity. footnoteThis provides some evidence that homeowners expect future drilling to occur, which implies that there may be some attenuation bias given future expectations. However, formally modeling these expectations of drilling is very data and computationally intensive and therefore is outside the scope of this research. See Bayer et al. (2011) for a description of the method and data needed to conduct such an estimation. Newly drilled bores tend to produce more natural gas than old bores; therefore, the number of new bores may be acting as a proxy for production.

5.2 Vicinity

We next estimate the effect of shale gas development on housing prices in the broader geographical area, which we refer to as vicinity effects. These impacts may include increased traffic congestion and road damage from trucks delivering fresh water to wells and hauling away wastewater, local wastewater disposal, and increased local employment and demand for goods and services, for example.

In measuring vicinity effects, we consider the impact on property values of the number of wellbores within 20km of each house, thus estimating the broader economic impacts of a shale boom.[30] We do this by regressing the natural logarithm of the transaction price for house i in year t ($\ln P_{it}$) on a variety of different regressors. Our simplest specification includes the counts of wellbores that have been drilled prior to

[29] In another specification, not shown, we found that the positive result is only driven by wells that have produced some natural gas; in the data, 42% of wells that have been drilled have not produced anything as of 2012.

[30] We choose to use counts of wellbores rather than well pads because wellbores are a more direct measure of productivity; the more wellbores there are, the more natural gas can be extracted. We expect the broader impacts on housing prices to be driven by immigration of natural gas workers and associated economic activity; thus we choose a measure more closely related to productivity at a broader scale—wellbores. Results using well pads rather than wellbores are qualitatively similar; given high levels of correlation between bores and pads, we are unable to include both in our regressions.

the time of sale within 20km, $bores20_{it}$.

$$\ln P_{it} = \zeta\, bores20_{it} + \nu_{it} + \mu_i + \epsilon_{it} \tag{3}$$

We use a vector of county × year fixed effects, ν_{it}, to control for macro effects, and either census tract fixed effects or property fixed effects, labeled here as μ_i, to control for time invariant unobservables at the property or neighborhood level.[31] Further regressions explore the impact of undrilled permits, production data, and the timing of the drilling on property values.

[31] Our choice of using either property or census tract FE is discussed in more detail below.

Table 5: Vicinity Effects from Wellbores

	Using On (1) ln(price)	Using On/Off (2) ln(price)	Using On/NY (3) ln(price)	Using On (4) ln(price)	Using On/Off (5) ln(price)	Using On/NY (6) ln(price)
A. Log Sale Price on Cumulative Wellbores in 20km						
Bores	2.2e-04	2.6e-04*	2.3e-04*	-1.1e-04	-1.1e-04	-8.0e-05
	(1.4e-04)	(1.5e-04)	(1.4e-04)	(1.5e-04)	(1.5e-04)	(1.4e-04)
B. Log Sale Price on Wellbores and Permits in 20km						
Bores	7.1e-04***	7.2e-04***	6.1e-04***	1.3e-04	1.1e-04	1.3e-04
	(1.5e-04)	(1.5e-04)	(1.4e-04)	(1.6e-04)	(1.6e-04)	(1.6e-04)
Undrilled Permits	-.0017***	-.0016***	-.0012***	-8.4e-04**	-8.1e-04**	-7.6e-04**
	(4.1e-04)	(4.1e-04)	(3.7e-04)	(3.7e-04)	(3.6e-04)	(3.4e-04)
C. Log Sale Price on Production in 20km						
Annual Production (MMcf)	1.9e-06***	2.0e-06***	2.0e-06***	3.0e-07	3.0e-07	3.8e-07
	(4.3e-07)	(4.5e-07)	(4.4e-07)	(4.2e-07)	(4.2e-07)	(4.1e-07)
D. Log Sale Price on Timing of Drilling						
New Bores ($\leq$ 365 days)	.0018***	.0018***	.0015***	8.6e-04**	8.1e-04**	8.8e-04**
	(3.8e-04)	(3.8e-04)	(3.7e-04)	(4.0e-04)	(3.9e-04)	(3.9e-04)
Old Bores (> 365 days)	5.9e-04***	6.2e-04***	5.9e-04***	9.3e-05	7.9e-05	9.0e-05
	(2.3e-04)	(2.3e-04)	(2.2e-04)	(2.6e-04)	(2.5e-04)	(2.5e-04)
New Undrilled Permits	-.0013***	-.0012***	-8.8e-04**	-3.5e-04	-3.3e-04	-3.1e-04
	(4.3e-04)	(4.2e-04)	(3.7e-04)	(4.3e-04)	(4.2e-04)	(3.8e-04)
Old Undrilled Permits	-.003***	-.003***	-.0026***	-.002***	-.0019***	-.0019***
	(7.0e-04)	(6.7e-04)	(6.5e-04)	(6.4e-04)	(6.2e-04)	(6.2e-04)
Property Effects	No	No	No	Yes	Yes	Yes
Census Tract Effects	Yes	Yes	Yes	No	No	No
County-Year Effects	Yes	Yes	Yes	Yes	Yes	Yes
n	378,518	743,529	466,062	226,775	425,342	268,807

Notes: Dependent variable is log sale price in 2012 dollars. Each column represents a different sample. All columns include properties that are on the Marcellus shale in Pennsylvania, excluding those that at some point in time are within 2km of a wellbore. Columns (2) and (5) also include properties that are off the Marcellus shale and in Pennsylvania. Columns (3) and (6) include properties on the Marcellus shale as well as properties in New York. Robust standard errors are clustered by census tract. *** Statistically significant at the 1% level; ** 5% level; * 10% level.

Results are reported in Table 5. This table includes three different samples. The first sample only includes properties that are located on the Marcellus shale. This initial specification implies that identification is based on the timing of when drilling in the vicinity occurred, given that the control group has positive and rational expectations of future drilling. The second sample adds to the control group homes in Pennsylvania that are off the shale. This identifies the vicinity effect based on the timing of drilling but also in comparison to areas that would never have any shale gas development due to geological constraints. The third sample instead adds to the control group homes in New York, where the current drilling moratorium may be lifted; thus, the control group has some rational expectation that drilling may occur in the (distant) future. Each of these three samples excludes homes that at any point in time of our sample period are within 2km of a shale gas well (i.e., inside areas A and C), in order to avoid confounding the vicinity and adjacency impacts.

The first three columns include census tract fixed effects with property characteristics while the following three columns instead utilize property fixed effects. We therefore control for time-invariant unobservables through different fixed effects. Utilizing census tract fixed effects assumes that the unobservables that are correlated with vicinity are at the neighborhood level. Alternatively, using property fixed effects assumes that there is something unobservable about the house that affects the number of wells within 20km. While the property fixed effects are essential to use in the adjacency and GWCR regressions, it is reasonable to assume that they are less important in the vicinity regressions, where it is unlikely that an unobservable property attribute would be associated with the number of wells within 20km. Instead, it is more likely that census tract attributes could affect the number of wells in the vicinity; for example, a census tract with lots of hills may be less amenable to high levels of development than a flat census tract area (which would require less land clearing). Furthermore, when comparing the variation in the number of wells drilled and total natural gas production *within* property sales to the variation *across* property sales there is much more within-property variation in the adjacency regressions than the vicinity regressions (about twice as much). Our preferred specifications are therefore those in the first three columns.

Examining the specification in Panel A, we find insignificant effects of increased exposure to wellbores within 20km, with weakly significant and positive impacts in columns 2 and 3. This provides some weak evidence that development increases property values in the vicinity.

In Panel B we introduce as an extra regressor the count of wellbores that have been permitted but are not yet drilled at the time of sale. Results show that undrilled permits have a negative impact on property values, regardless of the fixed effect or sample utilized. This is likely due to the fact that locations with undrilled permits are areas that have begun to be cleared for a well pad but have not stimulated economic activity through natural gas production. Thus, they only cause disamenities (which are then capitalized into the price of the home) without producing natural gas, which can be a source of wealth for those in the community. Moreover, areas with many undrilled permits could experience deflated expectations—i.e., they are areas that were expected to be highly profitable but have yet to deliver or have been shown to be unprofitable.[32] In this specification, we also find that the number of bores positively impacts properties (further strengthening the evidence found in Panel A), but this result only holds when we use census-tract fixed effects.

We next test whether having productive wells in the vicinity affects property values. In Panel C our regressor "Annual Production" is the total amount of natural gas produced by the wellbores within 20km of a property. We find that annual production positively impacts property values, although the coefficient is only significant when we include census-tract fixed effects.[33] The loss of significance when moving to property fixed effects may be due to the fact that property fixed effects soak up too much of the variation in prices; utilizing census-tract fixed effects instead allows for more of the variation in values given different levels of shale gas development.

We next separate out the wellbores based on the timing of the drilling. Panel D demonstrates that new bores (i.e., those that were drilled within a year before the time of sale) positively impact property values, presumably from increased economic activity in the region. However, wells drilled more than a year earlier only appear to have any economic impacts when using census tract fixed effects. Furthermore, undrilled permits have a negative economic impact, although the property fixed effects results only show significant negative impacts of old undrilled permits. These undrilled permits may be associated with the bust portion of the boom-bust cycle of development.

These results suggest that the broad economic impacts of shale gas development are felt when new wellbores are being drilled in the vicinity—drilling requires an influx of workers, which can boost the local economy. We find some evidence that production

[32] "Pa. fracking boom goes bust," *Philadelphia Daily News*, September 12, 2013.

[33] In this regression, areas that have wells within 20km but have no production are treated the same as areas with zero wells, and hence, zero production.

may lead to extra economic activity. However, leaving an area cleared without actually drilling on it or an un-fulfillment of expectations, as indicated by undrilled permits can produce a disamenity that is felt in the broader region. Thus, benefits from shale gas development appear to come quickly with the influx of drilling activity, and then fade once the drilling is done, providing some evidence of a boom-bust cycle.

6 Summary of Impacts

Our various difference-in-differences, nearest neighbor matching, and triple-difference specifications demonstrate that groundwater-dependent homes are negatively affected by shale gas development. These negative impacts are large in the 1-1.5km range, suggesting that the perception of groundwater contamination risk for homes that are located very close to shale gas wells can have substantial negative capitalization impacts on property values. Although data are not available to measure the impact of actual groundwater contamination, the perception of these risks is large, causing important, negative impacts on groundwater-dependent properties near wells.

While it is clear that the perceived risk of groundwater contamination is negatively impacting property values, homes that have piped water may in fact benefit from being adjacent to drilled and producing wells. These results appear to be driven by royalty payments (or expectations of royalties) from productive wells. However, it is evident from how the results change when we use different sized adjacency buffers that the positive impacts from being close to a well diminish as the property gets too close to a well. The overall positive impacts are in fact a net impact of being near a well; i.e., net of any negative environmental externality (such as light and noise pollution from drilling) that is common to all properties regardless of drinking water source. Thus, even homes with piped water are better off being slightly farther from a well, as long as they are able (i.e., not too far) to capitalize on lease payments. Consistent with the increase in property values being due to royalties and lease payments, we find that the property values increase with the quantity of natural gas produced by the adjacent wells. We also find that this positive finding is driven by wells that were drilled within a year prior to the sale, most likely because the highest production levels occur in the first year of a well's life. Coinciding with the visual disamenity of a shale gas well, we only find these positive effects for wells that are not visible from the property.

Similarly, for groundwater-dependent homes, the negative impacts of adjacency are large when the property is very close (1.5km or closer) to a shale gas well, and become more negative the closer a home gets to a shale gas well. We find that the costs of groundwater contamination risk are large and significant (ranging from -10% to -22.4%), suggesting that there could be large gains to the housing market from regulations that reduce the risk. In the most recent year of our data (April 2011 to April 2012) the average annual loss for groundwater-dependent homes within 1.5km of a well was $33,214.[34] The average annual loss for GW properties is larger than the average annual gain for piped-water properties within 1.5km of a shale gas well ($8,954).[35] These losses, when multiplied by the number of affected houses, may be quite important in terms of property tax revenues for local governments, which could potentially justify costly regulation to diminish groundwater contamination risk. Furthermore, it is important to keep in mind that our estimates do not fully capture the total costs associated with groundwater contamination risk. Owners of groundwater-dependent homes may purchase expensive water filters to clean their drinking water when faced with a shale gas well nearby; whole home filters can cost thousands of dollars[36]. Since we do not capture adaptation costs, our estimates are therefore a lower bound of the actual costs incurred by homeowners located near shale gas wells, implying that contamination risk reduction can have very large benefits to nearby homes.

The use of the properties in the band surrounding the PWSA boundary (relative to using the full sample of homes) demonstrates that failing to control for unobservable attributes that vary with location can lead one to understate the negative impacts on groundwater homes. This is intuitive: very rural groundwater-dependent neighborhoods may be different in unobservable but important ways when compared with more urban PWSA neighborhoods, and these differences might vary over time. Using a sample containing both PWSA and GW homes, but specifically limited to be within the PWSA boundary, helps to reduce the potential for these unobserved neighborhood differences to bias our results while still permitting comparison based on water

[34]This value is calculated using all groundwater-dependent properties that are within 1.5km of a well and sold between April 2011 and April 2012. For these properties, the number of well pads in 1km and between 1 and 1.5km are combined with the coefficients from our boundary sample (columns 2 and 4, Table 3).

[35]This is calculated using properties that have access to piped water, are within 1.5km of a well, and are sold in the most recent year of our data. If we also include properties within 2km of a well and include coefficients from column 6 for properties within 1.5km and 2km of a well, the groundwater losses are larger on average but have a smaller total loss (i.e., the average loss for GW homes within 2km of a well is $15,774 compared to gains for PWSA homes on average of $8,940).

[36]These water filters can cost about $1,480/year for a family of four (http://www.ezclearwater.com/wordpress/tag/whole-house-water-filtration-system/). Given the cost to adjacent groundwater dependent homes is $33,000, this implies a yearly cost of approximately $1,500, which aligns with the price of installing a filter to clean the drinking water.

source.[37]

We also find that all homes, regardless of water source, are affected by shale gas development at the vicinity level. There are positive impacts from having drilling in a property's vicinity, but these effects are larger for wells drilled within a year of the property sale; wells that were drilled more than a year earlier have little to no effect on property values, while wells that have been permitted but have not been drilled negatively affect homes in the vicinity. Undrilled permits have a particularly large effect if the permits were issued more than a year before the property sale. This implies that shale gas development causes a temporary boom in the economy, likely through increased in-migration and increased employment and economic activity caused by drilling activities. However, after a year has gone by, the boom diminishes and permitted pads that were never drilled can have detrimental impacts on property values. These results hold regardless of whether we include properties that have the potential for shale gas development, because they are located on top of the Marcellus shale, or properties that do not, because they are in New York or are off the Marcellus shale.

7 Conclusion

Shale gas development has become increasingly widespread due to advances in technology that allow for the inexpensive extraction of natural gas from shale rock. This rapid expansion in development has generated ample discussion about whether any benefits from a cleaner, domestic fuel and the accompanying economic development outweigh the potential local negative impacts associated with extraction. This paper addresses many of these questions by measuring the net capitalization of benefits and costs of shale gas development at various levels of proximity.

Shale gas development's ability to impact nearby groundwater sources has been a major point of discussion. We estimate the local impacts on groundwater-dependent homes to be large and negative, which is not surprising given the attention the media has been placing on this potential risk. As groundwater contamination can cause severe economic hardship on homes without access to piped water, the perception that a nearby shale gas well will cause irreversible harm to an aquifer can drop property values by affecting buyers' willingness to pay for proximity to shale gas wells. Moreover,

[37] Of course, any two houses in the PWSA boundary sample are not necessarily near one another as the boundary extends throughout the state.

we demonstrate that our estimates can be interpreted with some confidence as measures of marginal willingness to pay, as neighborhood characteristics are not found to have changed in an economically significant manner with the introduction of shale gas.

The potential for exposure to shale gas development to hurt property values is not just an econometric curiosity; rather, it is beginning to show up in the way housing markets on shale plays operate. In particular, there has been recent evidence that major national mortgage lenders are refusing to make loans for properties in close proximity to shale gas wells, and that insurance providers are refusing to issue policies on those houses.[38]

Shale gas development can bring positive impacts to small towns, for example, through increased employment opportunities and economic expansion. The growth of a boom town may be positively capitalized by the homes in the area, while lease payments can provide a great source of income for many homeowners (and these royalties may be spent locally, helping to boost the economy). However, negative externalities associated with shale gas development can extend beyond the immediate proximity surrounding a well. Netting out these different impacts, we find statistically significant evidence of boom town positive impacts in the general vicinity of shale gas development, as evidenced by property value increases from wells drilled within one year of sale. However, the long-term impacts of wells older than a year or never drilled are cause for concern, as the boom is short-lived.

In conclusion, our estimates suggest that there are localized benefits to homes that are adjacent to producing wells, once the drilling stage is complete. However, there are also localized costs of shale gas development borne particularly by groundwater-dependent homes. Benefits to the broader housing market from prominent drilling in the vicinity appear to be focused in areas with a lot of contemporaneous drilling, while areas without will likely see drops in property values. Wells that have been permitted in the vicinity but have remained undrilled for more than a year have a negative effect on property values. Hence, we would anticipate that long-term benefits from shale gas development are most likely to be realized nationally through increased energy security and low fuel costs.

[38]For example, "How the Fracking Boom Could Lead to a Housing Bust," *The Atlantic: Cities*, August 19, 2013.

References

Abadie, A. and G. Imbens (2002). Simple and bias-corrected matching estimators for average treatment effects, NBER Working Paper 283.

Abadie, A. and G. W. Imbens (2006). Large sample properties of matching estimators for average treatment effects. *Econometrica 74*(1), 235–267.

Abadie, A. and G. W. Imbens (2011). Bias-corrected matching estimators for average treatment effects. *Journal of Business & Economic Statistics 29*(1), 1–11.

Abbott, J. K. and H. A. Klaiber (2011). The value of water as an urban club good: A matching approach to HOA-provided lakes. In *2011 Annual Meeting, July 24-26, 2011, Pittsburgh, Pennsylvania*, Number 103781. Agricultural and Applied Economics Association.

Albrecht, S. (1978). Socio-cultural factors and energy resource development in rural areas in the West. *Journal of Environmental Management 7*, 73–90.

Andersson, H., L. Jonsson, and M. Ögren (2010). Property prices and exposure to multiple noise sources: Hedonic regression with road and railway noise. *Environmental and Resource Economics 45*(1), 73–89.

Bailey, A. J. (2010). Fayetteville shale play and the need to rethink environmental regulation of oil and gas development in arkansas, the. *Ark. L. Rev. 63*, 815.

Bajari, P. and C. L. Benkard (2005). Demand estimation with heterogeneous consumers and unobserved product characteristics: A hedonic approach. *Journal of Political Economy 113*(6), 1239–1276.

Bajari, P., J. Cooley, K. il Kim, and C. Timmins (2010). A theory-based approach to hedonic price regressions with time-varying unobserved product attributes: The price of pollution. *American Economic Review 102*(5), 1898–1926.

Bartik, T. J. (1987). The estimation of demand parameters in hedonic price models. *The Journal of Political Economy 95*(1), 81–88.

Bayer, P., R. McMillan, A. Murphy, and C. Timmins (2011). A dynamic model of demand for houses and neighborhoods. Technical report, National Bureau of Economic Research.

Bishop, K. and C. Timmins (2012). Hedonic prices and implicit markets: Estimating marginal willingness to pay for differentiated products without instrumental variables, Duke University Working Paper.

Black, S. E. (1999). Do better schools matter? Parental valuation of elementary education. *The Quarterly Journal of Economics 114*(2), 577–599.

Boxall, P. C., W. H. Chan, and M. L. McMillan (2005). The impact of oil and natural gas facilities on rural residential property values: A spatial hedonic analysis. *Resource and Energy Economics 27*(3), 248–269.

Brasier, K., M. Filteau, D. McLaughlin, J. Jacquet, R. Stedman, T. Kelsey, and S. Goetz (2011). Residents' perceptions of community and environmental impacts from development of natural gas in the marcellus shale: A comparison of Pennsylvania and New York cases. *Journal of Rural Social Sciences 26*(1), 32–61.

Brown, J. and S. Rosen (1982). On the estimation of structural hedonic price models. *Econometrica 50*(3), 765–768.

Bui, L. T. and C. J. Mayer (2003). Regulation and capitalization of environmental amenities: Evidence from the Toxic Release Inventory in Massachusetts. *Review of Economics and Statistics 85*(3), 693–708.

Burnham, A., J. Han, C. E. Clark, M. Wang, J. B. Dunn, and I. Palou-Rivera (2011). Life-cycle greenhouse gas emissions of shale gas, natural gas, coal, and petroleum. *Environmental Science & Technology 46*(2), 619–627.

Chay, K. Y. and M. Greenstone (2005). Does air quality matter? Evidence from the housing market. *Journal of Political Economy 113*(2), 376–424.

Cochran, W. G. and D. B. Rubin (1973). Controlling bias in observational studies: A review. *Sankhyā: The Indian Journal of Statistics, Series A*, 417–446.

Considine, T. J., R. W. Watson, and N. B. Considine (2011). The economic opportunities of shale energy development. *The Manhattan Institute, June*.

Davis, L. W. (2004). The effect of health risk on housing values: Evidence from a cancer cluster. *The American Economic Review 94*(5), 1693–1704.

Davis, L. W. (2011). The effect of power plants on local housing values and rents. *Review of Economics and Statistics 93*(4), 1391–1402.

Ekeland, I., J. Heckman, and L. Nesheim (2004). Identification and estimation of hedonic models. *Journal of Political Economy S1*, S60–S109.

Epple, D. (1987). Hedonic prices and implicit markets: Estimating demand and supply functions for differentiated products. *Journal of Political Economy 95*(1), 59–80.

Freudenburg, W. R. (1982). The impacts of rapid growth on the social and personal well-being of local community residents. *Coping with rapid growth in rural communities*, 137–70.

Gamper-Rabindran, S. and C. Timmins (2011). Does cleanup of hazardous waste sites raise housing values? evidence of spatially localized benefits. *Journal of Environmental Economics and Management, Forthcoming*.

Greenberg, M. and J. Hughes (1992). The impact of hazardous waste superfund sites on the value of houses sold in New Jersey. *The Annals of Regional Science 26*(2), 147–153.

Greenstone, M. and J. Gallagher (2008). Does hazardous waste matter? Evidence from the housing market and the superfund program. *The Quarterly Journal of Economics 123*(3), 951–1003.

Haninger, K., L. Ma, and C. Timmins (2012). Estimating the impacts of brownfield remediation on housing property values, Duke University Working Paper.

Harrison Jr, D. and D. L. Rubinfeld (1978). Hedonic housing prices and the demand for clean air. *Journal of Environmental Economics and Management 5*(1), 81–102.

Heckman, J., H. Ichimura, and P. Todd (1998). Matching as an econometric evaluation estimator. *The Review of Economic Studies 65*(2), 261–294.

Heckman, J., R. Matzkin, and L. Nesheim (2010). Nonparametric Identification and Estimation of Nonadditive Hedonic Models. *Econometrica 78*(5), 1561–1591.

Horizontal Well Drillers (2012). Second generation drilling rig: The HWD 1000, brochure.

Howarth, R., A. Ingraffea, and T. Engelder (2011). Natural gas: Should fracking stop? *Nature 477*(7364), 271–275.

Howarth, R., R. Santoro, and A. Ingraffea (2011). Methane and the greenhouse gas footprint of natural gas from shale formations. *Climatic Change Letters 106*(4), 679–690.

Hultman, N., D. Rebois, M. Scholten, and C. Ramig (2011). The greenhouse impact of unconventional gas for electricity generation. *Environmental Research Letters 6*(4), 1–9.

Kargbo, D. M., R. G. Wilhelm, and D. J. Campbell (2010). Natural gas plays in the Marcellus shale: Challenges and potential opportunities. *Environmental Science & Technology 44*(15), 5679–5684.

Kiel, K. A. and M. Williams (2007). The impact of Superfund sites on local property values: Are all sites the same? *Journal of Urban Economics 61*(1), 170–192.

Klaiber, H. A. and S. Gopalakrishnan (2012). The impact of shale exploration on housing values in Pennsylvania, SSRN Working Paper.

Kuminoff, N. V. and J. Pope (Forthcoming). Do "Capitalization effects" for public goods reveal the public's willingness to pay. *International Economic Review*.

Leggett, C. G. and N. E. Bockstael (2000). Evidence of the effects of water quality on residential land prices. *Journal of Environmental Economics and Management 39*(2), 121–144.

Lillydahl, J., E., E. Moen, K. Boulding, S. Yount, Scott-Stevens, and I. Gallon (1982). *Quality of Life, Expectations of Change, and Planning for the Future in Energy Production Communities*. University of Colorado.

Linden, L. and J. E. Rockoff (2008). Estimates of the impact of crime risk on property values from Megan's Laws. *The American Economic Review 98*(3), 1103–1127.

Linn, J. (2013). The effect of voluntary brownfields programs on nearby property values: Evidence from Illinois. *Journal of Urban Economics Forthcoming*.

Lovejoy, S. (1977). *Local Perceptions of Energy Development: The Case of the Kaiparowits Plateau.* Lake Powell R.

Mendelsohn, R. (1985). Identifying Structural Equations with Single Market Data. *The Review of Economics and Statistics 67*(3), 525–529.

Muehlenbachs, L., E. Spiller, and C. Timmins (2013). Shale Gas Development and the Costs of Groundwater Contamination Risk. *RFF Discussion Paper 12-40*.

New York State Department of Environmental Conservation (2011). Revised Draft Supplemental Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program, Well Permit Issuance for Horizontal Drilling and High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and Other Low-Permeability Gas Reservoirs.

Olmstead, S., L. Muehlenbachs, J.-S. Shih, Z. Chu, and A. Krupnick (2013). Shale gas development impacts on surface water quality in Pennsylvania. *Proceedings of the National Academy of Sciences 110*(13), 4962Ű–4967.

Osborn, S. G., A. Vengosh, N. R. Warner, and R. B. Jackson (2011). Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. *Proceedings of the National Academy of Sciences 108*(20), 8172–8176.

Palmquist, R. B., F. M. Roka, and T. Vukina (1997). Hog operations, environmental effects, and residential property values. *Land Economics*, 114–124.

Parmeter, C. and J. Pope (2009). Quasi-experiments and hedonic property value methods. *Available at SSRN 1283705*.

Poor, J. P., K. L. Pessagno, and R. W. Paul (2007). Exploring the hedonic value of ambient water quality: A local watershed-based study. *Ecological Economics 60*(4), 797–806.

Pope, J. C. (2008a). Buyer information and the hedonic: the impact of a seller disclosure on the implicit price for airport noise. *Journal of Urban Economics 63*(2), 498–516.

Pope, J. C. (2008b). Fear of crime and housing prices: Household reactions to sex offender registries. *Journal of Urban Economics 64*(3), 601–614.

Rahm, B. G., J. T. Bates, L. R. Bertoia, A. E. Galford, D. A. Yoxtheimer, and S. J. Riha (2013). Wastewater management and Marcellus shale gas development: Trends, drivers, and planning implications. *Journal of Environmental Management 120*, 105–113.

Ridker, R. G. and J. A. Henning (1967). The determinants of residential property values with special reference to air pollution. *The Review of Economics and Statistics 49*(2), 246–257.

Rosen, S. (1974). Hedonic prices and implicit markets: product differentiation in pure competition. *Journal of Political Economy 82*(1), 34–55.

Rosenbaum, P. R. and D. B. Rubin (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika 70*(1), 41–55.

Rubin, D. (1974). Estimating causal effects of treatments in randomized and nonrandomized studies. *Journal of Educational Psychology; Journal of Educational Psychology 66*(5), 688.

Rubin, D. B. and N. Thomas (1992). Characterizing the effect of matching using linear propensity score methods with normal distributions. *Biometrika 79*(4), 797–809.

Schmidt, C. W. (2011). Blind rush? shale gas boom proceeds amid human health questions. *Environmental Health Perspectives 119*(8), a348.

Smith, V. K. and J.-C. Huang (1995). Can markets value air quality? a meta-analysis of hedonic property value models. *Journal of Political Economy 103*(1), 209–227.

Theodori, G. (2009). Paradoxical perceptions of problems associated with unconventional natural gas development. *Southern Rural Sociology 24*(3), 97–117.

US Energy Information Administration (2013). Technically recoverable shale oil and shale gas resources: An assessment of 137 shale formations in 41 countries outside the united states. Technical report.

US Environmental Protection Agency (2011). Investigation of Ground Water Contamination near Pavillion, Wyoming, Office of Research and Development, National Risk Management Research Laboratory. *EPA 600/R-00/000*.

Walls, M., C. Kousky, and Z. Chu (2013). Is What You See What You Get? The Value of Natural Landscape Views . *Resources for the Future Discussion Paper RFF DP 13-25.*

Walsh, P. J., J. W. Milon, and D. O. Scrogin (2011). The spatial extent of water quality benefits in urban housing markets. *Land Economics 87*(4), 628–644.

Wang, Z. and A. Krupnick (2013). A retrospective review of shale gas development in the United States. *Resources for the Future Discussion Paper*.

Weber, J. G. (2012). The effects of a natural gas boom on employment and income in Colorado, Texas, and Wyoming. *Energy Economics 34*(5), 1580–1588.

Weinstein, A. and M. Partridge (2011). The Economic Value of Shale Natural Gas in Ohio, Ohio State University Swank Program in Rural-Urban Policy Summary and Report.

Wynveen, B. (2011). A thematic analysis of local respondents' perceptions of Barnett shale energy development. *Journal of Rural Social Sciences 26*(1), 8–31.

Zabel, J. and D. Guignet (2012). A hedonic analysis of the impact of LUST sites on house prices. *Resource and Energy Economics*.

A Appendix (For Online Publication)

A.1 Effects on Sociodemographics

In this subsection, we examine the effect of shale gas development on sociodemographic attributes at the vicinity level. As described in Section 2, if the hedonic price function moves over time, the change in price accompanying a change in exposure to shale gas may provide a poor approximation of the slope of the hedonic price function. Kuminoff and Pope (forthcoming) discuss a number of conditions that must hold in order for this not to be a concern. One important requirement is that the preferences of local residents for exposure to wells do not change over time. If preferences are a function of residents' attributes, a simple check can be performed by examining how tract-level sociodemographics change with changes in exposure. Table 6 describes the results of this analysis. In particular, we regress the change in 33 tract-level attributes, X, over the period 2000 to 2012 on the change in the number of cumulative wellbores within 20km of the centroid of the census tract in 2012.[39]

$$(X_{i,2012} - X_{i,2000}) = \rho\, bores20_{i,2012} + \epsilon_i$$

The first column reports the variable name, and the second column reports the mean of that variable in 2012. The third column reports the coefficient on wellbores, ρ, and the fourth column reports the percent change in the variable in question over the period 2000 to 2012 attributable to the average change in the number of wells in the corresponding vicinity of each census tract.

Out of the 33 variables that we consider, 23 have statistically significant wellbore effects. While statistical significance may be a cause for concern, very few of these effects are *economically* significant. In particular, considering the actual change in well exposure in each census tract over this period, the average of the resulting changes in tract attributes was no larger than 1% for any variable. Changes in neighborhood composition induced by shale gas development are, therefore, quite small. While this is not sufficient to rule out shifts in the hedonic price function over time, it is evidence in favor of a MWTP, as opposed to a simple capitalization effect, interpretation of our DDD results.

[39]Recall that cumulative wellbores is everywhere equal to zero in 2000.

Table 6: Change in Sociodemographic Characteristics, 2000-2012

Variable	Mean in 2012	Coefficient on Wellbores	Average % Δ from Wells
Household Income per Capita	30,080.30	-2.45E0	-0.154
Household Median Vehicles	1.803	1.30E-4***	0.071
Median Age	39.09	5.83E-3***	0.156
Median Age (Female)	40.294	5.19E-3***	0.135
Median Age (Male)	37.706	6.87E-3***	0.189
Population	3,964.24	-6.05E-1***	-0.291
% Asian	0.059	-6.25E-5***	-0.009
% Associate Degree	0.055	3.10E-5***	0.000
% Bachelor's Degree	0.122	-2.24E-6	0.000
% Black	0.155	-6.62E-6	0.000
% Family	0.784	-1.59E-5	0.000
% Female	0.515	-2.39E-5***	0.000
% High School	0.211	2.74E-5***	0.000
% Hispanic	0.131	-9.98E-5***	-0.004
% In Group Quarters	0.034	6.69E-6	0.001
% Less Than High School	0.093	-3.46E-5***	0.000
% Male	0.485	2.39E-5***	0.000
% Married, Female	0.202	-2.91E-5***	0.000
% Married, Male	0.204	-3.52E-5***	0.000
% Non-Family	0.182	9.22E-6	0.000
% Occupation, Construction	0.034	-1.05E-5**	0.000
% Occupation, Farming	0.002	-1.17E-6	0.000
% Occupation, Management	0.068	-1.07E-5	0.000
% Occupation, Production	0.054	-9.87E-6*	0.000
% Occupation, Professional	0.107	8.36E-7	0.000
% Occupation, Sales and Office	0.111	1.11E-5	0.000
% Occupation, Service	0.092	-1.81E-5**	0.000
% Other Race	0.052	5.56E-5***	0.013
% Some College	0.115	2.43E-5***	0.000
% Speaks English	0.728	1.16E-4***	0.000
% Urban	0.835	-9.92E-6***	0.000
% White	0.701	7.68E-5***	0.000
% White, Non-Hispanic	0.643	1.33E-4***	0.000

Note: % Δ from Wells is calculated as the average across census tracts of (Δ Wellbores*Coefficient on Wellbores)/(Mean in 2012)*100.

A.2 Effects on Likelihood of Transaction

Here we investigate whether shale gas development within 20km affects the number of properties that are sold in a census tract. The concern is that drilling activity may affect the likelihood of a transaction, so that our sample of observed sales will be selected based upon the drilling exposure treatment. Using aggregated CoreLogic data, we regress the log of the annual number of transactions in each census tract on exposure to shale gas development within 20km of the tract centroid, including year and census tract fixed effects. We find that the effect of cumulative well pads is small and statistically insignificant for the number of properties sold (Table 7). We therefore do not worry about sample selection in our housing transactions data induced by the well exposure treatment.

Table 7: Log Number of Sales on Drilling Activity

	Using Full Sample	
	(1)	(2)
	ln(# Sales)	ln(# Sales)
Wellbores in 20km	1.95e-04	
	(1.55e-04)	
Well Pads in 20km		4.18e-04
		(3.26e-04)
County-Year Effects	Yes	Yes
Census Tract Effects	Yes	Yes
n	28,565	28,565

Notes: Dependent variable is the log annual number of properties sold in a census tract, calculated using the property sales data. Regressor is the count of wellbores (or well pads) drilled within 20km of the centroid of the census tract in the year of observation. Standard errors are clustered by census tract.

A.3 Effects on Likelihood of New Construction

In this section, we perform two tests to investigate whether new construction associated with shale gas development may be driving down the size of the positive vicinity effect we find during the period around drilling. In particular, a strong increase in new housing supply may result in a failure to find any increase in prices in spite of a positive vicinity effect. Using CoreLogic data, we check first to see if the likelihood of a transaction for a newly constructed property is a function of exposure to cumulative wellbores within 20km at the time of sale.[40] In particular, we run a regression at the property level, where the dependent variable is equal to one if the sale refers to a newly constructed house, and zero otherwise; the regression includes census tract and year fixed effects. Results are reported in Column (1) in Table 8—we find that cumulative wellbores are weakly *negatively* correlated with the likelihood of a transaction being a new construction.

Table 8: New Construction on Drilling Activity

	Using All Property Sale Data		Using 2012 Census Tract Data	
	(1)	(2)	(3)	(4)
	Indicator (New=1)	Indicator (New=1)	% Built 2005 or later	% Built 2005 or later
Wellbores in 20km	-2.16e-04*		2.24e-04	
	(1.14e-04)		(7.56e-04)	
Well Padsin 20km		-3.68e-04*		-1.45e-03
		(2.13e-04)		(2.59e-03)
Census Tract Effects	Yes	Yes	No	No
County-Year Effects	Yes	Yes	No	No
County Fixed Effects	No	No	Yes	Yes
n	1,133,013	1,133,013	3,218	3,218

Notes: In columns (1) and (2), the sample includes all properties sold in the property sales data; dependent variable equals 1 if the property was a new building, zero otherwise. Regressor is the count of wellbores (or well pads) that have been drilled within 20km of the property at the time of sale. In columns (3) and (4), the sample includes 2012 census tract data from SimplyMap on the % of housing built 2005 or later. In the case of the census tract sample, regressor is the count of wells within 20km of the centroid of the census tract in 2012.

[40] Whereas we had dropped new construction homes from our previous analyses, we reintroduce them to the dataset here. If we were to include newly constructed homes in our previous analyses, our findings would not change.

In our second test, we use data from SimplyMap describing the percentage of houses in each census tract in 2012 that were built in 2005 or later. We regress this percentage on cumulative wellbores in 2012, using county fixed effects to help control for unobservables. This effect is statistically insignificant, providing further evidence that a positive supply response is not responsible for our failure to find any positive effects of drilling at the vicinity level.

EXHIBIT 3

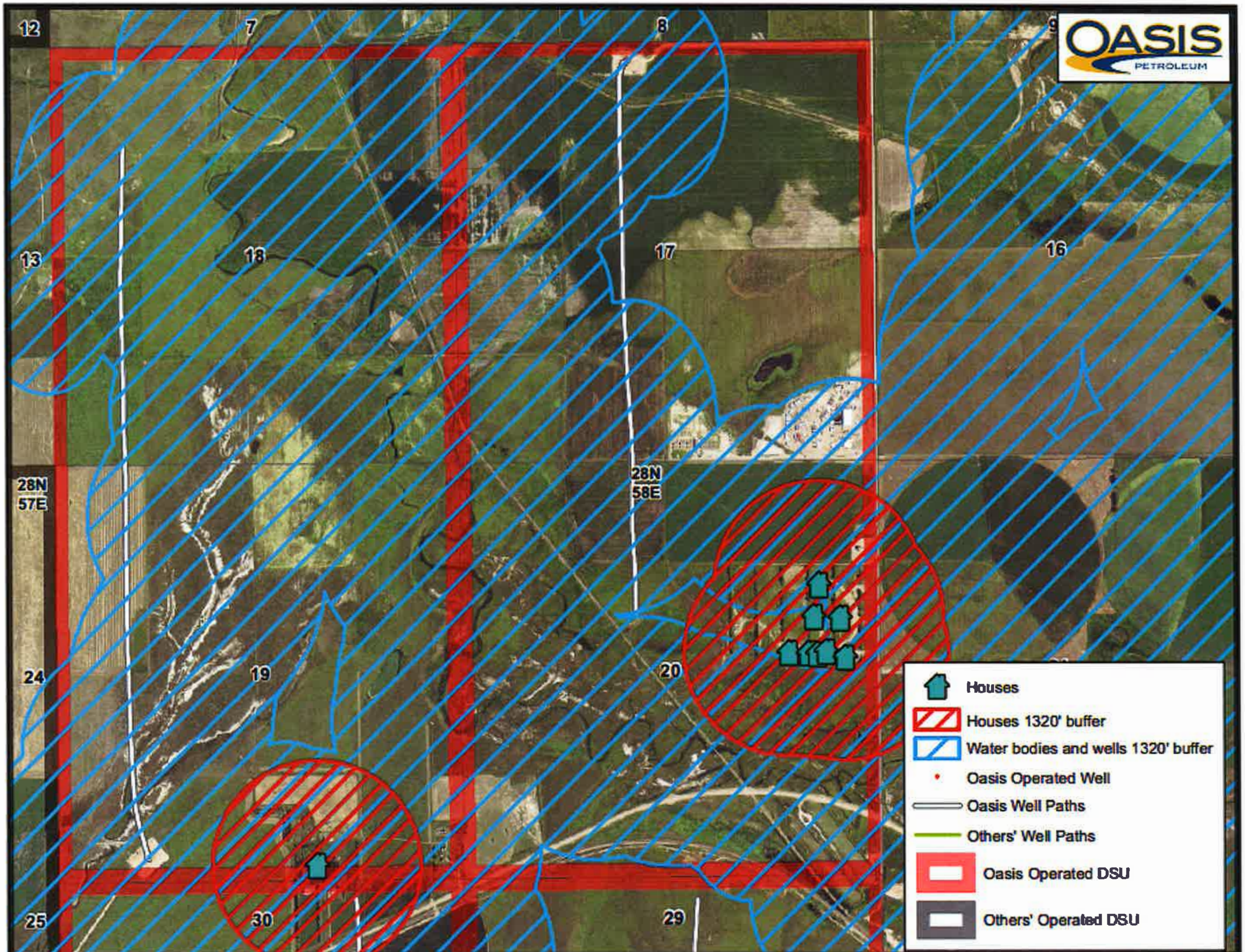
MT BOGCC Business Meeting

- Access to MTBOGCC hearings
- Solution without an attendant problem
- Separate estate ownership of surface and minerals
- Montana geology has unique small targets
- Negotiated locations are better than regulated locations

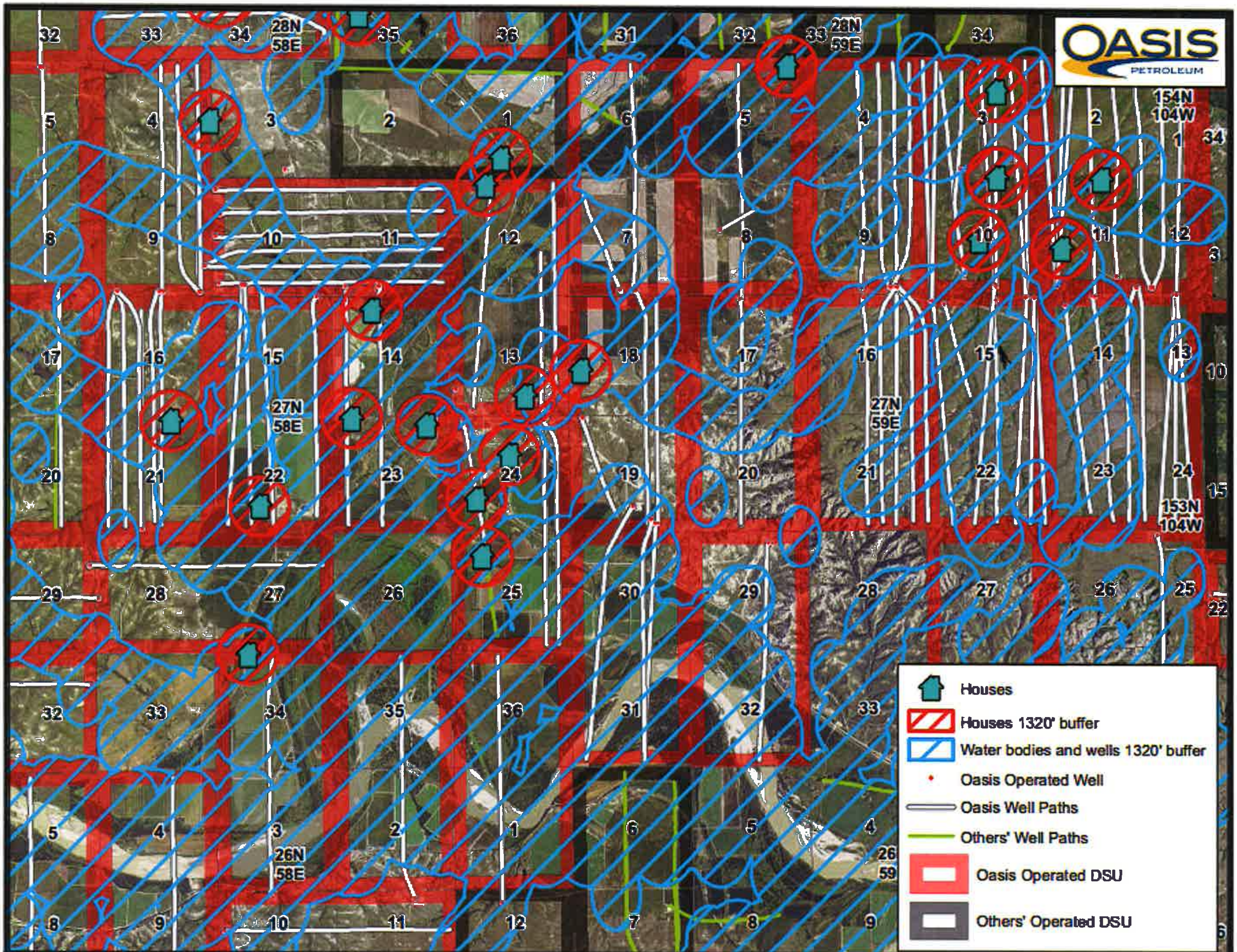
EXHIBIT 4

Drilling Setbacks

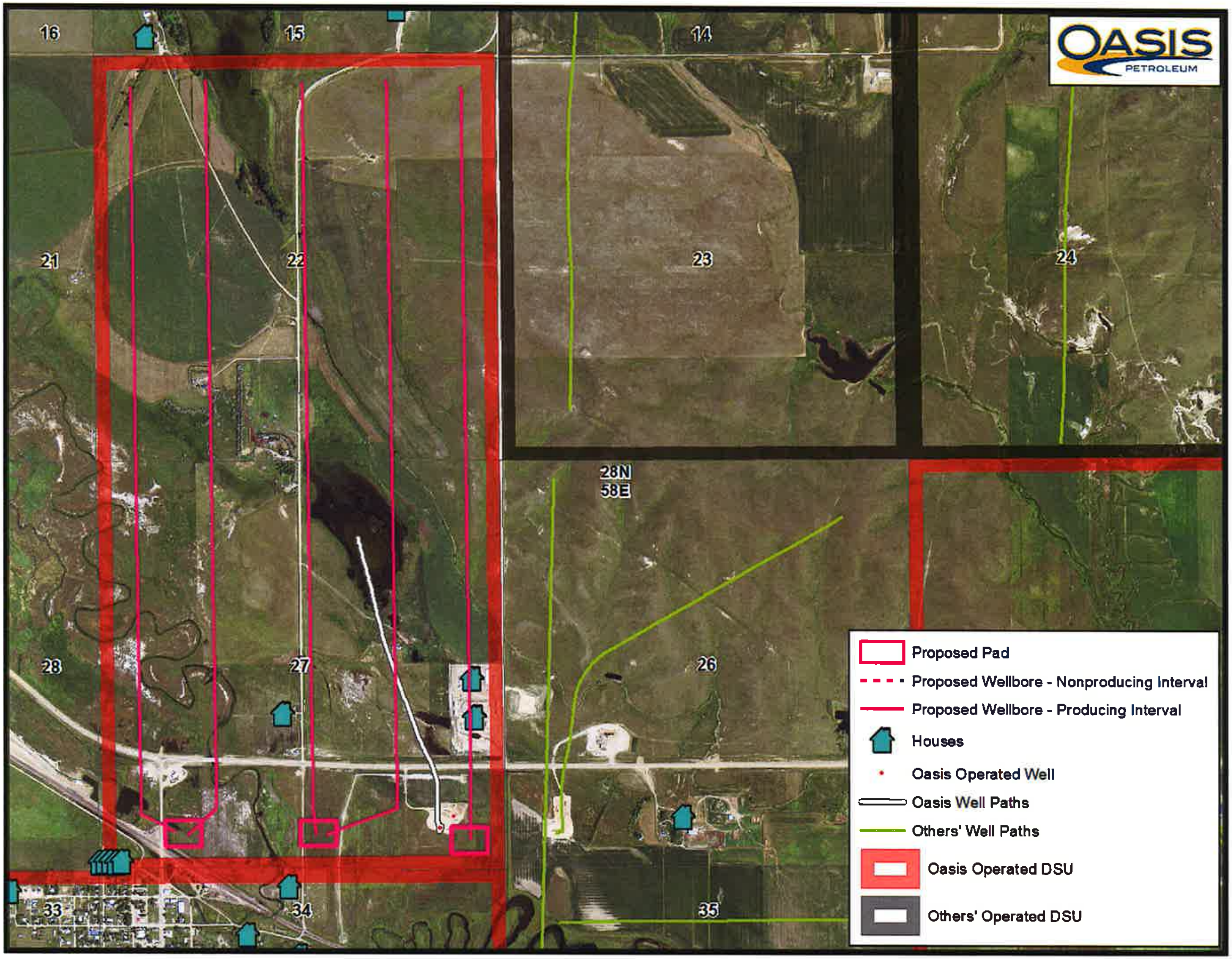
OASIS PETROLEUM

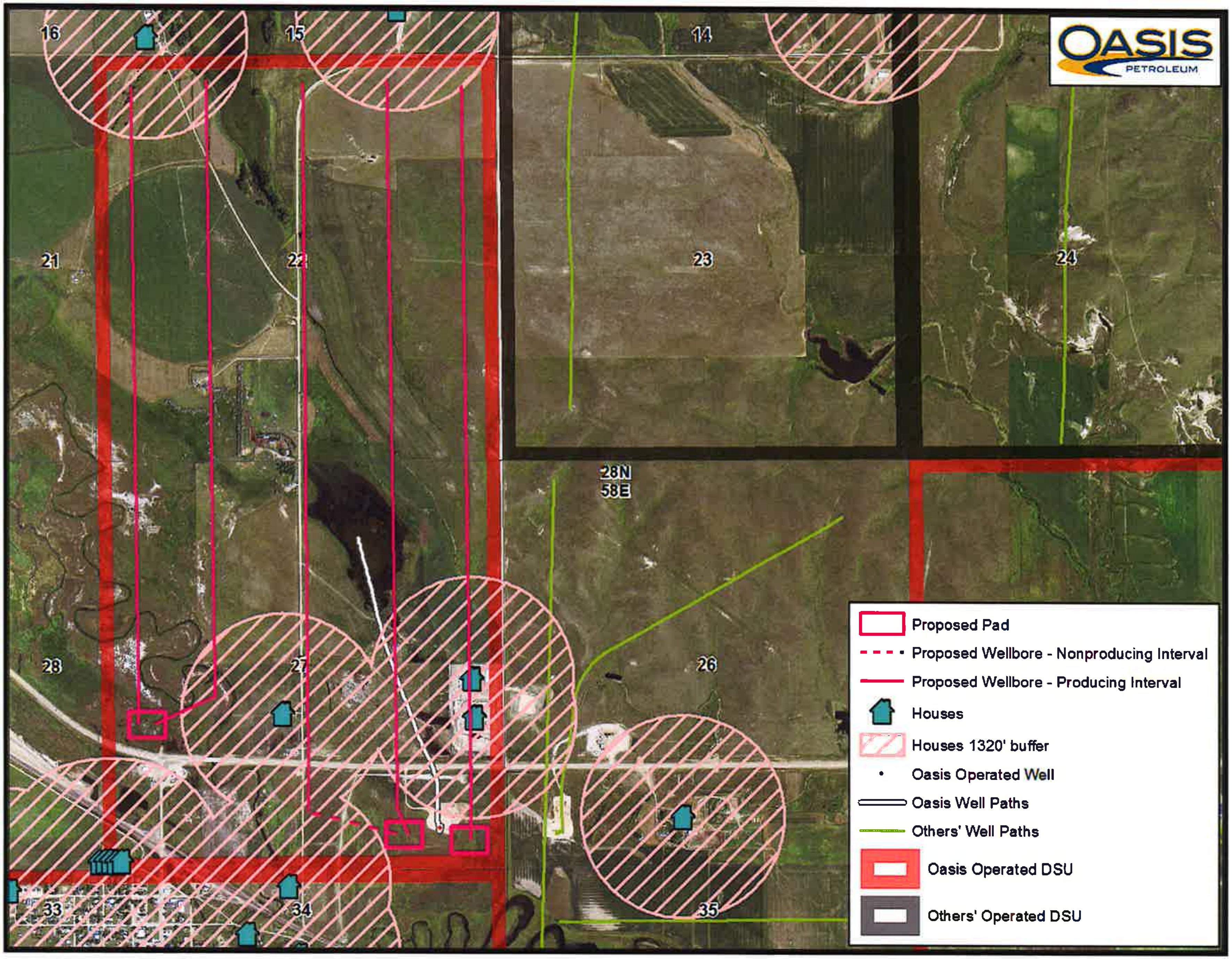


OASIS PETROLEUM
12
7
8
9
13
18
17
16
28N 57E
28N 58E
24
19
20
25
30
29
Houses
Houses 1320' buffer
Water bodies and wells 1320' buffer
Oasis Operated Well
Oasis Well Paths
Others' Well Paths
Oasis Operated DSU
Others' Operated DSU

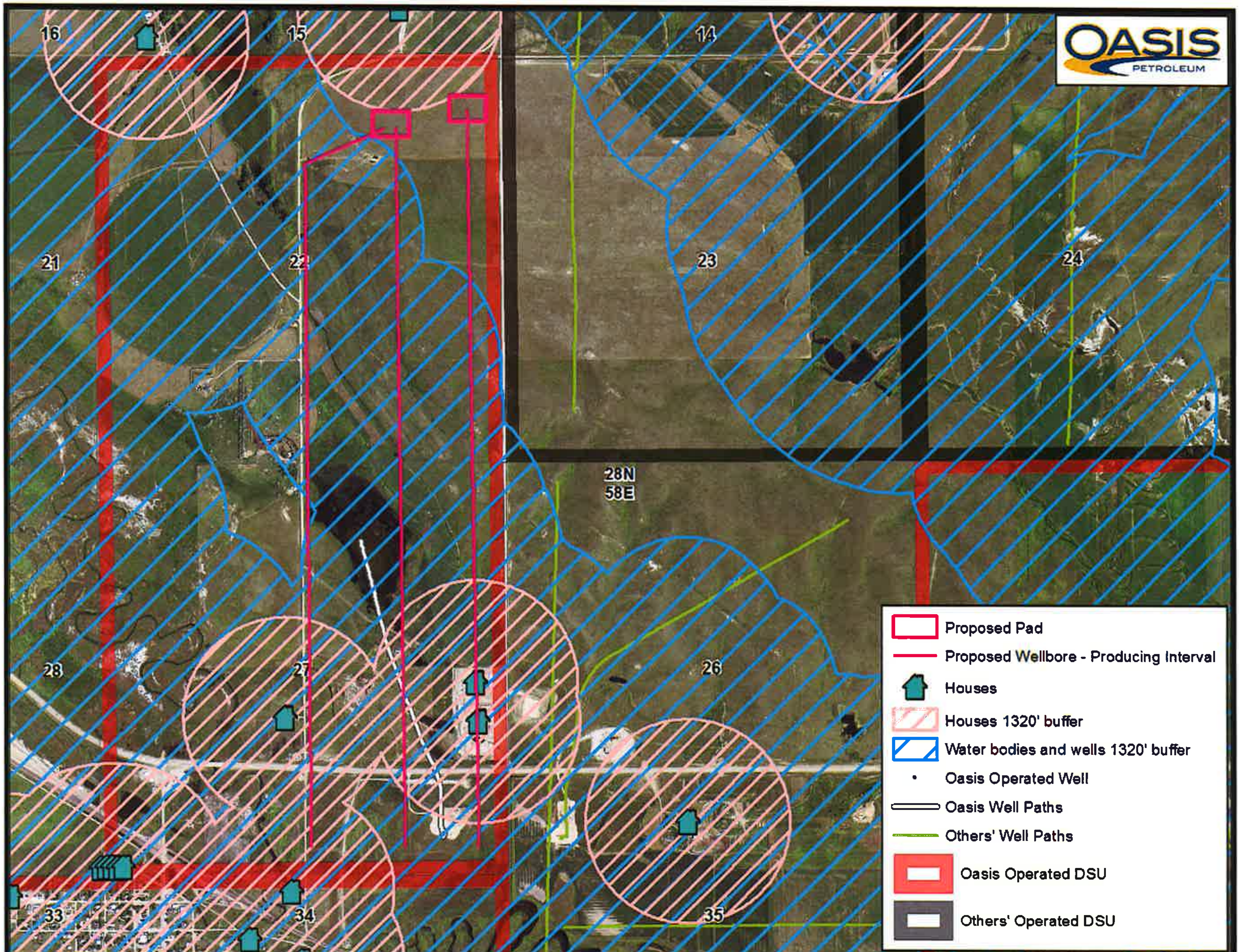


OASIS PETROLEUM
28N 58E
28N 59E
154N 104W
27N 58E
27N 59E
153N 104W
26N 58E
Houses
Houses 1320' buffer
Water bodies and wells 1320' buffer
Oasis Operated Well
Oasis Well Paths
Others' Well Paths
Oasis Operated DSU
Others' Operated DSU


OASIS PETROLEUM
16
15
14
21
22
23
24
28N
58E
28
27
26
33
34
35
Proposed Pad
Proposed Wellbore - Nonproducing Interval
Proposed Wellbore - Producing Interval
Houses
Oasis Operated Well
Oasis Well Paths
Others' Well Paths
Oasis Operated DSU
Others' Operated DSU



16
15
14
OASIS PETROLEUM
21
22
23
24
28N
58E
28
27
26
33
34
35
Proposed Pad
Proposed Wellbore - Nonproducing Interval
Proposed Wellbore - Producing Interval
Houses
Houses 1320' buffer
Oasis Operated Well
Oasis Well Paths
Others' Well Paths
Oasis Operated DSU
Others' Operated DSU


OASIS
PETROLEUM
16
15
14
21
22
23
24
28N
58E
28
27
26
33
34
35
Proposed Pad
Proposed Wellbore - Producing Interval
Houses
Houses 1320' buffer
Water bodies and wells 1320' buffer
Oasis Operated Well
Oasis Well Paths
Others' Well Paths
Oasis Operated DSU
Others' Operated DSU

PETRO-HUNT, L.L.C.

EXHIBIT 5

P.O. Box 935
Bismarck, ND 58502-0935
Phone: (701) 255-5684 FAX: (701) 258-1562
Email: mdewald@petrohunt.com

June 22, 2015

RE: 1320' Setbacks

In response to the BOGC's consideration of a 1320' setback of drilling rigs from occupied structures and "water resources" Petro-Hunt, LLC produced a set of maps showing; 1) 1320' setback around existing wells 2) area available for well placement not within 1320' from occupied structures and "water resources".

Information regarding "water resources" was taken from the National Hydrography Dataset that identified rivers, streams, water wells, etc. This leads to the following figures.

Total Acreage Figures Based on Dawson, Richland, and Roosevelt Counties MT:

Counties Total Acreage: 4,383,931.85 Acres (Approx.)

- Dawson – 1,524,044.39
- Richland – 1,345,330.09
- Roosevelt – 1,514,557.37

Based solely alone on water features of a setback of 1,320 feet (Rivers, Streams, Water Wells, etc.) NOTE: DOES NOT INCLUDE OTHER REGULATIONS:

Cannot Place a well because of setbacks – 3,960,342.35 Acres

- Dawson – 1,412,598.41
- Richland – 1,269,159.00
- Roosevelt – 1,278,584.94

Can Place a well - 423,589.51 Acres

- Dawson – 111,445.98
- Richland – 76,171.09
- Roosevelt – 235,972.43

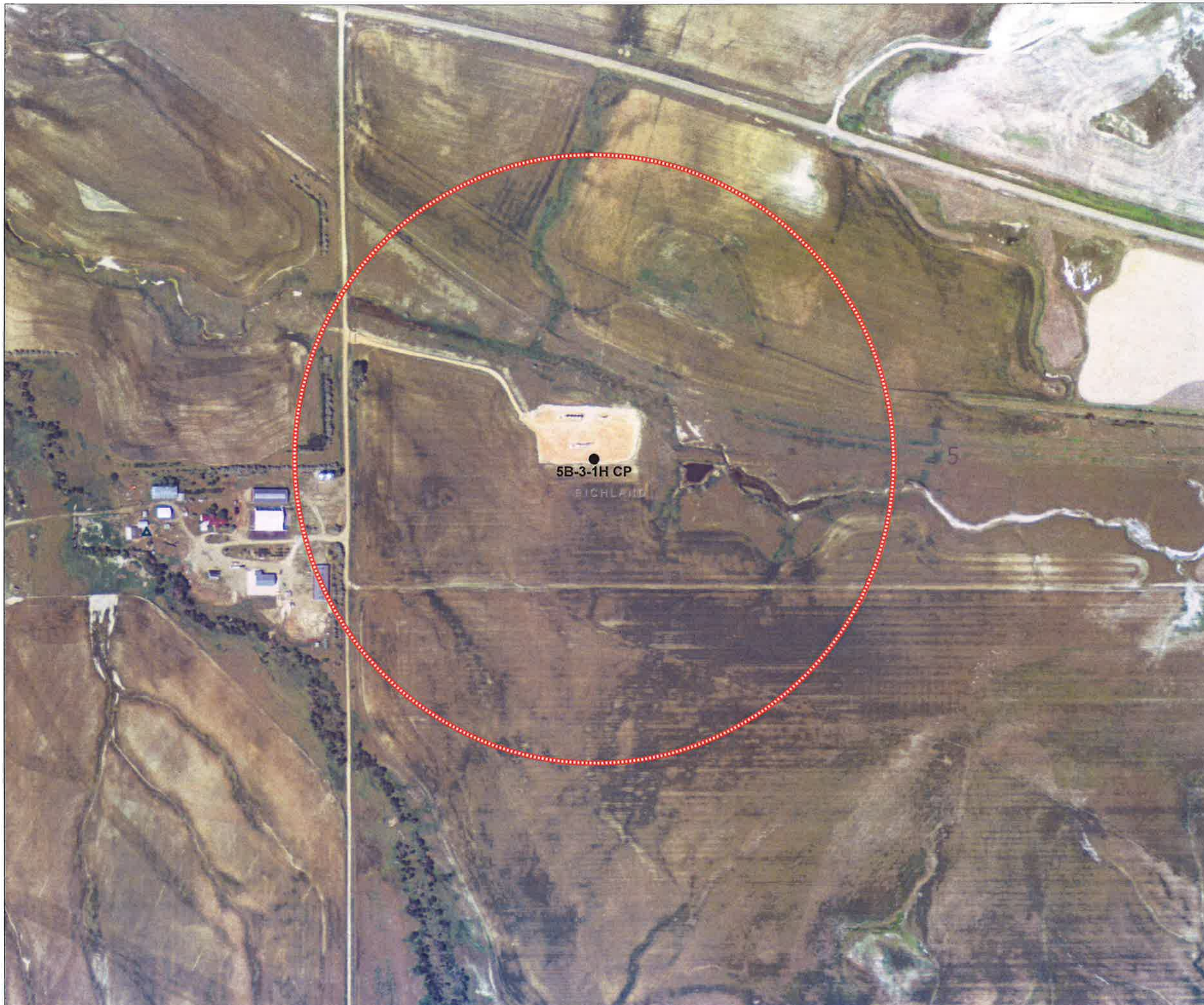
5

BR 5A-2-1

Date 06/05/2015

Prepared by:
Petro-Hunt L.L.C.
2101 Cedar Springs Rd., Suite 600
Rosewood Court Dallas, TX 75201
Tel: 214-880-8400 Fax: 214-880-7101

1 inch = 0.02 miles



Legend

- MT Water Wells
- PERMIT RECEIVED
- PRODUCING
- W/O PERMIT
- MT 1320 ft Setbacks

This document contains proprietary and/or confidential information which is the exclusive property of Petro-Hunt, L.L.C. Do not copy, distribute or disclose this document, or any portion of it, to without the prior express written permission of Petro-Hunt, L.L.C.
Date: 06/05/2015
Time: 1:06:20 PM
Path: \\dal-gis\GIS_Data\Petro-Hunt Print Maps\Montana\Special Request\Montana Setbacks\BR 5A-2-1.mxd

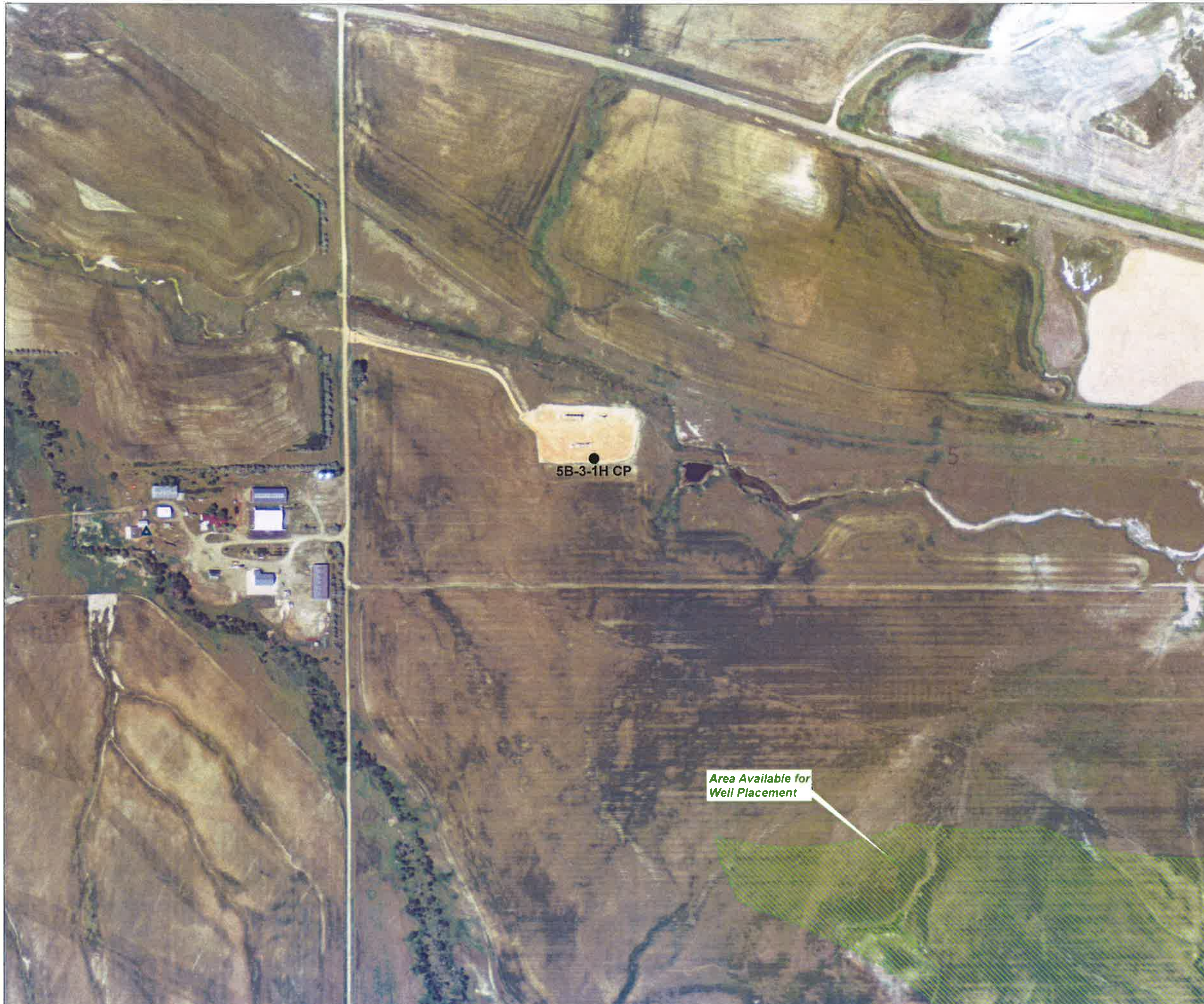
BR 5A-2-1

Date: 06/22/2015

Prepared by:
Petro-Hunt L.L.C.
2101 Cedar Springs Rd., Suite 600
Rosewood Court Dallas, TX 75201
Tel. 214-880-8400 Fax: 214-880-7101

1 inch = 0.02 miles

0 0.005 0.01 0.02 0.03 0.04 Miles



Legend

- Public Water Source
- Occupied Buildings
- Oil & Gas Well
- MT Water Wells
- Stream River
- Area Available for Well Placement

This document contains proprietary and/or confidential information which is the exclusive property of Petro-Hunt, L.L.C. Do not copy, distribute or disclose this document, or any portion of it, to without the prior express written permission of Petro-Hunt, L.L.C.

Date: 06/22/2015
Time: 2:43:44 PM

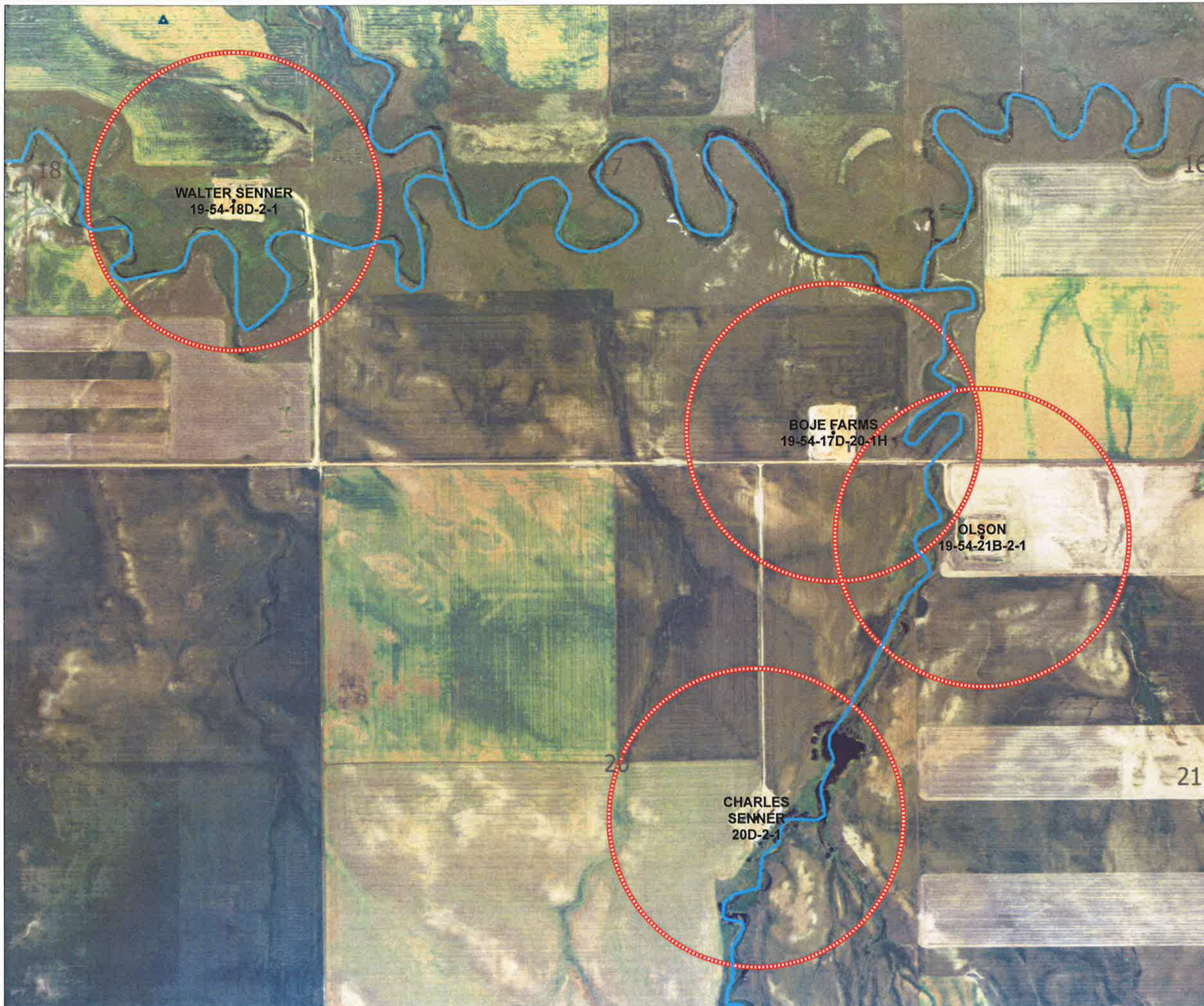
Montana Setback

Date 05/15/2015

Prepared by:
Petro-Hunt L.L.C.
2101 Cedar Springs Rd., Suite 600
Rosewood Court Dallas, TX 75201
Tel. 214-880-8400 Fax: 214-880-7101

1 inch = 0.05 miles

Miles



Legend

- MT Water Wells
- PERMIT RECEIVED
- PRODUCING
- W/O PERMIT
- MT 1320 ft Setbacks

This document contains proprietary and/or confidential information which is the exclusive property of Petro-Hunt, L.L.C. Do not copy, distribute or disclose this document, or any portion of it, to without the prior express written permission of Petro-Hunt, L.L.C..
Date: 05/15/2015
Time: 12:34:47 PM
Path: \\dal-gisup\GIS_Data\Petro-Hunt Print Maps\Montana\Special Request\Montana Setback.mxd

Montana Setbacks

Date 06/22/2015

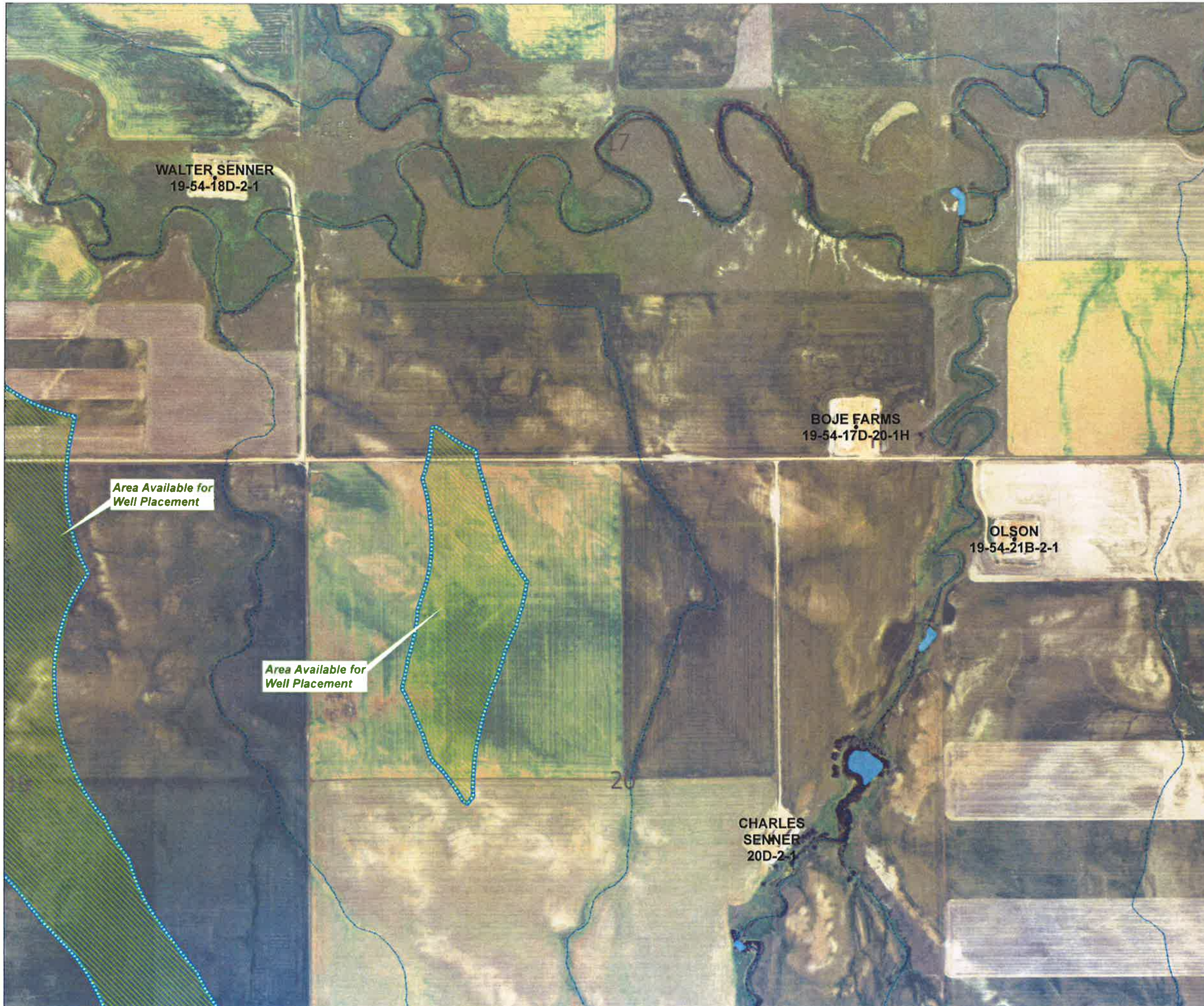
Prepared by
Petro-Hunt L.L.C.
2101 Cedar Springs Rd., Suite 600
Rosewood Court Dallas, TX 75201
Tel 214-880-8400 Fax: 214-880-7101

1 inch = 0.05 miles

0 0.01 0.02 0.04 0.06 0.08 Miles

Legend

- Public Water Source
- Occupied Buildings
- Oil & Gas Well
- MT Water Wells
- Stream River
- Area Available for Well Placement



This document contains proprietary and/or confidential information which is the exclusive property of Petro-Hunt, L.L.C. Do not copy, distribute or disclose this document, or any portion of it, to without the prior express written permission of Petro-Hunt, L.L.C..
Date: 06/22/2015
Time: 1:40:02 PM
Path: \\dal-gissql\GIS_Data\Petro-Hunt Print Maps\Montana\Special Request\Montana Setbacks\Walter Senner Boje Farms Charles Senner Olson.mxd

BORNTRAGER 2C-2-1

Date: 06/05/2015

Prepared by:
Petro-Hunt L.L.C.
2101 Cedar Springs Rd. Suite 600
Rosewood Court Dallas, TX 75201
Tel: 214-880-8400 Fax: 214-880-7101

1 inch = 0.03 miles

0 0.005 0.01 0.02 0.03 0.04 Miles

Legend

- MT Water Wells
- PERMIT RECEIVED
- PRODUCING
- W/O PERMIT
- MT 1320 ft Setbacks

This document contains proprietary and/or confidential information which is the exclusive property of Petro-Hunt, L.L.C. Do not copy, distribute or disclose this document, or any portion of it, to without the prior express written permission of Petro-Hunt, L.L.C.

Date 06/05/2015
Time 1:07:28 PM
Path: \\dal-gisse\GIS_Data\Petro-Hunt Print Maps\Montana\Special Request\Montana Setbacks\BORNTRAGER 2C-2-1.mxd

BORNTRAGER 2C-2-1

Date: 06/22/2015

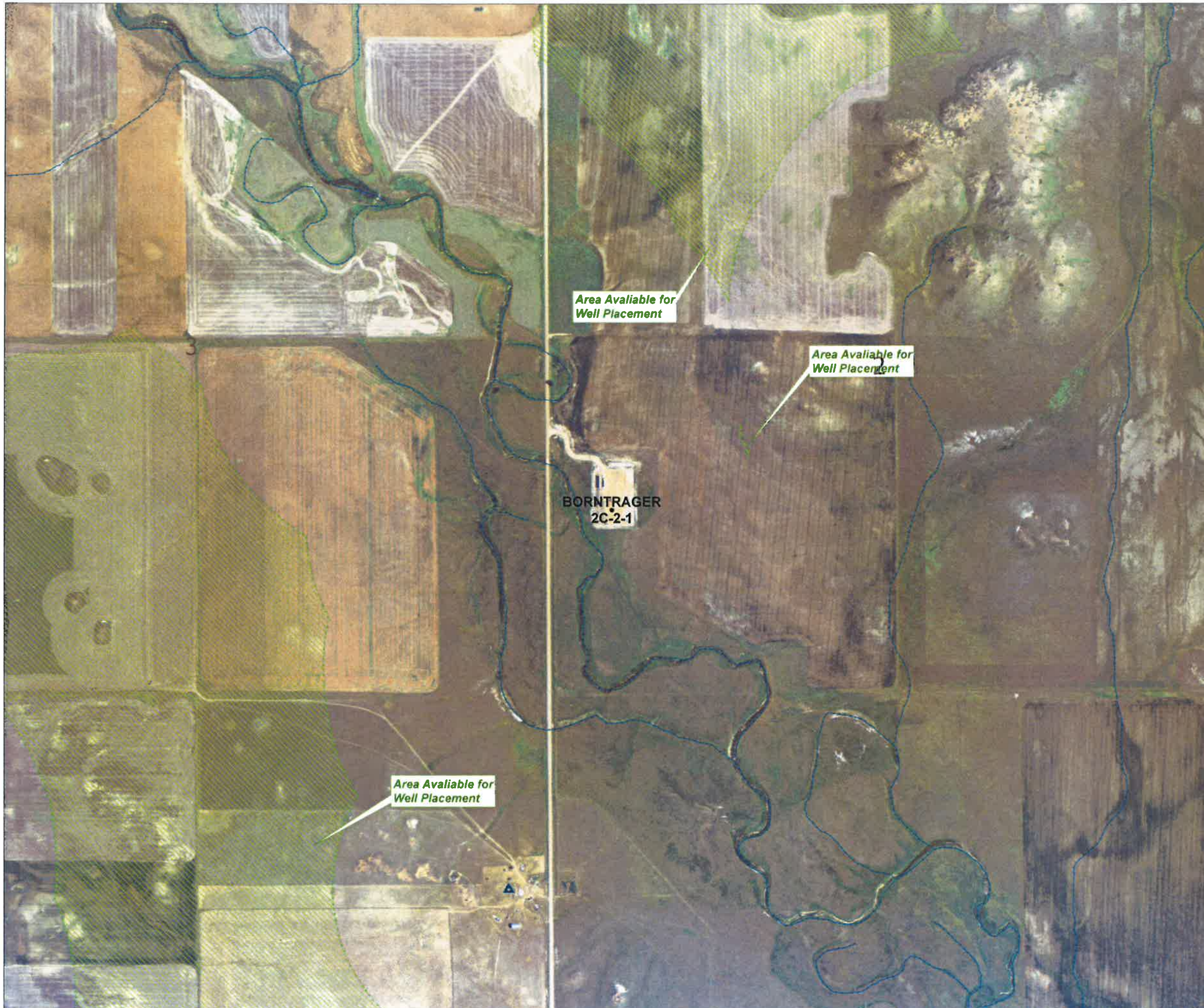
Prepared by:
Petro-Hunt L.L.C.
2101 Cedar Springs Rd., Suite 600
Rosewood Court Dallas, TX 75201
Tel: 214-880-8400 Fax: 214-880-7101

1 inch = 0.04 miles

0 0.01 0.02 0.04 0.06 0.08 Miles

Legend

- Public Water Source
- Occupied Buildings
- Oil & Gas Well
- MT Water Wells
- Stream River
- Area Available for Well Placement



This document contains proprietary and/or confidential information which is the exclusive property of Petro-Hunt, L.L.C. Do not copy, distribute or disclose this document, or any portion of it, to without the prior express written permission of Petro-Hunt, L.L.C.

Date: 06/22/2015
Time: 2:49:21 PM

TORGERSON 33C-1-1

Date: 06/05/2015

Prepared by:
Petro-Hunt L.L.C.
2101 Cedar Springs Rd. Suite 600
Rosewood Court Dallas, TX 75201
Tel: 214-880-8400 Fax: 214-880-7101

1 inch = 0.03 miles

Legend

- MT Water Wells
- PERMIT RECEIVED
- PRODUCING
- W/O PERMIT
- MT 1320 ft Setbacks

This document contains proprietary and/or confidential information which is the exclusive property of Petro-Hunt, L.L.C. Do not copy, distribute or disclose this document, or any portion of it, to without the prior express written permission of Petro-Hunt, L.L.C.

Date: 06/05/2015
Time: 1:10:47 PM

TORGERSON 33C-1-1

Date: 06/22/2015

Prepared by:
Petro-Hunt L.L.C.
2101 Cedar Springs Rd., Suite 600
Rosewood Court Dallas, TX 75201
Tel: 214-880-8400 Fax: 214-880-7101

1 inch = 0.03 miles

Miles

Legend

- Public Water Source
- Occupied Buildings
- Oil & Gas Well
- MT Water Wells
- Stream River
- Area Available for Well Placement

This document contains proprietary and/or confidential information which is the exclusive property of Petro-Hunt, L.L.C. Do not copy, distribute or disclose this document, or any portion of it, to without the prior express written permission of Petro-Hunt, L.L.C.

Date 06/22/2015
Time: 2:53:46 PM
Path: \\tidal-gis\GIS_Data\Petro-Hunt Print Maps\Montana\Special Request\Montana Setbacks\TORGERSON 33C-1-1.mxd

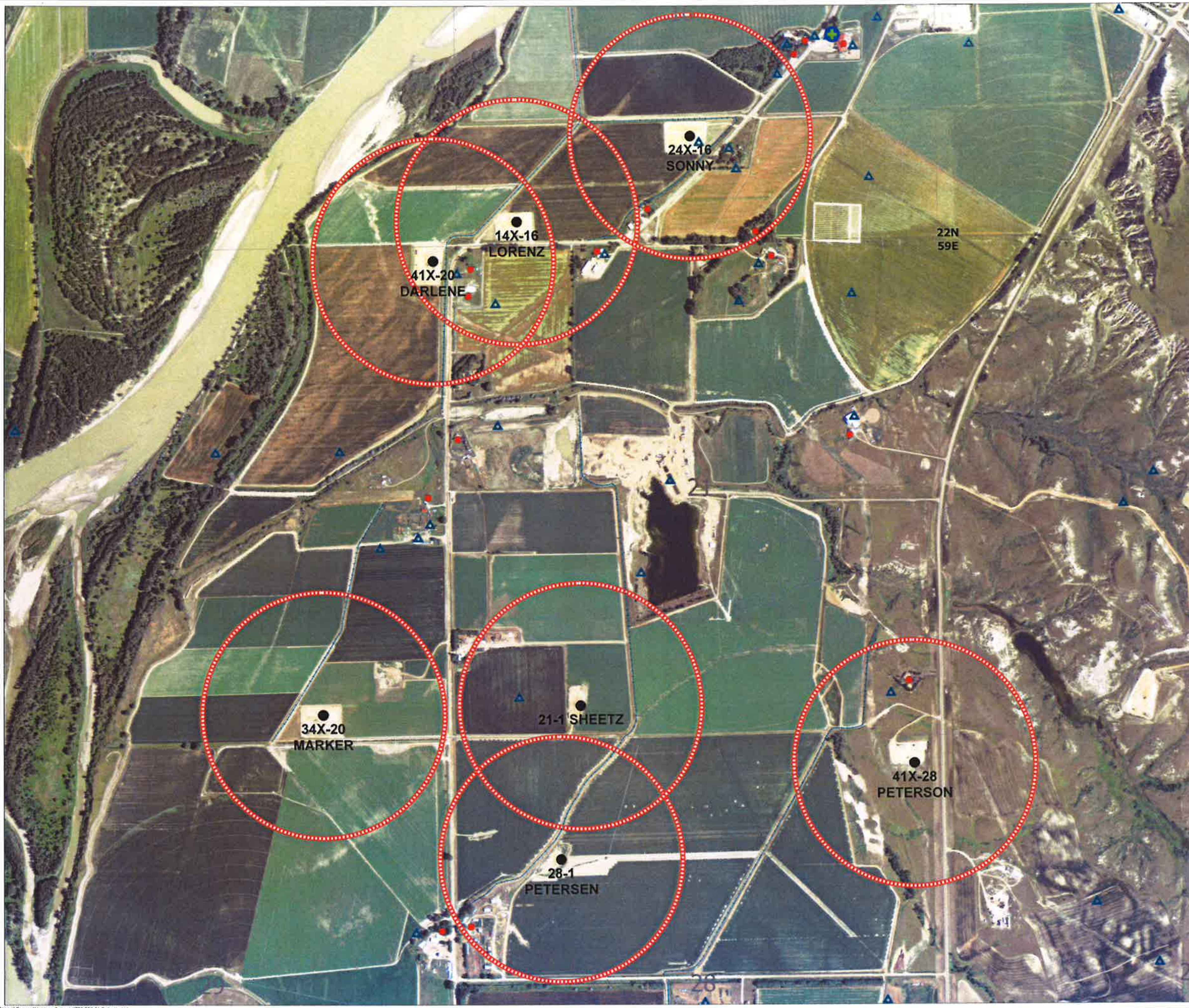
T22-R59-21 Setback

Date 06/15/2015

Prepared by
Petro-Hunt L.L.C.
2101 Cedar Springs Rd., Suite 600
Rosewood Court Dallas, TX 75201
Tel: 214-880-8400 Fax: 214-880-7101

1 inch = 0.06 miles

0.0150.030.060.090.12 Miles



Legend

- Public Water Source
- Occupied Buildings
- Oil & Gas Well
- MT Water Wells
- Irrigation Canals
- MT 1320ft Setbacks

This document contains proprietary and/or confidential information which is the exclusive property of Petro-Hunt, L.L.C. Do not copy, distribute or disclose this document, or any portion of it, to without the prior express written permission of Petro-Hunt, L.L.C..

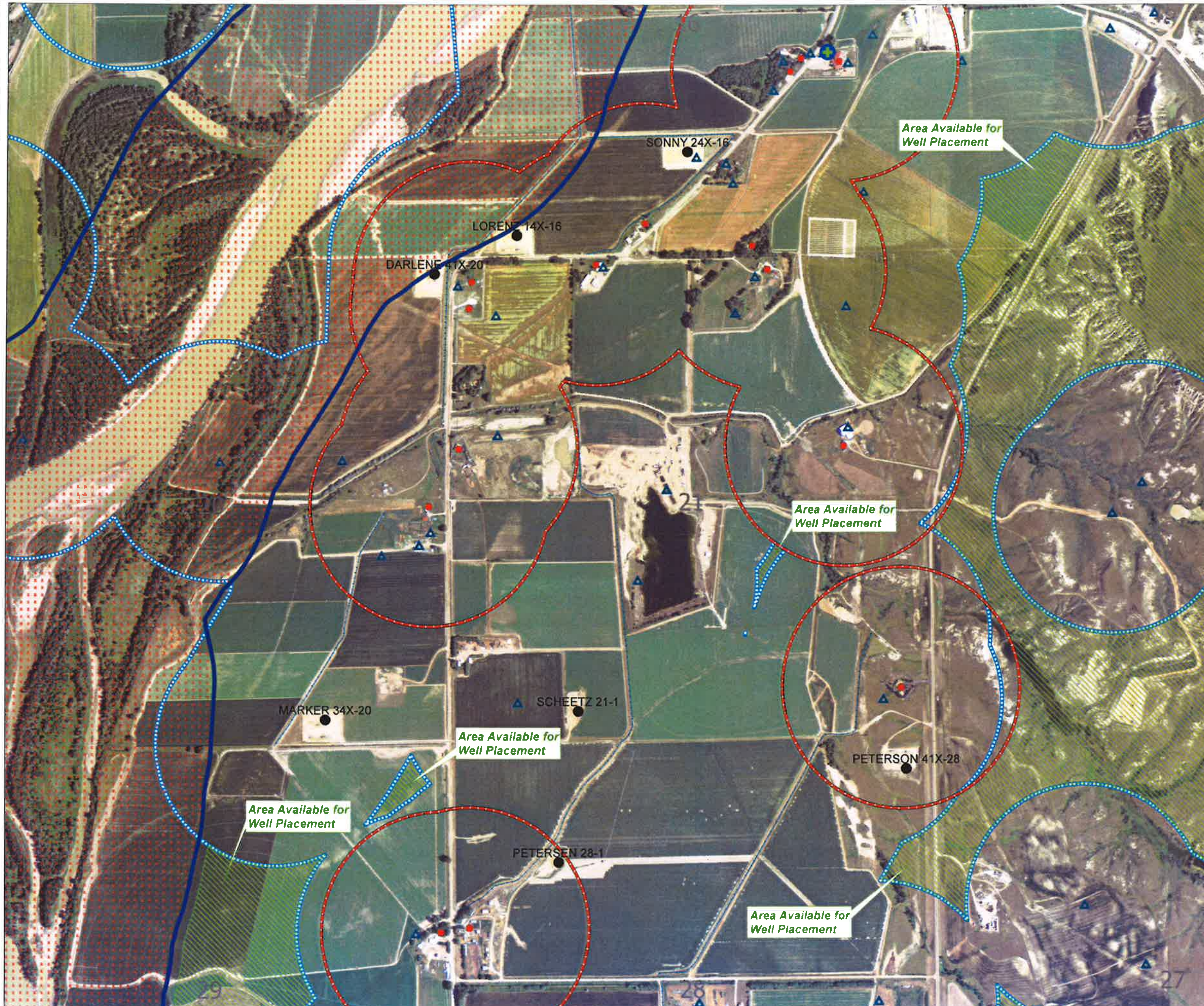
Date 06/15/2015
Time 2:06 52 PM

T22-R59-21 Setback

Date: 06/18/2015

Prepared by:
Petro-Hunt L.L.C.
2101 Cedar Springs Rd., Suite 600
Rosewood Court Dallas, TX 75201
Tel: 214-880-8400 Fax: 214-880-7101

1 inch = 0.06 miles

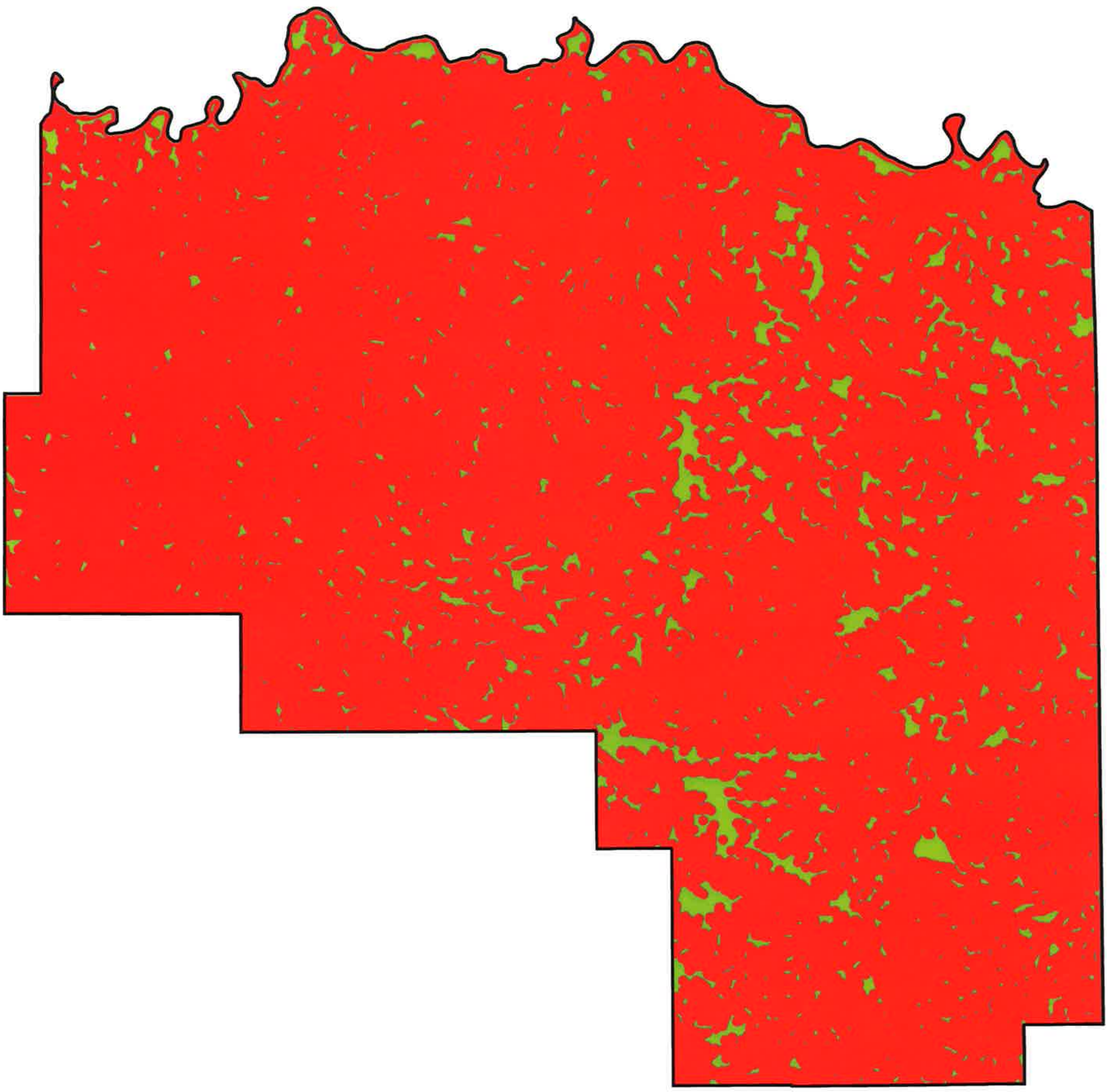


Legend

- Public Water Source
- Occupied Buildings
- Oil & Gas Well
- MT Water Wells
- Irrigation Canals
- Occupied Buildings 1320ft Setbacks
- River 1320ft Setbacks
- Water Source 1320ft Setbacks
- Area Available for Well Placement

This document contains proprietary and/or confidential information which is the exclusive property of Petro-Hunt, L.L.C. Do not copy, distribute or disclose this document, or any portion of it, to without the prior express written permission of Petro-Hunt, L.L.C.

Date: 06/18/2015
Time: 9:35:44 AM



Richland County Setbacks

Date: 06/22/2015

Prepared by:
Petro-Hunt L.L.C.
2101 Cedar Springs Rd., Suite 600
Rosewood Court Dallas, TX 75201
Tel: 214-880-8400 Fax: 214-880-7101

1 inch = 1.75 miles

0 0.75 1.5 3 4.5 6 Miles

Legend

- Area Available for Well Placement
- Area NOT Available for Well Placement

This document contains proprietary and/or confidential information which is the exclusive property of Petro-Hunt, L.L.C. Do not copy, distribute or disclose this document, or any portion of it, to without the prior express written permission of Petro-Hunt, L.L.C.

Date: 06/22/2015
Time: 4:23:57 PM
Path: \\dal-gissql\GIS_Data\Petro-Hunt Print Maps\Montana\Special Request\Montana Setbacks\Richland County Setbacks.mxd

Roosevelt County Setbacks

Date: 06/22/2015

Prepared by:
Petro-Hunt L.L.C.
2101 Cedar Springs Rd., Suite 600
Rosewood Court Dallas, TX 75201
Tel: 214-880-8400 Fax: 214-880-7101

1 inch = 2.03 miles

0 0.5 1 2 3 4 Miles

Legend

- Area Available for Well Placement
- Area NOT Available for Well Placement

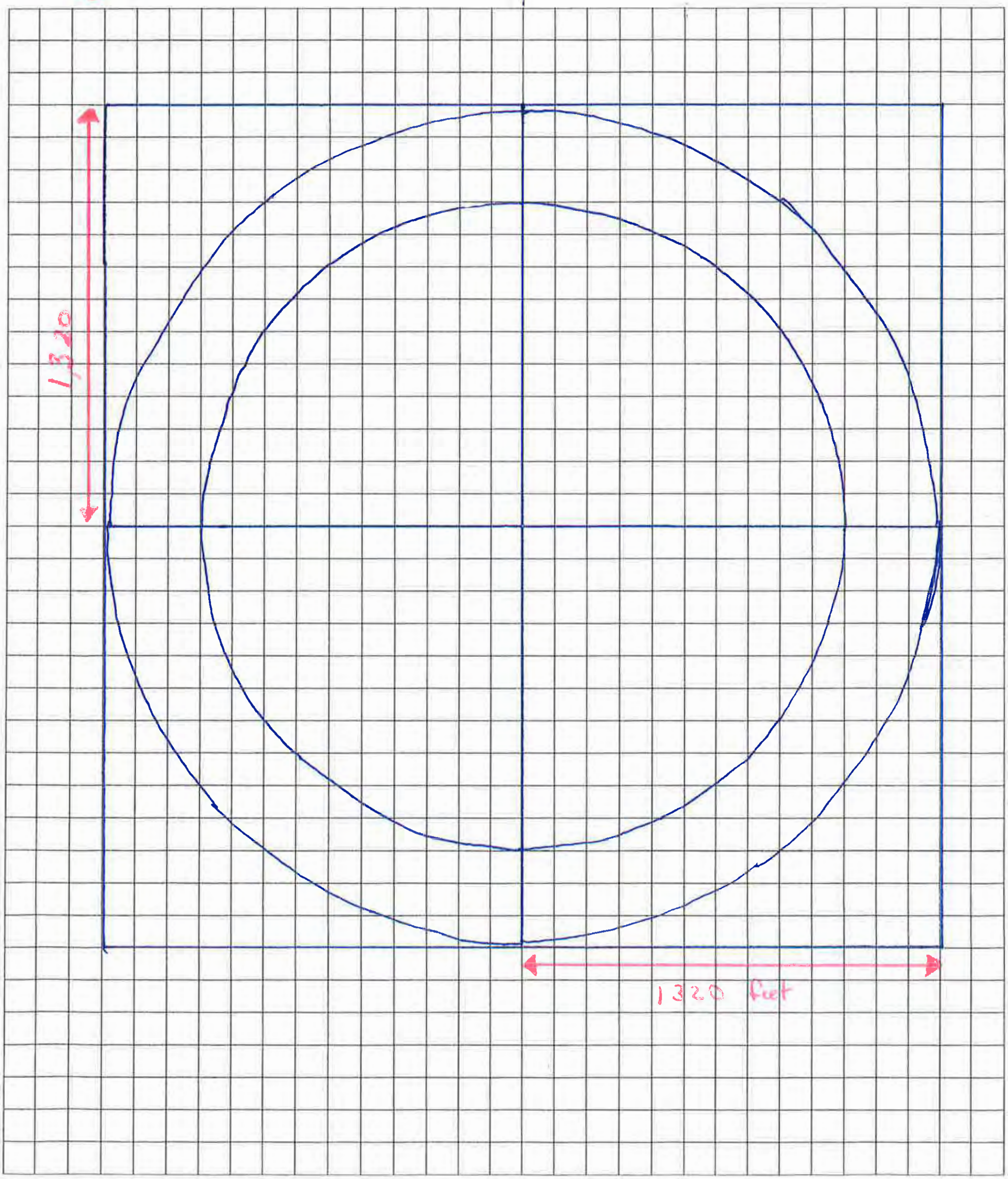
This document contains proprietary and/or confidential information which is the exclusive property of Petro-Hunt, L.L.C. Do not copy, distribute or disclose this document, or any portion of it, to without the prior express written permission of Petro-Hunt, L.L.C.

Date: 06/22/2015
Time: 4:27:17 PM
Path: \\dal-gissql\GIS_Data\Petro-Hunt Print Maps\Montana\Special Request\Montana Setbacks\Roosevelt County Setbacks.mxd

EXHIBIT 6

MCR, LLC

P.O. Box 716
Shelby, MT 59474
406-424-8216



I SUPPORT SETBACK REQUIREMENTS!

EXHIBIT 7

Dear Montana Board of Oil and Gas Conservation Members,

As oil and gas development has increased near my community, so have impacts to private property values and quality of life. Setback requirements are good common sense regulations that create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota and Wyoming have setback requirements and so should Montana.

Please make sure oil and gas development is done right!
Take up rulemaking on setback requirements.

Sincerely,

Name Frank & Mary DiFonzo

Address 1220 9th Ave. S.W. Sidney, MT

Additional comments:

I SUPPORT SETBACK REQUIREMENTS!

Dear Montana Board of Oil and Gas Conservation Members,

As oil and gas development has increased near my community, so have impacts to private property values and quality of life. Setback requirements are good common sense regulations that create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota and Wyoming have setback requirements and so should Montana.

Please make sure oil and gas development is done right!
Take up rulemaking on setback requirements.

Sincerely,

Name Steve Meagher

Address 501 N. Central Ave. Sidney Mt, 59270

Additional comments:

I SUPPORT SETBACK REQUIREMENTS!

Dear Montana Board of Oil and Gas Conservation Members,

As oil and gas development has increased near my community, so have impacts to private property values and quality of life. Setback requirements are good common sense regulations that create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota and Wyoming have setback requirements and so should Montana.

Please make sure oil and gas development is done right!
Take up rulemaking on setback requirements.

Sincerely,

Name Martha A. Johnson

Address P.O. Box 115 Sidney MT 59270

Additional comments:

I SUPPORT SETBACK REQUIREMENTS!

Dear Montana Board of Oil and Gas Conservation Members,

As oil and gas development has increased near my community, so have impacts to private property values and quality of life. Setback requirements are good common sense regulations that create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota and Wyoming have setback requirements and so should Montana.

Please make sure oil and gas development is done right!
Take up rulemaking on setback requirements.

Sincerely,

Name David & Karen Munoz

Address PO Box 221 Sidney Mt 59270

Additional comments:

I SUPPORT SETBACK REQUIREMENTS!

Dear Montana Board of Oil and Gas Conservation Members,

As oil and gas development has increased near my community, so have impacts to private property values and quality of life. Setback requirements are good common sense regulations that create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota and Wyoming have setback requirements and so should Montana.

Please make sure oil and gas development is done right!
Take up rulemaking on setback requirements.

Sincerely,

Name MARV Schulz

Address 1304 9th Ave SW Sidney, mt. 59270

Additional comments:

I SUPPORT SETBACK REQUIREMENTS!

Dear Montana Board of Oil and Gas Conservation Members,

As oil and gas development has increased near my community, so have impacts to private property values and quality of life. Setback requirements are good common sense regulations that create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota and Wyoming have setback requirements and so should Montana.

Please make sure oil and gas development is done right!
Take up rulemaking on setback requirements.

Sincerely,

Name MARV Schulz

Address 1304 9th Ave SW Sidney, mt. 59270

Additional comments:

I SUPPORT SETBACK REQUIREMENTS!

Dear Montana Board of Oil and Gas Conservation Members,

As oil and gas development has increased near my community, so have impacts to private property values and quality of life. Setback requirements are good common sense regulations that create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota and Wyoming have setback requirements and so should Montana.

Please make sure oil and gas development is done right!
Take up rulemaking on setback requirements.

Sincerely,

Mary Krouskop

Name Mary Krouskop

Address 400 Lincoln Ave NW Apt #123 Sidney, MT 59270

Additional comments:

I SUPPORT SETBACK REQUIREMENTS!

Dear Montana Board of Oil and Gas Conservation Members,

As oil and gas development has increased near my community, so have impacts to private property values and quality of life. Setback requirements are good common sense regulations that create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota and Wyoming have setback requirements and so should Montana.

Please make sure oil and gas development is done right!
Take up rulemaking on setback requirements.

Sincerely,

Name RICHARD E. STONE & JERI D STONE

Address 721 - 3RD ST N E SIDNEY, MT. 59270

Additional comments:

I SUPPORT SETBACK REQUIREMENTS!

Dear Montana Board of Oil and Gas Conservation Members,

As oil and gas development has increased near my community, so have impacts to private property values and quality of life. Setback requirements are good common sense regulations that create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota and Wyoming have setback requirements and so should Montana.

Please make sure oil and gas development is done right!
Take up rulemaking on setback requirements.

Sincerely,

Name Dan and Carrie Peters

Address 1902 Bitteroot Dr. Sidney, MT 59270

Additional comments: THANK YOU!

I SUPPORT SETBACK REQUIREMENTS!

Dear Montana Board of Oil and Gas Conservation Members,

As oil and gas development has increased near my community, so have impacts to private property values and quality of life. Setback requirements are good common sense regulations that create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota and Wyoming have setback requirements and so should Montana.

Please make sure oil and gas development is done right!
Take up rulemaking on setback requirements.

Sincerely,

Name Timothy Ullman

Address 524 3rd St SE Sidney Mt. 59270

Additional comments: I support Setback requirements

I SUPPORT SETBACK REQUIREMENTS!

Dear Montana Board of Oil and Gas Conservation Members,

As oil and gas development has increased near my community, so have impacts to private property values and quality of life. Setback requirements are good common sense regulations that create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota and Wyoming have setback requirements and so should Montana.

Please make sure oil and gas development is done right!
Take up rulemaking on setback requirements.

Sincerely, D Fedora

Name Diana J Fedora

Address 316 3rd St. NE. Sidney, Mt 59270

Additional comments:

I SUPPORT SETBACK REQUIREMENTS!

Dear Montana Board of Oil and Gas Conservation Members,

As oil and gas development has increased near my community, so have impacts to private property values and quality of life. Setback requirements are good common sense regulations that create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota and Wyoming have setback requirements and so should Montana.

Please make sure oil and gas development is done right!
Take up rulemaking on setback requirements.

Sincerely,

Mike Wood

Name Michael R. Wood

Address 34942 CTY RD 126 SIDNEY MT 59270

Additional comments:

I SUPPORT SETBACK REQUIREMENTS!

Dear Montana Board of Oil and Gas Conservation Members,

As oil and gas development has increased near my community, so have impacts to private property values and quality of life. Setback requirements are good common sense regulations that create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota and Wyoming have setback requirements and so should Montana.

Please make sure oil and gas development is done right!
Take up rulemaking on setback requirements.

Sincerely,
M McElfresh

Name Melissa McElfresh

Address 322 B 7th Ave, Sidney MT 59270

Additional comments: PO Box 152 (for Mailing)

I SUPPORT SETBACK REQUIREMENTS!

Dear Montana Board of Oil and Gas Conservation Members,

As oil and gas development has increased near my community, so have impacts to private property values and quality of life. Setback requirements are good common sense regulations that create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota and Wyoming have setback requirements and so should Montana.

Please make sure oil and gas development is done right!
Take up rulemaking on setback requirements.

Sincerely,

Name Roger & Rae Jean Kimble

Address 1370 22nd Ave NW, Sidney MT 59270

Additional comments:

Delphine A Tiesen
525 East Main St
Sidney, MT 59270

BILLINGS MT 591

13 JUN 2015 PM 1 T

FOREVER

USA

Montana Board of Oil and Gas Conservation
c/o Northern Plains Resource Council
220 South 27th Street, Suite A
Billings, MT 59101

59101$4106

I SUPPORT SETBACK REQUIREMENTS!

Dear Montana Board of Oil and Gas Conservation Members,

As oil and gas development has increased near my community, so have impacts to private property values and quality of life. Setback requirements are good common sense regulations that create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota and Wyoming have setback requirements and so should Montana.

Please make sure oil and gas development is done right!
Take up rulemaking on setback requirements.

Sincerely,

Name Raymond & Patricia Bell

Address 1101 11th St SW, Sidney, MT

Additional comments:

I SUPPORT SETBACK REQUIREMENTS!

Dear Montana Board of Oil and Gas Conservation Members,

As oil and gas development has increased near my community, so have impacts to private property values and quality of life. Setback requirements are good common sense regulations that create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota and Wyoming have setback requirements and so should Montana.

Please make sure oil and gas development is done right!
Take up rulemaking on setback requirements.

Sincerely, Gary A Kindopp

Name Gary A. Kindopp

Address 80 Aberdeen St. Glasgow, MT. 59230

Additional comments: Think about Oil Well Accidents + Disasters + Who Has Liability + who Needs insurance for same - (This idea good for oil + gas people too)

I SUPPORT SETBACK REQUIREMENTS!

Dear Montana Board of Oil and Gas Conservation Members,

As oil and gas development has increased near my community, so have impacts to private property values and quality of life. Setback requirements are good common sense regulations that create reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota and Wyoming have setback requirements and so should Montana.

Please make sure oil and gas development is done right!
Take up rulemaking on setback requirements.

Sincerely,

Name Kay Fullerson

Address Home: 823 N. Central 59270 Mailing 315 2nd St NW Sidney, MT 59270

Additional comments:

Attn: Montana Board of Oil and Gas
June 24' 2015
Re: oil and gas exploration and drilling Set backs needed

Dear Sirs:
Protection of public health, our waterways and wells is critical when hydraulic fracturing exploration and drilling for oil and natural gas is occurring. Providing a minimum 1/4 mile,but preferably 1/2 mile, setup from residences, schools, steams and private wells, decreases risk of harm to human health and contamination of our water. This is non negotiable, and essential to maintain two cornerstones of Montana's economy: family ranches & farms and recreational tourism. I urge you to implement 1/2 mile set back regulation immediately.

Thank you for considering this and future generations .

Laurie Lohrer
466 snowberry Lane
Lewistown, MT 59457

Rita Westrum <montanamountainhomes@gmail.com>

Wed, Jun 24, 2015 at 7:40 AM

Reply-To: montanamountainhomes@gmail.com
To: ogsetback.comments@northernplains.org

I strongly urge you to please consider establishing a 1/4 mile setback "buffer zone" between oil and gas wells and inhabited buildings. This seems to me to be a common-sense measure to help insure the health and safety of people living and working in the areas of oil and gas development.

Rita Westrum
Fishtail, MT

lynbobhilten@att.net <lynbobhilten@att.net> Tue, Jun 23, 2015 at 7:21 PM
To: "ogsetback.comments@northernplains.org" <ogsetback.comments@northernplains.org>

Dear BOGC,
I am Bob Hilten from Columbus, Montana. I have witnessed firsthand the devastation of having drilling rigs and flares literally in people's yard. Aside from the destructive effect of having your property made unsalable, the health issues of living next to such a facility are horrifying. It is time for the BOGC to quit hiding behind laws written by the industry and look at this issue from the human cost this industry is imposing on families who happen to be in their way. Please consider how you would react if your own families were exposed to the constant noise and fumes of a flare in your yard! How would you feel if you had a well in your own yard where your children played! This is absolutely insane!
It is both too much of a health risk and nuisance to allow these corporations to impose this type of operation on families in Montana. Stand up for Montanans for a change. You live here too and should realize that you are facing the same risk every family is facing. It is not necessary to ruin people's lives to extract oil! Make a decision that will make an enduring improvement in how people's lives are lived here in "The Last Best Place".

Bob Hilten

Sent from my iPad

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Jocelyne Houghton
1851 S Lane St
Seattle, WA 98144

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Nancy Beebe
528 Dell Place
Bozeman, MT 59715

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Janet McMillan
10120 Sunset Hill Rd
Greenough, MT 59823

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Laura Morris
815 S. 5th West
Box 107
Baker, MT 59313

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

David Gillanders
PO Box 2786
State University, AR 72467

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,
Scarlett Daley

Scarlett Daley
63 Kingsfather Dr
Livingston, MT 59047

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setbacks make sense! Please support the setback requirements.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,
Kathy Heffernan

Kathy Heffernan
3851 Duncan Dr
Missoula, MT 59802

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Craig CLEVIDENCE
304 Northridge dr
Kalispell, MT 59901

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Marilyn Kelly-Clark
4205 Red Fox Dr.
Helena, MT 59602

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Rosalind Bolach
122 N 5th Ave
Bozeman, MT 59715

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Deborah Muth
39 Lightning Lane
Red Lodge, MT 59068

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

D. Craig McClure
1207 11th Ave. E
Polson, MT 59860

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Amaya Garcia Costas

Amaya Garcia
206 Avenue E
Billings, MT 59101

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Kari Kaiser
550 Park Ln.
Billings, MT 59102

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Patti Steinmuller
14665 Spanish Breaks Tr.
Gallatin Gateway, MT 59730

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Linda Streett-Todd
PO Box 263
Fromberg, MT 59029

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Linnea Forseth
1056 Picador Way
Billings, MT 59105

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

gin holt
115 so. 6th
livingston, MT 59047

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Virjeana Brown
720 Northern Pacific Ave
Belgrade, MT 59714

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Robert Lindstrom
535 Lakeview Rd
West Yellowstone, MT 59758

Montanans enjoy a quality of life that they depend on. Those of us who live in rural Montana value our quiet, peacefulness and seclusion, to have a very noisy industry such as the oil and gas industry to set up next to our rural homes just destroys our quality of life. The Montana constitutions allows for us to maintain that quality of life. We in rural Montana that considers this our life blood should not lose our quality of life so someone from out of state can make money to our determent. We are asking for very little when we request a ¼ mile set back from our homes

Bonnie Martinell

Belfry Montana.

Henry J Lischer Jr <hjlischerjr@gmail.com> Wed, Jun 17, 2015 at 12:02 PM

To: ogsetback.comments@northernplains.org

I urge the Montana Board of Oil and Gas Conservation to adopt rules that would require any oil or gas well to be setback from certain structures or locations.

At an absolute minimum, the Board should adopt a setback rule requiring any oil or gas well to be sited no less than one-quarter mile (1,320 feet) from each inhabited building, school, park, and any other location at which persons may be expected to congregate on a recurring basis.

The health and safety of the public require that the Board adopt such a setback rule. Such a setback rule could incrementally increase the costs of oil and gas operations, but those costs would be far outweighed by the benefits to the public that would result from adoption of that rule.

Thank you for your consideration.

Henry J. Lischer

18 Waldstein Lane

Box 428

Nye, Montana 59061

Pamela Poon <pgracep@gmail.com> Thu, Jun 18, 2015 at 5:26 PM
To: ogsetback.comments@northernplains.org

Dear Northern Plains:

Please forward my comment below to the Oil and Gas Board.

Thank you.

Dear Oil and Gas Board:

Please let Montanans know you support their way of life by imposing mandatory setbacks on oil and gas production. Doing this makes sense for people's health, homes, their livestock and for the land. Most of us live out in the country because we value it as a special place to live. Keep Montana as special as it is by doing the right thing for all rural landowners.

Thank you.

Pamela G. Poon
Robin M. Houston
P.O. Box 665
Bozeman, Montana 59771-0665

Pamela G. Poon, P.L.L.C.
Attorney Mediator
pgracep@gmail.com
www.middlegroundsolutions.com

P.O. Box 665
Bozeman, MT 59771-0665

Resolving disputes for families and businesses since 1992

Jane Moses <mosesvb8@gmail.com> Wed, Jun 17, 2015 at 8:31 AM
To: "ogsetback.comments@northernplains.org" <ogsetback.comments@northernplains.org>

I am out of the country and unable to attend next week's meeting for public comment on establishing setbacks for oil and gas wells.

Requiring setbacks of at least one half mile between inhabited buildings and wells is critical. We need to establish responsible requirements for oil and gas development in our state. Right now companies have few rules to regulate the way they extract oil and gas, and the risks to water supplies are high. Water is precious for agriculture, drinking and recreation. Even when wells are carefully drilled and monitored, there is an unacceptable risk for chemical contamination of nearby water supplies. Requiring a setback of at least one half mile is one piece of the protections the Board must put into place.

Jane Moses

Sent from my iPhone

Thu, Jun 18, 2015 at 8:33 PM

Heidi Anderson <sysyrinchium@yahoo.com>
To: ogsetback.comments@northernplains.org

I would like the Board of Oil and Gas Conservation members to consider a quarter-mile setback, or 1,320 feet, between inhabited buildings and oil and gas wells. Studies show negative impacts to air quality and private property values as far as 1.25 miles away from oil and gas wells. Help us move in the right direction and support a quarter mile setback in Montana!

Sincerely,
Heidi Anderson
Gardiner, MT 59030

WE need very healthy and generous set backs to protect Montanans from polution and the loss of property values

1 message

Steve Mcarthur <stevemcarthur@aol.com> Thu, Jun 18, 2015 at 11:15 PM
To: ogsetback.comments@northernplains.org

Do the right thing and create laws that protect the folks near gas and oil wells! The health facts are clear and the loss of property values is also important to now harm the folks near these wells! Thank you , Steve
PS 1.25 miles is a good place to start not 1000+ feet! too short a distance.

Bob Hilten <c56a5b28@opayq.com>
Reply-To: c56a5b28@opayq.com
To: ogsetback.comments@northernplains.org

Fri, Jun 19, 2015 at 11:14 AM

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Bob Hilten
PO Box 1107
Columbus, MT 59019

Bob Hansen <ledouxhansen@gmail.com>
Reply-To: ledouxhansen@gmail.com
To: ogsetback.comments@northernplains.org

Fri, Jun 19, 2015 at 12:05 PM

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Bob Hansen
127 S Easy St
Missoula, MT 59802

Doug Modrow <lmodrow@yahoo.com> Fri, Jun 19, 2015 at 12:57 PM
To: "ogsetback.comments@northernplains.org" <ogsetback.comments@northernplains.org>

I support the 1/4 mile or preferably greater setbacks for oil and gas exploration in Montana !
Douglas Modrow
320 Clark Ave.
Billings MT 59101

Sent from my iPhone

Dave Sutton <suttondmd@netzero.com>
Reply-To: suttondmd@netzero.com
To: ogsetback.comments@northernplains.org

Fri, Jun 19, 2015 at 2:07 PM

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or "buffer zones" between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Dave Sutton
4104 Laredo Place
Billings, MT 59106

John Grove <skippy777@centurylink.net> Fri, Jun 19, 2015 at 3:34 PM
Reply-To: skippy777@centurylink.net
To: ogsetback.comments@northernplains.org

Dear Board of Oil and Gas Conservation Members,

Mr. Chairman and Members of the Board

Myself and my family support setback requirements for oil and gas drilling. We do not feel that 1/4 mile is adequate considering the known effects of underground fracking and the distance the horizontal wells are drilled. So the buffer or setback requirement should be more like 1 mile.

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements and be certain they are sufficient.

Sincerely,

John Grove
PO Box 77
Stevensville, MT 59870

William Woodcock <charlene@woodynet.net>
Reply-To: charlene@woodynet.net
To: ogsetback.comments@northernplains.org

Fri, Jun 19, 2015 at 4:31 PM

Dear Board of Oil and Gas Conservation Members,

Montana needs to protect Montanans, as other states do, from the dangers of nearby oil and gas drilling. I strongly support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

William Woodcock
2355 Virginia Street
Berkeley, CA 94709

Fri, Jun 19, 2015 at 8:51 PM

Randal and Maria Parthe <mcakos@gmail.com>
Reply-To: mcakos@gmail.com
To: ogsetback.comments@northernplains.org

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or "buffer zones" between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Randal and Maria Parthe
PO Box 164
Fishtail, MT 59028

maga@wispwest.net <maga@wispwest.net> Sat, Jun 20, 2015 at 11:17 AM

To: ogsetback.comments@northernplains.org

Please submit to the appropriate authorities:

We strongly urge the adoption of legal setbacks for any drilling for oil or gas to be set at a minimum of a quarter mile from any habitable structure, strongly enforced and diligently maintained.

Don & Margarita McLarty
85 Chicory Road
Livingston, Montana 59047

maga@wispwest.net

Catherine Logan <catherineplogan@gmail.com> Sun, Jun 21, 2015 at 3:28 PM
To: ogsetback.comments@northernplains.org

Please adopt protective setbacks of a quarter-mile setback, or 1,320 feet between inhabited buildings and oil and gas wells. Montanans deserve a buffer zone policy for our public safety & property values.

Thank you,
Catherine P. Logan

June 22nd, 2015

Montana Board of Oil and Gas Conservation
Linda Nelson, Chairperson
Attn: Jim Halvorson, Administrator
Montana Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102

Dear Members of the Montana Board of Oil and Gas Conservation,

I sincerely hope that the Montana Board of Oil and Gas will decide to begin rulemaking on setback requirements, in order to strike an equitable balance between development and landowner protections.
Currently, Montana has no setback requirements on private land. In contrast, our neighboring states of Wyoming, North Dakota, and Colorado require a setback of 500 feet between an oil and gas well and residences. On federal land, the Bureau of Land Management prohibits oil and gas development within ¼ mile (1,320 feet) of an occupied dwelling.

Split estate situations are common throughout the West—thus, residents may have no say about oil and gas development on their land. Montanans need to be provided with unbiased rules set by the Board of Oil and Gas in order to adequately protect their landowner rights. Studies have shown that the safest distance between a home and oil well is ¼ mile. Negative impacts of oil rigs include noise and light pollution, harmful emissions such as methane or diesel fumes, truck traffic, and water contamination. Please see yourselves as proactive in taking the initiative of a full discussion and subsequent rulemaking on the subject of balanced industry/landowner relationships.

Thank you for setting aside the time to discuss this important matter.

Sincerely,

Cindy Webber

Montana has many Boards, Commissions, Agencies and subdivisions of agencies that focus on one ore more aspects of the State's resources, rights and methods of beneficially developing or using them.

All too often the narrow missions of these entities conflict with the narrow missions of others, and many of these proscribed missions erode the Constitutionally embedded Right to a Clean and Healthful environment.

Is it too much to ask that members of these Boards engage in some common sense thinking about how their actions create ripple effects in other arenas while still giving due regard to their narrow mission?

If a Commission's raison d'etre was born of a different age, different circumstances and different understandings of the interconnectedness of things, is it too much to ask that Commission members develop larger, more accommodating views of their mission with the idea that better balanced reasoning will save immense future fractiousness. If a Commission is operating with antiquated setback policies, or worse yet, none at all, it's all the more important to engage in broader thinking that accommodates new realities in the industry they regulate.

Increasingly, water is the lifeblood. Reasonable setbacks from crucial water resources should be obvious and good policy, not contentious. Reasonable setbacks from existing human infrastructure and settlement ought to be just as obvious.

Montana should be "going to school" on the experiences, failures, successes and warning signs emerging from other states, and it should set its bars for higher standards of performance, not the lowest common denominators.

1,500' setback rules would establish that higher bar without depriving the industry of reasonable access to its precious mineral and hydrocarbon rights.
Buck up and do the needful, BOGC.

Bob Kiesling
46 S. Last Chance Gulch
Helena, MT. 59601

To The Montana Board of Oil and Gas Conservation:

I urge you to take up rulemaking on setbacks.

Setback requirements between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right.

Sincerely,

Marita Valencia

2498 Castle Butte Road

Lewistown, MT 59457

Central Montana Resource Council Member

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Hannah Hostetter
918 1/2 N 31st St
Billings, MT 59101

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Kevin Dowling
1825 10th Street West
Billings, MT 59102

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Gayle Joslin
2763 Grizzly Gulch
Helena, MT 59601

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Joan Brownell
P. O. Box 600
Fishtail, MT 59028

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Becca Fischer
native of Billings, MT

Becca Fischer
12375 Mount Jefferson Place Apt. 7E
Lake Oswego, OR 97035

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Ed Gulick
3015 10th Avenue North
Billings, MT 59101

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Leo Leckie
PO Box 84
Gardiner, MT 59030

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

Folks who live near oil and gas development, whether they chose to or not, ought to have the simple protection of a setback. Surface owners in other states like North Dakota, Colorado, and Wyoming have setback requirements and so should Montana.

Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Elizabeth Moran Stelk
214 Jim Street
Billings, MT 59101

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Carol Marsh
420 E. Front St #2
Missoula, MT 59802

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

David Lehnherr
P.O. Box 2469
Red Lodge, MT 59068

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Kathie Daviau
216 Lexington Dr
Billings, MT 59102

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,
Tom Tully and Barbara Archer
2210 Pryor Ln
Billings, MT 59102

Thomas Tully
2210 Pryor Lane
Billings, MT 59102

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I implore you to consider the implementation of setback requirements that are a quarter mile. I love this state and I love this land. Even more than that, I love and care for the people who live here. Communities should not be subjected to corporate interest that results in degradation of land, the possibility of contamination, and adverse health effects that are certain to come from flaring. Setback requirements promote best practices and allow industry to let communities live in peace. Other neighboring states have adopted such measures with the recognition that this is common sense.

As a former teacher, I think of children in schools and their vulnerability. They are extremely susceptible to health problems that can occur from lax oversight of oil and gas development. They are also not able to advocate for themselves. On behalf of students, and our youngest who need this requirement, I ask that you adopt a quarter mile setback requirement.

Sincerely,
Sarah FitzGerald

Sarah FitzGerald
3514 3rd Ave. S.
Billings, MT 59101

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Claire Coleman
1302 24th Street West, #207
Billings, MT 59102

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Dick Forehand
PO Box 1107
Red Lodge, MT 59068

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Lynn Hilten
PO Box 1107
Columbus, MT 59019

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Barbara Gulick
2018 12th St. West
Billings, MT 59102

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Patricia Dunkum
601 E Beckwith Ave
Missoula, MT 59801

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

James Davis
2004 Phoebe Drive
Billings, MT 59105

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Mary Ellen Wolfe
420 West Curtiss
Bozeman, MT 59715

Mary Ellen Wolfe
420 W Curtiss
Bozeman, MT 59715

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements of at least 1/4 mile or farther.

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a minimum of a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Laura Ferguson
1016 N Warren Street
Helena, MT 59601

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

As a Montana landowner I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Russell Blalack
1081 Milky Way
Cupertino, CA 95014

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Nancy Carrel
29 Red Bluff Loop
Birney, MT 59012

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Laulette Hansen
127 S. Easy St
Missoula, MT 59802

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Dolores Andersen
1204 Ponderosa Dr
Missoula, MT 59802

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

Setback requirements for oil and gas development are a sensible and needed protection for the health and property rights of surface owners.

North Dakota, Colorado, and Wyoming have such setback requirements. Montana landowners deserve similar protection.

Please begin rule making to establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Thank you for your attention to this important issue.

Sincerely,

Vicki Watson, 509 Daly, Missoula MT 59801

Vicki Watson
509 Daly Ave
Missoula, MT 59801

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Robert Barta
11825 Hanover Road
Lewistown, MT 59457

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Monte Brown
1315 Mill Road
Helena, MT 59602

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

William Clarke
1330 Lower Lincoln Hills Dr.
Missoula, MT 59802

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Jonathan Matthews
1633 Flowerree St.
Helena, MT 59601

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Virginia Cross
539 West Rosebud Road
Fishtail, Mt 59028

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Jeanne Sutton
4104 Laredo Place
Billings, MT 59106

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Doug MacCartney
PO Box 984
Gardner, MT 59030

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Geraldine Jennings
317 Fox Drive
Great Falls, MT 59404

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements are good for the health of thelandowner. These buffer zones between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Larry Winslow
2216 Patricia Lane
Suite A
Billings, MT 59102

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or "buffer zones" between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Liz Fordahl
608 Broadwater Ave
Billings, MT 59101

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Naomi Fink
4399 South 19th
Bozeman, MT 59718

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

Mr. Chairman and Members of the Board

Myself and my family support setback requirements for oil and gas drilling. We do not feel that 1/4 mile is adequate considering the known effects of underground fracking and the distance the horizontal wells are drilled. So the buffer or setback requirement should be more like 1 mile.

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements and be certain they are sufficient.

Sincerely,

Darlene Grove
PO Box 77
Stevensville, MT 59870

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Kathryn Kern-Levine
PO Box 2306
Red Lodge, MT 59068

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

Montana needs to protect Montanans, as other states do, from the dangers of nearby oil and gas drilling. I strongly support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Charlene Woodcock
2355 Virginia Street
Berkeley, CA 94709

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Ann Nagel
1385 Golden Gate Ave
Bozeman, MT 59718

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Jean Dahlman
3335 Old Highway 10 Road
Forsyth, MT 59327

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Joan Kresich
410 S 6th St
Livingston, MT 59047

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Lydia Garvey
429 S. 24th Street
Clinton, OK 73601

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Wade Sikorski
1511 Hwy 7
Baker, MT 59313

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Tom Heald
2714 W. Bridger
Billings, MT 59102

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Randy Parthe
P. O. Box 164
Fishtail, MT 59028

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Marilyn Hill
PO BOX 160277
Big Sky, MT 59716

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Becky Mitchell

Becky Mitchell
3124 Amelia Circle
Billings, MT 59106

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Julie A. Fraley

Julie Fraley
2904 Bunker Hill Dr
Billings, MT 59105

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Karen Heald
2714 W. Bridger
Billings, MT 59102

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

June Persons
HC71, Box 1160
Ashland, MT 59003

59003

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Don Bianchi
707 Minnesota Street, #B
Belgrade, MT 59714

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Kim Potts
54 Madison River Rd
Three Forks, MT 59752

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Marta Meengs
107 North Ave W
Missoula, MT 59801

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

Lets be respectful of private properties and keep at lease a 1/4 mile separate from oil and gas wells. Be a good neighbor and be partners with Montanans!

Thank you.

Patricia Simmons
357 Pine Creek Drive
Bozeman, MT 59718

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a half mile setback calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,
Grant Barnard

Grant Barnard
PO Box 1658
Red Lodge, MT 59068

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Ken Rand
606 Gerald Ave
Missoula, MT 59801

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Jeffrey Kreigler
807 N 31st
Billings, MT 59101

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Deborah Muth
39 Lightning Lane
Red Lodge, MT 59068

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Eric VanderBeek
PO Box 811
Lewistown, MT 59457

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Arthur Canfield
P.O. Box 758
Lewistown, MT 59457

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

KAY CARLSON
844 Yellowstone Ave
BILLINGS, MT 59101

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Susanne Galbraith
611 Orr St
Miles City, MT 59301

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

John Smillie
4111 June Drive
Billings, MT 59106

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Paula Berg
802 Lewis Ave
Billings, MT 59102

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

I have recently read about this, and I support to protect people from the harvesting of materials that cause danger to inhabitants.
thank you for your concern in reading this.
from a massachusetts inhabitant,
stephen.
Sincerely,

Stephen Hill
9 woodside cottage way
Framingham, MA 01701

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Kathleen Sinnott
920 Pine Drive
Felton, CA 95108

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Roger Lohrer
466 Snowberry Ln
Lewistown, MT 59457

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Elli Hawks
PO Box 188
Melville, MT 59055

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Roxanna McLaughlin
PO Box 11647
Bozeman, MT 59715

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Karen Peterson
3015 Parkhill Dr.
Billings, MT 59102

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Debra Frost
MT landholder, Cooke City

Debra Frost
2 Wellfleet Dr
Norfolk, MA 02056

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Susana Sweeters
2434 Indian School NW
Albuquerque, NM 87104

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Eleanor Parker
710 11th Avenue
Helena, MT 59601

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Liz Fordahl
608 Broadwater Ave
Billings, MT 59101

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Having lived in Western Colorado near the gas fields, I can attest to the importance of setbacks.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Suzy Sterling
409 Park Place
Bozeman, MT 59715

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Jeffrey Smith
105 Channel Drive
Missoula, MT 59804

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Judy Madden

Judy Madden
PO Box 23
Fishtail, MT 59028

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Sweetwater Nannauck
315 Roberts Way
Camano Island, WA 98282

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

William swift
6036 eaglewood ln
kingston, WA 98346

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

Dear Board Member,
I am writing to tell you that Isupport setback requirements. The setback requirements between homes and oil/gas wells are just good common sense policy that sets protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

I am in support of oil and gas development but please make sure it is done right. Take up rule-making on setback requirements.

Thank you for your service on the board.
Sincerely,
Shirley Howard and Terry Robinson

Shirley Howard
3981 Avenue D Unit 3
Billings, MT 59102

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Richard Liebert
289 Boston Coulee Road
Great Falls, MT 59405

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Carltina Johnson
820 Mann Pl
2
Cincinnati, OH 45229

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Eileen Morris
1323 Janie Street
Billings MT 59105

Eileen Morris
1323 Janie Street
Billings, MT 59105

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Laura Hyatt
138 12th St SE
Auburn, WA 98002

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Sheila Bjornlie
455 Almar Ave
Pacific Palisades, CA 90272

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Olivia Stockman Splinter
Billings, MT

Olivia Splinter
1034 Yale Ave.
Billings, MT 59102

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Leah Hoffert
1440 Lynn Ave #1
Billings , MT 59102

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

Yes, I strongly support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Anne Millbrooke

Anne Millbrooke
3410 Golden Valley Drive
Bozeman, MT 59718

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Paul Szymanowski
P.O. BOX 74
CURTICE, OH 43412

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Cate Campbell
1001 E. Broadway St. #2-206
Missoula, MT 59802

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Joel G. G. Vignere
PO Box 194
Lakeside, MT 59922

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Caroline Metzler
5033 CR 335 #165
New Castle, CO 81647

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Ellen Knight
5800 Rattlesnake
Missoula, MT 59802

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,
Representative Mary Ann Dunwell
Montana House District 84, Helena-East Helena

Mary Ann Dunwell
2520 Lookout Circle
Helena, MT 59601

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

Dear Montana Board of Oil and Gas Members,

I write today in support of setback requirements.

Setback requirements between homes and oil/gas wells make sense. We need a policy that sets reasonable protections for surface owners while allowing mineral owners to develop their mineral estates. The states of North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

To ensure oil and gas development is done right please have a rule-making on setback requirements.

Sincerely,

Michael H. Lee
P.O.Box 1013
Helena MT 59624

Michael Lee
PO Box 1013
Helena, MT 59624

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

H. Saron Anon-Coleman
640 Bailey Rd.
#491
Bay Point, CA 94565

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Carol Edwards
10641 North Fork Rd.
Polebridge, MT 59928

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Annette Bayley
2046 George St
Billings, MT 59102

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,
Christie Juarez

Christie Juarez
475 Main St.
Floweree, MT 59440

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Bill Milton

Bill Milton
PO Box 629
Roundup, MT 59072

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

Please make sure oil and gas development is done right. Take up rule-making on setback requirements.

Sincerely,

Heidi Anderson
319 W Main St.
Gardiner, MT 59030

Board Members
Board of Oil and Gas Conservation
2535 St. Johns Avenue
Billings, MT 59102
US

Dear Board of Oil and Gas Conservation Members,

I support setback requirements!

Setback requirements, or “buffer zones” between homes and oil/gas wells, are good common sense policy that sets reasonable protections for surface owners while still allowing mineral owners to develop their mineral estates. Our neighbors in North Dakota, Colorado, and Wyoming have setback requirements and so should Montana. Please establish a quarter mile setback (1,320 feet) calculated from the outer perimeter of a well pad.

I OWED A GAS WELL THAT HAD BEEN DRILLED IN THE 30'S AND IT WAS PROTECTED BY A SET BACK THEN SO PLEASE DON'T CHANGE THIS PLAN.IT IS A GOOD ONE!!! IT PROTECTS LAND OWNERS,WELLS,NEIGHBORS FROM CONTAMINATION,FIRES AND THEFT.I KNOW YOU WILL CONTINUE TO PROTECT MONTANA.
SINCERELY, DORCAS HALVERSON

Sincerely,

Dorcas Halverson
112 N Crawford
Hardin, MT 59034

EXHIBIT 8

Setbacks Summary

June 24, 2015

Guide to Setback Rules – Rocky Mountain Region

Montana

Summary

The BOGC does not have a defined setback distance from drilling activity. Setbacks are typically negotiated through surface use agreements with the surface owner and oil and gas operator. BOGC regulation 36.22.601, requires an operator intending to drill a well in a non-delineated field to publish notice in one issue of a newspaper in general circulation in Helena and a newspaper of general circulation in the county where the proposed well or hole is located. The purpose of this is to give any "interested person" an opportunity to be heard concerning the application for permit to drill. The protest of the permit must be received within ten days of publication of the notice. The definition of "interested person" is very general and gives a broad range of the public an opportunity to be heard with any concerns they might have about a drilling permit, including setbacks from dwellings.

North Dakota

Summary

The North Dakota setback rule is a 500 ft setback from occupied dwelling with a notification requirement for all owners of occupied dwellings within 1,320 ft of proposed well.

Rule

38-08-05. Drilling Permit Required

1. A person may not commence operations for the drilling of a well for oil or gas without obtaining a permit from the industrial commission under rules as may be adopted by the commission and paying to the commission a fee for each well in an amount to be determined by the commission. The applicant shall provide notice to the owner of any permanently occupied dwelling located within one thousand three hundred twenty feet [402.34 meters] of the proposed oil or gas well.
2. Unless waived by the owner or if the commission determines that the well location is reasonably necessary to prevent waste or to protect correlative rights, the commission may not issue a drilling permit for an oil or gas well that will be located within 500 ft of occupied dwelling. If the commission issues a drilling permit for a location within one thousand feet of an occupied dwelling, the commission may impose conditions on the permit:
   a. For wells permitted on new pads built after July 31, 2013, the conditions imposed under this subdivision may include, upon request of the owner of the permanently occupied dwelling, requiring that the location of all flares, tanks, and treaters utilized in connection with the permitted well be located at a greater distance from the occupied dwelling than the oil and gas well bore if the location can be accommodated reasonably within the proposed pad location; or

b. As the commission determines reasonably necessary to minimize impact to the owner of the occupied dwelling.

Wyoming

Summary

The Wyoming setback rule is a 500 ft setback from occupied structures with a notification requirement for all owners of occupied structures within 1,000 ft of proposed wells/production equipment.

Definitions

Occupied Structure shall mean a building that was specifically constructed and approved for human occupancy such as a residence, school, office, or hospital. Occupied structure shall not mean outbuildings such as, but not limited to sheds, barns or garages.

Rule

Chapter 3. Operational Rules, Drilling Rules

Section 47. Surface Setbacks

a) Well(s), drilling equipment and associated production facilities shall be located no closer than five hundred feet (500') to an existing Occupied Structure(s) as measured from the closest exterior wall or corner of the Occupied Structure(s) to the center of the wellhead. The Supervisor may approve a variance to increase or decrease the setback requirements for good cause. If for any reason the Supervisor shall deny a variance, the Commission may, after notice and hearing, consider the variance. If a well is not spud, a variance granted by the Supervisor or the Commission under this subsection shall expire one (1) year from the date the variance is granted.

b) Where a Well(s) and associated production facilities are proposed for location within one thousand feet (1,000') of an existing Occupied Structure(s), as measured from the closest exterior wall or corner of an Occupied Structure(s) to the center of the wellhead or exterior wall or corner of associated production facilities, the Owner or Operator shall:

   i. Inform each owner(s) of an Occupied Structure(s), as identified on county assessor tax records, no more than one hundred and eighty (180) days nor less than thirty (30) days before the commencement of drilling activity, in writing, of:

      A. The owner or operator name and contact information;

      B. Its plan to drill a new Well(s) and the estimated construction, drilling and completion timeline;

      C. The legal location of the Well(s), including Quarter-Quarter, Section, Township, Range, County;

      D. The name and API Number of the new Well(s); and

E. The site specific measures the Owner or Operator plans to take to mitigate any anticipated impacts to the owner(s) of Occupied Structure(s).

ii. Provide for the Supervisor's review and consideration, prior to spudding a Well(s) or construction of associated production facilities, a report which details the actions taken by the Owner or Operator to communicate with the owner(s) of an Occupied Structure(s) in accordance with subsection (b)(i). The report shall include the site specific measures the Owner or Operator will take to mitigate anticipated impacts. Nothing in this subsection is intended, and shall not be construed, to preclude or limit the Supervisor from requiring other site specific measures to mitigate anticipated impacts.

c) The Owner or Operator, in consultation with the Supervisor, shall schedule meetings to facilitate necessary information sharing with owners of Occupied Structures in an area in which an Owner or Operator has an approved Application for Permit to Drill or Deepen a Well (Form 1) located within one thousand feet (1,000') of an existing Occupied Structure(s) within the existing corporate limits of an incorporated municipality or within the boundary of an existing platted subdivision established in compliance with all applicable state and county laws and regulations. The Supervisor may waive this requirement for an Owner or Operator if the owner(s) of all Occupied Structures within this zone waive this requirement, in writing, on a form approved by the Commission.

d) If additional development requiring an Application for Permit to Drill or Deepen a Well (Form 1) occurs at an existing well location, an Owner or Operator shall be required to comply with all provisions of Chapter 3, Section 47(b).

Note: Wyoming also has a 350' setback for wells, pits, wellheads, pumping units, tanks, and treaters from any water supply. The Supervisor may increase or decrease this distance for good cause.

Colorado

Summary

While North Dakota and Wyoming's setback rule relatively brief and straight forward, the Colorado setback rule is very complex and takes up approximately 35 pages. This rule is a good example of how complicated trying to create a one size fits all setback rule for the entire state can get. There are many different scenarios that can each have different guidelines operators need to follow. This makes it very difficult to give a quick over view of the rule. The main definitions and parts of the rule are below, in addition to a chart that can be used as a more simplified look at the setback requirements depending on the scenario. The foundation of the rule calls for a 500 ft setback to occupied dwellings and 1,000 ft setback to hospitals and schools.

Definitions

BUILDING UNIT shall mean a Residential Building Unit; and every five thousand (5,000) square feet of building floor area in commercial facilities or every fifteen thousand (15,000) square feet of building floor area in warehouses that are operating and normally occupied during working hours.

DESIGNATED SETBACK LOCATION shall mean any Oil and Gas Location within, or proposed to be constructed within, a Buffer Zone Setback (1,000 feet), Exception Zone Setback (500 feet), within one thousand (1,000) feet of a High Occupancy Building Unit, or within three hundred fifty (350) feet of a Designated Outside Activity Area, as referenced in Rule 604. The measurement for determining any Designated Setback Location shall be made from the center of the Well or Production Facility nearest any Building Unit to the nearest wall or corner of such Building Unit.

DESIGNATED OUTSIDE ACTIVITY AREA: Upon Application and Hearing, the Commission, in its discretion, may establish a Designated Outside Activity Area (DOAA) for:

i. an outdoor venue or recreation area, such as a playground, permanent sports field, amphitheater, or other similar place of public assembly owned or operated by a local government, which the local government seeks to have established as a Designated Outside Activity Area; or
ii. an outdoor venue or recreation area, such as a playground, permanent sports field, amphitheater, or other similar place of public assembly where ingress to, or egress from the venue could be impeded in the event of an emergency condition at an Oil and Gas Location less than three hundred and fifty (350) feet from the venue due to the configuration of the venue and the number of persons known or expected to simultaneously occupy the venue on a regular basis.

The Commission shall determine whether to establish a Designated Outside Activity Area and, if so, the appropriate boundaries for the DOAA based on the totality of circumstances and consistent with the purposes of the Oil and Gas Conservation Act.

HIGH OCCUPANCY BUILDING UNIT shall mean:

i. any operating Public School as defined in C.R.S. § 22-7-703(4); Nonpublic School as defined in C.R.S. § 22-30.5-103.6(6.5); Nursing Facility as defined in C.R.S. § 25.5-4-103(14); Hospital; Life Care Institutions as defined in C.R.S. § 12-13-101; or Correctional Facility as defined in C.R.S. § 17-1-102(1.7), provided the facility or institution regularly serves fifty (50) or more persons; or
ii. an operating Child Care Center as defined in C.R.S. § 26-6-102(1.5).

RESIDENTIAL BUILDING UNIT means a building or structure designed for use as a place of residency by a person, a family, or families. The term includes manufactured, mobile, and modular homes, except to the extent that any such manufactured, mobile, or modular home is intended for temporary occupancy or for business purposes.

SURFACE OWNER shall mean any person owning all or part of the surface of land upon which oil and gas operations are conducted, as shown by the tax records of the county in which the tract of land is situated, or any person with such rights under a recorded contract to purchase.

SURFACE USE AGREEMENT shall mean any agreement in the nature of a contract or other form of document binding on the Operator, including any lease, damage agreement, waiver, local government approval or permit, or other form of agreement, which governs the operator's activities on the surface in relation to locating a Well, Multi-Well Site, Production Facility, pipeline or any other Oil and Gas Facility that supports oil and gas development located on the Surface Owner's property.

URBAN MITIGATION AREA shall mean an area where: (A) At least twenty-two (22) Building Units or one (1) High Occupancy Building Unit (existing or under construction) are located within a 1,000' radius of the proposed Oil and Gas Location; or (B) At least eleven (11) Building Units or one (1) High Occupancy Building Unit (existing or under construction) are located within any semi-circle of the 1,000 radius mentioned in section (A) above.

Rule
604. SETBACK AND MITIGATION MEASURES FOR OIL AND GAS FACILITIES, DRILLING, AND WELL SERVICING OPERATIONS

A. **Setbacks**. Effective August 1, 2013:
   (1) **Exception Zone Setback**. No Well or Production Facility shall be located five hundred (500) feet or less from a Building Unit except as provided in Rules 604.A.(1) a and b, and 604.B.
      a. Urban Mitigation Areas. The Director shall not approve a Form 2A or associated Form 2 proposing to locate a Well or a Production Facility within an Exception Zone Setback in an Urban Mitigation Area unless:
         i. the Operator submits a waiver from each Building Unit Owner within five hundred (500) feet of the proposed Oil and Gas Location with the Form 2A or associated Form 2, or obtains a variance pursuant to Rule 502; and
         ii. the Operator certifies it has complied with Rules 305.a, 305.c., and 306.e.; and
         iii. the Form 2A or Form 2 contains conditions of approval related to site specific mitigation measures sufficient to eliminate, minimize or mitigate potential adverse impacts to public health, safety, welfare, the environment, and wildlife to the maximum extent technically feasible and economically practicable; or
         iv. the Oil and Gas Location is approved as part of a Comprehensive Drilling Plan pursuant to Rule 216.
      b. Non-Urban Mitigation Area Locations. Except as provided in subsection 604.B., below, the Director shall not approve a Form 2 or Form 2A proposing to locate a Well or a Production Facility within an Exception Zone Setback not in an Urban Mitigation Area unless the Operator certifies it has complied with Rules 305.a., 305.c., and 306.e., and the Form 2A or Form 2 contains conditions of approval

related to site specific mitigation measures sufficient to eliminate, minimize or mitigate potential adverse impacts to public health, safety, welfare, the environment, and wildlife to the maximum extent technically feasible and economically practicable.

(2) **Buffer Zone Setback**. No Well or Production Facility shall be located one thousand (1,000) feet or less from a Building Unit until the Operator certifies it has complied with Rule 305.a., 305.c., and 306.e. and the Form 2A or Form 2 contains conditions of approval related to site specific mitigation measures as necessary to eliminate, minimize or mitigate potential adverse impacts to public health, safety, welfare, the environment, and wildlife.

(3) **High Occupancy Buildings**. No Well or Production Facility shall be located one thousand (1,000) feet or less from a High Occupancy Building Unit without Commission approval following Application and Hearing. Designated Setback Location and Exception Zone Setback mitigation measures pursuant to Rule 604.c. shall be required for Oil and Gas Locations within one thousand (1,000) feet of a High Occupancy Building, unless the Commission determines otherwise.

(4) **Designated Outside Activity Areas**. No Well or Production Facility shall be located three hundred fifty (350) feet or less from the boundary of a Designated Outside Activity Area. The Commission, in its discretion, may establish a setback of greater than three hundred fifty (350) feet based on the totality of circumstances. Designated Setback Location mitigation measures pursuant to Rule 604.c. shall be required for Oil and Gas Locations within one thousand (1,000) feet of a Designated Outside Activity Area, unless the Commission determines otherwise.

(5) **Maximum Achievable Setback**. If the applicable setback would extend beyond the area on which the Operator has a legal right to locate the Well or Production Facilities, the Operator may seek a variance under Rule 502.b. to reduce the setback to the maximum achievable distance.

Chart

Exceptions ***to*** Setback Rules					Requirements for Exception Approval					
RULE	Cultural Features	Setback Distance	Setback Zone	Exceptions	Mitigation*	Request Letter	Compliance Certification**	Waiver	Comment on Form	CDPHE Consult
603.a.(1)	Building, Public Road, Above Ground Utility, Railroad	200	n/a	502.b	possible	YES	NO	YES	YES	YES
603.a.(2)	Property Line	150	n/a	YES	possible	YES	NO	YES	YES	NO
604.a.(1)A	Building Unit	500' - Urban	Exception Zone	YES	YES	YES	YES	YES	YES	NO
604.a.(1)B		500' - Non-Urban		YES	YES	YES	YES	NO	YES	NO
604.a.(2)		1000	Buffer Zone	n/a	YES	NO	YES	NO	YES	NO
604.a.(3)	High Occupancy Building Unit	1000	Exception Zone	HEARING	YES	NO	NO	NO	YES (cite order)	NO
604.a.(4)	Designated Outside Activity Area	350	n/a	NO	n/a	n/a	n/a	n/a	n/a	n/a
		1000	Buffer Zone	n/a	YES	NO	NO	NO	YES	NO
604.a.(5)	Maximum Achievable Setback	500 - 1000	n/a	502.b	possible	YES				

*Mitigation - see Rule 604.c

**Compliance Certification - see Rules 303.b.(3)J.iii, 303.b.(3)K, and 306.e.(5)

Exceptions ***by*** Setback Rule 604.b: add a well or production facility to an *existing* or *approved* location if no technically or economically practicable alternative location exists			Requirements for Exception Approval			
RULE	Scenario	Exceptions	Mitigation	Request Letter	SUA Attached	Comment on Form
604.b.(1) A	Oil & Gas Location is within a Designated Setback as a result of Rule 604.a.	YES (may)	YES	YES*	n/a	YES
604.b.(1) B	Oil & Gas Location is within a Designated Setback due to Building Unit construction after approval	YES (may)	YES	YES*	n/a	YES
604.b.(2)	SUA or site-specific development plan executed on or before August 1, 2013	YES (shall)	YES	YES*	YES	YES
604.b.(3)	Building Units constructed after August 1, 2013 within setback per an SUA or site-specific development plan	n/a	YES	YES*	YES	YES
***IMPORTANT NOTE** : Exception Location Request Letter for Rule 604.b exception *must* explain why alternative locations are technically or economically impracticable						

BLM Rule

LEASE NOTICE No. 14-16 Setback from Human Occupied Residences Requirement

The lease area may contain human occupied residences. Under Regulation 43 CFR 3101.1-2 and terms of the lease (BLM Form 3100-11), the authorized officer may require reasonable measures to minimize adverse impacts to other resource values, land uses, and users not addressed in lease stipulations at the time operations are proposed. Such reasonable measures may include, but are not limited to, modification of siting or design of facilities, which may require relocating proposed operations up to 200 meters, but not off the leasehold.

The setback requirement of 500 feet from human occupied residences has been established based upon the best information available. The following condition of approval may be applied as a result of the Application for Permit to Drill (APD) process during the on-site inspection and the environmental review unless an acceptable plan for mitigation of impacts is reached between the resident, lessee and BLM:

- **Facilities will not be allowed within 500 feet of human occupied residences.**

The intent of this Lease Notice is to provide information to the lessee that would help design and locate oil and gas facilities to preserve the aesthetic qualities around human occupied residences.

36.22.601 NOTICE OF INTENTION AND PERMIT TO DRILL

(1) No person shall commence the drilling of an oil or gas well or stratigraphic test well or core hole without filing an application for permit to drill on Form No. 22 and obtaining a drilling permit from the board. If the proposed well or hole is not located within the boundaries of a delineated field for which, after public hearing, an order has been entered by the board that drilling permits may issue for locations within that field without further public hearing, the applicant must:

(a) At its own expense, cause publication of notice in a format prescribed by the board in one issue of a newspaper in general circulation in Helena and a newspaper of general circulation in the county where the proposed well or hole is located; and

(b) File proof of such publication in the form of a copy of the page on which the ad appears showing the ad and the date of publication or an affidavit of the publisher.

(2) Prior to the commencement of recompletion operations on any oil or gas well, notice shall be delivered to the board of such intention on Form No. 2, and approval shall be obtained.

(3) When a permit is sought for a 320 acre drilling or spacing unit, Form No. 22 as filed with the board shall include a description of the lands to be included.

(4) The staff of the board shall refer an application for permit to drill to the board for notice and public hearing if:

(a) An interested person shall, as to any application for permit to drill for which published notice is required, file in the form hereinafter set forth a written demand for an opportunity to be heard concerning such application; or

(b) The staff determines that a person applying for a drilling permit or approval of recompletion operations is not in substantial compliance with the board's rules governing the applicant's operations in Montana; or

(c) The planned drilling operations require further environmental review.

(5) In those instances where such requests for a permit to drill have been the subject of notice and public hearing, the board shall, after such hearing, either:

(a) Enter its order granting such permit under such conditions as the board shall find proper and necessary; or

(b) Enter its order denying the application for the permit.

(6) A demand for opportunity to be heard concerning any application for permit to drill for which published notice is required must:

(a) Be in writing; and

(b) Set forth the name, address, and telephone number of each party making the demand, and their ownership interest, if any, in the lands surrounding the drill site; and

(c) Set forth the specific reasons why the party requests a hearing regarding the issuance of the proposed drilling permit; and

(d) Be received by the board no later than ten (10) days after the date of the publication of the notice. Where the notice is not published on the same day in the newspapers specified in paragraph (1) (a) of this rule, the deadline for receiving demands for hearing will be measured by the later publication date. Service of such demand may be made on the board personally, by mail, or by FAX transmission; and

(e) Be simultaneously served upon the applicant for the permit by written copy mailed or FAX transmitted to the address or number set forth in the published notice.

A certificate of such service must accompany the demand as filed with the board.

(7) Surface owner concerns which are subject to the provision of 82-10-504 , MCA (Surface Damage and Disruption Payments) will not be the subject of a public hearing before the board.

History: Sec. 82-11-111, MCA; IMP, Sec. 82-11-122, MCA; Eff. 12/31/72; AMD, Eff. 6/4/77; AMD, 1982 MAR p. 1398, Eff. 7/16/82; AMD, 1983 MAR p. 82, Eff. 1/28/83; AMD, 1990 MAR. p. 305, Eff. 2/9/90.