2012

The context of public acceptance of hydraulic fracturing: is Louisiana unique?

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THE CONTEXT OF PUBLIC ACCEPTANCE OF HYDRAULIC FRACTURING: IS LOUISIANA UNIQUE?

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The Department of Environmental Sciences

by
Crawford White
B.S. Georgia Southern University, 2010
August 2012

Dedication

This thesis is dedicated to the memory of three of the most important people in my life, all of whom passed on during my time here.

Arthur Earl White

4.05.1919 – 5.28.2011

Berniece Baker White

4.19.1920 – 4.23.2011

and

Richard Edward McClary

4.29.1982 – 9.13.2010

Acknowledgements

I would like to thank my committee first of all: Dr. Margaret Reams, my advisor, for her unending and enthusiastic support for this project; Professor Mike Wascom, for his wit and legal expertise in hunting down various laws and regulations; and Maud Walsh for the perspective and clarity she brought this project. I would like to thank Keith Mauck for his assistance with my second survey, and all of the members of Gohaynesvilleshale.com as well. Finally, I would like to thank Shannon Ferguson, my fiancé and biggest fan, for her unending encouragement, love, and advice.

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Abstract

Hydraulic fracturing has received increased attention over the past decade. The rapid adoption of this technique coupled with accurate directional horizontal drilling has unlocked several US shale formations. Amid the possibility of 100% domestically sourced natural gas, public perception varies and opponents question the long-term risks and repercussions of the technique. This thesis will provide context to some of the variation seen in the public perception of hydraulic fracturing among three states: Louisiana, Pennsylvania, and Texas. Two surveys of Louisiana stakeholders were conducted in order to rank the state in terms of acceptance amongst previously conducted surveys of its two peers. Results show that of the three states, Louisianans have accepted hydraulic fracturing the most and Pennsylvanians the least. Factors have been identified that may explain differences in acceptance among these states. These include well densities, potentially affected populations, previous environmental contamination experiences, variations among state regulatory response, and the personal histories and experiences of each state's populations. Louisiana's unique history with oil and gas, high exposure to energy development, and vital role in the United State's energy market may all be contributing factors for the acceptance of hydraulic fracturing and horizontal drilling of shale as reasonable practices. Meanwhile, the increased frequency of fracking accidents and negative portrayal in documentaries may both contribute to Pennsylvania's low rate of acceptance.

Chapter One: Introduction, Problem Statement, and Methods

1.1: Introduction

Hydraulic fracturing of shale has become a popular method of natural gas extraction over the last five to ten years. Commonly called hydrofracking, or simply fracking, variants of the technology have been in use since Stanolind Oil (now Amoco) pioneered the technique in 1947 (Montgomery and Smith, 2006). Its usefulness for increasing permeability (or ability of the rock to transmit fluids) has made it a staple of well-stimulation techniques, with 90% of every well in The United States estimated to have been fracked at some point (Montgomery and Smith, 2006 and Independent Petroleum Association of America, 2008). The majority of these applications prior to 2006 were on vertical wellbores; once the technology needed for accurate horizontal drilling became available, the combination was proven able to unlock natural gas and oil from shale formations long thought unobtainable (Boyer et al, 2011 and Hyne, 2001). These shale formations had been on the radar of drillers for more than a century in some cases, but their permeability was so low that drilling through them often represented no more than a small “kick”; the formation would leak some gas initially, but never for prolonged periods (Boyer et al, 2011). Some wells would produce enough gas over their lifetime to be interesting, but never enough to make the shale a primary target (Boyer et al, 2011). When it was proven that horizontal drilling and hydraulic fracturing could together unlock the potential of these impermeable shales, it was like a modern gold rush—only everyone knew exactly where to look.

Figure 1 shows the location of the major shale plays in North America, and Figure 2 shows the current global picture. Almost overnight, estimated reserves in North America grew by over 86%; in Europe, over 371%– and these figures are continually increasing (Rogner 1997, and EIA, 2011). The first shale unlocked was the Barnett Shale, in Western Texas. That first demonstration of the modern use of hydraulic fracturing combined with horizontal drilling was twenty years in the making, and was started by Mitchell Energy & Development Corporation in 1981 (Boyer et al, 2011). Once they had shown how it could be done, shale gas development escalated rapidly. Other companies began following suit in other previously unproductive shale formations in Pennsylvania, North Dakota, Oklahoma, Louisiana, New Mexico, Colorado, Wyoming, and Arkansas (Rowe and Fortunato, 2010, and Montgomery and Smith 2006).

The rapid expansion of hydraulic fracturing as key to new natural gas development has led to increased scrutiny from the public (Hopey, 2010). NUMBY—Not Under My Backyard—has become a popular phrase for opponents (Kerr, 2010). Documentaries like Josh Fox's Oscar-nominated *Gasland* have created negative impressions (America's Natural Gas Alliance, 2012 and Smith, 2011). Meanwhile, proponents see fracking as a way of reducing our dependence on foreign oil and gas (Aguilera and Aguilera, 2012, Davenport, 2010, and Gissen, 2012).

Some argue that the major struggle the United States has faced since petroleum became king has always been about securing a healthy supply of oil, possibly necessitating two invasions in Middle Eastern Countries over the past 25 years (Levine 2010 and Parra, 2004). The US only imported only 10% of its natural gas demand in 2010, compared with 45% of its oil demand (Energy Information Administration [EIA], 2012). It is important to

note here that while natural gas is where most of the attention has been, shale formations like the Bakken in North Dakota offer similar promise in the form of oil (Carpenter, 2012).

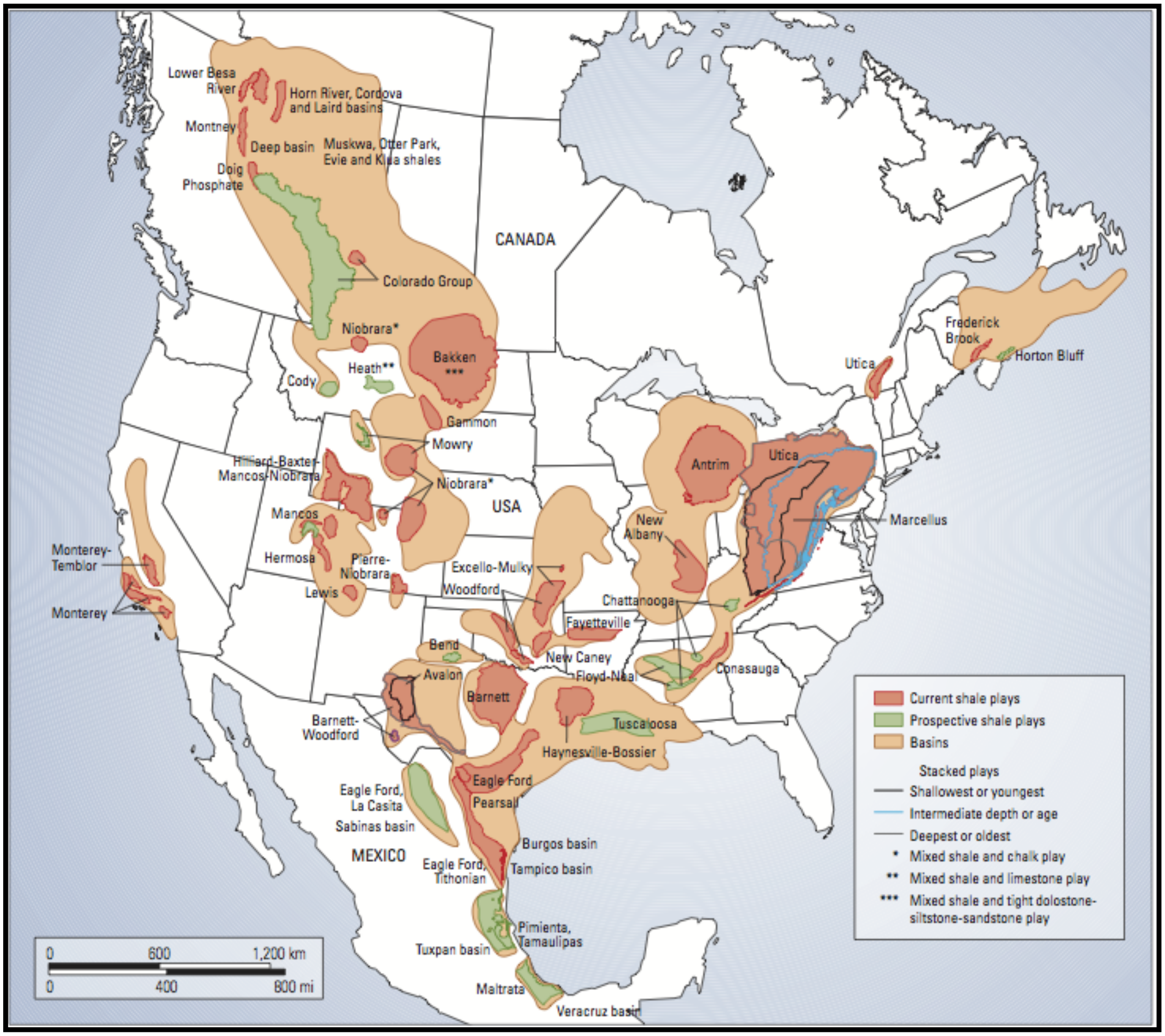

Figure 1. North American Shale Resources. (Boyer et al, 2011).

The goal of energy independence, at least with natural gas, does not seem unattainable. Independence will, however, come at the cost of increased exposure to the risks associated with oil and gas development. It is these risks that environmentalists oppose, leading to anti-fracking groups in every state home to developing shale gas—except Louisiana.

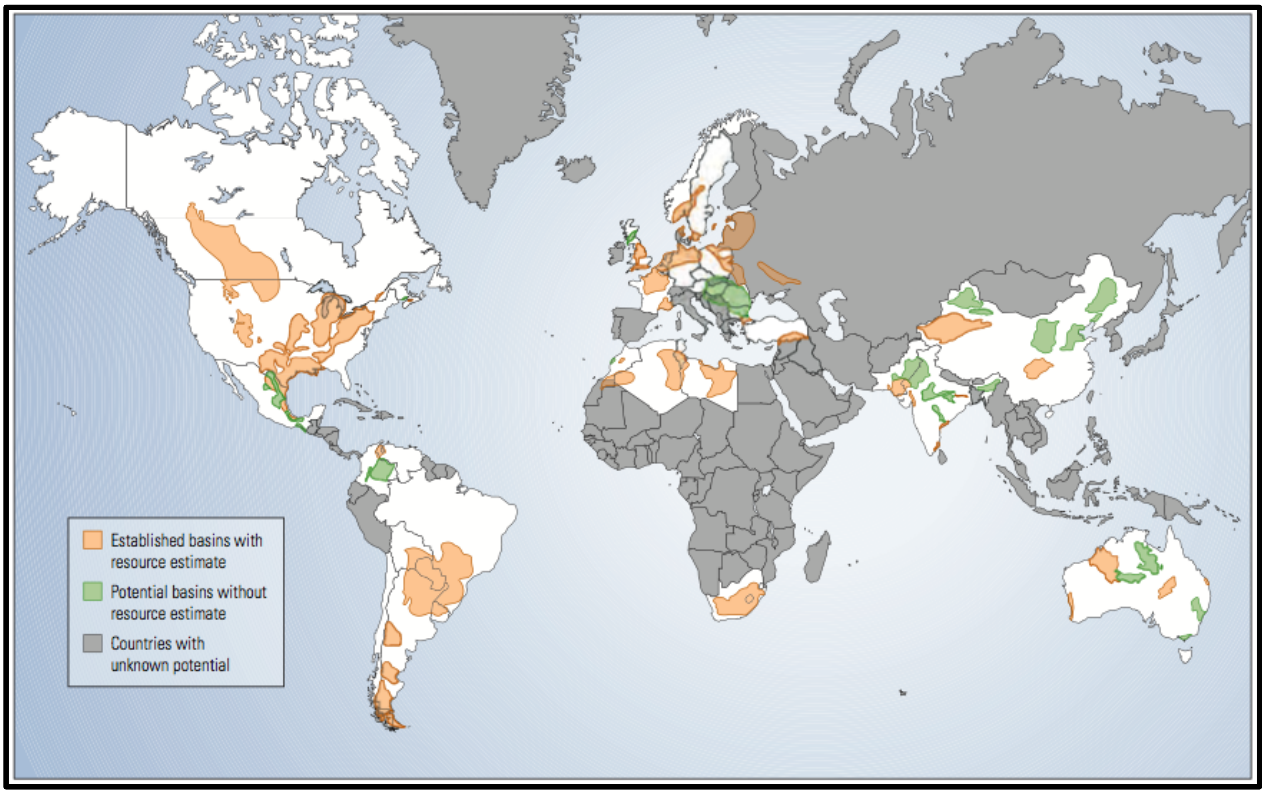

Figure 2. Global Shale Resources. (Boyer et al, 2011).

1.2: Objectives

The overall objective of this thesis is to examine the conditions under which hydraulic fracturing may be more likely to be accepted by communities. This thesis will (1) examine acceptance of hydraulic fracturing in three states, and (2) provide a historic, regulatory, geographic, socioeconomic, and environmental comparison between those three states. The selected states are both rich in oil history and home to modern hydraulic fracturing: Louisiana, Pennsylvania, and Texas.

1.3: Methods

The first objective will be addressed through a comparison of published surveys for Louisiana, Pennsylvania, and Texas, as well as a set of two original surveys of Louisianans conducted specifically for this thesis. The second objective will be addressed through a

mixed-methods approach both qualitative and quantitative in approach. The next three chapters will provide background information that largely represents a literature review, while the quantitative comparison of data will be presented with the results of the two surveys.

1.3.1: Survey Methodology

Responses from two surveys will be analyzed in order to understand the nature of public opinion towards hydraulic fracturing within Louisiana. The National Institutes of Health [NIH] Protecting Human Subject Research Participants Certification coursework has been completed, and the survey instruments used have been approved by the LSU Institutional Review Board [IRB].

The first survey intended to gather responses from individuals in positions of power in relation to the oil and gas industry throughout Louisiana. This group includes senators and representatives from the State Legislature, members of the Department of Natural Resources, the Office of Conservation, various state-level commissions and boards, representatives from the 5 major energy companies operating in the Haynesville Shale, and the webmasters for two prominent shale blogs. Questions focused on the importance of shale gas development, energy independence, perceived safety concerns of citizens, ethical responsibilities of the energy companies, and sources of information or misinformation. A Likert scale was implemented for questions that weren't categorical, open-ended, or dichotomous. Thirty individuals or representatives of various entities have been contacted via email and followed up with phone calls as necessary. This survey instrument has been included in Appendix A.

The second survey is a broader-based follow-up survey to the first, and targeted at a much larger audience that is likely pro-fracking. Members of the online community and blog GoHaynesvilleShale were contacted through the site administrator and asked to complete an online survey for this thesis. The survey was similar to the first in content, but was designed to be a more concise and clear instrument, with an expected average completion time of 10 minutes or less. Respondents had the opportunity to spend more time on four open-ended questions if they choose to do so.

The desired survey sample size for the second survey was calculated using the method described by Dillman et al, 2007.

$$N_s = \frac{(N_p)(p)(1-p)}{(N_p - 1)(B/C)^2 + (p)(1-p)}$$

Wherein N_s = required completed sample size, N_p = entire population size, p = proportion of population expected to choose one of two response categories, B = margin of error, and C= Z score associated with the desired confidence level (Dillman et al, 2007).

1.3.2: Mixed-Methods Profile

Developments in Louisiana, Pennsylvania, and Texas will be profiled. Chapter Two will provide a technical background of hydraulic fracturing, and will address the risks associated with it. Chapter Three will provide a historical background of the oil and gas industry as a whole, providing Louisiana, Pennsylvania, and Texas' own unique histories. Chapter Four will compare the various hydraulic fracturing regulatory constructs in these three states, and give special attention to the debate on increased federal oversight. Chapter Five will contain conclusions from already available survey data in Louisiana, Pennsylvania, and Texas. Chapter Six (Results) will contain the results of the two survey

instruments described in 1.3.1, followed by geographic, socioeconomic, and environmental damage comparisons for each state. These comparisons include calculated criteria such as well density, areal extent of hydraulic fracturing, potential percentage of population exposed to hydraulic fracturing operations, and other demographic variables within the affected and non-affected populations in those states. The specific sources for these data vary from state to state (with the exception of Census data), and will be covered in depth alongside the results. The environmental damage comparison will be based off of reported and anecdotal accidents related to hydraulic fracturing, and a state environmental "scorecard" produced by an affiliate of the Environmental Defense Fund [EDF].

1.4: Rationale for Selected Comparisons

Risk assessment research suggests that individuals have a hard time evaluating the risks of unknown or new technologies (Henrion and Fischhoff, 1986 and Slovic, 1987). In addition, once that initial evaluation has been made, it becomes increasing harder to change (Nisbett and Ross, 1980). Familiarity with the subject, in this study's case the practices of the oil and gas industry, may affect how these initial evaluations are formed (Fischhoff et al, 1978). The history of oil and gas is included in order to establish this concept of familiarity among these states. Well densities are also included for this purpose; a high density of standard oil and gas wells may suggest more familiarity with industry practices. Further geographic comparisons are included for these same reasons.

Currently, there are no federal regulations that cover hydraulic fracturing. This has led to a debate on the effectiveness of allowing individual states to create and enforce their own regulations (Willie, 2011). This uncertainty as perceived by the general public might play a part in whether or not hydraulic fracturing is considered acceptable. For this reason,

attention has been given to the debate. The specific regulations of these three states are included in the hope that some difference amongst them may correlate with a state's level of acceptance.

Hollander (2003) suggests that poverty leads to decreased concern for the environment. This, coupled with a desire to escape that poverty, may create a situation where oil and gas development is welcomed in poorer or less affluent areas. For this reason, a socioeconomic comparison is included.

Slovic (1987) explains that the total effect of a single negative incident may be hard to determine. Each incident may be seen as a stone dropped into a still pond; it will have some immediate effect, but it is the ripples that may eventually become the more important effects. Slovic relates this idea to the Three Mile Island nuclear disaster; in and of themselves the effects of the disaster were relatively minor—but the lasting effect was that it created massive anti-nuclear sentiment (1987). By this same relation, individual hydraulic fracturing accidents may not be overwhelmingly disastrous or long lasting, but they may help to build up anti-fracking sentiment. This may be especially true in areas where there have been multiple accidents related to hydraulic fracturing. A tally and record of hydraulic fracturing-related environmental accidents is included for this reason. The sentiment created by hydraulic fracturing accidents may be exacerbated by an area's cumulative exposures to environmental accidents of any kind. These accidents may create a population more sensitive to potentially environmentally dangerous practices. The environmental scorecards for Louisiana, Pennsylvania, and Texas are presented as a proxy for these cumulative exposures.

1.5: Hypotheses

It is hypothesized that Louisiana, Pennsylvania, and Texas exhibit varying levels of acceptance of hydraulic fracturing. It is hypothesized that the state with the most exposure to the oil and gas industry will exhibit the highest level of acceptance. This exposure will be measured through the histories and oil and gas well densities of these three states.

It is hypothesized that the state with the highest number of accidents related to hydraulic fracturing will exhibit the lowest level of acceptance. This high number of hydraulic fracturing accidents likely occurs within the state with the worst overall environmental record, as indicated by NPL counts on the environmental scorecards.

Consistent with the principle that poverty leads to decreased regard for the environment, it is hypothesized that the state exhibiting the least affluence will also be the state with the highest level of acceptance.

Finally, it is hypothesized that Louisiana will be the state that exhibits the highest level of acceptance, making it unique among its peers.

1.6: Significance

The integral role hydraulic fracturing plays in the US oil and gas industry is still relatively new. Numerous opinions on the subject have been given in editorials and documentaries, but there does still remain some question surrounding how citizens view risks, and why different areas experience varying levels of public support. Survey data exists for select populations and areas, and this thesis will add to this growing bank of knowledge. The collected surveys focus on Louisiana alone, and will therefore be invaluable to Louisiana energy companies, policy makers, and stakeholders. Currently, collected quantitative data only serves to place collected survey data in context; future

studies may choose to use similar quantitative comparisons among states with active hydraulic fracturing.

Chapter Two: Hydraulic Fracturing Overview

In order to understand the implications of hydraulic fracturing, this chapter will offer a broad overview of hydrocarbons (or simply, oil and gas). This overview explains how hydrocarbons are classified by industry, where and how they are found within the earth, and ends with an explanation of the modern hydraulic fracturing technique.

2.1 The Nature of Hydrocarbons

The term "hydrocarbon" describes any number of compounds occurring in nature fully composed of hydrogen and carbon atoms (Hyne, 2001). This encompasses liquids like petroleum, gases like methane and propane, and solids like coal[1] (Hyne, 2001).

Wells may produce crude oil and gas simultaneously or exclusively, and the varying qualities of the hydrocarbons produced make certain reservoirs more desirable or profitable than others (Hyne, 2001). If a well produces neither, it is called a "dry hole". Produced crude oils range from "heavy" to "light" depending on their viscosities; low viscosity oil is cheapest to produce (Hyne, 2001). The American Petroleum Institute [API] instituted a standard in 1921 to quantify this classification of crude oils, called the API°, or API gravity (Rue et al, 1951, Hyne 2001, and Schlumberger 2012). This standard is still used worldwide. It was designed so that most crude oil API°s would range from 5° to 55° (Hyne 2001, and Schlumberger 2012). Water has an API° of 10; almost all oils will be less

[1] Classification of coal as a hydrocarbon is somewhat debated, as it is more accurately described as hydrocarbon-*rich* (McLeod, 2005). Hydraulic fracturing first made headlines in 1997, when it was being used to free up methane produced from underground coal (11th Circuit, 1997). For clarification, the target of the modern shale gas revolution is not coal, but organic-rich shale.

dense and thus will float on water (Hyne, 2001). These concepts of oil classification are further illustrated in Figure 3.

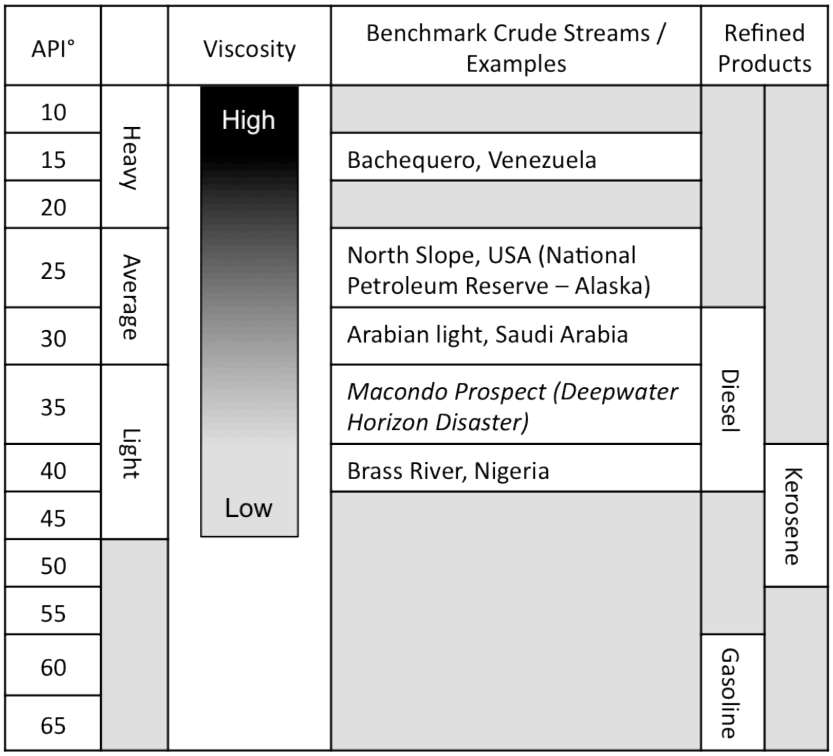

Figure 3. Example of API° Classification (after Hyne, 2001 and Oldenburg et al, 2011)

Both gases and crude oils also will range from "sweet" to "sour" depending on the presence of chemical impurities like hydrogen sulfide (Hyne, 2001). High sulfur content increases the overall cost of production and refinement (Hyne 2001). These concepts are illustrated in Figure 4.

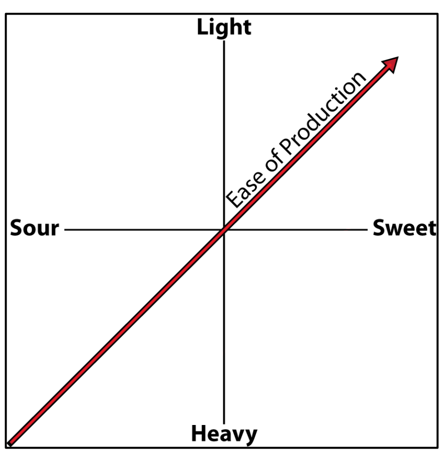

Figure 4. Concepts of Viscosity and Sulfur Content Related to Production Cost (after Hyne, 2001).

2.2: Reservoirs and Reservoir Quality

Historically, there have been three required geological conditions in order to have a commercially viable quantity of oil and/or gas. First, there must be subsurface stratum that has generated oil and/or gas in the past; this is the source rock. Second, there must be subsurface stratum somewhere above the source rock capable of holding the generated oil and/or gas; this is the reservoir rock. Third, there must be some sort of trap or seal to keep the generated oil and/or gas in place. Absence of any of these conditions usually means there can be no recoverable oil or gas (Hyne, 2001). However, hydraulic fracturing technology creates the potential to open up new fields where only a source rock is present, or where the reservoir rock is poor. Fracking may also open up abandoned fields where the reservoir rock has been depleted, but the source rock still contains trapped oil or gas.

2.2.1: Source Rock

An ideal source rock is relatively rich in kerogen, an oil-producing organic, and is commonly shale (Hyne, 2001). A modern depositional environment for this particular type of rock is the anoxic bottom of the Black Sea, as shown in Figure 5 (Alexander et al, 2011). Typical shales are between 1-3% organic by weight, but can be up to 20% (Hyne, 2001).

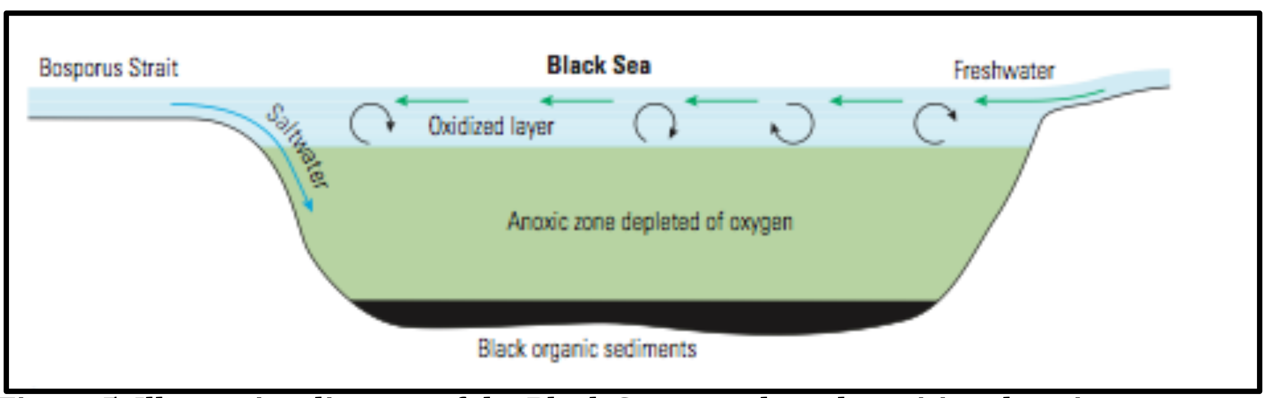

Figure 5. Illustrative diagram of the Black Sea, a modern depositional environment for shale (from Alexander et al, 2011).

After burial and under the right conditions of time and temperature, the source rock will produce hydrocarbons. Only around 30-70% of the organics in place will be converted. The type of organics in the source rock and the conditions of genesis will determine the quality of the hydrocarbon produced. Imagine baking a cake for two hours at 300° versus one hour at 600°; the same material can become two different products based entirely on diagenesis. Created hydrocarbons act counter to the overburden stresses on the buried source rock, and fracture it as they rise into a reservoir rock. These fractures close behind the exiting hydrocarbons (Hyne, 2001). Hydrocarbons will continue to rise as long as they are less dense than the rock or water around them (Hyne, 2001).

2.2.2: Reservoir Rock

An ideal hydrocarbon reservoir is sedimentary and has both high porosity and permeability. This combination of traits allows hydrocarbons to develop and accumulate, and provides pathways for them to flow through. Common reservoir rocks are sandstone and limestone (Hyne, 2001).

2.2.3: Trapping Mechanisms

Hydrocarbons will continue to migrate upward through a reservoir rock until they either escape at the surface (a seep), or hit an impermeable trapping mechanism. Only 0.36% to 36% of all generated oil is ever trapped (Hyne, 2001). Common traps are anticlines or domes, like the salt domes of Coastal Louisiana. Figure 6 is a schematic of how a source rock, reservoir rock, and trapping mechanism work together.

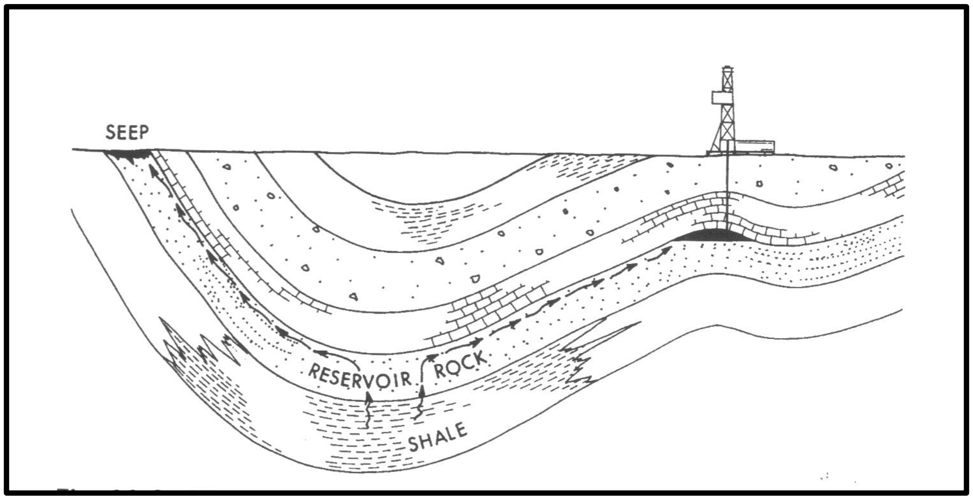

Figure 6. Source Rock, Reservoir Rock, and Trap Interactions. Oil and gas produced in the shale escape upwards. The left path illustrates a condition where there is no trap, and oil escapes at the surface (such as at La Brea Tar Pits). The right path shows how an anticline may serve as a trapping mechanism (from Hyne, 2001).

2.3: Oil and Gas Exploration and Production

Once a reservoir and trap have been found and proven cost-effective, the next step is place and drill wells (Hyne, 2001). Initially well spacing was very close, because engineers didn't fully understand the mechanics of reservoirs. Over time, well spacing increased and placements became more intelligent; more or less oil and gas can be recovered by a single well depending where on it is drilled. Figure 7 demonstrates this principle using a common anticline trap.

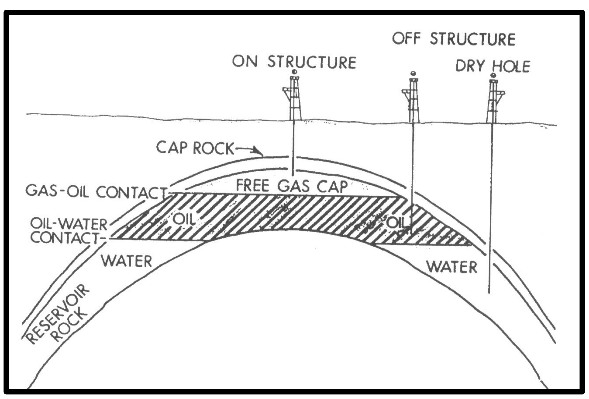

Figure 7. Intelligent Well Placement. Demonstrates how accurate knowledge of a trap location can lead to more recovery by a single well (from Hyne, 2001).

2.3.1: Improving Well Recovery

A well that is performing poorly may have its productivity greatly increased through the use of intelligently placed injection wells. Figure 8 is similar to Figure [7], but the producing well's rate of recovery has been augmented with two injection wells. There is much room for improvement on this frontier, as recovery of 50% of the oil in place [OIP] is considered good by current techniques (Hyne, 2001).

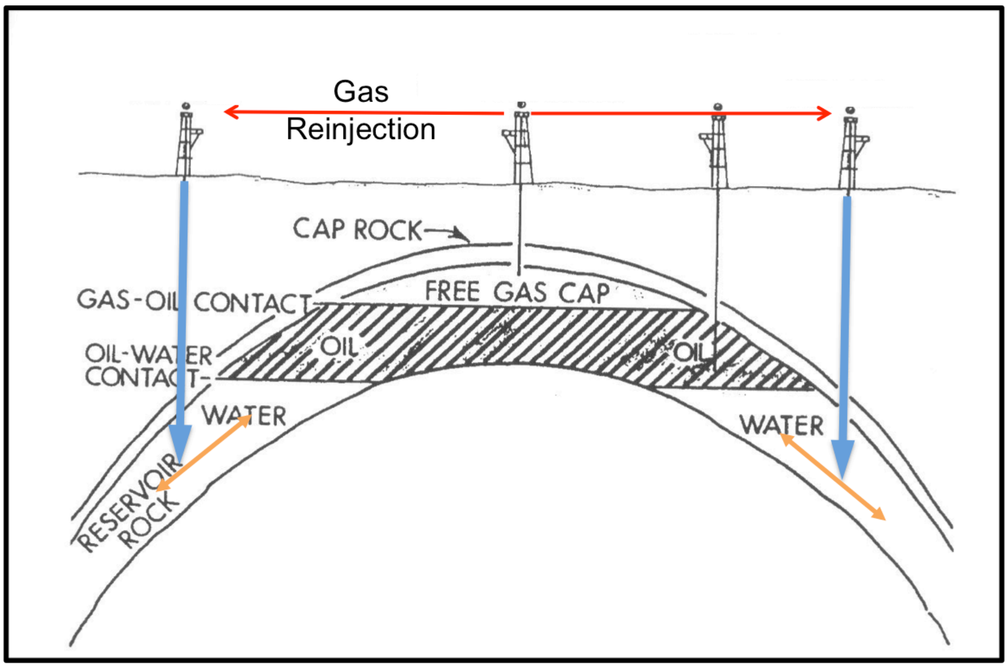

Figure 8. Use of Injection Wells to Increase Recovery. Using these wells to inject water into the reservoir formation will push the oil and gas in place towards the producing well. Utilizing proper placement and spacing of injection and production wells throughout a traditional reservoir can greatly increase not only the maximum efficient rate of recovery, but also the total amount of recovery (Adapted from Hyne, 2001).

Improving the porosity and permeability of a reservoir will also improve recovery of hydrocarbons. Regardless of the amount of oil or gas in place, the absence of appropriate porosity and permeability can make an entire field or play unproduceable, as was the case with shale reservoirs such as the Haynesville and Marcellus (Hyne, 2001). Early

experiments to increase well performance were as basic (and dangerous) as detonating dynamite within the wellbore at depth (Dixon, 2010 and Montgomery and Smith, 2006). Modern technologies use chemicals to dissolve away reservoir cements. This is especially effective on limestone, a common reservoir rock notorious for being rainwater soluble (Hyne, 2001). However, dynamite and chemicals could not do anything to open up the so-called "tight" shale gas reservoirs. This is where hydraulic fracturing comes into the equation.

2.4: Hydraulic Fracturing Comes of Age

Engineers were desperate for methods to increase permeability within tight reservoirs. According to Montgomery and Smith, drillers began experimenting with fracturing reservoirs in the 1860s using dynamite (2006). The explosives could release trapped fluids and gases that could then travel back along the introduced fractures to the well bore. Stanolind Oil (now Amoco) first demonstrated an effective technique instead using pressurized fluids at depth in 1947 (Montgomery and Smith, 2006). In 1949, Halliburton conducted the first commercial application of that method on two wells in Texas and Oklahoma (Montgomery and Smith, 2006). The generalized method uses a combination of water, formulated chemicals, and proppant (Louisiana Oil and Gas Association [LOGA], 2012). The mixture is pressurized at depth within the wellbore, eventually overcoming the strength and stresses of the target formation, in turn generating fractures. The mixture is then pumped back out of the wellbore, leaving proppant behind to hold open the generated fractures (LOGA, 2012). This method can be used to increase permeability in most wells; it is now estimated that 90% of all wells in the United States have undergone some form of hydraulic fracturing (Independent Petroleum Association of

America, 2008). However, it is not hydraulic fracturing alone that unlocked the resource potentials of shale plays; horizontal drilling techniques also had to be perfected.

Modern wells are drilled using a rotary rig, a drilling rig that saw its first use in 1895 (Hyne, 2001). The rotary drilling rig was a large improvement over the technique that it replaced, but it was originally somewhat hard to control directionally. When drilling downwards through very hard rocks, rotary bits would easily become deflected and drill crookedly in the direction the hard rock dips. Engineers eventually learned how to control these rigs, and today they can even accurately steer (geosteer) the drill directly to a subsurface target. Geosteering has also allowed for horizontal wells to be drilled, greatly increasing the contact a well may have with the pay zone (the portion of the reservoir in a well that produces oil and gas). Traditional vertical wells aiming for a three foot thick section of shale zone will get exactly that—three feet of exposure, but a vertical well that can then be steered horizontally through that three foot thick shale layer can have as many feet of exposure as desired; Figures 9 and 10 show these principles.

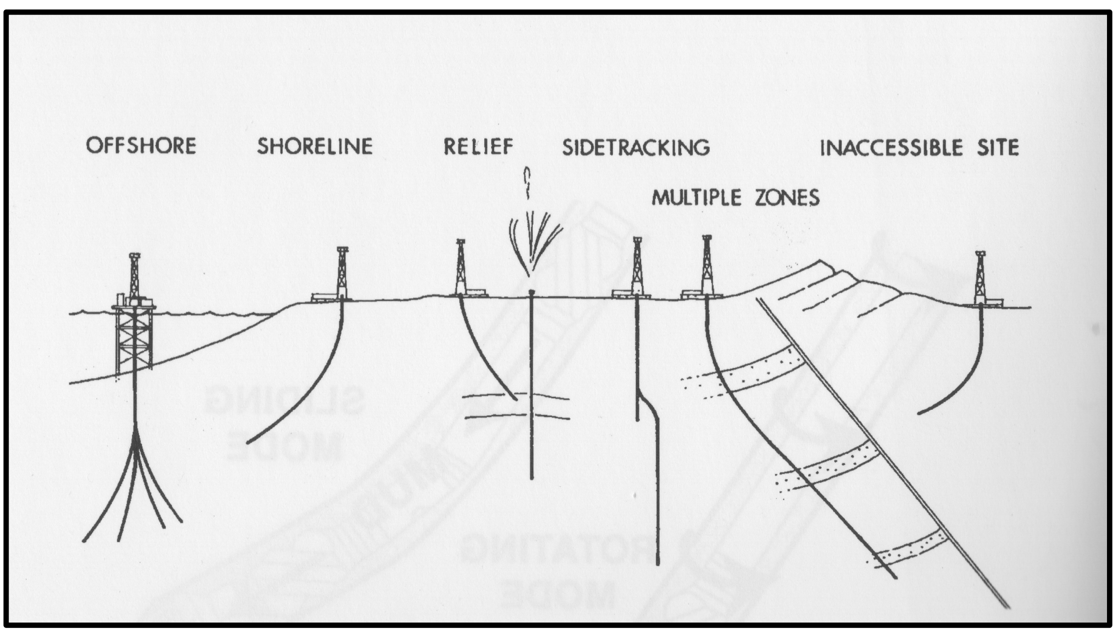

Figure 9. Geosteering to Accurate Subsurface Locations (from Hyne, 2001).

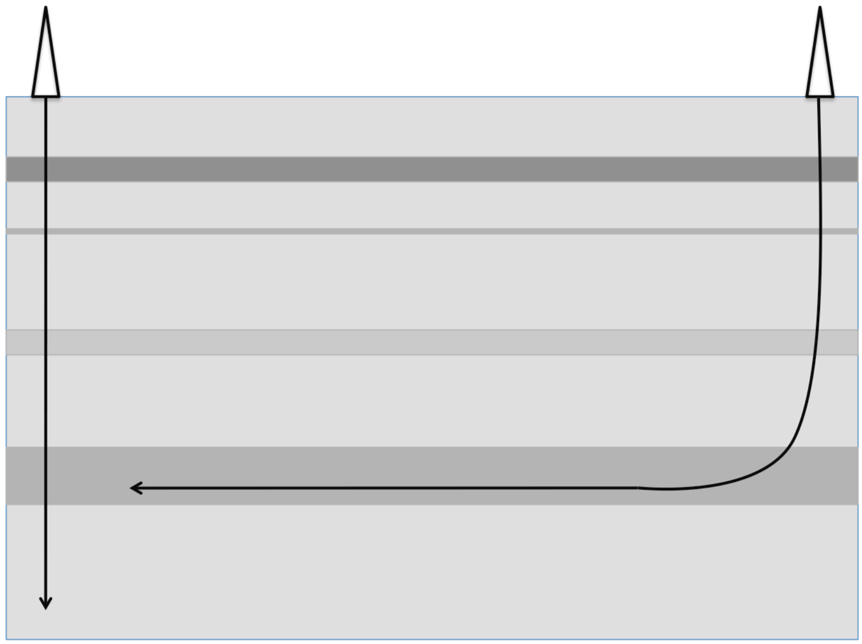

Figure 10. Using Horizontal Drilling to Increase Exposure to Targeted Shales. The traditional vertical well on the left receives minimal exposure to the relatively thin layer, whereas directional drilling allows the well on the right to stay receive maximum desired exposure.

Geosteering and Hydraulic Fracturing technologies were developed independently, and it took some experimenting and risk-taking to realize their combined potential. Mitchell Energy & Development Corporation took that risk, and became the seed of a modern shale gas revolution (Boyer et al, 2011). They started experimenting in 1981 in the Texas Barnett Shale, a shale believed to contain as much as 327 trillion cubic feet [TCF] of natural gas, but that was considered unproduceable because of its low permeability (Boyer et al, 2011). Their proven success took more than 20 years, and paved the way for others to follow and develop shale plays. Figure 11 shows how modern Hydraulic Fracturing is done at depths of up to 10,000 feet in the Haynesville Shale (LOGA, 2012).

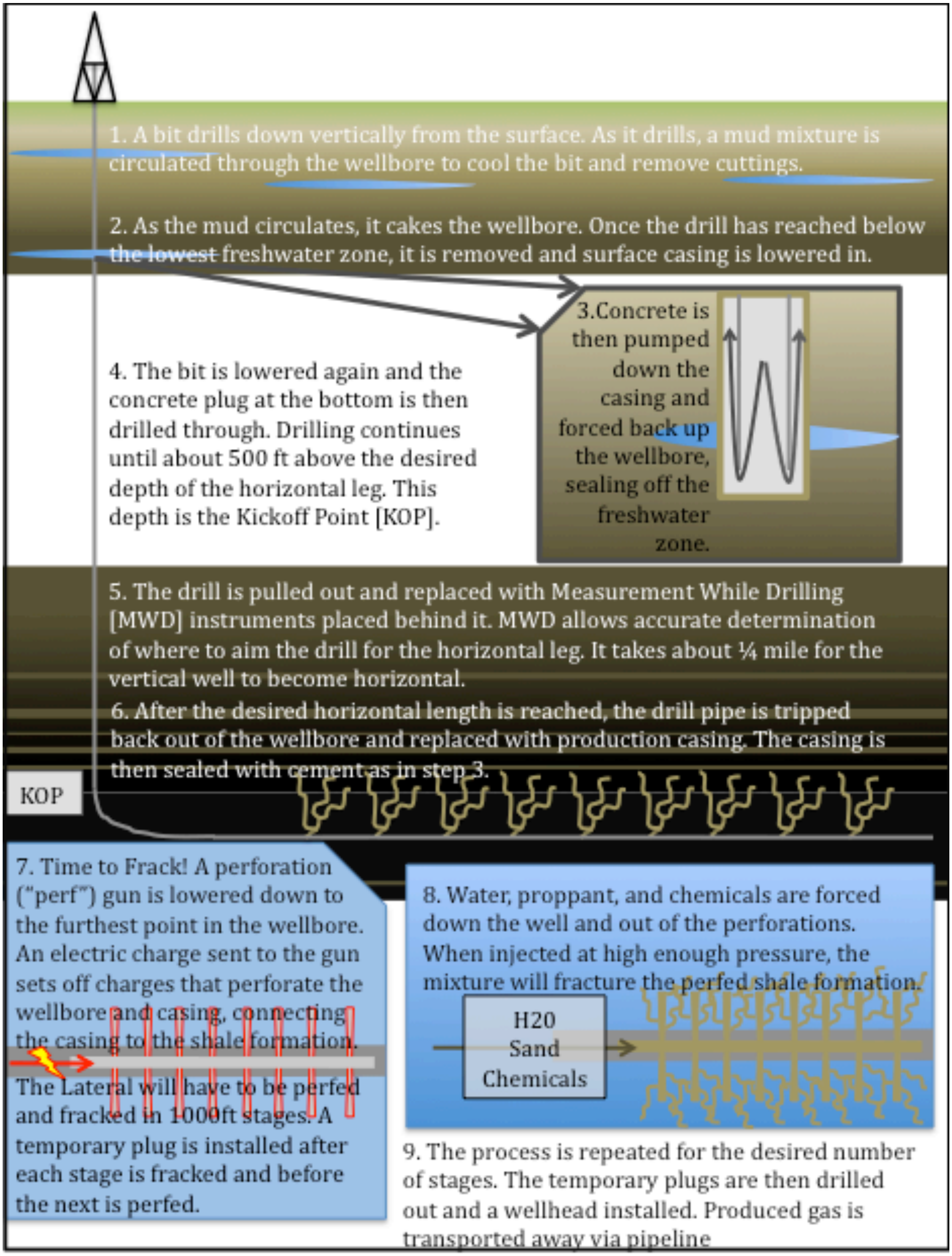

Figure 11. Illustration of Fracking Technology. It takes approximately 350 pieces of 30ft, 495lb drill pipe to complete a well in the Hayneville Shale.

2.4.1 Causes for Concern and Points of Failure

According to Vaughan and Pursell (2010), there are six points of contention Americans have with Hydraulic Fracturing: potential groundwater contamination, chemical handling, waste disposal, air quality, water use, and the "hassle" factor. There have also been complaints of fracking-induced earthquakes (Brown, 2010).

Concerns over groundwater contamination grow from the use of formulated chemicals and acids injected under pressure into the shale formations. There is fear of the possibility for induced fractures to connect wellbores and reservoirs with potential sources of drinking water, thus contaminating them. Another potential method of groundwater contamination is one common to all drilled wells: casing failure. As wells are drilled, a protective steel-walled casing is put in place around the wellbore. At various depths, drilling may be stopped and concrete placed around the current length of casing. Afterwards, another length (or "string") of casing is placed in the well bore and drilling continues (Hyne, 2001). There is always some inherent risk that if the casing should fail, the surrounding rock may be contaminated.

Chemical handling and waste disposal are serious concerns for residents in developing plays. In Louisiana, Pennsylvania, and Texas alone there have been at least 21 accidents over the past seven years involving chemical or waste spills either en route or on site of Hydraulic Fracturing operations (Vaughan and Pursell, 2010, Earthjustice, 2012). While significant, it is important to note that these risks are not unique to hydraulic fracturing, but apply to the industry as a whole.

Air quality and the hassle factor are also both concerns for communities that house development. Well operations create noise, as does the associated dramatic increase in

truck traffic. This increased traffic is also detrimental to air quality and damaging to road surfaces and infrastructure (Vaughan and Pursell, 2010). All natural gas wells and operations are know to release at least some volatile organic compounds [VOCs], which becomes a larger issue with more and more drilled wells (Brown, 2007).

The amount of water used in fracturing operations is also a major concern, especially since it is usually sourced from drinking water supplies. An average well in the Louisiana Haynesville Shale requires 21,500 m^3 of water to be fully fractured (Nicot and Scanlon, 2012). Proponents will argue that the water use is actually minimal when put in terms of gallons/MMBTU (millions of BTUs) generated, but many find the large one-time use of that much water is still concerning (Chesapeake, 2012).

Accidents occurring in Louisiana, Pennsylvania, and Texas have been summarized in Appendix B. This is not an exhaustive list, but includes the aggregated concerns of Vaughan and Pursell (2010) and the Sierra Club's Earthjustice program (Earthjustice, 2012).

Chapter Three: History of the Industry

Current demand for natural gas is on the rise as hydraulic fracturing opens up new fields and the dream of energy independence becomes a possibility. The history of oil and gas development is presented from the beginning here, including Louisiana, Pennsylvania, And Texas' unique and oil-rich histories. Louisiana will receive special coverage at the end, as it remains at the center of America's oil and gas industry.

3.1: Pre-1800 History

Although it has certainly influenced these past two centuries the most, man's relationship with crude oil extends much further than the last 200 years. References to tar can be found as far back as the Bible's tale of Noah's Flood:

> And God said unto Noah ... Make thee an ark of gopher wood; rooms shalt thou make in the ark, and shalt pitch it within and without with pitch. (King James Version, 1987)

Accepted as non-fiction or not, this description of using pitch (or tar) to seal a boat dates to a flooding event generally agreed to have happened 7,500 to 8,000 years ago (Kingsley, 2008).

According to Book I of Herodotus' *The Histories*, the River Is in present-day Iraq brought asphalt to its surface, which was used in the construction of the ancient city of Babylon approximately 6,000 years ago (Herodotus, 1988 and Totten, 2004). The Greeks were using asphalt to waterproof pots, baths, and boats, and created the term petroleum to describe it. The word is a portmanteau of the Greek "petros" for stone, and Latin "oleum" for oil; it was common for these ancient civilizations to simply label it "rock oil" (Totten, 2004).

The Chinese were the first to dig wells of any kind, about 2,200 years ago (Kuhn, 2008). These wells were dug by hand to find brine with which to make salt. After another 200 years, they stopped digging and started drilling. They used bamboo for pipe and bits and a primitive form of pile driving (Kuhn, 2008). By 347 AD, they had developed iron bits and had drilled the world's first oil well at just less than 800 feet (Kuhn, 2008 and Totten, 2004). It is unclear exactly when, but the Chinese soon realized that they could use this new rock oil as fuel for their brine production (Kuhn, 2008).

Oil was being collected from seeps in Baku, Azerbaijan at least 1200 years ago, according to the writings of Al Belazuri Ahmad (Mir-Babayev, 2002). By the time Marco Polo visited the region, enough oil was being collected that it was being exported to other countries. By 1594, wells were being dug in the area to depths of at least 100 feet (Mir-Babayev, 2002).

Native Americans were known to have used oil from springs and seeps for centuries as medicine and ointment, and it became known as "Seneca Oil" when they first offered it to settlers in the Northeast (Giddens, 1948). The first record of non-native use is from 1543, when what was left of the Spanish de Soto Expedition to North America sought relief from storms along the Louisiana-Texas Border in Sabine Lake (Rister, 1949). They found tar floating on the surface of the water there, and coated the bottoms of their ships with it. As of 1949, oil springs could still be found in the area (Rister, 1949).

3.2: 1800-1901: Genesis of the Industry

3.2.1: World Stage and Technological Developments

By 1835, the Chinese had perfected their drilling techniques enough to reach over 3,200 feet in depth (Kuhn, 2008). Around this time in 1837, the Baku field in Azerbaijan had its first distillery in operation (Mir-Babayev, 2002). There they had realized that they could separate crude oil into different components by weight. In 1846, the world's first modern oil well was drilled by cable tool by the Russian engineer F.N. Semyenov, near Baku (Mir-Babayev, 2002 and Totten, 2004).

Coal had emerged at this time as a major energy source, and in 1849 the Canadian Geologist Abraham Gesner developed a method to distill kerosene from coal (Totten, 2004 and Tait, 1946). Kerosene was cheap to produce and didn't spoil or smell like the whale oils it competed with. Because of his method, Gesner is known as the father of the petroleum industry (Totten, 2004). Expansion on Gesner's work led to a method to produce of kerosene from petroleum by Ignacy Łukasiewicz in Poland in 1853 (Totten, 2004). These new methods of distillation helped to modernize the industry, and led to the first modern refinery near Baku in 1858 (Mir-Babayev, 2002). By 1866, Baku needed above ground reservoirs to store its production, leading to environmental contamination that still persists (Mir-Babayev, 2002, and Ministry of Ecology and Natural Resources of Azerbaijan Republic, 2012). By 1900, Azerbaijan was producing more than half of the world's oil (Mir-Babayev). It was quickly overshadowed by a burgeoning oil industry in the United States.

3.2.2: North America Catches Up

In 1818, a man named Martin Beatty drilled a well in McCreary County, Kentucky in search of brine. Instead of joining the salt industry, however, Beatty's well began producing oil (Jillson, 1952). Other brine wells in Pennsylvania were beginning to do the same thing, and within 40 years the North American oil industry had begun (Totten, 2004). In 1858, oil was found in Canada by James Williams, who successfully drilled a well between Lake Erie and Lake Huron producing between 5 and 100 barrels of oil per day (Habashi, 2000). The Williams well was soon followed by a shallow 69.5 foot oil well in Titusville, Pennsylvania, that produced around 10 to 20 barrels per day (Rister, 1949). The Titusville well was drilled by a man who had given himself the title of "Colonel" to instill confidence in his investors, and most texts to this day will reference Colonel Drake and his well as the beginning of North America's oil industry (Rister, 1949, Ver Wiebe, 1930, Saltzman, 1999, Hyne, 2001). In 1865, a 6-inch diameter pipeline was built to deliver oil to Oleopolis and Pithole Creek (Totten, 2004). Fifty-six refineries using Gesner's distillation process were in operation by this time in North America (Tait, 1946).

> It is something to know that a cargo of petroleum may navigate a river, cross a lake or ocean, in a vessel propelled by steam it has generated, acting upon an engine it lubricates, and directed by an engineer who may grease his hair, anoint his body, perfume his clothing, enrich his food, rub his bruises, freshen his liver, and waterproof his boots with the same article. (Cone and Johns, 1870).

By 1895, Pennsylvania and New York were producing more than 19 million barrels of oil per year (McElwee, 2001). Records from this time period are spotty and often conflicting; they may underestimate true production (Mir-Babayev, 2002 and McElwee, 2001). Regardless of Mir-Babayev's claim that Azerbaijan was producing more than half of

the world's oil in 1900, McElwee shows through more convincing methods that the United States carried a collective lead over the rest of the world (2002 and 2001).

3.3: 1950-1973: The Booming Industry and Birth of OPEC

The worldwide petroleum industry of the 1900s exploded with exponential growth. Between 1950 and 1970, worldwide oil demand quintupled to reach a demand of 57 million barrels per day in 1970 (Parra, 2004). In 1950, America was the only place that the oil industry was truly developed and modernized. Between 1950 and 1973, the outside industry grew at a sustained pace of 10%+ per year for 23 years straight. The worldwide automobile industry was flourishing as well, with over 2.5 billion new vehicles put on the roads and over half of them in the United States (Parra, 2004).

The face of the industry was changing over this time, as well. Three fields in Iran discovered by 1938 had in them more than the total combined reserves of the United States (Parra, 2004). Enormous pipelines were built throughout the Middle East, where location didn't matter because the oil was so cheap to produce. Operating costs per barrel in 1960 Kuwait were less than $0.05 at a time when oil was selling for $1.50. Foreign influence was strong in these areas at the time, since the fall of the Ottoman Empire and the Iraq concessions following the end of World War I. The oil in these countries was under the control of no more than 10 companies (Parra, 2004).

Between the years of 1953 and 1957, estimated reserves in the Middle East grew by more 23 billion barrels per year; in each of these years more recoverable oil was proven than in the entire reserves of the United States. Most of these Middle Eastern countries had their oil industries dominated by French, American, and British interests and companies. Primary revenue for the exporting countries came from the taxes they imposed. As demand

increased, the formative members of the Organization of the Petroleum Exporting Countries [OPEC] sought new incentives to increase their supply—mostly through increased tax rates on exports.

OPEC was established in 1960 to protect the exporting governments' interests, but did not test its strength until late 1973. Venezuela and Iran were the original pair, and quickly convinced Iraq, Kuwait, and Saudi Arabia to join them. By the time OPEC flexed its muscles in 1973, Algeria, Libya, Nigeria, Qatar, and the United Arab Emirates had also joined (Parra, 2004).

3.4: Crises of 1973 and 1979: OPEC Changes The Market

The United States supported Israel in the Yom Kippur War, to the chagrin of several OPEC members. This, coupled with failed pricing negotiations with the operating major companies, led OPEC to unilaterally raise their posted prices by 70% and embargo exports to the US starting in October of 1973. Temporary panic set in, and President Nixon addressed the nation on November 7. He proposed mandatory fuel consumption cuts, fast tracking of nuclear energy projects, and the expansion of developing domestic fuel resources. This action by OPEC is the seed of a desire for US energy independence (Yergin, 1991).

In hindsight, the actual embargo was relatively short-lived. Instead of gaining complete control of the market as intended, OPEC had simply made some significant enemies in the major companies that it shunned; the 1973 embargo has been labeled a blunt weapon for this reason (Parra, 2004). By selectively embargoing a few countries, OPEC simply caused a shift in the marketplace of who was buying OPEC or non-OPEC oil. The decrease in supply actually hurt everyone in the market equally, a costly nuisance.

OPEC struggled from 1974 to 1978 with its new role as a price-controlling pseudo-cartel. The major companies that it had previously shunned were still their customers, only now much more weary. Parra cites a passage from Exxon's 1975 Annual Report that gives an accurate reading on the industry (2004):

> Since most industrialized nations will be dependent on the members of the Organization of Petroleum Exporting Countries (OPEC) for much of their oil in the years ahead, it is essential that Exxon find ways of working constructively with both producing and consuming countries even as we attempt to find new sources of oil and develop other forms of energy which will eventually lessen that dependence (Exxon, 1975, p.2).

Over this same time period, a spot market for oil was developed. The market grew rapidly, and offered some unprecedented transparency. In 1979, a new problem faced the market in the form of the Iranian Revolution. Oil exports stopped from Iran, and prices shot upwards in response. Spot price per barrel in 1978 was $12.80, 1979 almost $40, and in 1980 it was over $40. The subsequent adjustment by consumers and reduced demand meant that when Iran did begin exporting again, the market became saturated. Prices fell from 1981 onwards and throughout the 1990s (Parra, 2004).

3.5: Oil Demand Through 2012 and Growth of the Natural Gas Industry

3.5.1: The Gulf War and The War on Terror

In August of 1990, Iraq invaded neighboring Kuwait. Overnight, they gained control of an extra 10% of the world's total proven oil reserves, and were within striking distance of another extra 25% in Saudi Arabia. Through the UN, international sanctions and trade embargoes placed pressure on Iraq to abandon Kuwait, but nothing worked. Finally, in January of 1991, it was decided that force would be used. Ground forces eradicated Iraq

from Kuwait within five days. In their wake, the Iraqis set fire to over 600 oil wells, causing a loss of about 6,000,000 barrels of oil per day (Parra, 2004).

After the war, the US wanted an Iraq powerful enough to keep Iran in check, but not powerful enough to gain control over Kuwait and Saudi Arabia. Oil prices throughout this time were prone to sharp increases and decreases, but remained similar pre- and post-conflict (Parra, 2004).

Demand steadily increased in the 1990s, and about 55% of it was being met with foreign oil in 2000 (Parra, 2004). In 2011 this was down to 45% (EIA, 2012). After the 9/11-inspired invasion of Afghanistan in late 2001, the US invaded an unproductive Iraq in early 2003, ostensibly in the search for weapons of mass destruction (Parra, 2004). The country was suffering under various economic sanctions that had crippled its oil industry. A swift invasion and the lack of oil well fires as in 1991 Kuwait meant that crude prices only felt a minor bump. Post-conflict per barrel price in April of 2003 was $24.20. The US then found themselves in a country with oil reserves and potential rivaling Saudi Arabia, but with an infrastructure in shambles. According to some observers, tacit mission ever since has been to re-stabilize Iraq's oil industry in order to keep a balance in OPEC (Parra, 2004).

3.5.2: Rise of the US Natural Gas Industry

The US natural gas industry saw growth starting in 1993 after full governmental deregulation (Summers, 2011). By contrast, President Jimmy Carter had started deregulation of the oil industry earlier during the 1979 crisis following the Iranian Revolution (Parra, 2004). Initial growth came from the electricity industry, where 34% of 2009 demand was met by natural gas (Summers, 2011). Deregulation of the industry

created new markets for natural gas at pipeline intersections or hubs (MacAvoy, 2000). The most significant of these hubs is The Henry Hub [HH], located near Erath, Louisiana (Budzik, 2002). About 49% of U.S. natural gas production travels through or very near the HH as it moves to consumers. The New York Mercantile Exchange [NYMEX] natural gas market is based on HH spot and future prices (Budzik, 2002).

3.5.3: Demand for Oil and Gas Post-2003

The cost of oil rose through 2008, where it peaked at over $130 per barrel (Illinois Oil & Gas Association [IOGA], 2012). Demand fell sharply towards the end of that year, reining the price back down to $32 (IOGA, 2012). The market stabilized over the next year, and prices have been slowly rising since (IOGA, 2012). The cause of 2008's peak is debated, but is commonly attributed to the decreasing strength of the US Dollar (Domitrovik, 2012). Regardless of the cause, the 2008 peak highlighted America's inability to match the supply of oil with demand.

The US natural gas market is a bit different. Ninety percent of natural gas used in the US in 2010 came from domestic sources, more than 25% of which came from hydraulically fractured developed shale formations (EIA, 2012). These shale resources represent a potential answer to the hunt for secured sources of energy that oil cannot provide.

Yearly domestic demand for natural gas is around 24.1 trillion cubic feet [Tcf] (EIA, 2012). At that current rate of consumption, proven US natural gas reserves opened up by hydraulic fracturing offer enough gas for over 90 years (EIA, 2012). Table One below shows consumption end-uses for March 2012.

Table 1. Domestic Fuel Consumption for March 2012 in Millions of Cubic Feet

Use	March 2012
Total Consumption	2,108,817
Industry Use (Refinement and Production)	121,066
Pipeline Use	59,325
Total Delivered to Customers	1,928,426
Residential	409,010
Commercial	263,946
Industrial	572,632
Vehicle Fuel	2,790
Electric Power	680,047

3.5.4 Hydraulic Fracturing Changes the Market

Table Two below shows the increase in natural gas resources following what has become known as the "Shale Gas Revolution" (EIA, 2012). The estimates for available natural gas are constantly increasing as hydraulic fracturing develops and proves new reserves are accessible (EIA, 2012). Meanwhile, Louisiana and Texas have taken the stage, with the Haynesville Shale occupying the majority of drilling rigs throughout 2011 (Figure 12) (Newell, 2011).

Table 2. Estimated Resources in Trillions of Cubic Feet

	1997 (Rogner)	2011 Kuuskraa et al (EIA)	% Increase
North America	3,842	7,140	86%
South America	2,117	4,569	116%
Europe	549	2,587	371%

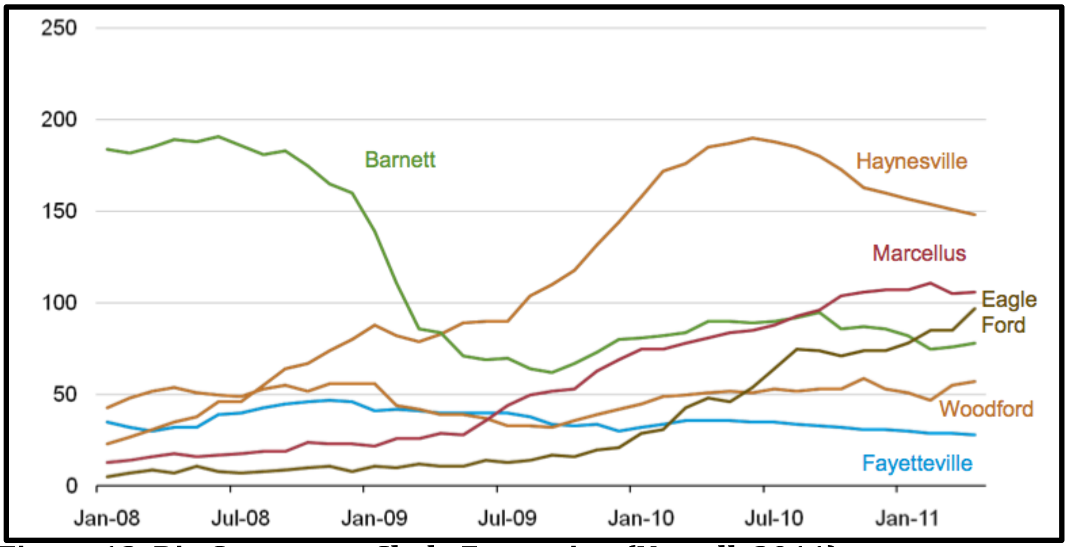

Figure 12. Rig Counts per Shale Formation (Newell, 2011).

3.6: Louisiana's Unique Place in History

Reference has already been made to the de Soto Expedition that sought shelter along the Louisiana-Texas border and found tar floating on Sabine Lake. The next historical reference to oil or gas in Louisiana comes in a book by Major Amos Stoddard, a Revolutionary War hero who was the first commandant of Upper Louisiana after the Lousiana Purchase (French and Lam, 1986). Stoddard writes of an island to the west of the Atchafalaya River that burned for at least three straight months (from French and Lam, 1986). In 1839, the American Journal of Science listed and described several oil springs occurring along the Calcasieu and Sabine Rivers (French and Lam, 1986). Interest was lacking however, as refining was still undeveloped at this time. When the Civil War started in 1861, the Governor of Louisiana requested a report on Louisiana's minerals, especially the oil springs along the Calcasieu. The full report wasn't finished by the end of the war, but the Governor was assured early on that there was enough oil in the Calcasieu area to support most of the Confederacy. The study was completed years later, and with the same results: there was plenty of oil around Calcasieu (French and Lam 1986).

Louisiana's first oil company, The Louisiana Petroleum and Coal Oil Company, was formed in 1866. The company drilled several wells in the Calcasieu area, but none produced commercial quantities. Outside money for further shows of oil and gas were sparse to nonexistent for the next 40 years, as investors from the oil industry to the north were hesitant to invest in a formerly rebel state (French and Lam, 1986). Attitudes began to change by around 1896, when Anthony Lucas began drilling in Louisiana's coastal salt domes looking for oil and gas (Lindstedt et. al. 1991, French and Lam, 1986, and Robinson, 1951). Lucas couldn't find what he was looking for in Louisiana, but hit oil big in 1901 after moving to Texas; he discovered oil in the swamps at "Spindletop" (Lindstedt et. al. 1991 and Robinson, 1951).

The 1901 discovery marked the beginning of a Texas Oil Boom (Wooster and Sanders, 2012). After several failed drilling attempts, oil was struck there at 1,139 feet deep in a salt dome. This was the world's first gusher, and the geyser spouted an estimated 900,000 barrels of oil before it was finally capped. Nearby Beaumont, Texas saw an economic boom that spread to the rest of the state; over $235 million was invested in the Texas oil industry in 1901 alone (Wooster and Sanders, 2012).

Despite Lucas' success, economic oil wasn't found under a salt dome in Louisiana until 1926 (Lindstedt et. al. 1991). Instead, interest peaked after the discovery of oil in Jennings, Louisiana, also in 1901. The Jennings well was Louisiana's own Spindletop, and together the two finds put Louisiana on the radar for serious oil and gas development (French and Lam, 1986 and Forbes, 1946). The well produced peak oil output at 9 million barrels per year in 1906 (French and Lam, 1986). Despite Jennings' location in southern Louisiana, the first new major developments were completed in the northern part of the

state; drillers preferred more solid ground to the south's marshy terrain (Lindstedt et. al. 1991). The huge oil and gas fields Caddo and Monroe were discovered in 1906 and 1916. These fields were profitable, and the natural gas produced was at first considered an unwanted by-product of producing oil; as many as 27 billion cubic feet of natural gas was wasted at the Caddo field over a period of five years (Lindstedt et. al. 1991).

In 1910, the world's first over-water well was completed in Caddo Lake near Shreveport, LA (French and Lam, 1986). This would be the beginning of over-water innovation for the state (French and Lam, 1986). It would also mark the beginning of the industry's intense development of Louisiana's marshes and swamps (Lindstedt et. al. 1991). Board roads were built and channels were dug to gain access to well sites. This was done with no regard to the natural environment (Lindstedt et. al., 1991) Louisiana was facing problems elsewhere as well; a refinery was built in Jennings in 1903, and shipping and refinement couldn't keep up with production. As in Azerbaijan, open pits were dug to hold excess produced oil. Ducks would mistake the oil for water at night, and caused problems when their carcasses clogged up intake pipes (Lindstedt et. al., 1991).

The Gulf of Mexico's first offshore well was completed in 1937, just over a mile from the Cameron Parish coast (French and Lam, 1986). Shortage of manpower and resources created a lull throughout World War II, but the economic climate had improved by 1947, when the first offshore platform with steel pilings was built (Lindstedt et. al., 1991). In 1947, a well 44 miles south of Morgan City, Louisiana was the first over-water well to be completed out of sight from land. One year later, almost 100 structures containing oil and gas were located within 31 miles of the Louisiana coast (French and Lam, 1986). A post-war America had just found plenty of oil. The developments off of the Louisiana and Texas

coasts prompted the 1953 Outer Continental Shelf Lands Act, giving the federal government control of the Gulf of Mexico Outer Continental Shelf [OCS]. Texas and Louisiana sued for jurisdiction, winning through the Submerged Lands Act, which gives coastal states control over the first three miles out to sea (French and Lam, 1986). By 1985, 93% of total Gulf OCS oil and 92% of total Gulf OCS natural gas had been produced on Louisiana's acreage of the OCS (French and Lam, 1986).

Louisiana is also home to the nation's only offshore oil port, the Louisiana Offshore Oil Port, or LOOP (Sprehe, 2003). US productions and imports were at an all-time high in 1972, and the major companies wanted a safe way to unload ultra and very large crude oil carriers [ULCC and VLCC]. LOOP was their answer, located 18 miles south of Grand Isle, in 110 feet of water. It was operational by 1981, and connects large oil tankers to about 50% of the nation's refining capacity via pipeline at a rate of up to 100,000 barrels per hour. LOOP also has access to 48,000,000 barrels of underground storage capacity near its onshore component, and another 25,000,000 barrels of capacity after it connects to a major hub in St. James, Louisiana. The two points (LOOP and St. James) may become references for spot and futures exchanges in the oil market in the near future, joining Louisiana's HH natural gas NYMEX reference (Argus, 2012). It is clear that Louisiana stands at the foundation of the US oil and gas industry, and will remain an integral part in the years to come.

Chapter Four: Regulatory Constructs

Currently there are no federal laws or regulations that explicitly cover hydraulic fracturing. In fact, as a result of the Energy Policy Act of 2005, experts interpret hydraulic fracturing as exempt from federal regulation (Willie, 2011 and Wiseman, 2009). The Act is what opponents like to call the “Halliburton Loophole,” because former Halliburton CEO Dick Cheney was Vice President of the United States at the time it was passed; Halliburton reportedly makes more than $1.5 billion dollars from Hydraulic fracturing technologies annually (Sutcliffe, 2009 and Union of Concerned Scientists, 2006). A study released by the US Environmental Protection Agency [EPA] in 2004 received similar disregard from Hydraulic fracturing opponents; the controversy in that case started from an internal whistle-blower who believed the EPA’s conclusion was unfounded (Pelley, 2003 and Wilson, 2004).

Apparent shortfalls in federal policies have been made up for with comprehensive individual state policies. Developed independently, each state has its own permitting requirements and regulations. Wyoming was first to require full disclosure of chemicals used in fractured wells starting in mid 2010 (Bleizeffer, 2010 and Binns, 2010). New York has been under a fracking moratorium since early 2010 (Cohen, 2011). Texas and Louisiana didn’t have specific hydraulic fracturing regulations until last year, but even educated opponents will agree that the encompassing oil and gas regulations in these states had always offered adequate protections (Willie 2011 and Wiseman, 2009). According to several sources, creating federal regulation may only serve to increase costs

for all parties while possibly encumbering development (Willie 2011 and Texas Railroad Commission [TRC], 2005).

4.1: Federal Regulations

Regulation of hydraulic fracturing has until recently fallen under the control of state and local governments. Even with increased outside pressure, there remains little federal interference with state regulations already in place. The modern push for increased federal participation and oversight started in 1997, in Alabama.

In 1997, The Legal Environmental Assistance Foundation [LEAF] filed suit with the Eleventh Circuit Federal Court against the EPA (11th Circuit, 1997). They argued that Alabama's EPA-approved Underground Injection Control [UIC] program should be rejected. The UIC program falls under the EPA's Safe Drinking Water Act [SDWA] and regulates the underground injection of fluids not otherwise permitted or allowed. In order to reduce EPA's burden and increase state autonomy, individual states may create and enforce their own UIC programs provided that the program receives EPA approval (Willie, 2011). LEAF was concerned that Alabama's UIC program did not regulate the underground injection of fluids used for hydraulic fracturing. The EPA argued that the UIC program was only designed to regulate fluids in wells that were used for storage or "placement," and that since the primary use of hydraulically fractured wells was oil and gas production, regulation of those fluids was not required. The Eleventh Circuit sided with LEAF, deciding that the UIC program should cover injected hydraulic fracturing fluids (1997). This was a clear victory for LEAF, but one that would only last until 2005 (Willie, 2011).

Congress passed the Energy Policy Act in 2005, which included the previously mentioned "Halliburton Loophole" (Sutcliffe, 2009 and Wiseman, 2009). The Act exempted

hydraulic fracturing fluids from regulation under the SDWA, with the exception of diesel-based fracturing fluids (Wiseman, 2009). This Act effectively removed hydraulic fracturing from the scope of Federal Government and came on the heels of a challenged 2004 study released by the EPA (Wiseman, 2009, EPA, 2004 and Wilson, 2004).

The 2004 study was designed to examine hydraulic fracturing used for coalbed methane extraction. Residents in Alabama, Colorado, Montana, New Mexico Virginia, West Virginia, and Wyoming had contacted the EPA voicing concerns that the process had affected their water wells. Most concerns were of well water loss, but some also reported well contamination and increased presence of methane in their homes as problems (Willie, 2011). The EPA study eventually concluded that hydraulic fracturing fluids posed little threat, as any toxic components were mostly diluted anyways; they cited that up to 95% of injected fluid by volume is water (EPA, 2004). Their conclusion was so firm that they determined further studies and fieldwork wouldn't be worth the cost (Wilson, 2004 and Willie, 2011). Several spoke out against their conclusions, including a senior scientist from within the EPA itself, Weston Wilson (Wilson, 2004). According to his letter to Congress, 5 of the 7 peer-reviewers for the study stood to benefit by convincing the EPA to not perform actual field studies (2004). The fact that this all occurred with the former CEO of Halliburton as Vice President did not help increase credibility. Others spoke about the possibility of corruption or misguidance of the panel, but none so accusatory as Wilson (Septoff, 2010 and Wiseman, 2009).

The controversy surrounding the 2004 EPA study did little to stop the Energy Policy Act from passing into law in 2005, but gained more attention from environmentalists as hydraulic fracturing became key to growth in the natural gas industry (Sutcliffe, 2009 and

Willie, 2004). It even prompted a new study by the EPA that will conclude later this year (EPA, 2012 and Willie, 2011). Until that study is published, it seems that hydraulic fracturing will receive no additional oversight from the federal government, but that individual states will continue to regulate as they see fit (Willie, 2011).

4.2 State Regulations

As stated earlier, hydraulic fracturing has been in use in various forms since the late 1940s (Montgomery and Smith, 2006). Because it is a method of well stimulation, it has always fallen under at least some regulatory or permitting oversight. The increased attention hydraulic fracturing has seen over the last decade is not requisitely indicative of poor regulations, but more a side effect of increased usage of the technology (Willie, 2011). Various states have in turn adopted their own methods of regulating hydraulic fracturing, which may be effective in their own respects, vary widely (Willie, 2011 and Zoback et al, 2010). This variation is denounced by some as reasoning for more federal oversight (Wiseman, 2009). Still others ague that state autonomy allows for better regulations that apply more directly for each state than a federal program would (Willie, 2011). Louisiana, Pennsylvania, and Texas' regulations and delegations of responsibility are implemented differently, but they each address all of the activities that occur within their respective jurisdictions.

4.2.1: Louisiana

Regulation of the petroleum industry in Louisiana comes in the form of oversight from the Office of Conservation [OOC] within the State Department of Natural Resources [DNR]. The Office is located in the LaSalle Building in downtown Baton Rouge, and split into

six divisions: Executive, Engineering, Environmental, Geological Oil and Gas, Injection & Mining, and Pipeline (Louisiana DNR, 2012).

The Engineering Division is in charge of administering Part 29-B of the Louisiana Administrative Code [LAC 43:XIX], also known as Statewide Order 29-B. This order dictates oversight of the technical aspects of oil and gas wells. This includes the full life cycle of these wells within the state, from permitting to plugging, to restoration of abandoned sites. Part 29-N covers Louisiana's UIC program (Louisiana DNR, 2010).

Most of the regulations and permitting requirements have only indirect controls on hydraulic fracturing, but the term is used occasionally. Prior to October 2011, the method was only directly mentioned twice in 29-B and once in 29-N. An entirely new section (29-B Section [§] 118) was added to address specifics of hydraulic fracturing in late 2011. This section of 562 words requires full disclosure of everything put into a well to be used for hydraulic fracturing. This includes the volume and concentration of all fluids, chemicals, and proppants. The requirement becomes less significant, however, in subsection 2a. Any chemicals or materials deemed to be trade secrets by the operator only need be identified by their broader chemical family. This reporting requirement is all that the October 2011 amendments added.

Part 29-B §303 has been part of the Louisiana Administrative Code since at least 2000. It begins to cover some of the concerns that have been voiced about hydraulic fracturing. It explicitly states that is illegal to inject produced water or waste into producing hydrocarbon formations or underground sources of drinking water [USDW]. §303 also gives explicit rules for on-site waste pits, and encourages the use of a closed exploration and production [E&P] waste storage system. §309 gives operators 30 days to

notify the Office of Conservation if monitoring shows that waste pits are contaminating underground sources of drinking water, and requires the operator to remediate affected sites. Most of §313 covers pit closure techniques, up to subsection §313.J, which gives specifics for E&P waste used for hydraulic fracturing of the Haynesville Shale. This subsection allows for "produced water, rainwater, drilling, workover, completion and stimulation fluids" to be transferred from one wellsite to another in order to be used for hydraulic fracturing. This is unique, as all other projects must either keep wastes on-site or dispose of them in accordance to §303.

Subsection §313.J.2 provides another rare glimpse at the perceived risks of hydraulic fracturing, as it explicitly removes all liability from the Commissioner of Conservation, the Secretary of the Department of Natural Resources, and the State of Louisiana from the consequences of using E&P waste for hydraulic fracturing. The next relevant mentioning of hydraulic fracturing comes in part 29-N. §101 defines it as a well stimulation technique, and it is subject to all permitting and reporting requirements of a class II well in the Louisiana UIC program.

An environmental advisory group called the State Review of Oil and Natural Gas Environmental Regulations, Inc. [STRONGER] periodically provides independent assessments of individual state oil and gas regulations. The group receives funding from The EPA, Department of Energy, and The API (STRONGER, 2012). STRONGER published an evaluation of Louisiana's regulatory system in March of 2011. Louisiana's current scheme was largely praised, thanks to prompt action by the OOC to adjust relevant policies and their encouragement of using surface water for hydraulic fracturing jobs (STRONGER, 2011). Recommendations were to increase well casing requirements, require spill

prevention and control plans from operators, and to require reporting of materials injected. In response, Louisiana created injection-reporting requirements (29-B §118), and is currently indentifying new casing requirements (STRONGER, 2011).

Louisiana's regulations appear adequate to address the risks, but do still leave room for improvement. Stiffer reporting requirements and easier public access to records would both be welcome improvements. Regardless, pro-federal regulations observers should note that the technology acknowledged and regulated before it emerged into the media spotlight.

4.2.2: Pennsylvania

The Pennsylvania Department of Environmental Protection [DEP] is responsible for regulating the petroleum industry in Pennsylvania (PA Code 25, 2012). This is done through the Office (formerly Bureau) of Oil and Gas Management, which is split into six sections: The Office of Oil and Gas Management, Industry Resources, Public Resources, Marcellus Shale, Oil and Gas Reports, and Marcellus Shale Advisory Commission (DEP, 2012). The advisory commission was established in early 2011 to give recommendations to the Governor on how to improve hydraulic fracturing regulations in the state (DEP, 2011). The Marcellus Shale section includes the oversight of hydraulic fracturing within the state. These regulations and requirements are outlined in Pennsylvania Code 25, §78.

§78 offers the same protections as Louisiana's administrative code. It includes permitting requirements and requires that operators provide full plans and proof of rights (§78.11-19). It also offers protections for USDW, going further than Louisiana's code and requiring that offenders provide victims of contamination with quality potable water (§78.51). Pennsylvania's code also mentions that operators should have a report of all

substances used to hydraulically fracture a well, but does not require that the report be actually submitted unless it is specifically requested by the DEP (§78.122d). This section does not include explicit language allowing for trade secret exemptions, but does say that chemicals without Chemical Abstracts Service numbers may be left out of the report (§78.122d).

In 2010, STRONGER released an independent assessment of Pennsylvania's hydraulic fracturing regulations. The group praised Pennsylvania's water management practices in the Marcellus, its requirement of a Prevention, Preparedness and Contingency (PPC) plan by all operators, and the state's program for tracking and reporting of post-exploration and production waste (STRONGER, 2010). They recommend stiffened well casing requirements, requiring a full report of chemicals and substances used, increased on-site monitoring of hydraulic fracturing operations by The DEP, and requiring secondary backup liners in pits containing hydraulic fracturing waste (STRONGER 2010). Since receiving these recommendations, Pennsylvania chose to increase casing requirements, but rules requiring secondary liners or full disclosure of injected substances had not passed as of this writing.

4.2.3: Texas

Texas regulations and requirements come down from the Texas Railroad Commission [RRC], an entity founded in 1891 to regulate the railroad industry (RRC, 2012). As the oldest regulatory entity in the state, it grew to regulate other industries, eventually including oil and gas (RRC, 2012). Interestingly enough, OPEC was originally created to emulate some of the functions the RRC had served in the 1950s; the evolution of OPEC eventually led the member countries away from this goal (Parra, 2004).

The RRC received criticism in recent years for its apparent lack of concern for hydraulic fracturing (Wiseman, 2009). This criticism has slowed, though, as it has become apparent that the encompassing oil and gas regulations already in place were designed to apply to hydraulic fracturing, even if it did not mention it by name (Wiseman 2009 and Willie, 2011). Also, The RRC recently adopted a new set of regulations to the Texas Natural Resources Code that requires full disclosure of materials used for hydraulic fracturing (§91.851). This requirement contains the same exclusions for chemicals or materials without a recognized name or Material Data Safety Sheets [MSDS] offered in Louisiana. STRONGER has completed two reports for Texas, the latest in 2003. Neither covered hydraulic fracturing regulations in the state, except when referencing general injection wells.

Chapter Five: Relevant Recent Hydraulic Fracturing Studies of Public Opinion

5.1: Louisiana: Goidel and Climek (2012)

Goidel and Climek are the publishing authors of the 2012 Louisiana Survey. The Louisiana Survey is annual state-funded survey designed to gauge public opinion of government and important political issues, and has been conducted by the Louisiana State University [LSU] Manship School Research Facility Public Policy Research Lab each year, since 2002. 2012 is the first year that this survey contains questions about hydraulic fracturing.

The survey was collected via landline and cellular telephone. There were a total of 731 respondents, 517 of which were contacted via landline. All of the respondents were residents of Louisiana. Respondents were 49% male and 51% female. Forty-six and a half perecent had higher than a high school education.

The hypothesis of the hydraulic fracturing portion of the study was that the harsh sound of the word "fracking" or "fracturing" may be at least part of the reason for negative public sentiment. In order to test this, they asked identical questions to two groups of respondents, using "fracking" in one set of questions, and a description of the process without the words "fracking" or "fracturing" in the other. Their results support their hypothesis, as the "fracking" group consistently answered questions in more negative ways. Figure 13 shows this overall result.

Surprisingly, 44% of respondents exposed to the word "fracking" and 46% of respondents exposed to its description claimed to know or have heard nothing so far about the technique. When exposed to the word, only 38.6% said the state should encourage

drilling (versus 35% who said the state shouldn't). However, when the technique was described instead of named, 51.6% said the state should encourage development.

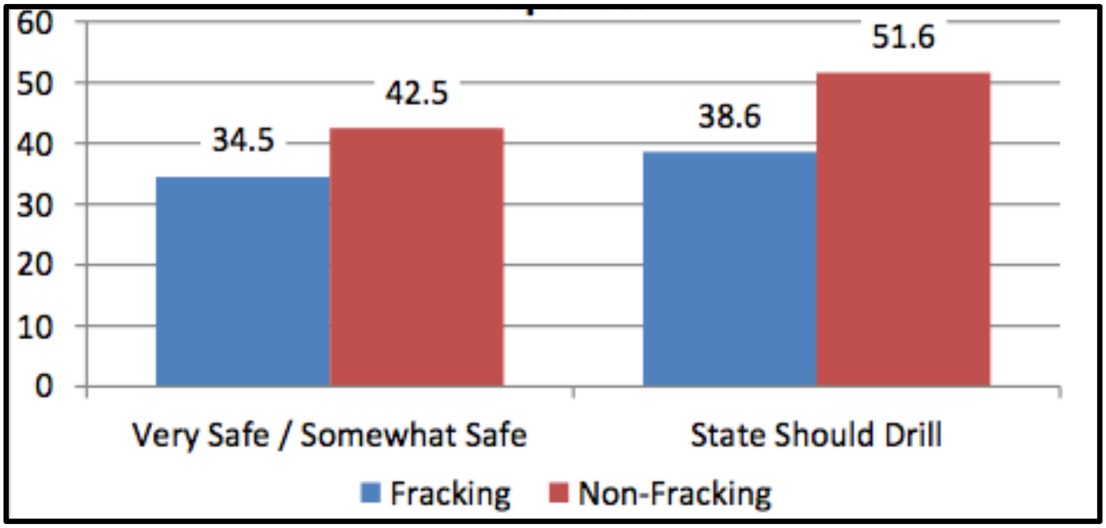

Figure 13. Comparison of groups who heard the words fracture or frack ("fracking") and those that did not (non-"fracking") (Goidel and Climek, 2012).

5.2: Pennsylvania: Civil Society Institute (2010)

The relative age of this study suggests recent heightened awareness of the fracking issue in Pennsylvania. The Civil Society Institute [CSI] is an environmental action research group "committed to improving society with breakthrough thinking and creative action" (2012). CSI does not list where it received funding for its 2010 survey of Pennsylvania residents. The title of their published results is ""Fracking" and Clean Water: A Survey of Pennsylvania Residents."

There were 403 survey respondents, 48% of which were male and 52% of which were female. More than 60% of these respondents claimed to know what hydraulic fracturing was, while 81% responded that they were concerned about the natural gas industry contaminating their water. Eighty-two percent support the addition of reporting requirements for materials injected during hydraulic fracturing. Seventy-nine percent of respondents said that they would be likely to get involved locally if an "energy project" was

located close enough to them that it might negatively affect their drinking water. Seventy-six percent hold public health and protection of the environment above energy production considerations, while 21% have the opposite opinion.

5.3: Texas: Groat and Grimshaw (2012)

Groat and Grimshaw published a report in February 2012 concerning public perceptions and patterns of support for hydraulic fracturing in Texas. Their study also included the Haynesville Shale in Louisiana. They performed analyses on media coverage of fracking, public perception through the use of surveys, and general public knowledge of fracking through surveys.

Their analysis of news media shows largely negative coverage, shown below in Table 3. They also found that few articles or reports actually referenced scientific research.

Table 3. Groat and Grimshaw Results of Media Coverage Tone Towards Hydraulic Fracturing (2012). *All television reports were grouped for this column.

<table>
<tr><th></th><th>Negative</th><th>Neutral</th><th>Positive</th><th>Percent Referencing Scientific Research</th></tr>
<tr><td>National Newspapers</td><td>64%</td><td>25%</td><td>12%</td><td rowspan="2">18%</td></tr>
<tr><td>Metropolitan Newspapers</td><td>65%</td><td>23%</td><td>12%</td></tr>
<tr><td>National Television</td><td rowspan="2">64%</td><td rowspan="2">19%</td><td rowspan="2">18%</td><td>25%*</td></tr>
<tr><td>National Radio</td><td>15%</td></tr>
<tr><td>Metropolitan Television</td><td>70%</td><td>27%</td><td>3%</td><td>25%*</td></tr>
<tr><td>Online News</td><td>63%</td><td>30%</td><td>7%</td><td>33%</td></tr>
</table>

Public perceptions and general knowledge of hydraulic fracturing was determined using an online survey of 75 questions. All participants opted-in to participate, and 1,473 responses were collected. The survey only covered residents of the Barnett Shale; it did not

cover any other shales including the Haynesville. Respondents were 63% female and 37% male, with an average age of 49. 93% had more than a high school education. 17% owned land leased to the natural gas industry, and 2% were employed by the natural gas industry. The study employed a 7-point Likert scale, and the summarized responses can be found below, in Table 4.

Table 4. Results of Groatman and Grimshaw Surveyed Respondents. Answers reflect what residents of the Barnett Shale replied when asked: "Hydraulic Fracturing is…" (2012)

	1	2	3	4	5	6	7	
Safe	4%	9%	14%	48%	12%	7%	5%	Unsafe
Good for the economy	12%	17%	22%	41%	4%	2%	2%	Bad for the economy
Good for the environment	3%	5%	11%	44%	15%	12%	10%	Bad for the environment
Important for energy security in the US	15%	18%	17%	40%	4%	3%	2%	Unimportant for the energy security in the US
Positive	7%	10%	14%	48%	10%	6%	4%	Negative
Useful	13%	17%	24%	39%	4%	1%	2%	Useless
Important	12%	16%	22%	43%	4%	2%	1%	Not important
Effective	11%	17%	20%	43%	5%	2%	2%	Ineffective
Valuable	11%	18%	20%	44%	3%	1%	2%	Worthless
Good	7%	10%	16%	48%	9%	6%	4%	Bad
Beneficial	7%	9%	14%	43%	13%	8%	6%	Harmful
Wise	7%	11%	16%	54%	6%	3%	4%	Foolish
Productive	11%	18%	22%	43%	3%	1%	2%	Unproductive
Helpful	9%	13%	18%	49%	6%	3%	3%	Unhelpful

Chapter Six: Results

6.1: Surveys

6.1.1: Survey of Louisiana Legislators, Energy Company Employees, and Prominent Stakeholders

Thirty individuals were contacted through their official means of communication and asked to participate in an entirely anonymous survey. They were told that there was absolutely no risk of exposure and that their names or companies would not be published alongside their responses. The first contact was made via email, and directed them to the web-based survey. The survey was created using Wufoo.com code and hosted on a Louisiana State University server via Tigerbytes, and responses were stored and analytics performed by Wufoo.

The response rate to the first email was very low; only one person contacted actually clicked the link and completed the survey. Aside from this lone response, the website received no other visits. A second round of emails was sent two weeks later, with similar results. One week later, potential respondents were contacted via telephone. It was hoped that a voice and the opportunity to converse freely about this study would encourage more responses. All governmental and legislative offices flatly said they would not participate. Energy companies were surprisingly more willing to participate, and a few individuals indicated they would complete the survey. However, the total response rate after exhausting every mode of contact was a low 6.6%; only two completed responses were submitted. Analytics inferred that 20% of those contacted eventually visited the survey, but did not finish it.

The two responses did offer some initial insight. One came from an energy company executive and one from the author of a shale reporting and investment advice website. Both were male, and both indicated that American energy independence was both imperative and made possible by the use of hydraulic fracturing. The survey instrument contained questions in parallel that asked how respondents felt an average Louisiana Citizen would respond to the same question; an example of this is shown below in Figure 14. The full context and the rest of the survey are available in Appendix A. Both respondents felt strongly about the questions in one way or another, and both thought that the average citizen generally felt the same, sometimes just to a lesser extent.

	No Importance	Some Importance	Important	Very Important	Imperative
How important is US energy independence?	1	2	3	4	5
Average Citizen's Response	1	2	3	4	5
How important is the development of the Haynesville Shale to obtaining US energy independence?	1	2	3	4	5
Average Citizen's Response	1	2	3	4	5
How important is the development of similar shales to obtaining US energy independence?	1	2	3	4	5
Average Citizen's Response	1	2	3	4	5
How important is the use of hydraulic fracturing in developing US shale plays?	1	2	3	4	5
Average Citizen's Response	1	2	3	4	5

Figure 14. Format of Survey One Likert Questions

6.1.2: Survey of GoHaynesvilleShale.com Forum Members

The low response rate of the first survey showed that potential respondents were either intimidated by the amount of questions or the time it would take to complete. It also demonstrated that in order for a web-based survey to attract respondents, it would need to reach a much wider audience.

The first problem was addressed by a reduction in page size in exchange for two pages of questions rather than one. Questions were also consolidated and nested when possible. See Figure 15 for example, which demonstrates how specific questions were only presented to an applicable audience.

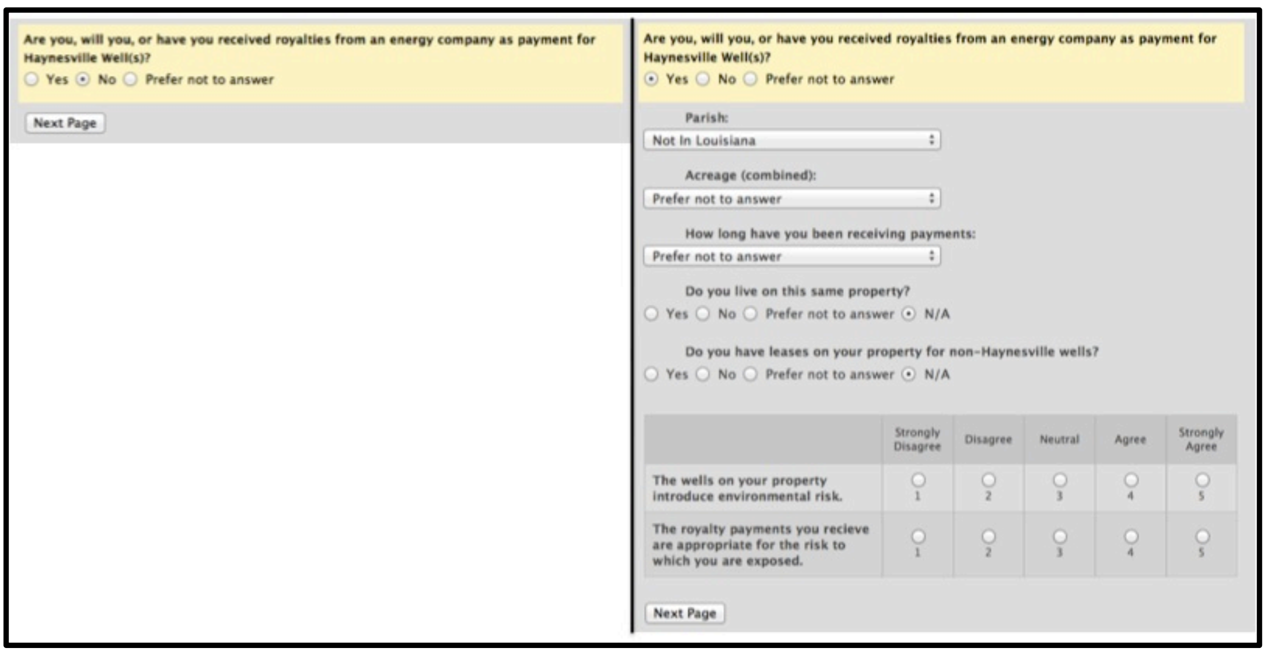

Figure 15. Example of Nested Questions Based on a Dichotomous Question.

The number of open-ended questions appearing at the end of the survey was also reduced, from 6 questions to 4. These changes were made in order to reduce the average amount of time it would take a respondent to complete the survey to less than 10 minutes. These changes proved worthwhile, as respondents completed the second survey in an average of 8.9 minutes.

The potential pool of participants for the survey was greatly enhanced after Keith Mauck, the site publisher for gohaynesvilleshale.com, was contacted. At the time of the survey, October of 2011, the site had just over 17,000 members. An average of 28 members are online during the day. The website and forum offer a place for anyone interested in the Haynesville Shale to communicate and learn more about its development. Landowners, oil and gas landmen, investment firms, environmentalists, and interested citizens all invited to come together in one site to discuss their individual concerns and questions. After publishing a forum post containing a description of and hyperlink to the survey, Keith featured the post in his weekly email to members and pasted it to the front page of the website. Two-hundred and thirteen unique visitors read through the description, 130 unique visitors clicked through to the survey, and 63 completed it. This occurred over a 28-day period at the end of 2011.

Sample sizes were calculated for varying population size, margin of error and confidence levels. These calculations used the equation provided by Dillman et al, and are shown below in Table 5 (2007).

The obtained sample size (63) comes very close to significant under two of the select cases, and is significant for two others. This sample is significant at a margin of error of $\pm 10\%$ at a 90% confidence level when the entire population is considered to be either the total number of visitors to the forum post or the estimated number of visitors to the website over the survey period. This is considered acceptable for the purposes of gauging the response of forum users that frequent the website to both give and receive advice and information on the Haynesville Shale.

Table 5. Sample Size Determinations

Actual Sample Size Obtained	63			
N_s Needed Sample Size	66.9	51.3	66.4	62.0
N_p Population Sampled	17,000 Total Members	213 Visitors to Forum Post		784 Average Daily Traffic * 28 Days
p **Proportion expected to choose one of two outcomes**	0.5 (50/50 split)			
B **Margin of error**	0.1 (± 10%)			
C **Z score**	1.64 (90% Level)		1.96 (95% Level)	1.64 (90% Level)

Responses were largely homogenous, with respondents trending towards similar responses for each question. Respondents were 53% male and 20% female, with a "prefer not to answer" from 27%. None were under the age of 24, and all but one claimed to have higher than a high school education. The largest age group was 61+, at 42% of all responses. 76% of respondents were 51+. Forty percent said they owned land that was being leased to an oil and gas company. Fifteen percent of these respondents felt that the royalty payments don't accurately reflect the introduced risk. Forty-eight percent of these landowners had 100 or more acres, and 16% had been leasing them for more than 5 years.

As a whole, the respondents have a positive view of hydraulic fracturing. Ninety-three percent said they understand how it works, and 75% said they don't think fracked wells introduce any extra risk. All agreed that development of the Hayneville Shale has had a positive effect on Louisiana's economy, employment opportunities, and rural areas. The

respondents were asked to categorically identify themselves, and the distribution is presented in Table 6 below.

Table 6. Self-Reported Respondent Roles

Elected Politician	0%
Government Office Employee	3%
Government Commission Member or Employee	0%
Energy Company Employee	8%
Citizen	35%
Investor	5%
Stakeholder	49%

6.2: Mixed Methods Profile of Louisiana, Pennsylvania, and Texas

6.2.1: Geographic Comparisons

Table 7 shows the results of a geographic comparison of Louisiana, Texas, and Pennsylvania. State areas and populations were collected from the 2010 Decennial Census. Figure 16 shows the counties and parishes used for this table.

The number of wells and number of fracked wells for Louisiana were collected from the Louisiana State Department of Natural Resources [DNR] GIS database (http://sonris-www.dnr.state.la.us/gis/sonris/viewer.htm, May 12, 2012). Fracturing Area and Fracturing Population for Louisiana was determined by an intersection operation in ESRI ArcMap 10, which determined which parishes contained fracked wells (Caddo, Bossier, Webster*, Red River, De Soto, Sabine, Natchitoches, and Bienville). The areas and populations of these parishes were then summed. The parishes that contained less than 10 wells were excluded from the sum, and are marked with an asterisk.

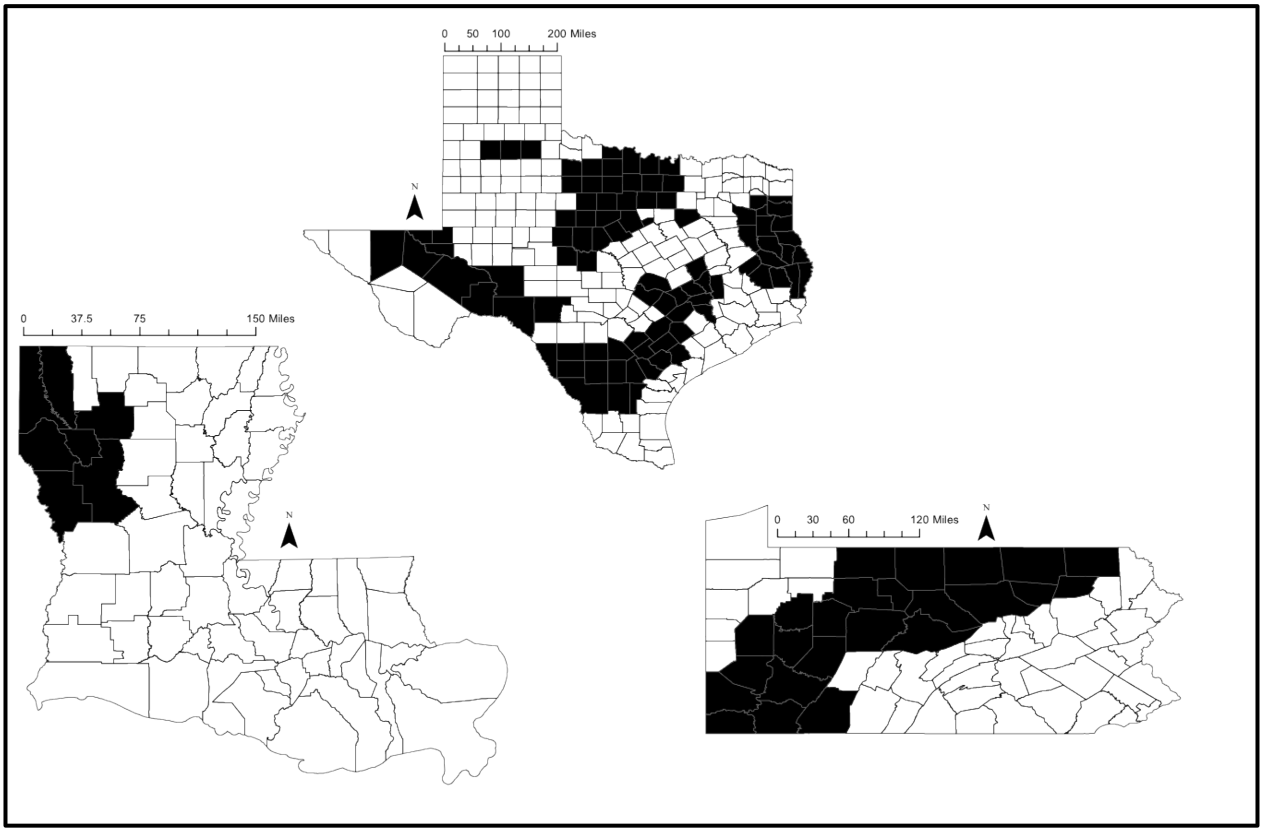

Figure 16. Counties in black have been potentially affected by hydraulic fracturing in Louisiana, Pennsylvania, and Texas.

The total number of oil and gas wells for Texas was calculated using counts provided by the Railroad Commission of Texas [RRC] (http://www.rrc.state.tx.us/data/wells/wellcount/index.php, May 12, 2012). The RRC provides monthly data on total well counts by county for both oil and natural gas. These counts were manually summed for the latest available data (February, 2012), and then E&P waste injection wells were subtracted, because these aren't included in the Louisiana Total Wells count. Prior to February 2012, the RRC did not maintain records of which wells were drilled using horizontal drilling and hydraulic fracturing; the count of 16,430 fractured wells is an estimate obtained by summing counts from individual Texas shale plays

provided in a March, 2012 paper in Environmental Technology & Science (Nicot and Scanlon, 2012).

Table 7. Geographic Comparison Results

Category	Louisiana		Texas		Pennsylvania	
	Statewide	Fracking Parishes	Statewide	Fracking Counties	Statewide	Fracking Counties
Area (km^2)	134,264	17,728	695,621	252,481	119,283	2.42
Percent of Total Area		13%		36%		43%
Population	4,468,976	485,847	20,851,820	7,154,815	12,281,054	1,924,476
Percent of Total Population		11%		34%		16%
Oil/Gas Wells	232,260	70,815	360,937	9,863	36,615	22,892
Well Density (wells/km^2)	1.73	3.99	0.52	0.04	0.31	0.45
Fractured Wells	2,401		16,430		5,397	
Fractured Well Density (wells/km^2)	0.02	0.14	0.02	0.07	0.05	0.11

Texas' Fracturing Area was determined in ESRI ArcMap 10, by running an intersection of the Texas Shale Plays with Texas Counties (ftp://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/maps/maps.htm, May 12, 2012 and http://www.census.gov/geo/www/tiger/, May 12, 2012).

These counties that overlaid productive shale plays were then compared with the RRC natural gas well count data from February 2012; any county with less than 10 natural gas wells was then removed from the intersection list as was done with the Louisiana Parishes. This left 91 Texas Counties: Archer, Angelina, Atascosa, Austin, Bastrop, Baylor, Bee, Brazos, Brown, Burleson, Callahan, Cherokee, Clay, Coleman, Comanche, Concho,

Cooke, Crockett, Culberson, Denton, DeWitt, Dimmit, Duval, Eastland, Edwards, Ellis, Erath, Fayette, Floyd, Frio, Goliad, Gonzales, Gregg, Grimes, Hale, Harrison, Haskell, Jack, Jasper, Jim Wells, Karnes, Knox, La Salle, Lavaca, Lee, Live Oak, Loving, McCulloch, McMullen, Marion, Maverick, Montague, Motley, Nacogdoches, Newton, Palo Pinto, Panola, Parker, Pecos, Polk, Reeves, Robertson, Runnels, Rusk, Sabine, San Augustine, Shackelford, Shelby, Smith, Somervell, Stephens, Tarrant, Taylor, Terrell, Throckmorton, Travis, Trinity, Tyler, Upshur, Val Verde, Victoria, Ward, Washington, Webb, Wichita, Williamson, Wilson, Winkler, Wise, Young, and Zavala. The population and areas of these counties were then summed from 2010 Decennial Census data.

The total number of Pennsylvania Oil and Gas wells was determined from Pennsylvania Department of Environmental Protection [DEP] reported counts from 1901 to February, 2012 (http://www.depreportingservices.state.pa.us/ReportServer/Pages/ReportViewer.aspx?/Oil_Gas/Wells_Drilled_By_County, May 12, 2012). The DEP also keeps track of which counties contain fracked wells, so those counties which contained more than 10 fracked wells were then determined (24 total): Allegheny, Armstrong, Bradford, Butler, Cameron, Centre, Clarion, Clearfield, Clinton, Elk, Fayette, Greene, Indiana, Jefferson, Lycoming, McKean, Potter, Somerset, Sullivan, Susquehanna, Tioga, Washington, Westmoreland, and Wyoming. The number of fracked wells was summed from DEP data, and the population and areas of these counties were summed from 2010 Decennial Census data.

6.2.2: Socioeconomic Comparisons

Data for the socioeconomic comparisons were collected using the same areas determined for the Geographic Comparisons. Data from four tables were collected for

Louisiana, Texas, and Pennsylvania. DP-1 data comes from the 2010 Decennial Census Profile of General Population and Housing Characteristics: 2010 table. DP-2 through DP-4 data comes from the American Communities Survey [ACS] 2006-2010 5-year estimate dataset, also published by the US Census Bureau. The categories available in this dataset represent the most recent available data for the selected geographies.

Table 8. 2010 Decennial Census DP-1 Data

Category	Louisiana		Texas		Pennsylvania	
	Statewide	Fracking Parishes	Statewide	Fracking Counties	Statewide	Fracking Counties
Median Age	35.8	38.2	33.6	39.1	40.1	42.5

DP-1 data show a consistent trend for the median age of residents in Fracking Counties residents to be higher than the Statewide median.

DP-2 data show an important trend between the Statewide and Fracking Parishes/Counties areas. A Pearson's Chi Square Test shows significant trends in the same direction for each category and for each state. Average household size, Average family size, Percent high school graduate or higher, and Percent bachelor's degree or higher all become smaller or lower in the Fracking Parishes/Counties for each state. Meanwhile, the Percent over 18 and Veteran and Native to State categories both see a rise (with the exception of Louisiana Native to State, which stagnates) when comparing Statewide with Fracking Parishes/Counties.

Table 9. 2006-2010 ACS DP-2 Data

Category	Louisiana		Texas		Pennsylvania	
	Statewide	Fracking Parishes	Statewide	Fracking Counties	Statewide	Fracking Counties
Average household size	2.62	2.58	2.78	2.64	2.47	2.42
Average family size	3.22	3.18	3.35	3.12	3.06	2.94
Percent high school graduate or higher	81%	80%	80%	77%	87%	87%
Percent bachelor's degree or higher	21%	16%	26%	17%	26%	18%
Percent over 18 and Veteran	10%	11%	9%	10%	11%	12%
Native to State	79%	79%	61%	75%	75%	82%

DP-3 data show a similar trend to DP-2. The change for every category and for each geography is in the same direction each time, with the exception of an anomalous rise in "Fracking Parish Unemployment" in Louisiana.

DP-4 data show the same trend seen in DP-2 and -3 data. This means that for each state, the direction and magnitude of change from Statewide to Fracking Parishes/Areas for each category stayed the same.

Table 10. 2006-2010 ACS DP-3 Data

Category	Louisiana		Texas		Pennsylvania	
	Statewide	Fracking Parishes	Statewide	Fracking Counties	Statewide	Fracking Counties
Percent in Labor Force	62%	58%	66%	58%	63%	62%
Percent Unemployment	8%	9%	5%	4%	5%	4%
Median Household Income	$43,445	$36,931	$49,646	$41,933	$50,398	$44,038
Mean Household Income	$60,003	$52,814	$68,700	$55,705	$67,282	$55,169
Median Family Income	$53,702	$47,599	$58,142	$50,698	$63,364	$54,465
Mean Family Income	$70,357	$63,090	$78,037	$63,978	$80,704	$64,796
Per Capita Income	$23,094	$20,869	$24,870	$21,144	$27,049	$22,752

Table 11. 2006-2010 ACS DP-4 Data

Category	Louisiana		Texas		Pennsylvania	
	Statewide	Fracking Parishes	Statewide	Fracking Counties	Statewide	Fracking Counties
Percent Occupied Housing Units	86%	80%	88%	79%	89%	80%
Percent Vacant Housing Units	14%	20%	12%	21%	11%	20%
Use of Natural Gas as Heating	39%	36%	39%	30%	51%	44%
Median Value of Owner-Occupied Homes	$130,000	$89,143	$123,500	$83,985	$159,300	$106,339

6.2.3: Environmental Damage Comparisons

Data collected on accidents related to hydraulic fracturing are shown below in Table 12. Some accidents include more credible sources or explanations than others; categories of substantiated and anecdotal have been created for each state. A full list of the related accidents is included in Appendix B.

Total National Priorities List [NPL] data are shown below in Table 13. The Current NPL List Category includes proposed and accepted sites. This data was provided by scorecard.goodguide.com, an environmental reporting group originally established by the Environmental Defense Fund [EDF].

Table 12. Accidents Related to Hydraulic Fracturing

			Unique to Hydraulic Fracturing	Common For E&P Wells of Any Type	
	Cause		Horizontal Drilling and Hydraulic Fracturing	Drilling or Surface Casing Accidents	Poor Surface Handling of Waste
Louisiana	**Substantiated**	2	0	1	1
	Anecdotal	0	0	0	2
	Total	2	0	1	3
Texas	**Substantiated**	0	0	0	0
	Anecdotal	7	2	4	1
	Total	7	2	4	1
Pennsylvania	**Substantiated**	29	0	13	16
	Anecdotal	4	1	2	1
	Total	33	1	15	17
Total Incidents		42	3	20	21

Table 13. Environmental Scorecards

	Louisiana	Texas	Pennsylvania
Current NPL List	16	45	95
TRI Land Sources	69	139	92
Pounds Released	18176763	35481969	12040196
TRI Underground Sources	15	32	0
Pounds Released	32425753	88249841	0
Threats to GW	2	7	59

Chapter Seven: Discussion

7.1: Public Acceptance of Hydraulic Fracturing

> I have no concerns [about hydraulic fracturing]. Life is about taking risks to improve human living conditions. We don't wander around gathering nuts, seeds, and berries any longer. We use our brains to exploit the earth for our benefit. Mother Nature is pretty good at overcoming our errors; and we are pretty good at managing risks (Anonymous, from Survey 6.1.2, 2012).

A review of the Louisiana State Survey suggests that hydraulic fracturing has been accepted as a reasonable technology among residents of Louisiana. Louisiana's level of acceptance is higher than Pennsylvania and Texas'. Eighty-one percent of Pennsylvanians that responded to the Civil Society Institute's survey expressed fears of water contamination, and only 21% responded that they felt increased energy production was more desirable than increased protections of public health. Respondents in Texas were more indecisive about the safety and potential positive aspects of fracturing, with the majority choosing a neutral answer to every single likert question in Table 4. Texans did, however, always lean in the pro-fracking direction among those surveyed that did not answer neutrally. This stands in contrast to the Louisiana responses collected in the surveys for this study, where 75% said that they didn't think hydraulic fracturing introduced any extra risk over standard wells. Every single respondent indicated that American energy independence was not only desirable, but made more attainable through the use of hydraulic fracturing. Every single respondent also indicated they felt that hydraulic fracturing was positively affecting the state as a whole.

These responses are consistent with the hypothesis that Louisiana, Pennsylvania, and Texas exhibit varying levels of hydraulic fracturing acceptance, and shows that acceptance in Louisiana is highest. Results indicate that Louisiana and Pennsylvania may exist on the opposite ends of a hydraulic fracturing acceptance continuum; Texas may lie somewhere in the middle of this continuum, certainly closer to Louisiana than Pennsylvania.

7.2: Why is Acceptance in Louisiana Different from Pennsylvania and Texas?

The historic, geographic, socioeconomic, and environmental damage comparisons of these three states may help to explain their varying rates of acceptance. Together, first two points below illustrate truth to the hypothesis that the state with the most exposure to the oil and gas industry does indeed exhibit the highest level of acceptance.

First, the oil and gas industry is deep in the history of Louisianans. Industry development has exploded within the state since 1901. Home to overwater innovations and techniques, the nation's only offshore supertanker oil port, and the NYMEX index for natural gas, it only seems natural that new drilling innovations may be welcome here in this state. Not only does Louisiana have a rich history, it is also filled with those who know that history best; it has the highest percentage of residents that are native to the state—not only between Texas and Pennsylvania, but also among the contiguous 48 states.

Second, Louisiana's industry has experienced a more concentrated fervor of oil and gas development. Pennsylvania and Texas may have both beaten Louisiana's Jennings Well, but Louisiana has experienced denser growth of wells; current E&P wells in Louisiana are found at 3.3 times the density of those in Texas, and 5.6 times the density of those in Pennsylvania. If just the parishes where fracking is occurring are cross-listed with all E&P

well counts in those areas, Louisiana has a density 7.7 times higher than the corresponding counties in Texas' and 8.9 times higher than corresponding counties in Pennsylvania. These higher densities imply that Louisianans may experience less strain on the existing infrastructure, and furthermore that they may be more exposed and accustomed to drilling and development activities.

Third, both the immediately affected population and square-mile area of Louisiana where fracking is occurring is much smaller than in both Texas and Pennsylvania. The affected portion of the total population in Texas is greater than in Louisiana by a factor of 3.3, and the affected proportional square area of Louisiana is less than that of both Texas and Pennsylvania by a factor of at least 3.

Fourth, both the number and rate of reported hydraulic fracturing accidents in Louisiana is lower than in both Texas and Pennsylvania. In the only two reported accidents within the state, responsible parties responded swiftly and with little to no urging by state officials (Vaughan and Pursell, 2010). This is in contrast to the multitude of accidents and accusations against energy companies in other fracking states, especially Pennsylvania (See Appendix B). This observation confirms the hypothesis that not only do the most hydraulic fracturing accidents occur in the state with the worst environmental record (Pennsylvania), but also that this state exhibits the lowest level of acceptance.

Fifth, the socioeconomic condition of Louisiana exhibits the lowest level of affluence. The corresponding relationship of relative poverty with a high level of acceptance of hydraulic fracturing confirms the last remaining hypothesis; poverty begets acceptance of potentially environmentally damaging practices.

The factors listed on the paragraphs above may combine and interact with one another to encourage the current state of acceptance seen among residents in Louisiana. These relationships are further illustrated below, in Tables 14 and 15.

Table 14. Comparison of Factors that May Discourage Public Acceptance

Number of NPL Sites			Pennsylvania (95)	Texas (45)	Louisiana (16)
Threats to Groundwater			Pennsylvania (59)	Texas (7)	Louisiana (2)
Proportion of State Fracked			Pennsylvania 42%	Texas 36%	Louisiana 13%
Density of Fracked Wells Statewide			Pennsylvania 0.045 wells/km^2	Texas 0.024 wells/km^2	Louisiana 0.018 wells/km^2
Pop Exposed to Fracking			Texas 34.3%	Pennsylvania 15.7%	Louisiana 11%
Income	**Median Household**	**State**	Pennsylvania $50,398	Texas $49,646	Louisiana $43,445
		Fracked	Pennsylvania $44,038	Texas $41,933	Louisiana $36,931
	Median Family	**State**	Pennsylvania $63,364	Texas $58,142	Louisiana $53,702
		Fracked	Pennsylvania $54,465	Texas $50,698	Louisiana $47,599
	Per Capita	**State**	Pennsylvania $27,049	Texas $24,870	Louisiana $23,094
		Fracked	Pennsylvania $22,752	Texas $21,144	Louisiana $20,869

Table 15. Comparison of Factors that May Encourage Public Acceptance

Population Native to State	Louisiana 79%	Pennsylvania 75%	Texas 61%
Density of Regular Wells in Fracked Parishes/Counties	Louisiana 4 wells/km^2	Pennsylvania 0.45 wells/km^2	Texas 0.04 wells/km^2
Density of Regular Wells Statewide	Louisiana 1.73 wells/km^2	Texas 0.52 wells/km^2	Pennsylvania 0.31 wells/km^2

7.3: Do the Regulatory Frameworks Correspond with State Levels of Acceptance?

The regulatory frameworks for these three states were found to be surprisingly uniform. Louisiana and Texas have both demonstrated the ability and willingness to update

their existing policies to address fracking as needed. Pennsylvania has done the same to a large extent, but frequent accidents and the increased pressures from a wary public have made possible regulatory shortcomings (such as the lack of reporting requirement if injected fluids) a significant source of public discussion.

The argument for increased federal oversight becomes somewhat less important in the context of comparing these three states. Willie makes an interesting point when referencing the debate concerning more involvement (2011):

> What is conspicuously missing from many of these groups' arguments, however, is an explanation of how and why federal regulation will actually diminish fracking's environmental risks. In fact, a closer look at much of the rhetoric against a state-centric regulatory system reveals not so much a push for federal regulation, but rather for federal *prohibition* of hydraulic fracturing (p. 1761).

Chapter Eight: Conclusions

The observations and inferences made by this study may yield insight into contextual factors that may explain variations in patterns of public support for hydraulic fracturing. However, the study is not without fault. The surveys conducted in Louisiana for this thesis are limited in scope and may overestimate true levels of acceptance. The retrospection afforded to future and larger studies may show that this study's survey of individuals belonging to a website whose name implies acceptance (GoHaynesvilleShale) may have been an inaccurate measure of statewide acceptance. However, the contributions this study has made to a young knowledgebase will be useful to these future studies. It is hoped that the quantitative data presented in Tables 7 – 15 may serve as a starting point for studies of both fracking development and acceptance in other areas and at other scales.

The overall objective of this thesis was to examine the conditions under which hydraulic fracturing may be more likely to be accepted by communities. Three states were established to exist at three different places along a spectrum of hydraulic fracturing acceptance. This allowed the corresponding differences in their presented historic, geographic, socioeconomic, and environmental comparisons to be presented as potential factors for acceptance or rejection of hydraulic fracturing.

Louisiana's unique history with oil and gas, high exposure to energy development, and vital role in the United State's energy market may all be contributing factors for the acceptance of hydraulic fracturing and horizontal drilling of shale as reasonable practices. Texas exhibits a similar history with oil and gas, but a relatively lower rate of exposure to traditional energy development, a higher number of accidents, and a higher proportion of

the population exposed to fracking may explain why acceptance there lags behind Louisiana. Pennsylvania acceptance is the lowest, possibly due to the increased frequency of fracking accidents and negative portrayal in films like *Gasland*.

Allowing individual states to create their own regulations and requirements seems to be an effective policy approach in the absence of an encompassing federal regulatory framework. Increased reporting casing requirements are likely to be the newest additions to any given state's fracking regulations. The EPA's new study on fracking's potential impact on drinking water resources should yield a preliminary report due at the end of this year. This report will likely inform the future of regulatory policies adopted by states, and may serve as the basis for increased federal oversight through existing channels such as the Clean Air and Clean Water Acts [CAA and CWA].

Future research in Louisiana and other states is needed to further corroborate or inform these conclusions. Ideally, new surveys would be conducted to determine levels of acceptance both over time and at varying scales. It is hoped that the potential influential factors and observations this thesis has made will serve as a foundation of inquiry for the future studies of hydraulic fracturing that its continued use will likely bring.

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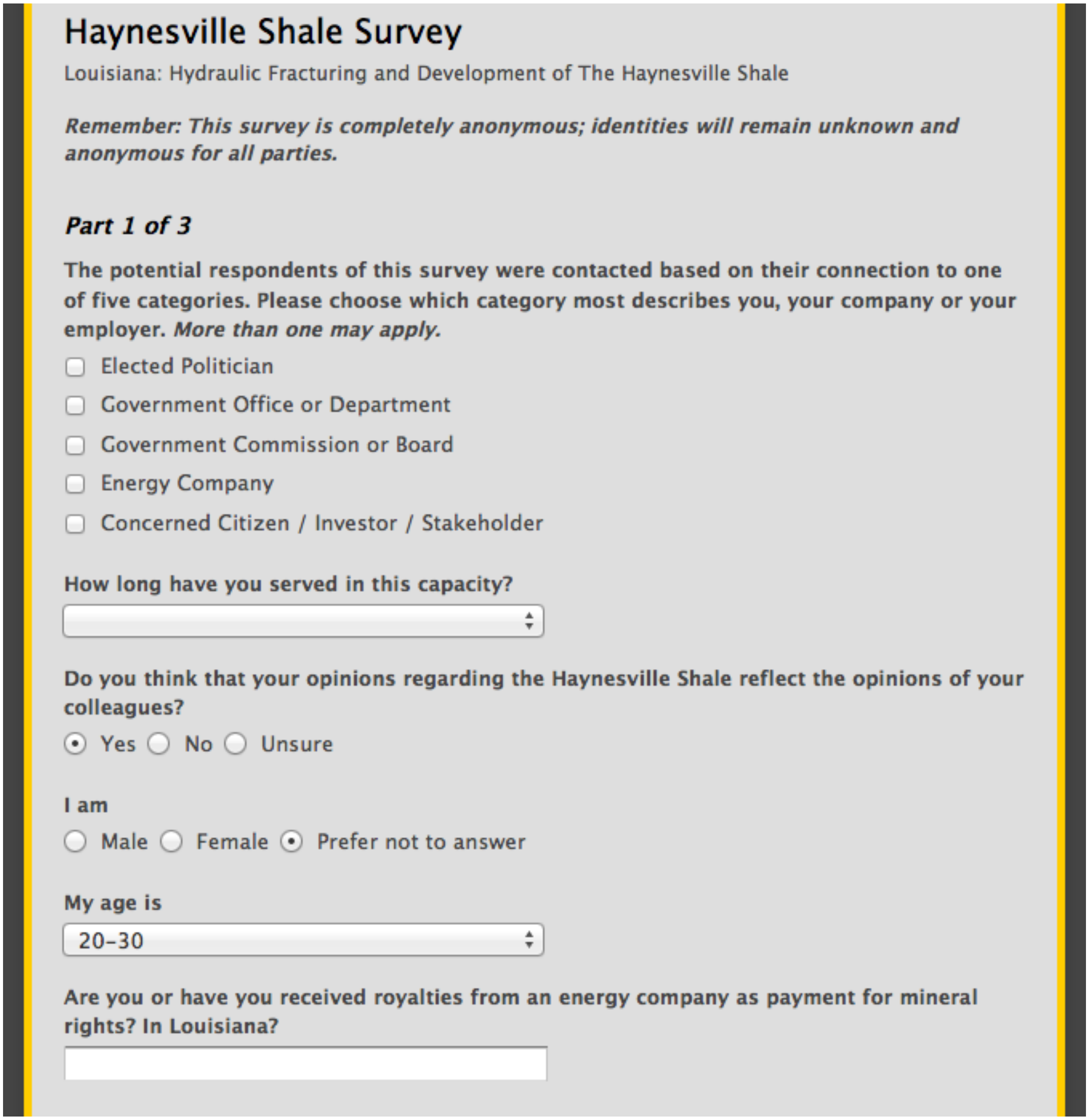
Appendix A: Survey Instruments Used

Survey 6.1.1: Survey of Louisiana Legislators, Energy Company Employees, and Prominent Stakeholders



Haynesville Shale Survey

Louisiana: Hydraulic Fracturing and Development of The Haynesville Shale

Remember: This survey is completely anonymous; identities will remain unknown and anonymous for all parties.

Part 1 of 3

The potential respondents of this survey were contacted based on their connection to one of five categories. Please choose which category most describes you, your company or your employer. *More than one may apply.*

- ☐ Elected Politician
- ☐ Government Office or Department
- ☐ Government Commission or Board
- ☐ Energy Company
- ☐ Concerned Citizen / Investor / Stakeholder

How long have you served in this capacity?

Do you think that your opinions regarding the Haynesville Shale reflect the opinions of your colleagues?

◉ Yes ○ No ○ Unsure

I am

○ Male ○ Female ◉ Prefer not to answer

My age is

20-30

Are you or have you received royalties from an energy company as payment for mineral rights? In Louisiana?

Part 2 of 3

These questions cover your opinions regarding development of the Haynesville Shale.

They then ask for what your impression of an average citizen of Caddo, Bossier, Webster, Bienville, Red River, De Soto, Natchitoches, or Sabine Parish would be. (These are Louisiana Parishes that contain Haynesville Wells.) Feel free to leave those questions blank if you are unsure.

	No Importance	Some Importance	Important	Very Important	Imperative
How important is US energy independence?	1	2	3	4	5
Average Citizen's Response	1	2	3	4	5
How important is the development of the Haynesville Shale to obtaining US energy independence?	1	2	3	4	5
Average Citizen's Response	1	2	3	4	5
How important is the development of similar shales to obtaining US energy independence?	1	2	3	4	5
Average Citizen's Response	1	2	3	4	5
How important is the use of hydraulic fracturing in developing US shale plays?	1	2	3	4	5
Average Citizen's Response	1	2	3	4	5

	Not Well	2	3	4	Very Well
How well do you understand the modern hydraulic fracturing process?	1	2	3	4	5
Average Citizen's Response	1	2	3	4	5

Development of the Haynesville Shale may have a positive or negative effect on Louisiana's...

	Very Negative	Negative	Neutral	Positive	Very Positive
Natural Environment	1	2	3	4	5
Average Citizen's Response	1	2	3	4	5
Economic Growth	1	2	3	4	5
Average Citizen's Response	1	2	3	4	5
Energy Independence	1	2	3	4	5
Average Citizen's Response	1	2	3	4	5

Do You Agree or Diasgree with the following statements:

(Do not answer the last two questions if you do not feel they apply)

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The energy companies operating in these parishes are adequately regulated.	○ 1	○ 2	○ 3	○ 4	○ 5
Average Citizen's Response	○ 1	○ 2	○ 3	○ 4	○ 5
The use of hydraulic fracturing to develop the Haynesville Shale presents risk of environmental contamination.	○ 1	○ 2	○ 3	○ 4	○ 5
Average Citizen's Response	○ 1	○ 2	○ 3	○ 4	○ 5
These risks are unavoidable.	○ 1	○ 2	○ 3	○ 4	○ 5
Average Citizen's Response	○ 1	○ 2	○ 3	○ 4	○ 5
The benefit of development outweighs the possibility of contamination presented by these risks.	○ 1	○ 2	○ 3	○ 4	○ 5
Average Citizen's Response	○ 1	○ 2	○ 3	○ 4	○ 5

Part 3 of 3

Feel free to answer as many or as few of these open-ended questions as you would like.

At what point in development of a well or field is risk the highest?

Please describe what risk(s) you perceive, short-term or long-term:

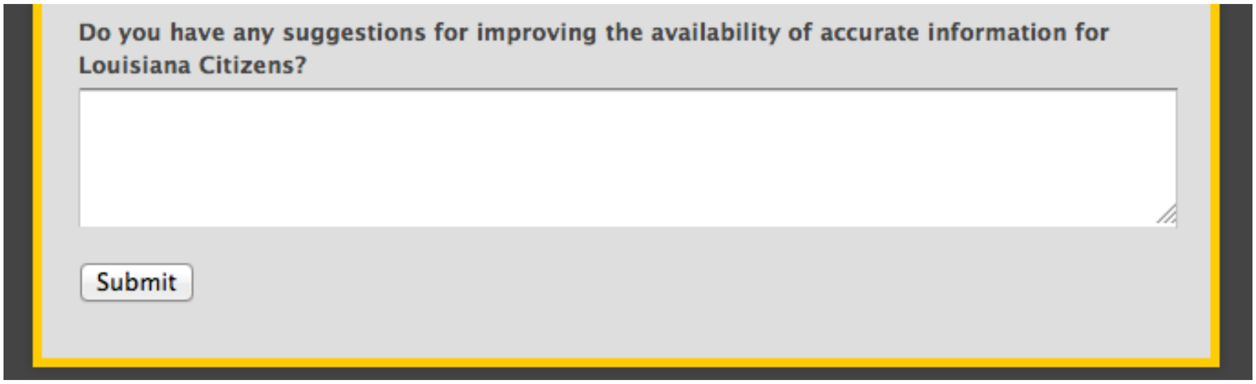
Where do you get updated information on the progression of Haynesville Shale development? (i.e. a particular website, organization, company...)

Do Louisiana Citizens use these same sources?

(•) Yes ( ) No ( ) Unsure

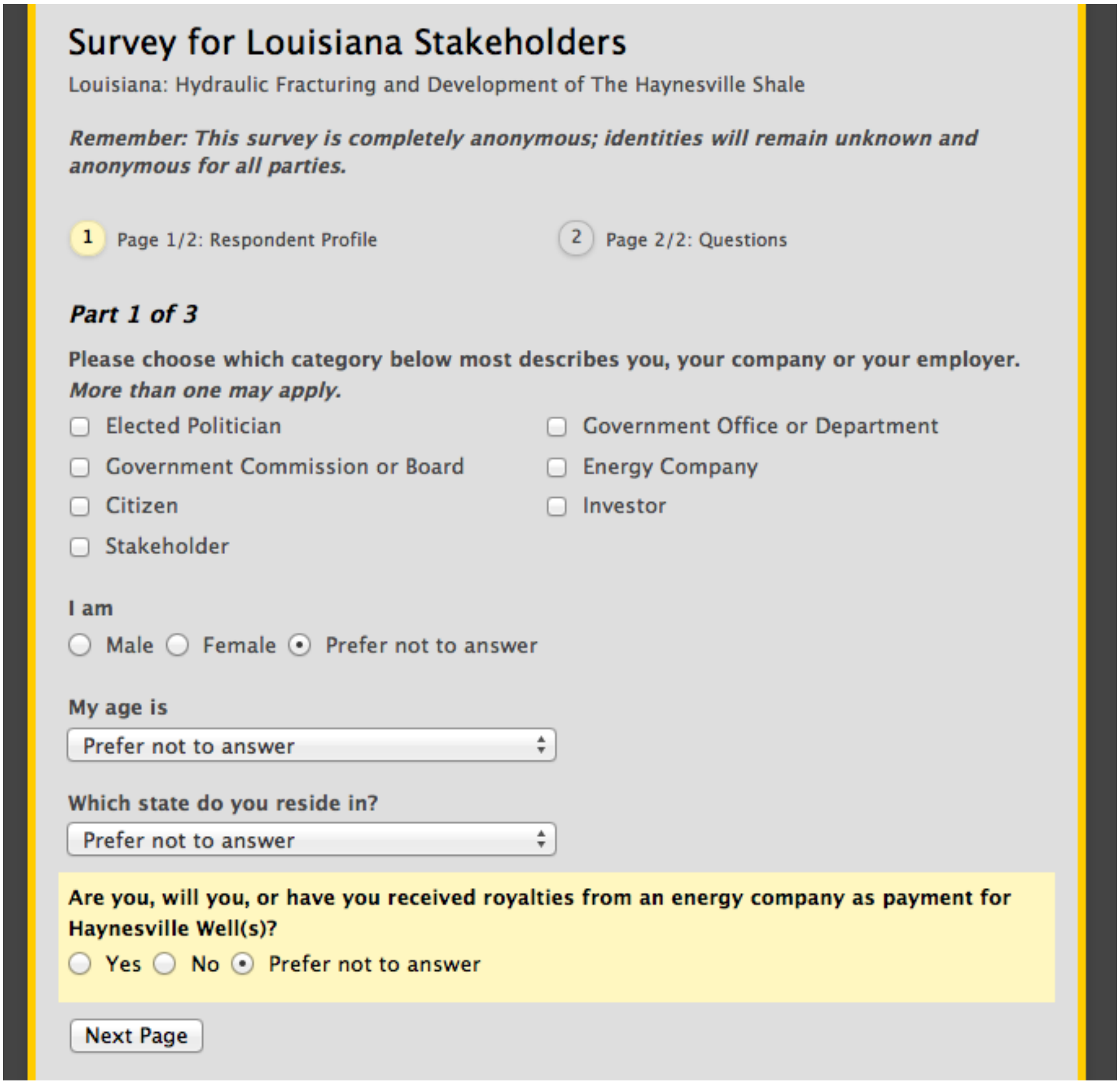
If *No* or *Unsure*, then where do you think most citizens are getting their information on modern hydraulic fracturing?

How does this compare to where you think they should be getting their information?


Do you have any suggestions for improving the availability of accurate information for Louisiana Citizens?

Submit

Survey 6.1.2: Survey of GoHaynesvilleShale.com Forum Members



Survey for Louisiana Stakeholders

Louisiana: Hydraulic Fracturing and Development of The Haynesville Shale

Remember: This survey is completely anonymous; identities will remain unknown and anonymous for all parties.

1 Page 1/2: Respondent Profile   2 Page 2/2: Questions

Part 1 of 3

Please choose which category below most describes you, your company or your employer. ***More than one may apply.***

- ☐ Elected Politician
- ☐ Government Office or Department
- ☐ Government Commission or Board
- ☐ Energy Company
- ☐ Citizen
- ☐ Investor
- ☐ Stakeholder

I am

○ Male ○ Female ⦿ Prefer not to answer

My age is

Prefer not to answer

Which state do you reside in?

Prefer not to answer

Are you, will you, or have you received royalties from an energy company as payment for Haynesville Well(s)?

○ Yes ○ No ⦿ Prefer not to answer

Next Page

Are you, will you, or have you received royalties from an energy company as payment for Haynesville Well(s)?

(•) Yes ( ) No ( ) Prefer not to answer

Parish:

Not In Louisiana

Acreage (combined):

Prefer not to answer

How long have you been receiving payments:

Prefer not to answer

Do you live on this same property?

( ) Yes ( ) No ( ) Prefer not to answer (•) N/A

Do you have leases on your property for non-Haynesville wells?

( ) Yes ( ) No ( ) Prefer not to answer (•) N/A

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The wells on your property introduce environmental risk.	1	2	3	4	5
The royalty payments you recieve are appropriate for the risk to which you are exposed.	1	2	3	4	5

Next Page

Survey for Louisiana Stakeholders

Louisiana: Hydraulic Fracturing and Development of The Haynesville Shale

Remember: This survey is completely anonymous; identities will remain unknown and anonymous for all parties.

1 Page 1/2: Respondent Profile

2 Page 2/2: Questions

Part 2 of 3

Scaled Answer Questions (Likert)

Do You Agree or Disagree with the following statements:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Increased development of domestic oil and gas prospects is desirable	1	2	3	4	5
Reduced dependence on foreign sources of oil and gas is desirable	1	2	3	4	5
Development of the Haynesville Shale is a major contribution to reducing US dependence on foreign sources of natural gas	1	2	3	4	5
Development of similar domestic shales will be a major contribution to reducing US dependence on foreign sources of natural gas	1	2	3	4	5
I understand the modern hydraulic fracturing process.	1	2	3	4	5
Development of the Haynesville Shale has a positive effect on Louisiana's economic growth.	1	2	3	4	5

Development of the Haynesville Shale has increased employment opportunities in Louisiana	1	2	3	4	5
Development of the Haynesville Shale is positively affecting rural NW Louisiana	1	2	3	4	5
The use of hydraulic fracturing to develop the Haynesville Shale presents risk of environmental contamination.	1	2	3	4	5
The benefit of development outweighs the possibility of contamination presented by these risks.	1	2	3	4	5
The energy companies operating in Louisiana are adequately regulated.	1	2	3	4	5

Part 3 of 3

Feel free to answer as many or as few of these open-ended questions as you would like. When you are finished, click submit.

Where do you get updated information on the progression of Haynesville Shale development? (i.e. a particular website, organization, company…)

☐ www.gohaynesvilleshale.com

Do you have any suggestions for improving the availability of accurate information for Louisiana Citizens?

If you have concerns over the use of hydraulic fracturing, please describe them here:

Do you have any additional comments you would like to share?

Submit Previous

Appendix B: List of Accidents Related to Hydraulic Fracturing

Louisiana

1. Sixteen cows are found dead near a natural gas well. They apparently drank fluid leaked from the well site (Lustgarten, 2009).
2. Hundreds evacuated in South Caddo parish when a drilling rig hit an unexpected pocket of natural gas. The word blowout may be an overstatement, but there was concern that the gas from this pocket may have reached a potential USDW (Lustgarten, 2010).

Pennsylvania

1. A 30-mile length of Dunkard Creek experiences a fish kill estimated to be at 10,000 individuals. Blame is placed on a toxic algae bloom caused from mining water discharge into the stream (Ward, 2009).
2. A valve on a 21,000-gallon tank containing hydraulic fracturing fluid is left open. 13,000 gallons of fluid are estimated to have leaked. The majority was vacuumed up at the surface, but some ground contamination did occur (Donlin, 2010).
3. Livestock begin behaving erratically and dying after hydraulic fracturing takes place on a farm in Clearville. Blame is placed on arsenic, found in the farmer’s water. It is unclear where the arsenic came from (Bateman, 2010).
4. Property owner reports fracking has contaminated his water. Arsenic, benzene, and naphthalene are found in elevated levels. Ethylbenzene and trichlorethene are both recorded, the first being a chemical used for drilling (Hurdle, 2009).

5. A pit containing 400,000 gallons of hydraulic fracturing wastewater exploded, with flames up to 100 feet in height (Crompton, 2012).
6. 5,000 gallons of wastewater are leaked into a Cross Creek Lake tributary, where a fish kill was later reported (Shankman, 2010).
7. A pit containing 750,000 gallons of mixed fresh and wastewater overflowed into another small tributary (Legere, 2010).
8. A wastewater treatment plant handling post-fracking fluids exceeded the limit on total dissolved solids over a 70-mile length of the Monongahela River. Human health was not threatened, but tap water was gritty and smelly for a short amount of time (Hopey, 2008).
9. A wastewater pit in Avella, PA catches fire and burns for six hours (Lofholm, 2009).
10. Resident claims her private well water was contaminated after drilling began nearby. Water smells bad and has a greasy feel to it. Resident's son also claims it may have killed five of his goats over a 6-month period (Campbell 2010).
11. Two homes explode due to leaking method around a failed casing that filled their basements (Lustgarten, 2009).
12. Natural gas well explodes in Indiana Township, killing two (McKinnon and Fuoco, 2010).
13. Unmapped abandoned wells leaked gas when a new adjacent well was fracked. Gas escaped from the abandoned wells and into a nearby neighborhood (Lustgarten, 2009).
14. A gas well exploded in Jefferson Township, killing one and injuring another (Hopey, 2007).

15. Two to three cubic yards of bentonite (clay) were leaked into Tubmill Creek during a drilling operation. There were no harmful effects (Phraner, 2010)
16. Some were evacuated in Dayton, PA, when a new well's casing failed and methane was able to leak into an adjacent abandoned well (Lustgarten, 2009).
17. Seven tons of drilling waste dirt was dumped along Route 220 when the tailgate on a truck broke open (Loewenstein, 2010).
18. Gas and wastewater spewed from a wellhead for 16 hours on private land in the middle of Moshannon State Park, (Legere, 2010).
19. A service company was found responsible for contaminating the drinking water of seven homes (Bradford Era, 2009).
20. A gas well exploded in Leidy Township, with the blowout fire lasting 12 days (Runkle, 2008).
21. A service company was found responsible for leaking methane and ethane into a public well to cause a small explosion (Legere, 2010).
22. Three residents report their drinking water being contaminated after nearby drilling activity. The service company is supplying them with fresh water (Zemach, 2008).
23. A service company knowingly violates the CWA by injecting 200,000 gallons of brine produced from drilling into a nearby abandoned well (Shankman, 2010).
24. Residents complained of murky tap water following nearby drilling. The service company involved installed water filtration systems (Lustgarten, 2009).

25. A patented drilling mud substitute (Airfoam HD) leaked and contaminated Pine Creek. The violator was fined for violating the Clean Streams Law and Solid Waste Management Act (Donlin, 2011).
26. Methane reached five water wells and a stream near Muncy, PA following drilling activity. The responsible party is providing affected residents with potable water (Associated Press, 2011).
27. A spill of another patented chemical, this one a friction-reducer, closes a 10-mile length of road in three townships (Holmes, 2011).
28. Twenty-eight cows may have drank toxic fluids leaked from a well site in Tioga County (Reuters, 2010).
29. Thirty thousand gallons of waste fluid spilled from an overfilled pit. It was diluted enough and cleaned up promptly enough to avoid adverse effects (Legere, 2010).
30. A blowout in the Tioga State Forest let 21,000 gallons of hydraulic fracturing fluid to escape, (Aaron, 2011).
31. A truck leaked 100 to 200 gallons of hydrochloric acid over a stretch of 2.5 miles. The driver was hospitalized after trying to stop the leak (Legere, 2010).
32. Two-hundred and ninety-five gallons of hydrochloric acid was also leaked nearby at a well site when it was placed in an inadequate tank (Legere, 2010).
33. Dimock, PA, the star of *Gasland*, has had its fair share of accidents. One site alone leaked an estimated 8,000 gallons of drilling fluids (Bateman, 2010). Another spill nearby resulted in a reported fishkill (Legere, 2010). Two 800-gallon diesel spills happened in the same area one month apart (Legere, 2010). Pets have also

reportedly lost their hair, creeks have turned red, and at least one water well has exploded (Lustgarten, 2009).

34. Hundreds of gallons of diesel fule leaked into a Springville Township wetland from a well site (Legere, 2008).

Texas

1. Benzene was found at double maximum safe levels in a Wise County private well. The owners ay it was contaminated quickly after nearby drilling (Evans, 2010).
2. Eleven compressors for a natural gas pipeline station in Dish, TX have created several complaints (Burnett, 2009). In addition to the increased noise, residents complain of foul smells, nausea and respiratory problems. Elevated levels of benzene have been recorded near one of the compressors (Burnett, 2009). One nearby family has reported a decrease in the quality of their well water, and reportedly must replace a filter once every four to five days to keep it drinkable (Heinkel-Wolfe, 2010). Another nearby has had two horse get sick and one die since the installation of the compressors (Burnett, 2009).
3. Underground injection waste wells have been blamed for seismic activity near the Dallas/Fort Worth International Airport. The wells were injecting brine produced from fracked wells (Korosec and Polson, 2009).
4. A resident in Tarrant County reported gold-colored, sandy water following hydraulic fracturing jobs on his property (Smith, 2010).
5. A family in Johnson County, TX has filed a lawsuit against a nearby drilling company. They claim that their water turns orange and smells foul occasionally, and is

contaminated with chemicals associated with drilling. They refuse to drink it and are using only bottled water (Newton, 2010).

6. Earthquakes in Cleburne, TX are being blamed on hydraulic fracturing. 200+ wells have been drilled within the town's borders, and all of the seismic activity has occurred since (Casselman, 2009).
7. Three families near Grandview, TX in close proximity to one another report contaminated well water following fracking operations. Water tests show elevated levels of touluene. One family had three goats, two kids, and a llama all die in short succession (Gorman, 2008).

Vita

Crawford is the son of Richard and Wendy White, and was born and raised in Savannah, Georgia. He is the youngest of three, with an older brother and sister. Crawford graduated cum laude from Georgia Southern University in 2010 with a B.S. in Geology. He came to the Department of Environmental Sciences at LSU in the fall of 2010 to learn more about public policy and regulations in regards to the natural environment. Ever the curious mind, Crawford will go on to pursue a doctorate degree from the LSU Department of Geology and Geophysics.