WHAT THE SHALE? ENVIRONMENTAL RISK PERCEPTIONS OF HYDRAULIC FRACTURING

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Abstract

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The boom in U.S. natural gas production has sparked a national debate about the known and unknown environmental risks of hydraulic fracturing. This paper analyzes real and perceived risks as a means to illustrate and explain the rise of hydraulic fracturing on the public agenda.

Through literature reviews, data analysis, and expert interviews, we explain the processes that build public agendas by first (1) analyzing media coverage and public interest in hydraulic fracturing, then (2) evaluating stakeholder groups and their mental models for perceiving and valuing risk, and conclude with (3) synthesizing how Pennsylvania has managed risk related to hydraulic fracturing.

Our research findings will be useful to those aiming to influence and understand how mass media, general public, and a range of stakeholder groups perceive and manage the environmental risks of hydraulic fracturing.
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Foreword

In 1998 Mitchell Energy successfully drilled the first commercial shale gas well in the Barnett formation.\(^1\) An engineer by the name of Nick Steinsberger successfully combined horizontal drilling with “slick water fracturing,” achieving production levels that competitors previously believed to be unattainable.\(^2\) Soon after the technology was deployed in shale formations throughout the U.S. and, eventually, expanded into the development of both shale gas liquids and oil. Today, the EIA estimates total recoverable shale resources in the lower 48 states to be 750 Tcf of natural gas; enough to supply the U.S. for over 75 years at current consumption rates.\(^3\)

Over a short period of time the United States has experienced a substantial paradigm shift from net importer, to potential exporter of natural gas. Moreover, the versatility of natural gas as a fuel source (i.e. electricity production, heating, and transportation) provides an opportunity for the United States to lessen our dependence on coal and oil; fossil fuels whose combustion has a larger carbon footprint per unit of energy.

However, hydraulic fracturing of shale resources is not without real risks and costs. Events in Pavilion, WY and Dimock, PA have shown the tremendous damage that hydraulic fracturing can inflict on a community. Even the consumption of water, approximately 2 to 4 million barrels per well, can present a serious hazard to the environment (DOE 2009). Other issues are less known, such as fugitive gas emissions, which may mitigate the environmental benefits promoted by supporters of hydraulic fracturing. These uncertainties have led to moratoriums in New York and outright bans in Vermont.

Identifying and understanding the risks attributed to hydraulic fracturing are imperative for effective stewardship of environmental public policy.

The aim of this paper is to encourage meaningful discourse on the role of hydraulic fracturing in shaping our political agenda.

\(^1\) Where the Shale Gas Came From, Breakthrough Institute, May 2012
\(^2\) http://online.wsj.com/article/SB10001424052970203630604578075063683097342.html Accessed 3/18/2013
\(^3\) http://www.eia.gov/analysis/studies/usshalegas/ Accessed 3/15/2013
1. Introduction

The development of shale gas resources through hydraulic fracturing has quickly become a highly controversial domestic issue in recent years. While some benefits of shale gas development are known and measurable, such as the amount of oil or gas extracted, many of the environmental and societal costs of hydraulic fracturing remain unclear.

However, there has been no shortage of actors willing to provide certainty on hydraulic fracturing’s societal costs in alignment with their own values. Scientists believe government-funded research will greatly aid in our understanding of the environmental impacts. Politicians claim legislation can contribute to effectively managing societal costs. Celebrities plead moratoriums are necessary to ensure public and environmental safety. Industry explains that technical innovation has resulted in a process that minimizes risk to human health. Irrespective of their relative validity, this cacophony of opinion, facts, and values demonstrates the substantial upward movement of hydraulic fracturing on the public agenda.

This report aims to illustrate and explain this rise of hydraulic fracturing in the public agenda. We take the position that understanding the process of building the public agenda is an important step towards empowering actors to effectively shape how shale gas resources are developed in the future. Ultimately, the extent and methods of this development will bear both societal benefits and costs that have yet to be realized.

Our research concentrates on the perception and realization of environmental risk from hydraulic fracturing as a means to shed light on the societal costs of shale gas development. By using environmental risk as a common theme throughout our analysis, we explain the process that builds the public agenda. Understanding the actors and drivers in this process will be useful to those desiring to influence how the media, public, stakeholder groups, and government entities perceive and manage environmental risks.

In the context of our analysis, our framework (Figure 1.1) is used to illustrate the primary pathways that environmental risk perceptions follow to influence environmental outcomes. This report explores the framework from top to bottom by first analyzing media coverage and public interest in hydraulic fracturing, then evaluating stakeholder groups and their mental models for perceiving and valuing environmental risk, and finally concluding with a synthesis of how Pennsylvania has managed environmental risk related to hydraulic fracturing.

We have thus divided our report into three sections (Figure 1.2), which each work to explain different relationships within this framework through literature
review, data analysis, and expert interviews.

In Part I, we evaluate media coverage of hydraulic fracturing, public interest in hydraulic fracturing, and the relationship between the two. First, we break down media coverage of hydraulic fracturing to determine the primary actors and the keywords they use to frame the issue. Next, we gauge public interest in hydraulic fracturing to determine which geographical areas are most relevant and what keywords they use to express their interest in the topic. Finally, we explore a set of temporal case studies to evaluate the relationship between media coverage and public interest to determine key drivers in media coverage that most significantly impact public interest in hydraulic fracturing.

Whereas Part One considers public interest in the aggregate, Part Two identifies groups of stakeholders within the larger public that drive the public policy agenda governing hydraulic fracturing. We discuss each stakeholder group and their differing agendas in the hydraulic fracturing debate based on their respective perceptions of environmental risk. We consider the mental models that each stakeholder group uses to evaluate risk and analyze how these lenses influence current and expected future prioritizations of risk. We synthesize these varying risk perceptions into recommendations for how each stakeholder group can evolve their risk and policy agenda to further their values in the context of the hydraulic fracturing debate. Finally, we conclude this section with a contrast between stakeholder risk perceptions and the scientific literature findings published on the environmental risks related to hydraulic fracturing.

While Part Two identified the stakeholder groups and environmental impact risks that primarily drive public policy governing hydraulic fracturing, Part Three uses Pennsylvania as a case study to examine real-world examples of hydraulic fracturing risk governance. By classifying realized risk events in Pennsylvania according to their environmental medium and relative impact severity, we illustrate the relative successes and failures that stem from relying on public policy to influence environmental outcomes.

When taken as a whole, this report empowers actors to effectively shape how shale gas resources are developed in the future by explaining the public agenda building process for hydraulic fracturing.
2. Media Coverage of Hydraulic Fracturing

2.1 Theory

As illustrated in the public agenda building process framework presented in the introduction of this report, our analysis of the agenda building process begins by looking at media coverage of hydraulic fracturing. We will start off with a brief introduction to modern media theory to explain how the media plays a key role in influencing public perception.

There are two primary methods of communication: mass communication and interpersonal communication. Mass communication, enabled by modern technology, allows for actors to create messages and transmit those messages to large, anonymous, and heterogeneous audiences. This communication technique is at the opposite end of the spectrum from interpersonal communication, where messages are transmitted between small, known, and homogenous participants.

Dr. Bill Chameides, dean of Duke’s Nicholas School of the Environment, serves as an appropriate case study of an actor who uses both styles of communication to receive and transmit messages concerning the risks of hydraulic fracturing. In a June 2012 trip, Chameides led a group of his colleagues on an “eco-fact-finding” trip with the objective being to learn more about hydraulic fracturing and shale gas development in western Pennsylvania. This small, known, and homogenous group of message recipients sought to benefit from receiving interpersonal communication on their trip through dinners, tours, and interviews. Following the trip, Chameides employed mass communication by leveraging numerous media properties, including National Geographic, Huffington Post, and his Green Grok Blog to transmit messages about his experience to a large, unknown, and heterogeneous audience. This example, along with our conversations with other thought leaders in shale gas development, reveal that while interpersonal communication is the preferred method to gather and disseminate information, this approach is also very inefficient for both message senders and receivers. Mass communication is the preferred method of communication for messages about hydraulic fracturing because it is both inexpensive and scalable.

The content of Chameides’ research also provides insight into the purpose of hydraulic fracturing media messages. The stated purpose of Chameides’ trip, an “eco-fact-finding” tour, makes clear that the participants in the tour aimed to find facts. However, the tour was organized to not just find, but also to support widespread dissemination of those found facts. In this light, Chameides’ trip combines scientific and political behavior into an activity known as “science communication”.

While Chameides has perhaps a personal motivation and doubtless a professional responsibility to transmit scientific messages from the trip, it is worth considering why a mass audience should be interested in receiving them. Modern media theory, as explained in Karen S Johnson-Cartee’s book News Narratives and News Framing, explains that message recipients are motivated to receive scientific communication because their reality is socially constructed. Social constructivism is the sociological theory that an individual’s reality is not objective, but is rather developed by knowledge gained from communications throughout that person’s lifetime. By
receiving interpersonal and mass messages, such as those from Chameides, an individual is able to more effectively function in their own social reality.

Mass media does not only help define social reality, it also helps to expand it. Innovations in communication technology, from the printing press to the internet, have enabled individuals to efficiently receive and send messages that define and influence their own social reality. However, this efficiency has resulted in greater volume and variation in these messages, resulting in a more complex social reality. As an individual comes to see himself or herself as living in a more complex social reality, this heightens their dependency on mass media actors to help define that reality. Ball-Rokeach and DeFleur explain in their research on dependency models of mass media effects that, “As the social structure becomes more complex, people have less and less contact with the social system as a whole... The mass media enter as... information systems vitally involved in maintenance, change, and conflict processes at the societal as well as the group and individual levels of social action.”

Mass media coverage of hydraulic fracturing has thus been instrumental in supporting science communication and the public understanding of science. The public’s understanding of science, in turn, drives social action, which then affects the public policy agenda and ultimately physical environmental outcomes, for better or worse.

This conclusion is supported by agenda-setting theory, which was initially developed by journalism scholars Max McCombs and Donald Shaw in a study of the 1968 presidential election. In their research, they showed a very strong correlation between what residents perceived to be the most important election-year issues compared to the frequency and prominence of local news coverage on those same issues. Thus, McCombs and Shaw were able to conclude that the media agenda, expressed as the frequency and prominence of coverage, significantly impacts the public agenda.

Whereas the agenda-setting theory explains that the media is influential in telling the public what to think about, media framing describes the rhetorical packaging of a media message. Individual frames, or mental models, are then used to unpack media messages to interpret their social meaning. In some respects, agenda-setting speaks to the salience of an issue while media framing focuses on the salience of individual attributes of that issue.

2.2 Methods

To evaluate mass media coverage of hydraulic fracturing, we will focus on the United States and will analyze media properties across three metrics: (1) actors and influence, (2) coverage frequency, and (3) coverage framing. Influence will reveal who is covering the issue, frequency will demonstrate when they provided coverage, and framing shows how that coverage was provided. We selected three of the forms of media for our analysis: print, social, and broadcast.

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We utilized numerous databases and resources to evaluate the influence of media actors, their coverage frequency, and framing used to discuss hydraulic fracturing. For print media, we relied on Factiva\(^6\), a research tool that aggregates both free and licensed content from over 36,000 sources. This resource was chosen due to their depth of sources and the tool’s ability to handle complex search strings we created to most effectively search for articles on hydraulic fracturing and its similes. We narrowed our search to include nine of the most relevant media properties and their coverage throughout 2012.

We utilized two data sources for social media coverage: Twitter\(^7\), an online social microblogging service, and Topsy\(^8\), a social media and communication insight platform. Topsy was used to view total tweets, tweet impressions, and their proprietary sentiment scoring. Twitter was used to evaluate tweet content and influence, based on their proprietary Top Tweet ranking system. While other forms of social media exist, namely Facebook, Digg, Reddit, and others, we narrowed our analysis to only include tweets sent in 2012.

To analyze broadcast coverage, we utilized The Internet Archive\(^9\), a non-profit digital library that offers a tool to search and watch television transcripts. This resource contains a database of recorded television broadcasts and allows the user to search the closed captions associated with each program. Due to the geographical variance in network television programming, we narrowed our search to include only cable news broadcast throughout 2012.

Our media research covers the following (Table 2.1):

<table>
<thead>
<tr>
<th></th>
<th>Print Media</th>
<th>Social Media</th>
<th>Broadcast Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actors and Influence</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Coverage Frequency</td>
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<td>✓</td>
</tr>
<tr>
<td>Coverage Framing</td>
<td>✓</td>
<td>✓</td>
<td></td>
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</tbody>
</table>

Table 2.1 - Media Research Coverage included in this report.

### 2.3 Results and Discussion

#### 2.3.1 Actors and Influence

##### 2.3.1.1 Print Media

To determine the actors most relevant in print media coverage of hydraulic fracturing, we began with a list developed by Nate Silver of the New York Times that lists the top thirty media properties most commonly often cited for original reporting.\(^{10}\) We selected the top nine of these sources to represent relevant media actors for analysis and counted their frequency of hydraulic fracturing coverage in 2012 in alignment with the agenda-setting theory that found coverage frequency to be a good indicator each actor’s media agenda.

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\(^7\) [http://www.twitter.com/search](http://www.twitter.com/search) Accessed 4/24/13  
\(^8\) [http://pro.topsy.com](http://pro.topsy.com) Accessed 4/24/13  
However, we sought to adapt Silver’s work by using the number of outside citations referencing each media property’s coverage of hydraulic fracturing as a proxy for their influence on the issue. We repurposed Solver’s methodology to reorder and rank the sources by using Factiva to search for articles from our media actors that referenced hydraulic fracturing in 2012 and then counted both the number of articles published by each source and the number of times all other major media publications accessible through Factiva referenced each media actor’s hydraulic fracturing coverage in 2012. (Figure 2.1)

By comparing the number of articles published against the number of outside citations, the result of our analysis (Figure 2.2) makes clear that hydraulic fracturing coverage differs in frequency and in citations across comparable media properties. Media agenda-setting theory states that the more Bloomberg News is the most commonly cited source of news for hydraulic fracturing, despite publishing fewer articles than many comparable sources of news. Looking further at the articles and citations, we believe this is due to Bloomberg’s credibility in economic news related to shale gas development.

A comparison of similar media properties reveals that The Wall Street Journal provides a greater frequency of hydraulic fracturing coverage and outside citations compared to The New York
Times. The Washington Post significantly trails both WSJ and NYT in coverage and citation frequency.

The semi-strong correlation between coverage counts and citation counts imply that greater frequencies of coverage lead to a greater number of related articles, implying that media coverage on specific issues may be self-perpetuating to some degree. That is to say, the more a media actor covers an issue, the more other media actors will cover that issue. This is an important finding because it provides justification for our assumption that hydraulic fracturing coverage published by our nine selected sources is influential in determining the broader media agenda.

TAKEAWAYS:
- There is a wide variation in hydraulic fracturing coverage frequency by media actors
  - Media agenda-setting theory explains that this variation will drive recipients of each media outlet to reach different conclusions about the societal relevance of hydraulic fracturing
- Media coverage frequency is positively correlated with outside citations
  - Media coverage published by the selected nine media actors serves as an indicator for the broader media agenda

2.3.1.2 Social Media

Whereas we looked at the frequency of coverage and citations to identify and rank the most influential print media actors, our methodology to determine the most influential actors in social media relies on the relevance of Twitter’s algorithm to identify Top Tweets to simplify which coverage was most relevant out of the 528,000 tweets about hydraulic fracturing that were sent in 2012.

To determine which actors were most active and influential in social media, we searched for tweets on hydraulic fracturing and its synonyms on throughout the year 2012 in alignment with the agenda-setting theory that found coverage frequency to be a good indicator of the media agenda. We applied Twitter’s Top Tweets filter to the tweets, which we took to be the most influential of the tweets based on Twitter’s proprietary algorithms. From the approximately 6,500 resulting tweets, a list of the most frequently mentioned media actors, in this case, Twitter handles, was developed as a percentage of total mentioned media actors. (Figure 2.3)

By looking at the frequency of mentions of social media actors in Twitter’s Top Tweets related to hydraulic fracturing, we are able to identify and rank the most influential social media actors.
Assuming that Top Tweets are a representative sample of influential social media messaging, our analysis (Table 2.2) reveals that a wide variety of media actors, including celebrity activists, news blogs, journalists, editors, and concerned citizens are influential in leveraging social media to provide frequent and prominent coverage of hydraulic fracturing issues. However, the data reveals that the most prolific Twitter handle only accounts for 2.16% of the influential hydraulic fracturing tweets. This implies that no one actor in social media has significant ownership over influential tweets about hydraulic fracturing and would thus be unable to individually drive the social media agenda.

We also used Topsy to compare the total number of tweets sent about hydraulic fracturing to the total number of impressions these tweets had. On average, we found that each tweet sent about hydraulic fracturing receives 3,400 impressions, due to the number of followers of the tweet author, retweets from their followers, and so on. This large number speaks to the power and efficiency of social media as a mass communication tool with respect to hydraulic fracturing messages.

We also looked at the Sentiment Score provided by Topsy for the 2012 sample set of 528,000 total tweets. This score was 24/100, implying that negative coverage outweighs positive coverage 3:1 in social media. The algorithm used to determine this score is likely very imperfect, but generally reflects our expectations.

**TAKEAWAYS:**

- There is a wide variation in hydraulic fracturing coverage frequency by media actors
  - Media agenda-setting theory explains that this variation will drive recipients of each media outlet to reach different conclusions about the societal relevance of hydraulic fracturing
- Media coverage frequency is positively correlated with outside citations
  - Media coverage published by the selected nine media actors serves as an indicator for the broader media agenda

<table>
<thead>
<tr>
<th>Actor</th>
<th>of Total Coverage</th>
<th>Actor</th>
<th>of Total Coverage</th>
<th>Actor</th>
<th>of Total Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>@huffpostgreen</td>
<td>2.16%</td>
<td>@guardian</td>
<td>1.03%</td>
<td>@thinkprogress</td>
<td>0.48%</td>
</tr>
<tr>
<td>@gaslandmovie</td>
<td>1.94%</td>
<td>@350</td>
<td>1.00%</td>
<td>@yokoono</td>
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<td>@ecowatch</td>
<td>1.70%</td>
<td>@revkin</td>
<td>0.96%</td>
<td>@guardianeco</td>
<td>0.43%</td>
</tr>
<tr>
<td>@frackaction</td>
<td>1.66%</td>
<td>@foodandwater</td>
<td>0.90%</td>
<td>@bencubby</td>
<td>0.41%</td>
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<td>@motherjones</td>
<td>1.60%</td>
<td>@nytimes</td>
<td>0.72%</td>
<td>@rollingstone</td>
<td>0.41%</td>
</tr>
<tr>
<td>@nrdd</td>
<td>1.49%</td>
<td>@bloombergnews</td>
<td>0.66%</td>
<td>@fracknation</td>
<td>0.39%</td>
</tr>
<tr>
<td>@nygovcuomo</td>
<td>1.43%</td>
<td>@waterdefense</td>
<td>0.58%</td>
<td>@heritage</td>
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</tr>
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<td>@propublica</td>
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<td>@gristmill</td>
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<td>@txsharon</td>
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<tr>
<td>@huffingtonpost</td>
<td>1.09%</td>
<td>@seanonolemon</td>
<td>0.51%</td>
<td>@truthout</td>
<td>0.37%</td>
</tr>
</tbody>
</table>

Table 2.3 - Social Media Actors and their Percentage of Total Influential Tweets in 2012. This analysis reveals which social media actors were most influential.
2.3.1.3 Broadcast Media

We chose these four broadcast media actors due to the quality of data available from the TVArchive database. Ideally, we would have included networks like NBC, ABC, CBS, and FOX, but as programming on these networks varies nationally, we determined that cable news best represented broadcast media coverage due to its homogenous national programming.

By viewing and recording every news clip from these networks that references hydraulic fracturing in 2012, we were able to count the frequency of hydraulic fracturing coverage in alignment with the agenda-setting theory that found coverage frequency to be a good indicator of each actor’s media agenda. (Figure 2.4)

![Figure 2.4 – Approach to identify influential actors in broadcast media](image)

We have taken the approach of ranking the influence of selected cable news networks based on their overall viewership reported by third party research firms. This is an imperfect approach, because it is not in direct reference to hydraulic fracturing coverage like our approaches to evaluate print and social media actors. However, this was determined to be the best available option given the data constraints.

We developed a graph (Figure 2.5) to show the total influence of FOXNEWS, MSNBC, CNN, and CNBC using total 2011 viewership as a proxy for influence along with a sum of hydraulic fracturing coverage frequency in 2012. This analysis reveals that FOXNEWS has a solid lead in viewership against their cable news rivals and also leads MSNBC and CNN in coverage of hydraulic fracturing. As we noted in our discussion of print media coverage, Bloomberg was found to be a leader in print coverage of hydraulic fracturing as measured by outside citations due to their credibility as a
source of financial news. The high level of coverage offered by CNBC similarly reflects that media actors that focus on financial news highly value hydraulic fracturing coverage.

Excluding CNBC as an outlier, and assuming that 2012 viewership is similar to that of 2011, total network viewership appears to be very well correlated with hydraulic fracturing coverage, implying that perhaps this issue, or controversy represented by this issue, might fit into a broader editorial strategy that attracts more viewers.

**TAKEAWAYS:**
- There is a wide variance in hydraulic fracturing reporting among the four leading cable news networks
  - A network’s focus on financial news both drives increased hydraulic fracturing coverage, similar to print media
  - FOXNEWS and CNN, often considered to be rival networks, cover hydraulic fracturing at a similar frequency

### 2.3.2 Coverage Across Time

Previously, we depicted hydraulic fracturing media coverage as a sum total of the 2012 coverage to both determine the primary actors of coverage and illustrate how the actors in each media group compare against one another. Now, we want to add the time dimension to depict when coverage occurred throughout the year. Analyzing time patterns of coverage has the potential to provide further context to understand not only who is providing the coverage, but also when.

To that end, we formatted the same data used previously to count the frequency of coverage occurring in each Sunday to Saturday week of 2012 and produced the following stacked line chart to illustrate our results.

#### 2.3.2.1 Print Media

We developed a chart (Figure 2.6) to illustrate print coverage density across 2012 by week for all of our nine selected print media sources.

Weekly major media coverage frequency across 2012 was very dynamic. The top line of the graph gives an overall impression of when total hydraulic fracturing coverage was highest and lowest throughout the year.
Adding the time dimension to the data reveals how public events are reflected by the totality of print media coverage. In the week before the presidential election, coverage was squeezed out and moved down the media’s agenda. Alternatively, coverage was heightened across a number of major media sources in mid-June, which reflects a high density of newsworthy items that period, including the release of a new study on the seismic risks of hydraulic fracturing, North Carolina house approval of hydraulic fracturing, activist activity in New York, and other events.

We then sought to apply a weighting to the coverage based on the previously determined influence factor (Citation Count/Coverage Count). We hypothesized that it might be possible to calculate a better measure of coverage than by simply using article counts per time period. However, this measure was shown to be 93% correlated with pure article counts and was determined to be overly complicated. From this point forward, we determined that simple article counts were sufficient to effectively demonstrate how the agenda of major media changed over 2012 with regard to hydraulic fracturing.

Correlating coverage between these print media sources has the potential to reveal possible interdependencies that exist within the media. This correlation reveals the strongest relationship of our sources was between AFP and the BBC (r=.61). By summing all the correlations for each source, we were able to make a proxy for the source that least well correlates with other media sources, which turned out to be The Washington Post.

**TAKEAWAYS:**
• Coverage frequency is somewhat variable for each media property and for the cumulative coverage
  ○ Because coverage for each media property is so variable, cumulative coverage is a better measure of the media agenda than any one source’s coverage
• The media agenda exhibits interdependencies, for example, the AFP is three times more strongly correlated with the other print media sources considered than The Washington Post
  ○ Some sources are more relevant than others at gauging the broader media agenda

2.3.2.2 Social Media
We would also like to evaluate social media coverage over time. However, we found three different ways to measure tweets. First, we can count the number of Top Tweets on hydraulic fracturing provided by Twitter. Second, we can use Topsy to find the total number of tweets about hydraulic fracturing for any given week. Third, we can use Topsy to find the total number of impressions a tweet received.

Adding the time dimension to the social media data reveals how the social media agenda is reflected by the sum of total tweets, the number of total impressions of those tweets, and also by an increased frequency of Top Tweets.

Each of these three measures represents a different way to track social media activity, and it is worth considering which is the best approach (Figure 2.7)

All three of the measures peak in early December, the same period that print media coverage peaked in 2012. Interesting, the total number of tweet impressions skewed upwards during the week of September 23, 2012 for reasons that cannot be determined.

![Figure 2.7 - Weekly Social Media Coverage in 2012. Analyzing cumulative media coverage across time provides insight into the ranking of hydraulic fracturing within the media agenda.](image-url)
Later in this report, we will discuss and conclude that using the Total Tweet count provided by Topsy proved to be a superior measure of the social media agenda compared to Top Tweets and Tweet Impressions. This finding implies that when considering the two aspects of agenda-setting theory, frequency and prominence, frequency is the more important of the two.

**TAKEAWAYS:**
- Social media coverage frequency, as measured by total tweets, is less variable than print media coverage
  - The social media agenda is generally more stable than the print media agenda

2.3.2.3 Broadcast Media
Similar to our analysis of major media and social media, we developed a chart to illustrate broadcast coverage density across 2012 by week for the four selected cable TV networks (Figure 2.8).

Compared to print media and social media, broadcast media coverage is more volatile. Normalizing each media’s coverage to 100% and taking the variance shows that social media is least variable, print media is more variable, and broadcast media is in fact the most variable source of hydraulic fracturing media coverage. However, this may be due to the fact that there were 528,000 total tweets, 4,300 print mentions, and 430 broadcast mentions in our sample, allowing for the larger sample sizes to smooth variability.

The greatest cumulative volume of coverage occurred during the week of March 25th, but no common theme could be found to pinpoint why cumulative coverage peaked that week.

Similar to our analysis of print media, broadcast coverage has the potential to reveal possible interdependencies that exist within this form of media. This correlation reveals the strongest
relationship of our sources was between FOXNEWS and CNBC \( (r = .30) \). By summing all the correlations for each source, we were able to make a proxy for the source that least well correlates with other media sources, which turned out to be MSNBC.

**TAKEAWAYS:**

- Broadcast coverage is very volatile
  - Some sources are more relevant than others at gauging the broader media agenda
- Broadcast coverage peaks in early March while print and social media both peak in early December
  - Cumulative broadcast coverage does not appear to have a strong relationship with print or social media

2.3.2.4 Comparison of Print, Social, and Broadcast Media

We also wanted to normalize and compare total print, social, and broadcast media coverage over time to see the relationship between the media types. (Figure 2.9)

By interpreting media coverage frequency as a proxy for the media agenda in accordance with the agenda-setting theory, this analysis effectively illustrates where hydraulic fracturing falls within the agenda of each media type. The previous media coverage charts support this finding, as evidenced by the comparative variation in coverage experienced by each sampled media actor across time. Agenda-setting theorizes...
that these divergent media agendas will support a similarly divergent public agenda, as each individual’s exposure to hydraulic fracturing messages at any given time will greatly depend the media type and actors utilized.

However, the resulting chart also illustrates that there is a relationship between the print media agenda and the social media agenda \((r=0.65)\). Neither of these show a correlation with broadcast media.

**TAKEAWAYS:**
- The print and social media agendas have a significant correlation, whereas broadcast media is uncorrelated
  - Agenda-setting theory implies that a public that predominantly receives their information from broadcast media will develop an agenda that is out-of-step from those that utilize print and social media
- Measuring cumulative correlations across media actors for each type indicates which media source best represents the media agenda
  - If you could only monitor one source from print, social, and broadcast media, you should read AFP wires, follow @huffpostgreen, and watch CNBC

2.3.3 *Print and Social Media Frames*

By identifying primary media actors, evaluating their relative influence, and then observing their coverage across time, we illustrated the media agenda-setting process for hydraulic fracturing. To take it a step farther, we sought to get a sense for the hydraulic fracturing media frames by analyzing the language the media actors. This analysis will explain how print and social media talks about the public policy process, stakeholders involved, and environmental risks of hydraulic fracturing.

This analysis is based on word search frequency counts of the full-text of the same data used in the media agenda analyses. Thus, we conducted a word frequency search across the full-text of the 4,300 articles published by our sample of nine print media actors and the 6,500 Top Tweets published throughout 2012. Broadcast transcripts were not available, so broadcast media was excluded from this analysis.

After looking through the most commonly used keywords in both datasets, we developed a list of about 250 words that were most applicable to hydraulic fracturing coverage and created groups for categorization: public policy process, stakeholders, and environmental risk. These keywords were then sorted, recounted, and normalized so that the most frequent keyword in each media type was at 100%.

2.3.3.1 Public Policy Process

The way the public policy process is framed in relation to hydraulic fracturing is important because this language illustrates how an individual is empowered to take social action. Comparing the top 10 public policy process frames against one another begins to reveal the similarities and biases inherent in each media type.
Our results (Figure 2.10) are sorted with the highest cumulative relative keyword frequency at the top. “Study” was the most commonly used public policy process frame across print and social media, indicating that science is perceived to be an important driver of public policy by social and print media.

Social media is relatively more active in framing hydraulic fracturing as facing banishment and also more frequently uses other extreme public policy process frames, such as gags, secrets, and loopholes than does print media. Alternatively, print media most often frames hydraulic fracturing as a process that faces rules, legislation, and standards. Most other keywords used to describe the public policy process are fairly well distributed ($r=0.77, n=69$) between print and social media, except for the word “government”.

There were zero mentions of the word “government” in the Top Tweets provided by Twitter, whereas print media used this word relatively often. It could be the case that not one of the 4,300 influential tweets about hydraulic fracturing in 2012 used the word “government”. However, it is far more likely that Twitter is systematically filtering tweets containing this word out of the Top Tweets stream. This has serious implications for any media actor looking to influence the public agenda using twitter, as a tweet appears to likely receive less exposure if it contains this one word. This has serious implications for media strategists and for the transparency of Twitter’s methodologies that support their dissemination of social media.

**TAKEAWAYS:**

- Extreme public policy process frames are frequently used in social media
  - Use of these keywords in social media messages may increase their salience and influence (words like “gag”, “ban” and “loophole”)
- Twitter filters out certain words from their Top Tweets feed
  - Use the word “government” in a tweet will result in less public exposure

2.3.3.2 Stakeholders
The way stakeholder groups are framed in hydraulic fracturing coverage is important because this language illustrates which groups are expected to be most influential in, or most affected by, policies surrounding hydraulic fracturing. Comparing the top 10 stakeholder frames against one another begins to reveal the similarities and biases inherent in each media type (Figure 2.11).

Our results are sorted with the highest cumulative relative keyword frequency at the top. “Industry” was the most commonly used stakeholder frame across print and social media, indicating that those stakeholders that develop shale gas are perceived to be important by social and print media.

**TAKEAWAYS:**

- Social media and print media stakeholder frames are in close alignment
  - This finding lines up with our previous finding that show a relationship between social and print media coverage across time

2.3.3.3 Environmental Risk

One of the primary societal costs associated with shale gas development are the environmental risks that stem from hydraulic fracturing. By exploring what frames the media uses to discuss the environmental risks of hydraulic fracturing, we can then begin to understand what outputs, exactly, the media perceives to be important about hydraulic fracturing. Our approach to understanding the environmental risk frames was similar to public policy frames and stakeholder frames; we made a list of commonly used terms in print and social media, then counted how many times each term was used in our dataset and normalized the maximum frequency in each set to 100% to compare print against social media (Figure 2.12).

“Water” was most frequently used environmental-risk-related term across both print and social media. Most terms appeared pretty well distributed between the two ($r=.87, n=138$), with the notable exception being “earthquakes”. Put simply, social media appeared to be far more fascinated by earthquakes than did print media.
TAKEAWAYS:

- The most frequently used environmental risk frame relates to water
  - Water is a frequently used frame that transcends differences between social and print media.
- The most skewed environmental risk frame frequency relates to earthquakes
  - Earthquake frames are uniquely frequent in social media, compared to print media, implying that earthquakes have characteristics that are especially salient in social media.

2.3.4 Environmental Risk Coverage Across Time

Having evaluated the public policy process, stakeholder, and environmental risk frames in print and social media, we next wanted to understand how these frame frequencies varied throughout 2012. Analyzing time patterns of coverage has the potential to see trends in the coverage of specific risks. By understanding risk coverage trends, we are in a better position to understand the media’s role in driving the public and policy risk agenda for managing hydraulic fracturing’s risks.

Using the frames as a guide, we developed risk categories for eight different types of hydraulic fracturing risk: air, climate change, earthquakes, land, traffic, wastewater, water contamination, and water use. By analyzing how frequently these risks appeared in coverage throughout 2012, we can understand individual and cumulative trends in coverage (Figure 2.13).
TAKEAWAYS:

- Print media shows stronger use of air and climate frames than social media
  - Air and climate has been determined to be more relatively important from an editorial standpoint in print than in social media
- Social media shows stronger use of earthquake frames than print media
  - The earthquake risks of hydraulic fracturing are very volatile and salient to social media actors
- Generally, environmental risk frames are more volatile in social media than in print media
  - Demonstration of the “virality” that exists in the social media sphere

Figure 2.13 – Comparison of Environmental Risk Frames Across Time. This analysis shows how some frames are more frequent, or more variable, across different media outlets and actors.
3. Public Interest in Hydraulic Fracturing

3.1 Theory

When mass media messages are sent, it is often unclear who receives them, or who among the recipients finds these messages relevant. Moreover, it is difficult to understand which issues in the public agenda are most important and how the public likes their messages to be framed to most neatly fit into their social constructions.

Because keywords entered into search engines can be a useful resource for detecting people’s information needs\(^\text{11}\), we are able to thus use search engine keyword histories to understand the public information need for hydraulic fracturing information. By understanding who is searching, how they are searching, what they are searching, and when, we will have a better sense for the public agenda as it relates to hydraulic fracturing.

3.2 Methods

Google Trends is an extremely valuable tool that can be used to analyze the frequency and density of search, news, and shopping searches across states, metropolitan areas, and regions of the country. Most famously, Google works in partnership with the CDC to predict flu trends across the country by tracking searches for flu symptoms and then estimating the spread of the virus. This has shown to be extremely effective, and has given the CDC a new tool to understand virus outbreaks.

Google Trends can be used to determine the frequency and time period that any term, or group of terms, has been searched in the United States and globally. We will be using search data on hydraulic fracturing to understand how the issue has fared in the public agenda. As we used coverage frequency counts to quantify and understand trends in the media agenda, we will also use search frequency counts to quantify and understand trends in the public agenda.

3.3 Results and Discussion

3.3.1 Actors

First, we wanted to understand which states had the strongest interest in hydraulic fracturing in 2012. Google Trends does not report the absolute number of times a term is searched.

\(^{11}\) http://link.springer.com/article/10.1007%2Fs00354-007-0035-3?LI=true
Rather, all Google Trends results are normalized, with the greatest search density in each report normalized to 100%. A search across time will be normalized with the largest search frequency time period normalized to 100%, a search across states will have the state with the greatest frequency set to 100%, and a search of multiple terms will have the most frequently searched term set to 100%.

Searching for hydraulic fracturing and its similes in the United States for 2012 reveals the following, with darker colors indicating states where searches for hydraulic fracturing were the highest compared to the total number of searches (Figure 3.1 and Table 3.1).

<table>
<thead>
<tr>
<th>State</th>
<th>Interest</th>
<th>Region</th>
<th>Interest</th>
<th>City</th>
<th>Interest</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Dakota</td>
<td>100</td>
<td>Syracuse</td>
<td>100</td>
<td>Columbus</td>
<td>100</td>
</tr>
<tr>
<td>Ohio</td>
<td>78</td>
<td>Albany</td>
<td>84</td>
<td>Denver</td>
<td>82</td>
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<tr>
<td>Wyoming</td>
<td>76</td>
<td>Cleveland</td>
<td>63</td>
<td>Washington</td>
<td>67</td>
</tr>
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<td>Columbus</td>
<td>53</td>
<td>New York</td>
<td>66</td>
</tr>
<tr>
<td>Vermont</td>
<td>64</td>
<td>Pittsburgh</td>
<td>48</td>
<td>Austin</td>
<td>64</td>
</tr>
<tr>
<td>New York</td>
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<td>Denver</td>
<td>46</td>
<td>Houston</td>
<td>60</td>
</tr>
<tr>
<td>Montana</td>
<td>63</td>
<td>Raleigh-Durham</td>
<td>42</td>
<td>Philadelphia</td>
<td>55</td>
</tr>
<tr>
<td>West Virginia</td>
<td>61</td>
<td>New York</td>
<td>33</td>
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<td>59</td>
<td>Houston</td>
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<td>Minneapolis</td>
<td>46</td>
</tr>
<tr>
<td>North Carolina</td>
<td>49</td>
<td>Philadelphia</td>
<td>31</td>
<td>Chicago</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 3.1 – Breakdown of Public Interest in Hydraulic Fracturing by State, Region, and City. This analysis reveals areas with the most dense interest in hydraulic fracturing.

TAKEAWAYS:
• States near shale gas reserves have a greater interest in hydraulic fracturing
  - Proximity to shale gas reserves is a key precursor to driving the public agenda

3.3.2 Interest Across Time
Similar to our analysis of media coverage across time, we now want to look at public interest across time. Analyzing time patterns of public interest

Figure 3.2 - Public Interest in Hydraulic Fracturing Across Time. This analysis reveals that hydraulic fracturing is similarly variable in the public agenda as in the media agenda.
has the potential to provide further context to understand not only what cities, regions, or states are searching for information, but also when.

To that end, we mined the Google Trends database to determine when hydraulic fracturing searches occurred throughout 2012 (Figure 3.2).

**TAKEAWAYS:**
- Public interest across time is most highly correlated with social media
  - Social media activity is a relevant indicator of the public interest in hydraulic fracturing

### 3.3.3 Public Interest Frames
The public often is not just searching for hydraulic fracturing and its similes. Oftentimes, members of the public make more complex inquiries that can effectively provide context into the public agenda.

Fortunately, Google Trends also provides this data for any state, region, or city specified. The top 50 related search phrases in the United States for 2012 and their relative frequencies are as follows (Table 3.2).

<table>
<thead>
<tr>
<th>Search Phrase</th>
<th>Freq</th>
<th>Search Phrase</th>
<th>Freq</th>
<th>Search Phrase</th>
<th>Freq</th>
</tr>
</thead>
<tbody>
<tr>
<td>what is fracking</td>
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<td>fracking ny</td>
<td>20</td>
<td>fracking process</td>
<td>10</td>
</tr>
<tr>
<td>gas fracking</td>
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<td>20</td>
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<td>10</td>
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<tr>
<td>water fracking</td>
<td>65</td>
<td>fracking in ohio</td>
<td>20</td>
<td>fracking in texas</td>
<td>10</td>
</tr>
<tr>
<td>oil fracking</td>
<td>65</td>
<td>epa fracking</td>
<td>20</td>
<td>fracking fluid</td>
<td>10</td>
</tr>
<tr>
<td>natural gas</td>
<td>45</td>
<td>fracking chemicals</td>
<td>20</td>
<td>ban fracking</td>
<td>10</td>
</tr>
<tr>
<td>shale</td>
<td>45</td>
<td>shale gas</td>
<td>20</td>
<td>fracking for oil</td>
<td>10</td>
</tr>
<tr>
<td>fracking definition</td>
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<td>Pennsylvania fracking</td>
<td>20</td>
<td>fracking video</td>
<td>10</td>
</tr>
<tr>
<td>fracking natural gas</td>
<td>40</td>
<td>marcellus shale</td>
<td>15</td>
<td>fracking dangers</td>
<td>10</td>
</tr>
<tr>
<td>fracking ohio</td>
<td>40</td>
<td>fracking colorado</td>
<td>15</td>
<td>define fracking</td>
<td>10</td>
</tr>
<tr>
<td>shale fracking</td>
<td>40</td>
<td>north dakota fracking</td>
<td>15</td>
<td>fracking wiki</td>
<td>10</td>
</tr>
<tr>
<td>hydraulic fracking</td>
<td>35</td>
<td>frack</td>
<td>15</td>
<td>shale oil</td>
<td>10</td>
</tr>
<tr>
<td>fracking earthquakes</td>
<td>30</td>
<td>fracking in pa</td>
<td>15</td>
<td>fracking facts</td>
<td>10</td>
</tr>
<tr>
<td>new york fracking</td>
<td>30</td>
<td>fracking sand</td>
<td>15</td>
<td>no fracking</td>
<td>10</td>
</tr>
<tr>
<td>fracking companies</td>
<td>25</td>
<td>shale gas fracking</td>
<td>15</td>
<td>hydro fracking</td>
<td>5</td>
</tr>
<tr>
<td>epa</td>
<td>25</td>
<td>obama fracking</td>
<td>15</td>
<td>fracking documentary</td>
<td>5</td>
</tr>
<tr>
<td>fracking jobs</td>
<td>20</td>
<td>fracking earthquake</td>
<td>10</td>
<td>halliburton</td>
<td>5</td>
</tr>
<tr>
<td>fracking map</td>
<td>20</td>
<td>fracking movie</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3.2 - Queries Used in Hydraulic Fracturing Searches by the Public

Clearly the public is interested in a wide variety of information on hydraulic fracturing, including available employment, facts and definitions, risks, and explanatory videos.

**TAKEAWAYS:**
• When attempting to influence the public, media actors should use keywords that align with public interest
  ◦ There is a strong public interest in receiving local, not national, information on hydraulic fracturing

3.3.3.1 Public Policy Process
Previously, we evaluated which frames the media uses to discuss the public policy process related to hydraulic fracturing. These same keywords were searched in Google Trends to determine which frames the public uses for information seeking (Figure 3.3).

We experienced data limitations, and Google Trends was only able to return three keywords related to the public policy process. Interestingly, these three results are very similar to the top three frames used by social and print media in reference to the public policy process. “Study” being at the top now paints a clear picture: both media and the public view hydraulic fracturing studies as key drivers in the public policy process. Bans were also of strong interest to the public, showing this word’s strength as a public policy frame.

Interestingly, “legislation” was used more frequently in public inquiries than in social or print media, which preferred to use the term “rules”. This gap indicates an opportunity for media actors to start using the word “legislation” in place of “rules,” as “legislation” better connects with public interest on the topic.

**TAKEAWAYS:**
• Hydraulic fracturing studies are commonly covered by the media and are of frequent interest to the public
  ◦ Both media and the public view hydraulic fracturing studies as an important part of the public policy process

3.3.3.2 Stakeholders
By searching for stakeholder groups that the public use in their information seeking, we can identify the stakeholders they feel are most relevant to the issue of hydraulic fracturing (Figure 3.4).

Only one word was used frequently enough in Google searches to appear as a result: “companies”. “Companies” was print and social media’s second most commonly used stakeholder frame, so again, we see a strong alignment between media coverage and public interest.
TAKEAWAYS:

- Companies involved in hydraulic fracturing are commonly covered by the media and are of frequent interest to the public
  - The media and the public appear aligned in their belief that hydraulic fracturing companies are an integral part of public policy

3.3.3.3 Environmental Risk

By searching for environmental risk frames that the public use in their information seeking, we can identify which risks they feel are most relevant to the issue of hydraulic fracturing (Figure 3.5).

Much like print and social media, water ranks as the number one environmental risk frame used by the public. However, the high frequency of the earthquake frame resonates strongest with social media, as opposed to print media. The remainder of the frames are roughly aligned with those found in print and social media.

TAKEAWAYS:

- The public has strong information seeking needs related to water and earthquake risks of hydraulic fracturing
  - Print and social media have a good presence of water frames, but earthquake frames are lacking in print media

3.3.4 Environmental Risk Interest Across Time

As previously mentioned, when search terms are compared against one another, Google Trends normalizes the results to reflect the maximum frequency of a search term in any given time frame. By running a series of comparative searches, we were able to compare the environmental-risk-related terms previously developed in our Media Framing analysis to see which words were most commonly used across 2012 (Figure 3.6).
We searched for the same 8 risk issues applied previously in our major and social media risk agendas, unfortunately insufficient data was available to look at the following risks: Climate Change, Traffic, and Wastewater. This indicates that interest in these issues was so low that insufficient data was available from Google Trends.

The public has a relatively stable interest in environmental risk compared to media’s coverage of these risks.

**TAKEAWAYS:**
- The public has a relatively stable interest in environmental risk compared to media’s coverage of these risks
  - Certain issues covered by the media may vary in their salience
- The public has strong information seeking needs related to water and earthquake risks of hydraulic fracturing
  - The extreme volatility of earthquake risks indicate that the public interest may be quickly upturned under the right circumstances

*Due to data/input limitations, water use and water contamination were merged*

Figure 3.6 – The Public Environmental Risk Agenda in 2012. Interest in water risks was stable while interest in earthquakes was volatile.
4. Media Coverage and Public Interest in Environmental Risks

4.1 Theory

The agenda-setting theory states that media coverage drives public interest. In this section, we will test that theory using collected data to find interrelationships between media coverage and public interest.

4.2 Methods

First, the eight days in 2012 where public interest in hydraulic fracturing, as measured by Google Trends, increased by the largest percentage were identified. Next, the full text of media coverage on hydraulic fracturing was collected for those eight days. By then running contextual clues back through Google Trends, we were in a position to confirm that certain media events were primarily responsible for driving public interest in hydraulic fracturing.

4.3 Results and Discussion

In seven of the eight cases examined, public interest was found to spike due to a media event. The unrelated spike occurred the day after Thanksgiving, which, apparently, is a popular day to discuss or controversial societal issues with family. These results confirm that media coverage of hydraulic fracturing drives public interest in hydraulic fracturing. The takeaways from each of these interest-generating events are a good start to understanding which media events most effectively garner public interest.

4.3.1 Case #1

The results of our analysis for the week of January 22, 2012 can be seen in Figure 4.1 and Figure 4.2.

![Figure 4.1 – Case #1: National public interest spikes on January 25th]
TAKEAWAYS:
• The media event that spurred the public interest in hydraulic fracturing on January 25th was the day after the President’s State of the Union address, when Barack Obama publicly came out in support of hydraulic fracturing and shale gas development.
  o While social media quickly moved hydraulic fracturing up their agenda this day, it fell in both broadcast and major media agendas.
  o There was a wide variance in how hydraulic fracturing moved up the public agenda by state.

4.3.2 Case #2
The results of our analysis for the week of May 13, 2012 can be seen in Figure 4.3 and Figure 4.4.
TAKEAWAYS:
• The media event that spurred the public interest in hydraulic fracturing on May 17th was the banishment of hydraulic fracturing by the state of Vermont, which became the first state to explicitly ban hydraulic fracturing.
  o Social and broadcast media seized on this development, moving the issue quickly up their agendas, while major media was much less responsive.
  o This item gathered the most interest in states with relatively little average coverage.

4.3.3 Case #3
The results of our analysis for the week of July 1, 2012 can be seen in Figure 4.5 and Figure 4.6.
TAKEAWAYS:
• The media event that spurred the public interest in hydraulic fracturing on July 4\textsuperscript{th} was the accidental legalization of hydraulic fracturing by North Carolina General Assembly member Becky Carney.
  o Broadcast media seized on this development, as it made for great TV fodder.
  o This event also caused hydraulic fracturing to move up in the major and social media agendas, however their coverage was primarily on the day the vote occurred, July 3\textsuperscript{rd}, rather than July 4\textsuperscript{th}.

4.3.4 Case #4
The results of our analysis for the week of July 8, 2012 can be seen in Figure 4.7 and Figure 4.8.
TAKEAWAYS:

- The media event that spurred the public interest in hydraulic fracturing on July 14th was the appearance of Yoko Ono and Sean Lennon on Jimmy Fallon the prior evening.
  - This event gathered no significant change in broadcast, social, or major media agendas, which imply that network TV coverage would ideally be included in our initial research set.
  - It’s also notable that this event occurred on the weekend, where the news cycle slows and current events fall substantially in both the media and public agenda.

4.3.5 Case #5
The results of our analysis for the week of November 11, 2012 can be seen in Figure 4.9 and Figure 4.10.

**Figure 4.9 – Case #5: National public interest spikes on November 12th**

**Figure 4.10 – Case #5: National public interest spike on November 12th, broken out by state**

**TAKEAWAYS:**
- The media event that spurred the public interest in hydraulic fracturing on November 12th was the issuance of an International Energy Agency report stating that hydraulic fracturing and other developments could stop US oil imports by 2035.
  - The Texas public agenda responded most significantly to this development
  - This event brought on a great deal of broadcast coverage

4.3.6 Case #6
The results of our analysis for the week of November 18, 2012 can be seen in Figure 4.11 and Figure 4.12.

**Figure 4.11 – Case #6: National public interest spikes on November 23rd**

**Figure 4.12 – Case #6: National public interest spike on November 23rd, broken out by state**

**TAKEAWAYS:**
- There was no media event found that could have spurred the public interest in hydraulic fracturing on November 23rd.
  - This was the day after Thanksgiving.
  - After some research, this seems to be a day when public interest in many controversial topics increases.

4.3.7 Case #7
The results of our analysis for the week of December 2, 2012 can be seen in Figure 4.13 and Figure 4.14.

**Figure 4.13 – Case #7: National public interest spikes on December 5th**

**Figure 4.14 – Case #7: National public interest spike on December 5th, broken out by state**

**TAKEAWAYS:**

- There were two media events that spurred the public interest in hydraulic fracturing on December 5th: the disruption of a Boulder County, CO oil and gas hearing and the premiere of the movie “Promised Land”.
  - Given the activist displays occurred in Colorado, the state experienced a significant spike in public interest in hydraulic fracturing this day.

4.3.8 Case #8
The results of our analysis for the week of December 23, 2012 can be seen in Figure 4.15 and Figure 4.16.

**Figure 4.15 – Case #8: National public interest spikes on December 28th**

**Figure 4.16 – Case #8: National public interest spike on December 28th, broken out by state**

**TAKEAWAYS:**
- The media event that spurred the public interest in hydraulic fracturing on December 28th was the release of the first reviews for the movie “Promised Land,” which is a film with a focus on hydraulic fracturing.
  - Similar to the premiere of the film, print media again best publicized these reviews and was most reflective of the growth in public interest.
5.0. Perception of Risk from Hydraulic Fracturing By Stakeholder Group

Specific elements of the public agenda must be investigated more closely in order to understand the foundation behind differential understandings of hydraulic fracturing risks. While this public agenda is influenced by a variety of sources such as media, specific stakeholder groups within the general public can have polarizing views on the same issue, and are the ones who influence policy. The purpose of this section is to analyze why different groups of stakeholders’ understand and characterize fracking risks differently. Given the range of risk events, probabilities, and severities that media portrays, we assess how each stakeholder group prioritizes risks and where differences lie.

5.1 Methodology

(1) We reviewed the most recent public surveys that have been conducted in the U.S. in order to establish a basic understanding of how exactly media has impacted public opinion. This analysis also demonstrates the level of support/opposition to fracking of the general public. It is this level of support/opposition that each stakeholder group must appeal to as it drives towards its mission.

(2) We conducted literature reviews and analyzed stakeholder groups’ websites in order to construct mental models representing how each stakeholder group “perceives” fracking risks.

(3) We created a risk matrix to characterize risk events by fracking activity. Through phone conversations with stakeholders, we demonstrate the impact of different stakeholders’ mental models based on their current and future prioritized risks. We use this matrix and our mental models as a basis for providing recommendations for each stakeholder group based on how best they might be able to advance their missions.

We emphasize that the characterization of risk perception for each stakeholder group is based on a limited sample size of stakeholders, and is highly generalized. There certainly are numerous exceptions and variations to the perception of risk, both within and between stakeholder groups. We simply are attempting to broadly understand where the discrepancies lie in stakeholders’ understanding of fracking risks.

5.2 Players

The three main players within the fracking context are government, industry, and public (Figure 5.2). Government can be divided into federal, state, and local stakeholders; industry is composed of companies involved in various steps of the fracking process, lobbyists and trade organizations, and technical experts; the public is composed of NGOs and non-profit organizations, community action and grassroots groups, and academia.
There are five stakeholder sub-groups that were analyzed throughout this section: (1) Landowners and residents; (2) Industry and industry outreach campaigns; (3) Community activists and grassroots groups; (4) NGOs and non-profits (both those that are decidedly opposed to fracking, and with moderate views towards fracking; and (6) Local/state government.

To varying degrees, each stakeholder group takes action to spread their views, research, and recommendations surrounding fracking. Stakeholder actions are composed of a portfolio of activities: education, lobby, protest, research, advise, and moderate.

6.0. Survey Results on Landowner/Resident Stakeholder Perception of Fracking

The purpose of this section is to understand how U.S. citizens and residents perceive fracking and its accompanying risks. This builds a basic understanding of the general view of fracking held by the common citizen. This analysis is based on a compilation of results from seven surveys over the 2011-2012 period. We can attribute the results of this survey, in part, to the how the influence of media has played out on public opinion (as discussed in previous sections). The following surveys were analyzed:

<table>
<thead>
<tr>
<th>Survey Name</th>
<th>Date</th>
<th># Participants</th>
<th>Survey Method</th>
<th>Additional Notes &amp; References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Louisiana</td>
<td>2012</td>
<td>731 in</td>
<td>Telephone</td>
<td>Goidel, K., and M.</td>
</tr>
</tbody>
</table>

12 Adapted from http://sites.lafayette.edu/egr5251-fa11 fracking/files/2011/11/Picture81.jpg
|------------------------------|-----------------------------------------|-------------------------------------------------------------------------------------------------------|

Two aspects of all surveys are analyzed: (1) the level of support for fracking, (2) the level of environmental/health impact of fracking. Surveys results on these two questions will be displayed and discussed, followed by other interesting finds. It is important to note that while survey responses to similar questions are compared over time, the surveys were delivered in different formats, different geographic populations of people were sampled, and survey questions in each of the two aspects are not exact replicas in terms of wording.

6.1 Public Support for Fracking

While the general public demands continuous energy supply, many are apprehensive about simultaneously sacrificing the quality of other natural resources. However, a significant number of people value natural gas for its advantages, namely the economic benefits it may provide. In total, support for fracking ranged from 34.5% of survey respondents to 57% of survey respondents, with an average of 45.3% of respondents in support of fracking (Figure 6.1). Opposition to fracking ranged from 22% to 32%, with an average of 27.6% of respondents in opposition. Respondents who were unsure or did not know their stance on the issue ranged from 17% to 41.7%, with an average of 27.2% responding with uncertainty. This latter, large percentage of the survey population who has not yet chosen a position on the fracking issue may be highlighted targets for stakeholder groups whose mission is to educate and persuade citizens on fracking views.

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16 http://www.siena.edu/uploadedfiles/home/parents_and_community/community_page/sri/sny_poll/SNY%20December%202012%20Poll%20Release%20-%20FINAL.pdf
18 See Appendix A for Survey Questions and Answers
6.1 This graph demonstrates the percent of survey respondents who have responded either in support of, in opposition to, or neutral to fracking. Survey responses are recorded over time between Fall 2011 and March 2012.

Chronologically over several months, the level of support for, opposition to, and neutrality with fracking fluctuates. However, there is always more support for than opposition to fracking. There is also a high percent of uncertainty over the fracking issue, indicating that many survey respondents have not developed a firm stance on the issue. This may be due to the large amount of conflicting evidence and claims from media and other sources.

6.2 Public Perception of Environmental Impact of Fracking

Over time, the view of respondents on fracking as an environmental threat significantly shifts. Those who thought fracking posed an environmental threat composed between 14% to 60% of respondents within the surveys, with an average of 34%. 20.5% to 63% of respondents did not view fracking as a significant environmental threat, with an average of 39% responding that fracking was not a significant environmental threat. Between Fall 2011 and Spring 2012, the majority vote shifts from fracking as a threat to fracking as a non-threat (Figure 6.2).

The Louisiana Survey sheds an interesting light on the word “fracking”. When “fracking” was used in the survey question, 38.6% of respondents answered that states should encourage drilling based on the economic benefits but potential environmental harms. When instead of the use of the word “fracking” in the survey question, “the process of natural gas extraction occurring in fracking” was used, 51.6% of respondents stated that states should encourage drilling, with the potential for economic benefit but environmental harm. It appears that the word fracking has a negative connotation, perhaps because of the way it is used in media, or because “frack” stems

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19 See Appendix B for Survey Results
from “fracture”, which may bear a negative connotation based on its “breaking, separation, or discontinuity” definition.

The survey responses of the general public on fracking are important to bear in mind as we analyze the positioning of other stakeholders in the fracking debate, since the “general public” is one segment to whom stakeholder groups communicate their messaging. In the following sections, we use the opinions of the general public survey respondents as a building block for a more detailed understanding of specific stakeholder groups’ perceptions of environmental risk.

7.0 Using mental models: Understanding how stakeholders perceive fracking and internalize fracking risks

We create mental models for each stakeholder group to (1) understand the thought foundation that each stakeholder uses when perceiving fracking risks, (2) highlight the “most important” fracking risks as viewed by each stakeholder group, (3) create recommendations for each stakeholder group.

Mental models are diagrams of how people generate mental representations of problems in order to make inferences and decisions. Mental models consist of two kinds of elements: variables, which refer to various components of a problem, and relationships between variables, which describe the interdependencies among the components. They are most frequently drawn as influence diagrams, consisting of nodes representing variables and arrows representing causal relationships connecting the nodes.

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Figure 6.2 – This graph shows the percent of survey respondents who view fracking as an environmental or public health threat, over time. From Fall 2011 to March 2012, a significant increase in survey respondents who do not view an environmental/public health threat from fracking, coupled with a simultaneous decrease in respondents who do view fracking as a threat.

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Mental models can be representations, understandings, or views on a specific issue. Because peoples’ ability to represent issues is limited and specific to each individual, mental models are known to be incomplete representations of reality. Since mental models are context-dependent and can change according to the situation at hand, they are also inconsistent representations of reality\(^\text{21}\). Therefore, mental models typically are functional rather than complete/accurate realities.

The variables within models are influenced by a person’s goals and motives, background knowledge, or existing knowledge structures. Thus, mental models allow the subject to filter incoming information in a way similar to the confirmation bias (i.e. seeking information that fits one’s current understanding of the world). Incoming information may reinforce mental models or may be rejected\(^\text{22}\). This is especially relevant in contentious issues such as hydraulic fracturing. A stakeholder who has a pre-existing belief or opinion about fracking may be inclined to filter out the news and information that does not align with their belief, meanwhile assimilating the information that aligns to further substantiate their opinion.

**The importance of using mental models**

The reliance on mental models in place of applied or core science depends on the degree of “decision stakes” and “system uncertainties” related to a given issue\(^\text{23}\) (Kolkman et al., 2005). System uncertainties refer to the degree that an issue is concerned with the understanding or management of a complex reality. Decision stakes refer to the degree that various stakeholders associate different benefits, costs, and values with an issue.

When an issue falls in either the high uncertainty quadrant or the high decision stakes quadrant, the issue enters the political/societal arena and shifts away from the core-science arena (Figure 7.0 below). Groups of stakeholders form and each group searches for the solution that matches their best interest. Stakeholders use various forms of knowledge to defend their positions and to critique opponents’ arguments.

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\(^{22}\) [http://www.ecologyandsociety.org/vol16/iss1/art46/](http://www.ecologyandsociety.org/vol16/iss1/art46/)

Fracking is one such issue that falls in the high uncertainty quadrant and high decision-stakes quadrant. Thus, an extensive array of stakeholder groups has formed to engage in the debate. In such issues, mental model mapping has been used as a technique to analyze risk controversy and discrepancies in perceptions, assumptions, and knowledge in order to stimulate communication and learning. Through understanding these mental models, risk communication efforts can be targeted to complete a stakeholders’ perception of risk through adding critical missing information and dispelling miscommunications. For this reason mental models are frequently used in environmental risk communication.

The ability of different stakeholders to move towards agreement or policy conclusions depends on learning to understand one another’s point of view. To do this each stakeholder would need to incorporate—in terms of his/her mental model—the understanding of the issue in terms of the other’s mental model. Thus, mapping mental models assesses current knowledge, broadens narrow understanding, highlights alternative perspectives, encourages negotiation and helps to reduce conflict.

### 7.1 Methodology for drawing mental models

Mental models for each stakeholder group were developed through a series of steps to analyze each group’s understanding and portrayal of hydraulic fracturing. First, the websites of industry/trade associations, non-profits, and grassroots/community groups were analyzed for language, tone, and topical coverage. Through the use of NVivo Software, five websites of each...
stakeholder group were analyzed for the frequency of use of various risk-related words (Figure 7.1), and for the language used to portray risk (Figure 7.1.1).

Figure 7.1 - This graph shows the frequency of various risk categories mentioned on stakeholder websites, analyzed using NVIVO software. Community grassroots and environmental non-profit organizations websites mentioned various risk categories significantly more frequently than industry websites. Industry and industry trade websites mentioned road congestion risk more frequently.

Figure 7.1.1 – This graph analyzes the frequency of various inflammatory language on risk found on stakeholder websites, using NVIVO software. Community grassroots use more inflammatory language on websites to convey and express risk related to fracking. This may indicate emotion and fear are foundations to this stakeholder groups’ mental models.

Using this word frequency analysis as a foundation, we conducted a literature review on each stakeholder group, and followed up with phone conversations with select stakeholders. This research was used to create the mental models in order to approximate the thought process of each stakeholder group when considering fracking risks.
Carley and Palmquist (1992) justify this methodology, proposing that a mental model representation composed of concepts and relations can be extracted from documents or text. The structure inherent within text is a symbol of the full representation of an individual’s cognitive structure.\(^{28}\)

### 7.2 Mental Models by Stakeholder Group

We created mental model diagrams in attempt to depict various stakeholder groups’ foundations for understanding fracking and the thought process flow in relation to fracking. Each model demonstrates the mental flow of risk understanding. A detailed description follows each model.

#### 7.2.1 Mental Model of Industry Stakeholders

![Diagram of Industry Stakeholders](http://www.ecologyandsociety.org/vol16/iss1/art46/)

**Figure 7.2.1** - Industry stakeholders’ “mental model” of hydraulic fracturing risks. Arrows represent flows of thought between different aspects of risk. Each node represents different components, or steps, in the way that industry stakeholders perceive hydraulic fracturing risks.

\(^{28}\) [http://www.ecologyandsociety.org/vol16/iss1/art46/]


**Industry Model**

The mission of the industry stakeholder group is to economically extract natural gas to meet the energy demand of our nation, and to do so in the safest way possible.

Industry perceives fracking risks in two layers. First, risks are understood based on the stage of the hydraulic fracturing process. Resources for the Future divides the process into 6 steps: Site Development and Drilling Preparation (locating site, excavating area, drilling preparation); Drilling Activities (boring of well shaft, drilling lateral wells); Fracturing and Completion (hydraulic fracturing); Well Operation and Production (bringing shale gas brought up from ground, separating shale gas from other gases and liquids before sending to pipeline); Fracturing Fluids, Flowback, and Produced Water Storage and Disposal; and Other Activities (removing production tubing, plugging well, testing well integrity). Industry approaches these fracking activities through a safety lens, associating each of the activities with safety protocol such as process planning, site testing, continuous real-time well monitoring, process management, and regulatory compliance. Second, within these six steps of drilling, risks are understood in two categories: surface risks and subsurface risks. Industry views surface risks air emissions, water supply/water handling/water reuse & disposal, and surface impact/truck traffic/road and infrastructure damage. Subsurface risks include protecting underground water resources, and frac fluid disclosure. When safety protocol, management, and planning fail, these risks are realized.

Regarding surface considerations, Industry views road and infrastructure damage from truck traffic as the most frequent risk event impacting local communities. Community disruption in the form of noise pollution is also a prominent concern. Industry views issues associated with water handling, reuse, and disposal as preventable if operators develop integrated water management plans that cover all phases of the water-use process. This includes a basin-wide analysis of land characteristics, water quality, water uses. Industry prefers water disposal wells as the means of disposal after the fracturing process (as opposed to water recycling & reuse, and water treatment facilities). In order to avoid well stress during this process, the water disposal well method must comply with EPA rules regarding the volume and rate in which pumping and injection can occur. Increased fluid pressure occurs when fluids are injected at a high rate for a sustained period of time (i.e. not in compliance with EPA rules). If fluid pressure occurs on an existing geologic stress, movement along a fault can occur and trigger seismicity. However, industry sees compliance with legislation and implementation of a thorough geological survey as means to minimize risk.

Regarding air quality risks, the majority of emissions during the drilling process come from fuel combustion for engines and pumps, from the venting of methane and other VOCs during operation completion, and in storage tanks and compressor stations. These emissions are mitigated by reduction technologies such as catalytic reduction, ultra-low sulfur diesel fuel, oxidation catalysts, vapor recovery units, leak detection units, etc. Industry views the significant decrease in greenhouse gas emissions from the downstream use of natural gas (in comparison to other fossil fuels) as a necessary consideration when discussing air quality impacts.²⁹

²⁹ http://www.rff.org/centers/energy_economics_and_policy/Pages/Shale-Matrices.aspx
²⁰ Yale Webinar by Southwestern Energy Company.
In regards to subsurface considerations, industry notes a failure in well integrity as the main factor in almost all reported instances of water contamination. Industry believes a regulatory framework for ensuring well integrity throughout the life cycle can resolve groundwater contamination risks. Some companies are developing their own framework for ensuring well integrity, for instance, Southwestern Energy Company uses a safety protocol based on: 1) Evaluation of stratigraphic confinement; 2) Development of well construction standards based on best available state regulation; 3) Evaluation of mechanical integrity of well; 4) Monitoring of frac job and producing well (in real-time).

The bottom line in this mental model diagram is the pervasive emphasis on safety planning, and the realization of risks solely when industry does not frack responsibly: when complete and thorough safety and contingency planning is not realized, state and federal legislation is not abided by, and assessment and planning for the entire fracking process in a conservative manner is not accomplished. Industry stakeholders that take all the precautions minimize risks, except for community disruption caused by increased truck traffic.

7.2.2 Community Grassroots Organizations’ Mental Models

![Mental Model Diagram]

Figure 7.2.2.1 - Community Grassroots stakeholders’ “mental model” of hydraulic fracturing risks. Arrows represent flows of thought between different aspects of risk. Each node represents different components, or steps, in the way that Community Grassroots stakeholders perceive hydraulic fracturing risks.
The mission of community grassroots groups is to protect their family, neighbors, and community environment. The main concern of community grassroots and activist groups is that the development of local plays, such as the Marcellus Shale, will have major environmental and health impacts. Many of these stakeholders seem to distrust both industry and state government, and want to see a permanent ban on natural gas drilling or a moratorium until comprehensive scientific studies and adequate legislative safeguards are implemented.

Community grassroots organizations see nearby fracking as a threat to environmental and public health. They believe that industry does not take adequate measures to ensure the safety of their operations and to mitigate the adverse environmental/health effects. They also view government stakeholders as failing to implement adequate legislation to ensure risks are not realized.

This stakeholder group perceives a range of risks resulting from industry fracking: with emotionally-charged arguments, they cite instances of drinking water source contamination by “explosive methane”\(^{31}\) and other dangerous substances that can cause cancer and other illnesses, runoff of toxic chemicals from drilling operations that harm streams and aquatic habitat, farmers’ livestock with health symptoms in close proximity to fracking operations, drilling emissions from rigs/storage tanks/truck traffic that contribute to harmful ozone levels, and methane emissions from production sites and pipelines that contribute to climate change and air pollution. In addition to environmental and health risks, this group emphasizes the risk of community degradation from fracking. The temporary “settlement” of industry within a community can decrease property value, drill operations can decrease aesthetic value of a community, and truck traffic can harm infrastructure and roads.

Community activist groups that are anti-fracking are either staunchly opposed to fracking—regardless of safeguard—or are opposed to fracking until robust scientific research and strict laws are in place. For instance, a local Pennsylvania NRDC chapter calls for the following stipulations before budging from their anti-fracking stance\(^{32}\):

- Compliance with sections of the Safe Drinking Water and Clean Water Acts from which industry is currently exempt
- Compliance with sections of the Clean Air Act from which industry is currently exempt
- Strengthening restrictions on noise and traffic
- Subject fracking waste to the Resource Conservation and Recovery Act
- Including industry in the EPA’s Toxics Release Inventory to disclose chemicals
- Baseline testing and monitoring of air and water quality
- Establishment of meaningful penalties for breaking law.

On the other hand, some organizations within this stakeholder category do not propose these policy and control mechanisms, but instead a hard stop to fracking regardless of safeguard. They are outraged by fracking in their community and devote efforts to advocacy efforts and outreach campaigns against fracking.

7.2.3. NGOs and Non-Profits Mental Models

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\(^{32}\) http://www.nrdc.org/energy/files/frackingrisks.pdf
The foundation for NGO mental models is their environmental mission, whether it be a specific mission such as better air quality or wilderness promotion, or more general such as environmental protection or climate change action.

NGOs tend to take a more measured approach to fracking risks. For instance, NGOs such as Environmental Defense Fund believe that substituting natural gas for coal may be able to net environmental value, including lower greenhouse gas emissions. This group of stakeholders also recognizes the harm that natural gas production can inflict on environmental and human health. Therefore, they devote significant resources towards advocating for effective regulation on the natural gas industry that controls for these impacts. EDF concludes that there are many processes to eliminate the hazards and reduce the risks from fracking, and opines that strong rules that
require such processes, backed by “effective oversight and enforcement with the necessary financial and human resources”, can help alleviate risk events.33

Because a largely touted benefit of natural gas usage is the reduction in carbon emissions and greenhouse gas reductions, a big concern of this stakeholder group is the uncertainty around methane emissions during the fracking process (ie during flaring and leakage). They advocate for a greater focus on methane leakage, and underscore the need to better understand—and mitigate for—climate impacts from methane leakage. NGOs are also concerned with leaks and spills from failure in drilling casing that may affect groundwater, and spills that could contaminate surface water. Ensuring a flawless method for disposal of frack wastewater is vital to risk alleviation.

Environmental non-profits have developed a mental model based on the understanding that natural gas and hydraulic fracturing are not going away. Therefore, their interpretation of risks is to work to eliminate and control for them, as opposed to what they view as an irrational goal of eliminating the fracking industry. The risks to water, air, and communities are viewed as avoidable in many cases through tough rules, oversight, and penalties for noncompliance.

The stakeholder group accepts that natural gas is entrenched in the U.S. economy, and that advocating for renewables and energy efficiency alone will not fully address the environmental impacts associated with producing it.34

Figure 7.2.3.1 summarizes the fundamental differences in processes and conclusions within these stakeholders’ mental models of fracking risk. These differences can be classified in four buckets: the foundation of the risk opinion; the flow of decisions and conclusions within the model; the view on repercussions of risk; and finally, the overall model characterization.

33 http://www.nytimes.com/2012/02/28/opinion/nocera-how-to-frack-responsibly.html?_r=0:
34 http://blogs.edf.org/energyexchange/2012/04/10/what-will-it-take-to-get-sustained-benefits-from-natural-gas/
8.0 Stakeholder Conversations: Prioritized Risks, Present and Future

To conclude this study of stakeholder perception of risk, we conducted targeted outreach to industry, government, and community activist groups. The goal was to understand how these mental models impact the risks that stakeholders prioritize. Specifically, we aimed to assess how stakeholders currently prioritize risks related to hydraulic fracturing, and how they anticipate their prioritization of risk would change 3-5 years from now. This will allow us to understand where each stakeholder group is focusing its resources (time and money), and where the mismatch in risk prioritization lies.

Each conversation was based on the risk matrix depicted in Figure 8.0, with risk categories on the x-axis, and development activities in the hydraulic fracturing process on the y-axis:
Fluid Storage & Disposal

Figure 8.0 - Risk Matrix that is used in each stakeholder conversation to analyze how stakeholders differentially prioritize risk. Risk categories are listed across the x-axis, and development activities in the fracking process are listed across the y-axis.

Stakeholders were asked to discuss which areas they felt represented the most important risk pathways. Below, we review the responses from conversations with each stakeholder group. We supplement our discussion of each stakeholder group with results from Resources for the Future’s expert survey, “Pathways to Dialogue: What the Experts Say about the Environmental Risks of Development”, a survey-based, statistical analysis of experts from government agencies, industry, academia, and nongovernmental organizations to identify the priority environmental risks related to shale gas development.

8.1 Stages of the Drilling Process

Below, we describe the sub-activities within each of the five “shale gas development activities” that relate to each risk category. Risks can be realized during multiple stages of the fracking process, and can be pinpointed to specific sub-activities within each development activity. Using Resource’s for the Future’s Risk Matrix, we categorize the activities and stages of the drilling process into five main activities, each including multiple sub-activities:

1) Site Development and Drilling Preparation: After site location, area must be prepared for the hydraulic fracturing
   a. Land clearing/Construction of roads, well pads, pipelines, infrastructure
   b. On-road/off-road vehicle activity

2) Drilling Activities: A vertical well shaft is bored into the targeted formation, followed by drilling one or more horizontal wells through the shale formation from the end of the vertical wellbore.
   a. Drilling equipment operation at surface
   b. Drilling of vertical and lateral wellbore
   c. Casing and cementing
   d. On-road/Off-road vehicle activity
   e. Use of surface water and groundwater
   f. Venting of methane
   g. Flaring of methane
   h. Storage of drilling fluids at surface
   i. Disposal of drilling fluids, drill solids, cuttings

3) Fracturing and Completion: Hydraulic fracturing is characterized by a mix of sand, water, and additives being pumped into the wellbore at high pressure. This fractures the shale rock.
   a. Use of surfacewater/groundwater
   b. Perforation of well casing/cementing
   c. Hydraulic fracturing initiation
   d. Introduction of proppant
   e. Flushing of wellbore
   f. Flowback of reservoir fluids
   g. Venting of methane
h. Flaring of methane
i. Storage of fracturing fluids at drill site

4) Well Operation and Production: Shale gas is brought up from the ground through the borehole, separated from other gases and liquids, and later sent to pipelines.
   a. Well production
   b. Condensate tank, dehydration unit operation
   c. Compressor operation
   d. Flaring of methane

5) Fracturing Fluids, Flowback, and Produced Water Storage and Disposal: The several million gallons of water required in the fracking process must be stored, treated, and disposed of during this stage.
   a. On-site pit or pond storage
   b. On-site tank storage
   c. Transport off-site
   d. On-site treatment and reuse
   e. Treatment, release by industrial or municipal wastewater treatment plants
   f. Removal of sludge and other solids to landfills
   g. Deep underground injection
   h. Application of wastewater for road de-icing, dust suppression

8.2 Risk Matrices

8.2.1 State Government

<table>
<thead>
<tr>
<th>Shale Gas Development Activity</th>
<th>Risk Category</th>
<th>Risk Priorities Today</th>
<th>Risk Priorities in 3-5 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Development &amp; Drilling Preparation Drilling Activities</td>
<td>Ground-water</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Fracking &amp; Completion</td>
<td>Surface Water</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Well Production &amp; Operation</td>
<td>Air Quality</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Fluid Storage &amp; Disposal</td>
<td>Habitat Disruption</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Community Disruption</td>
<td>M</td>
<td></td>
</tr>
</tbody>
</table>

Figure 8.2. - Risk matrix depicting future risk priorities as anticipated by government stakeholders: today and 3-5 years in the future. Risks that are high priority (highest probability, high severity) to government stakeholders are labeled with an "H". Risks that are medium priority are labeled with an "M". Priority classifications are based on phone conversations with stakeholders.

The assessment of the state government opinion is based on conversations within former and current employees in state departments of environmental protection and city government employees, in concert with results from Resources for the Futures’ Expert Survey.

As seen in Figure 8.2.1, government is focused on addressing the development of effective policy to regulate the gas industry and act in the best interest of the public sector. Their goal is to
develop legislation that effectively manages natural resources such as natural gas, land, and water, while simultaneously promoting economic development within the state. State government stakeholders immediately reacted to absence in the matrix of the risk of *not* using gas instead of coal. Not using natural gas presents a much greater risk through its alternative—the use of coal. Stakeholders opined that the siloed conversation on natural gas risk leaves out the conversation on detrimental environmental impacts of using coal and oil instead of gas.

When focusing exclusively on natural gas and its risks, the three most significant risks according to government stakeholders were (1) surface spills and leaks, (2) air emissions, and (3) subsurface methane migration as a result of the drilling activities. They noted that frack fluids coming from depth and contaminating aquifers is an unlikely risk event, with the possible exception of Pavillion Wyoming where irresponsible fracking practices were to blame.

Surface spills and leaks can occur in several stages of the fracking process. A surface spill or leak can impact surface water in the region, but also can seep into groundwater if it is not contained or properly managed. The matrix highlights the following four activities and their activity pathways that government stakeholders prioritize as high risk for surface spills and leaks that may impact surface/groundwater:

- **1) Drilling activities**
  - Drilling equipment operation at surface → Drilling fluids and cuttings
  - Storage of drilling fluids at surface → Drilling fluids and cuttings
- **2) Fracturing & completion**
  - Storage of fracturing fluids at drill site → Fracturing fluids infiltration to water
- **3) Well production and operation**
  - Well production → Flowback & produced water constituents
- **4) Fluid storage & disposal**
  - On-site pit or pond storage → Fracturing fluids, flowback, produced water constituents
  - Treatment, release by wastewater treatment plant → Fracturing fluids, flowback, produced water constituents
  - Deep underground injection → Flowback and produced water constituents
  - Application of wastewater for road deicing, dust suppression → flowback and produced water constituents

Air quality risks can occur through the following two activities:

- **1) Drilling activities**
  - Venting of methane
- **2) Fracturing & completion**
  - Venting of methane

Subsurface methane migration concerns occur during the following fracking activity:

- **1) Drilling activities**
  - Casing and cementing → Methane

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In looking out 3-5 years from 2013, stakeholders believe that surface spills and leaks will be the most significant risk consideration. They note that this risk is mainly a safety operations issue, and attention to detail, clear operations protocol, and safety checks are needed. Further, added safety can be built into operations through systems that incorporate the possibility of a spill/leak. Industry can anticipate safety issues through creating infrastructure upfront to contain accidents. Government stakeholders believe air emissions would not be a critical risk due to readily available methods to cut emissions. Air emissions reductions also rely on state legislation to mandate green completions. In addition to green completions, air emissions can be reduced by using best available pollution controls on compressor stations; fuel switching from diesel to gas for gas drilling rigs and fracking pumps; and excellent maintenance of gas delivery infrastructure. Stakeholders believed that these four strategies could reduce total air emissions from drilling by up to 90%.

8.2.2. Community Grassroots Organizations

![Risk Priorities Table]

Figure 8.2.2 - Future risk priorities as anticipated by government stakeholders: today and 3-5 years in the future. Risk matrices were created based on phone interviews and conversations with stakeholder groups.

Conversations with community grassroots stakeholders from the Marcellus Shale region indicated a diverse array of concerns related to major downstream effects of development. Stakeholder groups that had formed to represent fishing and river interests expressed fears of inadequate safeguards to protect local rivers, especially in the case of accidental spills and fear of contamination of drinking water. Other stakeholder groups that were united around a more general community cause expressed concerns with various health risks and a new legacy of pollution.

As seen in Figure 8.2.2, according to community grassroots, the most significant risks involved in fracking are: (1) freshwater withdrawals during drilling and fracturing; (2) methane emissions during drilling and fracturing; (3) VOC and air pollution during well production and completion; (4) surface- and ground-water pollution from drilling fluids, flowback, fracturing fluids, and produced water constituents during all steps of the drilling and fracturing processes; and (5) habitat fragmentation.
Below, we specify the corresponding fracking activity step and risk pathway for each of the risks identified by community grassroots organizations.

Freshwater withdrawals during drilling and fracturing:

- **1) Drilling activities**
  - Use of surface water & groundwater
- **2) Fracturing & completion**
  - Use of surface water & groundwater

Methane emissions:

- **1) Drilling activities**
  - Venting of methane
- **2) Fracturing & completion**
  - Venting/flaring of methane

VOC and air pollution:

- **1) Well production & operation**
  - Condensate tank, dehydration unite operation
  - Compressor operation
- **2) Fluid storage & disposal**
  - On-site pit or pond storage

Surface- and ground-water pollution:

- **1) Site development & drilling preparation**
  - Clearing of land/construction of roads, well pads, infrastructure → Stormwater flows
- **2) Drilling activities**
  - Disposal of drilling fluids → Drilling fluids & cuttings
- **3) Fracturing & completion**
  - Flowback of reservoir fluids → Flowback & produced water constituents
  - Storage of fracturing fluids at drill site → Fracturing fluids
- **4) Well production & operation**
  - Well production → Flowback & produced water constituents
- **5) Fluid storage & disposal**
  - On-site pit or pond storage → Flowback, produced water constituents, fracturing fluids
  - Treatment, release by wastewater treatment plants → Flowback & produced water constituents
  - Application of wastewater for road deicing, dust suppression → Flowback & produced water constituents

Habitat fragmentation:

- **1) Site development & drilling preparation**
  - Clearing of land/construction of roads, well pads, infrastructure

Community grassroots stakeholders did not anticipate significant changes in risk prioritization 3-5 years into the future. They viewed risks to habitat, surface water, and groundwater throughout the fracking process as a constant threat. This seems to be somewhat tied to distrust of industry and government. Stakeholders do not believe in industry’s ability to both successfully manage all risks and understand the domino effect of fracking on community and environment.
Stakeholders did foresee air pollution risk from methane emissions lowering in risk priority, however.

### 8.2.3. Industry

#### Risk Priorities Today vs Risk Priorities in 3-5 years

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<thead>
<tr>
<th>Shale Gas Development Activity</th>
<th>Risk Category</th>
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<tr>
<td>Site Development &amp; Drilling Preparation Drilling Activities</td>
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<td>Fracking &amp; Completion</td>
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<td>Fluid Storage &amp; Disposal</td>
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<td>Fluid Storage &amp; Disposal</td>
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**Figure 8.2.3.** - Future risk priorities as anticipated by government stakeholders: today and 3-5 years in the future. Risk matrices were created based on phone interviews and conversations with stakeholder groups.

Industry stakeholders noted the near impossibility in prioritizing one risk category over another: risk priorities vary based on geography, community size, climate conditions, and other local circumstances. Industry noted the high priority they place on all risk categories, and the need to build a program that minimizes as many possible risks overall.

As seen in Figure 8.2.3, risks with highest severity and highest probability are (1) fluid storage and disposal risk to groundwater and surface water; and (2) spillage during transportation and transfer points risk to groundwater. Medium risks were (1) spillage during fracturing and completion risk to groundwater; (2) air quality. While other risks not ranked as “high” priority because are important aspects of risk management and business activities, industry believes they are able to manage these risks well.

Below, we specify the corresponding fracking activity and risk pathway for each of the risks identified by industry.

**Groundwater and Surface-water Risks:**
- 1) Fluid storage and disposal
  - On-site pit or pond storage $\rightarrow$ Flowback & produced water constituents, fracturing fluids
  - Treatment, release by wastewater treatment plants $\rightarrow$ Flowback & produced water constituent
- 2) Fracturing & completion
  - Flowback of reservoir fluid $\rightarrow$ Flowback & produced water constituents
  - Storage of fracturing fluids at drill site $\rightarrow$ Fracturing fluids

**Air Quality:**
- 1) Fracturing & completion
  - Venting of methane $\rightarrow$ Methane leakage
Anticipating how risk priorities will shift 3-5 years into the future, industry stakeholders believed risk to ground- and surface- water from fluid storage and disposal would be significantly reduced through technological improvements in impoundments. Air quality risks will be diminished through new technology and increased legislation, conversion of fleet/drilling engines to natural gas, catalyst technology on drill rigs, no-bleed controllers on pneumatic pumps, more frequent testing for fugitive emission leaks, etc.

A common thread between all stakeholders is the belief that risks will diminish—at least slightly—over the next 3-5 years through technological advancement and new regulation. Specifically, air quality risks in the form of on-site methane leakage have high potential to significantly diminish. All groups emphasized the critical role of upfront investment in robust risk management planning, from pre-drilling subsurface analysis to continuous real-time monitoring.

Community grassroots stakeholders placed high priority on the same categories of risks (ie groundwater, air quality, surface water, habitat fragmentation) as government and industry stakeholders; however, they noted many more risk pathways throughout the fracking activity processes. Unlike the other stakeholder groups, community grassroots groups also did not believe risk priorities would significantly change 3-5 years from now (aside from slight air quality mitigation), and did not anticipate future industry practices or regulatory changes that would significantly curtail risk throughout the process.

### 9.0 Recommendations to Stakeholder Groups

In understanding the mental models of each stakeholder group, targeted recommendations for each group were developed based on each stakeholders’ mission in relation to fracking policy. Based on the impartial viewpoint of this Master’s Project, these recommendations are intended to advance the goals and missions of each stakeholder group individually.

**Recommendations for Industry**

In the long term, companies that address stakeholder concerns honestly and effectively will earn a competitive advantage. There is a critical gap in the way community activist, community resident, and local environmental group stakeholders understand fracking risks, and the manner in which industry stakeholders respond. Dramatized effects of fracking, such as people getting sick, tap water catching fire, are documented in press reports and movies like Gasland. However, responses and public relations efforts from industry do not engage enough with concerned stakeholders, and fail to address environmental issues strongly enough. Instead, industry focuses on the economic benefits of drilling, and speaks *at* stakeholders through television ads that highlight energy security.\(^{37}\)

Industry response to stakeholder demands is fodder for the continued discrepancy in stakeholders’ mental models of fracking. For instance, two current salient issues for Pennsylvanians are the disclosure of fracking chemical composition, and a severance tax on natural gas production. In regards to the disclosure issue, industry fought hard and won to not be regulated under the Clean Water Act of 2005. Therefore, industry does not need to disclose the

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chemicals used in fracking fluid, which is considered proprietary. This effort has likely resulted in fodder for anti-drilling stakeholders through further reinforcing the “slippery”, “evil” industry characters in their mental models.  For example, grassroots community groups likely believe that industry is “hiding” a fracking risk because of the effort to avoid subjection to disclosure laws, thus reinforcing the link of fracking to groundwater risks in mental models of community grassroots stakeholders. Further, industry’s opposition to a severance tax, used to build better roads that can withstand the increase in truck traffic or hire inspectors to oversee regulations and minimize accidents, has also contributed to discrepancies in mental models. This could contribute to some stakeholders’ perception of industry as having a lack-of-concern about their impact to communities and a sole interest in profit.

Therefore, for shale gas to continue becoming the true game-changer in the U.S. economy, industry must leap over extensive reputational and regulatory hurdles. Industry will need to elaborate, communicate, and educate in a way that makes up for gaps in knowledge by improving and “correcting” mental models and thereby having an indirect impact on people’s decisions.

To make this leap, there are a few actions industry can take:

1. Acknowledge prior risk events and current problems in order to become more accountable and transparent. Industry should acknowledge legitimacy of local grievances as opposed to blaming communities for unwarranted fear or misperception. In order to build public trust and acceptance, industry should move towards greater transparency and voluntary disclosure of frac fluids, a major point of contention. Instead of focusing on the presumed benefits of drilling, industry should acknowledge the real risks or uncertainties involved in fracking. Open and honest discussion on real risk can minimize the degree that false risk information is disseminated to stakeholder groups, whereby real risk and exaggerated risk converge into one mental model. Communication should occur early in the gas exploration process and often, instead of through reaction. For instance, when U.S. industry was forced to react to enraged media reports, documentaries, and NGO claims, it floundered and became an enemy to many public stakeholders. Media and special interest groups can put industry on the defensive. Shaping the emerging issue, rather than responding to one that has already developed, allows industry a better chance to successfully influence public agenda. Influencing public agenda involves replacing technical jargon and a discussion of natural gas benefits with face-to-face interaction and understandable language.

2. Reduce impacts
Industry should continue to invest in efforts to reduce adverse impacts across the risk categories. This means strengthening compliance, ensuring subcontractor performance, embracing and developing new technologies, making robust project decisions regarding drilling sites, well pad siting, routing of truckloads, measures to prevent leaks, rigorous assessment and monitoring of water requirements and waste water, measures to target venting and flaring of gas, and screening of light and noise. It means capital expenditures geared towards protecting the environment.

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International Energy Agency’s World Energy Outlook estimates the financial cost of maintaining a “social license to operate” could increase the cost of a typical shale-gas well by around 7%\textsuperscript{42}. (However, for larger development projects with multiple wells, investment in environmental impact reduction measures may be offset by lower operating costs.)

(3) Share the winning

Hand-in-hand with reducing negative impacts of shale gas development, industry should work to ensure benefits are distributed fairly. This could mean procuring as many jobs in local communities as possible, buying local supplies, paying required taxes, and making long-term investments in local economies. Industry should work with local government to create mutually agreed upon policy for tax regulation.

While there is much contention and disagreement between environmental protection and energy production, there are cases of common ground. Sustainable energy production requires energy from operators that can develop it responsibly. Natural gas is the cleanest burning fossil fuel and can help reduce emissions. Locally, natural gas development can provide economic benefits. Before emphasizing these long-term economic benefits, industry must acknowledge and address the short-term concerns\textsuperscript{43}.

**Recommendations for Community Grassroots Groups**

The large number of community activist grassroots groups that form in response to fracking, in concert with the local non-profit movement with anti-fracking views, makes for a variety of messaging and information dissemination on the “most important” risks for public to be aware of. Community grassroots and local environmental groups aim to educate the public on risks related to fracking, and ultimately create enough opposition to stop fracking (at least without more scientific studies and tighter regulation). In doing this, some of these stakeholders create laundry lists of all rumored fracking risks, others focus on several sub-surface issues, and others on surface issues. The wide range of messaging can seem bombarding to the intended audience, and overwhelming to industry and government stakeholders who must address the concerns.

Community grassroots stakeholders should instead develop a unified message to send a crisp, concerted message to the public, to government, and to industry. This group’s voice is more likely to be heard and answered if it demonstrates a large number of stakeholders united around a focused concern. Based on the assessment of peer-reviewed science and U.S. EPA studies, the most uncertain and pressing risks that must be addressed are upstream methane emissions, surface water withdrawals, and leaks/spills due to insufficient safety precautions (ie well casing cracks).

In addition to unifying messaging, community grassroots groups should collaborate to institute the strongest possible regulations when moratoriums or bans fail. Instead of simply staunchly opposing fracking and refusing discussion involving its continuation, the environmental community can come to the table ready to negotiate with industry, lawmakers, and regulatory agencies in order to build legislation that aligns with sustainable development.

\textsuperscript{42} http://www.iea.org/newsroomandevents/pressreleases/2012/may/name,27266,en.html

\textsuperscript{43} http://www.wpntonline.com/shalegasdevelopment.aspx
This method of regulatory participation and collaboration with other stakeholder groups recently saw success in Chicago Illinois:

“Just this month [February 2013] in Chicago, Illinois, a proposal was introduced that would create the strictest regulations for high-volume oil and gas drilling in the nation…it was drafted with the help and collaboration of industry and environmentalists. The Hydraulic Fracturing Regulatory Act would require oil and gas companies to test water before, during and after drilling, and hold them liable if contamination was found after drilling began. It also would require companies to disclose the chemicals used in the process and control air pollution, as well as provide for public hearings and allow residents to sue if they believed they had been harmed.

Allen Grosboll, co-legislative director at the Environmental Law and Policy Center, said the measure will likely pass the Legislature because of the unusual negotiations between industry, environmentalists, lawmakers, regulatory agencies and Attorney General Lisa Madigan. Grosboll explained that "One of the more stunning aspects of this is legislation is that (lawmakers) invited the environmental community and industry to the table and, in more than five months of negotiations (produced) what I think is the most comprehensive fracking bill in country". Grosboll said his group supported a moratorium that failed last fall, so it was crucial to help draft the strongest possible regulations.44

Recommendations for NGO/Non-Profit Organizations

Many NGOs view fracking as a critical component of the climate change debate and value increased regulation and controls as a prerequisite for continued fracking. These NGOs should play the critical role of bringing government, industry, and community together to collaborate and legislate fracking risks. Environmental Defense Fund, for instance, has been critical in helping to formulate environmental policy in the past (ie Clean Air Act), and groups like EDF may be instrumental in moving forward with fracking safely. Based on the risk categories that have been scientifically suggested as legitimate for concern, NGOs should partner to develop stringent federal regulations to address gaps in legislation related to air emissions, wastewater treatment and disposal, frac fluid disclosure, and fluid spillage risk management. NGOs should work with state governments to follow up on federal regulation with more state-specific regulations to address regional concerns.

In the case of slow-moving legislation, NGOs can also partner with industry to find cost-effective best practices and advances in risk management. For instance, EDF and Southwestern Energy have developed a partnership that is now working on a 40-page draft of possible regulations that can act as a model for state officials. The partnership aims to develop a proposal that will address a range of subsurface issues, from the composition of fracking fluids to the integrity of underground wells. For NGOs, partnerships are an opportunity to tighten standards for the growing fracking industry. For industry, such partnerships are an opportunity to counter public image and PR problems that threaten to undermine support for and success of domestic natural gas production through fracking.45

44 http://www.huffingtonpost.com/2013/02/22/illinois-fracking-bill-se_n_2741170.html
10.0 Hydraulic Fracturing “Real” Risks

As discussed, mental models are formed through integrating media stories, news articles, personal conversations, scientific studies, and white papers into an overall understanding and perception of the fracking issue. The mental models are typically not complete, can be distorted, and can selectively integrate some information while ignoring other information. In order to provide deeper insight and separation of those risks that have been demonstrated and substantiated through data and those that have yet to be confirmed, we review findings from credible scientific studies. (We define credible as either peer-reviewed, or released by a government agency.) This section links to the public agenda formation process in several ways. Results from these academic studies can penetrate and influence mental models and risk perception in varying degrees of impact, depending on the stakeholder group. Study results indicating environmental or health risks can also be foundations for policy development if stakeholders decide mitigation is necessary.

Below we briefly summarize each risk category, and then list related study results from peer-reviewed literature or government scientific studies.

10.1. Risk: Groundwater

The contamination of groundwater is a concern across stakeholder groups. Depending on stakeholder belief, groundwater contamination could occur through various failures during fracking activities 2-5 (Section 8.1, above). The general concern is the potential for migration to drinking water aquifers of stray gas, metal-rich formation brines, hydraulic fracturing fluids, and flowback fluids. Below we list and discuss the scientific findings on groundwater contamination.

I. A 2011 Duke University study46 tested the underlying foundation to one of the risks of groundwater contamination: whether there is hydraulic connectivity between shale gas formations and overlying shallow drinking water aquifers. The research found that pathways in northeastern Pennsylvania, though unrelated to drilling activities, exist in some locations between deep underlying formations and shallow drinking water aquifers. Mixing relationships were found between shallow groundwater and deep formation brine that caused groundwater salinization in some locations. The geochemical fingerprint of sampled groundwater suggested possible migration of Marcellus brine through naturally occurring pathways. The presence of the saline water suggest conductive pathways and specific formations in Pennsylvania that would be at increased risk for contamination of shallow drinking water resources because of natural hydraulic connections to deeper formations.

II. A 2011 Duke University study47 documented evidence for methane contamination of drinking water associated with shale gas extraction in aquifers overlying the Marcellus and Utica shales in northeastern PA and upstate NY. The study found that in active gas-extraction areas which had gas wells within 1 km, average maximum methane concentrations in drinking water wells increased with proximity to the

nearest gas well, and was at a level to be a potential explosion hazard (19.2 and 64 mg CH4 L−1). These data and ratio of methane-to-high-chain hydrocarbons found are consistent with deeper thermogenic methane sources such as the Marcellus and Utica shales at the active sites, and matched gas geochemistry from gas wells nearby. Dissolved methane samples in neighboring sites without gas wells within 1 km—and with similar geologic formations and hydrogeologic regimes—averaged significantly less (1.1 mg L−1). However, no background groundwater samples were available to compare methane levels before hydraulic fracturing operations.

**Risk Pathway:** John Hanger, a former head of the Pennsylvania Department of Environmental Protection (DEP), expressed the likely cause for this methane contamination to be poor gas well construction or design, not fracking itself. Hangar emphasized that repairs or plugging of gas wells eliminated contamination in 14 of 19 previously contaminated water wells tested in 2010 by the DEP. However, Duke University scientists maintain that fracking cannot be ruled out as a cause, given the high pressures used in the practice.48

### III. According to a draft report released in December 2012, U.S. EPA detected the presence of chemicals commonly associated with hydraulic fracturing in drinking water wells in Pavillion, Wyoming.49 Detection of high concentrations of benzene, xylene, gasoline range organics, diesel range organics, and total purgeable hydrocarbons in ground water samples from shallow monitoring wells near pits indicates that pits are a source of shallow ground water contamination in the area of investigation. A number of synthetic organic compounds were detected in two of the monitoring wells in Pavillion.50 Elevated levels of dissolved methane in domestic wells generally increase in those wells in proximity to gas production wells. Encana Oil and Gas, the company responsible for the natural gas wells, disputed the findings of the study, criticizing U.S. EPA’s testing methods and assumptions, as well as the processes used to construct and analyze the results of the monitoring wells.

**Risk Pathway:** The contamination was claimed to be associated with well casing integrity and wastewater disposal, not the process of injecting fluids underground.51

### IV. The U.S. EPA’s 2012 study on drinking water resources conducted a geomechanical simulation to investigate the possibility that hydraulic fracturing injections create a pathway for transport to groundwater through fault reactivation. The simulation did not appear to activate fault rupture lengths greater than 40 to 50 meters and could

48 [http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3222989/](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3222989/)
50 The EPA explains the link of the chemicals found in wells to fracking “Alternative explanations were carefully considered to explain individual sets of data. However, when considered together with other lines of evidence, the data indicates likely impact to ground water that can be explained by hydraulic fracturing. A review of well completion reports and cement bond/variable density logs in the area around MW01 and MW02 indicates instances of sporadic bonding outside production casing directly above intervals of hydraulic fracturing. Also, there is little lateral and vertical continuity of hydraulically fractured tight sandstones and no lithologic barrier (laterally continuous shale units) to stop upward vertical migration of aqueous constituents of hydraulic fracturing in the event of excursion from fractures. In the event of excursion from sandstone units, vertical migration of fluids could also occur via nearby wellbores. For instance, at one production well, the cement bond/variable density log indicates no cement until 671 m below ground surface. Hydraulic fracturing occurred above this depth at nearby production wells.”
only give rise to microseismicity (a magnitude of <1). The EPA states that this finding is consistent with field observations, and concludes that the possibility of a fault reactivation creating a pathway to shallow groundwater resources is unlikely.\footnote{http://www.epa.gov/hfstudy/pdfs/hf-report20121214.pdf}

V. The U.S. EPA’s 2012 study finds that flowback and produced water can contain high levels of total dissolved solids (TDS), which may include bromide and chloride.\footnote{http://www.epa.gov/hfstudy/pdfs/hf-report20121214.pdf} If treatment of flowback and produced water occurs at wastewater treatment facilities, it may be infeasible to remove bromide and chloride from hydraulic fracturing wastewater before discharge. If bromide ions are present in waters undergoing chlorination disinfection, brominated disinfection byproducts (DBPs) may be formed, which are more toxic than chlorinated DBPs and have higher molecular weight. This increases the likelihood of exceeding the EPA’s total trihalomethanes and haloacetic acids maximum concentration levels that are stipulated in weight concentrations.

VI. The U.S. EPA reviews data from a Marcellus study (Williams et al., 1998), citing that water wells completed in zones with more confined flow contain higher TDS (median concentration of 830 milligrams per liter), dissolved barium (median concentration of 2.0 milligrams per liter), and dissolved chloride (median concentration of 349 milligrams per liter) compared to zones with unconfined flow.\footnote{http://www.epa.gov/hfstudy/pdfs/hf-report20121214.pdf}

VII. Researchers at Pennsylvania State University studied water supply wells before and after drilling and hydraulic fracturing operations.\footnote{http://www.epa.gov/hfstudy/pdfs/hf-report20121214.pdf} Their study found that bromide levels in at least one water well increased after drilling or hydraulic fracturing. There are accompanying increases in chloride, hardness and other indicators after drilling and fracking had occurred, as well. The study found sediment and/or metals in the water testing results of a small number of water wells – the study then labeled these wells as being affected by disturbances due to drilling.

\textbf{10.2. Risk: Air Quality}

A common risk in all stakeholders’ mental models is fugitive methane emissions. When natural gas burns downstream it produces less carbon emissions than other fossil fuels, which offers a potential climate benefit through offsetting much more carbon intensive coal-fired energy production. However, uncombusted methane can leak from wells, pipelines and storage facilities. The resulting emissions might be high enough to minimize the potential positive climate impacts. Methane doesn’t stay in the atmosphere for as long as CO2, but it does have a much greater impact over the short-term through radiative forcing. For instance, over a 20-year span, one pound of methane is 72 times more potent than CO2 for increasing the retention of heat in the atmosphere.

The EPA estimates that 2.3% of total natural gas production is lost to leakage, but this estimate, based on early 1990’s data, is sorely in need of updating. The industry claims a leakage rate of

\footnotetext{52}{http://www.epa.gov/hfstudy/pdfs/hf-report20121214.pdf}
\footnotetext{53}{http://www.epa.gov/hfstudy/pdfs/hf-report20121214.pdf}
\footnotetext{54}{http://www.epa.gov/hfstudy/pdfs/hf-report20121214.pdf}
\footnotetext{55}{"North Carolina Oil and Gas Study under Session Law 2011276, North Carolina Department of Environment and Natural Resources and the North Carolina Department of Commerce (2012)"}
about 1.6%.\textsuperscript{56}

I. A 2011 study prepared by Eastern Research Group Inc. (ERG) and delivered to the City of Fort Worth in 2011\textsuperscript{57} analyzed reported routine emissions from over 250 well sites with no compressor engines in Barnett Shale gas well sites. They found a highly-skewed distribution of emissions, with 10% of well sites accounting for nearly 70% of total emissions. Natural gas leak rates were calculated based on operator-reported daily gas production data at these well sites. The leak rates ranged from 0% to 5%. Of the 203 sites, 6 sites showed lead rates of 2.6% or greater due to routine emissions alone.\textsuperscript{58}

II. A February 2012 study by NOAA/University of Colorado at Boulder\textsuperscript{59} studied the methane and VOCs produced at a field near Denver. The research team’s chemical fingerprinting showed that oil and gas equipment and activities – well pad equipment including condensate storage tanks, pipelines, compressors and more – leaked or vented an estimated 4 percent of all natural gas produced to the atmosphere. Using ambient monitoring data, benzene emissions were estimated to be between 385 and 2,005 metric tons.

III. A 2010 Cornell study\textsuperscript{60} (Howarth et al., 2010) evaluated methane leakage at four different steps in the fracking process.

a. Fugitive methane emissions during well completion: Using data from 2 shale gas formations and 3 tight-sand gas formations in the U.S., the study found between 0.6% and 3.2% of the life-time production of gas from wells is emitted as methane during the flow-back period. The highest methane emissions during flow-back were correlated with high initial pressures and initial production. Gas losses from flowback fluids: mean value of 1.6%. Gas losses during drill-out0.33% release of the total life-time production of wells as methane.

b. Routine venting and equipment leaks: Once a well is completed, fugitive emissions continue at the well site over the lifetime of the well through equipment such as heaters, meters, dehydrators, compressors. The Cornell study uses the U.S. General Accountability Office’s estimate that 0.3% to 1.9% of the life-time production of a well is lost due to routine venting and equipment leaks.

c. Processing losses: Some natural gas requires further processing to remove heavy hydrocarbons and impurities before being piped. The default EPA facility-level fugitive emission factor for gas processing indicates a loss of 0.19% of production (Shires et al. 2009). The Cornell study gives a range of processing losses from produced gas of 0% (i.e. no processing, for wells that produce “pipeline ready” gas) to 0.19%.

d. Transport, storage, and distribution losses: The study estimates between 1.4% to 3.6% gas leakage during transmission, storage, and distribution.

Summing all estimated losses, the Cornell study finds that during the life cycle of

\textsuperscript{56}http://blogs.edf.org/energyexchange/2013/01/04/measuring-fugitive-methane-emissions/
\textsuperscript{57}http://fortworthtexas.gov/gaswells/default.aspx?id=87074
\textsuperscript{58}http://blogs.edf.org/energyexchange/2013/01/04/measuring-fugitive-methane-emissions/
\textsuperscript{60}http://www.sustainablefuture.cornell.edu/news/attachments/Howarth-EtAl-2011.pdf
an average shale-gas well, 3.6 to 7.9% of the total production of the well is emitted to the atmosphere as methane

IV. An increase in heavy-duty truck traffic is associated with many stages of natural gas production. The increased truck traffic results in higher NOx, VOC and PM2.5 emissions in the area near the operation. The New York Supplemental Generic Environmental Impact Statement found that the resulting increase was less than 1 percent over the baseline emissions.\textsuperscript{61}

V. The Arkansas Department of Environmental Quality conducted limited monitoring in the Fayetteville Shale region of northeastern Arkansas.\textsuperscript{62} The study monitoring did not result in VOC or NOx concentrations above the monitoring instrument’s detection level at natural gas well sites or compressor stations. However, daily average and 15-minute rolling average concentrations of 678 ppb and 5,321 ppb, respectively were observed near the drilling sites.

VI. The PA Governor’s Marcellus Shale Advisory Commission study\textsuperscript{63} reports on the Southwest, Northeast and North central PA regions:

a. Concentrations of certain natural gas constituents including methane, ethane, propane and butane, and associated compounds, in the air near Marcellus Shale drilling operations were detected during sampling.

b. Elevated methane levels were detected in the ambient air during short-term sampling at most sampling locations.

c. Certain compounds, mainly methyl mercaptan, were detected at levels which generally produce odors.

d. Results of the ambient air sampling initiative did not identify concentrations of any compound that would likely trigger air-related health issues associated with Marcellus Shale drilling activities.

Carbon monoxide, nitrogen dioxide, sulfur dioxide and ozone sampling did not detect concentrations above National Ambient Air Quality Standards (NAAQS) at any of the sampling sites.

VII. An MIT study\textsuperscript{64} assessed 4000 horizontal shale gas wells brought online in 2010, and found that companies are already capturing about 70% of potential fugitive methane emissions. Specifically, the MIT researchers found that potential emissions per well in the Barnett and Haynesville sites were 157 Mg of methane and 633 Mg, respectively. When accounting for actual gas handling field practices, these emissions estimates were reduced to about 35 Mg per well of methane from an average Barnett well and 151 Mg from an average Haynesville well. The study estimates that the 2010 total fugitive emissions from U.S. shale gas-related hydraulic fracturing represented 3.6% of the estimated 6002 gigagrams of methane from fugitive emissions from all natural gas production-related sources in that year.

\textbf{10.3. Risk: Surface Water}

\textsuperscript{61} North Carolina Oil and Gas Study under Session Law 2011276, North Carolina Department of Environment and Natural Resources and the North Carolina Department of Commerce (2012).

\textsuperscript{62} North Carolina Oil and Gas Study


\textsuperscript{64} http://iopscience.iop.org/1748-9326/7/4/044030/
There are three main areas of risk to surface water from the fracking process: depletion of water sources, spills and leaks of fracking chemicals and fluids, and mismanagement of fracking waste.\textsuperscript{65} First, depletion of water sources can occur due to the large volumes of water that are required for fracturing operations, which are taken from local surface or subsurface water bodies. Depending on location, this can conflict with irrigation and other water needs, and aquatic ecosystem needs. Second, surface water can be contaminated through the potentially hazardous chemicals and proppant used in the fracturing process that are stored in tanks or pits on the surface. If storage is not executed properly, these tanks/pits can leak or spill. If fracking fluids are not stored at a centralized facility and are instead transported to a well location, there is the potential for leaks and spills during transit as well. Mechanical failure of tanks, valves, and pipes can also cause surface leaks. Lastly, mismanagement of the flowback fluid or produced water (naturally-occurring fluid brought to the surface along with produced oil or gas) that returns up the wellbore to the surface can be toxic or contain naturally occurring radioactive material. This wastewater is sometimes stored in surface pits, which if inadequately constructed or operated, could leak into surface water.

I. The U.S. EPA reports that fracturing shale gas wells requires between 2.3 million and 3.8 million gallons of water per well. An additional 40,000 to 1,000,000 gallons is required to drill the well.\textsuperscript{66} This is more water than is required for conventional gas wells and coalbed methane, because the wells to access shale gas are deeper. Water requirements for hydraulic fracturing of coalbed methane, for example, range from 50,000 to 350,000 gallons per well. The EPA notes that more and better data are needed on the volume of water required for hydraulic fracturing, and the major factors that determine the volume.

II. The U.S. EPA 2012 report on water states that for a hydraulic fracturing job that uses 5 million gallons of hydraulic fracturing fluid, between 500,000 and 3.5 million gallons of fluid will be returned to the surface. This wastewater is generally managed through disposal into deep underground ejection control wells, treatment followed by discharge to surface water bodies, or treatment followed by reuse. Contaminants present in the wastewater may be inadequately treated at publicly owned treatment works, and the discharges may threaten downstream drinking water intakes.\textsuperscript{67}

III. The U.S. EPA 2012 report states that high TDS levels—including bromide and chloride—have been detected in the Monogahela River in 2008 and the Youghiogheny River in 2010 (Lee, 2011; Ziemkiewicz, 2011). The source and effects of these elevated concentrations is unclear.\textsuperscript{68}

IV. The New York Supplemental Generic Environmental Impact Statement\textsuperscript{69} reviewed the impact of obtaining water for hydraulic fracturing through withdrawals from surface water bodies. The report states that without proper controls on rate, timing, and locations of withdrawals, modifications to groundwater levels, surface water levels, and stream flow results in adverse

\textsuperscript{65} http://www.nrdc.org/water/files/fracking-drinking-water-fs.pdf
\textsuperscript{67} http://www.epa.gov/hfstudy/pdfs/hf-report20121214.pdf
\textsuperscript{68} http://www.epa.gov/hfstudy/pdfs/hf-report20121214.pdf
impacts to aquatic ecosystems, downstream flow levels, wetlands, and aquifer recharge.

V. The North Carolina Oil and Gas Study\textsuperscript{70} found that heavy rainfall has the potential to overwhelm the excess storage capacity of open top tanks or pits containing process chemicals or waste materials, and berms that may be enclosing a well pad. This can cause releases of harmful materials along with the excess rainfall. The study reviewed the findings of the New York Department of Environmental Conservation, which found that an uncontrolled flow of hydraulic fracturing fluid occurred in 2011 during fracture stimulation of Chesapeake Energy’s Atlas 2H well in Bradford County, PA. The cause was a failure at the valve connection to the wellhead, which caused fluid to be discharged from the wellhead at high pressure. Approximately 60,000 gallons of fluid were discharged to the well pad, of which 10,000 gallons flowed over the top of the containment berms. A portion of this fluid flowed into a tributary of Towanda Creek. Also in 2011, Chesapeake was fined for impacting a wetland and allowing sediment to enter Sugar Creek in North Towanda Township. Part of the well pad was built in a wetland: a third of an acre of wetlands was filled without authorization, impacting the wetland through erosion and sedimentation.

VI. The North Carolina Oil and Gas Study cited a spill of approximately 8,000 gallons of hydraulic fracturing fluid from a broken pipe into Stevens Creek and a wetland in Dimock, Pa. in 2009, resulting in a fish kill.

10.4. Risk: Community Disruption

Hydraulic fracturing enters communities first through the leasing of land, with lawyers and gas companies negotiating deals with local landowners. Second, drilling operations begin with workers building a fracking site, installing drill pads and rigs, freshwater reservoirs, waste-water impoundments, and other construction. Hand-in-hand with this comes the creation of jobs (an Ohio State study\textsuperscript{71} estimates an additional 20,000 jobs from the industry). The actual fracking and ensuing gas production can last several years, followed by the disposal of fracking fluids into injection wells or as dust and ice control on public roads. More specifically, during these three steps, fracking can impact community roads, highways, and bridges due to tank truck deliveries with fracking fluid and disposal of wastewater. Traffic noise and air pollution through such increased truck traffic can occur. Some communities’ most severe concern is a loss in the quality of life and health, and a devaluation of property value.

I. In the NYS DEP’s draft environmental impact statement, the New York State Department of Transportation (NYDOT) estimated that the replacement costs for a bridge could range from $100,000 to $24 million per bridge, with an average of $1.5 million per bridge. NYDOT estimated the cost to repair local roads to range from $70,000 to $150,000 per lane mile for low-level maintenance, to $400,000 to $530,000 per lane mile for higher-level maintenance. Total reconstruction could range from $490,000 to $1.9 million per lane mile. State bridge replacement could range

\textsuperscript{70} North Carolina Oil and Gas Study under Session Law 2011276, North Carolina Department of Environment and Natural Resources and the North Carolina Department of Commerce (2012)

\textsuperscript{71} http://aede.osu.edu/sites/drupal-aede.web/files/Economic%20Value%20of%20Shale%20Dec%202011.pdf
from $100,000 to $31 million per bridge, averaging $3.3 million per bridge. Low-level maintenance for state roads could range from $90,000 to $180,000 per lane mile; higher-level maintenance would range from $540,000 to $790,000 per lane mile. “Full depth reconstruction” can range from $910,000 to $2.1 million per lane mile.  

II. The North Carolina Oil and Gas Study\textsuperscript{72} reviews 2010 earthquakes near the town of Guy in north-central Arkansas. Several thousand earthquakes migrated from the northeast to the southwest along a seven to nine mile linear trend in 2010, culminating in a 2011 magnitude 4.7 earthquake near the town of Greenbrier. The Arkansas Oil and Gas Commission discovered that four fracking disposal wells were located on a fault line. After two of the four wells stopped operating in March 2011, the number of earthquakes sharply declined.

\textbf{Role of Science in Public Agenda Framework}

We argue that robust science plays a key role in feeding back into the public- and policy-agenda building process. While rigorous studies have been conducted—as discussed above—science on fracking risk is still in a nascent state. There is a lack of certainty in linking some fracking activities to causation of risk events leading to environmental impact, in addition to a lack of agreement or confirmation between different studies on specific impacts. For instance, findings on natural gas production lost to methane leakage ranges from 1.6\% (industry finding) to 2.3\% (EPA) to 7.9\% (Cornell) (cited in discussion above). This lack of agreement and lack of volume of scientific findings feeds mixed messages and confusion up into the public agenda stage, driving discrepant views among stakeholders.

\textsuperscript{72} North Carolina Oil and Gas Study under Session Law 2011276, North Carolina Department of Environment and Natural Resources and the North Carolina Department of Commerce (2012)

\textsuperscript{73} North Carolina Oil and Gas Study under Session Law 2011276, North Carolina Department of Environment and Natural Resources and the North Carolina Department of Commerce (2012)
11. Pennsylvania Case Study: Introduction

To better understand the risks inherent to hydraulic fracturing we must identify and evaluate real events that have impacted the environment and violated best practice. Moreover, it is important to examine how state governments have managed these risks through sound regulation. This section aims to examine the development of unconventional resources and the response by state agencies to prevent activities that damage the environment.

We chose to perform a case study on the compliance of hydraulic fracturing activities in the state of Pennsylvania, more specifically, the Marcellus and Utica Shale. This state was selected because according to STRONGER’s September 2010 report, Pennsylvania has one of the best regulatory frameworks in place to manage hydraulic fracturing activities. Moreover, the Pennsylvania Department of Environmental Protection has maintained a rich database that is publicly available and details violations committed by operators within the state. This should allow us to develop a comprehensive data set that details the frequency and severity of violations within the state. We also examined how Pennsylvania’s regulatory framework has developed over time and attempted to measure the relative success (or lack thereof) in mitigating risky behavior. Data was collected starting in January of 2008, which marks the passage of new regulations designed specifically for hydraulic fracturing. We compiled violation data over this period and separated them into specific risk categories defined in section 8. The violations were then further analyzed within these categories using SPUD data and the frequency of inspections. Finally, the violation data was analyzed in conjunction with fines administered over the same time period to identify events that pose a severe risk to the environment.

The results show that Pennsylvania has had some success at managing environmental risks related to hydraulic fracturing over the past four years. However, the state does appear to be slow to adopt new regulations and relies on a database that has several flaws and limitations. Improvements in these last two categories could ensure that Pennsylvania maintains their leadership in the management of unconventional resources.

11.1. Background

11.1.1. Introduction to Hydraulic Fracturing in Pennsylvania

The process of using water to “fracture” rock has been in use since the early 1940’s. Hydraulic fracturing, as we know it today, originated when the “fracturing” process was combined with horizontal drilling in 1998. Together, these activities allow an operator to access a large volume of shale resources from a single well. The first well in Pennsylvania to use this technique was drilled in 2004 (MSAC 2011). Since then, over 6,039 wells have been drilled in Pennsylvania producing over 2 Tcf of natural gas in 2012. Total recoverable resources in Pennsylvania are estimated to be as high as 362 Tcf.

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74 SPUD refers to the spudding in of a well. It is defined as the first day of drilling.
For the purpose of this paper we define hydraulic fracturing to be any process necessary to prepare an unconventional (i.e. shale) well for production. We have further broken down this definition into three distinct stages:

- Site Preparation
- Drilling
- Finishing/Completion

These steps are not meant to categorize risks, but to clarify the activities we have understood to be integral to hydraulic fracturing.

**Site Preparation**: A well pad must be properly constructed before any drilling equipment is allowed on site. These activities include the clearing and leveling of land, construction of access ways, and any additional infrastructure anticipated for the well (i.e. equipment, pipes, storage tanks, storage pits, environmental barriers…etc). According to the 2011 NYDEC report a typical well requires 3.5 to 5.5 acres of land to support the fracturing process (NCDC et al. 2012).

**Drilling**: After the well pad meets the local regulatory standards the operator can proceed with drilling. In Pennsylvania a typical well is drilled between 5,000 and 7,000 feet below the surface of the earth; the water table in this region reaches no deeper than 350 feet (EPA 2012). As the drill reaches the depth of the Marcellus Shale the drill begins to travels horizontally, following the path of the shale formation. These drills can travel as far as over 4,000 feet horizontally for a single well (NYDEC 2011). Once the well is drilled cement is sent down the hole to create what is known as casing. Since the drill has traveled several thousand feet below the ground, including through the water table, operators install casing to help maintain the integrity of the whole and to prevent any drilling products or gas from entering the water table. The cement is placed down the well in several stages creating multiple levels of encasing to better protect the hole (Figure 11.1).

![Figure 11.1 - Well casing that is used to protect ground water. Multiple casings are used to provide the maximum protection from any migration issues.](image)

After the casing is completed a fluid is sent down the well to help fracture the rock and extract the natural gas. An average of 5 million gallons of fluid is required for a single well; over 90% is
water. Drinking water, surface water, recycled waste water, and ground water are all resources that are used to supply the well site. Depending on the circumstances the water can be stored onsite in an open pit or in storage containers. The remaining fluid consists of six to twelve chemicals that are meant to improve performance and maintain well integrity (EPA 2012). A list of common chemicals used in wells can be found in the appendix C; this list excludes chemicals that operators claim to be proprietary. Heavy trucks are relied on to deliver these products although water can be transported either by truck or pipeline. Once on site water is mixed with the necessary chemicals and sent down the well to fracture the rock. This process may be repeated several times, in stages, to maximize the access to gas within the shale. Below are diagrams that show the path of a drilled well and a well pad ready for fluid to be sent down the hole (Figure 11.2).

![Figure 11.2](image)

**Figure 11.2** - The picture on the left shows the difference between a horizontally drilled well (left) and a conventional well. The picture on right is of a well site that is preparing for the hydraulic fracturing process. (EPA 2012)

**Completion**: After the shale is successfully fractured the operator will release the pressure built up inside the well. This process will force natural gas to the surface in addition to flowback water, which consists largely of the fluid that was used to fracture the rock. Empirical data in Pennsylvania suggests the volume of flowback water to be about 15% of the total fluid placed into the well (NCDC 2012). Flowback water and produced water, which occurs later in the operational stages of the well, are considered to be hazardous and must be disposed of according to federal and state regulations. While the water is waiting to be moved offsite it is stored in an open pit or storage tanks. Once the fluid is separated from the gas it is moved off site to one of three locations: 1) a deep underground injection control (UIC) well, 2) a treatment plant where it is then discharged to surface water, or 3) a treatment plant follow by industry reuse (EPA 2012). After the flowback water leaves the site the drilling equipment is removed and operational equipment is installed. The operational well footprint will decrease to approximately 1.5 to 2.2 acres (NYSDEC 2011). Produced water will continue to be removed from the site throughout the life of the well. Once the well is no longer in service the operator is responsible for reclaiming the land. These guidelines are set at the state and local level.
Throughout this entire process it is estimated that operators require trucks to make 1,979 to 1,456 one-way trips to complete the well. The estimated time from beginning to completion is 38 to 56 days (NRDC 2012).

11.1.2. Regulation of Unconventional Resources
Pennsylvania relies on agencies at the local, state, and federal level to oversee the extraction of unconventional resources. However, the Pennsylvania Department of Environmental Protection (PADEP) is largely responsible with enforcing the laws and regulations covering oil and gas development. In 2008 the PADEP employed approximately 35 people to oversee 74,774 oil and gas wells. As hydraulic fracturing became increasingly popular the state government realized the need to pass additional laws and regulations to keep pace with the technology, as well as hire additional staff to manage the workload. Today, the PADEP oil and gas group has 202 employees, 84 of whom are devoted exclusively to well site inspections (MSAC 2011). These inspectors are tasked with enforcing several regulations designed specifically for the development of unconventional resources. Moreover, the state created the Marcellus Shale Advisory Committee in March of 2011 to develop “comprehensive, strategic proposal for the responsible and environmentally sound development of Marcellus Shale.” The commission is comprised of several stakeholder groups who meet regularly to evaluate the regulatory framework in place.

Table 11.1 lists regulations and laws enforced by the PADEP as of February of 2013.

### State Regulations
- Chapter 78 - Oil and Gas Wells
- Chapter 78 - Emergency Response Planning at Unconventional Well Sites
- Chapter 79 - Oil and Gas Conservation
- Chapter 91 - General Provisions
- Chapter 95 - Wastewater Treatment Requirements
- Chapter 102 - Erosion and Sediment Control
- Chapter 105 - Dam Safety and Waterway Management

### State Statutes
- PA ACT 13 of 2012
- PA ACT 214 - Coal and Gas Resource Coordination Law
- PA ACT 223 - Oil and Gas Act
- PA ACT 359 - Oil and Gas Conservation Law
- PA ACT 394 - Clean Streams Law

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Accessed on 2/21/2013

Accessed on 2/22/2013
Federal Regulations

- 40 C.F.R.
  - Clean Air Act
  - Safe Drinking Water Act
  - Resource Conservation and Recovery Act
  - Comprehensive Environmental Response, Compensation, and Liability Act (CERLA)
- 30 C.F.R – National Environmental Policy Act (NEPA)
- 18 C.F.R. – River Basin Compacts, FERC

Table 11.1 - Laws and regulations the PADEP enforces in regards to the development of unconventional resources.

To better understand the history of regulation of unconventional oil and gas resources in PA it is useful to summarize major developments, chronologically. Figure 11.3 shows major initiatives undertaken by the state of Pennsylvania to improve oversight of hydraulic fracturing.

![Figure 11.3 - Timeline of major regulatory events enacted by the state of Pennsylvania from 2008 to 2013.](image-url)
11.2. Methodology

To understand the risks observed by the PADEP from hydraulic fracturing and the role they play in our public agenda framework we will rely on the following methodology as illustrated in figure 11.4.

![Figure 11.4](image)

Figure 11.4 – The framework above illustrates the role the PADEP has in influencing the public agenda through the management of unconventional resources.

11.2.1. Violation Frequencies and Relationships

Leveraging the previous research on environmental risks to hydraulic fracturing, we explored the PADEP’s database to identify real risks events resulting from the development of unconventional (i.e. shale) resources. Risks were identified through violations charged to operators from over 33,400 well inspections starting on January 1, 2008 through February 17, 2013. This data can be found on the PADEP’s Oil and Gas Reports main page. We chose to include Administrative violations in this analysis to fully capture the risks attributed to hydraulic fracturing. This was done for two reasons: 1) in the research it was unclear as to what constituted an Administrative violation as opposed to an Environmental, Health, & Safety (EHS) violation. Emails to the PADEP for clarification on this issue were not returned. 2) Administrative violations that are the result of non-compliance were assumed to be negligent behavior (willful or not) that posed a meaningful risk. We also chose to collect and analyze data only reported by PADEP officials. In some instances operators have elected to object to violations given out on their well sites. Since we do not have the technical expertise to understand the complexity of these debates we have chosen to assume all violations submitted by the PADEP to be true and accurate. In total the PADEP employs 112 unique code violations (Appendix D: Code Violations Noted by PADEP) to enforce State and Federal regulations.
Next, we categorized the violations according to the risk categories defined in the previous section: *Ground Water, Surface Water, Habitat, Air Quality, and Community*. Due to the wording of some regulatory subsections certain violations can be applied to multiple risks. For example, violation code 601.101 has the description “O&G Act 223-General,” which lends little insight into the event that caused the inspector to note the violation. In addition, activities such as spills on site pose a threat to multiple categories. The determined approach for this analysis was to evaluate the violation reports as much as possible to get an understanding of what events the violation was intended to cover. If for any reason an event posed a risk to a category it was placed into said category. Once the violations were sorted, we looked at each violation according to each risk category (i.e. bucket). These categories were then analyzed to identify any trends or anomalies. After this analysis was performed we identified violations that applied only to specific risk buckets to see how those events compared to the larger groupings. One element in this analysis, and a subset we defined within the risk to Community, is the issue of reporting, or disclosing information. There are numerous violation codes for operators who have failed to submit paperwork or post relevant information in a public manner. The prevalence of these codes combined with the high frequency of violations made it important to look at this grouping on an individual basis. We do not consider this subset to be an environmental risk per se but a risk to public trust, hence the assignment to the risk to Community category.

Once we compiled the data according to the risk buckets we sorted the violations according to inspection type. The reports filled out by the inspectors note what type of inspection they are performing. These inspections are:

- Administrative/File Review
- Asbestos Program Inspection
- Bond Release
- Complaint Inspection
- Compliance Evaluation
- Construction
- Drilling/Alteration
- Facility Operations Inspection
- Follow-up Inspection
- Incident- Response to Accident or Event
- Nuclear Regulatory Commission
- Plugging(Includes Plugged/Mined Through)
- Routine Final Inspection
- Routine/Complete Inspection
- Routine/Partial Inspection
- Routine/Partial/Aerial Inspection
- Site Restoration

Segmenting this data according to inspection type will provide insight into potential stages of the hydraulic fracturing process that have specific patterns of risk behavior. That is, if the inspection types can be attributed to particular activities in the fracking process, there may be an
opportunity to identify what risks are more likely to occur. This theory will be developed further in the analysis.

After we acquired the violation data we normalized it according to the number of inspections and wells drilled per year. This data was also found on the PADEP Oil and Gas Reports website. This step was determined to be necessary in order to fully understand the trends and movements in violation data over time. This analysis was performed for each risk bucket and the top ten code violations were identified as the highest average violations over a monthly basis. Furthermore, linear correlations were performed against these data sets (wells drilled and inspections) for both the PADEP violation codes and inspection types to identify any strong relationships. Previous studies on violations in Pennsylvania have cited the information in the form of violations per well drilled.\(^79\) Since yearly inspections have increased while wells drilled have somewhat steadied we want to explore how these events influence the recording of violations. Top violations were determined to be those relationships that had the highest explanatory power, more than twenty points of data, and greater than 12% of the violations explained by the referenced data set.

11.2.2. Fines (Monetary Penalties)

In many instances the PADEP determined that a written notice of a regulatory violation was not sufficient and therefore imposed fines on operators. These fines were identified on an individual basis in order to examine the root causes and are assumed to be a proxy for the severity of an event. Preliminary analysis showed that fines are assigned to one whole event and not to individual violations. To better illustrate this issue we can look at fine levied in Dimock Township on April 15, 2010 for $120,000.\(^80\) This fine has over ten violation codes attributed to it ranging from: a failure to report well records, diesel fuel spilled on site, and a failure to prevent the migration of gas. While all of the violations played a part in determining the fine, it is relatively easy to discern that some violations may have attributed more than others. As a result, we needed to develop a method that would not overstate the severity of some violations that may be tied to larger, more serious ones. To achieve this we divided fines evenly among the number of violations attributed to the event. This was done so that fines would be assigned to all relevant violations and that those violations that were more likely to incur fines would eventually accrue a greater value to reflect their importance. In essence, we divided the fine money for two reasons: 1) to make the events more reflective of the economic impact by using the actual fine amount (as opposed to applying the total fine value to each violation, thus overstating the economic impact) and, 2) to recognize that each violation plays a part in determining a fine levied against an operator.

11.2.3. Risk Matrices

Once we had the fine and violation data we graphed the two data sets against each other to develop a scatter plot for all violation codes. This scatter plot provides the opportunity to identify and target violations of high importance. These data points were first evaluated using all violation data and then further categorized according to the environmental categories as defined in section 8.


\(^80\) [http://www.portal.state.pa.us/portal/server.pt/community/oil_and_gas_reports/20297](http://www.portal.state.pa.us/portal/server.pt/community/oil_and_gas_reports/20297) Accessed 2/21/2013
11.2.4. Understanding the Enforcement Process

The last part of research involved examining the PADEP’s engagement and response to severe risk events within the state. As a result, we chose to briefly look at the 2009 migration of methane into 18 water wells by Cabot Oil and Gas in Dimock Township. Through this process we hoped to examine how the PADEP’s activities have influenced the future risk of similar events.

11.3. Results

11.3.1. Timeline of Violations

Figure 11.5 shows all violations from January 2008 - February 2013. The colors represent different violation codes reported by the PADEP. Violations increase substantially from January of 2008 through April of 2011. This corresponds well with increases in drilling and regulatory oversight over the same period, particularly the increases in staffing at the PADEP (Figure 11.3). This position is also supported by the increase in diversity of violations that have occurred over time denoted by the color segmentation. The large block of red in-between years 2009 and 2010 is violation code “O&G Act 223 – General.” This code does not refer to any specific event or action and, in fact was usually followed with a reference to another code violation within the text. However, since this code was listed within the text it made it impossible to search for these codes in the PADEP database.

![Figure 11.5 - Total violations from January of 2008 through February of 2013. Each color segment represents a violation code issued by the PADEP during this time.](image)

After we collected the data we first attempted to remove violations that we interpreted to be “Reporting” issues, such as “201A – Failure to have a permit on site while drilling.” The result
of this filter can be seen in figure 11.6. When comparing this graph to figure 11.5 we observe the absolute number of violations decline, however, there does not appear to be any distinct trends or anomalies that highlight any particular event.

Observing the top ten total violations for the time period (Figure 11.7) we can get a better understanding of the events that are a significant percentage of total violations (Figure 11.5). For example, Code 102.4 covers erosion issues on site. This appears to be a large issue during the early years of drilling in Pennsylvania, but has since improved over the past few years. The spikes from 601.101 can again be seen on this graph as well as its sudden demise in June of 2010. Violation code SWMA301 states a “failure to store, transport, or dispose of residual waste.” Violations from this code do not appear to fluctuate greatly month by month. 402CSL is a more generic code that concerns an operator’s failure to adopt pollution prevention measures with a few operators per month being cited. 78.56(1) covers the storage of waste in pit and tanks that does not meet the capacity requirements set forth by the DEP. Most of these violations took place in early 2011 and have slowed a little since. Closely related to the previous code, 78.54 is issued when waste is improperly disposed of in commonwealth waters. Similar to SWMA301, this code was one of the more prominent citations over recent years. 401CSL, like 78.54, covers the disposal of waste in commonwealth waters showing up regularly in 2009 into 2010. A bit different from the previous codes, 78.86 states “the failure to report defective, insufficient, or improperly cemented casing.” 81 This is a recent occurrence starting around the end of 2010 up to present day. The Clean Stream Law is covered by violation code 691.1 and appears to be

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81 We do not consider this to be a just “Reporting” violation because the act implies negligent behavior and a real risk to the environment
concentrated around a series of events in early 2010 with a few violations per month. Finally, 201G is the violation code for the failure to post a drilling permit on site. The code appears to follow the wave in violations occurring during high violations times and less so during lower periods. This is also a code that we have classified as a “Reporting” violation as it does not directly relate to a specific environmental event.

Another interesting point of note from figure 11.7 is the sudden appearance of violation codes 402CSL, 78.56(1), and 78.54 around the time that code 601.101 nearly stops being cited.

Before we examine the violations according to the risk categories we wanted to evaluate total violations against two important benchmarks: wells drilled and inspections. By overlaying all three data sets on one graph we can observe how the data sets responded over time (Figure 11.8). From this graph it become clear that as the PADEP added more staff through the end of 2010 it coincides with the dramatic increase in wells drilled, topping out at 208 in August of 2011. However, as the number of wells drilled declines over more recent years, the number of inspections has steadied around 1,000 per month. Violations from 2008 to April of 2011 appear to follow both the increase in wells drilled and inspections. After, the violations follow a steady decline similar to the path of wells drilled.
11.3.2. Violations by Risk Category

After evaluating the data as a whole, we separated it into risk categories to understand how the violations behaved according to certain environmental categories. The first grouping or risk category we defined was risks to surface water (Figure 11.9). Much like the total violations in Figure 11.5, there tends to be a transition of violation codes from early 2010 to late 2011. Frequent early violations are 102.4, 601.101, 401CSL, issues maintaining the proper freeboard\textsuperscript{82} (78.56FRBRD), and an inadequate E&S plan (102.4INADPLN). These collective events peak around March of 2010 with approximately 120 violations. After this period the codes are more fragmented and peak exactly a year later with over a 120 violations in March of 2011. The violations then continue the same decline we have observed in other charts. The major violations that appear in the second half of this period are: SMA301, 401CSL, 78.54, 78.56(1), and 402CSL. It is interesting to note that the majority of these events cover the handling of waste, including those less cited.

After we analyzed the risks to surface water category was applied the same approach to the risks to groundwater. Since many of the violations that we applied to surface water also apply to groundwater, the chart exhibits very similar behavior (Appendix G: Figure G.1), particularly the magnitude of monthly violations. As a result, we instead attempted to identify events that were unique to groundwater to better understand the risks it is exposed to outside of those shared with surface water. According to the chart in Figure 11.10 there are three basic code violations that are

\textsuperscript{82} The space between the water level and the top of the pit
unique to groundwater. These violations are: 78.86, an improperly lined pit\textsuperscript{83}, and improper casing to protect fresh groundwater.\textsuperscript{84} Pit violations almost disappear around the end of 2010, while casing issues take center stage with a big spike in August of 2010. These violations, however, appear to be the result of one single operator, Talisman Energy. It is unclear if these are multiple wells or that Talisman was unable to bring one well into compliance within the required time. The majority of remaining violations are for improper casing or cementing procedures, including 78.86. However, the past few months appear to have violations for gas migrating into groundwater,\textsuperscript{85} particularly in October and December of 2012.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{violations}
\caption{All violations that are defined to be a risk to \textit{surface water}.}
\end{figure}

Figure G.2 in appendix G charts events that we determined to be unique to surface water. The chart is largely driven by 401CSL and other codes regulating the discharge of waste into common wealth waters.

Risks to \textit{habitat} are a combination of risks that are shared with either \textit{surface water} or \textit{groundwater}. With that said, a quick analysis reveals several codes that have shown up thus far: 102.4, 78.56FRBRD, SMA301, 78.56(1), 402CSL, 78.54, 691.1 are all violation codes that we have classified as a risk to \textit{habitat} and, therefore, are a large percentage of the violations for this category. No other items of note are found in this chart that has not already been discussed (Figure G.3).

\textsuperscript{83} 78.56LINEAR
\textsuperscript{84} 78.83GRNDWTR
\textsuperscript{85} 78.73A
Air quality risks are not as significant as the previous categories. On average, only a couple of citations have been written a month (Figure 11.11). Many of the violations cited during this period are for a rat holes not being filled (78.65(1)), improper best management practices (78.53), a failure to properly plug a well (210UNPLUG), and a failure to comply with the terms of the drilling permit (201E & 78.12). A majority of these codes were assigned to the risks to air quality category because they reference improper drilling techniques which can result in fugitive gases. Given the small amount of data, however, it is unwise to try and make any significant observations. Nonetheless, it should be noted that rat holes no longer appear to be an issue, while problematic abandoned wells are increasing.

The final category is risks to community, which includes the reporting sub category. Although the frequency of violations is not as high as that of the habitat, surface water, and groundwater categories, it does share a similar pattern to those charts. Violations peak around the same period with about 35 violations in July of 2010 and then again in August of 2011 (Figure 11.12). Prominent violations issued in this category are: 201G, 78.86, a failure to submit well records, the failure to notify DEP of pollution incident (91.33A), Administrative Code – general (51017), the failure to post approval number (78.57), and the failure to post approval number (201H). Most of these violations tend to be spread out throughout the time period with 201G, 78.86, and 91.33A occupying a majority of the violations since 2010. The large spike in February of 2009 from violation code 212WELLRCD was handed out to Cabot Oil & Gas Corp. for wells in both

86 212WELLRCD
Figure 11.11 – Violations that are a risk to air. Pink is violations code 78.53, the light green is 78.65(1), and the green-blue is 210UNPLUG.

Figure 11.12 – Violations that are a risk to the community. The chart is mainly comprised of the violations that we have categorized as reporting violations.
Dimock and Springville Township. There are two violations codes that we have categorized to be risks to *community* but are not reporting issues. These two codes are: 205A – Drilling within 200ft of a building and 6018.610 811 – Unlawful transfer of RSW (waste). Collectively, there have only been four instances in which these codes were issued.

11.3.3. Violation Yields
While evaluating the different risk categories in absolute terms is important, it is also necessary to see how they compare in relative terms. For this purpose, and with the goal of also removing some of the volatility induced by the boom in drilling over the past few years, we normalized the violations data. Figure 11.13 shows the results of this analysis for *surface water* risks per wells drilled and inspections. The figure shows a peak of early violations per well in June of 2008 (1.69 violations/well) with a subtle decline into 2010 (1.27 violations per well in June), including a concentration of high violations in 2009 that coincide with the absolute violations in figure 11.9. Also interesting to note is the violations per inspection peak a bit earlier than the absolute data in figure 11.9. The data below suggests a peak in June of 2009 with an almost constant decline through 2013.

![Figure 11.13 - Violations yields for risks to the *surface water* for both wells drilled and inspections. The data was calculated by taking the number of violations reported over the period and dividing by either the number of wells drilled or inspections made. The result can be interpreted as the number of violations that occur for every well drilled (red) or inspection (blue).](image)

Figures G.4 – G.7 in the appendix G show the results of the same analysis performed to the other risks categories. Both *groundwater* and *habitat* exhibit similar behavior in both the violations per well and violations per inspection as seen in figure 11.13. However, violations that pose risks to *habitat*, when measured per well, do appear to decline less so over time. The chart for *air quality*
risks provides little insight (Figure G.6) and does not appear to show any trends or behavior. Community violations (Figure G.7), on the other hand, appear to peak later than the other risk categories per well drilled, reaching their highest value in late 2010 and early 2011 followed by a slight decline.

Furthering the analysis of both violations per well drilled and violations per inspection, we decided to look at the top ten violations for both of these respective datasets. We determined the top ten to be the ten highest average violations over the period. We chose not to evaluate these yields according to the risk buckets because we wanted to identify some of the more responsive violations to these activities irrespective of the particular risk it posed to the environment. Figure 11.14 shows the results of this analysis with the legend ranking the violations from highest to lowest. Again, we notice the shift in segmentation of violations in around June of 2010. Early yields are dominated by violations related to the handling, disposal, and management of waste. One interesting point of note about violation code SWMA301 is that in the absolute analysis this shows up prominently in later years (2011-2013). However, when we adjusted these violations for the number of wells drilled we get almost the exact opposite effect. More recent violations address topics from a failure to comply with PA orders/requirements to a continuation of some waste management issues from earlier periods.

![Figure 11.14 – Top ten violations as measured by violations per well drilled. Top violations were calculated as the highest average yield over the time period. The violations code descriptions listed right rank yield from highest to lowest (top to bottom).](image)

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87 401CSL, 6018.301, SWMA301, and 301CSL
88 509, 206C, 203TAG and 91.33POLLINC
89 401CSL and 301CSL
Figure 11.15 shows top violations per well inspected and both 401CSL and SWMA301 appear on this chart as well. Whereas figure 11.14 indicates a subtle decline from 2008-2010, there is a more substantial drop off here. Yields peak in July of 2009 and then rapidly decrease as the number of inspections increase over more recent periods. Moreover, the magnitude of these events is much lower when compared to the yields from violations per well. The top ten violations per inspection largely cover broad topics such as E&S (erosion and sedimentation) issues and the management of waste. 691.1 and 601.101 are general codes so it is difficult to determine the exact type of events that have resulted in the issuance of these violations. SWMA301, 691.1 and 102.4 appear to account for the majority of the more recent violations.

11.3.4. Linear Correlations of Violation Frequency
The main question we wanted to answer from this analysis was if violations could be explained by an activity: drilling or PADEP inspections. Information gathered from this analysis can be useful in helping identify behaviors that result in violations. To this end, we calculated linear correlations between violations and the number of wells drilled, violations lagged one period and the number of wells drilled, and violations and the number of inspections. In this instance we did not allow violations to be assigned to multiple groups (i.e. violations per wells drilled and violations per inspection). If the linear correlation was higher for a specific violation then the violation was assigned to that particular group.

90 102.4, 102.4INADPLN, and 102.4NOPLAN
91 SWMA301, 401CSL, 78.56FRBRD, 78.56LINER
Figure 11.16 shows the ten violations per well drilled that meets the criteria set in the methodology. The chart mimics the absolute charts presented earlier, but in a more subtle fashion. The more prominent early violations are for improper construction of lined pits. A series of violations for improper discharge of waste (301UNPMTIW) occur in early 2010 at the height of drilling in Pennsylvania, but quickly disappear by the end of the year. The same can also be said for 51017, which is a general administrative violation. Immediately after this period is a violation code for the improper construction of pits (78.56(1)) in addition to code 78.86, which addresses the failure to report an issue with casing or submit a casing plan within the appropriate time frame. 402POTNLPOLL – potential for polluting substances reaching the commonwealth and 78.57 – failure to post approval numbers appear throughout the time period. The collective contribution of these violation codes results in a correlation of 0.65 with the monthly wells drilled for the time period.

Lagging the violation data one month resulted in five violation codes that responded in a measurable way to the monthly drilling numbers (Figure 11.17). The collection of data does not appear to be entirely active in early years, but is mostly concentrated from the end of 2010 through 2013. Over this later period there does appear to be some decrease in total yield. Most
**Figure 11.17** – Top linear correlations between violations lagged one period and wells drilled per month. Violations were lagged because the drilling process can take about one month to complete.

**Figure 11.18** – Top linear correlations between violations and inspections per month. Correlations listed.
notable among these codes is SWMA301, which also was present in both figures 11.11 and 11.12. This code has by far the largest yield per month and is also a current issue according to the time period. It also has a fairly strong correlation of 0.423. 201G and 201TAG are violations for the failure to post permit numbers, while 78.56(3) is for an improperly constructed impoundment. 91.33A was also prominent in the absolute community chart (Figure 11.12). The collective correlation of this data set is 0.81.

Lastly, we were able to identify seven codes that had a strong relationship with the number of inspections performed per month. The result of this analysis can be found in figure 11.18. Similar to figure 11.17 this data is concentrated in more recent years (2010-2013). However, the downward trends are not as strong with some significant upward movement in early 2012. We should also point out that these violations are dealing with much lower yield values per month compared to the previous figures given the extremely high number of inspections performed relative to wells drilled per month. Violation code 401CLS is very similar to 78.54, 6018.301, 402CSL, covering issues related to the discharge of pollution into commonwealth waters. While it does not show up frequently in this chart, it does correspond well to total monthly inspections with a correlation of 0.450. 78.54 and 402CSL are the more prominent violations with greatest yield over this period, but only 78.54 has somewhat of a high correlation at 0.237. 105NOPERMIT addresses encroachment issues, but the code is only cited during two early periods and then quickly disappears after July of 2010. 206C and 2010UNPLUG both address issues with the well site after drilling is completed and the operator has moved on. These events appear to have started to occur in the past year. This data set has a combined correlation of 0.83.

11.3.5. Violations by Inspection Type
Evaluating the same data set we sorted the violations according to the type of inspection performed by the DEP. Figure 11.19 shows that most violations result from complete inspections, partial inspections, follow up’s, compliance inspections, compliance evaluations, incident responses, and drilling inspections. Complete inspections appear to be the largest source of violations regardless of the time period. Follow up violations peaked during the frenzy of drilling boom in late 2010 and 2011, but have slowed noticeably since then. The same can be said for partial inspections, which have slowed at an even faster pace. The purple in more recent years is the result of violations from complaint inspections, not incident-response inspections which can be seen in both early 2010 and 2011.
Figure 11.19 – Total violations according to the inspection type performed by the PADEP. The color segments apply to the type of inspection listed above.

Because we have already evaluated the violation codes over time we wanted to instead look at the risk categories according to the inspection type. This type of analysis might indicate if one particular type of inspection resulted in a certain risk category showing up more frequently. Figure 11.20 shows the results of this analysis for risks to surface water. Not surprisingly, the majority of violations came from complete inspections (1,305) which correspond with the total data we evaluated in figure 11.19. Follow-up inspections came in at a distant second with 471 violations. Complaint, incident-response, and partial inspections follow at 328, 200, 297 violations respectively. SWMA301 appears to be a violation code that is used among all inspection types as well as 78.56(1). 102.4, on the other hand, is almost exclusively cited during complete inspections.
Figures G.9 and G.10 in appendix G show the results of this analysis for the risk categories groundwater and habitat with very similar results. Figure G.11 measures the violations that are identified to be a risk to the air quality. This chart shows that a majority of the violations are either cited during a complete inspection or drilling. Most of the drilling fines are for drilling without the appropriate permit or a failure to comply with PADEP terms.

Figure 11.21 looks at the violations determined to apply to the community risk category. While complete inspections are still responsible for the majority of the violations the proportion is not as large as the other categories. Many violations are also from drilling and follow up inspections. The majority of these violations are the result of the operator’s failure to disclose or post certain information (78.86, 201G, 78.57, 201H, 201F). The high number of administrative violations is from a failure to post well records within the appropriate timeframe.
Figure 11.21 – Total violations determined to be a risk to the community by inspection type. These violations are largely driven by routine inspections as well as drilling and follow-up inspections.

11.3.6. Linear Correlations by Inspection Type

Just as we did with the violation codes we calculated the linear correlations of violations according to inspection type against wells drilled and inspections per month. We also lagged the inspection data one month and calculated linear correlations against the number of wells drilled to see if this gave any better resolution. Table 11.3 provides a summary of this analysis. Results show that monthly well data not lagged provided the highest correlations for complaint, follow up, complete and partial inspections. Drilling inspection received their highest correlation with the lagged well data while incident-response was highest when regressed against monthly inspections.

<table>
<thead>
<tr>
<th>Inspection Type</th>
<th>Administrative/File Review</th>
<th>Complaint Inspection</th>
<th>Compliance Evaluation</th>
<th>Drilling/Alteration</th>
<th>Follow-up Inspection</th>
<th>Incident-Response to Accident or Event</th>
<th>Routine/Complete Inspection</th>
<th>Routine/Partial Inspection</th>
<th>Site Restoration</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPUD CORR</td>
<td>-0.242</td>
<td>0.245</td>
<td>0.162</td>
<td>0.206</td>
<td>0.438</td>
<td>0.030</td>
<td>0.398</td>
<td>0.253</td>
<td>-0.090</td>
</tr>
<tr>
<td>SPUD LAG1</td>
<td>-0.228</td>
<td>0.060</td>
<td>-0.032</td>
<td>0.262</td>
<td>0.348</td>
<td>0.083</td>
<td>0.393</td>
<td>0.197</td>
<td>0.00</td>
</tr>
<tr>
<td>Inspection CORR</td>
<td>-0.314</td>
<td>-0.001</td>
<td>-0.187</td>
<td>-0.039</td>
<td>0.028</td>
<td>0.418</td>
<td>0.254</td>
<td>-0.060</td>
<td>-0.127</td>
</tr>
</tbody>
</table>

Table 11.3 – Linear correlations between violations data and wells drilled and inspections.

11.3.7. Violation Fines
Fines were selected to act as a proxy for severity. Serious environmental events require the PADEP to recoup a specific dollar amount to help cover the cost to clean up the damage, or to account for the loss of some benefit to the community such as clean air. Figure 11.22 shows the total fines as we have defined them according to the methodology. It is important to note that while the dollar amounts identified represent actual fines administered by the PADEP, the treatment of these fines created values that are only representative values and should only be compared against their peers. Because fines were issued at inconsistent intervals we consolidated the chart to yearly fines in order to fully capture any trends. Fines appear to have peaked in 2010 at just over $2 million, although that may change as the data set only includes two months from 2013. Violation codes issued in combination with large fines are diverse. There are fines for improper well venting (78.74), a failure to post the pit approval number (78.57), and even a failure to submit a plugging certificate (78.124). In fact, while most of the violation codes below repeat in multiple years only 601.101 and 78.55 (large waste spill) do so with large fines in each year.

11.3.8. Risk Matrices
Lastly, we combined the violation and fine data producing scatter charts that measure the frequency of a particular violation code against its implied severity. Figure 11.23 shows the results of this analysis for all violation codes. Through this lens it is very easy to separate and identify violation codes that warrant special consideration. We highlighted the top fourteen codes as violations of high risk. These violations are:
• **209BOP** - Inadequate or improperly installed BOP, other safety devices, or no certified BOP operator
• **401CSL** - Discharge of pollutational material to waters of Commonwealth.
• **301CSL** - Stream discharge of 1W, includes drill cuttings, oil, brine and/or silt
• **78.83GRNDWTR** - Improper casing to protect fresh groundwater
• **78.56FRBRD** - Failure to maintain 2’ freeboard in an impoundment
• **91.33A** - Failure to notify DEP of pollution incident. No phone call made forthwith
• **402POTNLPOLL** - There is a potential for polluting substance(s) reaching Waters of the Commonwealth and may require a permit.
• **691.1** - Clean Streams Law-General. Used only when a specific CLS code cannot be used
• **78.54** - Failure to properly control or dispose of industrial or residual waste to prevent pollution of the waters of the Commonwealth.
• **402CSL** - Failure to adopt pollution prevention measures required or prescribed by DEP by handling materials that create a danger of pollution.
• **78.56(1)** - Pit and tanks not constructed with sufficient capacity to contain pollutational substances.
• **SWMA301** - Failure to properly store, transport, process or dispose of a residual waste.
• **102.4** - Failure to minimize accelerated erosion, implement E&S plan, maintain E&S controls. Failure to stabilize site until total site restoration under OGA Sec 206(c)(d)
• **601.101** - O&G Act 223-General. Used only when a specific O&G Act code cannot be used

Source: PADEP

Figure 11.23 – Total violations graphed against total fines. The highlighted codes are the top violations that are considered to be of high risk.

Figure 11.24 captures all of the risks that we have attribute to *surface water* risks. Violations of the Clean Streams Law are highly visible.\(^{93}\) **401CSL** is also a unique risk to *surface water*, so its position should be noted specifically for this environmental category. Another group of codes are those addressing the handling of waste.\(^{94}\) Taken as a whole, waste management issues represent

\(^{93}\) 401CSL, 301CSL, 402CSL and 691.1
\(^{94}\) 78.54, SWMA301, 78.56(1), and 78.56FRBRD
approximately ten percent of the 112 violation codes that the PADEP has issued for surface water risks.

![Graph showing total violations vs. total fines for violations considered to be a risk to surface water. Both 401CSL and 402POTNPOLL are high risk violations that are unique to surface water.](image)

As we have discussed in earlier sections the violations assigned to surface water risks are very similar to groundwater. Therefore, examining figure 11.25 we can observe the addition of 78.83GRNWTR, which we know to be violations administered for improper casings (a unique risk to this category). Groundwater risks have a total of eleven codes that appear to be of high importance. Figure 11.26 charts the risks to habitat. Violations that bear notice are events that address the handling of waste and erosion (102.4). A violation that we have not discussed is the presence of code 209BOP, which appears in all five risk categories. It is hard to determine what to do with this violation as the event has only been cited once; however, the fine that was handed in response to the event was significant ($353,419). There are only nine events of note for habitat risks.

Figure G.13 shows risks to air quality, or more accurately, a lack thereof. The only instance of note is code 78.74, which is for hazardous well venting. As we saw earlier in the analysis this violation appears to have only been cited once in July of 2012. It also does not meet the benchmark we instituted for high risk events. No other violations warrant much consideration.
Figure 11.25 – Total violations vs. total fines for violations considered to be a risk to groundwater. 78.83GRNDWTR is a unique high risk violation.

Figure 14.26 – Total violations vs. total fines for violations considered to be a risk to habitat.
The final category is risks to the community (Figure 11.27) and it has only one violation code that meets the benchmark, 91.33 – failure to notify the DEP of a pollution incident. This code is unique to this risk category.

![Graph](image)

*Figure 11.27 - Total violations vs. total fines for violations considered to be a risk to community. 91.33A is a unique high risk violation. Also notice the change in magnitude of the axis indicating less impactful violations.*

11.3.9. Dimock

On January 1, 2009 the well at Norma Fiorentino’s house exploded in Dimock Township. A subsequent investigation performed by the PADEP determined that drilling activities by Cabot Oil and Gas Corporation resulted in elevated levels of methane gas in eighteen drinking wells serving nineteen homes in and around Carter Road. In a consent order issued on November 4 the PADEP fined Cabot $120,000 and demanded the company perform the following activities:

- Cease all hydraulic fracturing activities in the area
- Plug and abandon three of the Dimock/Carter Road Gas wells
- Recondition the Ely 4 gas well
- Prepare and implement a plan to check the integrity of the Dimock/Carter Road gas wells
- Provide temporary, whole house water supplies to the owners of residences within the Dimock/Carter Road area, including to the property owners
- Provide new vent stack or extended existing vent stacks on water supplies
- Provide well casing and drilling plans before any additional drilling can be performed

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96 [http://files.dep.state.pa.us/OilGas/OilGasLandingPageFiles/FinalCO&A121510.pdf](http://files.dep.state.pa.us/OilGas/OilGasLandingPageFiles/FinalCO&A121510.pdf) Accessed 4/16/2013
Cabot was given until March 31, 2010 to comply with these activities or face a penalty of $1,000 per day. While Cabot signed the consent order the company stopped short of accepting responsibility for the well contamination. Cabot argued the methane came from sources other than the Marcellus Shale. The consent order was subsequently revised two times by the PADEP with the final document imposing a penalty of $500,000 for Cabot’s failure to comply in a timely manner as well as an order for Cabot to pay impacted homeowners twice their property values. Again, Cabot disagreed with the states findings but signed the final consent.

Once Cabot complied with the order they filed for, and received, permission to stop providing fresh water to homeowners on December 1, 2011. However, the order only required Cabot to offer filtration systems and provided no criteria regarding water testing. In January of 2012 the EPA responded to these events by performing their own tests and subsequently found dangerous levels of arsenic, barium, and other hazardous substances in four residential water wells. The EPA completed their study in July after determining the investigation no longer required additional action. Over this period the EPA sampled water at 64 homes finding “in all cases the residents have now or will have their own treatment systems that can reduce concentrations of those hazardous substances to acceptable levels at the tap.” However, the Agency for Toxic Substances and Disease Registry (ATSDR) is following up on the test results from the EPA study.

In August of 2012 Cabot settled with 32 of the 36 families for damages related to water wells in both Susquehanna and Dimock Townships, thus bringing an end to the contentious debate for most of the land owners and Cabot. The remaining four families have chosen to continue their fight with Cabot in court.

Four years later Cabot continues to have issues with water quality as dangerous methane levels were again detected in January of 2013 at two residential wells on Carter Road. The site had only been recently reopened to drilling. A PADEP investigation is currently underway.

### 11.4. Discussion

#### 11.4.1. Violation Frequency and Trends

Absolute violations appear to increase hand in hand with the increases in drilling and inspections from 2008 up to mid-2010. What is hard to evaluate is what exactly causes the increase in fragmentation in May of 2010? The changes could be the result of some combination of the inspectors becoming more knowledgeable about hydraulic fracturing, the introduction of new

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100 http://yosemite.epa.gov/opa/admpress.nsf/d0cf6618525a9efb85257359003fb69d/1a6e49d193e1007585257a46005b61ad/opendocument Accessed 4/16/2013
legislature, and the increase in staff dedicated to inspect sites. This theory would also help to 
explain the second peak in 2011 as it coincides with the PADEP updating their best practice 
requirements. While the sudden increase in fragmentation after May of 2010 is good, it is not 
clear if the violations are new or just a reclassification of old, more ambiguous codes, such as 
601.101 (General O&G). Moreover, there is a tremendous amount of overlap in the codes. 
Multiple violations reference either the Clean Streams Law, issues with the management of 
water, or erosion and sedimentation (E&S) practices on site. However, the PADEP provides no 
information that clearly states the difference between these potentially overlapping codes. Even 
reading the inspector notes from violation reports adds little clarity. In fact, many times 
inspectors use the same comments for similar violations. Increasing the number of violation 
codes in this sense may result in diminishing returns as violations from particular events may be 
spread among multiple codes and, therefore, underestimate the potential risk to the environment. The 
PADEP will likely need to balance the tradeoffs of using more or less codes over time to help 
inform their regulatory process.

The decision to group the violations according to the environmental risk categories in section 8 
provided little added value to our analysis. The framework does not accurately reflect the process 
of hydraulic fracturing and focuses too much on the impacts. For example, if one were unloading 
water into a pit they would be at risk of damaging the local habitat in addition to the 
groundwater and surface water. Since a majority of these activities pose a risk to multiple 
environmental categories the framework seeks only to validate risks instead of understand them. 
We would be interested to see how classifying violations according to operator activities may 
influence the PADEP’s approach to regulating hydraulic fracturing. We attempted to perform 
this analysis by examining violation codes according to inspection type (Figures 11.20 & 11.21), 
but the resulting data was not granular enough to provide the necessary information.

The normalized data we calculated for top ten violations (Figure 11.14 & 11.15) may be a 
questionable proxy for how violations behave according to the number of inspections or wells 
drilled. Violations were ranked according to the highest average yields over the time period. This 
leaves the data susceptible to outlier events and does not take into account any trends over time. 
Furthermore, the violations that occurred in both charts may appear in the wells drilled chart 
because the absolute number of wells being drilled declines while the number of inspections 
remained relatively constant. This type of “false positive” reinforces the downside to this 
analysis. However, it is worth noting that issues with waste management appear to be prevalent 
in both charts.

Since we were worried the yield analysis might provide some inaccurate data we wanted to 
supplement this information with linear correlations in order to determine if violation codes are 
more likely to be written during drilling or ongoing operations (inspections). We believe this to 
be important because it can help inspectors identify risks that are long-term and short-term (i.e. 
SPUD dates). SWMA301 (Failure to properly store, transport, process or dispose of a residual 
water) is a great example of this as it appears to be a violation that has a strong relationship with 
wells lagged one month (Figure 11.18); meaning the violation is likely to occur about a month 
after drilling is started. This is precisely around the time when flowback and produced water is 
pulled off the well. We believe that figures 11.16, 11.17, and 11.18 could be viewed as a short, 
medium, and long term outlook for environmental risks on a drill site. The PADEP could use this
information to identify operator processes that coincide with these codes and plan inspections accordingly.

Taking a more holistic view of the linear correlation data we can see the subtle improvement over time from mid-2010 to February of 2013 (Figures 11.16-11.18). This is important to note because it does indicate an improvement in the frequency of environmental events over this time period. Because the data has been normalized these numbers are not influenced by the rush in activity in 2010 or the decline in drilling over recent years. One can then infer that the activities of the PADEP have resulted in lower violations. Another interesting point of note is the grouping of risks in more recent times. Violations such as 402CSL (Clean Streams Law), 78.56(1) (Pit capacity not appropriate), and SMA301 are examples of codes that inspectors should be conscience of when heading to a drill site. This is not to say that other violations should be ignored but these graphs again show how the changes in the regulatory structure around 2010 have impacted the violation results. We would be curious to see how the PADEP perceives this shift and how the violations cited in previous years were carried over into more recent periods. The absence of violations in years prior to 2010 (figure 14.13) is a good representation of this shift.

As we noted earlier, the analysis by inspection type (Figures 11.20 & 11.21; Table 11.3) was meant to try and identify at what stages risks were occurring: drilling, clearing of land, or ongoing operations. Unfortunately, the data provided very little insight as it was unclear how the inspection types were used. There is no available information on the PADEP website regarding these categories and we were unable to identify any meaningful trends.

11.4.2. Evaluation of the PA Fines

Initial analysis of the fines data did not provide a tremendous amount of insight. The fines appear to be sporadic at best and cannot be linked to any one particular violation over others. The fines appear to be determined by circumstance which makes it difficult to define the severity of violations in specific terms. However, looking more generally at the data some of the larger fines have come from improper erosion, mishandling of waste, and the discharge of waste into commonwealth waters without approval. This is not unexpected considering the dangers that waste generated from hydraulic fracturing can pose to the environment. Secondary to these fines are more administrative type issues such as no permit, a failure to follow of best practices, and a failure to report information in a timely manner. This is surprising in that these events would not be described as a real impact, but more as the increased potential for one. It is reasonable to conclude that these fines are likely the result of the primary events listed above. These secondary violations are complementary to the primary and may be used to set precedence for a fine by the PADEP. This makes it extremely difficult to determine the value of one code when multiple violations are regularly issued.

11.4.3. Priority Risk Events in PA

The fourteen risks that were identified in the risk matrices are the events that pose the greatest risk to the environment. An overwhelming majority of these codes reference the improper storage, transfer, and disposal of waste (Figure 11.24). Only 78.83GRNWTR (Improper casing to protect groundwater) and 102.4 (E&S) are violation codes that do not directly deal with waste issues. However, 78.83GRNWTR is one the more prominently sited issues by those who are
opposed to hydraulic fracturing, and the data suggests there is validity in this concern. While the violation does not appear as frequent as others, the relatively high fine amount indicates the potential damage to the environment. This violation code is also one of four category unique codes out of the fourteen, which furthers the argument that the framework from section 8 provides little additional value. In fact, we can see from the community (Figure 11.27) and air quality (Figure G.13) risk matrices that there appear to be no substantive high risk events. While it is equally important to confirm the absence of risks, the lack of data from these groups combined with the relative homogeneity of the remaining categories continues to promote an alternative framework for capturing hydraulic fracturing risks. Two high risk codes also address the use of open pits. Recent news articles have indicated a shift towards the use of tanks over pits. It could be possible these events are a driving force behind this transition.

Violation code 601.101 was largely ignored for this analysis because it appears to be an older code that was replaced by others in recent times. If more time was available to us we would have attempted to reclassify the 601.101 violations into the more recent codes to see if this changed any of the results.

Overall, it is clear that PADEP efforts need to continue to address the handling of waste. Information that the PADEP could obtain to show how violation codes relate to each other may shed light on the chain of custody and help improve best management practices. Recording the specific activities of operators prior to a violation would also help to understand the processes that a more likely to result in environmental events.

11.4.4. PADEP’s Response to Dimock
The events in Dimock Township act as a microcosm for the hydraulic fracturing debate. Individuals and groups opposed to hydraulic fracturing often reference the potential to pollute water resource, particularly drinking water, as reason enough to ban the process. A simple Google search of the phrase “Dimock Hydraulic Fracturing” will lead to a myriad of blogs, news articles, and journals that have weighed in on the issue on both sides. How the Dimock story unfolds will likely have a considerable influence on the future of hydraulic fracturing. Thus, the involvement by stakeholders from federal agencies to local environmental groups is both understandable and important. It is extremely important that the events in Dimock be well understood to help inform the policy agenda going forward.

From the research we collected it is apparent that Cabot’s activities resulted in the increase of methane concentrations in the wells on Carter Road. While Pennsylvania’s laws assume operators guilty of any well contamination within 1,000 feet of drilling, the Dimock case highlights the importance of baseline testing in residential wells. Baseline testing would have informed environmental scientists if the wells on Carter Road already contained methane originating from deep below the surface. Additionally, if methane and other naturally occurring hazardous substances were present then residents could have enacted preventative measures to improve well quality and established a benchmark to compare against any impact’s from Cabot’s activities. Instead, the PADEP’s only course of action was to issue orders to Cabot to remedy the methane issues while the company publicly denied responsibility. This type of behavior

undermines the regulatory process, which likely pushed the residents of Carter Road to call on the EPA to intervene.

We choose to abstain from weighing in on the EPA’s involvement from a legal standpoint; however, we do believe that their participation verified that measures can be undertaken to mitigate groundwater contamination from drilling activities. Ensuring the safety of drinking water should be one of the main priorities of any government body regulating hydraulic fracturing. The EPA’s decision to investigate Dimock was an important step in achieving this goal as it validated the PADEP’s findings. The follow up study performed by the ATSDR should be viewed as an opportunity to look at contaminants that are not currently regulated by the EPA and assess if they pose any health risks to residents of Dimock Township. If so, this would provide further precedence to explore if these contaminants are the result of drilling activities.

The more recent issues reported in Dimock raise many questions. Most notable is the relationship this event may have to the issues discovered in 2009. If so, then it brings into question the ability of the PADEP and drilling companies to mitigate these risks long term. If not, then questions will need to be asked about Cabot’s ability to manage these risks and if the local geology is playing a role.

Regardless, the PADEP should learn from past mistakes and be actively engaged with the local community throughout the process. Not only should they be focused on determining the facts but also making sure the community members are being informed throughout the process.

Another issue that appears to be growing is the numerous definitions applied to hydraulic fracturing. In the instance of Dimock Township, many news reports attributed the methane migration into residents’ wells to be the result of hydraulic fracturing. Individuals who take a more industry perspective argue that methane migration is from bad casing and hydraulic fracturing is a completely different process. In essence, the argument around hydraulic fracturing can sometimes be an argument of semantics. We agree that the process of hydraulic fracturing should be looked at individually, but we also understand that the sum of the parts is necessary to complete an unconventional well. Thus, an unsafe casing makes an unsafe hydraulic fracturing process. We believe the definition that we have described in section 12.1 is a good balance between these two differing points of view.

11.4.5. Limitations
We acknowledge that there are some limitations to the analysis. First, violations were determined to apply to environmental risk categories based on the subjective interpretation of the PADEP’s codes. Adding or removing codes from one particular category could affect the data and conclusions. However, we spent a considerable amount of time evaluating these violation codes and are comfortable with the classifications we have determined.

Another potential limit to the analysis was the decision to spread the fine data among all violations codes issued on that day. It is reasonable to assume that the fines were administered with specific violations in mind, but there is no information on the PADEP database that
provides that information. In addition, evaluating each fine on an individual basis would take a considerable amount of time and subjective reasoning. There are also other fines that were issued to operators via revoked bonds and civil rulings that are not maintained on the PADEP database. These fines were excluded from the analysis.

Finally, and most important, is the analysis only captures risks identified by the PADEP. Potential risks, such as fugitive gas emissions, were ignored because the PADEP does not monitor them at this point. The analysis in this paper is meant to inform stakeholders about the current risks of hydraulic fracturing and develop framework to identify more in the future.

11.5. Pennsylvania Case Conclusion

The analysis performed in this section indicates that total violations have declined in Pennsylvania over the past few years independent of decreased drilling. Pennsylvania has often been credited with a strong regulatory program and the analysis supports this claim. However, there remains significant room for improvement. It is overwhelmingly clear that waste water management continues to be one of the more prominent issues. What the PADEP needs to understand is what behaviors precede these events. We believe that if the PADEP inspectors were to monitor hydraulic fracturing risks from a process oriented view it would help to inform these unknowns. Through this framework they will be able to gain a better understanding of how activities on site lead to environmental impacts. As a result, the focus would be less on preventing impacts and more on mitigating the hydraulic fracturing processes that precede them. We believe that the PADEP could easily add this dimension to their inspections by simply adding detailed process oriented options to their “Inspection Type” report category.

The PADEP should also continue to leverage the Marcellus Shale Coalition and other stakeholders to continue to improve their regulatory process. This should include a yearly revaluation of the reporting process into the eFACTS database. It is important that once the data is reported an individual is capable of retrieving it with ease. We observed that some violation codes are included in the inspector notes and, therefore, not searchable. Additionally, the PADEP should provide clarity on violation codes that appear to be redundant or ambiguous. The codes need to be well understood and differentiated in order to improve the reporting process both internally and externally. Fines issued to operators should be assigned to a particular violation or some basic framework should be presented for determining fines. Assigning the fines to a group of violations can be a distraction from the real risks. A great deal of the information in the eFACTS database is obscured by this reporting process. This greatly hinders the ability to learn from past events.

In addition to continuously evaluating their internal processes, the PADEP should monitor and explore all scientific research related to the environmental impacts of hydraulic fracturing. The PADEP’s recent announcement of a long term air monitoring study is a great example. The effects of localized air emissions are not entirely understood and further research is warranted given the numerous diesel generators required onsite during the fracturing process. Academic research and environmental and industry reports are other examples of content that can help inform the PADEP and improve their regulatory oversight. Moreover, they should support
initiatives such as the recent announcement by the Center for Sustainable Shale Development (CSSD) to certify gas wells that meet specific environmental standards. Industry partnerships with environmental advocacy groups are a tremendous way to quickly improve best practices, especially when they empower consumers of natural gas. The PADEP should continue to stay informed on these issues.

The state of Pennsylvania has worked hard to adapt to the revolutionary technology of hydraulic fracturing. More importantly, they have shown the ability to manage these risks with greater success each year. However, the state must not be complacent. They must continue to develop a framework that safely develops unconventional resources. The research has shown that there is still significant progressive to be made, and it is worth every effort to see that it is done.

12. Summary

Our analysis shows the framework (Figure 12) we have laid out in this paper can be used to inform stakeholders on the pathways through which environmental risks perceptions influence the political agenda. First, we examined how media and public interest of hydraulic fracturing relate. We observed the media’s coverage of hydraulic fracturing over time and contrasted this with public interest. Major events were also identified as case studies to examine how the media’s coverage can influence public perception. Next, stakeholders were identified who play a significant role in driving the public policy agenda of hydraulic fracturing.

Mental models and risk priority matrices were developed to understand how these stakeholders evaluate the risks of hydraulic fracturing over the near and long term. Recommendations were then made to maximize the stakeholder’s mission in the hydraulic fracturing debate. Finally, we used a case study of the Pennsylvania Department of Environmental Protection (PADEP) to explore the regulatory framework of hydraulic fracturing and observe the outcomes as public policy influences environmental events. Data was collected

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from the PADEP to identify high risk outcomes and their impact to environmental categories. Observations were made about the success to date in managing hydraulic fracturing and suggestions were given to improve the process and better inform the public agenda. The significant rise in hydraulic fracturing over recent years has fundamentally altered the energy landscape. In order to effectively shape our future we must understand the role the public agenda plays in this process. While we realize this framework is not the answer to all the questions surrounding hydraulic fracturing, we do believe that it can help stakeholders influence of the public agenda and develop sound policy.
APPENDIX A – Compiled Survey Questions and Answers, Part 1
(survey responses in chronological order)

Muhlenberg Institute of Public Opinion
Question: “In general do you feel that drilling for natural gas in the state will provide more benefits or problems in the future for the citizens of Pennsylvania?”
Response: “More benefits”: 50%
“More problems”: 32%
“About equal”: 17%

Center for Social and Urban Research
Question: “Considering everything, how do you feel about natural gas extraction from the Marcellus Shale?”
Response: “Strongly Oppose”: 8.6% Washington County, 12.5% Allegheny
“Somewhat Oppose”: 16.8% Washington, 16.6% Allegheny
“Neither oppose nor support”: 23.9% Washington, 30.1% Allegheny
“Somewhat support”: 26.6% Washington, 23% Allegheny
“Strongly Support”: 24.2% Washington, 17.9% Allegheny

Louisiana Survey
Question: “Do you think hydraulic fracturing or fracking is a very safe method to extract natural gas from the ground, somewhat safe, not very safe, or not at all safe?”
Response: “Don’t Know”: 41.7%
“Very Safe”: 12.3%
“Somewhat Safe”: 22.2%
“Not Very Safe”: 8.7%
“Not At All Safe”: 15.1%
Question: “Do you think the process of extracting natural gas that involves using a high-pressure injection of water, and chemicals to remove natural gas from rocks deep in the earth’s surface is a very safe method to extract natural gas from the ground, somewhat safe, not very safe, or not at all safe?”
Response: “Don’t Know”: 33.3%
“Very Safe”: 12.6%
“Somewhat Safe”: 29.9%
“Not Very Safe”: 12.4%
“Not At All Safe”: 11.4%

Rasmussen Reports
Question: “A process known as hydraulic fracturing, sometimes called fracking, is used to drill for oil and natural gas in shale oil reserves. Do you favor or opposed the use of fracking to produce more oil and natural gas in this country?”
Response: “Favor”: 57%
“Oppose”: 22%
“Unsure”: 23%
Siena Research Institute

Question: “Do you support or oppose the Department of Environmental Conservation allowing hydrofracking to move forward in parts of upstate New York?”
Response: “Support”: 42%
“Oppose”: 36%
“Not enough information/ Don’t know/ No opinion”: 22%

APPENDIX B – Compiled Survey Questions and Answers, Part 2

Muhlenberg Institute of Public Opinion

Question: “Natural gas drilling in Pennsylvania poses a major threat to the state’s water resources”
Response: “Strongly Agree”: 33%
“Somewhat Agree”: 27%
“Somewhat Disagree”: 13%
“Strongly Disagree”: 15%
“Not Sure”: 12%

Center for Social and Urban Research

Question: “To what extent do you think the Marcellus Shale represents a threat to the environment/public health?”
Response: “Significant threat”: 22.4% Washington County, 28% Allegheny County
“Moderate threat”: 25.3% Washington County, 32.4% Allegheny County
“Slight threat”: 23.2% Washington County, 26.2% Allegheny County
“Very little/no threat”: 19.2% Washington, 13.4% Allegheny

Louisiana Survey:

Question: “Some people say the state should encourage hydraulic fracturing because of the economic benefits, while other say the state would not encourage hydraulic fracturing or fracking because of potential environmental impact. Which comes closer to your view?”
Response: “Don’t know”: 26.4%
“States should encourage drilling”: 38.6%
“States should not encourage drilling”: 35%

Question: “Some people say the state should encourage drilling for natural gas by this process because of the economic benefits, while other say the state would not encourage drilling because of potential environmental impact. Which comes closer to your view?”
Response: “Don’t know”: 13.1%
“States should encourage drilling”: 51.6%
“States should not encourage drilling”: 35.3%

Rasmussen Reports

Question: Is it possible to develop shale oil reserves in the United States while still protecting the environment?
Response: It is impossible to develop without doing environmental damage: 14%
It is possible to develop without doing environmental damage: 63%

Pacific Institute
Question: What are the major concerns associated with hydraulic fracturing?
Response: Spills/Leaks: 87.5%
Wastewater: 81.25%
Water Withdrawals: 75%
Air Emissions: 62.5%

References


APPENDIX C – List of Popular Chemicals Used in Hydraulic Fracturing (EPA 2012)
APPENDIX D – Code Violations Noted by the PADEP from 2008 – February 2013

- 102.11 - Failure to design, implement or maintain BMPs to minimize the potential for accelerated erosion and sedimentation.
- 102.22 - Failure to achieve permanent stabilization of earth disturbance activity.
- 102.4 - Failure to minimize accelerated erosion, implement E&S plan, maintain E&S controls. Failure to stabilize site until total site restoration under OGA Sec 206(c)(d)
- 102.4HQBMP - Failure to implement Special Protection BMPs for HQ or EV stream.
- 102.4INADPLN - E&S Plan not adequate
- 102.4NOPLAN - No E&S plan developed, plan not on site
- 102.5NPDES - Failure to obtain an NPDES Permit for Stormwater Discharges Associated With a Construction Activity.
- 105.11 - Person constructed, operated, maintained, modified, enlarged or abandoned a water obstruction or encroachment but failed to obtain Chapter 105 permit.
- 105.11 - Water obstruction or encroachment constructed, operated, maintained, modified, enlarged or abandoned without a 105 permit.
- 105.44 - Failure to implement work according to specifications in 105 Permit.
- 105.44 - Permittee has failed to perform work according to specifications as approved.
- 105GEN - Encroachment-General
- 105IMP - Failure to implement Encroachment Plan
- 105NOPERMIT - Encroachment without Permit or Waiver
- 201A - Failure to have permit on site during drilling
- 201E - Failure to comply with terms and conditions of permit
- 201G - Failure to notify DEP, landowner, political subdivision, or coal owner 24 hrs prior to commencement of drilling
- 201G - Failure to post permit number, operator name, address, telephone number in a conspicuous manner at the site during drilling
- 201H - Failure to properly install the permit number, issued by the department, on a completed well.
- 201I - Drilling with an expired permit
- 201PRMT - Drilling, altering, or operating a well without a permit
- 201TAG - Failure to install, in a permanent manner, the permit number on a completed well
- 203TAG - Failure to affix, in a permanent manner, a registration number on a well within 60 days of registration
- 205A - Drilling w/in 200 ft of building or water well w/o variance
- 205B - Drilling w/in 100 ft of surface water or wetland w/o variance

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<tr>
<th>Chemicals</th>
<th>Category</th>
<th>No. of Products</th>
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<td>Carcinogen</td>
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<tr>
<td>p-Xylene</td>
<td>HAP</td>
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206C - Failure to restore well site within nine months after completion of drilling, failure to remove all pits, drilling supplies and equipment not needed for production.
206D - Failure to restore site w/in 9 months of plugging well
206EST - Failure to restore site w/in 9 months of completion of drilling or plugging
207B - Failure to case and cement to prevent migrations into fresh groundwater
208A - Failure to restore a water supply affected by pollution or diminution
209BOP - Inadequate or improperly installed BOP, other safety devices, or no certified BOP operator
210H - Failure to properly install the permit number, issued by the department, on a completed well.
210IMP - Failure to plug zones having bore gas, oil, or water
210UNPLUG - Failure to plug a well upon abandonment
212CMPLRPT - Failure to submit completion report within 30 days of completion of well
212PRODRT - Failure to submit annual production report
212WELLRC - Failure to submit well record within 30 days of completion of drilling
301 - Failure of storage operator to maintain and/or submit required information, such as maps, well records, integrity testing information, pressure data
301CLC - Stream discharge of IW, includes drill cuttings, oil, brine and/or silt
301UNPMFTIW - Industrial waste was discharged without permit.
307CLC - Discharge of industrial waste to waters of Commonwealth without a permit.
401CAUSEPOL - Polluting substance(s) allowed to discharge into Waters of the Commonwealth.
401CLS - Discharge of pollutational material to waters of Commonwealth.
401CLC - Discharge of pollutical material to waters of Commonwealth.
402610 - Failure to meet effluent limits of permit
402CLS - Failure to adopt pollution prevention measures required or prescribed by DEP by handling materials that create a danger of pollution.
402CLS - Failure to meet requirements of permit, rules and regulations, or order of DEP.
402POTNL - There is a potential for polluting substance(s) reaching Waters of the Commonwealth and may require a permit.
409 - Failure to comply w/ order, CO&A, hindrance to personnel, misrepresentation under OGA
51017 - Administrative Code-General
601.101 - O&G Act 223-General. Used only when a specific O&G Act code cannot be used
6018.301 - Operator has mismanagement Residual Waste.
6018.301 - Residual Waste is mismanaged.
6018.30A - Unlawful Management of RSW
6018.610 88II - Unlawful transfer of RSW
6018.610-2 - Person or municipality operates a facility without a permit.
6018.610-4 - Handles solid waste contrary to rules and regulations, or orders of the Department, or any permit condition, or in any manner as to create a public nuisance.
6018.610 - Clean Streams Law-General. Used only when a specific CLS code cannot be used
6018.401 WPD - Failure to prevent sediment or other pollutant discharge into waters of the Commonwealth.
6018.401 - Potential to pollute waters of the Commonwealth
6018.402WPP - Site conditions present a potential for pollution to waters of the Commonwealth.
78.11 - Well drilled or operated without a permit or registration from DEP.
78.12 - Oil or gas well drilled, altered or operated not in accordance with a permit or the regulations.
78.122 - Drillers Log not on site
78.124 - Failure to submit plugging certificate 30 days after well plugged
78.51A - Failure to restore or replace an impacted water supply.
78.51H - Failure to report receipt of notice from a landowner, water purveyor or affected person that a water supply has been affected by pollution or diminution, to the Department within 24 hours of receiving the notice.
78.53 - Failure to implement and maintain BMPs in accordance with Chapter 102.
78.54 - Failure to properly control or dispose of industrial or residual waste to prevent pollution of the waters of the Commonwealth.
78.55 - No Control and Disposal/PCC plan or failure to implement PCC plan
78.56(1) - Pit and tanks not constructed with sufficient capacity to contain pollutional substances.
78.56(2) - Failure to maintain 2’ of freeboard in an impoundment.
78.56(3) - Impoundment not structurally sound, impermeable, 3rd party protected.
78.56FRBRD - Failure to maintain 2’ freeboard in an impoundment
78.56LINER - Improperly lined pit
78.56PITCHN CST - Impoundment not structurally sound, impermeable, 3rd party protected, greater than 20’ of seasonal high ground water table
78.57 - Failure to post pit approval number
78.57C5 - Failure to construct properly plug, frac, brine pits
78.57PITAPPR - Failure to obtain pit approval/permit
78.60B - Tophole water discharged improperly
78.61A - Improper pit disposal of drill cuttings from above the casing seat
78.62 - Improper encapsulation of waste
78.64 - Inadequate containment of oil tank
78.65(1) - Rat hole not filled
78.65(2) - Failure to restore site within 30 days of permit expiration when well not drilled
• 78.65(3) - Failure to submit or submitting an inadequate well site restoration report within 60 days of restoration of the well site
• 78.66A - Failure to report release of substance threatening or causing pollution
• 78.66BRINE - Failure to report a reportable release of brine to DEP within 2 hours.
• 78.73A - Operator shall prevent gas and other fluids from lower formations from entering fresh groundwater.
• 78.73B - Excessive casing seat pressure
• 78.74 - Hazardous well venting
• 78.81D1 - Failure to maintain control of anticipated gas storage reservoir pressures while drilling through reservoir or protective area
• 78.81D2 - Failure to case and cement properly through storage reservoir or storage horizon
• 78.83A - Diameter of bore hole not 1 inch greater than casing/casing collar diameter
• 78.83B - Insufficient casing strength, thickness, and installation equipment
• 78.83C - Inadequate, insufficient, and/or improperly installed cement
• 78.83D - Failure to report defective, insufficient, or improperly cemented casing within 24 hours or submit plan to correct within 30 days
• 78.83E - Conservation well located less than 330' from lease or unit line without waiver.
• 78.83F - Insufficient casing, BOP, cement or wait on cement to prevent waste from conservation well.
• 78.84 - Inadequate, insufficient, and/or improperly installed cement
• 78.85 - Inadequate, insufficient, and/or improperly installed cement
• 78.86 - Failure to report defective, insufficient, or improperly cemented casing within 24 hours or submit plan to correct within 30 days
• 79.11 - Conservation well located less than 330' from lease or unit line without waiver.
• 79.12C - Insufficient casing, BOP, cement or wait on cement to prevent waste from conservation well.

APPENDIX E – Codes According to Risk Buckets (Administrative Codes are in Yellow)

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APPENDIX F – List of Inspections Performed by the PADEP

- Administrative/File Review
- Complaint Inspection
- Compliance Evaluation
- Drilling/Alteration
- Follow-up Inspection
- Incident- Response to Accident or Event
- Plugging(Includes Plugged/Mined Through)
- Routine/Complete Inspection
- Routine/Partial Inspection
- Site Restoration

APPENDIX G – Additional Charts
Figure G.1 – Total violations determined to be a risk to **groundwater**.

Figure G.2 – Total violations determined to be a unique to **surface water**.
Figure G.3 – Total violations determined to be a risk to habitat.

Figure G.4 – Violations yields for risks to the groundwater for both wells drilled and inspections. The results can be interpreted as the number of violations that occur for every well drilled (red) or inspection (blue).
Figure G.5 – Violations yields for risks to the habitat for both wells drilled and inspections. The results can be interpreted as the number of violations that occur for every well drilled (red) or inspection (blue).

Figure G.6 – Violations yields for risks to the air quality for both wells drilled and inspections. The results can be interpreted as the number of violations that occur for every well drilled (red) or inspection (blue).
Figure G.7 – Violations yields for risks to the community for both wells drilled and inspections. The results can be interpreted as the number of violations that occur for every well drilled (red) or inspection (blue).

Figure G.8 - Top Ten Violations per Well Drilled Less Reporting Violations
Figure G.9 – Total violations that were determined to be a risk to *groundwater* by inspection type.

Figure G.10 – Total violations that were determined to be a risk to *habitat* by inspection type.
Figure G.11 – Total violations that were determined to be a risk to air quality by inspection type.

Figure G.12 – Total violations vs. total fines.
Figure G.13 – Total violations vs. total fines for risks to air quality. Notice the lower frequency compared to figure G.12.

Figure G.14 – Totally yearly inspections by inspection type.
Figure G.15 – Total violations determined to be a risk to the *community*. Includes reporting violations.
What the shale? Environmental risk perceptions of hydraulic fracturing

Anna Chavis
Fred Robinson
Harrison Thomas

Duke University
April, 2013
Genesis of our project

• Shale gas has been a game changer in the energy landscape of the U.S.

• The U.S. public is exposed to significant volumes of information about the potential impacts on the economy and the environment

• Video: http://www.youtube.com/watch?v=lXnpW7nBcbg
Problem:
How to determine the most important environmental risks of hydraulic fracturing?
Problem: Most important risks?

Solution:

A framework to explain the development of hydraulic fracturing risk perceptions

Audience
## Project purpose

**Problem:** Most important risks?

**Solution:** Deliver a framework

**Audience:**

Actors aiming to improve environmental risk management and communication

- Industry
- Media
- Academia
- Advocacy
- NGOs
- Government
Project Approach

1. Develop Framework
   - Public Agenda Building Framework
     - Media Agenda
     - Public Agenda
     - Policy Agenda
     - Implementation
     - Management
     - Impact

2. Validate Framework
   - Environmental Risks of Hydraulic Fracturing
     - I. Media Coverage and Public Interest
     - II. Stakeholder Perceptions and Scientific Perspective
     - III. Environmental Risk Management in Pennsylvania

Public Agenda
Media Agenda
Implement Management Impact

Project Approach

1. Develop Framework
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Public Agenda
Media Agenda
Implement Management Impact
Project Inputs

• Experts
  - Journalists
  - Industry public relations
  - Advocacy groups
  - Government regulators
  - Published literature
  - Academic research
  - Non-profit organizations

• Data Analysis
  - Factiva
  - TVNews
  - Twitter
  - Google Trends
  - Resources for the Future
  - Pennsylvania Department of Environmental Protection
  - NVivo
Results and Discussion
Key Question
What determines the content and form of hydraulic fracturing information presented to the public?
• Does the Public agenda drive the Media agenda?
• Vice versa?

Results and Discussion
1. Determined actors and influence
2. Identified frames used
3. Evaluated trends and relationships in coverage and interest
Determined primary media/public actors their relative influence

<table>
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<tr>
<th>Print Media Actors, 2012</th>
<th>Social Media Actors, 2012</th>
<th>Broadcast Media Actors, 2012</th>
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Financial coverage dominates

66% against hydraulic fracturing

Financial coverage dominates

Proximity to shale gas is important
Identified frames (keywords)

Coverage/Interest Density (normalized)

Public Policy Frames
- Study
- Ban
- Legislation
- Rules
- Companies
- Industry
- Public

Stakeholder Frames
- Water
- Earthquakes
- Chemicals
- Safe
- Land
- Contaminate
- Health
- Drink
- Pollution
- Air
- Risks

Environmental Risk Frames
- Public Interest (Google)
- Print Media Coverage (New York Times)
- Social Media Coverage (Twitter)

**Media and public like studies**

**Public wants company, not industry, info**

**Print media needs more earthquake coverage to keep up with social media and public interest**
Evaluated frame trends

**Print Media** (Top 9, 2012)

- Air
- Climate Change
- Earthquakes
- Land
- Traffic
- Wastewater
- Water Cont.
- Water Use

**Social Media** (Twitter, 2012)

- Air
- Climate Change
- Earthquakes
- Land
- Traffic
- Wastewater
- Water Cont.
- Water Use

**Public Interest** (Google, 2012)

- Air
- Earthquakes
- Land
- Wastewater
- Water

- **Strong air, climate, and water frames**
- **Declining env risk frames**

- **Strong earthquake and water frames**
- **Volatile env risk frames**

- **Strong earthquake and water frames, Stable env risk frames**
Evaluated frequency trends

**Print and social media correlation**  
(r=.65)

**Social media and public interest correlation**  
(r=.57)

**Broadcast media is volatile and uncorrelated**
Evaluated relationships

Interactive relationship in 7/8 cases

No interactivity on the day after Thanksgiving
Public Agenda: Stakeholder perception of risk

Key Question
How do different stakeholders perceive risks of hydraulic fracturing?
• Differences in risk priorities today & tomorrow?
• Impact of environmental outcomes on stakeholder agenda?

Results and Discussion
• Surveys of “layperson” opinions
• Foundations for stakeholder understanding of risk
• Risk prioritizations by stakeholder
Surveys show trends in public agenda

Fracking as an Environmental/Public Health Threat

Increasing perception of fracking as “non-threat” to environment
Tools to analyze stakeholder perceptions of risk

- Stakeholder Mental Models: Foundations of Perception
- Stakeholder Conversations: Prioritizations of Risk, Present and Future
Mental models represent perceptions

- Mental models:
  - Diagrams of mental representations of problems
  - Context-dependent & incomplete
  - Analyze risk controversy in issues of high decision stakes and system uncertainties
  - Important to understand diverse points of views

Mental models increase ability to move towards policy conclusions, encourage negotiation, reduce destructive conflict
Fracking mental models: Multiple decision points and complex decision pathways

Meet U.S. Energy Demand

Fracking

Integrated Safety, Mgmt, Risk Planning

Storage and Disposal: Fracturing Fluids, Flowback, & Produced Water

Risk of Poor Planning for Water Disposal Wells

Failure to Comply with EPA Well Pump Rules

Triggered Seismicity

Spillage from Risk Management Failure

Well Integrity Risk from Incomplete Safety Planning; Failure to Monitor Frac Job in Real-time

Potential for Surface Water Contamination

Gas Migration to Underground Water Resources

Community Protests Fueled by Media/Hype

Necessity for Open Dialogue/Community Engagement

Need for Open Dialogue/Community Engagement

Community/Activist Protests

Onsite Air Emissions from Methane and VOCs

Onsite Emissions Offset by Significantly Low Downstream Emission

Site Development and Drilling Preparation

Drilling Activities

Fracturing and Completion

Well Operation and Production

Failure to Comply with Well-Construction Standards

Failure to Comply with Well-Construction Standards

Fines & Negative Press

Spillage from Risk Management Failure

Gas Migration to Underground Water Resources

Meet U.S. Energy Demand

Integrate Safety, Mgmt, Risk Planning
### Differences in foundation, processes, repercussions

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<th>Model Characterization:</th>
<th>Industry</th>
<th>Community Grassroots</th>
<th>NGOs</th>
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<td><strong>Foundation of Risk Decision</strong></td>
<td>Extract to meet demand</td>
<td>Distrust gov’t, industry</td>
<td>Environmental mission</td>
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<td><strong>Risk Decision Flow</strong></td>
<td>• Safety planning</td>
<td>• Negligence</td>
<td>Potential for:</td>
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<td></td>
<td>• Subsurface/surface failures</td>
<td>• Laundry list of risks</td>
<td>• Costs: Envi harm</td>
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<td>• Risk realization</td>
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<td>• Benefits: Reduced GHGs</td>
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<td><strong>Repercussion of Risk</strong></td>
<td>Company resources ($, time, image)</td>
<td>Harm to local community, health, environment</td>
<td>Necessities: stringent regs, scientific studies</td>
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- **Process-oriented, Safety-Planning lens**
- **Distrust with local lens**
- **Measured response, long-term lens**
Matrices show risk prioritization by activity, current & future

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<thead>
<tr>
<th>Shale Gas Development Activity</th>
<th>Ground-Water</th>
<th>Surface Water</th>
<th>Air Quality</th>
<th>Habitat Disruption</th>
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| Fracking & Completion Well Production & Operation | M | M | | | |
| Fluid Storage & Disposal | M | M | | | |

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| Site Development & Drilling Preparation Drilling Activities | | | | | |
| Fracking & Completion Well Production & Operation | | | | | |
| Fluid Storage & Disposal | | | | | |

Common: Diminishing risk over time, esp air quality
Differ: Number of pathways, ability to minimize risk
Nascent scientific findings drive cloudy perceptions

Lack of substantial scientific research creates misinformation, conflict in public-agenda building framework

Air Quality Findings: % of natgas production lost to methane leakage

- EPA: 2.3% leakage
- Industry: 1.6% leakage
- City of Ft Worth: 0-5% leakage
- Cornell: 3.5 – 7.9% leakage
- NOAA: 4% leakage
- MIT: 3.6% leakage
- EPA: 2.3% leakage

Media Agenda

Public Agenda

Policy Agenda

Implementation

Management

Impact
## Recommendations to stakeholder groups to advance respective missions

<table>
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<th>Stakeholder Group</th>
<th>Recommendation</th>
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| Industry          | 1) Acknowledge prior risk events and current problems to increase accountability and transparency  
                    2) Invest to reduce impacts  
                    3) Share the winning |
| Community Activists & Local Organizations | 1) Develop unified message instead of laundry list  
                                            2) Come to the table to negotiate with stakeholders for strong regulations when moratoriums/bans fail |
| NGOs              | 1) Work with government for stringent regulations addressing NGO-valued risks: methane emissions, wastewater disposal, fluid spillage management  
                    2) Partner with industry for cost-effective best practices in risk management |
Environmental Risk Management in Pennsylvania

January 2008 - February 2013
Pennsylvania Case Study

Key Question
• How has Pennsylvania managed the development of shale resources?
• Can governments mitigate the environmental risks of hydraulic fracturing?

Results and Discussion
• Collected data from PA DEP
• Identified trends
• Quantified risks
Implementation

Changes in the regulatory framework influence violations reported by the PA DEP
Risk Trends

Violations are issued for the failure to comply with state laws and regulations (112 unique codes)
Risk Trends

Violations Strongly Correlated to Wells Drilled Per Month

Violations peak in 2010 but decline shortly after
Risk Trends

Lagged Violations Strongly Correlated to Wells Drilled Per Month

New Staff

Tougher Laws

Violations appear to be associated with more recent regulations
Risk Trends

There appears to be a noticeable downward trend in all three scenarios
Environmental Impact

These impacts are largely from improper waste management and E&S
Environmental Impact

Only two violations can be defined as risks that are specific to surface water
Environmental Impact

Groundwater

Category
Unique Risk

Severity (Fines)

Frequency (Violations)

$0
$50,000
$100,000
$150,000
$200,000
$250,000
$300,000
$350,000
$400,000

0
50
100
150
200
250
300
350
400
450

78.83GRNDWTR is a violation for improper casing to protect fresh groundwater
Environmental Impact

Habitat

Habitat risks are shared with Surface Water and Groundwater
Air quality has no risks of note, which questions the use of this framework
Environmental risk analysis would be more effective if it were evaluated through a “process oriented” lens
Conclusion: Framework = Validated

- Media coverage and public interest are interactive
- Mental models code information
- Stakeholders drive policy based on their understanding of impacts
- Policies are set and implemented, creating new management practices, which in turn influence impacts

Studies define and interpret impacts
A Special Thanks to our MP Advisors:
Dalia Patino Echeverri
Simon Rich