An Overview of Research

From Journalist’s Resource, Oct 26, 2014, The environmental costs and benefits of fracking: The state of research gives a good overview of many of the issues related to hydraulic fracturing. It is noted that expo of domestically produced crude oil was directly related to fracking activities. Productivity is discussed with a focus on the generally short life of fracking wells and the need to continue drilling new wells in what “has been called the ‘Red Queen’ syndrome, named after the Alice in Wonderland’ character who must run fastr and faster just to stay in the same place. The validity of reserves estimates is called into question:

“Because fracking is still evolving and estimation of reserves is based on well productivity that can change over time, reserve estimations should be regarded with caution. For example, in 2011 the Energy Information Agency (EIA) estimated that the U.S. had 827 trillion cubic feet of shale gas, but the following year dropped its estimate to 482 trillion cubic feet, a 40% decrease. (Note that some nongovermental organizations have calculated even lower forecasts.)” (Productivity and reserves section) [1]

The volume of water required and the risks to water supplies is brought up as an issue as water usage is highly variable. It is noted that the volume of water used “is lower for fracking than other fossil fuels and nuclear:

“Coal, nuclear and oil extraction use approximately two, three and ten times, respectively, as much water as fracking per energy unit, and corn ethanol can use 1,000 times more if the plants are irrigated. By comparison, renewables such as wind and photovoltaic solar energy require almost no water.” (Water requirements and risks section) [1]

In the well integrity and failure rate two key issues are noted. The first of these is the quality of how abandoned wells are sealed:

“After the end of a well’s operational life, it is “plugged and abandoned” (P&A). In this process, “mechanical or cement barriers, such as packers, at different depths are used to prevent fluids from migrating up or down the well. Improperly abandoned wells provide a short circuit that connects the deeper layers to the surface.” (Well integrity and failure rates section) [1]

The second issue concerns transparency. “Publicly available data on well failure rates are still relatively scarce.” This makes it difficult to get an accurate “read” on the frequency which which such problems occur. It is noted that there is one criteria by which closed well performance can be monitored. This is the “sustained casing pressure” (SCP). Well integrity and failure rates section) This SCP can be a good indicator that the potential for contamination is exists. [1]
The section on Risks to surface and groundwater is worthy of inclusion here in full simply due to the complexity of these issues:

- **While it is theoretically possible for fissures created by hydraulic fracturing to connect well bores with shallow aquifers, in practice this is unlikely:** Targeted shale formations are generally 1 to 3 kilometers below the surface and the fissures created during operations rarely extend more than 600 meters. In general, contamination through existing fissures or abandoned wells is a “more plausible scenario,” as is poor well integrity. (Note that the EPA is investigating a contamination case in Wyoming where the sandstone formation being drilled was as close as 322 meters to the surface in an area with water wells that went as deep as 244 meters.)
- **Two studies of the drinking water of a total of 209 homes overlaying the Marcellus Shale in Pennsylvania found evidence of hydrocarbon pollution. The first study found “17 times higher methane concentrations for the homes,” while the second concluded that “casing and cementing issues were the likeliest causes for the fugitive GM that they observed in the shallow aquifers.” On the other hand, a study of 127 homes over Arkansas’s Fayetteville Shale found no evidence of contamination.
- **While the probability of groundwater contamination is “strongly debated and universally controversial,” drilling specialists have identified casing and cementing problems as one of their primary environmental concerns.**
- **Beyond the risk to groundwater supplies, U.S. oil and gas operations generate more than 2 billion gallons of wastewater daily:** “These naturally occurring brines are often saline to hypersaline and contain potentially toxic levels of elements such as barium, arsenic, and radioactive radium.”
- **More than 95% of the wastewater is injected deep underground; other disposal methods are “less common and far less preferable.” These include treating it at municipal waste facilities and spraying on public roads for purposes such as dust control. “An experimental application of [approximately] 300,000 liters of flowback water on 0.2 hectares of forest in West Virginia killed more than half the trees within two years.” [1]

While evidence of seismic effects are rare, the number of earthquakes that occur in the U.S. have increased in recent years. Specifically: “Between 1967 and 2000, geologists observed a steady background rate of 21 earthquakes of 3.0 Mw or greater in the central United States per year. Starting in 2001, when shale gas and other unconventional energy sources began to grow, the rate rose steadily to [approximately] 100 such earthquakes annually, with 188 in 2011 alone.” (Seismic effects section) [1]

Air pollution is an issue throughout the process. From establishing the drill site to using the product, there are complications of dust and the exhaust of machines. Stored waste water can contain volatile organic compounds which must be vented to the atmosphere. Is this enough to offset the benefits inherent when gas replaces coal for energy production? Perhaps that would be true if coal consumption does decline.

Conclusion:
“The researchers conclude with five recommendations. First, greater transparency is required from companies and regulating agencies. Some information is available on the FracFocus disclosure registry, but more is needed. Second, short- and long-term studies are required on the potential effects of fracking on operations on human health — “virtually no comprehensive studies have been published on this topic,” they note. Third, predrilling data, including environmental quality and human health, would be in all parties’ interests. Fourth, because most problems result from surface operations, including faulty wells, spills and leaks, additional work on best practices is required. Finally, funds should be created to address future, unknown problems that could arise from the current oil and gas boom. “Drilling millions of new oil and natural gas wells will inevitably lead to future issues,” they note, and authorities and firms should work to ensure that the resources are available to deal with them.” [1]

Anthropogenic emissions of methane in the United States [2]

Methane is one of the key components of natural gas and studies show that leaks, at various levels, do occur. Is this better than Carbon in the atmosphere? Maybe not:

The contribution of individual greenhouse gases to climate change is not just a function of their presence in the atmosphere and the amount emitted, however — another factor is their lifespan. Methane is less present in the atmosphere than carbon, but has up to 72 times the global-warming potential over 20 years. Nitrous oxide is rarer still, yet has 289 times the warming potential over the same time frame.

Studies have called into question the accuracy of the EPA estimates for methane leakage but does not that “…petroleum and natural gas systems, including fracking, constituted the second largest sector in terms of greenhouse gas emissions…”[2]

Wastewater Disposal from Unconventional Oil and Gas Development Degrades Stream Quality at a West Virginia Injection Facility [3]

In this study, wastewater from fracking was found to have an impact on pH and conductivity of water downstream from an injection disposal facility. Such changes can affect the aquatic flora and fauna of streams/rivers. Given that the researchers were unable to clearly identify the point of origin of the contaminants found in the water, the conclusion calls for: “Further investigations of potential contaminants, endocrine disruption activity of stream waters, as well as studies of aquatic organisms, and comparisons with impacts from other anthropogenic inputs are warranted to determine potential environmental health impacts of UOG wastewater disposal practices.

Hydraulic fracturing water use variability in the United States and potential environmental implications [4]

[Abstract] Until now, up-to-date, comprehensive, spatial, national-scale data on hydraulic fracturing water volumes have been lacking. Water volumes used (injected) to hydraulically fracture over 263,859 oil and gas wells drilled between 2000 and 2014 were compiled and used to create the first U.S. map of hydraulic fracturing water use. Although median annual volumes of 15,275 m$^3$ and 19,425 m$^3$ of water
per well was used to hydraulically fracture individual horizontal oil and gas wells, respectively, in 2014, about 42% of wells were actually either vertical or directional, which required less than 2600 m$^3$ water per well. The highest average hydraulic fracturing water usage (10,000–36,620 m$^3$ per well) in watersheds across the United States generally correlated with shale-gas areas (versus coalbed methane, tight oil, or tight gas) where the greatest proportion of hydraulically fractured wells were horizontally drilled, reflecting that the natural reservoir properties influence water use. This analysis also demonstrates that many oil and gas resources within a given basin are developed using a mix of horizontal, vertical, and some directional wells, explaining why large volume hydraulic fracturing water usage is not widespread. This spatial variability in hydraulic fracturing water use relates to the potential for environmental impacts such as water availability, water quality, wastewater disposal, and possible wastewater injection-induced earthquakes.

The following images are from this report:
Figure 1.

Average of the data within 1st–99th percentile of water volumes used (injected) per well to hydraulically fracture oil and gas wells (horizontal, directional, and vertical) drilled from January 2011 to August 2014 in watersheds (8 digit Hydrologic Unit Codes, HUCs) with at least two wells reporting water use ($n = 81,816$ wells). Shale-gas formations are numbered (not in any particular order): (1) Barnett (Bend Arch-Ft. Worth Basin), (2) Eagle Ford (Gulf Coast Basins), (3) Woodford (Anadarko and Arkoma Basins), (4) Fayetteville (Arkoma Basin), (5) Haynesville-Bossier (Gulf Coast Basins), (6) Tuscaloosa (Gulf Coast Basins), and (7) Marcellus and Utica (Appalachian Basin). Supporting information Table S1 contains data used to construct this figure.
Figure 2.

The (a) median national annual water volumes used (injected) per well to hydraulically fracture wells drilled from January 2000 to August 2014 delineated as a function of drill-hole direction (vertical, horizontal directional) and final status (oil or gas) \((n = 263,859)\) and (b) number of hydraulically fractured wells drilled from January 2000 to August 2014 as a function of drill hole direction and final status \((n = 371,607)\). Includes only well information gathered and reported by IHS, Inc. [IHS Energy, 2014] as of 28 August 2014. Note: 1 cubic meter \((m^3)\) is equal to 264.17 gallons. Supporting information Tables S2 and S3 contains data used to construct this figure.
Figure 3.

Percent of hydraulically fractured wells that were horizontally drilled from January 2011 to August 2014 in watersheds of the United States (n = 47,646). These horizontal wells represent about 47% of the total number of hydraulically fractured wells drilled during this period. Supporting information Table S4 contains data used to construct this figure.
Historical Hydraulic Fracturing Trends and Data Unveiled in New USGS Publications


p.1 “Water-intensive horizontal/directional drilling has also increased from 6 percent of new hydraulically fractured wells drilled in the United States in 2000 to 42 percent of new wells drilled in 2010. Increases in horizontal drilling also coincided with the emergence of water-based “slick water” fracturing fluids.”

p.1 “Hydraulic fracturing treatment base fluids are broadly categorized as water-based, acid-based, oil-based, or foam-based (Gulbis and Hodge, 2000; U.S. Environmental Protection Agency, 2004; Holditch, 2007), and the various treatment fluid types (treatment fluids) result from the addition of a number of different additives (Holditch, 2007). However, the exact mix of treatment base fluids, additives, and proppants is not a “one-size-fits-all” composition, but instead depends on reservoir properties, rock and hydrocarbon type, temperature, pressure, and the sensitivity of the reservoir system to water,…”

p.2 “In some cases, however, hydraulic fracturing is often discussed as if it has been a uniform practice, regardless of time and geologic setting, which may be due, in part, to the scarcity of publicly available and easily accessible published data and intermittent knowledge regarding the actual extent, locations, methods, and chemistry of hydraulic fracturing. As such, the controversy regarding hydraulic fracturing may have been confounded by improper comparisons between historical and current occurrences, applications, distributions, and chemistry of hydraulic fracturing and its rapid advancement over the past decades (Holditch and Ely, 1973).”

p.4 Map of fractured well count 1947-2010
Figure 1. Distribution of nearly 986,600 hydraulically fractured wells drilled in the contiguous United States from 1988 through 2018 by U.S. Geological Survey hydrologic unit. Offshore and Alaskan wells are not shown.
One of the most significant areas of this study is found on p.10 where it is noted that significant changes in hydraulic fracturing treatment fluids and additives occurred in the years 2000-2010. While fracturing has been used as a process for over 50 years, the way it which it has happened has changed. Any “longitudinal” studies concerning the impact of fracturing on the environment would not be valid comparisons given the changes of those 10 years. Additionally, the number of horizontal well went from 6% of wells drilled in 2000, to 42% in 2010. Keep in mind that prior to 1953 virtually all wells were vertical in nature.

Table 2 on page 11 shows the much higher volume of water that is required with horizontal wells compared to vertical wells. As the number of horizontal wells have increased, the volumes of water used have also increased significantly.

[Summary] These analyses have demonstrated that hydraulic fracturing treatments are neither temporally nor spatially equivalent; therefore, comparisons and assumptions regarding attributes of individual applications should be made with caution. There have been significant advancements in both drilling and treatment fluids since their initial applications, most strikingly since 2000. The most recent hydraulic fracturing production methods have resulted in a dramatic increase in oil and gas development, particularly in shale reservoir rocks previously considered too impermeable or uneconomic for exploitation. Between 2000 and 2010, the greatest number of hydraulic fracturing treatments were applied to wells drilled within the Appalachian, Gulf Coast, and Permian Basins, but hydraulic fracturing is in widespread use for the development of unconventional, continuous oil, natural gas, and natural gas liquid accumulations in most of the major oil and gas basins within the United States. Development of these resources, made newly accessible by directional/horizontal drilling and hydraulic fracturing technologies, are contributing to energy reserves in the United States. Although hydraulic fracturing is still primarily applied in vertically drilled wells, the use of horizontal drilling has rapidly emerged and is requiring an increased use of water resources.

Sources:


Cited Sources that were Reviewed:


Hydraulic fractures: How far can they go. (n.d.)


**Additional Sources Reviewed:**

Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources | EPA Science Advisory Board (SAB) | US EPA. (n.d.). Retrieved September 13, 2016, from [https://yosemite.epa.gov/sab/sabproduct.nsf/LookupWebReportsLastMonthBOARD/F7A9DB9ABBA C015785257E540052DD54?OpenDocument&TableRow=2.3](https://yosemite.epa.gov/sab/sabproduct.nsf/LookupWebReportsLastMonthBOARD/F7A9DB9ABBA C015785257E540052DD54?OpenDocument&TableRow=2.3)


EPA’s Voluntary Methane Programs for the Oil and Natural Gas Industry | US EPA. (n.d.). Retrieved September 1, 2016, from [https://www.epa.gov/natural-gas-star-program](https://www.epa.gov/natural-gas-star-program)


