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Hydraulic Fracturing: A Report as to the Implications Regarding Natural Gas

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WORCESTER POLYTECHNIC INSTITUTE

Hydraulic Fracturing

A Report as to the Implications Regarding Natural Gas

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Abstract

Hydraulic fracturing is currently at the forefront of energy debates around the country. It has the potential to help enhance the acquisition of natural gas, but may also pose risks to the environment if not done correctly. In an effort to help understand the issue, we have conducted extensive research on the possible impacts, benefits, and risks in regards to hydraulic fracturing. In accordance with the resulting information presented in this report, an evaluation system was created, and concluded that with proper regulations and procedures the benefits of hydraulic fracturing outweigh the potential environmental impacts.

Authorship

This report was written through the combined effort of all four members of our IQP team. We would like to extend a thank you to Professor Bergendahl and Professor Tao for their assistance in the writing of this paper.

Abstract

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Executive summary

Hydraulic fracturing is a relatively new mining practice powerful enough to rejuvenate the natural gas industry and allow for the retrieval of natural gas reservoirs that were previously thought unreachable. It does this with enormous amounts of water and what are called fracturing fluids and proppants that are injected underground to create fractures within the rock formations. At the cost of water and chemicals, these fracturing jobs can be carried out with tremendous return, and much cheaper than similar practices.

The down side to fracturing however, is the risk that it poses to the environment and communities involved with the companies that partake in this process. This ranges from potential water, air, and soil contamination to the possible correlation between fracturing and small scale seismic activity. In addition to these risks, the concerns that plague any involved party include land use, water usage, fracturing fluid recovery, wastewater management and any and all related chemicals utilized in the fluids.

Nevertheless, these concerns are not unfamiliar to those on both sides of the hydraulic fracturing issue. Currently, the United States is a battleground for political struggles involving those both for and against the wide spread use of this process. Regulations and bans are being restructured throughout the nation as the research to support or refute claims of fracturing is being conducted by organizations such as the EPA. Yet, the observed and expected benefits range from job creation to stronger energy independence for the country as a whole.

In light of the industry forming around hydraulic fracturing there have been alternate methods to the typical water and fluid approaches. These alternatives have been praised for innovation, and ridiculed for assumed risk, but just as the usual form of the practice, they are under the nation's magnifying glass. Likewise, an evaluation system has been constructed to analyze the potential risks and benefits of the most common forms of hydraulic fracturing. There within the trend leans in favor of economic benefits versus environmental risks.

Finally, the future of hydraulic fracturing is in the hands of the media, citizens, big corporations and the government. Whether or not the practice continues and expands will be determined by the research of the coming years. The fate of hydraulic fracturing will be decided soon.

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Chapter 1: Introduction

Hydraulic fracturing is a process by which the modern man “mines” for one of his most important resources – natural gas. In accordance with this method of extraction, billions of gallons of water and a variety of chemicals are pumped deep within the earth daily. In doing so the natural gas is displaced, collected, and eventually shipped and sold. This process, after decades of refinement and although still young relative to other common practices, has become quite profitable.

Hydraulic fracturing, despite its success, has been questioned and persecuted for the apparent damage, or the potential for such on the environment and populous. This worry stems from the various chemicals used in the fluids driven underground and the fact that some fluids are left with the hope that they will harmlessly decompose. Similarly, there is the issue of ground water and possible contamination in that capacity.

As a result of the potential consequences, and those that were believed to be a result of hydraulic fracturing, there have been several laws and regulations passed that deal with this method of extraction. These were written to direct and at times restrict the use of certain machinery, well locations, and chemicals used in the fluids needed to make this process a success. The question that has arisen however is whether these restrictions are enough to protect the environment and if hydraulic fracturing should even be legal. This of course has shown hydraulic fracturing to be a controversial issue marred by the risks and supported by the potential benefits; risks seen and feared most by local communities where fracturing occurs and benefits enjoyed most by those who do not get their hands dirty.

In spite of the controversy however, and considering the alternative methods for achieving the same goal, hydraulic fracturing is an extremely promising and worthwhile endeavor. The increased natural gas production coupled with reduced production cost and smaller operation sites is encouraging. This additional source of natural gas could both increase natural gas availability and allow for a smoother transition to green fuels and renewable forms of energy.

Chapter 2: Background

The United States lead the world in 2010 by consuming 683.3 billion cubic meters (m^3) of natural gas, over 160 billion m^3 more than the European Union that same year[i]. That being said, natural gas meets 24 percent of the U.S energy demand and is used to heat a majority of the nation's households[ii]. With an ever expanding nation, both in the senses of population and energy consumption, there has always been the quest for more efficient forms of energy production and the acquisition of natural gas is no different.

2.1 History

In 1947, a company by the name of Halliburton experimented with and named a new process by which to gather natural gas from underground reserves. Halliburton, founded in 1919, employs over 70,000 employees in almost 80 different countries, and has become a well-known advocator for their invention[iii]. Hydraulic fracturing, or hydro fracturing as it is sometimes called, was a new way by which mankind could gain access to one of its favored forms of energy in an infrastructure prepared to accept the results. As Halliburton advanced the technology used in hydraulic fracturing, they began to see profit and promise. In 1957, they introduced the HT-400 pump which became the standard for the next 50 years and contributed to their current fracturing job count of over 1.1 million[iv].

Since its invention almost 65 years ago the popularity and use of hydraulic fracturing as a method by which to extract natural gas has risen exponentially. The United States Environmental Protection Agency estimated that between 70 and 140 billion gallons of water were used to fracture 35,000 wells in 2010[v]. This is a steep comparison to the single well Halliburton drilled for Stanolind in Kansas when it all began.

2.2 What is Fracturing?

Hydraulic fracturing is mainly used for the extraction of natural gas and gas from shale formations, called shale gas. These reserves of natural gas can be up to 2 miles underground, and when they are within shale formations the difficulty of gaining access is dramatically increased. In order to understand what fracturing is, the process by which this gas is accessed and acquired, there are some elements that must be understood. Firstly, the puzzle that is hydraulic fracturing has several pieces: there is the well, the fracturing fluid, the pump, and the clean up. Additionally the well must first be drilled; employees work the site, fluids and gases must be stored, and clean up can at times be difficult.

2.2.1 Natural Gas

With natural gas as large of a part as it is in the modern world’s power infrastructure it is understandable where the focus of hydraulic fracturing lays. The gas itself is colorless, odorless, and most importantly it is combustible and abundant enough to have built entire infrastructures around it. The typical composition of raw natural gas includes methane, ethane, propane, butane, carbon dioxide, oxygen, nitrogen, and hydrogen sulphide. While it has this wide array of “ingredients,” refined natural gas is almost entirely methane[vi].

The reason that natural gas can be extracted from wells has to do with its physical properties. Clearly as a gas it is difficult to compress, but outside of that natural gas has a very low density that allows it to rise through rock formations once it has been formed (a process that usually takes place deep underground). A great majority of the natural gas that is formed underground is trapped within impermeable foundations of tight sand, sedimentary rock, or shale that can at times form a “dome” shape that catches all the gas trying to float to the surface.

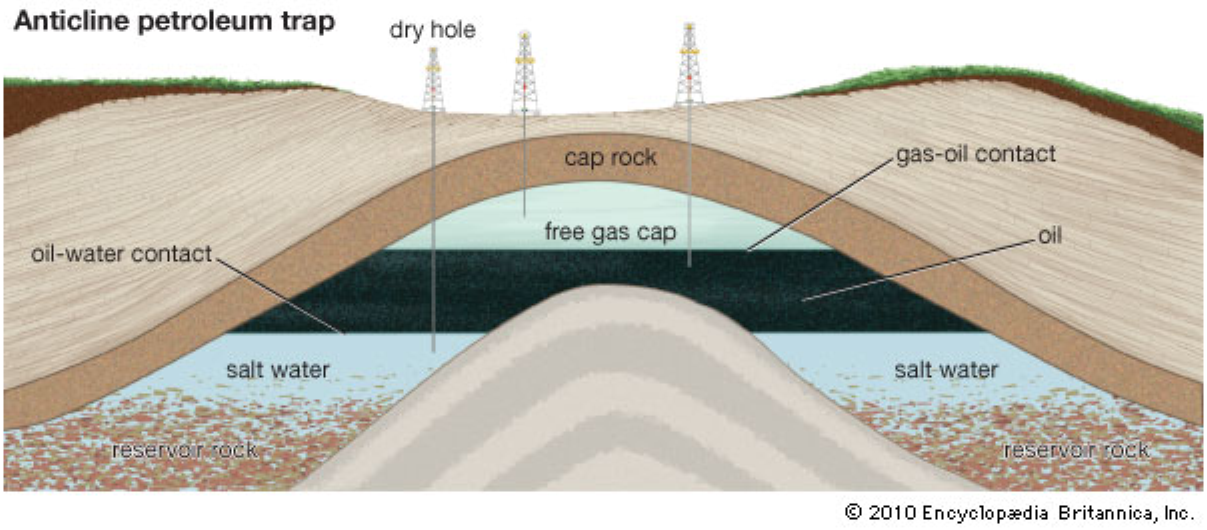


Figure 2.1: *An example of the dome shaping of cap rock formations trapping underground natural gas reserves.*

A commonly encountered term is “shale gas,” this is in reference to natural gas trapped within shale formations (as shown in Figure 2.1). This has garnered enough popularity to warrant a separate term because of the rich sources of natural gas and petroleum that shale usually hides. Also it stems from the very difficult task of drilling and or fracturing through the formations[vii].

2.2.2 Well Classification

In order to achieve the depths required to make hydraulic fracturing successful, deep wells must be drilled and supported. These are drilled through coal beds; tight sands, rock and shale, and all must be bypassed. The orientation of such a well is determined by the type of fracturing that is taken place, although a great majority of wells are done in a similar fashion known as horizontal drilling (shown in Figure 2.2). Of course this first required a vertical well to be drilled and cast (vertical drilling), but once the correct depth is reached drilling is then done approximately perpendicular to the original shaft. Off of this secondary cast will be the origin of most of the planned fractures. Another, but less common drilling is the diagonal well, which just as assumed is one drilled down at a certain angle.

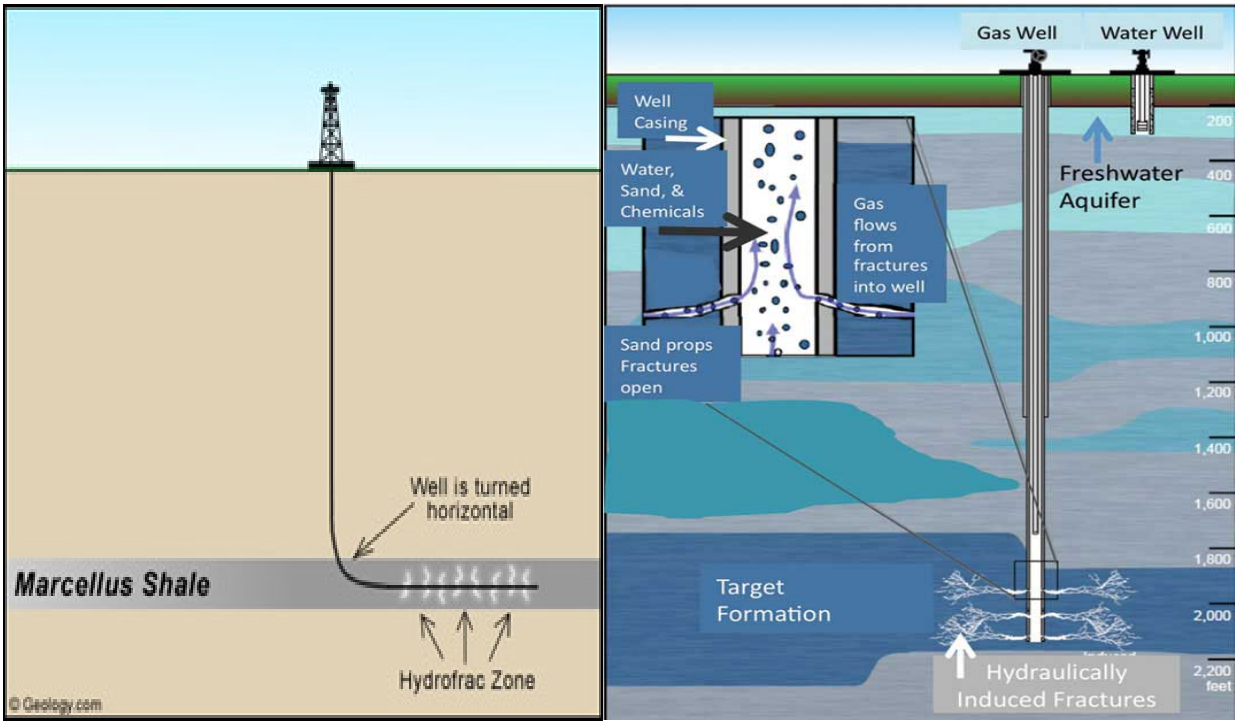


Figure 2.2: *Horizontal and vertical fracturing shown side by side*

When wells are drilled into any form of gravel or earth, the nearby water sources need to be taken into consideration. An underground source of drinking water, or USDW, is one that is the most common point of concern and debate. As defined by the EPA, USDWs include all fresh water aquifers, unless specifically exempted, that contain fewer than 10,000mg/Liter of dissolved solids[viii]. They are usually a current source of drinking water, but that is not a requirement of this classification, they must simply supply a public water system for some purpose. Closely related to USDWs by the process of hydraulic fracturing is underground injection, defined by the EPA as "placing fluids underground, in porous formations of rocks, through wells or other similar conveyance systems."

The Underground Injection Control Program (UIC) dictates the definitions and regulations involving USDW and underground injection. They differentiate between different injection types by using a well classification system, and one of the best distinctions between multiple types of hydraulic fracturing jobs and sites are the wells that are drilled and used for extraction. Currently there are six different classifications (as dictated by the EPA), the most common of which is the Class II well.

The wells used for HF are of different sizes, depths and specifications and as such have different classifications, denoted I-VI, where Class II is more relevant in this discussion[ix].

- Class I – Wells in which the hazardous wastes and non-hazardous liquids are injected below the lowermost USDW. Rightfully so the UIC regulations are very strict. They are further regulated under the Resource Conservation and Recovery Act (RCRA) (Figure 2.3)
- Class II – Wells in which brines and other fluids needed for natural gas production are injected below the lowermost USDW. States may apply their own regulations (in lieu of EPA regulations) to these wells (Figure 2.3).
- Class III – Wells in which fluids are injected below the lowermost USDW, but are usually associated with mineral mining such as salt, sulfur or uranium (Figure 2.3).
- Class IV – Banned unless authorized by RCRA and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) for ground water remediation fracturing. Injections are hazardous and made above USDWs (Figure 2.3).
- Class V – Wells that are experimental in nature or simply not included in classes I-IV. These include deep wastewater disposal systems and shallow “low-tech” wells such as septic systems and cesspools (Figure 2.4).

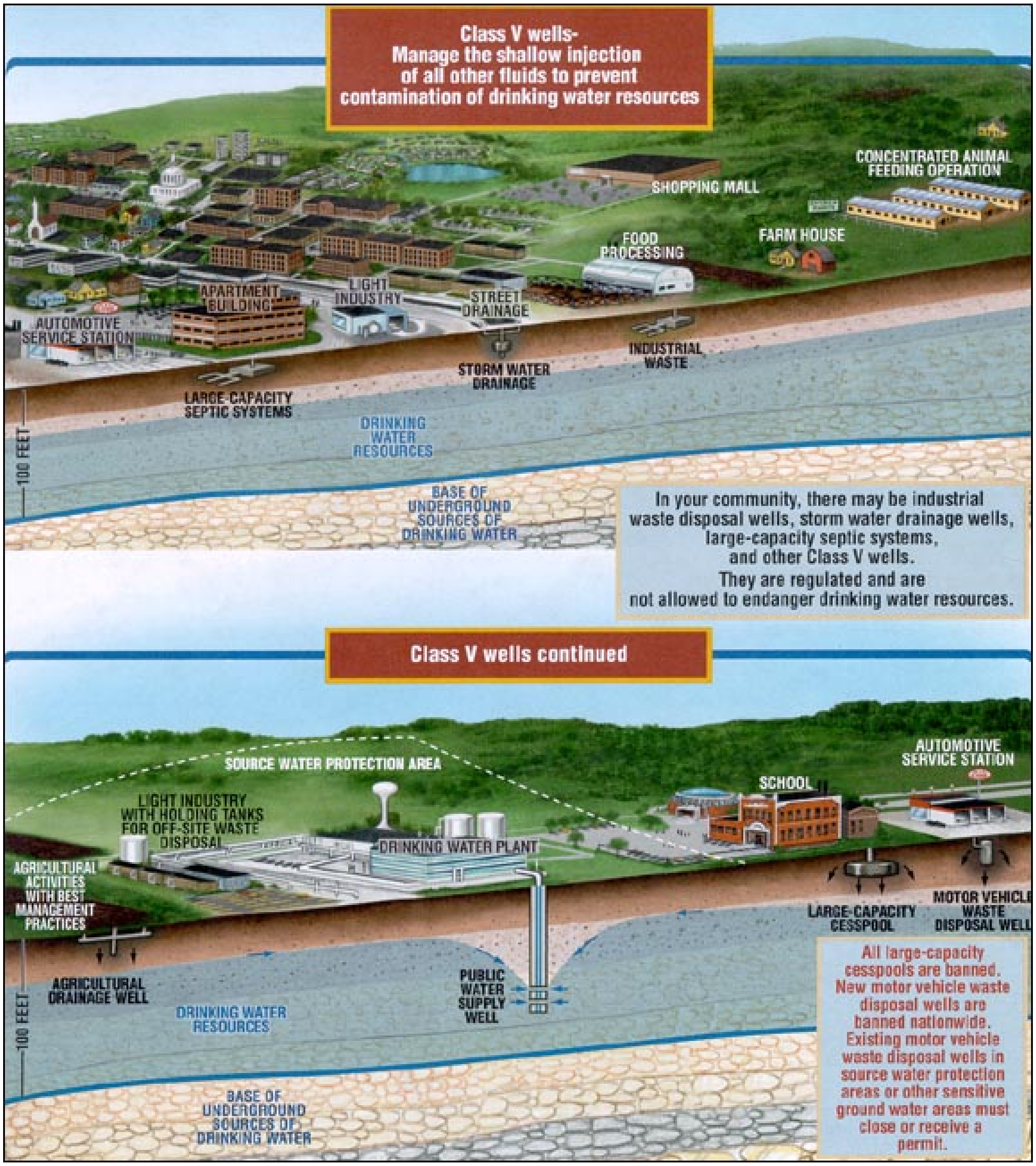
- Class VI – Newly named by the EPA in 2010. This refers to wells that will be used for the geological sequestration of carbon dioxide (Figure 2.4).

Figure 2.3: *The first four well classifications as dictated by the EPA*[x].

Each of the listed wells are regulated in some form by the UIC regulatory program and rules are constantly changing as new information is gathered. Regardless of the amount of information available or the class of well, they require permits in order to operate. Since hydraulic fracturing is mainly done in the search for oil and natural gas the regulatory requirements of Class II wells are most relevant, but also the types of said wells.

- Enhanced Recovery Wells (Secondary/Tertiary Recovery) – inject brine, water, steam, polymers, or $C0_2$ to recover residual oil by decreasing the viscosity of extractable oil and gas. A single injection well is usually surrounded by several production wells. These represent about 80 percent of Class II wells.
- Disposal Wells – injects brines and fluids associated with natural gas production or storage operations. These represent about 20 percent of Class II wells.
- Hydrocarbon Storage Wells – inject liquid hydrocarbons as part of the U.S. Strategic Petroleum Reserve. There are as few as 100 hydrocarbon storage wells in operation (less than 1 percent of Class II wells).[xi]

In terms of a Class II well, states have the opportunity to apply for primacy, or primary enforcement authority, which is required to implement the UIC program. This is a provision of the Safe Drinking Water Act (SDWA). Section 1422 of the SDWA requires programs to include construction, operating, monitoring and testing, reporting, and closure requirements for well owners and operators. Section 1425 of the SDWA "allows states to demonstrate that their existing standards are effective in preventing endangerment of USDWs[xii]." In order for a Class II well to be allowed to operate, a permit assigned through the UIC program with a specific "life of permit" period is required. Additionally a mechanical integrity test (MIT) must be performed before operation, and again every five years begins in order to pressure test the well. Testing of the well is continuous, with the injection pressure, flow rate and fluid volume used constantly being monitored. In certain areas, the requirements for well operation can be stricter and will have inspections more often than the yearly minimum.



In your community, there may be industrial waste disposal wells, storm water drainage wells, large-capacity septic systems, and other Class V wells. They are regulated and are not allowed to endanger drinking water resources.

All large-capacity cesspools are banned. New motor vehicle waste disposal wells are banned nationwide. Existing motor vehicle waste disposal wells in source water protection areas or other sensitive ground water areas must close or receive a permit.

Figure 2.4 *Class V wells as dictated by the EPA*[xiii].

Clearly a piece of what is required for understanding the drilling and extraction in the hydraulic fracturing process is a grasp of the concept of the fracture and what characteristics are desired. Ideally the fractures are wide enough so that gas can escape through them, but not so large that multiple layers of sand or sediment can reclog or close those paths. Fractures should be as long as possible without compromising their structural integrity so the deepest parts of the goal formations can be reached from the starting well cast. These fractures and the qualities thereof are determined mainly by the fracturing fluid and proppant.

2.2.3 Fracturing Fluids

Perhaps the most important tools in the hydraulic fracturing arsenal of any given fracturing company are their specialized fracturing fluids. As has been stated, hydraulic fracturing requires the use of a fluid to inspire displacement of natural gas deep underground in rock formations through fractures and into well castings in order to be collected. Clearly the properties of the fractures have a great impact on the effectiveness of the process, but perhaps less clear is the dependence that fractures have on the fluids used to create them. Fluids used in hydraulic fracturing hold a wide variety of traits, but all share the goals of being idealized for their application where their success is measured by how well they match the following design goals. They are ideally viscous enough to create fractures of adequate width, travel for maximum fracture length, carry large amounts of proppant and easily degrade into the soil or castings[xiv]. The level of viscosity that achieves the aforementioned goal depends on the rock formations that are being fractured, whether loose sand or shale. Longer fracture length allows for deeper penetration into areas containing natural gas or oil reserves, thus extending the life and usefulness of the well. Vital to the quality of the wells are the proppants which are tiny granular particles as small as sand that are used to “prop” open the fractures and allow gas to flow through them. They can be thought of as a support beam structure for the fractures. Clearly designing a fluid covering all of these requirements in addition to being biodegradable (so removal of the fluid is not an issue) and cost effective can be a quite difficult task.

In order to encompass everything that companies need for hydraulic fracturing applications, there has arisen several types of fracturing fluids, each more suited for one realm over another. The main groups of fluids are gelled, foamed, acids, any combination of these, and brine (salt water); keeping in mind that almost all fluids are close to 99.5 percent water. Fracturing fluids can also be oil, methanol, or a combination of water and methanol based. Most fracturing fluids are combined with a breaker, an acid used to degrade the fracturing fluid viscosity in order to enhance post-fracturing fluid recovery[xv]. Polymer-based fluids require 50-100 times the amount of breaker, which overshadows the improved fracturing results they attain.

Gelled fluids include linear or cross-linked gels and have higher viscosity than water alone, which allows them to carry more proppant. Advanced gels systems such as Halliburton's My-T-Oil V system can be controlled while the treatment is in progress[xvi]. Gels also tend to be more convenient in cold weather. A certain group of effective water-based fracturing fluids are called water gelling agents (WGA) that use light brines to enhance proppant transport properties of fresh water[xvii]. Zeta Gels are two component gels (anionic and cationic) that are effective up to 300 degrees Fahrenheit (149 degrees Celsius). There are hundreds of different gelled fluids, and each tends to have the same viscosity range, but one of the major advancements in fracturing fluid technology was the development of cross-linked gels in 1968 (Ely, 1985). "Cross-linking reduces the need for fluid thickener and extends the viscous life of the fluid indefinitely," which means that the fluid remains viscous until a breaking agent and polymer is added[xviii]. Cross-linking increases the price, but also considerably increases fracturing performance with only 1-2 gallons needed per 1,000 gallons of gel[xix].

Foamed gels do exactly as one would expect, they use foam bubbles to transport the proppant to fractures by adding gases with foaming agents into the fluid. This clearly reduces the total amount of fluid used for a fracturing job, and can still be extremely effective when combined with gelled fluids. The main job for foaming fluids however is in lower pressure formations, or to aid in clean-up that requires reduced fluid contact. The downside associated with foam fluids are their inherently low proppant concentrations and the cost of the foam fluid system field equipment (pumps, etc.)[xx].

Acids can also be used for hydraulic fracturing, meaning weak concentrations of substantially diluted acids such as hydrochloric acid are injected into water or gas based fluids for the purpose of dissolving rock formations such as limestone. The fault of such fracturing is that large amounts of acid much be pumped deep within the formation to etch the face of the fracture. Additionally acid can be used to clean the cement surrounding the well casing prior to actual fracturing jobs[xxi].

Fracturing fluids, regardless of which of the aforementioned types, contain additives in order to improve their effectiveness (Shown in Table 2.1). The common additives are breakers, biocides, fluid-loss additives, friction reducers and acid corrosion inhibitors. Simply put, biocides are added to kill bacteria that produce enzymes that break down gelling agents in fracturing fluids and reduce their effectiveness. Generally biocides, bactericides and microbicides are added to the mixing tanks to kill microorganism, but these can be inherently dangerous if not handled carefully. Fluid-loss additives help keep the fluids “together” and restrict leak-off of the fluid into exposed rock at the fracture face[xxii]. Friction reducers, as the name entails, are added to reduce friction in the wells and fractures that naturally exist due to the fluids being pumped at high velocity and pressure. These reducers are typically latex polymers such as cationic polyacrilate liquids. The final additive, acid corrosion inhibitors, work in acid fluid mixtures to prevent the corrosion of steel tubing, well casings, tools and fluid tanks.

Table 2.1 *Summary of the fluids and additives*

Fracturing Fluid Or Additive	Positive	Negative
Gelled Fluids	Increased proppant carrying capacity. Work well with low temperatures. Cross-Link Gels	Increased Cost
Foamed Gels	Good for low pressure formations Can be combined with gelled fluids to increase effectiveness	Reduced proppant carrying Expensive equipment
Acids	Can be used to clean wells	Requires large amounts
Breakers	Enhance post-fracturing fluid recovery	Some fluids require large amounts
Biocides	Kills bacteria and microorganisms	Can be dangerous to the environment
Fluid-Loss Additives	Reduce “leakoff”	Increased Cost
Friction Reducers	Reduce friction in well and pumps	Increased Cost
Acid Corrosion Inhibitors	Prevent corrosion of equipment	Increased Cost

2.3 The Set Up

After understanding all the fracturing fluids used, the depths that the well must reach, and what is needed for successful fracturing the logistics of storage and machinery are next.Storage, in whatever form, is needed for additives, wastewater, and freshwater. Similarly machinery to drill, and to transport the needed materials, are vital. Included in the set up for all hydraulic fracturing sites are the considerations for the cleanup or the recycle process.

2.3.1 Machinery

Independently the machinery used to perform hydraulic fracturing procedures are incredibly complex.

> "For a proposed 900+ meter near-horizontal section at roughly 5000 meter measured depth, Halliburton suggested the installation of a RapidShift™ ball drop multistage stimulation and production sleeve system along with Swellpacker® zonal isolation systems and a RapidStart™ Initiator sleeve at the toe to achieve intervention-free multistage fracturing in the open hole."[xxiii]

As such the amount of time spent on actual specifics of machinery and their operation will be null. The machinery needed however are as follows: drills of the appropriate size and power, pumps designed for the desired volume and psi (pound per square inch), drains and transports for the water and fluids going to and from storage, the actual storage tanks, installers of well casings and screens, and all of the required simulation and monitoring equipment of the control room on site. Each of these plays a vital role in the success of a fracturing operation. This is especially true since a majority of these, if done incorrectly or the machinery malfunctions can result in serious environmental damages. Well casings must be tight, drains must be secure, storage tanks must be well built, and the monitoring equipment must be functioning correctly to ensure a successful hydraulic fracturing job.

2.3.2 Water/Fluid Storage

The issue of water storage encompasses several considerations when it comes to hydraulic fracturing. The planning process must take account for water acquisition, transport of the water, storage, use and movement to the treatment well once on site, and the reuse or recycling of the fluids and additives[xxiv]. Companies have some freedom in these regards but regulatory requirements usually dictate water management options[xxv].

Fluid storage is also a pressing issue, and perhaps even more so since the chemicals used in the fluids can sometimes be dangerous. Prior to more reasonable regulations, the fracturing fluids were stored in “pits,” which could refer to excavated holes in the ground, or more appropriate steel tanks[xxvi]. Now the effectiveness of pits are the most critical element in the prevention of contamination of shallow ground water, which is one of the largest concerns regarding hydraulic fracturing[xxvii].

On a hydraulic fracturing site, the additives and the water are stored separately. They are combined either during the fracturing process or just before being injected into the well. As a result, when it comes to taking care of the waste, the additives and water are hand in hand.

Chapter 3: Environmental Impacts

3.1 Introduction

Hydraulic fracturing may be an advancement in technology for the mining world, but it still poses potentially hazardous consequences for the world around us. Similar to other “mining” techniques, hydraulic fracturing has impacts to the land, water, and air. Although hydraulic fracturing requires much less surface area for its operations in comparison to some mining practices, it still has machinery and materials stationed at site. The storage and use of these materials determines the potential hazard to the environment. The entire hydraulic fracturing process is reliant upon water and certain chemicals mixed and injected into the subsurface of the Earth, which leads to possible catastrophic results to the environment, aquifers, and surrounding organisms. Hydraulic fracturing also produces large amounts of wastewater and gas. The gas produced has a high possibility of leaking out of the system and into the atmosphere. Whereas wastewater does not necessarily leak into the atmosphere, it can be combusted or released into the environment through wastewater management practices. These potential hazards will be discussed in the subsequent sections.

3.2 Land Use

Although less land consuming than other mining practices, hydraulic fracturing still requires space for drilling pads and piping systems. Fracturing, in terms of shale gas drilling, encompasses three to ten acres of land.[xxviii] Implementing the drilling pad requires the clearing of land in what could be heavily forested areas, agricultural land, or community/residential property.

The drilling pad is required for hydraulic fracturing sites to house the necessary equipment. Some of the common findings on a drilling pad include space for vehicles delivering and/or removing water, wastewater and drilling debris, holding pits for wastewater, storage containers for materials and chemicals (see Figure 3.1), the actual drilling rig and its related equipment, and other human necessities like office housing.

Figure 3.1: *The fracturing fluid (water and chemical additives) is stored commonly on site in large, upright storage tanks. These tanks can contain anything from water, wastewater, or chemical additives.*[xxix]

The number of wells in the area will be the ultimate reason for the size of the drilling pad as well as the holding pits. Holding pits, depending on the number of wells that it is serving, can be as large as an American football field.[xxx] See Figure During the drilling process, the actual drilling rig itself can overshadow the landscape with a fifty to one-hundred foot tall structure. It is crucial to remember that much of the previously described equipment is used primarily during the actual drilling process. Once the well drilling is complete and the production of natural gas has begun, the drilling pad's contents decrease significantly. During natural gas production, well heads, water or condensate storage tanks, metering systems to measure the natural gas production, and smaller equipment dominate the pad. As production and the number of wells increase, the amount of storage tanks, as well as other materials, need to increase to meet the demand. In addition, it can occur on sites where the unorganized disarray of pipes and materials produce an environmental hazard as can be seen below in Figure 3.2 & 3.3.[xxxi] Ultimately, the increased size of the drilling pad allows for a larger amount of materials and a much greater risk for environmental hazards.

Figure 3.2: *The fracturing fluids, additives, and proppant are pumped to the wellhead and mixed just prior to injection.*[xxxii]

Figure 3.3: *Chemicals are stored on site in a support truck. Fracturing fluid additives such as the foaming agent can be pumped directly from storage containers to mix tanks.* [xxxiii]

Figure 3.4: *Drilling site in the Marcellus*[xxxiv]

The next step after the collection of natural gas is its transportation from the wellhead to the open market. This transportation infrastructure includes the placement of several low pressure, small diameter pipeline systems that transport the raw natural gas to a processing plant. From the processing plant, the natural gas will commonly enter a larger interstate or intrastate pipeline network that will then lead to its final distribution. Depending on the type of pipeline, whether it is underground or aboveground the full extent of the environmental impact will vary. Following the underground pipeline approach, the new pipelines can be installed through a customary trenching and boring system just under the surface. When the new pipeline system is completed, the area above the pipeline remains clear. These pipelines can hardly be detected amongst farm or open land, but when they are constructed through forests the clear-cutting of trees make the pipes easily noticeable. A number of factors have to be taken into account depending on the distance that the natural gas will have to travel (from site to processing plant). Some pipelines require the installation of field compressor stations that help move the gas to the processing plant. These stations are commonly 40 to 100 miles along the pipeline. Even though the entire hydraulic fracturing process creates enormous risks for companies, there are current initiatives being taken to resolve these fears. [xxxv]

Through trial and error, many companies have been taking a number of initiatives to reduce their environmental impacts that result from the production process. Companies have run across erosion, sediment runoff, and stormwater discharge problems, which they are working to resolve. Much of the processes are overseen by the Independent Petroleum Association of America (IPAA), which outlines a number of stormwater and erosion management practices. Hydraulic fracturing companies have become more aware of site locations to maximize productivity but also control and eliminate environmental issues. Canada’s Horn River Basin contains nearly 5,000 acres of available gas reserves that results in a high flexibility for deciding upon site locations, and can allow for more attention to be put on possible environmental concerns.[xxxvi] Sites like the Horn River Basin, which contains large amounts of gas and have a unique geographical land contour, are beneficial for not only producing natural gas but also for allowing research to occur and further advance the fracturing practice. Companies are also cooperating in sharing pipelines, which drastically reduces the effects on the surrounding land and environment. Companies are beginning to take responsibility for site use and are involved in landscaping and contouring the property used for drilling purposes to pre-drilling and pre-construction conditions. The surface at a site always has the potential for contamination but the injection of the fracturing fluid into the wells is one of the main hazards associated with hydraulic fracturing.

3.2.1 Seismic Activity

Geological activities, of the seismic nature, have become a concern resulting from the construction and drilling at fracturing sites. A norm by nature; however, it is not uncommon for induced seismic activity to occur surrounding mining, construction, hydro dams, and geothermal energy extraction areas. These earthquakes are by no means causing tsunamis or destroying buildings. They are rare and minor earthquakes that have yet to cause injury or property damage. In one North American study, the largest microseism recorded at a hydraulic fracturing site was roughly 0.8 which is about 2,000 times less energy than a magnitude 3.0.[xxxvii] To put it in comparison, a magnitude 3.0 can just barely be noticeable at the surface of the earth.[xxxviii] The point where hydraulic fracturing is accused of inducing seismic activity is the high pressure fracturing fluid injection into deep shale formations. The energy generated can result in seismic activity; however, it is rarely felt at the surface and normally is only recorded at 2,000 to 3,000 meter below the surface.[xxxix] An area where this concern has been raised and studied is Canada’s Horn River Basin, as described above. Initiatives to reduce the induced earthquakes from hydraulic fracturing are at its beginning stages. Currently, research on seismic detection is being conducted around the globe on hydraulic fracturing sites. One of the most studied sites is the Horn River basin due to its rich confinement of shale gas and unique geography. Ultimately, hydraulic fracturing has been guilty of seismic activity; however, it has yet to result in serious problems and is only researched to hopefully minimize its consequence from the fracturing process.[xl]

3.3 Water

Water is the primary component used in fracturing fluids where it makes up roughly 99.5 percent of the entire solution. Water is already a highly sought after component around the world for activities such as agricultural and industrial use, which creates a huge strain on water reserves already without including fracturing. The fear that plagues most concerned citizens is where the water and fracturing fluid comes from and ends up. Ultimately, a large portion of the fluid comes back to the surface as wastewater while some remains in the fractured well. The substance needed most in hydraulic fracturing is also the substance that creates most of the potential hazards for the process.

3.3.1 Freshwater Consumption

Water is the most used product in the entire hydraulic fracturing process. From the drilling and cementing of the wells, to the actual fracturing of shale gas formations, large volumes of water are required resulting in a net loss of water. Roughly, 50 percent to 95 percent of the hydraulic fracturing fluid injected into the well does not return to the surface.[xli] Although a great deal of water can be retrieved from the well it is no longer freshwater, but wastewater. Generally, the wastewater is recycled or disposed of in deep wells that make it unusable for other purposes.

Anywhere from one to eight million gallons of water is common for a fracturing well. Past water use for fracturing totaled 145 Mm^3 (117 thousand acre-feet, kAF; 1 AF = 325,851 gal) to June 2011 to stimulate roughly 15,000 wells. In 2010, the fracturing water used in the

Barnett Shale formation in Texas represented about 9% of the 308 Mm^3 (250 kAF or about 80,000 Mgal) used by the City of Dallas, the ninth-largest city in the U.S. (population 1.3 million 2010).[xlii] Also, fracturing water in the Barnett Shale for 2005 −2007 was estimated to be 60% from groundwater.[xliii] Nonetheless, the actual drilling process, not the fracturing process, uses much less water. The water used is commonly mixed with clay or sand and occasionally chemicals for its cooling and lubricating properties during the drilling process. According to Chesapeake Energy, drilling a normal shale natural gas well can require anywhere from 65,000 to 600,000 gallons of water, depending on the depth of the well.[xliv] The hydraulic fracturing process is extremely dependent upon water for not only the production of natural gas but also the drilling of the well itself.

It is impossible to give an exact answer for water used in fracturing a well, regardless of its depth, since every well is unique and every company has its own distinct methodology behind fracturing techniques. Range Resources, a hydraulic fracturing company, documents three to four million gallons of water used to fracture a well, which is roughly equivalent to the water usage at a typical golf course over a period of nine days.[xlv] Also, Range Resources claims that adding ten times as much water to the fracturing requirements is necessary to produce roughly the same amount of energy as coal, and production of ethanol can require anywhere from one thousand times more water to yield the equivalent amount of energy as natural gas.[xlvi] The amount of freshwater required for drilling and fracturing a typical horizontal well, according to ExxonMobil, is roughly three to six Olympic-size swimming pools (equivalent to 50 meters by 25 meters).[xlvii] Now the environmental impacts on the watersheds vary amongst locations and the size of the watersheds, i.e. it is much more detrimental to withdraw six Olympic size swimming pools worth of water from a small watershed then a large watershed. Determining the impact of water consumption is entirely dependent on the location of the fracturing site. For instance, the large number of hydraulically fractured wells in Texas (≥20 000) and high water used per well create the perception of large amounts of water use. Nonetheless, water use for only shale-gas production is relatively minor (<1%) when compared to other water consumption activities like irrigation (56%) and municipal (26%) in Texas in recent years.[xlviii] It is important to note that the previous facts are related to the percentages that water is broken up into in Texas and is not related to the total availability of water in Texas aquifers.

The impact of fracturing on water can be completely understood when comparing the water usage of fracturing with other fuels and water requirements. The United States Geological Service creates updated reports on this information; however, their most recent release, *Estimated Use of Water in the United States in 2010,* is behind schedule and is not expected to be released until 2014. Its last update was in 2005 which was prior to the widespread use of hydraulic fracturing of horizontal wells around the continent which renders that data moot. Nonetheless, Chesapeake provided the following in Table 3.1 comparing the range of gallons of water used per MMBTU (Million Metric British Thermal Units) of energy produced.[xlix]

***Table 3.1** Energy Resource Water Usage*

Energy Resource[1]	**Range of Gallons of Water Used per MMBTU of Energy Produced**
Chesapeake deep shale natural gas*	0.84-3.32[2]
Conventional natural gas	1-3
Coal (no slurry transport)	2-8
Coal (with slurry transport)	13-32
Nuclear (uranium ready to use in a power plant)	8-14
Chesapeake deep shale oil**	7.96-19.25
Conventional oil	8-20
Synfuel – coal gasification	11-26
Oil shale petroleum	22-56
Oil sand petroleum	27-68
Synfuel – Fisher Tropsch (from coal)	41-60
Enhance oil recovery (EOR)	21-2,500
Biofuels (Irrigated Corn Ethanol, Irrigated Soy Biodesiel)	> 2,500
Source: "Deep Shale Natural Gas: Abundant, Affordable, and Still Water Efficient", GWPC 2011 The transport of natural gas can add between zero and two gal-lons per MMBTU *Includes processing which can add 0-2 gallons per MMBTU **Includes refining which consumes major portion (90%) of water needed (7-18 gal per MMBTU) Solar and wind not included in table (require virtually no water for processing) Values in table are location independent (domestically produced fuels are more water efficient than imported fuels)	

Fracturing sites are commonly being restricted nowadays and limited on the source and amount of water used. Most sites, as part of getting a permit, require an analysis of how much water will be withdrawn from the watersheds. Some states have water resource boards, like the “Susquehanna River Basin Commission” and the “Delaware River Basin Commission,” to control the water withdrawals.[1] Nonetheless, some water resources are privately owned which allow withdrawal amounts to be at the discretion of the private owner.

3.3.2 Alternatives

With water being the most crucial and used material needed for the hydraulic fracturing process, it is of no surprise that companies are trying to find alternatives. This is especially true since water consumption is projected to increase from 46Mm^3 (37 kAF) to a peak of 145Mm^3 (117 kAF) by 2020-2030.[li] Companies have started recycling their own produced water and hydraulic fracturing fluids, using wastewater from various industrial sources and tapping brackish or saline aquifers. Some sites have even begun creating impoundment tanks. These impoundment tanks collect and store rainwater and/or surface water. The alternatives reduce the withdrawals from local aquifers and allow for the water to be used in other industries and for agricultural requirements.

As much of the controversy over the chemical additives continues, many companies are working towards reducing the amount and toxicity of the chemicals used. There are several reported instances of companies taking these initiatives to reduce toxicity and chemicals including: Chesapeake Energy, Baker-Hughes, Haliburton, and Frac Tech. Chesapeake Energy reported that it reduced the additives in its fracturing fluids by 25%. In 2011, Halliburton announced that "El Paso" was the first company to use three of its proprietary "CleanSuite" production enhancement technologies for hydraulic fracturing sites. Baker-Hughes promoted the use of its "BJ Smart Care", flexibility to combine compliant fluids, additives and specialty chemicals to create a fit-for-purpose environmentally friendly solution for each well. The “BJ Smart Care” category of additives was judged environmentally preferred in May of 2011. Lastly, Frac Tech introduced its "Slickwater Green Customizable Powder Blend" additive, which results in no leftover chemicals and reduces the risk of liquid chemical spills.[lii] The projections in this study are based on current fracturing technologies; new advancements in technologies could reduce reliance on fresh water, including use of fluids other than water (e.g., propane, N_2, CO_2), sonic fracturing with no added fluid and other waterless approaches with specialized drilling tools. As the cost of water increases, these previously described methods could become more attractive.[liii]

3.3.3 Groundwater Contamination

Concern over groundwater contamination is a debated topic regarding the hydraulic fracturing process and has been for decades. Close by communities, aquatic ecosystems, and drinking water aquifers have all been the reason for concern by the general public due to fracturing and its fluids. Other concerns for impacts to groundwater resources are based on: (i) fluid (water and gas) flow and discharge to shallow aquifers due to the high pressure of the injected fracturing fluids in the gas wells; (ii) the toxicity and radioactivity of produced water from a mixture of fracturing fluids and deep saline formation waters that may discharge to the environment; (iii) the potential explosion and asphyxiation hazard of natural gas; and (iv) the large number of private wells in rural areas that rely on shallow groundwater for household and agricultural use — up to one million wells in Pennsylvania alone – that are typically unregulated and untested. Nonetheless, it must be stated now that there have yet been instances where evidence has definitively shown contamination of drinking water samples with fracturing fluids.[liv] There are cases and EPA studies in progress like at Barnett Shale Wise County, TX; however, since these studies have yet to be released no comments can be made on them. For more cases in progress, see Appendix A.[lv]

Hydraulic fracturing has yet to be the proven source for the contamination of groundwater, but that does not mean that there has not been data collected showing fluctuations in groundwater concentrations. In active gas-extraction areas (one or more gas wells within 1 km), average and maximum methane concentrations in drinking-water wells increased with proximity to the nearest gas well and were 19.2 and 64 mg/l CH_4 ($n = 26$), which is a potential explosion hazard. In contrast, dissolved methane samples in neighboring non-extraction sites (no gas wells within 1 km) within similar geologic formations and hydro-geologic regimes averaged only 1.1 mg/l ($P < 0.05$; $n = 34$).[lvi] In addition, another source of contamination comes from the incredible pressures that the land is subjected to during fracturing. Fracturing fluid is injected into the wells at high pressures; for instance, typical fracturing activities in the Marcellus involve the injection of approximately 13–19 million liters of water per well at pressures of up to 69,000 kPa.[lvii] This high velocity and pressure of water is a commonly criticized source for claims of groundwater contamination and the addition of certain fracturing fluid chemicals seriously increases the potential hazard to the surrounding soil and aquifers.

3.4 Fracturing Fluid Chemicals

Fracturing fluid chemicals, although a small percentage of the fracturing fluid, contribute to the possible water and soil contamination that plague the hydraulic fracturing process. Over the past 60 years the chemicals used and the general use of the fracturing fluid has evolved and continues to change to this day. It must be stated now that the fracturing fluids used are unique to practically every company. Thus, it is difficult to state exactly the compositions of the fluid, but there are still general trends that most companies follow with fracturing fluids.

The fracturing fluid, for shale gas, is roughly 99.51% water and proppant (commonly sand), with the remainder, about 0.49%, being chemical additives. Fracturing wells require roughly 75,000 to 320,000 pounds of sand.[lviii] As previously stated, wells also require anywhere from one to eight million gallons of water; however, this data is unique to each site and commonly stated with different numbers amongst companies. The chemical additives to the fracturing fluids serve numerous purposes and each of the additives differs from one geological site to the next. Some of the general purposes of the chemicals are preventing scale and bacterial growth and reducing friction during the fracturing process. Many people would believe that with such a small percentage of chemicals used they would not really matter in the grand scheme of things. Nonetheless, when millions of gallons of the fluids are pumped into each well this can still add up to tens of thousands of gallons of chemicals per well.

The composition of fracturing fluids varies significantly, from simple water and sand to complex polymeric substances with a multitude of additives. The 0.49 percent of additives is composed of a number of compounds including a few described in Table 3.2 & 3.3 below.

Table 3.2: *Common Fracturing Fluid Chemicals*

Compound[lix]	**Purpose**	**Common Application**
Acids	Eliminates bacteria in the water	Disinfectant; Sterilizer for medical and dental equipment
Sodium Chloride	Allows a delayed break down of the gel polymer chains	Table Salt
N,n-Dimethyl formamide	Prevents the corrosion of the pipe	Used in pharmaceuticals, acrylic fibers and plastics
Borate salts	Maintains fluid viscosity as temperature increases	Used in laundry detergens, hand soaps and cosmetics
Polyacrylamide	Minimizes friction between fluid and pipe	Water treatment, soil conditioner
Petroleum distillates	“Slicks” the water to minimize friction	Make-up remover, laxatives, and candy
Guar gum	Thickens the water to suspend the sand	Thickener used in cosmetics, baked goods, ice cream, toothpaste, sauces, and salad dressing
Citric Acid	Prevents precipitation of metal oxides	Food additive; food and beverages, lemon juice
Potassium chloride	Creates a brine carrier fluid	Low sodium table salt substitute
Ammonium bisulfite	Removes oxygen from the water to protect the pipe from corrosion	Cosmetics, food and beverage processing, water treatment
Sodium/Potassium carbonate	Maintains the effectiveness of other components, such as crosslinkers	Washing soda, detergents, soap, water softener, glass and ceramics
Proppant	Allows the fissures to remain open so the gas can escape	Drinking water filtration, play sand
Ethylene glycol	Prevents scale deposits in the pipe	Automotive antifreeze, household cleansers, deicing, and caulk
Isopropanol	Used to increase the viscosity of the fracture fluid	Glass cleaner, antiperspirant, and hair color.

Table 3.3: *Common Fracturing Fluids Health Hazards*

Compound[lx]	**Health Hazards**[lxi]
Benzene	Long-term exposure may affect bone marrow and blood production. Short-term exposure to high levels of benzene can cause drowsiness, dizziness, unconsciousness, and death.
Ethylbenzene	irritant of the eyes, mucous membranes, and skin
Formaldehyde	Short-term exposure to formaldehyde can be fatal. Long-term exposure to low levels of formaldehyde may cause respiratory difficulty, eczema, and sensitization.
Methanol	Acute toxicity – Acidosis, Cumulative CNS Disturbances – Impaired vision, headaches, neurological damage, Narcosis, Irritation-Eye, Nose, Throat, Skin---Mild
Naphthalene	Irritation-Eye, Nose, Throat, Skin---Marked, Ocular damage, Hemolytic anemia
Toulene	Irritation - Eye, Nose, Throat, Skin---Moderate, Narcosis
Xylene	Xylene is an irritant of the eyes and mucous membranes at concentrations below 200 ppm, and it is narcotic at high concentrations

The EPA has identified chemicals for further review based on publicly available information on hazard and frequency of use. Tables 3.4 and 3.5 identify a subset of chemicals used in hydraulic fracturing fluids as reported to the US House of Representatives' Committee on Energy and Commerce by 14 hydraulic fracturing service companies as being used in hydraulic fracturing fluids between 2005 and 2009 (USHR, 2011). Table 3.4 lists chemicals that are suspected carcinogens, regulated by the Safe Drinking Water Act (SDWA), or listed as Clean Air Act hazardous air pollutants. The committee on Energy and Commerce included the hazardous air pollutant designation for listed chemicals because some may impact drinking water (e.g., methanol and ethylene glycol). Table 3.5 describes the chemical components appearing most often in over 2,500 hydraulic fracturing products used between 2005 and 2009, according to the information reported to the committee.

Table 3.4: *Chemicals identified by the US House of Representatives Committee on Energy and Commerce as known or suspected carcinogens, regulated under the Safe Drinking Water Act (SDWA) or classified as hazardous air pollutants (HAP) under the Clean Air Act. The number of products containing each chemical is also listed. These chemicals were reported by 14 hydraulic fracturing service companies to be in a total of 652 different products used between 2005 and 2009. Reproduced from USHR (2011).*[lxii]

Chemicals	Category	No. of Products
Methanol	HAP	342
Ethylene glycol	HAP	119
Naphthalene	Carcinogen, HAP	44
Xylene	SDWA, HAP	44
Hydrochloric acid	HAP	42
Toluene	SDWA, HAP	29
Ethylbenzene	SDWA, HAP	28
Diethanolamine	HAP	14
Formaldehyde	Carcinogen, HAP	12
Thiourea	Carcinogen	9
Benzyl chloride	Carcinogen, HAP	8
Cumene	HAP	6
Nitrilotriacetic acid	Carcinogen	6
Dimethyl formamide	HAP	5
Phenol	HAP	5
Benzene	Carcinogen, SDWA, HAP	3
Di (2-ethylhexyl) phthalate	Carcinogen, SDWA, HAP	3
Acrylamide	Carcinogen, SDWA, HAP	2
Hydrofluoric acid	HAP	2
Phthalic anhydride	HAP	2
Acetaldehyde	Carcinogen, HAP	1
Acetophenone	HAP	1
Copper	SDWA	1
Ethylene oxide	Carcinogen, HAP	1
Lead	Carcinogen, SDWA, HAP	1
Propylene oxide	Carcinogen, HAP	1
p-Xylene	HAP	1

Table 3.5: *Chemical appearing most often in hydraulic fracturing in over 2,500 products reported by 14 hydraulic fracturing service companies as being used between 2005 and 2009. Reproduced from USHR (2011).*[lxiii]

Chemical	No. of Products
Methanol	342
Isopropanol	274
Crystalline silica	207
2-Butoxyethanol	126
Ethylene glycol	119
Hydrotreated light petroleum distillates	89
Sodium hydroxide	80

Fracturing fluids can be broken up into four different categories: gelled fluids, foam gels, plain water and KCl water, and acids. These categories can exist solely in a fracturing fluid mixture or be combined with another category. Each of the categories previously stated consists of additives that commonly contain constituents of potential concern to the environment.

Gelled fluids include linear and cross-linked gels and are essential for their higher viscosity when compared to ordinary water. The gelling agents of linear gels are typically guar gum (see Figure 3.5), guar derivatives such as hydroxypropylguar and carboxymethylhydroxypropylguar, and cellulose derivatives like carboxymethylguar. Without any chemical modifications these individual agents are typically biodegradable. For instance, the seed of a guar plant is the source of guar, which is non-toxic and commonly used in foods such as ice cream. Diesel fuel is common as the dissolving agent for guar powder. The use of guar powder, in fact, relies mostly upon the use of diesel fuel as the dissolving agent, which has its own characteristics of concern.

Figure 3.5: *Gelled water is pre-mixed in a truck-mounted mixing tank. Photograph shows a batch of linear, guar-based gel. This gel is used to transport the sand proppant into the fracture propagated by the nitrogen foam treatment.*[lxiv]

A petroleum distillate, diesel fuel commonly contains known carcinogens such as benzene, toluene, and xylenes. The other viscous additive, cross-linked gels, are commonly metal ion-cross-linked guar. The metal ions used are typically chromium, aluminum, and titanium. These metals have the potential to contain boric acid, sodium tetraborate decahydrate, ammonium chloride, potassium hydroxide, zirconium sulfate, ethylene glycol, and monoethylamine. A number of health effects relate to the additives undiluted forms such as kidney, liver, heart, blood, and neurological damage. These health concerns are normally consistent with prolonged exposure although short-term exposures can affect the health of an individual.[lxv]

The use of foam gels in fracturing fluids induces the transport of proppants into the wells fracture points. These foaming agents commonly contain diethanolamine and alcohols such as isopropanol, 2-butoxyethanol, and ethanol. These additives can commonly cause health hazards such as liver and kidney failure; however, for further information refer to Appendix B. In comparison to the gelling agents, the water treatment processes commonly have little to no environmental impact depending on the chemicals used. Potassium chloride water treatment can be hazardous but it is normally used at low concentrations, which are harmless.[lxvi]

When considering acidic additives such as hydrochloric acid or formic acid used to dissolve underground limestone formations, the environmental consequences come from the acidic characteristics. The corrosive nature of acids can have digestive impacts and ecological consequences to the environment such as acid rain. The chemicals and agent categories used in fracturing fluids are primarily detrimental depending solely on the concentrations used and to what point they are diluted before injection.

A less popular additive, whose use is beginning to be restricted severely, is diesel fuel. The use of diesel fuel in fracturing fluids poses the greatest possible threat to USDWs because the BTEX constituents in diesel fuel exceed the MCL at the point-of-injection. A common component of gelled fluids, diesel fuel contains constituents of potential concern regulated under SDWA – benzene, toluene, ethylbenzene, and xylenes (BTEX compounds). The concentration of diesel gelling agent is between four and ten gallons to 1,000 gallons of water.[lxvii] This diesel gelling agent additive can still be found in fracturing fluid compositions, but it is indeed slowly becoming less popular at hydraulic fracturing sites.[lxviii]

Engineers commonly select fracturing fluids based on site-specific characteristics including formation geology, field production characteristics, and economics. Hydraulic fracturing operations vary widely in the types of fracturing fluids used, the volumes of fluid required, and the pump rates at which they are injected. Fluid chemicals are significantly diluted prior to injection to reduce the hazardous risks. Also, various additives may be used to obtain a fracturing fluid quality that produces the best results for the specific fracturing location.

3.4.1 Chemical concerns

Public concerns regarding hydraulic fracturing and the fluid additives used in the process can be broken into three points: 1) how certain chemicals are being deemed hazardous, 2) The secrecy behind company’s fracturing fluids, and 3) the ease of access to the information by the public.[lxix]

Practically every fracturing company has some variation in their fluid additives; however, every company still has reporting requirements that they must meet. Companies, nowadays, are required to produce a Material Safety Data Sheet (MSDS) that describes the additives used at each well site. The employees and first responders at the specific site can access these reports. Although, companies are required to do this they are only required to include chemicals deemed hazardous by the U.S. Occupational Safety and Health Administration (OSHA). This leaves a potential area of concern because other chemicals that could potentially build up through bioaccumulation are not required in the MSDS. There are several states (Arkansas, Colorado, Louisiana, Michigan, Montana, Pennsylvania, Texas, and Wyoming) that do require companies to provide listings of all the additives and chemicals used in the fracturing fluid and not just the ones required by OSHA.

Companies are allowed to keep secret, at least to the public, about the chemical compositions of their fracturing fluids. Many consider it proprietary information that they want to keep secret to hold a competitive edge over other fracturing companies. Appendix C describes many of the chemicals known to be used in fracturing fluids. Nonetheless, OSHA governs the standards for what can be considered a trade secret.[lxx] If a company decides to not describe a specific chemical's identity on the MSDS then they are allowed to do that; however, OSHA standards still require the company to disclose the hazardous chemical's properties and effects. OSHA has the authority, under certain circumstances, to have the specific chemical's identity made available for employees and health professionals.

As an ordinary member of the public it is very difficult to access fracturing fluid chemical information, because there are no federal laws that require public disclosure. In spite of this, many states are starting to implement voluntary and state-mandated disclosures. The reason behind this is the high level of public concern that companies and states are noticing. Nonetheless, most states are not requiring the disclosures of company trade secrets. In 2010, Range Resources, Halliburton, EQT, and Chief Oil & Gas, were some of the first companies to post their information regarding fracturing fluids. Nonetheless, not every company is on board with releasing their information including Cabot Oil & Gas and Carrizo Oil & Gas. Carrizo in its 2010 10-K report stated that “legislation would require, among other things, the reporting and public disclosure of chemicals used in the fracturing process, which could make it easier for third parties opposing the hydraulic fracturing process to initiate legal proceedings against producers and service providers."[lxxi] Cabot made a similar statement. As more concerns regarding the process are evaluated more information is becoming available even though some companies may not be supportive of it.

3.5 Wastewater

Wastewater is prevalent in the fracturing process and results from the drilling and extraction of shale gas. Commonly this fluid includes drilling debris, fracturing fluids, and produced water. After the fracturing of the well, the composition of the wastewater that flows back changes from residual fracturing fluids to a composition dominated by the salt level of the shale. The amount of wastewater and the composition of wastewater vary depending on the specific site location along with soil composition. The wastewater that flows back out of the well is known as "flowback."

This "flowback" period can commonly last from a few days to a few months and the recovery rate will decrease as time goes on, especially when gas production starts. Normally for the first few days of flowback, fluids are stored in facilities until they will be treated for reuse or disposed of as shown in Figure 3.6 below. Once the gas production commences, processing equipment will separate the water and gas.

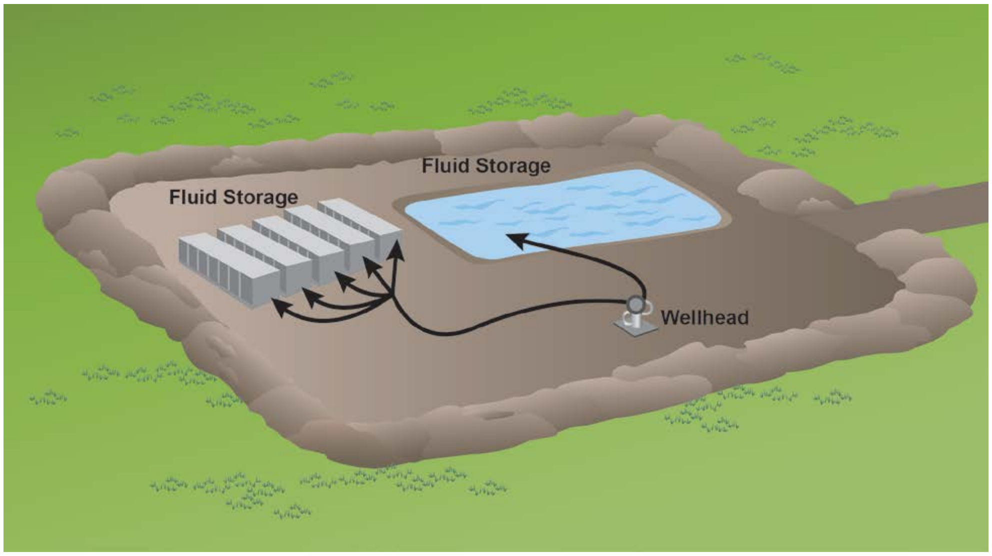


Figure 3.6: *Flowback and produced water. During this stage, the pressure on the hydraulic fracturing fluid is reduced and the flow is reversed. The flowback and produced water contain hydraulic fracturing fluids, native formation water, and a variety of naturally occurring substances picked up by the wastewater during the fracturing process. The fluids are separated from any gas or oil produced with the water and stored in either tanks or an open pit.*[lxxii]

Much of the public interest and critics of hydraulic fracturing commonly associate with the potential contamination from the hydraulic fracturing fluids used, but the produced water from the shale can contain natural and chemical contaminants as well. The produced water may include brine, common atmospheric gases, heavy metals, organic compounds, and naturally occurring radioactive elements (NORM). Most NORM materials are unusual; however, can be common in certain areas like Pennsylvania and New York. In 2010, the EPA was petitioned by the Natural Resource Defense Council (NRDC) to regulate oil and gas wastes under Subtitle C of the Resource Conservation and Recovery Act.[lxxiii] These include drilling fluids and cuttings, produced water, and fracturing fluids. It was claimed in the petition that produced water can contain arsenic, lead, hexavalent chromium, barium, chloride, sodium, sulfates, possible radioactive materials, and other minerals.[lxxiv] The composition of produced water can contain severe hazards that have the potential to contaminate the groundwater and spread to humans and the surrounding ecosystems.

3.5.1 Management Options

Laws forbid the direct discharge of wastewater into any environmental waterway; however, there are options to manage this wastewater such as treating it before discharge and evaporation in manmade open storage ponds. The two most commonly used options to manage wastewater are underground disposal and recycling.

Underground disposal involves the permanent ejection of wastewater into underground geological rock-formations. Compared to other removal options this can be the lowest cost; however, it is a region-specific option. As illustrated in Figure 3.7 and 3.8, the wastewater is generally managed through disposal into deep underground injection control (UIC) wells, treatment followed by discharge to surface water bodies, or treatment followed by reuse.

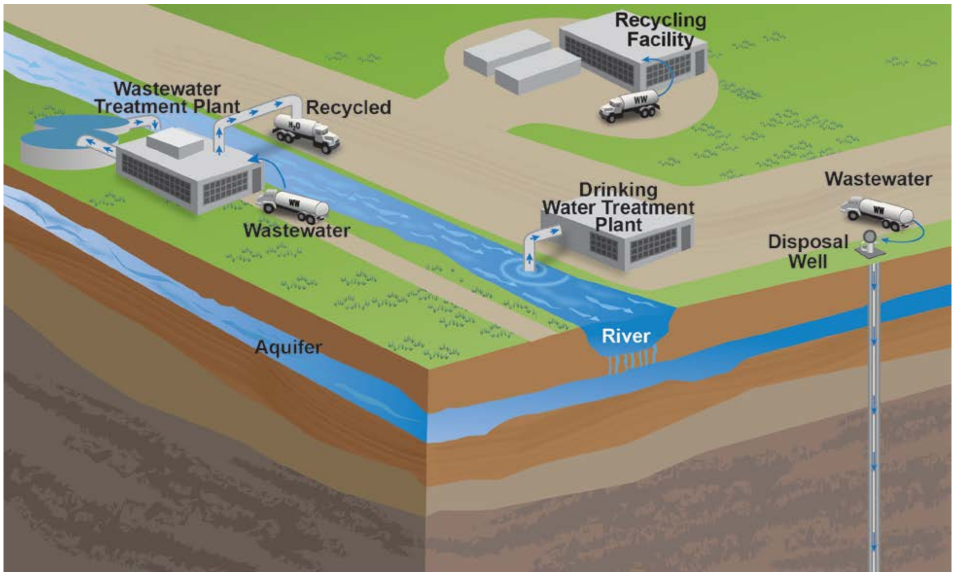


Figure 3.7: *Wastewater treatment and waste disposal. Flowback and produced water is frequently disposed of in deep injection wells, but may also be trucked, or in some cases piped, to a disposal or recycling facility. Once treated, the wastewater may be reused in subsequent hydraulic fracturing operations or discharged to surface water.*[lxxv]

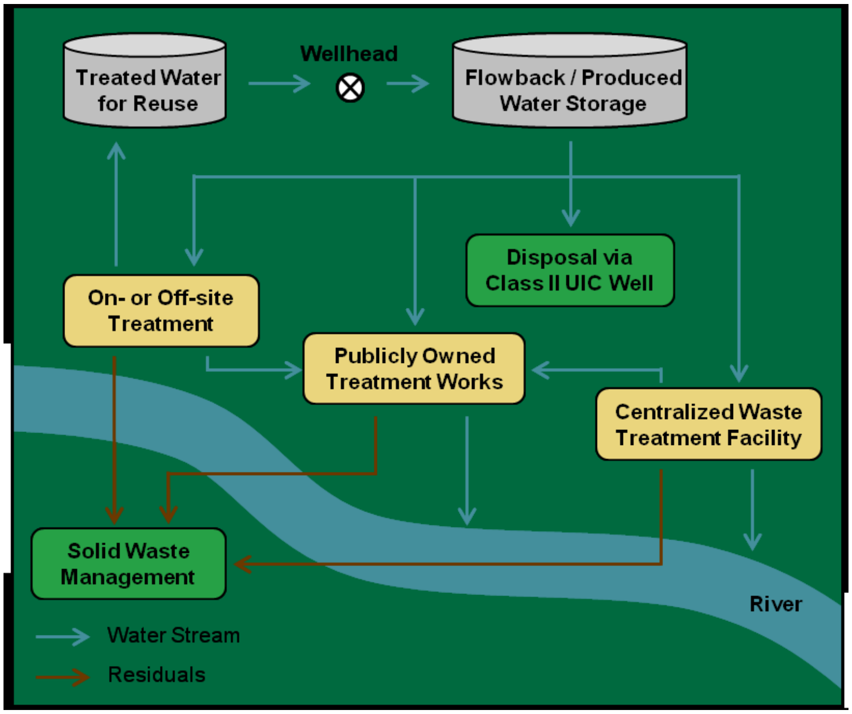


Figure 3.8: *Hydraulic fracturing wastewater flow in unconventional oil and gas extraction.*[lxxvi]

This option depends on the location of the fracturing site and thus the composition of the soil and the bedrock. For instance, in Texas' Barnett Shale wastewater can be injected into permeable rock more than a mile underground. The reason that this process is site specific can be seen in the Marcellus Shale region, in Pennsylvania, West Virginia, Ohio, and New York, because the land does not possess rock formations with sufficient porosity and permeability to withhold large quantities of wastewater. A current drawback to this process is that small earthquakes have been linked to this disposal technique.[lxxvii] The injection of the wastewater into the formations has the potential to change the stress regime, which can then possibly result in minor seismic activity as previously described in section 3.2.1. Although available data is insufficient in confirming this, some state regulators have begun to disallow the underground disposal method.

Recycling of wastewater, the other most commonly used disposal method, can be beneficial depending on the location of the site. The ability to recycle the wastewater differs substantially among the various shale locations. For instance, in the Eagle Ford Shale area of Texas there is very little water returned from the well after fracturing; however, in the Marcellus Shale area roughly 20-50 percent of the fracturing fluid is returned as wastewater. Due to this large return rate, roughly 60 percent of the recovered water at the Marcellus Shale area is reused for new fracturing sites.[lxxviii] Chesapeake Energy reported an annual savings of $12 million from recycling wastewater in the Marcellus Shale area. According to Range Resources, there can be about a $200,000 savings by recycling 100 percent of the flowback water in their fracturing site in southwestern Pennsylvania.[lxxix] The actual recycling process varies, just as the fracturing fluid composition does from company to company; however, the recycled wastewater is treated and then mixed with freshwater and chemical additives. The mixture of chemical additives is unique to each company since most fracturing companies have their own secret fracturing fluid compositions. The recycling process, although very effective in the reuse of the wastewater, can produce sludge. This sludge commonly contains a variety of chemicals, salts, radioactive materials, and other contaminants, which require special disposal as a solid waste.

Even though recycling the wastewater can save companies a great deal of money, there are still technologies being developed and implemented to improve the recycling of wastewater. In January of 2011, Integrated Water Technologies, developed the FracPure treatment process that can treat 100 percent of flowback to drinking water quality.[lxxx] Ecosphere Technologies created an oxidation technology that offers companies a chemical-free alternative to recycling high volumes of water.[lxxxi] Also, WaterTectonics have designed an electric coagulation treatment system that is used to recycle the wastewater without the use of chemicals.[lxxxii]

One of the other options that companies have is evaporation ponds. These ponds store wastewater or drilling aftermath water and debris, as shown in Figure 3.9, until they are disposed of or reused.

Figure 3.9: *Fluid that is extracted from the well during drilling or production is stored in a lined trench until treatment. This also shows the clearing of land that must occur to account for the trenches.*[lxxxiii]

Even though the evaporation ponds are most commonly used for wastewater, some companies have used these ponds to store freshwater for drilling or fracture use. These manmade ponds (see Figure 3.10) full of wastewater serve the purpose of evaporating the liquid from the solid pollutants. This disposal method, after evaporation, leave precipitated solids that then must be disposed of and are commonly put in landfills. The Resource Conservation and Recovery Act (RCRA) regulate these solids under subtitle D as nonhazardous waste; however, a petition is in the process between the RCRA and the EPA as to classify these solids as hazardous waste.[lxxxiv] Before entering the landfills these solids are tested for high concentrations of contaminates and occasionally radioactive properties. As stated, these ponds are a manmade construction that is usually regulated under state codes for specific dimensions and volume.

An accident occurred in Pennsylvania in the fall of 2011, when several wastewater ponds overflowed due to the Tropical Storm Lee. Even though this process may seem very simple, many controversies surround it. There are concerns regarding the ponds evaporation and what volatile organic compounds (VOC's) or other pollutants may be entering the atmosphere. In addition, there is a fear of the evaporated water coming back down to earth, in a form similar to acid rain. Lastly, wildlife conservatives are against the ponds because birds and other wildlife can mistake them for freshwater sources. Several companies have begun seeking alternatives to this process by employing a technique using closed-loop fluid systems that keep the wastewater in a series of pipes and closed tanks. General Electric has revealed a mobile evaporator in September 2010 that can be used on site to recycle the wastewater.[lxxxv] Nonetheless, some states, including New York, are proposing completely banning this evaporation process due to foreseen implications.[lxxxvi]

Figure 3.10: *Water impoundments in the Marcellus Shale.*[lxxxvii]

One of the last methods of wastewater management is general off-site wastewater treatment. According to an EPA press release in October 2011, well operators in Oklahoma, Pennsylvania, and Colorado were sending shale gas wastewater off-site to be treated prior to surface discharge and reuse.[lxxxviii] This method of off-site wastewater treatment commonly involves transport to a municipal wastewater treatment plant where it is treated and then disposed of in local rivers. This created a problem that was discovered in 2011 when Pennsylvania began to have drinking water concerns near Pittsburgh, Harrisburg, Baltimore, and Philadelphia.[lxxxix] It was noted that the treatment facility was not designed nor capable of removing the drilling waste contaminants and/or some of the fracturing chemicals used. It was noted in a letter from the EPA to the environmental officials in Pennsylvania in March of 2011 that, "variable and sometimes high concentrations of materials that may present a threat to human health and aquatic environment, including radionuclides, organic chemicals, metals and total dissolved solids."[xc] Ultimately, Pennsylvania regulators ended up requesting fracturing companies to stop sending wastewater to facilities that were not capable of treating the waste.

Off-site treatment, effective in that it almost immediately removes the wastewater from the site is not without flaw. One obvious problem is that, although it is highly attractive to remove the problem from a site, it can be very costly when transportation and handling fees are added up. Also, as previously discussed, not every treatment facility has the capability of filtering and cleansing a fluid of every contaminant. Other facilities can possibly be found which can treat the wastewater; however, then the problem of cost and transportation is observed again. Thus, even though off-site wastewater treatment can be attractive for many sites it also has its drawbacks.

A variety of protective measures have been implemented in the past few decades to combat the contamination of wastewater. These implementations include mats, catchments, buffers, ground water monitors, and the use of secondary containments. The Shale Gas Production Subcommittee of the Secretary of Energy Advisory Board (SEAB) has called for states to manifest all transfers of water that travels to different locations from the source, and to include measures and recording data from flowback operations. An additional step to the flowback operations involves the recovering and the recycling of fracturing fluids.

3.5.2 Fracturing Fluid Recovery

A process that is completed at all hydraulic fracturing sites is a recovery process. The injected fluids and ambient groundwater are pumped out of the ground through the production well in the recovery process. This stage is designed to reduce formation pressure, enable methane desorption, and extract remaining chemicals.

Many citizens are unaware that commonly anywhere from 68% to 82% of fracturing fluids and BTEX chemicals are recovered through this recovery process; however, it is practically impossible to have a full recovery of injected chemicals due to a number of factors.[xci]

One of the most common is the subsurface hydraulic gradients. The hydraulic gradients that cause fluids to flow away from the well during injection are much greater than the hydraulic gradients that occur during fluid recovery. Due to this process, some of the fracturing fluids are pulled beyond the capture zone of a production well; fluid recovery beyond the capture zone is rare. Even within the capture zone, the recovery process may not recover every injected substance. Gels contained in fracturing fluids may not be recovered because its properties differ from that of water and other highly soluble constituents.[xcii] Not all chemicals injected can be recovered but there is still the chance of the chemicals being almost completely diluted by groundwater that flows into the formation. In addition, biodegradation and diffusion may occur to reduce the chemical concentrations. The recovery process, in general, has proven to be an effective method of retrieving a majority of the fluids injected into the well throughout the hydraulic fracturing process.

3.6 Air Quality

Throughout the hydraulic fracturing process, especially in shale gas development, air emissions are a common consequence. Air emissions can include volatile organic compounds (VOC's); air toxics, such as benzene, ethyl benzene, and n-hexane; and methane.

The air contaminants that can be emitted through hydraulic fracturing of shale gas formations have the potential to cause serious health concerns. Methane is the primary constituent of natural gas, and is a greenhouse gas more than 20 times more potent than carbon dioxide. According to the EPA, production and processing of oil and natural gas accounts for roughly 40% of all U.S. methane emissions, which makes the oil and natural gas industry the largest source of methane in America.[xciii] VOC's are the oil and gas industries largest industrial emission and among the most prominent source of ozone and smog, which is connected to a number of health problems, including aggravated asthma, respiratory concerns, skin complications, and premature death, as reported by the EPA. The air toxins released also have the potential to cause cancer.

The majority of air emissions that result from the hydraulic fracturing process are through the preparation of wells for production. Data from the EPA's Natural Gas STAR Program show that some of the largest air emissions in the natural gas industry occur as natural gas wells that have been fractured.[xciv] Throughout the hydraulic fracturing process there are several stages that result in different amounts of contaminants and fluid flowback from wells. One stage of well completion that generally lasts from three to ten days results in fracturing fluids, shale gas formation fluids, and gas flowing to the surface at high velocity and volume. The flowback from this stage can contain a high volume of VOC's, methane, and general air toxins. The gas/liquid separators that are used are not sufficient to handle the high flow velocity of this stage and thus a common practice of separating the gas from the fluids is to flare (burn) the gas. The flaring process eliminates most VOC's, methane, and hazardous air pollutants; however, flaring also releases carbon dioxide and a variety of other pollutants into the atmosphere. Nowadays, companies are using reduced emissions completions (REC's) commonly known as "reduced flaring completions" or "green completions." Through this process, companies bring portable equipment on-site and separate the solids and liquids from the gas during the high-rate flowback, and acquire the gas and heavier hydrocarbons that can be treated and sold.[xcv]

Hydraulic fracturing, regarding oil consumption, can still have serious air emission consequences. Known as wet gas, the flowback commonly contains less methane and more hydrocarbons; however, this can pose larger air toxin problems than dry gas being extracted. The U.S. Energy Information Administration reported that more than one-third of North Dakota’s

2011 natural gas production, primarily in the Bakken Shale oil play, was flared, or otherwise not brought to market because of insufficient natural gas pipeline capacity and processing facilities.[xcvi]

While the fracturing process itself has a large impact on air quality, other factors contribute to the emissions too. Equipment and other processes emit VOC's, methane, and air toxins. Some of the equipment includes field compressors and compressor stations used for fracturing processes to move gas along the pipeline; pneumatic controllers, maintain liquid levels, pressure or temperature; storage tanks and pits; and leaks in the pipelines. Also, the drilling process for fracturing wells is a very energy-intensive business that uses numerous diesel engines and generators.

Emissions, especially as more complex chemicals and processes are beginning to be used, are a high concern amongst companies. For instance, the EPA stated that in Texas the Wise and Hood Counties and Dallas-Fort Worth area were documented for failing to meet federal ozone standards in December 2011.[xcvii] Much of the air emission concerns have been directed to population growth and the development of the oil and gas industry in these specific areas.

The future of hydraulic fracturing is progressing towards a better and sustainable process. The EPA has begun proposing new air regulations for hydraulically fractured wells.[xcviii] If the regulations are implemented then the EPA estimates that there would be an industry-wide 25% reduction in VOC's, a 26% reduction in methane, and roughly a 30% reduction in air toxins.[xcix] This process of reducing emissions is a key feature with the EPA's proposal of reduced emissions completions (REC's).[c] There are already states that are highly active in regulating air emissions, like Wyoming and Colorado, who require green completions in certain circumstances. Also, companies such as Devon Energy and WPX Energy are voluntarily using an active initiative for air regulations such as the EPA's Natural Gas STAR program.[ci]

The EPA is strongly encouraging industries to become proactive in the reduced emissions completions programs. The EPA estimated that an industry could potentially recover its invested cost in REC equipment within sixty days and even more savings after a year. Nonetheless, industries have different opinions regarding the EPA and their evidence towards the REC's improvement. For instance, the American Petroleum Institute estimated that the average cost per ton of VOC's without associated sales from the flowback is $33,748 versus the EPA's estimate of $1,516. The rough cost per ton of VOC's with sales is $27,579 verse the EPA's net gain of $99; lastly, the overall cost to an industry for doing REC's in 2015 would be $782.6 million versus the EPA's benefit estimate of $20.2 million.[cii] While conflicts have arisen to the accuracy of the EPA's information there is further action being implemented to retrieve more data. On the other hand, measures are being taken to reduce emissions small as they may be. These measures include: minimizing truck traffic, installing low-bleed and no-bleed pneumatic devices, stepping up leak detection, encompassing the use of infrared technology, implementing repair programs that aggressively seal condensers and pipelines, installing vapor recovery units on storage tanks, and reducing the use of diesel engines for surface power and replacing them with natural gas engines or electric engines.

3.7 Conclusion

The hydraulic fracturing process and its associated environmental impacts have been an intense topic of discussion especially within the past decade. With critics arguing for and against the practice it is very easy to see how the public can have varying opinions about it. The practice is full of potential environmental impacts that have the capability of being extremely detrimental to the community and surrounding environment. The key word is potential since there has yet to be documented proof of hydraulic fracturing having serious negative effects. Nonetheless, the practice still does cause environmental damage from the land use, transportation, emissions, and water consumption; however, some of the huge points of concern like groundwater contamination from the injected fracturing fluids have yet to be confirmed as a result of the practice. In fact, most of the proven environmental impacts are consequences that are commonly associated with every mining technique or construction processes. The serious environmental concerns mainly surround the water consumption and chemical additives used in the process. The study and implications of hydraulic fracturing are fairly young and recent; after analyzing the commonly associated environmental impacts they do have the potential to be detrimental, but are mostly fears of the process that have yet to be proven.

Chapter 4: Economic, Political and Social Impacts

4.1 Introduction

Hydraulic fracturing may be a scientific advancement in the field of resource extraction, but its influence reaches far beyond the mining ground of the wells. The practice of hydraulic fracturing has caused ripples throughout society in the United States, both in terms of political and economic realities. Politically, the process has raised questions regarding its safety and regulation due to its recent raise in popularity with energy companies. It has fallen to politicians to try and control and regulate hydraulic fracturing just as other mining practices. However, just determining which level of government, state or federal, should have the authority to regulate it has stirred up debate. This along with the issue of how to regulate the process properly in general needs to be addressed. Economically, the growth in the industries hydraulic fracturing affects shows there is little doubt of its direct impact on the markets, but there is also the economic ripple effect on society. The process directly affects the economy, but secondary effects also need to be accounted for as the process interacts with industries and society. These social ramifications from the process also influence the surrounding people and towns of the regions where the process is implemented, contributing to improved job rates and other factors in the community. These effects will be discussed in depth in the following section.

4.2 Political Impacts

The increasing popularity of hydraulic fracturing has garnered it a spot in the political arena of this country. The recent trends have resulted in many politicians taking up an interest with this mining process and the effects to satisfy their constituents. Some states have taken action as a result of the recent growth of the mining industry using hydraulic fracturing and the fact that it is currently still under study by government organizations such as the EPA. The state of Vermont has already banned the practice of hydraulic fracturing, and the state of New York has suspended the practice until further studies are completed. The effects of hydraulic fracturing on the political scene are seen in these laws and regulations, as the process has grown enough to warrant government interference on both the federal and state level.

4.2.1 State Response

Vermont is currently the only state in United States to have banned the practice of hydraulic fracturing.[ciii] The implementation of this regulation came in May 2012, in a bill signed by Governor Peter Shumlin.[civ] The bill came as a response to people's fear of pollution during the process from fracturing fluids. In other states however, lawmakers are implementing regulations to control the practice and its increasing growth. For instance, New York and Texas have been consistently regulating hydraulic fracturing in recent years. These regulations all have varied in what they regulate based on what the states find more important. Texas has been regulating the water intake of hydraulic fracturing and monitoring the predicted growth in demand.[cv] Studies by the University of Texas have shown the quantity of water required for hydraulic fracturing along with where that water comes from. This is important for states such as Texas that have concerns over the usage of water, an issue addressed further by the University of Texas study. This may take a more prominent position in states in the future with the recent severe drought that has swept the western United States during the summer of 2012.

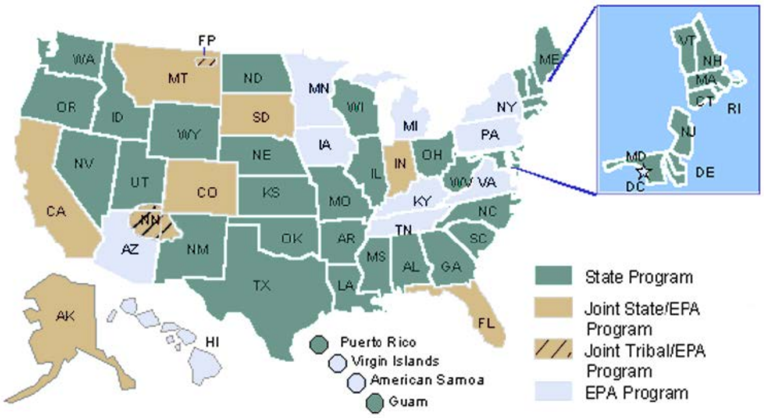
Mining was one of the fastest growing industries in Texas in 2011.[cvi] As such, it is not surprising to see hydraulic fracturing take hold there. Texas has reacted in a way to both understand and control the process of hydraulic fracturing. Introduced in 2011, the Texas house and senate passed the "Texas Hydraulic Fracturing Fluid Disclosure bill", which requires companies that drill using a hydraulic fracturing method to fully disclose all ingredients in the fracturing fluid being used anywhere in the state of Texas.[cvii] The bill, signed by Governor Rick Perry, shows the desire of the state to maintain public and environmental safety, but also establish a source of energy and economic growth for the future. Still the law has a few reservations, such as allowing companies to protect chemical ingredients or compounds that qualify as proprietary information.[cviii] This provision is not uncommon, since a similar component is a part of the federal FRAC ACT, allowing companies to protect trade secrets.[cix] Similarly, several other states have provisions that protect trade secrets, such as Wyoming.[cx]

In New York, the regulations are not so strict that they ban the practice of hydraulic fracturing, but the process has been subjected to strict regulations. New York has caused the largest impact on the process of hydraulic fracturing because the governor has temporarily suspended the practice.[cxi] In 2010, hydraulic fracturing was suspended and will remain so until more research is conducted into its potential environmental impacts by organizations such as the EPA. This political impact was brought about by the massive surge in hydraulic fracturing jobs following the discovery of the Marcellus Shale and the following rush in Pennsylvania. Yet, as of 2012, the process is still suspended pending further EPA tests.

There was little political interference with the energy companies during their expansion in Pennsylvania in 2008. Yet, public fear drove the political scene to take action before the growth could spread into New York. The politicians responded to their constituents with the temporary ban, but the constituents have also seen the potential benefits of the process, which is why the suspension was not permanent. Still the moratorium has been in place for longer than expected, and many companies are eager to resume drilling in New York.[cxii] The decision to resume the use of hydraulic fracturing rests in the hand of New York's Governor, a prime example of political impact on the hydraulic fracturing practice.

This process can rejuvenate wells that are losing profitability and re-inspire growth in the significant mining industries in states across America. Yet, with a lack of a federal mandate regarding the process, it has fallen upon these states to handle the issue. Many have taken to enforcing regulations similar to the federal Safe Water Drinking Act, often with variations from state to state. Still many states also follow EPA's UIC (Underground Injection Control), or share a joint program with them regarding the regulation of hydraulic fracturing within their borders.

Primacy Status for EPA's UIC Program



* The Fort Peck (FP) Tribes and the Navajo Nation (NN) are currently the only Tribes with UIC Primacy

Figure 4.1: *UIC status by state*[cxiii]

4.2.2 Federal Response

The political interest in hydraulic fracturing has been on the rise since the process became popular due to the increase in well production. Senators, house members, and state governments have taken an active interest in the practice. The highly controversial issues between those for and against hydraulic fracturing are the potential effects of the practice. Some U.S state senators, such as James Inhofe, have supported hydraulic fracturing and are against some of the findings by the EPA on the subject. In regards to these findings, he is claiming political contamination of the research. Senator Inhofe has been a longtime supporter of the hydraulic fracturing industry. Inhofe can be quoted supporting the industry back in 2009[cxiv]. He sees hydraulic fracturing as a major source of job stimulation for the United States and as a form of potential energy security for the nation. In a speech addressing President Obama, he is quoted saying "The National Petroleum Council reports that 60% to 80% of all wells in the next ten years will require fracturing to remain productive and profitable.[cxv]" Senators, such as Inhofe, have been a valuable force for the continued usage of fracturing and protecting it from potential harmful legislation. These senators believe that the mining process is critical for the United States' energy future, and its growth in economic fields. Reaching back to 2009, the numbers related the industries using the process are stated as, "Oil and gas development employs more than 26,000 and continued development in the Marcellus Shale is forecasted to create over 100,000 jobs. These jobs pay more than $20,000 above the average annual salary in Pennsylvania." Senator Inhofe has also acted when government agencies might rule against hydraulic fracturing. He has been quoted disagreeing with EPA findings and claiming they are "not based on sound science but rather on political science**",**[cxvi] these actions continue through the present day following the recent EPA release in December of 2012. With the EPA delaying its comment period for the third time on its hydraulic fracturing research, Inhofe has continues to believe the reports are based on faulty science. He is quoted as saying,

> "Using shoddy science to pursue an agenda that prevents America from responsibly using our own energy resources is unacceptable. It damages our own energy independence at a time when the nation is on the verge of outpacing countries like Saudi Arabia with the natural gas industry leading the way. These wrong-headed efforts to over

> regulate this important sector of our economy would mean lost jobs, lost revenues, and increased costs for every American family.[cxvii]"

Still, his active role in support of the process has helped the industry grow and increase production, even amongst growing government intervention.

On the other side of the political spectrum, some politicians are against the use of hydraulic fracturing. One such politician is Greg Ball, a republican from New York. In 2011, he gave a speech at the Lewisboro library in Brewster, NY. Senator Ball had visited the town of Dimrock, Pennsylvania following the claims for pollution and many other negative effects as a result of hydraulic fracturing.[cxviii] He witnessed the effects and returned against the use of the process. He in turn worked to educate the public on the potential effects of hydraulic fracturing, and encouraged all other members of the state legislature to visit the sites before allowing hydraulic fracturing in New York. Politicians such as him are slowing the growth of hydraulic fracturing in the hope of completely understanding its potential side effects before allowing it to be used as a standard mining practice.

With recent controversy surrounding the issue, the EPA has taken action in regards to the hydraulically fractured wells. Many of the wells that are hydraulically fractured are classified as Class II wells.[cxix] Under this classification, Congress has the authority to nationally regulate them as it pleases. At the same time, the EPA holds the right to reclassify the wells to another class if it chooses to do so.[cxx] If regulated as a Class II well, the hydraulically fractured mines would be subjected to certain requirements as seen in Table 4.1.

Table 4.1: *Minimum EPA Regulatory Requirements for Class II Wells*

Requirements	**Explanation**
Permit Required	Yes, except for existing Enhanced Oil Recovery (EOR) wells authorized by rule
Life of Permit	Specific period, may be for life of well
Area of Review	New wells—¼ mile fixed radius or radius of endangerment
Mechanical Integrity Test (MIT) Required	Internal MIT: prior to operation, and pressure test or alternative at least once every five years for internal well integrity. External MIT: cement records may be used in lieu of logs.
Other Tests	Annual fluid chemistry and other tests as needed/required by permit
Monitoring	Injection pressure, flow rate and cumulative volume, observed weekly for disposal and monthly for enhanced recovery
Reporting	Annual
* **Source: U.S. Environmental Protection Agency, Technical Program Overview: Underground Injection Control**	

Currently The EPA is working on introducing the UIC program to the states. This program would allow the EPA to produce and enforce regulations in states that have adopted the program and allow the EPA to protect drinking water from harmful underground injections. The program would also require state permits for the use of other "underground injection".[cxxi] Still, the states retain the authority to enforce the UIC provided they meet specific EPA requirements. As of 2012, hydraulic fracturing is exempt from the program by means of the SWDA of 2005, with exception given to the process if it includes the injection of diesel fuel. If the SWDA provision is repealed, the hydraulic fracturing may be subject to the UIC regulations.

4.2.2.1 Water Regulation

Most of the groups who oppose hydraulic fracturing are not entirely against its use as a mining process. While some see it as a damaging practice that should not be used at all, such as the state legislators of Vermont, some believe it is simply being misused. Some politicians believe that the process should be used, provided the proper regulations are in place. Many politicians have acted on the recent rise of hydraulic fracturing, in response to their constituents. In February of 2012, Diana DeGette and Jared Polis, House members from Colorado, and Maurice Hinchey of New York asked president Obama for stronger regulations on hydraulic fracturing.[cxxii] Colorado only has seven Congress members in the House of Representatives, so two of them confronting the president shows their constituents have an interest on the matter. The representatives judged the issue important enough to bring directly to president's current attention, so the president would be currently aware of the implications hydraulic fracturing may have on the country.

The most controversial regulation in regard to hydraulic fracturing has to do with the Safe Drinking Water Act of 2005. Under this regulation, hydraulic fracturing is excluded from the Act.[cxxiii] The SDWA defines underground injection as "the subsurface emplacement of fluids by well injection," but excludes the "injection for natural gas for purposes of storage" and "of fluids or propping agents" other than diesel fuels. Under this terminology, the energy and mining industries are free to pursue hydraulic fracturing as a means of resource collection and mining, provided that the fracturing process does not include diesel.[cxxiv] Some people and politicians have protested this classification of hydraulic fracturing, feeling that it should be subject to the SWDA as other practices. The states retain the power to regulated hydraulic fracturing in regards to the SWDA and several do, using their current authority under section 1425.[cxxv]

Table 4.2 *States Regulating Oil and Gas (Class II) UIC WELLS Under SWDA Section 1425*

Alabama	Louisiana	Oklahoma
Alaska	Mississippi	Oregon
Arkansas	Missouri	South Dakota
California	Montana	Texas
Colorado	Nebraska	Utah
Illinois	New Mexico	West Virginia
Indiana	North Dakota	Wyoming
Kansas	Ohio	

Note: With primacy granted under Section 1425, states regulate Class II wells using their own program requirements rather than following EPA regulations, providing significant regulatory flexibility to the states. EPA notes that state requirements “can be, and often are, more stringent than minimum federal standards.” Underground Injection Control 101, Permitting Guidance for Hydraulic Fracturing Using Diesel Fuels, Technical Webinars, May 9-16, 2011.cxxvi

The issues regarding the SWDA were brought to court on May 23, 2008, and the EPA has been given the issue for further proceedings.[cxxvii] In March 2011, Senator Robert Casey of Pennsylvania put forward the bill to reintroduce the Fracturing Responsibility and Awareness of Chemicals Act (S. 587/H.R. 1084). This act, also known as the FRAC ACT, would put hydraulic fracturing under the EPA’s regulation authority via the Safe Drinking Water Act. The bill also had several additional components, such as requiring companies to disclose all contents of the fracturing mixtures, chemical abstract service numbers for each chemical, material safety datasheets when available, and the anticipated volume of each chemical used.[cxxviii] Most companies however, refuse to disclose ingredients, due to considering them company secrets. In addition to requiring chemical disclosure to the EPA the act went one step further by requiring the disclosure of chemical information to medical professionals in the case of a medical emergency, a provision that bears resemblance to the Occupational Safety and Health Act, also known as OSHA.[cxxix]

The federal government may not currently regulate the hydraulic fracturing process, but many companies are wary of the prospect that it could be. As such, they are focusing on keeping the process safe for both society and the environment to avoid the intrusion of the federal government. One such example of this movement can be seen by the organization known as FracFocus. The organization is made up of many companies who practice hydraulic fracturing and choose to reveal the chemicals they use, though they are not mandated by law to do so. This process is voluntary and the companies following it are located in several states throughout the country. With this organization spreading to states that do not require disclosure, it shows businesses are wary of their public image and as such are willing to do what it take to keep the process of hydraulic fracturing respectable and clean.

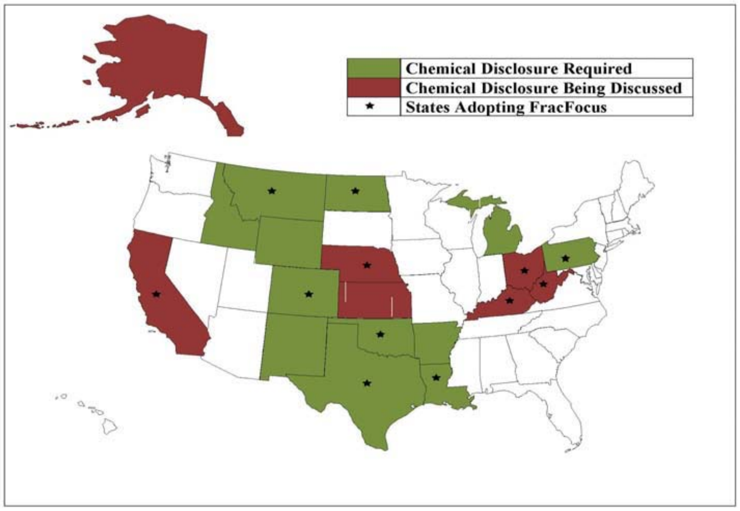


***Figure 4.2:** Hydraulic Fracturing Chemical Disclosure by State*

Source: Ground Water Protection Council, June 2012

Notes: GWPC reports that legislation is pending in California, Massachusetts, New York, and North Carolina.[cxxx]

One of the more recent regulative acts introduced to the House of Representatives is the Fresh Act, introduced in March of 2012. This regulation would eliminate the federal government from the overall process of hydraulic fracturing regulation, and delegate all responsibility to the states themselves. The bill was co-sponsored by several ranking members of the Senate Committee on Energy and Natural Resources.[cxxxi] This legislation gives the states the power to control the development of hydraulic fracturing within their own borders, as they would best know their land, and control the expansion of the fracturing process for the benefit of all parties involved. The bill would even allow the state regulations to be enforced on federal lands if the hydraulic fracturing takes place within that state's boundaries.

However, this federal regulation does currently allow states to control and regulate the process by which underground resources are extracted. The EPA has the authority to regulate when diesel is involved in the hydraulic fracturing process, and recently released a finalized guideline on the matter. After that, the implementation of these guidelines in the states is expected. These guidelines were discussed earlier in regards to the UIC program put forth by the EPA. While hydraulic fracturing is exempt from the SWDA, the use of diesel for injections is not. Still, some businesses in the energy industry are worried about how they may be punished for their past use of diesel, "Industry officials say their key fear is not whether they will be allowed to use diesel or whether it will be regulated but whether they can be punished for having used it in the past without a permit."[cxxxii]The impact this could have on the industry is wide ranging and hence a very important decision for the EPA on how it handles the situation.

The Clean Water Act is another federal regulation that affects hydraulic fracturing and its application process. The main factor connecting this act to hydraulic fracturing is the wastewater treatment. Due to the rapid growth of the mining industry in regions that had previously had no major mining operations of this kind, many treatment plants are finding themselves unprepared to handle in influx of fracturing wastewater. The EPA expressed its concern with the issue in October 2011: '"some shale gas wastewater is transported to treatment plants, many of which are not properly equipped to treat this type of wastewater."'[cxxxiii] However, as of February 2013, the issue has remained an issue for the private sector to handle.

Regulations are implemented on businesses as a means of controlling and regulating the industry, to avoid them abusing the public. Hydraulic fracturing is an industry practice and as such is subject to being regulated as other business practices are. Currently, the oil and gas industries are exempt from the 2005 Safe Drinking Water Act for this hydraulic fracturing process, which is where most of the concerns regarding hydraulic fracturing lie. In 2009, the three house members mentioned above, along with Senator Bob Casey, introduced companion bills to safeguard drinking water from hydraulic fracturing.[cxxxiv] The senator who put forward this regulation did not see hydraulic fracturing as a practice that had to be stopped, but rather as a potential future tool for the industry of the state. He just wanted to make sure the public health would not be put at risk during the growing usage of the method. This shows that some people view the practice as one that shows potential, but simply needs to be controlled.

Other politicians are simply afraid of hampering the growth of the industry with federal laws. Federal regulations affect all states equally, so once a standard is set, every business in every state must adhere to it. However, some government officials do not believe this is in the best interest of anyone, public or private. Senator John Hoeven of North Dakota put forward legislation cosponsored by Senator Lisa Murkowski that would give the states the power to regulate the process of hydraulic fracturing.[cxxxv] To every state, hydraulic fracturing holds a different value, so allowing each state to regulate it as they see fit is a method that would allow for maximum flexibility in handling the issues at hand.

4.2.2.2 Air Regulation

The EPA has proposed regulations to regulate hydraulic fracturing's impact on air pollution. The EPA created its proposal based on current technology and the best practices in some states today. The four regulations that affect the energy industry are:

1) A new source performance standard for VOCs;

2) A new source performance standard for sulfur dioxide;

3) An air toxics standard for oil and natural gas production; and

4) An air toxics standard for natural gas transmission and storage. [cxxxvi]

These proposed regulations were intended for control of emissions from work sites of industries. As such, fractured wells could be subject to the same regulations as every other process that the energy and mining industry comply to. Yet, as of 2013, the federal government has not regulated the emission standard for the fractured wells. Instead, the process is regulated by the Clean Air act, a process that has not seen a major amendment since 1990.[cxxxvii] Nonetheless, companies currently are using a new proven process known as “reduced emissions completions” or “green completion”.[cxxxviii] This process has resulted in close to a 95 percent reduction in VOC’s showing the energy industry interest in public health. Still, the EPA is seeking to install a baseline for federal regulation of the process in terms of emission and hence implement a new standard for the process. Still some environmental groups’ say the regulations do not go far enough, as it does not address existing conventional wells that have already been fractured. Still, these proposals show the EPA’s interest in hydraulic fracturing emission, and its future role as an environmentally safe method for industries.

4.3 Economic Impacts

America’s economic growth has slowed and with the damage of the recent recession, the recovery is paramount to the success and well-being of the nation’s citizens, businesses, and industry. Hydraulic fracturing provides the potential economic boost that helps guarantee a future for many industries and business located in America. Not only that, the process allows for the spread of wealth as the process creates side effects that span to the average citizen. As such, the economic growth and developments related to hydraulic fracturing have and will continue to have a major impact on the economic situation of citizens, states and the country.

4.3.1 Society Impact

The recent growth in the natural gas industry has been the result of the increase in the application of hydraulic fracturing. New discoveries of massive shale deposits containing natural gas in the United States, such as the Marcellus Shale deposit, have sped development and implementation of hydraulic fracturing. This trend is apparent in several states, but one of the most notable is in Pennsylvania. The Marcellus Shale has drawn the energy industry and corporations to the state due to the potentially enormous supply of natural gas located there. Due to the depth that natural gas is located, hydraulic fracturing is one of the most effective and cost efficient means of accessing and mining the resource. Yet, citizens privately own a majority of the land and the corporations have had to enter into negotiations to gain the right to drill on their land.

Businesses seeking to drill have had to offer contracts to the owners of the property in order to get their permission to use their land. These offers have ranged from cash grants, to royalties, to access to the supplied natural gas in exchange for the allowance of mining on their property. Companies offer contracts to residents who live on the desired land, with the cash offers ranging from two thousand dollars lump sum, and royalties of up to twelve percent on the natural gas mined.[cxxxix] With the tough economic situation of the country at the time of this rush, offers like this have had a huge impact on the economic wellbeing of the citizens engaging in the deals. The potential economic impact on the people of Pennsylvania and New York is potentially massive as the state of Pennsylvania currently has an unemployment rate of 8.2 percent[cxl] while the state of New York is currently struggling with an 8.9 percent unemployment rate.[cxli] To the average family, the income could be a life changer, and the potential for free natural gas energy provided by the process is another way for the family to save money over the long term.

Once the companies have gained the right to drill, hydraulic fracturing creates another layer for the economic boom. The need for workers to run and maintain the mining rigs is a source of job creation. In some areas, the larger mining operations also allowed for the traditional growth of jobs that fall in line with the needs of the workers of the rigs. People living in the area of these developing mining operations have begun leading to the development of new small businesses focusing around these needs. While some locals complain that the average person cannot do certain jobs working on the rigs; the industry's presence still encourages the growth of small businesses. At the minimum, there are jobs available on the rig, and they pay well. These jobs provide solid income to families, and are sometimes two or three times the rate that some of the average local jobs offer.

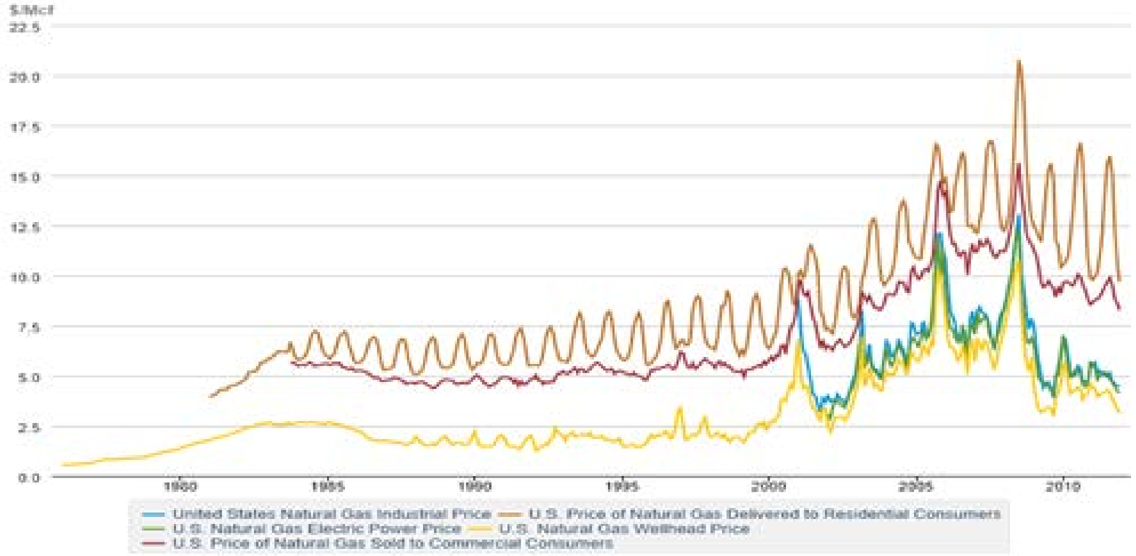
In the county of Woodward, Oklahoma, this effect can be seen as the product of the industries mining growth. There are many cases of citizens in this county drastically increasing their income by performing the jobs that the oil companies offer/employ/require. One such worker found his salary increased from two thousand a month to four thousand a month once he found work on a hydraulic fracturing crew.[cxlii] The county itself is actually finding itself with a shortage of workers as the unemployment rate dropped to around three percent. Over the next decade Oklahoma's mining industry is expected to be the second fastest growing industry sector. It is predicted to see a job growth of 19.2 percent increase of almost 13,820 jobs.[cxliii] Growth like this is why, according to the September 2012 survey, Oklahoma only has an unemployment rate of 5.2 percent.[cxliv] That is approximately 4 percent lower than the national average in December 2012.[cxlv] The growth in the mining industry, provided by the increased use of hydraulic fracturing, has helped the state's economic growth. The potential job market in states where mining is abundant is a valuable argument supporting the case of hydraulic fracturing and its continued use and growth.

Waste management and removal for hydraulic fracturing waste is an example of a small business that can grow around the fracturing wells.[cxlvi] These are jobs created and can be done by a wide range of workers, which helps the economic growth of an area. The fact that over three thousand wells have been drilled in the state of New York in the past three years shows that there has been a constant growth in the energy industry. Some people of the region, however, fear the potential for "Boom Bust" in the region. They fear it will be similar to towns that would spring up overnight, and then be abandoned shortly thereafter.[cxlvii] The people of the region see the pattern, and have caution that a company's interest in the region may be hurtful over the long term.

4.3.2 Industry Impact

Hydraulic fracturing has led to a massive economic impact on the United States energy industry as a whole. API claims that about 7.7% of the entire United States economy is from the energy industry.[cxlviii] Hydraulic fracturing provides a potentially revolutionary impact on the energy and mining industry, due to its ability to access resources previously believed to be unobtainable. The ability to access these pockets means the energy industry has the ability to influence the U.S economy and everyday life of its citizens. This can be viewed in the current average pricing of natural gas in the United States, compared to a few years ago. The price increases visibly coincide with the years where hydraulic fracturing was starting to become more popular. Since it was a newer process, the price was expected to increase, but over recent years, the price has continually dropped now that it is becoming more commonplace. The oscillation in the residential prices that can be seen in Figure 4,3, can easily be linked to the winter and fall months, when heating is more in demand, thus increasing the price compared to the spring and summer months.

The lower prices increase the competitiveness of natural gas in the energy market, increasing the consumer base and demand.[cxlix] Lower costs help society by providing cheaper energy, especially in states where cold winters often require residents to have a heating source, see Figure 4.3 for price relations.



Source: U.S. Energy Information Administration

Figure 4.3: *Natural Gas prices*

While hydraulic fracturing cannot be blamed as the only reason for the change in price, its rise in popularity over the last few years has contributed greatly. Over the last few years, the prices have dropped steadily, also showing the effect of the increased shale gas reserves. These lower prices make natural gas a more affordable means of energy, contributing to its rise in popularity, and overall growth for the energy industry.

The growth in the natural gas industry over the last few years is apparent, and the recent studies back up growth reports. A Penn State study published in July 2009 helps reveal the impact of this industry on the country in a time of a major recession. This study, conducted by

Timothy Considine, PH.D, Robert Watson, PH.D, Rebecca Entler, and Jeffer Sparks, reveals the economic impact that hydraulic fracturing has helped bring to the gas industry.[cl]

> “This study finds that the Marcellus gas industry in Pennsylvania generated $2.3 billion in total value added, more than 29,000 jobs, and $240 million in state and local taxes during 2008. With a substantially higher pace of development during 2009, economic output will top $3.8 billion, state and local tax revenues will be more than $400 million, and total job creation will exceed 48,000.”

Added to these numbers is the prediction for the future, where the expected increase in the Marcellus energy industries value could be as much as 13.5 billion dollars, in addition to the creation of almost 175,000 jobs.[cli] The advances in well drilling cited in the Penn State study refers to the growing use of hydraulic fracturing as its popularity first began to increase. They found that the activity located in the Marcellus shale would continue to expand in the future.[clii] It is predicted that by 2020, the Pennsylvanian section of the Marcellus Shale could increase its daily production of natural gas by 4 billion cubic feet (bcf).[cliii] Still, the study also shows insight into the potential political implication that regulation has on the economic impact of the industry. The Penn State study cites another by HIS Global Insight, which determined that if the Safe Drinking Water Act had been implemented against hydraulic fracturing, then the natural gas production by wells on the Marcellus Shale would fall by almost 22 percent, and oil production in the region would fall by 8 percent by 2014.[cliv] These numbers reveal the tight connection between the energy industry and the economic ramification of those regulations. This study holds enough weight that senators debating hydraulic fracturing regulations in 2009 cited it. The Penn State study allows for a glimpse of what the industry holds, and the potential benefits it can create for the United States.

Along with the growth of the natural gas industry, the number of wells that use hydraulic fracturing has increased drastically in recent years. Horizontal drilling, which was described earlier in this paper, combined with the process of hydraulic fracturing allows for the increased mining production of natural gas. In the Barnett Shale in Texas, this process and its growth can easily be seen by the increase of in production of natural gas. The production has increased over tenfold, most coming from the horizontal wells.[clv] This increase in production is a result of the combination of the previously stated processed.

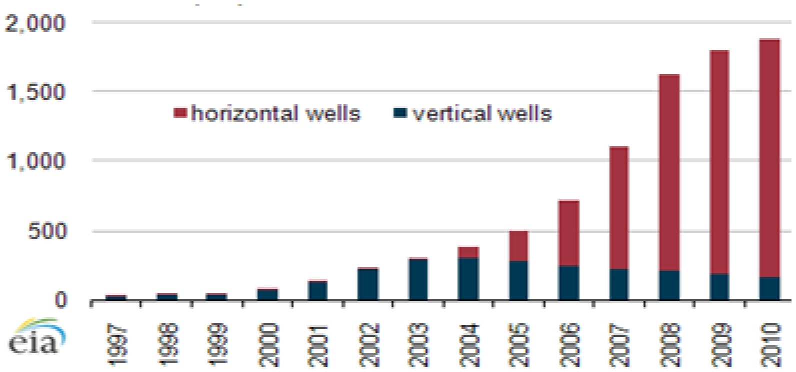


Figure 4.4: *Annual Barnett shale natural gas production by well type*

Source: U.S. Energy Information Administration based on HPDI, LLC

4.3.3 Mining Production

The environmental impacts are just one of the potential impacts of hydraulic fracturing. The massive increase in shale gas and other resources that can be mined has affected the United States natural gas consumption. With the rise in oil prices, natural gas's boom has provided an alternate way for many Americans to fulfill their energy needs. Energy companies are keen to take advantage of this situation The growing production in states such as Pennsylvania, where natural gas consumption has increased by 100MMcf over the past 6 years, has resulted in increased consumption.

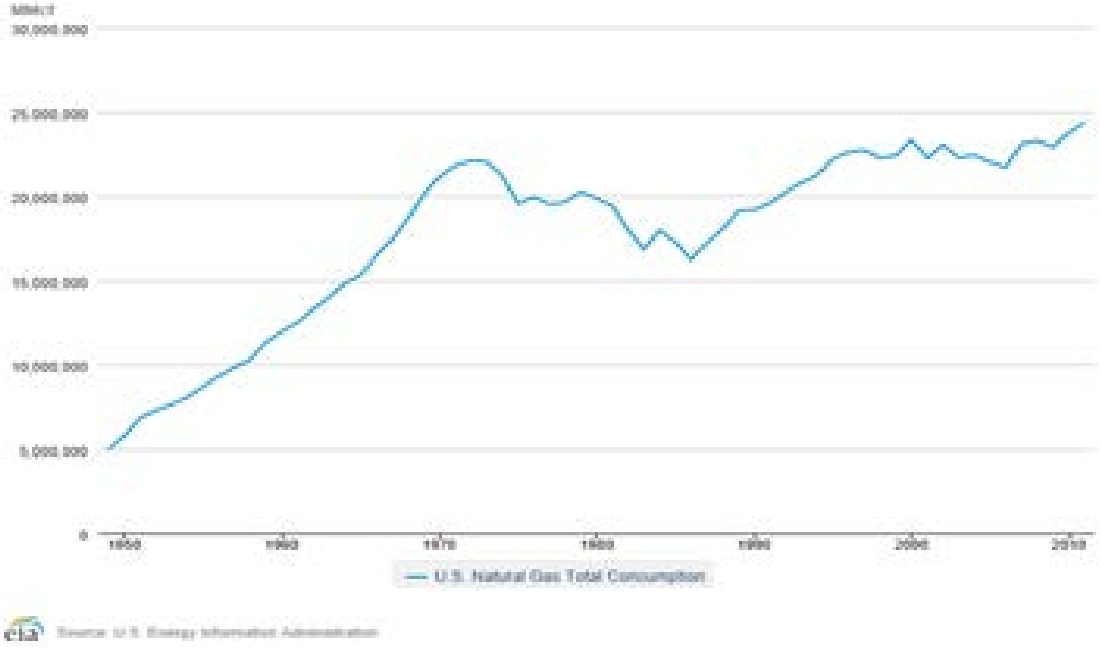


Figure 4.5: *Natural Gas consumption by the United States*

Source: U.S Energy Information Administration

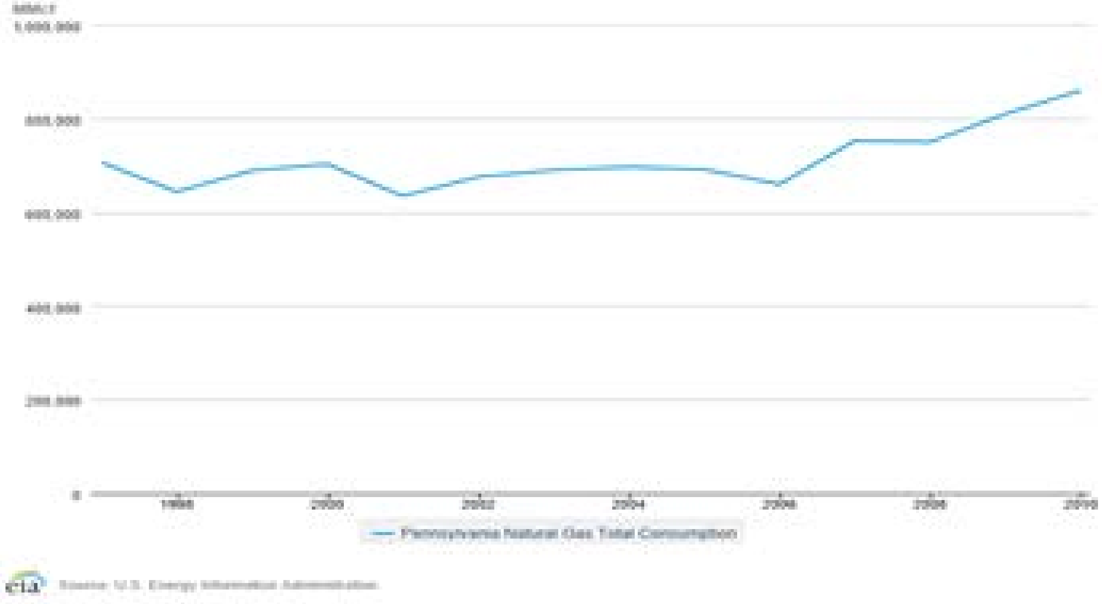


Figure 4.6: *Natural Gas consumption in Pennsylvania*

Source: U.S Energy Information Administration

Along with consumption, the process plants that are required to handle the increase in raw natural gas supply are also affected. Though there has been a decrease of 8 percent of the total number of factories in the U.S, there has been a 12 percent operating capacity increase between 2004 and 2009.[clvi] The decrease in the number of plants comes from the fact that older plants were being shut down as newer more efficient plants were coming online this increases overall plant productivity. This means that more raw natural gas can be processed in less time with fewer factories. The influx of natural gas from the improvement in hydraulic fracturing is providing an increase in the processing industry as well. These social impacts affect the everyday life of the workers of these factories as newer factories are coming online to increase the processing capacity of the nation.

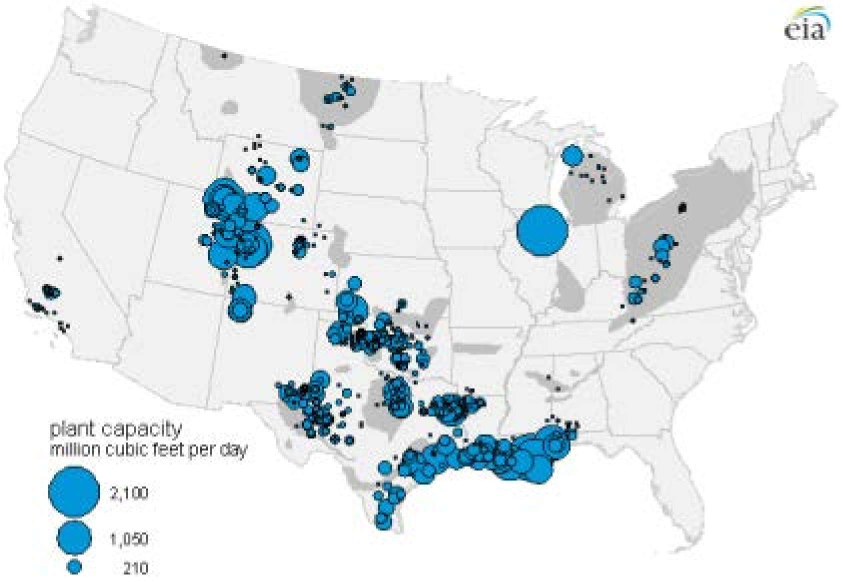


Figure 4.7: *Natural gas plant capacity*

Source: U.S. Energy Information Administration, Form EIA-757A, Natural Gas Processing Plant Survey Schedule A: Baseline Report

Note: *Gray-shaded areas represent current U.S. shale plays.*

4.4 Social Impacts

The social impact of hydraulic fracturing has increased over the years. Since the process of hydraulic fracturing has become more frequently used by businesses and industries, the communities and surrounding societies it is used in have felt its effects. The economic effects as explained previously have affected the communities, but at the same time, there are social impacts that have been becoming more and more frequently reported. These effects vary from job creation, to the fear of potential pollution. These impacts, though drastically different, stem from the process of hydraulic fracturing and its growing use.

4.4.1 Pollution Fears

Publically, the most prominent issues revolving around hydraulic fracturing is the possible pollution it can create. People have claimed the pollution has ranged from well-water contamination to creating murky tap water. Some of the people making these claims state that the problem only occurred after hydraulic fracturing had begun on the wells near their property. People also claim that the nearby drilling has caused property value to decline, as well as complaints about the noise of the mining operation. Individuals and some groups have formed to bring lawsuits against the companies responsible for drilling. One such group, called “Fleased”, formed to help property owners get out of their leases and fight the energy companies.[clvii] Similar groups are against hydraulic fracturing on their land, and claim the companies deceived them when they offered the contract. Yet, there has not been one judicially proven instance of hydraulic fracturing being the source of groundwater pollution. Nonetheless, these lawsuits regarding some instances of contamination are still pending. In relation to these pollution claims, Duke University conducted a study into possible the contamination. The study by the University regarding levels of methane in well water found a similar result.

> “The study found no evidence of contamination from chemical-laden fracking fluids, which are injected into gas wells to help break up shale deposits, or from "produced water," wastewater that is extracted back out of the wells after the shale has been fractured.”[clviii]

As explained earlier in the environmental section, there have been no confirmed cases of hydraulic fracturing causing any groundwater contamination. Along with many companies voluntarily complying with emission standards and using processes that reduce emissions[clix], any pollution would more likely be a result of company negligence rather than any issues with the process of hydraulic fracturing.

4.4.2 Natural Gas Reserves

The discovery of large shale deposits with natural gas has also invigorated the debate about an energy independent America. These massive reserves of natural gas have increased the United States natural gas reserve significantly over the last few years. As seen in the graph below, the U.S overall natural gas reserve has seen its shale gas increase by 20 percent over the span of 2007 to 2010.[clx] Since 2011, 94 percent of the natural gas used by the United States came from domestic sources; the increasing supply provides the possibility for growth into other energy usages, helping to create a possible independent and domestic energy source. This increase in the availability and importance of shale gas to the U.S has influenced the country, and its outlook towards future energy possibilities.

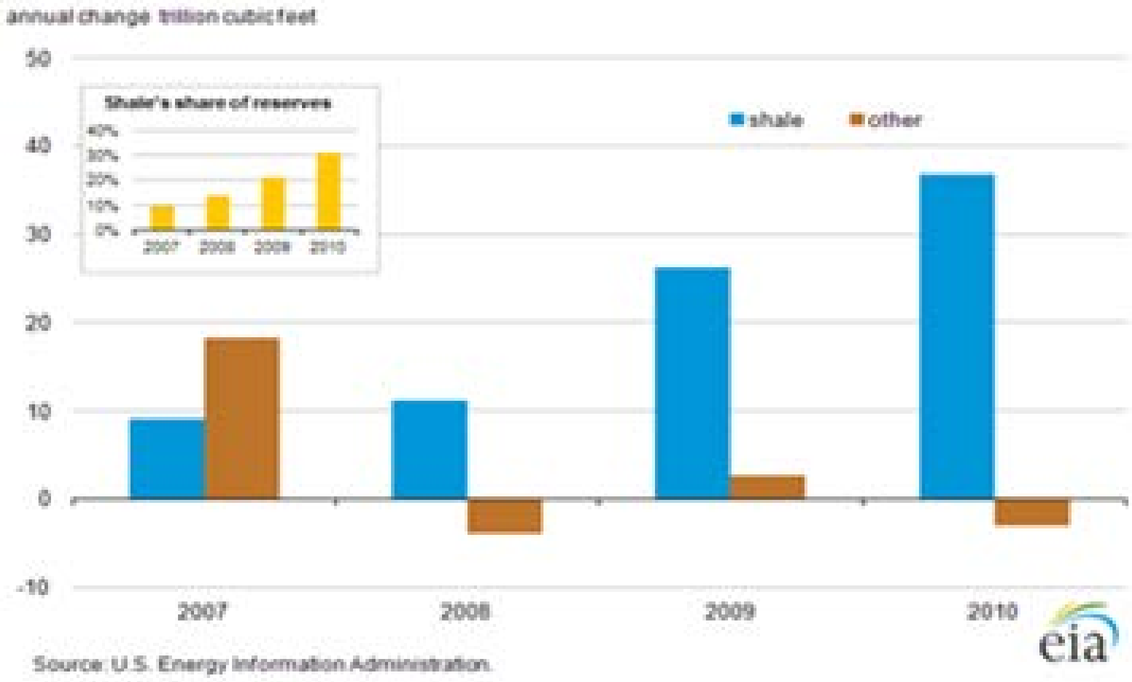
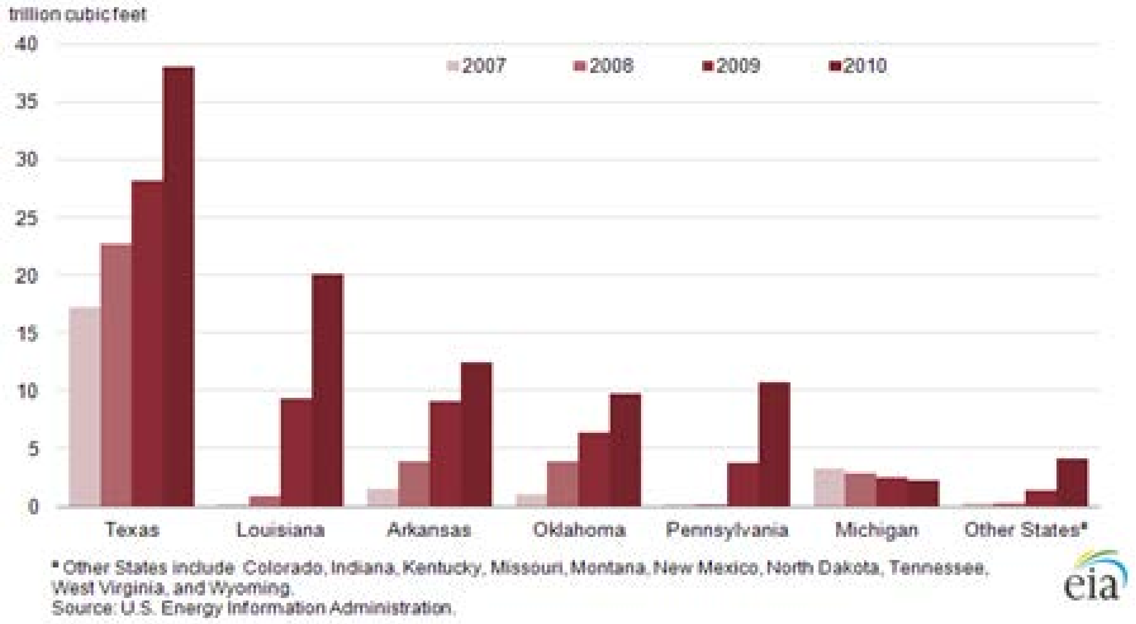


Figure 4.8: *Annual change in U.S natural gas reserves*

As shown in Figure 4.8, Natural gas reserves over recent years has spiked drastically. The increase of the natural gas reserve by state can be seen in Figure 4.9, and states with large shale deposits have had major increases in their reserves. Since its introduction, hydraulic fracturing helped to increase shale gas access, thus aiding in the increasing national reserves.



* Other States include Colorado, Indiana, Kentucky, Missouri, Montana, New Mexico, North Dakota, Tennessee, West Virginia, and Wyoming.
Source: U.S. Energy Information Administration.

Figure 4.9: *Shale gas reserves by state*

The desire to exploit the massive shale reserves of natural gas under the U.S has led to an increase in the usage of hydraulic fracturing, being as it is one of the most efficient means to gain access to the shale sources. It has helped the energy industry in a variety of sectors. While the natural gas sector is the most prominent in the news, the process is also used in oil wells. Many of the benefits that the process brings to the natural gas energy sector, it also brings to other mining sectors, but currently its largest impact is on the natural gas mining process.

4.4.3 Water Usage

Hydraulic fracturing requires a large amount of water and as such increases the water consumption in the areas it is used. As a result, companies that use hydraulic fracturing often need to locate very large amounts of water. While this may not seem to be a pressing social impact in some regions, it is in regions where water is scarce. In states such as Pennsylvania where the farming industry is large, water is usually used in large qualities. In others, such as Texas or Oklahoma, water is a far scarcer commodity. If the hydraulic fracturing industry, backed by large energy companies, buys up available water reserves of an area then farmlands, industries, and many other sectors may face the possibility of lacking water. This means that a massive growth in the hydraulic fracturing may lead to adverse effects in any other industry that has large reliance on regional water supplies.

Water usage for shale gas production in Texas was addressed in a study as the University of Texas, which was published in March of 2012. The published results help to demonstrate the effects that the growth of the energy industry and its use of fracturing will have on water reserves of the state. In Texas, the Barnett Shale accounted for 66 percent of shale gas production in the United States from 2007-2009.[clxi] The article reveals that the average annual rate of production of natural gas in the United States has increased by nearly 50 percent from 2006-2010. In addition, that overall production in the United States may increase by 47 percent by 2035. This information shows, not only the economic and supply growth, but also the growing need for water to help continue the hydraulic fracturing spear heading this natural gas boom.

In Texas, well operators are required to report water used in the fracturing process, which allows a glimpse of the water consumption of the wells. The amount of water consumed to complete the hydraulic fracturing process on the Barnett shale was 9 percent of the water used annually by the city of Dallas.[clxii] The growing functions of recycle and reuse of wells have shown the potential to allow up to 20 percent of water to be reused in the drilling process by 2060 for the Barnett and Eagle Ford Shale in Texas in relation to the net water used.

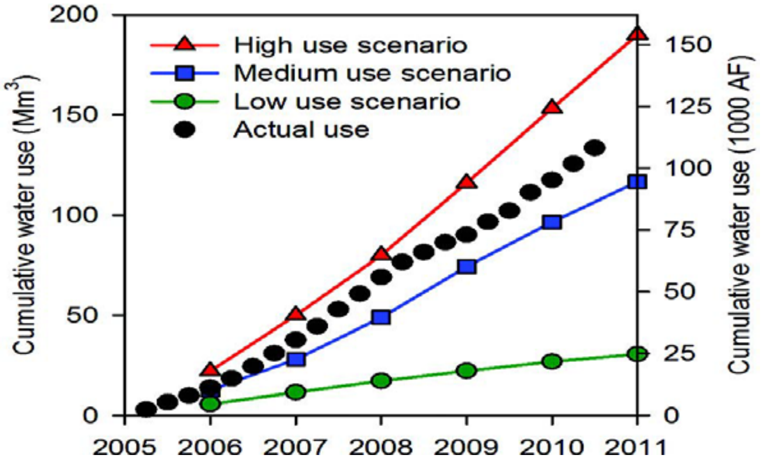


Figure 4.10: *Hydraulic fracturing water consumption predictions in Texas*[clxiii]

The study shows the amount of water used by these wells vary depending on the wells. In the Eagle Ford Shale, fractured well water usage varied from 4600 to 33900 m^3. This range for water usage by well fell between the 5th and 95th percentile, showing that each well's water usage can vary greatly. As a comparison, over 168,000 m^3 of water falls from Niagara Falls a minute.[clxiv]The average U.S family of four uses 400 gallons of water a day or 1.51m^3, which over a year can reach 550m^3.[clxv] These numbers show the relationship between high and low percentile water consumption of the fracturing process. Since 2008, fracturing has made up 66 percent of the mining industry's water usage in Texas. However, this is still less than 1 percent of the state of Texas's overall water usage in 2008 (See Chapter 3.1 for exact numbers).

As this shows, the average citizen of Texas would mostly deal with water limitation created by farmlands, rather than fracture mining. This water usage may shift the fracturing industry to the use of brackish water to reduce this potential competition with other industries. This possible competition may still affect the local population of regions where the industries clash. The competition to secure water between the farming and mining industry may eventually affect the average citizen of the regions near the water supply more than anyone else.

Conclusion

From top to bottom, hydraulic fracturing affects everyone: whether it is the engineers placing the pipe, the company conducting the mining, or the citizen buying it for fuel. Hydraulic fracturing has penetrated to the head of the United States government and has politicians working to affect its future. With Senators, House members, and even the President involved in law making, the political implications on both the politicians and their constituents are vast. States also have major legal battles revolving around hydraulic fracturing, all stemming from their social and economic impacts. The economic benefits serve as one of the main arguments in support of fracturing. With increases in mining production and natural gas reserves, there are plans to take advantage of these benefits in order to achieve a more energy independent nation. These profits bring social changes to communities, in the form of more jobs, but also bring disturbances, in the form of noise and political intrigue. In the end, hydraulic fracturing will continue to be a source of economic benefits, political debate, and social impacts that will shape the coming years.

Chapter 5: Alternate Methods

5.1 Introduction

Although this paper focuses on the most common practices in the hydraulic fracturing industry, there are some companies trying to make major changes. Some gas companies, including some of the industry's giants, are looking for ways to make fracturing better for the environment and more economically productive. This race is being led by GasFrac, Halliburton, and Chesapeake Energy. These companies all have products in use, or at least at the prototype stage designed to revolutionize the industry. Many other companies are also funding projects for this same reason.

5.2 GasFrac

The most promising development in alternate methods for hydraulic fracturing actually does not involve water at all. Developed by a Canada based company called GasFrac, it is a waterless fracturing system that uses gas instead. The process is liquid propane gas fracturing, known as LPG fracturing. The liquid propane is in a gelled state that acts as the fracturing fluid instead of the more traditional use of water. There are many benefits to this, the most obvious being the reduction of most of the water related problems in hydraulic fracturing. Although it is a new process, GasFrac has had this setup implemented for several years now. Unfortunately, they are the only company that has pursued the waterless fracturing route so there is limited information on the subject.

The fracturing fluid developed by GasFrac consists of mostly propane, C_3H_8. GasFrac claims that their LPG fluid have beneficial properties such as low surface tension, low viscosity, low density, and is soluble with naturally occurring reservoir hydrocarbons.[clxvi] A comparison with water of those specifics is shown in table 5.1. Low viscosity means that the pressure required to move the fluid can be greatly reduced. This results in a larger effective fracture length and improves post fracturing fluid recovery according to GasFrac.[clxvii] The lower surface tension has a similar effect as it also reduces the pressure required to move the fluid. This results in more fluid recovery in a shorter period as shown in Table 5.1 and Figure 5.1.[clxviii]

Table 5.1: *LPG compared with Water*[clxix]

Property	Water	LPG
Viscosity	.66 cps (@105°F)	.08 cps (@105°F)
Specific Gravity	1.02	0.51
Surface Tension	72 dynes/cm	7.6 dynes/cm
Reaction with Formation Clays/Salts	Potentially Damaging- Reactive with Formation Clays/salts	Non Damaging- Inert with the Formation Clays/Salts

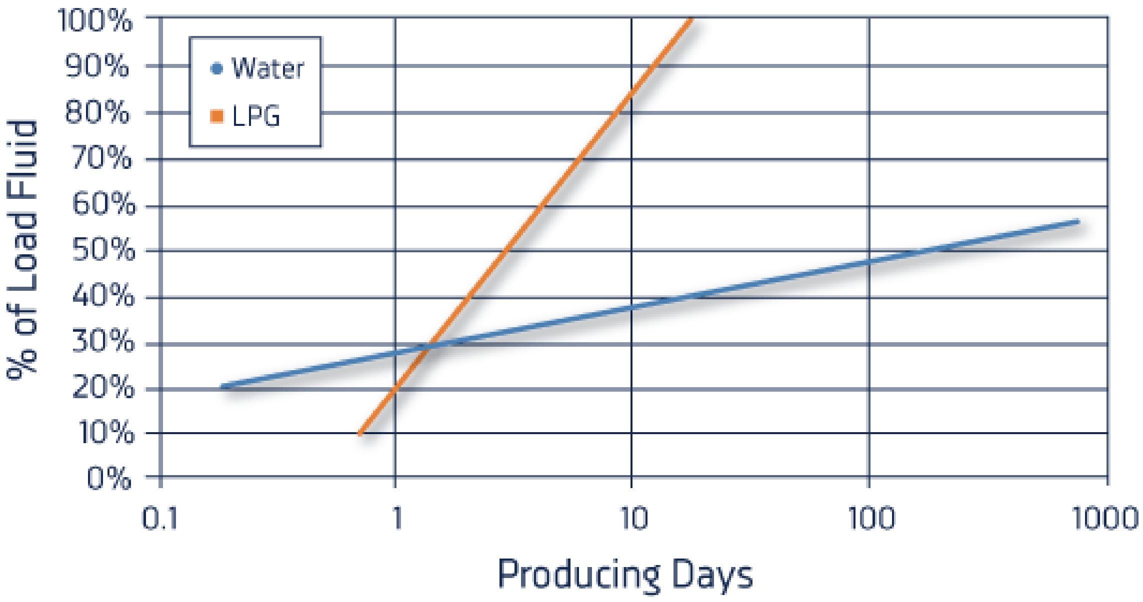


Figure 5.1: *Fracturing fluid recovery over production days*[clxx]

Some of the greatest economic and environmental impacts revolve around the fact that most water related problems are reduced or non-existent in LPG fracturing. This fluid is much easier to clean up and even has a 100% recovery after several days, which is shown in Figure 5.1. The fluid also retains the potential of being reused. In traditional hydraulic fracturing it is impossible to remove all of the water from the well and it is a very time consuming process. Since propane is reusable, there is the economic benefit of possibly not having to transport new fluid to the site. There is also no need to pay for the disposal of waste fluid. GasFrac is still in the process of developing a system to easily reuse the LPG fracturing fluid, but the current system still uses much less fluid than a hydraulic fracturing well. The recaptured propane could also be sold for other uses. Other benefits include reducing the risk of contamination in local drinking water as well and not reducing the local water supply.

One reason that the LPG fluid can be recovered so easily is that it mixes readily with the natural gas that is being extracted. Figure 5.2 shows the temperature/pressure combinations from which different propane/methane mixtures change from a liquid to a gas. This can be used because methane is a large portion of the extracted natural gas. Also, Figure 5.2 shows that as more methane is added the curve moves up and to the left. This means the propane can be in a gas state at much lower pressure and temperatures. Therefore, when the natural gas is extracted, it will mix with the propane and turn it into a gas as well. Then they can be removed at the same time more easily than removing water.

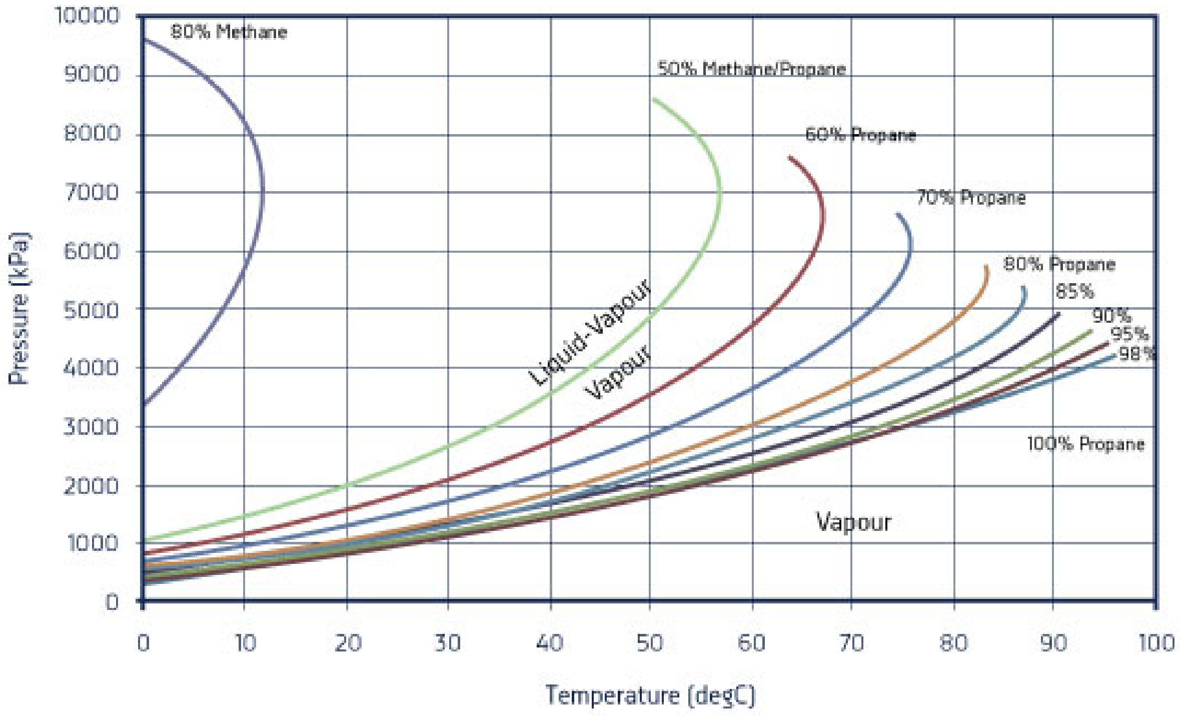


Figure 5.2: *Vapor lines of propane methane mixture*[clxxi]

LPG fracturing fluid also has the added benefit of not dissolving salts, metals, and radioactive compounds brought to the surface with hydraulic fracturing. This is because it is made up of non-polar molecules versus polar (water). GasFrac claims that their process produces more natural gas and in a shorter time than other methods of natural gas extraction. This can be shown on the figure 5.3. Although these tests have been done by GasFrac there may still be some merit to these results as several companies that used GasFrac claimed to have seen an improvement in production. Chevron, a large oil and gas company, used GasFrac at a Colorado well and said it "significantly increased production while minimizing water usage." [clxxii]

Although it appears that GasFrac cannot go wrong with their LPG fracturing methods, it still has not been completely proven. Many people still have their doubts in terms of safety and the claims by GasFrac about its environmental and economic benefits. Much of the uncertainty is a result of GasFrac being the only company pursuing propane as a fracturing fluid. Although it appears to be much better for the environment, actual environmental impacts are completely unknown. This is something that will take more time for total acceptance in the natural gas industry.

Most of GasFrac's client base is in Canada, although it has had limited use in Colorado. They are looking into expanding more in the United States, with New York as a possibility; however some environmental groups had concerns with this and wrote a letter to the New York Department of Environmental Conservation to conduct a thorough environmental review on GasFrac before allowing it into the state.[clxxiii] Another issue the environmental groups have is just the overall issue of safety within the GasFrac system. Unlike water, propane is flammable and can be very dangerous if not treated properly. This concern is a real issue as there were two accidents at GasFrac facilities in early 2011. [clxxiv]GasFrac has fixed the problems and there have been no issues since. Now they really need to prove to the industry and the community that they really are safe.

Despite some of these problems, GasFrac profits are still on the rise. A sample of their quarterly financial reports over the last three years can be shown in Table 5.2. Although it appears that GasFrac took a financial hit in 2012,it is only because there was a $20.9 million equipment sale to Husky Energy.[clxxv] The revenue increased by 12 percent in 2012 if you subtract this from 2011's totals.[clxxvi] What is clear from these results is that the revenue per day has increased significantly. This is very good for the future of LPG fracturing as this technology could die with the company that created it if they go under.

***Table 5.2**: Comparative Quarterly Financial Information*[clxxvii]

For the three months ended	September 30 2012 (CAD$)	September 30 2011 (CAD$)	September 30 2010 (CAD$)
Revenue	40,851	57,437	25590
Operating expenses	35,381	42,318	18046
Selling, general and administrative expenses	5,786	4,423	3202
EBITDA	1,060	10,960	4874
(Loss) Profit for the period	(7,144)	5,911	2318
(Loss) Earnings per share- basic	(0.11)	0.10	0.06
(Loss) Earnings per share- diluted	(0.11)	0.09	0.06
Weighted average number of shares- basic	63,043	61,567	41245
Total assets	323,748	287,632	182280
Total non-current liabilities	35,794	2,123	48
Treatments	175	191	137
Revenue per treatment	233	191	194
Revenue days	91	87	83
Revenue per revenue day	448	420	320

There is a noteworthy case study on GasFrac and LPG fracturing from the McCully gas field in New Brunswick, Canada. These wells started its use of hydraulic fracturing in 2003, and by 2009 there were functioning LPG fracturing wells. Data was collected at the hydraulic wells from 2005-2008 and then in 2009 with the liquid propane.[clxxviii] It is easily apparent from Figure 5.3 that using much less proppant was used in the LPG fracturing and still resulted in a higher flowback rate. The overall productivity of the wells were also studied by measuring the fracture half lengths from pressure transient analysis, rate-time analysis, and analytical modeling. It can be seen in Figure 5.4 how much more productive the propane fractures are compared to the water fractures.

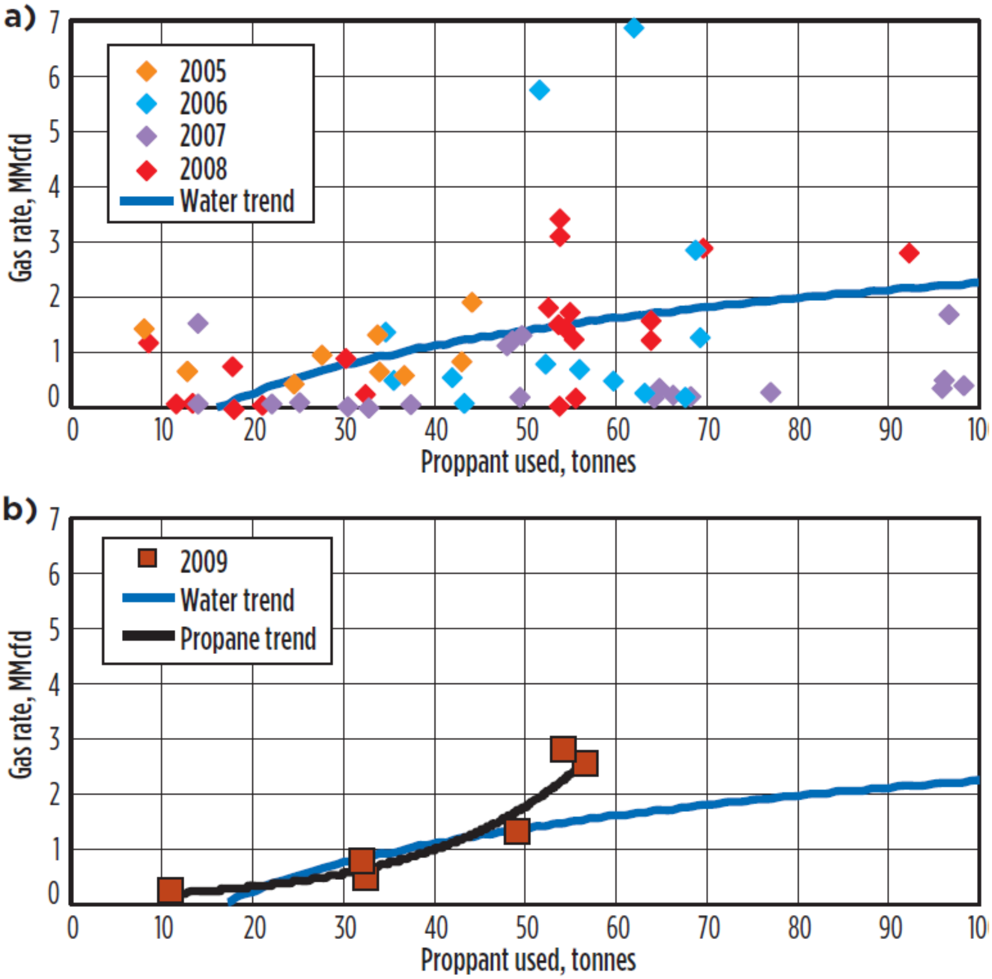


Figure 5.3: Proppant used with propane and water trends for recent years[clxxix]

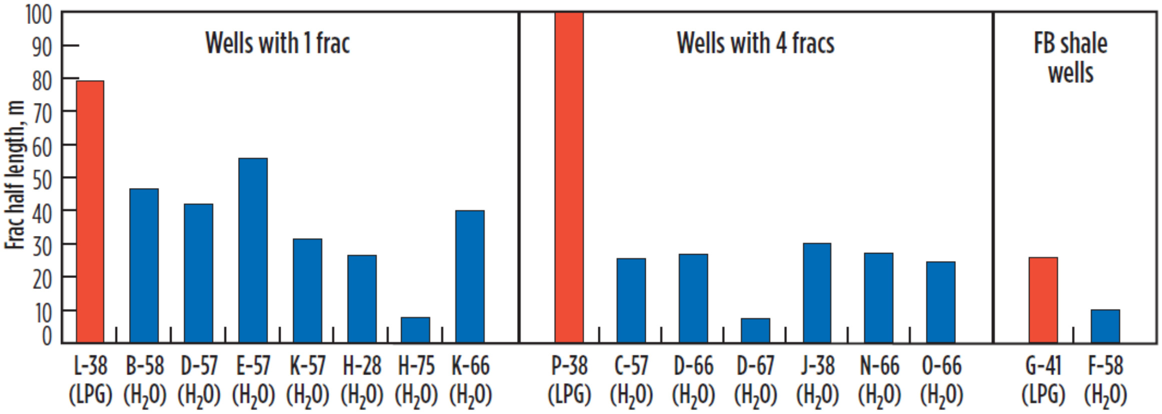


Figure 5.4: Fracture half-lengths with number of fractures per well[clxxx]

5.3 Halliburton

It was only a matter of time before the world leader in natural gas production started developing greener methods of hydraulic fracturing. Halliburton is trying to address key environmental issues related with hydraulic fracturing, which are fluid additives and water usage. They are currently working on two projects for the production of green natural gas: CleanStim® and CleanWave®. Both of these developments are intended to revolutionize hydraulic fracturing in terms of its environmental effects. Although they are very new and have had little testing done, there is still a lot of hope for these methods with the funding from a corporate giant like Halliburton. It should not be long before some major progress is made in this department.

The first product that Halliburton has created is known as CleanStim®. The purpose of this was to create a hydraulic fracturing fluid additive that is environmentally friendly. Most current fluid additives have major environmental concerns. Halliburton is trying to create a fluid containing all ingredients from the food industry, although they are making it clear that it is not edible. The goal is to make something that is less harmful to people, animals, and the environment. Halliburton claims that the CleanStim® fluid system provides exceptional performance in terms of pumpability, proppant transport and retained conductivity. Laboratory tests showed that after 24 hours, over 90% of the fluid retained its conductivity.[clxxxi] They are also claiming that it may be used for not only water fracturing, but also gelled fracturing, although they do not mention GasFrac by name. This technology is very new and has very few field results but it was tested successfully in a "Midcontinent well, a Permian Basin well, and a Southeast Texas well over a temperature range of 120 to 225°F. In all three cases, it provided excellent proppant transport, a clean break and better-than-expected fluid recovery."[clxxxii] There has been testing by a third party, although it is unknown who, and the results can be shown in Figure 5.5.

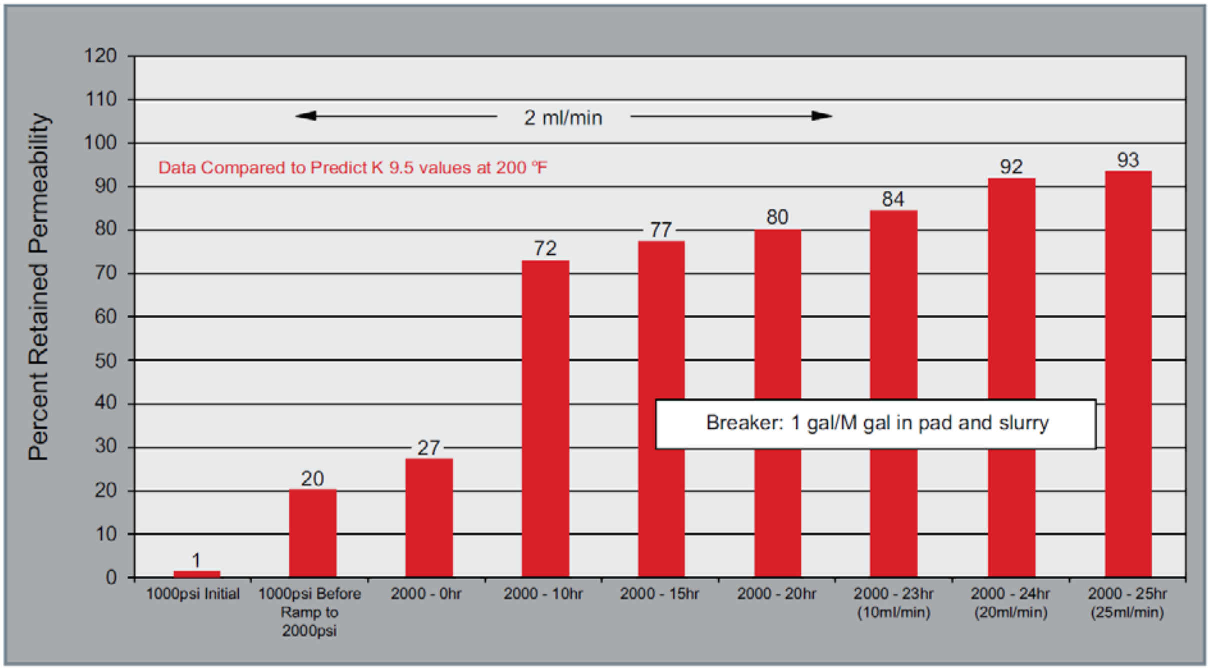


Figure 5.5: *Permeability of recovered fracturing fluid*[clxxxiii]

Halliburton also has a list of ingredients for their CleanStim® that anyone can readily see on their website. This information is shown in Table 5.3. Although the ingredients are very generic, it is possible to grasp a rough understanding of the makeup of the CleanStim®. It is noted that several of the ingredients are still considered hazardous based on physical or health effects.[clxxxiv] This did not stop Halliburton from having an employee drink some CleanStim® at a press conference.[clxxxv] In addition, if it got into drinking water it would be in much smaller concentrations so it seems relatively safe, at least according to Halliburton. Overall CleanStim® seems like a viable alternative to the current fracturing fluid additives but it is still clear that there is still much work to be done.

Table 5.3: *CleanStim® Formulation*[clxxxvi]

Generic Consituent Name	Common Use	Hazardous as Appears on MSDS
Enzyme	Soybean Pase, Fruit Juices and Nectars, Laundry Detergent, Dishwasher Detergent, Toilet Cleaner, Industrial Pulp, and Paper Processing Aid	Yes
Exthoxylated Sugar-Based Fatty Acid Ester	Synthetic Food Flavoring Substance, Natural Baby Wipes, Baby Wash, and Shampoo	No
Inorganic Acid	Chesse, Alcoholic Beverages, Wheel Cleaner, Rust Dissolver, Dishwashing Detergent	Yes
Inorganic Salt	Food Starch, Water Clarifier, Fish Tank Water Treatment	Yes
Maltodextrin	Sweetener, Glaze and Icing Sugar, Coconut Milk and Coconut Cream, Shower Gel	No
Organic Acid	Fruit Juice, Dishwasher Cleaner, All-Purpose Cleaner, Hand Soap	Yes
Organic Ester	Liquid Egg Products, Food Resinous and Polymeric Coatings, Hairspray	Yes
Partially Hydrogenated Vegetable Oil	Confectionary Chocolate Coating, Hair Detangler, Body Lotion, Lip Liner, Soap, Lotion, Cream, and other Skin Care Formulations	No
Polysaccharide Polymer	Canned Fish, Processed Cheese, Dairy-Based Desserts and Drinks, Beer, Toothpaste	Yes
Sulfonated Alcohol	Egg White Solids, Marshmallows, Dishwashing Liquid, Home Dilutable Cleaner, Shampoo, Acne Scrub, Shaving Cream, Liquid Hand Soap	Yes

Halliburton also wanted to address the issue of water in conventional hydraulic fracturing setups. This led them to the development of their CleanWave® program. The goal of this was to be able to recycle as much of the fracturing water as possible. This process does not make the water drinkable, but it allows the water to be continuously reused at the well site. This has obvious positive environmental and economic effects. It reduces the cost to transport, obtain, and dispose of fracturing fluids. This also means less clean drinking water will be needed at the well site. The CleanWave® service can treat up to 26000 bbl/day using a mobile electrocoagulation component. When the water passes through the system, positively charged ions are released which bond to the negatively charged colloidal particles in the water. Gas bubbles are also released that attach to the coagulated matter and cause it to rise to the surface where it can easily be extracted. Heavier coagulates sink to the bottom where they can also be easily removed.[clxxxvii] The resulting water is clean enough to be used again and again in the fracturing well. Unlike CleanStim®, the CleanWave® service has been in use for a short amount of time at several well sites. In the Haynesville shale this system was used to treat 4.8 million gallons of water.[clxxxviii] Additionally a drill site in Utah saved $250,000 as a result of the CleanWave® service.[clxxxix] This kind of system is essential if the hydraulic fracturing industry is going to take steps to become more environmentally friendly and more economical.

5.4 Chesapeake Energy

Chesapeake Energy is also trying to create a green fracturing fluid. Their Green Frac program was created in 2009. The main goal of this was to take out all unnecessary chemicals from the common fracturing fluids and replace the necessary ones with safer alternatives. So far the company has taken out 25% of the additives in its fracturing fluids.[cxc] The desired product is to be 100% environmentally green, according to Chesapeake's manager of environmental and regulatory affairs Jody C. Jones.

> " 'It's not quite there yet' … 'The main concern with testing something like this is you just spent $4 to $6 million to drill a well and taking an untested frack system and shooting it down a well could ruin a reservoir and you'd be throwing away all that money.' "[cxci]

This is a valid point and it shows the situation that the company is currently in. This program does appear to be making progress. It should not be long before Chesapeake begins more extensive testing of this green fracturing fluid.

5.5 Vertical Drilling

It is hard to discuss hydraulic fracturing and its horizontal methodology without mentioning its origins: vertical drilling. Although vertical drilling is technically an alternate method of procuring natural gas, there is little to no benefit in it today. The first form of vertical drilling was cable tool drilling. This consists of repeatedly dropping a heavy bit into the ground, eventually breaking the rock.[cxcii] This form of drilling is virtually obsolete today. One of the only benefits is that the initial cost to setup the well is much cheaper, although the amount of gas that can be obtained from the well will be much lower. Also, it is a much more simple and time-tested design that the general public is much less weary about. Overall, it did have practicality during its first introduction but is not very practical in today's world.

5.6 Conclusion

There are a number of other companies pursuing greener fracturing systems including Baker Hughes with their Vapor Frac, Weathorford International, Universal Well Services, and Frac Tech Services.[cxciii] Right now the leaders in alternate methods for hydraulic fracturing are GasFrac, Halliburton, and Chesapeake Energy. GasFrac's LPG fracturing, Halliburton's CleanStim® and CleanWave® services, and Chesapeake's Green Frac program lead the pack in a race to create an environmentally safe and economically better extraction of natural gas.

Chapter 6: Evaluation System for Overall Impact of Fracturing

6.1 Introduction

The trend points to economic effects being positive and environmental being negative, and in that way, this Evaluation scheme seems slightly biased. This, however, is simply due to circumstance. When analyzing something as large and widespread as the issue of hydraulic fracturing, one must look at the extremes first, and narrow the view as they learn and dial in to the topic. With so much research still to be done on the process of hydraulic fracturing it was decided that this scale analyze and grade the hot topic points most commonly debated by those on both sides of the issue.

It is understood by the creators of this scaling system that with every attempt to be objective there is something that limits that and injects subjectivity into a practice. In this case it is that of the weight of environmental and economic issues as a whole. To some parties it is clear which has a more direct and significant impact in their personal lives, their business, or the environment, but not everyone orders those in the same way in way of importance. In light of this scaling system, being presented simply as a guide and a helping tool to improve the readers understanding and provide more information to help them come to their own conclusion about hydraulic fracturing, it is advised that the reader use what they have learned to make an informed decision.

6.2 Environmental Rankings

The main concern with the process of hydraulic fracturing is with its negative consequences, and as discussed in this document, the *potential* negative consequences. With that in mind, the environmental issues graded with this system are as follows: potential water contamination, water usage, potential drilling damage, potential soil contamination and potential damage to the eco-system. While the water usage is clear-cut, it was and is a pressing concern for many involved. Keeping with the theme of these potential disasters the scaling system is designed to consider worst-case scenarios and the reader is urged to remember this when comparing scores between environmental effects and economic ones. The environmental rankings are to analyze risk, and whether that risk is significant, or not does not necessary mean it is likely to happen.

In order to avoid any confusion the environmental and economic issues will not be compared to one another based strictly on the numerical side of this ranking system seeing as those values may disagree with previously stated ideas. Instead, it is advised that the raw numbers be used to compare issues within their category and the final judgment to happen later on.

The issues, being that they are all potential negative occurrences, have been ranked on a scale from 0 → -10, where -10 is the most extreme outcome. The categories in which they have been graded are as follows: scale, location, and severity. Scale accounts for the area of which the issue could affect, a more negative number indicating a larger area. Location accounts for the populous, bodies of water and the density of the flora and fauna in the area. Severity accounts and predicts the length of time it would take to resolve an issue and/or the amount of people it would affect.

6.2.1 Environmental Issues

The potential water contamination is perhaps the biggest and most brought about concern regarding hydraulic fracturing, and as important as water is it is an understandable fear. Of all of the issues being examined it has the potential to affect the largest area. Water travels quickly and regardless of how sever the contamination is, or how large the body of water is (worst case is an aquifer) the water source is likely to reach far and wide. Also, because of the relative location of most hydraulic fracturing sites under scrutiny in relation to cities or towns it also has the highest rating in said category. The evaluation rubric for the rankings are shown in Figure 6.1 and explained in Table 6.1.

Water usage is a large concern with the aforementioned volume of water needed for the hydraulic fracturing process to be successful. With regard to this volume and the impact that water shortages have around the country daily this is a realistic concern. As such, it is rated as shown.

Table 6.1: *Evaluation Rubric for Environmental Effects*

Rating (Negative sign indicates a negative effect)	**Scale/Area**	**Location (Values are all negative if issue has negative effects)**	**Severity (Judged based on a potential worst case scenario)**
-8 → -10	Effects everything within a respectable distance, that is, it has the potential to affect the whole of small states or several large counties in larger states. Significant and noticeable.	Aquifers, waterways, flora, fauna, and well-populated areas are relatively nearby. Close enough to be effected.	A majority of the following are negatively affected as a result of the listed issue: waterways, ground and surface water, personal wells, drinking water (other sources) and/or death or damage to nearby flora and fauna. Worst cases: contaminated aquifer or drought Damage could potentially last decades
-6 → -7.9	Effects in area involved, surrounding area, and has the potential to indirectly or directly cause significant issues or benefits outside the city/county.	Waterways, flora, fauna, and near a well-populated area.	Some are negatively affected as a result of the listed issue: ground water, surface water, personal wells, and or drinking water. Resolution could teak upwards of five or so years.
-4 → -5.9	Effects area directly around event and has a notable effect on the surrounded areas and perhaps inhabitants.	Waterways, flora, fauna, and near a populated area.	Damage is on the verge of uncontainable if not so, and the clean up or resolution could take several years.
-2 → 3.9	Effects area directly around event, while also having the potential to influence neighboring areas.	Lightly populated, has water ways and or a strongly defined eco-system	Damage can be contained, but resolving the issue or fixing the damage could take months.
0 → -1.9	Effects area directly around the event. Does not have significant potential to hurt neighboring areas.	Not or lightly populated	A few personal wells, or simply the damage is contained.
0	Little to arguably no effect	Little to arguably no effect	Little to arguably no effect

Potential drilling damage, eco-system damage, and soil contamination are all of lesser concern than water contamination, but these are risks of the process nonetheless. Each of these would occur around the same place and as such, the location score is the same for each of them. Similarly, the scale scores are close, because they would be generally localized to where the hydraulic fracturing was occurring. Additionally they differ in severity, soil contamination being the most pressing of the three. This is the case, because soil contamination can lead to water contamination (and vice versa), and once soil is contaminated it takes a much longer time (if ever) to recover than other bodies of water that could be filtered. Contamination of water sources is still more of a concern; however, because it is much easier to simply avoid contaminated land than to find new bodies of clean, or drinkable water.

6.3 Economic Rankings

As stated previously the topic of economics is complex and just as rankings between environmental and economic issues are somewhat subjective when comparing the two groups to each other, there is a similar cloudy area within the group itself. The noted issues chosen for this grading system are as follows: Increase in jobs, self-sufficiency, effect on local businesses, increased natural gas production and the relocation of citizens. Theses share some common traits and to illuminate on them they will be ranked (based on Table 6.2) in the following categories: effect on industry, effect on people, and the effect on the economy.

The purpose of the ‘effect on industry’ category is to analyze how much a business (in the natural gas industry) benefits. The ‘effect on people’ category is focused on how much the people nearby or involved in hydraulic fracturing will be affected. Finally, the effect on the economy category focuses on how much it will hurt or benefit a countrywide economy. This can be either negative or positive.

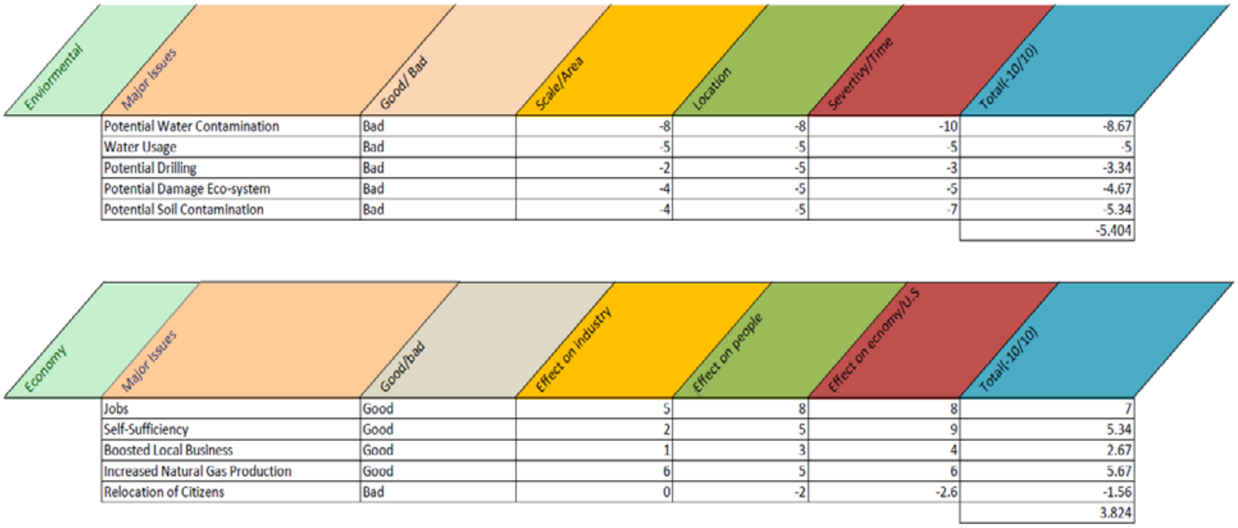
Table 6.2: *Evaluation Rubric for Economic Effects*

Rating (Negative sign indicates a negative effect)	**Effect on Industry**	**Effect on people**	**Effect on Economy**
8 → 10	Will inspire significant change, on the order of entire new practices, products or organizations within the industry. The worst case negative effect would be crippling the reputation or actual use of certain aspect of the industry.	Makes a significant change in the day to day lives of people involved, or possibly across the country in related fields. A large increase or decrease in the quality of life.	Significant change for either the better or worse in terms of stock price and strength within the nation. Potential shifts of power within the market.
6 → 7.9	Has the potential to change the mindset of companies, perhaps even changing which form of energy they focus on. Could also sit along the lines of damaging natural gas's or energy industry's standing with the public.	May change the day to day workings of people's lives, but mostly indirectly.	Potentially a significant boost or very harmful event for the nation's economy. The change seems very likely, but not as definite or detrimental as in the 8-10 range (positive or negative respectively).
4 → 5.9	Increases or decreases the profitability of the process, along with either helping or hurting the public image.	Prices, media, and perhaps day to day works are different, but the changes are small.	The change will be public and noticeable. It will be advised to either invest or run away from the industry.
2 →3.9	Mostly superficial, changes remain within the realm of the industry's public image, or small changes in profitability.	Changes are still small, but smaller and local media will make it an issue or support it and as such areas with hydraulic fracturing will be much more biased.	A noticeable change, one that can be talked about as a positive or negative of the process, but something that will never be "Front-Page" material.
0 →1.9	Inconsequential in the large scale of things either positive or negative, but it could be defined as one.	Changes will be small and mostly indirect. Perhaps a majority of the change will come in the form of prices that are paid for different forms of energy, or in a change on what the media focuses on.	Small, the boost or damage will either be ignored, or the overshadowed soon after.
0	Little to arguably no effect	Little to arguably no effect	Little to arguably no effect

6.3.1 Economic Issues

The increase in jobs is one of the most pressing and important benefits to hydraulic fracturing, and by coincidence, most of the economic effects being analyzed here appear to be positive. While this is the case, these are simply issues that are commonly cited in the hydraulic fracturing discussion. The jobs created by hydraulic fracturing have a positive effect on industry, citizens and the economy as a hole, although more significantly on the latter two. This is because the more citizens that are working, the more tax revenue the government can collect, and the more money that can be pumped into the economy by all related parties. While industry benefits from the positive media. Closely related to the increase in jobs is a boost to businesses in the local of any fracturing operation. A boost would result from the increased traffic and of course the increase in revenue into the area. This could potentially backfire as well if larger companies saw the increase in traffic and chose to move in, subsequent running the small business owners out of such.

In the United States, along with other Western nations, there is a dependency on foreign energy and part of the appeal of hydraulic fracturing is the potential for a self-sufficient United States. This would come from the increased natural gas production resulting from a successful hydraulic fracturing process implementation. This would be huge for the economy first, and it would allow for lower prices and more readily available resources. There is the possibility of this benefiting industry as well, especially since people will choose to buy local if it is cheaper and the option is available.



Enviormental	Major Issues	Good/ Bad	Scale/Area	Location	Severtiy/Time	Total(-10/10)
	Potential Water Contamination	Bad	-8	-8	-10	-8.67
	Water Usage	Bad	-5	-5	-5	-5
	Potential Drilling	Bad	-2	-5	-3	-3.34
	Potential Damage Eco-system	Bad	-4	-5	-5	-4.67
	Potential Soil Contamination	Bad	-4	-5	-7	-5.34
						-5.404

Economy	Major Issues	Good/bad	Effect on industry	Effect on people	Effect on ecnomy/U.S	Total(-10/10)
	Jobs	Good	5	8	8	7
	Self-Sufficiency	Good	2	5	9	5.34
	Boosted Local Business	Good	1	3	4	2.67
	Increased Natural Gas Production	Good	6	5	6	5.67
	Relocation of Citizens	Bad	0	-2	-2.6	-1.56
						3.824

***Figure 6.1*:** Numerical rankings for economic and environmental issues.

6.4 Overall Comparison

Comparing topics such as economic and environmental effects is difficult enough before considering the fact that four of the five environmental effects are only potential risks, while those of the economic realm almost certain. Clearly, some adjustment is in order to compare the two values found in Figure 6.1. The final values here are simply an average of the overall scores for each issue within a group. The reader is encouraged to revisit the relevant chapters if a sufficient understanding has yet to be attained.

First it must be clear that this evaluation system does not assume that all economic effects (or most) are positive and all environmental effects are negative, it just so happens that these are the potential benefits and risks that have been presented. There are of course more than those listed, but these were chosen to draw an adequate picture of the hydraulic fracturing issue. In light of this, and what seems to be almost clear-cut separation between pros and cons, it is even more important that the comparison between these two groups is not done blindly. Admittedly, there is no avoiding the inherent subjectivity that is present when comparing substantial monetary benefit and the risk of significant damage to the environment. It is a matter of values.

In an effort to be objective, the ratings of this grading system will be used as guidelines for a final decision. Clearly if the rankings were written in a certain way, one issue or the other would certainly be better represented. Here, however, it can be seen when reading over the grading rubric for economic that it is slightly more difficult to make clear distinctions between score brackets and likewise it is more difficult to define them. As a result of this the economic scale seems to progress slower and as such the scores are lower than that of the absolute value of the environmental scores. At the baseline, it seems that the potential environmental risks outweigh the economic benefits of a successful practice.

The only reason why this comparison calls for an adjustment is in fact the “potential” environmental risks. They are just that – potential. The economic benefits are almost certain, and as documented throughout this study much more prevalent. With cleaner practices, more regulation and an eye kept on the industry the risk could be lowered, and the profits increased. With this in mind, along with the EPA conducting an extensive study to be concluded and released for public review in 2014, it seems that the risks that do exist will be uncovered and addressed. While the risk can never be reduced to zero, it is very difficult to disregard the benefit of increased natural gas production within one’s nation. In light of the evidence stated in this study an adjustment factor of “+3” will be added to final economic scores when compared to environmental risk.

6.5 Conclusion

The potential risk is greater than the “guaranteed” benefit, but with the ability to limit and restrict these possible disasters that risk is reduced. The risk of environmental disaster can be reduced through proper regulation and safe practices, but it can never be eliminated. Similarly, the economic benefits are very likely, but cannot be guaranteed. When comparing these two the latter seems to be worth it. With safe practices, and the correct regulations hydraulic fracturing can be a real boom to the US economy. Hydraulic Fracturing is currently far from perfect, but the reward of doing it correctly is enormous.

Chapter 7: Future of Hydraulic Fracturing

7.1 Introduction

Hydraulic fracturing can potentially have a major impact on the country if its use by mining industries continues. As explained in previous sections, the increase to natural gas production is a major benefit that the process can bring. On the other hand, there is a potential for water, soil, and air contamination if the process is mishandled. From this, it is clear that the future of hydraulic fracturing in the United States will rely on its citizens, and their impact on the political processes that determine regulations. These regulations could greatly restrict, or free the companies involved. The future, therefore, is in the hands of the voters and the politicians that will seek to eliminate, either control, or expand the use of hydraulic fracturing in the years to come. The voter, however, can be influenced by many sources, many of which will play a role when it comes to the future of this process. Of these sources, there are several aspects that have to be looked at and discussed. The sources and their impact upon society will one day be the determining factor as to whether hydraulic fracturing will continue.

7.2 Businesses' Opinion

Hydraulic fracturing has become a popular method of drilling and extracting natural gas among many corporations. The energy industry sees the process as a way to increase natural gas production from the massive shale reserves located around the country. As such, these businesses and the energy industry support hydraulic fracturing and the expected increase in gas production that it promises. These businesses are searching for land and water to expand their mining operations; they are the primary defenders of the process. They are the ones willing to pay a generous amount to secure the right to drill on public land and discoveries such as the Marcellus

Shale reserve gave these companies a way to reap the benefits. The economic advantages that it entrails for them and the country are a main discussion point. The benefits associated are the main reason companies want to continue hydraulic fracturing as a standard mining practice. Since it is not limited to natural gas, the practice allows for the exploitation of resources that were previously unreachable. The profits that companies experience clearly show why they are willing to keep hydraulic fracturing around for years to come. In 2011, multiple energy companies banded together to fight to support the method of hydraulic fracturing. The group they formed spent over 2.8 million[cxciv] dollars lobbying to support politically, hydraulic fracturing. With companies spending this much money, it is clear to see they value it highly and wish to see it continue, seeing as they outspent the opponents by a margin approaching four to one.[cxcv]

Still, the industries can also influence public support on the issue by showing that the method is safe and then by letting the public be the ones who reap the economic rewards of hydraulic fracturing. Hydraulic fracturing can have a ripple effect on the communities where it is used and these ripples can boost the small businesses in a community and help create jobs for the residents. Also on a large scale, the access to larger quantities of natural gas allows for other benefits that the public can enjoy. By letting the public reap the tangible rewards, the businesses can potentially shift the public opinion to supporting hydraulic fracturing.

7.3 Public Opinion

The public's overall opinion is another sector where the future of hydraulic fracturing must be determined. A strong reputation for a company can go a long way for them in terms of consumer trust and loyalty. If hydraulic fracturing were to gain a negative connotation, then companies that continue to use the process would be subject to public scrutiny. This scrutiny would bring both negative press and relations with their consumers. From this it is easy to see how just one section of public opinion can influence the use of the system. It can be seen in the same light as the food industry. Currently businesses label their food as not having certain ingredients that the public dislikes or does not trust, such as corn syrup or artificial preservatives. This is because of public opinion towards these ingredients and the belief that foods without them are better. While this is a subjective view, if there is a major public outcry, the people can then potentially alter an industries' method of operation, or at the very least advertising. It is because of this that businesses that use these ingredients try to not mention it, as to avoid the risk of losing sales. The same can be related to hydraulic fracturing if the practice could come under intense scrutiny from a majority of the population. People could avoid buying their natural gas from companies that are known to use hydraulic fracturing, and the companies would have to either stop mining with it, or attempt to hide the fact from the public that they used it. Either way would make fracturing a much less desirable practice compared to alternatives. From this, it is clear that the businesses practices can be swayed by public opinion.

7.3.1 Media

As many realize, the media is a major player in the influence that new ideas have in regards to the public. With hydraulic fracturing being a relative newcomer to the public eye, the coverage provided by the media will serve as a major influence as to whether the public accepts or rejects the practice. Both those for and against rely on public relations in order to further their goals, and the main way each side exposes the masses to their ideas is through the media. News sites, television and radio are some of the main methods of spreading ideas and it is clear that both sides are trying to take advantage of the media's influence over the masses. Anti- fracturing groups take aim at the public's fear of big corporations and the fear of potential water and soil contamination. Corporations are left defending themselves from these attacks and trying to disprove every allegation levied against the process. This back and forth struggle can be seen in states where hydraulic fracturing has become a major issue in the political debate such as Texas or Colorado. As such, it becomes clear that the side that takes advantage of the media to a degree over the opposition would have an advantage in public opinion.

A movie was recently released in 2012, involving hydraulic fracturing titled “A Promised Land”. The movie stars Matt Damon, and revolves around the practice of industries going to towns and offering the residents money and other benefits as discussed in earlier sections in return for the right to drill. The movie depicts a town embroiled in a debate over the issue, and the attempts at persuasion by both sides for and against hydraulic fracturing. The issues regarding the future of hydraulic fracturing, however, comes at the end where the corporation that was seeking the rights to drill is portrayed as nothing more than a greedy business that would attempt to gain money at the expense of moral ethics. This is important to the future of hydraulic fracturing, not because it portrays the practice of fracturing in a bad light, but the corporations that use it. By making it seem that corporations that use this process are nothing more than money hungry businessmen, it paints all energy companies as villains. If the public believes the companies that use the process are like this, then when it comes time to vote over the issue of hydraulic fracturing, people will oppose it as a way of opposing the companies without regard for any potential benefit. This gains more precedence with the times as more and more people are blaming major corporations as the cause for the tough economic times that the country is currently enduring.

As of the writing of this paper, hydraulic fracturing is the topic of a battle between two groups for the public’s opinion on the subject. Anti-fracturing groups in states such as New

York, where this issue is up for political debate, have been attempting to influence the populace to join them in banning the process from New York. In New York, Yoko Ono and Sean Lennon, the family of John Lennon, a late member of the rock band “The Beatles,” voiced their opposition to the process of hydraulic fracturing.[cxcvi] With celebrities such as these and Matt Damon bringing their weight into the fray on the subject of hydraulic fracturing, public opinion will be subject to influence, and this will in turn have an influence on the future of hydraulic fracturing. The fear is that the public will accept a celebrity’s word at face value, when they should research the subject and make a decision themselves, either for or against the process. Still, as is the culture in America, celebrities can have a major impact on the opinion of their fans. With celebrities coming into the debate over hydraulic fracturing, it is clear that the public opinion has been recognized as the main source of power in the debate regarding the issue of the continuation of hydraulic fracturing.

7.3.2 EPA

The EPA was recently recruited to study the effects of hydraulic fracturing and to produce a report on the subject. In December 2012, the EPA released a progress report for their final publication, which is scheduled to be released for late 2014.[cxcvii] Due to this release date, the potential impact of the research on current issues will be delayed. Still, when this report is public, it will be used for garnering support for or against hydraulic fracturing. While the research is in progress, it is already under fire from some senators as mentioned before.

The environmental ramifications of the process can be potentially serious, but at the same time, if properly managed, the risks can be minimized and the economic benefits maximized. Therefore, the weight behind the EPA’s decision cannot be understated, as it is a respected source of environmental information and research. As such, the EPA's study will eventually bring a lot of weight to bear on the future of hydraulic fracturing in the country.

7.4 Political

While the future of hydraulic fracturing in the United States is by no means secure at the political level, it does seem to have a bright future. With more companies adopting the practice due to its ability to revitalize dying wells, in addition to its ability to access resources that were previously inaccessible by conventional means, hydraulic fracturing isn't going to be leaving the mining scene anytime soon. The process has become very popular with many mining industries and consequently mining industry lobbyists will fight against any law that seeks to limit or ban hydraulic fracturing in the United States. While the EPA is conducting research on hydraulic fracturing, that could either strengthen or weaken its position in the national spotlight, there are also groups against the practice that feel hydraulic fracturing will result in pollution and the contamination of the surrounding environment. While there are no judicial findings to support a claim of pollution caused directly by fracturing, there are lawsuits currently ongoing based on the claims of citizens. Since these cases are ongoing, commenting on them regarding their resolution would be unfair; thus, there will be no further comments until the conclusion of the trials.

Since New York implemented its temporary suspension of the hydraulic fracturing, it has become a major political battleground in regards to the issues. Energy businesses have been pressuring to lift the suspension on the process so they can resume action.[cxcviii] With this pressure and other pressure coming from the opposing side, the political outcome in New York is expected at some point in 2013, and will be a critical milestone for either direction. If allowed, the use of the process may encourage usage in other states. Yet from the other side, if the process is banned, it may encourage other states to ban the process. As such, New York has become an important political battleground, where the potential future of hydraulic fracturing rests in the hands of New York’s governor.

While the states have been individually debating and drawing up plans regarding the regulation of hydraulic fracturing, the federal government has been taking action on both fronts. The previous political chapter explained the approaches and people taking up the fight for and against hydraulic fracturing. It is clear that the federal government has the most power in the debate of the continuation of hydraulic fracturing, but that does not mean it will ultimately make the decision. The federal government has to consider the needs of every state and the country as a whole. Doing this is difficult, and much more so because of the need for it to pass through congress and the senate where the representatives desires and beliefs differ.

7.5 Result

It is clear that the future of hydraulic fracturing depends on many groups and many variables in the country today. Once the EPA’s research is concluded and it releases the results, it could provide a strong case for those either in favor or against the practice of hydraulic fracturing. Along with this, the political scene is another arena with state governments debating the regulation and the potential banning of the practice. Still, the public will be the most important factor regarding the future of the practice. Making people informed to the subject so that reasonable decisions can be made regarding hydraulic fracturing is vital to the survival of the practice. The weight the public can bring to bear can either end the process or allow its continued use and growth as a mining implement.

From this, it is clear that no one can know for sure what the future of hydraulic fracturing will have. The process has drawbacks and benefits, so it will have defenders and persecutors. In the short term, it is clear that hydraulic fracturing will most likely continue to be used by companies as a mining process due to its output capabilities. In the long term however, no one can clearly say, as there are more than a few variable that could affect the process, for better or worse.

Glossary

A:

API – American Petroleum Institute
Aquifer – A body of permeable rock that can contain or transmit groundwater.

B:

BCF – Billion Cubic Feet
Brackish Water – Combination of fresh and salt water
Brine – Salt Water
BTEX – Benzene, Toluene, Ethylbenzene, and Xylenes

C:

Capture Zone – The capture zone of a production well is the portion of the aquifer that contributes water to the well. The size of this zone will be affected by regional groundwater gradients and by the drawdown caused by the well
CASRN – Unique numerical identifiers assigned by the Chemical Abstracts Service to every chemical described in the open scientific literature
CERCLA – Comprehensive Environmental Response, Compensation and Liability Act

D:

Desorption – A substance is released from or through a surface
Drilling Aftermath Water – Water and debris used for the actual drilling of the well

E:

EIA – United States Energy Information Administration
EPA – United States Environmental Protection Agency

F:

FRAC Act – Fracturing Responsibility and Awareness of Chemicals Act
Fracture – The breaking or cracking of a hard object or material like rock

G:

GWPC – Ground Water Protection Council

H:

I:

IPPA – Independent Petroleum Association of America
IUPAC – International Union of Pure and Applied Chemistry

J:

K:

kPA – Kilopascals

L:

M:

M^3 – Cubic Meter
Mm^3 – Million Cubic Meters
MCL – Maximum Contaminate Level
MMBTU – Million British Thermal Unit
MMcf – Million Cubic Feet
Microseism – A very small earthquake, less than 2 on the Richter scale.
MIT – Mechanical Integrity Test
MSDS – Material Safety Data Sheet

N:

NORM – Naturally occurring radioactive elements
NRDC – Natural Resource Defense Council

O:

OSHAct – Occupational Safety and Health Act

P:

Produced Water – Term used in the oil industry to describe water produced alongside oil and gas

Q:

R:

RCRA – Resource Conservation and Recovery Act
REC – Reduced Emission Completion

S:

SEAB – Secretary of Energy Advisory Board
Shale – A fissile rock that is formed by the consolidation of clay, mud, or silt
STAR Program – A flexible, voluntary partnership that encourages oil and natural gas companies—both domestically and abroad—to adopt cost-effective technologies and practices that improve operational efficiency and reduce emissions of methane, a potent greenhouse gas and clean energy source
SWDA – Safe Water Drinking Act

T:

U:
UIC – Underground Injection Control Program
USDW – Underground Source of Drinking Water

V:
VOC – Volatile Organic Compound

W:
WGA – Water Gelling Agent

X:

Y:

Z:

Appendix A: Case Studies – EPA

	Key Issues to be Investigated	Potential Outcomes	Companies Involved
Bakken Shale—Killdeer and Dunn Counties, ND	•Production well failure during hydraulic fracturing •Suspected drinking water aquifer contamination	•Identify sources of well failure •Determine if drinking water resources are contaminated and to what extent	•Denbury Resources Inc.
Barnett Shale—Wise County, TX	•Possible drinking water well contamination •Spills and runoff leading to suspected drinking water well contamination	•Determine if private water wells are contaminated •Obtain information about the likelihood of transport of contaminants via spills, leaks, and runoff	•Aruba Petroleum, Inc. •Primexx Energy Partners Ltd •XR-5, LLC •White Stone Energy, LLC
Marcellus Shale—Bradford and Susquehanna Counties, PA	•Ground water and drinking water well contamination •Suspected surface water contamination from a spill of •Methane contamination of multiple drinking water wells	•Determine if drinking water wells are contaminated •Determine source of methane in private wells •Transferable results due to common types of impacts	•Chesapeake Energy Corporation •Cabot Oil and Gas Corporation •Chief Oil and Gas, LLC
Marcellus Shale—Washington County, PA	•Changes in drinking water quality, suspected •Stray gas in wells, surface spills	•Determine if drinking water wells are contaminated •Determine if surface spills affect surface and ground water •If contamination exists, determine potential source of contaminants in drinking water	•Range Resources Corporation •Atlas Energy, L.P.
Raton Basin, CO	•Potential drinking water well contamination (methane and other contaminants) in an area with intense concentration of gas wells in shallow surficial aquifer (coalbed methane)	•Determine source of methane •Identify presence/source of contamination in drinking water wells	•Pioneer Natural Resources Company •Petroglyph Energy, Inc.

Appendix B: Fracturing Fluid Characteristics

Characteristics of Undiluted Chemicals Found in Hydraulic Fracturing Fluids (Based on MSDS)

Product	**Chemical Composition Information**	**Hazards Information**	**Toxicological Information**	**Ecological Information**
Linear gel delivery system	30-60% by wt. Guargum derivative 60-100% by wt. Diesel	Harmful is swallowed Combustible	Chronic effects/Carcinogenicity- contains diesel, petroleum distillate and known carcinogen Causes eye, skin, respiratory irritation Can cause skin disorders Can be fatal if ingested	Slowly biodegradable
Water gelling agent	60-100% by wt. Guar gum 5-10% by wt. Water .5-1.5% by wt. Fumaric acid	None	May be mildly irritating to eyes	Biodegradable
Linear gel polymer	<2% by wt. Fumaric acid <2% by wt. Adipic acid	Flammable Vapors	Can cause eye, skin and respiratory tract irritation	Not determined
Linear gel polymer slurry	30-60% by wt. Diesel oil #2	Causes irritation if swallowed Flammable	Carcinogenicity- Possible cancer hazard based on animal data; diesel is listed as a category 3 carcinogen in EC Annex I May cause pain, redness, dermatitis	Partially biodegradable
Crosslinker	10-30% by wt. Boric Acid 10-30% by wt. Ethylene Glycol 10-30% by wt. Monoethanolamine	Harmful if swallowed Combustible	Chronic effects/Carcinogenicity D5 may cause liver, heart, brain reproductive system and kidney damage, birth defects (embryo and fetus toxicity) Causes eye, skin, respiratory irritation Can cause skin disorders and eye ailments	Not determined
Crosslinker	10-30% by wt. Sodium tetraborate decahydrate	May be mildly irritating to eyes and skin and if swallowed	May be mildly irritating	Partially biodegradable Low fish toxicity
Foaming agent	10-30% by wt. Isopropanol 10-30% by wt. Salt of alkyl amines 1-5% by wt. Diethanclamine	Harmful if swallowed Highly flammable	Chronic effects/ Carcinogenicity- may cause liver and kidney effects Causes eye, skin, respiratory irration Can cause skin disorders and eye ailments	Not determined
Foaming agent	10-30% by wt. Ethanol 10-30% by wt. 2-Butoxyethanol 25-55% by wt. Ester salt .1-1% by wt. Polyglycol	Harmful if swallowed or absorbed through skin	May cause nausea, headache, narcosis May be mildly irritating	Harmful to aquatic organisms

	ether 10-30% by wt. Water			
Acid treatment-hydrochloric acid	30-60% by wt. Hydrochloric acid	May cause eye, skin and respiratory burns Harmful if swallowed	Chronic effects/Carcinogenicity-prolonged exposure can cause erosion of teeth Causes severe burns and skin disorders	Not determined
Acid treatment-formic acid	85% by wt. Formic acid	May cause mouth, throat, stomach, skin and respiratory tract burns May cause genetic changes	May cause heritable genetic damage in humans Causes severe burns Causes tissue damage	Not determined
Breaker fluid	60-100% by wt. Diammonium peroxidisulphate	May cause respiratory tract, eye or skin irritation Harmful if swallowed	May cause redness, discomfort, pain, coughing, dermatitis	Not determined
Microbicide	60-100% by wt. 2-Bromo-2 nitrol, 3-Propanedol	May cause eye and skin irritation	Chronic effects/Carcinogenicity-not determined Can cause permanent eye damage, skin disorders, abdominal pain, nausea, and diarrhea if ingested	Not determined
Biocide	60-100% by wt. 2,2-Dibromo-3-nitrilopropionamide 1-5% by wt. 2-Bromo-3-nitrilopropionamide	Causes severe burns Harmful if swallowed May cause skin irritation; may cause allergic reaction upon repeated skin exposure	Harmful if swallowed; large amounts may cause illness Irritant; may cause pain or discomfort to mouth, throat, stomach; may cause pain, redness, dermatitis	Not determined
Acid corrosion inhibitor	30-60% by wt. Methanol 5-10% by wt. Propargyl alcohol	May cause eye and skin irritation, headache, dizziness, blindness and central nervous system effects May be fatal if swallowed Flammable	Chronic effects/ Carcinogenicity-may cause eye, blood, lung, liver, kidney, heart, central nervous system and spleen damage Causes severe eye, skin, respiratory irritation Can cause skin disorders	Not determined
Acid corrosion inhibitor	30-60% by wt. Pyridinium, 1-(Phenylmethyl), Ethyl methyl derivatives, chlorides 15% by wt. Thiourea 5-10% Propan-2-ol 1-5% Poly(oxy-1, 2-ethanediyl)-nonylphenyl-hydroxy 10-30% Water	Cancer hazard (risk depends on duration and level of exposure) Causes severe burns to respiratory tract, eyes, skin Harmful if swallowed or absorbed through skin	Carcinogenicity- Thiourea is known to cause cancer in animals and possibly causes cancer in humans Corrosive- short exposure can injure lungs, throat, and mucous membranes; can cause burns, pain, redness swelling and tissue damage	Toxic to aquatic organisms Partially biodegradable

Appendix C: Known Fracturing Fluid Chemicals

Note: In the third column "x" means recognized by IUPAC.

CASRN	Chemical Name	IUPAC NAME and Structure
120086-58-0	(13Z)-N,N-bis(2-hydroxyethyl)-N-methyldocos-13-en-1aminium chloride	x
123-73-9	(E)-Crotonaldehyde	x
2235-43-0	[Nitrilotris(methylene)]tris-phosphonic acid pentasodium salt	x
65322-65-8	1-(1-Naphthylmethyl)quinolinium chloride	x
68155-37-3	1-(Alkyl* amino)-3-aminopropane *(42%C12, 26%C18, 15%C14, 8%C16, 5%C10, 4%C8)	x
68909-18-2	1-(Phenylmethyl)pyridinium Et Me derivs., chlorides	x
526-73-8	1,2,3-Trimethylbenzene	x
95-63-6	1,2,4-Trimethylbenzene	x
2634-33-5	1,2-Benzisothiazolin-3-one	x
35691-65-7	1,2-Dibromo-2,4-dicyanobutane	x
95-47-6	1,2-Dimethylbenzene	x
138879-94-4	1,2-Ethanediaminium, N, N'-bis[2-[bis(2hydroxyethyl)methylammonio]ethyl]-N,N'bis(2hydroxyethyl)-N,N'-dimethyl-,tetrachloride	x
57-55-6	1,2-Propanediol	x
75-56-6	1,2-Propylene oxide	x
4719-04-4*	1,3,5-Triazine-1,3,5(2H,4H,6H)-triethanol	x
108-67-8	1,3,5-Trimethylbenzene	x
123-91-1	1,4-Dioxane	x
9051-89-2	1,4-Dioxane-2,5-dione, 3,6-dimethyl-, (3R,6R)-, polymer with (3S,6S)-3,6-dimethyl-1,4-dioxane-2,5-dione and (3R,6S)-rel-3,6-dimethyl-1,4-dioxane-2,5-dione	x
124-09-4	1,6-Hexanediamine	x
6055-52-3	1,6-Hexanediamine dihydrochloride	x
20324-33-8	1-[2-(2-Methoxy-1-methylethoxy)-1-methylethoxy]-2propanol	x
78-96-6	1-Amino-2-propanol	x
15619-48-4	1-Benzylquinolinium chloride	x
71-36-3	1-Butanol	x
112-30-1	1-Decanol	x

2687-96-9	1-Dodecyl-2-pyrrolidinone	x
3452-07-1*	1-Eicosene	x
629-73-2	1-Hexadecene	x
111-27-3	1-Hexanol	x
68909-68-7	1-Hexanol, 2-ethyl-, manuf. of, by products from, distn. Residues	
68442-97-7	1H-Imidazole-1-ethanamine, 4,5-dihydro-, 2-nortall-oil alkyl derivs.	
107-98-2	1-Methoxy-2-propanol	x
2190-04-7*	1-Octadecanamine, acetate (1:1)	x
124-28-7	1-Octadecanamine, N,N-dimethyl	x
112-88-9	1-Octadecene	x
111-87-5	1-Octanol	x
71-41-0	1-Pentanol	x
61789-39-7	1-Propanaminium, 3-amino-N-(carboxymethyl)-N,Ndimethyl-, N-coco acyl derivs., chlorides, sodium salts	
61789-40-0	1-Propanaminium, 3-amino-N-(carboxymethyl)-N,Ndimethyl-, N-coco acyl derivs., inner salts	
68139-30-0	1-Propanaminium, N-(3-aminopropyl)-2-hydroxy-N,Ndimethyl-3-sulfo-, N-coco acyl derivs., inner salts	
149879-98-1	1-Propanaminium, N-(carboxymethyl)-N,N-dimethyl-3[[(13Z)-1-oxo-13-docosen-1-yl]amino]-,	x
5284-66-2	1-Propanesulfonic acid	x
71-23-8	1-Propanol	x
23519-77-9	1-Propanol, zirconium(4+) salt	x
115-07-1	1-Propene	x
1120-36-1	1-Tetradecene	x
112-70-9	1-Tridecanol	x
112-42-5	1-Undecanol	x
112-34-5	2-(2-Butoxyethoxy)ethanol	x
111-90-0	2-(2-Ethoxyethoxy)ethanol	x
112-15-2	2-(2-Ethoxyethoxy)ethyl acetate	x
102-81-8	2-(Dibutylamino)ethanol	x
34375-28-5	2-(Hydroxymethylamino)ethanol	x
21564-17-0	2-(Thiocyanomethylthio)benzothiazole	x
27776-21-2	2,2'-(Azobis(1-methylethylidene))bis(4,5-dihydro-1Himidazole)dihydrochloride	x

10213-78-2	2,2'-(Octadecylimino)diethanol	x
929-59-9	2,2'-[Ethane-1,2-diylbis(oxy)]diethanamine	x
9003-11-6*	2,2'-[propane-1,2-diylbis(oxy)]diethanol	x
25085-99-8	2,2'-[propane-2,2-diylbis(4,1phenyleneoxymethylene)]dioxirane	x
10222-01-2	2,2-Dibromo-3-nitrilopropionamide	x
73003-80-2	2,2-Dibromopropanediamide	x
24634-61-5	2,4-Hexadienoic acid, potassium salt, (2E,4E)	x
915-67-3	2,7-Naphthalenedisulfonic acid, 3-hydroxy-4-[2-(4-sulfo1-naphthalenyl) diazenyl] -, sodium salt (1:3)	x
9002-93-1	2-[4-(1,1,3,3-tetramethylbutyl)phenoxy]ethanol	x
NA	2-Acrylamide -2-propanesulfonic acid and N,Ndimethylacrylamide copolymer	x
NA	2-acrylamido -2-methylpropanesulfonic acid copolymer	x
15214-89-8	2-Acrylamido-2-methyl-1-propanesulfonic acid	x
124-68-5	2-Amino-2-methylpropan-1-ol	x
2002-24-6	2-Aminoethanol hydrochloride	x
52-51-7	2-Bromo-2-nitropropane-1,3-diol	x
1113-55-9	2-Bromo-3-nitrilopropionamide	x
96-29-7	2-Butanone oxime	x
143106-84-7	2-Butanone, 4-[[[(1R,4aS,10aR)-1,2,3,4,4a,9,10,10aoctahydro-1,4a-dimethyl-7-(1-methylethyl)-1phenanthrenyl]methyl](3-oxo-3-phenylpropyl)amino]-, hydrochloride (1:1)	x
68442-77-3	2-Butenediamide, (2E)-, N,N'-bis[2-(4,5-dihydro-2-nortalloil alkyl-1H-imidazol-1-yl)ethyl] derivs.	
111-76-2	2-Butoxyethanol	x
110-80-5	2-Ethoxyethanol	x
104-76-7	2-Ethyl-1-hexanol	x
645-62-5	2-Ethyl-2-hexenal	x
5444-75-7	2-Ethylhexyl benzoate	x
818-61-1	2-Hydroxyethyl acrylate	x
13427-63-9	2-Hydroxyethylammonium hydrogen sulphite	x
60-24-2	2-Mercaptoethanol	x
109-86-4	2-Methoxyethanol	x
78-83-1	2-Methyl-1-propanol	x

107-41-5	2-Methyl-2,4-pentanediol	x
2682-20-4	2-Methyl-3(2H)-isothiazolone	x
115-19-5	2-Methyl-3-butyn-2-ol	x
78-78-4	2-Methylbutane	x
62763-89-7	2-Methylquinoline hydrochloride	x
37971-36-1	2-Phosphono-1,2,4-butanetricarboxylic acid	x
93858-78-7	2-Phosphonobutane-1,2,4-tricarboxylic acid, potassium salt (1:x)	x
555-31-7	2-Propanol, aluminum salt	x
26062-79-3	2-Propen-1-aminium, N,N-dimethyl-N-2-propenyl-, chloride, homopolymer	x
13533-05-6	2-Propenoic acid, 2-(2-hydroxyethoxy)ethyl ester	x
113221-69-5	2-Propenoic acid, ethyl ester, polymer with ethenyl acetate and 2,5-furandione, hydrolyzed	x
111560-38-4	2-Propenoic acid, ethyl ester, polymer with ethenyl acetate and 2,5-furandione, hydrolyzed, sodium salt	x
9003-06-7*	2-Propenoic acid, homopolymer, sodium salt	x
9003-06-9*	2-Propenoic acid, polymer with 2-propenamide	x
25987-30-8	2-Propenoic acid, polymer with 2-propenamide, sodium salt	
37350-42-8	2-Propenoic acid, sodium salt (1:1), polymer with sodium 2-methyl-2-((1-oxo-2-propen-1-yl)amino)-1propanesulfonate (1:1)	x
151006-66-5	2-Propenoic acid, telomer with sodium 4ethenylbenzenesulfonate (1:1), sodium 2-methyl-2-[(1oxo-2-propen-1-yl)amino]-1-propanesulfonate (1:1) and sodium sulfite (1:1), sodium salt	
71050-62-9	2-Propenoic, polymer with sodium phosphinate	x
75673-43-7	3,4,4-Trimethyloxazolidine	x
51229-78-8	3,5,7-Triazatricyclo(3.3.1.1(superscript 3,7))decane, 1-(3chloro-2-propenyl)-, chloride, (Z)	x
5392-40-5	3,7-Dimethyl-2,6-octadienal	x
104-55-2	3-Phenylprop-2-enal	x
12068-08-5	4-(Dodecan-6-yl)benzenesulfonic acid – morpholine (1:1)	x
51200-87-4	4,4-Dimethyloxazolidine	x
5877-42-9	4-Ethyloct-1-yn-3-ol	x
121-33-5	4-Hydroxy-3-methoxybenzaldehyde	x
122-91-8	4-Methoxybenzyl formate	x

150-76-5	4-Methoxyphenol	x
108-11-2	4-Methyl-2-pentanol	x
108-10-1	4-Methyl-2-pentanone	x
104-40-5	4-Nonylphenol	x
26172-55-4	5-Chloro-2-methyl-3(2H)-isothiazolone	x
106-22-9	6-Octen-1-ol, 3,7-dimethyl	x
75-07-0	Acetaldehyde	x
64-19-7	Acetic acid	x
25213-24-5	Acetic acid ethenyl ester, polymer with ethenol	
90438-79-2	Acetic acid, C6-8-branched alkyl esters	x
68442-62-6	Acetic acid, hydroxy-, reaction products with triethanolamine	x
5421-46-5	Acetic acid, mercapto-, monoammonium salt	x
108-24-7	Acetic anhydride	x
67-64-1	Acetone	x
7327-60-8	Acetonitrile, 2,2',2"-nitrilotris	x
98-86-2	Acetophenone	x
77-89-4	Acetyltriethyl citrate	x
107-02-8	Acrolein	x
79-06-1	Acrylamide	x
25085-02-3	Acrylamide/ sodium acrylate copolymer	x
38193-60-1	Acrylamide-sodium-2-acrylamido-2-methlypropane sulfonate copolymer	x
79-10-7	Acrylic acid	x
110224-99-2	Acrylic acid, with sodium-2-acrylamido-2-methyl-1propanesulfonate and sodium phosphinate	x
67254-71-1	Alcohols, C10-12, ethoxylated	x
68526-86-3	Alcohols, C11-14-iso-, C13-rich	x
228414-35-5	Alcohols, C11-14-iso-, C13-rich, butoxylated ethoxylated	
78330-21-9	Alcohols, C11-14-iso-, C13-rich, ethoxylated	x
126950-60-5	Alcohols, C12-14-secondary	x
84133-50-6	Alcohols, C12-14-secondary, ethoxylated	
78330-19-5	Alcohols, C7-9-iso-, C8-rich, ethoxylated	x

68603-25-8	Alcohols, C8-10, ethoxylated propoxylated	
78330-20-8	Alcohols, C9-11-iso-, C10-rich, ethoxylated	x
93924-07-3	Alkanes, C10-14	x
90622-52-9	Alkanes, C10-16-branched and linear	
68551-19-9	Alkanes, C12-14-iso	x
68551-20-2	Alkanes, C13-16-iso	x
64743-02-8	Alkenes, C>10 .alpha.	x
68411-00-7	Alkenes, C>8	
68607-07-8	Alkenes, C24-25 alpha-, polymers with maleic anhydride,docosyl esters	x
71011-24-0	Alkyl quaternary ammonium with bentonite	
85409-23-0	Alkyl* dimethyl ethylbenzyl ammonium chloride*(50%C12, 30%C14, 17%C16, 3%C18)	x
42615-29-2	Alkylbenzenesulfonate, linear	x
1302-62-1	Almandite and pyrope garnet	
60828-78-6	alpha-[3.5-dimethyl-1-(2-methylpropyl)hexyl]-omega-hydroxy-poly(oxy-1,2-ethandiyl)	x
9000-90-2	alpha-Amylase	
98-55-5	Alpha-Terpineol	x
1302-42-7	Aluminate (AlO21-), sodium	x
7429-90-5	Aluminum	x
12042-68-1	Aluminum calcium oxide (Al2CaO4)	
7446-70-0	Aluminum chloride	x
1327-41-9	Aluminum chloride, basic	x
1344-28-1	Aluminum oxide	x
12068-56-3	Aluminum oxide silicate	x
12141-46-7	Aluminum silicate	x
10043-	Aluminum sulfate	x

01-3		
68155-07-7	Amides, C8-18 and C18-unsatd., N,N-bis(hydroxyethyl)	
68140-01-2	Amides, coco, N-[3-(dimethylamino)propyl]	
70851-07-9	Amides, coco, N-[3-(dimethylamino)propyl], alkylation products with chloroacetic acid, sodium salts	
68155-09-9	Amides, coco, N-[3-(dimethylamino)propyl], N-oxides	
68876-82-4	Amides, from C16-22 fatty acids and diethylenetriamine	
68155-20-4	Amides, tall-oil fatty, N,N-bis(hydroxyethyl)	
68647-77-8	Amides, tallow, N-[3-(dimethylamino)propyl],N-oxides	
68155-39-5	Amines, C14-18; C16-18-unsaturated, alkyl, ethoxylated	
68037-94-5	Amines, C8-18 and C18-unsatd. alkyl	
61788-46-3	Amines, coco alkyl	
61790-57-6	Amines, coco alkyl, acetates	
61788-93-0	Amines, coco alkyldimethyl	
61790-59-8	Amines, hydrogenated tallow alkyl, acetates	
68966-36-9	Amines, polyethylenepoly-, ethoxylated, phosphonomethylated	
68603-67-8	Amines, polyethylenepoly-, reaction products with benzyl chloride	x
61790-33-8	Amines, tallow alkyl	
61791-26-2	Amines, tallow alkyl, ethoxylated	
68551-33-7	Amines, tallow alkyl, ethoxylated, acetates (salts)	
68308-48-5	Amines, tallow alkyl, ethoxylated, phosphates	
6419-19-8	Aminotrimethylene phosphonic acid	x
7664-41-7	Ammonia	x
32612-48-9	Ammonium (lauryloxypolyethoxy)ethyl sulfate	x
631-61-8	Ammonium acetate	x
10604-69-0	Ammonium acrylate	x

26100-47-0	Ammonium acrylate-acrylamide polymer	x
7803-63-6	Ammonium bisulfate	x
10192-30-0	Ammonium bisulfite	x
12125-02-9	Ammonium chloride	x
7632-50-0	Ammonium citrate (1:1)	x
3012-65-5	Ammonium citrate (2:1)	x
2235-54-3	Ammonium dodecyl sulfate	x
12125-01-8	Ammonium fluoride	x
1066-33-7	Ammonium hydrogen carbonate	x
1341-49-7	Ammonium hydrogen difluoride	x
13446-12-3	Ammonium hydrogen phosphonate	x
1336-21-6	Ammonium hydroxide	x
8061-53-8	Ammonium ligninsulfonate	
6484-52-2	Ammonium nitrate	x
7722-76-1	Ammonium phosphate	x
7783-20-2	Ammonium sulfate	x
99439-28-8	Amorphous silica	x
104-46-1	Anethole	x
62-53-3	Aniline	x
1314-60-9	Antimony pentoxide	x
10025-91-9	Antimony trichloride	x
1309-64-4	Antimony trioxide	x
7440-38-2	Arsenic	
68131-74-8	Ashes, residues	
68201-32-1	Asphalt, sulfonated, sodium salt	

12174-11-7	Attapulgite	
31974-35-3	Aziridine, polymer with 2-methyloxirane	x
7727-43-7	Barium sulfate	x
1318-16-7	Bauxite	
1302-78-9	Bentonite	
121888-68-4	Bentonite, benzyl(hydrogenated tallow alkyl) dimethylammonium stearate complex	
80-08-0	Benzamine, 4,4'-sulfonylbis	x
71-43-2	Benzene	x
98-82-8	Benzene, (1-methylethyl)1	
119345-03-8	Benzene, 1,1'-oxybis-, tetrapropylene derivs., sulfonated	
119345-04-9	Benzene, 1,1'-oxybis-, tetrapropylene derivs., sulfonated, sodium salts	
611-14-3	Benzene, 1-ethyl-2-methyl	x
68648-87-3	Benzene, C10-16-alkyl derivs.	x
9003-55-8	Benzene, ethenyl-, polymer with 1,3-butadiene	x
74153-51-8	Benzenemethanaminium, N,N-dimethyl-N-(2-((1-oxo-2propen-1-yl)oxy)ethyl)-, chloride (1:1), polymer with 2propenamide	x
98-11-3	Benzenesulfonic acid	x
37953-05-2	Benzenesulfonic acid, (1-methylethyl)-,	x
37475-88-0	Benzenesulfonic acid, (1-methylethyl)-, ammonium salt	x
28348-53-0	Benzenesulfonic acid, (1-methylethyl)-, sodium salt	x
68584-22-5	Benzenesulfonic acid, C10-16-alkyl derivs.	x
255043-08-4	Benzenesulfonic acid, C10-16-alkyl derivs., compds. with cyclohexylamine	x
68584-27-0	Benzenesulfonic acid, C10-16-alkyl derivs., potassium salts	x
90218-35-2	Benzenesulfonic acid, dodecyl-, branched, compds. with 2-propanamine	x
26264-06-2	Benzenesulfonic acid, dodecyl-, calcium salt	x
68648-81-7	Benzenesulfonic acid, mono-C10-16 alkyl derivs., compds. with 2-propanamine	x
65-85-0	Benzoic acid	x
100-44-7	Benzyl chloride	x

139-07-1	Benzyldimethyldodecylammonium chloride	x
122-18-9	Benzylhexadecyldimethylammonium chloride	x
68425-61-6	Bis(1-methylethyl)naphthalenesulfonic acid, cyclohexylamine salt	x
111-44-4	Bis(2-chloroethyl) ether	x
80-05-7	Bisphenol A	x
65996-69-2	Blast furnace slag	x
1303-96-4	Borax	x
10043-35-3	Boric acid	x
1303-86-2	Boric oxide	x
11128-29-3	Boron potassium oxide	x
1330-43-4	Boron sodium oxide	x
12179-04-3	Boron sodium oxide pentahydrate	x
106-97-8	Butane	x
2373-38-8	Butanedioic acid, sulfo-, 1,4-bis(1,3-dimethylbutyl) ester,sodium salt	x
2673-22-5	Butanedioic acid, sulfo-, 1,4-ditridecyl ester, sodium salt	x
2426-08-6*	Butyl glycidyl ether	x
138-22-7	Butyl lactate	x
3734-67-6	C.I. Acid red 1	x
6625-46-3	C.I. Acid violet 12, disodium salt	x
6410-41-9	C.I. Pigment Red 5	x
4477-79-6	C.I. Solvent Red 26	x
70592-80-2	C10-16-Alkyldimethylamines oxides	x
68002-97-1	C10-C16 ethoxylated alcohol	x
68131-40-8	C11-15-Secondary alcohols ethoxylated	x
73138-27-9	C12-14 tert-alkyl ethoxylated amines	x
66402-68-4	Calcined bauxite	
12042-	Calcium aluminate	x

78-3		
7789-41-5	Calcium bromide	x
10043-52-4	Calcium chloride	x
10035-04-8	Calcium dichloride dihydrate	x
7789-75-5	Calcium fluoride	x
1305-62-0	Calcium hydroxide	x
7778-54-3	Calcium hypochlorite	x
58398-71-3	Calcium magnesium hydroxide oxide	
1305-78-8	Calcium oxide	x
1305-79-9	Calcium peroxide	x
7778-18-9	Calcium sulfate	x
10101-41-4	Calcium sulfate dihydrate	x
76-22-2	Camphor	x
1333-86-4	Carbon black	x
124-38-9	Carbon dioxide	x
471-34-1	Carbonic acid calcium salt (1:1)	x
584-08-7	Carbonic acid, dipotassium salt	x
39346-76-4	Carboxymethyl guar gum, sodium salt	
61791-12-6	Castor oil, ethoxylated	
8000-27-9	Cedarwood oil	
9005-81-6	Cellophane	
9012-54-8	Cellulase	
9004-34-6	Cellulose	x
9004-32-4	Cellulose, carboxymethyl ether, sodium salt	
16887-00-6	Chloride	x
7782-50-5	Chlorine	x

10049-04-4	Chlorine dioxide	x
78-73-9	Choline bicarbonate	x
67-48-1	Choline chloride	x
16065-83-1	Chromium (III), insoluble salts	x
18540-29-9	Chromium (VI)	x
39430-51-8	Chromium acetate, basic	x
1066-30-4	Chromium(III) acetate	x
77-92-9	Citric acid	x
8000-29-1	Citronella oil	
94266-47-4	Citrus extract	
50815-10-6	Coal, granular	
71-48-7	Cobalt(II) acetate	x
68424-94-2	Coco-betaine	
68603-42-9	Coconut oil acid/Diethanolamine condensate (2:1)	
61789-18-2	Coconut trimethylammonium chloride	x
7440-50-8	Copper	x
7758-98-7	Copper sulfate	x
7758-89-6	Copper(I) chloride	x
7681-65-4	Copper(I) iodide	x
7447-39-4	Copper(II) chloride	x
68525-86-0	Corn flour	
11138-66-2	Corn sugar gum	
1302-74-5	Corundum (Aluminum oxide)	x
68308-87-2	Cottonseed, flour	
91-64-5	Coumarin	x
14464-46-1	Cristobalite	x

15468-32-3	Crystalline silica, tridymite	x
10125-13-0	Cupric chloride dihydrate	x
110-82-7	Cyclohexane	x
108-94-1	Cyclohexanone	x
18472-87-2	D&C Red 28	x
533-74-4	Dazomet	x
1120-24-7	Decyldimethylamine	x
7789-20-0	Deuterium oxide	x
50-70-4	D-Glucitol	x
526-95-4	D-Gluconic acid	x
3149-68-6	D-Glucopyranoside, methyl	x
50-99-7	D-Glucose	x
117-81-7	Di(2-ethylhexyl) phthalate	x
7727-54-0	Diammonium peroxydisulfate	x
68855-54-9	Diatomaceous earth	
91053-39-3	Diatomaceous earth, calcined	
3252-43-5	Dibromoacetonitrile	x
10034-77-2	Dicalcium silicate	x
7173-51-5	Didecyldimethylammonium chloride	x
111-42-2	Diethanolamine	x
25340-17-4	Diethylbenzene	x
111-46-6	Diethylene glycol	x
111-77-3	Diethylene glycol monomethyl ether	x
111-40-0	Diethylenetriamine	x
68647-57-4	Diethylenetriamine reaction product with fatty acid dimers	
38640-62-9	Diisopropylnaphthalene	x
627-93-0	Dimethyl adipate	x
1119-40-0	Dimethyl glutarate	x
63148-62-9	Dimethyl polysiloxane	x

106-65-0	Dimethyl succinate	x
108-01-0	Dimethylaminoethanol	x
7398-69-8	Dimethyldiallylammonium chloride	x
101-84-8	Diphenyl oxide	x
7758-11-4*	Dipotassium monohydrogen phosphate	x
25265-71-8	Dipropylene glycol	x
31291-60-8	Di-sec-butylphenol	x
28519-02-0	Disodium dodecyl(sulphonatophenoxy)benzenesulphonate	x
38011-25-5	Disodium ethylenediaminediacetate	x
6381-92-6	Disodium ethylenediaminetetraacetate dihydrate	x
12008-41-2	Disodium octaborate	x
12280-03-4	Disodium octaborate tetrahydrate	x
68477-31-6	Distillates, petroleum, catalytic reformer fractionator residue, low-boiling	
68333-25-5	Distillates, petroleum, hydrodesulfurized light catalytic cracked	
64742-80-9	Distillates, petroleum, hydrodesulfurized middle	
64742-52-5	Distillates, petroleum, hydrotreated heavy naphthenic	
64742-54-7	Distillates, petroleum, hydrotreated heavy paraffinic	
64742-47-8	Distillates, petroleum, hydrotreated light	
64742-53-6	Distillates, petroleum, hydrotreated light naphthenic	
64742-55-8	Distillates, petroleum, hydrotreated light paraffinic	
64742-46-7	Distillates, petroleum, hydrotreated middle	
64741-59-9	Distillates, petroleum, light catalytic cracked	
64741-77-1	Distillates, petroleum, light hydrocracked	
64742-65-0	Distillates, petroleum, solvent-dewaxed heavy paraffinic	
64741-96-4	Distillates, petroleum, solvent-refined heavy naphthenic	
64742-	Distillates, petroleum, steam-cracked	

91-2		
64741-44-2	Distillates, petroleum, straight-run middle	
64741-86-2	Distillates, petroleum, sweetened middle	
71011-04-6	Ditallow alkyl ethoxylated amines	
10326-41-7	D-Lactic acid	x
5989-27-5	D-Limonene	x
577-11-7	Docusate sodium	x
112-40-3	Dodecane	x
123-01-3	Dodecylbenzene	x
27176-87-0	Dodecylbenzene sulfonic acid	
26836-07-7	Dodecylbenzenesulfonic acid, monoethanolamine salt	x
12276-01-6	EDTA, copper salt	x
37288-54-3	Endo-1,4-.beta.-mannanase.	
106-89-8	Epichlorohydrin	x
44992-01-0	Ethanaminium, N,N,N-trimethyl-2-[(1-oxo-2propenyl)oxy]-, chloride	x
69418-26-4	Ethanaminium, N,N,N-trimethyl-2-[(1-oxo-2propenyl)oxy]-, chloride, polymer with 2-propenamide	x
26006-22-4	Ethanaminium, N,N,N-trimethyl-2[(2-methyl-1-oxo-2-propen-1-yl0oxy]-, methyl sulfate 91:1), polymer with 2propenamide	
27103-90-8	Ethanaminium, N,N,N-trimethyl-2-[(2-methyl-1-oxo-2-propenyl)oxy]-, methyl sulfate, homopolymer	x
74-84-0	Ethane	x
64-17-5	Ethanol	x
68171-29-9	Ethanol, 2,2',2"-nitrilotris-, tris(dihydrogen phosphate)(ester), sodium salt	x
61791-47-7	Ethanol, 2,2'-iminobis-, N-coco alkyl derivs., N-oxides	
61791-44-4	Ethanol, 2,2'-iminobis-, N-tallow alkyl derivs.	
68909-77-3	Ethanol, 2,2'-oxybis-, reaction products with ammonia,morpholine derivs. Residues	
68877-16-7	Ethanol, 2,2-oxybis-, reaction products with ammonia,morpholine derivs. residues, acetates (salts)	
102424-23-7	Ethanol, 2,2-oxybis-, reaction products with ammonia,morpholine derivs. residues, reaction products with sulfur dioxide	
25446-78-0	Ethanol, 2-[2-[2-(tridecyloxy)ethoxy]ethoxy]-, hydrogen sulfate, sodium salt	x

34411-42-2	Ethanol, 2-amino-, polymer with formaldehyde	x
68649-44-5	Ethanol, 2-amino-, reaction products with ammonia, by-products from, phosphonomethylated	
141-43-5	Ethanolamine	x
66455-15-0	Ethoxylated C10-14 alcohols	x
66455-14-9	Ethoxylated C12-13 alcohols	x
68439-50-9	Ethoxylated C12-14 alcohols	x
68131-39-5	Ethoxylated C12-15 alcohols	x
68551-12-2	Ethoxylated C12-16 alcohols	x
68951-67-7	Ethoxylated C14-15 alcohols	x
68439-45-2	Ethoxylated C6-12 alcohols	x
68439-46-3	Ethoxylated C9-11 alcohols	x
9002-92-0	Ethoxylated dodecyl alcohol	x
61790-82-7	Ethoxylated hydrogenated tallow alkylamines	
68439-51-0	Ethoxylated propoxylated C12-14 alcohols	x
52624-57-4	Ethoxylated, propoxylated trimethylolpropane	x
141-78-6	Ethyl acetate	x
141-97-9	Ethyl acetoacetate	x
93-89-0	Ethyl benzoate	x
97-64-3	Ethyl lactate	x
118-61-6	Ethyl salicylate	x
100-41-4	Ethylbenzene	x
9004-57-3	Ethylcellulose	x
107-21-1	Ethylene glycol	x
75-21-8	Ethylene oxide	x
107-15-3	Ethylenediamine	x
60-00-4	Ethylenediaminetetraacetic acid	x
64-02-8	Ethylenediaminetetraacetic acid tetrasodium salt	x
67989-88-2	Ethylenediaminetetraacetic acid, diammonium copper salt	x
139-33-3	Ethylenediaminetetraacetic acid, disodium salt	x
74-86-2	Ethyne	x

68604-35-3	Fatty acids, C 8-18 and C18-unsaturated compounds with diethanolamine	
70321-73-2	Fatty acids, C14-18 and C16-18-unsatd., distn. residues	
61788-89-4	Fatty acids, C18-unsatd., dimers	x
61791-29-5	Fatty acids, coco, ethoxylated	
61791-08-0	Fatty acids, coco, reaction products with ethanolamine,ethoxylated	
61790-90-7	Fatty acids, tall oil, hexa esters with sorbitol, ethoxylated	
68188-40-9	Fatty acids, tall oil, reaction products with acetophenone, formaldehyde and thiourea	
61790-12-3	Fatty acids, tall-oil	
61790-69-0	Fatty acids, tall-oil, reaction products with diethylenetriamine	
8052-48-0	Fatty acids, tallow, sodium salts	
68153-72-0	Fatty acids, vegetable-oil, reaction products with diethylenetriamine	
3844-45-9	FD&C Blue no. 1	x
7705-08-0	Ferric chloride	x
10028-22-5	Ferric sulfate	x
17375-41-6	Ferrous sulfate monohydrate	x
65997-17-3	Fiberglass	
50-00-0	Formaldehyde	x
NA	Formaldehyde amine	x
29316-47-0	Formaldehyde polymer with 4,1,1-(dimethylethyl)phenol and methyloxirane	x
63428-92-2	Formaldehyde polymer with methyl oxirane, 4nonylphenol and oxirane	x
28906-96-9	Formaldehyde, polymer with 2-(chloromethyl)oxirane and 4,4'-(1-methylethylidene)bis[phenol]	x
30704-64-4	Formaldehyde, polymer with 4-(1,1-dimethylethyl)phenol,2-methyloxirane and oxirane	x
30846-35-6	Formaldehyde, polymer with 4-nonylphenol and oxirane	x
35297-54-2	Formaldehyde, polymer with ammonia and phenol	x
25085-75-0	Formaldehyde, polymer with bisphenol A	x

70750-07-1	Formaldehyde, polymer with N1-(2-aminoethyl)-1,2ethanediamine, benzylated	x
55845-06-2	Formaldehyde, polymer with nonylphenol and oxirane	x
153795-76-7	Formaldehyde, polymers with branched 4-nonylphenol, ethylene oxide and propylene oxide	x
75-12-7	Formamide	x
64-18-6	Formic acid	x
590-29-4	Formic acid, potassium salt	x
68476-30-2	Fuel oil, no. 2	
68334-30-5	Fuels, diesel	
68476-34-6	Fuels, diesel, no. 2	
8031-18-3	Fuller's earth	
110-17-8	Fumaric acid	x
98-01-1	Furfural	x
98-00-0	Furfuryl alcohol	x
64741-43-1	Gas oils, petroleum, straight-run	
9000-70-8	Gelatin	
12002-43-6	Gilsonite	
133-42-6	Gluconic acid	x
111-30-8	Glutaraldehyde	x
56-81-5	Glycerin, natural	x
135-37-5	Glycine, N-(carboxymethyl)-N-(2-hydroxyethyl)-, disodium salt	x
150-25-4	Glycine, N,N-bis(2-hydroxyethyl)	x
5064-31-3	Glycine, N,N-bis(carboxymethyl)-, trisodium salt	x
139-89-9	Glycine, N-[2-[bis(carboxymethyl)amino]ethyl]-N-(2hydroxyethyl)-, trisodium salt	x
79-14-1	Glycolic acid	x
2836-32-0	Glycolic acid sodium salt	x
107-22-2	Glyoxal	x
298-12-4	Glyoxylic acid	x
9000-30-0	Guar gum	
68130-15-4	Guar gum, carboxymethyl 2-hydroxypropyl ether, sodium salt	
13397-24-5	Gypsum	x

67891-79-6	Heavy aromatic distillate	
1317-60-8	Hematite	
9025-56-3	Hemicellulase enzyme concentrate	
142-82-5	Heptane	x
68526-88-5	Heptene, hydroformylation products, high-boiling	
57-09-0	Hexadecyltrimethylammonium bromide	x
110-54-3	Hexane	x
124-04-9	Hexanedioic acid	x
1415-93-6	Humic acids, commercial grade	
68956-56-9	Hydrocarbons, terpene processing by-products	
7647-01-0	Hydrochloric acid	x
7664-39-3	Hydrogen fluoride	x
7722-84-1	Hydrogen peroxide	x
7783-06-4*	Hydrogen sulfide	x
9004-62-0	Hydroxyethylcellulose	x
4719-04-4*	Hydroxylamine hydrochloride	x
10039-54-0	Hydroxylamine sulfate (2:1)	x
9004-64-2	Hydroxypropyl cellulose	x
39421-75-5	Hydroxypropyl guar gum	
120-72-9	Indole	x
430439-54-6	Inulin, carboxymethyl ether, sodium salt	
12030-49-8	Iridium oxide	x
7439-89-6	Iron	x
1317-61-9	Iron oxide (Fe3O4)	x
1332-37-2	Iron(II) oxide	x
7720-78-7	Iron(II) sulfate	x

7782-63-0	Iron(II) sulfate heptahydrate	x
1309-37-1	Iron(III) oxide	x
89-65-6	Isoascorbic acid	x
75-28-5	Isobutane	x
26952-21-6	Isooctanol	x
123-51-3	Isopentyl alcohol	x
67-63-0	Isopropanol	x
42504-46-1	Isopropanolamine dodecylbenzenesulfonate	x
75-31-0	Isopropylamine	x
68909-80-8	Isoquinoline, reaction products with benzyl chloride and quinoline	x
35674-56-7	Isoquinolinium, 2-(phenylmethyl)-, chloride	x
9043-30-5	Isotridecanol, ethoxylated	x
1332-58-7	Kaolin	x
8008-20-6	Kerosine (petroleum)	
64742-81-0	Kerosine, petroleum, hydrodesulfurized	
61790-53-2	Kieselguhr	x
1302-76-7	Kyanite	
50-21-5	Lactic acid	x
63-42-3	Lactose	x
13197-76-7	Lauryl hydroxysultaine	x
8022-15-9	Lavandula hybrida abrial herb oil	
4511-42-6	L-Dilactide	x
7439-92-1	Lead	x
8002-43-5	Lecithin	
129521-66-0	Lignite	
8062-15-5	Lignosulfuric acid	
1317-65-3	Limestone	x

8001-26-1	Linseed oil	
79-33-4	L-Lactic acid	x
546-93-0	Magnesium carbonate (1:1)	x
7786-30-3	Magnesium chloride	x
7791-18-6	Magnesium chloride hexahydrate	x
1309-42-8	Magnesium hydroxide	x
19086-72-7	Magnesium iron silicate	
10377-60-3	Magnesium nitrate	x
1309-48-4	Magnesium oxide	x
14452-57-4	Magnesium peroxide	x
12057-74-8	Magnesium phosphide	x
1343-88-0	Magnesium silicate	x
26099-09-2	Maleic acid homopolymer	x
25988-97-0	Methanamine-N-methyl polymer with chloromethyl oxirane	x
74-82-8	Methane	x
67-56-1	Methanol	x
100-97-0	Methenamine	x
625-45-6	Methoxyacetic acid	x
9004-67-5	Methyl cellulose	x
119-36-8	Methyl salicylate	x
78-94-4	Methyl vinyl ketone	x
108-87-2	Methylcyclohexane	x
6317-18-6	Methylene bis(thiocyanate)	x
66204-44-2	Methylenebis(5-methyloxazolidine)	x
68891-11-2	Methyloxirane polymer with oxirane, mono (nonylphenol)ether, branched	x
12001-26-2	Mica	
8012-95-1	Mineral oil -includes paraffin oil	
64475-85-0	Mineral spirits	

26038-87-9	Monoethanolamine borate (1:x)	x
1318-93-0	Montmorillonite	
110-91-8	Morpholine	x
78-21-7	Morpholinium, 4-ethyl-4-hexadecyl-, ethyl sulfate	x
1302-93-8	Mullite	
46830-22-2	N-(2-Acryloyloxyethyl)-N-benzyl-N,N-dimethylammonium chloride	x
54076-97-0	N,N,N-Trimethyl-2[1-oxo-2-propenyl]oxy ethanaminimum chloride, homopolymer	x
19277-88-4	N,N,N-Trimethyl-3-((1-oxooctadecyl)amino)-1propanaminium methyl sulfate	x
112-03-8	N,N,N-Trimethyloctadecan-1-aminium chloride	x
109-46-6	N,N'-Dibutylthiourea	x
2605-79-0	N,N-Dimethyldecylamine oxide	x
68-12-2	N,N-Dimethylformamide	x
593-81-7	N,N-Dimethylmethanamine hydrochloride	x
1184-78-7	N,N-Dimethyl-methanamine-N-oxide	x
1613-17-8	N,N-Dimethyloctadecylamine hydrochloride	x
110-26-9	N,N'-Methylenebisacrylamide	x
64741-68-0	Naphtha, petroleum, heavy catalytic reformed	
64742-48-9	Naphtha, petroleum, hydrotreated heavy	
91-20-3	Naphthalene	x
93-18-5	Naphthalene, 2-ethoxy	x
28757-00-8	Naphthalenesulfonic acid, bis(1-methylethyl)-	x
99811-86-6	Naphthalenesulphonic acid, bis (1-methylethyl)-methyl derivatives	x
68410-62-8	Naphthenic acid ethoxylate	x
7786-81-4	Nickel sulfate	x
10101-97-0	Nickel(II) sulfate hexahydrate	x
61790-29-2	Nitriles, tallow, hydrogenated	
4862-18-4	Nitrilotriacetamide	x
139-13-9	Nitrilotriacetic acid	x

18662-53-8	Nitrilotriacetic acid trisodium monohydrate	x
7727-37-9	Nitrogen	x
872-50-4	N-Methyl-2-pyrrolidone	x
105-59-9	N-Methyldiethanolamine	x
109-83-1	N-Methylethanolamine	x
68213-98-9	N-Methyl-N-hydroxyethyl-N-hydroxyethoxyethylamine	x
13127-82-7	N-Oleyl diethanolamide	x
25154-52-3	Nonylphenol (mixed)	x
8000-48-4	Oil of eucalyptus	
8007-25-7*	Oil of lemongrass	
8000-25-7	Oil of rosemary	
112-80-1	Oleic acid	x
1317-71-1	Olivine	
8028-48-6	Orange terpenes	
68649-29-6	Oxirane, methyl-, polymer with oxirane, mono-C10-16alkyl ethers, phosphates	
51838-31-4	Oxiranemethanaminium, N,N,N-trimethyl-, chloride,homopolymer	x
7782-44-7	Oxygen	x
10028-15-6	Ozone	x
8002-74-2	Paraffin waxes and Hydrocarbon waxes	
30525-89-4	Paraformaldehyde	x
4067-16-7	Pentaethylenehexamine	x
109-66-0	Pentane	x
628-63-7	Pentyl acetate	x
540-18-1	Pentyl butyrate	x
79-21-0	Peracetic acid	x
93763-70-3	Perlite	
64743-01-7	Petrolatum, petroleum, oxidized	
8002-05-	Petroleum	

9*		
6742-47-8	Petroleum distillate hydrotreated light	
85-01-8	Phenanthrene	x
108-95-2	Phenol	x
25068-38-6	Phenol, 4,4'-(1-methylethylidene)bis-, polymer with 2(chloromethyl)oxirane	x
9003-35-4	Phenol, polymer with formaldehyde	x
7803-51-2	Phosphine	x
13598-36-2	Phosphonic acid	x
29712-30-9	Phosphonic acid (dimethylamino(methylene))	x
129828-36-0	Phosphonic acid, (((2-[(2hydroxyethyl)(phosphonomethyl)amino)ethyl)imino]bis(m ethylene))bis-, compd. with 2-aminoethanol	x
67953-76-8	Phosphonic acid, (1-hydroxyethylidene)bis-, potassium salt	x
3794-83-0	Phosphonic acid, (1-hydroxyethylidene)bis-, tetrasodium salt	x
15827-60-8	Phosphonic acid, [[(phosphonomethyl)imino]bis[2,1ethanediylnitrilobis(methylene)]]tetrakis	x
70714-66-8	Phosphonic acid, [[(phosphonomethyl)imino]bis[2,1ethanediylnitrilobis(methylene)]]tetrakis-, ammonium salt (1:x)	x
22042-96-2	Phosphonic acid, [[(phosphonomethyl)imino]bis[2,1ethanediylnitrilobis(methylene)]]tetrakis-, sodium salt	x
34690-00-1	Phosphonic acid, [[(phosphonomethyl)imino]bis[6,1hexanediylnitrilobis(methylene)]]tetrakis	x
7664-38-2	Phosphoric acid	x
7785-88-8	Phosphoric acid, aluminium sodium salt	x
7783-28-0	Phosphoric acid, diammonium salt	x
68412-60-2	Phosphoric acid, mixed decyl and Et and octyl esters	
10294-56-1	Phosphorous acid	x
85-44-9	Phthalic anhydride	x
8002-09-3*	Pine oils	
25038-54-4	Policapram (Nylon 6)	
62649-	Poly (acrylamide-co-acrylic acid), partial sodium salt	x

23-4		
26680-10-4	Poly(lactide)	x
9014-93-1	Poly(oxy-1,2-ethanediyl), .alpha.-(dinonylphenyl)-omega.-hydroxy	x
9016-45-9	Poly(oxy-1,2-ethanediyl), .alpha.-(nonylphenyl)-.omega.hydroxy	x
51811-79-1	Poly(oxy-1,2-ethanediyl), .alpha.-(nonylphenyl)-.omega.hydroxy-, phosphate	x
68987-90-6	Poly(oxy-1,2-ethanediyl), .alpha.-(octylphenyl)-.omega.hydroxy-, branched	x
26635-93-8	Poly(oxy-1,2-ethanediyl), .alpha.,.alpha.'-[[(9Z)-9octadecenylimino]di-2,1-ethanediyl]bis[.omega.-hydroxy	x
9004-96-0	Poly(oxy-1,2-ethanediyl), .alpha.-[(9Z)-1-oxo-9octadecenyl]-.omega.-hydroxy	x
68891-38-3	Poly(oxy-1,2-ethanediyl), .alpha.-sulfo-.omega.-hydroxy-, C12-14-alkyl ethers, sodium salts	
61723-83-9	Poly(oxy-1,2-ethanediyl), a-hydro-w-hydroxy-, ether with D-glucitol (2:1), tetra-(9Z)-9-octadecenoate	x
68015-67-8	Poly(oxy-1,2-ethanediyl), alpha-(2,3,4,5tetramethylnonyl)-omega-hydroxy	x
68412-53-3	Poly(oxy-1,2-ethanediyl), alpha-(nonylphenyl)-omegahydroxy-,branched, phosphates	x
31726-34-8	Poly(oxy-1,2-ethanediyl), alpha-hexyl-omega-hydroxy	
56449-46-8	Poly(oxy-1,2-ethanediyl), alpha-hydro-omega-hydroxy-, (9Z)-9-octadecenoate	x
65545-80-4	Poly(oxy-1,2-ethanediyl), alpha-hydro-omega-hydroxy-, ether with alpha-fluoro-omega-(2hydroxyethyl)poly(difluoromethylene) (1:1)	
27306-78-1	Poly(oxy-1,2-ethanediyl), alpha-methyl-omega-(3(1,3,3,3-tetramethyl-1-((trimethylsilyl)oxy)-1disiloxanyl)propoxy)	x
52286-19-8	Poly(oxy-1,2-ethanediyl), alpha-sulfo-omega-(decyloxy)-, ammonium salt (1:1)	x
63428-86-4	Poly(oxy-1,2-ethanediyl), alpha-sulfo-omega-(hexyloxy)-, ammonium salt (1:1)	x
68037-05-8	Poly(oxy-1,2-ethanediyl), alpha-sulfo-omega-(hexyloxy)-, C6-10-alkyl ethers, ammonium salts	x
9081-17-8	Poly(oxy-1,2-ethanediyl), alpha-sulfo-omega-(nonylphenoxy)	x
52286-18-7	Poly(oxy-1,2-ethanediyl), alpha-sulfo-omega-(octyloxy)ammonium salt (1:1)	x
68890-88-0	Poly(oxy-1,2-ethanediyl), alpha-sulfo-omega-hydroxy-, C10-12-alkyl ethers, ammonium salts	x
24938-91-8	Poly(oxy-1,2-ethanediyl), alpha-tridecyl-omega-hydroxy	x
127036-24-2	Poly(oxy-1,2-ethanediyl), alpha-undecyl-omega-hydroxy-, branched and linear	x
68412-	Poly(oxy-1,2-ethanediyl),alpha-(4-nonylphenyl)-omegahydroxy-,branched	x

54-4		
34398-01-1	Poly-(oxy-1,2-ethanediyl)-alpha-undecyl-omega-hydroxy	x
127087-87-0	Poly(oxy-1,2-ethanediyl)-nonylphenyl-hydroxy branched	x
25704-18-1	Poly(sodium-p-styrenesulfonate)	x
32131-17-2	Poly[imino(1,6-dioxo-1,6-hexanediyl)imino-1,6hexanediyl]	x
9003-05-8*	Polyacrylamide	x
NA	Polyacrylate/ polyacrylamide blend	x
66019-18-9	Polyacrylic acid, sodium bisulfite terminated	x
25322-68-3	Polyethylene glycol	x
9004-98-2	Polyethylene glycol (9Z)-9-octadecenyl ether	x
68187-85-9	Polyethylene glycol ester with tall oil fatty acid	
9036-19-5	Polyethylene glycol mono(octylphenyl) ether	x
9004-77-7	Polyethylene glycol monobutyl ether	x
68891-29-2	Polyethylene glycol mono-C8-10-alkyl ether sulfate ammonium	x
9046-01-9*	Polyethylene glycol tridecyl ether phosphate	x
9002-98-6	Polyethyleneimine	
25618-55-7	Polyglycerol	x
9005-70-3	Polyoxyethylene sorbitan trioleate	x
26027-38-3	Polyoxyethylene(10)nonylphenyl ether	x
9046-10-0	Polyoxypropylenediamine	x
68131-72-6	Polyphosphoric acids, esters with triethanolamine,sodium salts	
68915-31-1	Polyphosphoric acids, sodium salts	x
25322-69-4	Polypropylene glycol	x
68683-13-6	Polypropylene glycol glycerol triether, epichlorohydrin,bisphenol A polymer	
9011-19-2	Polysiloxane	

9005-64-5	Polysorbate 20	x
9003-20-7	Polyvinyl acetate copolymer	x
9002-89-5	Polyvinyl alcohol	x
NA	Polyvinyl alcohol/polyvinyl acetate copolymer	x
9002-85-1	Polyvinylidene chloride	
65997-15-1	Portland cement	
127-08-2	Potassium acetate	x
1327-44-2	Potassium aluminum silicate	x
29638-69-5	Potassium antimonate	x
12712-38-8	Potassium borate	x
20786-60-1	Potassium borate (1:x)	x
6381-79-9	Potassium carbonate sesquihydrate	x
7447-40-7	Potassium chloride	x
7778-50-9	Potassium dichromate	x
1310-58-3	Potassium hydroxide	x
7681-11-0	Potassium iodide	x
13709-94-9	Potassium metaborate	x
143-18-0	Potassium oleate	x
12136-45-7	Potassium oxide	x
7727-21-1	Potassium persulfate	x
7778-80-5	Potassium sulfate	x
74-98-6	Propane	x
2997-92-4	Propanimidamide,2,2’'-aAzobis[(2-methyl-, amidinopropane) dihydrochloride	x
34090-94-8	Propanol, 1(or 2)-(2-methoxymethylethoxy)	x
107-19-7	Propargyl alcohol	x
108-32-7	Propylene carbonate	x
15220-	Propylene pentamer	x

87-8		
106-42-3	p-Xylene	x
68391-11-7	Pyridine, alkyl derivs.	
100765-57-9	Pyridinium, 1-(phenylmethyl)-, alkyl derivs., chlorides	
70914-44-2	Pyridinium, 1-(phenylmethyl)-, C7-8-alkyl derivs., chlorides	x
289-95-2	Pyrimidine	x
109-97-7	Pyrrole	x
14808-60-7	Quartz	x
308074-31-9	Quaternary ammonium compounds (2-ethylhexyl) hydrogenated tallow alkyl)dimethyl, methyl sulfates	
68607-28-3	Quaternary ammonium compounds, (oxydi-2,1ethanediyl)bis[coco alkyldimethyl, dichlorides	
68153-30-0	Quaternary ammonium compounds, benzylbis(hydrogenated tallow alkyl)methyl, salts with bentonite	
68989-00-4	Quaternary ammonium compounds, benzyl-C10-16alkyldimethyl, chlorides	x
68424-85-1	Quaternary ammonium compounds, benzyl-C12-16alkyldimethyl, chlorides	x
68391-01-5	Quaternary ammonium compounds, benzyl-C12-18alkyldimethyl, chlorides	x
61789-68-2	Quaternary ammonium compounds, benzylcoco alkylbis(hydroxyethyl), chlorides	
68953-58-2	Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with bentonite	
71011-27-3	Quaternary ammonium compounds, bis(hydrogenated tallow alkyl)dimethyl, salts with hectorite	
68424-95-3	Quaternary ammonium compounds, di-C8-10alkyldimethyl, chlorides	x
61789-77-3	Quaternary ammonium compounds, dicoco alkyldimethyl,chlorides	
68607-29-4	Quaternary ammonium compounds, pentamethyltallow alkyltrimethylenedi-, dichlorides	
8030-78-2	Quaternary ammonium compounds, trimethyltallow alkyl,chlorides	
91-22-5	Quinoline	x
68514-29-4	Raffinates (petroleum)	
64741-85-1	Raffinates, petroleum, sorption process	
64742-01-4	Residual oils, petroleum, solvent-refined	
64741-67-9	Residues, petroleum, catalytic reformer fractionator	

81-88-9	Rhodamine B	x
8050-09-7*	Rosin	
12060-08-1	Scandium oxide	x
63800-37-3	Sepiolite	
68611-44-9	Silane, dichlorodimethyl-, reaction products with silica	
7631-86-9	Silica	x
112926-00-8	Silica gel, cryst. -free	
112945-52-5	Silica, amorphous, fumed, cryst.-free	x
60676-86-0	Silica, vitreous	x
55465-40-2	Silicic acid, aluminum potassium sodium salt	
68037-74-1	Siloxanes and silicones, di-Me, polymers with Me silsesquioxanes	
67762-90-7	Siloxanes and Silicones, di-Me, reaction products with silica	
63148-52-7	Siloxanes and silicones, dimethyl,	
5324-84-5	Sodium 1-octanesulfonate	x
2492-26-4	Sodium 2-mercaptobenzothiolate	x
127-09-3	Sodium acetate	x
532-32-1	Sodium benzoate	x
144-55-8	Sodium bicarbonate	x
7631-90-5	Sodium bisulfite	x
1333-73-9	Sodium borate	x
7789-38-0	Sodium bromate	x
7647-15-6	Sodium bromide	x
1004542-84-0	Sodium bromosulfamate	x
68610-44-6	Sodium caprylamphopropionate	x
497-19-8	Sodium carbonate	x
7775-09-9*	Sodium chlorate	x

7647-14-5	Sodium chloride	x
7758-19-2	Sodium chlorite	x
3926-62-3	Sodium chloroacetate	x
68608-68-4	Sodium cocaminopropionate	
142-87-0	Sodium decyl sulfate	x
527-07-1	Sodium D-gluconate	x
126-96-5	Sodium diacetate	x
2893-78-9	Sodium dichloroisocyanurate	x
151-21-3	Sodium dodecyl sulfate	x
6381-77-7	Sodium erythorbate (1:1)	x
126-92-1	Sodium ethasulfate	x
141-53-7	Sodium formate	x
7681-38-1	Sodium hydrogen sulfate	x
1310-73-2	Sodium hydroxide	x
7681-52-9	Sodium hypochlorite	x
7681-82-5	Sodium iodide	x
8061-51-6	Sodium ligninsulfonate	
18016-19-8	Sodium maleate (1:x)	x
7681-57-4	Sodium metabisulfite	x
7775-19-1	Sodium metaborate	x
16800-11-6	Sodium metaborate dihydrate	x
10555-76-7	Sodium metaborate tetrahydrate	x
6834-92-0	Sodium metasilicate	x
7631-99-4	Sodium nitrate	x
7632-00-0	Sodium nitrite	x
137-20-2	Sodium N-methyl-N-oleoyltaurate	x
142-31-4	Sodium octyl sulfate	x
1313-59-	Sodium oxide	x

3		
11138-47-9	Sodium perborate	x
10486-00-7	Sodium perborate tetrahydrate	x
7632-04-4*	Sodium peroxoborate	x
7775-27-1	Sodium persulfate	x
7632-05-5*	Sodium phosphate	x
9084-06-4*	Sodium polynaphthalenesulfonate	x
7758-16-9	Sodium pyrophosphate	x
54-21-7	Sodium salicylate	x
533-96-0	Sodium sesquicarbonate	x
1344-09-8	Sodium silicate	x
9063-38-1	Sodium starch glycolate	
7757-82-6	Sodium sulfate	x
7757-83-7	Sodium sulfite	x
540-72-7	Sodium thiocyanate	x
7772-98-7	Sodium thiosulfate	x
10102-17-7	Sodium thiosulfate, pentahydrate	x
650-51-1	Sodium trichloroacetate	x
1300-72-7	Sodium xylenesulfonate	x
10377-98-7	Sodium zirconium lactate	x
64742-88-7	Solvent naphtha (petroleum), medium aliph.	
64742-96-7	Solvent naphtha, petroleum, heavy aliph.	
64742-94-5	Solvent naphtha, petroleum, heavy arom.	
64742-95-6	Solvent naphtha, petroleum, light arom.	
8007-43-0	Sorbitan, (9Z)-9-octadecenoate (2:3)	x
1338-43-8	Sorbitan, mono-(9Z)-9-octadecenoate	x

9005-65-6	Sorbitan, mono-(9Z)-9-octadecenoate, poly(oxy-1,2ethanediyl) derivis.	x
9005-67-8	Sorbitan, monooctadecenoate, poly(oxy-1,2-ethanediyl) derivis.	x
26266-58-0	Sorbitan, tri-(9Z)-9-octadecenoate	x
10025-69-1	Stannous chloride dihydrate	x
9005-25-8	Starch	
68131-87-3	Steam cracked distillate, cyclodiene dimer, dicyclopentadiene polymer	
8052-41-3	Stoddard solvent	
10476-85-4	Strontium chloride	x
100-42-5	Styrene	x
57-50-1	Sucrose	x
5329-14-6	Sulfamic acid	x
14808-79-8	Sulfate	x
68201-64-9	Sulfomethylated quebracho	
68608-21-9	Sulfonic acids, C10-16-alkane, sodium salts	x
68439-57-6	Sulfonic acids, C14-16-alkane hydroxy and C14-16alkene, sodium salts	
61789-85-3	Sulfonic acids, petroleum	
68608-26-4	Sulfonic acids, petroleum, sodium salts	
7446-09-5*	Sulfur dioxide	x
7664-93-9	Sulfuric acid	x
68955-19-1	Sulfuric acid, mono-C12-18-alkyl esters, sodium salts	x
68187-17-7	Sulfuric acid, mono-C6-10-alkyl esters, ammonium salts	x
14807-96-6	Talc	
8002-26-4	Tall oil	
61791-36-4	Tall oil imidazoline	
68092-28-4	Tall oil, compound with diethanolamine	

65071-95-6	Tall oil, ethoxylated	
8016-81-7	Tall-oil pitch	
61790-60-1	Tallow alkyl amines acetate	
72480-70-7	Tar bases, quinoline derivatives, benzyl chloridequaternized	
68647-72-3	Terpenes and Terpenoids, sweet orange-oil	
8000-41-7	Terpineol	x
75-91-2	tert-Butyl hydroperoxide	x
614-45-9	tert-Butyl perbenzoate	x
12068-35-8	Tetra-calcium-alumino-ferrite	
629-59-4	Tetradecane	x
139-08-2	Tetradecyldimethylbenzylammonium chloride	x
112-60-7	Tetraethylene glycol	x
112-57-2	Tetraethylenepentamine	x
55566-30-8	Tetrakis(hydroxymethyl)phosphonium sulfate	x
681-84-5	Tetramethyl orthosilicate	x
75-57-0	Tetramethylammonium chloride	x
1762-95-4	Thiocyanic acid, ammonium salt	x
68-11-1	Thioglycolic acid	x
62-56-6	Thiourea	x
68527-49-1	Thiourea, polymer with formaldehyde and 1phenylethanone	x
68917-35-1	Thuja plicata donn ex. D. don leaf oil	
7772-99-8	Tin(II) chloride	x
13463-67-7	Titanium dioxide	x
36673-16-2	Titanium(4+) 2-[bis(2-hydroxyethyl)amino]ethanolate propan-2-olate (1:2:2)	x
74665-17-1	Titanium, iso-Pr alc. triethanolamine complexes	x
108-88-3	Toluene	x
126-73-8	Tributyl phosphate	x
81741-28-8	Tributyltetradecylphosphonium chloride	x
7758-87-4	Tricalcium phosphate	x

12168-85-3	Tricalcium silicate	x
87-90-1	Trichloroisocyanuric acid	x
629-50-5	Tridecane	x
102-71-6	Triethanolamine	x
68299-02-5	Triethanolamine hydroxyacetate	x
68131-71-5	Triethanolamine polyphosphate ester	x
77-93-0	Triethyl citrate	x
78-40-0	Triethyl phosphate	x
112-27-6	Triethylene glycol	x
112-24-3	Triethylenetetramine	x
122-20-3	Triisopropanolamine	x
14002-32-5	Trimethanolamine	x
121-43-7	Trimethyl borate	x
25551-13-7	Trimethylbenzene	x
7758-29-4	Triphosphoric acid, pentasodium salt	x
1317-95-9	Tripoli	x
6100-05-6*	Tripotassium citrate monohydrate	x
25498-49-1	Tripropylene glycol monomethyl ether	x
68-04-2	Trisodium citrate	x
6132-04-3*	Trisodium citrate dihydrate	x
150-38-9	Trisodium ethylenediaminetetraacetate	x
19019-43-3	Trisodium ethylenediaminetriacetate	x
7601-54-9	Trisodium phosphate	x
10101-89-0	Trisodium phosphate dodecahydrate	x
77-86-1	Tromethamine	x
73049-73-7	Tryptone	
1319-33-1	Ulexite	
1120-21-4	Undecane	x
57-13-6	Urea	x
1318-00-	Vermiculite	

9		
24937-78-8	Vinyl acetate ethylene copolymer	x
25038-72-6	Vinylidene chloride/methylacrylate copolymer	x
7732-18-5	Water	x
8042-47-5	White mineral oil, petroleum	
1330-20-7	Xylenes	x
8013-01-2*	Yeast extract	
7440-66-6	Zinc	x
3486-35-9	Zinc carbonate	x
7646-85-7	Zinc chloride	x
1314-13-2	Zinc oxide	x
13746-89-9	Zirconium nitrate	x
62010-10-0	Zirconium oxide sulfate	
7699-43-6	Zirconium oxychloride	x
21959-01-3	Zirconium(IV) chloride tetrahydrofuran complex	x
14644-61-2	Zirconium(IV) sulfate	x
197980-53-3	Zirconium, 1,1'-((2-((2-hydroxyethyl)(2hydroxypropyl)amino)ethyl)imino)bis(2-propanol) complexes	x
68909-34-2	Zirconium, acetate lactate oxo ammonium complexes	
174206-15-6	Zirconium, chloro hydroxy lactate oxo sodium complexes	
113184-20-6	Zirconium, hydroxylactate sodium complexes	
101033-44-7	Zirconium,tetrakis[2-[bis(2-hydroxyethyl)aminokN]ethanolato-kO]	x

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