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A COMMON SENSE GUIDE TO A BETTER UNDERSTANDING OF THE RISKS AND BENEFITS OF HYDRAULIC FRACTURING

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In its Thursday, December 9, 2011 edition, the Denver Post published an article concerning water wells in the vicinity of the Pavilion, Wyoming gas field. The article was entitled “Hydraulic Fracking Linked for First Time Groundwater Pollution”. Frank Smith, in his capacity as an organizer for the Western Colorado Congress, a self-defined environmental group, observed: “This could be a game changer”. The Denver Post in that article reported: “Hydraulic fracking … has been linked for the first time to groundwater pollution in a case near Pavilion, Wyoming”.[3]

The previous day, Diane Mitsch Bush in her capacity as the Chairperson of the Routt County Board of Commissioners noted:

> “… The more I study the issues, looking at case studies, data from quantitative studies such as the just released EPA initial findings on the monitoring wells in Pavilion, Wyoming, the more I realize how little we know and how much we need to know to adequately protect peoples’ health, water quality and quantity, air quality, soils, agricultural operations, neighbors’ private property rights, visuals and our tourism amenities/tourism economy, among other issues…”

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[3] In a harbinger of things to come later in this paper, Encana, the well operator asserted that the EPA “… made mistakes and misjudgments at almost every step of the process”. Encana claims the chemicals in question are actually from those used in those same wells, but that the presence of these chemicals date back to the 1960’s.

No one seriously disputes the notion that good decisions are a product of better information. The purpose of this paper is to attempt to provide information to the general public for their consideration and digestion concerning a multitude of issues involving hydraulic fracking, often referred to in this paper as simply "fracking"[4]. This paper is an attempt to bridge the considerable gap between technical information used by industry professionals, which tend to be far too complicated for general consumption and gross simplification advanced with equal impunity by both the oil and gas industry and those vehemently opposed to fracking.

As one will read, fracking is not itself a drilling process. Fracking occurs after a drilled hole has been completed. We introduce the reader to the process of fracking by stating one fracks a well to stimulate oil and/or gas production. Specifically prepared fluids are injected (in effect, pumped) into a wellbore with substantial pressure to fracture (in effect, crack) a formation so as to allow oil and/or gas to flow more readily into a wellbore.

We will start by providing general insights into the fracking dispute, then some history of fracking itself including moving to an overall explanation of how fracking is accomplished, next providing some information about fracking complications that have been observed to date, and concluding with a discussion as to ongoing litigation involving fracking as well as some of our own general observations. As one might expect, this paper is not meant to provide a conclusive treatment of all the multitude of issues that arise or may arise from this controversial topic. Rather, it is hoped that this paper provides a point of departure for future analysis of these and other issues by a more knowledgeable reader.

Lastly, try not to be frustrated by the author's attempt to gradually introduce information so that the basics of fracking can be understood. Part of the paper is intentionally repetitive because this is an attempt to educate the reader by building knowledge through a gradual, but redundant process of exposure and explanation.

STRICKING A BALANCE IN DRAFTING THIS PAPER

The sheer volume of available information as to fracking is formidable. On November 3, 2011, the EPA announced its Final Study Plan to Assess Hydraulic Fracturing. This document is 174 pages in length. The Future of Natural Gas, an Inter-Disciplinary Massachusetts Institute of Technology ("MIT") Study copyrighted in 2010 is some 79 pages. These papers are just the "tip of the iceberg" as to information that is available. The point of these authors is that to expect any reader to dedicate significant amounts of time to reviewing available literature - some of which are very misleading - is unrealistic.

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[4] Depending on the source, one sees this also referred to as "fracing". For no good reason, these authors simply use fracking. Although either spelling–fracking or fracing-is acceptable. In fairness, industry tends to use "fracing". However, such can cause difficulty for the uninformed as to how that is pronounced. The use of "fracking" avoids the problem of pronunciation. Here, this paper uses "fracking" (rhymes with "packing").

What is attempted here is the drafting of a paper to acquaint a reader with an adequate understanding of technical issues and analysis concerning fracking without being over-burdened by the sheer volume or complexity of the same. As a result, there are many topics that might otherwise be meritorious of inclusion that are entirely omitted and other issues that no doubt do not receive adequate attention. That which is treated in this paper is done in a fashion to make individuals knowledgeable, but this paper is not by any means comprehensive. One of the core philosophies in the drafting of this paper is to attempt to provide unbiased information to the reader. As already referenced, this paper is not intended to be an exclusive treatment of all of the issues that are raised or could have been raised about fracking.

COMMENTS ON INCREASING MILITANCY IN THE FRACKING DISPUTE

The ultimate complication that these authors encounter is that the public relations pertaining to fracking have become poisonous to the point where securing accurate or reliable information of the topic is becoming increasingly difficult. Opposition to fracking has resulted in the oil and gas industry adopting a wide breadth of public relations tactics to minimize and counter balance growing fears (in some instances hysteria) about fracking. A senior executive at Anadarko was not long ago recorded on tape stating: "… download the U.S. Army/Marine Corp Counterinsurgency Manual, because we are dealing with an insurgency" while referring to opponents of fracking.

A spokesman for Range Resources readily admitted to his organization employing psychological warfare operations veterans from the U.S. military. These individuals were specifically hired to take experience derived during the wars in Iraq and Afghanistan so as to incorporate these same "psych-ops" type tactics in Pennsylvania. The objective of Range Resources in attending local meetings and advising local officials in the drafting and consideration of oil and gas regulations and ordinances was to incorporate mass psychology tactics while addressing fracking. To presume this type of extreme partisanship would not be happening elsewhere is almost certainly naïve.

Where does this type of partisanship end? While not a significant oil and gas producer, France entirely banned hydraulic fracturing in 2011. There is no doubt that there exist individuals and organizations committed to obtaining that same result in the United States.

COMPLICATIONS RESULTING FROM FRACKING: PRELUDE TO A CONTROVERSY

An untold number of claims have been made alleging that hydraulic fracturing has contaminated the private water wells and other domestic groundwater resources. Certain landowners in close proximity to shale gas operations have reported unpleasant odors, salting of waterways, discoloration of water, the unexplained appearance of natural gas, and the presence in water and soils of chemicals such as benzene, mercury, naphthalene, and selenium. A common complication in analyzing these circumstances involves the fact that some of that being observed may not be the result of any new drilling (whether horizontal or vertical) or fracking. In impacted areas where there has been a history of industrial activity, including mining, there rarely exist any reliable historic baseline data to evaluate the source of the existence of these chemicals. Thus, industry and regulators have found it difficult to distinguish between pre-existing contamination with that of new contamination; the latter being directly traceable to hydraulic fracking. Any attempt at gathering baseline data has been further complicated by the reality that many wells, particularly those located in more rural areas, tend to be privately owned. There exists a very limited ability of most local, state, or federal agencies to conduct even rudimentary baseline studies to provide data as they have no access to the land or water in question absent consent of owners[5]. Likewise, there often is not a direct relationship between pollutants associated with hydraulic fracking and those same or similar pollutants who have as a source one which is not fracking. In many instances what is observed in waterways may be accounted for as a result of a multitude of alternate migratory pathways for those same pollutants that reach effected water supplies which have nothing to do with fracking. The possibility exists that the same chemicals found in fracking fluid that are found in contaminated waterways can be explained by alternative sources.

AN EXAMPLE OF THE COMPLEXITY

Even the significance of the presence of such an abundant natural gas such as methane[6] can be very difficult to analyze. Duke University researchers began investigating the presence of unusually high methane levels contained in drinking water near shale gas wells located in Pennsylvania and New York. The methane found in those targeted wells possessed a similar geochemical makeup to that found in shale gas reservoirs, opposed to the geochemical makeup of the methane found naturally in these shallow waters. However, these researchers were not able to identify any exact pathway leading to a scientifically reliable conclusion that methane contamination had occurred as a result of fracking. They could not conclude whether in this case the methane found in that drinking water migrated as a result of leaky oil well casings. These scientists were not able to determine whether any migration of methane had as a point of origin a depth associated with hydraulic fracking[7].

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[5] PlikuMas, *et al*, Considering Shale Gas Extraction in North Carolina: Lessons from Other States, p 4. On the afternoon of March 6, 2012 it was called to the attention of Ralph A. Cantafio that the earlier version of this paper did not properly attribute work and research provided by these authors by either citation or reference. This allegation correct and effort was made to immediately correct the same. Initially, this omission was the fault of Mr. Cantafio and NOT his co-author. For this mistake, for which there is no good excuse, a personal apology is provided to Ms. PlikuMas, Ms. Pearson, Mr. Jonas, Mr. Vegosh, and Mr. Jackson.

[6] Methane is a chemical compound with a chemical formula CH_4. It is the principal component of natural gas. However, the specific molecular composition of natural gas is not as simple as that of methane. The precise molecular composition of any given natural gas is quite diverse.

[7] PlikuMas, *et al*, *supra*, at p 6.

While we tend to think that "methane is methane", from the point of view of the chemical analysis of natural gas, that is not true. Natural gas actually describes a host of chemical structures that involve the CH_4 molecular structure and are said to be members of the methane family. Ultimately, the Duke University researchers were unable to conclude to any level of confidence that the drinking water in question was contaminated as a result of fracking.

EXEMPTION FROM THE SAFE DRINKING WATER ACT

Indeed, induced hydraulic fracturing by its very nature reaches into natural gas and oil formations far deep beneath the earth's surface, generally to a depth of 5,000 feet (when producing oil) to 20,000 feet (when producing gas). This 15,000 foot range equates to a distance close to three miles. A point of contention between industry representatives and detractors includes the fact that the process of hydraulic fracking for the purpose of oil, natural gas, and geothermal production was specifically exempted under the Safe Drinking Water Act. This exclusion in large part was based upon the theory that drinking water is not obtained at the depths natural gas and oil is explored. However, critics complain that this exemption was of a political, not scientific, consequence.

The Energy Policy Act of 2005 has what is specifically and decisively referred to as the "Halliburton Loophole". This reference is made because of the perceived involvement of former Vice President Dick Cheney in securing this exemption. Mr. Cheney was a former Halliburton Chief Executive Officer. As critics emphasize, the 2005 exemption is environmentally offensive not only because of the perceived direct relationship between fracking and possible drinking water pollution, but more succinctly (and as will be explained in this paper) because of the significant risk to drinking water resulting from the handling and treatment of wastewaters produced by the fracking process.

POTENTIAL SOURCES OF GROUNDWATER CONTAMINATON

It is important to understand that groundwater contamination is not solely a result of the injection of threatening chemicals far below the earth's surface into shale rock formations. No doubt, these deeper water aquifers found thousands of feet below the earth's surface are well beneath any domestic water reserves. However, complications arise not only from the direct, but the indirect. Above and beyond the discussion included hereafter as to injection waters and flow back, it is believed by certain critics that it is wastewater evaporation ponds and poorly constructed pipelines, among other structures responsible for moving wastewater and chemicals to processing facilities, which create a significant number of points of potential contamination to water and soil.

Evaporation ponds by their nature and design allow chemicals, some volatile, to evaporate directly into the atmosphere. Particularly after heavy rains, these ponds can overflow with runoff migrating into groundwater systems. There is also the concern as to the integrity of poorly constructed pipelines transporting wastewater to water treatment plants. These pipelines can leak or potentially all together fail allowing wastewater and fracking chemicals to flow dangerously into groundwater systems. Even removal of wastewater by trucks allow for the possibility of contaminating substances being lost as a result of motor vehicle accidents or any number of garden variety of mishaps.

FRACKING AND THE CREATION OF MIGRATORY PATHWAYS

Irrespective of the potential of contamination to groundwater wells, it is the objective of fracking to improve and create migratory pathways. The following will make more sense later in this paper, but to introduce the concept, it is a lack of porosity[8] and permeability[9] in a native state which does not allow adequate volumes of natural gas or oil to migrate from rock traps into the wellbore[10] so that adequate amounts of gas or oil can be captured that result in the need for fracking. Fracking is used to create conductive fractures so as to offset the low natural permeability of formations with low porosity and permeability such as shale. It is these enhanced fractures that provide a conductive pathway creating a larger reservoir area so as to replenish the well increasing productivity and, hence, profitability. Fracking is all about creating new and better pathways. While these pathways can be a benefit as you will see they can also have potential environmental costs.

A SUMMARY OF THE FRACKING PROCESS

Generally speaking, a hydraulic fracture is created by pumping fracturing fluid into the wellbore at a rate sufficient to increase down-hole pressure to exceed the natural pressure otherwise found in the rock formation in question. These fracking fluids being introduced at high pressure crack the rock compromising the formation with a goal to have fracture fluids migrating deeper into the rock further widening and extending existing cracks creating a more significant flow. The introduction of fracking fluids into a targeted formation also creates new cracks. As one might expect, merely creating a more significant fracture in a formation is not a long term solution to the problem of lack of porosity and permeability in that formation. Once these fractures are opened and the initial injection ends, a solid propellant or “proppant”, typically emphasizing ground sand, is among other substances next added to the fracking fluid. This “propped fracture” or the widening of the existing fractures is now sufficiently permeable to allow the increased flow of gas or fluids. The embedding of a proppant permanently allows these fractures to remain open thereafter.

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[8] Porosity is also referred to as void fracture and is a measure of the empty spaces in material, typically as a fraction of the void over the total volume. One may think of this as the Swiss cheese holes in Swiss cheese.

[9] Permeability is a measure of the ability of porous material (like rock) to allow fluids or gas to pass through that porous material.

[10] The wellbore is simply the hole drilled by the bit.

To provide a preview of that later explained in this paper, the precise location of the actual fracturing along the length of the wellbore is controlled by inserting composite plugs, referred to as “bridge plugs”, above and below the fractured region. These bridge plugs allow a borehole to be systemically fractured along the length of the bore without allowing fluid to leak into previously fractured regions. Additional fluant and proppant are routinely introduced to the working region through piping and the upper plug. This method is referred to as “plug and perf”.

DRILLING, WELL CASING, AND CEMENT

While it is clearly important to understand the well injection process used in fracking, it is also important to understand at a minimum rudimentary level how cement casing is introduced into the well for the purpose of, among other things, protection of the soils and water adjacent to the well.

The target of drilling is referred to as a pay zone. The bottom of a well is referred to as the borehole. A drill bit is connected to surface equipment through the drill pipe. A drill bit will be lowered to the borehole. Drilling mud is fed to the bottom of the borehole through a heavy walled tube. Drilling mud is a specialized mix generally made of fluids and solids used in drilling the wellbore. The drill bit is manipulated downward in a vertical well and sideways in a horizontal well until drilling is completed.

The well itself consists of casing strings. One can think of this as a set of smaller straws inside large straws. These casings fit one inside the other and go down to different depths for different purposes. These casing strings are an essential component of well completion. Casings are utilized to isolate and separate groundwater from fresh water, from fracking fluid, etc.

While the casing is important to the integrity of a well, so too is the cement. Proper sealing by cement afford vertical and horizontal barriers controlling a host of fluid migrations. The initial cement treatment is important in preventing fluid movement from deeper zones into groundwater.

As to fracking, production casing is perforated so as to accommodate the injection of frack fluids through the casing and into the formation. These perforations (holes) allow the injected fluid to enter the target formation to frack that formation. Formations can be fractured in either a single stage or in multiple stages. In a multistage frack, the frack operation typically begins with the stage furthest from the wellhead and works its way backward until an entire length of fracture zone has been completed.

FRACKING AND NATURAL GAS

As the reader should now appreciate, fracking is the utilization of materials mixed into fluid so as to create, restore or enlarge fractures in a geological formation to stimulate production of oil and gas by creating either new or larger pathways for the purpose of increasing the rate at which oil and gas can be extracted from its reservoir formation. While this fracking process has only recently received significant attention, it has been around for over 60 years. Depending on the rendition preferred, the first successful commercial fracking was achieved in either the Hugoton Field located in Kansas in 1946 or outside of Duncan, Oklahoma in 1949.

A SHORT HISTORY OF FRACKING

The history of fracking as such applies to our current chapter of oil and gas extraction leads to a Houston oil and gas producer by the name of George P. Mitchell. A graduate of Texas A&M University, George Mitchell was the President of an oil and gas business known as Mitchell Energy. It had as its humble origin beginning in a one room office located over a Houston drug store. Over the course of decades, Mr. Mitchell developed his business into, at the bare minimum, a regional power.

Through the early 1980's, geological analysis emphasized that while natural gas could typically be located in traditional reservoirs, there were also vast quantities of natural gas trapped in shale rock. Unfortunately, this shale created a formidable barrier literally and figuratively to profitable development of these oil and gas resources. The problem as to physical extraction included permeability and porosity. This shale rock acted as a physical perimeter lying on top of natural gas trapping that same natural gas below, but also within. Fracking for oil as opposed to natural gas was not even seriously considered at that point in time as the emphasis was on the capture of natural gas. In fact, fracking for oil has been in vogue for only approximately a year now.

The most significant challenge in extracting natural gas from shale rock was initially the high cost. The cost of extracting natural gas from these formations far exceeded any anticipated financial benefit. However, this financial reality did not deter George Mitchell in any significant way. Mitchell focused on a region in and around Dallas and Fort Worth, Texas referred to as the "Barnett Shale". These earlier efforts of George Mitchell at fracking the Barrett Shale were systemically (and some say shockingly) unproductive. These initial attempts to locate natural gas liberating then from these shale formations proved highly unsuccessful. They resulted in the loss of millions of dollars to Mitchell Energy.

However, the law of unanticipated consequences was about to come into play. When the Carter administration in 1980 implemented what is referred to as the "Windfall Profit Tax Bill" in an effort to rein in what was thought to be obscene profits by oil companies resulting from the oil crisis of 1974 and 1979, this tax structuring included the "Section 29 Federal Tax Credit". The Windfall Profit Tax was generally seen by many to be punitive to the oil and gas industry. However, it is inarguable that the Section 29 Tax Credit was designed to provide financial stimulation and incentive so as to develop unconventional natural gas.[11]

"Unconventional gas reserves" refer and applied to the low permeability reservoirs that typically produce dry natural gas. These reserves can be found in sandstone, low permeability carbonates, shales, and coal bed methane. A vertical well drilled into an unconventional reservoir must be successfully stimulated to produce at adequate flow rates natural gas in commercial quantities. It is fracking that is used to stimulate these reservoirs and make them productive. The Committee on Global Oil and Gas of the Natural Petroleum Counsel has defined unconventional gas as: "Natural gas that cannot be produced at economic flow rate nor in the economic volumes of natural gas unless the well is stimulated by a large hydraulic fracture treatment, a horizontal wellbore, or by using multilateral wellbores or some other technique to expose more of the reservoir to the wellbore". Through the 1990's, this Section 29 Tax Credit provided financial incentive for development of and experimentation of unconventional natural gas techniques.

Mitchell Energy was not the only entity attempting to unlock profits from unconventional gas. Even with the advent of emerging technology such as 3D seismic studies, the mysteries of the subsurface of shale could not be yet solved to produce natural gas in paying quantities. There were many industry professionals at that time who thought accessing any commercially productive natural gas fields in the Barnett Shale was never going to be achieved. After several decades of research and development, Mitchell Energy had invested untold millions of dollars in exploring and developing Barnett Shale. Many were not at all confident that Mitchell was any closer to success after all that time and money than at the beginning.

The problem of not being able to adequately stimulate these low permeability reservoirs would be solved by hydraulic fracturing. Not by any means a new technique, fracking shale formations called for the injection of extremely large amounts of water thereby utilizing high pressure and combining that high pressure with sand and other chemicals so as to fracture or, more specifically, establish pathways that would allow otherwise trapped natural gas to find its way so as to be removed in bulk.

As 1998 came to a close, Mitchell Energy made a significant breakthrough known as Light Sand Fracking ("LSF"). Although successful in advancing fracking technology; it also now became clear to Mitchell Energy that the continued cost of production using LSF would be even more significant than even it had anticipated. What Mitchell found was that by injecting highly pressurized fracking fluid one created new pathways through rock increasing porosity and permeability. However, the new pathway did little good if that pathway soon thereafter was allowed to close. So as to not allow these fractures to

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[11] Conventional resources are ones that can be produced economically without assistance from stimulation treatments such as fracking because there exist natural pressure to allow for production at economic flow rates without assistance.

close, fracture width was maintained by the use of what is referred to as a "proppant". Here, the proppant consisted of copious amounts of light sand to increase flow by maintaining the increased porosity and permeability within the Barnett Shale without harming the formation itself. The fracking fluid contained light sand and it was that light sand that remained after fracking to keep newly formed and widened fractures open.

Mitchell Energy would continue to develop and improve its technology for more than another ten (10) years. However, when the amount of natural gas production of Mitchell Energy was noticed by a competitor out of Oklahoma City, Oklahoma known as Devon Energy ("Devon"), a new and more affluent player became involved in the development of fracking.

Devon had observed that Mitchell's production of natural gas had been increasing steadily through the late 1990's and into the new century. This increase in production was greater than that of competitors drilling in the same areas. Devon presumed that this increase of production was a direct consequence of success in fracking by Mitchell Energy. In 2002, Devon successfully acquired Mitchell Energy, in large part to purchase its fracking technology.

At that point, Devon Energy now added its own innovation above and beyond the fracking process. Mitchell Energy focused on traditional vertical drilling. Devon had its own specific and unique expertise in horizontal drilling. Unlike vertical drilling that went straight down into the ground, Devon had developed expertise in allowing its operators to first drill to a certain depth in a traditional vertical path, but to then move at an angle or sideways, thereby going "horizontal". Sometimes this horizontal drilling could go on for miles.

Upon purchasing the assets of Mitchell Energy primarily for its fracking expertise, Devon now combined the fracking expertise it had recently acquired from Mitchell Energy with its own expertise concerning horizontal drilling. By 2003, Devon was certain that it had successfully married its own expertise of horizontal drilling with the fracking expertise of Mitchell Energy. As a result, by 2003 Devon Energy itself was producing natural gas in significant volume in the Barnett Shale. Soon, other independent oil and gas companies took advantage of the same technology and began utilizing these same techniques in other areas and in other shale formations, most notably the Marcellus. Fracking with horizontal drilling that had been at first experimental had now become routine.

WHAT IS SHALE GAS[12]?

Conventional natural gas is extracted when gas migrates upward through the earth's surface from organic rich source rock ultimately becoming trapped by a layer of impermeable rock[13]. No stimulation is necessary with conventional natural gas because of adequate permeability and porosity. Existing pathways are sufficiently unencumbered since that natural pressure allows for the migration of gas. Traditionally, natural gas producers access this conventional natural gas by drilling vertical wells into the area where this natural gas is thought to be present. The same is true of oil. Drilling vertical wells alone with existing pressure allows natural gas to migrate to the surface[14].

Unlike these traditional natural gas reserves, unconventional natural gas reserves, including shale gas reserves, are contained within the relatively impermeable, low porosity source rock that interferes with the natural gas migrating out of the source rock into a traditional reservoir where the natural gas accumulates and can then be easily accessed by drillers[15].

AN OVERVEIW OF HORIZONTAL DRILLING

To drill and fracture a shale gas reserve, operators begin by drilling vertically until they reach a known shale formation[16]. Once reaching the targeted formation, the operators next manipulate the drill bit to drill horizontally ultimately establishing lateral wells throughout the shale rock. Thus, instead of going vertically into a formation accessing the (for lack of a better term) height of the same, the pipe can be set horizontally parallel to the formation vastly increasing the contact of the well. This allows the well bore to run parallel with the formation and can increase production by a factor of up to 20%. To give an example, in the Marcellus shale formation after first drilling vertically, a horizontal well may then extend an additional 2,000-6,000 feet and at times approach 10,000 feet. Once this horizontal well is completed, the producers next inject (i.e. pump) fracturing fluids into the drilled area at an allocated pressure to fracture the rock formation. It is these fractures that allow natural gas to better flow from their place of origin into the part of the formation now accessible to the well. One can thus see why fracking is itself not a drilling process.

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[12] It merits noting that this paper addresses the recovery of oil and gas from unconventional reserves - primarily shale. This is not to be confused with what is referred to as "shale oil". Shale oil generally speaking involves the consumption of the shale itself to create oil. In this paper we are talking about the extraction of oil and gas from shale formations not the process of converting shale itself into oil.

[13] PlikuMas, *et al*, *supra*, at p. 3, citing U.S. Energy Information Administration Energy in Brief: What is Shale Gas and Why is it Important? http: www.eic.gov/energy_in_brief/about_shale_go.cfm, ("Energy In Brief").

[14] If the reader is having difficulty with this concept, think of the example of gas that is let out when opening a can or bottle of soda pop.

[15] PlikuMas, *et al*, *supra*, at p. 3, also city "Energy in Brief".

[16] PlikuMas, *et al*, *supra*, at p. 4.

A SUMMARY OF THE INJECTION PROCESS

The fracturing process itself includes a series of injections typically using different volumes and compositions of frack fluids. On occasion, a test fracking (or "test frack") may occur in determining reservoir properties so as to better design the fracture process, including the fluid used on a given well. The fracturing process begins by introducing frack fluid, typically without proppant, pumping the frack fluid violently down the well at high pressures to initiate the fracture. This initial fracture and the amount of pressure utilized will itself be based upon the depth and geological properties of the formation in question. These very technical issues and decisions as to the same are made by professional engineers. After this initial introduction of injection fluid, a frack fluid with proppant is next pumped in, typically in various doses and concentrations. This process of blending the frack fluid and proppant could be said to be the art of fracking. After this combination of frack fluid and proppant is pumped downward, water flush is used to flush out the frack fluid evacuating the desired amount of fluid (but not all) and leaving proppant. This evacuation of the frack fluid is known as flow back.

FRACKING FLUID 101

Fracturing fluid itself is customarily composed of up to 99% water. This precise composition of fracking fluid and the amount of water will vary depending upon the formation in question and the designer of the frack fluid. However, it is the other 1% of the fracking fluid that contains significant chemical additives. These additives include propping agents that are commonly referred to as proppants. Chemicals introduced in fracturing fluid include fracturing reducers, surfactants, gelling agents, scale inhibitors, pH adjusting agents, corrosion inhibitors, antibacterial agents, clay stabilizers, and others. It is the sand that remains behind after the flow back phase (as discussed throughout this paper) that allows the fractures to remain open after this original injection fluid introduction. Operators can at a later point also re-fracture a well so as to further stimulate the flow of natural gas or oil as such might be as necessary in the future[17].

TRENDS AS TO THE FREQUENCY OF FRACKING

The U.S. Energy Information Administration predicts an almost fourfold increase in shale gas production between 2009 and 2035. The potential economic implications of this increase in the production of shale gas are extremely significant. So too are its environmental and ecological implications. This increase in the frequency of fracking can be significantly attributed to these technological improvements in horizontal also know as directional drilling and hydraulic fracking. Evidence of this rapid expansion of shale gas extraction is best evidenced by the Marcellus Shale. In Pennsylvania alone, there

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[17] PlikuMas, *et al*, *supra*, at p. 4.

were 195 wells drilled in 2008, 768 wells drilled in 2009, and 1,386 wells drilled in 2010[18].

THE FRACKING WATER LIFECYCLE

A vast majority of the literature criticizing fracking involves a host of perceived environmental threats resulting from the use of water in the fracking process. Thus, it is important to understand this process of water use in fracking to gauge the weight of the various arguments advanced for and against fracking.

AMOUNT OF WATER USED IN FRACKING

The amount of water utilized in fracking in the first instance will be dependent upon a combination of variables[19]. These variables include the type of geological formation in question (coal bed methane, shale, or the type of sands), the drilling characteristics of the well in question (parameters such as the well depth and horizontal length, the specific fracking fluid properties being utilized, and the frack job design-to mention only a few). For instance, water requirements for fracking a coal bed methane formation without horizontal drilling range from 50,000 to 350,000 gallons per well. However, in shale plays which typically include horizontal drilling, the amount of water used is dramatically larger. These shale plays with fracking and horizontal drilling can consume from 2-4 million gallons of water per well. Ultimately, the location of the shale play itself, the depth of the formation, porosity as defined by percentage, organic content as defined by percentage, and the depth of fresh water will all impact the amount of water used in a given well.

These raw numbers alone can be somewhat deceptive. It is sometimes difficult to conceptually appreciate what these numbers of gallons mean in real terms. Perhaps the following will help. If one were to use as a yard stick a city of 50,000 people, the amount of water consumed in fracking the Barnett Shale alone is equivalent to what 60 cities of this size of 50,000 people utilize in a year. By way of a different example, this same amount of water used in fracking the Barnett Shale in a year is said to be equal to what would be used in a city of 2.5 million inhabitants also in a single year. A different study concludes that in examining solely the Barnett Shale, approximately 1.7% of the fresh water utilized by all domestic fracking related activity occurred here. Of course, fracking is not 100% consumption or water. As we shall see, much of the water used in this injection fluid is ultimately recaptured.

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[18] PlikuMas, *et al*, *supra*, at p. 4.

[19] There is a general rule of thumb of producing one barrel of oil for every three barrels of water used in fracking. A barrel contains 42 gallons.

IMPACT ON SOURCE WATERS

It is source water that is used to ultimately create fracking fluids that will be injected into a well. Source water is mixed with chemical additives to make fracking fluid. Above and beyond the obvious fact that these withdrawals of larger volumes of groundwater to create fracking fluid can in many instances lower water level aquifers and create other stress on historic water supplies, there are other resulting water impacts that are not so obvious.

It does not take too much imagination to realize that the removal of larger volumes of source water could stress drinking water supplies in drier areas where the volume of water located in aquifers or the recharge of surface water is very limited. The use of large volumes of water can also result in the lowering of water tables or over the course of time the exhaustion of certain drinking water aquifers. The decrease of stream flows could potentially decrease the volume of downstream water reservoirs in a negative way. Significant decline of water levels and aquifers might, where applicable, necessitate the utilization of pumps or the deepening of replacement wells. This phenomenon of declining water tables has already been reported outside of Shreveport, Louisiana. If nothing else, it is clear that the increased use of fracking causes traditional water management strategies to be reevaluated in even less arid areas.

Lowering water level aquifers can expose naturally occurring minerals that exist in oxygen rich environments causing them to undergo chemical changes that might impact the solubility and mobility of a given mineral found in the water. The degradation of traditionally rich oxygen environments can cause the saliantion of water potentially causing a fall of the proverbial molecular dominos resulting in chemical contamination. Lowered water tables may also inadvertently stimulate new or different bacteria growth potentially resulting in the change of the taste or odor of the water itself. The depletion of aquifers might also cause what is referred to as “upwelling”. Upwelling is a phenomenon where water existing at lower depths and other substances from deeper within a given aquifer (for instance methane from shallower deposits) are no longer dormant. These traditionally dormant waters with a different molecular makeup become an active part of the watershed leading to a potential chemical based destabilization of water, soils, and geological formations.

Withdrawals of large quantities of water from streams, lakes, and ponds can also significantly impact the hydrology and hydrodynamics of these water sources. One can easily imagine how the systematic taking of water from streams might alter the stream flow by changing that streams depth, velocity, or temperature. The removal of significant volumes of water in the face of a stable amount of existing chemicals also may reduce the ability of these waterways to dilute these existing chemicals thereby increasing the concentration of the same contaminants. This change in the reaction of water to existing chemicals can result in a stream historically being able to dilute contaminants to an acceptable level losing its absorption ability.

All of this change in the chemistry of streams and water ways does not even take into account the relationship between ground and surface water and the fact that these hydraulically connected waters impact each other. It can be fairly stated that anything that affects the quantity and quality of surface water at some level impacts the quality and quantity of groundwater and *vice versa*.

HOLDING OF SOURCE WATER

No matter how the water is ultimately stored, the source water itself usually originates from either ground or surface water. The means of transporting source water to a well site is site specific. In some areas, trucks are used to transport source water to the well site. Where topography or other factors allow, a network of pipelines may be installed to transfer source water from the source to the impoundment or frack tanks.

We know now that source water is the water treated with chemical additives that will ultimately become fracking fluid. So as to satisfy these large volume requirements of water, source water is customarily stored in 20,000 gallon portable steel tanks. These are called "frack tanks"[20]. These frack tanks are typically located on the well site. As an alternative, impoundments can be substituted instead of using fracking tanks. These impoundments can be large, lined ponds ranging often in capacity from 8 million gallons servicing 4-20 gas wells to 163 million gallons satisfying 1,200-2,000 gas wells.

THE COMPLICATION OF SURFACE SPILLS

A distinct and different threat of water contamination is not only created from the utilization of water in the injection and (as we shall soon see) the flow back processes, but the challenge of inevitable surface spills at or near well pads whether during mixing, injection, or flow back. It is important to recall that fracking fluids have two general purposes: (1) to create pressure to increase fractures; and (2) to introduce proppants into the fracture itself leaving the proppants after flow back to keep the fractures open. As set forth previously, chemical additives and proppants are mixed to create fracking fluids. While the precise composition of the fracking fluids are a science in and unto itself, the specific formula for the chemical additives and proppants used in any fracking fluid will depend upon any number of factors. These factors include the identity of the specific operator, the geology of the formation being fractured, the project objectives, and the like. These chemical additives to be used in the frack fluid are often stored in frack tanks on the well site and are ultimately blended with water and proppant prior to injection into the well. The process of mixing the injection fluid is closely monitored. Flow, pressure, density, temperature, and viscosity are typically measured before and

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[20] Frack tank is actually a fairly generic term for any steal storage tank used to hold liquids. A frack tank can be used to hold source water, with or without proppant or additives. Ultimately, the frack tank is typically connected to a hose or a pipeline to pump whatever fluid is being injected into the wellbore at high speed to open formations thereafter using the proppant to keep pathways open.

after mixing. High pressure water pumps then send this mixture from the “blender” injecting the fracking fluid into the well to commence fracking.

It becomes clear that larger fracking operations require extensive quantities of supplies, equipment, water, labor, and vehicles. This paper does not even attempt to discuss the financial burdens of fracking. The chemical components used in a fracking job independently and collectively each create their own risk of accidental release; including spills or leaks. Spills or leaks can occur from many obvious causes such as tank ruptures, impoundment failure, equipment malfunction, fluid overfill, human error, vandalism, or ground fire (to name only a few). Once inadvertently released, these fluids can potentially migrate into nearby surface or ground water. These fluids also might infiltrate soils. All in all, one can see that there are many ways in which these released fluids can potentially reach drinking water, both sooner or in the long term.

GEOGRAPHICAL IMPACT ON WATERUSE

The most significant variable as to the use of any specific amount of water in fracking is itself site specific. This specific amount of water is also based upon the area of the country where the drilling occurs. In more arid areas, such as the Bakken Shale in North Dakota, the utilization of approximately 5.5 billion gallons of water per year in the fracking process has created significant local concern. In less arid parts of the country where water is abundant, such as Pennsylvania (which is home to a large part of the Marcellus Shale), water use concerns have not so much focused on the large volume of water being used in the fracking process, but the rate at which water withdrawals drawn from smaller streams as well as headwaters potentially diminish supplies of drinking waters. As one might suspect, it is necessary to examine the environment indigenous to each site when analyzing these water related issues. Issues as to water consumption are different not only from region to region, but state to state, county to county, township to township, and section to section.

COMPLICATIONS RESULTING FROM INJECTION

Unfortunately, the injection process is not perfect. Complications can emerge because fractures extend beyond the target formation and reach elsewhere unexpectedly, including at times into adjacent aquifers. In addition, if the well casing or cement fails, particularly under the extreme pressure exerted during fracking, contaminates can migrate into unintended areas. Substances found beneath the earth’s surface may also be dissolved by the fracking fluid then flushed to the surface with the flow back. Hence, the flow back might include substances not found in the injection fluid yet still might be found in the flow back.

Well construction practices play a significant role in the fracking process. Numerous reports have concluded that improper well construction or improperly sealed wells have created inadvertent subsurface pathways. These inadvertent pathways can allow the migration of ground and surface water pollution by allowing unintended subsurface contaminate migration. There is also concern that the repeated fracking of wells over the course of a wells lifetime may result in a circumstance where fracking is tolerated without incident during initial injection or even subsequent injections, but problems arise from later injections.

THE INJECTION PHASE AND FLOW BACK

The shear amount of water being used in fracking requires significant thought, planning, and resources as to the recycling of water so as to accommodate flow back produced from the fracking process. As mentioned previously, after the injection phase there is next the flow back phase. There comes a point in time when the target formation is not capable of absorbing the frack fluid at a rate greater than injection. At that point, fractures have been established, injection is stopped and the water begins to “flow back” generally to the surface. It is the flow back phase that not only evacuates large amounts of water for the wellbore and areas adjacent to the same, but leave the proppants in the formation to allow pathways to remain open.

It needs to be understood that the rate of flow back is not even. Estimates as to the amount of fracking fluid that is recovered during the first two weeks after injection differ from well to well. Flow back recovery during this initial flow back phase ranges anywhere from 25-75% of the total amount of original fluid injected. This is quite a wide range. This rate of recovery of injected water depends on numerous variables. These variables include the formation in question and the actual flow back techniques utilized. In some instances, flow back water may be treated and reused for later fracking. As to reused flow back water, additional chemicals are introduced to the fracking fluid adding fresh water to compose new (one might think recycled) fracking solution. However, there exist significant challenges associated with reusing flow back waters.

These complications as to the reuse of flow back waters are in part a result of a high concentration of what is referred to as “TDS” (total dissolved solids) and other dissolved chemicals found in the flow back. These TDS’s can include calcium, magnesium, iron, barium, and strontium. TDS’s also include ions such as chloride, bicarbonate, phosphates, and sulfates. Recycled flow back water can at times be so concentrated with contaminates that the flow back water requires either outright disposal or reuse only after significant dilution. Issues as to flow back water have also provided opportunity for scientific creativity.

As an alternative to other forms of source water it has been suggested that acid mine drainage be used because of its lower TDS concentration makes such a potential source water for fracking. So too has the use of non-potable groundwater including brackish water, saline, and brine been contemplated as a replacement for source water. For the purposes of this paper, it is important to understand that the source water utilized for fracking may come from a variety of sources including groundwater, surface water, recycled flow back, or alternative forms.

RECOVERY OF FRACKING WATERS

The complications arising from water introduction, use and disposal during injection are immeasurable. However, injection after the introduction of fluid to the wellbore creates two separate sets of issue: (1) issues concerning the extracted flow back water and (2) issues involving injection water that is never recovered. No matter the volume of water drawn for fracking it is the reality that much of the water will never be recovered after its injection. Setting aside the fact that complete recovery of injection water is not practical; the environmental impact of the withdrawal of water is potentially significant. As one would expect, this environmental impact will vary from geographical area to geographical area. The impact of flow back water will be dependent upon its quantity, the quality as a matter of chemical composition, and the specific characteristics of the sources of water being used.

MIGRATION OF WATERS AND GEOLOGY

Existing geological features found in any given formation also create a host of variables. Fracking by its very nature embraces significant uncertainty as the precise location and extent of existing fractures in any given formation are not well qualified or quantified. There really exists no precise map of the formation being fracked. The same uncertainty is true as to the precise location of existing geological features (veins, water, etc.) and, in some instances, man-made features (old mine shafts, water wells, etc.). These existing features are not generally well known at the time of fracking. If fractures that are created during fracking extend into pre-existing and unforeseen faults or fractures, fracking has the potential to create an opportunity for fracking fluids, oil, natural gases being exploited as well as other naturally occurring substances to migrate; including into nearby aquifers.

It is a common presumption as to shale gas formations that the shale itself acts as natural protector of unintended migrations. These presumptions exist because the rock strata seals natural gas within the target formation preventing vertical migration of fracturing fluids. After all, it is the presence of these same rock strata that makes fracking necessary in the first place. In essence, it is thought that the same geological formations that create the need to frack to begin with by trapping natural gas simultaneously prohibits the uncontrolled migration of fracking fluids to the surface. It is further presumed that during production the flow direction of natural gas moves toward the wellbore as a result of decreasing pressure gradients (gas migrates from greater pressures to lesser pressures - think of what happens when one pops a balloon). These presumptions taken together result in a more global presumption that natural gas is unlikely to move outside of its designed pathway so long as the well is in operation and maintains its integrity. After all, natural gas is predicted to flow in a direction consistent with the intended well design to trap natural gas for production.

Unfortunately, natural gas does not always move where intended. This unanticipated movement of gas creates potential complications. Poorly constructed, sealed, or cemented wells in the presence of the unanticipated movement of gas create issues above and beyond those of mere design, but rather application. Such defects unwittingly can create conduits for methane gas migration into unintended areas, possibly impacting domestic water wells, soils, and other property.

THE SIGNIFICANCE OF THE DISCLOSURE OF CHEMICALS USED IN FRACKING

One also can easily see why the disclosure by industry as to the chemical contents of the exact fracking fluid used at each site is so fundamental as a matter of science to developing base information concerning assessment of any true dangers (or not) of these inevitable spills as well as the injection and flow back of the same into and from the wellbore. Without knowing the specific content of the fracking fluid being used in each well, it becomes difficult to correlate the finding of contaminants with nearby fracking. An ability to have at easy disposal the contents of fracking fluids not only gives the public peace of mind, but disclosure can protect industry from inaccurate or false claims. This lack of disclosure of core information is precisely the concern of many as to the unwillingness of industry, to until recently, to disclose their fracking solutions[21]. This failure to disclose by industry is especially troublesome because it is a bit difficult for much of the general public to accept that such information as to the content of fracking fluid might be proprietary. Whether such is or is not proprietary, however, somewhat misses the point.

What is important is the developing of a base of data so as to be able to examine the cause and effect of locating chemicals and contaminants by comparing those found to fracking solutions actually used. It is important to understand that this is not and never will be a perfect “one to one” relationship. There are many contaminants that may be part of a given fracking solution, but while the same contaminant may be found in nearby drinking water it might easily be the case that this same chemical is introduced from an entirely different source. The science of the contamination of soils and drinking water is extremely complex because there exist so many variables. However, where there exist certain “fingerprint” chemicals located in both drinking water and fracking solution such that where a correlation exists, such correlation should be allowed to be made.

The disclosure of not only the chemical, but physical properties of fracking additives can further assist in the identification of potential human health exposure pathways. Disclosure also allows an examination of the mobility of these chemical additives so as to study any potential chemical reactions associated with the same.

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[21] Colorado adopted hydraulic fracking fluid ingredient regulations effective April 1, 2012 requiring the disclosure of all chemicals, but also establishing a mechanism to protect proprietary information. The new regulation allows disclosure through the Frac Focus Website, which will be jointly operated by the Interstate Oil and Gas Compact Commission and the Ground Water Protection Council. The regulation also includes a provision to protect proprietary information requiring the filing of a form which includes contact information and an explanation of how the information constitutes a trade secret. Even in the case of withheld information, state officials, health professionals, and emergency responders can obtain the same.

IMPACT OF CHEMISTRY ON FRACKING FLUIDS

It is important to appreciate that chemicals do not exist in a static state. A chemical will act differently depending upon, for instance, its density. Density alone can influence a chemicals melting point, boiling point, flash point, and other characteristics. Just as density can alter the reactivity of chemicals, density impacts the reaction of chemicals when they are mixed with other chemicals. Because of the way chemicals interact with each other, there results a need for analysis as to how fracking fluid reacts with chemicals found in the formation as a result of increased or decreased pressure, modifications of diffusion coefficients, alterations to partition and distribution coefficients, and variations in solubility. All of these reactions will depend upon the presence of a given chemical in any given fracking fluid. While it is not the point of this paper to engage in extensive lecture on chemistry, the point is made that knowledge pertaining to the contents of fracking fluids creates at a bare minimum a significant base of information so as to engage in scientific examination of any number of these variables to better understand how chemicals act and react with each other and how these interactions may impact drinking water as well as soils.

As alluded to above, the injection of fracking fluid, and particularly the chemical additives used in the same, into these targeted geological formations as a matter of chemistry might cause changes in the chemical structure of both the injected chemicals themselves and the chemicals that naturally can be found in the subsurface. There exist a multitude of reasons for this change in molecular structure.

Certain chemicals may act differently in the presence of smaller water amounts than when large amounts of water are introduced. Further, certain chemicals may act as accelerants as a result of introduction to others causing a change in complex chemical interactions when they otherwise might not. This chemical reaction might impact not only the chemical process found in a given formation, but the physical and biological process as well.

THE COMPLICATION OF MIGRATING WATERS

As referenced above, once released into the environment, chemical additives found in fracking fluids have the potential to contaminate groundwater, surface water, and soils. It is important to emphasize the word potential. The specific path by which chemical additives may migrate from the point of its origin to its point of detection is very complex. Any migratory path will be dependent upon many specifics involving the site. These variables include the chemicals in question and a multitude of other fluid specific factors. Anyone who has drilled for domestic water benefitting a residence knows how uncertain that rather simple process can be. The process of searching for potable water several hundred feet below the surface pales as to complexity in comparison to the drilling of a vertical well, a horizontal well and then fracking the same. Not attempting to over simplify, but because there exist such a vast set of variables pertaining to the fracking process and the fluids used at any location, a great deal of anxiety has been created in the general public. There is so much information available that it at times is difficult for scientists, let alone a lay person, to adequately digest the subject matter.

THE FLOW BACK COMPLICATION

The conclusion of the injection phase does not result in a cessation of environmental threats. Flow back produces water with the potential for surface spills on or near well pads. After fracking, injection pressure is decreased so that the direction of flow fluids is ultimately reversed. This reversal of pressure allows fracking fluid along with absorbed naturally occurring chemical substances to flow back out of the wellbore returning to the surface after which the well is placed into production. This returned mix of fluids from a well to the surface is referred to as “flow back”.

The flow back includes some, but not all, of the injected waters. The recovery of injected waters is not 100% included in the waters captured in the flow back. By definition, the flow back is a mere subset of the injected fluids. Currently, there exists no monolithic definition that is generally recognized as to what waste water constitutes flow back. Also, the period of flow back precisely defining the end of the injection phase (which formally is the beginning of flow back) or the beginning of the production phase (formally concluding flow back) is likewise not universally defined. Such definition depends upon the differences found well-to-well and project-to-project. Further, the amount of time it takes for the flow back period to elapse also differs from well-to-well, as too does the amount of frack fluid recovered as flow back. It is fair to state this lack of uniform definitions makes quantification of the various phases very difficult.

Generally speaking, it seems to be universally accepted that the flow rate tends to be relatively high during the first few days of flow back, but then rapidly diminishes over the course of time. Hence, analysis is often undertaken making reference to points in time as defined by what is referred to as the fracking/production gradient. Because the production (extraction) process of natural gas itself also includes the presence of water, there exists no clear delineation between what constitutes flow back water as opposed to that of produced water[22]. The issue is further complicated because both flow back and produced water contain fracking fluid. They each also possess naturally occurring chemicals.

The actual physical and chemical properties of flow back and produced water will vary from well to well. Their properties will be dependent upon, among other things, the frack fluid composition, the geographical location of the well, and the geological formation. The properties of flow back water and produced water also will change over the course of time. As to the specific chemical properties present at a given time, the precise concentration of any chemical component found in flow back or produced water will change dependent upon where on the fracking/production gradient a sample in question is taken. No pun intended, but this is a most fluid of situations.

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[22] Produced water is generally considered to be the fluid that is used during oil and gas production.

STORAGE OF FLOW BACK AND PRODUCTION WATER

Both flow back and produced water from fracking operations are ultimately held in frack tanks or waste impoundment ponds prior to or during treatment, recycling, or disposal. Depending upon any number of circumstances, an impoundment may be either temporary or long term. The location of these impoundments and the specific characteristics of these impoundments are different from jurisdiction to jurisdiction.

To date, it remains significantly unclear as a statistical matter as to how often spills occur. Reporting requirements differ from state to state. Actual compliance with existing law is not really known either. Such general lack of compliance as well as a lack of incident information results in an incomplete database as to the severity of these spills and precisely what causes spills when they do occur. Hence, issues pertaining to impoundment and reservoir safety are somewhat murky at best at this point in time.

EXISTING CHEMICALS AND THE FORENSIC COMPLICATIONS

There also exist questions as to what extent flow back or produced water merely mirror naturally occurring chemicals, minerals and materials already present in any target formation and to what extent any reaction or degradation occurs as a result of fracking. There exists a significant body of scientific information pertaining to pH and TDS measurements, but far less is known at this point in time as to composition of flow back and produced water as such pertains to other chemical additives. The reaction or any degradation resulting from the introduction of fracking fluids or production fluids to existing environments is not at this time well understood.

Apparently, even far less is known as to the impact of the introduction of fracking fluid and production fluid on any radioactive materials. The specific composition of flow back and produced water itself varies from time to time and/or location to location. In other words, the specific chemical content of flow back in the first few days can be different several weeks later when flow back diminishes, as it inevitably does. Hence, determining how fracking and production fluids impact radioactive materials is difficult and is further complicated depending on the chemical composition of the fracking fluid and production fluids, the formation in question, and where at any point in time the process is on the fracking/production gradient.

Independent issues exist pertaining to the treatment of flow back waters. As mentioned previously, wastewaters inherent to the fracking process are typically managed through capture, treatment, and then followed by either discharge or reuse. Currently, regulation and actual best management practices of the disposal of fracking wastes varies from location to location. In turn, all of this is impacted by local and regional infrastructure development (for instance, the availability of water treatment facilities) as well as the geology, climate, and formation composition as to where the well in question is located. By way of example, water disposal issues impacting the Marcellus Shale where extraction often occurs at or near significant population centers would not be anticipated to be the same as to the fashion in which flow back would be disposed in the Barnett Shale. Likewise, the water conditions in the Williston Shale are different than that of the Barnett Shale. As such, it is important not to paint with too broad a brush pertaining to these disposal issues.

FRACKING IN THE NIOBRARA

As fracking pertains to Northwest Colorado, Southwest Wyoming and Eastern Utah the actual debate may be somewhat different as a result of the nature of the Niobrara Formation[23]. This distinction is very important.

The Niobrara Formation is actually referred to by geologists as the Niobrara Chalk. This is significant because fracking which utilizes significant amounts of water as such is applied elsewhere may not be productive in portions of the Niobrara Formation. In fact, it may be very counterproductive. Simply put, there is a very high likelihood that traditional fracking with the use of significant amounts of water might lead to the degradation of the Niobrara Chalk formations inhibiting the production of oil and gas as opposed to simulating increased production. Some history may assist.

Generally speaking, the Niobrara Chalk is a reminisce of what was once the Western Interior Seaway. The Western Interior Seaway is believed to be the inland sea that physically divided the North American continent during a period of time referred to by archeologists as the Late Cretaceous. That Seaway, which generally speaking spanned north and south if one were to draw a line through the United States and Southern Canada from western Colorado to eastern Nevada, ceased to exist and literally dried up. The resulting geological formations were created between 87 and 82 million years ago. The geological foundation that remains is generally composed of two structural layers. The Chalk itself was probably created from the accumulation of the coccoliths from micro-organisms once living then dying in the Western Interior Seaway. Archeology shows significant evidence of vertebrate life including plesiousaurs, mossasaurs, and pterosaurs as well as a multitude of primitive aquatic birds once inhabiting the area. The Niobrara Formation itself is overlain by the after created Marine Pierre Shale.

Unlike the Barnett Shale or the Marcellus Shale, the Niobrara Formation is much more delicate. It is important to further appreciate that notwithstanding the fact that this area was once a seaway, these areas are as a matter of more recent history relatively dry. The introduction of significant amounts of water it is believed by some might tend to do very little to create any increased yield of oil or natural gas. In the most simplistic way, the introduction of water would be like attempting to increase the porosity of baby powder by wetting it.

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[23] The Niobrara Chalk was first studied by Othniel Charles Marsh of Yale University in approximately 1870. Mr. Marsh conducted significant expeditions in 1871 and 1872 capturing significant fossil vertebrae remains.

Hence, the Niobrara Chalk potentially presents a very different environment when it comes to fracking.

Instead of using copious amounts of water to stimulate production, a blend of propane and butane can instead be injected into a shale formation. It is heat, not water, which increases porosity. As it is with injection water, most of this liquid petroleum and flammables that are injected would be expected to be recovered then resold or recycled for use in subsequent wells after flow back. This process is a vast departure from the traditional hydraulic fracking which would use millions of gallons of water mixed with chemicals and sand as described above and thereafter injected at high pressure into the earth to free otherwise trapped oil and gas reserves. An advantage of the use of propane and butane is that such perhaps avoids traditional fracking results inherent from the introduction of significant amounts of water some of which will be remaining trapped underground or otherwise having to be disposed of as contaminated waste water. By replacing water with propane, it is hoped by some that the Niobrara Chalk can be exploited for increased production without significant degradation of the Chalk based formations themselves. The relative environmental costs and benefits of that fracking are not well known at this point in time.

CURRENT SUPPLY AND DEMAND OF ENERGY

Currently, the United States imports approximately 11 million barrels of oil a day. Of this, approximately 41% is imported from OPEC Nations. It is against this backdrop that virtually all respected energy economists conclude that increased domestic production appears inevitable.

To date, some of the results in the Niobrara have been impressive. On November 16, 2011, Anadarko Petroleum Corporation provided an update as to its horizontal Niobrara and Codell Drilling Program from the Wattenberg Field located in Northeast Colorado. Anadarko reported production from 11 horizontal wells. The company announced:

> “Based upon the early results of Anadarko’s program in the Wattenberg Field, we are confident that the liquids rich horizontal Niobrara and Codell opportunity provides a net resource potential of 500 Million to 1.5 billion BOE (Barrels of Oil Equivalent); and is located in the heart of one of our existing core areas”.

Anadarko concluded:

> “Outside the Wattenberg Field, we are also exploring additional liquids rich horizontal opportunities where we hold another 550,000 net acres in the greater DJ Basin and 360 net acres in the Powder River Basin. Each area is perspective for horizontal

> Niobrara, as well as other horizons that we will evaluate over time".

It is little wonder that currently the U.S. Energy Information Administration is predicting a four-fold increase in shale gas production from that produced in 2009 to that anticipated in 2035. In 2009, according to the U.S. Energy Information Administration, approximately 14% of the United States natural gas came from shale. By 2035, this is projected to rise to 46%. Increased supply is not the only necessary examination of the overall formula. Demand for natural gas is also expected to dramatically increase.

However, it would be unwise to merely examine only the supply side of the curve pertaining to either oil or natural gas. Not only is there expected to be an increased reliance upon electricity produced utilizing natural gas, but there is hoped to be a significant conversion of motor vehicles using compressed natural gas.

On November 9, 2011, Oklahoma City, Oklahoma hosted the Governors Energy Conference. The focus on natural gas was significant. Governor Mary Fallon of Oklahoma announced in a joint pledge with Governor John Hickenlooper of Colorado to stock their respective states fleet of vehicles by those powered by compressed natural gas ("CNG"). Although the first generation of alternative energy cars is in its infancy, it is very clear that America's automakers are already in the midst of significant research and development so as to provide vehicles with additional options above and beyond petroleum as to their source of fuel. Alternative energy as a source of fueling motor vehicles is currently hindered by many things, not the least of which is the lack of supply. It is hard for many to be enthused as to a car powered by CNG when there are so few stations that provide this fuel. The entire CNG refueling system is in its infancy, but the energy industry is expected and is already engaged in planning to make significant strides in the upcoming years and decades so as to provide adequate facilities to service such vehicles.

Gas stations as we know them are not going away anytime soon. However, they may offer a vastly different selection of products in future years than from today.

THE CRITICISM OF FRACKING

The entire process of fracking has undergone increased scrutiny. This scrutiny is anticipated to only intensify. To date, fracturing discharge has been blamed for contaminating drinking water in Arkansas, Colorado, Louisiana, New York, Pennsylvania, Texas, and West Virginia. As a consequence of fracking and its using large volumes of water, there is ongoing intense evaluation of the injection of these large volumes of water, flow back, production, and treatment all as inherent parts of the fracking process. It is claimed by some that flow back waters contain trace amounts of dangerous chemicals that seep into nearby groundwater thereby polluting drinking water creating unnecessary risk to long term health. Currently, many states are examining their regulatory practices so as to adequately balance responsible production of oil and gas, on the one hand, with the protection of the general population, on the other. As things now stand, the United States Congress has issued a directive to the United States Environmental Protection Agency to assess whether or not fracking poses a risk to drinking water. The EPA this past summer produced its draft study which is now being reviewed by the EPA Science Advisory Board. It is anticipated that the initial review of the study will be available in 2012.

A SHORT OVERVIEW OF FRACKING RELATED TO LITIGATION

In the absence of any strict regulation of the fracking process, there have emerged a series of lawsuits focusing on purported water contamination resulting from fracking. The typical dynamic of these litigations involves claims by landowners requesting damages from those operating the well sites. A common fact pattern as alleged in these lawsuits involves accusations that the fracking process has polluted groundwater or drinking water resulting in serious health problems to a plaintiff group. Many of these lawsuits include claims of negligence. Those lawsuits assert that chemical exposure to Plaintiffs has resulted from improper cementing and defective protective casing of the well, not to mention violation of applicable state law. In addition, Plaintiffs sometimes seek injunctive relief which would result in immediate Court ordered cessation of fracturing by the companies in question. Damages sought include requests for compensation for damage to real and personal property, reduction of property value, the loss of the use and enjoyment of the property, and general damage to water sources. In certain cases, Plaintiffs have not only alleged property damage, as set forth above, but also damages related to physical injury. These claims of physical injury can be very tricky to prove because as we know from, by way of example, Agent Orange or tobacco litigation, there typically exists an extended latency period between the exposure to the chemicals in question and that long period of time before any known impact on an individual is actually perceived. To date, this author is not aware of any successful claim for damages involving personal injury as a result of fracking[24].

Certain of the theories of litigation are impressively creative. Recently, five residents of Arkansas filed a class action lawsuit against various energy companies claiming that fracking of wells in Arkansas caused several recent minor earthquakes in that area. These Plaintiffs claim that since September 10, 2010 that region of the country, which is not typically prone to any significant seismic activity, has experienced approximately 599 seismic events. These events include a magnitude 4.7 earthquake which is reputed to be the largest that has hit the state in some 35 years. Interestingly, on March 4, 2011, the Arkansas Oil & Gas Commission ordered a temporary cessation of the fracking of wells to investigate the cause of these earthquakes. Energy companies argue that the earthquakes were merely coincidental and in any event were nothing more than typical

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[24] While in no fashion endorsing the same, an example of a website focusing upon such litigation is the Fracking Lawsuit News at www.fracking-lawsuit.com.

seismic activity. Critics noted that in the week immediately following this moratorium, while these earthquakes did occur they did not occur with the same frequency[25].

SUMMARY OF THE SCIENCE OF FRACKING

Whether or not the reader is able to digest all of this information, it is hopefully clear that a scientific understanding of the impact upon water and soils by the fracking process and production is a combination of many different disciplines. The sciences of biology, chemistry, bio-chemistry, and physics (not to mention others) all have a place in the conversation. In addition, the specific location of any given well has a tremendous impact on the specific issues associated with that well. Variables include everything from the volume of water introduced so as to accomplish the fracking, the volume of flow back, the formation, the precise chemical composition of the fracking fluid, the identity of proppant utilized, and … well, one could go on and on.

SUMMARY OF THE ROLE OF COMPLEXITIES

The most important concept the authors hope to communicate to our readers is to have the reader appreciate that the mere presence of contaminants does not alone result in the conclusion that this presence is the result of fracking. However, in these cases one cannot blindly exclude fracking as a potential cause either. There is just more that needs to be learned in each case. What the authors are hoping to accomplish is that the reader will as a result of this paper have a sense as to whether information, irrespective of the source, is inherently reliable or not.

CONCLUSION

Energy Policy is complicated. Importing oil from the Mid-East brings with it a host of negative consequences - economic, political, cultural, etc. However, while domestic self-reliance sounds great in the abstract, there are a host of costs and benefits that are encountered wherever there is domestic development and extraction of oil and gas.

The reality is that the oil and gas business is environmentally risky. However, before anyone gets too carried away, so too is driving a car risky. The authors point this out because everyone personally knows someone either killed or seriously injured in a motor vehicle accident. However, virtually all of us drive.

Risks must be controlled and minimized. However, the process of risk management takes time and has its own course of evolution. Accepting risk is part of the human

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[25] Of course, to those of us in Colorado the ultimate “fracking” was attempted by the United States in what is known as “Project Rulison”. To stimulate oil and gas production, a nuclear weapon was detonated outside of Rulison, Colorado in November 1969. Project Rulison is no doubt a topic worthy of its own paper.

experience. The goal in fracking, as with any endeavor, is to manage and minimize risk. Eliminating risk is impossible. Establishing what are and are not appropriate risks is essential. However, the cost of entirely avoiding risk as some advocate by the elimination of fracking may be a cost that is much, much higher than moving forward while embracing education and innovation so as to over the course of time systematically reduce and manage risk[26].

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