PARTIAL LITERATURE AND WEB RESOURCES REVIEW OF TECHNICAL AND RESOURCE ISSUES SURROUNDING HYDRAULIC FRACTURING OF HYDROCARBON RESERVOIRS

DRAFT DATE 11/6/13

The information in this document was compiled from Web resources by Dr David Chipping, Environmental Alternate on the SLO County Water Resources Advisory Committee (WRAC). It is intended as a general reference to existing information, and does not reflect any position taken by WRAC or any recommendations. A companion white paper addresses regulatory issues. Additional information and corrections are welcome and can be directed to Dr Chipping (dchippin@calpoly.edu).

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PART 1 FRACKING AND ITS REGULATION IN CALIFORNIA

What is "Fracking" or Hydraulic Fracturing? (Sources on the Nature of the Process)

The process essentially involves drilling into an otherwise impermeable geologic formation and injecting a high pressure mixture of water, chemicals and sand-like "propants" that both creates cracks in the bedrock around the well bore and props those cracks open with the injected sand.

The process is described at many internet sites, including the following. Wikepedia's treatment is fairly extensive but is an 'open source' document. The first part on the process is extensive. http://en.wikipedia.org/wiki/Hydraulic_fracturing E.P.A. offers background information at http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/wells_hydrowhat.cfm If you like it in pictures: (http://www.propublica.org/special/hydraulic-fracturing-national) Another good site with plenty of information, but nothing specific to California, can be found at: http://fracfocus.org/hydraulic-fracturing-how-it-works/hydraulic-fracturing-process I would also recommend the Science News article "The facts behind The Frack" at http://www.sciencenews.org/view/feature/id/343202/title/The_Facts_Behind_the_Frack

Does "Fracking" take place in California now?

The DOGGR information page "Hydraulic Fracturing in California" makes the point that the process is a standard procedure in well completion in California, but is conducted at hydraulic pressures less than that which would result in the fracture of overlying

caprock. The quote is:
"In California, most oil and natural gas reservoirs are "conventional." That is, the reservoirs are found in layers of underground rock ("reservoir rock") beneath a layer of less permeable rock ("cap rock"). Over millennia, this less permeable cap rock trapped the oil and natural gas in the reservoir rock; without the cap rock, the oil and natural gas likely would have seeped to the surface long ago. These conventional reservoirs typically were under pressure. When they were first tapped, many would have had a natural "artesian" flow to the surface through the wells. Some would even have appeared as "gushers." Today, after recovery of some of the reservoirs' hydrocarbons, most of California's oil and gas reservoirs require some form of stimulation to flow.

One way to stimulate flow is to fracture the rocks in the reservoir, creating channels through which the oil and/or natural gas can reach the well. The fluids are injected into the reservoir at high enough pressures to cause breaks in the reservoir rock. This type of hydraulic fracturing is conducted below the pressure at which the cap rock would fracture. This practice not only complies with Division regulations to protect groundwater and public health and safety, but is also common-sense practice for the oil producer. No producer wants to take a chance on breaking the cap rock because doing so can cause a loss of production capacity from the reservoir.

In some other parts of the United States, natural gas is trapped not in a reservoir protected by cap rock, but inside uncapped rock formations. In these "unconventional" cases, hydraulic fracturing is necessary to free the resource for production. Unconventional natural gas resources are common in places like the East Coast's Marcellus Shale gas deposits. The Marcellus Shale covers parts of New York, Pennsylvania, Ohio, Maryland, Virginia and West Virginia. In California, by contrast, hydraulic fracturing is principally a means of ensuring that individual, conventional wells attain maximum production, often a preferable alternative to drilling additional wells to produce the same resources.

There are other differences between the typical use of hydraulic fracturing in California and elsewhere. For instance, in other states the extraction of unconventional natural gas resources requires lengthy fracturing periods along lengthy stretches of horizontally-drilled production wells. Millions of gallons of water are injected under constant pressure, a process that may take days or weeks in order to effectively open the reservoir rock. In California, much less water is used and the period of pressurizing the reservoir rock is much shorter. In other states, the extent of fracturing in unconventional rock stretches for hundreds of yards along the horizontal well and the fractures stretch farther away from the well. In California, fracturing projects tend to use far less fluid to fracture within a narrow vertical band along a well, generally starting at a point several thousand feet underground, with the fractures extending only tens to hundreds of feet away from the well.
"

http://www.conservation.ca.gov/dog/general_information/Pages/HydraulicFracturing.aspx

KQED Public TV Station notes a report by the Environmental Working Group that is fully referenced. The EWG report has many quotes from industry literature that shows that 'fracking' is common. For example the following references Chevron operations in the Lost Hills Oil Field. Citation numbers are from the EWG document.

"A decade later, Chevron Corp. scientists wrote that as of July 1, 1994, "over 2,000 fracture stages have been performed during the completion of over 600 wells" in California's Lost Hills field, an area that was not subjected to much fracking until the mid-to-late 1980s. [13, 14, 15] The article said fracking had become more than commonplace, stating: "Massive hydraulic fracturing treatments… are an integral part of developing these reserves." [16] That same year, an industry publication reported that Chevron and Dowell Co. performed a world record "frac" in the Lost Hills, pumping 2.97 million pounds of sand proppant into a single well. [17]"

The EWG document "CALIFORNIA REGULATORS: SEE NO FRACKING, SPEAK NO FRACKING has 60 citations and can be found at http://static.ewg.org/reports/2012/fracking/ca_fracking/ca_regulators_see_no_fracking.pdf

http://science.kqed.org/quest/2012/04/12/fracking-in-california-any-cause-for-concern/

Earth Justice, in current litigation regarding "fracking", has established a database of problems. However they state *"Fracking in California has yet to begin in earnest, but that could soon change. In Monterey County, officials have given a green light to Denver-based oil company Venoco to drill exploratory wells in the Hames Valley using fracking technology. The area has long been home to plenty of oil drilling and a new boom could be on its way, thanks to fracking. Oil and gas companies are also eyeing the large tracts of Bureau of Land Management (BLM) land with mineral rights over the Monterey Shale formation."* The Hames Valley is part of the larger Paso Robles Groundwater Basin.

http://earthjustice.org/features/campaigns/california-and-fracking

The Groundwater Resources Association of California has reported on the conference " Hydraulic Fracturing and Water Resources – A California Perspective. Held in Long Beach in July, 2012. It stated:

"California is a relative latecomer to this revolution and was the focus of the symposium. Following the first large-scale development of shale gas reserves in north-central Texas, and the recent exploration for gas in the Marcellus Shale in the Eastern U.S., it has now come to California—mainly the Monterey Shale—but the target is oil instead of gas."

This is an important distinction, especially as Monterey Shale oil is usually a thick and heavy crude that frequently requires treatment before it can be brought to the surface, and the nature of the recovery will be distinctly different from that of Marcellus Shale gas. This may be evident at the San Ardo Oilfield, where steam heating and chemical methods have been used in oil recovery, and where the steam is highly visable on cold days.

At the conference James Melrose of Haliburton indicated that the primary areas of interest in California are the Santa Maria/Ventura/Los Angeles Basins (onshore and offshore) and the San Joaquin Basin (mainly Kern County), all involving the Monterey Shale.

http://www.grac.org/fall12.pdf

The AllGov web site indicates that several hundred fracking operations have taken place on offshore rigs in California. Regulators inside the Bureau of Safety and Environmental Enforcement (BSEE) gave "categorical exclusions" to oil companies for frack jobs on existing offshore oil rigs, allowing them to proceed with the activity in the federal waters off the Golden State without any public disclosure or environmental impact analysis.

The GAO reports that the Monterey Formation in California may contain 15.4 billion barrels of technically recoverable oil.

http://www.gao.gov/assets/650/649241.txt

Tupper Hull of the Western States Petroleum Association (WSPA) stated at the conference 'Hydraulic Fracturing and Water Resources – A California Perspective' that WSPA members performed hydraulic fracturing on 628 wells.

http://www.grac.org/fall12.pdf

Science News reports that "Today hydraulic fracturing is used in about nine out of 10 onshore oil and gas wells in the United States, with an estimated 11,400 new wells fractured each year. In 2010, about 23 percent of the natural gas consumed in the United States came from shale beds."
http://www.sciencenews.org/view/feature/id/343202/title/The_Facts_Behind_the_Frack

The L.A. Times recently demonstrated wide spread use of fracking in California, but stated "*Regulators, legislators, know very little about the extraction process is employed*."

http://articles.latimes.com/2012/mar/14/local/la-me-oil-fracking-20120315

If "Fracking" take place in California's Monterey Formation already, why the existing concern?

Concerns surrounding 'fracking' has been stimulated by the rise of drilling elsewhere in the nation, and an extrapolation that drilling in similar geology and under similar circumstances may take place in California. The principle shale target is the Monterey Shale, which is found in the southern Coast range and southern San Joachim Valley. Industry interest in this shale is covered in the following source:

http://oilshalegas.com/montereyshale.html

This article states that the Monterey has been an oil producer since the late 1800s, but *"in 1999-2000 a new technique consisting of large-volume hydrofluoric acid jobs was tested on horizontal shale wells which proved to increase the flow of oil by a considerable amount. Vertical shale wells were then acidified using the same method which increased the average well production by 110 barrels/day*."

The article also quotes from the USGS states that the Monterey Shale has great potential: *"From the USGS: Potential reserve growth in existing oil and gas fields in the San Joaquin Basin Province was calculated……we estimate that another 3.5 billion barrels of oil may be added to reserves in existing fields"*.

The concern is that increased production efficiency might be applied to areas which hitherto had Monterey Shale or related units, but had showed low production potential. Combinations of fracking and chemical treatment might result in new fields being developed or in the peripheral expansion of existing fields. The idea of areal expansion, combined with stories of problems elsewhere in the nation, appear to be the prime reasons for concern.

Venoco is an oil company strongly invested in developing the Monterey Formation. In an interview in the Oil an Gas Financial Journal with Venoco's Tim Marquez we find that horizontal drilling in the Santa Maria Basin has already taken place.

"OGFJ: Some people may not be aware of this, but historically, the Monterey Shale has been the largest producing oil play in the continental United States. Since Venoco is now focused more on the development of this resource, what has changed in recent years to make this play work and what areas of the shale is Venoco targeting?

MARQUEZ: Without question, it's the processes, procedures, and technology that have revolutionized onshore development of the Monterey Shale. While most of the production from the Monterey Shale has been from conventional traps and natural fracture dominated fields, we believe that advances in horizontal drilling techniques, well completion technology, and 3-D seismic combined with new petrophysical models developed for mid-continent shale plays are what is going to unlock opportunities in the play.

OGFJ: You've recently started a horizontal drilling program in the Monterey Shale. What is the status of this drilling program and what results, if any, can you discuss?

MARQUEZ: The Monterey Shale program continues to be one of the most exciting and promising opportunities at Venoco, and for that matter, the entire industry. By year-end 2010, we will have drilled six vertical evaluation wells — our "science" wells — and four-to-five horizontal wells in the Monterey.

The first horizontal well we drilled was in the San Joaquin Valley to a total measured depth of 14,000 feet. While this particular lateral proved to be uneconomic because of a high water cut, we had good oil shows in that zone while drilling through it in the vertical evaluation well, so we are still interested in this prospect. We are completing our second horizontal well, in the Santa Maria Basin, and expect initial results in early November. The rig was moved to a nearby location in the Santa Maria Basin, and we

spud our third horizontal well around the 20th of October. This is a very active time at Venoco, and we are all excited about the impact the Monterey Shale play can have on the company."

http://www.ogfj.com/articles/print/volume-7/issue-11/cover-story/venoco-has-comfort-zone-in-california-plans.html

In a different story by Earth Justice Venoco's interest near San Luis Obispo's northern border is addressed : http://earthjustice.org/features/campaigns/california-and-fracking where it is stated that'fracking' of the Monterey Formation are already taking place in the Hames Valley in southern Monterey County.

The full potential for the Central Coast's Monterey Formation was reported in a New Times article in 2011 sourcing the U.S. Energy Information Administration's release of its estimates of readily recoverable gas and oil within all the shale deposits in the United States. The report said *"the Monterey shale formation contained 15.5 billion barrels of oil, accounting for 64 percent of the total shale oil resources in the United States. By those numbers, the Monterey reserves dwarf those at the Bakken and Eagle Ford fields. The federal estimates came as a shock to many in the industry. If the numbers in the report are true, new onshore oil fields might easily pump up the nation's oil output by 25 percent in just a few years. The report affirmed what many oil speculators had been claiming for years: California might be the center of a new oil boom. If it's right, California has more recoverable reserves in its shale than big oil-producing countries like Mexico, Brazil, or Angola. If all of California's oil can be extracted, it could equal Saudi Arabia's output for more than a decade. It would be more oil than Alaska has produced in the last 25 years."*

http://www.newtimesslo.com/cover/6555/californias-silent-oil-rush/

CBS News on 10./26/12 reported out of its San Francisco station the following

"SAN ARDO (CBS 5) — Hydraulic fracturing or "fracking" could make 14 billion barrels of oil reserves in the hills and valleys beyond the Monterey County town of San Ardo accessible.

Standup oil wells are nothing new for ranchers in southern Monterey County. The area is home to the San Ardo oil fields, where companies such as Chevron have been pumping for 60 years. New technology could allow the drilling to expand to places where oil lies much deeper, in an area known as the Monterey Shale.

"This formation has been known about for a very long period of time; now we have technologies, enabling technologies, that allow these reservoirs to be produced economically," said Stanford geophysicist Mark Zoback.

He said shale oil is harder to harvest because an oil drill needs to go down and then out horizontally using the controversial technique hydraulic fracturing. With oil at almost $90 a barrel, Zoback predicts things are about to quickly change.

In Monterey County, oil prospectors are knocking on landowners' doors trying to buy up their leases.

"Now all of a sudden the people that drill for oil are more interested in going out and getting these mineral rights from property owners," said county assessor Steve Vagnini.

"There is just a lot more activity and a lot of that activity is in places where there hasn't been much activity for a long period of time," said Zoback"

http://beta.local.yahoo.com/news-oil-fracking-may-come-southern-monterey-county.html?woeid=12797130&lat=37.419200897217&lon=-122.07553863525&statecode=CA&cityname=Mountain%20View

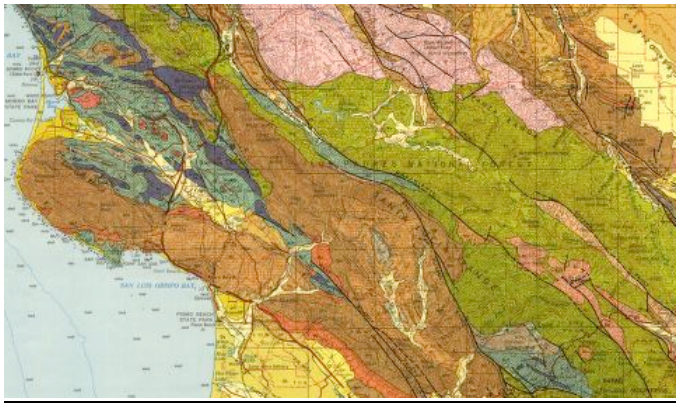
Fracking Combined With Other Secondary Recovery Methods.

It is not uncommon to see columns of steam rising from California Oil Fields such as San Ardo in Monterey County and Price Canyon in San Luis Obispo County. California crude oil is often highly viscous, but can be warmed and forced to move when steam is applied. There are various ways to doing this, including "Huff and Puff" where steam is injected, left in contact with the oil for several days, and then the oil and water is extracted. The process does not use chemical other than water to move the oil. Companies such as eSteam advertise to process as 'steam fracking' but emphasize the lack of chemical used.

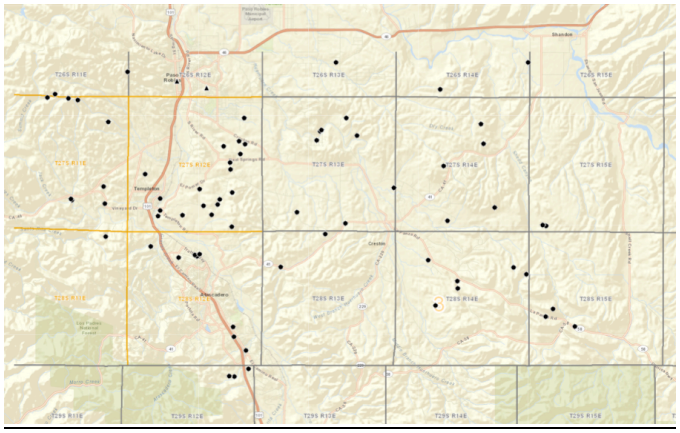
The use of low gravity hydrocarbons as a diluent for the targeted heavy oil is also used. Diluent leaks caused major problems in the Guadalupe Dunes of San Luis Obispo County, but have been used in the offshore rigs in the Santa Barbara Channel.

Are There Potential Monterey Shale Targets in SLO County?

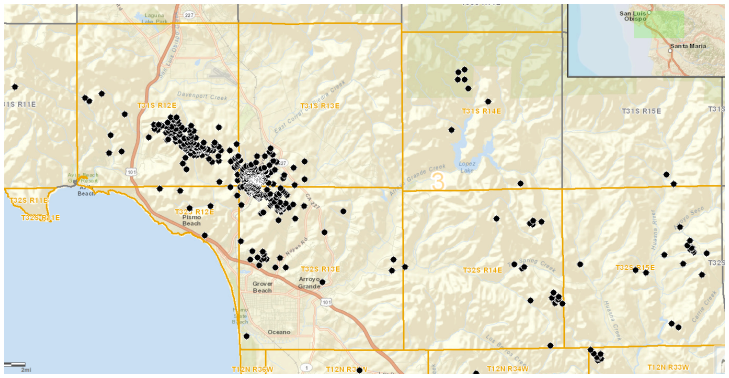
From San Luis Obispo Sheet: Geologic Atlas of California: Shows Monterey Formation associated rocks as brown colored rocks along southern edge of the Irish Hills, the hills around the Edna Valley and Lopez Lake, and west of the Carrizo Plain and Shell Creek, Shandon areas, and in the Huasna area. The Temblor Range is another possible target.



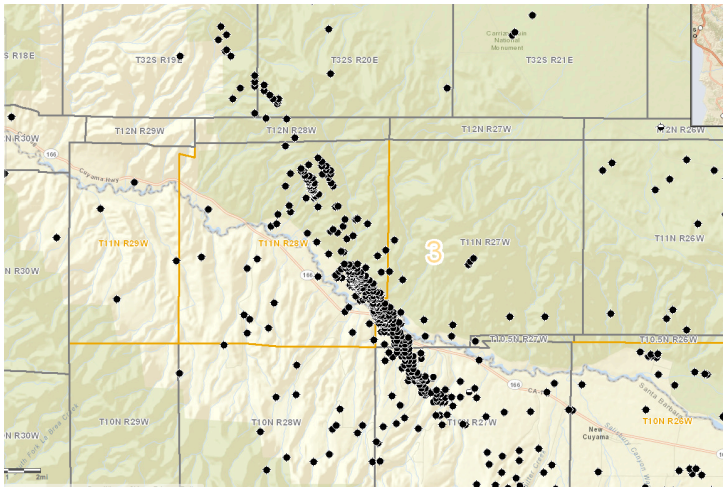
DOGGR has maps of oil and gas wells drilled in the County.



DOGGR Map of Oil Plays South of Paso Robles



DOGGR Map of Oil Plays South of San Luis Obispo



DOGGR Map of Oil Plays in Northern Cuyama Valley

It is reasonable to presume that, if fracking were to take place, it would be in the areas already suspected as having some oil potential.

As Monterey Formation plays are possible on BLM lands, it is useful to note that the agency is preparing some extensive regulation.

http://www.doi.gov/news/pressreleases/loader.cfm?csModule=security/getfile&pageid=293916

Is There Any Evidence of Pollution generated by Fracking in California

We have not found any documentation of a fracking-caused pollution of water resources in California that results from the process forcing pollutants into the water. However accidental spillage from surface operations may have taken place. DOGGR either cannot or will not provide information beyond stating that there are no known problems in California. In Shafter, California, an oil sump pit was found to be contaminated with chemicals used in fracking (October 2013- Fresno Bee).

PART 2 -MAJOR ENVIRONMENTAL ISSUES ARISING FROM USA OPERATIONS

Introduction

This part of the document deals with issues surrounding the increase in fracking throughout the USA. A map is included (below) that shows the main ateas of action at this time.

Map Source: Energy Information Administration

Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI.
Updated: May 9, 2011

Problematic issues can be bundled into three or four main issues: (1) High demand for water (2) Chemical contamination of domestic water supplies from fracking fluids (3) release of methane and other hydrocarbons into domestic water supplies (4) generation of earthquakes from fluid injection. These will be discussed in sequence, with the industry response to claims of injury given at the end of each section of the sequence..

(1) The Issue of Water Demand

(a) Potential or Real Problem on Water Demand

"Fracking" in the tight gas-bearing formations of the Rocky Mountain Front and East Coast uses a lot of water. This poses a problem regarding (1) competition with other water needs in the area, and (2) the treatment requirement for contaminated water returning to the surface. Regarding water demand DOGGR states "DOGGR is unaware of projects using unusual amounts of water."

http://static.ewg.org.s3.amazonaws.com/reports/2012/fracking/ca_fracking/DOGGR_2010_fact_sheet_1.pdf

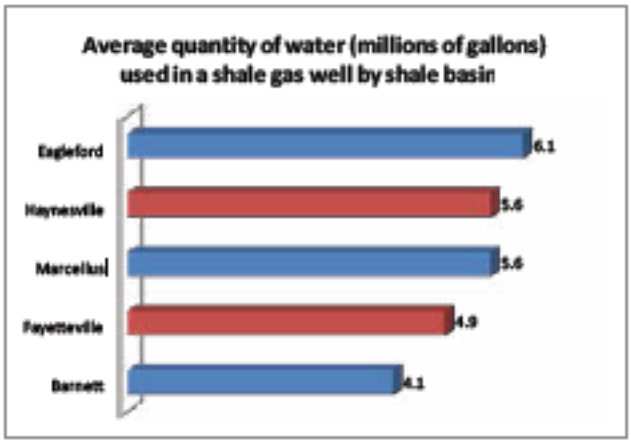
Science News states “A typical fracked well uses between 2 million and 8 million gallons of water. At the high end, that's enough to fill 12 Olympic swimming pools.”

http://www.sciencenews.org/view/feature/id/343202/title/The_Facts_Behind_the_Frack

The following information comes from the KPMG Global Energy Institute, and is a summary of fracking water use outide of California. Their source for the following graphic was The Energy Institute at The University of Texas at Austin, *Fact-Based Regulation for Environmental Protection in Shale Gas Development*, February 2012, http://energy.utexas.edu

Graphic by KPMG 2012.

Figure 4: Volume of water used in a shale gas well by region[18]



http://www.kpmginstitutes.com/global-energy-institute/insights/2012/pdf/minimizing-water-risks-in-shale-gas.pdf

In testimony before the South Coast Air Quality management District Mr. Rock Zierman stated that hydraulic fracturing in California was using between 80,000-300,000 gallons per well.

http://www.aqmd.gov/hb/attachments/2011-2015/2012Oct/2012-Oct5-029.pdf

The Bakersfield Californian on April 16. 2012, reported on fracking water use. Taking data from the FracFocus database they state:

"*Although it is unclear how complete the database is, and its records go back no further than last year, the website shows what chemicals and how much water have been injected where and at what depths at 78 California frack wells, all but five of them in Kern County.*

For instance, FracFocus pinpoints a cluster of 58 wells fracked last year between Lost Hills and McKittrick by XTO Energy/ExxonMobil. Many of these frack jobs pumped several hundred thousand gallons of water into wells about 3,000 feet deep.

Another cluster of 12 wells in the Wasco-Shafter area was fracked last year by Occidental Petroleum Corp. These generally used greater volumes of water than the McKittrick wells -- in one case, more than 1.5 million gallons, or close to 5 acre feet of water -- at depths of about 6,000 to 8,000 feet, according to data Oxy posted to the website."

In Dimmit County, Texas the San Antonio Express News reported that fracking is severely depleting the Carrizo-Wilcox Aquifer, using a "double digit" percent of the water and depleting water available to ranches.

(b) Industry Position on Water Demand

The industry has an extremely long multi-author web page in defense of 'fracking'. Here is a quote from a section that responds to the charges in the current lawsuit against DOGGR by four California environmental organizations:

"While in some parts of the country hydraulic fracturing requires two to four million gallons of water, spread out over several days, in California the fracturing process takes a day or two and generally uses a small fraction of this amount of water — a couple hundred thousand gallons.

A little perspective: the average California golf course uses 312,000 gallons of water per day. If we assume 200,000 gallons per fracturing job, and 628 fracturing operations (out of more than 2,000 new wells drilled), the total water use of all the hydraulic fracturing in California last year equals the amount of water used by California's 1,140 golf courses in half of one day."

http://www.energyindepth.org/tag/hydraulic-fracturing/

In commentary, the industry has many times tried to put water use 'in perspective' as in the golf course story told above. This argument has little value if water is taken away from competing uses, especially in conditions when a basin is in overdraft or there are similar stressors to supply.

James Melrose of Haliburton stated at the conference Hydraulic Fracturing and Water Resources – A California Perspective that because the targeted oil is viscous, hydrofracturing operations require more proppant than in other areas and a very viscous hydrofracturing fluid to carry the proppant. The result likely will be less hydrofracturing fluid used per well, and thus lower water demand than in other areas of the country. Mr. Melrose also indicated that vertical wells may prove to be economically viable, relieving the need for more expensive and water-intensive horizontal wells for hydrofracturing operations. Thus, the per-well volume of hydrofracturing fluid may be significantly less in California than in other areas.

http://www.grac.org/fall12.pdf

Halliburton make a valid point that shales are very different from each other, and it appears extrapolation from other basins into the Monterey Formation may be difficult.

http://www.halliburton.com/public/solutions/contents/shale/related_docs/H063771.pdf

The suggestion by James Melrose (above) that we will see less horizontal drilling is not born out by drilling in Monterey County. In offshore plays into the Monterey Formation, Michael Edwards of Venoco Inc. states "We decided that we'd do some recompletions in those wellbores into a zone called the M2," he said. "We tested anywhere from 30 to 80 bbl per day from the vertical recompletions. We then decided to drill a horizontal into that interval. We had IPs of 150, 600, and 800 bbl per day."

http://www.epmag.com/Production-Drilling/Monterey-Shale-Californias-Sleeping-Giant_83897

The above source notes that Venoco Inc. has interests in the Salinas Valley Monterey Formation.

KPMG Global Energy Institute report that much of the high water demand may be offset by efficient reuse of the water using something called air floatation technology that can treat up to 900 gallons per minute. In commentary, this would involve substantial above ground storage, and leaking waste water storage has long been an issue in the oil industry.

http://www.kpmginstitutes.com/global-energy-institute/insights/2012/pdf/minimizing-water-risks-in-shale-gas.pdf

(2) Contamination of domestic water with drilling chemicals or with hydrocarbons

(a) Potential or Real Problem –In General, Methane Contamination, and Benzene/BTX contamination.

(i) General:

Science News, in an article based on operations throughout the USA, states "*Companies have their own specific mixes, but generally water makes up about 90 percent of the fracking fluid. About 9 percent is "proppants," stuff such as sand or glass beads that prop open the fissures. The other 1 percent consists of additives, which include chemical compounds and other materials (such as walnut hulls) that prevent bacterial growth, slow corrosion and act as lubricants to make it easier for proppants to get into cracks.*

As the gas comes out of a fracked well, a lot of this fluid comes back as waste. Until recently, many companies wouldn't reveal the exact chemical recipes of their fluids, citing trade secrets. A report released in April 2011 by the House Energy and Commerce Committee did provide some chemical data: From 2005 to 2009, 14 major gas and oil companies used 750 different chemicals in their fracking fluids. Twenty-five of these chemicals are listed as hazardous pollutants under the Clean Air Act, nine are regulated under the Safe Drinking Water Act and 14 are known or possible human carcinogens, including naphthalene and benzene.

In addition to the fracking fluid, the flowback contains water from the bowels of the Earth. This "produced" water typically has a lot of salt, along with naturally occurring radioactive material, mercury, arsenic and other heavy metals."

http://www.sciencenews.org/view/feature/id/343202/title/The_Facts_Behind_the_Frack

Cornell University has published a list of chemical additives and their functions.

Additive Type	*Main Compound*	*Purpose*
Diluted acid (15%)	*Hydrochloric acid **	*Dissolve mineral/sand initiates cracks in rock*
Biocide	*Glutaraldehyde*	*Bacterial control*
Corrosion inhibitor	*N,n-dimethylformamide*	*Prevents corrosion*
Breaker	*Ammonium persulfate*	*Delays breakdown of gel polymers*
Crosslinker	*Borate salts*	*Maintains fluid viscosity at high temperature*
Friction reducers	*Polyacrylamide **	*Minimize friction between the fluid and the pipe*
Potassium chloride		
Mineral oil		
Gel	*Guar gum or Hydroxyethylcellulose **	*Thickens water to suspend the sand*
Iron Control	*Citric Acid*	*Prevent precipitation of metal oxides*
Oxygen scavenger	*Ammonium bisulfite ***	*Remove oxygen from fluid to reduce pipe corrosion*
pH adjusters	*Potassium or sodium carbonate*	*Maintains effectiveness of other compounds (e.g. crosslinker)*
Proppant	*Silica quartz sand*	*Keeps fractures open*
Scale inhibitor	*Ethylene glycol*	*Reduced deposition on pipe*
Surfactant	*Isopropanol*	*Increase viscosity of fluid*

** indicates degree of health hazard in concentrated form*

http://www.cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/City%20and%20Regional%20Planning%20Student%20Papers/CRP5072_Water%20Quality%20Final%20Report.pdf

Mr. Henry Hogo, in testimony before the South Coast Air Quality Management District, indicated that the most used chemicals include methanol, ethyl glycol, diesel mixture (which contains benzene, toluene, ethylbenzene, and xylenes), naphthalene, and xylene were the top five chemicals used in around 652 fracturing fluid products between 2005 and 2009 (Source: U.S. House of Representatives Committee on Energy and Commerce Minority Staff Report, April 2011).

http://www.aqmd.gov/hb/attachments/2011-2015/2012Oct/2012-Oct5-029.pdf

http://democrats.energycommerce.house.gov/sites/default/files/documents/Hydraulic%20Fracturing%20Report%204.18.11.pdf

Pennsylvania Pollution Data Possibly Biased by Agency Philosophy

While California's DOGGR has been accused of pro-industry bias, the issue of differences of philosophy has been well illustrated by the differing views of Pennsylvania's Dept. of Energy and Power and the Dept. of Environmental Protection. For example, a contamination incident that polluted water in 18 wells was considered a single incident by DEP.

Wyoming Oil and Gas Conservation Commission Fracking Fluid Disclosure

High Country News reports that WOGCC has forced Encana Inc. to reveal most of the chemicals used in stimulation of wells in the Jonah Oil Field. However the list is not complete as it excluded about 70 chemicals with "trade secret status". The HCN article contains a chart which also has a correction below it in the electonic version. The chart shows the percentage of each revealed chemical in the Encana cocktail, together with information from the Endocrine Disruption Exchange that shows the health risk associated with the chemical.

http://www.hcn.org/issues/43.3/unpacking-health-hazards-in-frackings-chemical-cocktail

Pavillion, Wyoming: Example of Possible Water Pollution from Fracking.

The residents of Pavillion, Wyoming suffered from serious hydrocarbon and other chemicals in their well water, and it was associated with fracking. It was shown as an example in the movie Gasland. As a result the EPA conducted tests and have issued a draft report. This is considered a test case that could show a definitive relationship between water pollution and fracking. The draft can be read at:

http://www.epa.gov/region8/superfund/wy/pavillion/EPA_ReportOnPavillion_Dec-8-2011.pdf

The industry has attacked the EPA study with accusation that the sampling methods and standards for putting in the monitoring wells were deeply flawed. They claim that pollutants could have been introduced by EPA itself from a shallower horizon.

http://www.energyindepth.org/tag/hydraulic-fracturing/

EPA subsequently claimed that their findings are inconclusive and have withdrawn from the project. This has the claimed justification that the State of Wyoming has a sufficiently rigorous program to complete the study. Funding for the state's work is paid partly by the owner of the gas field that is under investigation.

Pro-Publica has suggested that this is one of several 'pull-backs' by the EPA on fracking investigations and are suggesting the possibility of strong political pressures at play.

http://www.propublica.org/article/epas-abandoned-wyoming-fracking-study-one-retreat-of-many

(ii) Methane:

The issue of methane appearing in domestic water supplies was a central feature of the recent movie 'Gasland' which has inspired much of the concern about 'fracking'. A central challenge to 'Gasland' has been that elevated methane levels could exist in domestic wells simply because they are close to geologic sources of natural gas that raise the background levels in the water supply. Science News reports on attempts to locate the sources of elevated methane

"….in 60 private water wells in northeastern Pennsylvania and upstate New York found that average methane concentrations in wells near active fracturing operations were 17 times as high as in wells in inactive areas. Methane naturally exists in groundwater — in fact, the study found methane in 51 of the 60 water wells — but the higher levels near extracting sites raised eyebrows."

There was no salt contamination which suggested that the methane did not come from the 'fracked' horizons, but instead may have come from methane present above the target horizons that leaked up poorly cemented seals outside of the pipe stem into overlying aquifers. Salt water will usually be produced from 'fracked' geologic units, and is itself a disposal problem

http://www.sciencenews.org/view/feature/id/343202/title/The_Facts_Behind_the_Frack

The town of Dimock, Pennsylvania, was featured in the movie Gasland. Isotopic analysis of the gas indicates that it did not come from the fracking target Marcellus Shale, but from younger overlying formations. Leakage of this gas was, however, linked to the drilling operations

The issue of 'fracking' resulting in an overall increase in methane reaching the surface has become part of the national policy debate regarding clean fuels. Methane escape from gas fields, while not linked directly to "fracking", have become a major issue in estimation of total impacts as methane is a greenhouse gas that is 20% more effective in trapping heat than carbon dioxide. Global methane levels have increased but flattened lately. The information can be found at:

http://www.epa.gov/methane/scientific.html

The EPA's 2012 estimation that methane escapes to the atmosphere during gas production may be as much as 7% of production volume. A paper supporting a 4% leakage is referenced below:

http://www.nature.com/news/air-sampling-reveals-high-emissions-from-gas-field-1.9982

The EPA in 2013 lowered its estimate of methane escapes to about 1% of production volume based on engineering estimates rather than measurement, totaling an annual 1.2

million tons. A later project using actual downwind data reduced this to 957,000 tons. Neither of these included estimation of post-production gas losses.

Industry Position on Methane Contamination of Air and Water

(ii) The industry has challenged the EPA estimation that methane escapes to the atmosphere during gas production may be as much as 7% of production volume, but use a possibly biased report by the gas industries IHS-CERA as rebuttal. It can be found in EPA's document as an attachment to the U.S. Chamber of Commerce's request of a correction of EPA's methane data.

http://epa.gov/quality/informationguidelines/documents/12003-attA.pdf

The industry position can be found through extensive rebuttal in:

http://www.energyindepth.org/tag/hydraulic-fracturing/

The industry also appears to attack a story in Nature v.482, Issue 7384, News, Article on 2/7/12 that describes a study showing a 4% leakage from a Colorado gas field. Rebuttal can be found at the site URL above the paragraph.

http://www.nature.com/news/air-sampling-reveals-high-emissions-from-gas-field-1.9982

The movie 'Gasland' addrssed methane contamination in groundwater. The industry site quotes from a GAO report

http://www.gao.gov/assets/650/647791.pdf

• *The risk of contamination from improper casing and cementing is not unique to the development of shale formations." (GAO, p. 45)*

• *"Fractures created during the hydraulic fracturing process are generally unable to span the distance between the targeted shale formation and freshwater bearing zones." (GAO, p. 46)*

• *"When a fracture grows, it conforms to a general direction set by the stresses in the rock, following what is called fracture direction or orientation. The fractures are most commonly vertical and may extend laterally several hundred feet away from the well, usually growing upward until they intersect with a rock of different structure, texture, or strength. These are referred to as seals or barriers and stop the fracture's upward or downward growth." (GAO, p. 47)*

• *"In addition, regulatory officials we met with from eight states—Arkansas, Colorado, Louisiana, North Dakota, Ohio, Oklahoma, Pennsylvania, and Texas—told us that, based on state investigations, the hydraulic fracturing process has not been identified as a cause of groundwater contamination within their states." (GAO, p. 49)*

http://www.energyindepth.org/tag/hydraulic-fracturing/

In commentary, it appears that industry is quibbling with the facts when it states that methane in wells cannot be definitively associated the fracked gas. The industry has

attributed gas to such things as failed casings in old wells or even recent biogenic origins. It appears certain that the operations associated with the fracking process are associated in both time and location to fracking.

Science News states:

"To get at where the methane was coming from, the researchers looked at the gas's carbon, which has different forms depending on where it has been. The carbon's isotopic signature, and the ratio of methane to other hydrocarbons, suggested that methane in water wells near drilling sites did not originate in surface waters but came from deeper down.

But how far down and how the methane traveled aren't clear, says Duke's Jackson, a coauthor of the study, published last year in the Proceedings of the National Academy of Sciences. He proposes four possibilities. The first, most contentious — and, says Jackson, the least likely — is that the extraction process opens up fissures that allow methane and other chemicals to migrate to the surface. A second possibility is that the steel tubing lining the gas well, the well casing, weakens in some way. Both scenarios would also allow briny water from the shale and fracking fluid to migrate upward. The well water analysis found no evidence of either.

Newly fracked gas wells could also be intersecting with old, abandoned gas or oil wells, allowing methane from those sites to migrate. "We've punched holes in the ground in Pennsylvania for 150 years," Jackson says. Many old wells have not been shut down properly, he says. "You find ones that people plugged with a tree stump." In some places in Pennsylvania, West Virginia and elsewhere (especially those with existing coal beds), methane turned up in well water long before hydraulic fracturing became widespread.

A fourth possibility, which Jackson thinks is most probable, is that the cement between the well casing and the surrounding rock is not forming a proper seal. Cracking or too little cement could create a passageway allowing methane from an intermediate layer of rock to drift into water sources near the surface. Such cases have been documented. In 2007, for example, the faulty cement seal of a fracked well in Bainbridge, Ohio, allowed gas from a shale layer above the target layer to travel into an underground drinking water source. The methane built up enough to cause an explosion in a homeowner's basement."

http://www.sciencenews.org/view/feature/id/343202/title/The_Facts_Behind_the_Frack

(iii) Benzene and BTEX:

The Environmental Working Group in January 2011 stated: "*The Environmental Working Group (EWG) commends the important investigation of hydraulic fracturing released today (Jan. 31) by U.S. Reps. Henry A. Waxman (D-Calif.), Edward J. Markey (D-Mass) and Diana DeGette (D-Colo.). Their disturbing findings show that 1) oil and natural gas drilling companies injected more than 32 million gallons of diesel fuel or fluids containing diesel fuel in hydraulically fractured wells in 19 states between 2005 and*

2009; and 2) no state and federal regulators have issued the required permits for this use of diesel fuel, an apparent violation of the Safe Drinking Water Act. "Drilling companies have won exemption from just about every piece of federal environmental law except the requirement to get permits if they use diesel in their fracking fluids," said EWG Senior Counsel Dusty Horwitt. "This report shows they haven't even complied with this limited provision. How can communities trust these companies to drill responsibly?"
"Companies are increasingly drilling in populated areas and using ever more intensive hydraulic fracturing in shale formations," Horwitt said. "Reps. Waxman, Markey and DeGette deserve credit for pursuing this important investigation and working to ensure that drilling is conducted carefully and in compliance with our laws." Under the 2005 Energy Policy Act, Congress generally exempted hydraulic fracturing or "fracking" from the permitting requirements of the Safe Drinking Water Act – except when diesel fuel is used……..Last August, EWG and more than 25 conservation organizations wrote to Reps. Waxman and Markey urging them to follow up on their investigation last year that found that drilling companies B.J. Services and Halliburton had injected diesel in hydraulic fracturing operations in at least 15 states between 2005 and 2007.

http://www.ewg.org/release/congress-confirms-gas-drillers-fracked-diesel

Industry Position on Benzene and BTEX:

The industry defense is essentially that, while benzene might be present as both VOC emissions and in groundwater, the concentrations are very low. A purported high level of contaminants in the town of Dish, Texas was attributed to other activities such as smoking. Several other studies showing lack of a problem are quoted at the web site below.

Final Report: Dish, Texas Exposure Investigation, Dish, Denton County, Texas, May 12, 2010. Link from http://www.energyindepth.org/tag/hydraulic-fracturing/

(3) Induced Earthquakes or Ground Movement

There does not appear to be a large problem concerning water-injection generated earthquakes in California. Salon.com quotes the USGS Earthquake Science Center's Art McGarr

"In any event, there is little likelihood that any fracking operation could perturb a nearby active fault so as to trigger a major earthquake," he added. "The stress changes associated with fracking are much too small and localized to interact with a fault capable of producing a significant earthquake. In other parts of the country where fracking has enabled gas production from tight shales, the fracking has not caused earthquakes of any consequence."

http://www.salon.com/2012/04/09/californias_unregulated_fracking_problem/singleton/

There is a record of earthquakes associated with injection wells elsewhere in the USA. However the spatial association is a connection only by inference. The Environmental Working Group describes a USGS study published in the Seismological Society of America *"The study found that the frequency of earthquakes started rising in 2001 across a broad swath of the country between Alabama and Montana. In 2009, there were 50 earthquakes greater than magnitude-3.0, the abstract states, then 87 quakes in 2010. The 134 earthquakes in the zone last year is a sixfold increase over 20th century levels."*

The article continues: *"The USGS authors said they do not know why oil and gas activity might cause an increase in earthquakes but a possible explanation is the increase in the number of wells drilled over the past decade and the increase in fluid used in the hydraulic fracturing of each well. The combination of factors is likely creating far larger amounts of wastewater that companies often inject into underground disposal wells. Scientists have linked these disposal wells to earthquakes since as early as the 1960s. The injections can induce seismicity by changing pressure and adding lubrication along faults."*

http://www.ewg.org/analysis/usgs-recent-earthquakes-almost-certainly-manmade

The link to the paper is from conference abstracts and is long!:

http://www2.seismosoc.org/FMPro?-db=Abstract_Submission_12&-sortfield=PresDay&-sortorder=ascending&-sortfield=Special+Session+Name+Calc&-sortorder=ascending&-sortfield=PresTimeSort&-sortorder=ascending&-op=gt&PresStatus=0&-lop=and&-token.1=ShowSession&-token.2=ShowHeading&-recid=224&-format=%2Fmeetings%2F2012%2Fabstracts%2Fsessionabstractdetail.html&-lay=MtgList&-find

The EnergyWire site states *"EPA looking for ways to 'manage or minimize' injection earthquakes"*

http://www.eenews.net/public/energywire/2012/03/15/2

There is an ongoing issue of small earth movements associated with the Inglewood Oil Field in Los Angeles, which residents claim has become serious since 'fracking' commenced. The ABC news story is at:

http://abclocal.go.com/kabc/story?section=news/local/los_angeles&id=8848711

In commentary, movement could be due to fluid withdrawals or injection from or into the oil field, and also the sum of motions on the underlying Newport-Inglewood fault that has generated the anticlinal structure of the oil field. Subsidence of the Navy Pier in Long Beach Harbor was generated by excess fluid removal and rectified with waste water reinjection. See: http://gsabulletin.gsapubs.org/content/60/3/461

There is some proof that the act of fluid injection in a single well can raise the ground surface. This is shown in a technical paper on inducing permeability through hydraulic fracture. Please note Figure 9 in:

http://www.armarocks.org/documents/newsletters/dussealt_massive_multistage_hydrolic_fracturing.pdf

There are actually two opportunities to raise hydraulic pressure and generate quakes with fracking. One is the fracking in the production well and the other is the disposal of the unrecycled fracking fluid down a different disposal well. NPR reports an example of the latter in Youngstown, Ohio.

http://www.npr.org/2012/01/05/144694550/man-made-quakes-blame-fracking-and-drilling

Reinjection of waste fluids under high pressure has generated quakes at Rocky Mountain Arsenal near Denver at at an oilfield in Rangely, Colorado in 1966.

http://www.saveballona.org/gasoilfields/RangleySeismicGC.pdf (Rangely)

http://academic.emporia.edu/aberjame/student/moran4/index.htm (Rangely)

http://www.onepetro.org/mslib/servlet/onepetropreview?id=00002558 (Rocky Mt. Arsenal)

Industry Position on Induced Earthquakes or Ground Movement

The industry site quotes a GAO report that includes the issue of seismicity induced by 'fracking'. They note the U.S. Geological Survey and the National Research Council have studied that topic and determined there is no link between gas production and quakes.

"According to several studies and publications we reviewed, the hydraulic fracturing process releases energy deep beneath the surface to break rock but the energy released is not large enough to trigger a seismic event that could be felt on the surface." (GAO, p. 52).

http://www.gao.gov/assets/650/647791.pdf

http://www.energyindepth.org/tag/hydraulic-fracturing/

Litigation based on fracking-induced earthquakes

Colleyville, Texas- A lawsuit has been filed by landowners on the basis of damage to homes and real estate values. This is based in purported damage to homes caused by earthquakes that could have been caused by fluid injection. The Cleburne Times-Review stated on August 1, 2013:

A recent study conducted by England's Durham University and published in the journal Science has confirmed that seismic activity, and possibly major earthquakes, can be triggered by injection wells, according to a blog posted July 24 on the Christian Science Monitor website by guest blogger Llewellyn King.

King said that it is not the fracking that causes seismic activity but rather the method in which the brine used in fracking is disposed of and that fracking is banned in the United Kingdom and much of Europe.

According to an Oct. 2, 2012, article posted on the Mother Nature Network website, www.mnn.com, Cliff Frohlich, associate director and senior research scientist with the University of Texas at Austin's Institute for Geophysics, said a magnitude 3 earthquake had never been recorded in the Dallas area before Halloween 2008. United States Geological Survey data indicates that since then, the area has had at least one earthquake each year at or above a magnitude 3, except for 2010.

At least nine small earthquakes struck Johnson County between June 5 and July 13, 2012. A 2.7 quake hit March 10, centered about four miles northeast of Godley. It was the fourth small earthquake in North Texas since Feb. 24.

Cooke said Wednesday that the plaintiffs in the lawsuit filed Tuesday have "all had significant structural damage" to their property because of the earthquakes, and they believe the earthquakes are a direct result of fracking in the area.

"We believe the damage from these earthquakes is a lot more pervasive than just these two families. We think other folks may have suffered some damage, too," Cooke said. "There are people have had damage to their property that they just thought was due to shifting soil and the drought. Those things are certainly a factor, but we think the fracking process plays a much bigger role than people have realized.

- See more at: http://www.cleburnetimesreview.com/local/x1664875143/Property-owners-sue-for-fracking-damages#sthash.TiAQD1gi.dpuf

Fracking Entangles Water and Air Resources Issues

When methane enters well water it will eventually get vented into the air, as seen in the documentary movie 'Gasland' . Some of this is discussed in the section on methane. A recent study concerned health effects of drilling in the Inglewood Field in Los Angeles.
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Public Health Issues Raised in Inglewood Oil Field

The operator of the Inglewood Oil Field in the Los Angeles Basin, PXP, in a settlement agreement of a lawsuit filed against L.A. County and PXP challenging the validity of the Baldwin Hills Community Standards District (CSD). The CSD was set up with the goal of improving the compatibility of oil production with adjacent urban land use. The lawsuit was settled July 15, 2011. A study of Hydraulic Fracturing in the oilfield is the direct result of Term 13 of the Settlement In October 2008.

Plains Exploration and Production Co. (PXP) conducted two hydraulic fracturing tests in the Inglewood Oil Field and had an independent industry contractor, Cardno ENTRIX, monitor emissions and produce a peer-reviewed report that showed that there were no

emissions. This was the result of a settlement agreement beteen PXP and L.A. County. The Cardno ENTRIX report, which found no problem with either the fracking or other operations, can be read at:

http://www.inglewoodoilfield.com/res/docs/102012study/Hydraulic%20Fracturing%20Study%20Inglewood%20Field10102012.pdf

The Cardno ENTRIX report is being questioned on the basis of the large amount of data provided by PXP and has resulted in threats of further legal action in Culver City and Baldwin Hills.

A public protest in Culver City against "fracking" in the Inglewood Oil Field that, as yet, has not resulted in litigation, took place on 6/12/12.

http://latimesblogs.latimes.com/lanow/2012/06/protesters-take-to-culver-city-streets-to-decry-fracking-.html

http://latimesblogs.latimes.com/california-politics/2012/10/fracking-lawsuit-california.html

Analysis of 'Fraccidents' listed on the Earth Justice web site.

http://earthjustice.org/features/campaigns/california-and-fracking

(4) EXAMPLES FROM EAST COAST

2006-Summer Hamilton Township, Pa: Methane causes domestic water and pond to turn blood red

2006 –August: Penobsquis, New Brunswick, Canada: Spill of 3,000 liters of 'frac sand' that contained a low level radioactive substance

2007-Fall: Varick, New York: Domestic well water quality damaged during fracturing of gas well 660 ft. away.

2007-2008 Alleghany National Forest, Pa. Illegal dumping of 200,000 gals of brine into an abandoned well. Felony conviction

2008-Spring: Bradford, Pa.: Residential water turned smelly and murky. Methane found in 3 wells, metals in 6 other wells

2008-Summer: Artesian well becomes contaminated with briny taste and gas smell.

2008- Fall: Leidy Township, Pa: Gas well explodes

2009-Spring: Allegany County, New York: Gas pollutes domestic well after fracturing.

2009- Roaring Branch, Pa: Casing failure causes gas to contaminate wells

2010-Spring: Tioga County, Pa: Spill from waste pit. No long term damage.

2010- Dimock, Pa: Drilling fluid spill (8,000 gals), creek turned red, water turned brown in taps, well exploded, loss of animal hair

2011-Summer Kashequa, Pa: Explosive levels of methane and ethane in residential water supplies

2011- Waterville, Pa.: Chemical spill to creek

2011- Muney, Pa: Gas contaminates domestic wells and creek

(5) EXAMPLES FROM SOUTH

2005- Fall: Water well contaminated after fracking

2007- Winter. Hill County, Tx. Three families have wells contaminated with gas.

2009- Caddo Parish LA. Cattle killed by fracking fluid

2009- Cleburne Tx: Earthquakes in area of fracking

2010- Fort Worth Tx. 15 dangerous compounds in ambient air within home

2010- Johnson County Tx. Well contaminated.

2010- Tarrant County, Tx.Fall: Water well contaminated after fracking

OTHER SOURCES OF INFORMATION

http://ftp.sourcewatch.org/index.php?title=California_and_fracking

http://www.sciencenews.org/view/feature/id/343202/title/The_Facts_Behind_the_Frack