To what extent does the vertical depth of the kickoff point in a fracking operation correlate to thermogenic methane concentrations in groundwater resources?

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There is a problem with hydraulic fracturing and water contamination. Despite Safe Drinking Water Act regulations, risk to water resources remains in areas of water acquisition, chemical mixing, well injection, produced water handling, and wastewater disposal and reuse. This problem has negatively impacted some relying on groundwater resources surrounding hydraulic fracturing operations because of inadequate information (e.g. unmapped faults, abandoned/unfilled wells, unknown mechanisms of risk, etc.). Perhaps a study which investigates the correlation between the vertical depth of the kickoff point (point at which fracking fluids are dispersed underground in vertical wells)[1] and thermogenic methane concentrations in groundwater resources could remedy this situation by filling a gap in the research and identifying a potential risk to groundwater resources.

Keywords: Fracking; Hydrualic Fracturing; Kickoff Point; Vertical Depth

Literature Review

Hydraulic fracturing, also known as fracking, is an unconventional method of extracting oil and gas resources by means of injecting fracking fluids at high pressures to create fractures in surrounding rock formations. The newly freed fossil fuels are then extracted. Questions revolving around risks to water resources (among others) as a result of fracking are being raised, and there are strong proponents on both sides of the "to frack or not to frack" debate. For example, the effects of refracturing existing fracking wells remain a concern. Many studies have been done regarding the true impact of fracking on water quality but the results lack consensus. The stark variation might have stemmed from the parties conducting research and their differing interests, namely Oil and Gas (O&G) sponsorship and not. The National Groundwater Association[2] notes, "No widespread water quality or quantity issues have been definitively documented that are attributable to the hydraulic fracturing process itself. However, there have been several cases related to oil and gas activities... that are suspected to have or have negatively impacted groundwater, surface water, or water wells."

Many sources cited the then upcoming and now newly released United States Environmental Protection Agency (EPA) article regarding fracking and water contamination as a major step in delving into the issue; it defined and assessed the set parameters of risks to water resources because of fracking. Each stage of the hydraulic fracturing water cycle was assessed to identify the potential for impacts on drinking water resources and factors that affect the frequency or severity of impacts. To perform the risk assessment, the EPA analyzed existing data, conducted case studies, lab studies, and scenario evaluations. The EPA's "Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources" lists well injection as one of five stages in which there is potential risk to water quality, the others being water acquisition, chemical mixing, flowback and produced water, and wastewater treatment and waste disposal:

> "Water Acquisition: the withdrawal of groundwater or surface water to make hydraulic fracturing fluids; Chemical Mixing: the mixing of a base fluid (typically water), proppant, and additives at the well site to create hydraulic fracturing fluids; Well Injection: the injection and movement of hydraulic fracturing fluids through the oil and gas production well and in the targeted rock formation; Produced Water Handling: the on-site collection and handling of water that returns to the surface after hydraulic fracturing and the transportation of that water for disposal or reuse; and Wastewater Disposal and Reuse: the disposal and reuse of hydraulic fracturing wastewater."[3]

There appears to be a gap in the research specifically regarding well injection and vertical depth of the kickoff point to groundwater sources.

Delving deeper into the fracking universe, very few studies encountered elaborated on vertical depth and none investigated the extent to which it plays a role. Distance of water wells to the fracking site has been analyzed, but not vertical depth – and those articles that do present vertical depth lack consensus.

Information presented by the EPA and others conflicts with some sources: "In many cases (depending on fracture depth, height, and direction), the distance between the producing formation and the drinking water resource is one of the most important

[1] U.S. EPA. December 2016. "Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States". Office of Research and Development, Washington, D.C. EPA/600/R-16/236Fa.
[2] National Groundwater Association. "Hydraulic Fracturing: Meeting the Nation's Energy Needs While Protecting Groundwater Resources" 1 January 2017.
[3] Ibid, p 1.

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factors affecting the possibility of fluid migration between these formations."[4] And contrasting with this assertion: "Microseismic data suggest that the deformation and fractures developed following hydraulic fracturing typically extend less than 600 meters above well perforations, suggesting that fracture propagation is insufficient to reach drinking-water aquifers in most situations."[5] This assertion is supported by noble gas data from northeastern Pennsylvania[6], Additionally, Jackson et al suggests, "In principle, hydraulic fracturing could open incipient fractures (cracks) thousands of meters underground, connecting shallow drinking-water aquifers to deeper layers and providing a conduit for fracturing chemicals and formational brines to migrate upward. In practice, this occurrence is unlikely because of the depths of most target shale and tight-sand formations (1,000–3,000 [meters]) and microseismic data show that man-made hydro-fractures rarely propagate >600 [meters]."[7] According to Jackson et al, "A somewhat more plausible scenario would be for man-made fractures to connect to a natural fault or fracture, an abandoned well, or some other underground pathway, allowing fluids to migrate upward."[8]

As demonstrated, sufficient discord exists regarding the extent of the role vertical depth plays when considering water contamination. Some sources present alternative points of view than those previously presented. Mooney elaborates, "Here Jackson and Engelder can only hypothesize. When methane is first released from the rock, enough initial pressure exists to drive water and chemicals back up the hole. That pressure subsides rather quickly, however. Thereafter, although gas has enough buoyancy to move vertically, the water does not."[9]

Considering these differing stances, I chose methane as an indicator for stray gas migration for reasons elaborated in methodology. Choosing dissolved methane in groundwater as a dependent variable as opposed to choosing a substance found directly in fracking fluid means this paper takes the route of stray gas migration as the possible mechanism for contamination. As discussed, there's a problem with fracking and contamination of groundwater resources. I hope to fill the gap by examining the relationship between fracking well vertical depth and concentration of methane in groundwater resources. Fractures, faults, cement casing failures, and unmapped abandoned mines is the most likely routes to contamination: the EPA states, "Fluids [liquids or gases] can move via pathways adjacent to or through the production well that are created in response to the stresses exerted during hydraulic fracturing operations."[10] Contamination pathways, fluid or gas, to groundwater resources are a major concern in existing literature; these pathways can be created because of the pressures exerted during the fracking process, abandoned unfilled mines or wells, unmapped faults near fracking zones, and inadequate construction or degradation of fracking wells. (Specifically, this fluid movement is categorized as being through the aforementioned pathways that are created because of the fracking or through induced fractures/other features within subsurface formations.) Among these, vertical distance isn't cited as a risk factor for contamination pathways and I hope to investigate whether or not there is a correlation between changing water quality and fracking with vertical distance as a possible risk factor. If in some cases contamination pathways exist for possible fluid migration, they should exist too for Stray gas migration. For this reason also methane was chosen as a dependent variable. Additionally, assuming it's probable that fracking fluids rarely migrate up, upon investigation I'm specifically interested in stray gas migration, as the pressure forces it up.

Considering the conflict surrounding the probability (or lack of which) of direct fluid migration, vertical depth and methane migration are specifically the connections I'm interested in. While fracking well depths can be vertical, horizontal, or deviated, approximate vertical depth between the groundwater table and fracking fluid dispersal site is the independent variable investigated in this paper. Shale depths vary starkly, and therefore, so do the depths of the kickoff point. The depth of the targeted rock formation determines whether the fracking well is relatively shallow or relatively deep.[11] For example, a well in Milam County, Texas is 685 feet deep, while another well in Sam Augustine, Texas is 19, 349 feet deep. Once discovering these stark differences, I wondered if there was any correlation between the depths and water contamination.

Vertical depth was mentioned briefly, but not specifically was the extent to which it exacerbated the situation of methane in water in the same USEPA report. Especially considering the discord surrounding this area, I found this to be a suitable gap in which to conduct my research.

As part of the EPA's broader study of the potential impacts of hydraulic fracturing for oil and gas on drinking water resources, it conducted retrospective case studies at five locations where hydraulic fracturing had already occurred, and where residents had reported concerns about impacts to drinking water resources. Through these case studies, the EPA sought to identify whether an impact had occurred, and if so, to better understand the potential causes of those impacts.

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[4] Reagan, M.T. et al. "Numerical simulation of the environmental impact of hydraulic fracturing of tight/shale gas reservoirs, short term gas, and water transport." Water Resour. Res. 51. AGU Publications. doi:10.1002/2014WR016086. 11 March 2015.; Jackson, Robert B. et al. "Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction." PNAS. Vol. 110, No. 28. doi: 10.1073. 9 July 2013.

[5] Flewelling, S. A.; Tymchak, M. P.; Warpinski, N. "Hydraulic fracture height limits and fault interactions in tight oil and gas formations". Geophys. Res. Lett. 2013, 40 (14), 3602−3606.

[6] Darrah, T. H.; Vengosh, A.; Jackson, R. B.; Warner, N. R.; Poreda, R., "Constraining the Source and Migration of Natural Gas in Shallow Aquifers within Active Shale Gas Production Zone: Insights from Integrating Noble Gas and Hydrocarbon Isotope Geochemistry"; Geological Society America Annual Meeting: Charlotte, NC, 6 November 2012.

[7] Jackson, Robert B. et al. "The Environmental Costs and Benefits of Fracking". Annual Review of Environment and Resources. doi: 10.1146/annurev-environ-031113-144051. 11 August 2014.

[8] Ibid, p 4.

[9] Mooney, Chris. "The Truth About Fracking". Scientific American. Vol 305. Issue 5. November 2011.

[10] Ibid, p 1.

[11] Ibid, p 1.

The case studies provide valuable insights into vulnerabilities and potential pathways for impacts to drinking water from hydraulic fracturing activities, such as; surface activities (including impoundment, well pads, and associated spills), and well construction and integrity. The case studies highlight the value of site-specific background data, including the chemicals used on site, and local geological information. States worked cooperatively with the EPA on these case studies, and have independently taken follow-up steps to protect water resources at all the case study locations.

Methodology

I hypothesize that there exists a correlation between the vertical depth of the kickoff point and methane concentration in groundwater resources because it creates potential for gas migration pathways when connecting to existing faults and cracks.

To investigate the extent to which vertical depth of a kickoff point in a fracking operation plays a significant role in groundwater contamination when fracking, I looked to reject the null hypothesis: Vertical depth plays no significant role in determining concentration of methane in groundwater. Taking the route exalted by Karl Popper in The Logic of Scientific Discovery,"...whenever we propose a solution to a problem, we ought to try as hard as we can to overthrow our solution, rather than defend it."[12]

In a commentary on The Logic of Scientific Discovery, Tom Butler-Bowdon elaborates: “... [science] can no longer be about finding evidence to prove a theory – this wasn't rigorous enough. A real philosopher or scientist would work to prove *themselves* wrong, attempting to find the holes in any existing theory. Only then can knowledge be worthy of its name."[13] This is why rejecting the null hypothesis is how I planned to support my hypothesis that the vertical depth of the fracking operation significantly impacts the presence of methane in groundwater.

Stray gas migration, specifically that of methane, has been a growing concern. However, O&G companies note that the presence of new gases in water can be of naturally occurring causes and unrelated to fracking operations[14] Still, I chose methane to determine the effect of fracking. While methane presence in water alone doesn't necessarily indicate stray gas contamination as a result of fracking because it can be naturally occurring, it can still serve as an appropriate indicator of migration. Thermogenic methane specifically is unique to deeper shale formations, as opposed to less mature biogenic methane.[15]

Before deciding on methodology, I searched data bases, including those of the University of Michigan, for articles generally related to fracking until I decided on a linear regression test. I read foundational texts to learn how to execute this method. Though Popper rejects probability, In All Likelihood by Yudi Pawitan describes its merit. I followed the process described in this foundational text to the best of my ability in order to obtain novel results:

> “Planning: making decisions about the study design or sampling protocol, what measurements to take..., sample size, etc.; [d]escribing: summarizing the bulk of data in a few quantities, finding or revealing meaningful patterns or trends, etc.; [m]odelling: developing mathematical models with a few parameters to represent the parents, or to explain the variability in terms of relationship between variables; [i]nference: assessing whether we are seeing a real or spurious pattern or relationship which typically involves an evaluation of the uncertainty in the parameter estimates; [m]odel [c]hecking: assessing whether the model is sensible for the data. The most common form of model checking is residual analysis.”[16]

I extensively searched the universe for fracking related material, focusing on finding papers with high sample sizes, among other criteria, rather than those with the results I tentatively hypothesized in order to avoid harking. Because the studies tested different effects I coded for research articles to be used for the linear regression test; the following criteria were included: published, peer-reviewed, included vertical depth of the fracking operation, sample size > 14, published after 2011, and recorded methane amounts. Also, excised were articles specifying only microbial methane as criteria.

I ran a linear regression test to compare methane concentrations found in water wells and the corresponding depth of the fracking well in relation to the ground water resource to test for correlation. Though water well depths varied, the groundwater resource depth remained relatively stagnant because the water wells sampled in all case study areas were drawn from the same aquifer. In order to perform the test, I did a systematic review of the existing literature. My goal was to find the correlation of kickoff point depth on methane concentrations, so linear regression was best suited my purposes.

I chose linear regression to find probability, hypothesizing to find data leaning towards the rejection of the null, and in order to avoid type 1 and type 2 errors. Linear regression was also the best method for my topic because it synthesizes data from common accredited research to be able to say something about an important aspect of the fracking universe and it allowed me to run tests on research without having to conduct my own samplings, producing a novel contribution. The fracking universe, though experiencing discord regarding the true effect of fracking on groundwater, has many studies in which water well samples were taken and analyzed. These conflicting articles, ranging in positions on the spectrum, present an opportunity for a unique linear regression test to occur to try to find a correlation between vertical depth of the kickoff point and methane presence.

The papers not included were not yet consistent/formatted to fit into the linear regression test. I calculated the mean amount of methane in the wells of each study site for each date and recorded the sample sizes for each. I converted meters to feet to stay

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[12] Popper, Karl R. *The Logic of Scientific Discovery*. New York: Harper & Row. 1934.
[13] Butler-Bowdon, Tom. "Thinking, Being, Acting, Seeing, Profound Insights and Powerful Thinking from 50 Key Books". Online.
[14] Ibid, p 1.
[15] Scotchman, Iain C. "Shale gas and fracking: exploration for unconventional hydrocarbons". Proceedings of the Geologists' Association. Elsevier. 1 October 2016.
[16] Pawitan, Yudi. *In All Likelihood: Statistical Modelling and Inference Using Likelihood*. Oxford: Clarendon Press, 2001.

consistent. Further modifications are described in limitations. Data from 25 samplings was run from 9 articles (meaning 9 sample locations across the U.S.) passing the excision process. I inputted the dependent and independent variables and ran the test.

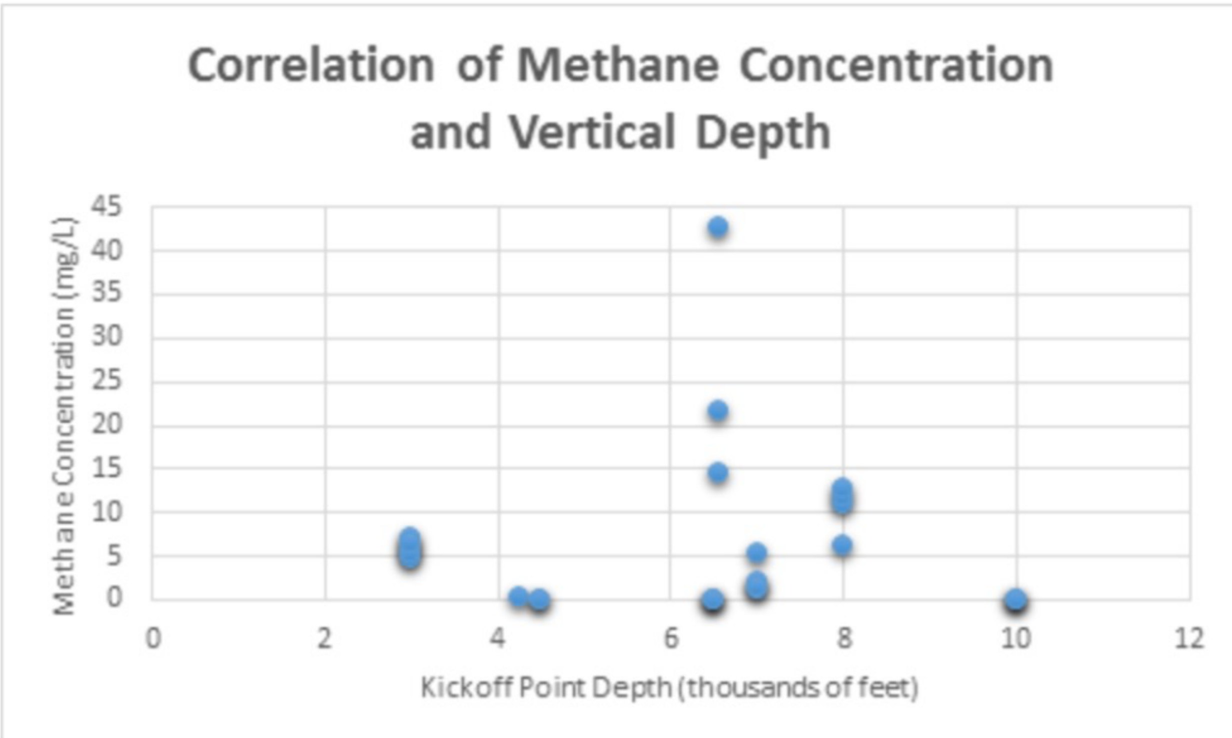
Results

Within In All Likelihood, likelihood is described as "the central concept in statistical modeling and inference."[17]

My linear regression considered parts of the following shale containing formations: Raton Basin, Bakken Formation, Marcellus Formation, Barnett, Deep River Basin, and Fayetteville.

Again, my null hypothesis was that vertical depth has no significant effect on methane concentrations in groundwater. In other words, a deeper kickoff point wouldn't likely result in a lesser concentration of methane, and a shallower kickoff point wouldn't likely result in higher methane concentrations. After running a linear regression test, I was unable to reject the null hypothesis.

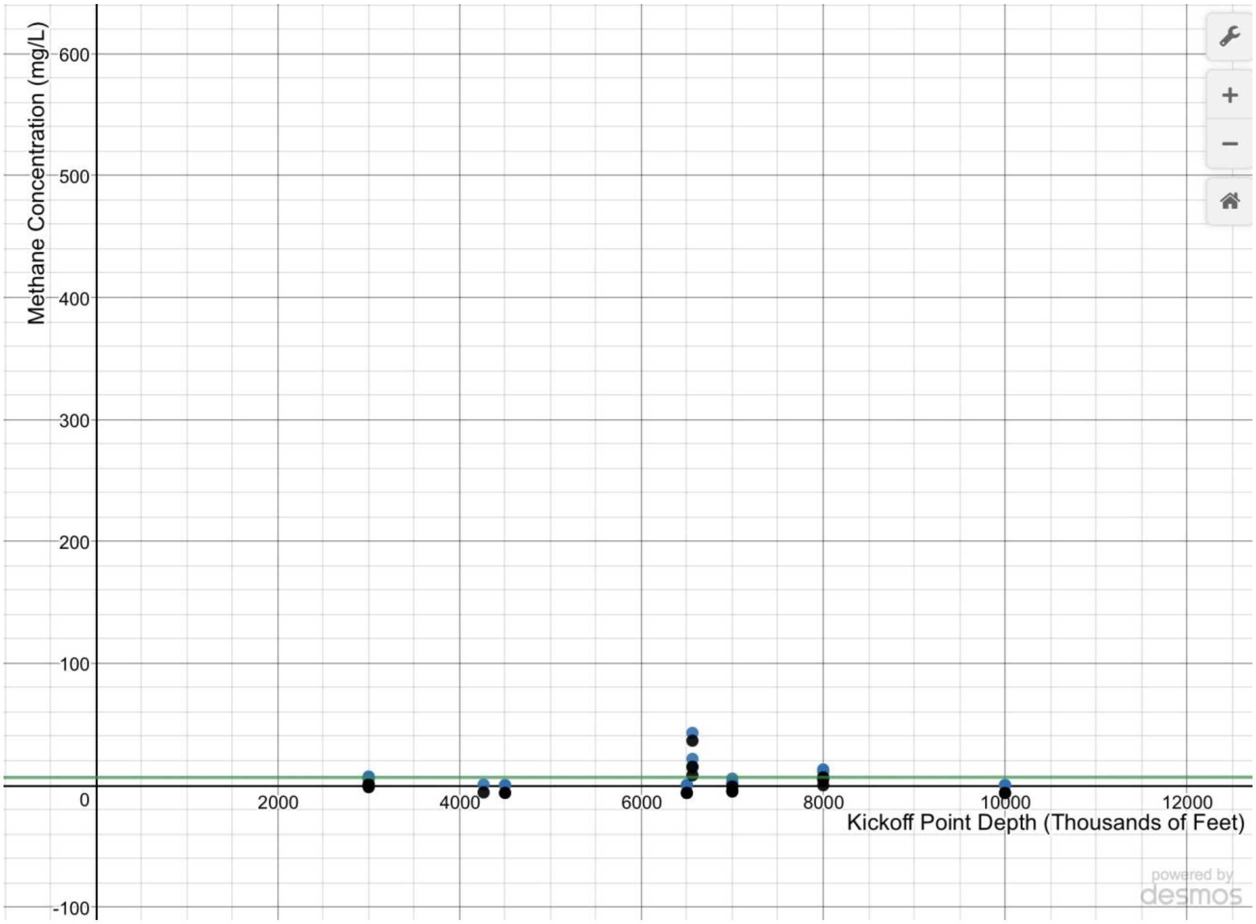
Figure 1:



My R/correlation value was .0031. This suggests that there is a very weak to no linear correlation that deeper kickoff points would likely indicate lesser to no methane concentrations in groundwater. An R-value very close to -1 would indicate a strong correlation, meaning that evidence would support the rejection of the null hypothesis. This value indicates how closely the data fits the best fit line.

[17] Ibid, p 9.

Figure 2:



The P-value of the linear regression test was .98. The P-value is the probability that the data outcome is linear. Though according to Pawitan, "...it is more correct to say that P-value measures the 'extremeness' or 'unusualness' of the observed data given a null hypothesis." Also, "The null hypothesis is doubtful if it is associated with the small P-value."[18] So, this high P-value indicates that the correlation is very much so not linear. There exists a close relationship between the P-value and normalized likelihood. As a form of inference, P-value has some attractive properties. Only the null model is needed to compute P-Value.[19]

I have 95% confidence that the true slope lies somewhere between -.0018 and .00184. This further supports the null hypothesis. See figure 2. The slope is very close to 0

Sample sizes of wells were accounted for through taking the mean concentration levels of each sampling. In this way incorrect weighing of studies was avoided.

Thermogenic methane concentrations exceeding standards were numerous, as were those that didn't exceed. The results suggest not the possibility of groundwater contamination when fracking, but instead that vertical depth is not a likely mechanism for methane migration.

Limitations

I was looking at meta analysis as a method but changed course to a linear regression test based on my findings. There exist meta analysis based articles in the fracking universe, but those looking at vertical depth as a determinant of methane concentration are scarce based on my investigation. Still, changing course best fit my question. Other changes of course occurred throughout the research process. I allowed unexpected findings to shape my research as opposed to continuing on the path I expected. In this way as well I worked to avoid harking. For example, learning of gas migration probability as opposed to that of

[18] Ibid, p 9.
[19] Ibid, p 9. (125-126).

fluid migration led me to decide on methane as a dependent variable. The discord led me to the gap, but didn't prepare me for the shift from data I'd collected regarding components in water wells also found in the fracking fluid itself.

That few resources specifically investigating my topic were available was also limiting in the process; this can be explained by the research gap regarding my question being so wide. No statistical analyses I encountered were asking the question I asked so finding data sets passing my excision process left relatively few to run a linear regression test on.

Special attention had to be payed to avoid harking – many sources were biased, leaning one way or the other in the fracking debate, or the authors had affiliations that might influence credibility. I had to be sure to chose data sets in which the collectors had none of two in order to ensure data integrity. Still, these sources and many others were sifted through and influenced my writing to some extent, but this influence was kept very clear of the linear regression test.

Only recently has there been a boom in fracking popularity, as discussed later. A benefit of the contemporary and significant nature of this universe is that there exist many articles, but because many are so recent special attention had to be payed to ensure credibility because they've not withstood further research and verifications. This risk was limited however because all articles used for linear regression data were peer reviewed, published articles passing excision criteria described in methodology.

Kickoff point depth had to be approximated in some cases. For those depths that offered a range, the median was taken.

The linear regression test run was an empirical model. According to In All Likelihood, "The rise of empirical modeling was a liberating influence...the rise of statistical modelling coincides with empirical modelling." Still, the source goes on: "While empirical models are widely applicable, we must recognize their limitations... A mechanistic model is more satisfying than an empirical model, but a current empirical model may be a future mechanistic model."

Discussion and Conclusions

Methane presence in groundwater has consequences. Though it's not directly regulated in the National Primary Drinking Water Regulations (NPDWR) nor in secondary drinking water standards required by the Safe Drinking Water Act, it still has potential dangerous effects. There does exist an action level for hazard mitigation; the U.S. Department of the Interior recommends a warning if water contains 10 mg/L of CH_4 and immediate action if concentrations reach 28 mg/L.[20] Vidic et al warn of methane presence: "When present, however, methane can be oxidized by bacteria, resulting in oxygen depletion. Low oxygen concentrations can result in the increased solubility of elements such as arsenic or iron. In addition, anaerobic bacteria that proliferate under such conditions may reduce sulfate to sulfide, creating water- and air-quality issues."[21]

Investigating the risk that fracking poses to groundwater resources is important because of the communities it affects. The Flint water crisis, taking place an hour's drive from my home, was not caused by stray gas migration – and lead, neither arsenic nor iron, was the main harmful ingested substance. But consider consequences of freed elements when ingested. Corrosive actors in the Flint River freed lead from aging pipes, causing it to leach into the water supply.[22] Possible negative health effects would vary depending on the elements which high methane concentrations altered, but lead in Flint water caused impaired cognition, decreases in IQ and hearing, delayed puberty, and other adverse effects in children. Pregnant women and adults faced other health hardships as a result of the lead-contaminated water.[23]

Taking contemporary water crises as a warning that U.S. systems are not infallible and real people suffer real consequences, further investigation of potential risks regarding fracking and water contamination is vitally important, as was investigating the relationship between vertical depth and methane concentration. As elaborated in the literature review, there are five established potential risks to water surrounding fracking, and subcategories to be researched below them.

This is still a relatively new field and there is much research to be done, especially considering the boom of this industry. "Although hydrofracking was first used in the 1940s, the practice was not widely applied until the 1990s, when natural gas prices increased and advances in horizontal drilling made the technique more productive."[24] According to the U.S. Energy Information Administration (EIA), "Shale gas production in the US is expected to increase threefold and will account for nearly half of all natural gas produced by 2035"[25] If fracking as a means of extraction is to have such a dominating presence, similar research seeking to find correlations and fill gaps must be conducted.

Also existing is controversy surrounding fracking: from popular culture references like the Simpsons "Opposites A-Frack" episode to the highly publicized debate regarding the Dakota access pipeline to ship fracked oil, consensus on consequences of fracking related practices is obviously lacking. Sifting the biased rhetoric from fact remains a challenge.

Principles of "Not in my Backyard" (NIMBY) shape the debate. In principle, fracking is often supported because of its benefits (natural gas is lauded as the cleanest burning fossil fuel). People generally want the economic stimulus and other positive effects of the operation, but none want it to take place in their own backyard.

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[20] K. K. Eltschlager, J. W. Hawkins, W. C. Ehler, F. J. Baldassare, "Technical measures for the investigation and mitigation of fugitive methane hazards in areas of coal mining". U.S. Dept. of the Interior, Office of Surface Mining Reclamation and Enforcement, Pittsburgh, PA, 2001.

[21] Vidic, R.D. et al. "Impact of Shale Gas Development on Regional Water Quality". AAAS. Vol 340. doi: 10.1126/science.1235009. 17 May 2013.

[22] Kennedy, Merrit. "Lead-Laced Water In Flint: A Step-By-Step Look At The Makings Of A Crisis. 20 April 2016. NPR.org

[23] "Lead". National Institutes of Health U.S. Department of Health and Human Services. https://www.niehs.nih.gov/health/topics/agents/lead/index.cfm. October 2013.

[24] Entrekin, Sally et al. "Rapid expansion of natural gas development poses a threat to surface waters". The Ecological Society of America. Front Ecol Environ 2011; 9(9): 503-511. doi: 10.1890/110053. 6 Oct 2011.

[25] "Shale gas production drives world natural gas production growth". eia.gov. 15 August 2016.

The Trump administration has expressed interest in further pursuing this type of extraction so there exists a dire need for investigation to realize further mechanisms for contamination.[26] Proponents of fracking hold that benefits of cleaner burning fossil fuels, keeping energy acquisition domestic, job creation, safety of the operation, and other factors outweigh the risks. Those against consider loose natural gas from fracking adding to the bad tropospheric ozone layer and accelerating climate change, potential risks to water resources, and habitat destruction. All ranges of the spectrum hold legitimate concerns which should be investigated. This considered, before further acceleration or definitive action taken by the current U.S. administration, taking place should be research on fracking and its myriad of potential consequences. Not only water quality should be investigated, but also other environmental and economic factors. Early in my broad investigation I encountered research suggesting hydraulic fracturing and refracting correlated with increased earthquakes. Opposition also existed, arguing that the earthquakes were too small to have any significant effect. While I haven't investigated this avenue, many others like it exist. That the current administration considers pushing back on regulations to promote fracking further demonstrates the contemporary and significant nature of this topic and therefore those of this paper. Strides can be made so smart policy can follow, similarly to the widespread reaction and change following Rachel Carson's revealings in Silent Spring regarding pesticide consequences in the 1970s. If no correlation between variables is found, policy would be shaped around those results as well.

All in all, though my outcomes lacked sufficient statistical probability to support my hypothesis that vertical depth of the kickoff point to the groundwater table played a significant role in determining the concentration of thermogenic methane, the research looked at a contemporary and significant issue. It sought to fill a gap in the research where discord exists, and the findings were novel. The question this paper investigated was important because further research is critical to the lives of real people and the shaping of governing policy regarding fracking regulations.

Future Research

Impacts (any change in the quality or quantity of drinking water resources, regardless of severity, that results from an activity in the hydraulic fracturing water cycle)[27], and the factors determining them, must be monitored to ensure the safety of drinking water resources. A way to find hypothetical mechanisms for contamination or the extent to which a factor plays a role in determining impact, linear regression tests can be run to find correlation and likelihood of contamination regarding particular mechanisms. It is crucial that this issue be held as a priority for future research. If I were to continue investing the fracking universe, other questions of water quality I would ask would be regarding water acquisition's effect on biogeochemical cycles, likelihood of fluid migration correlating with refracturing (to do this I might compare concentrations of substances in fracking fluid found in groundwater resources near refracturing operations to those found in groundwater resources of first-time fracking operation), processes of chemical mixing, handling of produced water/produced water disposal, and wastewater disposal/potential treatment and how these processes relate to the environment.

Investigation not directly related to water resources should also occur. I would want to find if any correlation exists between fracking operations and loss of biodiversity or an increase in earthquakes/the severity of earthquakes. I would ask questions regarding EPA standards and the boom of fracking operations and how these have affected employment, considering West Virginia coal miners. I am especially interested in Arctic/seismic testing for oil, and in the geopolitical sphere, who has control over new reserve discoveries? This relates to the Dakota Access Pipeline purposed to ship crude oil, as questions were raised about possible water contamination and access to tribal lands. This might also connect to the Senkaku Islands dispute, in which territorial claims and discord followed the discovery of potentially rich oil deposits beneath the seabed.[28] (Roy-Chaudhury, Shantanu. "The Senkaku Islands Dispute". International Policy Digest. 1 August 2016. intpolicydigest.org.) Other questions revolving around fracking's loose gas contribution to climate change or factors that affect it or how it compares to other extraction methods might be asked.

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[27] Ibid, p 1.

[28] Roy-Chaudhury, Shantanu. "The Senkaku Islands Dispute". International Policy Digest. intpolicydigest.org. 1 August 2016.

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