

Methane Concentrations in Water Wells Unrelated to Proximity to Existing Oil and Gas Wells in Northeastern Pennsylvania

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Presentation Overview

- Research question
- Data analysis
- Key results
- Summary

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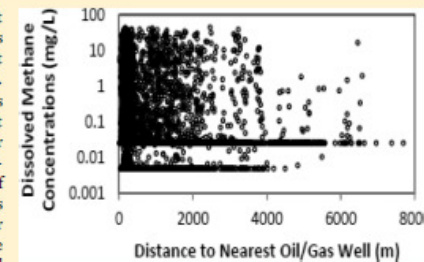
Methane Concentrations in Water Wells Unrelated to Proximity to Existing Oil and Gas Wells in Northeastern Pennsylvania

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Supporting Information

ABSTRACT: Recent studies in northeastern Pennsylvania report higher concentrations of dissolved methane in domestic water wells associated with proximity to nearby gas-producing wells [Osborn et al. *Proc. Natl Acad. Sci. U. S. A.* **2011**, *108*, 8172] and [Jackson et al. *Proc. Natl. Acad. Sci. U. S. A.*, **2013**, *110*, 11250]. We test this possible association by using Chesapeake Energy's baseline data set of over 11,300 dissolved methane analyses from domestic water wells, densely arrayed in Bradford and nearby counties (Pennsylvania), and near 661 pre-existing oil and gas wells. The majority of these, 92%, were unconventional wells, drilled with horizontal legs and hydraulically fractured. Our data set is hundreds of times larger than data sets used in prior studies. In contrast to prior findings, we found no statistically significant relationship between dissolved methane concentrations in groundwater from domestic water wells and proximity to pre-existing oil or gas wells. Previous analyses used small sample sets compared to the population of domestic wells available, which may explain the difference in prior findings compared to ours.



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Fundamentally, A Simple Question

Is dissolved concentration related to distance?

Unique because:

- Large dataset ($n=11,309$)
- Many non-detects
- Two different laboratory reporting limits

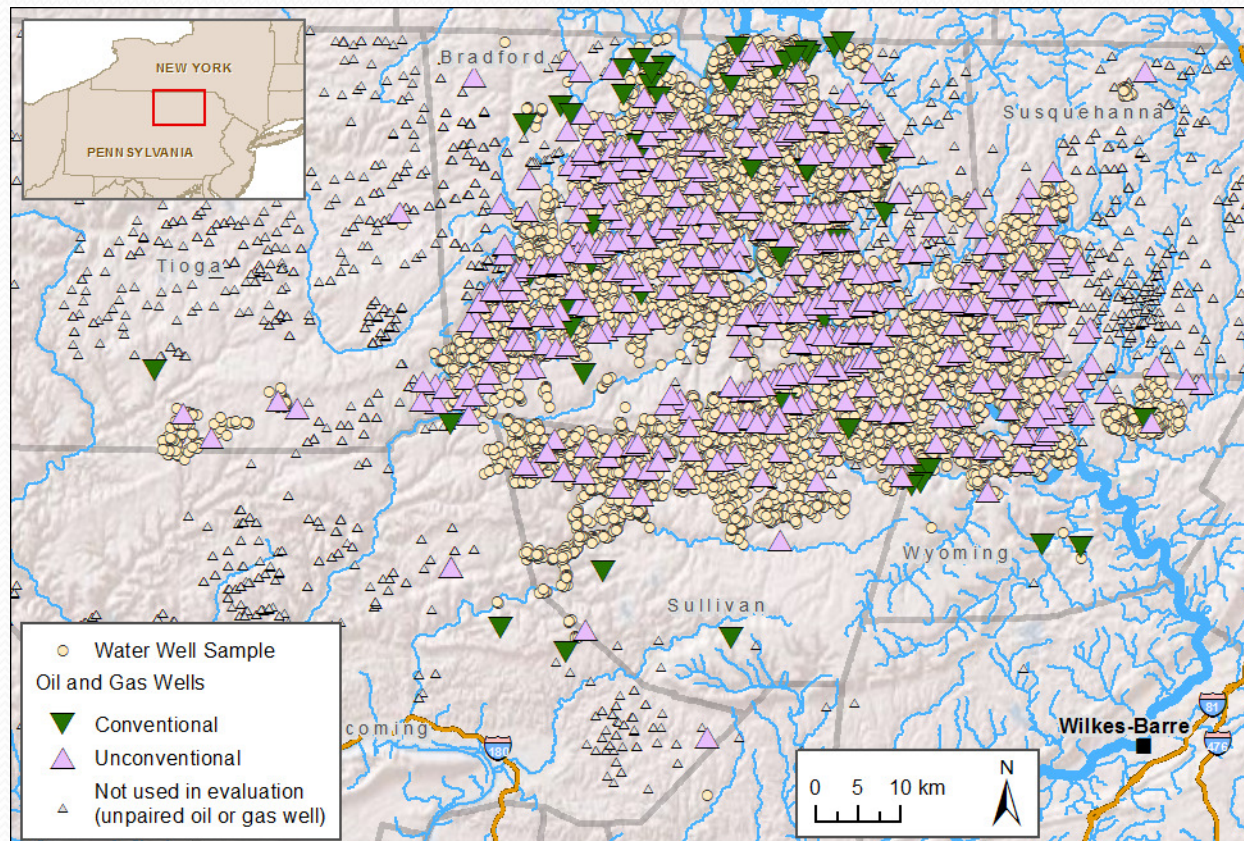
Sample I.D.	Distance from Oil or Gas Well (meters)	Dissolved Methane Conc. (mg/L)	Detect Flag (0=detect; 1=ND)
1	218	0.005	1
2	1,090	3.550	0
3	311	1.510	0
4	276	2.320	0
5	179	2.990	0
...	2,794	0.026	1
11,309	156	2.090	0



Key Data Inputs

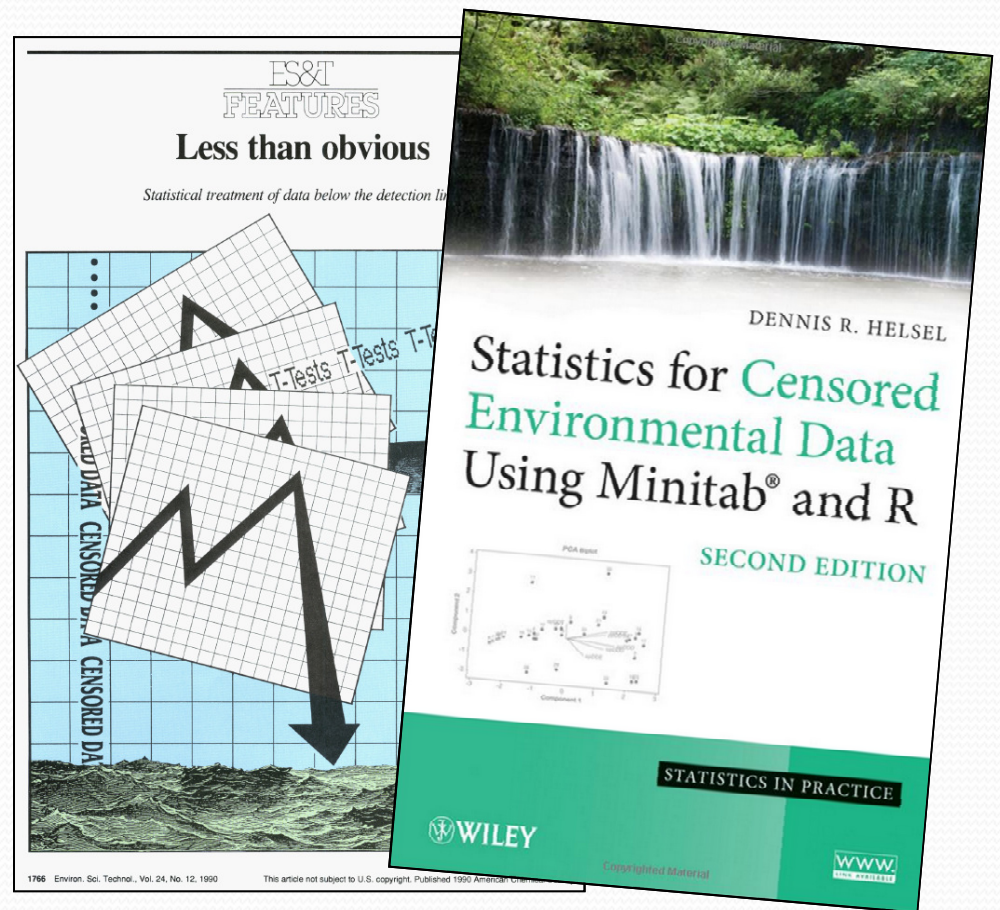
- **Pre-existing wells:** Pennsylvania Department of Environmental Protection database
- **Distance:** GIS-based computation to pair each water sample to the nearest oil or gas well
- **Dissolved methane:** Water samples collected from water taps 3 to 6 months before drilling

Water Well Sample Locations and Pre-Existing Oil / Gas Wells

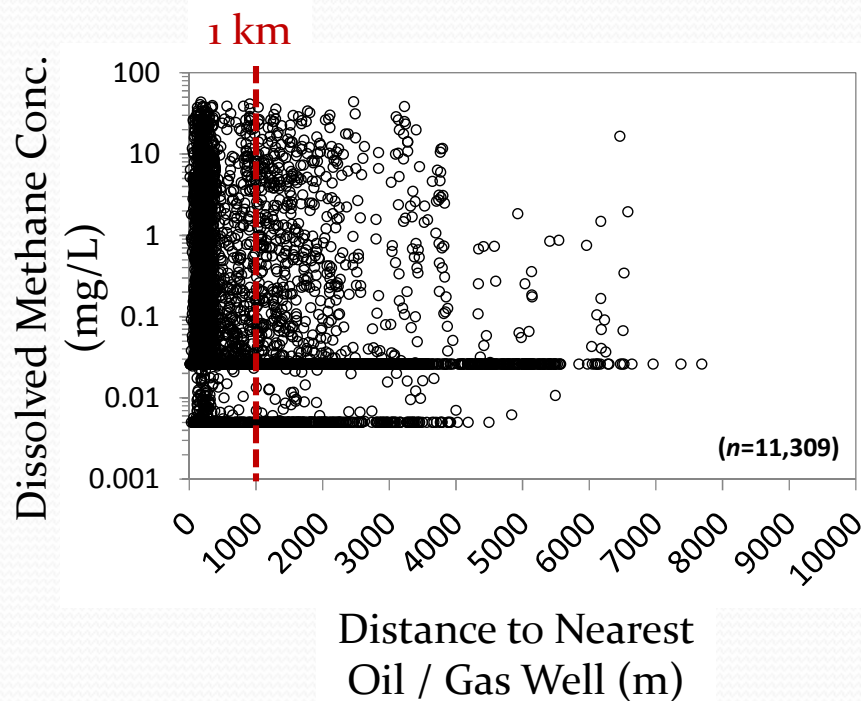


Weight-of-Evidence Approach

- Graphical assessment
- Test of proportions
- Logistic regression
- Survival analysis
- Correlation analysis

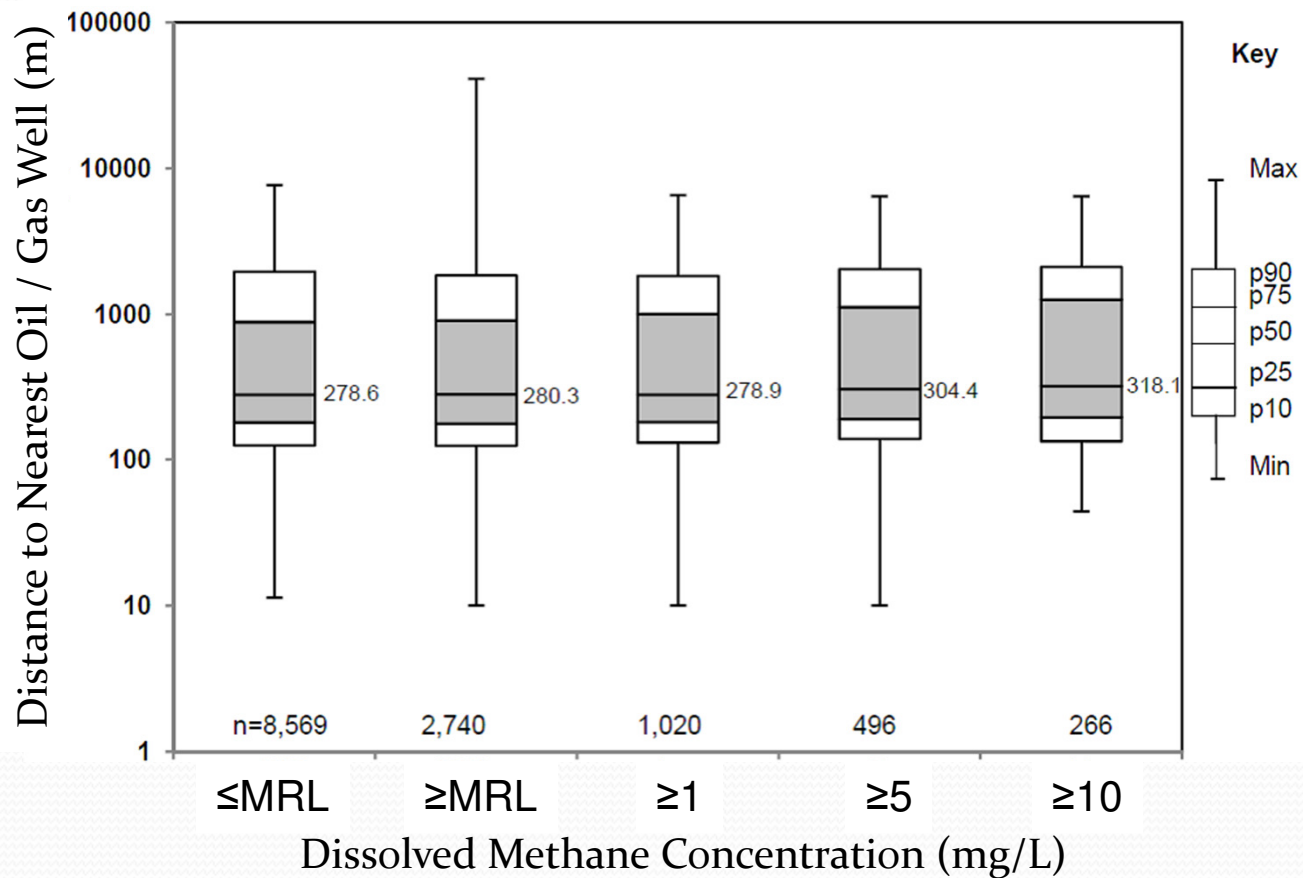


Graphical 1: Scatterplot of Concentration vs. Distance



- No *visual* correlation between concentration and distance
- No “1-km threshold”
- Many non-detects
- Two lab reporting limits

Graphical 2: Boxplots as a Function of Distance and Concentration



Test of Proportions

- Dichotomizes the concentration data into proportions of detects/non-detects above a threshold value
- No significant differences between groups within or beyond a distance threshold

		Group 1 Proportions			
Distance (m)	<i>n</i>	% Det >MRL	% ≥1 mg/L	% ≥5 mg/L	% ≥10 mg/L
≤500 m	7,608	24.0	8.8	4.0	2.0
≤1000 m	8,691	24.1	8.8	4.1	2.1
≤1500 m	9,625	24.4	9.0	4.2	2.2
		Group 2 Proportions			
Distance (m)	<i>n</i>	% Det >MRL	% ≥1 mg/L	% ≥5 mg/L	% ≥10 mg/L
>500 m	3,701	24.7	9.5	5.2	3.0
>1000 m	2,618	24.7	9.8	5.4	3.1
>1500 m	1,684	23.2	9.0	5.2	3.3
		Test of Proportions Results			
Distance Threshold (m)		<i>p</i> -value			
		% Det >MRL	% ≥1 mg/L	% ≥5 mg/L	% ≥10 mg/L
500 m		0.798	0.878	0.999	0.999
1000 m		0.738	0.951	0.998	0.998
1500 m		0.140	0.526	0.968	0.996

$$H_0: p_{\text{Group1}} - p_{\text{Group2}} = 0$$

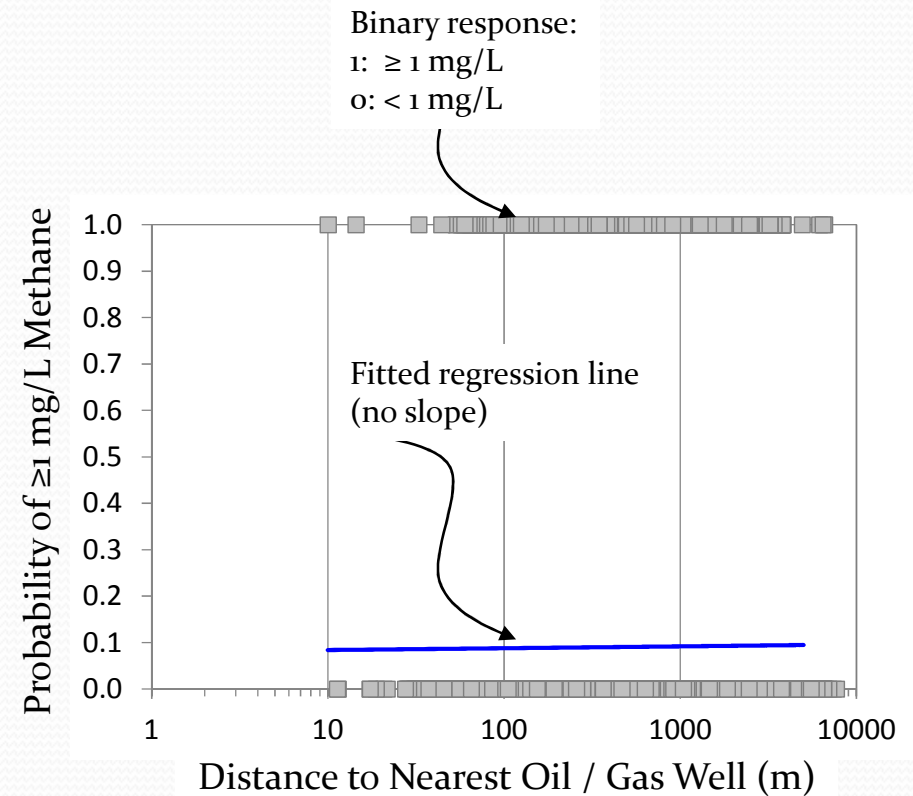
$$H_A: p_{\text{Group1}} - p_{\text{Group2}} > 0$$

Logistic Regression

- Same “y” as test of proportions
- “x” = ln(distance)

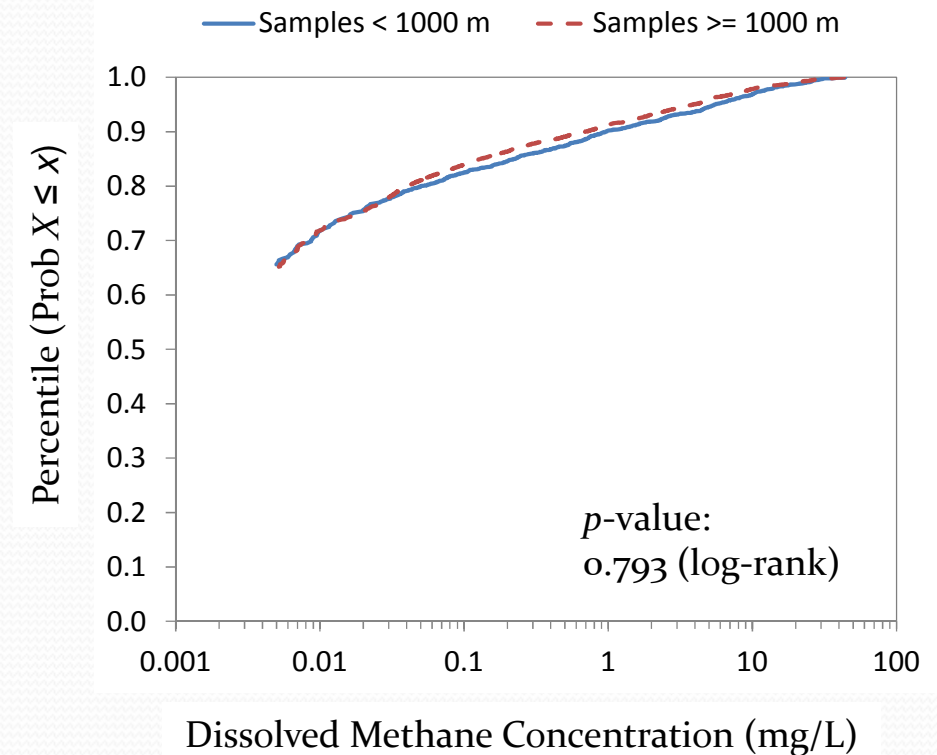
$$\text{Prob} = \frac{\exp(\beta_0 + \beta_1 x)}{1 + \exp(\beta_0 + \beta_1 x)}$$

- No significant increase in the probability of detection above the MRL or the probability of being above 1, 5, or 10 mg/L dissolved methane as you get closer to an oil/gas well



Survival Analysis

- Kaplan-Meier (K-M) method to compute percentiles
- Distributions of dissolved methane concentrations do not differ as a function of distance to the nearest oil/gas well.
- Survival function curves for the two groups are virtually indistinguishable.



Correlation Analysis

Method	Correlation Coefficient	<i>p</i> -value
Spearman's <i>rho</i> , censored at 0.026 mg/L	-0.004	0.676
Kendall's <i>tau</i> , censored inputs, full record	-0.002	0.700

- Spearman's *rho* and Kendall's *tau* both conclude a correlation coefficient of effectively zero that is not statistically significant.

$$\text{Kendall's } \tau_b = \frac{N_c - N_d}{\sqrt{\left(\frac{N(N-1)}{2} - \text{\#ties}_x\right) \left(\frac{N(N-1)}{2} - \text{\#ties}_y\right)}}$$

Where,

N_c = # of concordant pairs (Y increases as X increases – positive slope)

N_d = # of discordant pairs (Y and X going opposite directions or negative slope)

N = total number of pairs



Summary

- In aggregate, the combined results of the graphical assessment and all four statistical tests yields a compelling argument that there is no significant correlation with dissolved methane concentrations and proximity to the nearest oil/gas well.
- Suggests that documented incidents (~0.24%) are the exception, not the rule
- Highlights the need for incorporating non-detects into monitoring programs for shale gas development



Questions?

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