ON THE REPORTING OF WATER USE AND THE EFFECTS OF HYDRAULIC FRACTURING ON GROUNDWATER LEVELS IN TEXAS

Camp Resources

August 13, 2018

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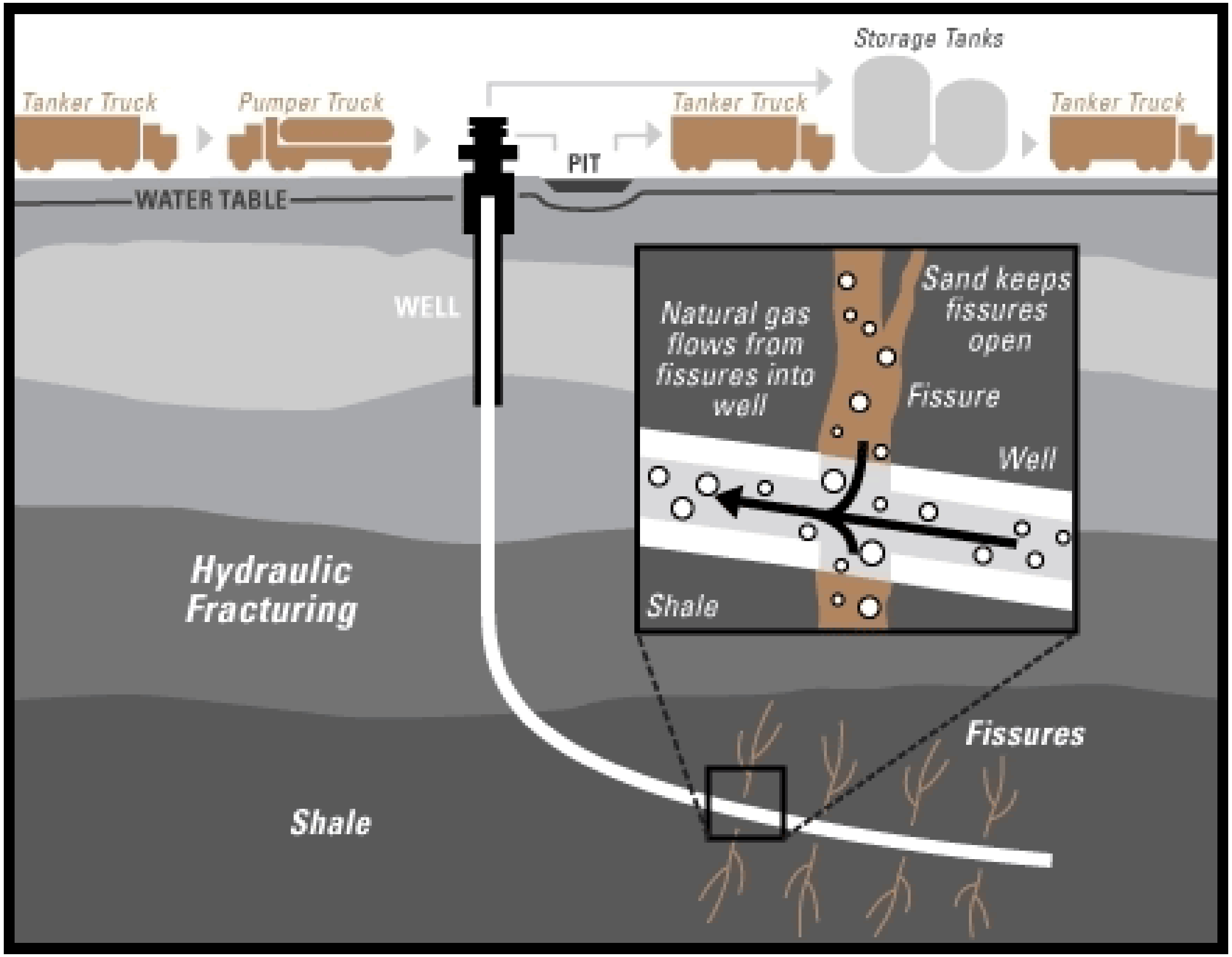
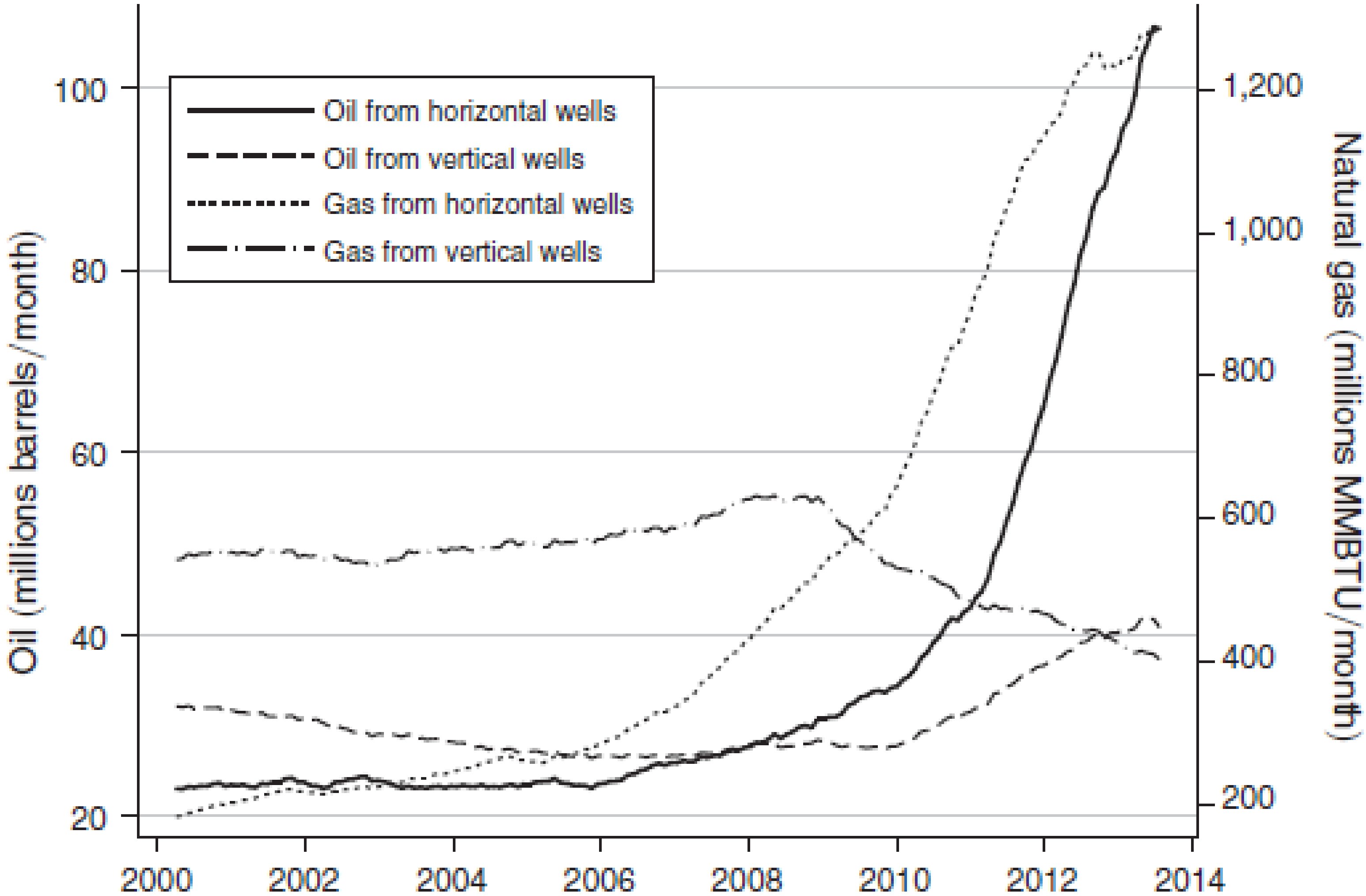
Funding for this project was provided by the Center for Growth and Opportunity at Utah State University

Introduction – *Hydraulic Fracturing* (HF)



Oil and Gas Production Trends - Nationwide



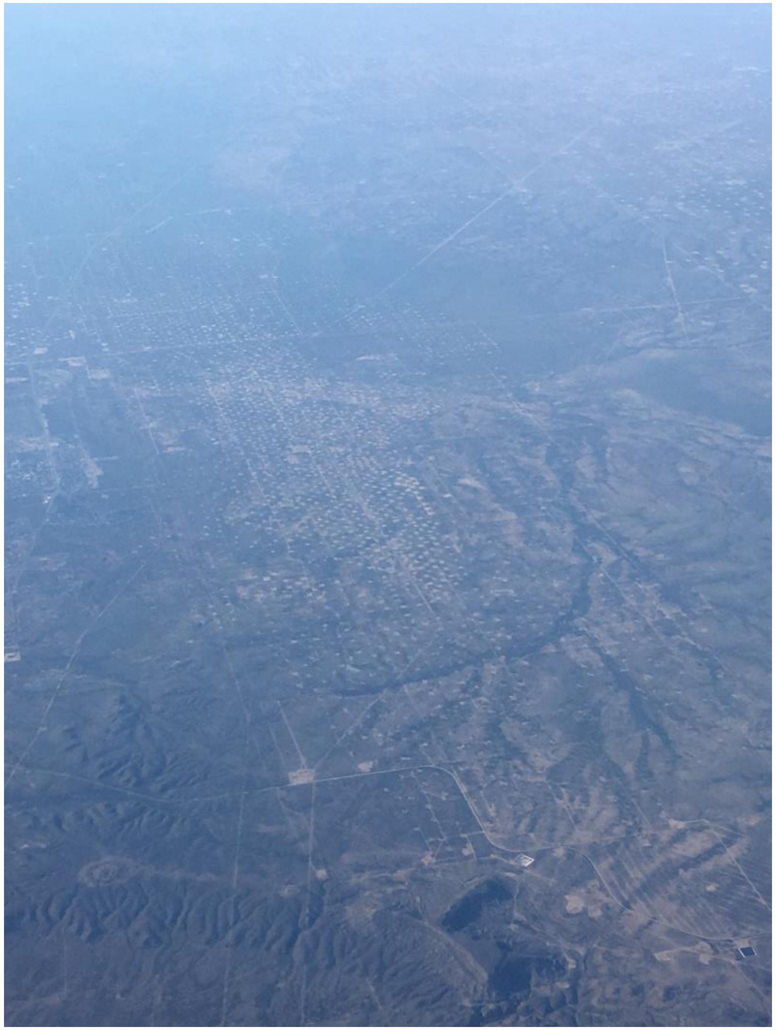
Source: Feyrer, Mansur, and Sacerdote (2017, AER)

Well Pad Concentrations

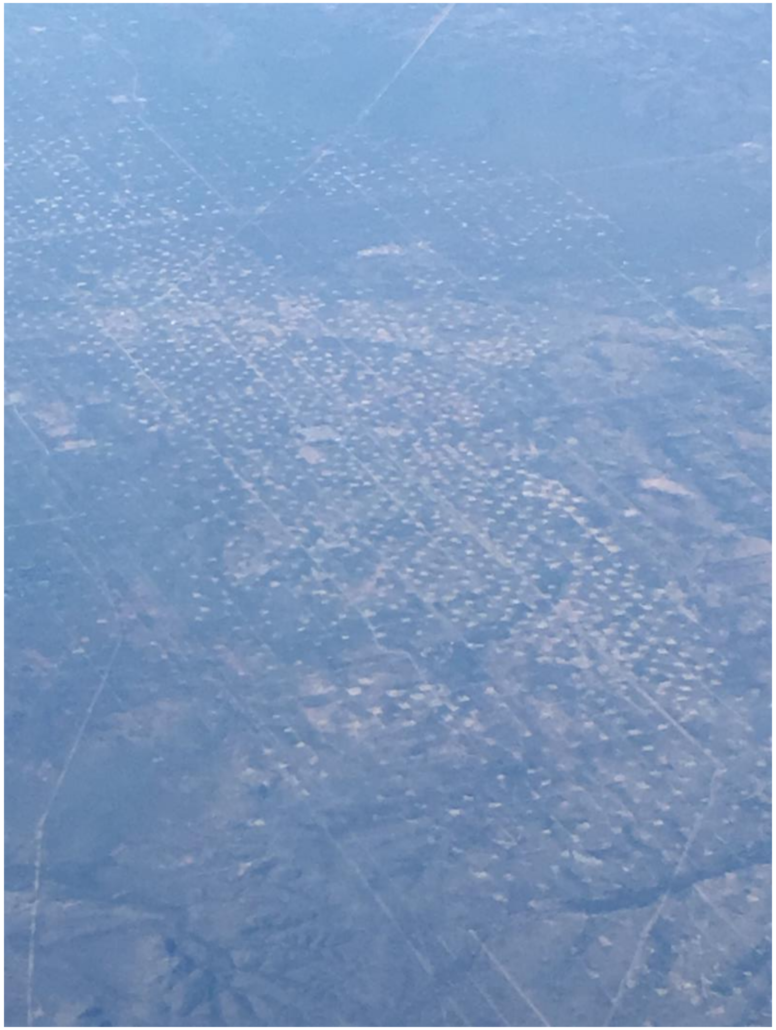
West Texas / East New Mexico

West Texas / East New Mexico

West Texas / East New Mexico



West Texas / East New Mexico



Motivation: People Fear a Lack of Water Availability

With increasing HF activity, water use in the industry has become center stage.

- 11 million gallons were used per well in west Texas' Permian Basin in 2016, equivalent to supplying ~69,000 households with water for a day.
- If combined with drought (e.g. Texas drought in 2011), water use in HF has the potential to affect water availability in water scarce regions (EPA 2016).
- Example: in the Bakken shale, instances of private stock dams running dry were reported, forcing landowners to haul in water and leading to a communal fear of displacement due to water availability (Kusnetz 2012).
- Tax write-offs available for groundwater level decline in certain counties.

Transparent information on water use is important. Yet, water use *reporting* in HF has not been studied.

Literature Review

Growing literature on issues related to HF, with a particular emphasis on the localized impacts:

General

- Housing market
- Employment and wages
- Tax and royalty revenues
- Crime rates
- Increased truck traffic and accidents
- Health effects
- Attitudes and perception
- Cost-Benefit analysis

Environmental

- Air
  - greenhouse gas emissions and local air quality
- Water *quality*
  - concerns over ground and surface water contamination
- Seismic activity
  - associated with wastewater disposal
- Noise and light pollution
- Water *quantity*
  - generally from a qualitative perspective

Research Questions

1) Does the level of detail when reporting water use vary for oil & gas wells located in a local groundwater conservation district area?

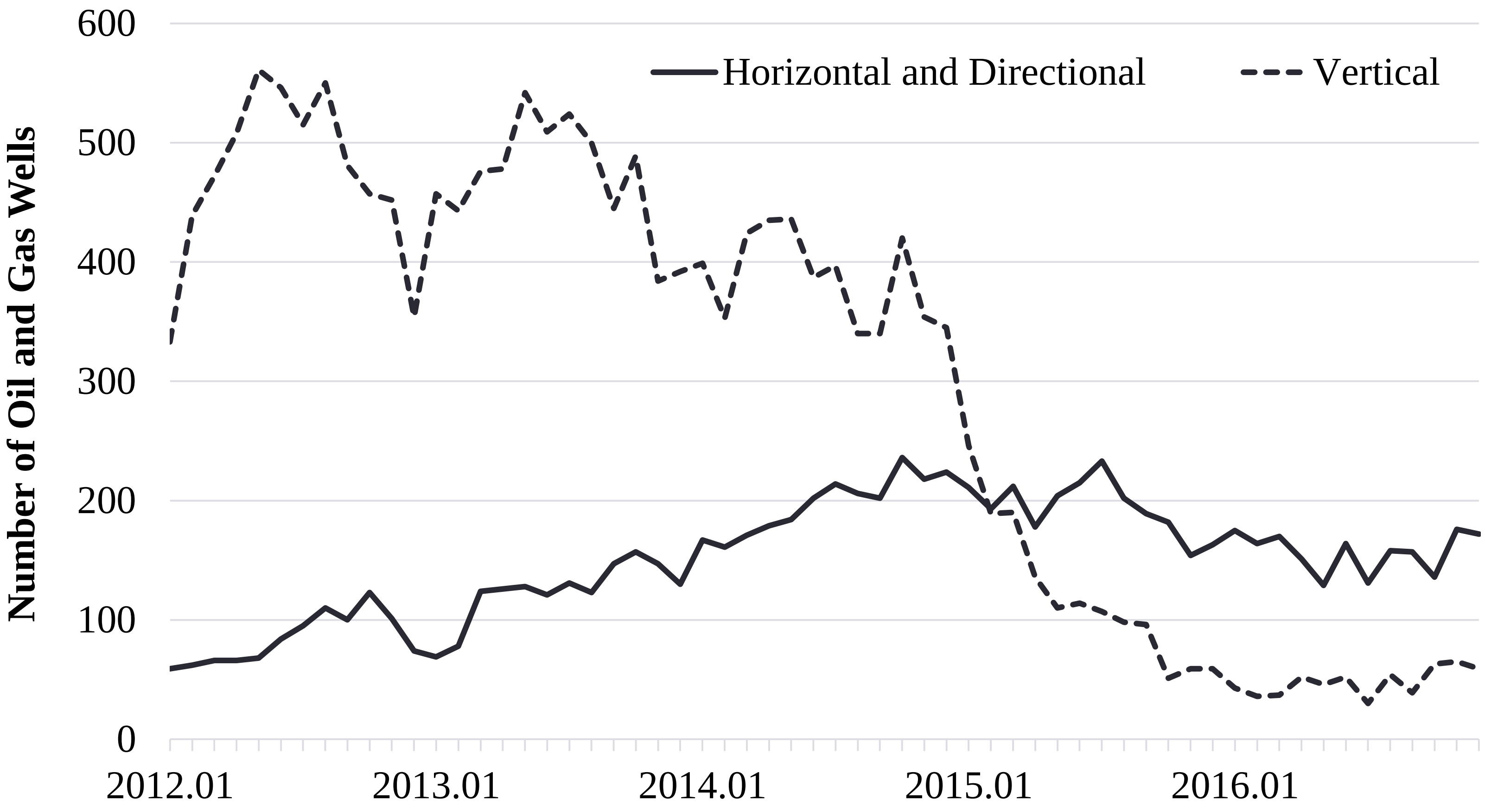
2) Is water use in HF large enough to have an effect on local groundwater levels?

Why Texas?

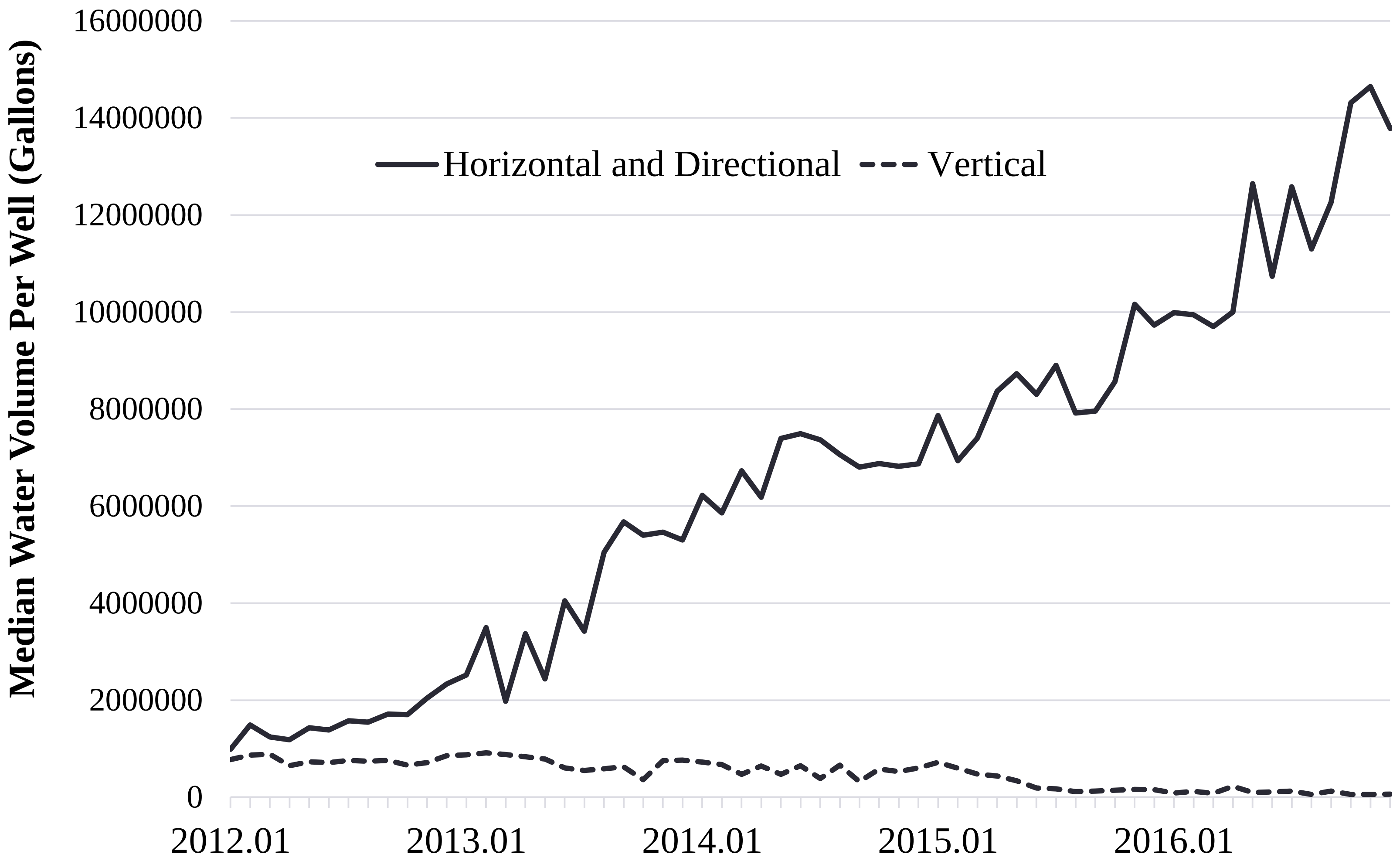
Texas is a unique place to study for several reasons:

1. Permian Basin is the hottest shale play in the world.
2. Complex, but somewhat ambiguous groundwater regulations.
3. Low surface water availability in parts of Texas, meaning groundwater is a primary source.
4. Information on water use in HF (e.g. source and type) is limited by relatively weak state-level reporting requirements.

Hydraulically Fractured Wells - Permian



Median *Reported* Water Use - Permian



Water Use Reporting

Two major laws with respect to water use in HF in Texas:

1. The reporting of total water use to *fracfocus.org* is required by House Bill 3328 for permitted wells as of February, 2012.
   - Water *source* and *type* are not required to be reported in Texas.
   - In my sample, a water type (e.g. brackish water, freshwater, slickwater, recycled wastewater) is listed in about 97% of well reports.

2. Water use exemption in hydrocarbon production – Chapter 36 Section 117(b)(2) of the Texas Water Code.
   - Major questions over how far the exemption reaches.
   - Important because the industry wants the exemption to stay.
   - Currently can use any amount of water.

FracFocus Disclosure Requirements - Texas

Required reporting for permitted wells as of February, 2012:

(1) **Total volume of *water*** used in the HF treatment(s) of the well.

(2) Each **additive** used in the HF treatment(s) and the trade name, supplier, and a brief description of the function of each additive.

(3) The **actual or maximum concentration** of each chemical ingredient in percent by **mass**.

Groundwater Law in Texas

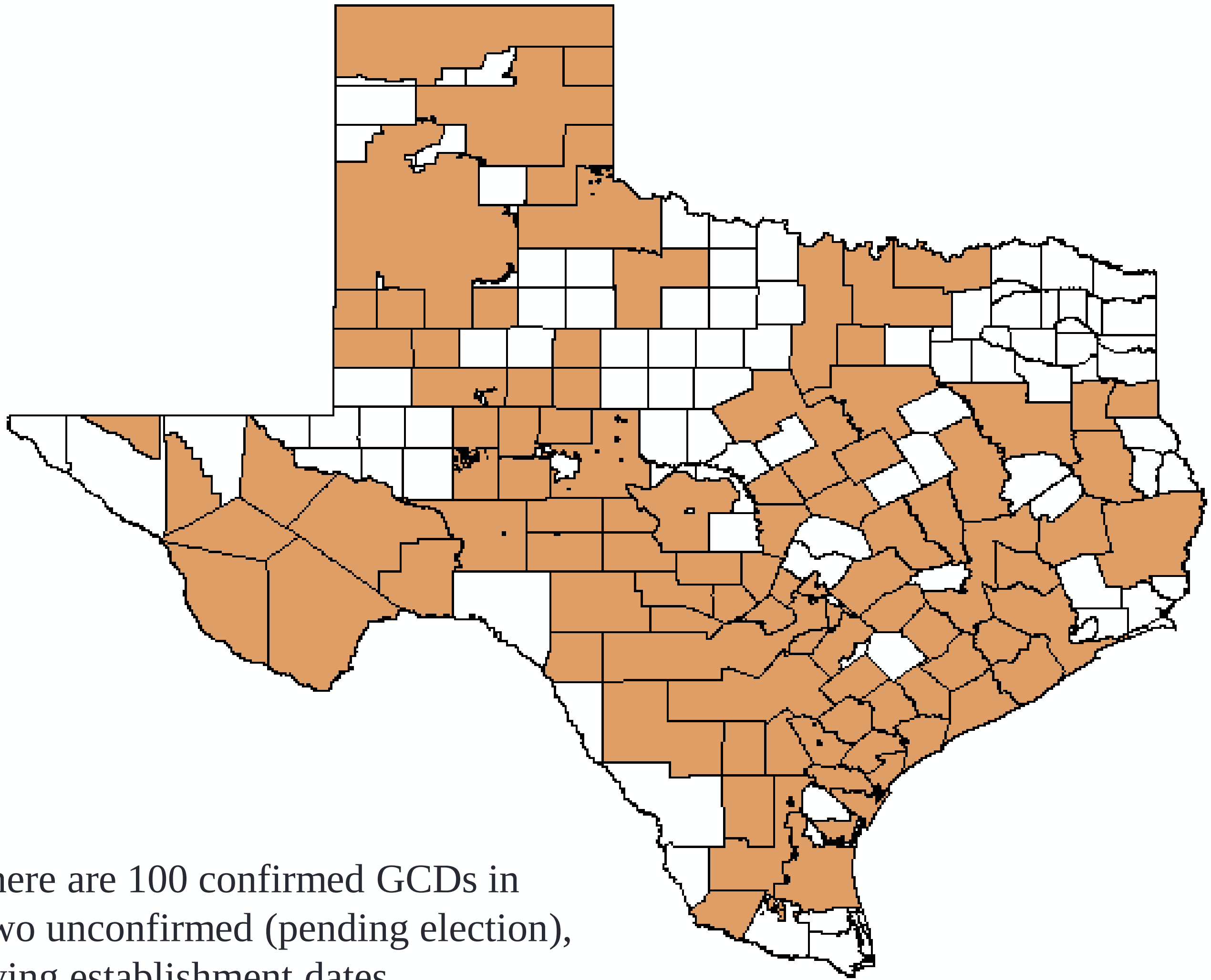
Common Law: *Rule of Capture*

- Established to protect private property and grants landowners the right to pump and capture whatever water is beneath their property regardless of the effects on neighboring wells.

Groundwater Conservation Districts (GCDs)

- Legal entities charged with managing groundwater by providing for the conservation, protection, recharging, and prevention of waste of groundwater.
- Empowered with three primary legislatively-mandated duties:
  1. Permitting water wells.
  2. Developing a comprehensive management plan.
  3. Adopting necessary rules to implement the management plan (e.g. regulating access to water).

TX Counties and GCD Areas



Currently, there are 100 confirmed GCDs in Texas and two unconfirmed (pending election), all with varying establishment dates.

Data – Part I

Source

- Primary Vision – a company in Houston, TX – provided a dataset of well-level completion reports from oil and gas wells over 2012-2016.

Outcome Variable

- Indicator for the level of water use information reported for well record *i*:

$$Y_i = \begin{cases} 1 \; if\ more\ water\ use\ information\ (than\ required)\ was\ reported \\ 0 \; if\ required\ amount\ of\ water\ use\ information\ was\ reported \end{cases}$$

Independent Variables

- Location of well i within a GCD or non-GCD area (some variation in start date)
- Total water volume (100k gallons) used in well stimulation for well i
- Whether the well record associates with a new completion or a refrac
- Fixed effects for month of sample

Outcome Variable Explanation

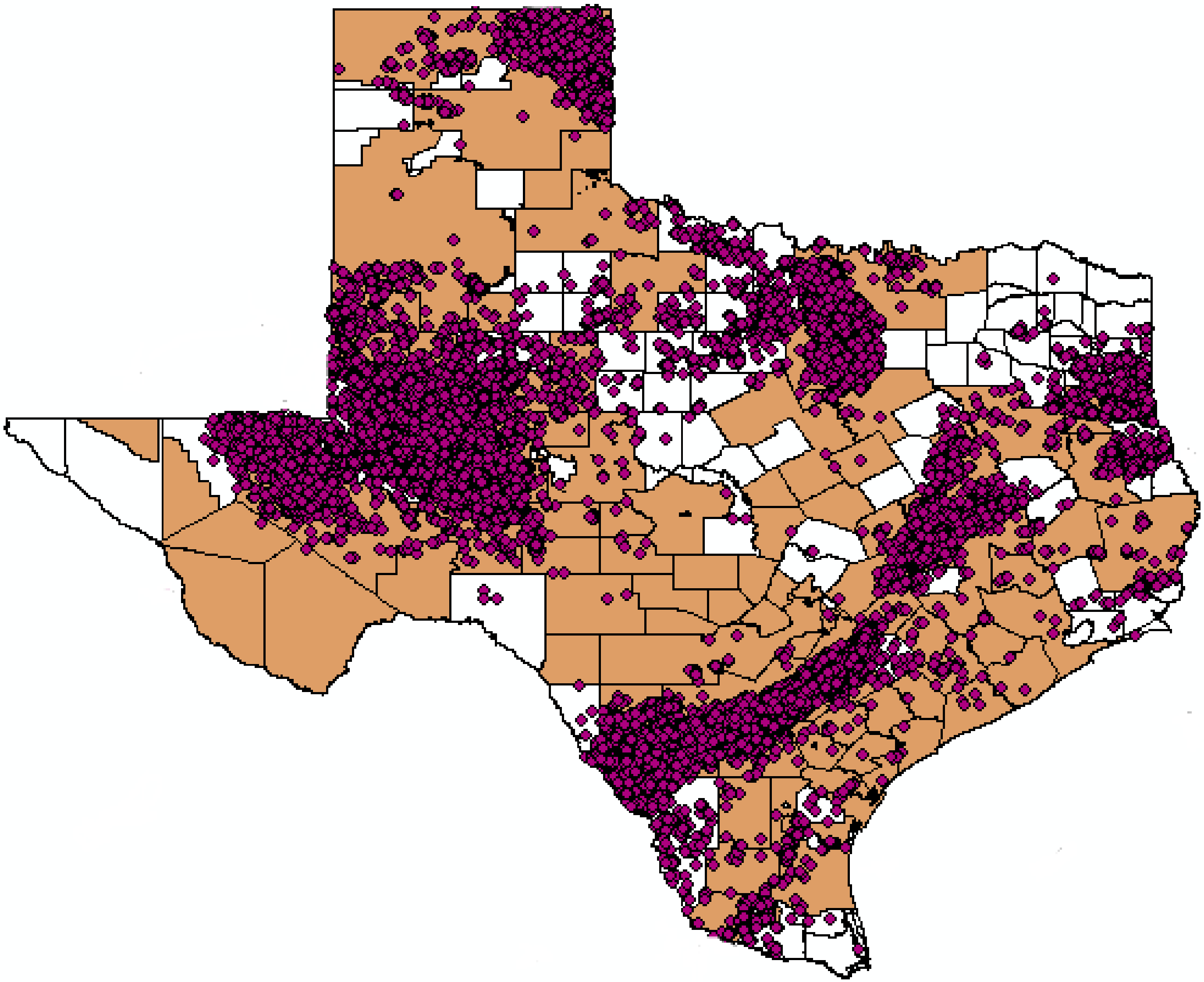
Calculated by Primary Vision if a well completion report specified a water type(s)

	objectid	HF_FluidMass	TWV	orientation	GCDest
1	57951	142440156	15569493	HOR	.
2	47677	999999999	15557808	HOR	1989.08

$$\text{HF Fluid Mass} = f(water\ volume\ by\ type, water\ density\ by\ type, chemical\ mass, frac\ sand\ mass, others)$$

$$Y_i = \begin{cases} 1\ if\ \text{HF Fluid Mass} \neq 999999999 \\ 0\ if\ \text{HF Fluid Mass} = 999999999 \end{cases}$$

Oil and Gas Well Locations



Linear Probability Model Results

Outcome Variable: Report Extra Water Use Information (1 or 0)

Outcome: Reporting (mean=.975)	1	2	3	4
GCD (1 or 0)	-0.0145*	-0.0137*	-0.0414***	-0.0343***
	(0.0080091)	(0.0076011)	(0.0126319)	(0.0110418)
Total Water Volume (Unit = 100k Gallons)		-0.0002***	-0.00023***	-0.000018***
		(0.0000609)	(0.0000856)	(0.0000639)
Refrac (1 or 0)			0.0063	0.005
			(0.0060392)	(0.55506)
TWV*GCD				-0.0001721
				(0.0001375)
Month of Sample Fes	Yes	Yes	Yes	Yes
Operator FEs	Yes	Yes	Yes	Yes
Observations	48,284	48,284	48,284	48,284

Standard errors in parentheses. Clustered at county level.
*** $p<0.01$, ** $p<0.05$, * $p<0.10$

Logit Model Results

Outcome Variable: Report Extra Water Use Information (1 or 0)

	1	2	3	4
GCD (1 or 0)	-0.6423**	-0.5786***	-1.0737***	-1.0453***
	(0.0080091)	(0.2040982)	(0.2200761)	(0.2357256)
Total Water Volume		-0.0092***	-0.01135***	-0.01068***
(Unit = 100k Gallons)		(0.0014636)	(0.003027)	(0.0000639)
Refrac (1 or 0)			-0.5028*	0.502*
			(0.2763365)	(0.2764084)
TWV*GCD				-0.00087
				(0.00516)
Month of Sample Fes	Yes	Yes	Yes	Yes
Operator FEs	Yes	Yes	Yes	Yes
Observations	38,137	38,137	38,137	38,137

Standard errors in parentheses. Clustered at county level.
*** $p<0.01$, ** $p<0.05$, * $p<0.10$

Data - Part II

Outcome Variable

- Average daily distance from the surface to groundwater level of monitoring station *i* in month *t* (Unbalanced panel of daily groundwater levels from 273 monitoring stations over 2011-2017)

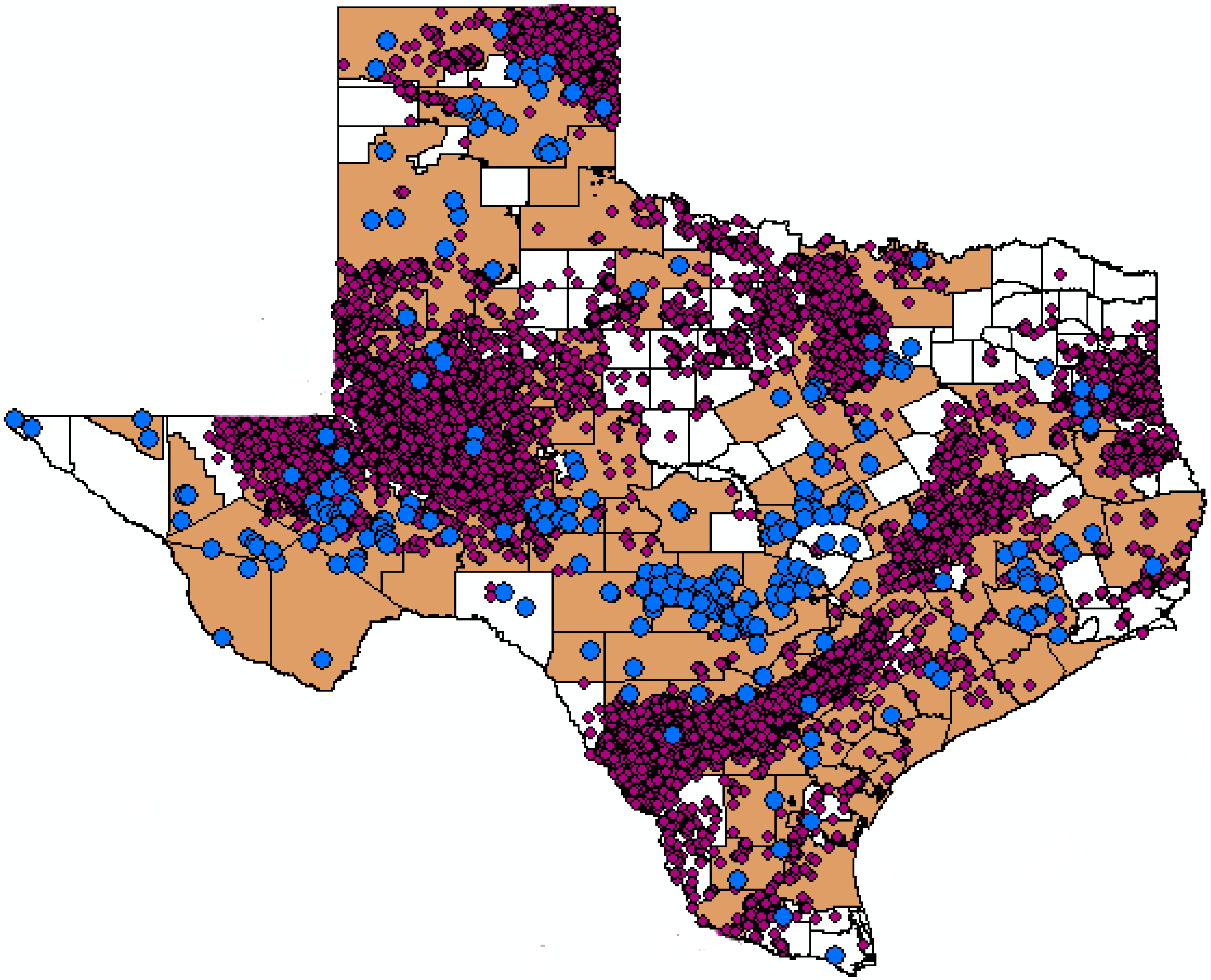
Independent Variables

- Total water volume used in hydraulically fractured wells within the vicinity of monitoring station *i* in month *t*
- Drought severity index in county of monitoring station *i* in month *t*
- Precipitation, wind, and temperature in county of monitoring station *i* in month *t*
- Year-month fixed effects
- Groundwater monitoring station fixed effects

Sources

1) Texas Water Development Board
2) Primary Vision
3) US Drought Monitor
4) NOAA – National Center for Environmental Information

Groundwater Level Monitoring Stations



Fixed Effects Model

$$DistGW_{i,t} = \beta_1 TWVradius10_{it} + \sum_{j=2}^{n} \beta_k TWVring_{kit} + \boldsymbol{x_{it}\beta_{k+1}} + \lambda_t + \gamma_i + \varepsilon_{it}$$

$DistGW_{i,t}$ - distance (from the surface) to groundwater level of station i in month t

$TWVradius10_{i,t}$ - total HF water volume (in 100s of barrels) used within 10 miles of station i in month t

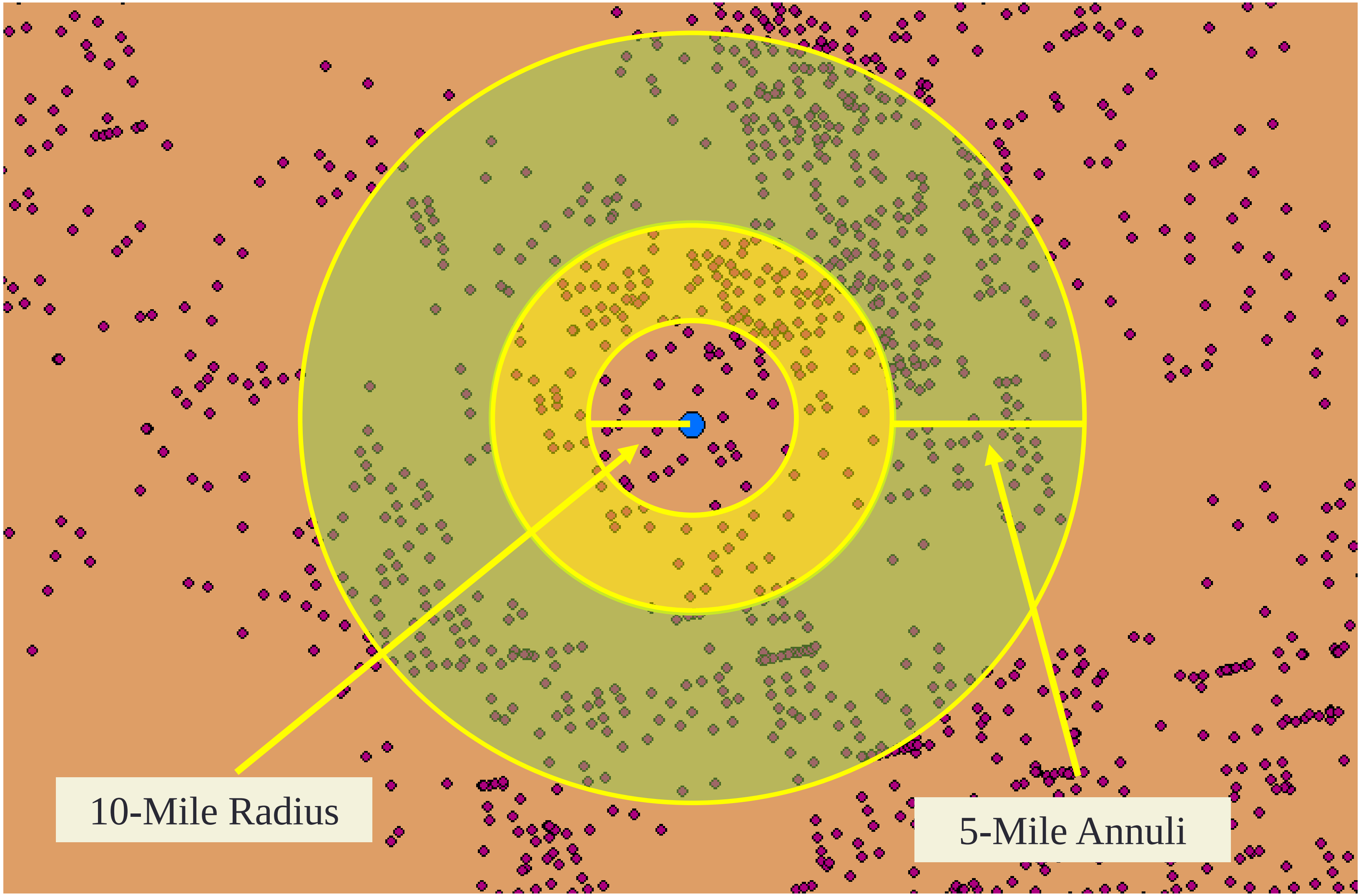
$TWVring_{k,i,t}$ - total HF water volume used within ring k of station i in month t

$\boldsymbol{x_{i,t}}$ - controls for average drought severity, precipitation, temperature, and wind speed in the county of station i in month t

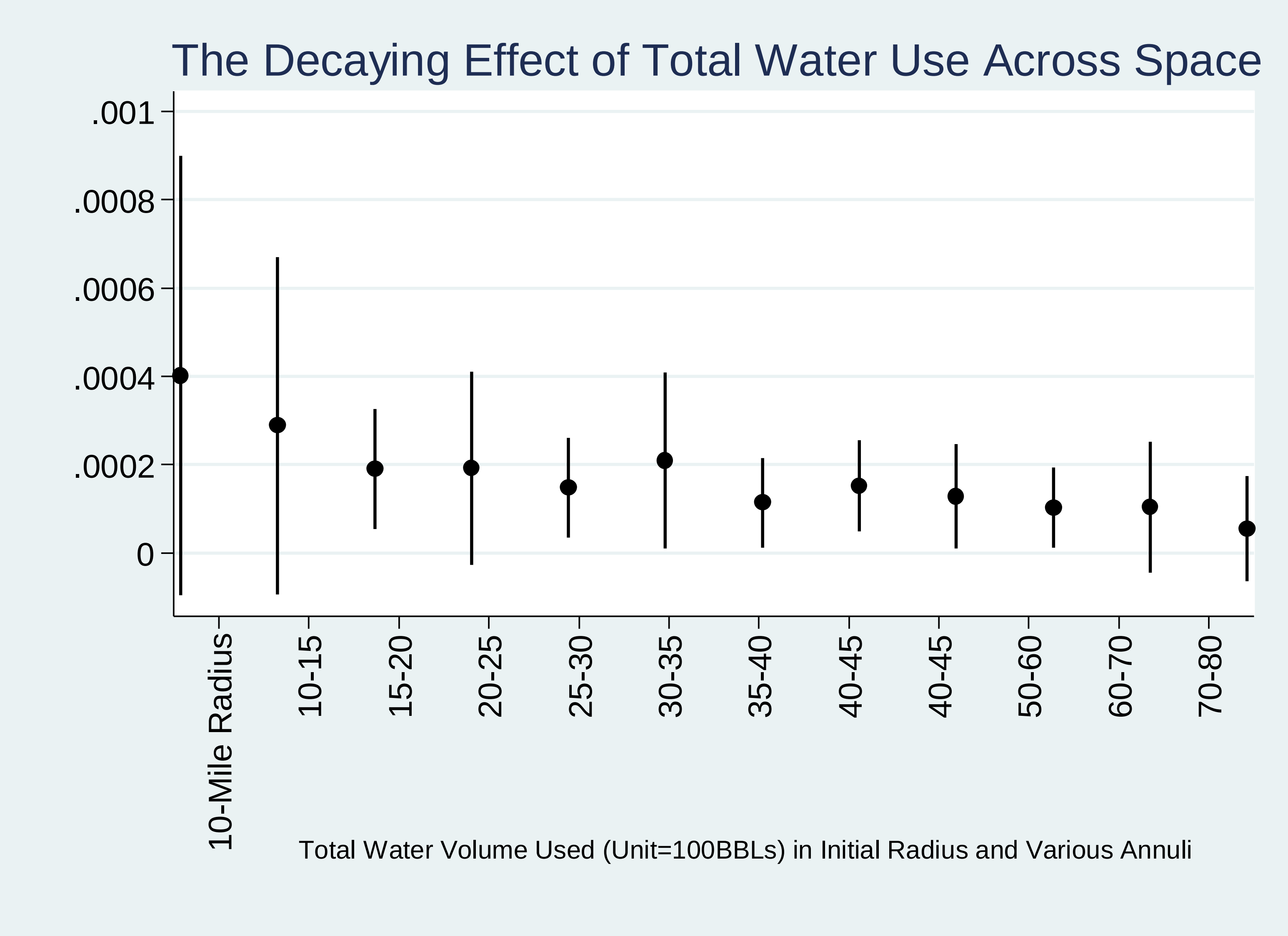
λ_t - year-month fixed effects

γ_i - groundwater level monitoring station fixed effects

Water Volumes Explained



Coefficient Plot



Fixed Effects Model Results

Outcome: Distance to Groundwater Level	1	2	3	4
TWV_radius10	0.00043	.00043	.00163***	.00043
	(0.0002834)	(0.0002839)	(0.0002423)	(0.0002821)
Controls				
Drought	No	No	No	Yes
Rain	No	Yes	Yes	Yes
Rain (Lags)	No	Yes	Yes	Yes
Temp	No	No	Yes	No
Wind	No	No	Yes	No
Year-Month Fes	Yes	Yes	Yes	Yes
Monitoring Station FEs	Yes	Yes	Yes	Yes
Observations	14,207	13,943	5,455	13,943

Standard errors in parentheses. Clustered at county level.
*** p<0.01, ** p<0.05, * p<0.10

Endogeneity Issue

$$Groundwater\ Level \quad \Leftrightarrow \quad Total\ Water\ Volume\ in\ HF$$

Solutions?

1. IV for Total Water Volume
2. Normalize to water use per lateral foot
3. Use lags for Total Water Volume, also check leads
4. Check if acreage is a limiting resource (less space to drill in productive areas?)
5. Use *changes* in the distance to groundwater level in *leading* months, i.e., changing the outcome variable to be:

$$\Delta DistGW_{i,t} = DistGW_{i,t+h} - DistGW_{i,t} \quad \text{for } h = 1,2,3$$

Outcome: Distance to Groundwater Level	1	2	3	4
TWV_radius10	.0000872	.000088	.00044***	0.000088
	(0.0000694)	(0.0000694)	(0.0000524)	(0.0000708)
TWV_radius10 (1)	.00011*	.00011*	.000365***	.000114*
	(0.0000622)	(0.0000629)	(0.0000247)	(0.0000622)
TWV_radius10 (2)	.000145*	.000151*	.000495***	.000153**
	(0.0000753)	(0.0000761)	(.0000231)	(0.0000752)
TWV_radius10 (3)	.000167**	.000168**	.00042***	.00017***
	(0.0000655)	(0.0000656)	(0.0000246)	(0.0000642)
TWV_radius10 (4)	.00019**	.00019**	.000574***	.00019**
	(0.0000815)	(0.0000812)	(0.0000645)	(0.0000819)
Controls				
Drought	No	No	Yes	Yes
Rain	No	Yes	Yes	Yes
Rain (Lags)	No	Yes	Yes	Yes
Temp	No	No	Yes	No
Wind	No	No	Yes	No
Year-Month FEs	Yes	Yes	Yes	Yes
Monitoring Station FEs	Yes	Yes	Yes	Yes
Observations	14,234	13,961	5,382	13,961

Summary

Part I – evidence that hydraulic fracturing operators are more likely to report less detailed information on water use in areas where a localized groundwater management plan exists.

- **GCD**: ~1.5-4 percentage point decline in reporting when located in a GCD area
- **Total Water Volume**: very small percentage point decline in reporting when water volume increases by 100k gallons

Part II – evidence that water use in hydraulic fracturing is large enough to affect groundwater levels.

- For a one-standard deviation increase (i.e. ~17.275 million gallons) in the total water volume in HF used within a 10-mile radius of a groundwater monitoring station, I find an increase in the distance to the groundwater level of .86 feet.

Policy Questions and Further Needs

The results suggest several important policy questions:

- Are GCDs a potential mechanism to induce (better) reporting?
- Should Texas require more thorough reporting of water use (such as water source and type) to FracFocus? This is a requirement in Louisiana.
- Is FracFocus even an effective platform for reporting? There are significant discrepancies in the data across states.
- There is a "green" incentive for operators to report the use of recycled wastewater in stimulations.

Further needs:

1. Find an IV for total water volume, or differenced independent variable?
2. Expand water reporting analysis to the whole state of Texas.
3. Find a better indicator for the level of reporting.
4. Evaluation of mechanisms to incentivize the use of freshwater alternatives.
5. Tax credits for groundwater level declines in several counties near Dallas/Fort Worth.
6. Normalize the areas in rings around monitoring stations.

Questions?

References

1. Kondash, A., and A. Vengosh. 2015. “Water Footprint of Hydraulic Fracturing.” *Environmental Science & Technology.* 2: 276-280.

2. Kusnetz, N. 2012. ‘The Bakken Oil Play Spurs a Booming Business – In Water.’ High Country News. Available at: http://www.hcn.org/issues/44.13/the-bakken-oil-play-spurs-a-booming-business-in-water.

3. U.S. EPA. 2016. ‘Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States.’ Final Report. Available at: https://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=332990.

4. USGS. 2016. ‘Water Questions & Answers: How much water does the average person use at home per day?’ Available at: https://water.usgs.gov/edu/qa-home-percapita.html.

Example 1 – FracFocus Disclosure

Hydraulic Fracturing Fluid Product Component Information Disclosure

Job Start Date:	3/21/2017
Job End Date:	4/17/2017
State:	Ohio
County:	Carroll
API Number:	34-019-22702-00-00
Operator Name:	Chesapeake Operating, Inc.
Well Name and Number:	ELLIE 19-14-6 8H
Latitude:	40.47837900
Longitude:	-81.15753700
Datum:	NAD27
Federal Well:	NO
Indian Well:	NO
True Vertical Depth:	7,731
Total Base Water Volume (gal):	18,028,752
Total Base Non Water Volume:	1,193,522

Hydraulic Fracturing Fluid Composition:

Trade Name	Supplier	Purpose	Ingredients	Chemical Abstract Service Number (CAS #)	Maximum Ingredient Concentration in Additive (% by mass)**	Maximum Ingredient Concentration in HF Fluid (% by mass)**	Comments
Fresh Water	CHESAPEAKE ENERGY	Carrier/Base Fluid					
			Water	007732-18-5	100.00000	81.20643	
Northern White Sand	FTS INTERNATIONAL	Proppant - Natural					
			Crystalline Silica (Quartz Sand, Silicon Dioxide)	014808-60-7	100.00000	12.08665	
Recycled Produced Water	CHESAPEAKE ENERGY	Carrier/Base Fluid					
			Water	007732-18-5	100.00000	4.45188	
7.5pct HCl	FTS INTERNATIONAL	Acid					
			Water	007732-18-5	93.00000	0.83257	
			Hydrochloric Acid	007647-01-0	8.00000	0.06751	
10.1 - 15 HCL	FTS INTERNATIONAL	Acid					
			Water	007732-18-5	85.00000	0.09117	
			Hydrochloric Acid	007647-01-0	15.00000	0.01609	

Example 2 – FracFocus Disclosure

Hydraulic Fracturing Fluid Product Component Information Disclosure

Job Start Date:	3/13/2017
Job End Date:	4/12/2017
State:	Colorado
County:	Weld
API Number:	05-123-42814-00-00
Operator Name:	Noble Energy, Inc.
Well Name and Number:	Lapp A15-635
Latitude:	40.48547387
Longitude:	-104.50640344
Datum:	NAD83
Federal Well:	NO
Indian Well:	NO
True Vertical Depth:	6,704
Total Base Water Volume (gal):	26,974,509
Total Base Non Water Volume:	0

FracFocus Chemical Disclosure Registry

GROUNDWATER PROTECTION COUNCIL

INTERSTATE Oil & Gas COMPACT COMMISSION

Hydraulic Fracturing Fluid Composition:

Trade Name	Supplier	Purpose	Ingredients	Chemical Abstract Service Number (CAS #)	Maximum Ingredient Concentration in Additive (% by mass)**	Maximum Ingredient Concentration in HF Fluid (% by mass)**	Comments
Water	Operator	Carrier					
			Water	7732-18-5	100.00000	91.85050	None
Crystalline Silica, Quartz / Unimin Corp	Liberty Oilfield Services	Sand					
			Crystalline Silica in the form of Quartz	14808-60-7	99.90000	7.63915	None
HCL-15	Liberty Oilfield Services	Solvent					
			Water	7732-18-5	85.00000	0.14582	None
			Hydrochloric Acid	7647-01-0	15.00000	0.02573	None
CSA-23	Liberty Oilfield Services	Permanent clay stabilizer					