

Wellbore Integrity: Failure Mechanisms, Historical Record, and Rate Analysis

Anthony Ingraffea, PhD, PE

Cornell University

Physicians, Scientists, and Engineers for Healthy Energy (PSE)

Renee Santoro

Physicians, Scientists, and Engineers for Healthy Energy (PSE)

Seth B. Shonkoff, PhD, MPH

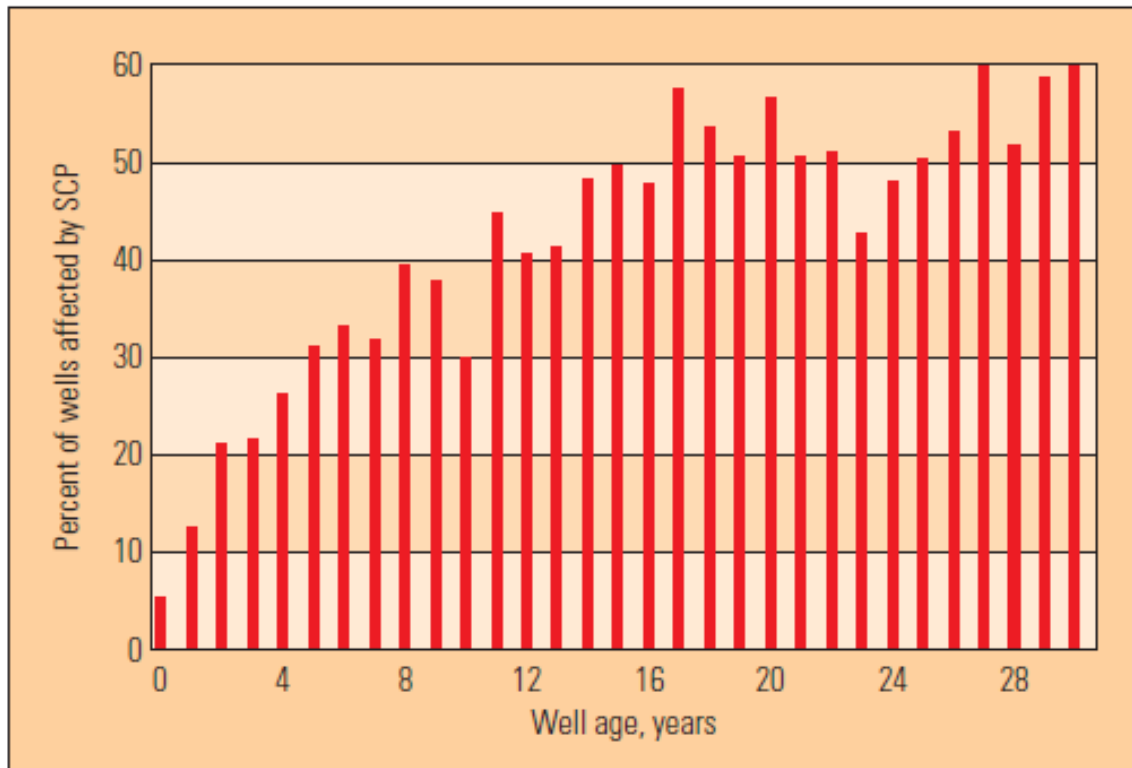
Physicians, Scientists, and Engineers for Healthy Energy (PSE)

University of California, Berkeley

Outline of Presentation

- Failure Mechanisms (Covered in Extended Abstract)
- **Record**
 - **Historical Offshore public data**
 - **Historical Onshore public data**
 - Recent: Pennsylvania Marcellus play public data
- Implications for impact on underground sources of drinking water

Industry-Reported Data On Loss of Wellbore Integrity: Offshore Wells



SCP=Sustained Casing Pressure. Also called sustained annular pressure, in one or more of the casing annuli.

- About 5% of wells fail soon
- More fail with age
- Most fail by maturity

^ Wells with SCP by age. Statistics from the United States Mineral Management Service (MMS) show the percentage of wells with SCP for wells in the outer continental shelf (OCS) area of the Gulf of Mexico, grouped by age of the wells. These data do not include wells in state waters or land locations.

Industry-Reported Data On Loss of Wellbore Integrity: Onshore Wells

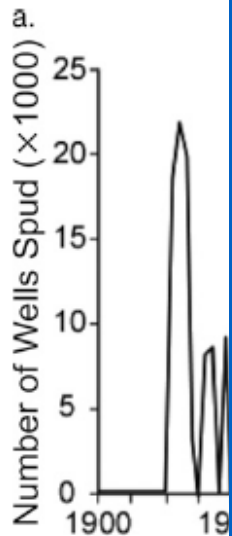
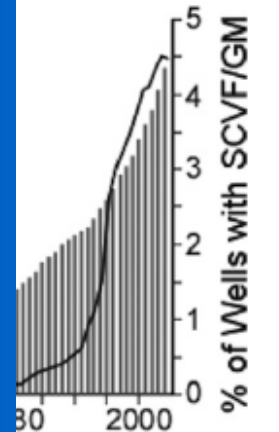
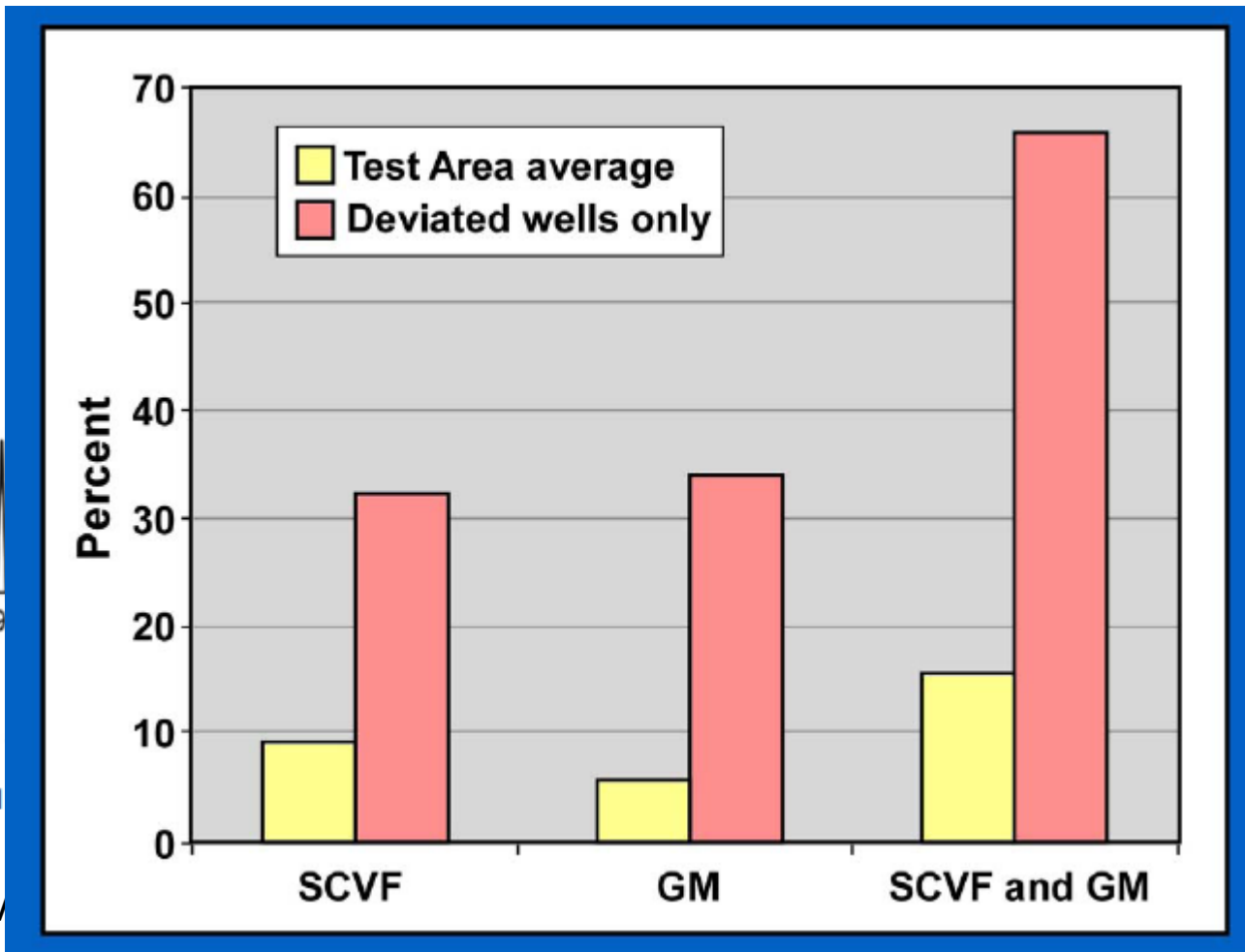


Fig. 8—Historical wells drilled.

SCV



SCVF/GM

y cumulative wells

Watson and Bachu, SPE 106817, 2009.

Industry well integrity outlook

- ❖ Industry will drill more wells in next decade than have been drilled in last 100 years
- ❖ Global well population is +/- 1.8 million, of which +/- 35 % has sustained casing pressure
- ❖ Public awareness and concern of zonal isolation requirements is increasing (USA / Australia / Europe)
- ❖ Geothermal wells and CO2 sequestration wells are on the increase
- ❖ Subsidence is a risk in some depleting reservoirs
Life cycle extension of aging assets is becoming a pre-requisite of legislators
- ❖ Zonal isolation challenges and assurance does need push in technology
- ❖ Abandonment of legacy wells is becoming more of a focus
- ❖ Industry collaboration is an inevitable pre-requisite on all topics

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Recent Operator Performance in the Pennsylvania Marcellus Play: Protocol

- Access Pennsylvania Department of Environmental Protection Violations Database online.
- First Pass: Count wells with violations for “leak” codes; eliminate duplicate wells in database.
- Second Pass: Count wells with leakage noted via inspection *but which had not been issued violations.*
- Divide total number of wells found leaking per year by number of wells drilled that year.

Codes Used to Identify Wells with Violations

78.73A - Operator shall prevent gas and other fluids from lower formations from entering fresh groundwater.
78.81D2 - Failure to case and cement properly through storage reservoir or storage horizon
78.83A - Diameter of bore hole not 1 inch greater than casing/casing collar diameter
78.73B - Excessive casing seat pressure
78.83 GRNDWTR - Improper casing to protect fresh groundwater
78.83 COALCSG - Improper coal protective casing and cementing procedures
78.85 - Inadequate, insufficient, and/or improperly installed cement
78.86 - Failure to report defective, insufficient, or improperly cemented casing
207B - Failure to case and cement to prevent migrations into fresh groundwater

Recent Operator Performance in the Pennsylvania Marcellus Play: Examples of Inspection Comments without Violation

“Stray gas observed. Inspected wellhead only. Purpose of inspection was not to address any open violations on pad.”

“Check on flow back pressure on failed casing, no pressure on 5-1/2x9-5/8 annulus flowing at 3-4 barrels an hour”

“Follow up on plugging of well. Since last inspection have run a CBL and Temp Log in 7" casing. Based on anomalies shown on logs - have perf'd and attempted to squeeze cement to eliminate bubbling at surface. At time of inspection tripping out of hole and will be perforating later today and will see if can establish injection rate and squeeze cement. Bubbling still present in cellar on 9 x 7" annulus. No violations observed at this time...”

Additional Counts of Wells with Loss of Integrity

2010	64 wells with violations, 47 additional wells with loss of integrity noted in Inspection Comments
2011	97 wells with violations, 45 additional wells with loss of integrity noted in Inspection Comments
2012	44 wells with violations, 76 additional wells with loss of integrity noted in Inspection Comments

Recent Operator Performance in the Pennsylvania Marcellus Play: Results of Survey

1,609 wells drilled in 2010.
97 well failures.
6% rate of failure.

1,972 wells drilled in 2011.
140 well failures.
7.1% rate of failure.

1,346 wells drilled in 2012
120 well failures.
8.9% rate of failure.

Consistent with previous industry
data, and not improving.

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The Dimock, Pa, “Affected” Area, About 9 Square Miles



2008-2009:

29 pads

63 wells

Typical lateral
spacing between
pads: $< \frac{1}{2}$ mile

Impacted Water Supplies Identified in Pennsylvania Department of Environmental Protection Consent Order, Dimock, PA, 2008-2009: Water Supplies of 13 Families Impacted

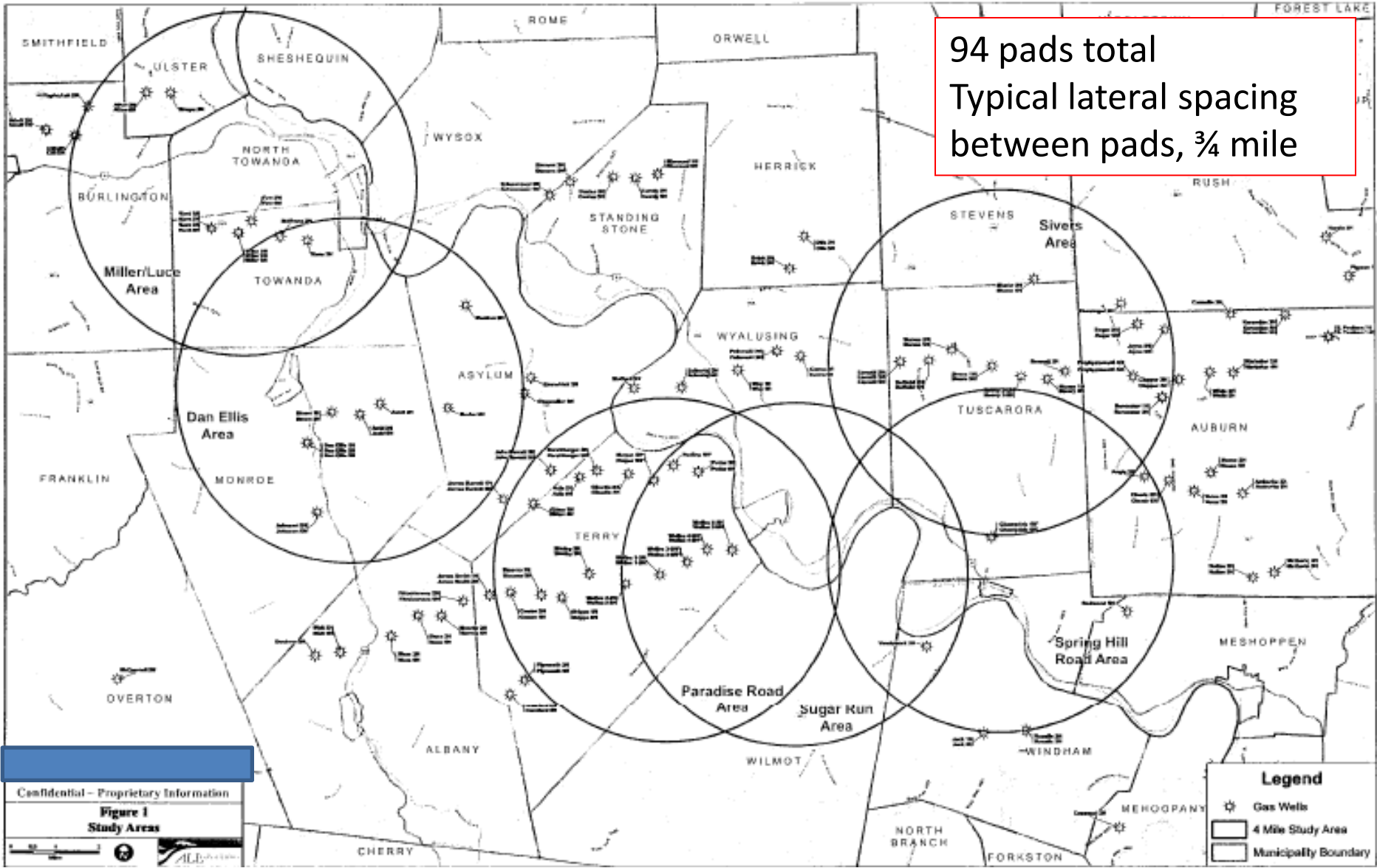
Discharge of Natural Gas into the Groundwater

L. Based upon its investigation since January 2009, the Department has determined the following:

1. [REDACTED] had caused or allowed the unpermitted discharge of natural gas, a polluting substance, into the groundwater, which constitutes a “water of the Commonwealth,” as that term is defined in 35 P.S. §691.1.
2. As of the date of this Consent Order and Agreement, [REDACTED] has taken certain actions approved by the Department to prevent the ongoing, unpermitted discharge of natural gas into the waters of the Commonwealth.

The Bradford County, PA, Affected Areas, 2011

94 pads total
Typical lateral spacing
between pads, $\frac{3}{4}$ mile



Confidential - Proprietary Information
Figure 1
Study Areas

Legend
☆ Gas Wells
○ 4 Mile Study Area
— Municipality Boundary

Impacted Water Supplies Identified in Pennsylvania Department of Environmental Protection Consent Order, Bradford County, PA, 2011: Water Supplies of 15 Families Impacted

EXHIBIT C

List of Water Supplies

Determination letters pursuant to Section 208(b) of the Oil and Gas Act

Sugar Run

6 families	Sugar Run, PA	18846
	Sugar Run, PA	18846
	Sugar Run, PA	18846
	Sugar Run, PA	18846
	Sugar Run, PA	18846
	Sugar Run, PA	18846
	Gettysburg, PA	17325

Paradise Rd

3 families	Wyalusing, PA	18853
	Wyalusing, PA	18853
	Wyalusing, PA	18853

Brocktown/Dan Ellis

3 families	Monroeton, PA	18832
	Monroeton, PA	18832
	Monroeton, PA	18832

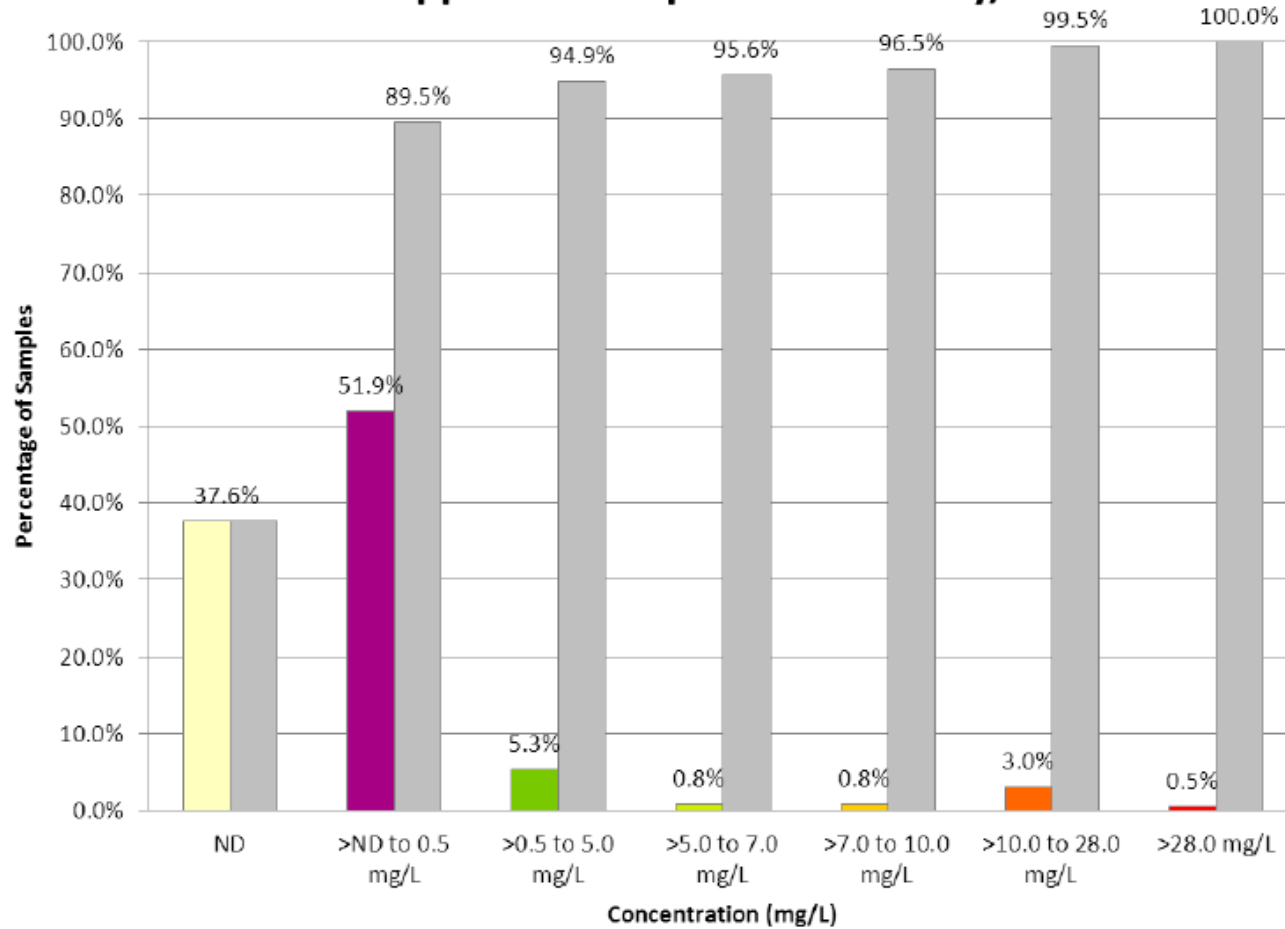
Springhill Rd

2 families	Laceyville, PA	18623
	Laceyville, PA	18623

Vargson

1 family	Granville Summitt, PA	16926
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Frequency Distribution of Methane Concentration in Water Supplies in Susquehanna County, PA



Data collected by PA DEP on methane concentration in private water wells in Susquehanna County, PA. 2433 water supplies were tested:

89.5% had concentrations of methane < 0.5 mg/L,
95.6% had concentrations of methane < 7.0 mg/L.

Courtesy of Seth Pelepko, PA DEP.

Summary

- Loss of wellbore integrity a well-understood and chronic problem
- Recent experience in PA Marcellus play no exception
- Methane is prevalent in water wells in PA, but at very low levels
- Pressing need for scientific investigation of possible links between leaking gas wells and water well contamination