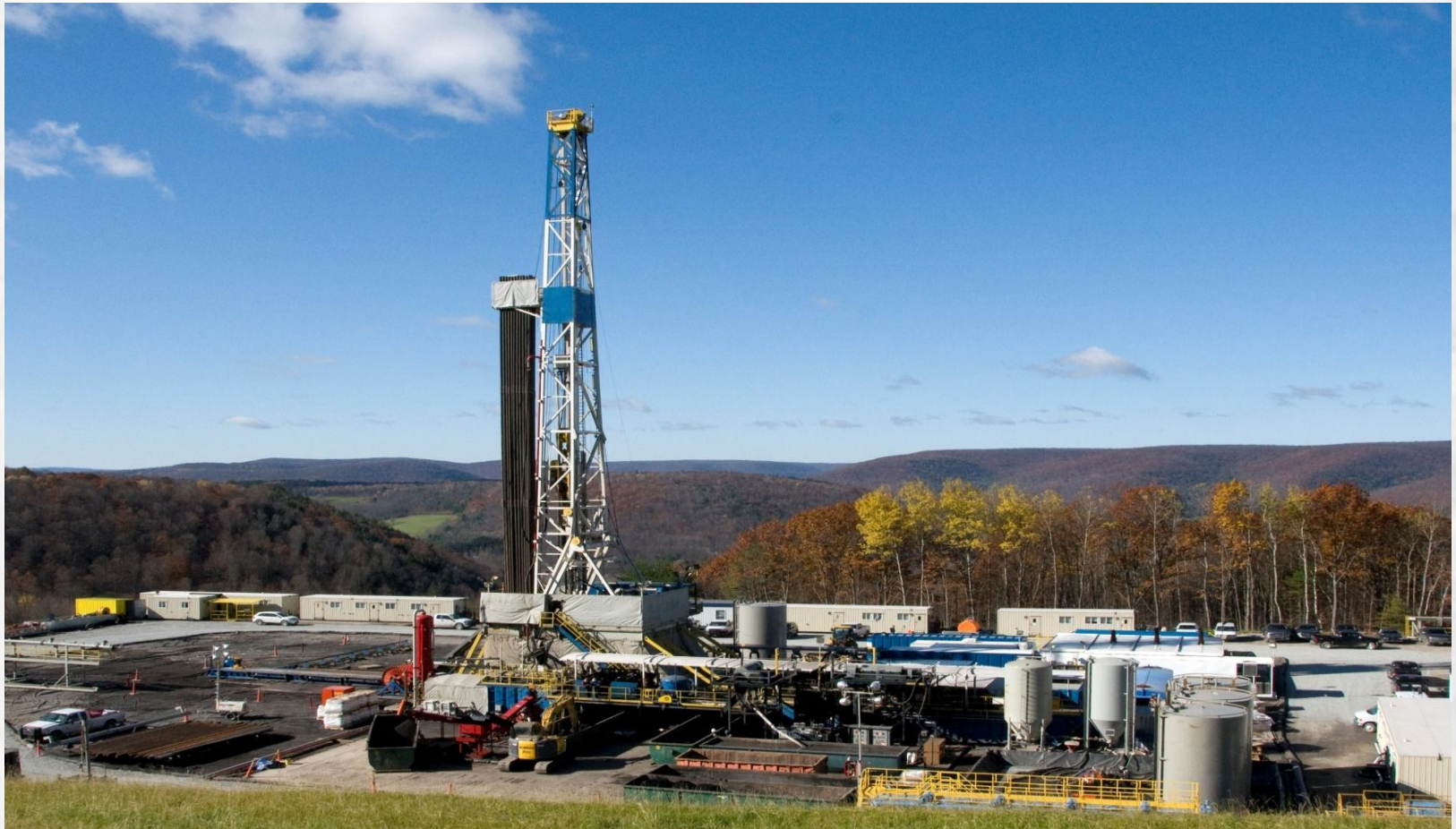


New Natural Gas Production: *Evolving Process, Best Practices, Mitigating Risk*





Marcellus Center for Outreach and Research (MCOR)

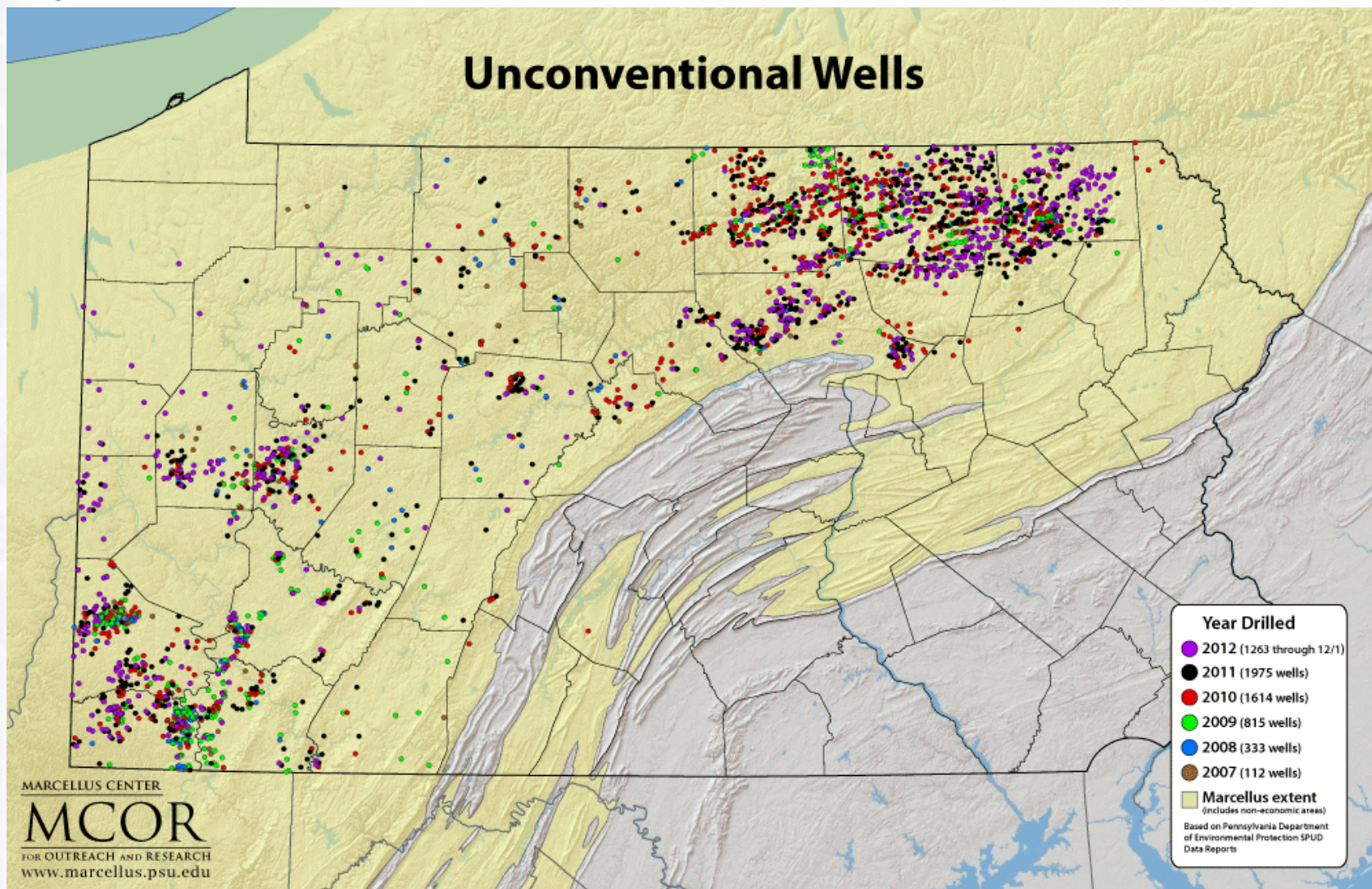
- Conduct research related to shale development in PA, the U.S., and globally
- Coordinate throughout Penn State University system
- Collaborative approach with other institutions, government agencies, NGOs, etc
- Research related to downhole technologies and above ground impacts--best management practices (BMPs)
- Science-based outreach sessions to various stakeholders and the public



Developing Shale Trends

- Greening of the products and technologies used in the drilling/completion process
 - New chemistry, food grade products
- Emerging technology followed by regulations
 - Closed loop systems w/tanks vs. pits
 - Emerging move to “green completions” -- air emissions
- Evolving hydraulic fracturing technology
 - Fewer chemicals, reduced sand volumes, changing water needs
- Trained & knowledgeable inspectors
- Public understanding of regulatory process
- Transparency – FracFocus.org

Marcellus Wells Drilled (12/1/12)



Cross-Section of Typical Horizontal Marcellus Well

24" conductor casing (brown) is installed up to 50 feet deep and cemented (grey) to the surface.

20" casing is installed through the 24" casing and continuing up to 500 feet deep. This casing is cemented to surface to isolate and protect near-surface groundwater.

13 3/8" casing is installed through the 20" casing and continuing up to 1000 feet deep. This casing is also cemented to the surface to protect the groundwater aquifer from the gas well.

5 1/2" casing continues down and is turned laterally into the Marcellus formation at a depth of 5000 to 9000+ feet below the surface.

Fresh groundwater zone up to 1000 feet deep

Vertical portion of well

Kick off point for the bend from vertical to horizontal drilling.

Horizontal, "lateral" portion of well extends from 3,000 to over 10,000 feet within Marcellus formation.

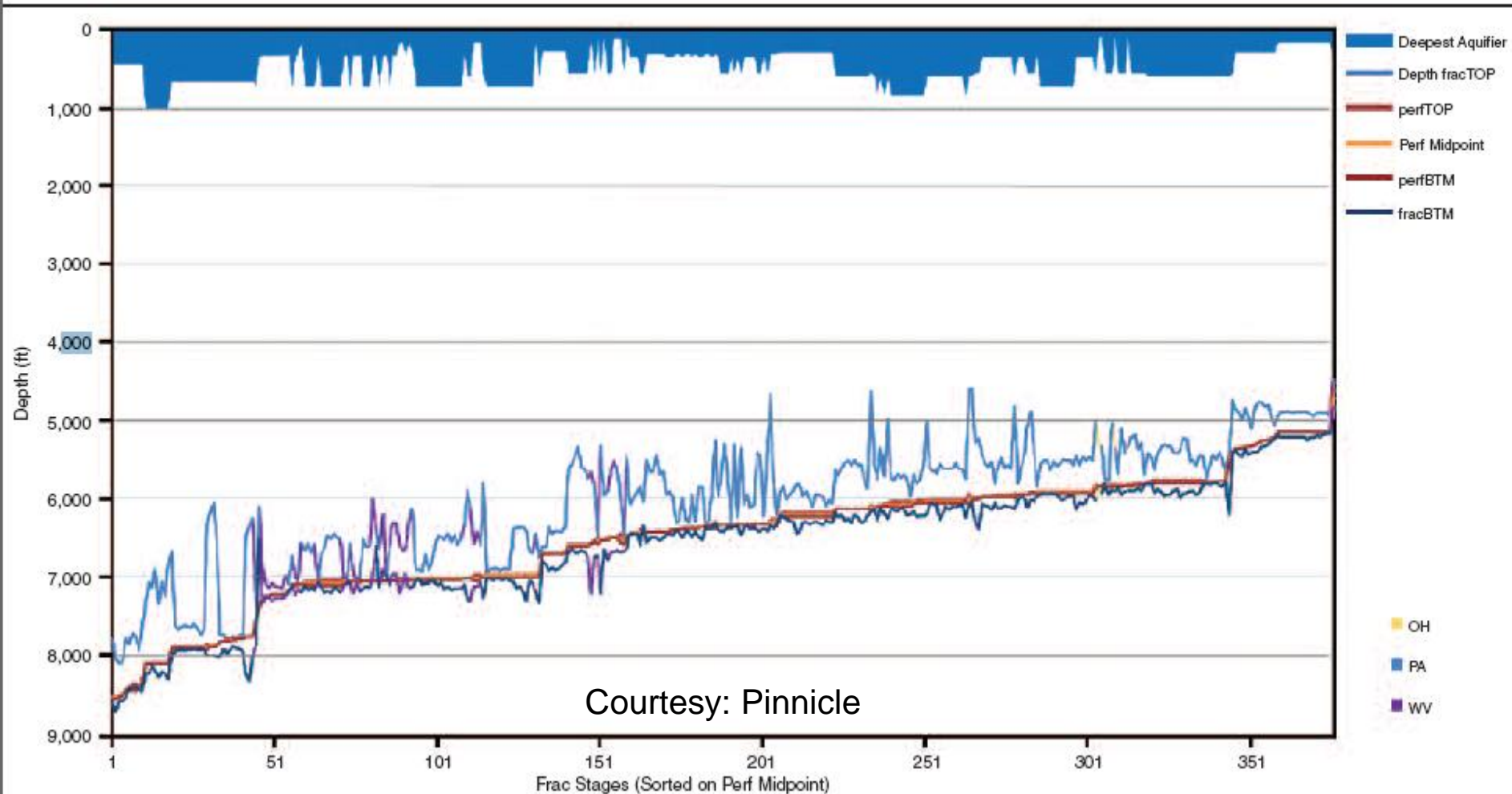
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Height-Depth of Fracturing Based on Microseismic Data

Marcellus Shale Mapped Fracture Treatments (TVD)



“Frac Barriers” of Onondaga Ls. below & Tully Ls. above. Marcellus Sh. thousands of feet below fresh water aquifers. Induced fractures cannot extend upwards because of overburden stress and horsepower limitations.

Chapter 78 Well Construction Standards

- Goal – further prevent methane migration and protect water supplies
- Comprehensive update to well construction, casing and cementing standards
- Expanded well completion reporting requirements, including disclosure of hydraulic fracturing chemicals
- Revised well plugging standards
- Evolving technology and regulations greatly mitigating risk
- Transparency

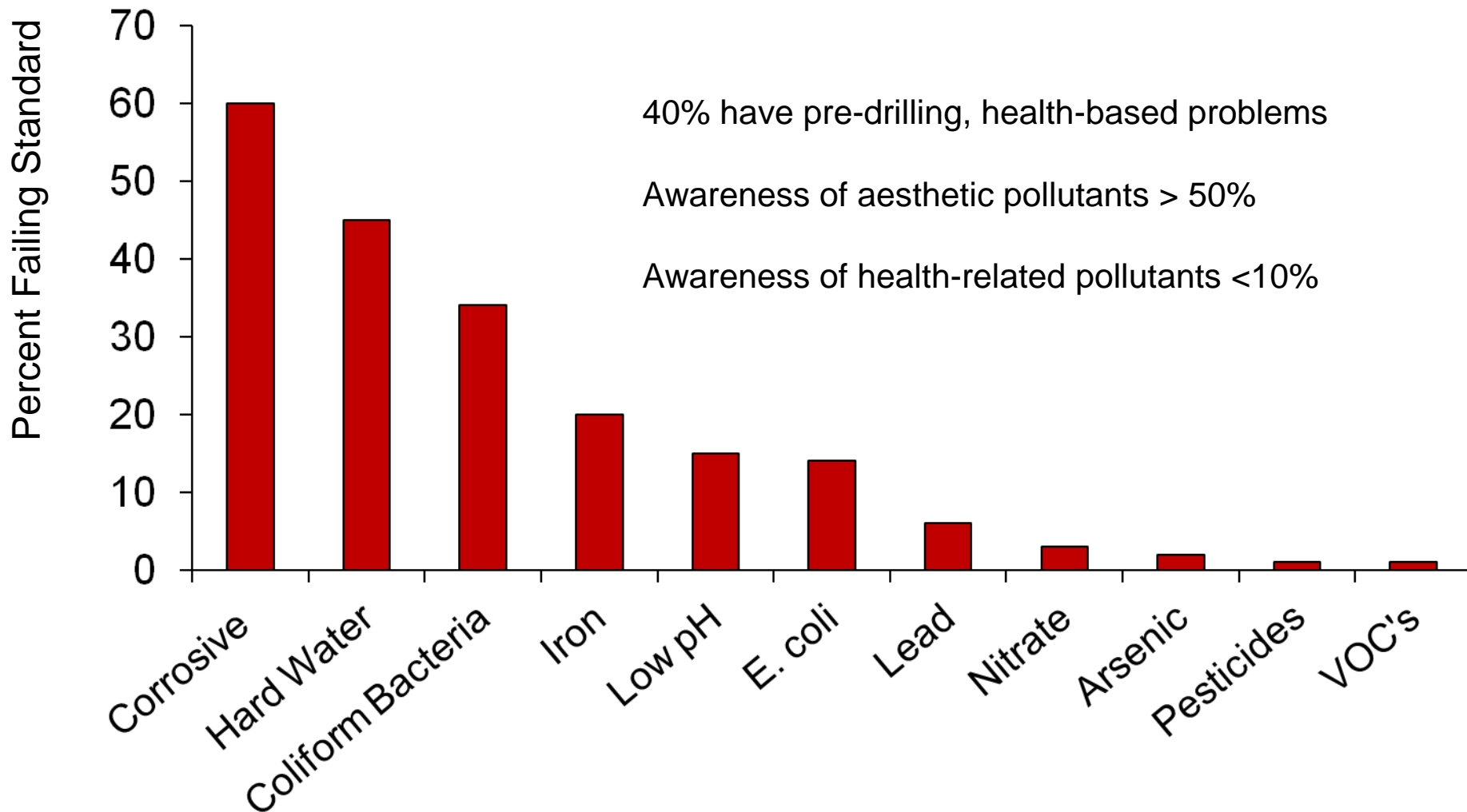


Increased Groundwater Protection



Pre-Drilling Problems are Common

(2006-07 survey of 701 water wells)



Impact of Marcellus Gas Drilling on Rural Drinking Water Supplies

- Five Penn State project coordinators
- Funded by the Center for Rural Pennsylvania (a legislative agency of the Pennsylvania General Assembly) and the Pennsylvania Water Resources Research Center at Penn State University

Objectives:

- Provide an unbiased and large scale study of water quality in private water wells both before and after the drilling of Marcellus gas wells nearby.
- Document both the enforcement of existing regulations and the utilization of voluntary measures by homeowners to protect water supplies.

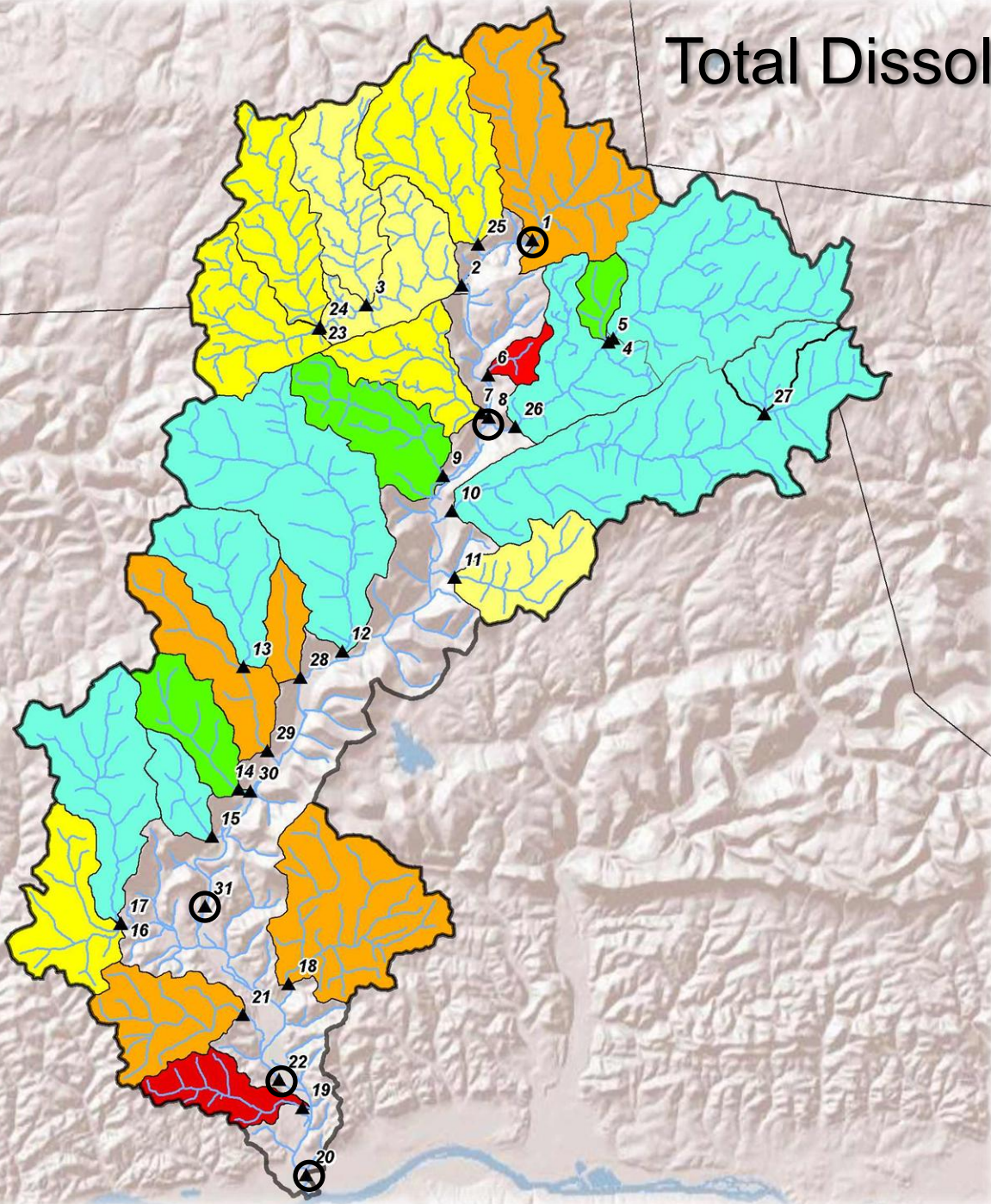


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Total Dissolved Solids(TDS)



Site	Trib	ROE
9	Frozen	10
14	Wolf Upper	12
5	Hounds	14
4	Rock Upper	28
15	Daugherty	28
13	Trout Upper	30
12	Grays	32
10	Pleasant	34
16	Hogeland	38
26	Rock Lower	42
27	North Pleasant	44
30	Wolf Lower	44
17	Stoney	59
3	Salt	61
24	Brion	62
11	Slacks	65
23	Roar Head	72
25	Mill (head)	74
7	Red	78
2	Roar Roar	79
28	Hagerman	92
21	Beautys	102
29	Trout Lower	104
18	Mill (mouth)	106
6	Dutchman	191
19	Bottle	202

Chapter 95 Regulation Revisions

14

- This new rule is the first of its kind in the country
- Limits the discharge of Total Dissolved Solids(TDS) from new or expanded facilities that take oil and gas wastewater – now at drinking water standards.
- Does not allow for new discharges that exceed 250 mg/l for chlorides and also removes radium
- Increases the use of recycled water, promotes the development of alternative forms of disposal
- Promotes the use of alternative sources of water for fracturing fluid

Alternative Water Sourcing

- Acid mine drainage
- Cooling tower water
- Treated waste water

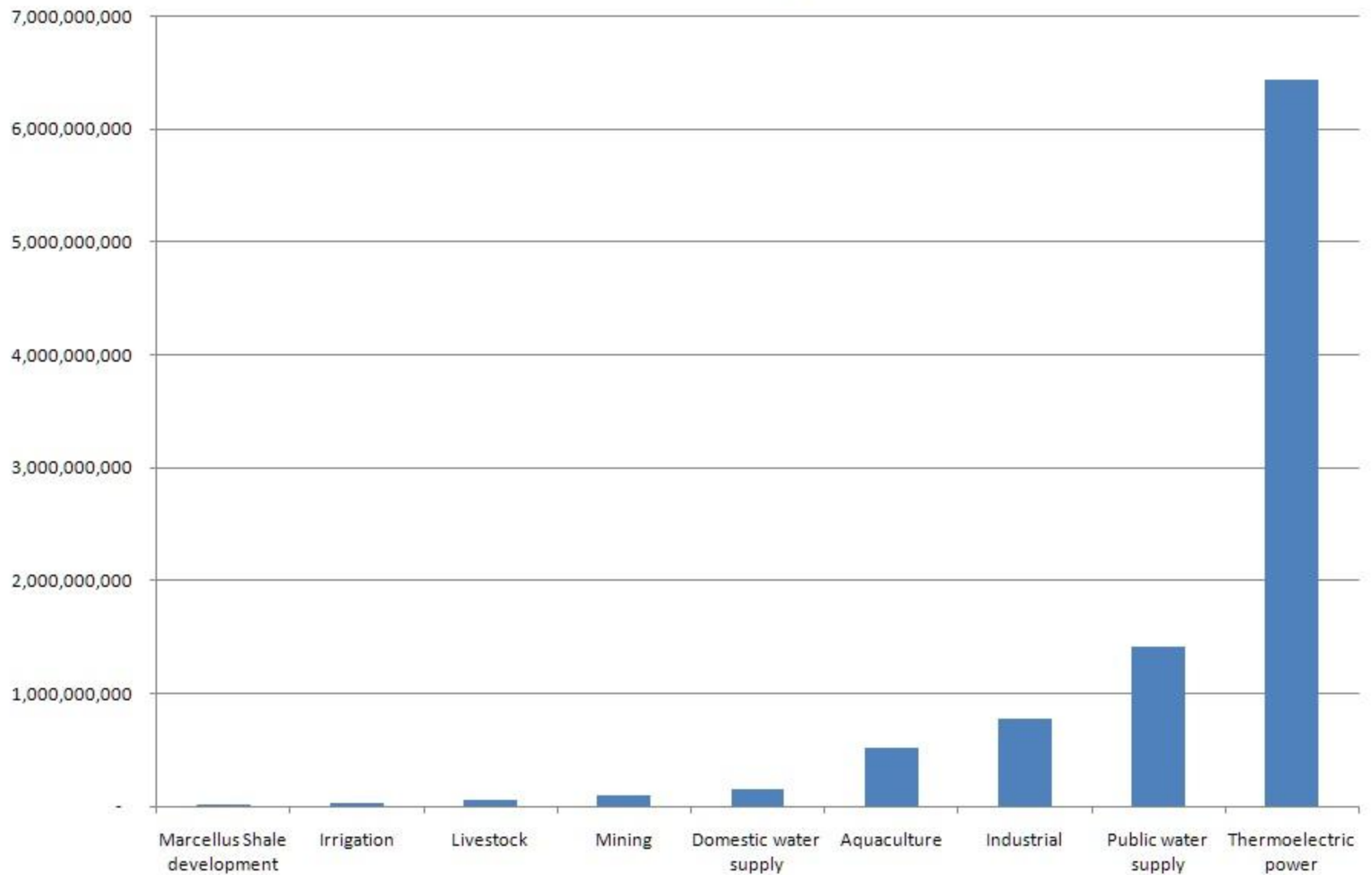




Water Usage and Sourcing

- 16.5 million liters per well (ave)
- 40 million liters used in PA per day
 - 0.1% of all water withdrawals in PA daily
 - 40 billion liters/day
- 75% of water used is trucked
 - Trend towards piping water is increasing strongly
- 75% is sourced from surface supply vs. wells
 - Costs from municipal well sources is \$5-16/3800L

Pennsylvania Surface and Groundwater Withdrawals by Industry Gallons Per Day



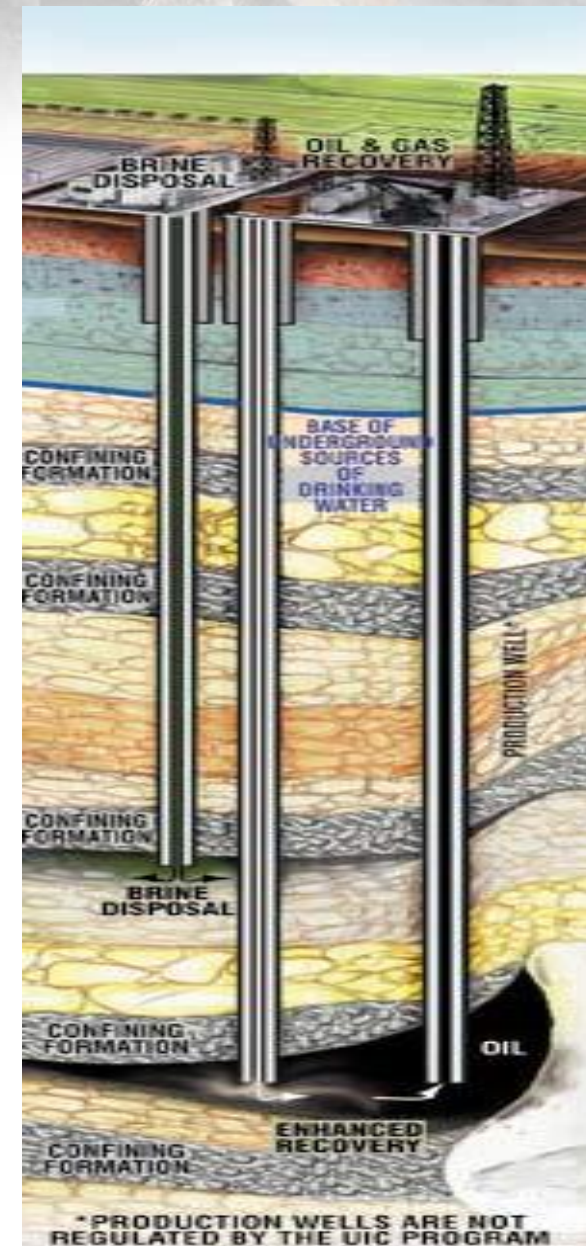


Fluid Remediation/Disposal

- 1.75 billion liters of fluid recovered 1H '12
- 90% recycling of flowback and produced
- Approx. 10% of fluid returns to surface in Marcellus
- Currently 98% of flowback is recycled
 - 89% infield recycling
 - 9% centralized plant recycling
 - 1.6% stored
 - 0.3% disposal wells

Fluid Management

- Produced fluids – 86% recycled
 - 76% infield recycling
 - 10% centralized plant recycling
 - 14% disposal wells



Water Storage Trends

- Vertical storage units – more storage, less footprint
- Closed loop systems
- Transportable and can be reused
- Piped to location for hydraulic fracturing
 - Greatly reduces truck traffic
- Redundant systems for spill prevention



Groundwater/Pad Protections





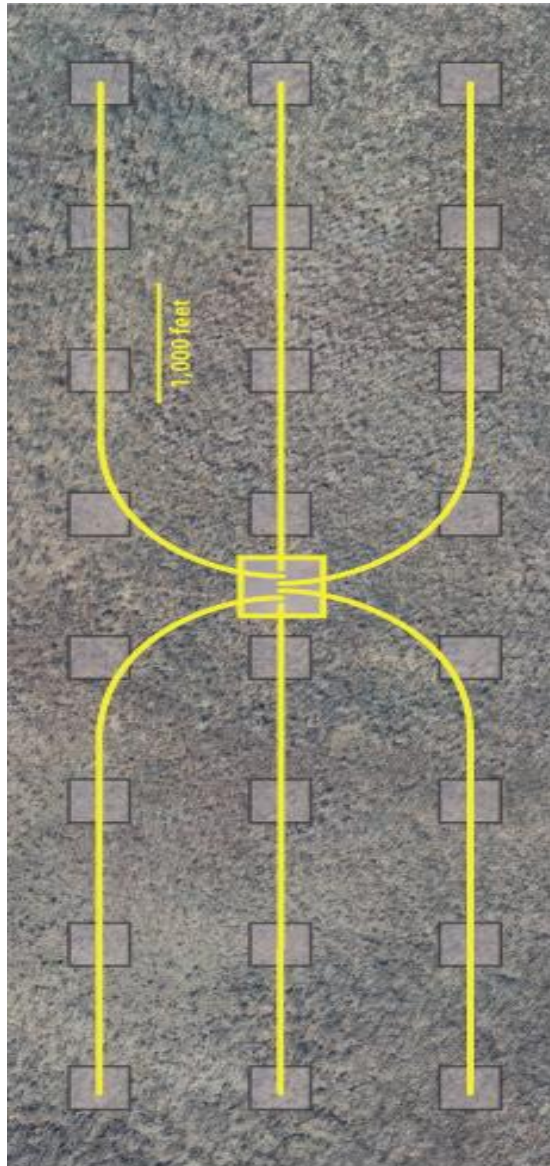
Hydraulic Fracturing Process and Impacts



Common NGS Well Sites



Horizontal Drilling Patterns



- Smaller overall footprint
 - 2% land disturbance vs. vertical ~19%
 - One drilling pad
 - Fewer roads, pipeline connections
- Drilling Unit
 - 1-2 square mile

Noise Abatement Techniques



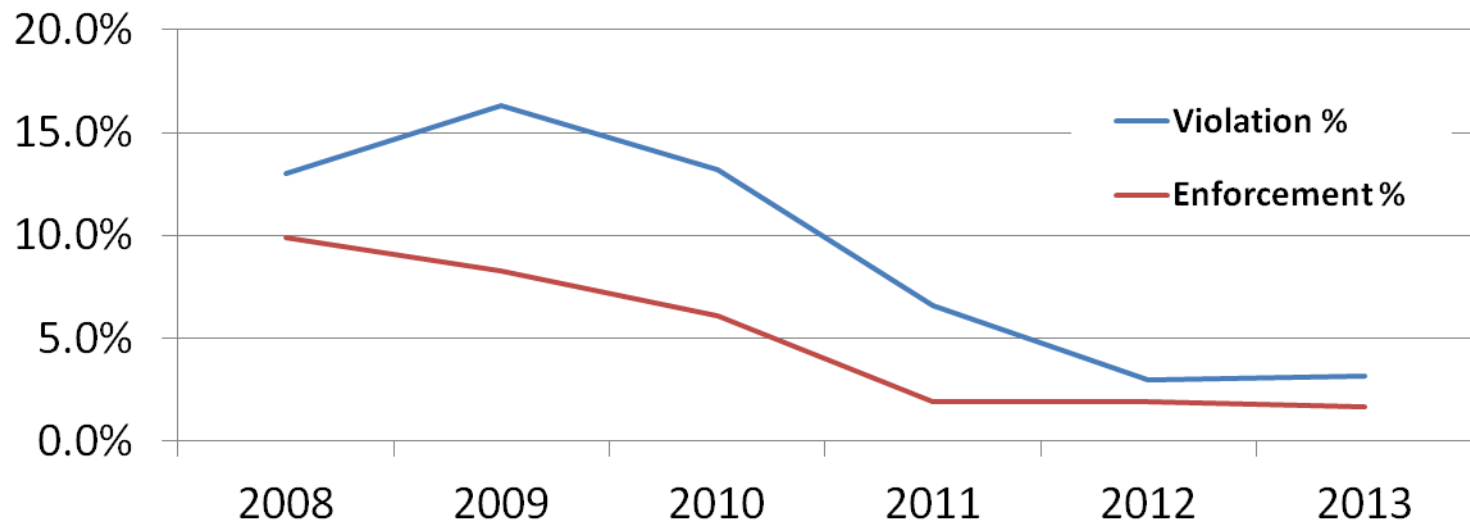
Drill Cuttings Management

- Current common “disposal” is with landfill as cover material
- Looking at beneficial reuse
 - As proppant material
 - Road base
 - Pad stabilization
 - Construction
- Green fields vs. brownfield
- Typically remediated and treated
- Emerging technology



Violations & Enforcements

Year	Inspections	Inspections with violations	Total Violations	Enforcements	% Inspections with violations	% Inspections with enforcements
2013*	2,175	69	118	38	3.2%	1.7%
2012	12,561	378	714	241	3.0%	1.9%
2011	10,099	662	1159	191	6.6%	1.9%
2010	4,990	659	1218	305	13.2%	6.1%
2009	2,094	342	638	173	16.3%	8.3%
2008	1,267	165	178	126	13.0%	9.9%



*3/1



www.marcellus.psu.edu
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