Common Issues Experienced with Unconventional Oil and Gas Extraction in the United States

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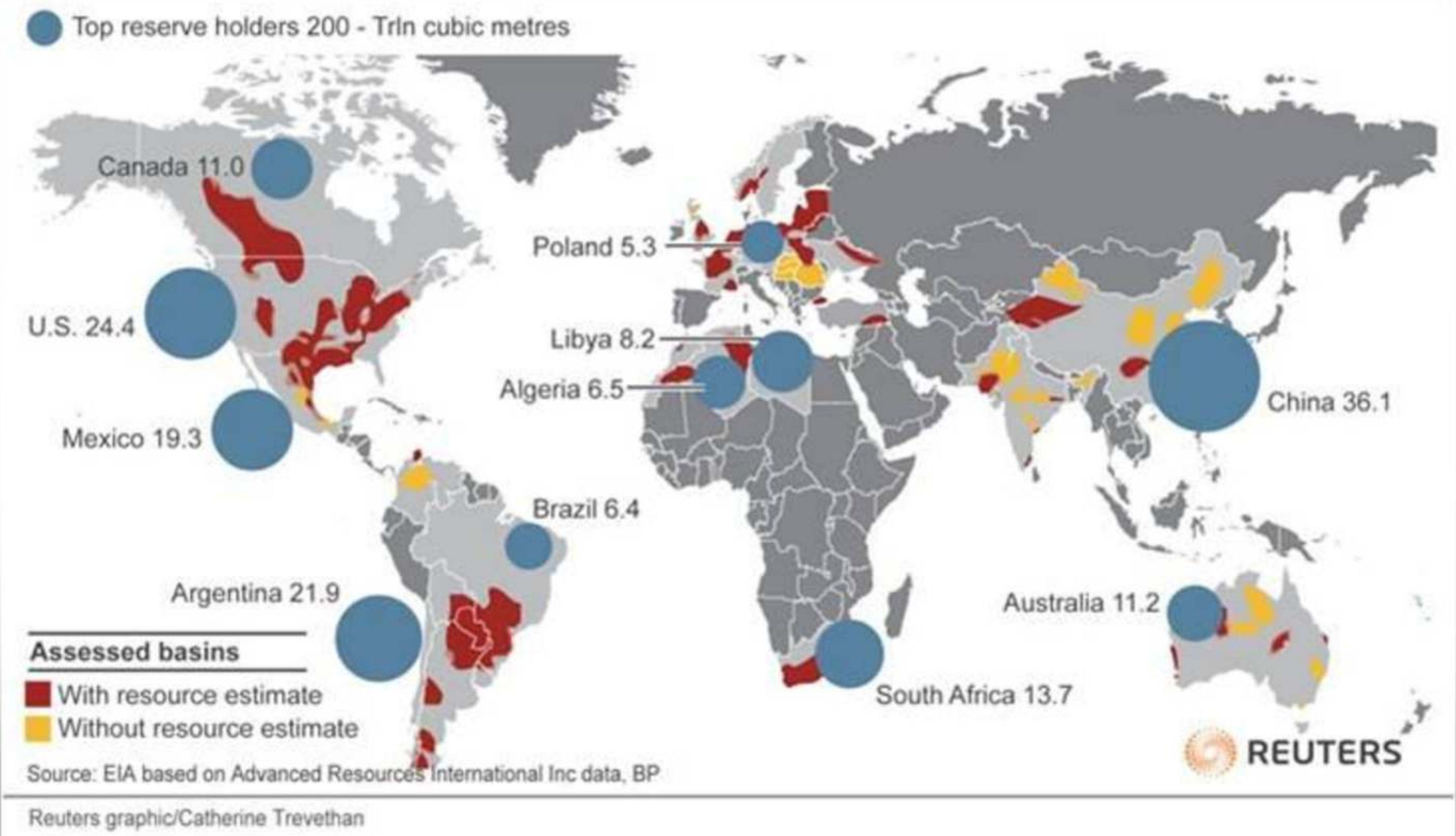
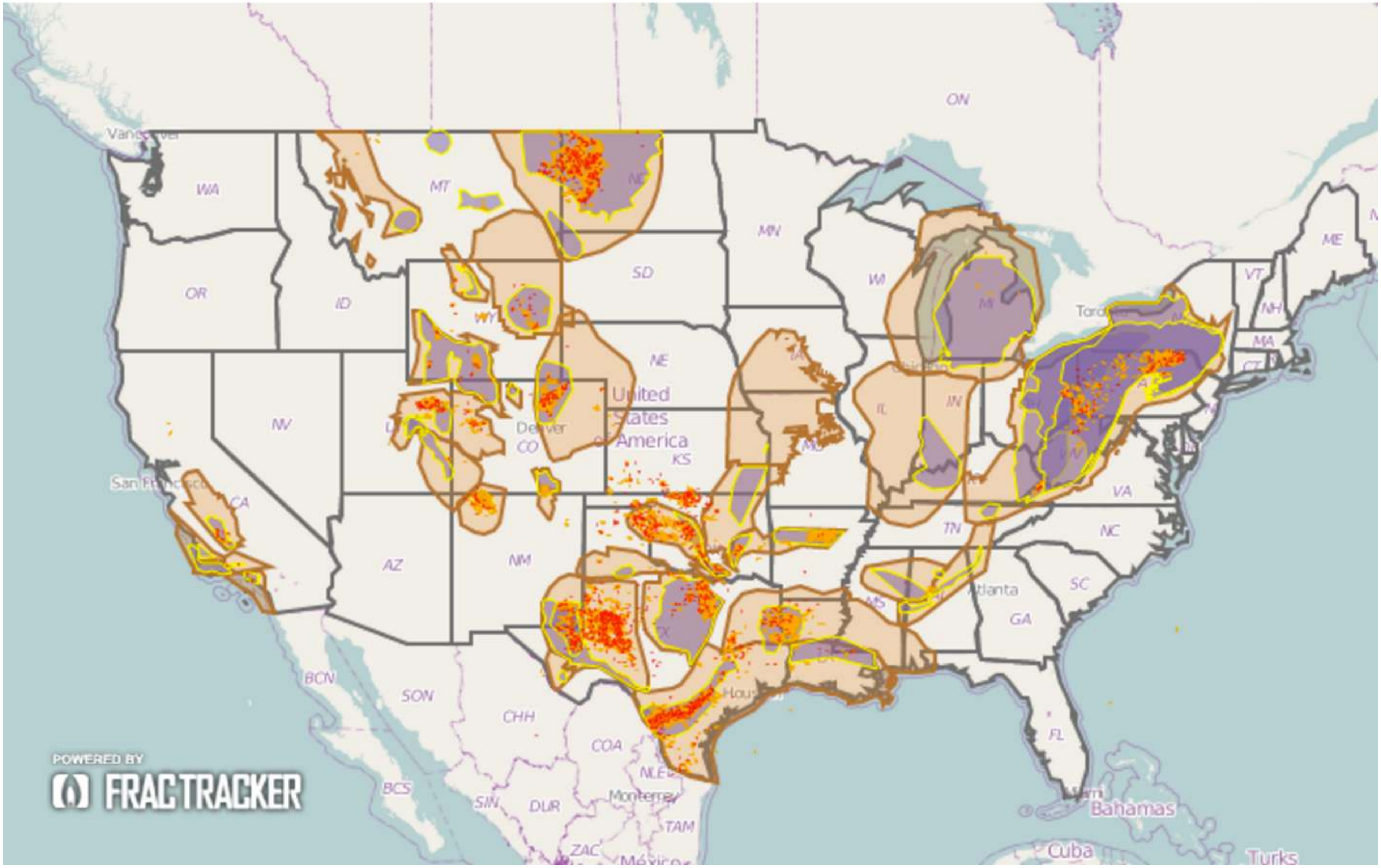
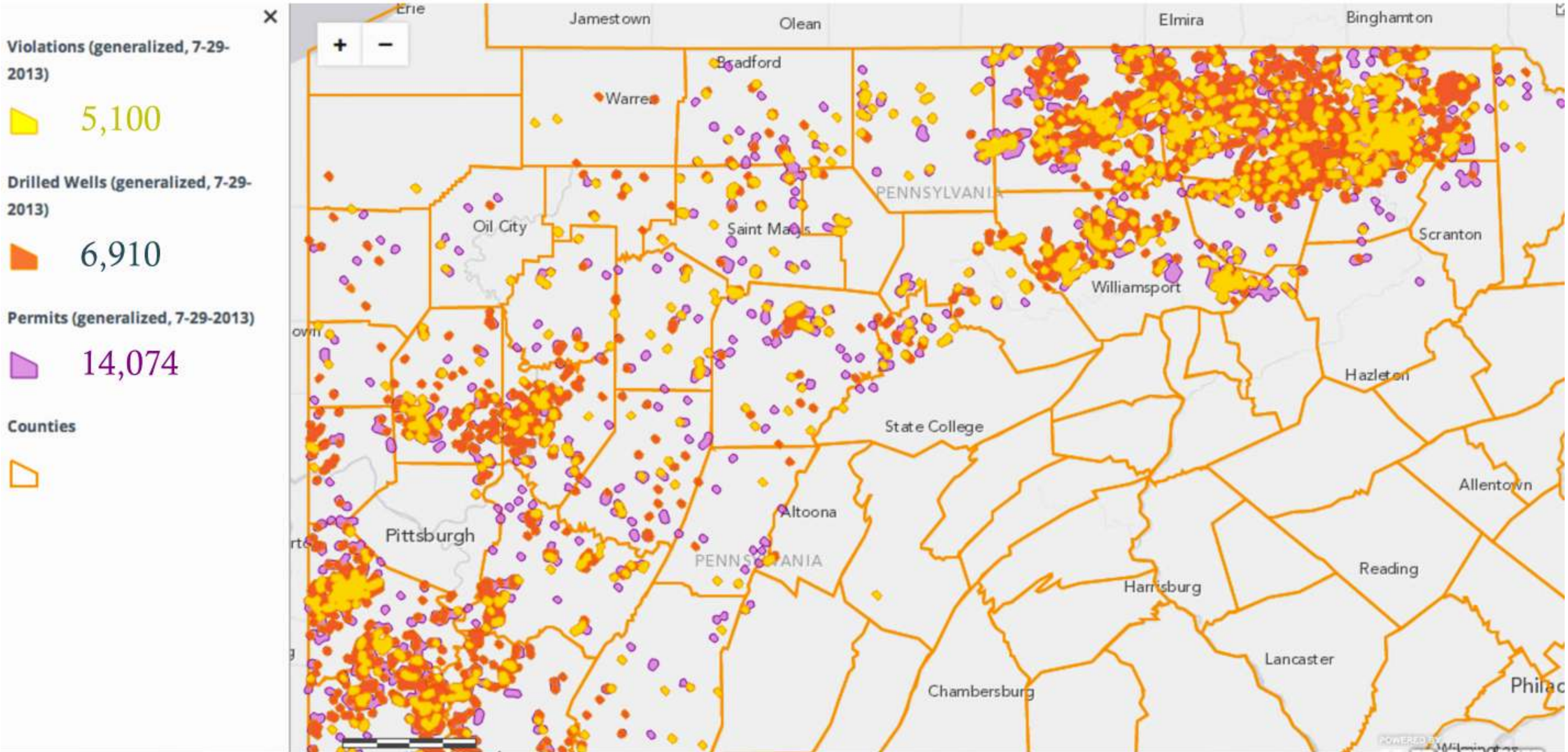
Global Shale Gas Basins, Top Reserve Holders



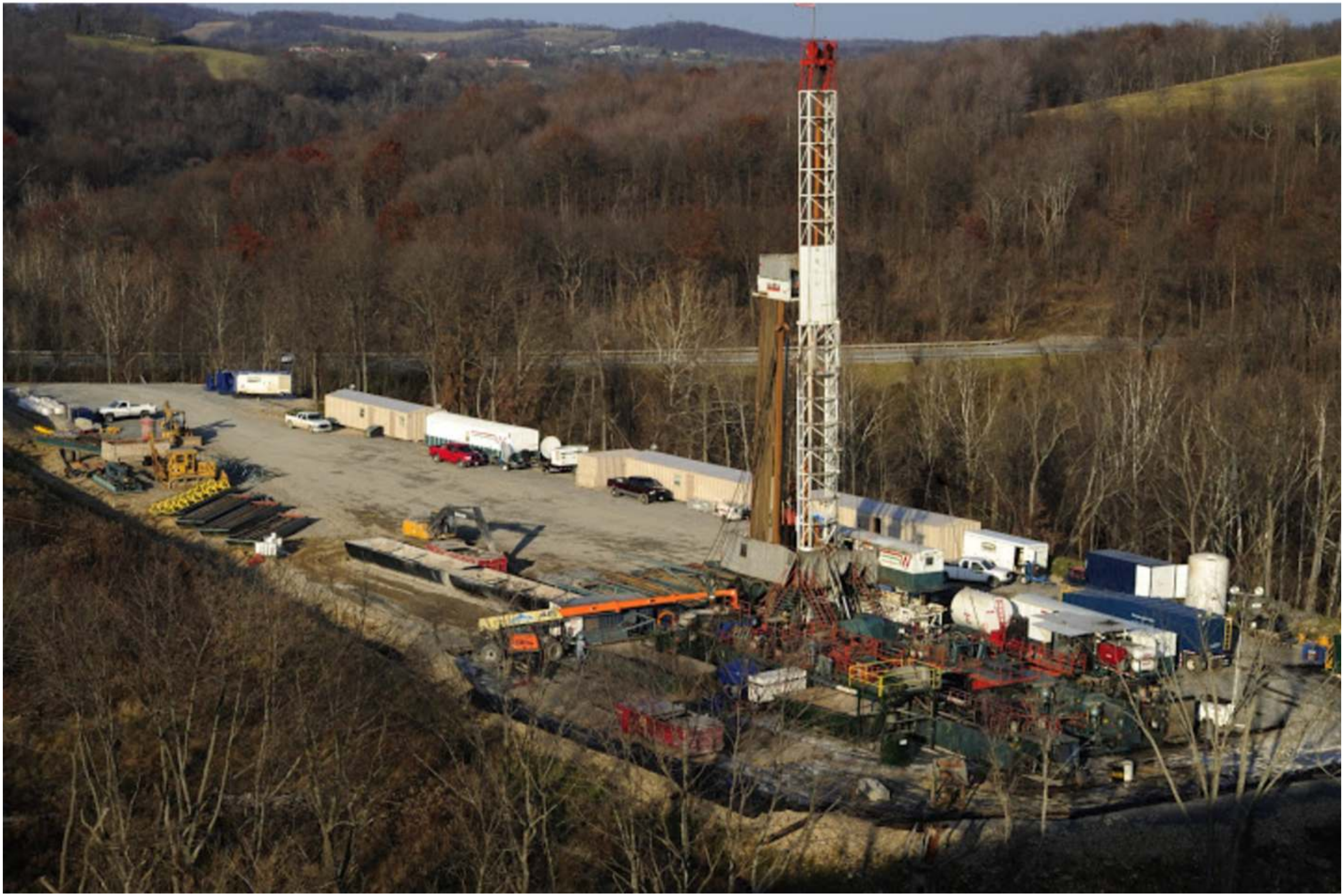
Shale Gas Plays in the Continental United States



Example of heavy unconventional drilling activity. Pennsylvania, U.S. (2005 – July 2013)



WELL PAD



Shale Gas Extraction Process

1. **Exploration** – find the gas reserves. Utilizes seismic testing.

2. **Obtain leases & permits** – Leases obtained from mineral rights owners – not always the same as landowners. Permits purchased from the PA DEP.

3. **Prepare the site** – Clear the land cover and flatten to a degree. May have several well pads on 1 site. Some sites can be up to 40 acres in size. Haul in all of the components needed to drill the well. Prepare the frac fluid (see next slide for more information).

4. **Drill the well**
    - Drilled down vertically into the shale layer of interest
    - Turn the drill to continue drilling horizontally (sometimes over a mile in length)
    - Case the well (steel tubes and cement) to prevent compounds from escaping well
    - Hydraulic fracturing: Inject ~5 million gallons of fresh water, and small percentage of sand and chemicals under high pressure (10,000-11,000 psi) to release the gas

Continued…

ADDITIVE TYPE	DESCRIPTION OF PURPOSE	EXAMPLES OF CHEMICALS
Proppant	"Props" open fractures and allows gas / fluids to flow more freely to the well bore.	Sand [Sintered bauxite; zirconium oxide; ceramic beads] & sometimes silica sand
Acid	Cleans up perforation intervals of cement and drilling mud prior to fracturing fluid injection, and provides accessible path to formation.	Hydrochloric acid (HCl, 3% to 28%) or muriatic acid
Breaker	Reduces the viscosity of the fluid in order to release proppant into fractures and enhance the recovery of the fracturing fluid.	Peroxydisulfates
Bactericide / Biocide	Inhibits growth of organisms that could produce gases (particularly hydrogen sulfide) that could contaminate methane gas. Also prevents the growth of bacteria which can reduce the ability of the fluid to carry proppant into the fractures.	Gluteraldehyde; 2-Bromo-2-nitro-1,2-propanediol
Buffer / pH Adjusting Agent	Adjusts and controls the pH of the fluid in order to maximize the effectiveness of other additives such as crosslinkers.	Sodium or potassium carbonate; acetic acid
Clay Stabilizer / Control	Prevents swelling and migration of formation clays which could block pore spaces thereby reducing permeability.	Salts (e.g., tetramethyl ammonium chloride) [Potassium chloride]
Corrosion Inhibitor	Reduces rust formation on steel tubing, well casings, tools, and tanks (used only in fracturing fluids that contain acid).	Methanol; ammonium bisulfate for Oxygen Scavengers
Crosslinker	The fluid viscosity is increased using phosphate esters combined with metals. The metals are referred to as crosslinking agents. The increased fracturing fluid viscosity allows the fluid to carry more proppant into the fractures.	Potassium hydroxide; borate salts
Friction Reducer	Allows fracture fluids to be injected at optimum rates and pressures by minimizing friction.	Sodium acrylate-acrylamide copolymer; polyacrylamide (PAM); petroleum distillates
Gelling Agent	Increases fracturing fluid viscosity, allowing the fluid to carry more proppant into the fractures.	Guar gum; petroleum distillate
Iron Control	Prevents the precipitation of carbonates and sulfates (calcium carbonate, calcium sulfate, barium sulfate) which could plug off the formation.	Ammonium chloride; ethylene glycol; polyacrylate
Solvent	Additive which is soluble in oil, water & acid-based treatment fluids which is used to control the wettability of contact surfaces or to prevent or break emulsions.	Various aromatic hydrocarbons
Surfactant	Reduces fracturing fluid surface tension thereby aiding fluid recovery.	Methanol; isopropanol; ethoxylated alcohol

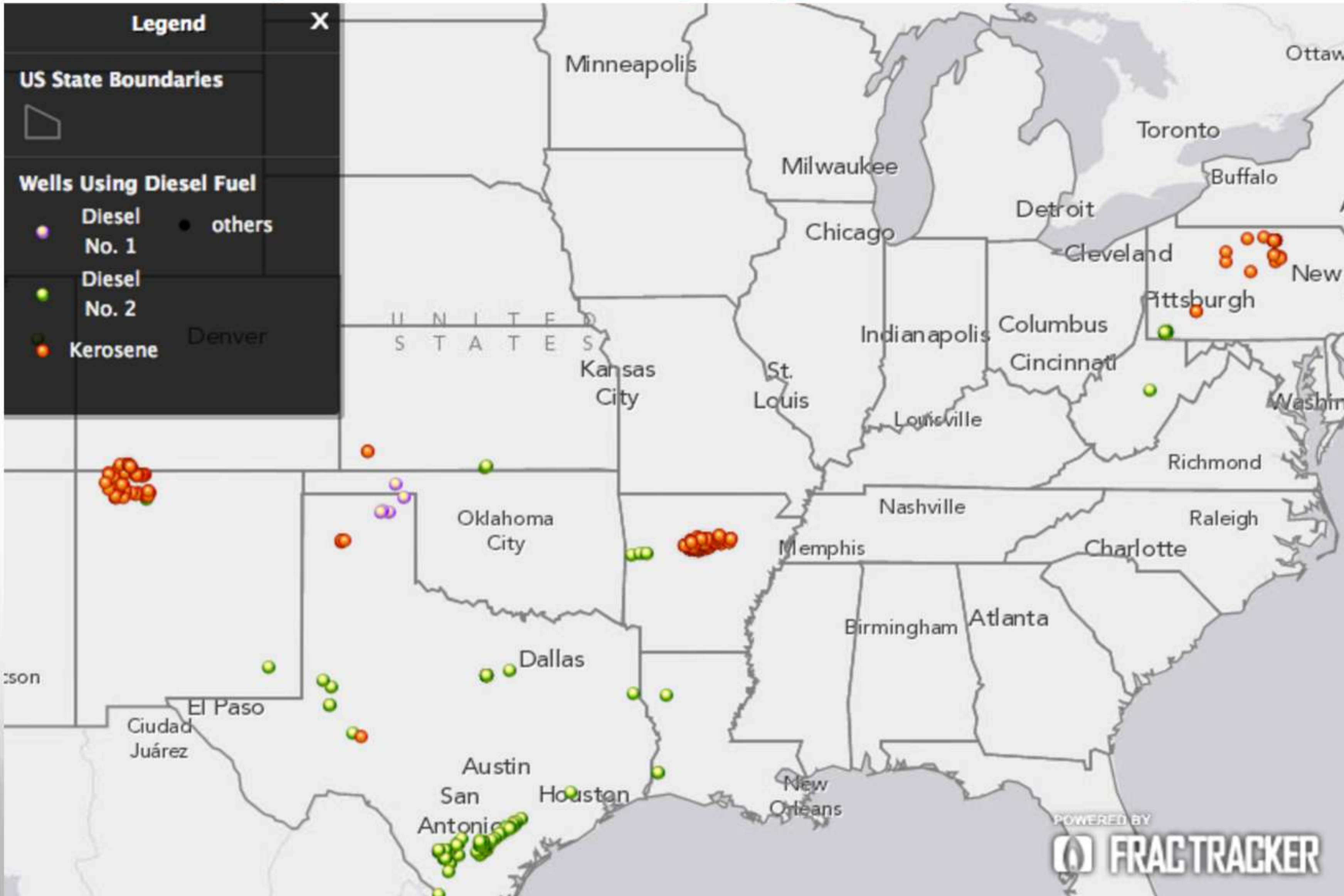
NY State's Draft Supplemental Generic Environmental Impact Statement, 2011

Select Chemicals in Frac Fluid

- 1% of injected fluids, still equates to a large quantity
  - Ex: a 4 million gallon fracturing operation would use 80–330 tons of chemicals (Hazen and Sawyer, 2009)
- Many known to be toxic to humans and wildlife. Several known to cause cancer.
  - Petroleum distillates such as kerosene and diesel fuel (contain benzene, ethylbenzene, toluene, xylene, naphthalene and other chemicals)
  - Polycyclic aromatic hydrocarbons
  - Methanol
  - Formaldehyde
  - Ethylene glycol
  - Glycol ethers
  - Hydrochloric acid
  - Sodium hydroxide

Wells using Diesel Fuel in Frac Fluid

As reported on FracFocus.org, Mapped on FracTracker.org



Extraction Process Continued

5. Process the Returns (25-100% fluid returns to surface)

- Separate natural gas from other constituents of the flowback fluid, which occur due to contact with shale
- Waste initially stored on site: closed containers or lined frac ponds (below)

6. Waste Handling

Discussed in detail later…

Options:

A. Recycle on site

B. Disposal:

- Solid waste to landfills
- Surface water facilities limited
- Class II deep well injection sites

Water Management Research

- **Drinking/Ground Water**
  - Potential to negatively impact ground water quality still being investigated
  - NM has database of instances where pits contaminated ground water (>600 cases) – Likely shallow ground water zone
  - Important studies: Osborn, Vengosh, Warner, & Jackson (2011) and US Environmental Protection Agency's hydraulic fracturing study (in progress).

- **Surface Water**
  - Potential to pollute surface waters has been demonstrated on a number of occasion

Photos next slide →
See FracTracker.org for more information.

Buckeye Creek spill, Sept. 2009
Both photos courtesy of WV Host Farms Program
(www.wvhostfarms.org)

Drill site, Harrison County, WV. Landowner reported seeing oily substance bubbling up from ground and into stream. Driller later cited for putting a well pad on top of a wetland area.

Waste Management

FLOWBACK COMPOSITION:

- In addition to injected frac fluid, components of the shale formation are picked up:
  - e.g. iron, calcium, magnesium, barium, sulfur, bromide, chloride, strontium, barium, arsenic, hydrogen sulfide, hydrocarbons, chlorides, sodium, and sulfates
- May also contain radioactive elements, e.g. radium
- High concentrations of total dissolved solids (TDS)
  - Range: 70,000 - 250,000 mg/L

RECYCLING:

- Depending on who you ask, approximately 80-90% of fluids are recycled for future hydraulic fracturing purposes
- Some companies do not have the capacity to recycle to that degree
- Reverse osmosis and distillation for water treatment: high cost, not likely to be utilized

Continued…

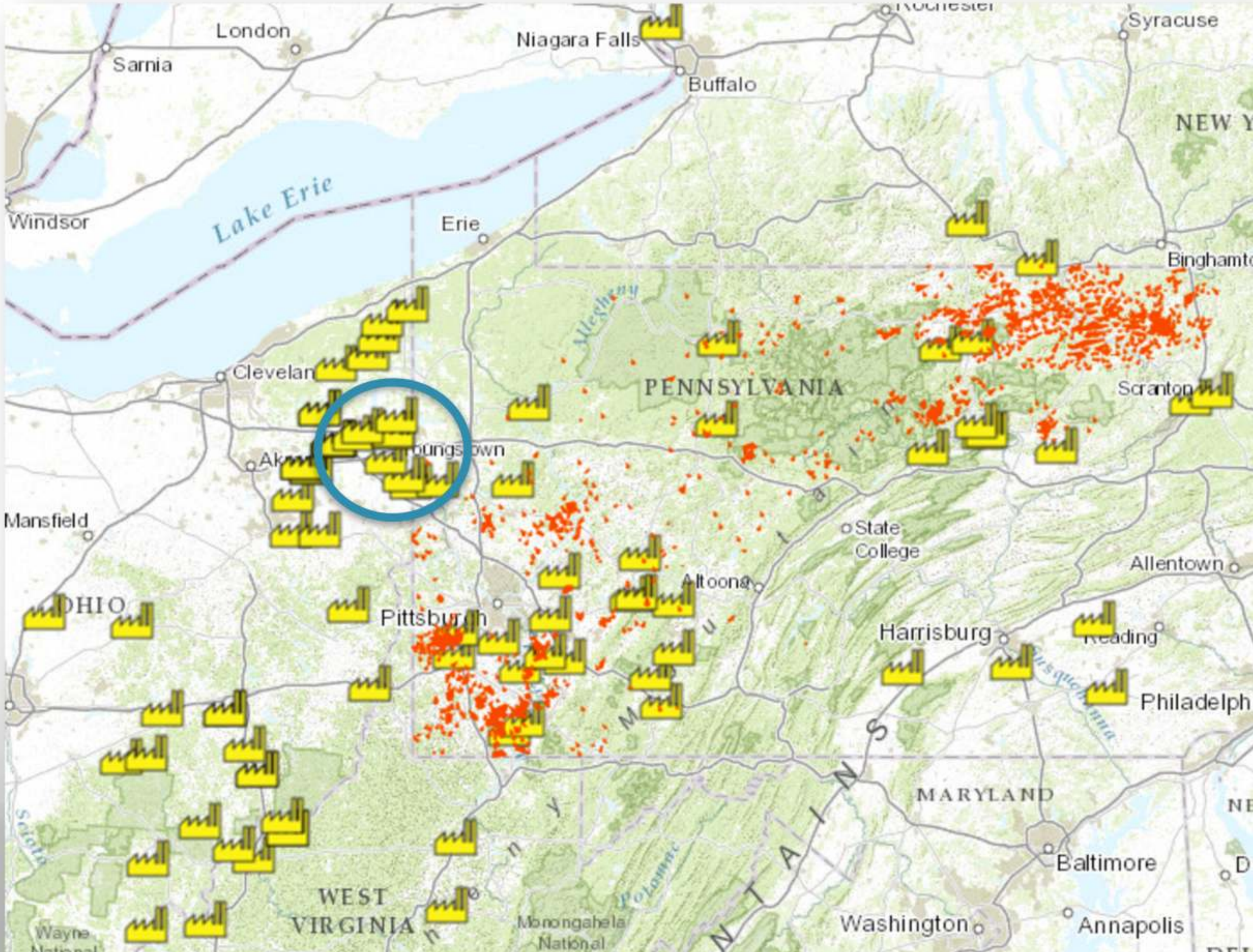
Waste Management Continued…

DISPOSAL:

1. In PA and OH, brine solution may be used as road surface application / dust control
2. Surface waters:
   - In PA, at least 63 POTWs allowed to take up to 1% of total daily output of produced fluids
   - POTWs not designed to "treat" produced water; merely dilute the salts (Ferrar, Michanowicz *et al.* 2013)
   - In effluent, new or expanding facilities must not exceed:
     500 mg/L TDS, 250 mg/L chloride, 10 mg/L barium and strontium
3. Class II deep well injection sites
   - PA's geology doesn't readily support deep well injection
   - PA wastes often shipped to OH or NY for deep well injection.

Youngstown Earthquake

Linked to Deep Well Injection (Not Drilling)



Air Pollution Risks

Conclusions from Health Assessment Study in CO

- Closer to well pad, the higher the risk of respiratory and neurological effects due to air pollutants

- If living close to natural gas well, higher risk of cancer than residents who live farther from the wells

- Emissions measured by the fenceline at well completion statistically higher ($p \leq 0.05$) than emissions at fixed location station

- Pollutants included benzene, toluene, and several alkanes

(Mckenzie *et al*. 2012)

Air Pollution Risks

Sources of Air Emissions from Operations*

	Fugitive Emissions	Dehydration	Vehicles/ Engines	Flaring	Pits
PM		X	X		
H_2S	X			X	
Ozone	O	O	O		
CO			X	X	
NOx			X	X	
SO_2			X	X	
VOCs	X	X	X	X	X
BTEX	X	X	X	X	X
Methane	X	X			X
NORMs	X	X			X

(Mckenzie *et al*. 2012) * Table compiled by Leslie Walleigh MD, MPH (7-20-12)

Recognized Health Effects of Air Emissions from Natural Gas Activities*

	Pulmonary	Neurologic	Reproductive	Dermal	Hematologic
PM	X			X	
H_2S	X	X		X	
Ozone	O				
CO		X	X		
NOx	X				
SO_2	X				
VOCS	X	X	X	X	X
BTEX	X	X	X	X	X
Methane					
NORMs			X	X	X

* Table compiled by Leslie Walleigh MD, MPH (7-20-12)

Air Pollution Risks

Silica Dust, a Significant Worker Hazard

- Silica sand used as a proppant in frac fluid

- NIOSH identified respirable crystalline silica as a major risk to shale gas workers – even above well-known hazard of H_2S

- Refers to the portion of crystalline silica small enough to enter gas-exchange regions of the lungs if inhaled: particles < 10 μ m

Silica dust clouds from delivery trucks loading into sand movers. Photo credit: NIOSH

- Can cause silicosis of the lung (disability/death). Human carcinogen.

- *Extraction* of silica sand has its own environmental and public health risks

Light, Noise, Smell Pollution

- Uncommon smells from shale gas extraction have been reported, often noxious
  - Known hazard to oil and gas extraction (Gurevich, Endres, Robertson Jr., Chilingar, 1993)
- Light and noise effects studied readily as they relate to industrial activity. Known health effects (Navara and Nelson 2007)
  - Not studied extensively in shale gas, however

Light Pollution

- There are connections between light on sleep and other health impacts (Navara and Nelson, 2007)

Noise Pollution

Reported by Witter *et al.*

Noise levels (dB) during drilling (not flaring)

Within 100 ft : 83-78 dB

- >76-83 dB : garbage disposal

Within 200 ft. : 75-70 dB

- >69-71 dB : kitchen exhaust fan

Within 1000 ft. : 69-65 dB

- >42-52 dB : forced air heat

Health Effects

30 dB: Sleep disturbance

55 dB: Fatigue, cognition, mood

70 dB: School performance

Global Climate Change Implications

Benefits:

- Natural gas burns more cleanly than traditional fossil fuels like coal
- Sulfur is not released during combustion of natural gas

Drawbacks:

- Methane often released during extraction and distribution
- Methane is a more potent (yet less pervasive) greenhouse gas than CO_2 (significant quantities are released when coal is burnt)
- Some CO_2 released during the lifecycle of unconventional natural gas extraction
- Natural gas – like other fossil fuels – not quickly renewable

Drilling is occurring close to residences and vulnerable populations…

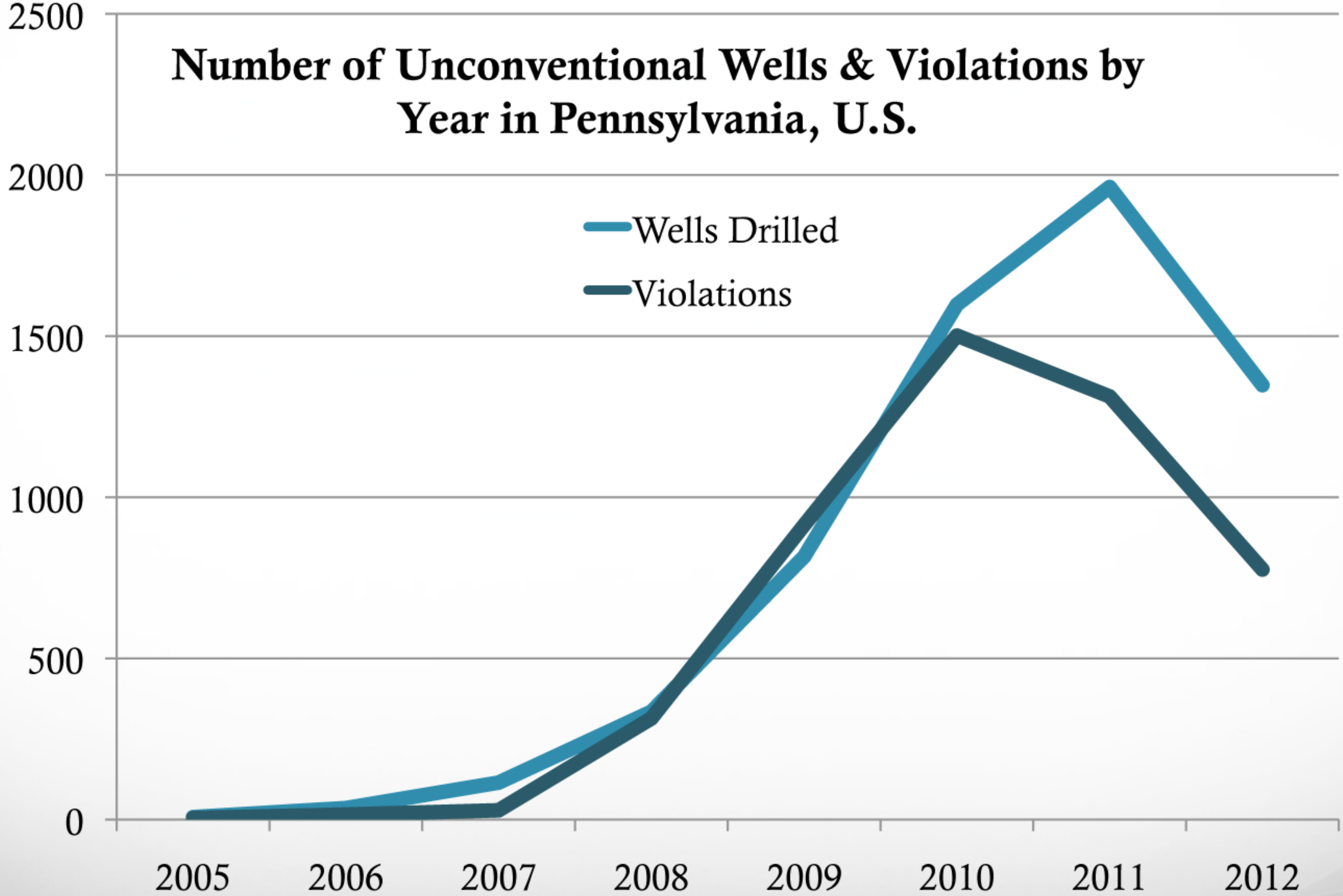
Reported Symptoms

More research needed

- For people living near operations, perceived health effects were reported in Ferrar, Kriesky *et al.*, 2013.
- Key findings:
  - 59 unique health impacts and 13 stressors attributed to Marcellus Shale development
  - Stress most frequently-reported symptom
  - Over time (after 19-22 months) perceived health impacts increased (P=0.042)
  - While stressors remained constant (P=0.855)
  - Preliminary study, more research needed.

… And Accidents Happen

Fire on McDowell B well site near Wetzel County, WV. Burned for 9 days
Photo Credit: Wetzel Co. Action Group, Ed Wade, Jr. (Sept. 2010)



"Environmental" violations peaked in 2011. "Administrative" violations peaked in 2010.
Distinctions between categories not reliable.
PA is currently the only U.S. state providing free, publicly accessible shale violations data

Recommendations

- Chemicals related to or mobilized by natural gas activities should be monitored
- Pre- and post- testing of private drinking water wells needed, along with testing during the entire lifecycle of natural gas activities at each site
- Studies should include all the ways people can be exposed, such as through air, water, soil, plants and animals
- Micro-seismic monitoring of hydraulic fractures & wastewater injection
- Increased and improved data transparency

Questions?

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Maps courtesy of FracTracker.org

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