

Shale Gas Fundamentals

John R. Duda, Senior Advisor

U.S. Department of Energy/NETL

July 15, 2013



U.S. DEPARTMENT OF

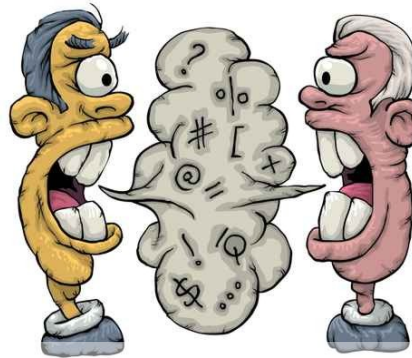
ENERGY

National Energy
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...As We Get Started...



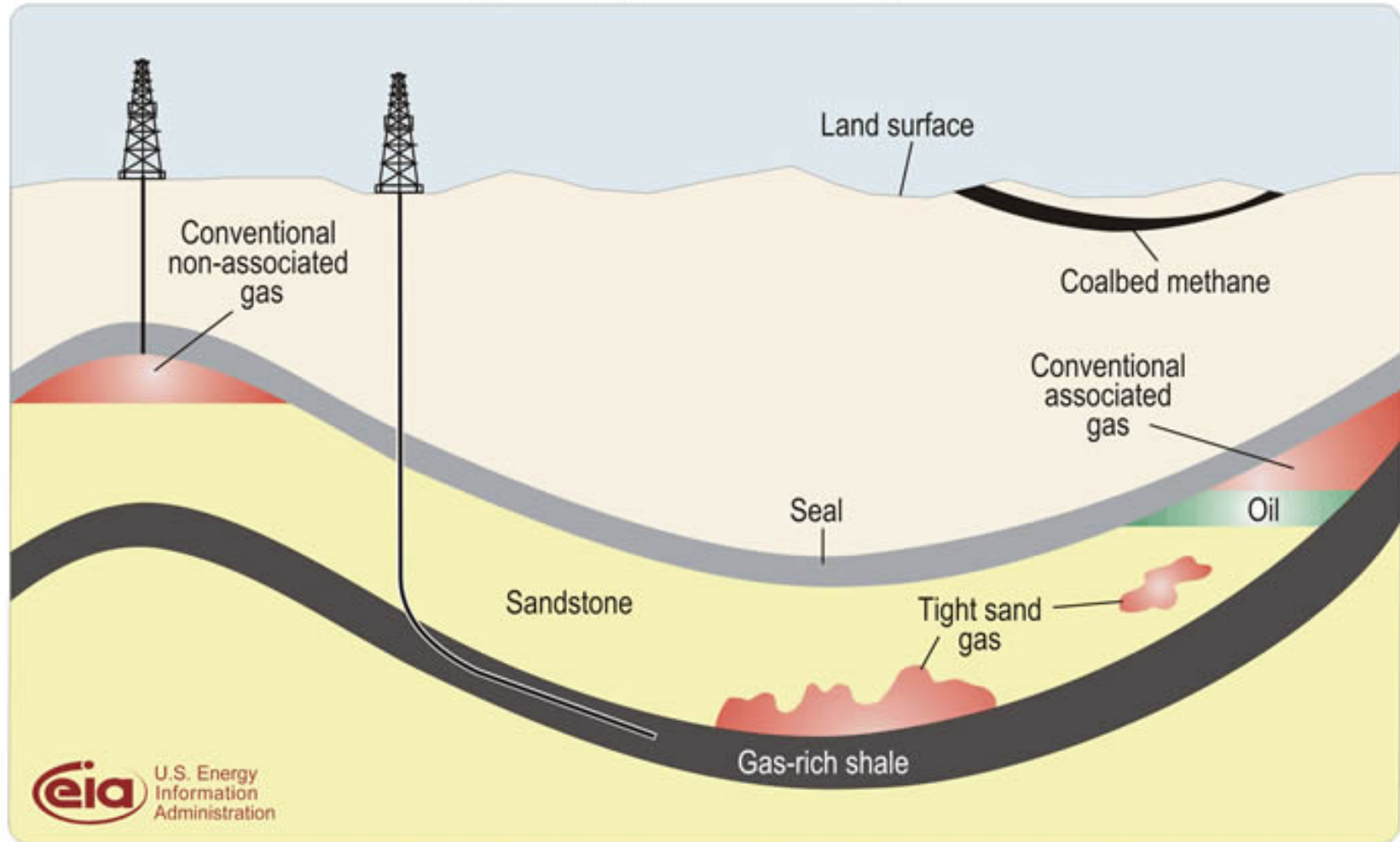
FRAC



Communication

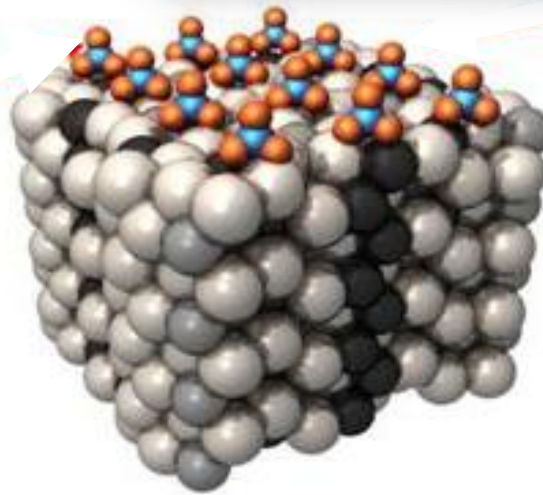
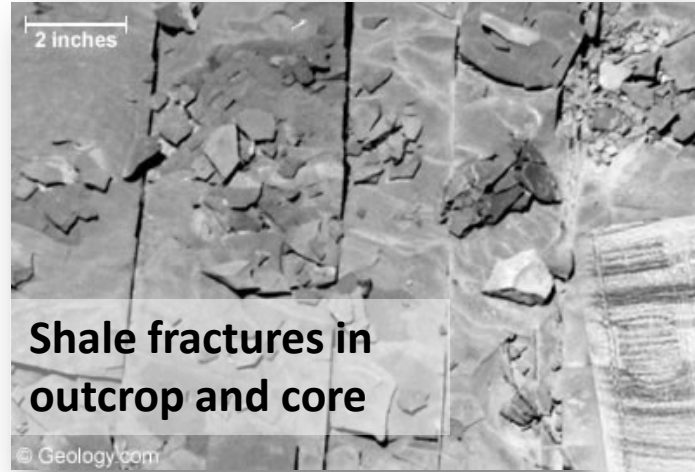
Shale: Source Rock and Reservoir

Schematic geology of natural gas resources



Natural Gas Storage in Shale

- Natural gas is stored in shales in different ways:
 - **Adsorbed gas** – CH_4 molecules attached to the surface of organic matter
 - **Free gas** – methane and other hydrocarbon molecules held within the rock pores and natural fractures
 - **Solution gas** – gas molecules dissolved within oil



Methane molecules
adsorbed to shale
matrix

U.S. Shale Gas Plays



Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI.
Updated: May 9, 2011

Estimates on the Increase

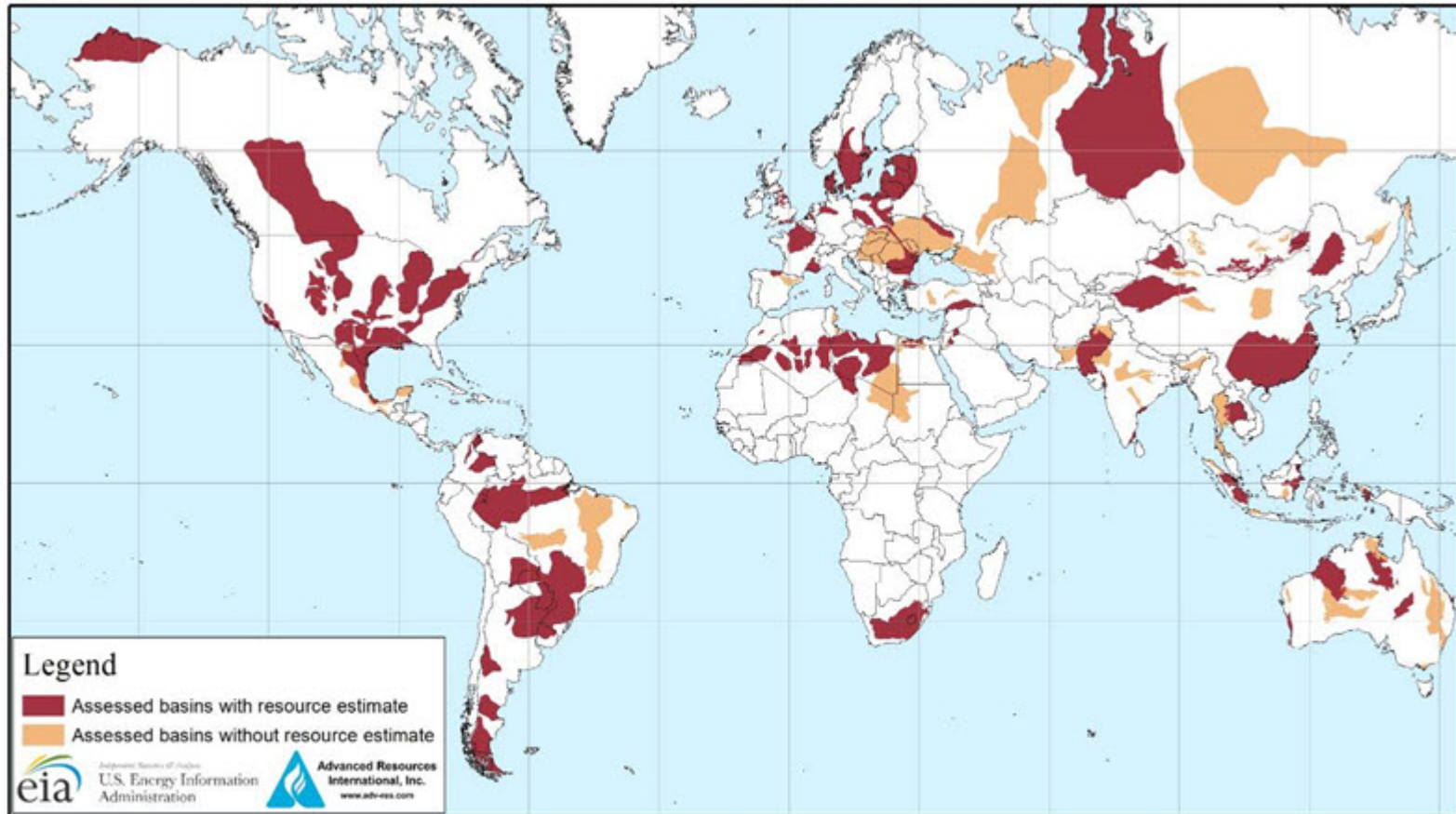
Trillion cubic feet (Tcf)

Source	Play	Technically Recoverable
EIA (Jan. 2008)	All shales	347
ARI (Jan. 2009)	Five main plays	475
PGC (Jan. 2009)	All shales	616
EIA (June 2011)	All shales	862
NPC (Sept 2011)	All shales	700 to 1,800
EIA (June 2012)	All shales	482*
PGC (April 2013)	All shales	1,073

* Drop from EIA 2011 due to reduction in Marcellus TR to make it consistent with USGS assessment

Assessed International Shale Gas Plays

Figure 1. Map of basins with assessed shale oil and shale gas formations, as of May 2013



Source: United States basins from U.S. Energy Information Administration and United States Geological Survey; other basins from ARI based on data from various published studies.

Assessed International Shale Gas Plays

Geographic Region	Technically Recoverable Resource (Tcf)
Europe	470
FSU	415
North America	1,685
Asia/Pacific	1,607
South Asia	201
Middle East/N. Africa	1,003
Sub-Saharan Africa	390
South America/Caribbean	1,430
Total (TRR)	7,201
<u>Proved Reserves</u>	97

Grand total reported is 7,299 (RE: rounding)

Energy in Depth

INTERNATIONAL

Chevron says Europe needs broad framework to explore shale gas. [Reuters](#). Europe needs an EU-wide framework if it is to tap into its shale gas reserves quickly enough to reap the benefit, a senior executive at Chevron Corp said on Tuesday.

Iraq Minister: Shale to have Minimal Effect on Oil Demand. [Rigzone](#). Rising U.S. shale oil production will have only minimal effect on demand for crude oil from the Organization of the Petroleum Exporting Countries, meaning most members of the group want to leave their output ceiling unchanged at 30 million barrels a day, said Iraqi Oil Minister Abdul Kareem Luaiby Thursday.

Province looking for shale gas underneath Russell, Ont. [CBC News Video](#). An eastern Ontario municipality full of black shale rocks has the province researching if there could be any natural gas underneath.

Tinapple fires shot at activists. [West Australian](#). WA's most senior petroleum bureaucrat has fired a broadside at the environmental movement and accused some shale gas opponents of deliberately circulating false and misleading information.

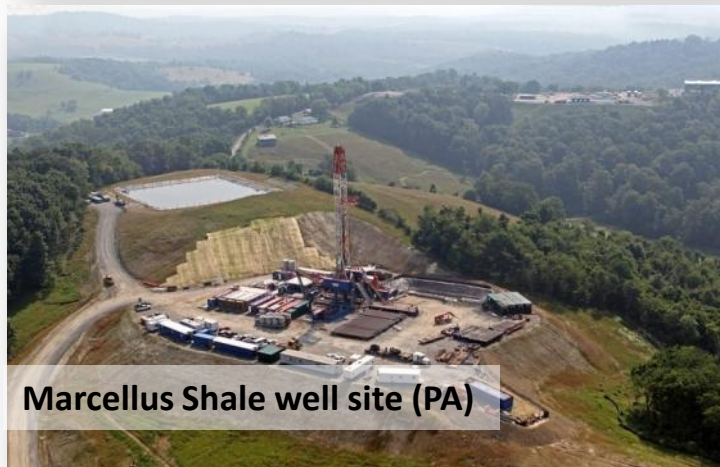
Northern Petroleum Enters Shale Prospective Play in Australia. [Rigzone](#). Northern Petroleum Plc has won 100 percent interest in Petroleum Exploration License (PEL) 629 in the Otway Basin, South Australia. The award is for five years and the company's first planned program will include geochemical analysis and seismic re-processing.

Building A Location

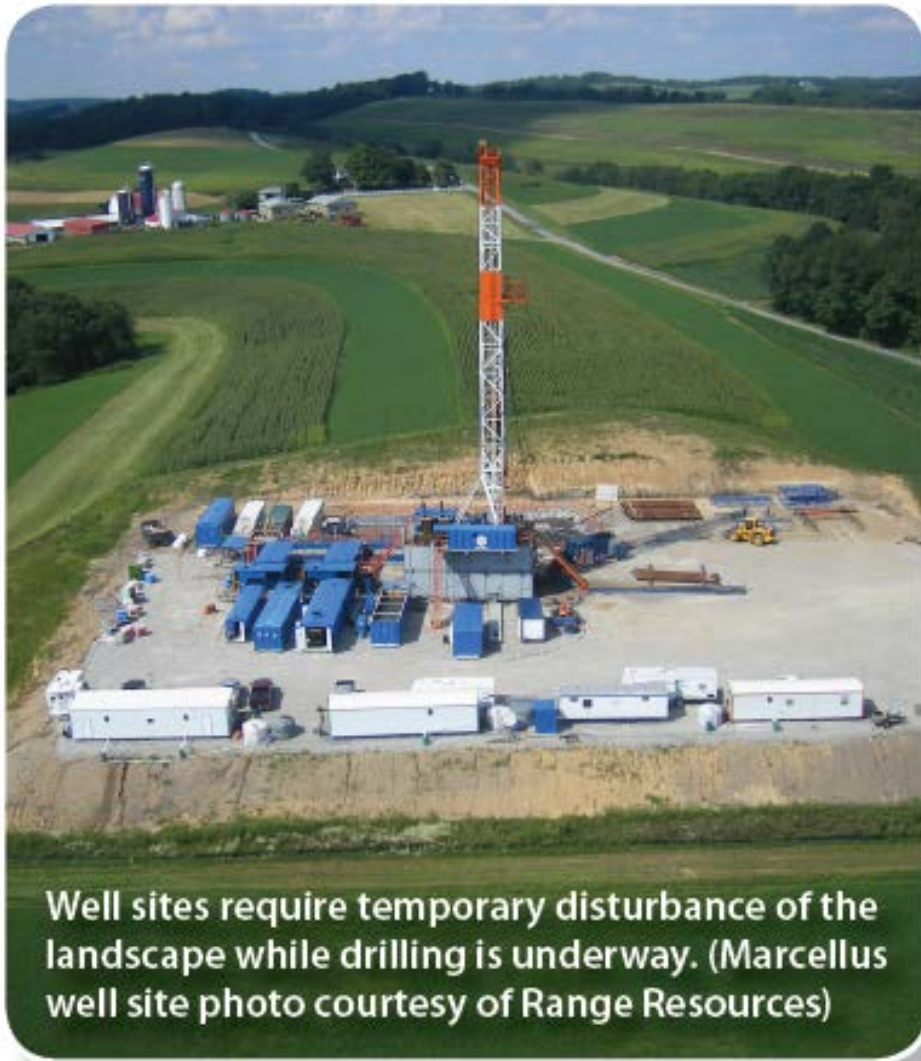


All photos from Penn State University (<http://marcellusfieldguide.org/index.php/gallery/>)

Health, Education, Commerce, ... Energy



Drilling



- Drill vertical portions of 6 to 10 wells from single pad using air rig
- Drill horizontal laterals of all wells (up to 5000') using conventional mud rig
- Move rig off location and wait for fracture equipment



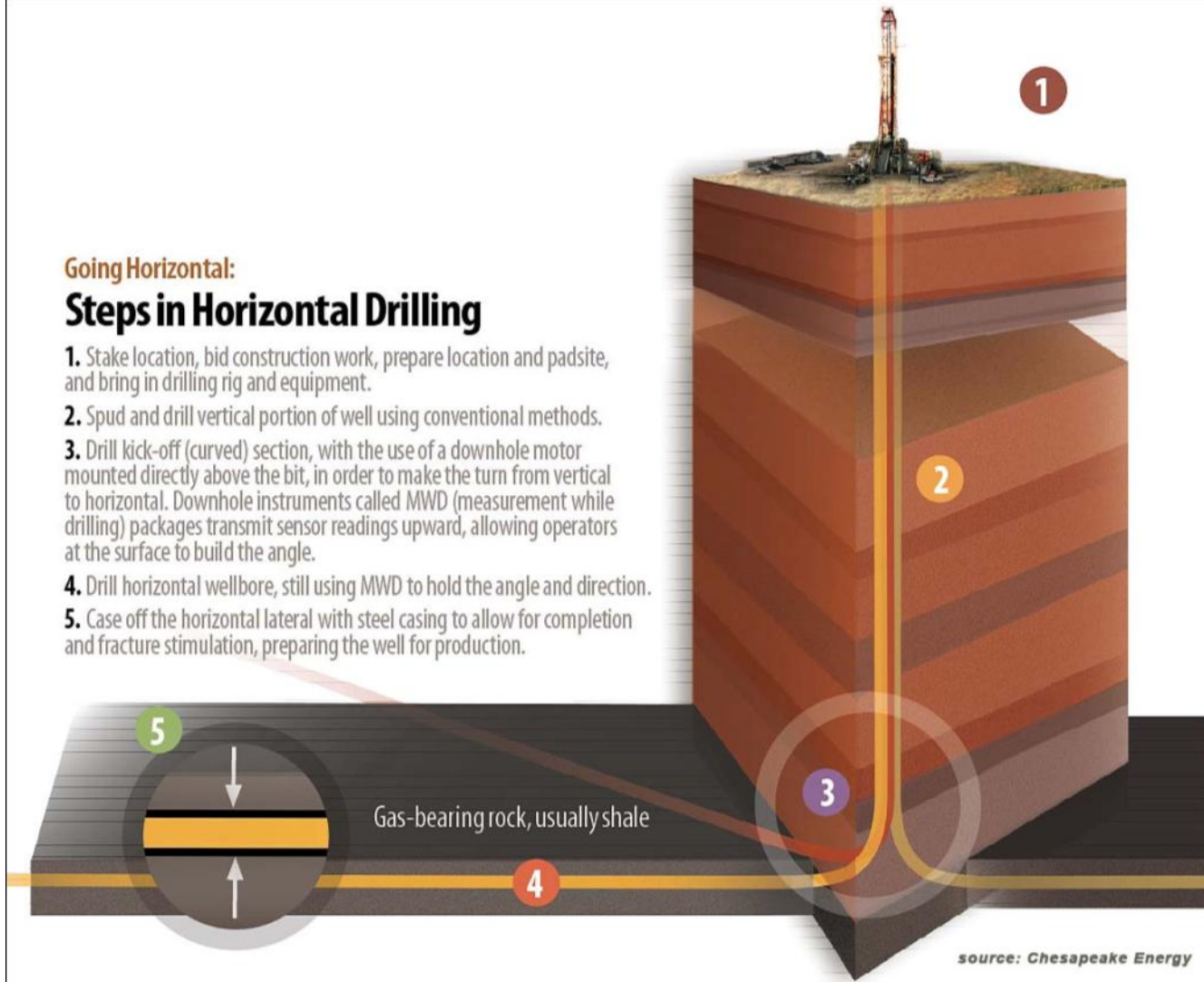
Photo; Shell US

Horizontal DRILLING

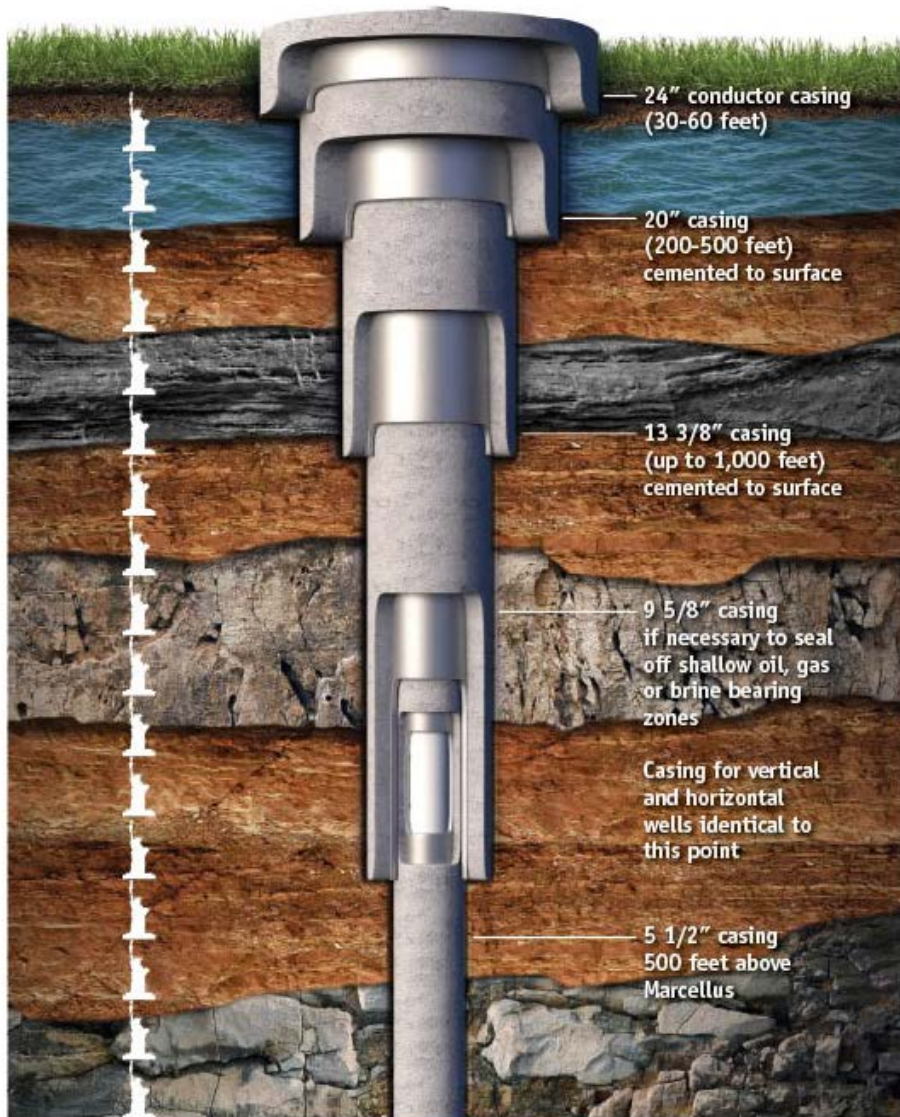
Going Horizontal:

Steps in Horizontal Drilling

1. Stake location, bid construction work, prepare location and padsite, and bring in drilling rig and equipment.
2. Spud and drill vertical portion of well using conventional methods.
3. Drill kick-off (curved) section, with the use of a downhole motor mounted directly above the bit, in order to make the turn from vertical to horizontal. Downhole instruments called MWD (measurement while drilling) packages transmit sensor readings upward, allowing operators at the surface to build the angle.
4. Drill horizontal wellbore, still using MWD to hold the angle and direction.
5. Case off the horizontal lateral with steel casing to allow for completion and fracture stimulation, preparing the well for production.



Top Hole Casing Program (Marcellus)



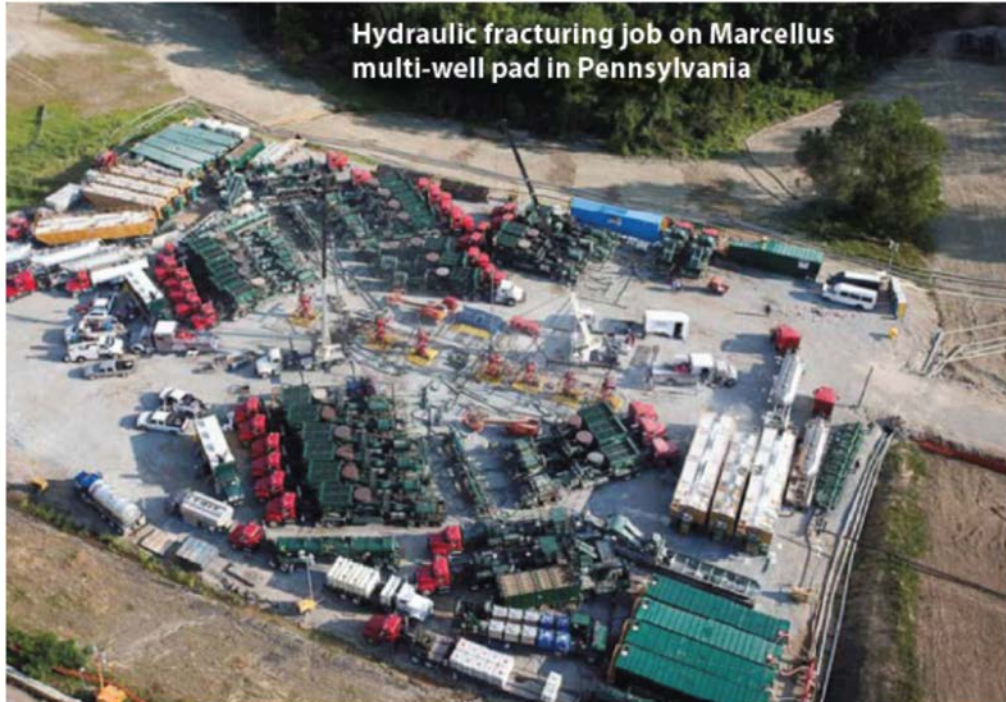
www.marcelluscoalition.org

Courtesy of Range Resources

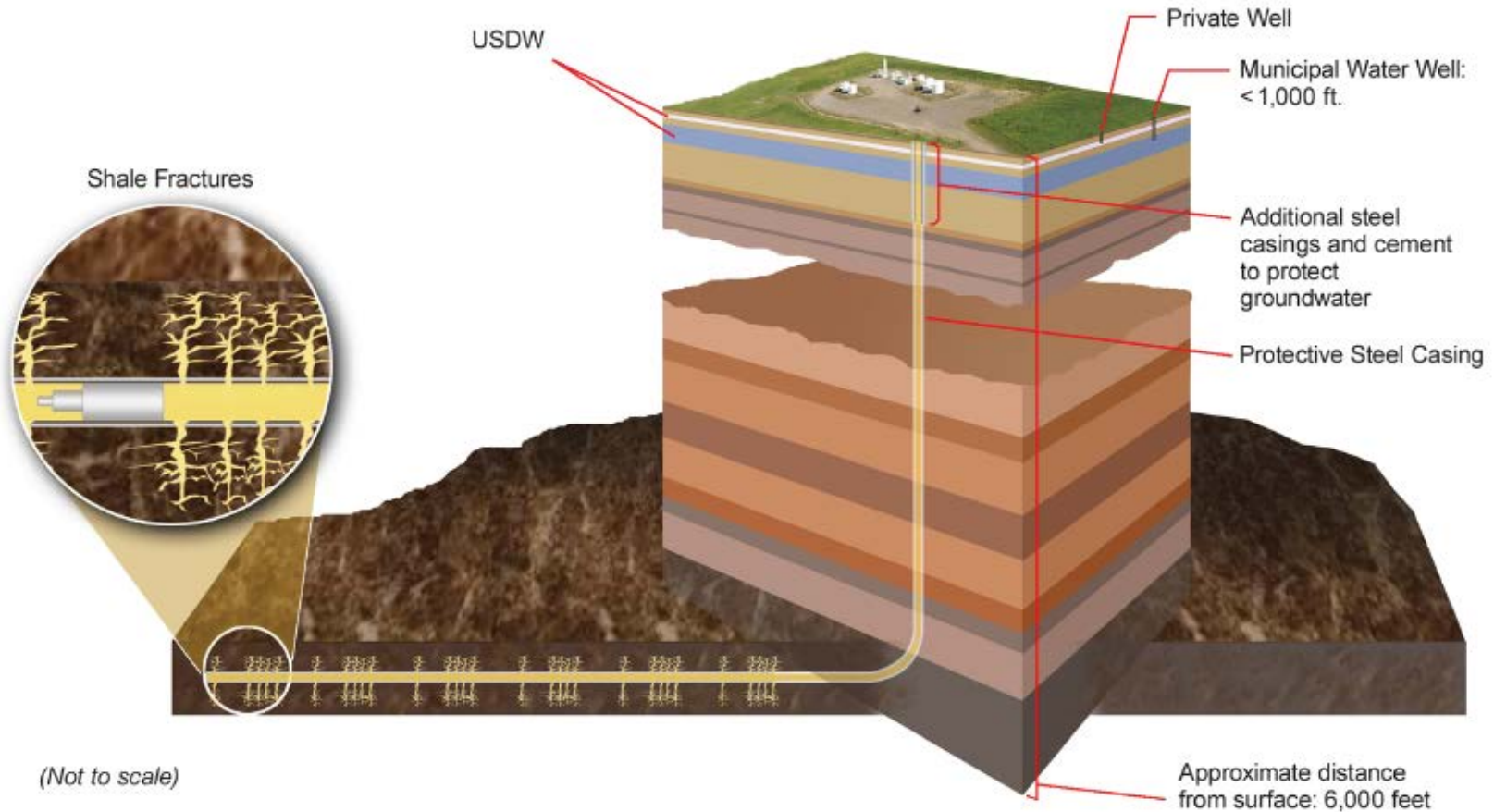
- Four layers of steel casing and cement protect potable water aquifers
- Distance from aquifer to Marcellus Shale is equal to 17 Statues of Liberty



Fracturing: Surface Operations



Multi-stage Hydraulic Fracturing



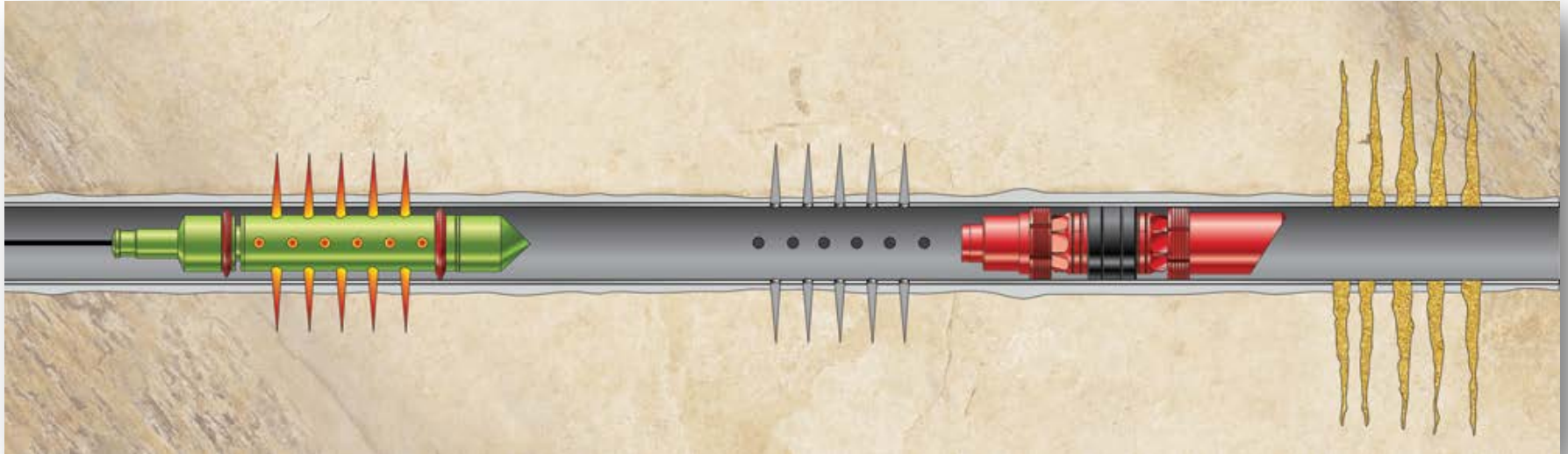
- Fracture all laterals successively in multiple stages (8 to 25 stages per lateral)
- Move off fracturing equipment and use coiled tubing unit to drill out plugs and flow back all wells in succession

Coiled Tubing Unit on Shale Well

Coiled tubing unit rigging up on a recently drilled 3,800 foot lateral for Devon Energy in Ashland Co., OH

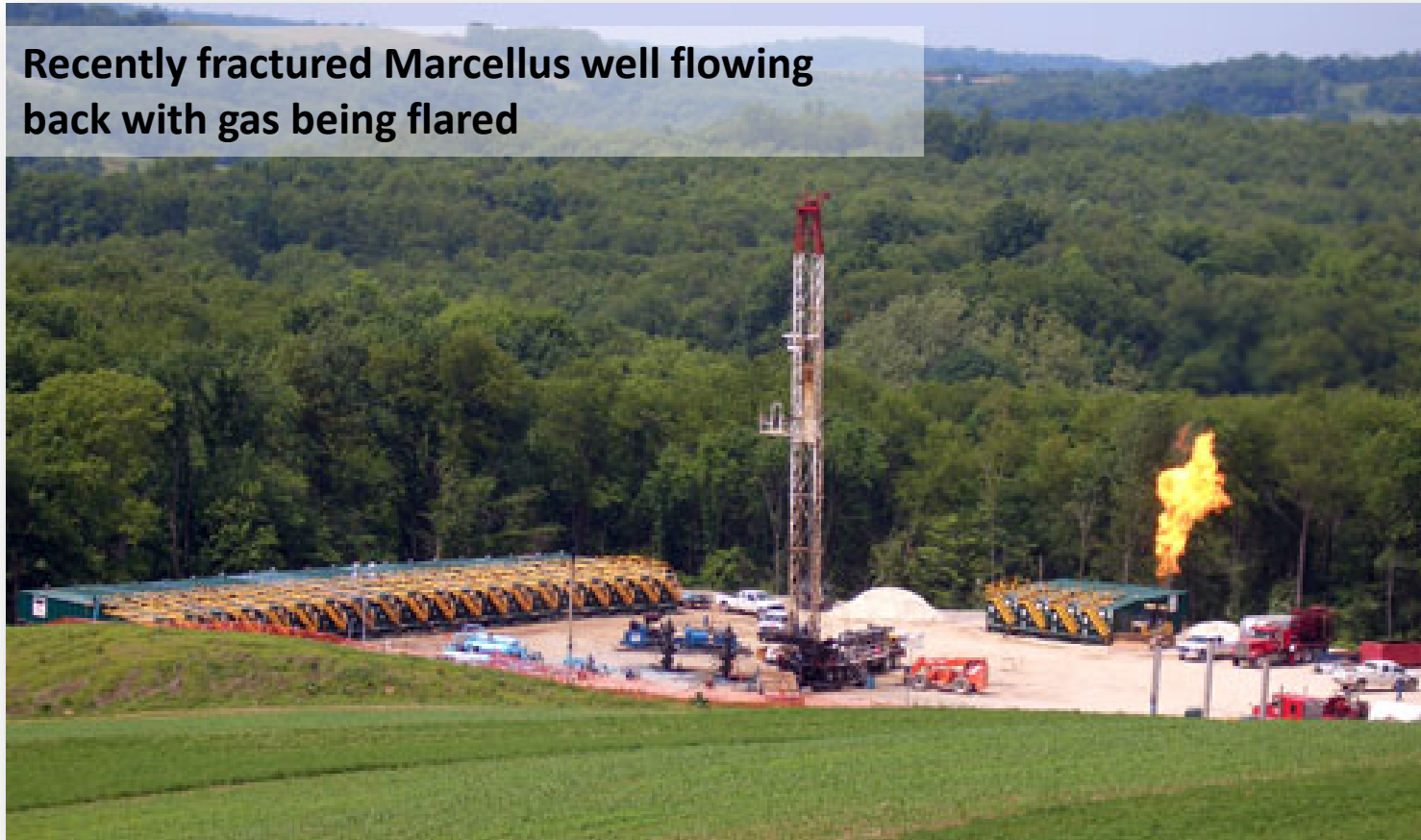


“Plug and Perf”



Fracture Flowback Operations

Recently fractured Marcellus well flowing back with gas being flared



Shale Gas Production Operations



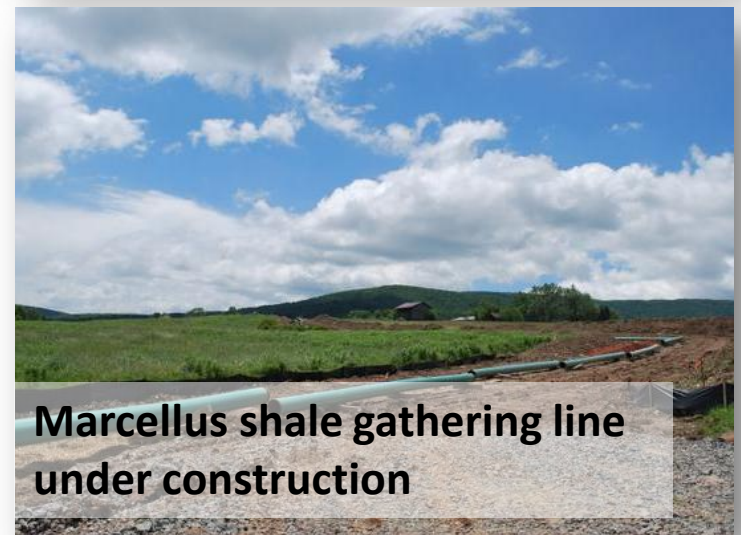
Condensate tanks at single well location



Compressor station for multiple well pads



Marcellus wellhead



Marcellus shale gathering line under construction

Capturing the Entire Value Chain

MarkWest's Majorsville
NGL plant



- NGLs from gas processing
- Ethylene from ethane
- *Myriad* petrochemicals



Shell announces plans to build an ethylene "cracker" to produce ethylene, a primary petrochemicals feedstock, from Marcellus shale ethane production



“Issues”



Primary “Concerns”

- 1. Water On the Ground (Surface Water)**
- 2. Water Below the Ground (Groundwater)**
- 3. Trucks On the Roads**
- 4. Fumes In the Air (Emissions)**
- 5. Induced Seismicity**
- 6. “New Neighbors” In the Neighborhood**
- 7. *Local* Workforce Development**

Water on the Ground

- Competition for water resources
- Potential for spills/contamination
- Impoundment safety
- Stream sediment



Photo Courtesy of Susquehanna River Basin Commission



Water on the Ground: Responses



Fracturing trucks on location at a Pennsylvania Marcellus location. (Photo courtesy of John Veil, Argonne National Laboratory)



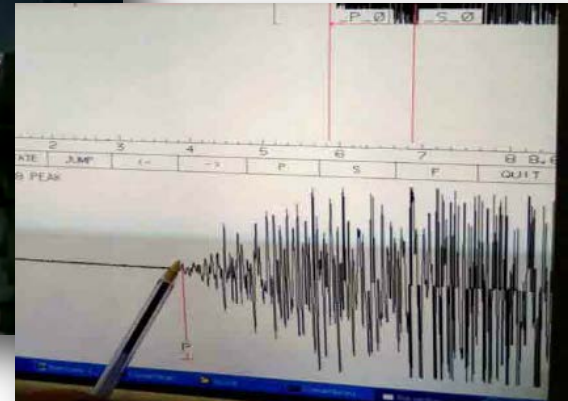
Water stored in tanks with spill barriers



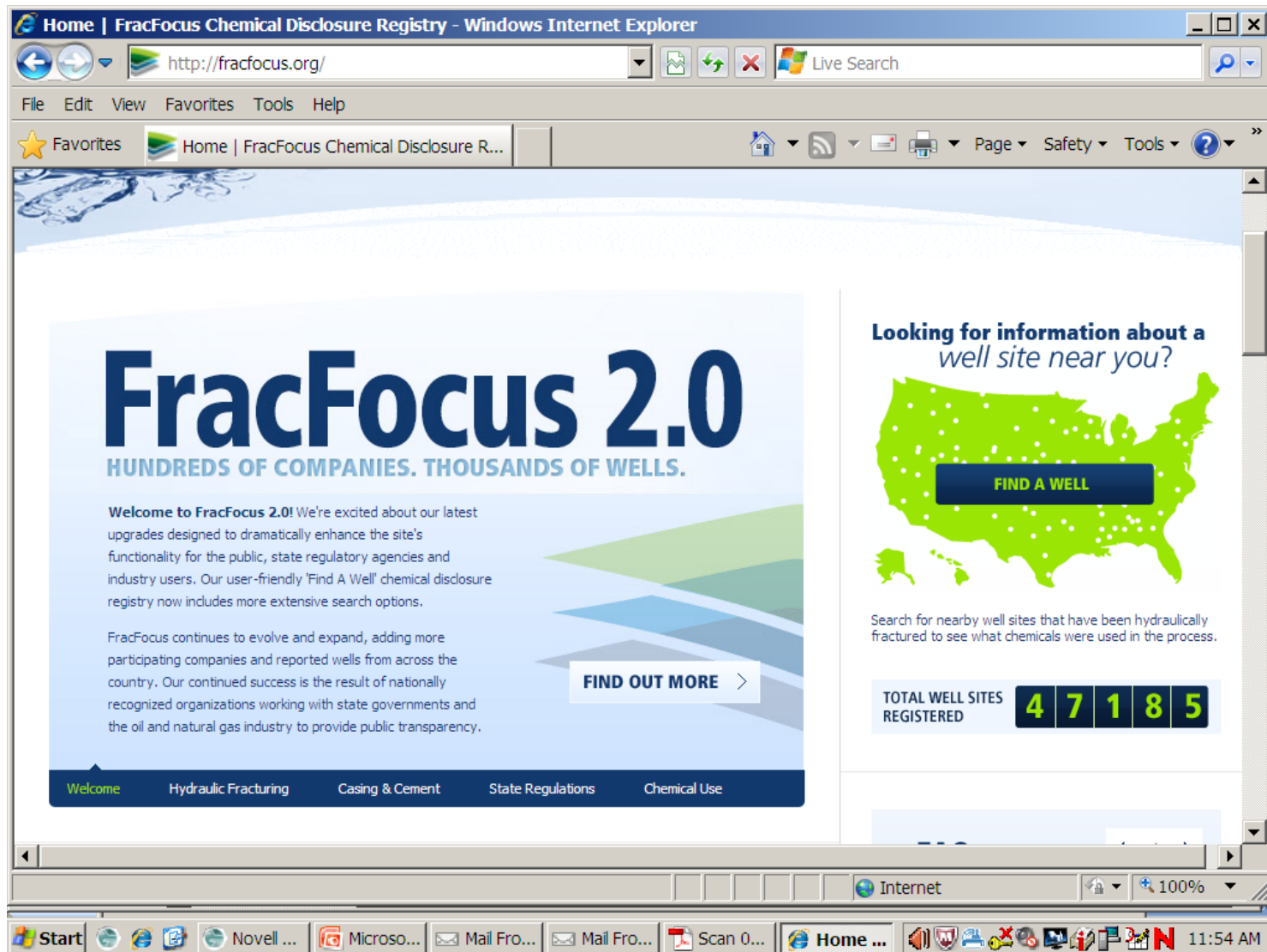
Fracturing make-up water is stored in lined pits to protect groundwater. (Photo courtesy of John Veil, Argonne National Laboratory)

Water Below the Ground

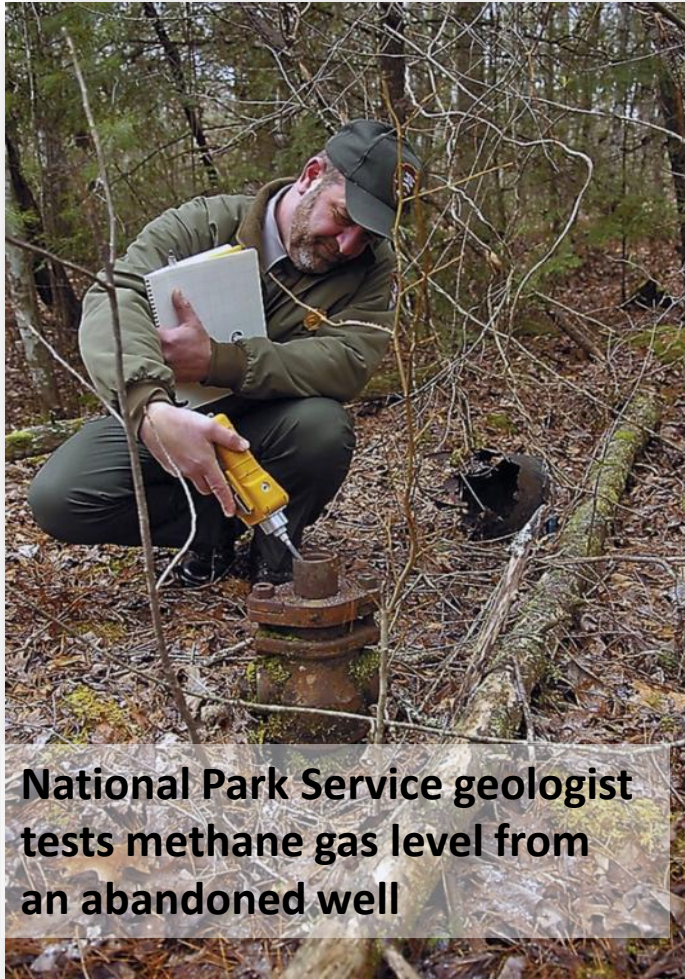
- Fear of fracturing-caused contamination
- Methane in groundwater
- Impacts of subsurface wastewater disposal



Fracture Fluid Disclosure



Methane in Groundwater



National Park Service geologist tests methane gas level from an abandoned well



Methane buildup in well water can be hazardous



100+ year history of shallow well completions has created many pathways for methane to communicate with water bearing strata

Trucks on the Roads

- Road wear on typically unimproved rural roads
- Increased traffic in residential areas and narrow rural roads
- Fear of accidents due to increased traffic



Fumes in the Air

- Exhaust and other emissions from equipment
- Compressor emissions
- VOC emissions during drilling, fracturing, flowback, and subsequent production



New Neighbors in the Neighborhood

- Setbacks
- Noise and lights from 24/7 operations
- Notice of operations
- Damage compensation
- Negative economic impacts (property values, rents, employment competition)
- Lifestyle impacts



Family's dream become 'pure hell'

May 15, 2011, The Dominion Post



DREAM

FROM PAGE 1A

Stacie's dad, Tim Sanders, and neighbors Rick and Rebecca Humphreys met with The Dominion Post to talk about the challenges of Marcellus operations in their community. Their complaints and concerns echo those of other residents of rural communities seeing a rise in horizontal well drilling: Jammed and broken roads, noise, water contamination, property damage, the industrialization of rural communities, the challenges of dealing with drillers, and the failure of state officials to provide any help.

Plum Run is between Mannington and Farmington. Sanders describes it as a close-knit community where people know each other.

Family's dream becomes 'pure hell'

Says Marcellus drilling causes many problems

BY DAVID BEARD

The Dominion Post

MANNINGTON — Stacie and Casey Griffith stand in front of the Plum Run dream home they built in 2005. The view isn't what it once was.

"Nobody being compensated," Casey said. "But there's a right way and a wrong way to do it."

They contend Waco went about it the wrong way.

There used to be a \$2,000 artificial pond behind their cedar-sided dream house. Silty runoff from the Donna pad kept filling it in. After four

rounds, they got tired of digging it out. So they asked Waco to fill it in for good, and put a cedar-sided playhouse on the spot.

Waco seeded and mulched the pad's downslopes, they said, but spread the hay either too thick or too thin. The ground is slipping and they get water in their yard.

When Waco built the impoundment pond, they said, the company moved their water line for them, but didn't tighten a crucial fitting. The Griffiths didn't know until the water company called and told them it was turning off their water because they had drained 46,000 gallons from the water tank in four days.

Waco reimbursed them, but Casey said:

"In. They were thankful I had no emergencies, and when the woman returned, she lectured her: 'Have a little common courtesy,'" he told me.

The road is barely two lanes, and the wide rigs don't drive over for cars. They're supposed to travel in no more than pairs, but a caravan of 20 rigs and pickups one day clogged the Griffiths to be late church. Another day Stacie — a middle school teacher — was 15 minutes late for work because eight rigs used to let her by.

"Eight, 10, dozens" of rigs will rumble by at 3 a.m., disrupting sleep. Night and day, their Jake breaks down.

Stacie said:

"I don't have to live with a code of common courtesy. I live with a company and its employees. They seem to ignore."

As parents, Rick and Rebecca agreed not to lay down rules they knew they'd never enforce. "It doesn't do any good to pass 47,000 laws," Rick said. "The gas and oil companies are like a bunch of kids. If you're going to pass a law, be willing to enforce it. Or forget it. I'm angry at the gas and oil companies, but I'm probably more angry at the representatives who are entrusted with the job they're not doing."

Finally they scoff at threats by various companies to high-tail it elsewhere if the state passes harsh regulations. "If we don't treat these people right, they'll go somewhere else," Rick said he has heard politicians worry. "I've got a news flash for you, The Marcellus shale isn't under South Carolina. It's under West Virginia. So if you want it you've got to drill here, you've got to play by our rules."

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You can't build a place to park? You can put a pond in this guy's field, but you have to park in the road? Don't tell me it can't be done."

When Waco was working at the Donna pad — during the first of four bores permitted at the site — workers tossed trash over the hill. Casey looked outside of his house and saw a worker urinating over the side of the hill. He was thankful his child didn't see it.

Stacie summed up her frustrations in a letter to Waco: "My family had endured much unnecessary stress because of your company."

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"You have nobody you can call on the phone," Rick said. "You can't call the Department of Oil and Gas. You can't call the DEP. You can't call the police. You can't call the Division of Highways. You can't call anyone to get any satisfaction whatsoever. The only thing you can do is reach into your retirement and start shelling out money to attorneys and take them to court."

They're all hopeful and skeptical about what the Legislature and state government might accomplish with future legislation.

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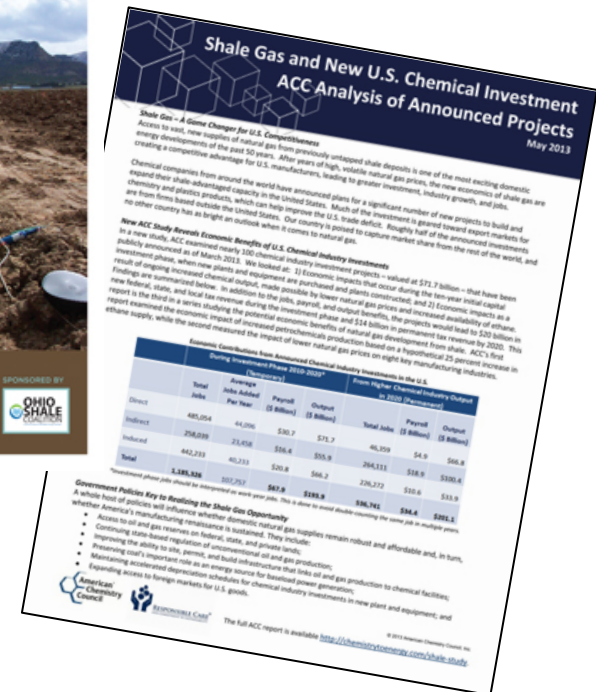
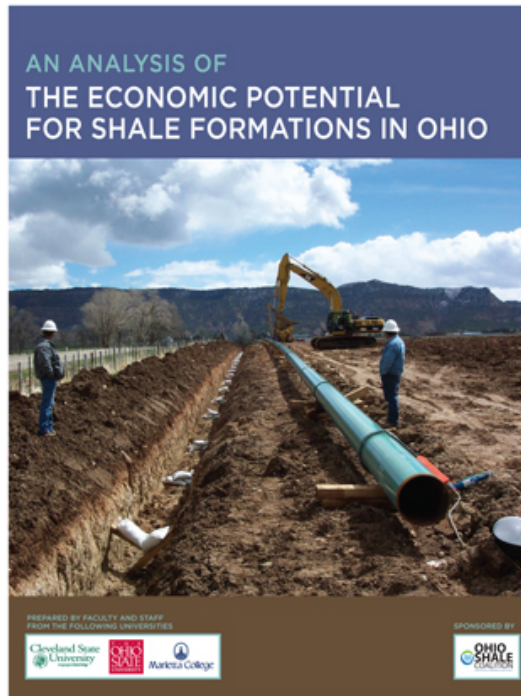
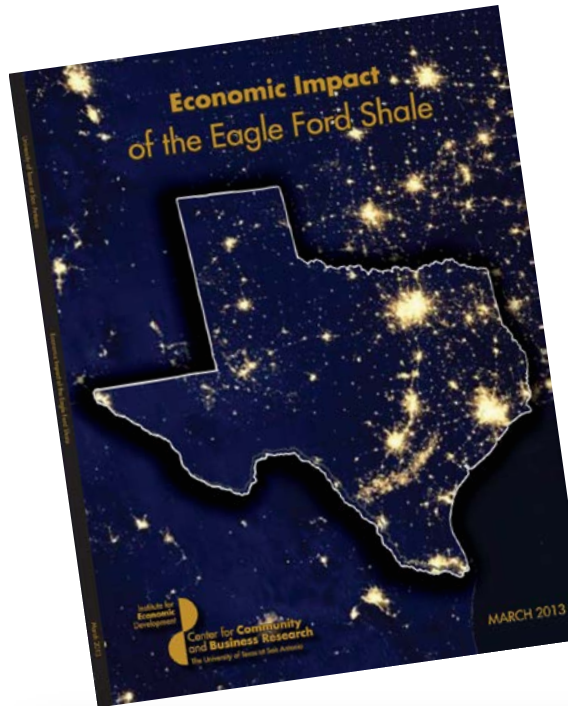
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A pond (left) holding water for future fracking jobs on the Donna pad sits at the edge of the Griffiths' yard, on land owned by Rick Humphreys' father-in-law, Terry Herder. Stacie Griffith (below) stands on the Donna pad and points to her backyard.

David Beard/The Dominion Post photo

Quantifying Benefits



“Between 2010 and 2015, PA will lead the nation in employment generated by unconventional gas with a compound annual employment growth rate of 14%” – IHS-CERA

Workforce Development

News > Petroleum Technology Program Announced | WVNC | West Virginia Northern Community College - Windows Internet Explorer

http://www.wvnc.edu/news/petroleum-technology-program

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WEST VIRGINIA NORTHERN COMMUNITY COLLEGE
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News Petroleum Technology Program Announced

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5/29/2013
FAIRMONT, W.Va. - Gov. Earl Ray Tomblin, joined by Community and Technical College Chancellor Jim Skidmore, today announced the establishment of the Appalachian Petroleum Technology Center in Fairmont. The Center will address the growing workforce need and provide training opportunities for individuals who are interested in the industry.

"This new Center, and its hands-on curriculum, will better prepare West Virginia students for the high-demand jobs needed to meet the demand of our growing oil and gas industry. Through joint programs offered by Pierpont Community and Technical College (Pierpont) and Northern Community College (WVNC), the Appalachian Petroleum Technology Center will provide a pathway for students to gain the skills and experience needed to enter the workforce."

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2012 REGIONAL HIGH-PRIORITY OCCUPATIONS RELATED TO MARCELLUS SHALE

The occupations listed in the table below are found within the staffing patterns of Marcellus Shale related core industries and have been identified as High-Priority for certain Workforce Investment Areas (WIAs).¹ High Priority Occupations (HPOs) are identified as in demand by employers, have higher skills needs, and are most likely to provide family sustaining wages.

A Standard Occupational Code (SOC) is provided for each occupation. For a complete list of terms, please refer to the Staffing Pattern definition on page 18.

SOC Code	SOC Title	Education Level	HPO in WIA Numbers
47-2061	Construction Laborers	Short-term OJT	1,2,3,4,5,7,10,14
47-5011	Derrick Operators, Oil & Gas	Short-term OJT	3,11,12,13,18,19,20,21,22
17-2071	Electrical Engineers	Bachelor's degree	1,2,4,5,7,8,10,14
53-7032	Excavating & Loading Machine Oprs		
53-7071	Gas Compressor Oprs		
49-3042	Mobile Heavy Equipment Mechanics		
53-7072	Pump Operators		

Source: The Center for Workforce Information

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724-925-6892

INFORMATION SESSIONS

February 27
4 p.m. & 6:30 p.m.

WCCC
Greene County Center

Westmoreland County Community College
GREENE COUNTY EDUCATION CENTER
100 EverGreene Drive, Suite 102, Waynesburg

WCCC is an affirmative action, equal opportunity college.

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References

EIA's (with ARI) Technically Recoverable Shale Oil and Shale Gas Resources.....41 Countries....

June 2013

<http://www.eia.gov/analysis/studies/worldshalegas/>

EPA's hydraulic fracturing study website

<http://www2.epa.gov/hfstudy>

Energy in Depth (website)

RE: international news

<http://energyindepth.org/>

API/hydraulic fracturing

<http://www.api.org/policy-and-issues/hf?page=2>

recommended/best practices; API HF1, 2 and 3

International Energy Agency's Golden Rules for a Golden Age of Gas

<http://www.iea.org/publications/freepublications/publication/name,27408,en.html>

Resources for the Future

The State of State Shale Gas Regulation

http://www.rff.org/RFF/Documents/RFF-Rpt-StateofStateRegs_Report.pdf

Induced Seismicity Potential in Energy Technologies (pre-publication)

NRC/NAS

http://www.nap.edu/openbook.php?record_id=13355