

# Natural Gas Resources of the Marcellus Shale

**Conservation and Natural Resources  
Advisory Council**, Pennsylvania Department of  
Conservation and Natural Resources

**Citizens Advisory Council**, Pennsylvania  
Department of Environmental Protection

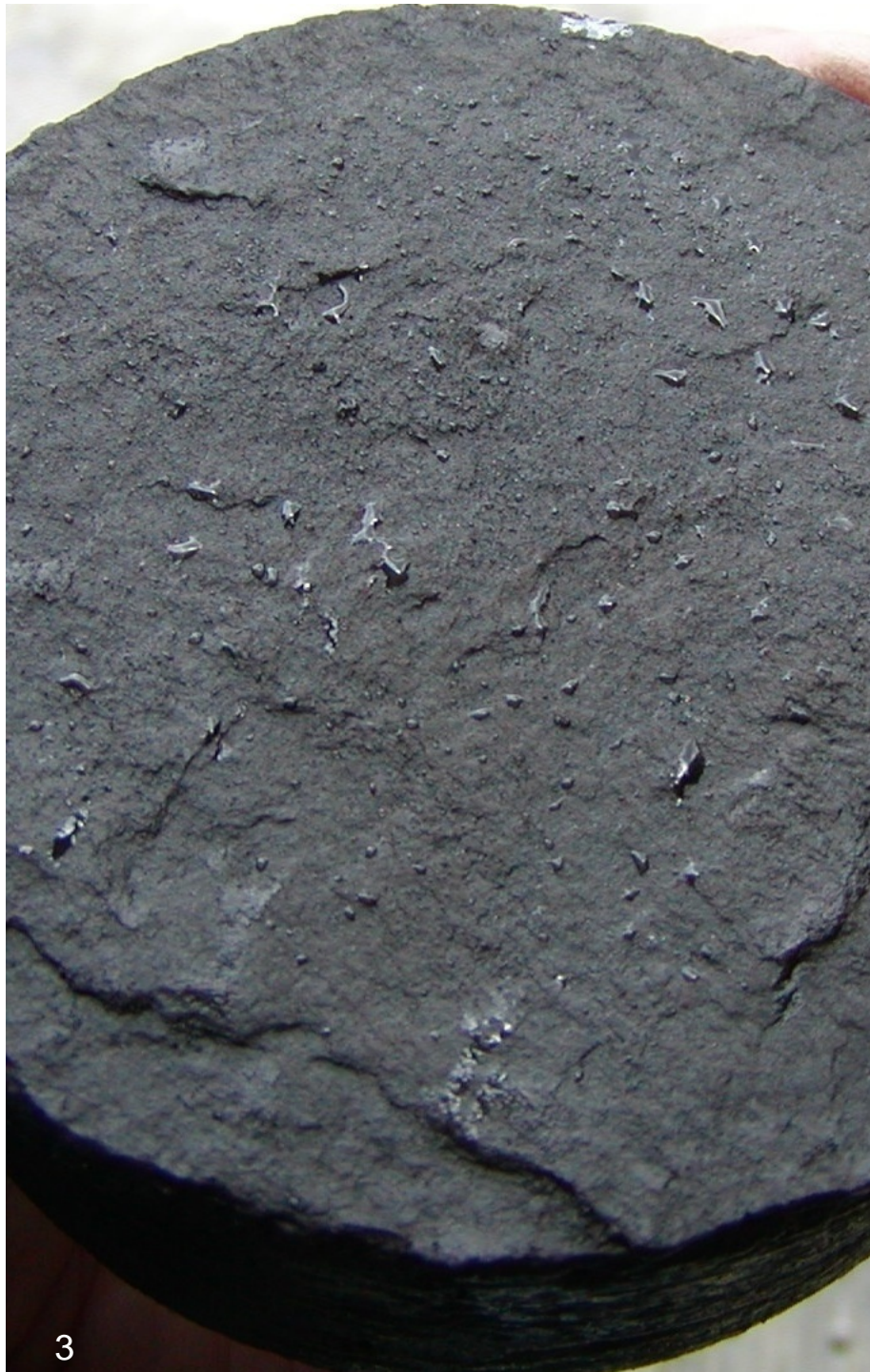
July 28, 2010



# Range Resources

- Natural gas production company
- Included in S&P 500
- Committed to Pennsylvania
- Regional Headquarters in Washington County
- Pioneered Marcellus Shale, 2004
- Over \$1 Billion invested in Keystone State
- Employs more than 300 Pennsylvanians, support over 1,200 contractor jobs and many more indirect and induced jobs





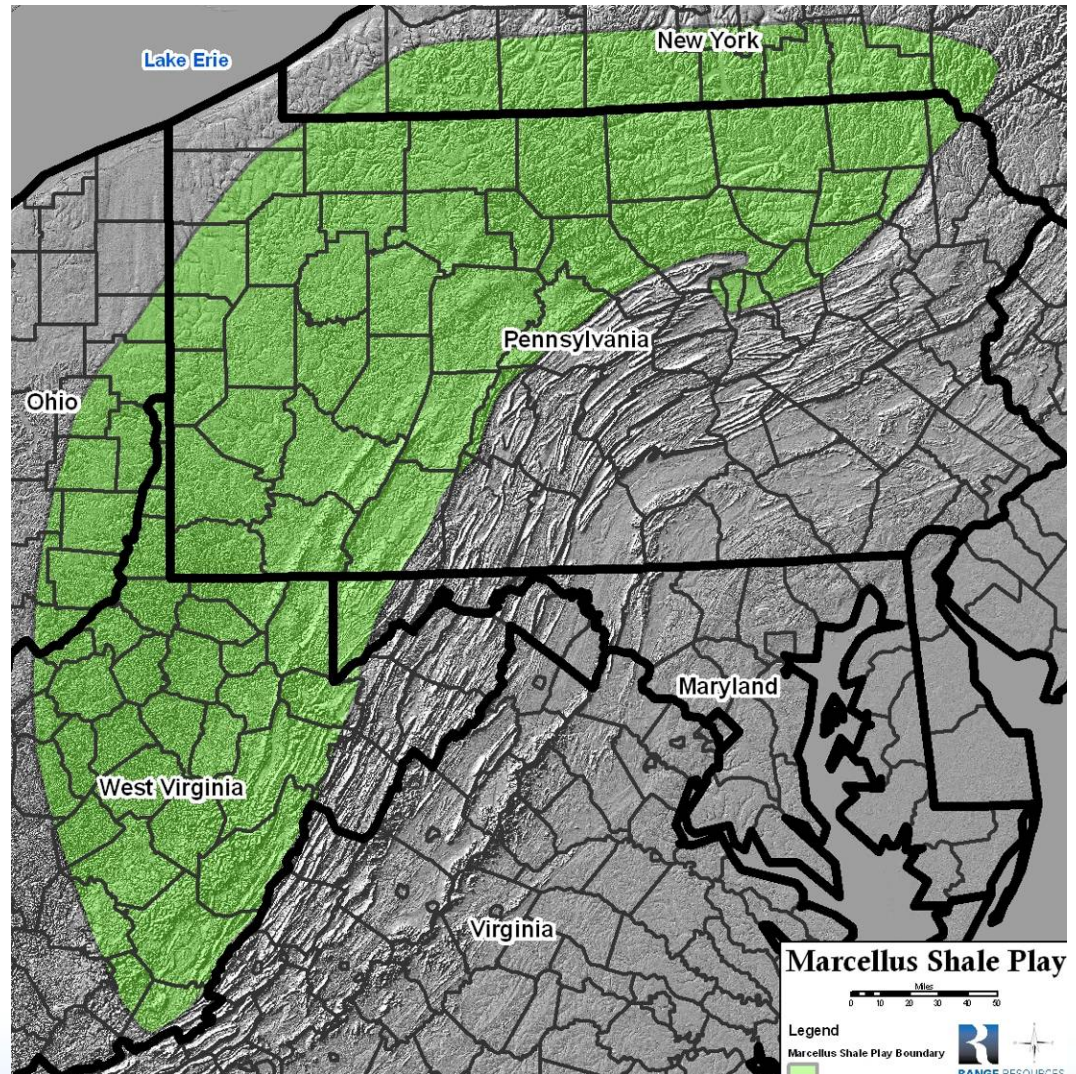
## What is the Marcellus Shale?

- organic-rich, shale
- 5,000 – 9,000 foot depth
- Mud that settled on ocean floor 380 million years ago; turned to rock
- Natural gas and hydrocarbons are trapped in tiny micropores between grains of mud
- Extremely low permeability

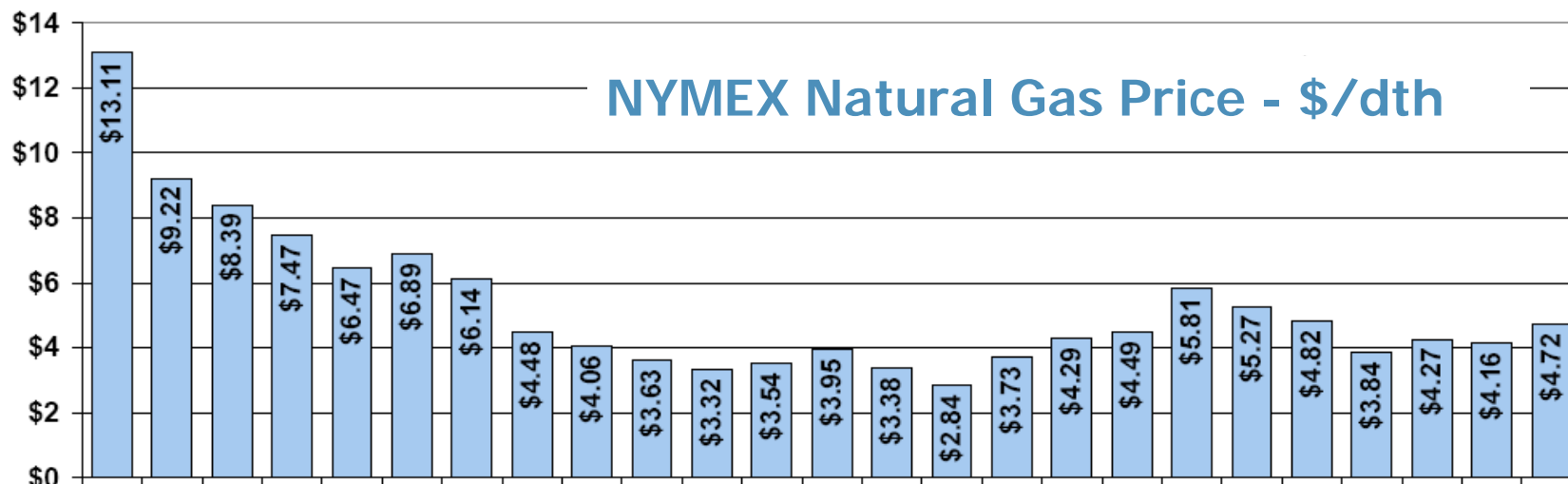
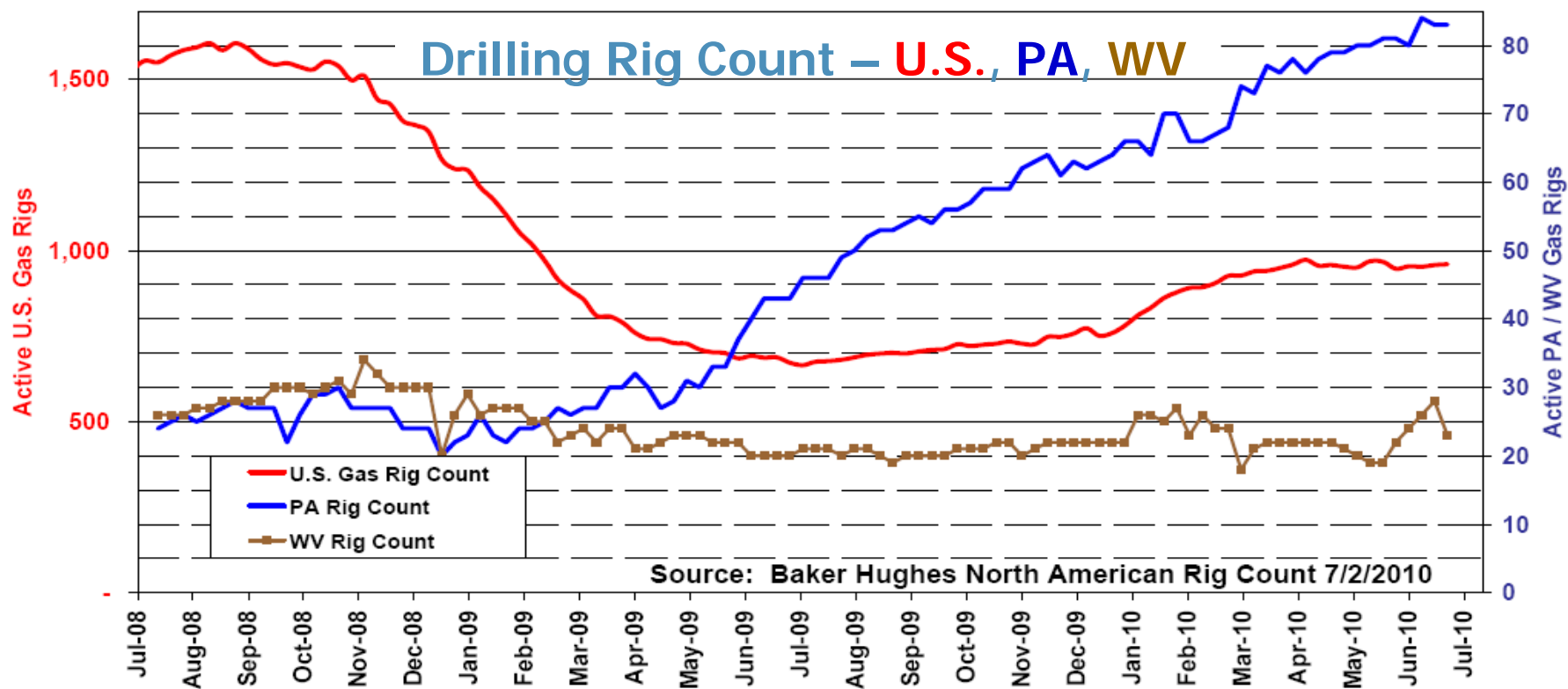


# Marcellus Shale is big

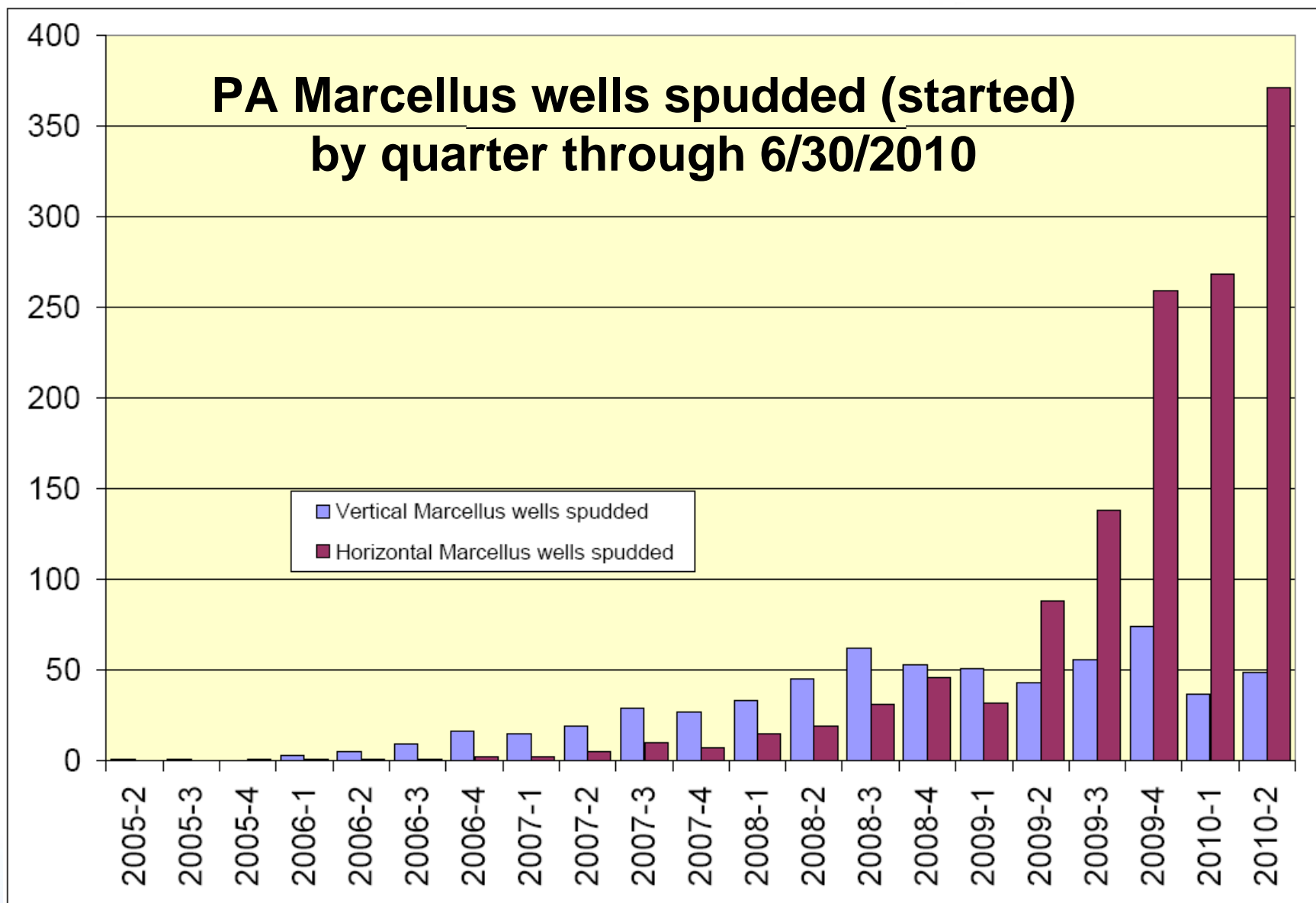
- Marcellus fairway is 40,000 – 50,000 square miles
- Estimates of recoverable reserves up to 500 tcf; current U.S. natural gas demand is 23 tcf per year
- Could be the 2<sup>nd</sup> largest gas field in the world







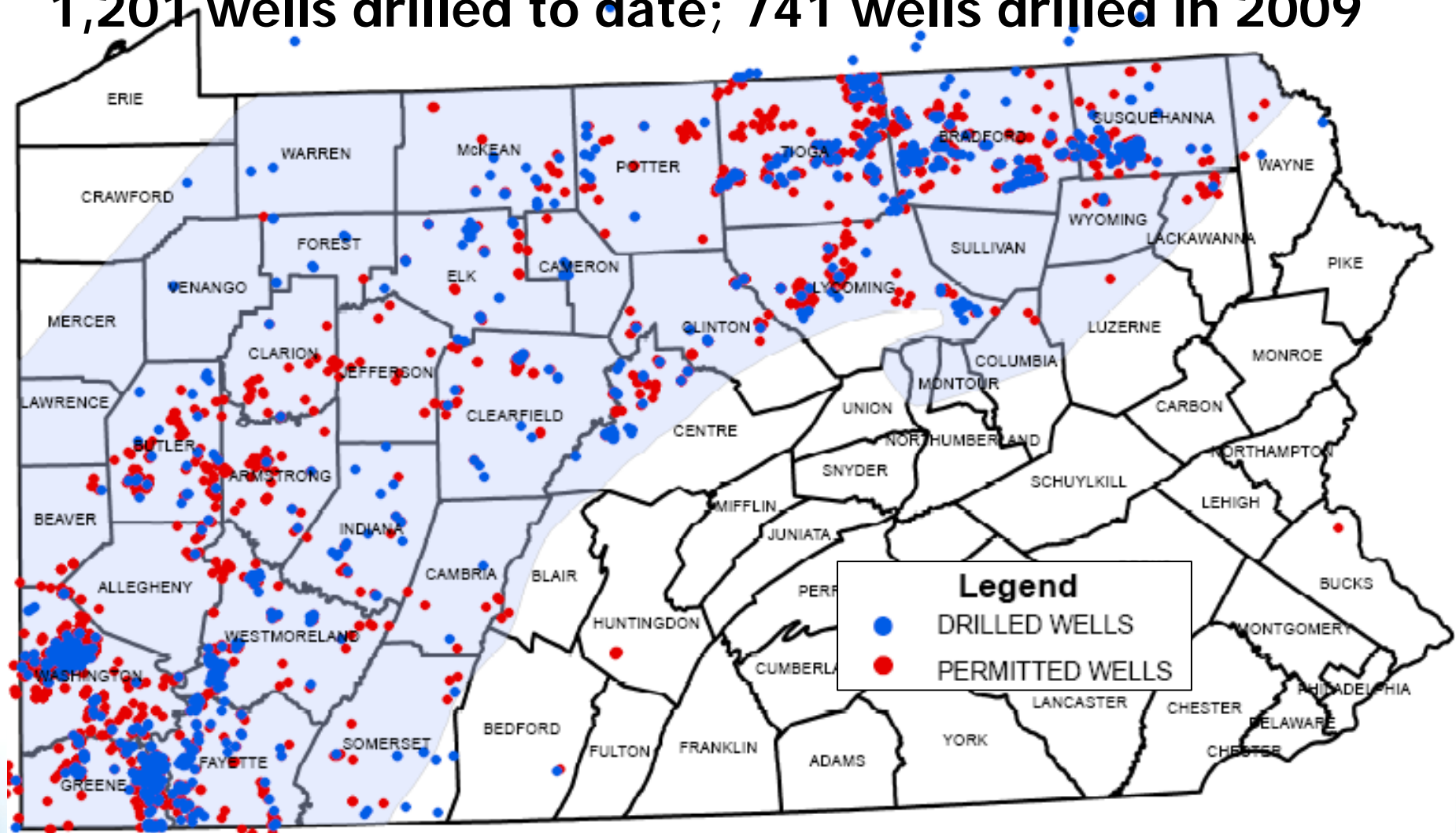
## PA Marcellus wells spudded (started) by quarter through 6/30/2010





# Marcellus Drilling Activity - 12/31/2009

1,201 wells drilled to date; 741 wells drilled in 2009



# Economic Impact Study by economists and industry experts at Penn State University May, 2010

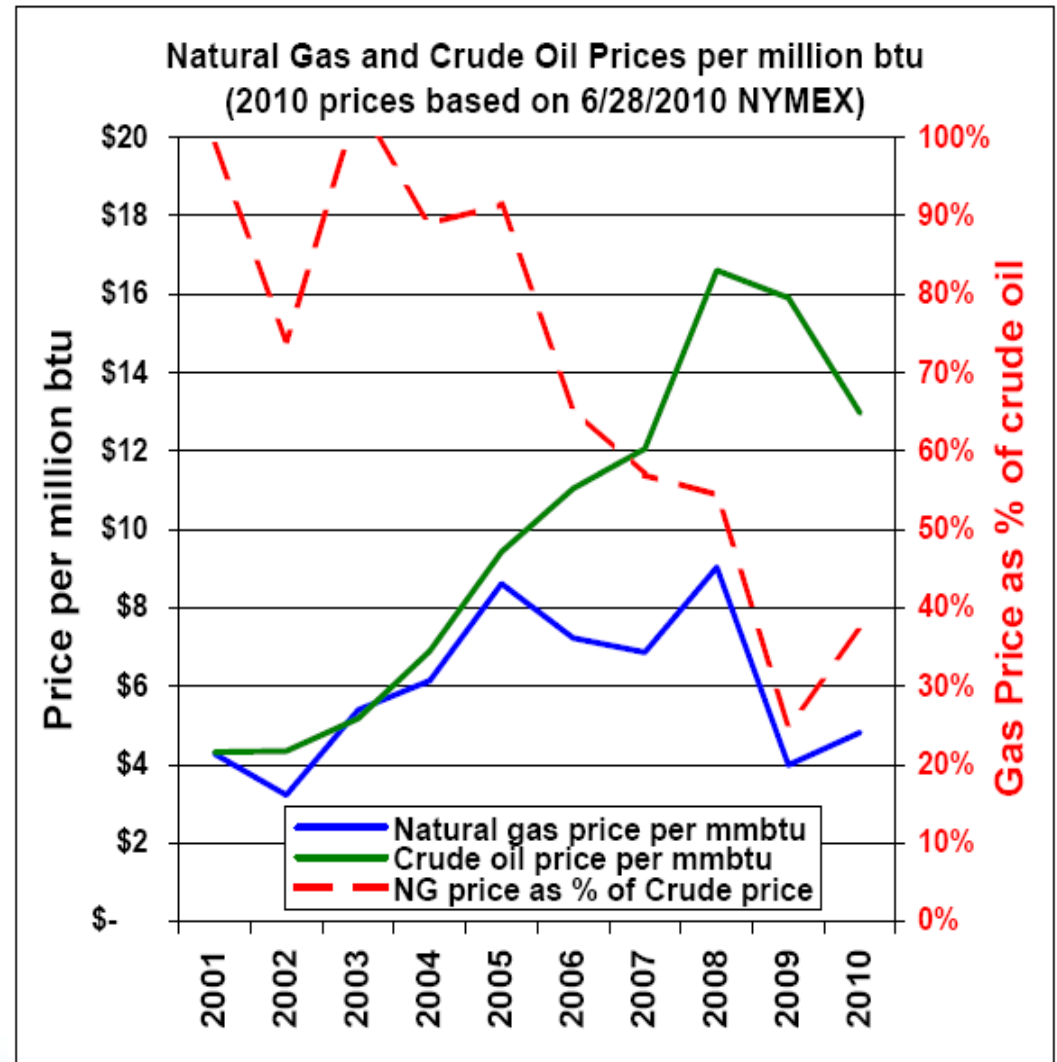


	2009	2010	2011	2015	2020
Jobs created - thousands	44	89	111	160	212
Expenditures (leasing, drilling, pipelines) - \$billions	4,535	8,774	11,011		
Value added - \$millions	3,877	8,039	10,129	14,415	18,853
State & Local taxes - \$millions	389	785	987	1,417	1,872
Production rate - bcf/d	0.30	1.00	2.50	7.60	13.50
Gas price/mcf		\$ 5.42	\$ 5.53	\$ 5.98	\$ 6.61
Wells drilled	680	1,700	2,200	2,875	3,500
Lease bonus & royalty - \$millions	\$ 1,784	\$ 1,854	\$ 2,211		



# Economic Benefits

- Discovery of 100+ years of gas supply from U.S. gas shales since 2005 has caused a divergence of oil and natural gas markets since 2005
- Natural gas prices were \$12/mmbtu lower than oil in 2009 and projected to be more than \$8/mmbtu lower in 2010
- **PA natural gas consumers will save over \$6 billion in 2010**; U.S. will save nearly \$200 billion
- Natural gas is a bargain



# Expanded uses for natural gas



Compressed natural gas  
for vehicle fuel

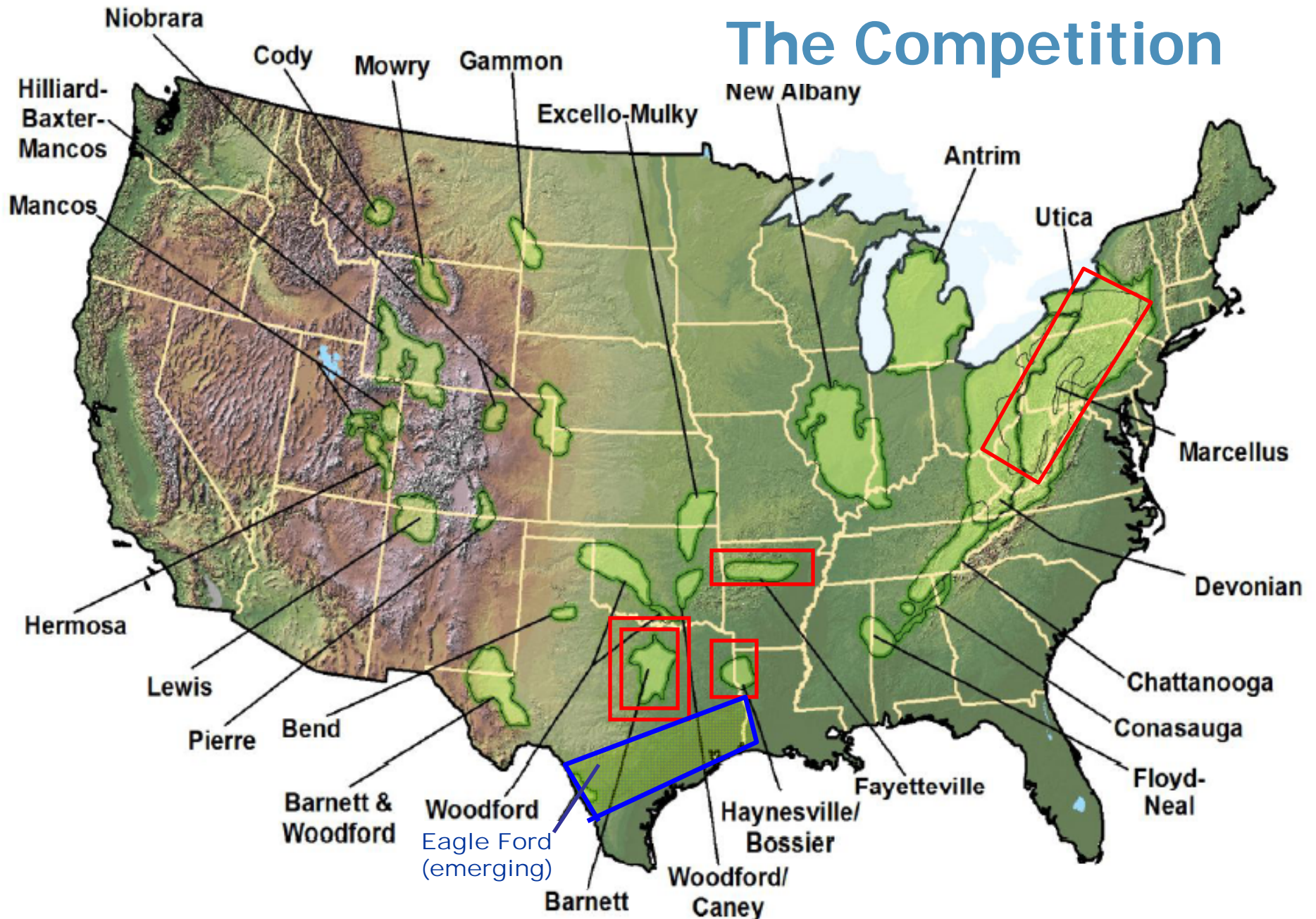


Gas-fired electric  
generation

- Advantages
  - o 50% less CO<sub>2</sub> than coal; 30% less than oil
  - o 80% less nitrogen oxides
  - o Almost no sulfur or particulates
  - o One third the cost of crude oil or gasoline
  - o Reduced dependence on oil imports



# The Competition



U.S. Department of Energy, U.S. Shale Basins

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# Policy Issues

- Taxation – Any discussion of an extraction tax should include a holistic discussion of:
  - A tax model that does not put investment in Pennsylvania's Marcellus Shale at a competitive disadvantage to other **shale** producing states
  - Modernizing PA's statutory and regulatory framework for natural gas development to improve the investment climate, provide predictable rules and protect the environment
- Regulation
  - We support good, science-based regulation
  - We believe that DEP has done a good job regulating the rapid increase in drilling activity and will continue to tailor their regulatory program to protect Pennsylvania's citizens and its natural resources
  - We oppose emotional, politically driven regulation that ignores basic science



# Marcellus Shale development is safe and well regulated



**Preparation**



**Drilling**



**Completion  
& Production**



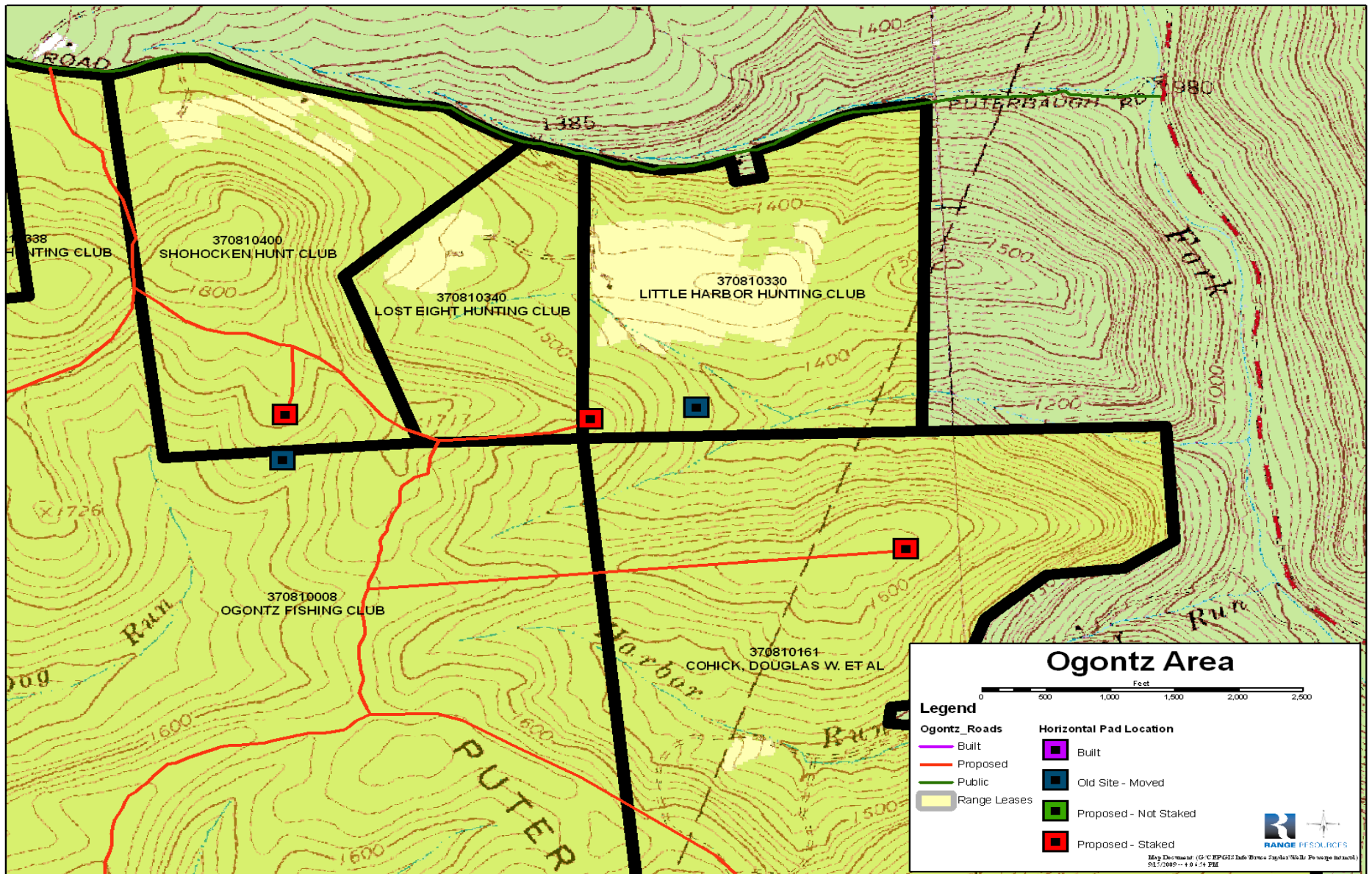
**Reclamation**



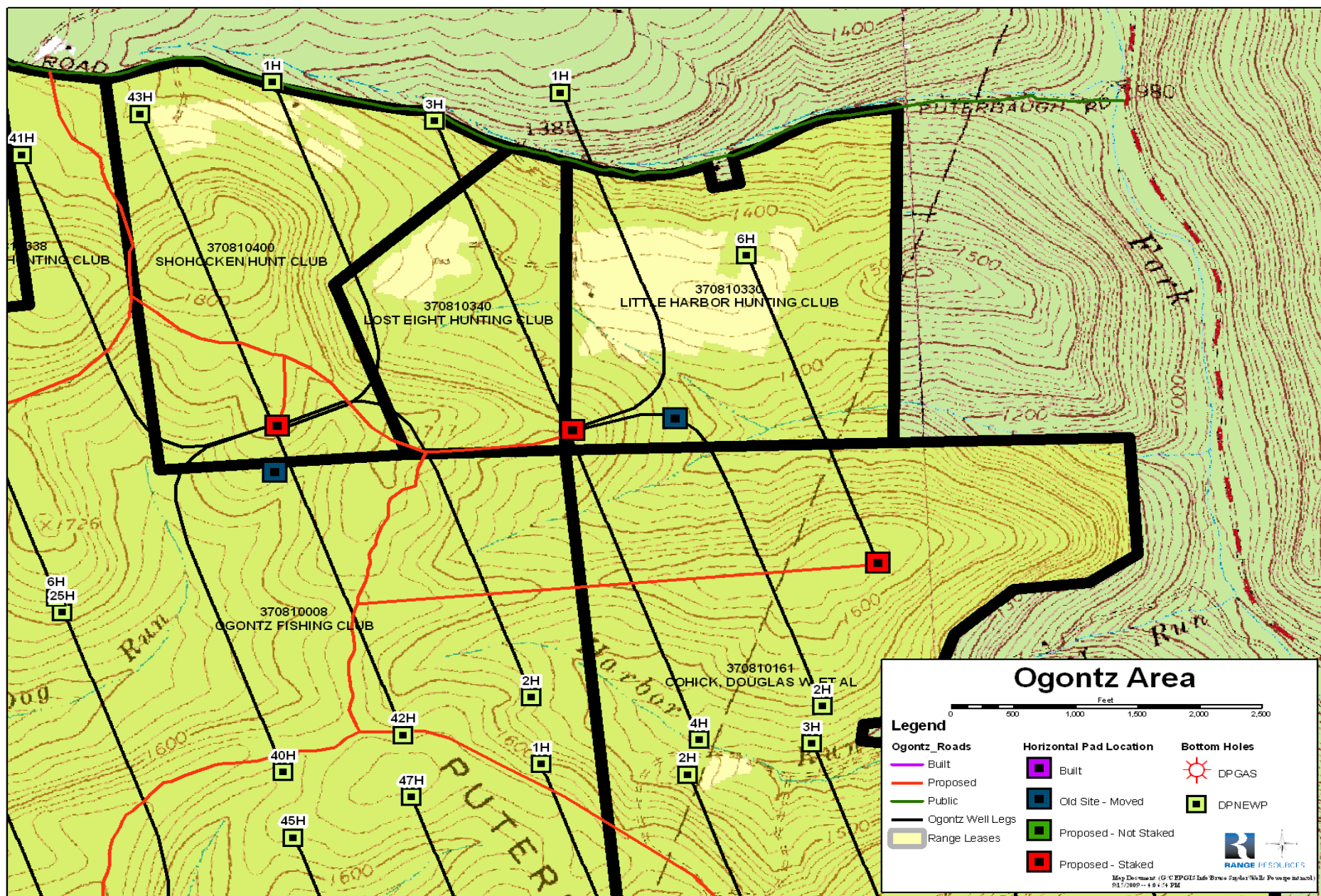
# Staking Wells







## Planning well locations



## Planning well locations



## Site Preparation

- Engineered site design
- ESCGP-1 Permits required
- E&S controls prevent sediment contamination of streams from runoff







**PNDI**

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## Pad with Limestone





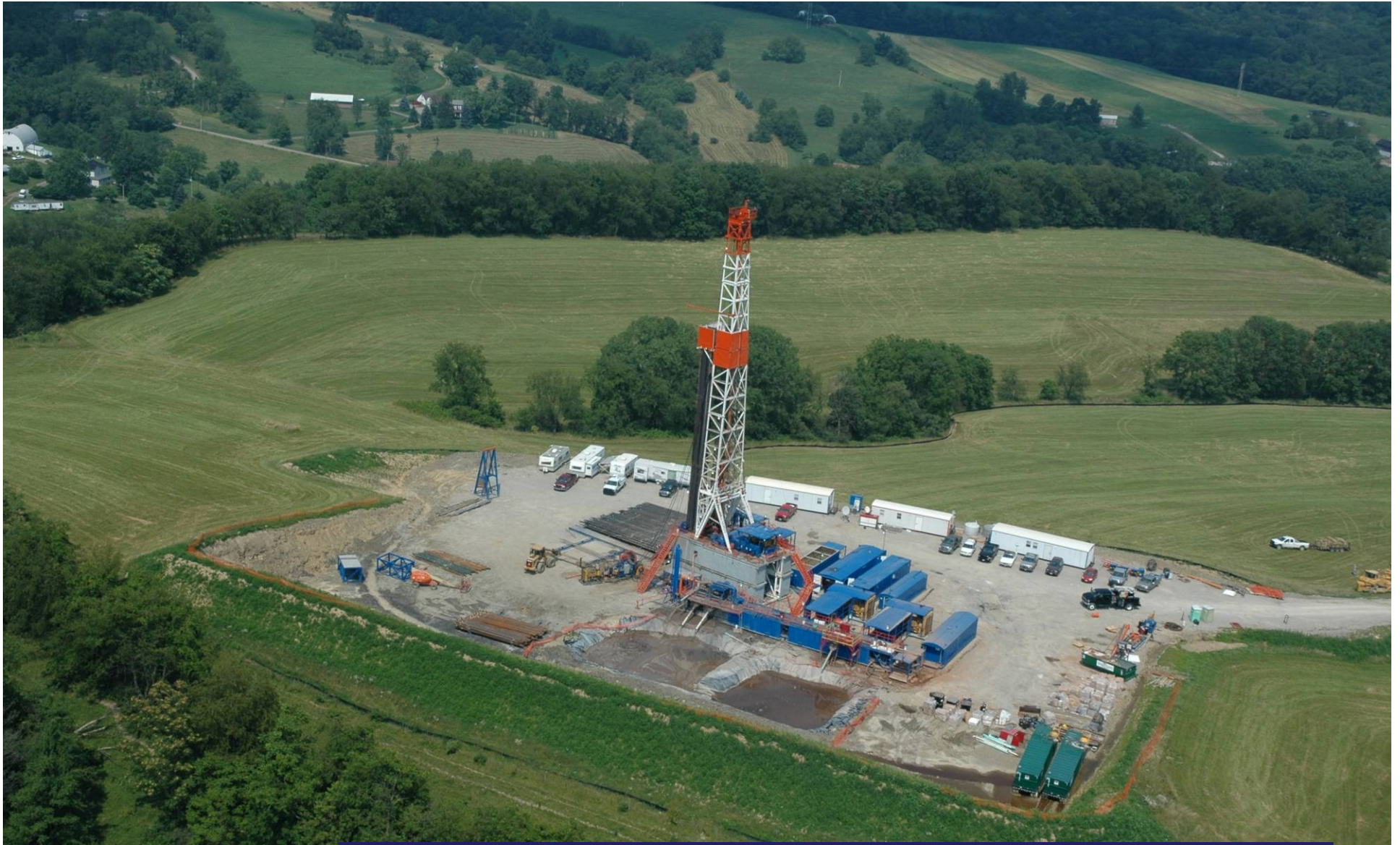
## Gates to limit access





## Stabilized road





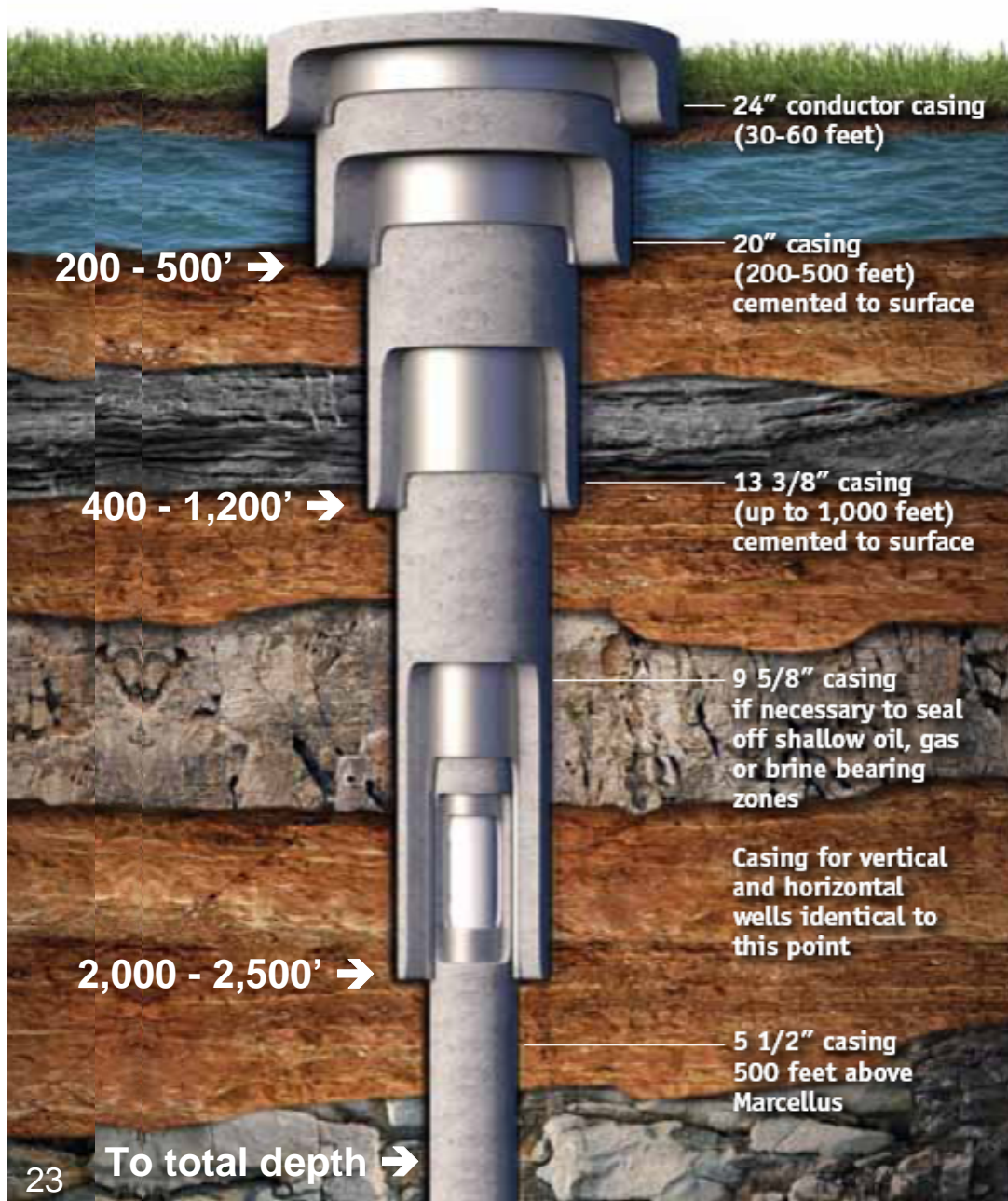
## Drilling

- Access road and drilling pad are stabilized with crushed rock
- Slopes are stabilized with vegetation and appropriate erosion and sedimentation controls



### General Casing Design for a Marcellus Shale Well

The Marcellus Shale is more than a mile below the Earth's surface.  
It would take 17 Statues of Liberty on top of one another to reach the formation.



## Ground Water Protection

- Fresh water is generally less than 500-foot depth; below that, water is salty
- Each casing string is cemented by pumping cement down pipe and circulating back up between the outside of pipe and the wellbore
- More than a **million pounds** of steel casing in each well

# Ground Water Protection

- PA casing and cementing regulations among toughest in the U.S. DEP has recently proposed Chapter 78 revisions to specifically address shale drilling.
- 1,000' rebuttable presumption rule
- DEP aggressively investigates all claims
- DEP issued only 80 orders to repair or replace water supplies impacted by drilling in past 15 years; 32,000 oil and gas wells drilled; 0.25% incident rate; all impacted water supplies replaced by drillers (6/1/2009). Impacts all related to:
  - Physical drilling through aquifers
  - Improper design or installation of surface or intermediate casing
  - Operator negligence
- By comparison, Penn State 2009 study indicates over 40% of PA's 1.2 million private water wells and springs do not meet safe drinking water standards; common causes of contamination are on lot septic systems, agricultural practices, poor well construction



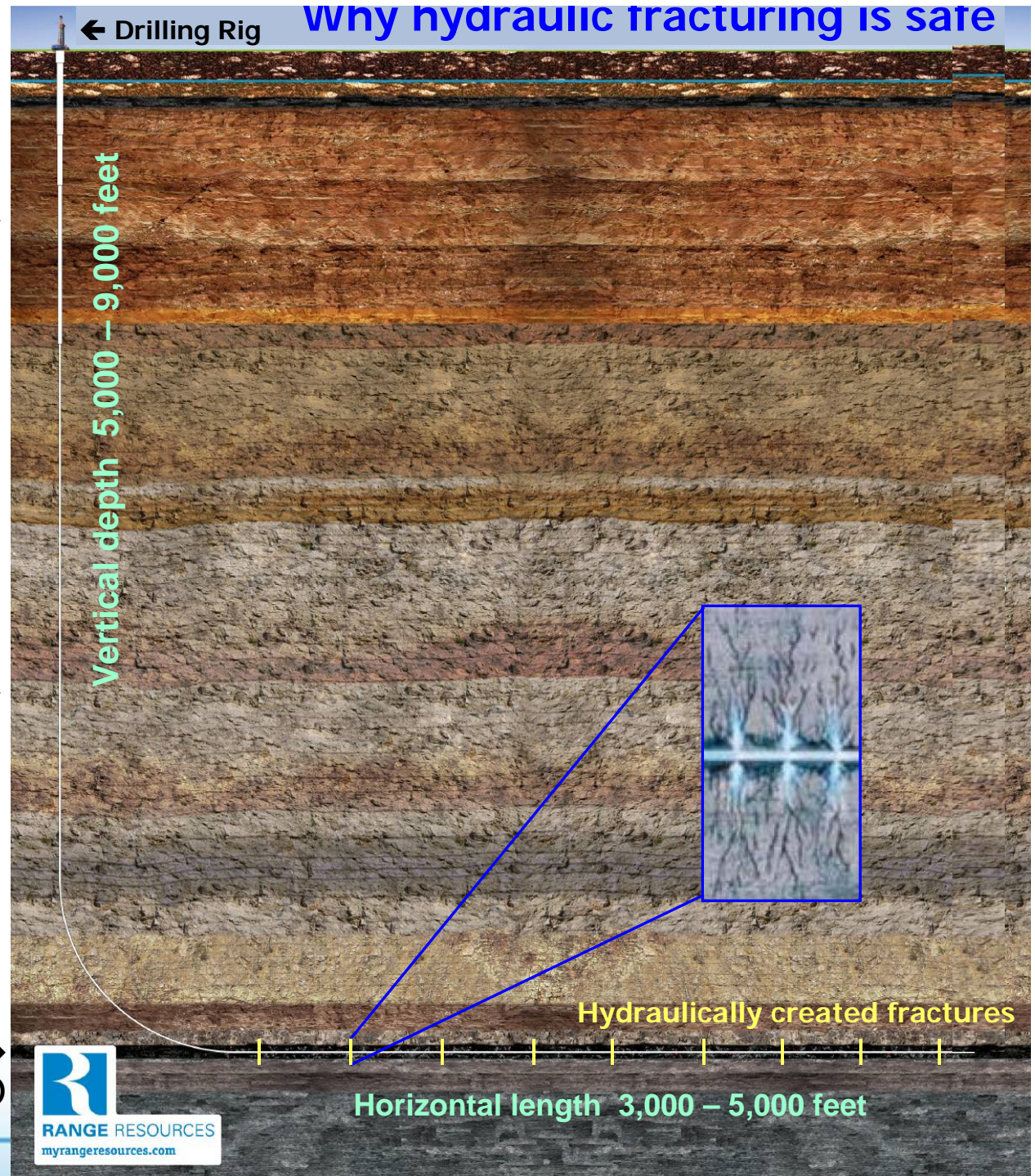
Fresh water aquifers - generally less than 500 foot depth →

The same several thousand of feet of impermeable rock that have kept oil and gas in deeper rocks for hundreds of millions of years –

also prevent fracturing fluids from contacting fresh ground water aquifers

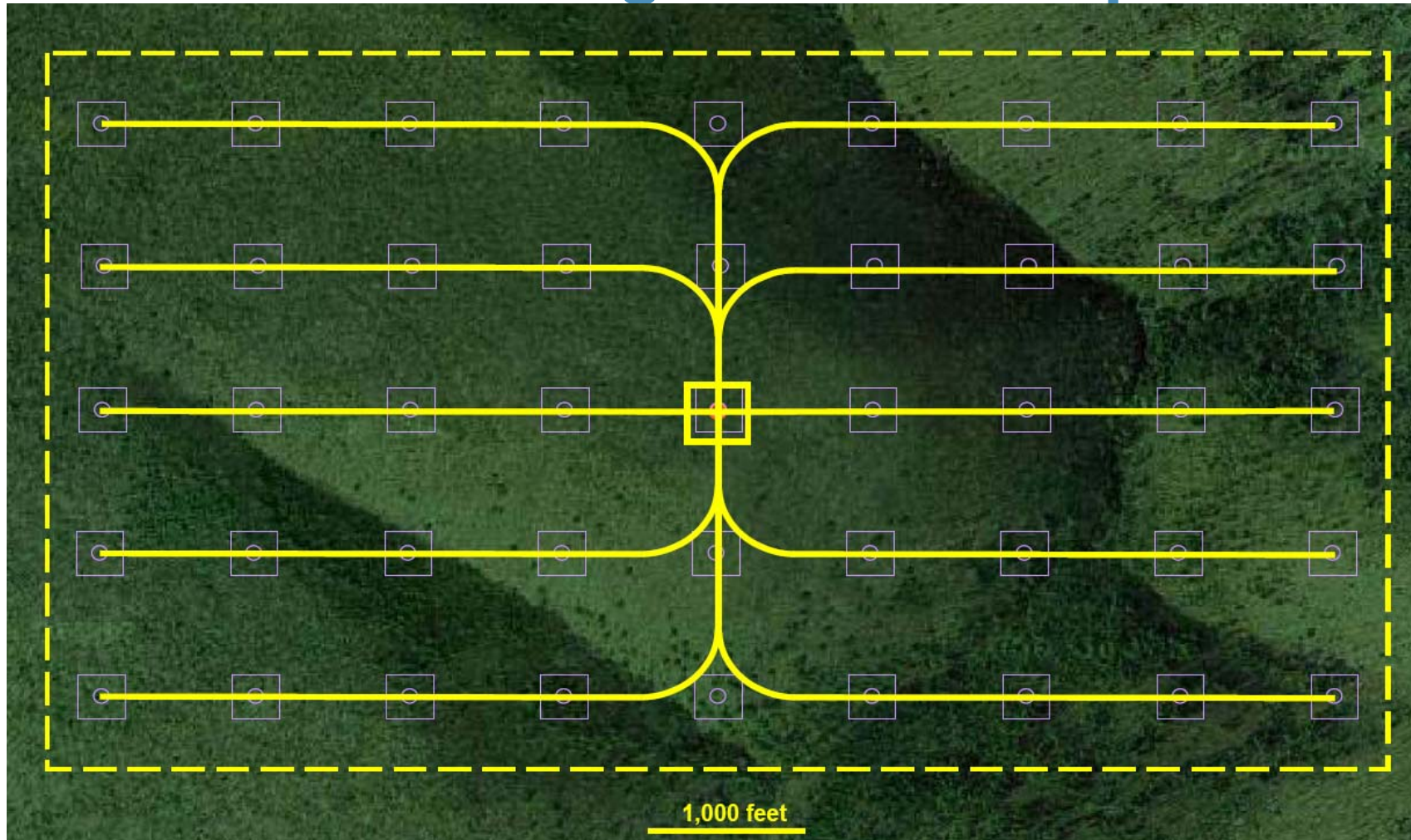
Traditional shallow production 1,500 – 4,500 foot depth

Marcellus Shale →  
(100 – 300 feet thick)





# Horizontal Drilling – small footprint



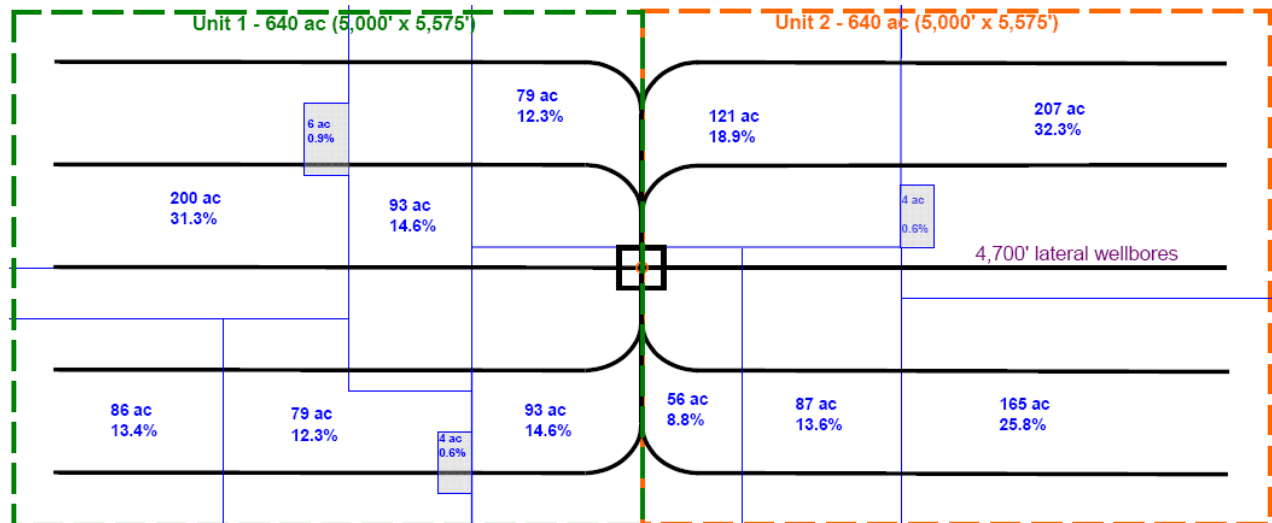
**Total surface disturbance during drilling, including access road, drilling pad and required pipeline infrastructure:**

- Horizontal (yellow) develop 1,000 acres per pad with 1% surface disturbance
- Vertical (purple) on 1,000-foot spacing develop 23 acres per well with 19% total surface disturbance

# Why we need fair pooling

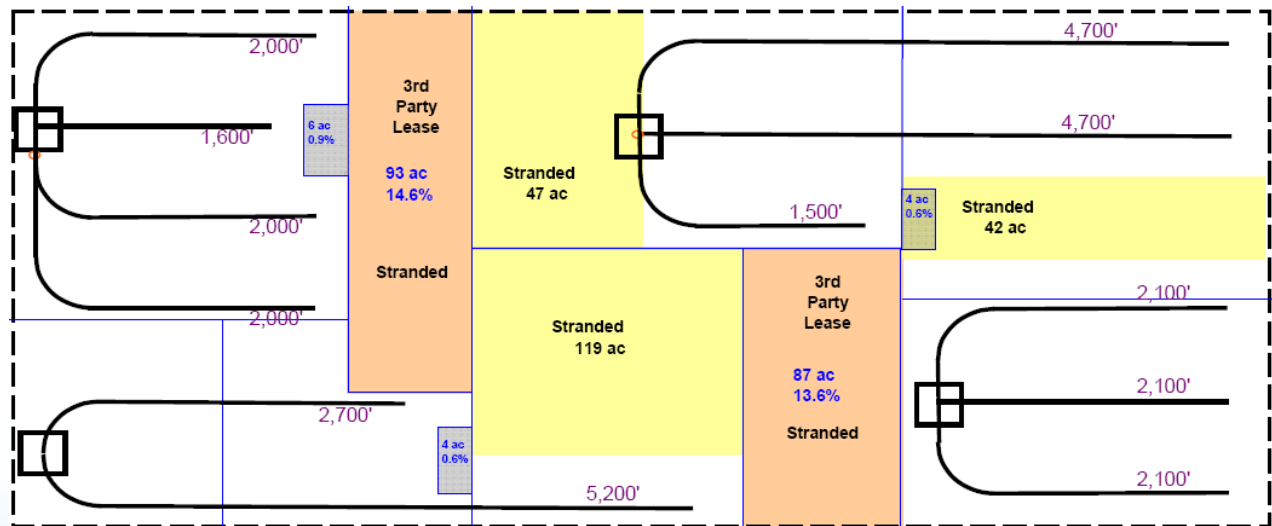
## We need this ==>

- 1280 acres developed from single pad – two 640 ac units
- Temporary disturbance 10 ac
- Orderly development
- Maximum recovery
- Landowners get fair share



## Not this ==>

- 3 small tracts (1.1%) unleased
- 2 tracts (14%) leased to 3<sup>rd</sup> party
- 4 well pads required – 40 ac disturbed
- Short, inefficient laterals
- Only 69% resource recovery
- Willing landowners totaling 30% stranded forever







## Fracing

# Water Requirements for Marcellus

- Fracing a typical horizontal well requires 3-5 million gallons
- Is that a lot of water?
  - 4 million gallons is 1.8 inches of water over an area of 80 acres, the approximate drainage area of a well
  - PA receives about 40 inches of rainfall per year
  - If the productive area of the Marcellus takes 50 years to drill, annual water use over the productive area would be 0.04 inches of water per year or 1/10<sup>th</sup> of 1% of annual rainfall



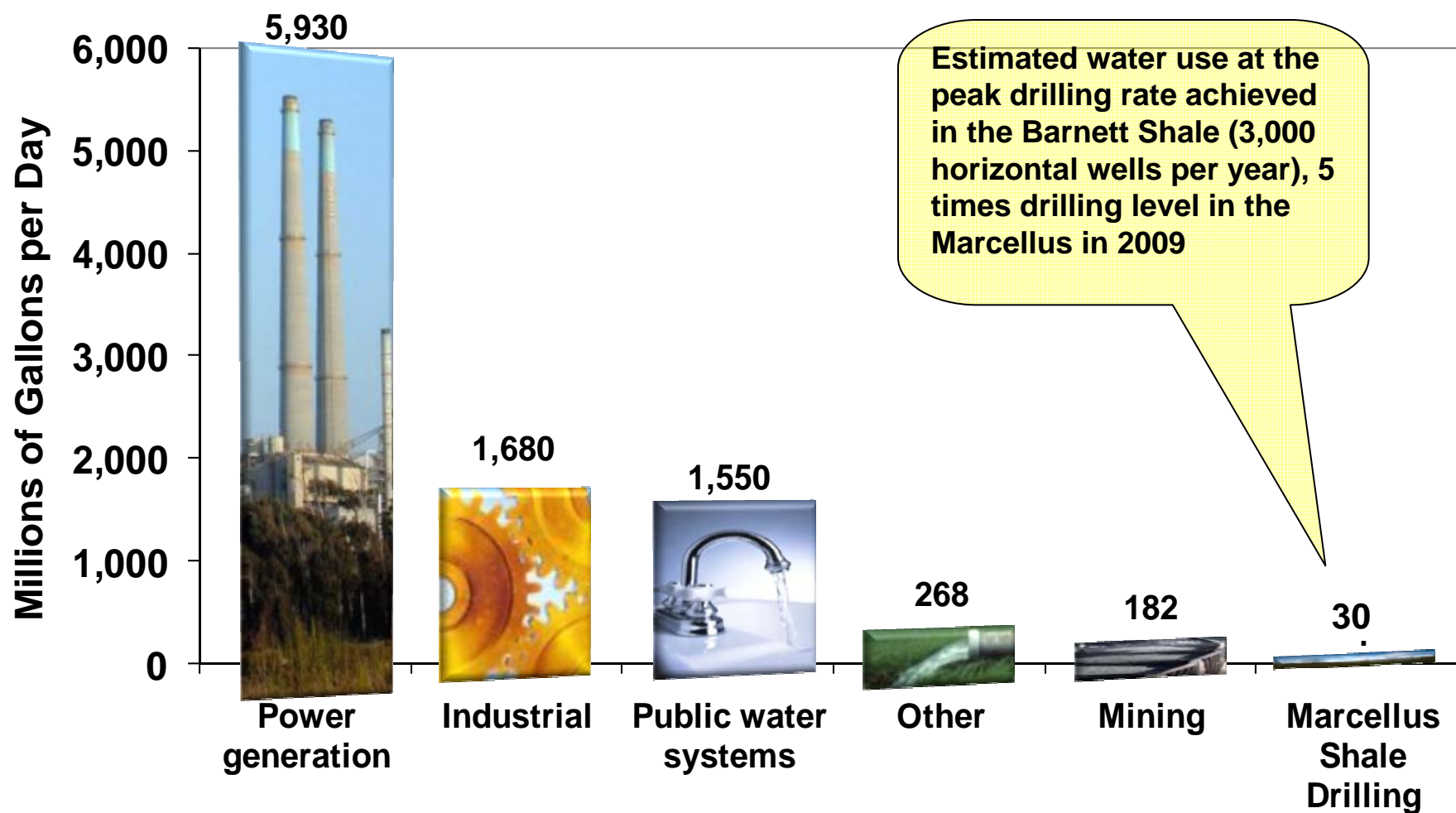
# Water Requirements for Marcellus

## Water use per million btu of energy:

•Deep shale natural gas	0.60-5.80 gallons
• <b>Marcellus Shale gas – avg</b>	<b>1 gallon</b>
•Nuclear (uranium ready to use in a power plant)	8-14 gallons
•Conventional oil	8-20 gallons
•Synfuel-coal gasification	11-26 gallons
•Coal (delivered power plant)	13-32 gallons
•Oil shale	22-56 gallons
•Tar sands/oil sands	27-68 gallons
•Fuel ethanol from corn	2,510-29,100 gallons (irrigation)
•Biodiesel from soy	14,000-75,000 gallons (irrigation)

**Shale gas production uses less water than any other significant energy source**

## How Our Water Usage Stacks Up



Source: USGS, Pennsylvania Water Consumption



# Water supply sources

- Larger streams and rivers
  - Pennsylvania has abundant water supplies
  - Water can be safely withdrawn at reasonable rates during all but the very driest periods
  - Susquehanna and Delaware River Basin Commissions have regulated water withdrawal for many years; no such regulation presently exists in the Ohio River basin
  - Industry and DEP have agreed to adopt SRBC rules; DEP is approving all water management plans
  - Protection of downstream uses
- Municipal water supplies
- Acid mine drainage – suitable for use with proper treatment



## **Water Impoundments**

- Engineered design
- DEP construction standards
- ESCGP-1 Permits required
- Enhanced permit requirements with leak detection or groundwater monitoring if used to contain flow back water





## Water management





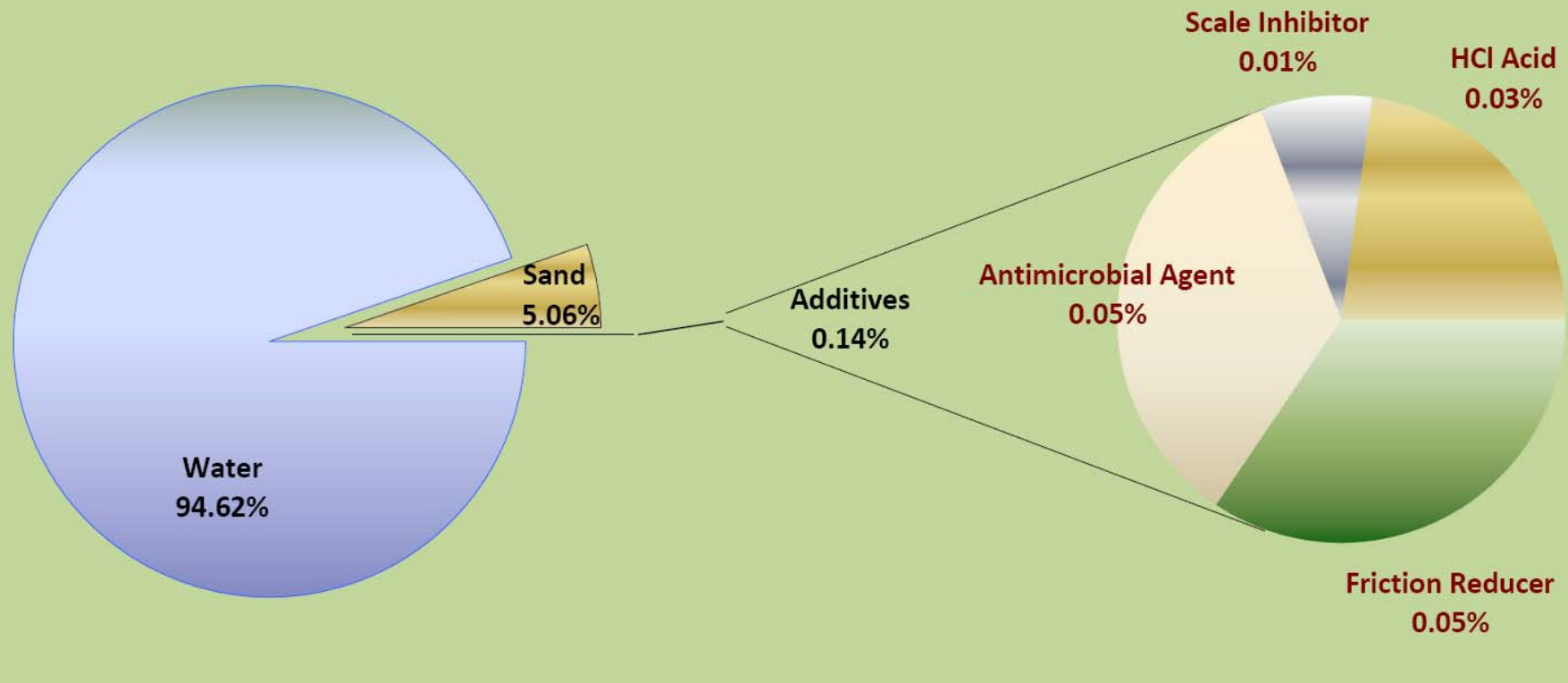
## **Water Transfer**

- Saves thousands of trucks on highways
- Can pump water several miles from impoundment to well during fracturing operation
- Aluminum irrigation pipe for fresh water
- HD Polyethylene or PVC for pumping recycled water



# What goes into the well?

## Composition of Hydraulic Fracture Fluid (by volume)



Chemical additives are safely handled and mixed to very dilute concentrations. MSDS sheets required by US DOT and OSHA list all chemicals that are physical or human hazards in concentrated form. These make up less than 3/100ths of 1% of frac fluid.

# Typical additives used in frac water

Additive type	Main ingredients	Purpose	Common use
Friction reducer	Polyacrylamide (non-hazardous)	Reduces friction between fluid and pipe	Cosmetics; soil conditioner; some children's toys
Anti-Microbial Agent	Glutaraldehyde	Eliminates bacteria in the water that produce corrosive byproducts	Disinfectant; sterilize medical and dental equipment and surfaces
Scale inhibitor	Ethylene glycol	Prevents scale deposit in the pipe	Automotive anti-freeze, household cleaners, de-icing agent
Diluted Acid	7.5% Hydrochloric Acid	Help dissolve cement and minerals and help initiate fractures	Swimming pool chemical and cleaner



1,2,4 Trimethylbenzene	Glycol Ethers (includes 2BE)
1,3,5 Trimethylbenzene	Guar gum
2,2-Dibromo-3-Nitrilopropionamide	Hemicellulase Enzyme
2,2-Dibromo-3-Nitrilopropionamide	Hydrochloric Acid
2-butoxyethanol	Hydrotreated light distillate
2-Ethylhexanol	Hydrotreated Light Distilled
2-methyl-4-isothiazolin-3-one	Iron Oxide
5-chloro-2-methyl-4-isothiazotin-3-one	Isopropanol
Acetic Acid	Isopropyl Alcohol
Acetic Anhydride	Kerosine
Acie Pensurf	Magnesium Nitrate
Alcohol Ethoxylated	Mesh Sand (Crystalline Silica)
Alphatic Acid	Methanol
Alphatic Alcohol Polyglycol Ether	Mineral Spirits
Aluminum Oxide	Monoethanolamine
Ammonia Bifluoride	Naphthalene
Ammonia Bisulfite	Nitilotriacetamide
Ammonium chloride	Oil Mist
Ammonium Salt	Petroleum Distillate Blend
Ammonia Persulfate	Petroleum Distillates
Aromatic Hydrocarbon	Petroleum Naphtha
Aromatic Ketones	Polyethoxylated Alkanol (1)
Boric Acid	Polyethoxylated Alkanol (2)
Boric Oxide	Polyethylene Glycol Mixture
Butan-1-01	Polysaccharide
Citric Acid	Potassium Carbonate
Crystalline Silica: Cristobalite	Potassium Chloride
Crystalline Silica: Quartz	Potassium Hydroxide
Dazomet	Prop-2-yn-1-01
Diatomaceus Earth	Propan-2-01
Diesel (use discontinued)	Propargyl Alcohol
Diethylbenzene	Propylene
Doclecybenzene Sulfonic Acid	Sodium Ash
E B Butyl Cellosolve	Sodium Bicarbonate
Ethane-1,2-diol	Sodium Chloride
Ethoxlated Alcohol	Sodium Hydroxide
Ethoxylated Alcohol	Sucrose
Ethoxylated Octylphenol	Tetramethylammonium Chloride
Ethylbenzene	Titanium Oxide
Ethylene Glycol	Toluene
Ethylhexanol	Xylene
Ferrous Sulfate Heptahydrate	
Formaldehyde	
Glutaraldehyde	

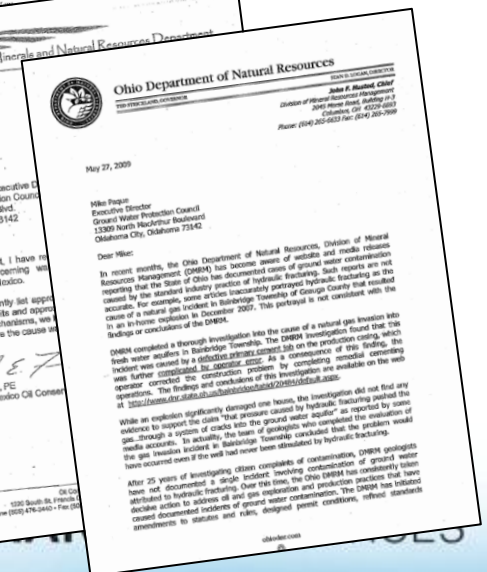
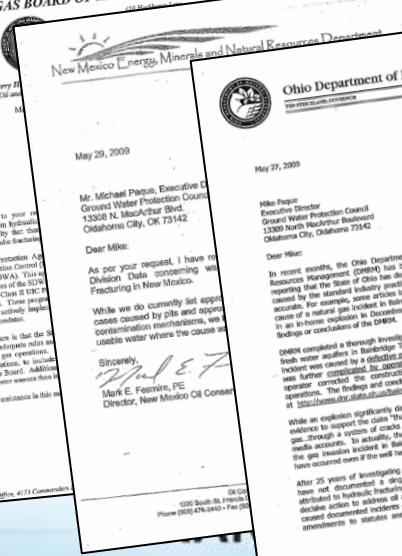
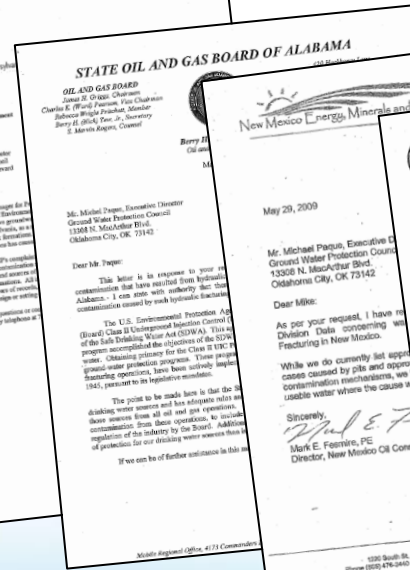
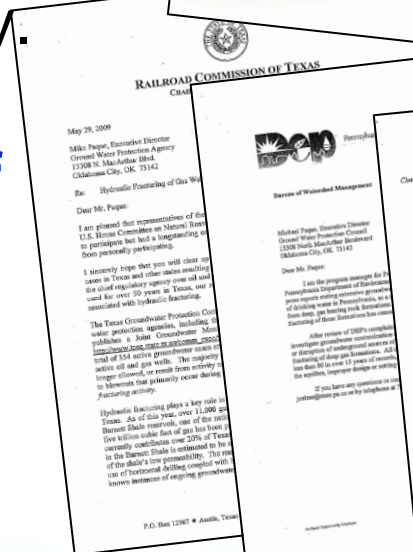
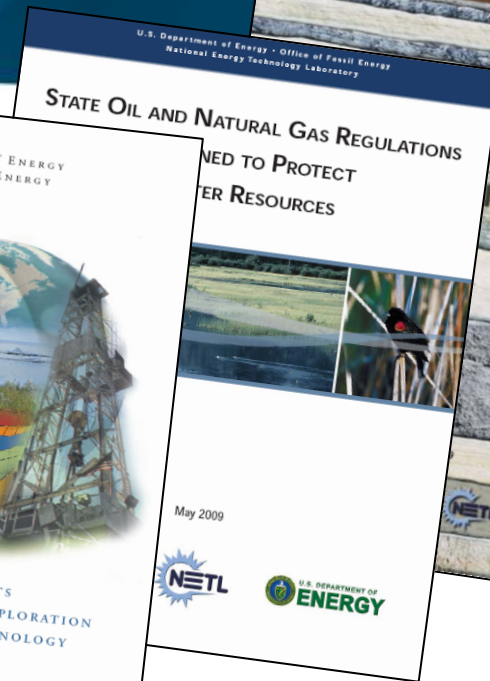
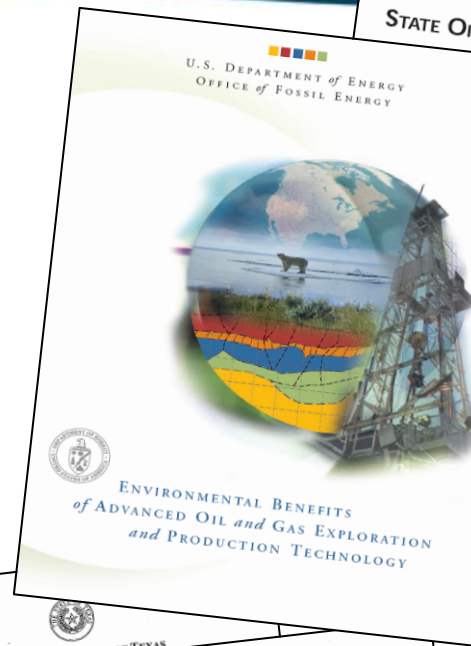
## All frac fluid additives disclosed on DEP website

[www.dep.state.pa.us/dep/deputate/minres/oilgas/new\\_form\\_s/marcellus/Reports/Frac%20list%206-30-2010.pdf](http://www.dep.state.pa.us/dep/deputate/minres/oilgas/new_form_s/marcellus/Reports/Frac%20list%206-30-2010.pdf)

# Safe and Proven

More than 30 state and federal regulatory agencies have extensively studied hydraulic fracturing technology.

There are zero confirmed cases of groundwater contamination in over one million wells fraced over the last 60 years





# Water Treatment and Disposal

- Water flowed back after frac contains salts and other naturally occurring dissolved solids present in ancient sea water
- Water is gathered and removed from site by either truck or pipeline
- Traditional treatment of natural gas wastewater in PA:
  - Removal of heavy metal constituents, then discharge to large streams or rivers where safely diluted
  - Deep well injection (limited)
- DEP and Industry are aware and prepared for Marcellus waste water



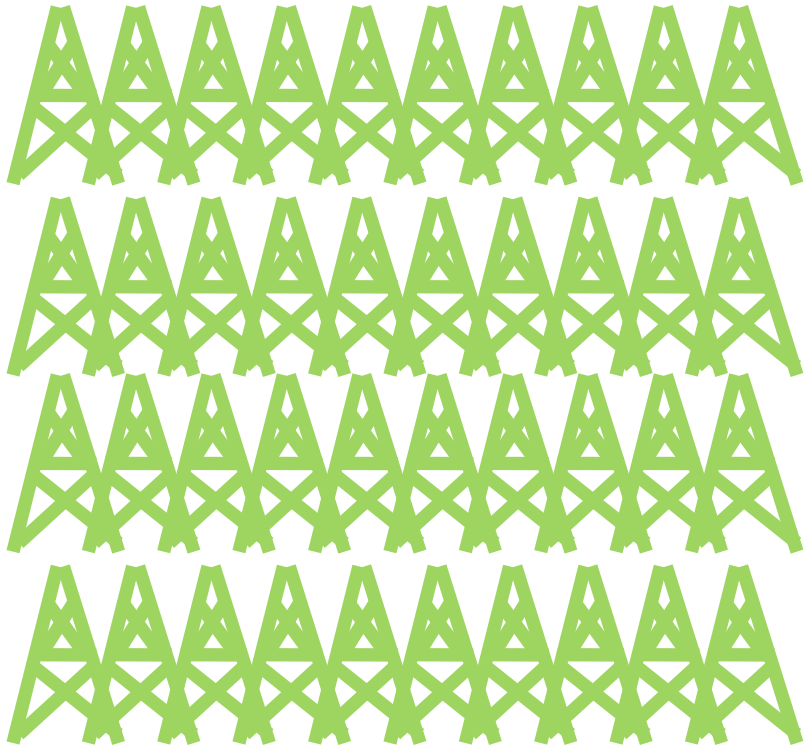
# How much water?

Year	2009	2010	2011	2012	2013	2014	units
Est. % of flowback water recycled	50%	80%	80%	80%	80%	80%	
New wells drilled	561	1,519	1,974	2,253	2,376	2,501	Wells
Fresh water requirement	5.7	14.6	19.0	21.7	22.9	24.1	M gals per day
Fresh water requirement - % of annual rainfall	0.012%	0.032%	0.041%	0.047%	0.050%	0.053%	
Fresh water requirement - % of PA water use	0.059%	0.152%	0.198%	0.226%	0.238%	0.251%	
waste water generated	0.5	0.5	0.6	0.7	0.8	0.8	M gals per day

Assumes drilling levels forecasted by PSU economic impact study (5/2010) and recycling at the percentages indicated above



# How Much Salt?



8 million gallons per day  
of flow back water



salt dumped on only state  
roads annually (750,000 tons)

**With proper management and recycling, estimates of waste water from Marcellus drilling are expected to be less than 2 million gallons per day at peak drilling levels**

# Water Disposal Solution

There won't be a "silver bullet" or single technology, the solution will consist of a portfolio of disposal options, many of which are already being utilized including:

- Traditional disposal methods – limited to existing capacity due to new TDS regulation
- recycling of flow back water – most promising solution
- deep well injection
- zero liquid evaporation, crystallization, and land filling







**Topsoil being spread**





## Seeding and mulching





## Revegetation





**Reclaimed site**

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## **Production**

- Site is reclaimed to a small fraction of its original size during drilling
- Production equipment will remain for life of the well
- Produced fluids will be removed and safely disposed





**Production**





## Well access road





## Reclaimed well location





15 year old well site



# Is there adequate regulation?

## **Act 223 - The Oil & Gas Act of 1984**

- **Primary statute regulating oil and gas drilling activity**
- **Details permitting and operations requirements for the following:**
  - **Well drilling permits**
  - **Well registration and identification**
  - **Inactive status of wells**
  - **Well location restrictions**
  - **Well site restoration**
  - **Site restoration requirements**
  - **Casing and cementing requirements – Protection of fresh groundwater**
  - **Plugging requirements**
  - **Protection of water supplies**
  - **Reporting requirements**
  - **Bonding**
  - **Enforcement and remedies**



## **PA Code 25, Chapter 78**

- Detailed regulations promulgated under Act 223.

## **Act 214 - Coal and Gas Resources Coordination Act of 1984**

- This Act covers governs placement of wells and special regulations in areas containing active coal mines and unmined coal seams.

## **Act 359 - Oil and Gas Conservation Law of 1961**

- Governs spacing of deep wells which penetrate the Onondaga Formation (directly beneath the Marcellus Shale).

## **PA Code 25, Chapter 102**

- Regulations with respect to erosion and sedimentation control for earth disturbance activities.
- Basis for Erosion and Sedimentation Control Manual for oil & gas development (well pads, pipelines, impoundments).
- Requires ESCGP-1 for earth disturbance over 5 acres; applies to all Marcellus wells, pipelines and water impoundments.

## **PA Code 25, Chapter 105**

- **Requires permits for stream and wetland crossings.**
- **Requires permits for stream and wetland encroachments.**
- **Requirements for dam permits for impoundments if the impoundment is to be used for collection/storage of flowback and/or produced water.**
- **Construction Guidelines for the construction of impoundments**

## **Federal Clean Water Act and Pennsylvania Clean Streams Law**

- **These are the laws that allow Pennsylvania to enact the permitting requirements described above associated with Chapter 102 and Chapter 105.**

## **PA Code 25, Chapter 287, Residual Waste**

- **regulates disposal of wastes from drilling or completion operations**
- **regulates transportation of wastes from drilling or completion operations and the record keeping**
- **annual chemical analysis of the waste stream.**



## **Act 220 - Water Resources Planning Act Of 2002**

- Under Act 220, the PADEP has mandated that operators submit a comprehensive Water Management Plan for all Marcellus Shale wells prior to conducting hydro-fracturing operations on wells.

## **Title 40 of the Code of Federal Regulations, Part 112**

- Mandates Oil Pollution Prevention and regulates by requiring Spill Prevention Control and Contingency Plans

## **SRBC - Susquehanna River Basin Commission**

- Interstate Compact Commission that regulates all water usage within the Susquehanna River Basin in PA (and other states).
- Requires reports, plans and procedures to be filed and followed prior to any activity on a wellsite in the SRBC area. Also includes significant fees for water consumptive use.

## **US Army Corp of Engineers**

- ACOE performs a review of the stream/wetland crossing General Permit applications submitted to the PADEP when impacts from the crossings exceed thresholds defined by the ACOE.



# Thank You

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