

# Public Health Implications for Marcellus Shale Development

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# A CALL FOR HELP



WHAT  
IS GOING ON

?

**MORE  
QUESTIONS  
THAN  
ANSWERS!!**

## AN INTERSECTION OF:

- POLITICS – A balance of gains and losses, costs and benefits
- ECONOMICS – Labor, Industry, Capital, Growth, True Cost and Benefit

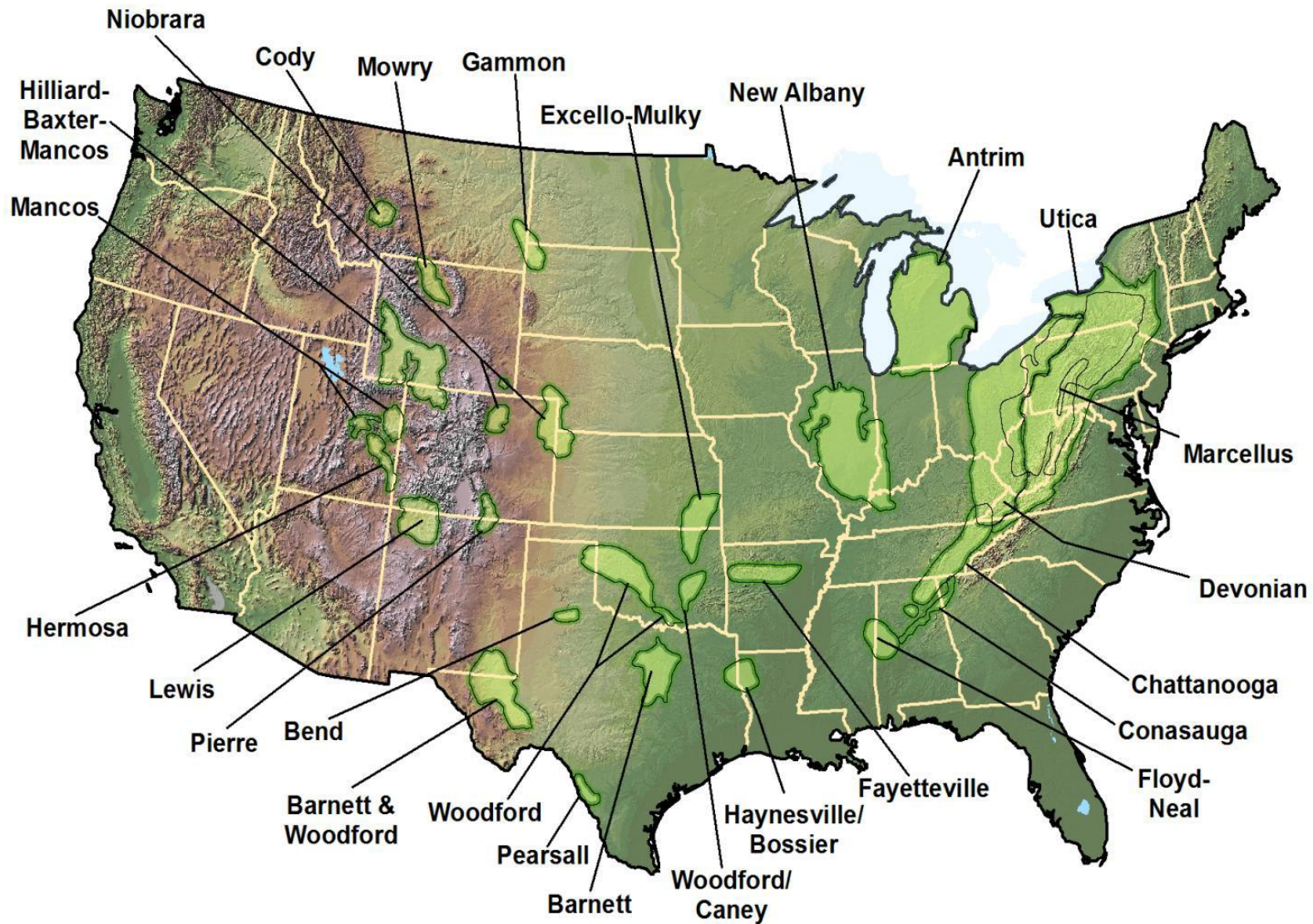
SCIENCE – Civil and Environmental Engineering, Geology, Hydrology, Environmental Health, Forestry, Ecology, Medicine, Behavioral and Community Health

POLICY - A balance of needs and resources, long term effects, quality of life

REGULATION – new techniques, inadequate regulations, law and policy meet reality, industry confused on how to plan

ENVIRONMENTAL PRESERVATION – What are the environmental impacts, how will these be weighed with the benefits to income, what is the long term costs and challenges.

# UNITED STATES SHALE BASINS

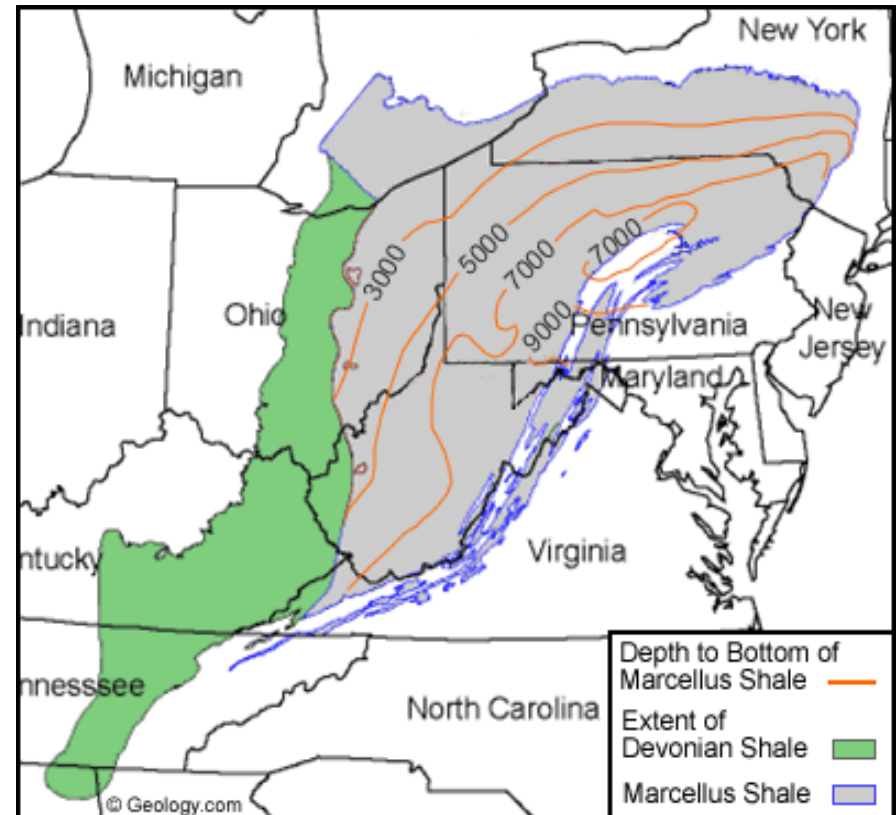


# Marcellus Shale Range and Production Estimates<sup>1</sup>

- Early 2008, Engelder and Lash, estimated that about 50 TCF (trillion cubic feet) of recoverable natural gas could be extracted from the Marcellus Shale.
- November 2008, on the basis of production information from Chesapeake Energy Corporation, the estimate of recoverable gas from the Marcellus Shale was raised to more than 363 TCF (Esch, 2008).
- Currently estimates by geologists vary, 116 to 516 tcf, though it is not currently known how much is recoverable.

<http://www.dec.ny.gov/energy/46288.html>

The United States uses about 23 TCF of natural gas per year (U.S. Energy Information Administration, 2009), so the Marcellus gas resource may be large enough to supply the needs of the entire Nation for roughly 15 years at the current rates of consumption.



de Witt, Wallace et al. (1993) Principal Oil and Gas Plays in the Appalachian Basin (Province 131). U.S. Geological Survey Bulletin 1839-I, 37 p.

# A SHIFTING LANDSCAPE

- Rick Weber, President of Atlas just declared in a town hall meeting on Thursday Sept 9, 2010 that they are seeing production from their wells at 6 billion cubic feet (bcf) of gas per day, which amounts to  $6 \times 365 = 2.19$  trillion cubic feet (tcf) of gas per year in 10 years for one company that is 20.19 tcf.
- The question remains what is the total recoverable gas?
- This question is important to understanding economic impact and reasons to shift resources and infrastructure.





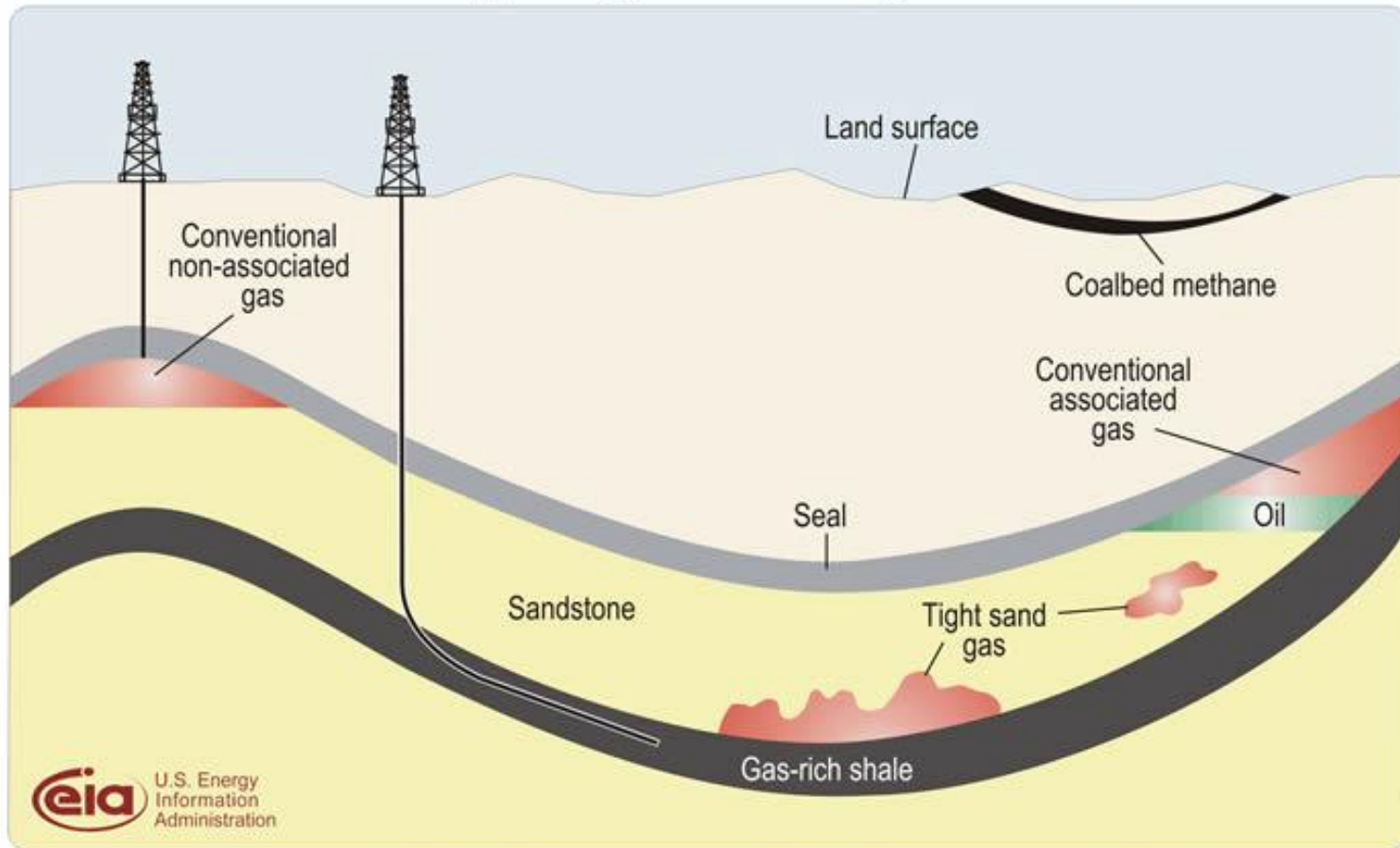
A WORK IN  
PROGRESS

# Natural Gas

- Natural gas as we use it is almost entirely methane.
- Natural gas as we find it underground can be associated with a variety of other compounds and gases as well as oil and water.
  - Methane
  - Propane
  - Butane
  - Other products
- Natural gas transported through pipelines must meet purity specifications to be allowed in, so most gas processing is done at the well site.

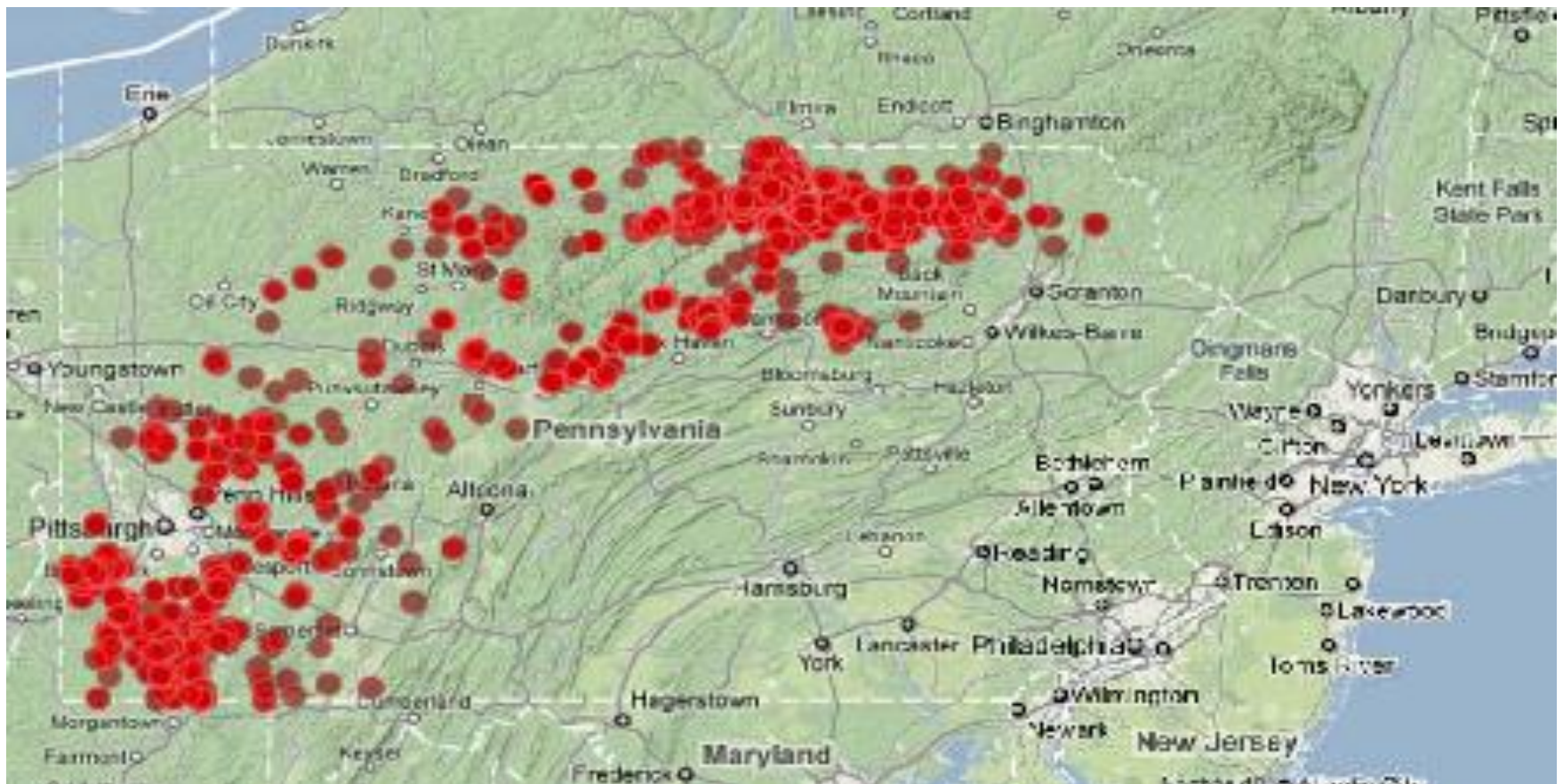
# Conventional and Non-conventional Natural Gas Extraction Methodologies<sup>2</sup>

Schematic geology of natural gas resources



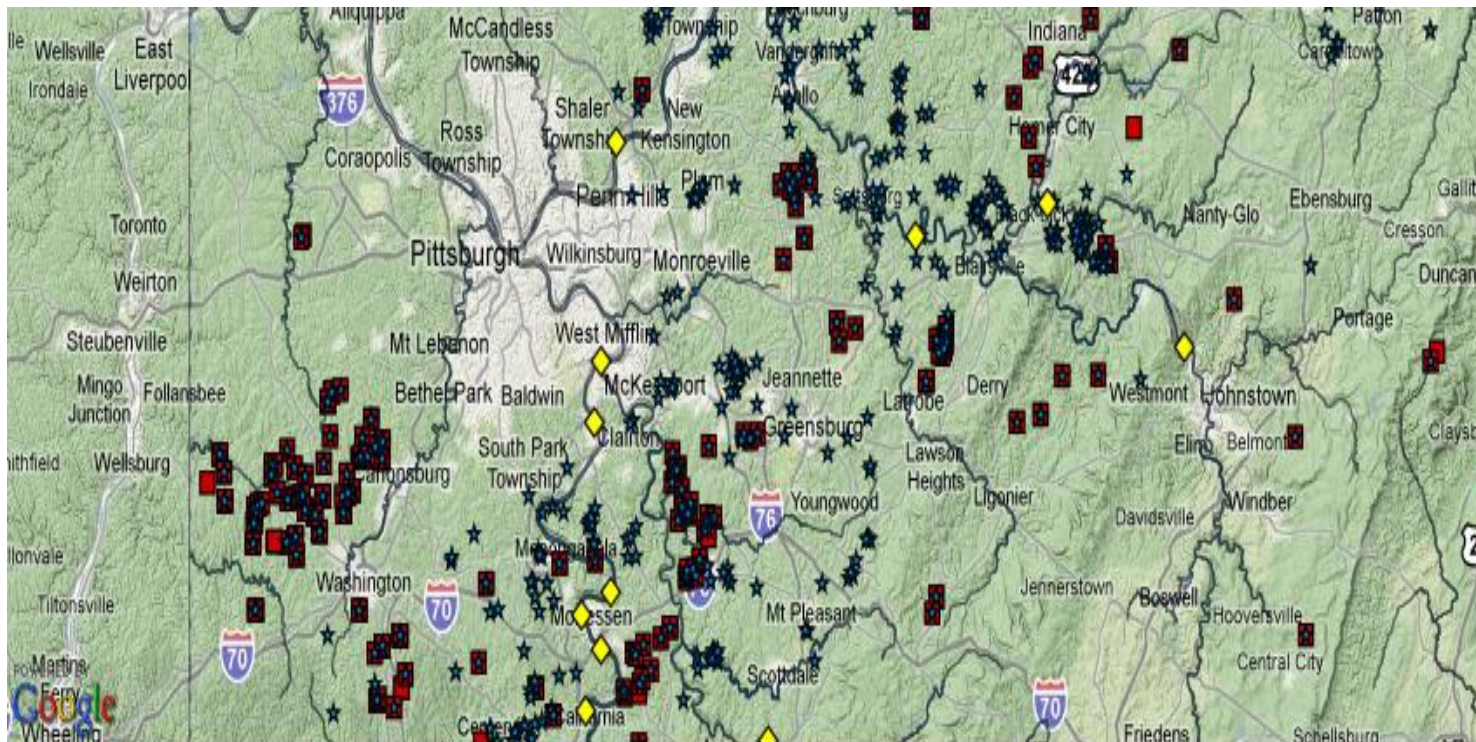
A COMBINATION OF  
NEW TECHNOLOGY,  
THE PRICE OF GAS,  
THE PERCEIVED NEED FOR  
NEW ENERGY SOURCES  
COMBINE  
TO PRODUCE A BOOM IN THE  
MARCELLUS SHALE.

# Marcellus Shale Well Permits from 2007 through June 2010





# Activity Related to the Marcellus Shale Development



Wastewater Treatment Facilities Acce...

All records



Pennsylvania Rivers

All records



NY\_PA\_WW\_Post 2008 Permit Wells

All records



Marcellus Shale Drilled Wells in PA 20...

All records



# What is Involved in the Development

- Landsmen obtaining leases from the owners of mineral rights
- Seismic testing performed to determine well site
- Permits obtained from PADEP by the gas industry
  - Involves a water management plan
  - Plan for pad development and drilling
- Development of the well pad
  - 4-6 acres of land is stripped and leveled for well construction and drilling
  - Roadway development
  - Impoundment dug for fresh water and flow back fluid



Seismic  
Vibrator Truck

Source –  
Natural  
Resources  
Canada



- A vertical well is drilled to depths of over 2000 ft
  - During the drilling process steel and concrete casings are put in place to preserve well integrity and provide a barrier between the well and underground aquifers.
- The drilling rig for the vertical well is replaced with a larger drilling rig for horizontal drilling.
  - It is possible to drill up to 5000 feet horizontally from the vertical well (<http://www.srbc.net/whatsnews/doc>)
  - Each well can access gas trapped beneath 200-400 acres
  - Multiple horizontal wells can be drilled from one drilling pad.
  - Horizontal wells are also cased with concrete

## *Drilling Rig in Rural Upshur County, West Virginia*



Source: WVSORO, Modern Shale Gas Development in the U.S.: A Primer, (2009) U.S. Dept of Energy

# Drilling in Fairfield Township, PA



Source:  
CHEC  
Photo  
Archives

- **Fracturing of the shale**

- A mixture of 99% water and sand/propanant is injected into the rock at very high pressure
- Fractures within the rock are created that provide the natural gas a path to flow to the wellhead.
- Volumes of fracturing fluid needed depend on the stages of fracturing. A four stage operation can use 2.3 million gallons of water (Marcellus Shale Primer: Dept of Energy)
- In various basins and shale gas plays, the volume of produced water may account for less than 30% to more than 70% of the original fracture fluid volume.<sup>295</sup> In some cases, flow back of fracturing fluid in produced water can continue for several months after gas production has begun



*Lined Fresh Water Supply Pit from the Marcellus  
Shale Development in Pennsylvania*



Modern Shale Gas Development in the U.S.: A Primer, (2009) U.S. Dept of Energy

## *Hydraulic Fracturing of a Marcellus Shale Well, West Virginia*



Modern Shale Gas Development in the U.S.: A Primer, (2009) U.S. Dept of Energy





- **Gas Production**

- Well head is capped
- In many areas of the Marcellus Shale, the extracted gas is in liquid form and must be treated
- Separators are added to the well pad, along with glycol tanks, and produced water tanks.
- Compressors may be added to pump gas to processing plants

- **Gas Distribution**

- The extracted gas product is sent through supply lines to a processing plant where it is further refined and odorant added
- Purified methane gas is distributed to the main distribution facility via pipelines
- .



# Product Water Tanks - Punxsatawny PA



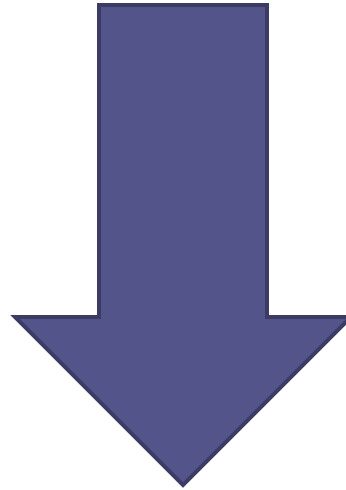
# The Center for Healthy Environments and Communities Involvement

- A community based participatory environmental research center
- Residents of Clearville in Bedford PA notify the Center with concerns about water wells igniting and gas storage drilling.
- Citizens in Hickory, PA report to CHEC their perceptions of water contaminations, air quality concerns and perceived related health issues.
- Heinz Endowment project officers call for Citizen Surveillance to provide additional resources to PADEP.

# Questions Develop

1. How is flow back and produced water disposed of?
2. Is the disposal of water affecting ground water?  
And municipal and private drinking water supplies?
3. Is there an additional burden to already compromised air quality in Southwestern, PA?
4. What kind of stress and health issues are related to people living in communities where gas extraction and development activities are taking place?

# CONCERNS



# Reported Spills and Accidents

5/30/09	The impoundments draw significant amounts of water per day from nearby waterways. Such large volume diversions could impair the existing uses of the waterways.	Cogan House Township & Mifflin Township, Lycoming County, PA	Water withdrawal	n/a	DEP ordered Range Resources - Appalachia LLC & Chief Oil & Gas LLC to suspend a portion of their operations. The orders will remain in effect until the DEP has received & approved a water management plan from both companies, & each firm has obtained the necessary permits.
6/5/09	A leaking waste water pipe from a Range Resources Marcellus shale gas well drilled in polluted water, killing fish, salamanders, crayfish & aquatic insect life.	Cross Creek Lake, Washington County, PA	Returned frac fluid, waste water discharge	Unknown	DEP fined Range Resources as of January 2010.
9/1/09	A toxic algae bloom resulted in a massive fish kill (complete mussel kill). Favorable algae growth conditions were caused by high TDS levels, dry weather & water withdrawals for fracturing operations.	Along 43 miles of Dunkard Creek (Along WV & PA border)	Golden algae	Unknown	Lower chlorides & TDS levels. Consol Energy is now allowed to pumped out water from its Blackville No. 2 mine on specific conditions issued by the WV DEP.
9/24/09	Cabot Oil & Gas Corp. experienced 3 separate spills in less than 1 week, which polluted Stevens Creek & a nearby wetland.	Heitsman well in Dimock Township, PA	Water/fluid mixture	8,000 gallons	The DEP's order stopped all hydro fracturing operations at each site throughout the county. Cabot has since submitted the necessary forms according to DEP specifications, & resumed operations.
10/10/09	A Range Resources temporary above-ground water transfer line connection failed. Minnows, crawfish & frogs died/ were impaired.	Brush Run Creek, Hopewell Township, Pa	Partially recycled flowback & fresh water, Chlorides	250 barrels (10,500 gallons)	PA DEP officials inspected about 4/10 of a mile of Brush Run near the spill. Fines for this incident have not yet been published, but should be announced in Spring 2010.
2/1/10	Proper ownership information missing, flow-back fluids discharging into tributary	3 natural gas wells, Troy Township, Bradford County, PA	Flow-back fluids	Unknown	Fortuna Energy Inc. promptly placed a pump into the sediment basin to pump the fluids back into tanks & hired a consultant to conduct appropriate sampling. PA DEP has fined the company \$3,500 for the violations.
3/15/10 (Approx)	Fluid leak into the ground water caused by a hole in the pit liner	Dimock, Susquehanna County, PA	Black drilling liquid	Unknown	PA DEP issued a notice of violation to Cabot Oil & Gas.
3/15/10	A substance used in the natural gas drilling process is discoloring & distorting the texture of spring water runoff.	Cummings Township, PA	Airfoam HD	Unknown	Representatives of PA General Energy, w/whom DEP members have been communicating, are investigating the problem.
3/17/10	Dumping of fluid onto a road from a tanker truck	Bee Branch, AR	Fluid (unknown components)	5,000 gallons	Unknown
3/17/10	Cummings C-West gas well pad site, run by Williams Production: frac fluid spill while conducting flowback activities	Town of Flower Mound, TX	Flowback water w/frac fluid	80 barrels- or 3,000 gallons	Sampling & remediation of the spill will be conducted by the Texas Railroad Commission. The Texas Commission on Environmental Quality has been notified.
3/21/10	Range Resources: Broken pipe & flushing of water in field	Hickory, PA (Caldwell St.)	Water (unknown components)	Unknown	PA DEP investigating. Incident reported to researchers by witness.
3/26/10	Mud overflowed Anadarko Corp. well pad	Sproul State Forest, PA	Mud used as a cooling agent	8,000 - 12,000 gallons	A contractor has begun cleanup.
3/31/10	Atlas Energy gas well fire (natural gas storage tank or liner)	Hopewell Township, PA	Fire, smoke	n/a	Emergency personnel let the fire burn itself out. Investigation being conducted.



# Drillings and Casings<sup>3</sup>

- The effect of higher temperature on cement setting behavior, poor mud displacement and lost circulation with depth makes cementing the deep exploration and production wells in the Marcellus Shale quite challenging.
- For example following a recent report by residents of Dimock, PA, of natural gas in their water supplies, inspectors from the Pennsylvania Department of Environment Protection (PADEP) discovered that the casings on some gas wells drilled by Cabot Oil & Gas were improperly cemented, potentially allowing contamination to occur.

# Drilling

- During drilling into the tight Marcellus Shale, there is a slight risk of hitting permeable gas reservoirs at all levels. This may cause:
  - shallow gas blowouts and underground blowouts between subsurface intervals.
- Other geo-hazards that may pose challenges to drillers in the Marcellus Shale include:
  - (1) disruption and alteration of subsurface hydrological conditions including the disturbance and destruction of aquifers,
  - (2) severe ground subsidence because of extraction, drilling, and unexpected subterranean conditions, and
  - (3) triggering of small scale earthquakes

# Long Term Considerations<sup>4</sup>

- Construction of gas wells in the Marcellus formation requires drilling through shallow freshwater aquifers and penetrating deeper geologic formations that contain naturally-occurring contaminants such as hydrocarbons, metals, radionuclides, and high salinity. The well borehole creates a conduit for fluid to flow between these previously isolated geologic formations. To prevent such flow, the annular space between the well casing and the formation is filled with grout.



# Fluid Disposal

- Many focus on the issue of fracing fluid disposal
- Flow back and product fluid are of high concern. These fluids are:
  - High in salinity 5-10 x that of saltwater.
  - Total dissolved solids
  - Hydrocarbons which are volatile organics such as benzene, ethylene, toluene, and xylene (BETX)
  - Heavy metals
  - Radionuclide
  - Other heavy metals such as arsenic and mercury
- Treatment plants exist, but the industry is not required to use these
  - Secretary Hanger of the PA DEP has stated “The treating and disposing of gas drilling brine and fracturing wastewater is a significant challenge for the natural gas industry because of its exceptionally high TDS concentrations. Marcellus drilling is growing rapidly and our rules must be strengthened to prevent our waterways from being seriously harmed in the future.”<sup>5</sup>
- New regulations for disposal of flow back and product are water have been enacted and scheduled to be in place early next year.

# Fluid Disposal

- Open poly lined impoundments for the storage of flow back water for recycling must be enclosed to prevent accidental entry by wildlife and humans.
  - These open impoundments have been reported by those living close by to emit foul odors.
  - Tears or leaks in liners, especially due to fires, such as in Hopewell Township, can allow this fluid to leak into the soil.

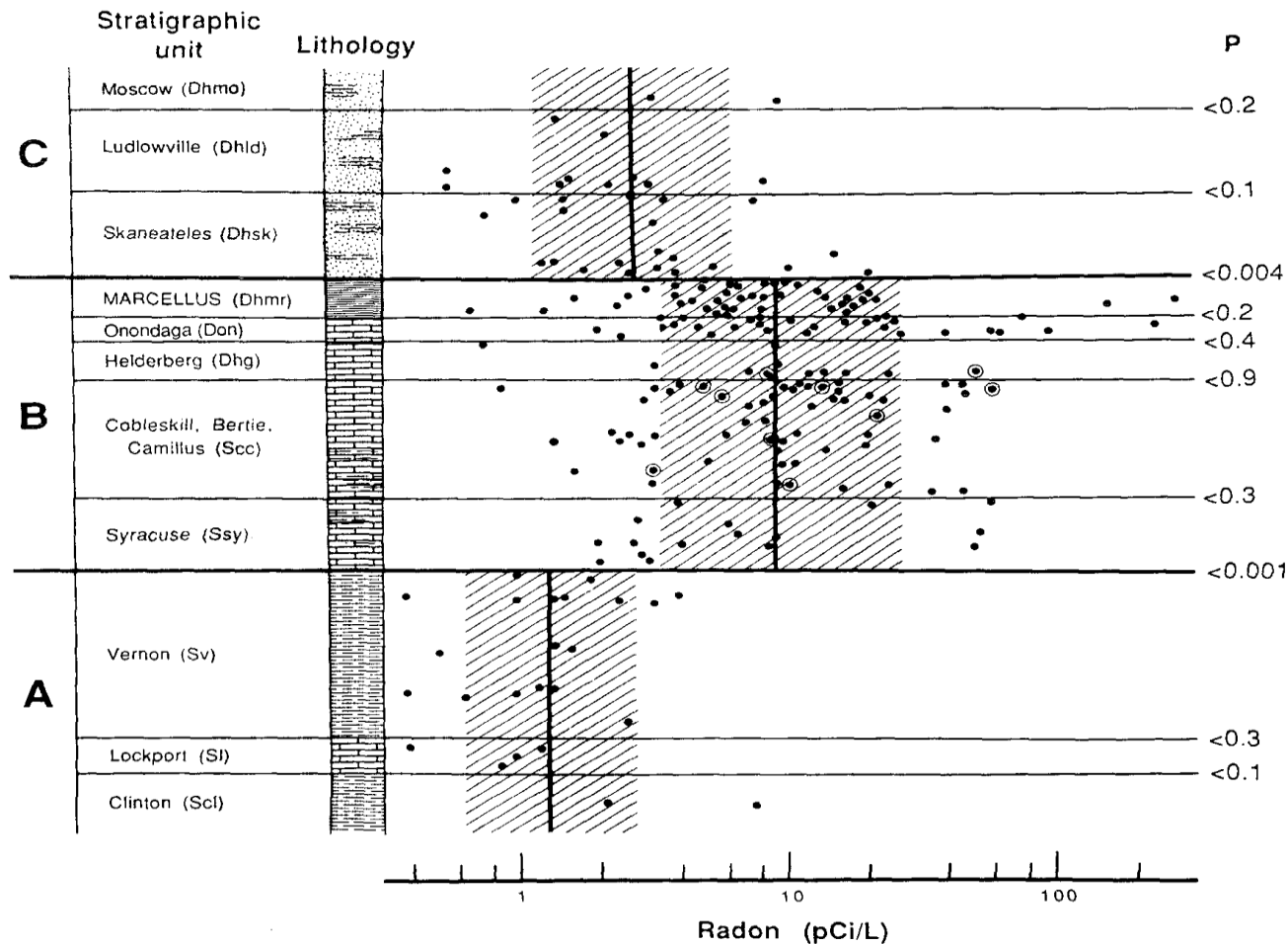


Fracking Pond Fire – Hopewell Township, PA – reported by Post Gazette April 1, 2010



# Radon Activities in Homes over the Marcellus Shale Formation- Indicates the Intrinsic Activity of the Shale Layer Itself

Formation is enriched in Uranium-decays to Radium and then to Radon<sup>6</sup>



**Figure 3. Radon activities plotted against stratigraphic position. Vertical lines indicate geometric means; diagonal rule pattern = area within 1 standard deviation of mean. A, B, C correspond to regions in Figure 1. Circled data points are homes north of Rock Cut, now inaccessible to ground water that has passed through Marcellus Shale. P is probability (based on Student's t test) that data from adjacent formations might represent single population. Parenthetical symbols designate units differentiated on Geologic Map of New York (Fisher et al., 1971).**

# Radon

- Pennsylvania's water wells are among the only ones in the nation with “high contaminant concentrations” for every one of the Big 3: arsenic, nitrates and radon<sup>7</sup>
- Concerns are about the disturbance of the Marcellus Shale layer due to gas exploration and development and the migration of Uranium and ultimately Radium possibly increasing levels of radon in these areas.
- CHEC will be conducting studies of radon in homes and private well water sites near drilling activity.

# Air Quality

- Oil and gas air emissions are the largest for VOCs, comprising over 40 percent of the regional total in 2002. Emissions of NO<sup>x</sup>, CO, and SO<sup>2</sup> contribute approximately 15 percent, 9 percent, and 4 percent to the regional totals, respectively (Colorado and Wyoming)<sup>8</sup>

# Air Quality

- Open lined impoundments holding flow back water stored for recycling in other fracturing operations.
  - Fluids in these impoundments contain volatile organics which off gas into the open air.
- Natural gas flaring can produce many hazardous chemicals including polycyclic aromatic hydrocarbons (PAHs, including naphthalene), benzene, toluene, xylenes, ethyl benzene, formaldehyde, acrolein, propylene, acetaldehydehexane.<sup>9</sup>

# Air Quality and Monitoring

- Current air monitoring stations and equipment are inadequate to monitor gas industry operations, including compressors, relief valve emissions from separators, and produced water tanks
- Fugitive natural gas emissions from separators and produced water tanks may contain many contaminants:
  - Methane and other hydrocarbons (ethane, propane, butane) and water vapor are of relatively low human toxicity.
  - Others such as hydrogen sulfide (H<sub>2</sub>S) are of more significant toxicity.
  - Some natural gas wells produce a condensate which can contain complex hydrocarbons and aromatic hydrocarbons such as benzene, toluene, ethyl benzene and xylene (BTEX).
  - These substances are important human toxics with multiple non-cancer and cancer endpoints



# Emergency Services Planning and First Responder Training

- There is a lack of information related to long range planning of drilling sites and gas industry related activities.
- This lack of information makes it difficult for emergency services planning throughout the state and regionally.
- We also recognize that coordination with the gas industry and emergency management agencies such as PEMA is necessary to train first responders in the event of accidents, spills, and industry related disasters.

# Emergency Services Planning and First Responder Training

- MOUNDSVILLE, W.Va. — Volunteer firefighters had to jump in "blind" at the scene of a massive explosion and raging gas fire early yesterday when injured workers, some with severe burns, left to seek medical treatment. "It was just a big ball of fire," said Danny Holmes, chief of the Moundsville Volunteer Fire Department, which arrived first at the Chief Oil & Gas LLC well site about four miles outside Moundsville. "We didn't know what we were going into. There was nobody there to feed us any information for a while." (*Chris Togneri and Tim Puko, Pittsburgh Tribune-Review, Tuesday, June 8, 2010*)

# Crime and Police Response- Rocky Mountain Energy Boomtowns<sup>10</sup>

- Thousands seeking well-paying jobs have expanded energy town populations beyond the capacity of housing and public services to cope with their needs.
- Many coming into the towns have criminal records, and the pressures of long hours at work, poor public facilities, and limited recreation opportunities have produced sizeable mental health and alcoholism problems.
- The frequency and seriousness of crime has soared. In addition, the police in Evanston, a typical 'boom town,' complain about lack of equipment, staff, and facilities.
- Although new personnel and equipment are added each year, the demand for police response continues to exceed the department's capability. Because of this, most police work is reactive, with little time for preventive measures and little time to train personnel in new techniques or plan for the future.

# Crime and Police Response - PA<sup>11</sup>

- Pawlowski reported more arrests and incidents involving drugs, assaults and illegal weapons.
- **"More and more, it seems the police reports coming out of the northern tier include arrests because of drug use and trafficking, fights involving rig workers, DUIs, and weapons being brought into the state and not registered properly," said the commissioner. "We've even encountered situations where drilling company employees who have been convicted of a sexual assault in another state come here to work and do not register with our Megan's Law website. Each of these issues is unacceptable and places an even greater burden on our law enforcement and local social programs meant to help those in need."**
- Pawlowski and Biehler both said the state and local governments need additional resources to address the problems that have accompanied the arrival of drilling companies to Pennsylvania.

# Pipelines

- Gathering Lines will need to be installed to carry gas from well sites to distribution centers connecting produced gas to consumers through supply lines.
- Expanded supply lines will also need to be installed.
- **Safety-** the PUC has called a hearing (6/11/2010) because of the stated concerns about public safety. The existing regulations are dated. Until the safety requirements of such an immense infrastructure as the Marcellus Shale development will require are fully assessed, moving forward with pipelines would not be prudent nor would it protect the residents of PA.

**Social Justice-** the PUC has determined that Class 1 areas will not be subject to inspections. Class 1 areas are areas with less than 10 homes over one mile. This is unequal protection. The federal government does not inspect Class 1 lines either. Rural residents are being put at unacceptable risk. Our safety is deemed expendable.



# Pipelines (con't)

- Pipeline and Hazardous Material Safety Administration (PHMSA) has identified excavation as the most significant source of serious pipeline incidents over the past 20 years. Because gas wells may be drilled as close as 200 feet to residences in Pennsylvania, without consent of the owner. (*Earth Justice, (2010) En Banc Hearing of the Pennsylvania Public Utility Commission on Jurisdictional Issues Related to Marcellus Shale Gas Development, Docket No. I-2010-2163461, June 11*)

## Vehicular Traffic<sup>12</sup>

- Hauling of water, wastewater, and equipment to and from the drill site requires on the order of 1,000 or more truck trips per well.
- The entire process, from site development through completion, takes approximately four to ten months for one well.
- Multiple horizontal wells are typically drilled from a common well pad roughly five acres in size.

# Vehicular Traffic<sup>13</sup>

- “PennDOT Secretary Allen D. Biehler, P.E. and Pennsylvania State Police Commissioner Frank Pawlowski today said that in the wake of the drilling, there have been increases in truck traffic, traffic violations, crime, demand for social services, and the number of miles of roads that are in need of repairs.”
- “According to Biehler, hundreds of miles of secondary roads in Pennsylvania's northern tier have been damaged or even rendered impassable because of heavy truck traffic associated with drilling activities. While drilling companies have committed to repairing roads they use, Biehler said, their efforts have not kept pace with the damage in a number of cases.”
- State Police Commissioner Pawlowski attributed much of the road damage to overweight trucks serving the gas industry. He cited a Feb. 9 enforcement effort in Susquehanna County that found 56 percent of 194 trucks checked were found to be over the weight limit. Fifty percent of those trucks were also cited for safety violations

# Noise Impacts

- Noise from compressors associated with drilling sites and completed well sites are a concern.
- Noise from truck traffic at all hours during the drilling process
- What are the implications for an urban environment.
- Low frequency noise, produced from oil and gas compressors, may be of concern in the surrounding communities. A small number of studies reported the following symptoms related to low frequency noise: annoyance, stress, irritation, unease, fatigue, headache, adverse visual functions and disturbed sleep. (Berglund, 1999, Pawlaczy-Luszczyniska, 2005)<sup>14</sup>

# Stress<sup>15</sup>

- Individuals working or living in communities involved in oil and gas exploration often experience greater mental health concerns than individuals who live in areas not involved in these industrial activities.
- Some researchers report that individuals in these regions have a certain vulnerability to psychological or psychiatric problems. (Lester & Temple, 2006)
- For example, oil and gas development has been associated with high rates of mental and psychological stress.
- Furthermore, increasing mental health concerns such as anxiety and depression, have been linked to communities in Wales, India, and the Peruvian Amazon that are involved in oil and gas drilling activities. (Bhatia, 2007; Gallacher et al., 2007; Izquierdo, 2005; Lester & Temple, 2006; Murthy et al., 2005; Wernham, 2007)



# References

1. Daniel J. Soeder and William M. Kappel , (2009) Water Resources and Natural Gas Production from the Marcellus Shale, USGS - - From USGS Fact Sheet 2009-3032
2. PA Department of Environmental Protection (PA DEP) , Oil and Gas Management, Online Services, E-facts, <http://www.ahs2.dep.state.pa.us/eFactsWeb/default.aspx>
3. Kargbo, David M., Wilhelm, Ron G., Campbell, David J., (2010) Natural Gas Plays in the Marcellus Shale: Challenges and Potential Opportunities, *Environmental Science and Technology*, DOI: 10.1021/es903811p Publication Date (Web): June 2.
4. Oil and Energy News, May 24, 2010, Harrisburg, PA, PRNewswire-USNewswire
5. Commonwealth of PA Dept. of Environmental Protection, Commonwealth News Bureau. Press Release, April 10.2010.
6. Hand, Bruce M. and Banikowsky, Jeffery E. (1988) Radon in Onondaga County, New York: Paleohydrogeology and Redistribution of Uranium in Paleozoic Sedimentary Rocks, *Geology*, Vol. 16, p.775-778.
7. Marcellus Shale Coalition, About Water in Your Well, Press Release July 9, 2010
8. Witter et al. (2008) Potential Exposure-Related Human Health Effects of Oil and Gas Development: A Literature Review (2003-2008), University of Colorado.
9. Environmental Protection Agency (EPA), (2008) An Assessment of the Environmental Implications of Oil and Gas Production: A Regional Case Study, Region 8, Working Draft.
10. Taft, P.B., (1981) Keeping the Peace in the New Wild West, *Police Magazine* Vol. 4 (4) Dated:(July 1981) Pages:8-15, 17.
11. Oil and Energy News, May 24, 2010, Harrisburg, PA, PRNewswire-USNewswire
12. New York DEP, (2009), Final Impact Assessment Report, Hazen and Sawyer Environmental Engineers and Scientist, December.
13. Op. Cit, Oil and Energy News, 2010.
14. Op. Cit., Witter et al, 2008.
15. Op. Cit. New York DEP, 2009.
16. Op. Cit., Witter et al, 2008.