Public Health Implications for Marcellus Shale Development

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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

- 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.

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.
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$^2$
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

Marcellus Gas Activity in the Greater Pittsburgh Area

[Map showing the distribution of Marcellus Shale wells in the Greater Pittsburgh Area]
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

Drilling in Fairfield Township, PA

Source: CHEC Photo Archives
Fracturing of the shale

- A mixture of 99% water and sand/propant is injected into the rock at very high pressure.
- Fractures within the rock a 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. 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

Hydraulic Fracturing of a Marcellus Shale Well, West Virginia

• **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 - Punxsatawney 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

<table>
<thead>
<tr>
<th>Date</th>
<th>Description</th>
<th>Location</th>
<th>Impacted Resource</th>
<th>Amount/Details</th>
<th>Responsible Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/30/09</td>
<td>The impoundment drain significant amounts of water from nearby waterways. Such large volume diversions could impact the existing uses of the waterways.</td>
<td>Cogan House Township &amp; Mifflin Township, Lycoming County, PA</td>
<td>Water/Sludge</td>
<td>Water level</td>
<td>DEP ordered Range Resources - Appalachian LLC &amp; Chief Oil &amp; Gas LLC to suspend a portion of their operations. The order will remain in effect until the DEP has received and approved a water management plan for both companies. A staff member obtained the necessary permits.</td>
</tr>
<tr>
<td>6/5/09</td>
<td>A leaking waste water pipe from a Range Resources Marcellus gas well drilled in polluted water;100 fish, 40 skunks, 64 garter snakes, and 600 aquatic insects were observed near the fish kill.</td>
<td>Cross Creek Lake, Washington County, PA</td>
<td>Water/Sludge</td>
<td>Unkown</td>
<td>DEP fined Range Resources as of January 2010.</td>
</tr>
<tr>
<td>9/1/09</td>
<td>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 &amp; water withdrawals for fracking operations.</td>
<td>Along 43 miles of Dunkard Creek (Along WV &amp; PA border)</td>
<td>Water/Sludge</td>
<td>Gomshallage</td>
<td>Lower Clithero &amp; TDS levels; CEP Energy now allowed to pump-out water from its Blacklick No. 3 well on specific conditions issued by the WV DEP.</td>
</tr>
<tr>
<td>9/24/09</td>
<td>Cabot Oil &amp; Gas Corp. experienced a separate spill in September 3, which polluted Stevens Creek &amp; a nearby wetland. The creek is as well in Dimock Township, PA.</td>
<td>Heitman as well in Dimock Township, PA</td>
<td>Water/Fluid mixture</td>
<td>8,000 gallons</td>
<td>The company stopped all fracking operations at the site and the DEP to stop the spill. The DEP has since been submitting the necessary forms according to DEP specifications.</td>
</tr>
<tr>
<td>10/10/09</td>
<td>A Range Resources temporary above-ground water transfer line connection failed. Fish and aquatic wildlife were impacted.</td>
<td>Enrich Run Creek, Hopewell Township, PA</td>
<td>Partially recycled flowback &amp; fresh water, Chlorides</td>
<td>250 barrels (10,500 gallons)</td>
<td>PA DEP staff reportedly removed about 400 of a total of 320 barrels near the spill. The spill was not yet been published but will be announced in spring 2010.</td>
</tr>
<tr>
<td>2/1/10</td>
<td>Proper ownership information was missing, flowback fluids discharging into tributary.</td>
<td>Natural gas wells, Troy Township, Bradford County, PA</td>
<td>Flowback Fluids</td>
<td>Unknown</td>
<td>Fortuna Energy Inc. promptly placed a pump into the entrance to pump the fluids back into the reservoir. The DEP has fined the company $25,000 for the violations.</td>
</tr>
<tr>
<td>3/15/10</td>
<td>Fluid leak at the ground water caused by a hole in the pitliner.</td>
<td>Dimock, Susquehanna County, PA</td>
<td>Black drilling liquid</td>
<td>Unknown</td>
<td>PA DEP issued a notice of violation to Cabot Oil &amp; Gas.</td>
</tr>
<tr>
<td>3/15/10</td>
<td>A substance used in the natural gas drilling process is leaking &amp; distorting the texture of spring water runoff.</td>
<td>Cummings Township, PA</td>
<td>Air foam HD</td>
<td>Unknown</td>
<td>Representatives of PA General Energy, who is DEP members have been communicating, are investigating the problem.</td>
</tr>
<tr>
<td>3/17/10</td>
<td>Dumping of fluids onto an area from a tanker truck.</td>
<td>Bee Branch, PA</td>
<td>Fluid (unknown components)</td>
<td>5,000 gallons</td>
<td>Unknown</td>
</tr>
<tr>
<td>3/17/10</td>
<td>A Range Resources: Broken pipe &amp; flushing of water inlet.</td>
<td>Hickory, PA (Caldwell St.)</td>
<td>Water (unknown components)</td>
<td>Unknown</td>
<td>PA DEP investigating; incident reported to Pennsylvania Fish Commission by outsource.</td>
</tr>
<tr>
<td>3/21/10</td>
<td>Mud overflowed around pipeline, well pad.</td>
<td>Sproul State Forest, PA</td>
<td>Mud used as a cooling agent</td>
<td>8,000 - 12,000 gallons</td>
<td>A contractor has begun cleanup.</td>
</tr>
<tr>
<td>3/31/10</td>
<td>Atlantic Gas well fire (natural gas storage tank or liner).</td>
<td>Hopewell Township, PA</td>
<td>Fire, smoke</td>
<td>n/a</td>
<td>Emergency personnel at the fire were held in; investigation being conducted.</td>
</tr>
</tbody>
</table>
Drillings and Casings

- 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

- 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 fracturing 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.”
• 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.
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\(^6\)

<table>
<thead>
<tr>
<th>Stratigraphic unit</th>
<th>Lithology</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Moscow (Dhmo)</td>
<td></td>
<td>&lt;0.2</td>
</tr>
<tr>
<td>Ludlowville (Dhld)</td>
<td></td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Skaneateles (Dhsk)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MARCELLUS (Dhmr)</td>
<td></td>
<td>&lt;0.004</td>
</tr>
<tr>
<td>Onondaga (Doh)</td>
<td></td>
<td>&lt;0.2</td>
</tr>
<tr>
<td>Helderberg (Dhg)</td>
<td></td>
<td>&lt;0.4</td>
</tr>
<tr>
<td>Cobleskill, Burtie, Camillus (Scc)</td>
<td></td>
<td>&lt;0.9</td>
</tr>
<tr>
<td>Syracuse (Say)</td>
<td></td>
<td>&lt;0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Vernon (Sv)</td>
<td></td>
<td>&lt;0.3</td>
</tr>
<tr>
<td>Lockport (Sl)</td>
<td></td>
<td>&lt;0.1</td>
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<tr>
<td>Clinton (Scl)</td>
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</tbody>
</table>

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.

- 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\textsuperscript{x}, CO, and SO\textsuperscript{2} contribute approximately 15 percent, 9 percent, and 4 percent to the regional totals, respectively (Colorado and Wyoming)\textsuperscript{8}
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.⁹
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 (H2S) 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\textsuperscript{10}

- 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.
• 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

- 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.
“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-Luszcyniska, 2005)
Stress

- 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

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](http://www.ahs2.dep.state.pa.us/eFactsWeb/default.aspx)