Baseline Testing and Marcellus Shale Issues Related to Groundwater

Groundwater Resource Management and Baseline Testing

Mr. Brian Oram, PG
Professional Geologist, Soil Scientist,
PASEO, Licensed Well Driller
Lab Director, Center for Environmental Quality
Wilkes University
Environmental Engineering and Earth Sciences
Wilkes Barre, PA 18766
http://www.wilkes.edu/water

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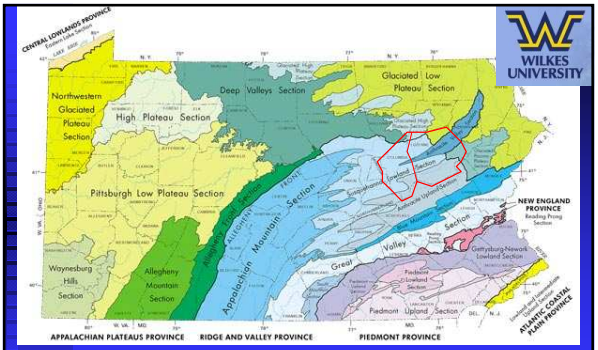
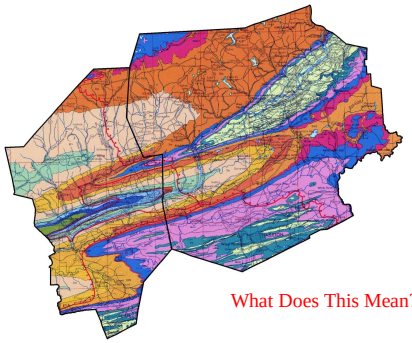
New Free Publication is Online !



Columbia and Luzerne Counties were glaciated and they are within the Appalachian Plateau and the Ridge and Valley Provinces

Source: DCNR - http://www.dcnr.state.pa.us/topogeo/map13/map13.aspx

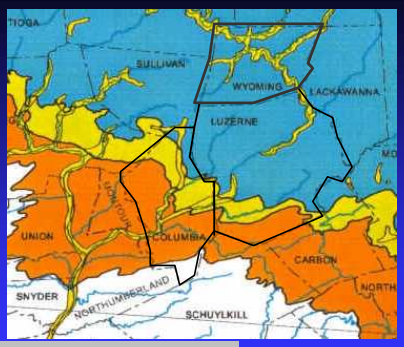
GEOLOGY



What Does This Mean?

Source: Luzernecounty.org

GLACIATION



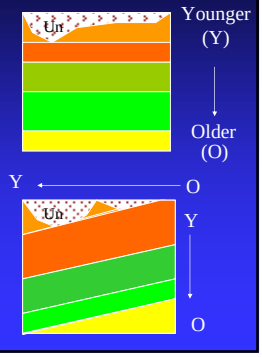
Wisconsinan (17,000 to 22,000 yrs)
Late-Illinoian (132,000 – 198,000 yrs)
Pre-Illinoian (> 770,00 yrs)

Source: DCNR - http://www.dcnr.state.pa.us

Appalachian Plateau Province

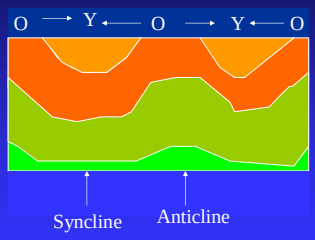
- Broad to Narrow Valleys
- Rounded Hills and Valleys Associated with Glaciation
- Valleys filled by glacial fluvial material

Unconsolidated Material (Un)

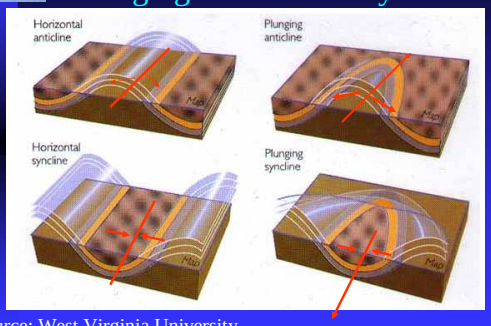


Ridge and Valley Province

- Bedrock has been folded into a series of anticline and synclinal structures.



Plunging Anticlines / Synclines



Source: West Virginia University
http://www.geo.wvu.edu

Geological Sequence

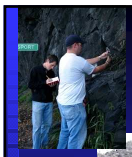
OLDER

Time	Period	Deposit or Rock Type
0 to 1.8 million years	Quaternary – Glaciation	sand, silt, clay, and gravel
1.8 to 290 million	Tertiary to Permian	**Not present (eroded and weathered)**
290 – 320 million	Pennsylvanian	**Llewellyn (coal) and Pottsville (minor coal)**
320 – 354 million	Mississippian	**Mauch Chunk Pocono and Spechty Kopf**
354 - 417 million	Devonian	**Catskill Formation Trimmers Rock Formation Mahantango Formation Marcellus Formation (Black Shale)- Target Onondaga Formation (calcareous sandy shale)**
417 – 443 million	Silurian	

Ridge and Valley Province – Rt 309

Mahantango Formation

Source: flickr.com/photos/ (ID –stillriverside)- Site Milford, PA

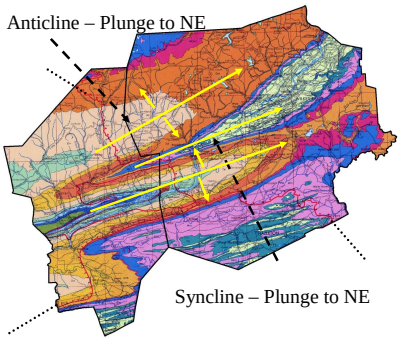


Marcellus Shale Photo

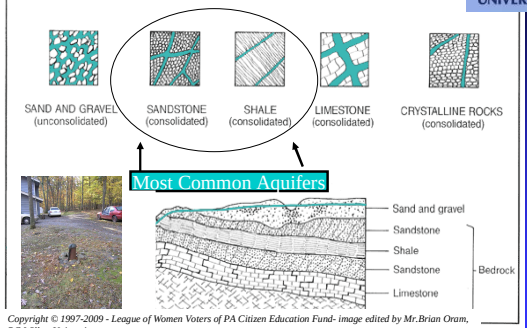
Outcrops Along the Southeastern Border of Pike County Along Route 209

Main Fracture Orientation

Geology of Columbia and Luzerne County



Primary Aquifers in PA



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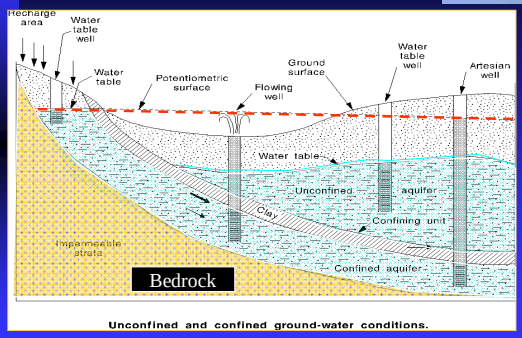
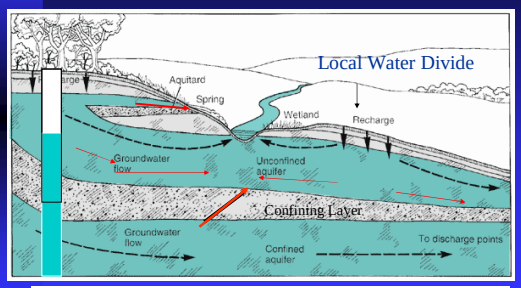
Well Geology (Unconsolidated)



Source: Water Watch Alliance

Surfacewater & Groundwater They Are Related and Connected !



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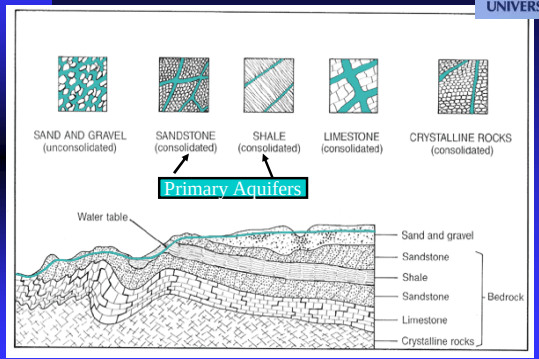
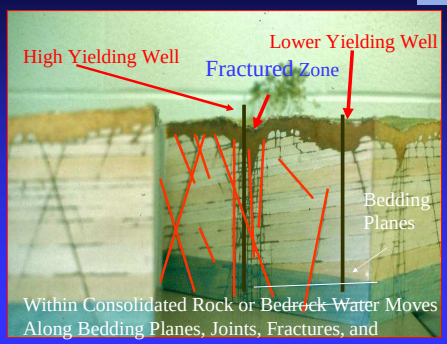
Primary Aquifers in PA

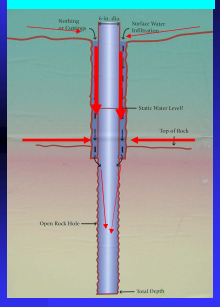


Bedrock Fractures and Fractured Zones

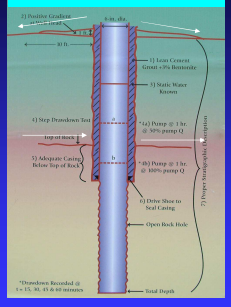


Within Consolidated Rock or Bedrock Water Moves Along Bedding Planes, Joints, Fractures, and Faults.

An Ungrouted Residential Well



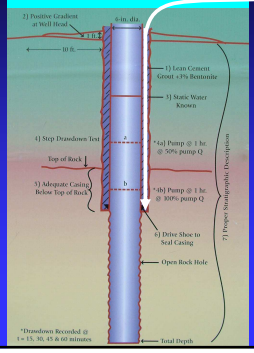
A Properly Grouted Well



Source: Pennsylvania State University – Master Well Owner Program - Carbon County Groundwater Guardians (edited by Mr. Brian Oram)

A Properly Grouted Well

Tremie Pipe



Primary Standards (NPDWR)

National Primary Drinking Water Regulations

Primary standards protect drinking water quality by limiting the levels of specific contaminants that can adversely affect public health and are known or anticipated to occur in water. They take the form of Maximum Contaminant Levels or Treatment Techniques.

There are over 100 chemical and biological primary drinking water standards, which include: trace metals, disinfection agents, disinfection by-products, radiological, microbiological agents, and organic chemicals.

Examples: Arsenic, Lead, MTBE, total coliform, *Giardia*, Trihalomethanes, Asbestos, Copper, Benzene, Trichloroethane, etc.

Secondary Standards

National Secondary Drinking Water Regulations

These standards were established more for cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor or color) in drinking water.

These are not regulated standards, but recommended limits.

The secondary standards include: aluminum, chloride, color, corrosivity, fluoride, foaming agents, iron, manganese, odor, pH, silver, sulfate, total dissolved solids, and zinc.

Why Test My Water ?

A USGS survey found that 70% of private wells were contaminated. This contamination could result in acute or chronic health concerns.

In general, there are no regulations related to well construction, placement, or required testing. It is up to you to determine the safety of your water.

EPA recommends, at minimum, an annual water test for private wells.

Now – With Marcellus Shale We Need to Develop a "Baseline".

What is a Baseline Test?

- Sampling by a Third Party Un-Biased Experienced Individual – there are "no" certified collectors.
- A certified laboratory must ensure the collector is following protocols in order for to accept the lab, this is part of chain-of-custody.
- A state-certified laboratory must follow approve methods and holding times and must be approved for each parameter or method group. This is also part of chain-of-custody.
- Baseline testing should provide a bases to characterize the quality of the water, but should include parameters to target the gas development.
- Baseline testing should characterize existing conditions and other related permits.
- Baseline testing should be done on untreated water and if possible include an assessment of your well yield, water level, and aesthetic characteristics of the water.

What Should I Test

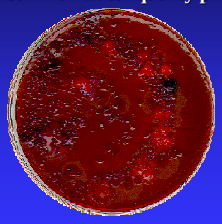
The Selection of the Appropriate Testing Parameters Depends on YOUR Water

- How does it taste?
- Do you have odor problems ?
- Are there any aesthetic problems, such as: color, turbidity, grittiness, or staining ?
- Where are you located – Is there drilling?
- How much do you want to spend ?

Comprehensive testing can cost over $2500.00

Groundwater Pocono's Region: Luzerne County

Based on the geology of Luzerne County, the common water quality problems are as follows:



Corrosive Water
Low pH
Soft Water (low hardness) to Moderate Hardness
Iron and Manganese
Discolored Water – Reddish to Brown Tints
Total Coliform Bacteria
Sulfur Odors and Elevated Sulfates
Methane – Columbia County
Portions Luzerne County

Air Quality Issues – Radon In Air !

Less Common Problems

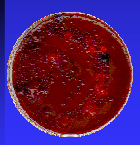
These water quality conditions are not common to groundwater in Columbia and Luzerne County.

Elevated Nitrate- Nitrite Levels
Radiological (Uranium, Alpha Beta, and Radium)
Arsenic (local issues)

Organic Contamination
Elevated Trace Metals
(except corrosion by-products like Copper, Lead, Aluminum, Zinc)

Salty or Brackish Water (very deep wells)
Trihalomethanes
Pathogenic Organisms

Coliform Bacteria



Coliform Bacteria
Absent or < 1 colony/100 ml

Testing Purpose
Used as an Indicator of Sanitary Condition of Water Source

Sources
Natural Soil Bacteria
Human and Animal Waste
Insect Waste

Radon (In Air)- Luzerne County, PA

Luzerne County in the Red Zone –
Suggests indoor air radon levels greater than 4 pCi/L

Zip Code	Number of Tests	Minimum Result pCi/L	Maximum Result pCi/L	Average Result pCi/L
18612	1620	0.1	173	5.1

http://www.dep.state.pa.us/RadiationProtection_Apps/Radon/

Methane in Water

- Methane has been a hidden issue in NEPA. The gas is colorless, tasteless, and odorless and there are no known health effects.
- Potential concerns relate to flammability/ explosiveness of gas.
- The Coal regions and deep wells in northern portion of NEPA, and areas associated with the Mahantango / Marcellus Shale.
- No drinking water limit, but Office of Surface Mines recommends monitoring for concentrations from 10 to < 28 mg/L and immediate action for concentrations > 28 mg/L- I recommend starting this at about 7 mg/L.
- Primary treatment options would include ventilation or aeration systems and potentially changing the electrical and heating system for the home.

Announcement: Free Radon in Air Test Program

The American Lung Association of the Mid Atlantic has obtained a supply of radon test kits from a laboratory certified by the Pennsylvania Department of Environmental Protection.

A limited number of tests are available for each region of PA. To determine the availability of a kit go to

http://www.lunginfo.org/freeradonkit

Enter your zip-code

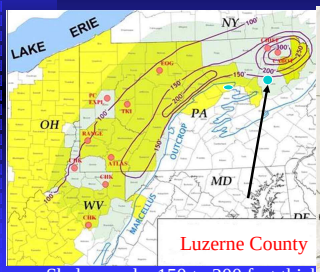
Please allow four to eight weeks for delivery.

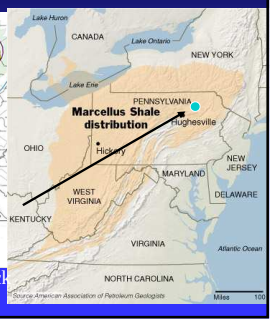
Marcellus Shale Photo

Outcrops Along the Southeastern Border of Pike County Along Route 209

Main Fracture Orientation

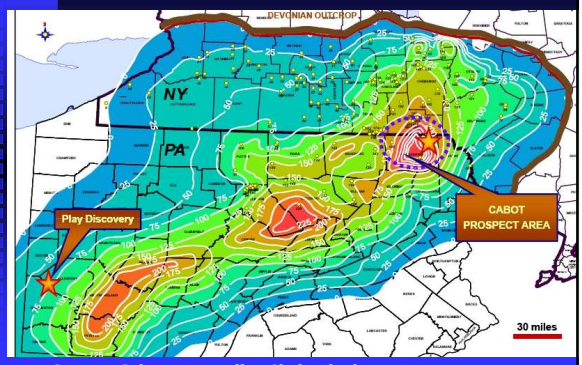
Marcellus Shale- Natural Gas Play 50 to 200 trillion cubic feet





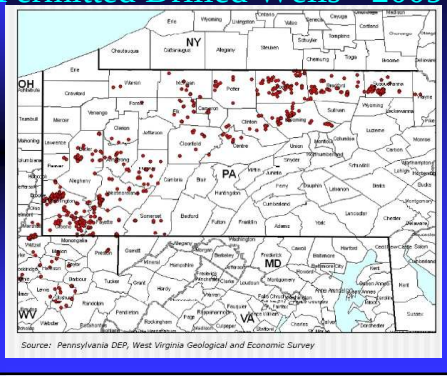
Shale may be 150 to 200 feet thick

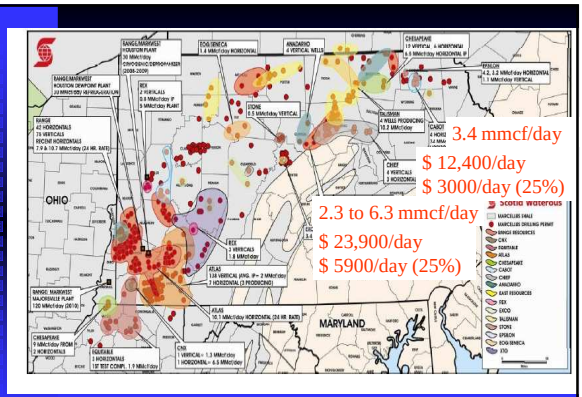
This is why the term – Fairway is being used to describe the play.



Source- Cabot – Marcellus Shale Thickness Map

Permitted Drilled Wells - 2009





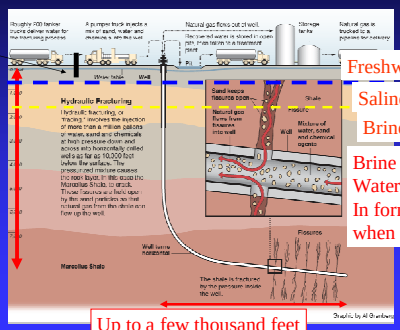
1 ***MMcf*** = 1000 ***MMBtu*** $3.64 per MMBtu

Multiple Cement Casings (i.e. Strings) of Piping Used in Drilling Process (centralizers are critical)

Marcellus Shale Drilling Site

Pads can be 5+ acres – but one pad may support drilling multiple horizontal wells.

Getting to The Natural Gas



Freshwater Well

Freshwater

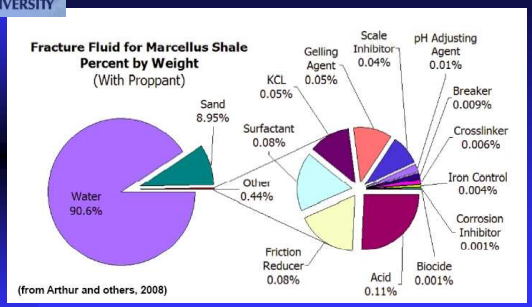
Saline

Brine

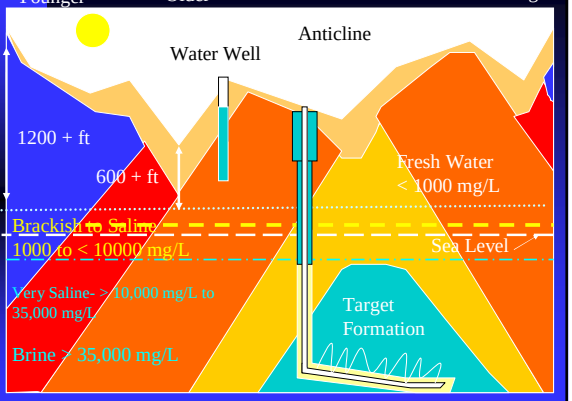
5000 to 7000 feet

Brine / connate Water- Trapped In formation when deposited

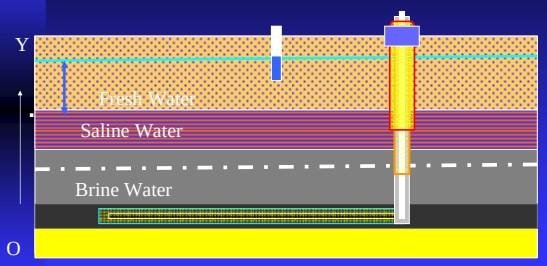
Up to a few thousand feet



Arthur et. al., 2008 – All Consulting – " Natural Gas Wells of the Marcellus Shale". Presented at Groundwater Protection Council 2008 Annual Forum.



General Geology Horizontal Bedding



Use a Multiple Casing Approach

Geology of Appalachian Plateau Provinces

Concerns Related to Marcellus Shale

- Based on Community Location – this could be a major concern or impact.
- In general, the concerns are related to the following:
  - Erosion and Sedimentation
  - Volume of Water Used In Hydrofracturing- 2 to 9 million gallons per well.
  - Loss of Freshwater Aquifer or contamination by brine water and drilling fluids.
  - Drilling fluids may contain environmental contaminations (metals and organics).
  - Impacts to Roadways, Tourism, and Ecology

EPA Tip Line

- EPA's Mid-Atlantic Region has a natural gas drilling tip line for reporting dumping and other illegal or suspicious hauling and/or disposal activities.
- Tip line number (toll free): 1-877-919-4372
- (877-919-4EPA)
  URL:
  http://www.epa.gov/region03/marcellus_shale/tipline.html
  Tip email address: eyesondrilling@epa.gov

Types of Fluids

- Top hole fluids – typically the water from the freshwater aquifer. This water from the first 600 to 800 feet.
- Bottom hole fluids – brine or connate water.
- Stimulation Fluids – fluid used to improve recovery (frac process)
- Production Fluids – water produced along the natural gas release – similar to bottom hole fluid.

Active Marcellus Production Site – Frac Fluid Chemistry

Typically Frac Water is comprised of clean water with a low probably for scale formation, but treated effluents and other sources being evaluated.
The components include:

Friction Reducer – anionic polymer high molecular weight (hold frac sand and other particles)

Wetting Agent- nonionic surfactant – reduce surface tension and improve frac water flowback.

Biocides- control growth or regrowth of microorganisms.

Scale Inhibitor – phosphate based chemicals to inhibit precipitate formation and scale formation.

Available Flowback Water Chemistry

Good Indicators

Parameter	Units	Concentration	Drinking Water Limit	MultipleAbove PWS Standard
Aluminum	mg/L	1.2	0.2	6
Arsenic	mg/L	0.014	0.01	1.4
Barium	**mg/L**	**410**	**2**	**205**
Iron	mg/L	17	0.3	56
Manganese	mg/L	0.89	0.05	17.8
Hardness	mg/L	1750	500	3.5
T. Dissolved Solids	**mg/L**	**31324**	**500**	**62**
Nirate @ N	mg/L	90.1	44	2
pH	su	6.73	6.5 - 8.5	oK
Bromide	**mg/L**	**61.8**	**0.01**	**6180**
Chloride	**mg/L**	**27000**	**250**	**108**
Gross Alpha	pCi/L	223.3	15	15
Gross Beta	mrem/yr (Sr)	38.65	4	10
Radium 228	pCi/L	18.55	5	4
Radium 226	pCi/L	69.63	5	14

Source: http://www.prochemtech.com/

Flowback Water Chemistry

Flowback water is generated from drilling and it is what gets produced from the first 5% of water returned after a well is started

Parameter	Frac 1	Frac 2	Frac 3	Frac 4
barium mg/l	3,310	2,300	7.75	4,300
calcium mg/l	14,100	5,140	683	31,300
iron mg/l	52.5	11.2	211	134.1
magnesium mg/l	938	438	31.2	1,630
manganese mg/l	5.17	1.9	16.2	7.0
strontium mg/l	6,830	1,390	4.96	2,000
dissolved solids mg/l	175,268	69,640	6,220	248,428
suspended solids mg/l	416	48	490	330
chemical oxygen demand mg/l	600	567	1,814	2,272

May contain elevated levels of trace metals, nitrogen, bromide, uranium, and hydrocarbons. Most of the dissolved solids includes chloride and sodium.

Production Water

Produced water is wasted water that accompanies oil extraction and is high in saline. Typically, separated stored on site and then hauled to treatment/disposal facility.

Parameter	Result	Parameter	Result
pH	4.79	conductivity mmhos	366,600
total oil/grease mg/l	9	chemical oxygen demand mg/l	2,332
surfactants mg/l	105.7	barium mg/l	690
calcium mg/l	23,200	iron mg/l	160
magnesium mg/l	2,240	manganese mg/l	10.1
strontium mg/l	732	dissolved solids mg/l	224,300
suspended solids mg/l	33		

May contain elevated levels of trace metals, nitrogen, bromide, uranium, and hydrocarbons. Most of the dissolved solids includes chloride and sodium.

Injection Wells – Class II

Class II wells inject fluids associated with oil and natural gas production. Most of the injected fluid is salt water (brine), which is brought to the surface in the process of producing (extracting) oil and gas.

Regulated by:
EPA - http://www.epa.gov/safewater/uic/wells_class2.html

Does the UIC Program regulate hydraulic fracturing?
Sometimes. The UIC Program regulates the following activities:

- Well injection of fluids into a formation to enhance oil and gas production (Class II wells).
- Fracturing used in connection with Class II and Class V injection wells to "stimulate" (open pore space in a formation).
- Hydraulic fracturing to produce methane from coal beds in Alabama.

Water Testing Recommendations

- Package # 1 – Based on Penn State University Recommendations and Workshops.
- Parameters: total coliform, e. coli, chloride, barium, bromide, pH, strontium, methane/ethane, sodium, and total dissolved solids.
- Estimated Cost w/o Chain-of-Custody and Collection – Approximately $ 200.00 - $ 275.00/sample.
- Very inadequate – This is the minimum!

Water Testing Recommendation

Package # 2- Based on what the PADEP is Recommendations.

- Chloride, T. Hardness, Magnesium, Selenium, Strontium, Iron, Manganese, pH, Sodium, Conductivity, Bromide, Barium, Calcium, Alkalinity, Sulfate, Arsenic, and Total Dissolved Solids
- Oil & Grease, MBAS, and Methane/Ethane.
- Estimated Cost w/o Chain-of-Custody and Collection – Approximately $600.00 - $ 800.00 /sample.
- Missing radiologicals, organics, other trace metals.

Water Testing Recommendation

Package # 3- Based on a combination of what local gas company's are doing as part of their background or baseline analysis, plus added total coliform and pH.

- Alkalinity, pH, Barium, Bromide, Calcium, Chloride, Conductivity, T. Hardness, Iron, Magnesium, Manganese, Oil/Grease, Potassium, Sodium, Sulfate, Total Dissolved Solids, MTBE/VOC's (includes BTEX), Sulfide, MBAS (Surfactants), Total Coliform, pH, Methane/Ethane, Strontium, Selenium, and Total Suspended Solids.
- Estimated Cost w/o Chain-of-Custody and Collection $ 900.00 - $ 1,200.00 per sample
- Problem – Does not include some metals and radiological.

Water Testing Recommendations

Package # 4 Based on Gas Company Background Testing and a review of the chemical analysis of used Frac Water.

- **pH, standard plate count, total coliform, nitrate, nitrite, alkalinity, chloride, bromide, barium, sulfate, color, odor, conductivity, corrosion index, alpha/beta count, T. Hardness, Mercury, trace metals (13 metals- including strontium and lead), acidity**
- **VOC & MTBE, Radium 226/ 228, Total Dissolved Solids, Uranium, Ammonia, Nitrate, Total Kjeldahl Nitrogen, total suspended solids, MBAS, Methane/Ethane , Oil/ Grease, and Sulfide.**
- **Missing Synthetic Organic Compounds and unknowns- SOCs may add over $ 900.00 per sample.**
- **Estimated Cost w/o Chain-of-Custody and Collection**
  - **$ 1850.00 - $ 2200.00 per sample.**

Background Testing and Baseline (Work as a Community !)

- Test wells within at least 1000 feet of proposed well location- May be better to go to 2500 feet.
- Test wells along horizontal testing leg with a minimum of 500 feet radius from horizontal leg.
- Document static water levels, well production capacity, and spring flows
- Post Drilling Testing – within 6 months of completion (May not be needed if testing cycles are staggered).

Groundwater Resource Management and Baseline Testing

Mr. Brian Oram, PG
Professional Geologist, Soil Scientist,
PASEO, Licensed Well Driller
Lab Director, Center for Environmental Quality
Wilkes University
Environmental Engineering and Earth Sciences
Wilkes Barre, PA 18766
http://www.wilkes.edu/water