Game Plan

- Introduction to ALLARM
- Science of Shale Gas
- Monitor Protocol
- Quality Assurance / Quality Control
- Findings
- Questions
- Hands-on Meter Testing
About ALLARM

- Director: Julie Vastine
- Assistant Directors: Jinnie Monismith & Holden Sparacino
- Science Advisor/Founder: Candie Wilderman
- 13 Dickinson College Students
- Program of Dickinson College
- 40% supported by the college, 60% funded by federal, state, family foundation grants
ALLARM History

<table>
<thead>
<tr>
<th>Monitoring Program</th>
<th>Region</th>
<th>Volunteers</th>
<th>Model of C Science</th>
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<tbody>
<tr>
<td>Acid Rain</td>
<td>Statewide</td>
<td>Individuals</td>
<td>Contributory</td>
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<tr>
<td>WatershedTA</td>
<td>Southcentral PA</td>
<td>Groups</td>
<td>Co-created</td>
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<tr>
<td>Shale Gas</td>
<td>Marcellus &amp; Utica</td>
<td>Groups &amp; Individuals</td>
<td>Collaborative</td>
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Empower communities to use scientific tools to monitor, protect, and restore waterways.
ALLARM Areas of Assistance

Scientific
• Study design creation
• Chemical monitoring
• Quality Assurance/ Quality Control
• Biological Monitoring
• Visual assessment
• Data interpretation and communication
• Shale-gas monitoring
• Coming soon: Chesapeake Bay Monitoring

Programmatic
• Strategic planning
• Volunteer recruitment and retention
Depth to Marcellus Shale
Depth to Utica Shale

Utica Shale Depth
- <2000 feet
- 2000 - 4000 feet
- 4000 - 6000 feet
- 6000 - 8000 feet
- 8000 - 10000 feet
- 10000 - 12000 feet
- 12000 - 14000 feet
- 14000+ feet

Highly folded region

Utica Shale depth is an MCOR interpretation based on multiple data sources.
Shale Gas Wells in Region

12,964 Unconventional Wells Drilled

Year Drilled
- 2004-2005 (111 wells)
- 2006-2007 (875 wells)
- 2008-2009 (1,825 wells)
- 2010-2011 (4,190 wells)
- 2012-2013 (3,710 wells)
- 2014-March 31, 2015 (2,253 wells)

Marcellus, Utica, and Upper Devonian Shale Outline
http://marcellus.psu.edu
Unconventional vs. Conventional

Hydraulic Fracturing (Fracking)

Hydraulic fracturing, or “fracking,” involves the injection of more than a million gallons of water, sand and chemicals at high pressure down and across into horizontally drilled wells as far as 10,000 feet below the surface. The pressurized mixture causes the rock layer, in this case the Marcellus Shale, to crack. These fissures are held open by the sand particles so that natural gas from the shale can flow up the well.

This protocol documents flowback pollution and visual observations in small streams.
## Differences in Drilling

<table>
<thead>
<tr>
<th>Traditional Hydrofracking</th>
<th>High Volume Hydrofracking (HVHF)</th>
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<tbody>
<tr>
<td>• Typically 20,000 to 80,000 gallons of fluid were used each time a well was hydrofractured.</td>
<td>• HVHF uses between 2 and 10 million gallons of fluid (on average 5.6 million), the exact amount depends upon the length of the well bore and the number of fractures created along the lateral extent.</td>
</tr>
<tr>
<td>• Traditional hydrofracking used 700 to 2,800 lbs. of chemical additives</td>
<td>• HVHF uses between 205,000 and 935,000 lbs. of chemical additives, per well many of which are toxic to humans and wildlife.</td>
</tr>
<tr>
<td>• 1940s</td>
<td>• Late 1990s</td>
</tr>
</tbody>
</table>

www.TCgasmap.org  Marcellus Accountability Project-Tompkins
Flowback water

Water that returns to surface - it consists of frack water plus chemicals released from underground rock formations.

- Quantity: 10-15% of frack water flows back
- Quality:
  - Brine (salty water) including high concentrations of chlorides, sodium, sulfates: very high TDS
  - Metals, e.g. barium iron, manganese, arsenic, strontium, lead, cadmium, chromium, aluminum
  - Naturally occurring radioactive materials such as uranium, radium, and radon
  - Bacteria
  - Methane
- Pathway to environment: spills, incomplete treatment, well casing leaks, migration through bedrock, illegal dumping
What Do Monitors Test For?

1. **Flowback Monitoring:**
   - **Chemical Parameters**
     - Indicator chemicals
     - Conductivity & TDS
     - Signature Chemicals
       - Barium
       - Strontium
   - **Stage Monitoring**
     - Relationship to conductivity

2. **Physical Impacts**
   - **Visual Observations**:
     - Land disturbances
     - Spills and discharges
     - Gas migration/leakages
     - Pipeline impacts
Goal: Red flag monitoring

- Document violations
- Report to agencies to respond
Why Conductivity and TDS?

• Frack water mixes with natural brine, found in the shale
• Flowback water contains high concentrations of salts and metals

Picture by Amy Bergdale, US EPA
Barium and Strontium

- Naturally-occurring metals found deep underground
- Indicate contamination from Marcellus Shale activities (signature chemicals)

https://www.msu.edu/~zeluffjo/periodic_table.gif
Stage Monitoring
Visual Assessment

- Earth Disturbances
- Spills and Discharges
- Gas Migration/Leakages
- Pipelines

Marcellus Shale Well Sites in Dimock, PA; 2010
Earth Disturbances

Photo courtesy of PA Council of Trout Unlimited

http://www.postcarbon.org/reports/shale-gas-well.jpg
Spills and Discharges

Drilling fluid spill at Cabot site
Dimock, PA
September 2009
Gas Migration or Leakages
Pipeline Erosion & Sedimentation
Dickinson students, faculty, and staff helped test conductivity/TDS meters to determine which meter is most accurate, precise, and easy to use.
Tailoring the ALLARM Protocol

Well Location Information
Establish where wells are located and where they will be located.

Laboratory Testing
Find an entity who is willing to perform QA/QC checks (conductivity & TDS) and barium & strontium analysis (signature chemicals).

Agency Reporting
Determine which agency you to report violations (multiple) & understand how they will respond.
Well Location Information

- State agency
- Non-profit entity

Develop a protocol for monitors to find/track well locations and status.
Laboratory Testing

- State agencies
- State-certified labs
- Colleges/universities

Develop an agreement and create a protocol for monitors to follow.
Agency Reporting

- Local, state & federal agencies
- Interested parties

Develop a decision tree and a contact list for monitors to use if they witness a violation.
Data Use: Decision Trees

Chemical Monitoring
* Visual Assessment
* Pipelines

Report monitoring information when values exceed criteria in decision trees

Chemical Monitoring Decision Tree

Baseline Data Available
- Is conductivity 3x baseline conductivity at comparable flow?
  - YES
    - Collect a sample at the stream for certified lab analysis of barium and strontium.
  - NO
    - Is conductivity >3x the previous week conductivity or 2x upstream conductivity?
      - YES
        - CONTACT:
          * PA DEP Regional Office
          * PA Fish and Boat Commission
          * EPA Region 3 Pipeline
          * County Conservation District
          * Local Community/Environmental Group
          * Facility Owner/Operator
      - NO

ALLARM’s QA/QC Program has led to:
1. Agreement with PA DEP to prioritize calls from volunteers with information about a suspected pollution event
2. EPA approved Quality Assurance Project Plan (QAPP)

• Training provided:
  ▪ Care for equipment
  ▪ Calibrate equipment
  ▪ Collect and test a water sample
• Documented procedures
• Replicates
• Split sample analysis (twice/year)
• Monitors send samples to ALLARM twice a year.
• Samples are analyzed by ALLARM for conductivity and total dissolved solids.
• Monitor’s results are compared to ALLARM’s results for precision.
Data collected 2010 – 2013

Dataset was reduced
• Monitoring frequency
• QA/QC

Conductivity values compared to watershed characteristics
• Watershed size
• Geology
• Land cover
• Number/density of wells in watershed
Most of the monitoring sites were in small, headwater streams.
• 58% of the watersheds were less than 10 square miles.
• 88% of the watersheds had a drainage area of less than 50 square miles.

Watershed size did not influence conductivity values.
For the purpose of the analysis, the geology was categorized as:

<table>
<thead>
<tr>
<th>Geology Type</th>
<th>Predominant Geology of all Watersheds</th>
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<tbody>
<tr>
<td>Shale</td>
<td>49%</td>
</tr>
<tr>
<td>Sandstone</td>
<td>46%</td>
</tr>
<tr>
<td>Limestone</td>
<td>5%</td>
</tr>
<tr>
<td>Igneous &amp; Metamorphic</td>
<td>0%</td>
</tr>
</tbody>
</table>

There was a strong relationship between conductivity and the percent limestone in the watershed.
Most of the watersheds were predominately in forested areas (101 of 116).

Sites with the highest average conductivity values (1245 – 1647 µS/cm) were generally found in developed areas. The eight urban sites also had a large amount of limestone in the watershed.
Drilled Wells

Only 23 (of 116) sites were downstream from a shale gas well.

The number of wells drilled in each watershed ranged from 1 – 475, although only two watersheds had more than 12 shale gas wells.

Conductivity was not influenced by the number of wells or the density of wells in the watershed.
Conclusions

Average conductivity values in streams were related to the amount of **land development** (urban area) and **limestone** (geology) in the watershed. It is not significantly related to the size of the watershed or the number/density of drilled wells (although only 23/116 watersheds had wells drilled at the time of sampling).

The ALLARM Shale Gas Volunteer Monitoring Program has demonstrated the value of a large volunteer-collected dataset in detecting patterns related to watershed characteristics. The dataset shows similar patterns to data reported in the scientific literature.
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Toolkit: blogs.dickinson.edu/marcellusmonitoring/
Social Media: @allarmwater facebook.com/allarmwater
Hands-on Activity

Monitor Equipment:

1. LaMotte Tracer PockeTester and calibration solution vial
2. 84 µS/cm & 1413 µS/cm standard calibration solution
3. Distilled water wash bottle
4. Stream testing bottle
5. 3 sample bottles
   - Two sample bottles for QA/QC
   - One bottle for pollution event Ba and Sr analysis
6. Gage Stick