The EFD Program

Addressing Environmental Issues and Increasing Environmental Awareness

Shale Development 101

June 10, 2014
Discussion

- Environmentally Friendly Drilling Systems Program (EFD: www.efdsystems.org)
- Shale?
- Well Construction
- Hydraulic Fracturing
- Gas Processing
- Environmental Concerns
EFD Program

A collaborative effort

Industry
Academia
Government
Environmental Organizations

Team Formed in 2005

Mission
Provide unbiased science to identify, develop and transfer critical, cost effective technologies that provide policy makers and industry with ability to develop reserves safely and environmentally friendly.

What We Do
Produce Enabling Data, Best Practices and Information to operators, regulators and stakeholders.
The EFD Team

Co-funded by RPSEA, US Fish and Wildlife, Industry, Environmental Organizations

Thank-you for your support!
All Areas are Environmentally Sensitive

• The value of oil and gas resources are increasing.
• The value of protecting the environment is becoming more important.
• The public’s interest in energy development is becoming more and more significant.
• The O&G Industry must engage the public in a more significant way.

Identify and develop technologies to get access with minimal impact. Determine how to measure the effect of low impact practices.
What is Shale?
Shale Gas
Chestnut Ridge Park, NY
How Much Gas is There?

Source: U.S. Energy Information Administration, Annual Energy Outlook 2013 Early Release
Environmental Issues

Fort Beeler Facility Next to a Drilling Location
(from www.marellus-shale.us/MARCELLUS)
Well Construction
From the Past
(single wells at multiple sites)

To the Present
(multiple wells at single sites)
Modern Pads Have Low Environmental Impact
Drilling from Pads

Pad size about 2ha or 140 x 140 m
Ground Water Protection

Required: Defining best practices in casing and cementing

Fresh Water Municipal Well
Less Than 1,000 feet

Approximately 8,000 feet
To Shale

Multiple Layers of Casing and Cement
Intended to Isolate Drinking Water from Completion and Production Fluids

Graphic Courtesy of Texas Oil and Gas Association
Environmental Friendly Drilling (EFD)
Zero Harmful Emissions – Size Reduction

EFD addresses:
• New low-impact technologies that reduce the footprint of drilling activities
• Light weight drilling rigs with reduced emission engine packages
• On-site waste management

22 modules (ISO container) footprint 50x200 ft 400 tons hook load

Rig concept (Source: AADE-11-NTCE-61)
Environmental Friendly Drilling Rig
“Green” drilling is more than drilling

• Get in, drill and get out as fast as possible with minimal disturbance to the land

• Protect surface and ground water

• Access roads

• Pad Drilling

• Reduce traffic, dust, noise, emissions, excessive lights that disturb nearby residences

• Aesthetics
Hydraulic Fracturing
Hydraulic Fracturing History

More than 1 million wells hydraulically fractured

As shown in this historic photograph, the first hydraulic fracture treatment was performed by Halliburton under license to Stanolind Oil Company on March 17, 1949, east of Duncan, Ok. Hydraulic fracturing has since allowed commercial hydrocarbon recovery from more than 1 million wells that could not have produced economically, and that number grows by the day with nearly every U.S. gas well and the majority of all U.S. oil wells now being hydraulically fractured.
What is Hydraulic Fracturing?

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.
Hydraulic Fracturing in South Texas

A well head at a fracturing operation near Carrizo Springs, TX
Source: SA Express News
Chesapeake Energy
Hydraulic Fracturing Operation
Eagle Ford Shale near Carrizo Springs

Source: San Antonio Express News
The Controversy
Groundwater contamination from additives in fracture fluids

- Fracturing fluids contain 90% water, 9.5% sand or other particles, and less than 1% additives
- All additives are used in common household products. Exposure not unique to fracturing chemicals
## What is Really Pumped?

<table>
<thead>
<tr>
<th>Product Category</th>
<th>Main Ingredient</th>
<th>Purpose</th>
<th>Other Common Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>99.5% water &amp; sand</td>
<td>Expand fracture and deliver sand</td>
<td>Landscaping and manufacturing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Allows the fractures to remain open so the gas can escape</td>
<td>Drinking water filtration, play sand, concrete and brick mortar</td>
</tr>
<tr>
<td>Other</td>
<td>approximately 0.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid</td>
<td>Hydrochloric acid or muriatic acid</td>
<td>Helps dissolve minerals and initiate cracks in the rock</td>
<td>Swimming pool chemical and cleaner</td>
</tr>
<tr>
<td>Antibacterial agent</td>
<td>Glutaraldehyde</td>
<td>Eliminates bacteria in the water that produces corrosive by-products</td>
<td>Disinfectant; Sterilizer for medical and dental equipment</td>
</tr>
<tr>
<td>Breaker</td>
<td>Ammonium persulfate</td>
<td>Allows a delayed break down of the gel</td>
<td>Used in hair coloring, as a disinfectant, and in the manufacture of common household plastics</td>
</tr>
<tr>
<td>Corrosion inhibitor</td>
<td>n,n-dimethyl formamide</td>
<td>Prevents the corrosion of the pipe</td>
<td>Used in pharmaceuticals, acrylic fibers and plastics</td>
</tr>
<tr>
<td>Crosslinker</td>
<td>Borate salts</td>
<td>Maintains fluid viscosity as temperature increases</td>
<td>Used in laundry detergents, hand soaps and cosmetics</td>
</tr>
<tr>
<td>Friction reducer</td>
<td>Petroleum distillate</td>
<td>&quot;Slicks&quot; the water to minimize friction</td>
<td>Used in cosmetics including hair, make-up, nail and skin products</td>
</tr>
<tr>
<td>Gel</td>
<td>Guar gum or hydroxyethyl cellulose</td>
<td>Thickens the water in order to suspend the sand</td>
<td>Thicken used in cosmetics, baked goods, ice cream, toothpaste, sauces and salad dressings</td>
</tr>
<tr>
<td>Iron control</td>
<td>Citric acid</td>
<td>Prevents precipitation of metal oxides</td>
<td>Food additive; food and beverages; lemon juice ~7% citric acid</td>
</tr>
<tr>
<td>Clay stabilizer</td>
<td>Potassium chloride</td>
<td>Creates a brine carrier fluid</td>
<td>Used in low-sodium table salt substitute, medicines and IV fluids</td>
</tr>
<tr>
<td>pH adjusting agent</td>
<td>Sodium or potassium carbonate</td>
<td>Maintains the effectiveness of other components, such as crosslinkers</td>
<td>Used in laundry detergents, soap, water softener and dishwasher detergents</td>
</tr>
<tr>
<td>Scale inhibitor</td>
<td>Ethylene glycol</td>
<td>Prevents scale deposits in the pipe</td>
<td>Used in household cleansers, de-icer, paints and caulk</td>
</tr>
<tr>
<td>Surfactant</td>
<td>Isopropanol</td>
<td>Used to increase the viscosity of the fracture fluid</td>
<td>Used in glass cleaner, multi-surface cleansers, antiperspirant, deodorants and hair color</td>
</tr>
</tbody>
</table>
Green Hydraulic Fracturing Program

- Program instituted by Chesapeake Energy in 2009
- Researching additives to:
  - Find which are unnecessary
  - Find which are necessary, but harmful
  - Find more environmentally friendly replacements for harmful additives

An employee of Chesapeake Energy pours a chemical mixture called cross linked gel that is mixed with sand and used in the hydraulic fracturing process

Source: SA Express News
Developed/managed by GWPC

Provide Transparency

Protect Groundwater

Engage Public

  – Explain hydraulic fracturing process
  – Provide well information

Hydraulic Fracturing Chemical Registry

www.fracfocus.org
How much water needed?

• A multi-stage fracturing of a single horizontal shale gas well can use several million gallons of water.

• Most water used in hydraulic fracturing comes from surface water sources such as lakes, rivers and municipal supplies.
Water Sourcing

Source: ALL Consulting, 2008

Lined Fresh Water Supply Pit from the Marcellus Shale Development in Pennsylvania
HYDRAULIC FRACTURING - ITS GROWTH AND RISKS

THE PROCESS
Hydraulic fracturing is the creation of fractures in rock formations in the earth using pressurised fluid, generally for the purpose of extracting natural gas.

Common Fracturing Equipment
- Data monitoring van
- Chemical storage trucks
- Wellhead
- Frac tanks - stimulation fluid storage
- Frac pumps
- Sand storage units
- Frac blender

RISKS
- Air emissions
  Methane gas associated with natural gas extraction can leak into air
- Drinking water
  Chemicals used in fracturing process have the potential to contaminate aquifers
- Earthquakes
  The disposal of waste fluid from the fracturing process is cited as a cause of earthquakes. Disposed fluids migrate below the injection area, destabilising the natural fractures in the rock formation.

Horizontal Drilling
1. Well drilled horizontally at 914-1,524 m
2. Production casing inserted into borehole, then surrounded with cement
3. Charges then detonated inside a perforating gun, blasting small holes into the shale
4. Pressurised mixture of water, sand and chemicals then pumped into the well at 15,900 litres a minute
5. The fluid generates numerous small fissures in the shale, freeing trapped gas that flows to the surface

Illustration not to scale
Gas Processing

Reports indicate that a shortage of processing capacity in the northeast may be a bottleneck in the continuing development of the Marcellus shale.
Gas Gathering Lines

12” Gas Gathering Lines (25.03 miles)
8” Condensate Gathering Line (25.03 miles)
14 POD’s with 68 wells producing into the CGP
Commissioned
Gas Train November 17, 2010
Condensate Train December 18, 2010
Environmental Risks
Potential Environmental Issues of Shale Gas Development

- Drill Pad Construction and Operation
- **Groundwater Contamination** *(most controversial issue)*
- Hydraulic Fracturing and Flowback Water Management *(another controversial issue)*
- Blowouts/Explosions
- Water Consumption and Supply
- Spill Management and Surface Water Protection
- Small earthquakes from injecting wastewaters in deep underground reservoirs

![Diagram of shale gas development with potential environmental issues labeled]
Fractures are necessary for hydrocarbons to flow from the tight shale formations.

Fractures are typically thousands of feet below water table.

They extend only hundreds of feet at most in any given direction.
Risks to Groundwater

• Primary risk for contamination of groundwater is compromise of mechanical integrity of well

• Contamination of ground water with flow back water resulting from well design very unlikely due to long distances and natural barriers between the reservoirs and the ground water zones.

• Contamination of ground water with shale gas resulting from well design or leaking faults is more likely to happen.
Mitigating Risks to Groundwater

- Leaky well design can be repaired, the risk for leaking faults can be minimized by fracture monitoring during the job and by designing a proper job based on best knowledge about the subsurface geology.

- Monitoring ground water quality is required prior and after a fracturing job.
MIT Study (2011) on Shale Gas Accidents in the US

All reported US cases from 2000-2010

Source 1

Source 2
Hydraulic Fracturing: Preliminary Analysis of Recently Reported Contamination; September 2009; Prepared for: Drinking Water Protection Division (DWPD) Office of Ground Water and Drinking Water (OGWDW) U.S. Environmental Protection Agency (EPA); Prepared by The Cadmus Group Inc.

Source 3
Fractured Communities — Case Studies of the Environmental Impacts of Industrial Gas Drilling; September 2010; Craig Michaels, Program Director; James L. Simpson, Senior Attorney; William Wegner, Staff Scientist; Watershed

<table>
<thead>
<tr>
<th>Type of incident</th>
<th>Number reported</th>
<th>Fraction of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater contamination by natural gas</td>
<td>20</td>
<td>47%</td>
</tr>
<tr>
<td>On-site surface spills</td>
<td>14</td>
<td>33%</td>
</tr>
<tr>
<td>Off-site disposal issues</td>
<td>4</td>
<td>9%</td>
</tr>
<tr>
<td>Water withdrawal issues</td>
<td>2</td>
<td>4%</td>
</tr>
<tr>
<td>Air quality</td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td>Blowouts</td>
<td>2</td>
<td>4%</td>
</tr>
</tbody>
</table>

40,000+ shale gas wells drilled in the US during this period
Working to Reduce Impacts

For more Info see:

www.oilandgasbmmps.org
www.strongerinc.org/p
www.efdsystems.org
www.fracfocus.org
www.lawatlas.org/oilandgas
What to take home

- The USA has an abundant supply of natural gas.

- Gas shales are ubiquitous across the USA.

- Hydraulic fracturing is required to produce the gas from shales and other low permeability rock.

- Safety & environmental awareness are important.
It’s not so hard to be green

Questions?

Thank you

www.efdsystems.org
www.efdvirtualsite.org
www.facebook.com/EFDSystems