Modeling *versus* The Real World Of Hydraulic Fracturing

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Objectives

- Overview of potential migration pathways
- Identify and discuss key fate and transport (F&T) modeling parameters
- Review available data for key F&T parameters
- Identify data gaps and discuss implications for EPA study
Potential HF Related Migration Pathways

- Surface releases of HF and flowback fluids
  - Migration to groundwater
  - Migration to surface water

- Subsurface migration of HF additives (upward migration) to drinking water aquifers
  - Migration from the target zone
Sensitive F&T Model Parameters

- Key model “source” characterization information for surface release simulations
  - Spill volume
  - Spill area
  - Chemical constituents/concentrations in spilled fluid

- Source characterization considerations for migration from bedrock (upward migration)
  - Fraction of trapped HF fluid/flowback (e.g., 9 to 35% in Marcellus shale, 68 to 82% in CBM)
  - Geochemistry of brine and HF additives in target formation
Sensitive F&T Model Parameters

- **Surface Releases:** Key parameters that typically control transport downgradient from source area
  - Hydraulic conductivity of soils and aquifers
  - Direction and magnitude of hydraulic gradient relative to drinking water well locations
  - Biodegradation of organic chemicals
  - Adsorption

- **Upward Migration:** Factors that control potential vertical migration of subsurface fluids
  - Direction and magnitude of natural head gradient
  - Bedrock stratigraphy and hydraulic properties
  - Distance between HF induced fractures and drinking water units
  - Strength of attenuation processes
Sensitive F&T Model Parameters (cont)

- Key sensitive F&T parameters can be grouped into four general categories:
  - Source chemical characterization
  - Surface release
  - Upward migration
  - Hydrogeological and attenuation processes

- Available data, gaps, and modeling challenges for each of these categories are discussed as follows
Source Chemical Characterization

- **HF additives**
  - Halliburton and other service companies have provided EPA-requested data
  - EPA should be able to use this information to assess F&T characteristics of HF fluids

- **Flowback characterization**
  - Data for Marcellus shale is being continually generated (e.g., Hayes, 2009; NYSDEC, 2009; The Palmerton Group, 2011), other formations are also being analyzed

- EPA should identify key marker HF-related compounds for F&T evaluation
  - HF additives vary by job and formation
  - Appropriate to identify group of marker compounds
# Flowback Quality Variability

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<th>#2</th>
<th>#3</th>
<th>#4</th>
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Surface Releases

- Understanding “actual” spill characteristics critical for evaluating release significance and F&T modeling
  - E.g., spill volume, area, location

- Spill databases maintained by various states (e.g., PA, CO, WV)
  - Data are difficult to extract (by public) to perform meaningful statistical analysis
  - If EPA has access, would be useful to characterize the size and frequency of spills associated with HF stimulations
# Data Collected As Part of Spill Response Measures

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<tr>
<th>Measurement Type</th>
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<th>WV</th>
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<td>Nature of spill</td>
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<td></td>
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<td>Volume or flow rate of spill</td>
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<td>Chemical analysis/identity/kind of spilled fluid</td>
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<td></td>
<td></td>
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<tr>
<td>Area and vertical extent of spill</td>
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<td></td>
</tr>
<tr>
<td>Distance to nearest surface water, water wells, groundwater</td>
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- **States Reporting Requirements**
- Unclear, but may include this information
- Spill volume is required for brine spills, but unclear for other spills
- Required
Number of Oil and Gas Well Permits For Wells Drilled Directionally From Common Well Pads in Colorado
03-07-11

Figure from the COGCC website, Weekly & Monthly Oil & Gas Statistics
## COGIS - Inspection/Incident Inquiry

You requested: Spill/Release Information

Maximum records are limited to 10

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<th>Submit Date</th>
<th>Doc.#</th>
<th>Complainant #</th>
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Link to more detailed info
Description of Spill:

Date of Incident: 11/16/2010
Type of Facility: WELL
Well Name/No.: RIGBY A-2AX
Fac. Name/No.: RIO BLANCO
County Name: RIO BLANCO
Section: 24
Township: 2N
Range: 103W
Meridian: 6

Volumes spilled and recovered (bbls):

- Oil spilled: 0
- Water spilled: 21
- Other spilled: 0

- Recovered: 0
- Recovered: 20

Area and vertical extent of spill: 277 FT X 2-1N

Current Landuse: NON DROP LAND
Weather conditions: DRY WITH MODERATE CLOUDY

Soil/Geology description: SILTY CLAY

Immediate Response:
The line was isolated immediately upon detection. Vacuum trucks removed all of the free fluid. Estimated recovery is ~20 bbls of brine water. The fluids were picked up by vacuum truck and recycled at the truck unloading facility at the main water plant.

Emergency Plugs:
NA

How extent determined:
Visual inspection, Chevron HCA Spill Calculation Worksheet.

Further Remediation:

Prevent Problem:
The piping will be replaced and the line returned to service.

Detailed Description:
A leak occurred in a three inch cement lined steel pipe ~200 feet south of Rigby A-2AX wellhead. The cause of the leak was internal corrosion in the pipe body. There was no impact to surface water. The spill potentially contained a trace of crude oil, but there was no visible sheen. Time required for control of event: ~10 minutes.
Upward Migration

- Data collected at the time of well installation and stimulation
  - Could be used to perform screening level analysis to assess migration potential to drinking water aquifers
- Modeling of field conditions impracticable
  - Not aware of any standard models that can simulate transport processes
  - Data requirements to develop/calibrate a model make this unrealistic
- Migration of “stray gas” also common issue
  - Understanding F&T and modeling a challenge
# Data Currently Reported During Well Installation and Stimulation

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<th>PA</th>
<th>WV</th>
</tr>
</thead>
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<td>Depth interval of freshwater aquifers</td>
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<tr>
<td>Depth of target formation</td>
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<tr>
<td>Casing/wellbore size, type, and depth</td>
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<td>Electrical, radioactive or other geophysical logging</td>
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<td>Core/drill cutting analyses/logs</td>
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<tr>
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<td>Flowback chemical analysis</td>
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<tr>
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<td>b</td>
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Notes:

- a) Colorado requires chemical analysis of the injected fluid.
- b) Pennsylvania requires operators to list the chemicals or additives used.
Link to diagram of wellbore
Link to reports and permit docs
Casing and cement data
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<td>D SANO</td>
<td>6775</td>
<td>6706</td>
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<td>J SAND</td>
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<td>6810</td>
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</table>

**Completed information for formation JSND**

- **1st Production Date:** 3/10/2006
- **Status Date:** 11/16/2005
- **Commingled:** N
- **Formation Name:** J SAND
- **Formation Treatment:** FRAC 5H2O@OF 2040 SAND
- **Tubing Size:** 2.375
- **Tubing Packer Depth:** 6845
- **Open Hole Top:** Initial Test Data
- **Initial Test Data:** 11/18/2008
- **Test Method:** FLOWING
- **Gas Disposal:**
  - **Test Type:** Measure
  - **BBLS H2O:** 3
  - **BBLS OIL:** 1
  - **BTU GAS:** 1130
  - **CALC GOR:** 100000
  - **CASING PRESS:** 1200
  - **GRAVITY OIL:** 60
  - **MCP GAS:** 100
  - **TUBING PRESS:** 950
- **Perforation Data:**
  - **Interval Bottom:** 8850
  - **Interval Top:** 6954
  - **# of Holes:** 16
  - **Hole Diameter:** 0.36
Induced Fracture Data

Figure from Fisher, K. 2010.
Induced Fracture Data

Figure from Fisher, K. 2010.
Stray Gas Migration

- Migration of natural stray methane to drinking water aquifers a common issue – no correlation with fracking
- Old improperly abandoned wells are typically the cause
  - Serve as preferential migration pathway
  - EPA’s 2004 study found this to be a significant mechanism in investigated case studies
- Understanding communication of such wells to stray gas reservoirs and drinking water aquifers is difficult
  - No standard tests available for measuring such communication
  - Case-by-case analysis needed
- Credible modeling of such scenarios likely not possible
- Proper abandonment is the key to the solution
Hydrogeological & Attenuation Processes

- Hydrogeological and attenuation data (e.g., hydraulic gradient, conductivity) typically not collected as part of HF jobs
- However, extensive data available in the literature for F&T analyses, especially for surface releases
- Attenuation process expected to have a significant influence on HF additives F&T in shales
  - High organic carbon resulting in high retardation
  - Biodegradation expected to be significant due to long travel times
  - Nonetheless, modeling of such processes will be challenging
Overall Implications for EPA Study

- Key data required for F&T evaluations are available
  - E.g., spill databases, gas well construction details
  - Data will provide perspective on relatively low frequency and magnitude of spill incidents, distance to drinking water aquifers
  - Some gaps exist, but can be addressed by using literature values/limited data collection

- HF fluid composition data and flowback characterization data are also available
  - Additive information provided by Halliburton and others
  - Flowback data are being continually generated

- EPA should utilize all data and assess human health risks associated with drinking water
  - EPA study draft places significant emphasis on case studies
  - Unclear how broad conclusions will be drawn on the basis of a few case studies
  - EPA should instead conduct a human health risk assessment that utilizes all available information including that from case studies
References


