Water Availability and Management in Shale Gas Operations

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Acknowledgments

- DOE- Office of Fossil Energy
- DOE – Office of Policy and International Affairs
- NETL- Strategic Center for Natural Gas and Oil
- RPSEA (Research Partnership to Secure Energy for America)
  - Environmentally Friendly Drilling Program
Topics for Discussion

- Background on shale gas
- Water issues
  - Water supply needs
  - Hydraulic fracturing
  - Wastewater management
- Statistics on water requirements
Importance of Shale Gas

Source: DOE/EIA Annual Energy Outlook 2010 (EIA 2010). Note that Tcf refers to trillion cubic feet.
Shale Gas Plays

- The most active U.S. shale plays to date are:
  - the Barnett Shale,
  - the Fayetteville Shale in Arkansas,
  - the Antrim Shale in Michigan,
  - the Haynesville Shale in Louisiana,
  - the Marcellus Shale in Pennsylvania, New York, and West Virginia, and
  - the Woodford Shale in Oklahoma

- Two important Canadian shale plays:
  - the Horn River Shale in British Columbia, and
  - the Montney Shale in British Columbia and Alberta

Source: DOE/EIA website
### Steps in the Shale Gas Process

- Steps involving water are shaded

<table>
<thead>
<tr>
<th>Steps in the Shale Gas Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaining Access to the Gas (Leasing)</td>
</tr>
<tr>
<td>Searching for Natural Gas</td>
</tr>
<tr>
<td>Preparing a Site</td>
</tr>
<tr>
<td>Drilling the Well</td>
</tr>
<tr>
<td>Preparing a Well for Production (Hydraulic Fracturing)</td>
</tr>
<tr>
<td>Gas Production and Water Management</td>
</tr>
<tr>
<td>Moving Natural Gas to Market</td>
</tr>
<tr>
<td>Well Closure and Reclamation</td>
</tr>
</tbody>
</table>
Water Issues in Site Preparation

- Need to consider stormwater runoff from all land areas disturbed during construction
  - Follow proper sediment control practices
  - Stabilize exposed surfaces
Water Issues in Drilling

- Water is needed to make up drilling fluids
  - Ranges from 1 MG in the Haynesville Shale to 60,000 gallons in the Fayetteville Shale
  - Depends on the types of drilling fluids used and the depth and horizontal extent of the wells
  - The Marcellus Shale drilling volume falls near the lower end of this range at 80,000 gallons per well.

- Disposal of liquid components of drilling waste pits
Water Needed for Frac Jobs

- A single well may require 1 to 5 million gallons
  - Individual volume is not critical, but collectively can be important within a region

- Source of water:
  - Stream, river, or lake
  - Well
  - Impoundment created by producer
  - Public water supply

- Piped to site vs. delivery in tank trucks
Water Handling Onsite
Hydraulic Fracturing (Frac Job) Is Equipment-Intensive
Management of Frac Flowback Water (1)

- Large volume of flowback returns to the surface in first few hours to few days
  - Typically collect in pits/ponds
- Over time, smaller volume returns
  - Collect in tank
Management of Frac Flowback Water (2)

- Collected water must be removed from site
- Typically is collected by tank trucks and hauled offsite to:
  - Commercial disposal wells
  - Wastewater treatment plants
  - Treatment and reuse facilities
- Producers may install their own injection wells or reuse the flowback water
Natural Gas Wastewater Management Facilities in Pennsylvania

- PA DEP maintains a list of wastewater management facilities.
- As of June 2010, 27 commercial wastewater treatment facilities are permitted by the PADEP to treat flowback and produced water and then discharge the treated water to surface water bodies.
  - Some are in-house facilities, others accept outside wastewater
- 4 other commercial facilities treat the water and then discharge it to municipal sewers that flow to POTWs.
- The PADEP list also includes 25 other commercial wastewater treatment facilities that have applied for permits but have not yet received permission to operate and discharge
Commercial Disposal Sites in Pennsylvania Visited by Author in May 2010

- Facilities provide treatment for pH and metals but do not treat TDS
  - Eureka Resources installed additional thermal distillation units in June 2010
- Existing facilities grandfathered under new PA rules
  - New facilities will need to meet limit of 500 mg/L TDS

1. Eureka Resources
2. Pennsylvania Brine – Franklin
3. Tunnelton Liquids
4. Hart Resource Technologies
Ohio Counties with Commercial Disposal Wells

- In most shale gas plays, wastewater is disposed of through injection wells
- Marcellus region has very few permitted wells
- Some operators haul wastewater to Ohio
Statistics on Water Requirements for Marcellus Shale

- Make estimate of maximum volume of water needed to meet Marcellus Shale fraccing needs
  - Estimate volume of water per well
  - Estimate maximum number of wells in a year
Pennsylvania Drilling Permits and Wells Drilled

<table>
<thead>
<tr>
<th>Year</th>
<th>Marcellus Shale Drilling Permits Issued</th>
<th>Marcellus Shale Wells Drilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>99</td>
<td>18 (July – December)</td>
</tr>
<tr>
<td>2008</td>
<td>519</td>
<td>196</td>
</tr>
<tr>
<td>2009</td>
<td>1,985</td>
<td>763</td>
</tr>
<tr>
<td>2010</td>
<td>1,398 (January – June)</td>
<td>564 (January - June)</td>
</tr>
</tbody>
</table>

- the number of wells actually drilled during the first six months of 2010 can be doubled to estimate a full year (1,128).
- The ratio of 2010 extrapolated drilled wells to 2009 drilled wells (1,128 to 763) = 1.48.
- Assuming the same 48% increase over the 2010 estimate for future growth, a hypothetical maximum is $1,128 \times 1.48 = 1,669$ wells.
# West Virginia Drilling Permits and Wells Drilled

<table>
<thead>
<tr>
<th>Year</th>
<th>Marcellus Shale Drilling Permits Issued</th>
<th>Marcellus Shale Wells Drilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>152</td>
<td>143</td>
</tr>
<tr>
<td>2008</td>
<td>400</td>
<td>274</td>
</tr>
<tr>
<td>2009</td>
<td>424</td>
<td>47</td>
</tr>
<tr>
<td>2010</td>
<td>176 (January – June)</td>
<td>1 (January – June)</td>
</tr>
</tbody>
</table>

Source: WV DEP website

- The ratio of drilled wells to drilling permits was 95% in 2007 and 69% in 2008.
- Applying the 2008 ratio to the total number of drilling permits in 2009 (0.69 x 424) gives an estimated hypothetical maximum of **293 wells**.
New York Drilling Permits and Wells Drilled

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Drilling Permits Issued (not necessarily Marcellus Shale)</th>
<th>Total Wells Drilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>744</td>
<td>??</td>
</tr>
<tr>
<td>2009</td>
<td>552</td>
<td>??</td>
</tr>
<tr>
<td>2010</td>
<td>302 (January – August)</td>
<td>??</td>
</tr>
</tbody>
</table>

Source: presentation made by Jack Dahl, NY DEC, August 24, 2010

- New York has moratorium on Marcellus Shale wells
- No good way to predict maximum number of wells
- Chose to estimate maximum New York wells to be the same as maximum West Virginia wells = 293
## Hypothetical Maximum Water Demand for Marcellus

<table>
<thead>
<tr>
<th>State</th>
<th>Hypothetical Maximum Number of Wells Drilled in a Year</th>
<th>Annual Volume under Scenario 1: 1 MG of water needed per well</th>
<th>Annual Volume under Scenario 2: 2.8 MG of water needed per well</th>
<th>Annual Volume under Scenario 3: 3.9 MG of water needed per well</th>
<th>Annual Volume under Scenario 4: 5 MG of water needed per well</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA</td>
<td>1,669</td>
<td>1,669 MG</td>
<td>4,673 MG</td>
<td>6,509 MG</td>
<td>8,345 MG</td>
</tr>
<tr>
<td>WV</td>
<td>293</td>
<td>293 MG</td>
<td>820 MG</td>
<td>1,142 MG</td>
<td>1,465 MG</td>
</tr>
<tr>
<td>NY</td>
<td>293</td>
<td>293 MG</td>
<td>820 MG</td>
<td>1,142 MG</td>
<td>1,465 MG</td>
</tr>
<tr>
<td>Total</td>
<td>2,255</td>
<td>2,255 MG</td>
<td>6,314 MG</td>
<td>8,795 MG</td>
<td>11,275 MG</td>
</tr>
</tbody>
</table>

### Caveats

- estimates of maximum wells drilled could significantly overestimate or underestimate the actual quantity
- assumed maximum number in one state will not necessarily correspond to the maximum in each of the other states
- As gas companies refine and improve their efforts to recycle and reuse flowback and produced water from wells already fracced, the water needed per well may decrease
- if operators drill longer horizontal wells with more frac stages, the volume per well could increase
# Actual Water Withdrawals for 2005 (in MGD)

<table>
<thead>
<tr>
<th>Category</th>
<th>New York</th>
<th>Pennsylvania</th>
<th>West Virginia</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public Supply</td>
<td>2,530</td>
<td>1,420</td>
<td>189</td>
<td>4,139</td>
</tr>
<tr>
<td>Domestic</td>
<td>140</td>
<td>152</td>
<td>34</td>
<td>326</td>
</tr>
<tr>
<td>Irrigation</td>
<td>51</td>
<td>24</td>
<td>&lt;1</td>
<td>75</td>
</tr>
<tr>
<td>Livestock</td>
<td>30</td>
<td>62</td>
<td>5</td>
<td>97</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>63</td>
<td>524</td>
<td>53</td>
<td>640</td>
</tr>
<tr>
<td>Industrial</td>
<td>301</td>
<td>770</td>
<td>966</td>
<td>2,037</td>
</tr>
<tr>
<td>Mining</td>
<td>33</td>
<td>96</td>
<td>14</td>
<td>143</td>
</tr>
<tr>
<td>Thermoelectric</td>
<td>7,140</td>
<td>6,430</td>
<td>3,550</td>
<td>17,120</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10,288</strong></td>
<td><strong>9,478</strong></td>
<td><strong>4,811</strong></td>
<td><strong>24,577</strong></td>
</tr>
</tbody>
</table>

Source: USGS report (Kenny et al. 2009)
## Comparison of Marcellus Shale Water Needs with Actual Withdrawal

<table>
<thead>
<tr>
<th></th>
<th>Volume</th>
<th>Percentage Water Required for Shale Gas Production Compared to Total Withdrawal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water needed for shale gas</td>
<td>6.2 – 31 MGD</td>
<td>100%</td>
</tr>
<tr>
<td>Total water withdrawal</td>
<td>24,577 MGD</td>
<td>0.03% – 0.13%</td>
</tr>
<tr>
<td>Total water withdrawal excluding thermoelectric uses</td>
<td>7,457 MGD</td>
<td>0.08% – 0.42%</td>
</tr>
</tbody>
</table>
New NETL-Funded Report by Argonne

- July 2010 deliverable from Texas A&M and Argonne project

Available at

Plenty of Challenges Ahead

Source: C.B. Veil – taken in Ithaca, NY, June 2010