Water Management for Unconventional Oil and Gas Production

AWWA/NWRA Workshop
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Overview

- Water use and scarcity in shale development
- Disadvantaged water resources for fracturing
- Water storage
- Groundwater protection
- Water management and treatment
  - Source water
  - Flowback and produced water
  - Water quality
  - Treatment technologies
- Wastewater disposal
- Opportunities for optimization
  - Reusing water between operators
  - Drilling and water infrastructure
- Water costs
- Conclusions
Hydraulic Fracturing

- High-pressure water-based fluid used to fracture low-permeability hydrocarbon formations
- Fracture fluid chemistry has changed significantly over the last 10 years.
- Evolution in water management shows how recycle and reuse can be utilized
Water Use in Shale Development

- Water use varies significantly by shale play
- Complex water management

USGS, Water Resources Res., 2015
U.S. is now world’s largest oil and natural gas producer.
Water Scarcity Assessment

• Operators should understand water risks by assessing water scarcity
• Tools for modeling water stress. e.g.:
  – Aqueduct (WRI)
  – Global Water Tool (WBCSD)
• Water management plans should be informed by local water stresses in the development area
• Incorporate impacts of climate change and demand growth in assessing water resources
• Groundwater sustainability: are aquifers being over-drafted?
• Stakeholder engagement is critical for understanding water use in the watershed and understanding the value of water to stakeholders
Hydraulic Fracturing

- Water quality for fracturing has moved towards much higher TDS levels over the past 10 years
- Typical water use is 4-6 million gal per well
- Additives: sand (proppant), friction reducer, thickener, corrosion and scale inhibitor, acids and antimicrobials
- Injection fluid is 99% water and sand, 1% chemicals
  - Water can be highly saline
  - Match water quality with chemicals

This picture is changing
- Water reuse (internally and externally)
- Salt recovery
Life-Cycle Water Use

- Hydraulic fracturing accounts for greatest water use in well life-cycle

Use of Disadvantaged Water Resources

• Drivers
  – Water scarcity
  – Truck traffic
  – Supply reliability (e.g. permits)
  – Public relations

• Treated flowback water
  – Common for Marcellus shale
  – Not common where injection well capacity is plentiful

• Brackish groundwater
  – Drought-proof water resource
  – Less competition and social/environmental impacts than freshwater

• Acid Mine Drainage water
  – PA SB 875 to incentivize (approved 6/2015)

• Treated municipal wastewater
  – Pioneer in Odessa, TX (to be built)
  – Shell in British Columbia
  – Anadarko in Aurora, CO

Brackish water resources, USGS,
Water Treatment/Management

- Water management strategy varies greatly between unconventional resources plays
- Cost is usually dominated by transportation and treatment
- Mobile treatment units are common due to dynamic nature of water treatment needs (in space and time)
Source Water Treatment

• Filtration
  – Remove TSS
  – Remove sulfate reducing bacteria and acid producing bacteria
  – Reduces scaling and corrosion potential
  – Reduces chemical demands in fracturing
• Aeration: prevent $H_2S$ formation
• Biocides: kill bacteria
• $ClO_2$: remove bacteria, sulfides, particulates and insolubles
• Hardness removal (ion exchange)-e.g. Boron can cause problems with crosslinked gel formulation
• Sulfate removal
  – May cause scaling with Ba and Sr from formation
Water Storage: Tanks and Pits

• PA Department of Environmental Protection announced plans to ban temporary waste pits at Marcellus and Utica shale gas well sites (3/2015)
• Impoundments are prone to leaking, with potential groundwater contamination
• Impoundments also have VOC emissions and have negative impacts on wildlife
• Vertical tanks reduce the environmental footprint of well development
Groundwater Protection

- Shale formations are much deeper than drinking water aquifers
- Drinking water aquifer contamination can occur from surface spills, migration pathways in the well or sub-surface fractures or other wells
- Proper well design and mechanical integrity are critical
- Failure of the cement or casing or completion assembly surrounding the wellbore poses a risk to water supplies
- Cementing is critical
  - Proper cement placement and quality
  - Fully cemented surface casing that extends through the base of drinking water resources is critical
- If the annulus is improperly sealed, gases and fracturing fluids can access drinking water aquifers

Source: EPA, 2015
Groundwater Protection

- Location of offset well relative to fracked well determines the likelihood of a “frac hit” (well communication incident) - migration pathway to drinking water
  - Frac hits most commonly occur on multi-well pads with inadequate spacing
  - Induced fractures must not intersect with existing fractures or permeable zones
- Older wells have more integrity problems...stresses from re-fracturing etc. (aging of steel casing and cement)
- Fluid migration along natural faults/fractures to drinking water zone is unlikely
- Monitoring
  - Baseline and post-completion groundwater testing (req’d in CO & WY)

Source: EPA, 2015
## Flowback Water Quality Variability

Concentrations in mg/L

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J. Häggström, Halliburton, 2011

- Huge variability in water quality from different wells
- Treatment technology needs to be robust to handle variations in water quality
Time and Location Dependence

Flowback water water quality and flowrate for 3 Marcellus shale wells (Hayes, 2009)

- Large variability in TDS over first 90 days
- TDS of initial flowback does not predict long-term TDS trends
- Injection volume not correlated with flowback volumes
- Logistics are challenging with such variability
Water Management Drivers

• Key drivers
  – Environmental sensitivity
  – Water availability and quality
  – Wastewater disposal options
  – Quality of flowback water
  – Volume of water required for fracturing and flowrates of flowback and produced water
  – Regulations and permits

• Economic analysis
  – Model water management scenarios to determine lowest cost alternatives
  – Account for environmental and social impacts in analysis
  – Risk management – consider liabilities and regulatory impacts of alternatives
Water Treatment Technologies

- Constituents of concern: TSS, metals, organics, radionuclides (NORM), frac fluid additives, TDS
- Hydrocarbon removal: hydrocyclones, DAF, cartridge filtration, nutshell filtration, biological treatment
- Clarification
  - Chemical precipitation & settling
  - Filtration and membrane separation
- Electrocoagulation: remove solids, organics, bacteria and heavy metals
- Microbiological control: biocides, UV, ozone
- Softening: ion exchange, nanofiltration
- Desalination
  - Reverse Osmosis (up to ~ 50,000 ppm TDS)
  - Mechanical Vapor Recompression, Multi-Effect Distillation, Forward Osmosis, Membrane Distillation, Carrier Gas Extraction for brine concentration
  - Concentrated brine may have market value (e.g. drilling)
- Crystallization
  - Zero liquid discharge
  - Sell salt product
Reusing Water Between Operators

• Creating a market for water sourcing and reuse will facilitate efficiencies in the industry

• An example is Sourcewater
  – Start-up out of MIT
  – Web-based system for sourcing water, recycling water, and selling water

• Full-service water management companies handle sourcing, treatment, storage and disposal
  – Opportunity for these companies to share in costs of developing water infrastructure to service the industry

• Issues over liability must be managed
  – Texas HB 2767 shifts liability from producer to the recycler
  – Recycler is immune once water is sold to new producer
Wastewater Disposal

• POTW disposal used to be common but has been prohibited in PA and other places
• Wastewater disposal options include deepwell injection and dust suppression & deicing
  – Induced seismicity from injection into disposal wells
  – Env. concerns over land application
• May states prohibit brine transport in pipelines due to concerns over leaks and spills
• Wastewater pipelines used in North Dakota and recently approved in Texas
  – Reduce truck traffic
  – Must be monitored for leaks

Drilling and Water Infrastructure

- O&G well drilling should be planned with water infrastructure development
- Need to drill on leases scattered over a wide area to maintain them can lead to sub-optimal water management
- Burdening individual O&G development projects with water infrastructure costs may make them cost-prohibitive
  - Better to make strategic investments in water infrastructure development
  - Systems-level development planning
- Truck traffic is major impact of shale development
  - Cost
  - Environmental impact
  - Safety (accidents) and traffic congestion
  - Damage to roads
Water Costs

• Reduce water costs by
  – Reducing truck traffic
  – Water reuse
  – Optimizing schedule for water delivery, use and disposal (waiting times can be very expensive)

• Bakken: water recycling can save $200-400K/well (Halliburton)

<table>
<thead>
<tr>
<th>Producing Area</th>
<th>Total Water Cost ($/BBL)</th>
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<tr>
<td>Bakken</td>
<td>6-15</td>
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<tr>
<td>Eagle Ford</td>
<td>2-6</td>
</tr>
<tr>
<td>Permian Basin</td>
<td>3-8</td>
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<tr>
<td>Marcellus</td>
<td>4-20</td>
</tr>
<tr>
<td>Denver-Julesburg</td>
<td>4-8</td>
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</tbody>
</table>
Conclusions

• Industry has improved water management in many ways
• Shale development is highly dynamic
  – Opportunities for logistics optimization
  – Many treatment technologies to choose from: make fit for purpose
• Monitor groundwater quality and use well construction best practices
• Utilize frac tanks instead of pits for wastewater storage
• Many opportunities for water reuse
  – Water scarcity and disposal issues are drivers
  – Recover valuable materials (salts, metals, organics)
  – Emerging business models to reuse water between operators
• Opportunities to invest strategically in water infrastructure
  – Utilize pipelines instead of trucks
  – Centralized or mobile treatment facilities