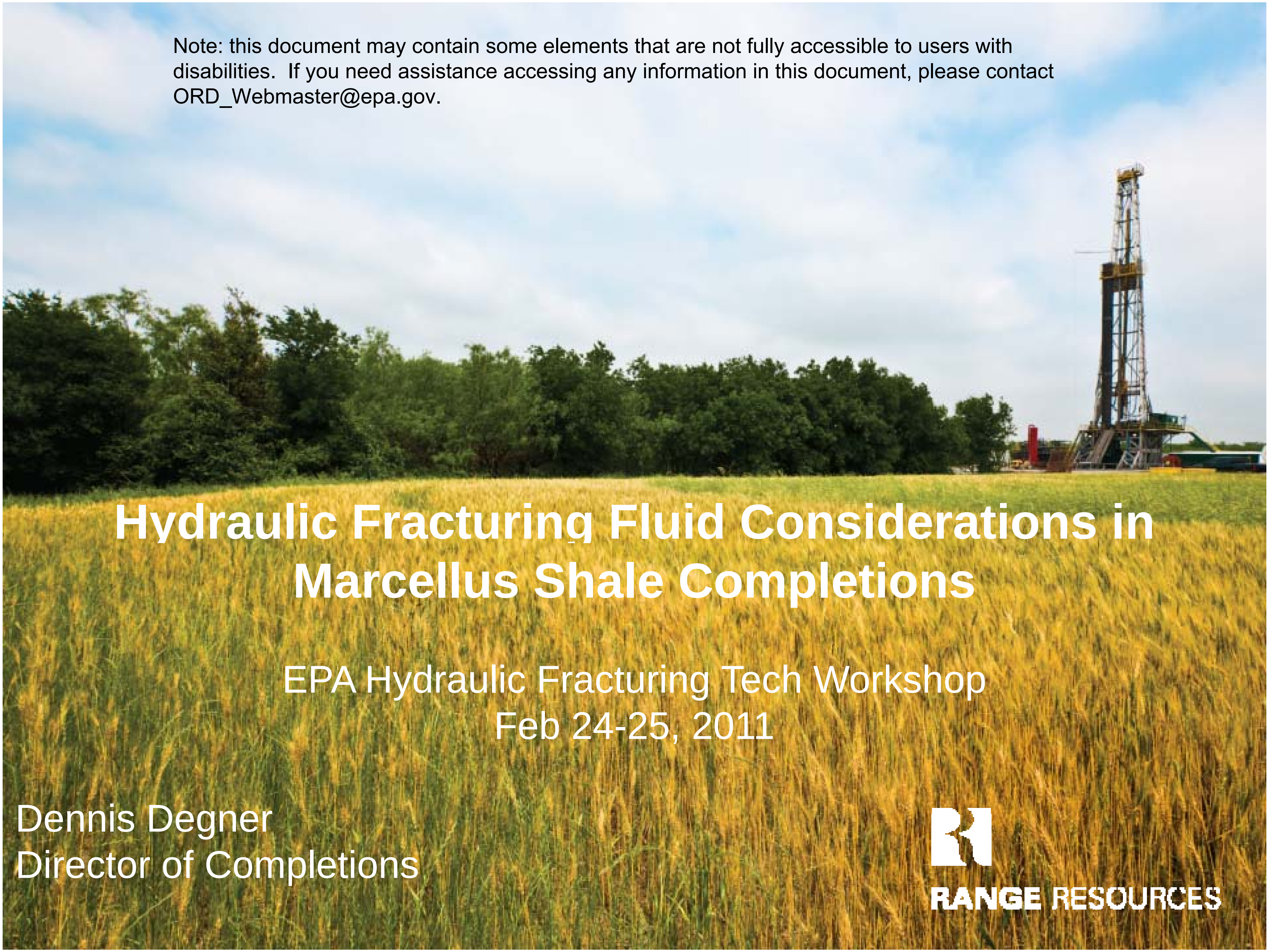

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Hydraulic Fracturing Fluid Considerations in Marcellus Shale Completions

EPA Hydraulic Fracturing Tech Workshop
Feb 24-25, 2011

Dennis Degner
Director of Completions

RANGE RESOURCES

Agenda

- **Introduction**
- **Additives used in Marcellus Shale fracturing**
- **Why we use these additives**
- **Testing performed**
- **Where do we go from here**

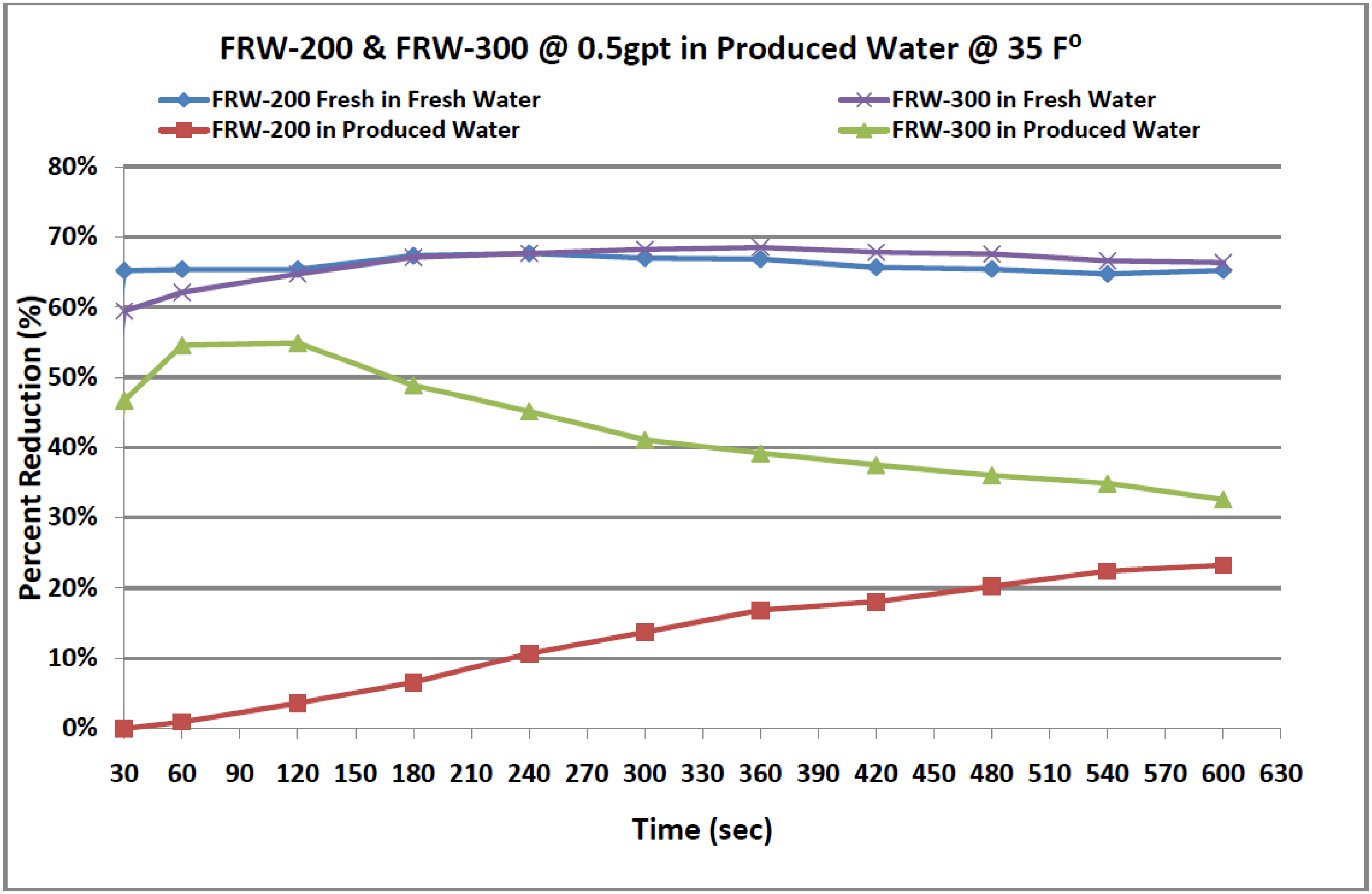
Introduction

- **Hydraulic fracturing is key to shale development**
  - **Fracturing creates a small conductive flow path for hydrocarbon to flow from low permeability reservoirs**
  - **"Slickwater" style design most commonly used in Marcellus as well as other shale reservoirs**
    - **Slickwater design consists of water, proppant (sand) and small amounts of additives for placement and water management**
- **Additives used**
  - **Friction Reducer**
  - **Biocide**
  - **Scale inhibitor**
- **Why do we use these additives in Marcellus fracturing?**

Friction Reducer

- **A key to shale fracturing is pumping fluid at high rates**
  - **High rate helps to transport proppant (usually sand)**
  - **Creates a fracture network**
- **To reach required pump rates friction reducer is added reducing pressure at surface**
- **What is friction reducer?**
  - **Polyacrylomide polymer**
  - **Comes in dry powder and liquid form with mineral oil base**
  - **Also used for soil stabilization and some children's toys**
- **Friction reducer selection impacted by:**
  - **Chemistry of source water for fracturing**
  - **High salinity vs. fresh water = different products**

Friction Reducer - flow loop test data



Biocide

- **Various water sources are used for Marcellus fracturing**
  - **Ground water**
  - **Surface water**
  - **Produced water**
- **Pre-job water testing is conducted to assess pre-existing bacteria present**
- **Test involves inoculating specific media in a serial dilution bottle with 1 ml of frac source water**
- **Change in bottle color directly relates to bacteria count**
- **Results guide additive concentrations used during fracturing**

Biocide

- What are some impacts of untreated bacteria?
  - Microbiological influenced corrosion
  - Formation souring (creation of H_2S in the formation)
  - Microbial growth downhole restricting production
- How do we control bacteria?
  - Add an organic biocide to sterilize the fluid
  - Glutaralehyde/quaternary ammonium blend
  - Added at low concentrations (± 0.5 gal/Mgal)
  - Post fracturing testing conducted over life of a well
  - Results used for biocide optimization
- Similar approach seen in medical equipment sterilization and hand sanitation

Scale Inhibitor

- **Due to minerals in the source water scale can form**
- **What are some ways scale can form?**
  - **Pressure drop**
  - **Temperature changes**
  - **Mixing of different waters**
  - **Agitation**
- **To prevent scale from forming a solvent based scale inhibitor is added to the fracturing water**
- **Added at low concentrations (± 0.1 gal/Mgal)**
- **Similar additives used in municipal water treatment, de-icing agents and household cleaners**

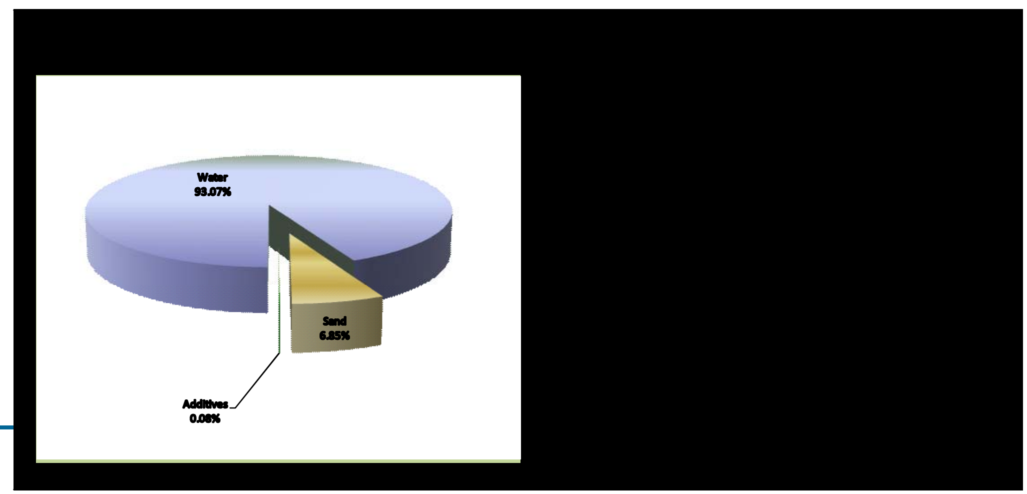
Scale Inhibitor

- Common scale that could form in Marcellus Shale wells
  - Barium Sulfate ($BaSO_4$)
  - Calcium Carbonate ($CaCO_3$)
- Scale is difficult and expensive to remove
  - Can require remedial large volume chemical treatment
  - In certain cases mechanical removal is required
- Water testing can determine scale tendency
- Test results drive additive plan
- Produced water dissolves small amounts of minerals from the shale
  - As a result scale inhibitor becomes more important

Where do we go from here?

- **Continue additive advancement with service provider and University partnerships with focus on salt water re-use (recycling)**
- **Develop fluid systems in line with 12 principles of Green Chemistry**
- **We share chemical best practices with:**
  - **Industry**
  - **State agencies**
  - **Trade groups**
- **Keep volume used low**
  - **< 1% of job volume**
- **Transparent operations**

% Composition of Hydraulic Fracture Fluid (by volume)						
Product Name	**Additive**	**Purpose**	**Use and Dillution**	**Volume**	**Overall %**	**Common Uses**
Water	Carrier Fluid	Creates fracture network in shale and carry proppant to the formation	Primary constituent	2,434,801 gal	93.07%	Water is the most abundant molecule on the Earth's surface
Sand	Sand	Allows fractures to remain open so gas can escape	Second most common constituent, making up almost 6% of the fluid	179,232 gal	6.85%	Drinking water filtration, play sand
FRW-200	Friction Reducer	Reduces friction between fluid and pipe	Diluted at one-half gallon per 1,000 gallons of water	1,033 gal	0.04%	Water treatment; soil conditioner; some children's toys
MC B-8650/Bioban	Antimicrobial Agent	Eliminates bacteria in the water that produce corrosive byproducts	Diluted at one-half gallon per 1,000 gallons of water	0,692 gal	0.03%	Water treatment, disinfectant; sterilize medical and dental equipment and surfaces
MX 588-2	Scale Inhibitor	Prevents scaling in pipe	Diluted at one-tenth gallon per 1,000 gallons of water	243 gal	0.01%	Water treatment, household cleaners, de-icing agent



Thank You

Questions?

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Hydraulic fracturing (completion) has become a key operation when developing shale gas reservoirs. Like all industries and even families, the natural gas industry uses certain chemicals as a normal part of its daily business. Chemicals used during the fracturing process are a vital component to a successful completion. The chemicals used help reduce surface treating pressures, aid in placement of the propping agent (sand) within the deep, downhole formation, and help maintain fluid properties that meet design specifications. The chemicals most commonly used in Marcellus Shale fracture treatments are friction reducer, biocide, and scale inhibitor. These chemicals are mixed in very low concentrations with water (referred to as a slickwater frac) and make up < 1% of the total job volume.

A friction reducer (FR) is one of the common chemicals used in Marcellus hydraulic fracturing operations. The friction reducer is necessary to reduce the frictional effects (extra pressure) that occur as water is pumped down the long pipe (wellbore) during the hydraulic fracture treatment. In Marcellus completions, there is often 10,000 ft of pipe cemented into the ground. Without using a friction reducer, the surface pressure would be higher than desired to reach the required pump rate during the treatment. Friction reducers are commonly a polyacrylamide polymer that is added at low concentrations (± 0.5 gal/Mgal). Once FR is added to the base fracturing fluid the viscosity remains close to that of water (< 5 cps) while the frictional effects are greatly reduced. FR often comes from the manufacturer in dry powder form, but is most commonly pumped as a liquid by mixing with a mineral oil base fluid to stabilize the material until it's injected into the water stream and pumped downhole. Historically they have worked best with fresh water fluids, but recent advancements in technology have made it possible to pump salt tolerant versions when re-using produced salty water in Marcellus completions. Flow loop testing was conducted in the development of these new chemicals to aid in selection based on fluid salinity. When using produced water in the completion, pre-job water testing is done to verify which FR is required to ensure proper application. A polyacrylamide is commonly used in many industries and can be found in children's toys, and used for soil stabilization in addition to several other uses.

Hydraulic fracture treatments are pumped with various water sources ranging from ground, surface, and produced water environments. Once the source water is identified, samples are captured and tested to determine the amount of bacteria present. The source water and ambient temperature can be strong drivers in the amount of bacteria present, similar to the drivers controlling growth of pond algae. Based on the level of bacteria already present in the water a biocide chemical will be added to the water at a proper loading rate to prevent microbiological influenced corrosion of the downhole pipe, formation souring (H_2S), or other safety/production concerns. Biocide is also added to prevent microbial growth from occurring downhole which could restrict flow from the created hydraulic fracture network. Due to the high biomass content already existing in the water sources used for Marcellus Shale fracturing, an organic biocide is required to achieve the necessary sterilization. A similar chemical approach can be seen in medical equipment sterilization and hand sanitation. Similar to the friction reducer, the biocide is added in a liquid form to the water pumped downhole during the hydraulic fracturing process. Once the well is completed, post-job samples are taken, and testing performed to assess effectiveness of the treatment and for future design optimization. Additional sampling and culture testing occur during the life of a well to ensure bacteria levels remain low.

Based on minerals present in the various fresh and produced frac water sources, there is a potential to create scale during production. Extensive water analysis performed prior to fracturing can detect the tendencies to form scale and identify types most likely to form based on the minerals present in the water and in the Marcellus Shale. Two common scales that can generate in this environment are calcium carbonate ($CaCO_3$) and barium sulfate ($BaSO_4$). Both are expensive to clean within the pipe if they occur, so the purpose of this chemical is to inhibit their formation. $CaCO_3$ can be simple to remove with remedial chemical treatment while $BaSO_4$ requires mechanical removal. To prevent scale from generating, a solvent based scale inhibitor is added into the water pumped downhole. As the volume of produced water used for fracturing increases, the need for adequate scale control will also increase due to minerals dissolving from the shale reservoir into the produced water. Scale inhibitors are added in low concentrations (± 0.1 gal/Mgal) with low level residuals observed after fracturing that help prevent scale from occurring. Similar applications can be seen in municipal water treatments, de-icing agents and household cleaners.

Lastly, a surfactant chemical is pumped on a low percentage of Marcellus Shale completions. The addition of a surfactant reduces surface tension on the fracture face making it easier to recover produced fluids. Testing results have varied resulting in basin specific application. Examples of surfactants can be found in soaps and foaming agents.

Each chemical is electronically monitored and manually strapped for accuracy during the treatment ensuring proper loading. With site specific testing and new chemical development with service companies, industry is able to optimize chemical application while reducing environmental impact in hydraulic fracturing. Best practices with chemical use are shared with industry partners, state agencies and trade groups for transparency and responsible chemical use in Marcellus Shale completions.