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HYDRAULIC FRACTURING: WHAT IS IT AND WHY IS IT IMPORTANT TO ENVIRONMENTAL LABORATORIES

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PRESENTATION OVERVIEW

- **Keys to Deep Shale Natural Gas and Oil Development**
  - › Horizontal Drilling
  - › Hydraulic Fracturing
- **What does Hydraulic Fracturing Mean to Environmental Laboratories?**
- **What do Environmental Laboratories Need to Be Doing?**

KEYS TO DEEP SHALE NATURAL GAS AND OIL DEVELOPMENT

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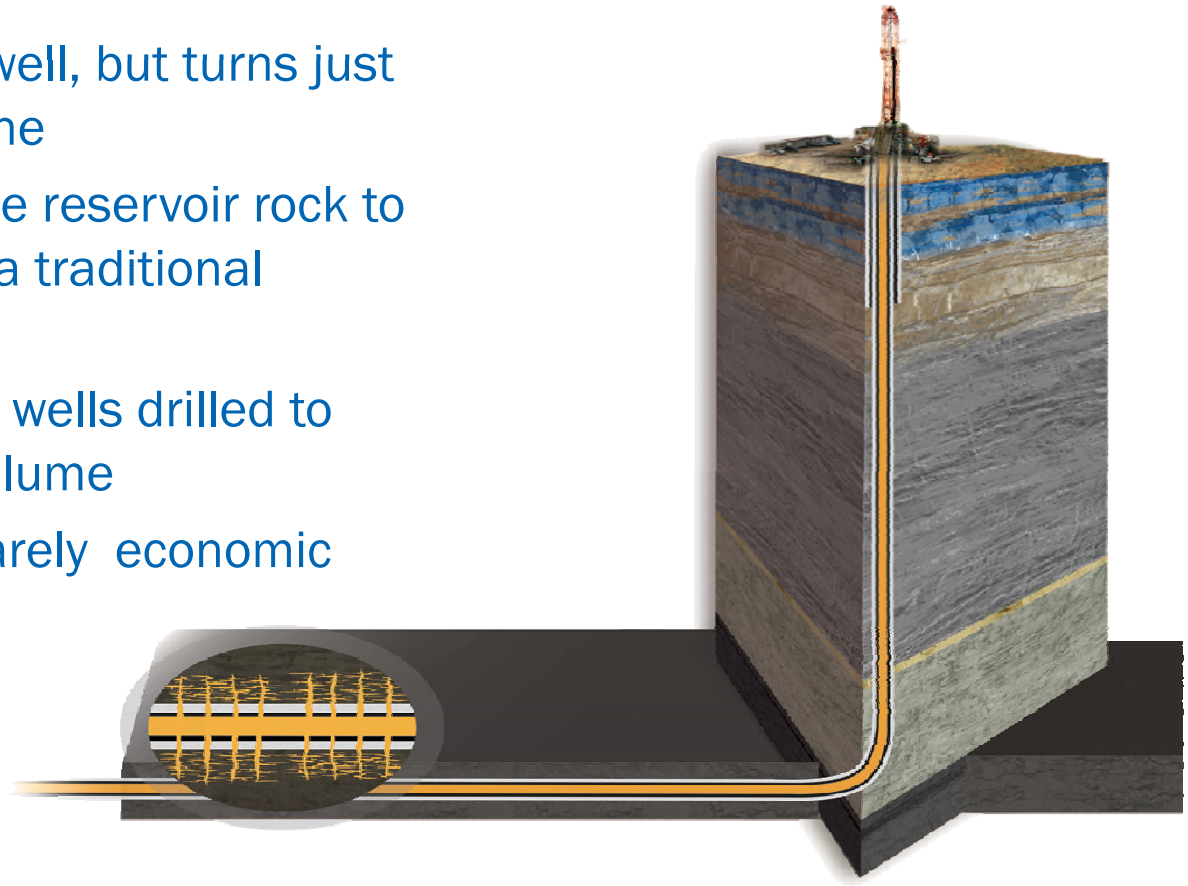
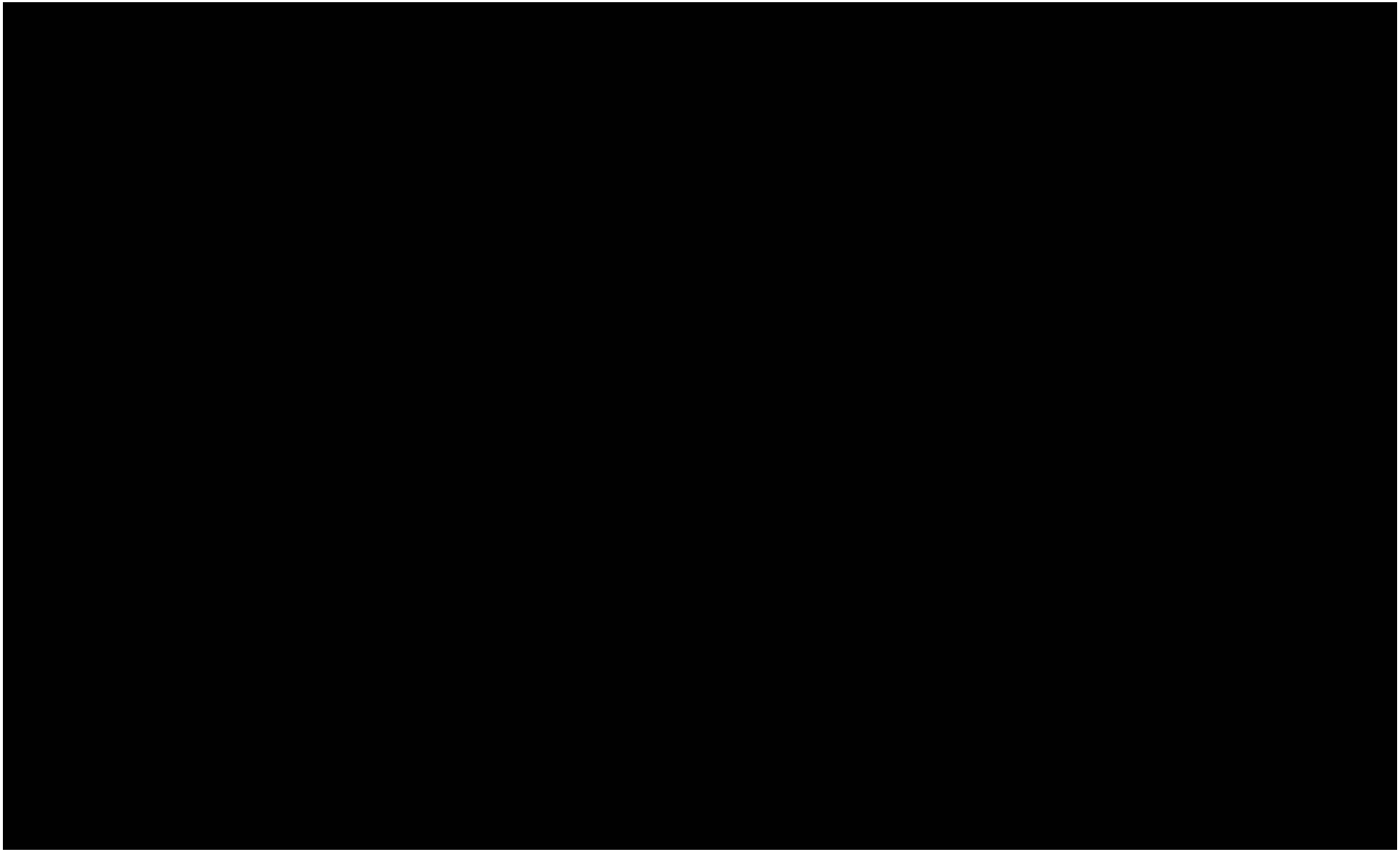
KEYS TO DEEP SHALE NATURAL GAS & OIL DEVELOPMENT

- **Horizontal Drilling**
  - Begins same as vertical well, but turns just above target reservoir zone
  - Exposes significantly more reservoir rock to well bore surface versus a traditional vertical well
  - Major advantage is fewer wells drilled to access same reservoir volume
  - Vertical shale wells are rarely economic



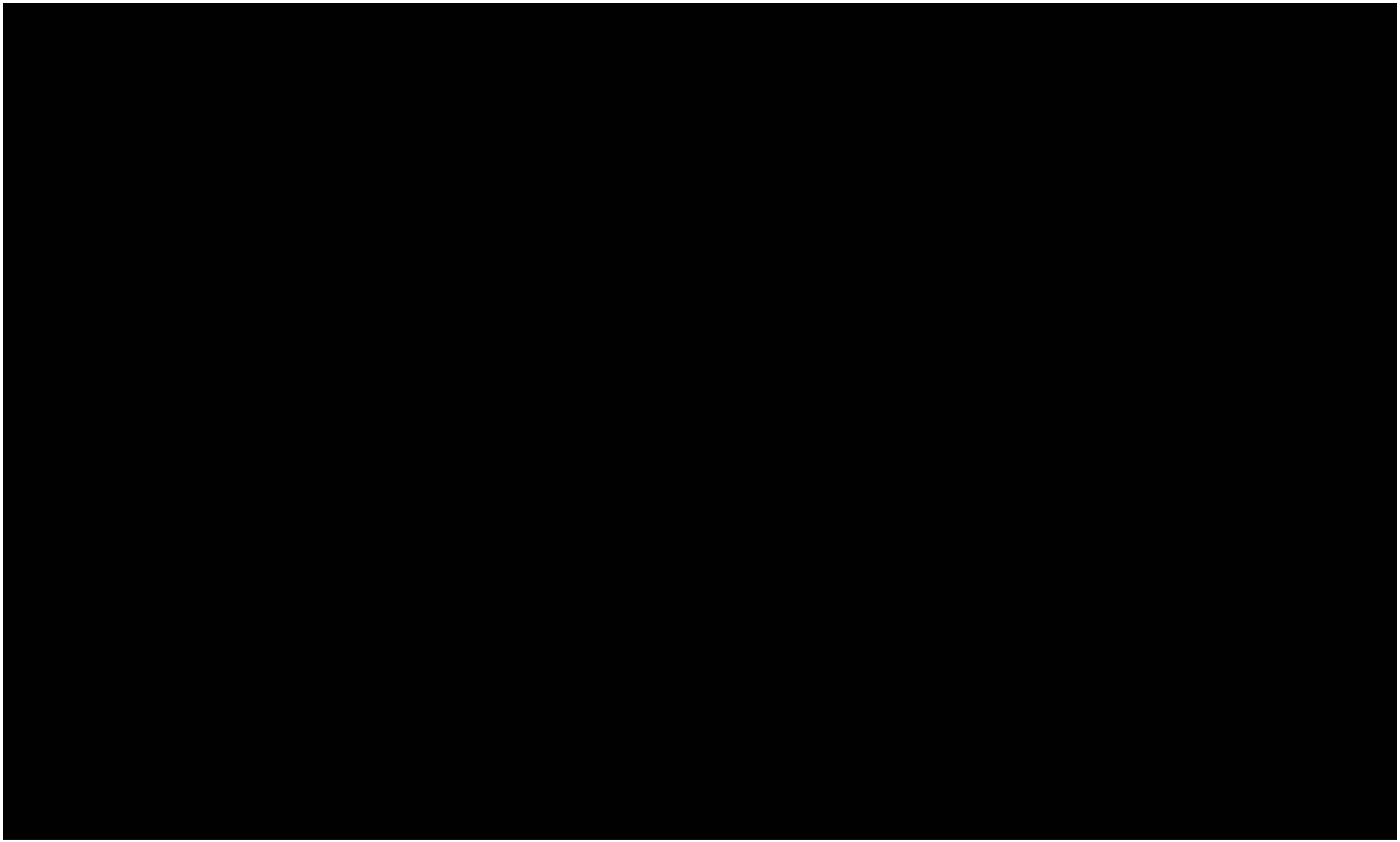
DRILLING ANIMATION



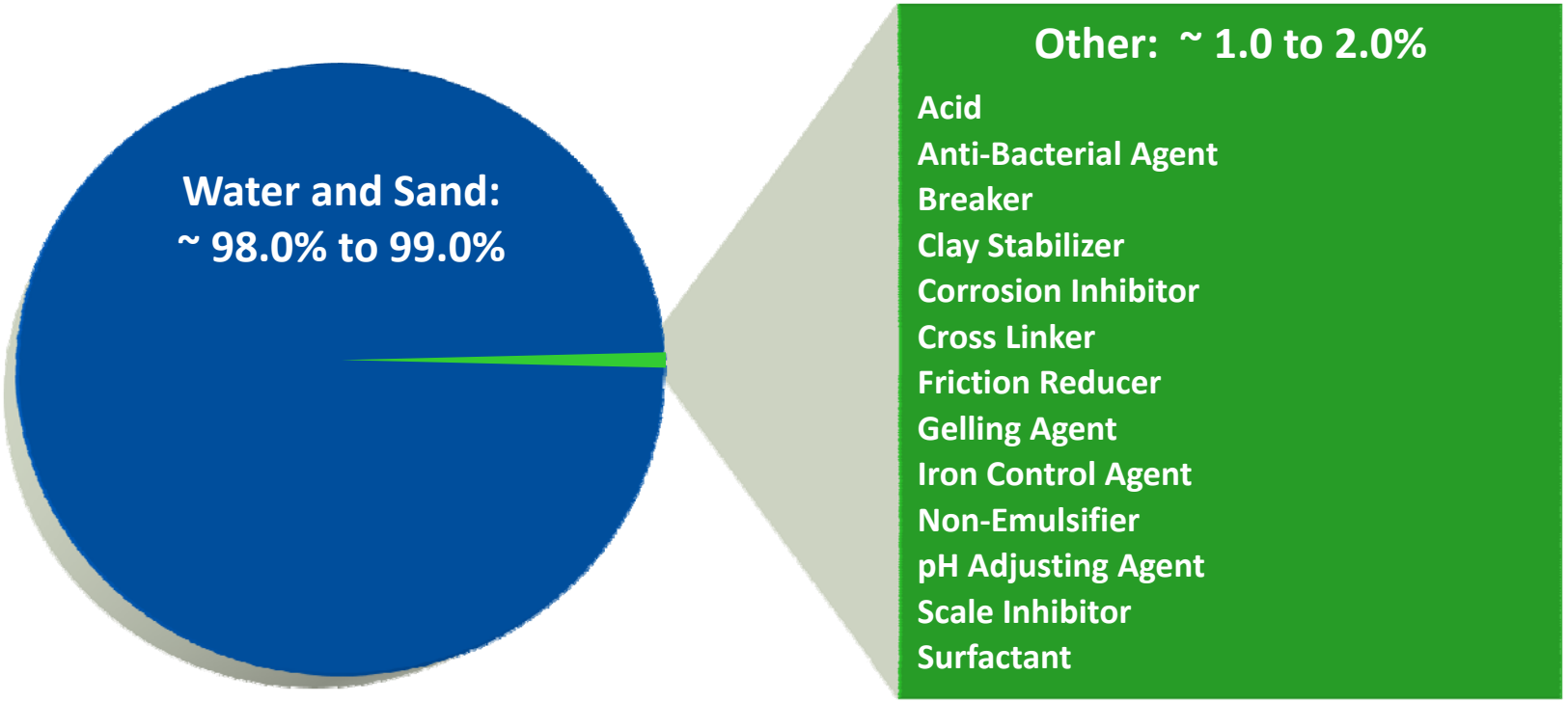
KEYS TO DEEP SHALE NATURAL GAS & OIL DEVELOPMENT

- **Hydraulic Fracturing**
  - Process of creating thin fractures in shale formations deep underground
  - Water with a small percentage of special chemical additives is injected under high pressure to fracture the rock
  - A “propping agent” (usually sand) is pumped into the fractures to keep them from closing when pumping pressure is released
  - Natural gas or oil can then flow freely from the rock pores to the fractures, into the wellbore, and up to the surface

HYDRAULIC FRACTURING ANIMATION



TYPICAL DEEP SHALE FRACTURING FLUID MAKEUP



Most Shale Gas Plays utilize closer to 99% water/sand and ~1% chemicals
Most Liquid Rich Plays utilize closer to 98% water/sand and ~2% chemicals

MAJOR HYDRAULIC FRACTURE FLUID SYSTEMS

- **"Slickwater" Systems**
  - Utilized in majority of Shale Gas plays
  - Primarily water and friction reducer (polyacrylamide)
  - Benefit: Imparts minimal damage on formation
- **"Linear Gel" Systems**
  - More complex, made up of a gelling agent and a breaker
  - Moderately viscous allowing for enhanced proppant transport
  - Most common gel is guar gum (found in many food products)
- **"Cross-Linked Gel" Systems**
  - Higher viscosity and most complex, used in most liquid plays
  - Include a cross-linker and a pH adjusting agent in addition to the gelling agent and breaker
  - Borate salts are the most typical cross-linkers

In many of the emerging liquid rich plays, "hybrid" systems are utilized which incorporate slickwater at the beginning of the stage and progress to linear and cross-linked gel systems

TYPES OF PRODUCTS USED IN HYDRAULIC FRACTURING

HF Fluid Component	Purpose
Water	Expands the fracture and delivers sand
Sand (Proppant)	Allows the fracture to remain open so that the natural gas and oil can escape
Acid	Helps dissolve minerals and initiate cracks in the rock
Anti-Bacterial Agent	Eliminates bacteria in the water that produces corrosive by-products
Breaker	Allows a breakdown of the gel
Clay Stabilizer	Prevents formation clays from swelling
Corrosion Inhibitor	Prevents corrosion of the pipe
Cross Linker	Maintains fluid viscosity as temperature increases
Friction Reducer	Maintains a laminar flow regime to minimize friction
Gelling Agent	Thickens the water to suspend the sand
Iron Control Agent	Prevent precipitation of metal in the pipe
Non-Emulsifier	Prevents oil/water emulsions from forming which inhibit liquid hydrocarbon production
pH Adjusting Agent	Maintains the effectives of other components, such as cross linkers
Scale Inhibitor	Prevents scale deposits downhole and in surface equipment
Surfactant	Maintains desired wettability characteristics of the formation

WHAT DOES HYDRAULIC FRACTURING MEAN TO ENVIRONMENTAL LABORATORIES?

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SHALE NATURAL GAS AND OIL DEVELOPMENT HAS …

- **Presented challenges for environmental laboratories**
  - Sample volumes for baseline programs and incident response
  - Rapid turnaround times and rapid notification of critical results
  - Electronic data processing and submittal
- **Created demands for analyses that go beyond the regulatory agency approved analytical methods**
  - Analyses of additional matrices, such as brackish and produced formation water
    - *Salt concentrations which are higher than typical wastewater or drinking water*
  - Identification of surrogate or indicator compounds
    - *Account for downhole transformation of hydraulic fracture fluid components*
    - *Compounds, such as hydrogen chloride, which do not lend themselves to direct analysis*
  - Analyses of water replacement fluids, such as propane or nitrogen

Sufficient indicator parameters do exist and environmental laboratories play an important role in identifying those parameters.

PREDICTED DOWNHOLE FATE FOR HYDRAULIC FRACTURING FLUID COMPONENTS

HF Fluid Component	Predicted Downhole Fate
Acid	Reacts with minerals to create salts, water and CO_2
Anti-Bacterial Agent	Broken down by micro-organisms and small amount returned with produced water
Breaker	Reacts with “gel” and “cross linker” to form ammonia and sulfate salts which are returned with produced water
Clay Stabilizer	“Adheres” or “Bonds” to clay particles in formation
Corrosion Inhibitor	Bonds with pipe surfaces, broken down by micro-organisms and/or returned in produced water
Cross Linker	Combines with the “breaker” in formation to create salts returned in produced water
Friction Reducer	Portion remains in formation while part is broken down by micro-organisms with a small amount returned in produced water
Gelling Agent	Broken down by “breaker” and returns with formation water
Iron Control Agent	Reacts with minerals to create salts, water and CO_2
Non-Emulsifier	Returned with produced water or produced natural gas
pH Adjusting Agent	Reacts with other minerals to create salts, water and CO_2
Scale Inhibitor	Attaches to the formation with portion returning with produced water
Surfactant	Returned with produced water or produced natural gas

FATE AND TRANSPORT OF COMPONENTS IN FRACTURING FLUIDS

- **Elevated temperatures and pressure as well as the interactions within the fluid itself changes the form of most components**
- **Reactions between hydraulic fracturing fluid components and/or the formation produce constituents which can be measured as surrogates, e.g. salts, sulfates, nitrogen compounds, etc., using accepted analytical methods**
  - Salts can be measured as Total Dissolved Solids
  - Nitrogenous compounds – Total Kjeldahl Nitrogen and Ammonia used as surrogate
- **Often can not measure for the chemical itself, can only measure the individual pieces**
  - KCl – can not easily measure KCl but instead measure Potassium and Chloride
  - Sodium Hydroxide – measure Sodium as an indicator

The matrix of fracturing fluids are products rather than typical environmental samples, therefore holding times, etc. are not valid

WHAT DO ENVIRONMENTAL LABORATORIES NEED TO BE DOING?

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WHAT DO ENVIRONMENTAL LABORATORIES NEED TO BE DOING?

- Become proactive with the oil and gas industry
- Identify appropriate laboratory methods which can be used or adapted for environmental media
  - Adapt existing methods to better account for potential matrix interferences
- Develop working relationships with the product testing laboratories to identify analytical capability that would be appropriate for polymers, biocides, etc.
- Assist clients in selection of the most appropriate analytical methods to achieve defendable, accurate and reproducible results

WHAT DO ENVIRONMENTAL LABORATORIES NEED TO BE DOING?

- **Develop modifications of existing laboratory methods to deal with salt-driven matrix**
  - Anticipate an increase in analyses of brackish and produced water as water reuse programs are expanded
- **Develop analytical methods which can be utilized with alternative fracturing fluids, such as propane, natural gas, nitrogen, etc.**

CONCLUSIONS

- Hydraulic fracturing plays a key role in shale natural gas and oil development and utilizes one or a combination of three different fluid systems (slickwater, linear gel, cross-linked gel)

- Chemical additives account for < 2% of the total fluid pumped during the majority of hydraulic fracturing activities

CONCLUSIONS (CONT)

- Environmental laboratories play an important role in shale natural gas and oil development and should be taking the lead role in working with appropriate federal and state agencies to get additional laboratory methods accepted for use in compliance and reporting activities
- Environmental laboratories should play a key role in educating the general public, non-governmental organizations, federal and state regulatory groups regarding the capabilities and limitations of laboratory analyses

QUESTIONS?

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