Shale Energy Fluids Management Practices

ANH
AGENCIA NACIONAL DE HIDROCARBUROS

Forum on Hydraulic Fracturing

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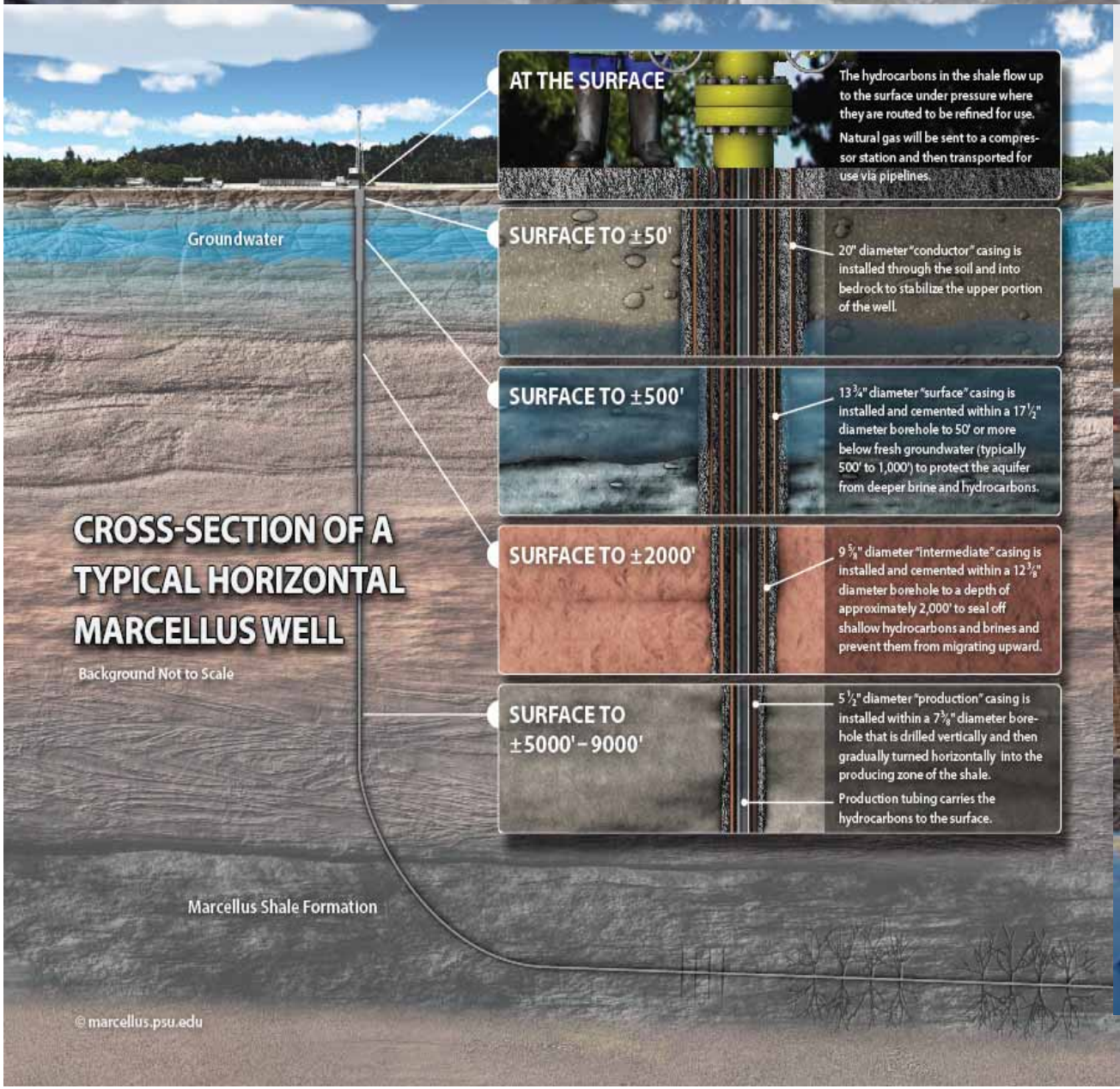
Well Site in Operation

Closed Loop Drilling System

Well Integrity is Crucial to Protect Water Resources



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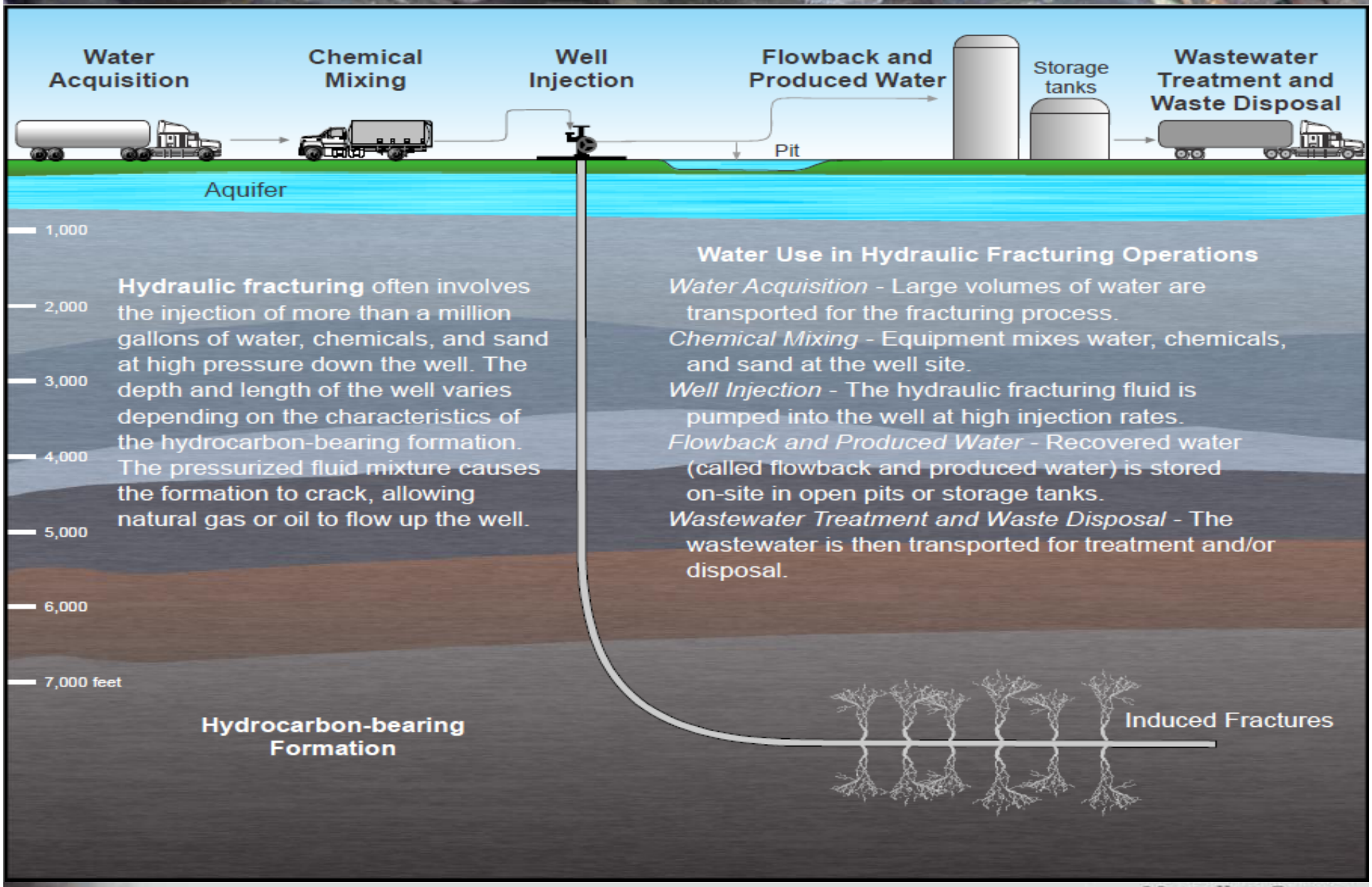
Hydraulic Fracturing Water Use

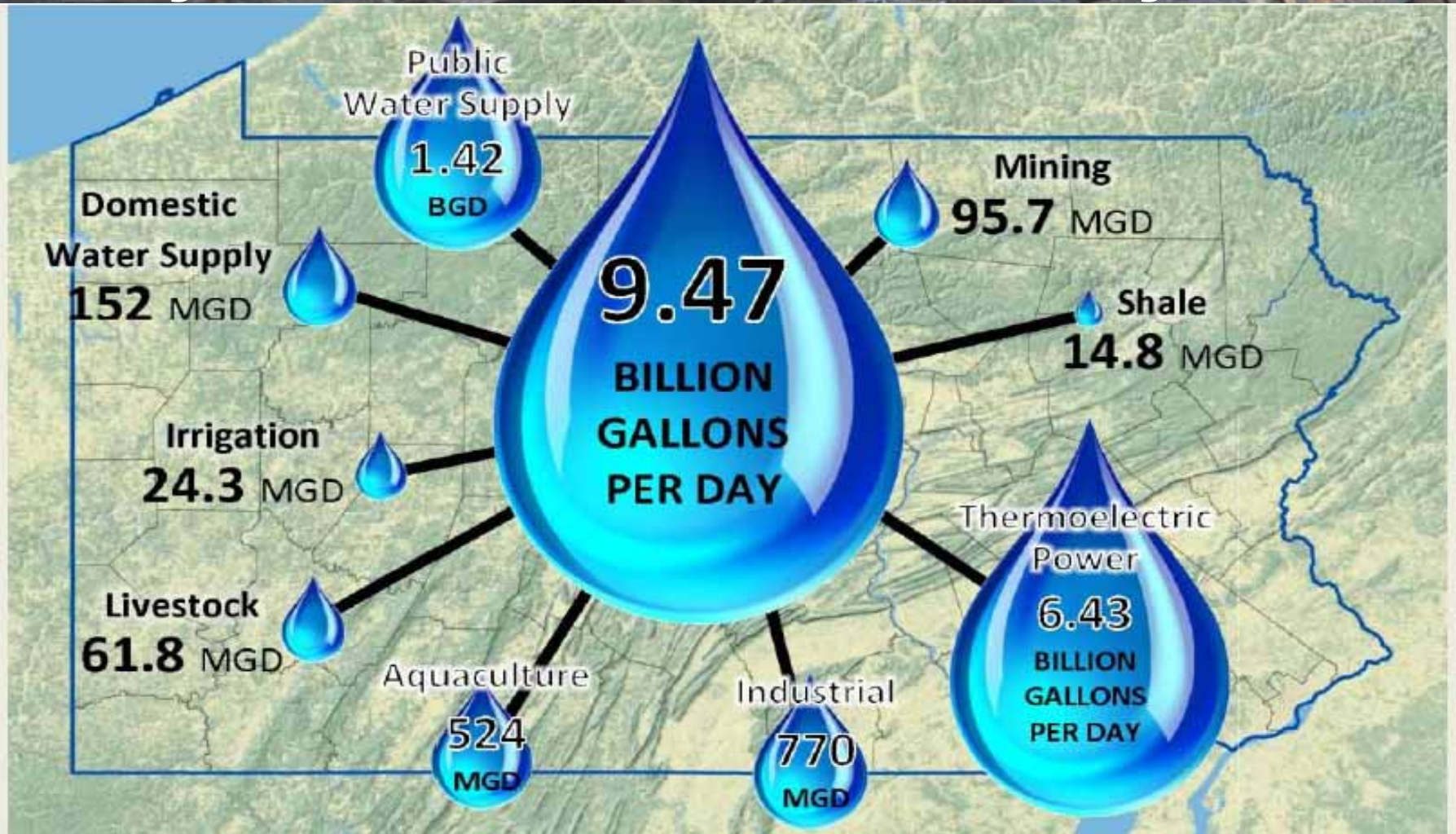
- **Typically use about 4 million liters (24 MBBLs) per 300 meters of lateral, commonly 20 million liters per well**
- **Return of fluids (flowback and produced fluids) ranges from approximately 5-50%**
- **Produced fluids range from 5-10 BBLs for every 1 MMCF of gas or 1 BBL of oil produced**
- **Water sources in Appalachian Basin are primarily surface water (80%)whereas ground water is the primary source in Western US plays**

Shale Energy Water Cycle



Source: EPA Hydraulic Fracturing Study Workplan

Daily Withdrawals in Pennsylvania



Sources: J. F. Kenny, N. L. Barber, S. S. Hutson, K. S. Linsey, J. K. Lovelace and M. A. Maupin. 2009. Estimated Use of Water in the United States in 2005, U.S. Geological Survey, Circular 1344
Shale Estimate based on 1,200 wells per year at 4.5 million gallons per well

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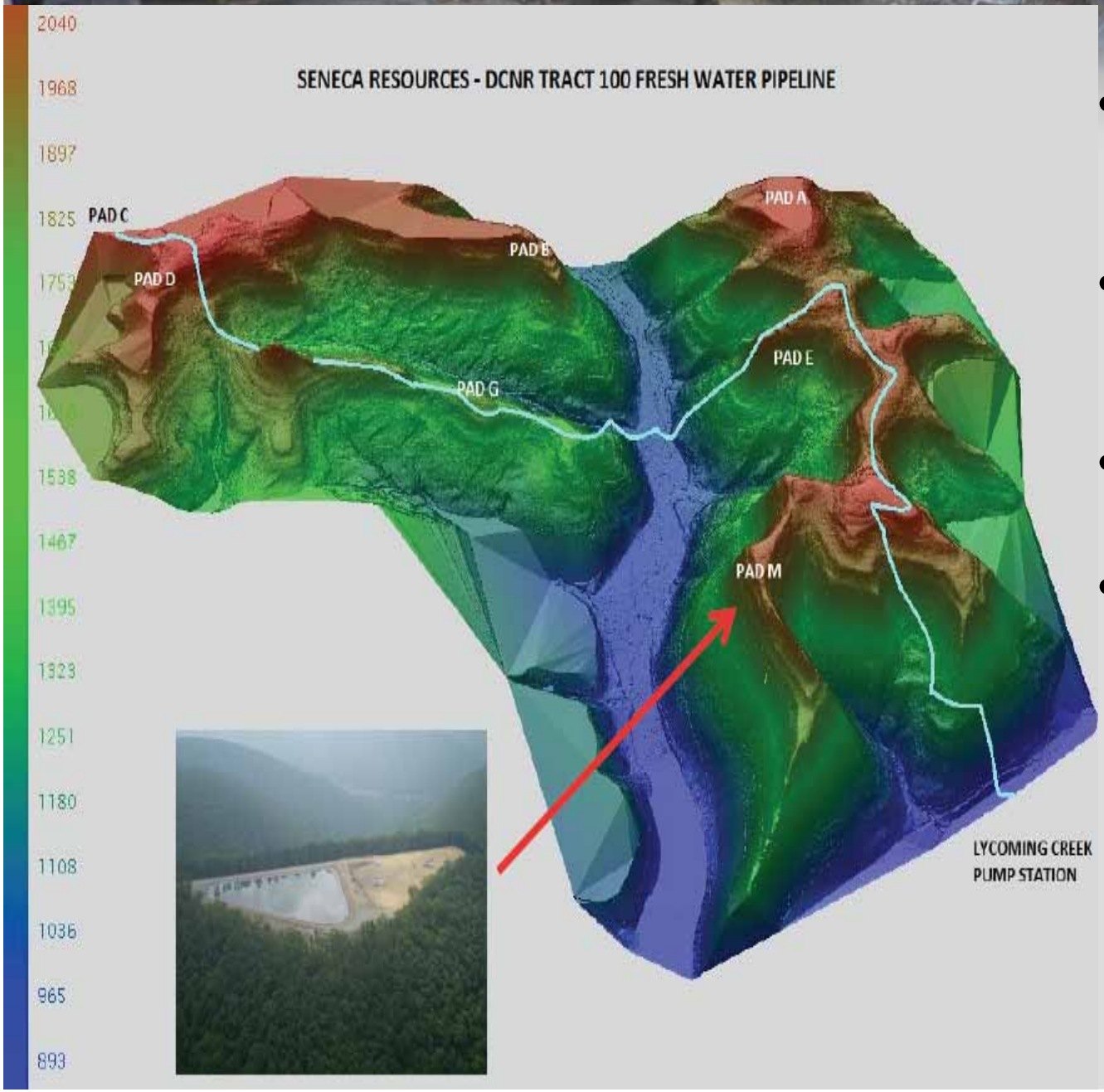
Water Supply Considerations

Number of factors to consider when developing a water supply for oil and gas development:

- Access to water near the drilling project area
- Proximity to well site: piping vs. trucking
- Availability: seasonal or perennial
- Will pass-by flows be required?
- Water quality
- Drilling schedule vs. permitting schedule
- Permitting complexity
- Budget

Efficiency of Piping Water



- Each well could require ~1000 truck trips
- Cost to install 12 km pipeline was ~$10MM
- Trucking water cost ~$20MM
- Recognize ~50% savings while minimizing fuel missions, truck traffic, and road impacts

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Fresh Water Storage Options

Water storage can occur in engineered impoundments, steel tanks, or temporary modular above ground storage impoundments (as shown from top left)

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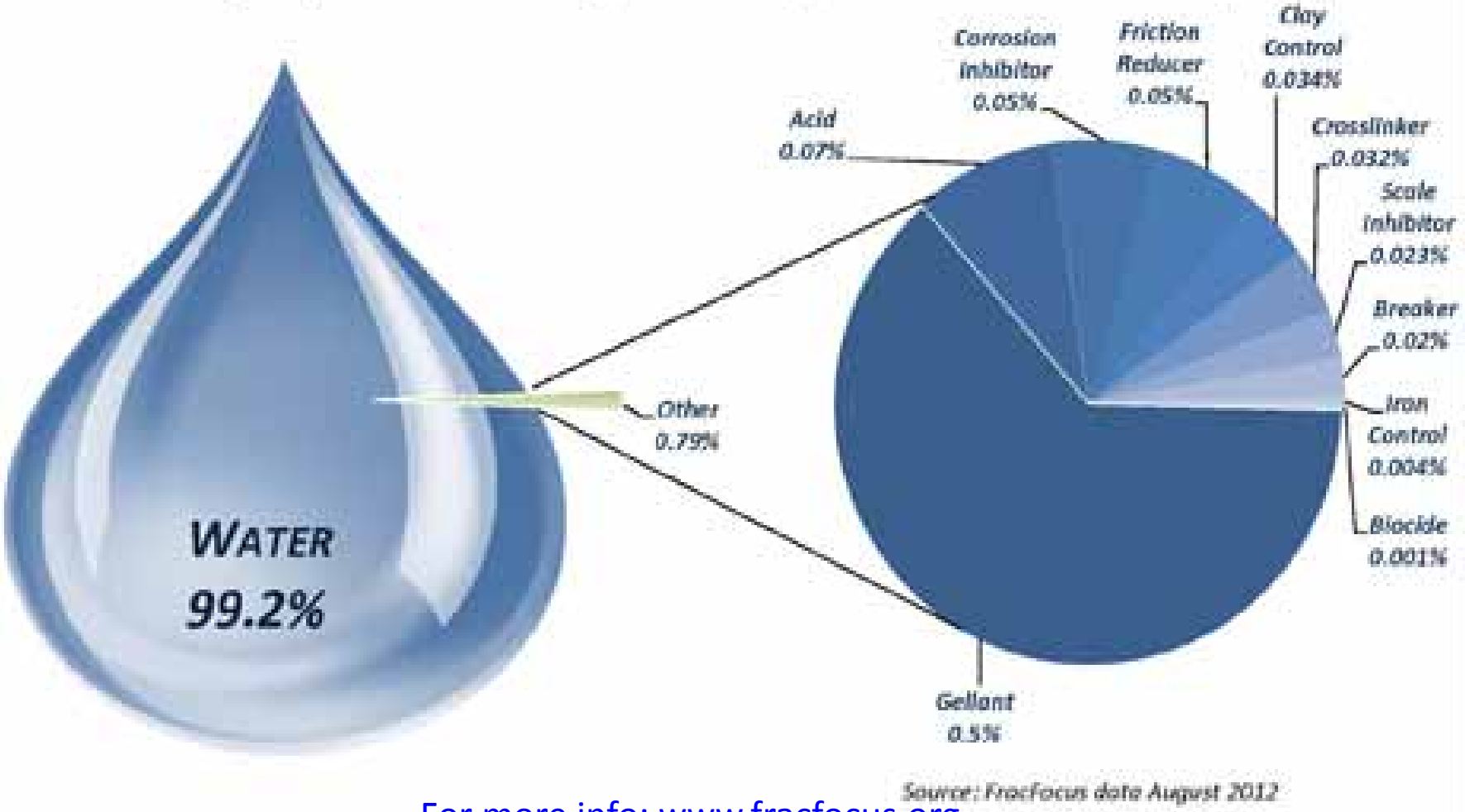
Average Hydraulc Fracturing Fluid Composition for US Shale Plays



Source: FracFocus data August 2012

For more info: www.fracfocus.org

Produced Fluids Storage

Produced fluids may be stored in lined impoundments for reuse with the following requirements

- Dual liner systems
- Groundwater monitoring wells and leak detection
- Fencing and bird netting

Steel tanks are often used to store produced fluids

- Minimizes potential for spill
- Fluids are emptied when tanks become full and treated, recycled, or ultimately disposed

Produced Fluid Management Options

Produced fluid management options

- Direct reuse (blending)
- On-site treatment w/reuse
- Off-site treatment w/reuse
- UIC well disposal

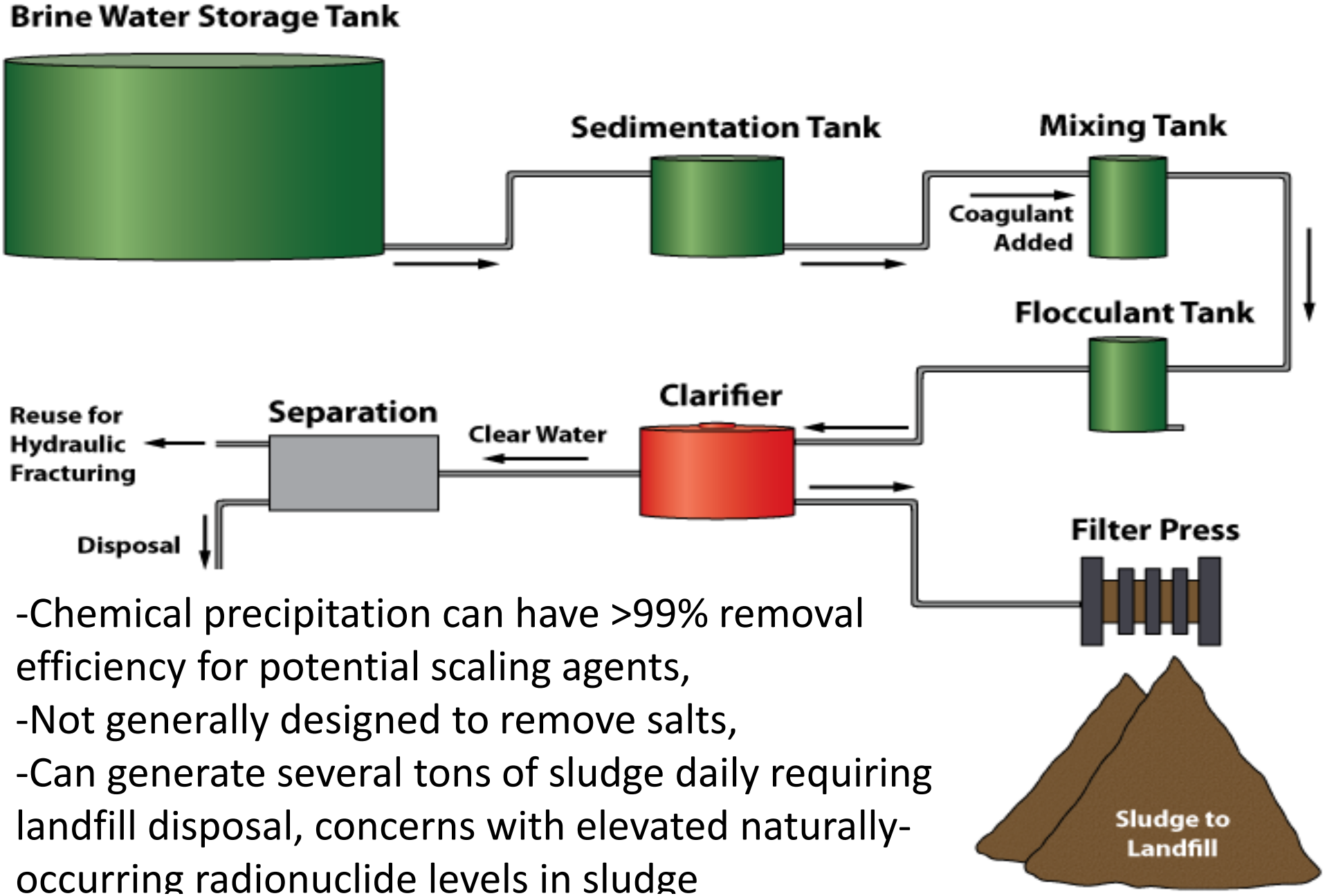
Treatment technologies include

- Filter socks
- Chemical precipitation
- Electrocoagulation
- Evaporation (MVR)
- Filtration
- Costs of <$2 to $10+/BBL

Most major shale plays recycle 10-50% of produced fluids and use disposal wells for the balance

In Pennsylvania during 2013 ~87% of shale gas flowback and produced water was recycled and ~13% disposed (mainly via injection wells) at cost of $15-20/BBL

Typical Treatment Scheme for Reuse



-Chemical precipitation can have >99% removal efficiency for potential scaling agents,
-Not generally designed to remove salts,
-Can generate several tons of sludge daily requiring landfill disposal, concerns with elevated naturally-occurring radionuclide levels in sludge

Field Treatment Technology

Field treatment use increasing due to:

-Cost effective

-Improving technology

-Less trucking transport

-Minimize fresh water use

-Improving efficiency

-Less overall environmental impact

Produced Water Treatment Specifications

Example industry produced fluid treatment levels for recycling purposes:

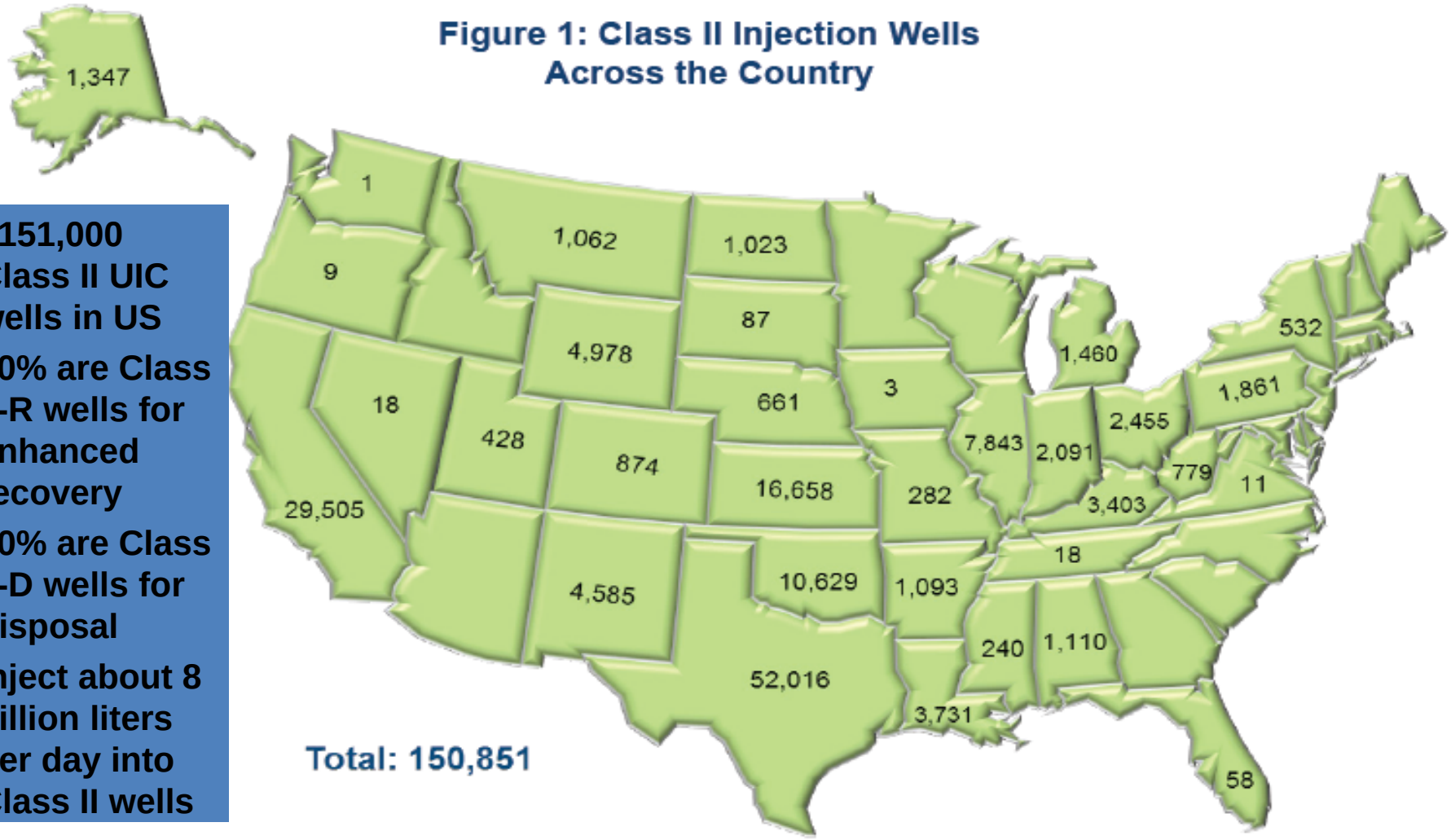
- TDS <50,000 ppm
- Hardness <26,000 ppm
- Ba, Sr , Fe, Mn < 10 ppm
- Ca <8,000 ppm
- Mg <1,200
- Sulfate <50 ppm
- TSS <30 ppm

Source: DOE Project DE-FE0001466

Presence of Brine Disposal Wells in US

- ~151,000 Class II UIC wells in US
- 80% are Class II-R wells for enhanced recovery
- 20% are Class II-D wells for disposal
- Inject about 8 billion liters per day into Class II wells

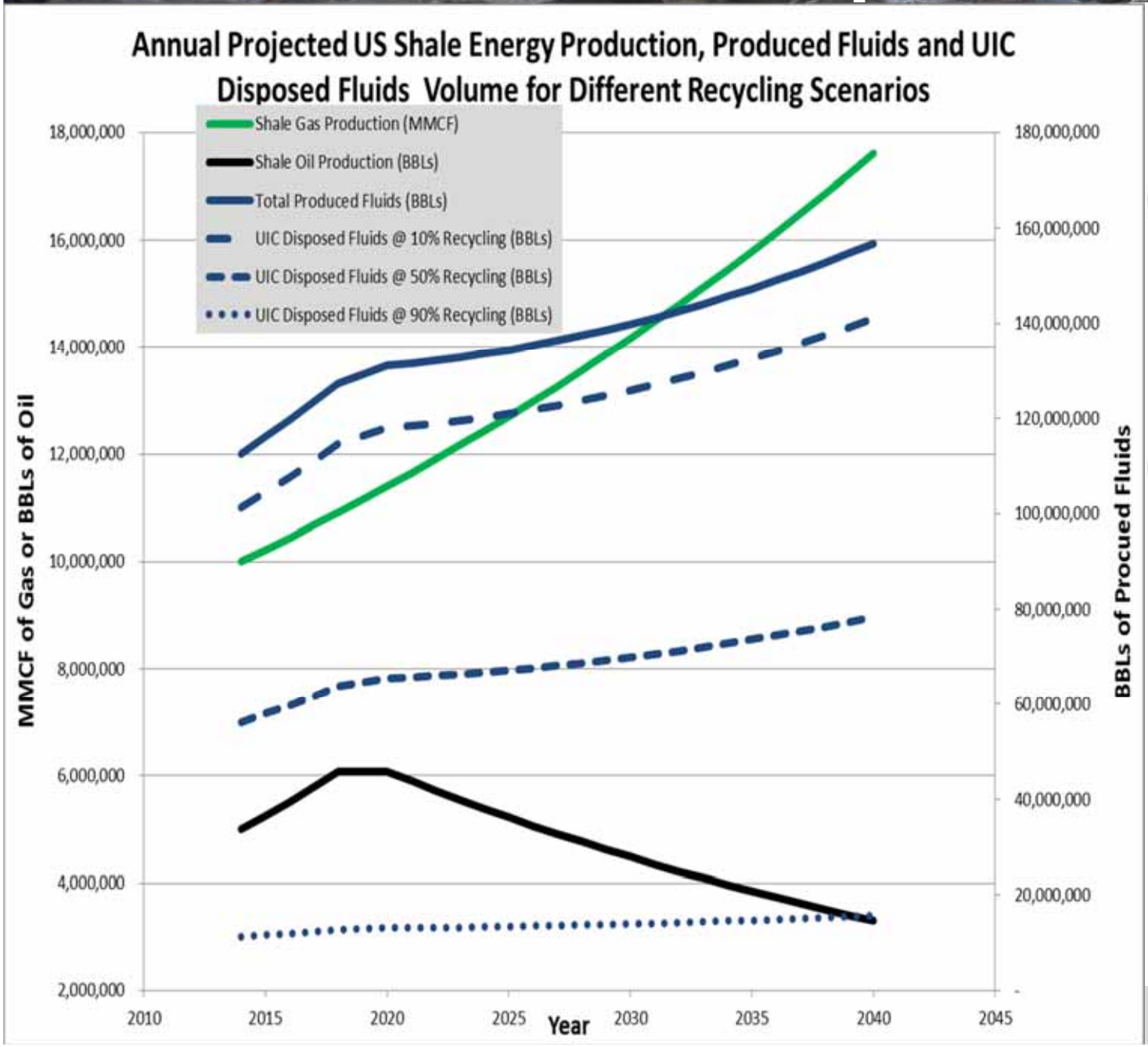
Figure 1: Class II Injection Wells Across the Country

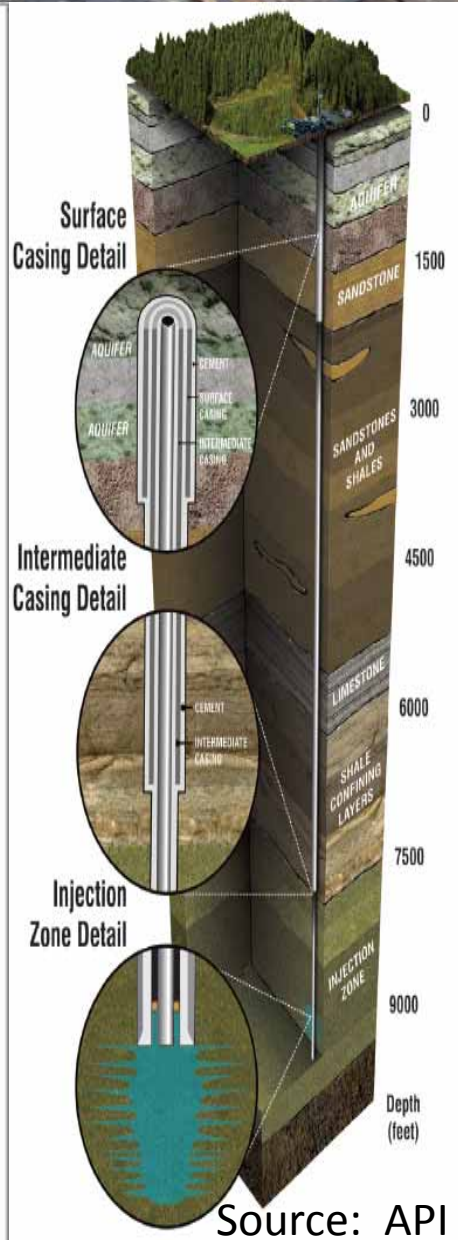


Data: EPA

Review of the literature published in the past 5 decades indicates that fewer than 40 incidents of seismic activity that were felt at the surface were potentially associated with Class II injection wells in the United States.

Use of Brine Disposal Wells





Source: API

Potential Water Quality Impact Pathways

- Methane migration into groundwater/surface water due to faulty well construction
- Migration of drilling fluids into the aquifer
- Direct spill of fluids to ground surface via leaking pipes, impoundments, spills or a blowout
- Erosion and sedimentation from pads and roads
- Cumulative water withdrawal impacts on stream flow or aquifer levels
- Connecting into abandoned wells during drilling or fracturing operations
- Fracturing fluid migration (??)

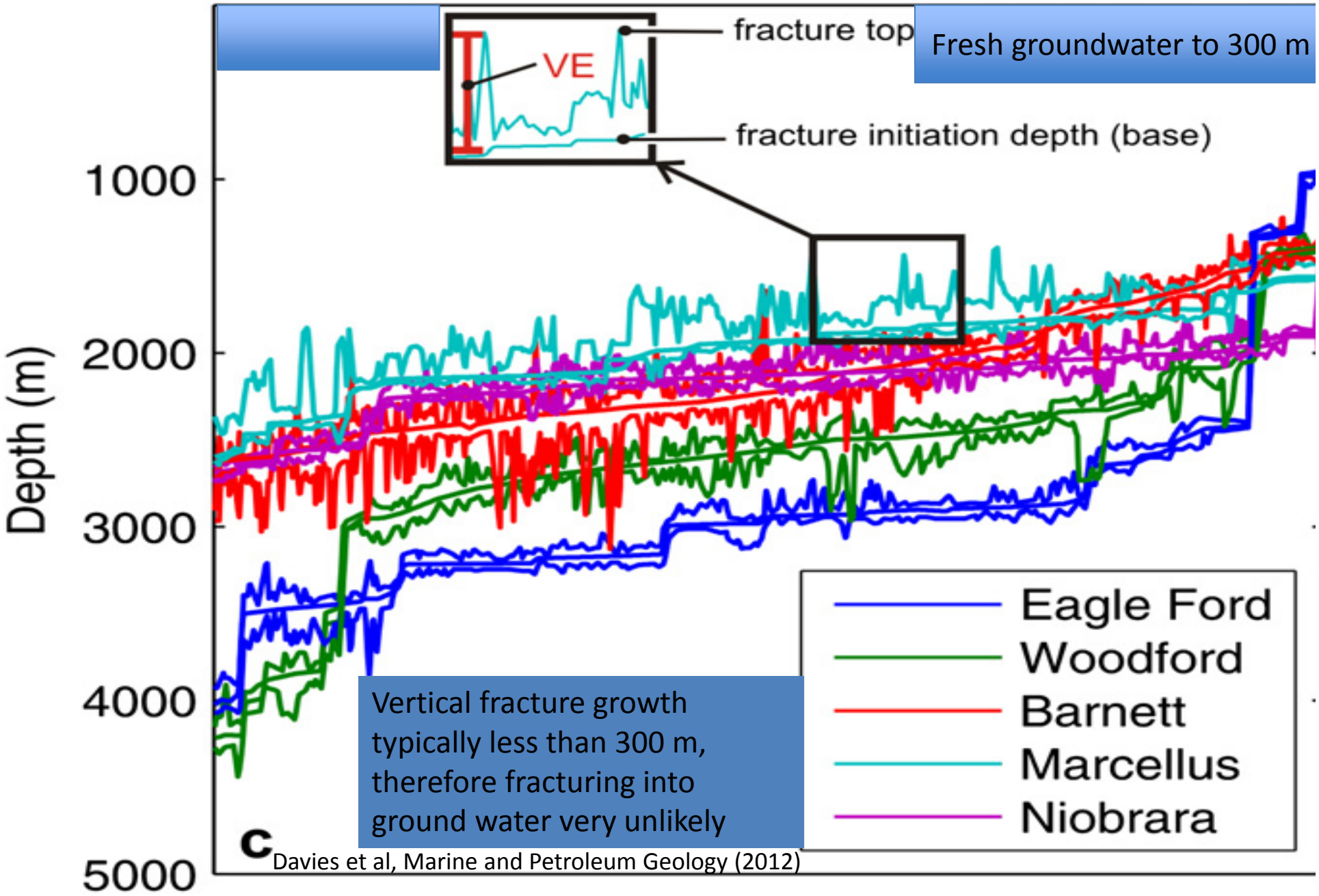
Study of Groundwater Quality Before and After Drilling

- Study: *The Impact of Marcellus Gas Drilling on Rural Drinking Water Supplies,* Center for Rural PA, October 2011
- PSU Researchers collected pre- and post-drilling water sample from private wells
- Collected and analyzed nearly 230 samples within 1,000 feet and within 1 mile of Marcellus wells
- No significant before/after changes in water quality
  - ~40% of wells fail at least one drinking water standard and background methane found in ~24% of the wells.

Impacts from Drilling Process

- Some companies have used drilling foams during shallow casing installation
- These foams can migrate away from the well bore and impact the aquifer, nearby private wells, or springs
- The industry now uses air drilling when going through fresh groundwater

Fracture Growth in US Shale Plays



Pennsylvania Recommended Pre-Drilling Water Quality Testing Parameters

Analyte (Inorganic)
Alkalinity*
Chloride*
Conductivity
Hardness
Bromide
pH*
Sulfate**
Total Dissolved Solids*
Turbidity*
Total Suspended Solids

Analyte (Trace Metal)
Barium*
Calcium*
Iron*
Magnesium
Manganese*
Potassium
Sodium*
Strontium
Arsenic
Zinc
Aluminum
Lithium
Selenium

Analyte (Organic)
Methane*
Ethane*
Propane*
Total Petroleum Hydrocarbons***

Additional Suggested Testing[1]
Total Coliform Bacteria

[1] While not related to drilling activities, Total Coliform Bacteria testing is suggested due to health concerns and as a way to assess overall drinking water quality.

Considerations for pre-drilling testing:

-Have an independent third party collect and analyze samples

-Need to have proper chain-of-custody for samples

-Need to use certified lab for analysis

-If change in water quality within 12 months and 2,500 feet of shale well then operator assumed liable and must remedy

Note - *As a minimum, a homeowner wishing to have their private water supply well tested should analyze for these parameters. **Consider where coal formations are present. ***Consider in western Pennsylvania's oil-producing regions.

Water Protection Best Practices

- Adequate geologic to allow proper well construction and cementing
- Conduct pre-drilling water supply sampling to establish background
- Characterize methane when found in water sources
- Line well pads, secondary containment and careful fluid handling
- Sufficient setback distances from water supplies and surface waters
- Recycling produced fluids
- Informing the public of drilling operations to be aware of any impacts

Thank you!

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