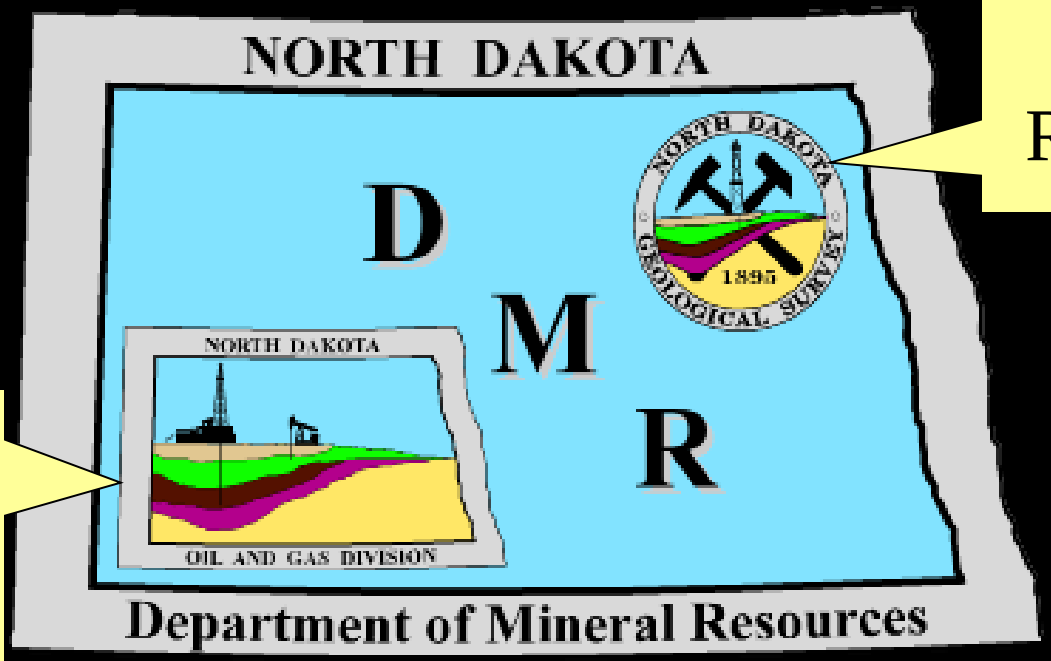
North Dakota Department of Mineral Resources



NDGS
Research Arm

OGD
Regulatory
Arm

https://www.dmr.nd.gov/oilgas/ *https://www.dmr.nd.gov/ndgs/*

600 East Boulevard Ave. - Dept 405
Bismarck, ND 58505-0840
(701) 328-8020 *(701) 328-8000*

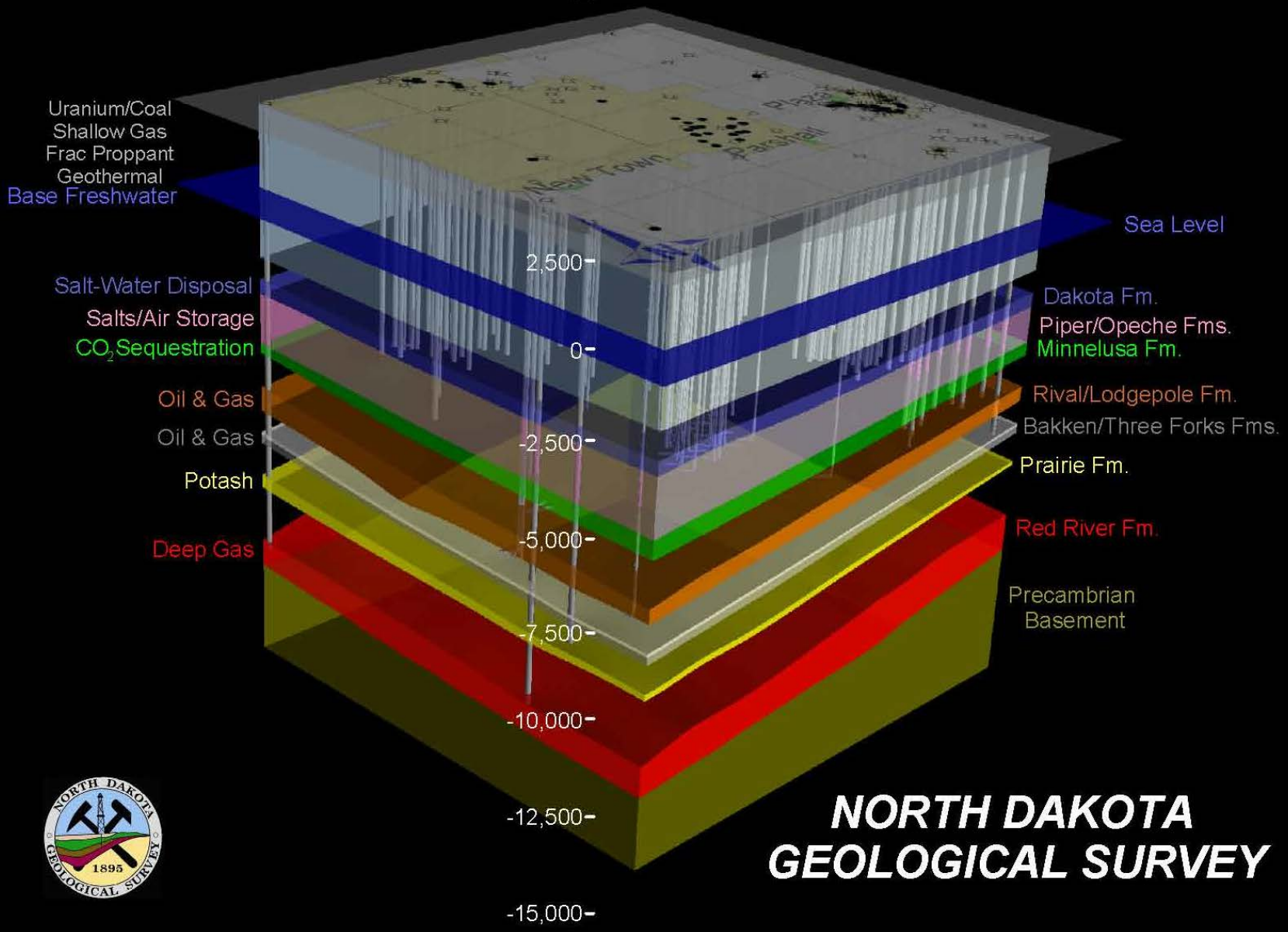
Hydraulic Fracturing

Lifeline to Domestic Independence

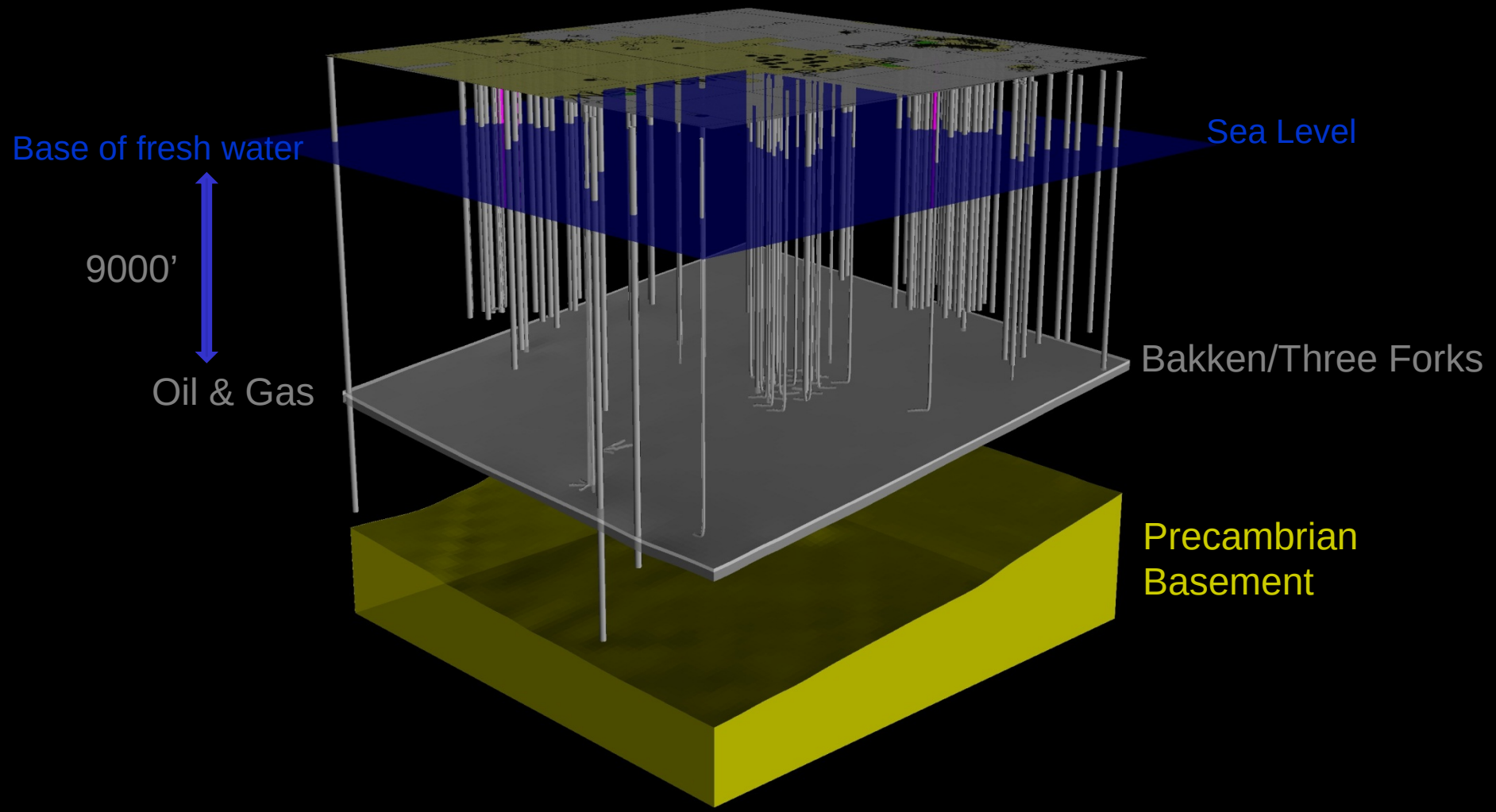
- Hydraulic Fracturing
- Frac water
- State Regulation
- North Dakota results

Bruce E. Hicks
Assistant Director
NDIC-DMR-OGD
Bismarck, ND

Three-Dimensional Geologic Model of the Parshall Area



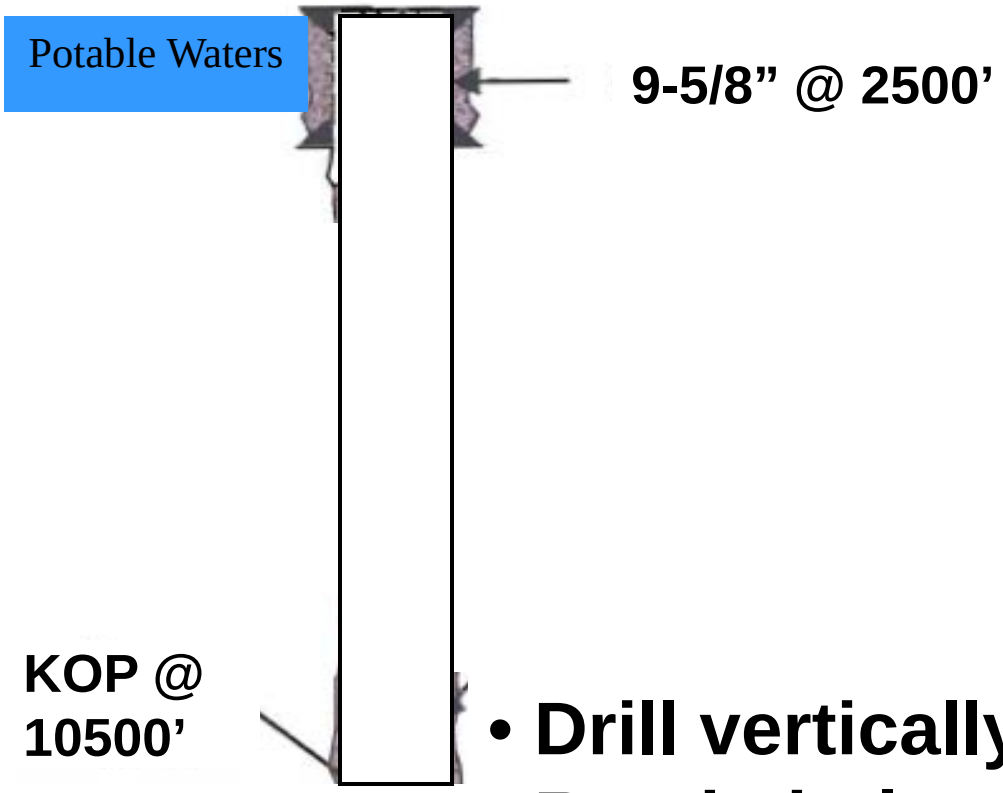
NORTH DAKOTA GEOLOGICAL SURVEY


Base of fresh water
9000’
Oil & Gas
Sea Level
Bakken/Three Forks
Precambrian
Basement

TYPICAL HORIZONTAL OIL WELL

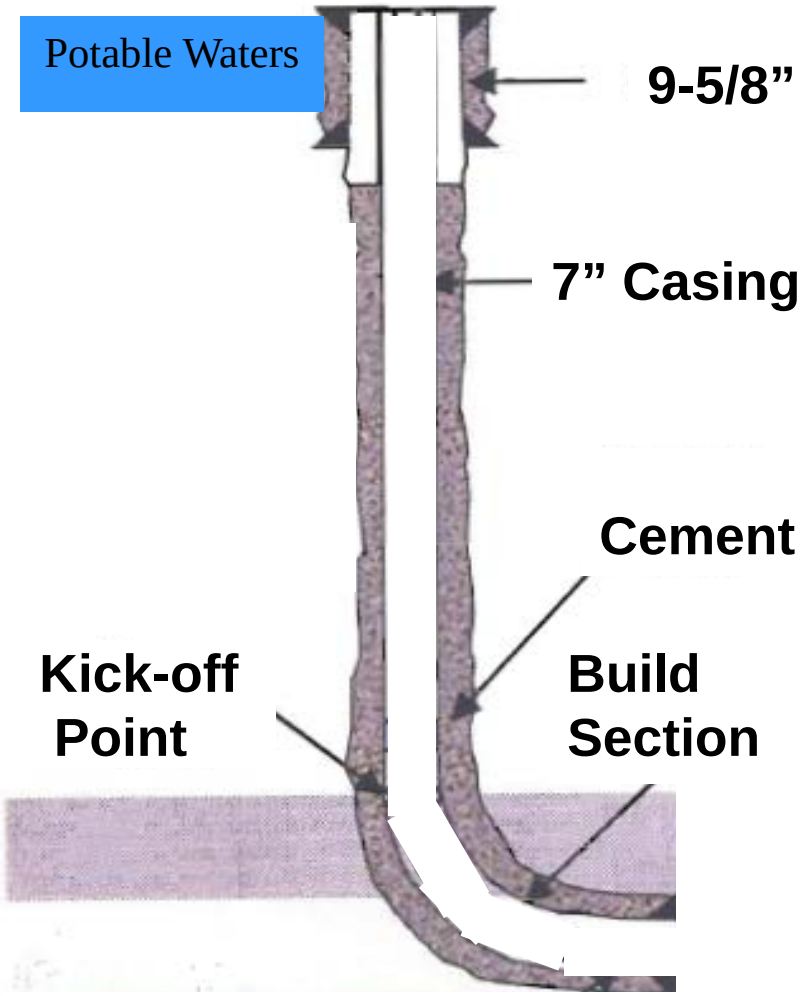
- **Drill with fresh water**
- **Total depth below lowest potable water**
- **Run in hole with surface casing**
- **Cement casing back to surface of ground**
- **1st layer of surface water protection**

TYPICAL HORIZONTAL OIL WELL



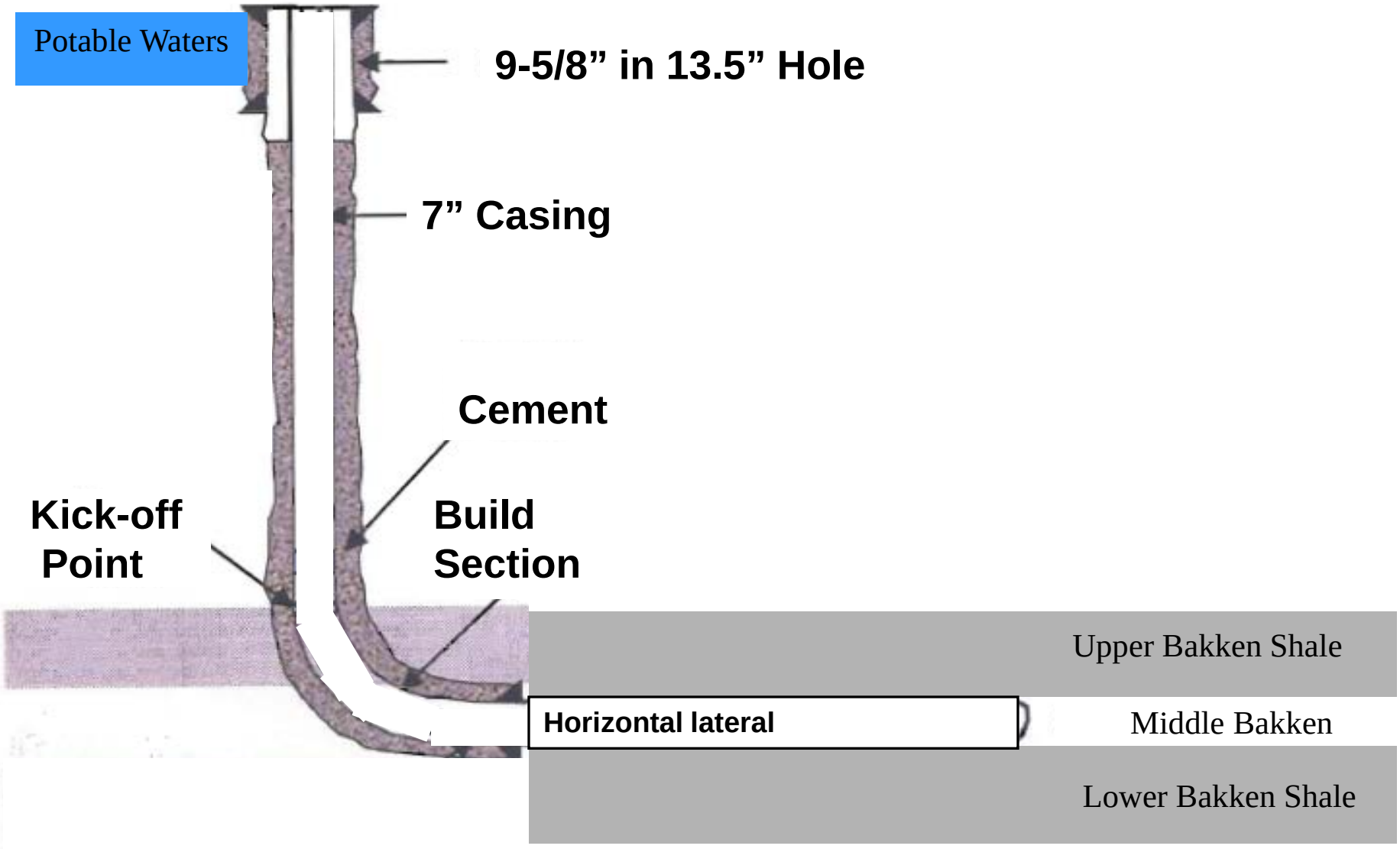
- Drill vertically to kick-off point
- Run in hole with bent assembly
- Downhole mud motor

TYPICAL HORIZONTAL OIL WELL

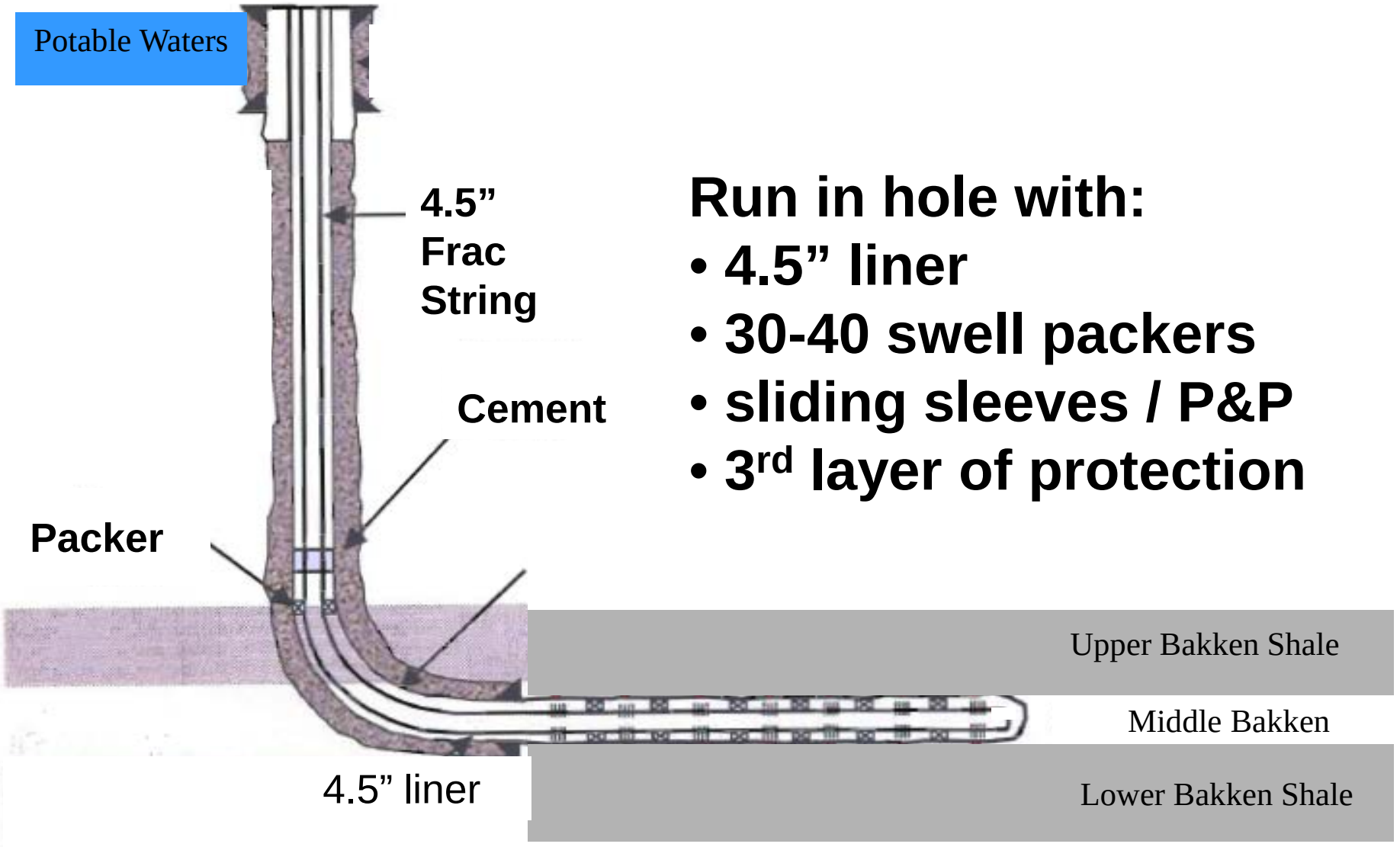


- Drill 8-3/4” hole to pay
- Run in hole with 7” casing
- Cement 7” casing
- 2nd layer of protection

TYPICAL HORIZONTAL OIL WELL



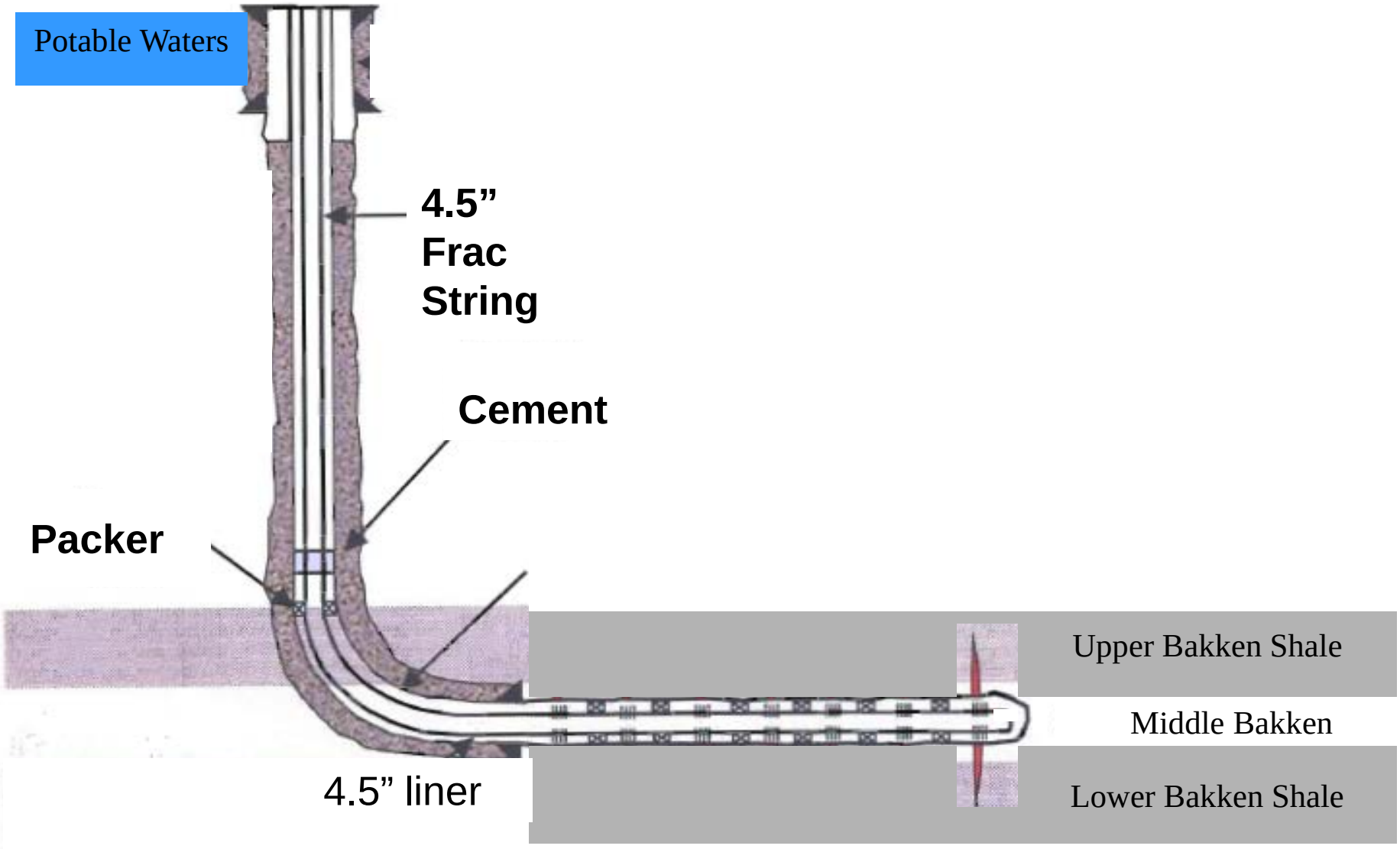
TYPICAL HORIZONTAL OIL WELL



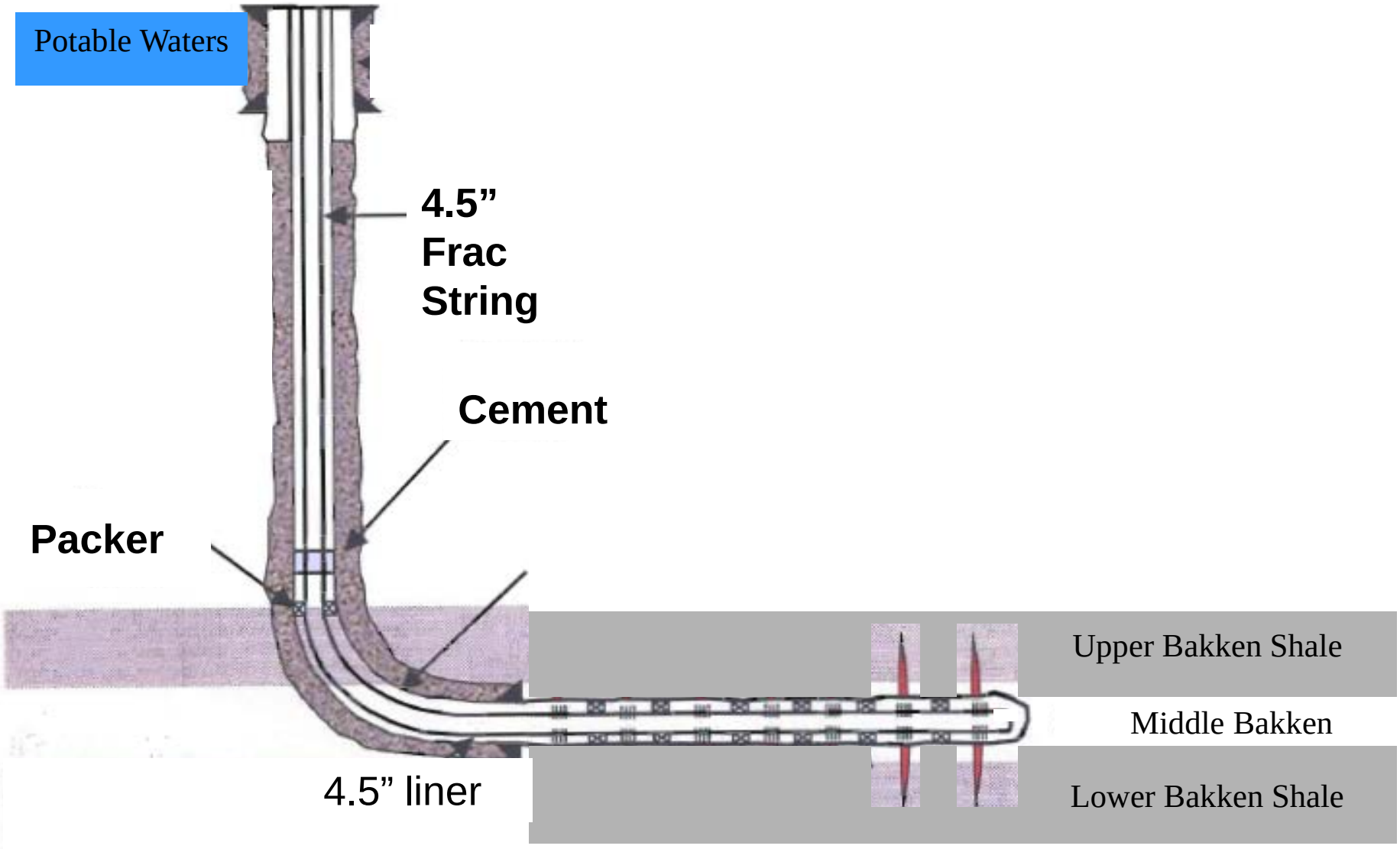
Run in hole with:

- **4.5” liner**
- **30-40 swell packers**
- **sliding sleeves / P&P**
- **3rd layer of protection**

TYPICAL HORIZONTAL OIL WELL



TYPICAL HORIZONTAL OIL WELL



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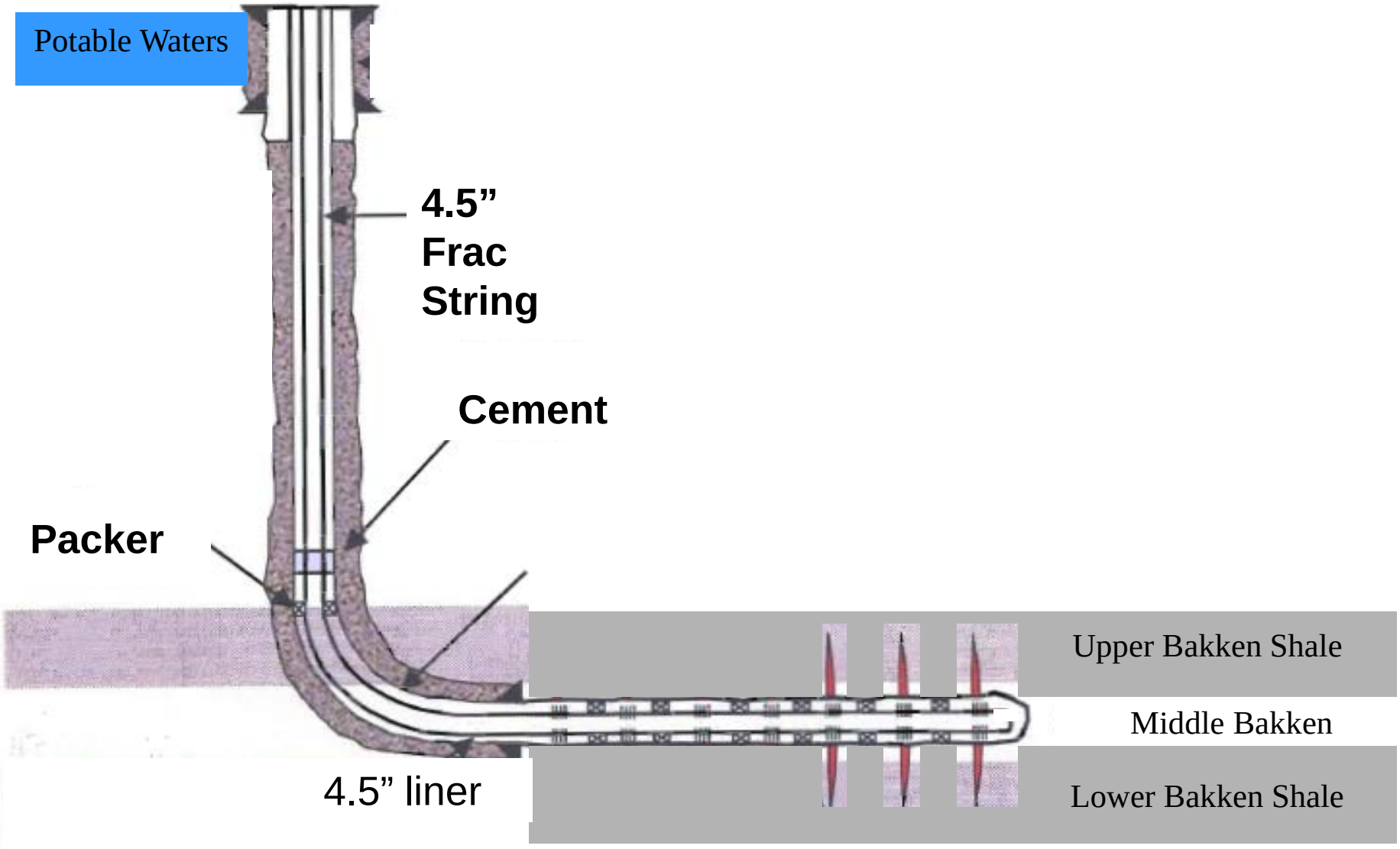

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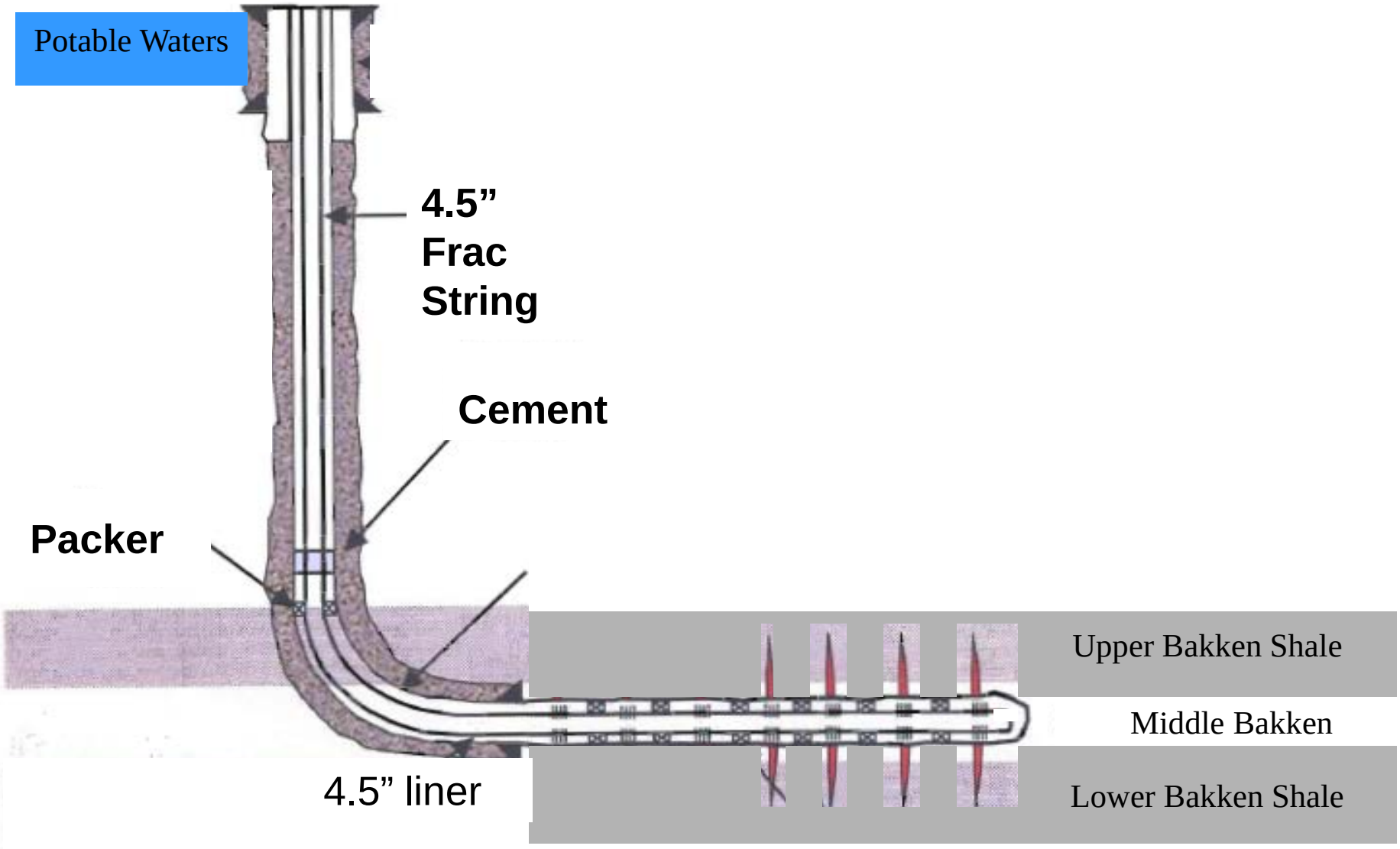
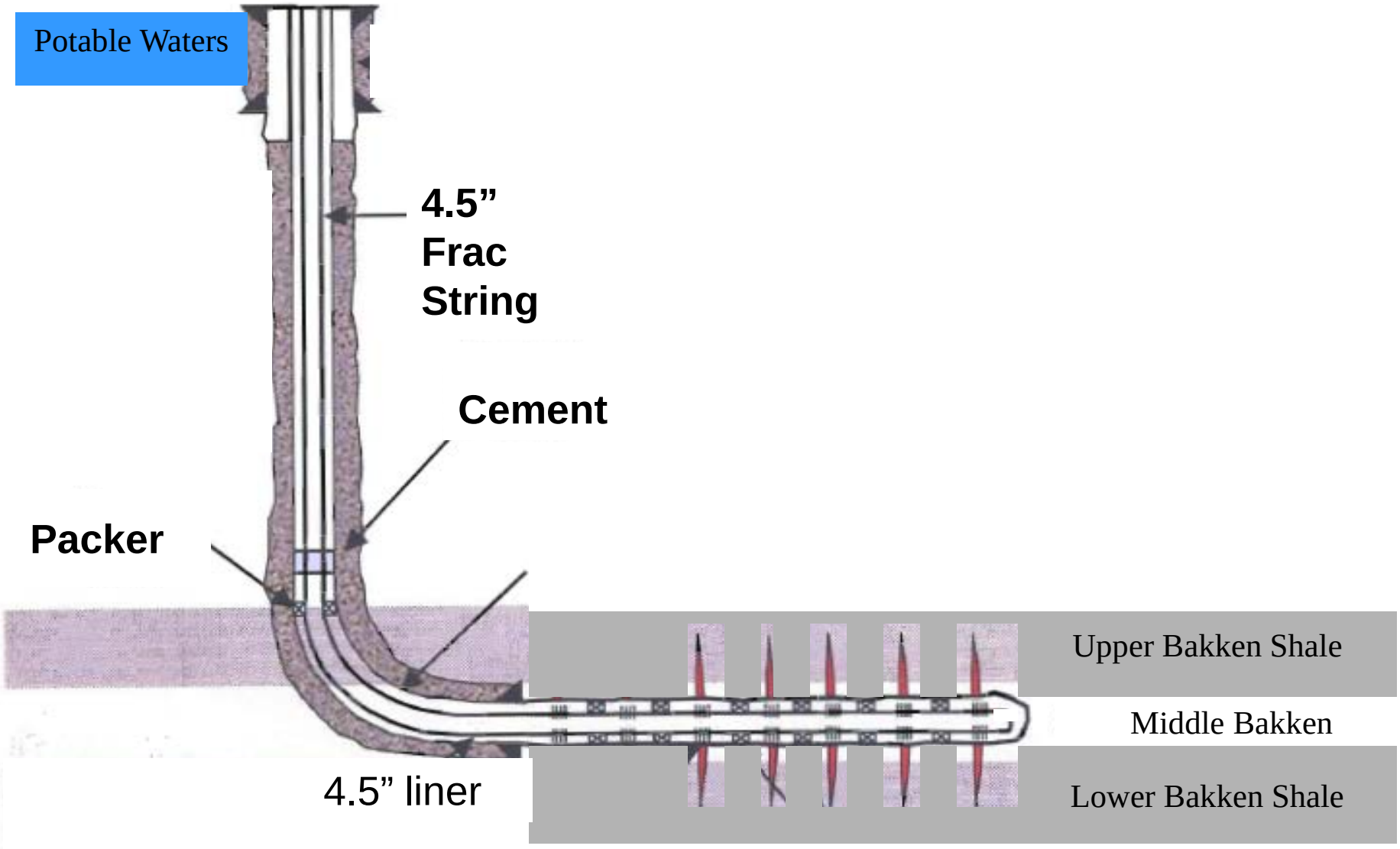
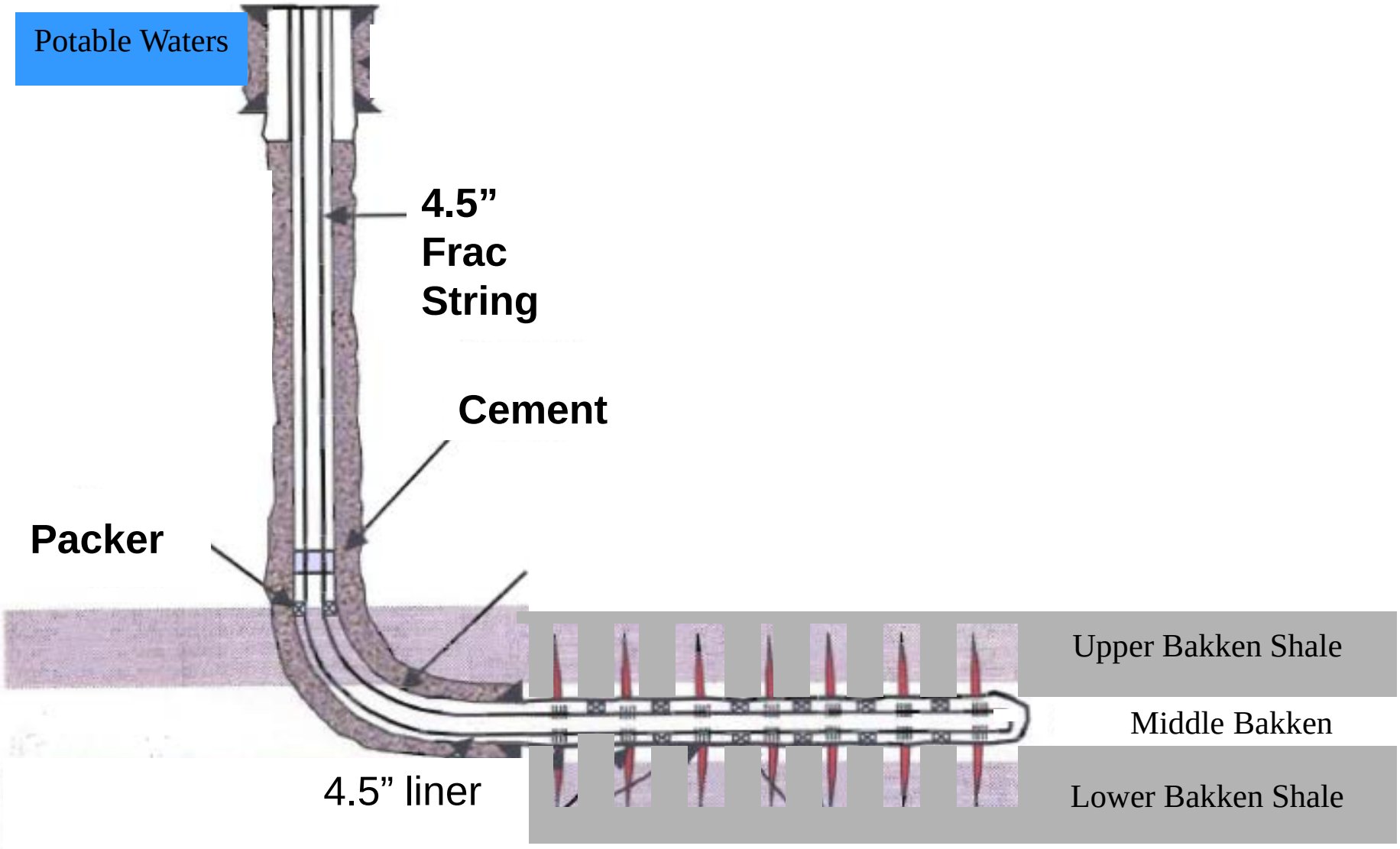


TYPICAL HORIZONTAL OIL WELL



TYPICAL HORIZONTAL OIL WELL



Industrial Commission Regulation

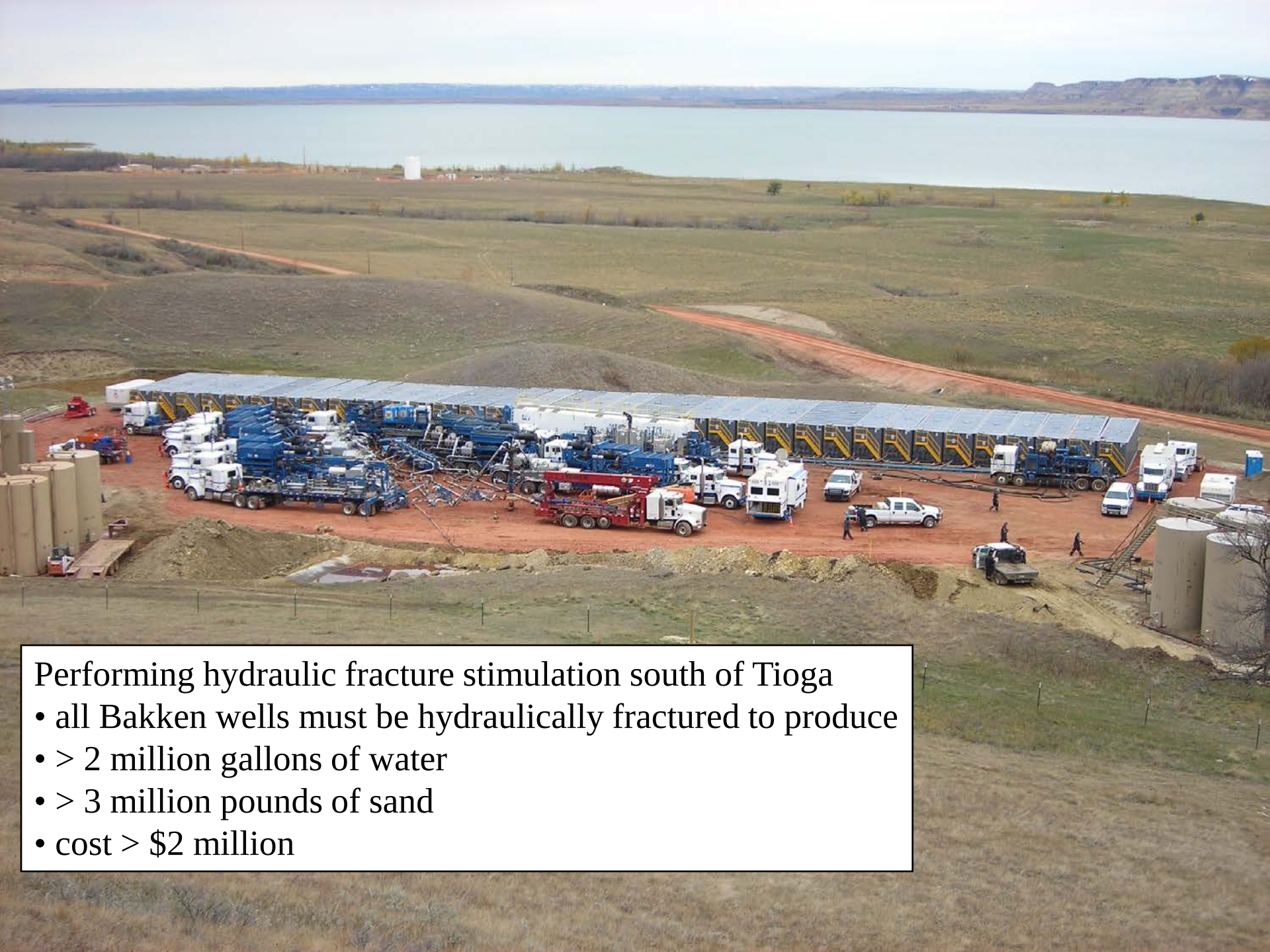
- Hydraulic fracturing regulation
  - NDAC Section 43-02-03-27.1
    - https://www.dmr.nd.gov/oilgas/
  - sur csg open + diversion line to pit/vessel
  - relief valve on treating lines w/ck valves
  - remote operated frac valve on treat lines
  - if sur csg press > 350 psi notify NDIC
  - 60 days post FracFocus chem registry

- Frac down 4-1/2” frac string
  - sting into liner or set pkr below Kd
  - press and monitor 4-1/2” X 7” ann
  - press relief valve on treating lines
    - set </= 85% of yield press
  - press relief valve on 4-1/2” X 7” ann
    - set </= 85% of weakest 7” yield
    - diversion line run to pit or vessel

- Frac down 7” csg string
  - max treating press 85% of csg rating
  - csg eval tool to verify wall thickness
  - inspect + photo of top 7” csg jt
    - reduce treating press if warranted
  - cmt eval tool to confirm cmt
    - run frac string if defective cmt
  - press test 7” and wellhead
  - if wellhead press rating < frac design
    - use wellhead protection system

- Incidents—mechanical issues
  - a dozen failures prior to new rules
  - zero failures after implementing rules
  - completing new wells
    - relief valves allow press to spike
      - set at 7000 psi, spike at 9000 psi
    - wear on 7” top jt
      - rig not centered over well
    - light 7” csg jt in string

- Incidents—operator error
  - recent workovers
    - tapered tbg string
      - BOP had only one pipe ram
    - no blind rams in BOP
      - perfed sub caught in BOP



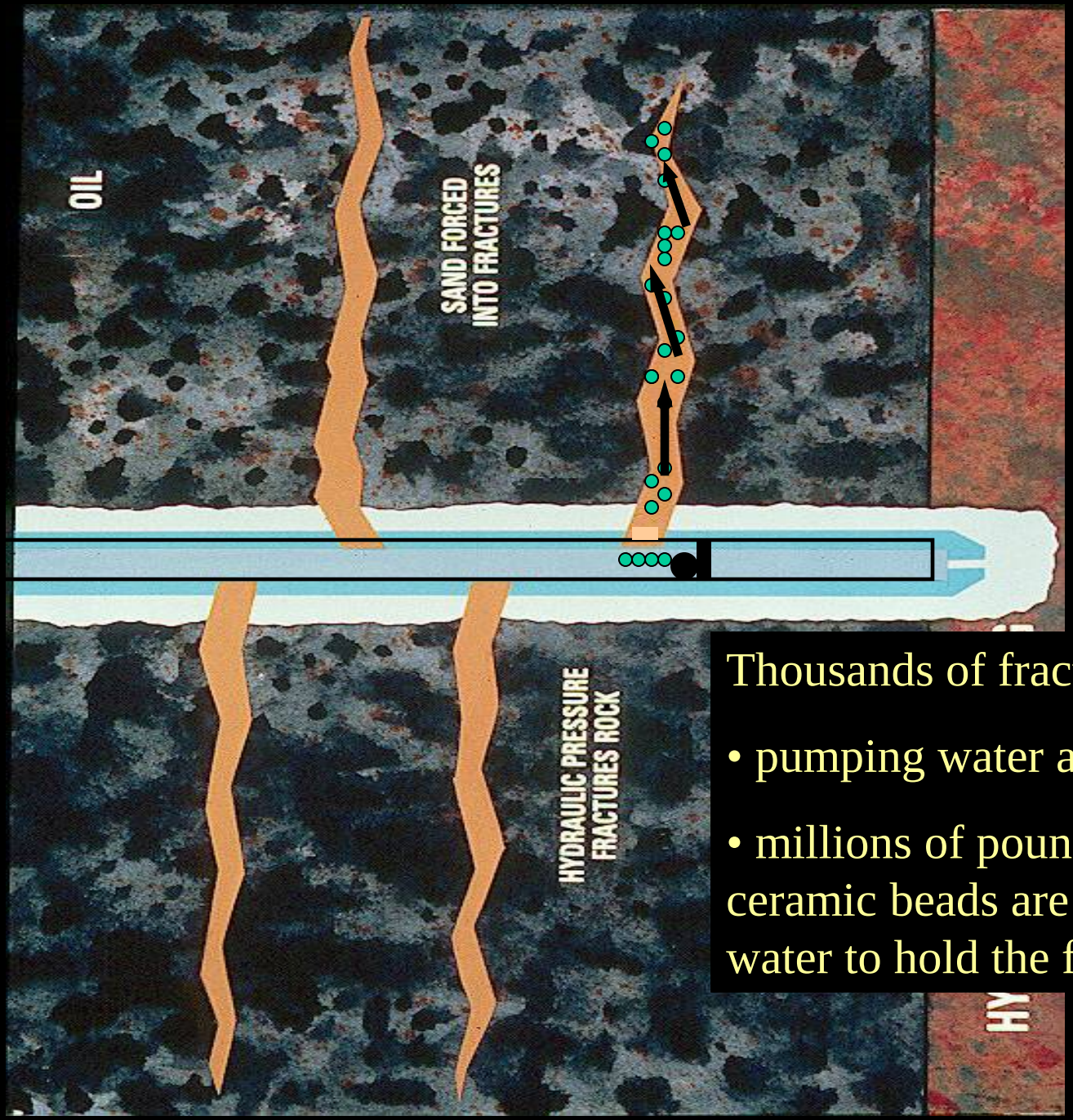
Performing hydraulic fracture stimulation south of Tioga

- all Bakken wells must be hydraulically fractured to produce
- > 2 million gallons of water
- > 3 million pounds of sand
- cost > $2 million

WHY FRAC THE ROCK?

- already developed easy oil
  - oil flows easily without fracking

- Unconventional Reserves
  - reservoirs are tight
  - look at sample
  - uneconomic to produce w/o fracing
  - must create a path for oil to flow

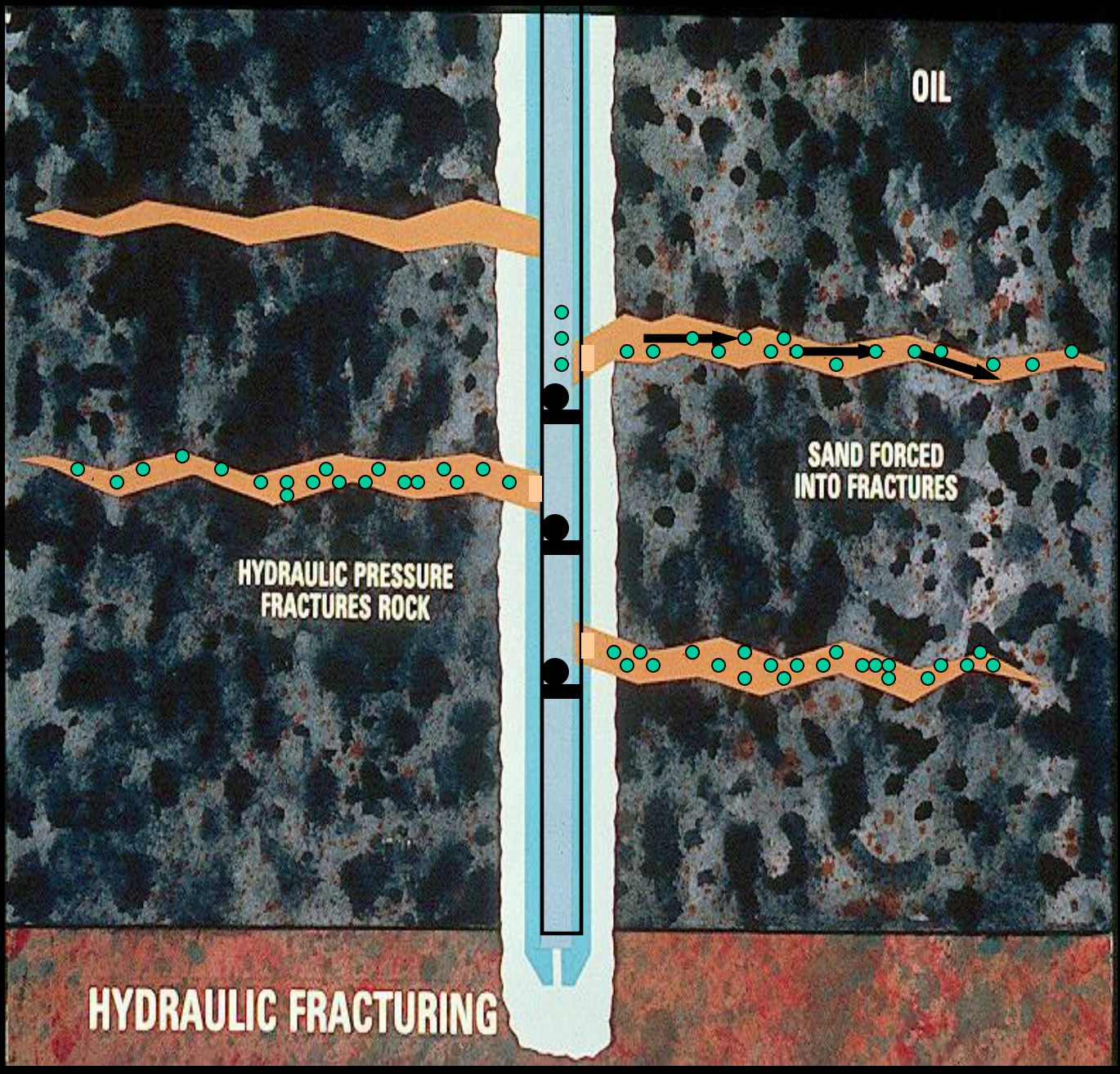


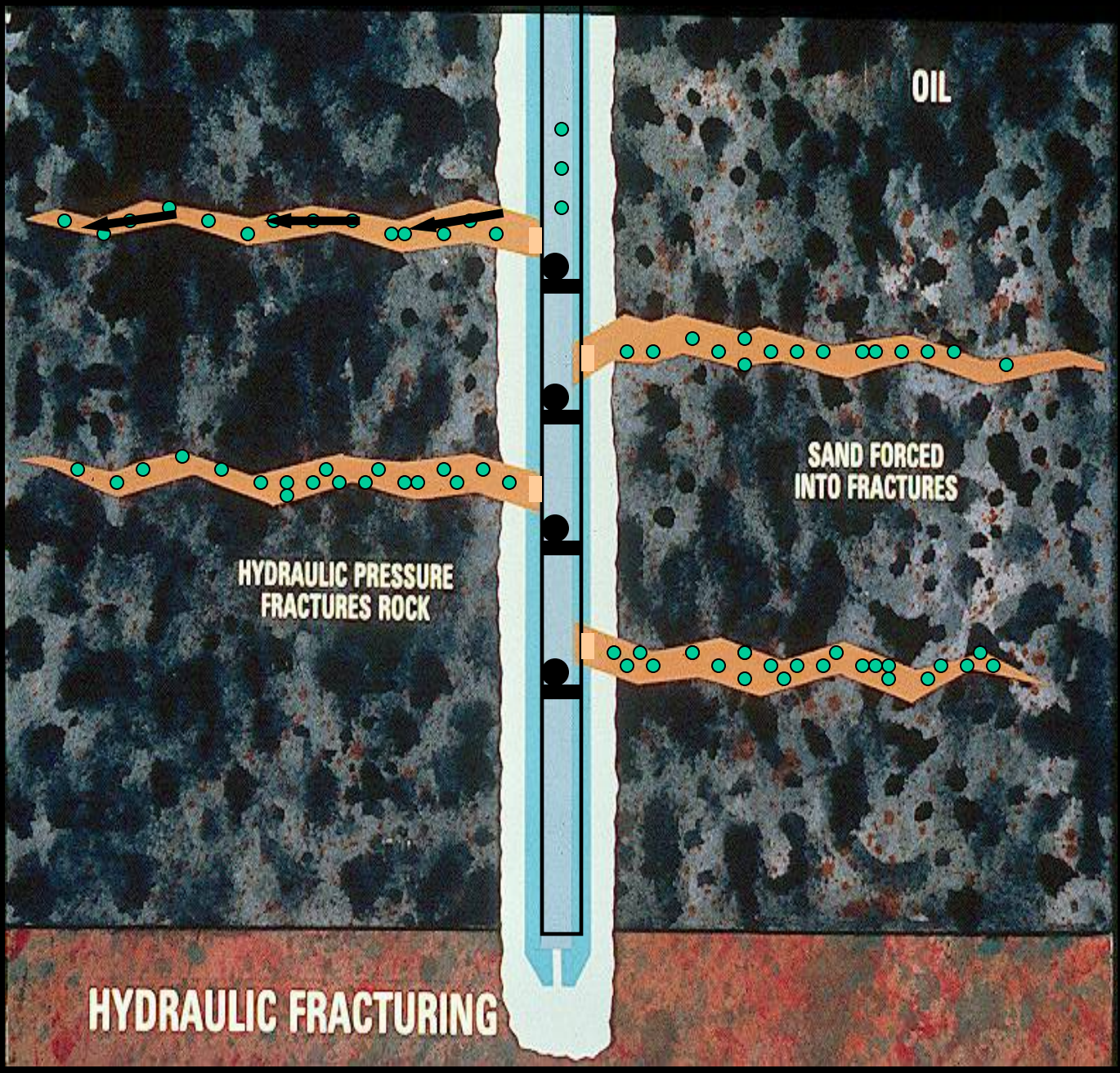
Thousands of fractures are created

- pumping water at 6,000-9,000 psi
- millions of pounds of sand and ceramic beads are pumped with the water to hold the fractures open.

Stage Fracturing

- up to 40 stages


OIL
SAND FORCED
INTO FRACTURES
HYDRAULIC PRESSURE
FRACTURES ROCK
HYDRAULIC FRACTURING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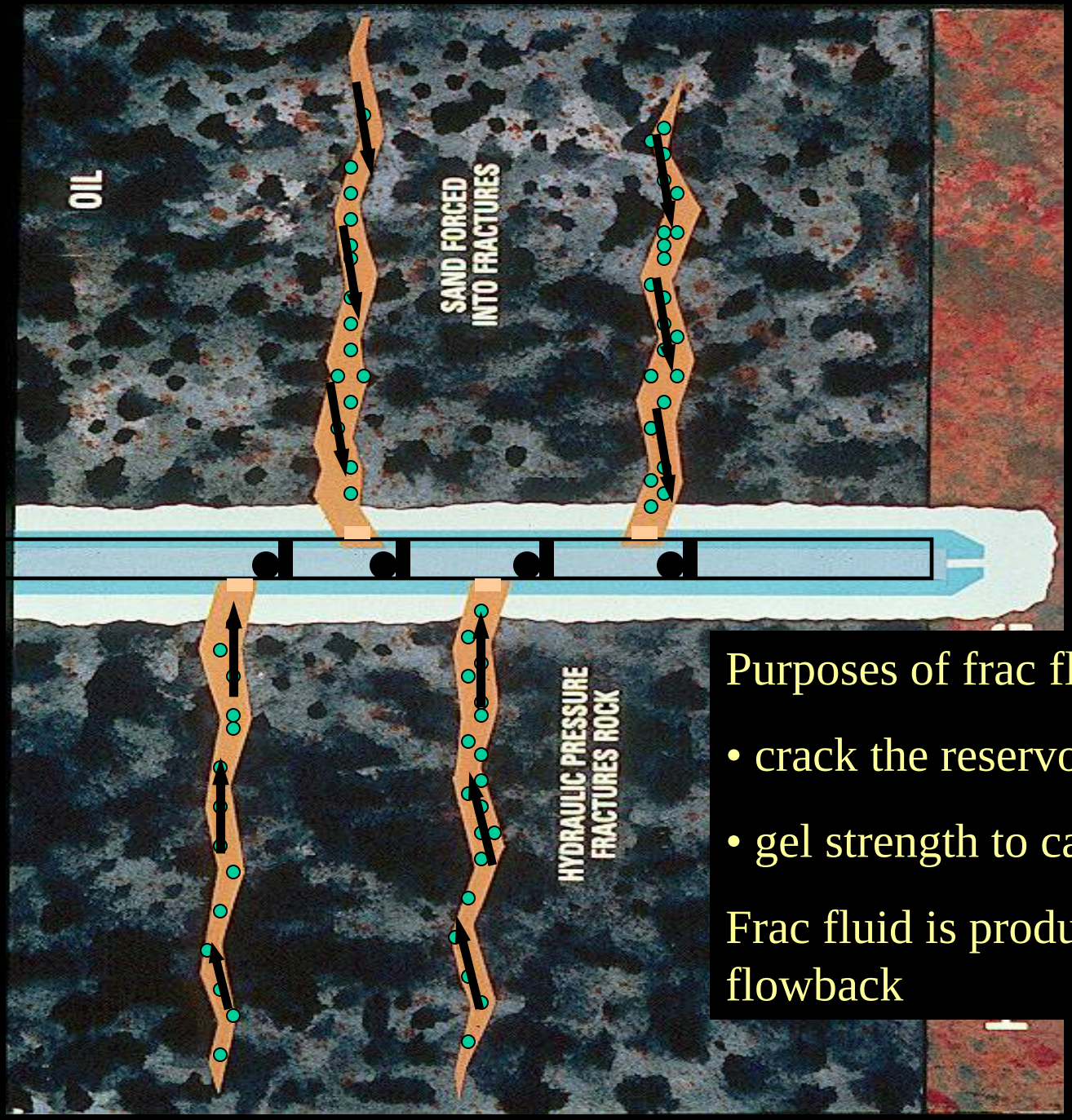


Purposes of frac fluid

- crack the reservoir
- gel strength to carry sand

Frac fluid is produced back as flowback

Hydraulic Fracturing: Mixture of water, sand and chemicals pressurized and pumped into the well to form microscopic fractures in shale.

States have been regulating the full life cycle of hydraulic fracturing for decades

- Water Appropriation Regulation
- Oil & Gas Regulation
- Health Department Regulation
- Geologic setting in each basin different

Hydraulic Fracturing Stimulation is Safe

- IOGCC survey—no contamination
- GWPC study verifies State's regs
- GWPC National Registry f/chemicals

North Dakota has been regulating the full life cycle of hydraulic fracturing for decades

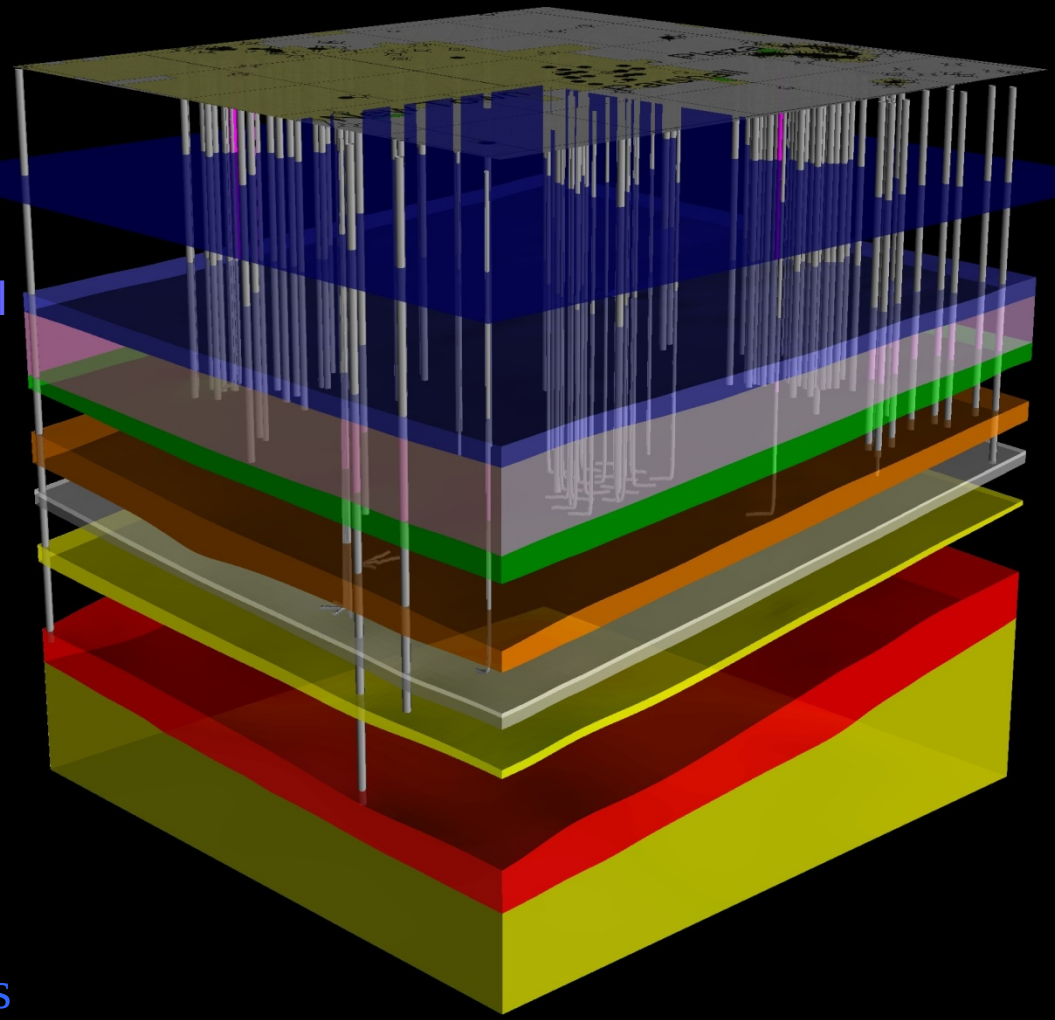
- Water Comm—water withdrawls
- Industrial Comm—well permitting & disposal of flowback water
- Health Dept—spill cleanup

Water Commission Regulation

- Regulate water appropriations
- Guard against withdrawls exceeding recharge

Industrial Commission Regulation

- Water flowback after frac
  - Storage in open pits prohibited
  - Disposal wells permitted through Underground Injection Program
  - Disposal zone is 2,500 feet below potable waters



336 disposal wells

720,000 barrels per day

Health Department Regulation

- Cleanup of discharge to environment
- Coordinate w/local Emergency offices
- Emergency Planning and Community Right-to-know Act (EPCRA)
  - Congress passed to protect against storing and handling chemicals
  - Requires material safety data sheet (MSDS) for each chemical on location

Thirsty Horizontal Wells

- 2,000 wells / year
- 15-25 years duration
- 20 million gallons water / day

FRAC WATER NEEDS

- Lake Sakakawea best water resource
  - one inch contains 10 billion gal water
    - 5000 wells @ 2mil gal wtr/well
    - 2.5-year supply

FRAC WATER ADDITIVES

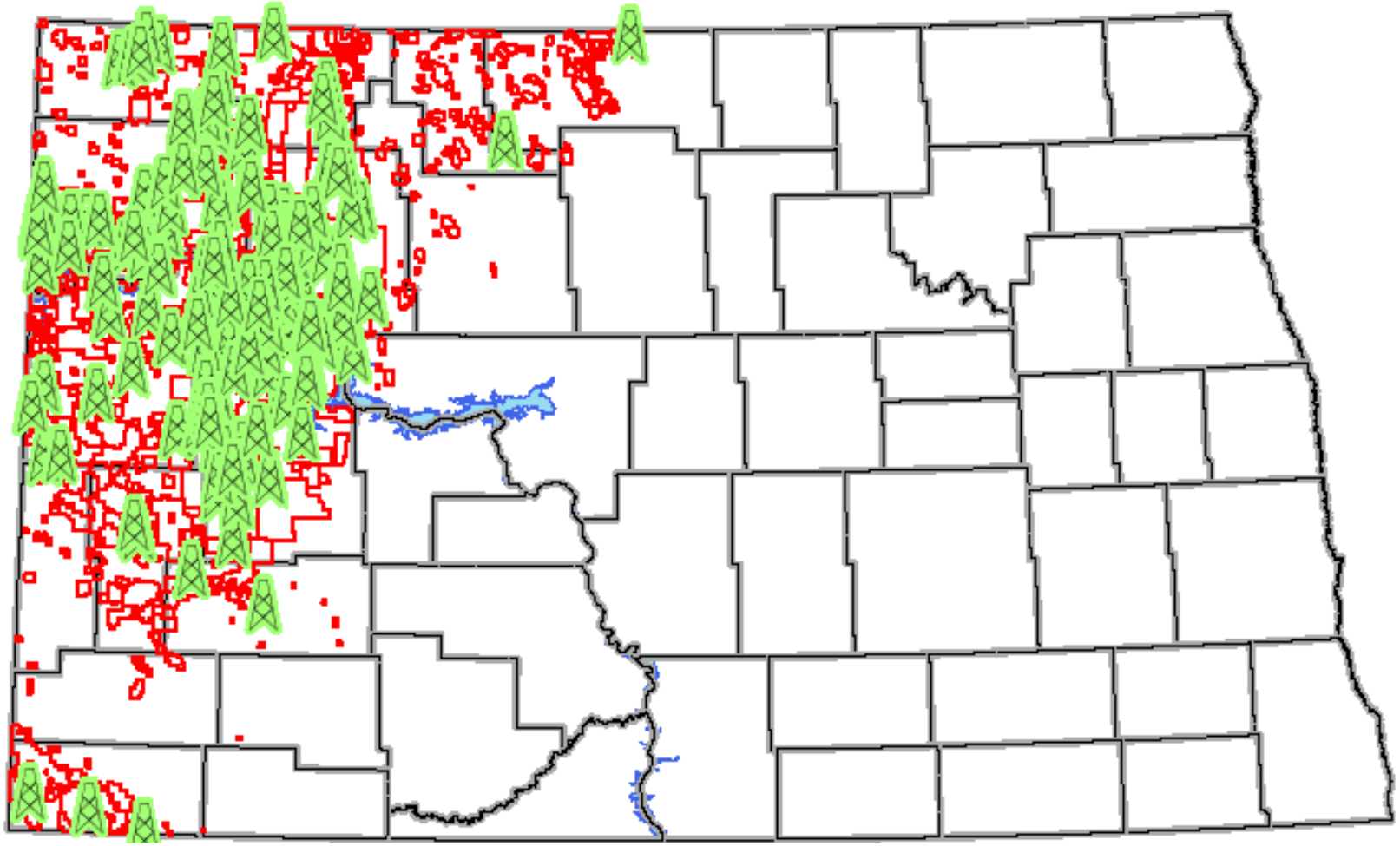
- 99.5% water and sand
  - 80.5% water
  - 19.0% proppant
  - 0.5% chemicals
    - most are found in every household

- **Compound**
  - **Purpose**
    - **Common application**

- Fresh **Water** – 80.5%
- Proppant – 19.0%
  - Allows the fractures to remain open so the oil and gas can escape
    - Drinking water filtration, **play ground sand**
- Acids - 0.12%
  - Help dissolve minerals and initiate fractures in rock (pre-fracture)
    - **Swimming pool cleaner**
- Petroleum distillates – 0.088%
  - Dissolve polymers and minimize friction
    - **Make-up remover**, laxatives, and candy
- Isopropanol – 0.081%
  - Increases the viscosity of the fracture fluid
    - **Glass cleaner**, antiperspirant, and hair color
- Potassium chloride – 0.06%
  - Creates a brine carrier fluid
    - Low-sodium **table salt substitute**
- Guar gum – 0.056%
  - Thickens the water to suspend the sand
    - **Thickener used in cosmetics**, baked goods, ice cream, toothpaste, sauces, and salad dressing
- Ethylene glycol – 0.043%
  - Prevents scale deposits in the pipe
    - Automotive **antifreeze**, household cleansers, deicing, and caulk

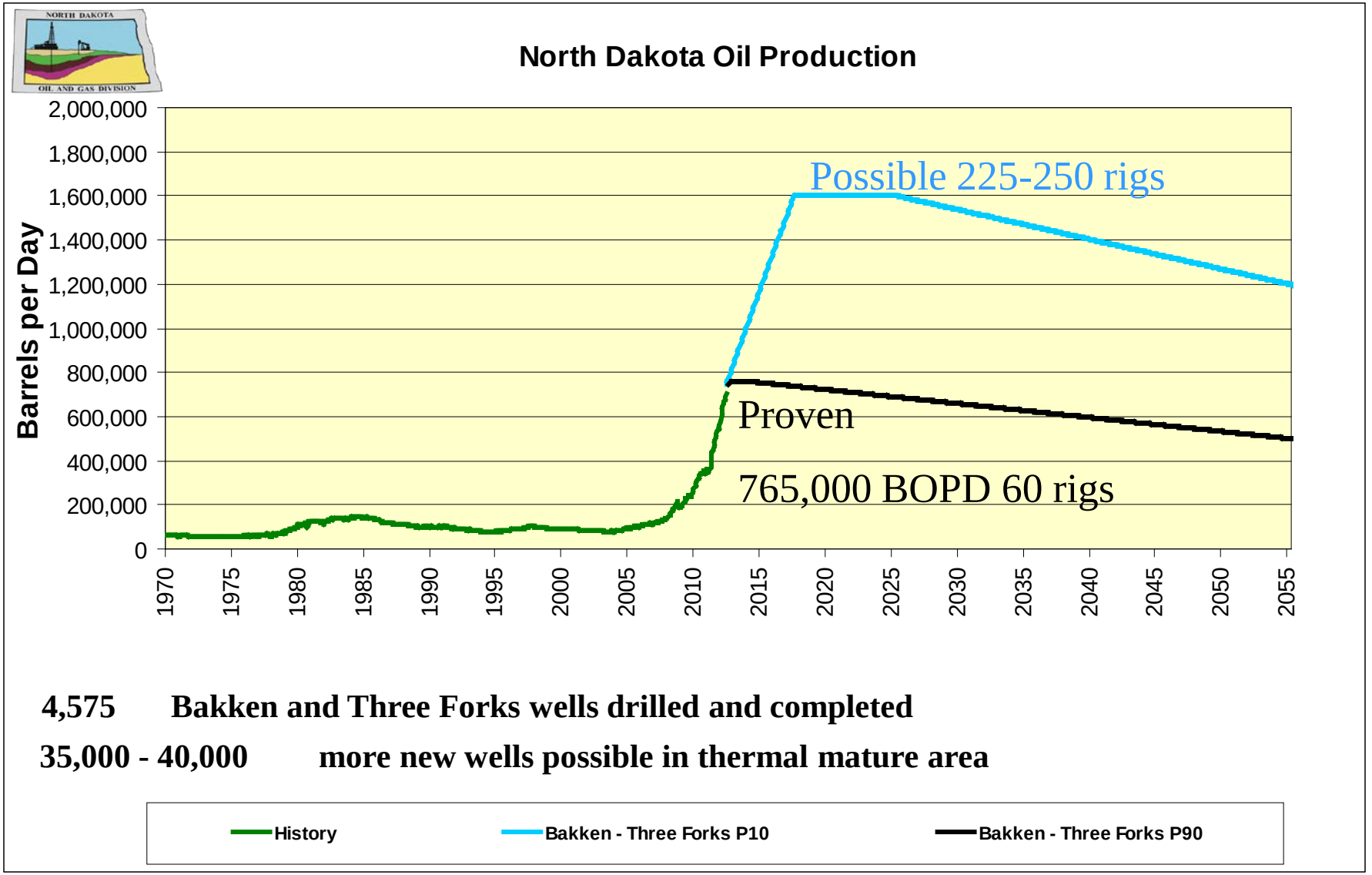
- Sodium or potassium carbonate – 0.011%
  - Improves the effectiveness of other components, such as cross-linkers
    - Washing soda, detergents, **soap**, water softeners, glass and ceramics
- Sodium Chloride – 0.01%
  - Delays break down of the gel polymer chains
    - **Table Salt**
- Polyacrylamide – 0.009%
  - Minimizes friction between fluid and pipe
    - **Water treatment**, soil conditioner
- Ammonium bisulfite – 0.008%
  - Removes oxygen from the water to protect the pipe from corrosion
    - Cosmetics, **food and beverage processing**, water treatment
- Borate salts – 0.007%
  - Maintain fluid viscosity as temperature increases
    - Used in laundry **detergents**, hand soaps and cosmetics
- Citric Acid – 0.004%
  - Prevents precipitation of metal oxides
    - **Food additive**; food and beverages; lemon juice
- N, n-Dimethyl formamide – 0.002%
  - Prevents the corrosion of the pipe
    - Used in **pharmaceuticals**, acrylic fibers and plastics
- Glutaraldehyde – 0.001%
  - Eliminates bacteria in the water
    - **Disinfectant**; Sterilizer for medical and dental equipment

NORTH DAKOTA – 190 DRILLING RIGS – Jan 2013



Current drilling activity is focused

in Mountrail, Dunn, McKenzie, and Williams Counties.



4,575 Bakken and Three Forks wells drilled and completed

35,000 - 40,000 more new wells possible in thermal mature area