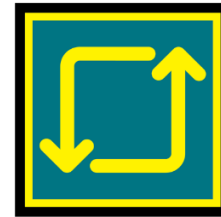


Enhanced Oil Recovery and the State of Wyoming



Enhanced Oil
Recovery Commission

“WY-EOR”



Enhanced Oil
Recovery Institute

Lon Whitman

Director, EORI

Lon.Whitman@uwyo.edu

307-760-0577

eoriwyoming.org

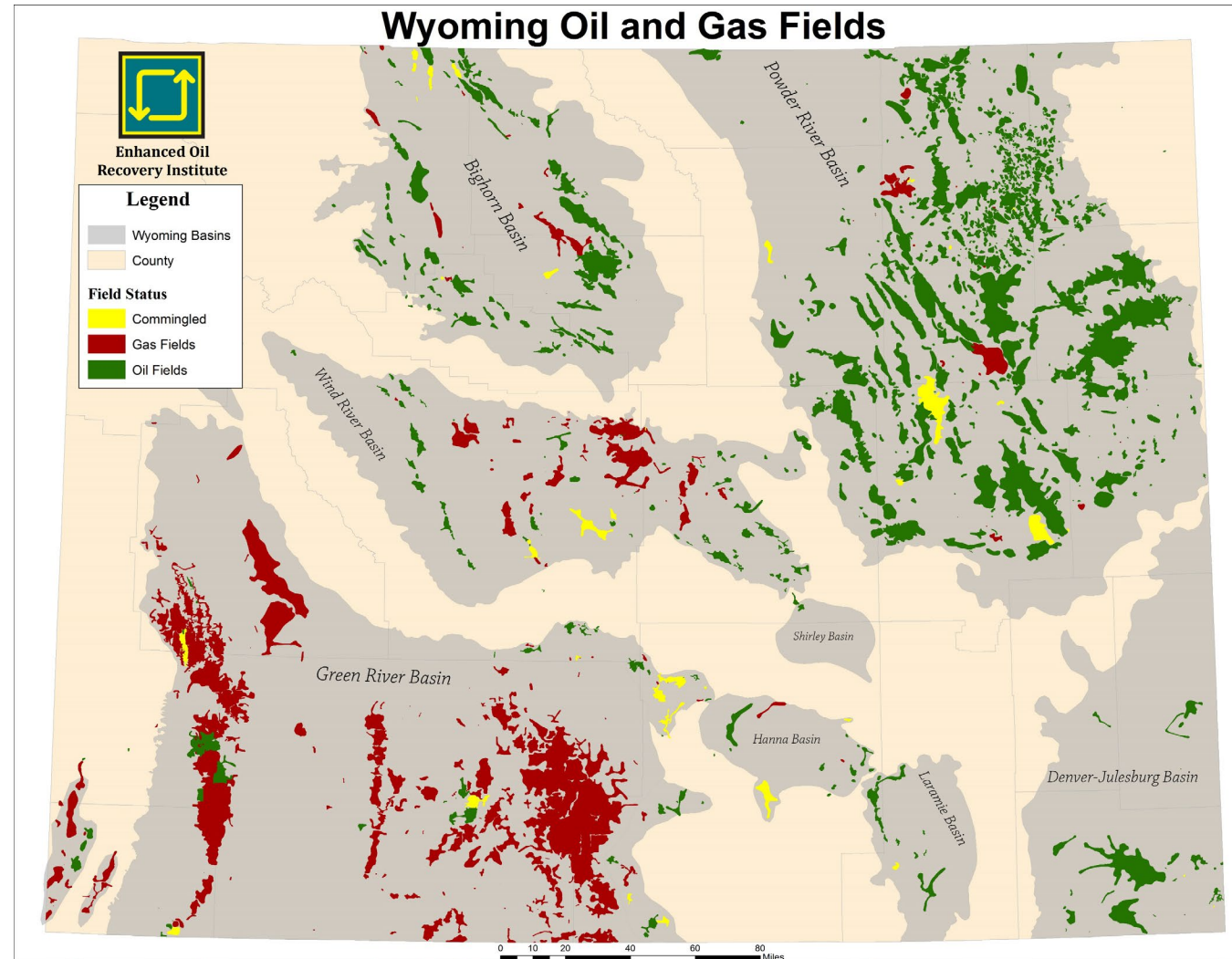
IOR & EOR: Critical to Wyoming's Future

Multiple studies show that Wyoming has approximately 2 Billion Barrels of Stranded Oil in existing oil fields in all producing basins in the state.

There is potential to recover a significant portion of this stranded oil through Improved (IOR) and Enhanced Recovery (EOR) methods.

EORI is focused on its mission to work collaboratively with industry to recover and minimize stranded oil in Wyoming.

Economics drive IOR and EOR projects. It is important to understand the costs behind the economics of these projects.



WY-EOR: Significant Revenue to the State

The 1st CO₂-EOR flood in WY at Lost Soldier/Wertz began in 1986

From 1986 through December of 2024 (7 fields)

CO₂-EOR: 173 Million Barrels of Incremental Oil

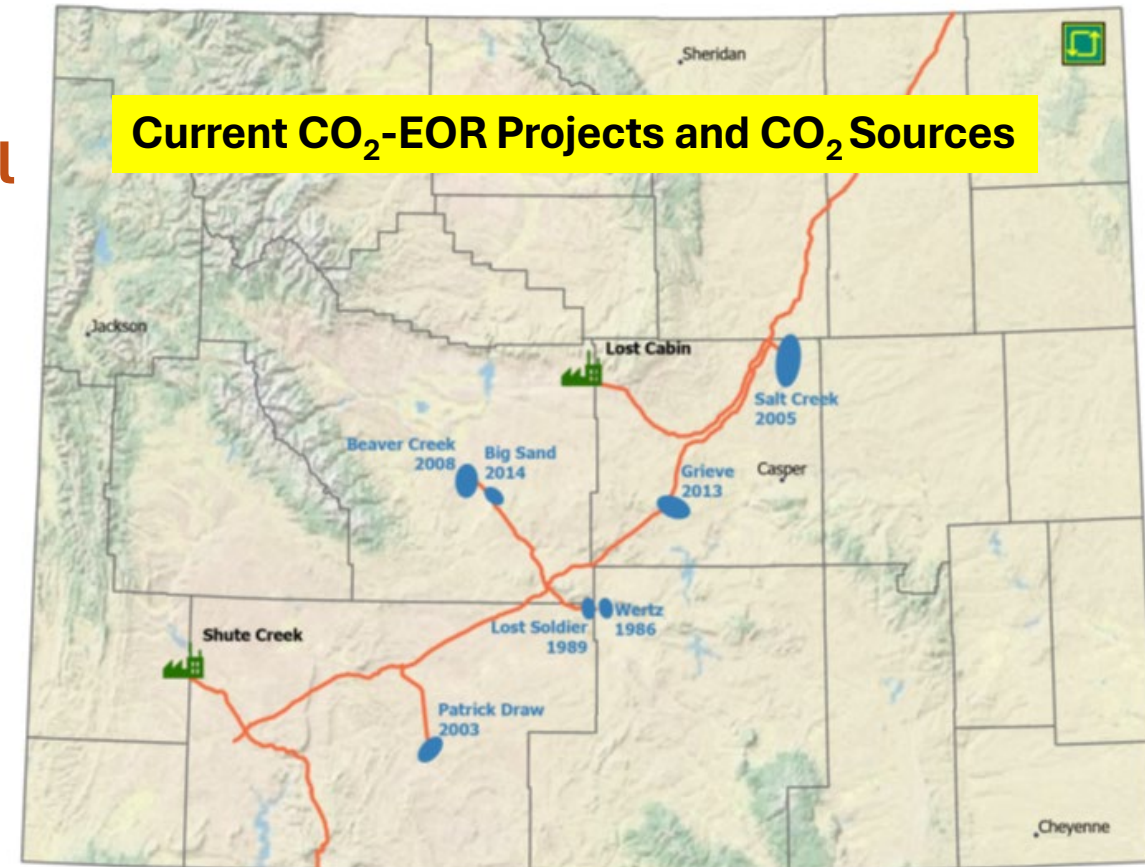
Associated tax revenue: \$1.16 Billion

(Average Wyoming oil price (1986-2024): \$51.57 per barrel)

(Average severance and ad valorem tax rate: 13%)

Incremental Recovery from CO₂ Floods in Wyoming

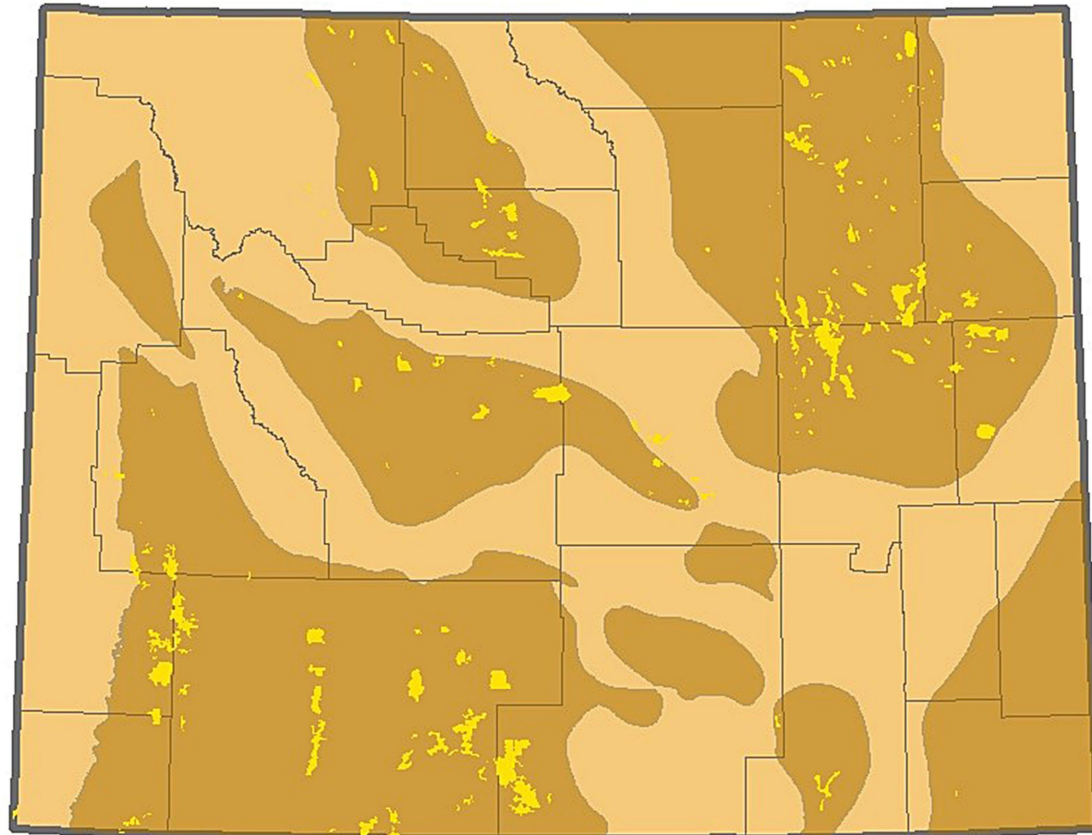
| Field Name | Formation | Incremental Oil MMBO (through 2024) |
|---------------------------|------------------|-------------------------------------|
| Lost Soldier/Wertz (1986) | Tensleep | 65.4 |
| Salt Creek (2003) | Wall Creek 1 & 2 | 55.0 |
| Patrick Draw (2004) | Almond | 30.8 |
| Beaver Creek (2008) | Madison | 15.9 |
| Grieve (2013) | Muddy | 1.4 |
| Big Sand Draw (2014) | Tensleep | 4.4 |
| | | 173 Million Barrels |



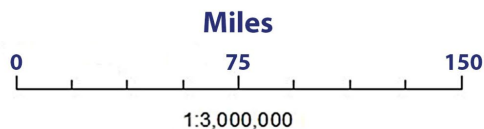
In Wyoming, CO₂ for EOR applications comes from the ExxonMobil Shute Creek Capture Project and the Contango Lost Cabin Gas plant. Currently about 370 MMcfd is available for EOR.



Fields on “Primary Production” in Wyoming



Primary Fields in Wyoming



Legend

- Primary Fields
- Basin
- County Boundary
- State Boundary

Many oil fields in Wyoming are still on Primary Production

These fields are important and strategic targets for Secondary Recovery Projects

Challenges to initiating Secondary (or Enhanced) Oil Recovery include:

- Remaining reserves
- Costs and project economics
- Availability of water
- Incompatibility of available injection water with the reservoir
- Lack of necessary infrastructure



Categories of Oil Recovery (from SPE, Oct 2024)

Primary Oil Recovery

Includes only the naturally occurring recovery drive mechanisms without using any additional pressure assistance, injection, or enhancements



Improved Oil Recovery (IOR)

Assisted Oil Recovery (AOR)

Can be used to improve Primary Oil Recovery Processes

Main Oil Recovery Processes

Secondary Oil Recovery

Enhanced Oil Recovery (EOR)

Pattern & Fluid Sweep Adjustments

Drilling & Well Intervention

Production Mechanics

Pressure Maintenance

Chemical & Biological Methods

Gas Injection (Miscible or Immiscible)

Thermal & Other Energy

Injection & production fluid rebalancing
Pattern re-design
Infill drilling

Horizontal wells
Multilateral wells
Well Stimulation
- Acidizing
- Fracturing
- Water shutoff
- Gas shutoff

Artificial lift & improvements
Plunger lift
Rod pumping
ESP's
Gas lift
Hydraulic jet pumps

Water injection
Polymer-augmented waterflood
Produced gas injection
Other fluid injection

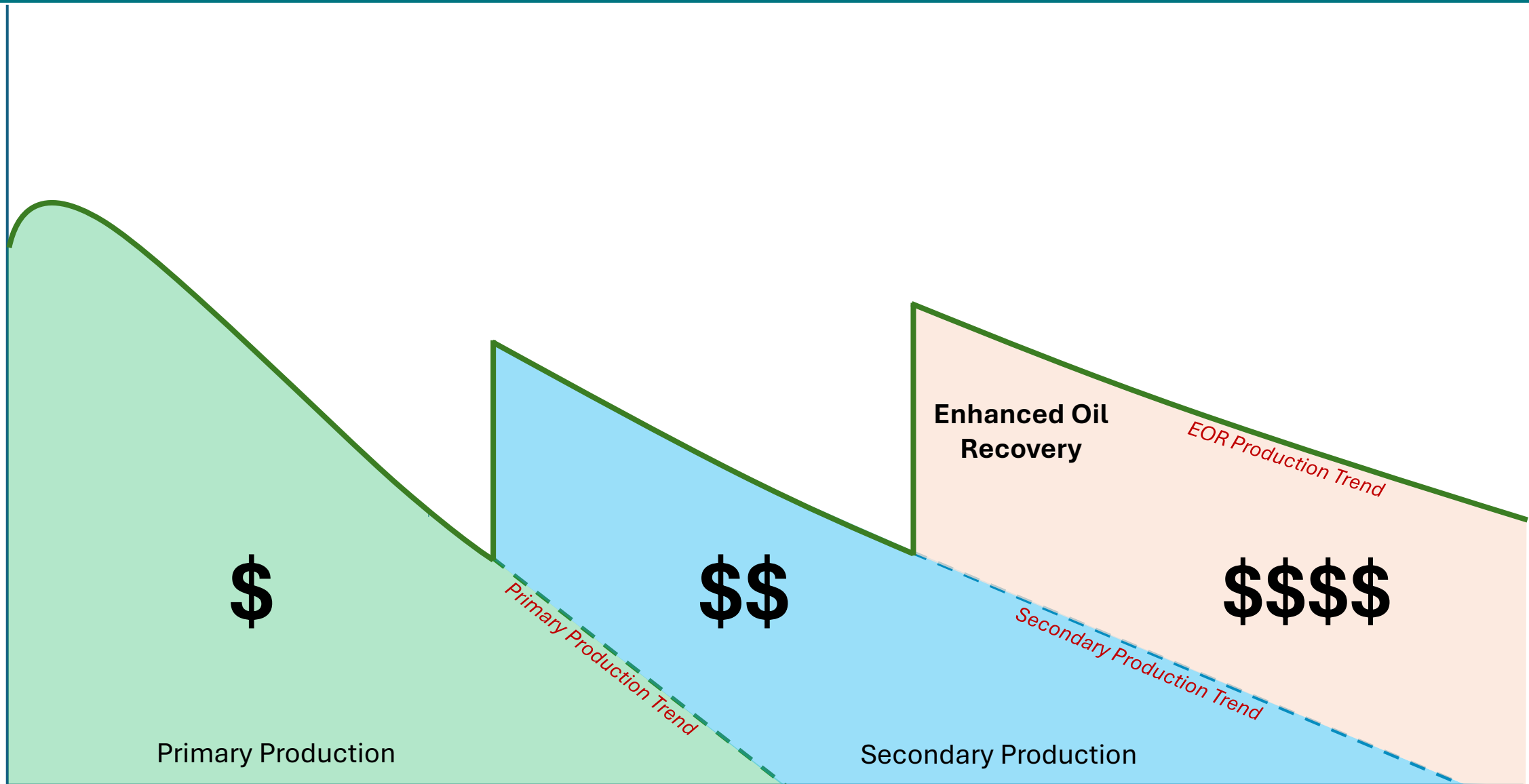
Surfactants (S)
Alkali-Surfactants (AS)
Alkali-Surfactant-Polymer (ASP)
Microbial
Solvent (e.g. NGL)

Hydrocarbon gas
CO₂
WAG (Water alternating gas)
Nitrogen
Flue gas

In-situ combustion
Steam injection
Cyclic steam injection
Steam with foam
Microwave (EM)
Acoustic wave



Oil Recovery Phases and *Relative* Costs



Schematic of Primary Production

Green shaded area represents oil recovery during the Primary Recovery phase.

Primary Oil Recovery

The naturally occurring production drive mechanisms in the reservoir.
No additional pressure assistance, injection, or enhancements.

Typically recovers ~15% of Original Oil in Place

\$

Costs: equipment, labor, repairs, utilities

Primary Production

Primary Production Trend



Schematic of Secondary Production

Now we're into Incremental Production

Blue shaded area represents the **incremental** oil recovery if Secondary Recovery methods are applied.

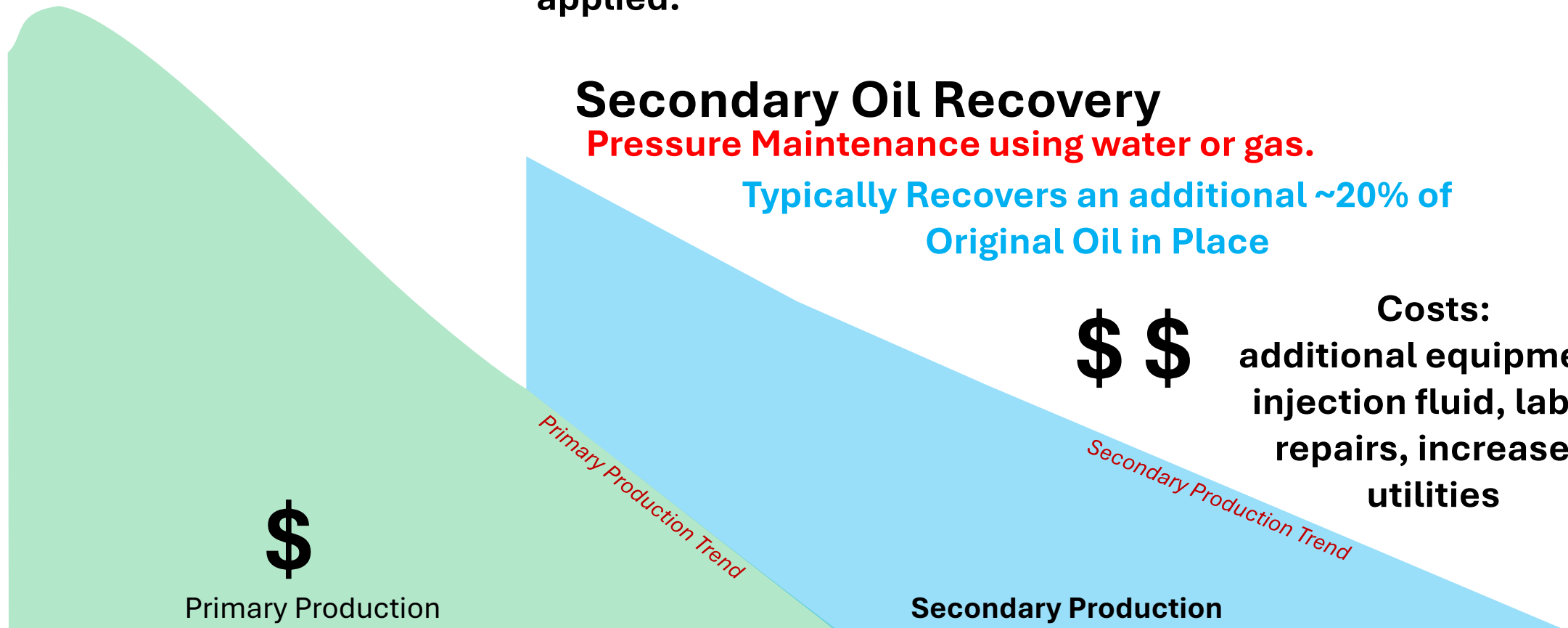
Secondary Oil Recovery

Pressure Maintenance using water or gas.

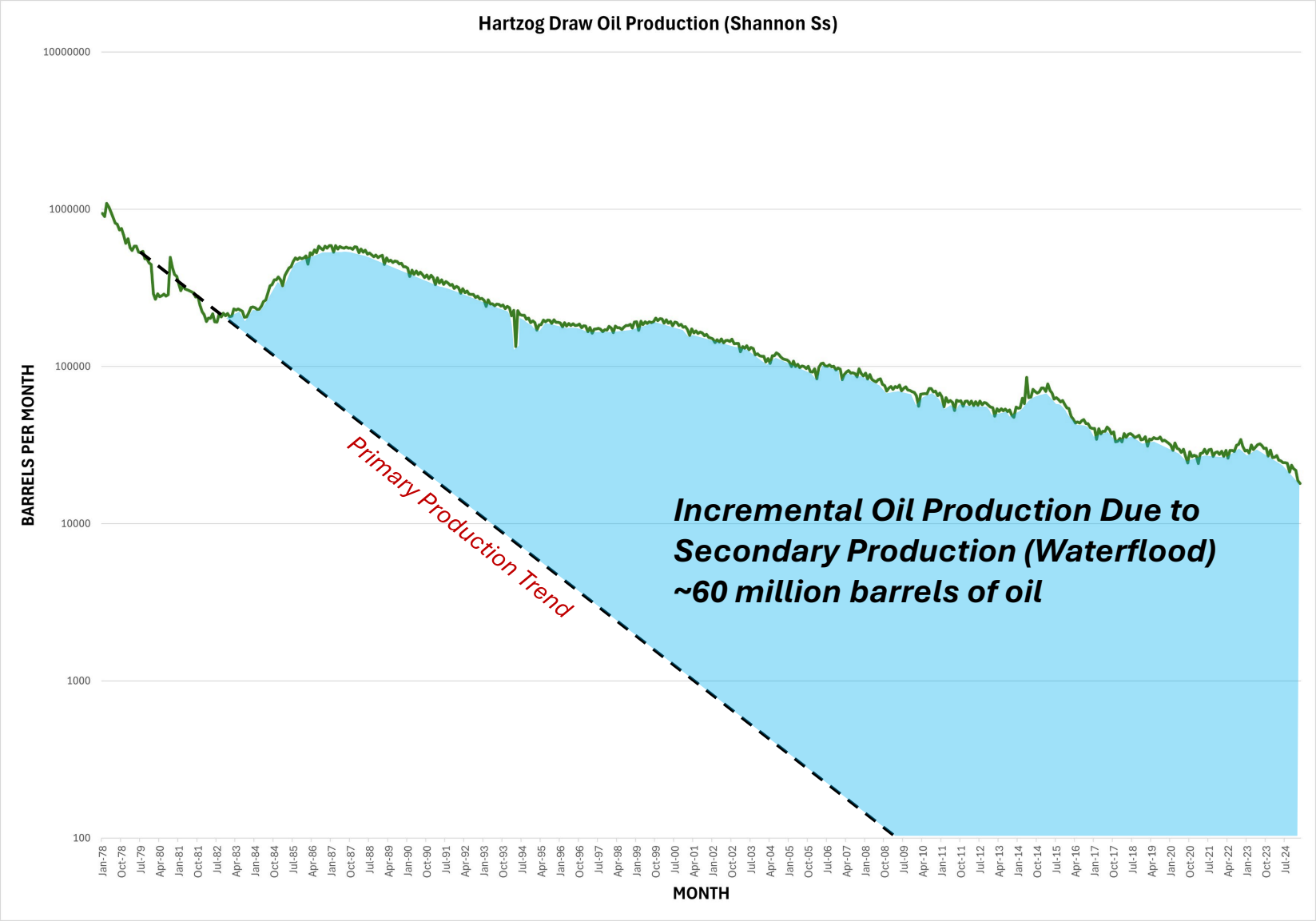
Typically Recovers an additional ~20% of Original Oil in Place

\$ \$

Costs:
additional equipment,
injection fluid, labor,
repairs, increased
utilities



WY Examples: Incremental Production from Secondary Recovery



Schematic of Enhanced Oil Recovery

Pink shaded area represents the **incremental** oil recovery due to the application of EOR methods.

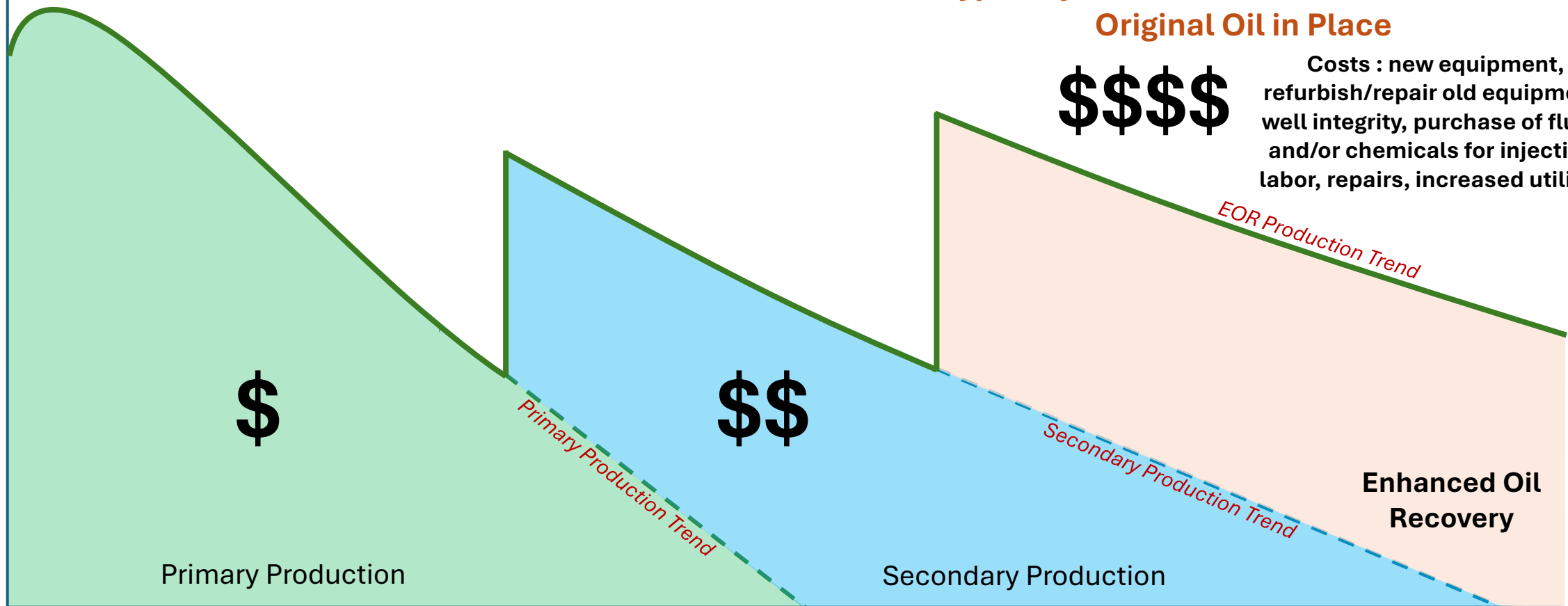
Enhanced Oil Recovery

Adding agents that change reservoir or mineral properties.

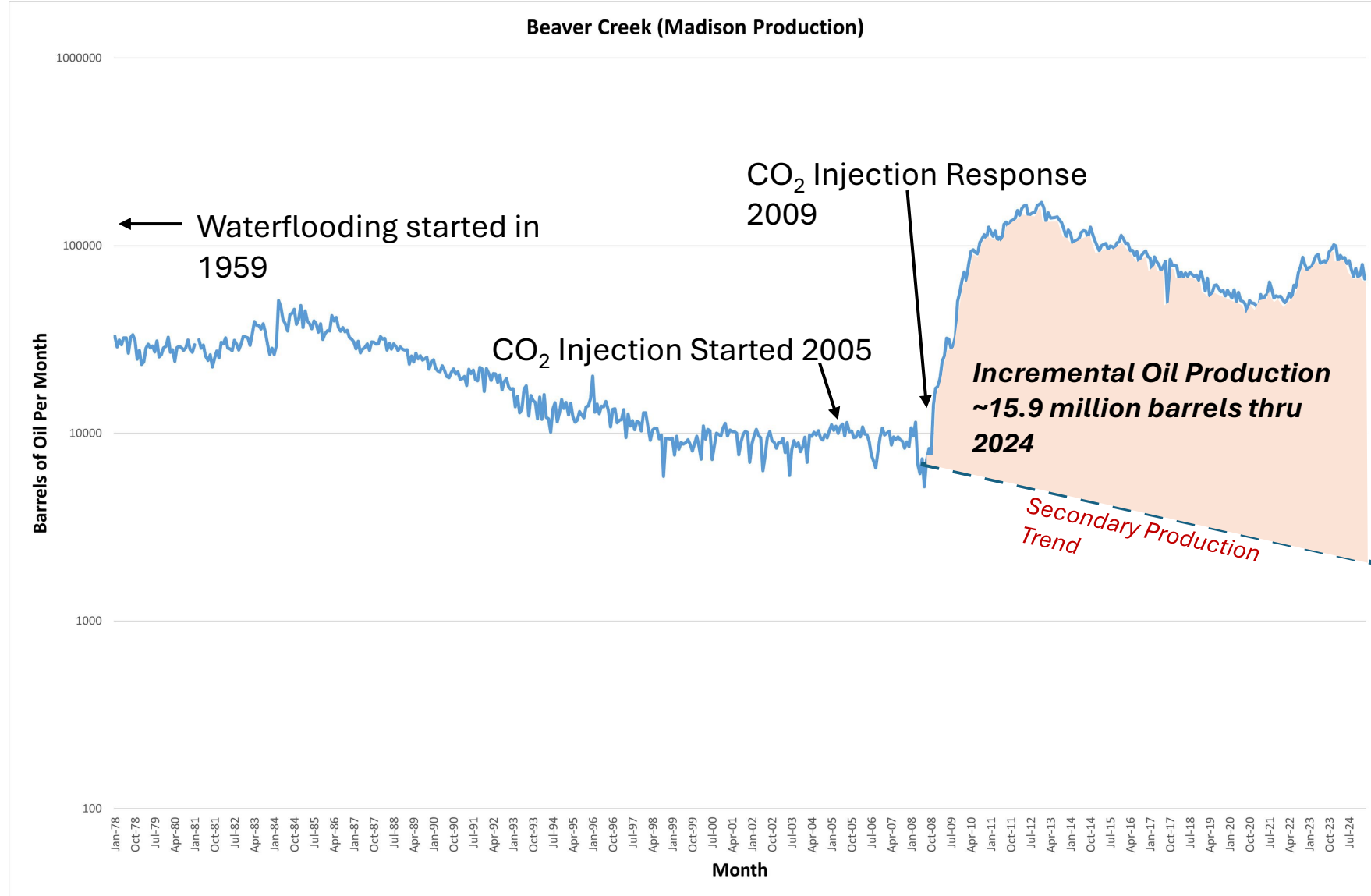
Typically recovers an additional ~25% of Original Oil in Place

\$\$\$\$\$

Costs : new equipment, refurbish/repair old equipment, well integrity, purchase of fluids and/or chemicals for injection, labor, repairs, increased utilities



WY-EOR Examples: Incremental Production from EOR



WY-EOR: TR Operating CO₂-EOR Project

Raven Creek Field:

Estimated Recovery: ~35 Million Barrels of Incremental Oil

Start Date: June 2025

Estimated Capex: \$175,000,000

CO₂ Pipeline Spur: \$ 50,000,000
\$ 225,000,000

Planned *Initial* CO₂ Purchase: 50 MMcfd (Million Cubic Feet per Day)

CO₂ Injection Start: October 2026

Estimated Payout: ~60 months

Cost for CO₂ :

Industry “Rule of Thumb” for CO₂ Purchase Price:

2% of West Texas Intermediate (WTI) per 1 Mcf of CO₂ (Thousand Cubic Feet)

2% of WTI

Use WTI: \$63.00/bbl

$0.02 \times \$63.00 = \$1.26/\text{Mcf of CO}_2$

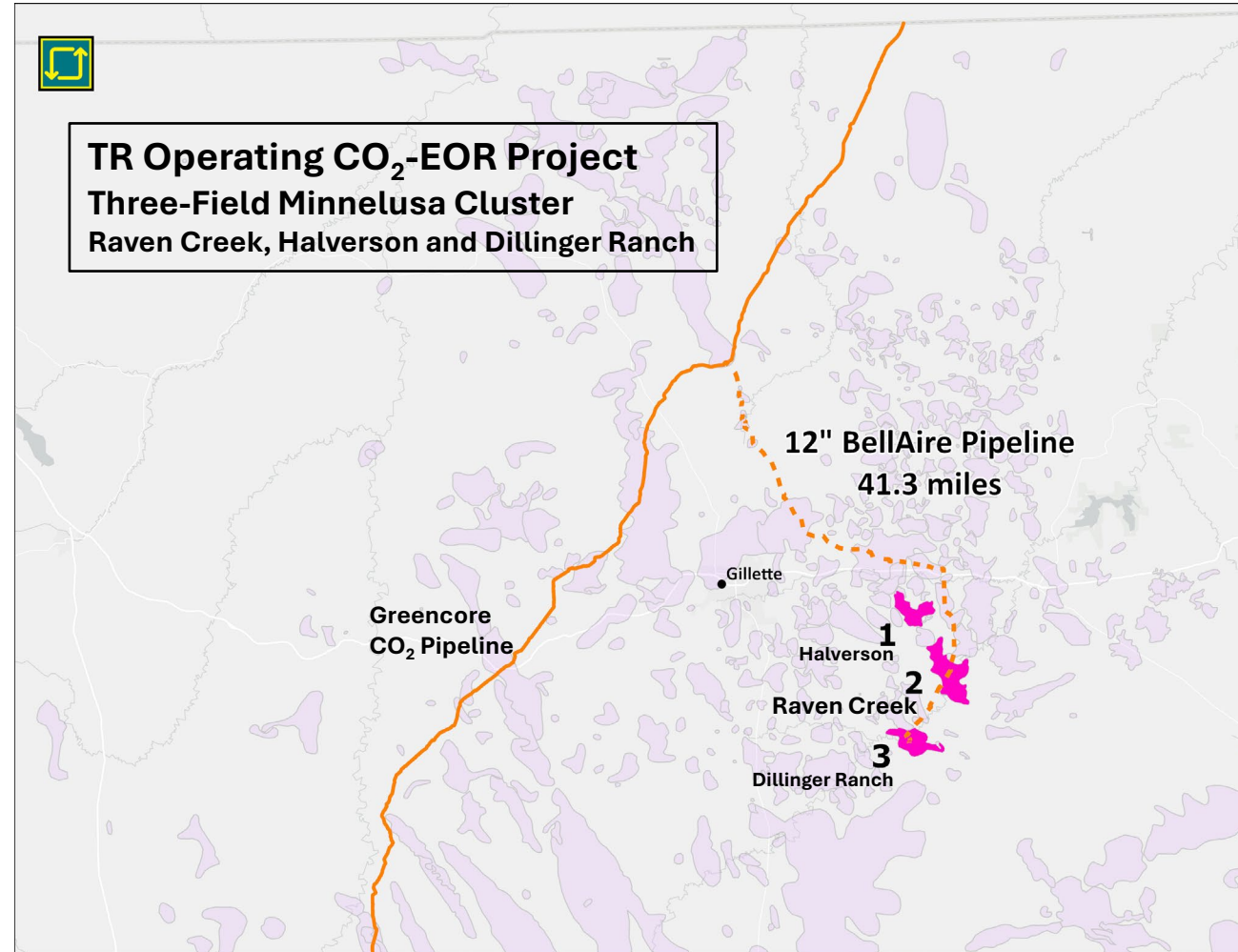
$\$1.26 \times 50,000 = \mathbf{\$63,000/\text{day for 50 MMcfd of CO}_2}$
(\$22,995,000 per year)

Remember Beaver Creek Field?

4 years to see a response to CO₂

\$64,386,000 for just CO₂ !!

THIS IS PRICEY STUFF



EORI is collaborative partner with TR Operating on this project.



WY-EOR: Glenrock Energy CO₂-EOR Project

Big Muddy Field

South Glenrock B Unit (SGBU):

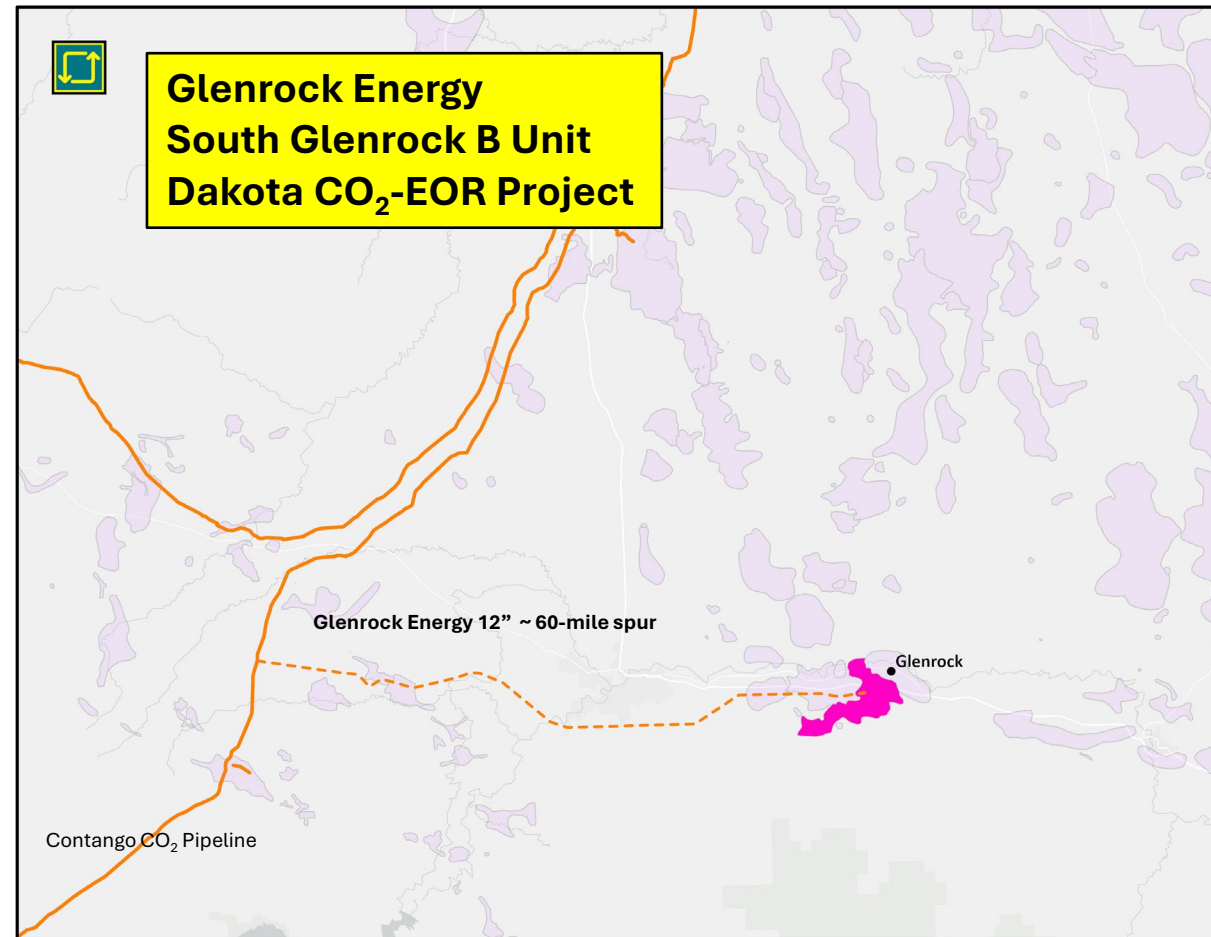
(Three reservoirs within the Unit will be flooded)

Estimated Recovery: ~37.8 Million Barrels of Incremental Oil

Estimated capex: \$349,500,000

CO₂ pipeline spur \$ 96,800,000
\$ 446,300,000

Estimated Payout Time: ~60 months



EORI is collaborating with Glenrock Energy on this project.



Current CO₂ Pipeline Infrastructure in Wyoming



CO₂-EOR and BEYOND

We know that not all fields in Wyoming are applicable for CO₂-EOR
- Reserves, location, costs to prepare the field, CO₂ costs, etc.

It is essential to expand EOR in Wyoming through the implementation of other EOR techniques beyond CO₂-EOR.

EORI is currently advancing other EOR technologies in the State of Wyoming to minimize stranded oil in Wyoming oil fields.

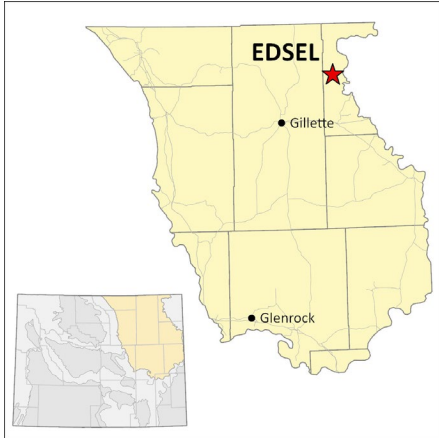
Let's look at three “other” EOR techniques that are being used or are in development in the state:

- Polymers**
- NGL-EOR**
- Enriched Air-EOR**



WY-EOR: Edsel Polymer-Augmented Waterflood

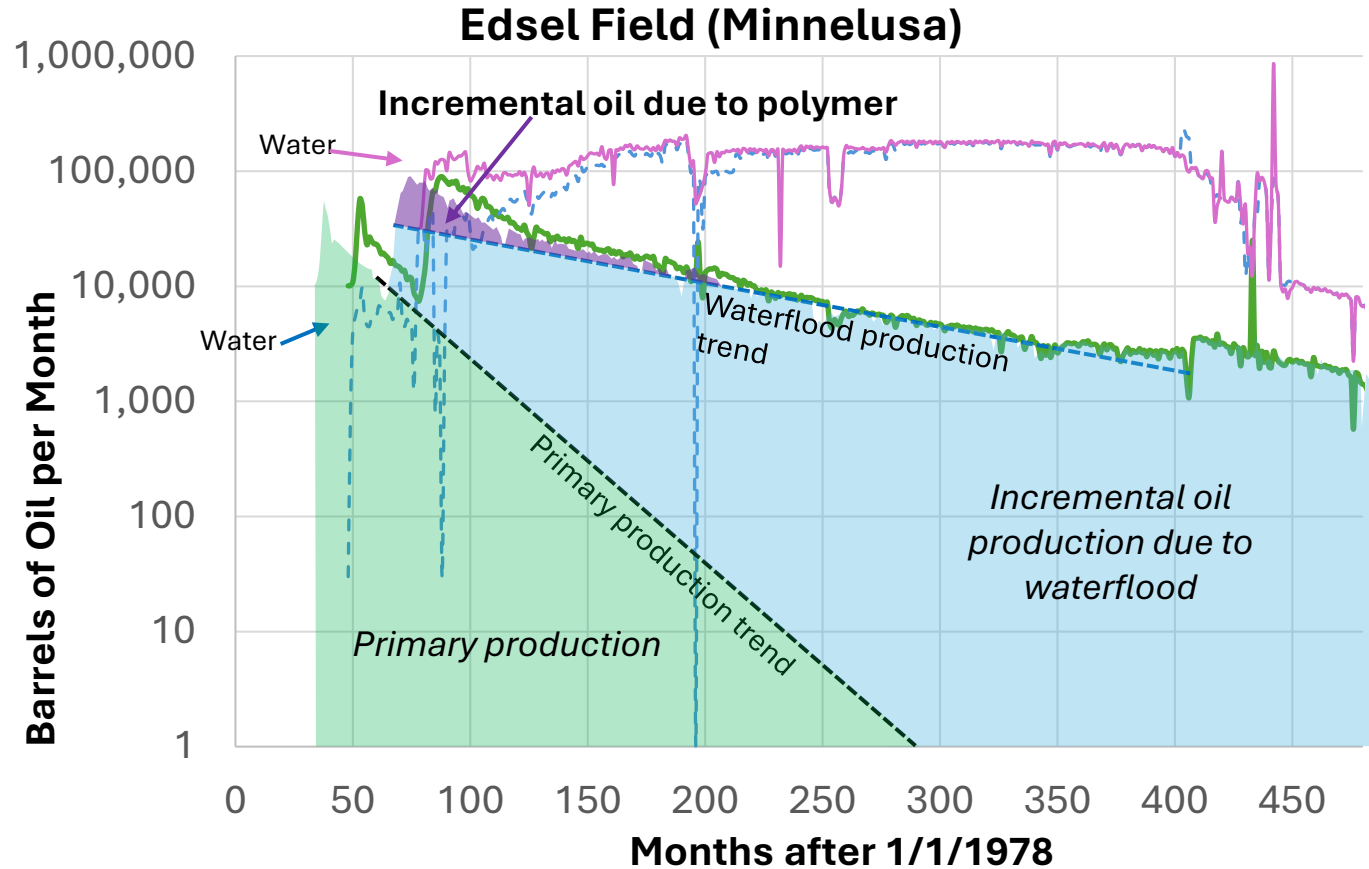
Polymers have proven to be effective agents for enhancing oil production



A polymer-augmented waterflood was initiated at Edsel Field at the onset of a secondary recovery project

The polymer-augmented waterflood lasted for 5 years before the operator reverted to a normal waterflood

The polymer-augmented flood at Edsel is credited with producing 1,902,500 barrels of oil. This is significantly more than would have been produced from a waterflood alone



Natural Gas Liquids (NGLs) for EOR and IOR

Natural Gas Liquids (NGLs) have proven to be effective agents for enhancing oil production

CO₂-EOR is very costly and is not economically viable for many Wyoming fields

NGL-EOR can produce an additional 20% of the Original Oil In Place (OOIP) from mature conventional oil fields and reduce stranded oil

The cost of NGLs has dropped to the point that it has become economically viable to use for EOR in Wyoming

Unlike CO₂ which, after purchase and use, remains stored in the reservoir, NGLs can be reused or sold as a valuable commodity to recoup much of their cost

EORI is currently involved in testing NGLs for EOR and IOR and the economics of this technology in two Wyoming oil fields



WY-EOR: XOil/Sunshine Valley NGL-EOR Project

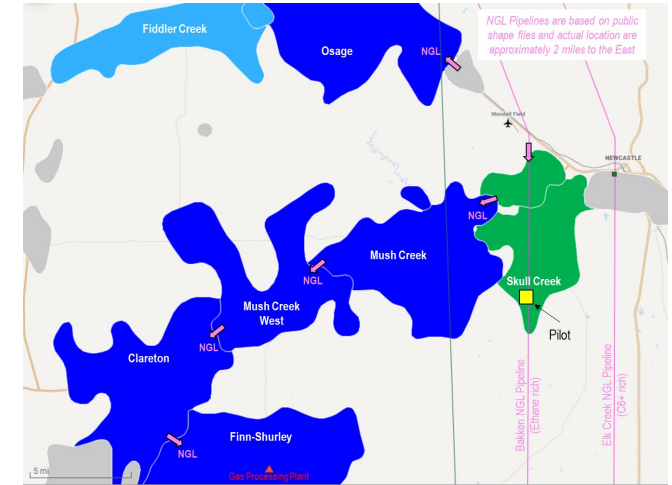


Operator: XOil / Sunshine Valley Petroleum
Skull Creek Field, Weston County, WY

NGL Cost: \$2,000,000
Initial Injection ~15% of Pore Volume (18,000 bbl)
Field Workover Costs: \$2,000,000
Total Project Cost: \$4,000,000

Incremental Oil Recovery: 5.6 MMBO
(OOIP ~28.1 MMBO)

Project Start Date: July 1, 2025



If this project is successful, this technology can be applied in numerous fields in Wyoming

EORI has been collaborating with XOil and Sunshine Valley Petroleum on this project for over 3 years

XOil was awarded \$2,000,000 from the Wyoming Energy Authority (EMF) program



WY-EOR: Alpha Enriched-Air-EOR



Operator: ATR – Advanced Thermal Resources

Total Project Cost: \$19,700,000

Estimated EOR Incremental Recovery: 4,800,000 barrels

Estimated Production Increase from current 5 BOPD to 500 BOPD within 2 years

Project Status:

- Drilled and Completed the Alpha 1-11 (Injector)
- Drilled and Completed the Alpha 1-12 (Offset Producer)
- Reactivated the Alpha 2 and the Alpha 13-1R
- Completing two Air Separation Plants
- Enriched Air Injection Start-Up Anticipated mid-May 2025.

The ATR project uses enriched air to facilitate in-situ combustion, creating CO₂ through the process. The project will also investigate the feasibility of producing Hydrogen commercially

This technology, once verified, will be applicable to numerous fields in Wyoming

EORI has been collaborating with ATR on this project for over 2 years

ATR was awarded \$9,850,000 from the Wyoming Energy Authority (EMF) program



EORI Collaboration in Projects

Reservoir Characterization, Modeling, & Simulation

- Detailed mapping of reservoir quality and of flow units helps operators to understand the internal “plumbing” of their reservoirs
- Detailed reservoir characterization & mapping helps improve performance of all IOR & EOR methods
- Reservoir simulations help operators understand how different scenarios can affect production efficiency

Field Testing of Different IOR & EOR methods

- Collaboration with operators helps to evaluate the effectiveness of different recovery strategies
- Publications and presentations transfer the knowledge gained from collaborative studies
- Cost Share for Pilot testing when funding is available



Factors Affecting Ability to Conduct EOR

Economics & Lack of Technology Biggest Factors

Economics drive the ability to conduct IOR and EOR methods in Wyoming oil fields

- **Crude oil prices**
- **Regulations**
- **Taxes**
- **Royalties**
- **Operating Expenses**
- **Costs of implementing IOR or EOR technologies**

Technologies

- **Costs for conducting CO₂- EOR are substantial**
 - **Capital Startup Costs**
 - **Price for CO₂**
 - **Transport and Pipeline Infrastructure**
- **The cost for independent operators in Wyoming to conduct research for new, effective, and economic recovery methods is daunting**



Factors Affecting Ability to Conduct EOR

Factors Beyond the Direct Control of Legislation

Crude Oil Prices

- Crude oil prices vary widely within Wyoming
- Some fields must be abandoned earlier than others due to lower prices compared to other areas

Climate

- Wyoming has a challenging climate that interferes with year-round operations that can affect the ability to generate revenue to pay for expensive EOR programs in a timely manner

Terrain

Rugged terrain sometimes prevents being able to drill a well in an optimal location

Drilling Costs

- Costs to drill have increased dramatically over the last several years, commonly making drilling new wells in old fields uneconomic – a 6000' well can easily cost over \$2 Million

Operating Costs

- Costs for labor, material, and utilities often result in premature abandonment of oil fields



Factors Affecting Ability to Conduct EOR

Factors Beyond State Control: Federal issues

Wyoming has the highest percentage of oil-prone areas under federal control in the entire USA

Regulations

Delays in the permitting process on federal lands deter operators

Requirements to plug idle wells, regardless of EOR potential, add significant costs in both money and time



THANK YOU



Enhanced Oil
Recovery Institute

Lon Whitman
Director

307-760-0577

Lon.Whitman@uwyo.edu

2435 King Blvd, Ste 313
Casper, WY 82604



Enhanced Oil
Recovery Commission

eoriwyoming.org

