Energy & Environmental Research Center (EERC)

Unitized Legacy Oil Fields: Prototypes for Revitalizing Conventional Oil Fields in North Dakota

NDIC G-045-086

OGRC Meeting

Bismarck, North Dakota

July 22, 2024

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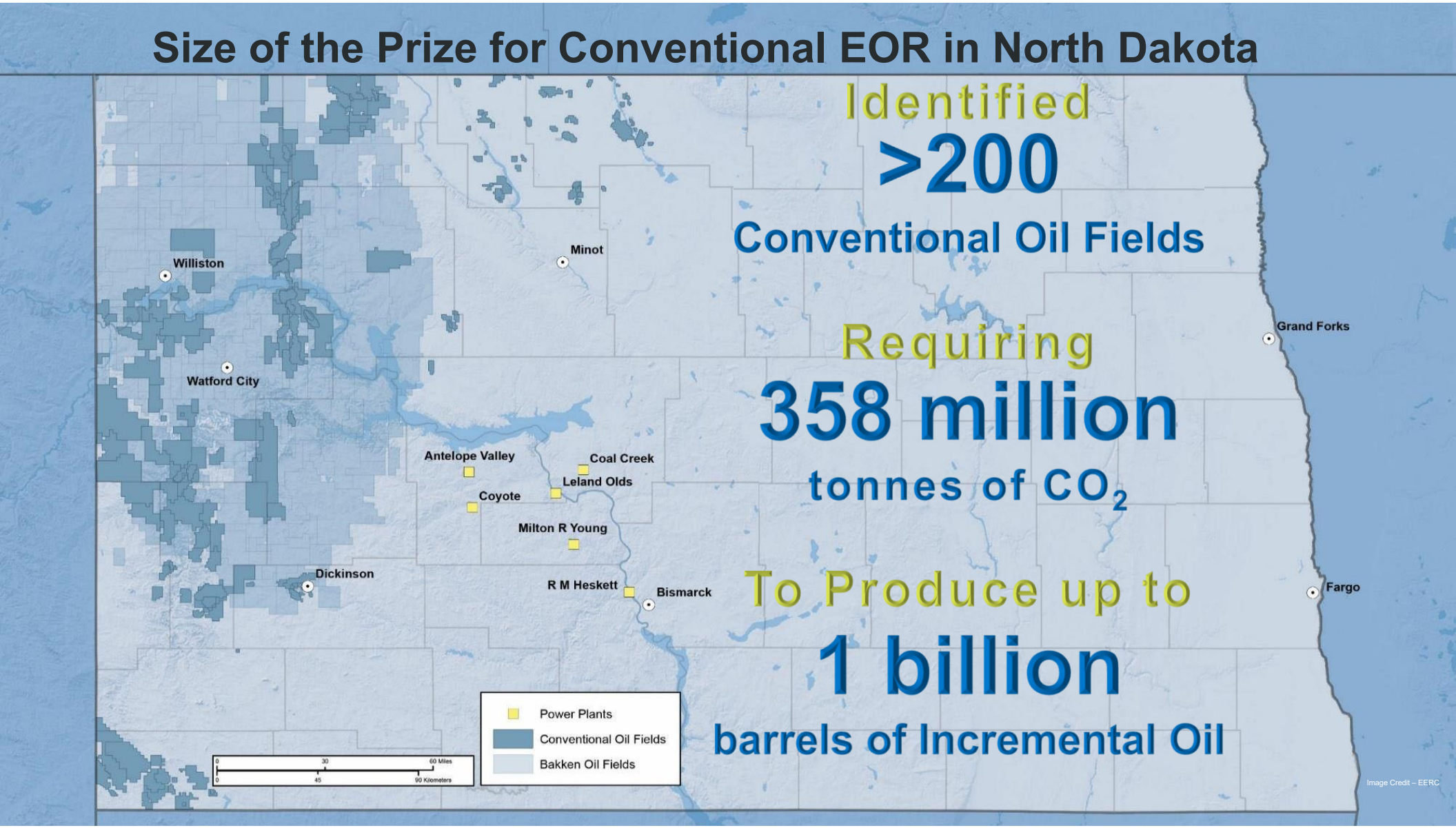
Size of the Prize for Conventional EOR in North Dakota



Hypothesis and Goal

- **Hypothesis:**
  - Conventional reservoirs in ND can be revitalized by optimization of waterflood in preparation for tertiary EOR using CO_2.
- **Goal:**
  - Enable revitalization of conventional oil fields in North Dakota, ultimately resulting in increased daily oil production and prolonging the operational lifetime of these fields.

Approach

Investigate waterflood optimization as a precursor for CO_2 EOR in a conventional Madison reservoir as a prototype for the revitalization of conventional oil fields in North Dakota

- Evaluate waterflood optimization and CO_2 EOR potential in conventional fields.
- Develop cost-effective operational strategies that address key technical challenges, optimize facilities, and systematically consider new approaches.
- Frame the results from this project as a prototype for revitalizing analogous conventional oil fields in North Dakota in anticipation of tertiary CO_2 EOR.

- Provided the investment needed to revitalize field.
- Provided reservoir and operational surveillance data.
- Collected new characterization data from a newly drilled stratigraphic well.
- Operated and updated the field infrastructure to accomplish objectives of study.

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- Conducted reservoir characterization, including new core & logs, and laboratory-based rock and fluid studies to improve simulation performance.
- Generated updated geomodels.
- Conducted simulations to update reservoir performance forecasts to assess waterflood and EOR effectiveness.

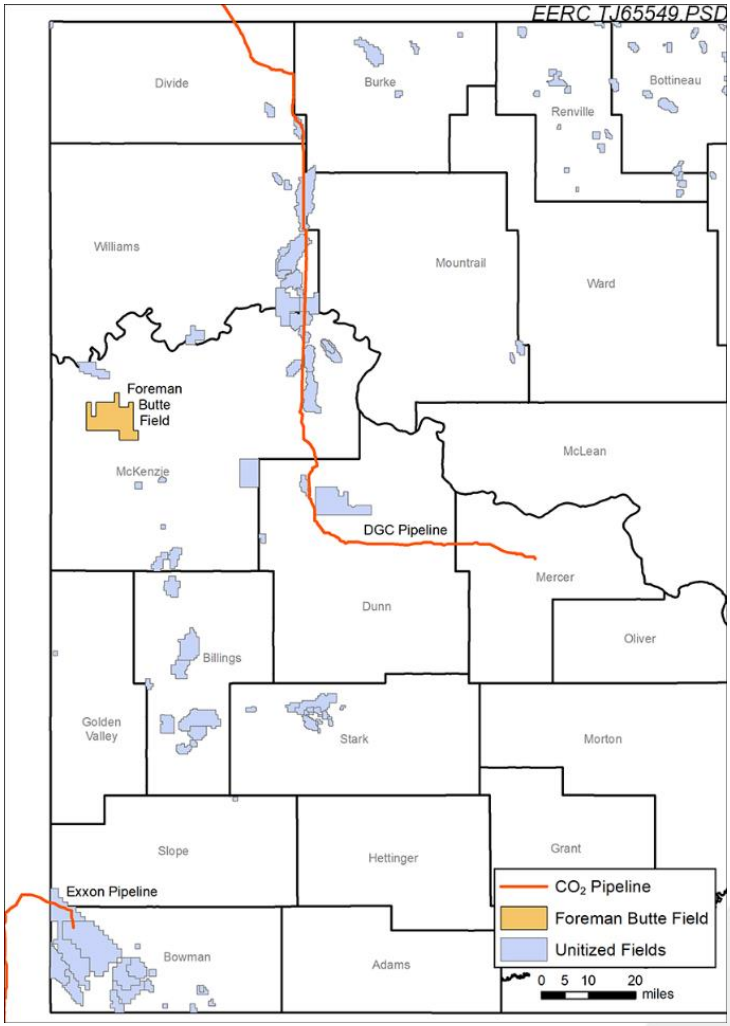
Eagle & EERC Together:

- Designed infrastructure, operating schemes, and monitoring to assess and optimize waterflood operations in preparation for CO_2 EOR.
- Created knowledge that can guide stakeholders looking to revitalize conventional reservoirs in North Dakota.

Eagle Energy operates the **Foreman Butte Field** located in McKenzie County that produces from the **Ratcliffe interval of the Charles Formation of Madison Group**.

During the Project:

- A stratigraphic test well was drilled.
  - Core and fluids collected and analyzed.
  - Well logs collected.
- Geologic model was built using historic and new data.
- A water injection pilot was conducted.
- History match of past fluids production and water injection pilot was conducted.
- Dynamic simulations conducted to predict future performance under different EOR scenarios.
- Machine Learning techniques applied to develop a means of “Scoring” EOR potential of other reservoirs.



Foreman Butte oil field location and unitized legacy oil fields identified as near-term candidates to investigate CO_2 EOR

Key Findings for Foreman Butte Field

- Natural fractures, tight rock matrix, and residual oils were observed from cores acquired from a stratigraphic well drilled through the Ratcliffe interval of the Charles Formation.

- Core flooding experiments using water and CO_2 suggested ***water flooding may not be as effective as CO_2 flooding, due to the rock's oil-wet and mixed-wet characteristics.***

Lesson for Others: Advanced geologic characterization and core testing provide valuable insight for designing an EOR project.

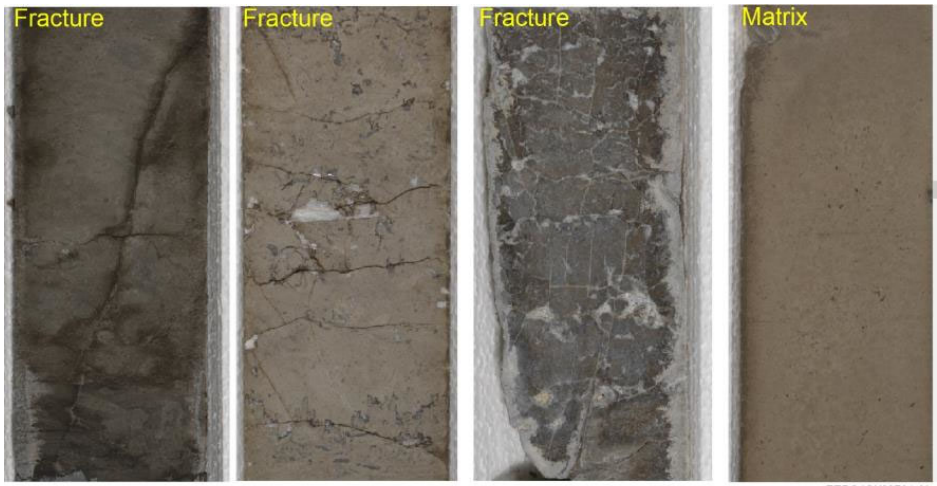
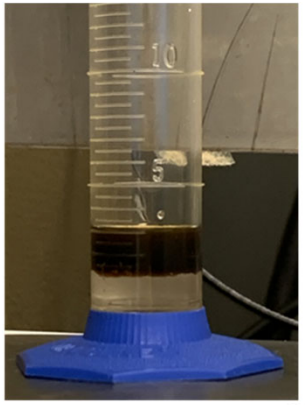


Illustration of natural fractures observed on the core samples collected from stratigraphic well



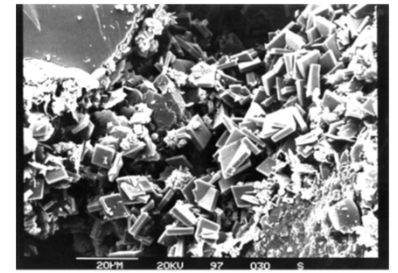
Water Recovery

CO_2 Recovery

Key Findings for Foreman Butte Field

- High paraffin and other heavy constituents in the oil can precipitate as pressure and temperature decreases.
  - Can block flow pathways in the reservoir.
  - Can cause scale in wells, flow lines, surface facilities. Regular wellbore clean-out operations and/or scale inhibitors can mitigate those issues.

Lesson for Others: Thorough understanding of reservoir chemistry, especially with respect to oil, can guide both reservoir management and surface facilities operations.



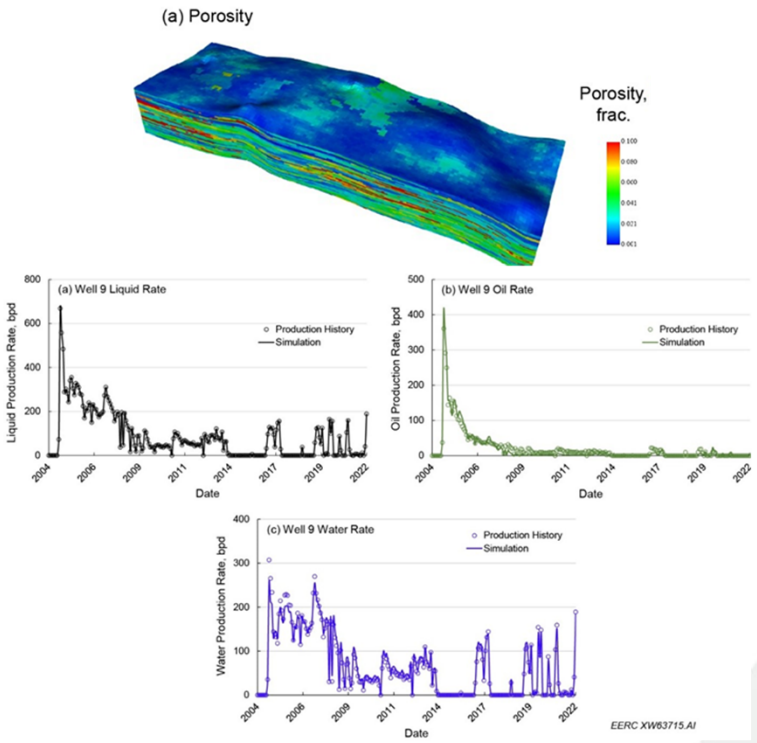
Organic constituent	Mass, %
Saturates(=Paraffins)	39.00
Aromatics	3.80
Resin(=Polars)	2.40
Asphaltenes	1.00
Others	46.20
Total:	100

SARA analysis for the oil sample

Modeling-Based Performance Forecasts of Waterflood and CO_2-EOR for Foreman Butte Field

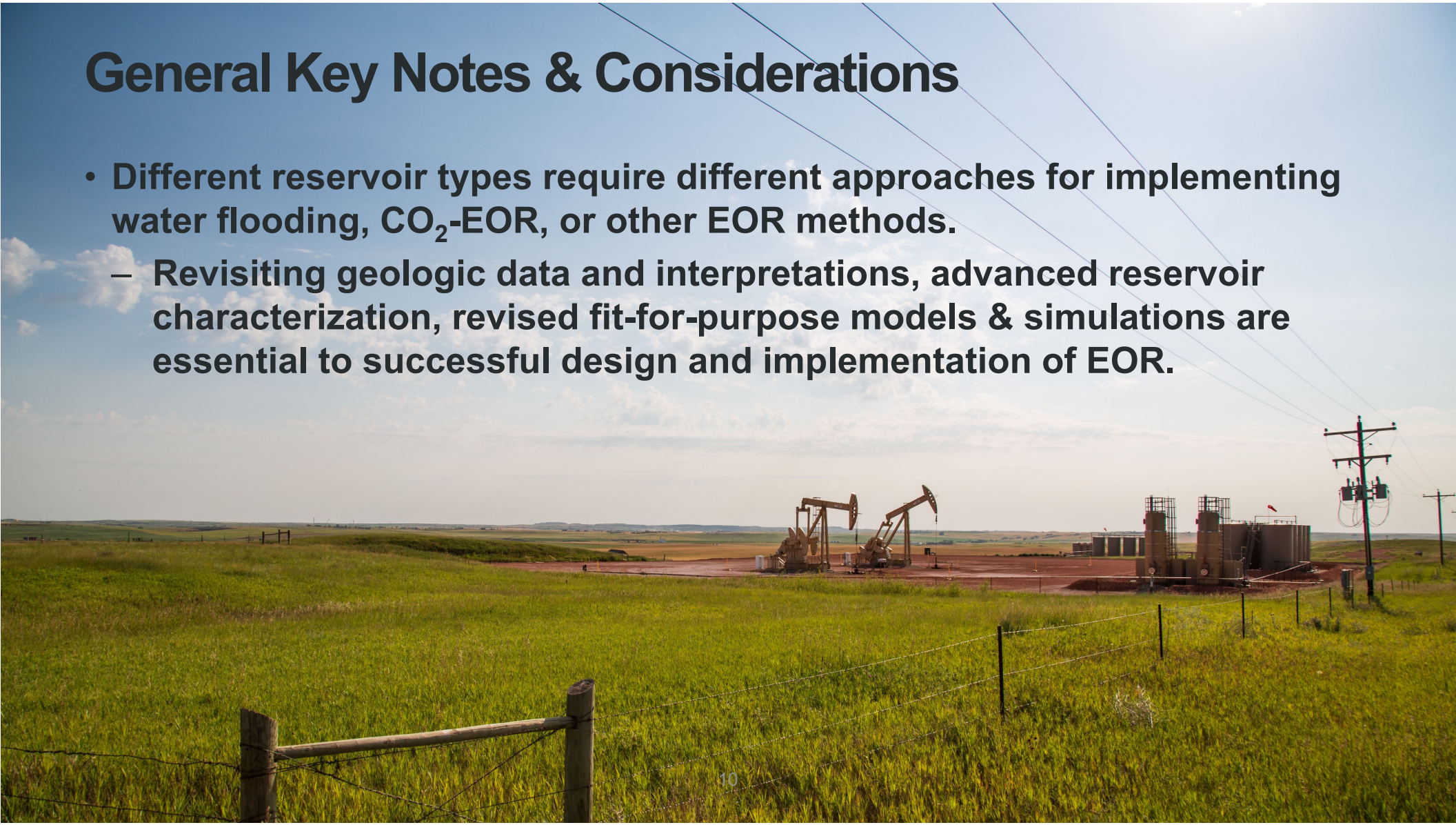
- History matched the production & water injection pilot.
- Used a matched model to predict 10 years of operation to evaluate effectiveness of waterflood and CO_2 EOR
  - ***Producers' response to water injection is not as strong as CO_2 injection.***
  - ***Higher CO_2 injection rate results in higher incremental oil production.***

Lesson for Others: A robust geologic model, properly history matched, is necessary to conduct simulations that provide invaluable guidance regarding the selection of working fluids and design of injection & production schemes.



General Key Notes & Considerations

- Different reservoir types require different approaches for implementing water flooding, CO_2-EOR, or other EOR methods.
  - Revisiting geologic data and interpretations, advanced reservoir characterization, revised fit-for-purpose models & simulations are essential to successful design and implementation of EOR.



General Key Notes & Considerations

- Waterflooding may not be needed as precursor to successfully apply CO_2 EOR in the Williston Basin. Depending on the fields' characterization, some fields could benefit from CO_2 EOR without waterflooding.
- Methods such as Engineered Water Injection (EWI), Low Salinity Waterflooding (LSWF), or chemical EOR (e.g. surfactants) could be considered as alternatives, as they have the capability to induce reservoir wettability changes.

Project Financial Information

Table 1. Budget and Expenses at the End of the Project

Funding Source	Budget	Expenses as of 6/30/2024
NDIC	$3,000,000	$3,000,000
EEPT – In-Kind	$3,000,000	$3,279,788
Total	**$6,000,000**	**$6,279,788**

Slide 12

JT0 Jim, I am still waiting for the final numbers as BA and Accountant are still finalizing the numbers.
Jiang, Todd, 2024-07-15T16:24:31.432

ACKNOWLEDGMENT

The EERC acknowledges Eagle Energy Partners Tundra, LLC for their in-kind support and NDIC for financial support.

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