



January 27, 2023

Mr. Reice Haase  
North Dakota Industrial Commission  
State Capitol, 14th Floor  
600 East Boulevard Avenue, Department 405  
Bismarck, ND 58505-0840


Dear Mr. Haase:

Subject: Quarterly Report Entitled “Unitized Legacy Oil Fields: Prototypes for Revitalizing Conventional Oil Fields in North Dakota”; Contract No. G-045-086;  
EERC Fund 23459

Attached is a copy of the subject quarterly status report for the period October 1 – December 31, 2022.

If you have any questions, please contact the project manager, Todd Jiang, by phone at (701) 777-5343 or by email at [tjiang@undeerc.org](mailto:tjiang@undeerc.org).

Sincerely,

DocuSigned by:  
  
4E5F948EDBBF43C...

Todd Jiang  
Principal Reservoir Engineer

TJ/ro

Attachment

c: Karen Tyler, North Dakota Industrial Commission  
Brent Brannan, North Dakota Industrial Commission



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# UNITIZED LEGACY OIL FIELDS: PROTOTYPES FOR REVITALIZING CONVENTIONAL OIL FIELDS IN NORTH DAKOTA

Research Performance Progress Report (quarterly)

*(for the period October 1 – December 31, 2022)*

*Prepared for:*

Reice Haase

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600 East Boulevard Avenue Dept. 405  
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Contract No. G-045-086

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## TABLE OF CONTENTS

LIST OF TABLES .....	i
EXECUTIVE SUMMARY .....	iii
INTRODUCTION .....	1
ACCOMPLISHMENTS .....	2
Task 1.0 – Assessing the Potential of a Unitized Legacy Oil Field .....	2
Subtask 1.1 – Data Reconnaissance and Conditioning.....	2
Subtask 1.2 – Reservoir Modeling and Engineering .....	2
Subtask 1.3 – Operability Assessment.....	3
Subtask 1.4 – Strategic Characterization.....	3
Task 2.0 – Prototype to Revitalize a Unitized Legacy Oil Field.....	4
FINANCIAL INFORMATION .....	4
FUTURE ACTIVITIES .....	5
PROGRAM MANAGEMENT AND REPORTING.....	5

## LIST OF TABLES

1    Project Cost .....	5
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**UNITIZED LEGACY OIL FIELDS: PROTOTYPES FOR REVITALIZING  
CONVENTIONAL OIL FIELDS IN NORTH DAKOTA**  
**Quarterly Progress Report**  
**October 1 – December 31, 2022**

**EXECUTIVE SUMMARY**

The Energy & Environmental Research Center (EERC) was awarded a contract by the North Dakota Industrial Commission (NDIC) to pursue the Unitized Legacy Oil Fields: Prototypes for Revitalizing Conventional Oil Fields in North Dakota project. The goal of this research program is to enable revitalization of unitized conventional oil fields in North Dakota, ultimately resulting in increased daily oil production and prolonging the operational lifetime of those fields. The three major objectives to meet this goal are to 1) evaluate waterflood optimization and CO<sub>2</sub> enhanced oil recovery (EOR) potential and implementation approaches specific to Madison producing field(s) or other legacy conventional fields producing from suitable horizons; 2) explore operational strategies that address key technical challenges, optimize current facilities, and systematically consider necessary new facilities; and 3) frame project results and experience as a prototype for revitalizing analogous conventional oil fields in North Dakota in anticipation of CO<sub>2</sub> EOR. These objectives are being executed through two corresponding tasks:

- Task 1.0 – Assessing the Potential of a Unitized Legacy Oil Field
- Task 2.0 – Developing a Prototype to Revitalize a Unitized Legacy Oil Field

To maintain the operational timeline of project partner, Eagle Energy Partners Tundra (EEP Tundra), the following accomplishments were achieved during the preceding calendar quarter: 1) fine-tuned history matching simulation; 2) performed fracture sensitivity analysis on history match to identify its role on production performance using embedded discrete fracture model fractures network; 3) developed a CO<sub>2</sub> EOR database based on the information collected from the public domain; 4) conducted laboratory evaluation using oil and cores collected from Foreman Butte Field, and different gas mixtures.; 5) conducted production data survey from NDIC database to build conventional oil fields database. EEP Tundra and the EERC will also continue to work with the Oil and Gas Research Council and the North Dakota Petroleum Council to identify and implement opportunities for EOR education in North Dakota.

Progress on project milestones and deliverables will continue to be tracked and reported in accordance with the NDIC contract.

**UNITIZED LEGACY OIL FIELDS: PROTOTYPES FOR REVITALIZING  
CONVENTIONAL OIL FIELDS IN NORTH DAKOTA**  
**Quarterly Progress Report**  
**October 1 – December 31, 2022**

**INTRODUCTION**

The Energy & Environmental Research Center (EERC) will conduct this North Dakota Industrial Commission (NDIC)-funded project in close collaboration with project partner, Eagle Energy Partners Tundra (EEP Tundra). Information generated by this project will positively affect ultimate recovery from North Dakota’s conventional oil pools and will lead to additional projects, processes, ideas, and activities to facilitate implementation of oil exploration and production technologies presently not used in the state. The potential to revitalize conventional oil fields and increase ultimate recovery will bring new investment to North Dakota, resulting in the growth of oil and gas jobs, wealth, and tax revenues. The goal of this 3-year research program is to enable the revitalization of unitized conventional oil fields in North Dakota, ultimately resulting in increased daily oil production and prolonging the operational lifetime of those fields.

Major objectives to be accomplished to meet the stated goal are to 1) evaluate waterflood optimization and CO<sub>2</sub> enhanced oil recovery (EOR) potential and implementation approaches specific to the Madison or other suitable production horizons; 2) develop cost-effective operational strategies that address key technical challenges, optimize current facilities, and systematically consider necessary new facilities; and 3) frame the results from this project as a prototype for revitalizing analogous conventional oil fields in North Dakota in anticipation of tertiary CO<sub>2</sub> EOR. The first objective will be achieved by using new and existing geologic and reservoir engineering characterization data (e.g., core analyses, well logs, oil analyses) and modeling/simulation to optimize waterflood operations in preparation for near-term CO<sub>2</sub>-based EOR operations. To achieve the second objective, results of new characterization and geologic assessments will be combined with refined performance forecasts to conduct a CO<sub>2</sub> EOR scenario analysis. The results will be used to develop strategies for the design and operation of prudent EOR schemes that will be applicable to other unitized fields producing from similar pools. The third objective will be achieved through the synthesis of project results into a guidance document for producers and investors looking to revitalize analogous conventional unitized fields in North Dakota with CO<sub>2</sub>-based EOR.

Project activities are organized within two tasks: 1) assessing the potential of a unitized legacy oil field and 2) developing a prototype to revitalize a unitized legacy oil field.

## ACCOMPLISHMENTS

### **Task 1.0 – Assessing the Potential of a Unitized Legacy Oil Field**

The goal of Task 1.0 will be to gather, assess, and construct much of the data needed to complete the overall goal of the proposed project.

#### ***Subtask 1.1 – Data Reconnaissance and Conditioning***

Subtask 1.1 focuses on compiling, organizing, managing, screening, vetting, digitizing, and interpreting the various types of data for integration into Subtasks 1.2 and 1.3 and reporting. Much of the data needed are available through either publicly available sources (e.g., NDIC database, scholarly studies) or available from EEP Tundra. A gap analysis process will identify missing key data and guide new data acquisition. Existing data (e.g., well logs, well files, core data, fluid and rock properties) are anticipated to be in a variety of formats and will require conditioning prior to use.

Significant accomplishments for Subtask 1.1 during the reporting period include the following:

- Developing a database for the conventional oilfields in North Dakota to identify whether a CO<sub>2</sub> EOR method is feasible or not based on key geologic and reservoir properties.

#### ***Subtask 1.2 – Reservoir Modeling and Engineering***

Subtask 1.2 activities include geologic and engineering characterization of the study field. Geologic and simulation models representative of the geology and physical performance of the producing horizon will be constructed, history-matched, and calibrated. The geologic and simulation models will be assessed based on sensitivity and uncertainty in performance to define and prioritize data needs.

Significant accomplishments for Subtask 1.2 during the reporting period include the following:

- Performed a detailed history match for the Foreman Butte Field by tuning reservoir, fracture, and rock-fluid parameters including matrix permeability, fracture permeability, fracture width, water saturation distribution, relative permeability curves, etc. The overall production history has been matched for the field.
- Performed natural fractures sensitivity analysis to identify the role of the natural fracture system on production and the natural fracture property changes over time due to production.

- Developed a CO<sub>2</sub> EOR database based on the information collected from the public domain. A total of 180 CO<sub>2</sub> EOR cases were collected based on the key parameters for screening such as CO<sub>2</sub> EOR include reservoir depth, reservoir temperature, permeability, porosity, oil viscosity, oil density, etc.
- Programming a variety of machine learning (ML) algorithms including random forest, XGBoost, ensembled voting classifier, neural network, decision tree, etc., to test whether ML algorithms can identify whether a reservoir is suitable for CO<sub>2</sub> EOR.
- Drafted a technical paper abstract based on the generalized learnings from Task 1.2 activities and other data collected from the public domain. The abstract was submitted to the 2023 Unconventional Resources Technology Conference (URTeC).

### ***Subtask 1.3 – Operability Assessment***

Existing facilities, infrastructure, and data monitoring used in the Foreman Butte oil field will be assessed with the development strategies and operating scenarios investigated in Subtask 1.2. Data collection, management, and a facility upgrade plan for the fields will be developed.

Significant accomplishments for Subtask 1.3 during the reporting period include the following:

- Monitored the average monthly production for Eagle Operating’s wells, starting in January 2021 through November 2022 per the NDIC website, that have been cleaned out to observe production changed over time as compared to other wells in the unit.
- Discussed and assessed the field production results with the operator after operator utilized a chemical agent to help stimulate the wells and provide some cleanup of paraffin in the tubing string.

### ***Subtask 1.4 – Strategic Characterization***

Based on the results of Subtasks 1.2 and 1.3, new data will be collected, analyzed, and interpreted (e.g., well logs, pressure testing, production profiles, core testing) to support the research program. The data from this subtask will be used to calibrate and improve geologic and simulation model performance (Subtask 1.2), evaluate operating scenarios, and inform development strategies to revitalize the selected field (Subtask 1.3).

Significant accomplishments for Subtask 1.4 during the reporting period include the following:

- The reservoir teams improved the injection bottomhole pressure (BHP) results of the water injection well. The simulated injection BHP trend is similar to the injection BHP history calculated by the available water level field data. However, the simulated water cut of the offset wells after the start of the water injection could not match the historical

data. The reservoir teams are working on improving the water cut results of the offset wells.

- Collected six oil samples from different fields/formations in North Dakota for experimental investigation of oil–gas interactions during EOR processes. The fields/formations include Foreman Butte, Madison, Cut Bank, Middle Bakken, Three Forks, and Cedar Hills.
- Preparing two core samples from the Foreman Butte Field to perform EOR tests in the next stage of the project. The core samples have been cleaned, and they are being saturated now.

### **Task 2.0 – Prototype to Revitalize a Unitized Legacy Oil Field**

Task 2.0 will synthesize Task 1.0 activities and results (e.g., performance response derived from scenario analysis) to assess potential development strategies for CO<sub>2</sub> EOR that can be applied to revitalize analog legacy oil fields in North Dakota. This information will be incorporated into a guidance document and included as part of the final report (Deliverable [D] 6).

Significant accomplishments for Task 2.0 during the reporting period include the following:

- Completed the draft “Prototype to Revitalize a Unitized Legacy Oil Field Using the Foreman Butte Field and General Guidelines for Carbonate and Fractured Reservoir Characterization and Modeling.” Finalized and documented technical review of all work carried out for Foreman Butte field characterization. Guidance document for general carbonate reservoir characterization and modeling based on the above work is 90% complete and will be sent to internal review and editing by the end of January 2023.
- Conducted a production data survey based on the NDIC oil and gas database, and over 200 conventional oil fields were identified in North Dakota. More detailed data-collecting activities will be performed to build a conventional oil field database in the next stage.

### **FINANCIAL INFORMATION**

This project is sponsored by NDIC, with in-kind cost-share support from EEP Tundra. At the time of this reporting, EEP Tundra has provided certification of \$2,572,027 of in-kind expenditures toward its committed cost-share amount. The in-kind contribution certification letter was received by the EERC on January 24, 2023, which listed documented costs incurred by EEP Tundra from October 1, 2022, through December 31, 2022, that are associated with this project. Table 1 shows the budget of \$6,000,000 over 3 years for this project and expenses through December 31, 2022.

**Table 1. Project Cost**

<b>Funding Source</b>	<b>Cash</b>	<b>Expended</b>	<b>Balance</b>
NDIC	\$3,000,000	\$1,289,707	\$1,710,293
EEP Tundra – In-Kind	\$3,000,000	\$2,572,027	\$427,973
<b>Total</b>	<b>\$6,000,000</b>	<b>\$3,861,734</b>	<b>\$2,138,266</b>

## **FUTURE ACTIVITIES**

The planned activities for the next quarter are as follows:

- Cut a section out of the history-matched model to perform a detailed water injection simulation based on the existing field operation. The injectivity of the injector and the waterflooding effect on offset wells will be evaluated.
- Conduct a simulation study to test different improved/enhanced oil recovery (IOR/EOR) methods for increasing oil recovery in the selected section. The methods include but are not limited to near-wellbore stimulation, multiple lateral drilling, infill drilling, water flooding, CO<sub>2</sub> (or rich gas) flooding, CO<sub>2</sub> (or rich gas) huff ‘n’ puff (HnP), etc.
- Perform a series of experimental measurements including minimum miscibility pressure (MMP), interfacial tension (IFT), contact angle (CA), etc., to understand the oil–gas interactions under a variety of injection conditions.
- Continue review of operations with the operator, reviewing updates to cleanout or stimulation treatments on the wells.
- Finalize the document Carbonate Reservoir Characterization and Modeling.

## **PROGRAM MANAGEMENT AND REPORTING**

Continue with project progress and assembling deliverables to carry through with timely quarterlies and final reports.