Energy & Environmental Research Center
15 North 23rd Street, Stop 9018 • Grand Forks, ND 58202-9018 • P. 701.777.5000 • F. 701.777.5181
www.undeerc.org

January 25, 2024

Mr. Reice Haase
Deputy Director
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 26645

Attached is a copy of the subject quarterly status report for the period October 1 – December 31, 2023.

If you have any questions, please contact me by phone at (701) 777-5343 or by email at tjiang@undeerc.org.

Sincerely,

DocuSigned by:
4E5F948EDBBF43C...
Todd Jiang
Principal Reservoir Engineer

TJ/ro

Attachment

c: Brent Brannan, NDIC
Brenna Jessen, NDIC

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, 2023)

Prepared for:

Reice Haase

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

Contract No. G-045-086

Prepared by:

Todd Jiang
Lu Jin
Stephen N. Guillot
Michael P. Warmack
Neil W. Dotzenrod
Jamie A. Schod

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

January 2024

EERC DISCLAIMER

LEGAL NOTICE This research report was prepared by the Energy & Environmental Research Center of the University of North Dakota (UND EERC) as an account of work sponsored by the North Dakota Industrial Commission (NDIC) (SPONSOR). Because of the research nature of the work performed, neither UND EERC, nor any of its employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement or recommendation by UND EERC. SPONSOR understands and accepts that this research report and any associated deliverables are intended for a specific project. Any modifications of the report or of any associated deliverables or use or reuse other than for the intended project is at the sole risk of the SPONSOR and without liability or legal exposure to UND EERC or to its directors, officers, or employees.

NDIC DISCLAIMER

LEGAL NOTICE: This research report was prepared by UND EERC as an account of work sponsored by NDIC through the Oil and Gas Research Program. To the best of UND EERC's knowledge and belief, this report is true, complete, and accurate; however, because of the research nature of the work performed, neither UND EERC, NDIC, nor any of their directors, officers, or employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the use of any information, apparatus, product, method, process, or similar item disclosed or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement or recommendation by UND EERC or NDIC. NDIC understands and accepts that this research report and any associated deliverables are intended for a specific project. Any reuse, extensions, or modifications of the report or any associated deliverables by NDIC or others will be at such party's sole risk and without liability or legal exposure to UND EERC or to their directors, officers, and employees.

TABLE OF CONTENTS

LIST OF TABLES

UNITIZED LEGACY OIL FIELDS: PROTOTYPES FOR REVITALIZING CONVENTIONAL OIL FIELDS IN NORTH DAKOTA
Quarterly Progress Report
October 1 – December 31, 2023

EXECUTIVE SUMMARY

Funded by the North Dakota Industrial Commission (NDIC), the Energy & Environmental Research Center (EERC), in partnership with Eagle Energy Partners Tundra (EEP Tundra), is undertaking this research program 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_2 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_2 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 EEP Tundra's operational timeline, the following activities and accomplishments occurred during the quarter:

- Continued to assist EEP Tundra in analyzing data collected from field operations, offering recommendations to address challenges observed in the field.

- Conducted various laboratory assessments and investigations, including analysis of oil characterizations from an external lab, working on improved oil recovery (IOR)/EOR using methods such as waterflooding, gas flooding, and surfactant flooding on core samples collected from Foreman Butte.

- Continued synthesis of finished Foreman Butte simulation cases.

- Completed construction of an upper Red River Formation geologic model, and started assessing its IOR/EOR predictive performance, aiming to analyze the effectiveness of utilizing CO_2 for revitalization.

EEP Tundra and the EERC will also continue to work with the Oil and Gas Research Council and 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, 2023

INTRODUCTION

The Energy & Environmental Research Center (EERC) is conducting 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_2 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_2 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_2-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_2 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_2-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 is 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 from either public sources (e.g., NDIC database, scholarly studies) or 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:

- Collected 234 minimum miscibility pressure (MMP) data sets for different gas–oil combinations from the public domain. The gases included pure CO_2 and CO_2 with impurities such as nitrogen, methane, ethane, etc. All data were experimentally measured in laboratories by various methods including slim tube, vanishing interfacial tension, and rising-bubble apparatus.

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:

- Selected a subsection of the upper Red River Formation from the Cedar Creek Field for the simulation study of primary depletion, waterflooding, and CO_2 EOR in the field. Five wells were included in the model, including two vertical and three horizontal wells.

- Processed the historical production and injection data for the selected wells for simulation, and analyzed oil production and performance of water injection and gas injection in the chosen section. Results indicated better production and injection responses attributable to distinct reservoir properties.

- Processed the well trajectory and perforation data from NDIC for the five wells; two horizontal wells have multiple branches completed at different times. The data were converted into grids suitable for use in the simulation model.

- Converted the rescue model into a simulation model for the selected section, integrating all processed historical data and equation of state (EOS). The model will be utilized for a detailed CO_2 EOR study once the history match is completed.

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:

- Reviewed current production methods on active wells and resulting production volumes, assessing the need to increase oil production. Discussed with a vendor the possibility of performing well tests with submersible equipment. EEP Tundra is currently testing the installation of larger pumping equipment on selected wells. Additionally, the company has requested and received a proposal from a service provider for an electric submersible pump (ESP) installation to assist in enhancing fluid production.

- Continued discussions with EEP Tundra and reviewed operational issues observed in wells, such as paraffin, scale, asphaltene, or other problems. Discussed and presented options for combating these issues.

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:

- Performed a series of surfactant EOR experiments to investigate the effects of injection rate, soaking time, surfactant type, and injection volume on EOR response using the rock samples collected from the Foreman Butte Field under actual reservoir conditions.

- An external laboratory performed a SARA (saturate, aromatic, resin, and asphaltene) test on the Foreman Butte oil to characterize the composition and properties of heavy oil by fractionating it into smaller quantities or fractions based on polarizability and polarity. The results of the test confirmed the potential for wax deposition as an issue in the field, consistent with observations from some wells.

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_2 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:

- Developed a ten-component EOS for the upper Red River Formation reservoir model from the Cedar Creek Field based on the pressure, volume, temperature (PVT) data from the field. The EOS has five individual gas components—CO_2, N_2, CH_4, C_2H_6, and C_3H_8—to ensure the model can be used to simulate different gas injection EOR scenarios.

- A detailed history match is being performed for the selected wells in the Cedar Creek Field. The historical data include over 60 years of production, 50 years of water injection, and approximately 10 years of gas injection. The data provided representative production and injection history for legacy oil fields in North Dakota.

- Refined prediction of oil production and CO_2 demand for potential CO_2 EOR development of 12 legacy oil fields along the Dakota Gasification Company pipeline in Williams and McKenzie Counties.

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 $202,687.72 of in-kind expenditures toward its committed cost-share amount. The in-kind contribution certification letter was received by the EERC on January 4, 2024, which listed documented costs incurred by EEP Tundra from October 1 through December 31, 2023, 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, 2023.

Table 1. Project Cost

Sponsors	Budget	Actual Expenses as of 12/31/23	Balance
NDIC	$3,000,000	$2,520,756	$479,244
Industry Share – In-Kind	$3,000,000	$2,978,622	$21,378
Total	**$6,000,000**	**$5,499,378**	**$500,622**

FUTURE ACTIVITIES

Activities planned for the next quarter are as follows:

- Develop a comprehensive database with all MMP data sets included. Each data set includes multiple variables: independent variables include gas and oil composition, reservoir temperature, and mole weight of heavy hydrocarbons in the oil; the dependent variable is MMP. The database will serve as the main data source for a machine learning study on MMP prediction.

- Perform gas flooding and bump tests after surfactant flooding using the Forman Butte rocks to evaluate maximum theoretical oil recovery in the field. Rock samples will be flipped and flooded with the same injection rate to test the possible formation damage effect during the waterflooding and surfactant-flooding processes.

- Select a set of tight rocks from the Foreman Butte Field to perform liquid-unloading experiments, which will reveal the maximum liquid displacement by gas injection for tight reservoirs in North Dakota. Water, surfactant, and gas will be used in the experiments.

- Continue to perform the history match for the upper Red River Formation reservoir model from the Cedar Creek Field. A series of CO_2 EOR simulation activities will be performed to investigate the EOR potential in this field considering the irregular well distribution that is different from regular flooding patterns.

- Monitor results seen on selected wells with increased production rates, and evaluate the use of ESPs to increase production from selected wells.

PROGRAM MANAGEMENT AND REPORTING

A team member attended the 2023 CO_2 Conference in Midland, Texas. This year's conference focused on large-scale carbon capture, utilization, and storage (CCUS) and carbon capture and storage (CCS) projects. The EERC team actively participated in discussions and panels with operators, regulators, and consulting firms, addressing the current status of CO_2 management and policy, planning for CCS and CCUS projects, and examining CO_2 EOR cases in the United States and internationally.

The project team will continue project progress and assembling deliverables to carry through with timely quarterlies and the final report.