



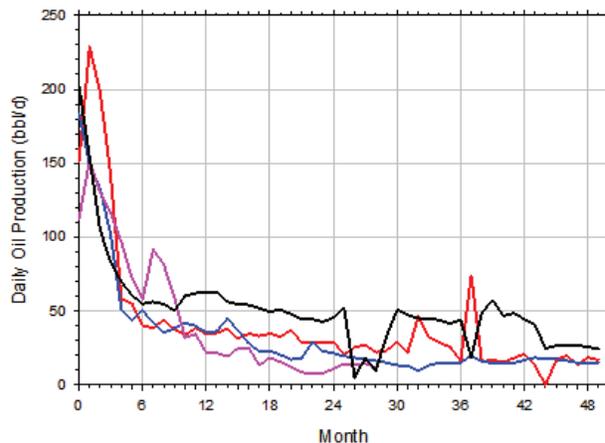
Effective EOR Technologies in Tight Bakken Oil Reservoirs An SRC Consortium R&D Approach

Motivation

The Bakken Formation underlies much of the Williston Basin and is estimated to contain up to 500 billion barrels of light oil. Application of horizontal wells with multistage hydraulic fracturing has unlocked the huge potential of this shale oil play. Since 2004, Bakken production in southeast Saskatchewan has risen an average of 760 barrels of oil per day (BOPD) to 71,300 BOPD. Bakken production in Canada and the US now exceeds 1.1 million BOPD.

While new Bakken wells are highly productive, they decline rapidly from their initial peak production, at rates sometimes in excess of 85 per cent per year. This is because of the complex nature of the Bakken formation, which consists of mainly dolomitic siltstone and sandstone with very low permeability (± 0.01 md). The formation pore size is so small that individual pores are very poorly interconnected, dramatically limiting the flow of oil within the reservoir.

There is a major industry need to increase recovery and sustain production from new and existing Bakken wells to increase reserves and reduce costs. The Saskatchewan Research Council (SRC) has many years' proven expertise and experience in characterizing, screening and evaluating EOR techniques for "light and tight" reservoirs, including the Bakken, particularly focused on developing waterflood and gas injection solutions for our clients.



Typical oil production decline curves for Bakken wells in southeast Saskatchewan

For more than 30 years, SRC has worked with large and small oil companies to develop Western Canadian Sedimentary Basin's light oil resources. Our R&D was instrumental in the engineering design of the Weyburn field CO₂ miscible flood, and we have helped other clients assess immiscible/miscible gas injection for their holdings. SRC also has well-reputed expertise in chemical-enhanced waterflooding.

SRC's Approach

SRC's work in this area focuses on screening and evaluating particular EOR processes to arrest production decline rates and improve ultimate recovery in clients' Bakken reservoirs of interest. We augment experimental studies conducted with equipment specially designed for tight oil with numerical simulation to design pilot programs and understand and advance tight oil recovery.

We invite you to participate in a consortium-based program to evaluate EOR technologies for your Bakken oil reservoirs.

Project Objectives

- Provide a highly cost-effective route to delivering real EOR solutions through a multi-client program tailored to individual client's needs.
- Design technically viable and cost-effective EOR technologies for Bakken tight oil reservoirs.
- Apply demand-oriented R&D, helping tight oil operators tackle injection and production challenges during EOR operations.
- Assist our clients in designing and implementing field pilot and commercial projects.

Project Scope

The entire program is designed to comprise three phases, each of which is completed in 12–14 months. The detailed work statement for each Tier-1 participant is summarized below.

Phase 1 — Fundamental Data Collection

Task 1 — Fluid and Core Characterization

1. Fluid cleaning and characterization
 - ✓ Collect field fluid samples
 - ✓ Clean brine samples by filtration/prepare synthetic brine
 - ✓ Measure various ion concentrations of cleaned brine along with other physico-chemical properties
 - ✓ Characterize separator gas by gas chromatography
 - ✓ Measure carbon number distribution, molecular weight, densities and viscosities of dead oil

2. Core characterization
 - ✓ Reservoir core plug acquisition
 - ✓ Lithofacies description
 - ✓ Petrophysical and petrographic measurement
 - ✓ X-ray diffraction analysis
 - ✓ Scanning electron microscopy
 - ✓ Capillary pressure curves
 - ✓ Wettability measurement

Task 2 — Phase Behavior (PVT) Studies

1. Live oil preparation and PVT measurements
 - ✓ Reconstitute live oil with separator oil and gas
 - ✓ Measure bubblepoint, density, viscosity, gas/oil ratio and live oil composition at reservoir conditions
2. Reservoir oil–injection gas phase behavior tests
 - ✓ Determine equilibrium properties of reservoir fluid mixed with different proportions of injection gas
 - ✓ Measure these equilibrium properties: bubblepoint, gas/oil ratio, density, viscosity, formation volume factor, and swelling factor
3. Reservoir oil–injection gas recovery tests
 - ✓ Saturate reservoir oil with injection gas inside Bakken cores in a high-pressure visualization cell
 - ✓ Deplete cell pressure at different rates/steps, measure oil recovery
4. Minimum miscibility pressure measurements
 - ✓ Rising bubble method
 - ✓ Optional slim tube test at extra cost

Task 3 — Enhanced Waterflooding Studies

Various surfactant candidates and complexing agents are evaluated for possible application of surfactant flooding at Bakken fields, through these experiments:

- ✓ Compatibility, long-term stability at reservoir conditions
- ✓ Interfacial tension (IFT) reduction
- ✓ Adsorption on reservoir rocks
- ✓ Contact angle and wettability measurements
- ✓ Spontaneous imbibition testing
- ✓ Geochemical modelling

Phase 2 — Core Displacement and Numerical Simulation

Task 1 — Core Displacement Tests

Two coreflood tests are conducted for each Tier-1 participant in reservoir core plugs that have been cleaned and aged. Based on each participant's selection, initial primary production is followed by enhanced waterflooding in different chemical injection scenarios, and by gas flooding with different types of gas and injection schemes.

Task 2 — Coreflood History Match

First, an equation-of-state model based on measured PVT data is built and tuned. For each coreflood, a laboratory-scale numerical simulation study is carried out to obtain relative permeability curves to be used in follow-up field-scale simulation. The following are reported:

- ✓ Matched oil and water production
- ✓ Matched pressure drop along the core stack
- ✓ Oil/water and oil/gas relative permeability curves

Task 3 — Field-Scale Simulation

A field-scale geological model is generated from openhole well logging and digitized contour maps. Field production data is matched by adjusting the bottomhole pressures and relative permeability curves in each well region. Finally, various development strategies that include primary and EOR schemes are investigated.

Phases 1 and 2 Deliverables

- ✓ Quarterly progress reports summarizing progress, challenges, solutions, next steps
- ✓ Semi-annual meetings presenting results and recommendations for path forward
- ✓ Comprehensive final report providing technical solutions and engineering design guidance for suitable EOR technologies at Bakken reservoirs

Cost of Consortium Participation

Cost is per phase and two tiers of client participation are offered:

Tier-1 Participation: Individual client field-specific fluid and core tests; participation in meetings; access to reports and decision making: **C\$80,000**

Tier-2 Participation: Participation in meetings; access to all reports, data and decision making: **C\$40,000**

SRC Funding Contribution

There is a leverage fund contribution of 20 per cent for the total program budget from the Government of Saskatchewan.

Phase 3 — Pilot Test Design and Implementation

Assist clients in applying for suitable EOR pilots.

- ✓ Pilot test risk assessment
- ✓ Selection of potential pilot sites
- ✓ EOR injection scheme and production optimization
- ✓ Pilot well production monitoring and surveillance to improve production performance

Cost of Participation for Phase 3

The participation fee for Phase 3 is determined according to specific work scope and number of participants.

Benefits of Consortium Participation

All participants gain practical insight into the EOR processes for their Bakken oil assets. Tier-1 participants have the Phase 1 and 2 work scope performed on their own field fluids and cores to gain a comprehensive assessment of the suitability of that field for a particular EOR process. Tier-2 participants benefit from internal access to all reports and data from a large multi-client, financially-leveraged program.