PROJECT facts

Petroleum Exploration and Production

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U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Enhanced Oil Recovery by Horizontal Waterflooding, Osage County, OK

Partners

Grand Resources, Inc.
Tulsa, OK

Main Site

Wolco Field
Osage County, OK

Background

Oil fields in the Osage Nation are in a mature stage of depletion, yet millions of barrels of bypassed but potentially recoverable oil remain in the Bartlesville sandstone, a low-permeability and shallow, naturally fractured reservoir. Conventional waterfloods using vertical wells in this formation are often unsuccessful because water cannot be injected below the reservoir parting pressure and at a rate high enough to improve oil recovery. Channeling and poor oil recovery often occur if the operator exceeds the fracture-parting pressure of the reservoir. A substantial amount of additional oil can be recovered by using a technology that would allow large volumes of water to be injected below the reservoir parting pressure. In this project, a horizontal waterflood is demonstrated to improve oil recovery from an abandoned oil reservoir found 100 years ago.

Project Description/Accomplishments

This three-year project tested horizontal waterflooding as a means of improving oil recovery from the Middle Pennsylvanian Bartlesville Formation in Wolco field in Osage County, OK. Three horizontal wells were drilled—an injector surrounded by two producer wells—in a heel-to-toe configuration to minimize heel-to-heel interaction between the injection well and the horizontal producers.

The selection of Wolco field for the pilot location was based on cumulative oil production, remaining recoverable reserves, reservoir characteristics, and available infrastructure. Numerical simulations were conducted to determine whether project economics were favorable.

Although Wolco field had never been waterflooded, the nearby North Avant Unit had showed early water breakthrough from high water injection rates that exceeded the fracture parting pressure. This knowledge was used to design injection rates below the fracture parting pressure.

The Bartlesville Formation was deposited in a fluvial incised valley and ranges from braided fluvial deposits in the formation's lower zone to meandering fluvial deposits in the upper portion of the reservoir. In the pilot area, the sandstone is 80 feet thick, with an average permeability of 20 millidarcies and porosities ranging from greater than 20% in the lower zone to 15-20% in the upper zone. The formation is fractured with surface fractures dominantly oriented N35E.

Simulation studies indicated that the horizontal injection well should be drilled 20 feet from the bottom of the sand, with the two producing wells 20 feet from the top of the sand. The horizontal wells were drilled parallel to the suspected prevailing fracture orientation within the field.

The wells were drilled with a curve-drilling assembly configured to drill a 70 foot radius curve. A lateral drilling assembly was used to drill the horizontal sections of the wells. The vertical part of the wells was drilled with air, the short-radius curve with water, and the lateral section of the wells with air/foam to minimize formation damage. The wells were open-hole completions.

During water injection, rapid water breakthrough was accompanied by disappointingly low production—8 barrels of oil per day (BOPD) and 700 barrels of water per day. A spinner survey run in the injection well indicated that all injected fluids were entering the formation within only a 15 foot section of the well. Well log surveys on both producing wells suggested that the laterals should be nearer the top of the formation, where oil saturation was higher.

Redrilling the production wells closer to the top of the formation in a thin oil layer and drilling a vertical injection well resulted in increasing the production by 15 BOPD, making the horizontal waterflood project economic.

Benefits/Impacts

This project demonstrated that horizontal waterfloods can be a cost-effective method to improve oil recovery in mature Midcontinent fields. The technologies and methods employed to evaluate, manage, and adjust both injection and production performance were well-chosen and executed. They included evaluating production results, conducting step rate and injection profile tests, running a full suite of open hole logs, employing numerical simulation, adjusting injection rates to maintain adequate reservoir pressure, and redrilling the horizontal producing wells closer to the top of the reservoir. The methodology applied in this project will serve as a guide for other companies wanting to apply horizontal waterfloods in the Midcontinent.

The researchers determined that the heels of horizontal injection wells may be fractured, limiting the injection profile in the horizontal section of the well. They also found that oil saturation profiles need to be known for optimum placement of horizontal producing wells. The lessons learned from the problems encountered and overcome in the project can be used to prevent other companies from experiencing the same pitfalls.

Osage County, OK production well.

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COST

Total Project Value
$877,393

DOE/Non-DOE Share
$399,640/$477,753

CUSTOMER SERVICE

1-800-553-7681

WEBSITE

www.netl.doe.gov