IMPROVING OIL RECOVERY IN MATURE FIELD WITH INNOVATIVE COMPLETION SOLUTION: DUMPFLOOD APPLICATION

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Palabras claves

Dumpflood, mature field, EOR, OPEX, CAPEX

Abstract

Maximize oil production at the lowest cost, reduce the process facilities used for secondary recovery water injection projects and increase the static pressure of mature reservoirs was a need in Field due to the challenging oil market conditions and the declining oil production rates. The legacy solution used by Operator consisted in producing water with artificial lift and then re-injecting it through horizontal pumping systems. This water injection method did not maximize oil recovery with the available resources.

The state operator and the company implemented the Dumpflood completion with electrical submersible pumping to address the challenges encountered in the field. The Dumpflood completion is a closed loop concept where water is produced and injected in a single well avoiding surface processes. This implementation allowed Operator to develop secondary oil recovery in a simplified and cost effective completion.

This paper will present the results of the first pilot of Dumpflood completion in Field in Colombia. This Promoted enhanced oil recovery in the target injection zones, in addition, significant savings in capital expenditures were obtained due to the reduction of surface production tubing and required licenses for the oil industry in Colombia. Operating expenditures such as maintenance, water treatment, and energy costs were also reduced.

The success of the Dumpflood completion with electrical submersible pumping permitted the initiation of a change in the legacy water injection method in the field. It was demonstrated that the oil market is continuously in need of innovative completions solutions to optimize resources and oil recovery.

Resumen

Maximizar la producción de petróleo al más bajo costo, reducir las facilidades del proceso utilizadas para los proyectos de recuperación secundaria de inyección de agua e incrementar la presión estática de los yacimientos maduros era una necesidad en el campo debido a las difíciles condiciones del mercado del petróleo y la disminución de las tasas de producción del mismo. La solución tradicional usada por el operador consistía en producir agua mediante un sistema de levantamiento artificial y

luego reinyectarla a través de un sistema de bombeo horizontal. Este método de inyección de agua no maximizo la recuperación de petróleo con los recursos disponibles.

El operador estatal y la compañía implementaron el completamiento Dumpflood con bombeo electrosumergible para abordar los desafíos encontrados en el campo. El completamiento Dumpflood es un concepto de circuito cerrado donde el agua es producida e inyectada en un solo pozo evitando procesos en superficie. Esta implementación permite al operador a desarrollar un recobro secundario del petróleo con un completamiento simplificado y rentable.

Este documento presentará los resultados del primer piloto de completamiento Dumpflood en un campo en Colombia. Este promovió una recuperación mejorada de petróleo en las zonas objeto de inyección, además, se obtuvieron ahorros significativos en gastos de capital debido a la reducción de tubería de producción de superficie y las licencias requeridas para la industria petrolera en Colombia. Los gastos operativos como mantenimiento, tratamiento de agua y costos de energía también se redujeron.

El éxito del completamiento Dumpflood con bombeo eléctrico sumergible permitió el inicio de un cambio en el método tradicional de inyección de agua en campo. Se demostró que el mercado petrolero necesita continuamente soluciones innovadoras de completamiento para optimizar los recursos y la recuperación de petróleo.

Introduction

The improved recovery methods have a primary recovery stage of hydrocarbons from the reservoir, this involves natural flow lifting and/or artificial lift systems. Once energy and/or recovery of hydrocarbons from the reservoir loses efficiency, it is necessary to carry the methodology for secondary recovery. This recovery method, is a water injection process aimed at maintaining or increasing the recovery of remaining hydrocarbons from the reservoir by means of displacement. The water injection methods to improve the recovery, contemplate different applications on the surface and the economic analyzes of the projects show high associated costs.

Conventional water injection systems in the oil fields, are challenging the market. It because of their high investment and process chains that require high operating and capital costs. Today, due to the global situation of the hydrocarbon industry, is required economically feasible injection projects and for this requires the reduction of investment and simplification of the injection processes currently installed.

The existing applications for water injection and improvement of the recovery, show great opportunities for improvement, which means that the conventional method of water injection is considered. Trying to eliminate the limitations that currently stop the projects, becomes a challenge that drives us to generate innovative proposals for non-conventional injection models, leading to minimum levels of capital expenditures and operating expenses.

This paper will present the results of the Dumpflood completion implementation in oil Field in Colombia This promoted enhanced oil recovery in the target injection zones. In addition, significant savings in capital expenditures were obtained due to the reduction of surface production tubing and required licenses for the oil industry in Colombia. Operating expenditures such as maintenance, water treatment, and energy costs were also reduced

Oil Field Background

The oil field is one of the main assets of the Colombian state oil company. It is in the Meta Department at the east part of the country with a surface area of 1853.29 acres with a reservoir area of 924,174 acres. It was discovered in 1969, but began production in 1985. It initially produced from a cretaceous formation named Guadalupe with API gravities from 16˚ to 25˚ under a partnership contract. In 2000, it passed to full management by state Operator and further exploitation studies were conducted leading to the production of extra-heavy crude with API gravities between 7° and 9° from tertiary formation San Fernando. It corresponds to the T2 unit which is at the average depth of 8500 ft (TVD), making it one of the deepest extra-heavy oil reservoirs in the world.

The oil field has 235 producing wells and provides a total production of 78,000 bbl/day. It is divided into three areas: the north area, (68% BSW); the central area (26% BSW); and the south west area (12% BSW). 93% of the wells produced with electrical submersible pumping systems. Current conditions shows a decrease in reservoir pressure and a challenge to improve the recovery of remaining hydrocarbons, as a consequence of this effect, the artificial lift systems of the field have been deepened in the last years to setting depths ranging from 5000ft to 8000ft approximately, in order to achieve the required submergency of the application.

At present, the oil field has 5 water injection wells with two purposes:

The provision of water in a structure for storage
The improved recovery

This improved recovery method allows the injection of approximately 29,000 bbl / day. It is important to note that the traditional field injection methods are composed of horizontal injection pumps and crossflow wells in the background. These recovery methods are in place to be able to inject an additional 30,000 bbl/day.

Traditional Injection System

The traditional injection system can be seen in Figure-01. It is composed of: a primary process of treatment and stabilization of water from hydrocarbon production processes in the field, where the water to be injected complies with the approvals of the current legal regulations. It is transported to a horizontal pumping system, which is composed of multi-stage pumps that generate a differential pressure between their diffusers and impellers, a skid that provides a platform suitable for the correct assembly of the components, avoiding vibrations that could compromise the proper functioning of the system, an electric motor with its respective spacer to withstand the required workload and a thrust chamber with designed seals to withstand axial thrust, transmitting the motor torque to the pump and sealing the ambient fluid. After the water is dislodged from the horizontal pump, it is injected into a well labeled as an injector as it allows the injection of water.

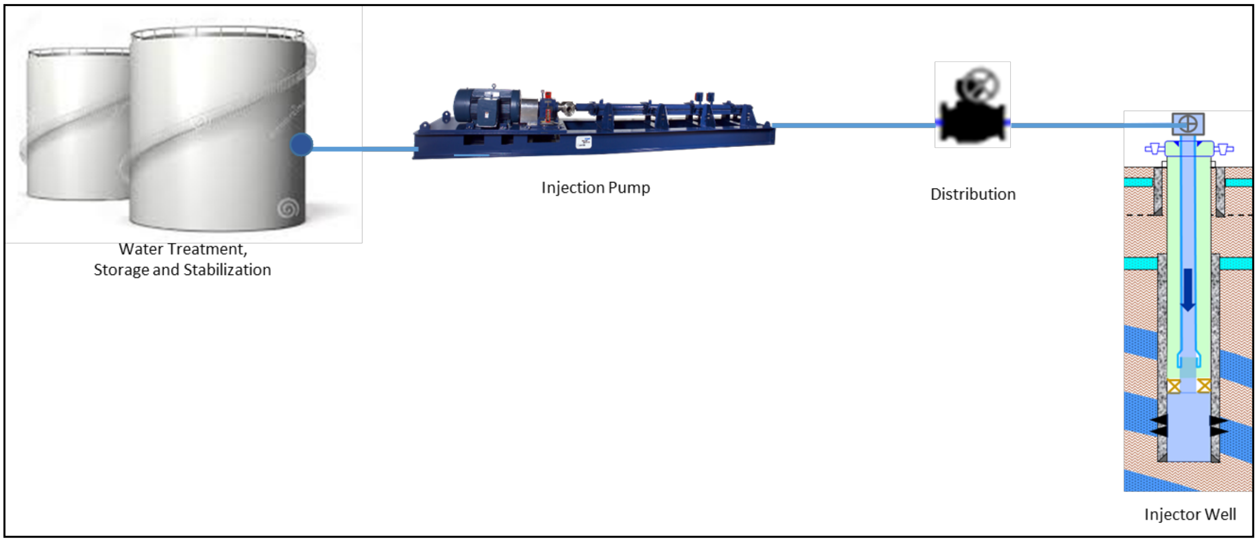


Figure-01. Traditional injection system

Crossflow Injection System

This model of water injection can be visualized in Figure-02. Consists of the production of the fluid of the zone of production of water (Lower zone) and by the pressure of the deposit manages to exceed the injection pressure of the zone of interest (Upper zone). The hydraulic packages arranged for the application segment the injection zone, allowing to isolate and increase the pressure in the injection zone. The mechanical jacket installed between the packages, allows the fluid to flow out into the annular space from the pipe that communicates the Upper zone from the lower zone. The implemented configuration may be limited in face of the amount of fluid injected and the pressure required to increase the current rate of injection, that is to say, it is required to increase the injection pressure to increase the injected flow rate.

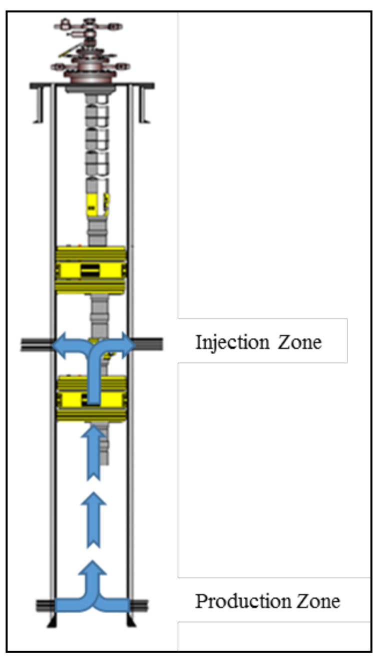


Figure-02. Traditional injection system

Dumpflood Concept

The Dumpflood system is an innovative bottom application that allows the production and injection of fluid in the same well, that is to say, allows fluid from a lower zone to be produced with an electro submersible pump and by means of the isolation of an upper zone with hydraulic packing and mechanical jackets, the fluid injection can be performed.

The application of the injection systems, in this case the Dumpflood, allows the fields to show improvements in the bottom pressure of the wells of influence, as well as to improve the secondary recoveries of crude oil in reduced times. Conventional injection systems projects are of high cost and require advanced surface technology and the time to recover the investment would have to be projected over long periods.

When selecting a candidate well for Dumpflood completion, some considerations regarding well characteristics and component selection should be taken into account, compliance with the characteristics increases the probability of having an ideal well for the application of injection system:

a) Compatibility of fluid produced with Injection reservoir: Fluid compatibility analyzes should allow for acceptance of fluid from the lower zone (Aquifer) in the upper zone (Injection).

b) The objective zones must allow the proper installation of the electro-submersible pump. This must be located between the area of supply and the area of injection of the fluid, this to guarantee the adequate cooling of the ESP systems. In case it is not possible to carry out the installation of the ESP equipment above the perforated area should include the installation of an additional cooling system (Encapsulation, Jackets, Recirculators, etc.).

c) Well injection index: is the construction of the flow rate injected into the zone of interest versus the pressure required to perform the injection.

d) Well Construction (Casing, Inclination, DLS and Depth): The well lining should facilitate the installation of the submersible electro pump and the hydraulic packing. The inclination angles should be found below 90° and the DLS at the depth of the ESP should not exceed 1° / 100ft. However, the DLS to which the injection string is subjected must be evaluated.

e) Quality of the well cement for the adequate settlement of the hydraulic packages.

f) Selected Electro Submersible Pumping Equipment must have the lifting capacity required by the well. Must be able to handle high volumes of fluid with an outside diameter that does not exceed the drift limits of the settlement casing.

g) Hydraulic packages for zone insulation must allow the correct installation of ESP systems. Must allow the passage of capillary injection cable, its anchoring system must allow the recovery and repair of the same.

h) Mechanical shirts: designed to allow the correct outlet of the fluid from the pipe to the area of interest (annular space). The design must allow the correct location of the power cable of the ESP system without risking the integrity of the system, besides allowing the option of being closed (Surface production) or open (injection in background).

The mechanical state proposed for the application of the Dumpflood injection system can be seen in Figure-03:

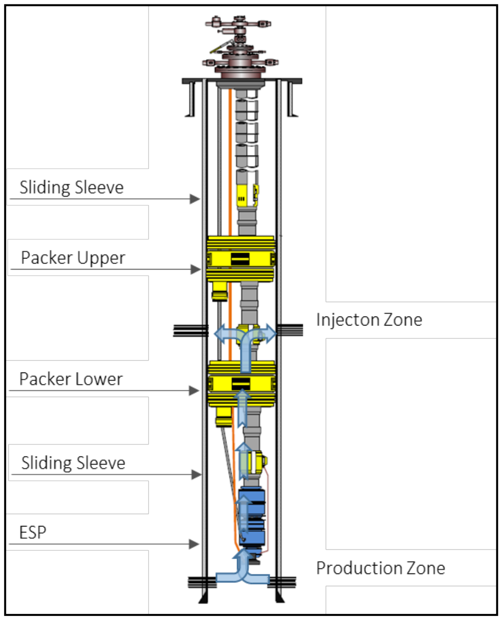


Figure-03. Dumpflood Injection System

The components that make up the injection string should be at least the following:

Hidraulic Packers

The selected hydraulic packages are designed to facilitate the use of a Submersible Electro Pump. The packaging has threaded connections to accept a feed-through packaging system, or a penetrating cable. It has holes that allows the installation of lines for the injection of chemicals in the background. These packages allows that the background installation be in tandem, that is to say, they can be placed in the well without having to make additional trips. These packages allows a differential pressure up to 7500psi, this allows the oscillation of high ranges of flow and pressure between the different areas of interest. Additionally the packaging has the option of being fully recoverable and repairable. Due to the current requirement of zone insulation, it is important to select a package that guarantees the tightness of the zones

Mechanical Shirts (Sliding Sleeves)

The shirts have a design that allows the proper installation of the power cable of the submersible electro-pump system. The jacket is constructed in a material that does not allows erosion since it will be exposed to the continuous outlet of fluid in different pressures and temperatures. Installed mechanical sleeves must additionally have a profile that allows the installation of plugs or "standing valve" type, this to be able to configure the injection string with different modules.

Electrical Sumergible Pump

The selected electro-submersible pumping equipment must have the capacity to handle different injection flow rates with different discharge pressures. Should consider a design that allows the installation of the system in reduced diameters.

The selected pump must have a "Stabilized Severe Duty" stabilization configuration that basically uses tungsten carbide bearings at the pump ends and radial tungsten carbide supports in the middle of the drive stages. This configuration must allow the pump, among other things, to stabilize vibrations and loads. The pump stages must have the capacity to handle extended flow ranges, that is to say, they must have flexible stages to the well injection requirements. The design of the stages should allow to improve the efficiency of the system, reflecting a decrease in the energy consumption.

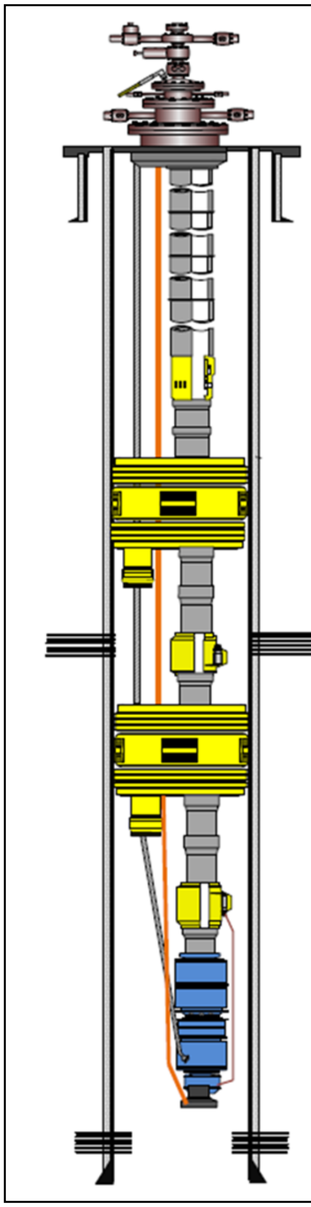
The selected seals should ensure that the rooms will operate within acceptable expansion parameters and that the thrust bearing is loaded within acceptable limits. Additional to this, should be contemplated double bag to allow further expansion of the oil due to the temperatures handled by the motor. A high load bearing shoe must be provided to support the pump thrust and an axis must be selected to increase the reliability taking into account the radial and axial thrust of the system.

The selected bottom motor must have the required power capacity. A three-phase induction motor with two poles and a rotation of approximately 3500RPM @ 60Hz must be selected. This motor must be constructed of overlapping rotors that are housed inside of a coiled stator.

The background sensor selected should allow the reading of background variables such as: fluid temperature, background temperature, intake pressure, system leakage currents, vibrations and is indispensable that is has the reading of discharge pressure of the pump to evaluate the flow rates and injection pressure.

Dumpflood Implementation in the oil Field

After evaluating the information of the wells, the completion line for the Dumpflood system was designed in the Oil field. Followed, the Figure-fig04, shows the proposed mechanical state for the implementation in the oil field:



No.	Depth, m	Length, m	OD, in.	ID, in.	Description
					FINAL INSTALLATION
1	0.000	0.000			Tubing Hanger
2	8,130	8,130	4.500	2.991	Tubing, 3-1/2" EUE BoxxPin (+/-271 joints)
3	8,138.0	8.00	4.500	2.991	Pup Joint, 3-1/2" EUE BoxxPin
4	8,142.1	4.07	4.260	2.812	2.812"Sliding Sleeve F profile , 3-1/2" eue BoxxPin
5	8,172.1	30.00	4.500	2.991	Tubing, 3-1/2" EUE BoxxPin (+/-1 joints)
6	8,173.0	0.88	4.200	2.750	Seating Nipple 2.75"R, 3-1/2"eue BoxxPin & blanking
7	8,203.0	30.00	4.500	2.991	Tubing, 3-1/2" EUE BoxxPin (+/-1 joints)
8	8,203.75	0.80	4.50	2.441	Crossover Sub, 3-1/2" EUE Boxx2-7/8" EUE Pin
9	8,209.83	6.08	3.500	2.441	Pup Joint 2-7/8" EUE BoxxPin
10	**8,217.1**	**7.25**	**5.937**	**2.362**	**Twin Seal Packer Upper , 7" 29#/ft , 2-7/8" eue box x pin**
11	8,223.11	6.03	3.500	2.441	Pup Joint 2-7/8" EUE BoxxPin
12	8,223.9	0.80	4.500	2.441	Crossover Sub, 2-7/8" EUE Boxx3-1/2" EUE Pin
13	8,283.9	60.00	4.500	2.991	Tubing, 3-1/2" EUE BoxxPin (+/-9 joints)
14	8,284.7	0.80	4.500	2.441	Crossover Sub, 3-1/2" EUE Boxx2-7/8" EUE Pin
15	8,290.8	6.08	3.500	2.441	Pup Joint 2-7/8" EUE BoxxPin
16	**8,294.6**	**3.85**	**3.753**	**2.312**	**Sleeve, 2-7/8" eue Box x Pin**
17	8,300.7	6.03	3.500	2.441	Pup Joint 2-7/8" EUE BoxxPin
18	8,301.5	0.80	4.500	2.441	Crossover Sub, 2-7/8" EUE Boxx3-1/2" EUE Pin
19	8,871.5	570.00	4.500	2.991	Tubing, 3-1/2" EUE BoxxPin (+/-14 joints)
20	8,872.3	0.80	4.500	2.441	Crossover Sub, 3-1/2" EUE Boxx2-7/8" EUE Pin
21	**8,883.1**	**10.80**	**5.937**	**2.362**	**Twin Seal Packer Lower , 7" 29#/ft , 2-7/8" eue box x pin**
22	8,889.2	6.10	3.500	2.441	Pup Joint 2-7/8" EUE BoxxPin
23	8,919.2	30.00	2.880	2.441	Tubing 2-7/8" EUE BoxxPin (+/-1 joints)
24	**8,923.0**	**3.85**	**3.753**	**2.312**	**2.312" Sliding Sleeve, 2-7/8" eue Box x Pin**
25	8,929.1	6.10	3.500	2.441	Pup Joint 2-7/8" EUE BoxxPin
26	8,930.2	1.07	3.500	2.250	Seating Nipple 2.25"R, 2-7/8"eue BoxxPin
27	8,990.2	60.00	2.880	2.441	Tubing 2-7/8" EUE BoxxPin (+/-2 joints)
28	8,990.7	0.50	3.500	2.441	Check Valve 2 7/8" EUE 8RD
29	9,020.7	30.00	2.880	2.441	Tubing 2-7/8" EUE BoxxPin (1 joints)
30	9,021.2	0.50	4.000	2.441	DSCHARGE
31	9,021.7	0.50	4.000	2.441	DGU SENSOR
32	9,045.2	23.50	4.000	-	PUMP UPPER SERIE 400
33	9,068.7	23.50	4.000	-	PUMP MEDIUM SERIE 400
34	9,092.2	23.50	4.000	-	PUMP LOWER SERIE 400
35	9,093.2	1.00	4.000	-	INTAKE 400 HV
36	9,098.8	5.60	4.000	-	SEAL UPPER 400
37	9,104.4	5.60	4.000	-	SEAL LOWER 400
38	9,104.4	0.00	4.880	-	MOTOR LEAD EXTENSION
39	9,125.9	21.50	4.500	-	MOTOR 450 UPPER
40	9,147.4	21.50	4.500	-	MOTOR 450 LOWER
41	9,149.2	1.84	4.000	-	SENSOR
42	9,150.2	1.00	4.880	-	CENTRALIZADOR DE COLA
	9,241.0	90.77			Perforations K2

Figure-04. Dumpflood Schematic

The design of the Dumpflood water injection string and the construction of the mechanical state were constructed taking into account the following conditions:

a) The perforated intervals are shown in Table-01, taking into account the location of the perforated intervals, it is evident that there is a sufficient distance to perform the correct installation of the submersible electro-pumping system without problems.

Interval Name	Perf MD (ft)	
	Top	Bottom
T2 (Injection Zone)	8,300.00	8,629.00
K2 (Production Zone)	9,183.00	9,241.00

Table-01. Perforated Intervals

b) The survey of the well shows that the maximum inclination of the well is 5.63 Degrees and the DLS where the electro submersible pump will be sitting is 0.79 Grates/100ft.

c) The cement quality records show an adequate state of the zones where the settlement of the hydraulic insulation gaskets will be made.

d) It is evident that the well casing has a production casing of 9 5/8" of 47lb/ft (0'-8267'), followed by a 7" production liner of 29lb/ft (8029'- 9540'). The entire Dumpflood injection system, will be seated in the liner.

e) The designed injection system string allow the flexibility to produce fluid to surface and/or to inject in bottom, with a process of opening / closing of mechanical shirt, this allows us to have sanples of the injected fluid in surface

Results

The company and state operator performed the successful installation of the dumpflood injection system in a pilot well in the oil field, the completion of the well was executed successfully and following the proposed guidelines.

After the installation of the dumpflood injection system in the pilot well, an increase in production was obtained in the wells located within the area of influence of the injection well.

The pilot injection well allowed to increase the injected flow an average of 4600bbl / during its period of operation. The Injection of these additional water barrels did not need to implement additional surface facilities.

The dumplood application allowed to demonstrate the reduction of capital expenditures and operational expenses needed in water injection projects, helping to make feasible the expansion of the project of improved recovery with dumpflood systems. This expansion led to increase the project to 7 additional wells which have a total capacity to inject 30,000bbl / day of water.

The results of the installation of the dumplflood injection system allowed the feasibility of additional water injection projects in the oil field. Also, it permitted the design of complex completion strings with segmentation of the zones of interest, and the installation of mandrels to regulate the flow passage with pressure differentials

Conclusions and recommendations

The dumpflood completion string is a fast, innovative and effective water injection technology for the improvement of secondary recovery of hydrocarbons from a field.

It was calculated a reduction in CAPEX of 60% in comparison with a conventional water injection system. The savings were achieved with the elimination of the construction of surface facilities and the required licenses that usually are needed in a conventional water injection project.

The OPEX reduction calculated was about of 30% when compared to a conventional water injection system, this is due to the reduction of operations activities performed on surface facilities and the elimination of maintenance usually required in standard water injection surface equipment.

The pilot dumpflood application designed for downhole water injection allowed the economic feasibility of projects for improved oil recovery in a fast and effective way.

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