Determining The Most Select Injector Well Pattern For Improving Oil Recovery Using Eclipse Soft Ware (A Case Study of Sparrow Field, UK)

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Abstract - Oil can be recovered naturally from the reservoir by difference drive mechanism such as Depletion drive, Gas cap drive, Water drive, Combination drive. When this drive mechanism becomes depleted or production need to be enhanced, secondary or tertiary oil recovery techniques are used. Determination of optimal number of injector wells and the best well pattern for the injection wells is a very important step in reservoir development plan in order to maximize production at a minimal cost. Optimization of injector well numbers was done by testing five different patterns by four, eight, and twelve injector wells. Results show that all the injector well pattern best work with increased number of injectors for this case except the staggered line drive. Economic analysis show maximum Goss Profit Margin from all the cases but staggered line drive had a better profitability index than the rest.Further studies need to be done with varying pressure, production and injection rates so as to completely prove if the results found are true.

Keywords - Location, Injector, Pattern, Water flooding, Recovery.

1.0 Introduction

The objective of obtaining the maximum profit from investments in oil fields is everyday more demanding. The problem of optimizing an oil field is an extraordinarily complex one. In it there are many variables to consider such as; geological variables like reservoir architecture, production variables such as well placement, well number, type of platform, platform position and monetary variables like oil and gas prices among other (Guyaguler B. H., 2000).

Oil can be recovered naturally from the reservoir by difference drive mechanism such as Depletion drive, Gas cap drive, Water drive, Combination drive. When this drive mechanism become depleted or production need to be enhanced, secondary and enhance oil recovery techniques are used. Secondary recovery techniques increase the reservoir's pressure by water injection, natural gas reinjection and gas lift, which inject air, carbon dioxide or some other gas into the bottom of an active well, reducing the overall density of fluid in the wellbore (Bittencourt, Oct, 1995). Enhanced oil recovery is also called improved oil recovery or tertiary recovery. It includes implementation of various techniques for increasing the amount of crude oil that can be extracted from an oil field. There are three primary techniques of EOR: gas injection, thermal injection, and chemical injection.

The primary objective of water flooding (Water injection) is to fill the voidage created by the produced oil fractions thus avoiding the reservoir pressure to decrease with the increased production. When the water is injected in the reservoir, it tends to push the oil upwards, thereby increasing the life and the ultimate recovery of the reservoir (Zhang, Li, Reynolds, & Yao, 2010).

The injection pattern for an individual field is based on the location of existing wells, reservoir size and shape, cost of new wells and the recovery increase associated with various injection patterns. Common injection patterns are direct line drive, staggered line drive, two-spot, three-spot, peripheral, five-spot, seven-spot and nine-spot (Mezzomo, 2002).

Oil companies will want to maximize the value of a field by getting as much of the hydrocarbons from the reservoir as possible. However, the cost of drilling a well in the North Sea is very high so the engineers have a big tusk of optimizing injector wells so as to improve ultimate oil recovery. This is what this project will be mainly based on.

2.0 Abbreviations and Acronyms

CAPEX…………………...Capital Expenditure
FOE ………………………..Field Oil Recovery Factor
FOIP………………………Field Oil in Place
FOPR……………………..Field Oil Production
FPR………………………..Field Pressure
FWCT……………………..Field Water-Cut
FWPR……………………Field Water production rate
NPV………………………Net Present Value
OPEX……………………..Operation Expenditure
WBHP……………………Well Bottom-Hole Pressure
WOPR…………………..Well Oil Production Rate

WWCT…………………..Well Water-Cut

3.0 Problem statement

Oil companies will want to maximize the value of a field by getting as much of the hydrocarbons from the reservoir as possible at a minimum cost. This is done by optimizing the injector wells so as to improve ultimate oil recovery. The problem faced during optimization of injector wells is that an appropriate well pattern and the right number of injector wells to be used has to be defined for the specific field.

3.1 Objectives

3.2.1 General

The general objective of the project is to maximize oil recovery in Sparrow oil field using water flooding in an economically viable manner.

3.2.2 Specific objectives

- To determine the optimum number of injector wells to optimize oil production by a particular pattern
- To identify the appropriate water flooding pattern that will maximize oil recovery
- To access the economic viability of water flooding in sparrow oil field

3.3 Expected outcomes

At the end of this project, I should be in a position to suggest the best well pattern and the right number of injector wells to be used in Sparrow oil field.

3.4 Scope of the study

The scope of this project is mainly optimization of injector well to improve ultimate oil recovery in Sparrow oil field North Sea. It involves comparing various well patterns and determining the appropriate numbers of injector wells that can be used during the process of water flooding given the pressure and production rates are kept Constance. ECLIPSE simulator is used to run the codes and display the results.

3.5 Sparrow Field Location

The Sparrow Field was discovered in 1974 in the Southeastern part of the East Shetland Basin in the UK North Sea; about 140 km east of the near most Shetland Island and about 400 km Northeast of Aberdeen. It lies 4 and 10 km south of Strathspey and Brent field, 7 km east of Ninian field, and 10 km north of Dunbar field respectively (Mwinje, 2012). The water depth is about 130 m.

3.6 Sparrow field Sedimentology

The Sparrow Field is divided into three main units: the Lower Brent (Broom, Rannoch and Etive formations), the Middle Brent (Ness formations), and the Upper Brent (Tarbert formations). The last two are the only oil-bearing formations in the Brent East panel.

- ✓ The Lower Brent formation was deposited in a shoreface to coastal barrier environment. The clastic reservoir is made of transgressive sandstone and prograding sandstones. Thus, the petro-physical properties range from low to medium permeability. This unit does not contain any oil in the Brent East reservoir.
- ✓ The Middle Brent formation was deposited in a deltaic to alluvial plain (Ness 1) and lagoon to lower delta plain (Ness 2) environment. Thus, sandstones are inter-bedded with clay and coal. In general, Ness 1 unit has poorer petro-physical characteristics than Ness 2 unit and its oil-bearing leg is much lower especially to the East of the reservoir.
- ✓ The Upper Brent was deposited in a prograding lower shoreface environment. Three different types of sandstone are identified. At the top (Tarbert 3), are massive sands with very good reservoir characteristics. This is the main oil bearing unit in the Brent East reservoir. Below (Tarbert 2), there are mica-rich sandstone with lower permeability. These mica-rich sandstones exhibit a high natural radioactivity. The base of the Tarbert formation (Tarbert 1) is very similar to the top sandstone. Despite its lower average permeability, Tarbert 2 unit is not considered as a permeability barrier.

3.7 Drilling, Production and injection constraints

- ✓ To develop the Brent East reservoir, a 40-slot well platform will be used.
- ✓ The maximum well deviation should not exceed 46° with respect to vertical.
- ✓ Production program should start at the beginning of 2017.
- ✓ The minimum bottom-hole flowing pressure (BHFP) is 260bar.
- ✓ The perforations of the wells are chosen to optimize recovery depending on the well location.
- ✓ Drainage radius for vertical wells is about 400 m.
- ✓ The averaged maintenance down time is 10% for all the wells.
- ✓ Due to surface facilities on platforms, the maximum allowable GOR is 1500 m^3/m^3 and the maximum allowable water cut is 90%.
- ✓ The production plateau should be maintained for 60% of the total oil production.
- ✓ The production profiles should be evaluated over 16 years.
- ✓ The skin is taken as -4 since we are injecting sea water which is very cold into the reservoir and this will result in hydraulic fracturing of the reservoir.
- ✓ The water injection pressure in 480 bars
- ✓ The amount of water available for injection per day is 15000m3/day
- ✓ The rate of each well is at 1800 m3/day

3.8 Coding

This involves coding the data in notepad under the different key words which are used for different functions, they include: GRID Section, defines the geometry of the simulation grid and the various rock properties such as geometry and rock properties. The RUNSPEC Section which contains general information such as title of simulation, phase present, number of grid cells in model, start date of simulation and etc. PROPS Section contains fluid properties such as fluid densities, PVT properties of; dead oil, live oil, dry gas, wet gas and water, rock compressibility and relative permeability tables. SCHEDULE Section, drives the simulator by defining well locations and completions, production and injection rates and pressures and time steps; for calculations and reports. SUMMARY Section contains specifies items to be output to summary files at each time step.

4.0 Methodology

4.1 Reservoir model

Data coded on a note pad and run on an Oil simulator ECLIPSE 100. The simulation model was designed to investigate the optimum injector well pattern for improve oil recovery of Brent East reservoir.

The reservoir model was built for testing six different patterns by four, eight, and twelve injector wells.

The model size is geometrically 36x51x18. There are two equilibration regions defined in the EQUNUM keyword in the Regions section. However, there is no evidence of compartmentalization, all the regions have the same water-oil contact (WOC) and pressure regime.

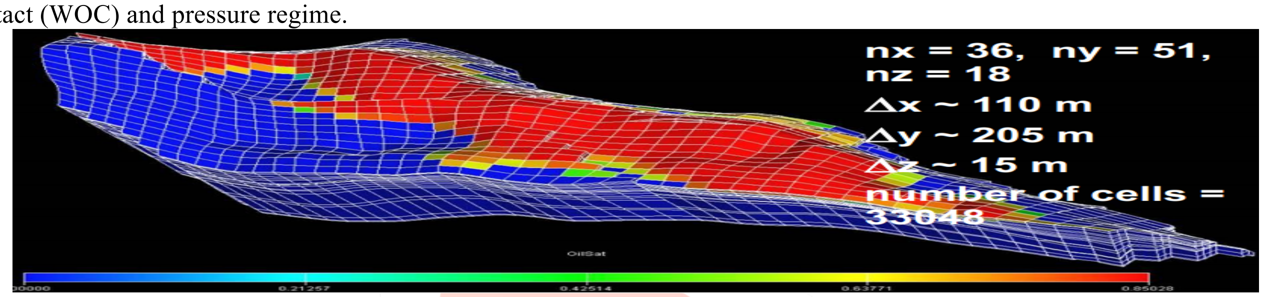

Fig. 1: Shows reservoir model of sparrow oil field

4.2 Optimization of well number

To effectively optimize the number of injector wells to use, the above well patterns were used to determine the appropriate number of wells. This was done by testing each pattern by three different groups of injector wells.

4.2.1 Scenario 1: Comparison of well numbers when using three spots pattern

In this scenario, the three spots pattern was put under investigation by comparing recoveries when four, eight and twelve injector wells were used.

Table 1: Shows all the three cases used in three spots scenario

Cases	**Injector well numbers**
Case 1	4
Case 2	8
Case 3	12

4.2.2 Scenario 2: Comparison of well numbers when using five spots pattern

This scenario involves comparing the recoveries from four, eight and twelve injectors when five spots pattern was used.

Table 2: Shows all the three cases used in five spots scenario

Cases	**Injector well numbers**
Case 1	4
Case 2	8
Case 3	12

4.2.3 Scenario 3: Comparison of well numbers when using peripheral pattern

In this scenario, peripheral system was try out with various number of injector wells. Peripheral involves placing injector wells all around the reservoir. This pattern was investigated using four, eight and twelve injectors.

Table 3: Shows all the three cases used in peripheral pattern

Cases	**Injector well numbers**
Case 1	4
Case 2	8
Case 3	12

2.2.4 Scenario 4: Comparison of well numbers when using direct line drive

Direct line drive which involves placing both the producers and injector wells directly offsetting to each other was investigated using different number of injector wells as illustrated by the table below.

Table 4: Shows all the three cases used in direct line drive

Cases	**Injector well numbers**

Case 1	4
Case 2	8
Case 3	12

4.2.5 Scenario 5: Comparison of well numbers when using staggered line drive

Staggered line drive was investigated with three different number of injector wells as illustrated by the table below.

Table 5: Shows all the three cases used in the last scenario

Cases	Injector well numbers
Case 1	4
Case 2	8
Case 3	12

5.0 RESULTS AND DISCUSIONS

5.1 Well pattern selection

Well pattern selection was done to determine the pattern that produces the field best. To make this possible, the best case for each scenario was selected; their different recoveries were compared to select the best among them, was done as illustrated by the graphs below. However, we can only conclude until economic analysis is made.

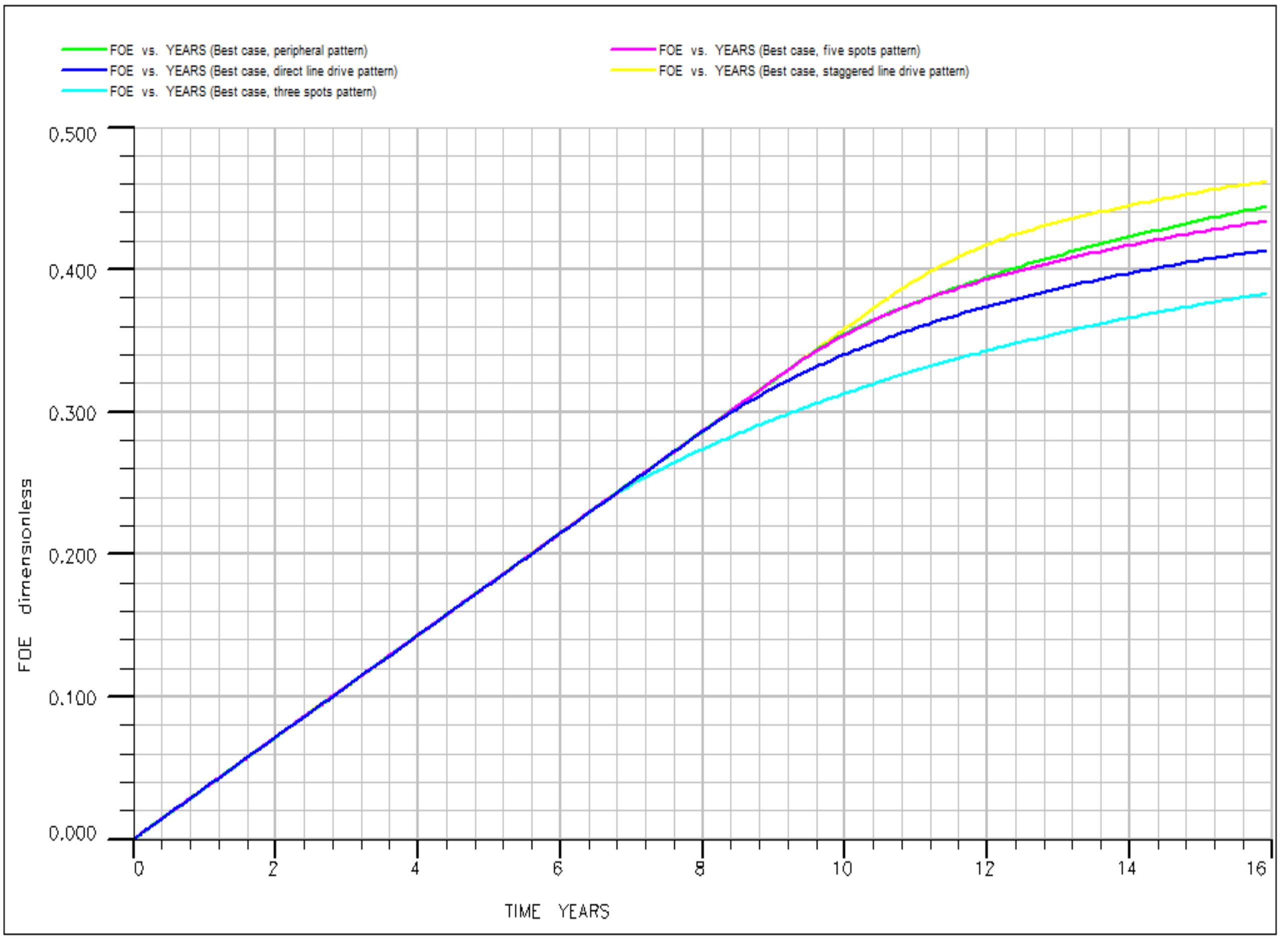

Fig. 2: Graph of field oil recoveries for the best cases all the scenarios

From the above graph, the staggered line drive provided the best recovery of 46.2%. I cannot however conclude that it was the best pattern without putting economic analysis into play.

5.2 Economic analysis

	Three spots pattern	**Peripheral pattern**	**Staggered line dive**	**Direct line drive**	**Five spots pattern**
Total Oil Production (MM bbl)	85.717	99.629	103.688	92.674	97.835
Total Investment (MM $)	1094	1094	1046	1094	1094
Gross Revenues (MM $)	4285.85	4981.45	5184.4	4633.68	4891.75
Gross Profit Margin, GMP	3191.85	3887.45	4138.4	3539.68	3797.75

(MM$)					
GMP per Barrel ($/bbl)	37.24	39.02	39.91	38.2	38.81
Profitability Index	0.554	0.537	0.63	0.47	0.51
Net Present Value, CNPV	606.7	587.41	659.558	513.383	558.955
Internal Rate of Returns IRR	62%	75%	70%	57%	67%
Pay Back Period, PBP	3.8 years	6.2 years	5.9 years	5.2 years	4.2 years

Fig. 3: Summary of economic analysis

6.0 Conclusions

The main objectives for this project were to determine the optimum number of injector wells to optimize oil production by a particular pattern, to identify the appropriate water flooding pattern that will maximize oil recovery, to access the economic viability of water flooding in sparrow oil field and importantly to maximizes oil recovery in Sparrow oil field using water flooding in an economically viable manner.

From the results of the project, it can be seen that the objectives have been achieved. All well patterns used can be best produced using twelve injector wells except for the staggered line drive which best produces when eight injectors are used rather than twelve.

Staggered line drive produced better recovery throughout the project. This was due to the fact that our reservoir is tilting and in staggered line drive the injectors were placed on the lower side of the reservoir has producing better recovery than the rest of the pattern.

In this project, economic analysis of the best cases for each scenario indicates that I attain maximum Goss Profit Margin from all the cases; however staggered line drive has a better profitability index.

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