A Comparision Study of Five-Spot and Nine-Spot Water Injector Patterns to Enhance Oil Recovery of Maesoon Oil Field by Computer Simulation

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ABSTRACT: *This research aims to enhance oil production by water a flooding method of Maesoon oil field which is a sub-oil field of Fang oil field using computer reservoir simulation. The study comprises of five main parts such as (1) well logging and well test data collecting, (2) computer reservoir models simulating, (3) comparison study of enhance oil recovery of five-spot and nine-spot water injector patterns by computer simulation, (4) comparison study of economics potential of five-spot and nine-spot water injector patterns, and (5) result's conclusions and analysis. Result from the computer reservoir simulation tests indicated that the oil recovery could be raised up to approximately 10 to 20 percent with depended on water injection rate and water well distributions. Result from the comparison studies found that the water injector pattern gave more oil production was nine-spot pattern. This pattern could give the maximum recovery factor as 36.98 percent. Result from the economics potential analysis was also indicated that the nine-spot water injector pattern could give the maximum internal rate of return and profit to investment ratio as well.*

KEYWORDS *-Maesoon oil field, water flooding, Enhance oil recovery, Computer reservoir simulation*

I. INTRODUCTION

The primary objective of this research is to improve oil recovery by reducing the residual oil in the Maesoon oil field which is a sub-oil field of Fang oil field North of Thailand. The method is used in this study is the waterflooding technique which is the one of the enhanced oil recovery techniques. In a suitable reservoir condition and proper flooding design waterflooding can help to increase 20 to 30 percent of primary production. This research is to study waterflooding plans which are the most suitable between five-spot and nine-spot patterns in Maesoon oilfield. The research effort running reservoir simulation by using "ECLIPSE" software to design the flooding pattern. Since typical waterflooding project involves both technical and economic considerations. Then the production efficiency and reserve for both primary recovery and waterflooding were computed and the results were compared. Furthermore, the economic consideration regarding on flooding pattern. Therefore, the results of this research may be supporting information for develop and/or improve oil recovery in Thailand.

II. HEADINGS

Materials

This study use the existing and published data provided by Northern Petroleum Development Center, Defense Energy Department, Thailand. Data are collected from Maesoon oil field which is a sub-oil field of Fang oil field, Chiang-Mai, Thailand. The data required for the simulation includes reservoir data, rock and fluid properties and well data shown in Table 1 (Chatetha, 2004).

Maesoon oil field

Maesoon oil field that is a part of the Fang basin which is located in Fang district of Chiang Mai province, Thailand.Covering an area of approximately 5 square kilometers in Maesoon sub district, Fang district, Chiang Mai province. In 1985, Settakul revised the stratigraphy into five sand units by using the welllogging data (Electric log) of well FA-MS-26-39, namely D, E, F, G and H sand unit starting from the top to bottom. Detailed descriptions of each unit are discussed as follows (Settakul et al., 1985). The main reservoir interval ofMaesoon oil field is H sand unit or AngKhang sand. This sand unit is the most important in production zone. This research is applied from H sand unit only.

Reservoir Simulation Model

The reservoir model is hypothetical model which based on available data of H sand unit of Maesoon oil field. The reservoir model is a three-phase model that has a 3 dimentional model with domal structure, no faults and simple geometry, This model cover an area about 400 acres, contains 6 layer, 3,750 cells(25x25x6 Grid

Blocks). The oil inplace is about 27 MMSTB was developed by utilizing "Eclipse office" software (E100). Shown in figure 1.

III. Methods

Reservoir simulation

Reservoir simulation is a technique in which a computer-based mathematical representation of the reservoir is constructed and then use to predict its dynamic behavior. Simulation is the only way to describe quantitatively the flow of multi-phases in a heterogeneous reservoir having a production schedule determined not only by the properties of the reservoir, but also by market demand, investment strategy, and government regulations. The reservoir is a gridded up into a number of grid blocks. The reservoir rock properties (porosity, saturation and permeability) and the fluid properties (viscosity and PVT data) are applied for each grid block. This research used black-oil reservoir simulation by Eclipse Office E100 to simulate water flooding which based on available data of Maesoon oil field and some of data assumptions. Comparisons study of five-spotpattern (4 production wells and 9 injection wells) and nine-spot pattern (6 production wells and 19 injection wells) of water injector, the result of production with primary production (natural flow) and the secondary production (water injection) .Water inject at the 4^{th} year of the production time 20 years.Constant production rate at 400bbl/day and the constant injection rate at400bbl/day. Case study shown in Table 2.

IV. RESULTS AND DISCUSSION

Reservoir simulation results

The recovery factor of primary production in this reservoir model is low. The effects of water flooding method are increased reservoir pressure and oil recovery. The result showscase of 5-spot and 9-spot flood patterns that have high performance oil recovery efficiency when compared with natural flow flooding. Natural flow (no water) can produce 21.24% of oil in place.The oil recovery of 5-spot and 9-spot flood patterns increased to 31.5% and 36.98%, respectively. Summary of reservoir simulation results are shown in Figure 2and Table 3.

Economic evaluation

Economic evaluation is the final step in this research, objective is to determine economic parameters that used to analyze project investment possibility including on the profit after income tax, internal rate of return (IRR) and profit to investment ratio (PIR). Compare with all cases study to find the best case for the Maesoon oil field. Economic evaluation of this research is based on a constant oil price rate through the project life time (100$/BBL), the 10% discounted rate. Lists of the economic evaluation parameters used in this research shown in Table 4.

The best operation case for this research is used 9-spot flood pattern. That hasthe profit after income tax is 3,983,766,732 THB,IRR after tax and 10% discounted is 114.44% and PIR is 3.0644. The economic results summary of all case studies are shown in Table 5 and the summary of IRR results and PIR results shown in Figure 3.

V. FIGURES AND TABLES

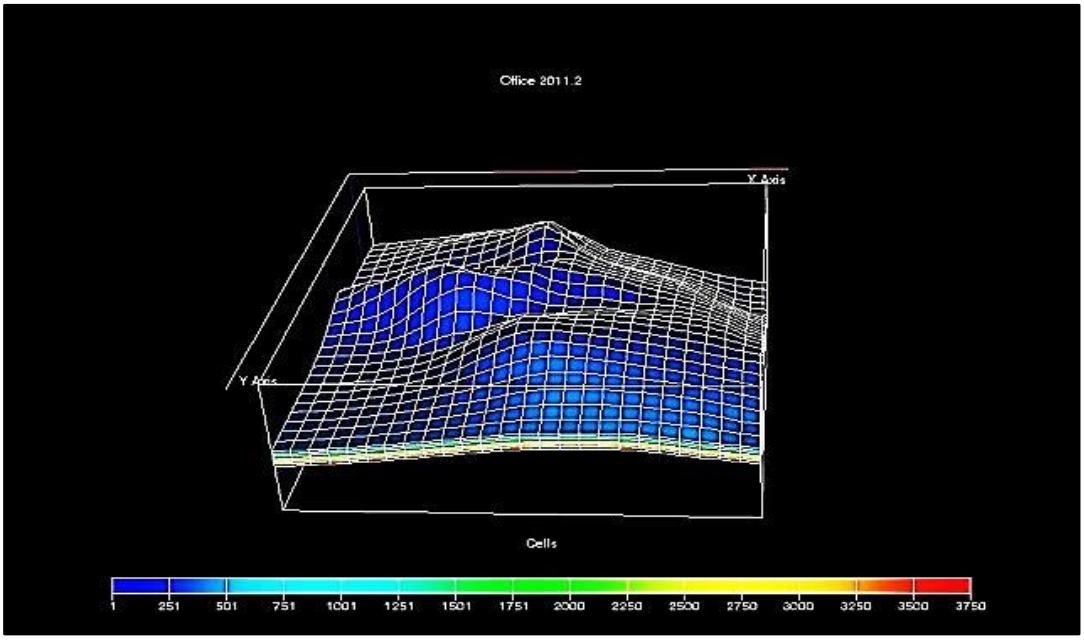

Figure 1. Reservoir structure model

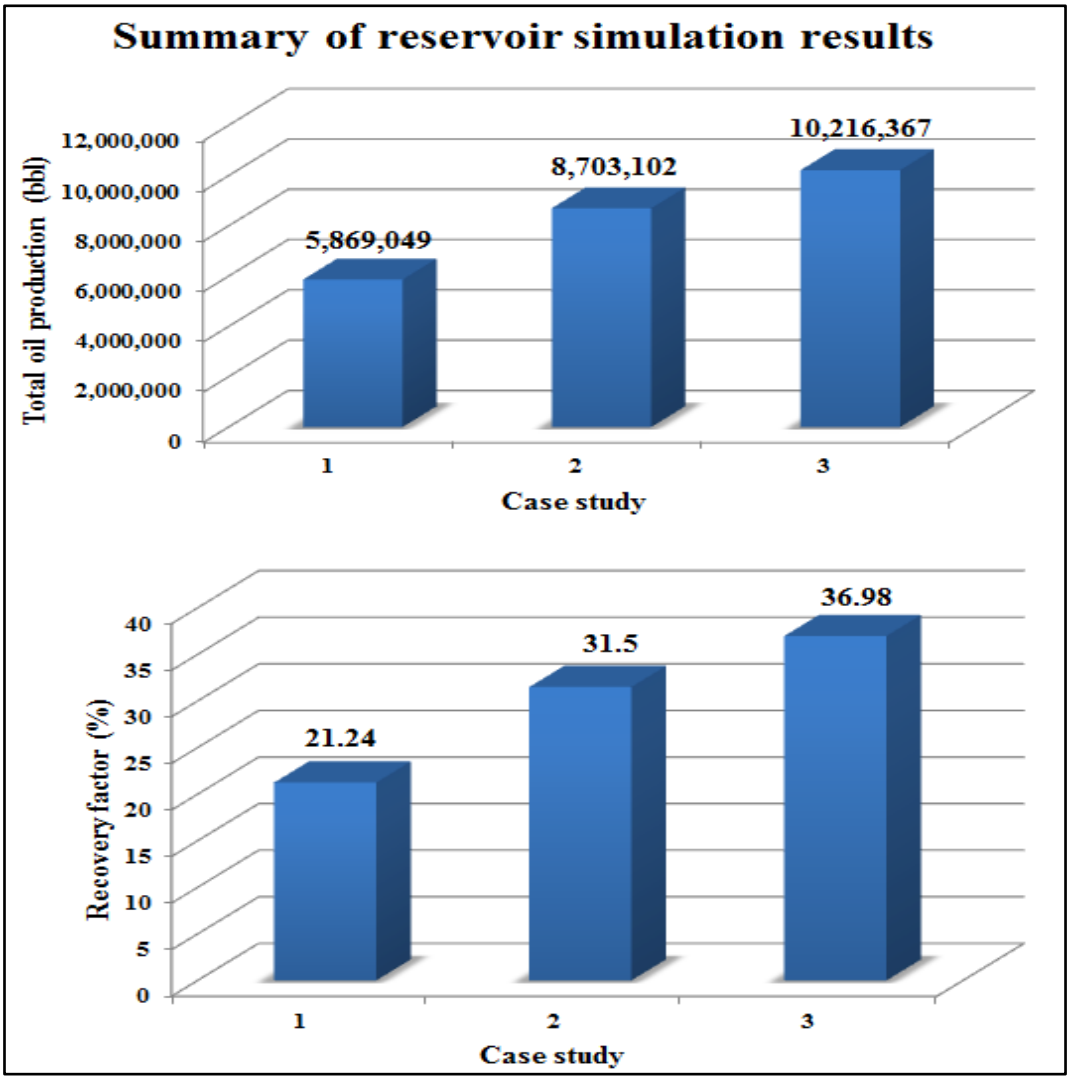

Figure 2. Summary of reservoir simulation results

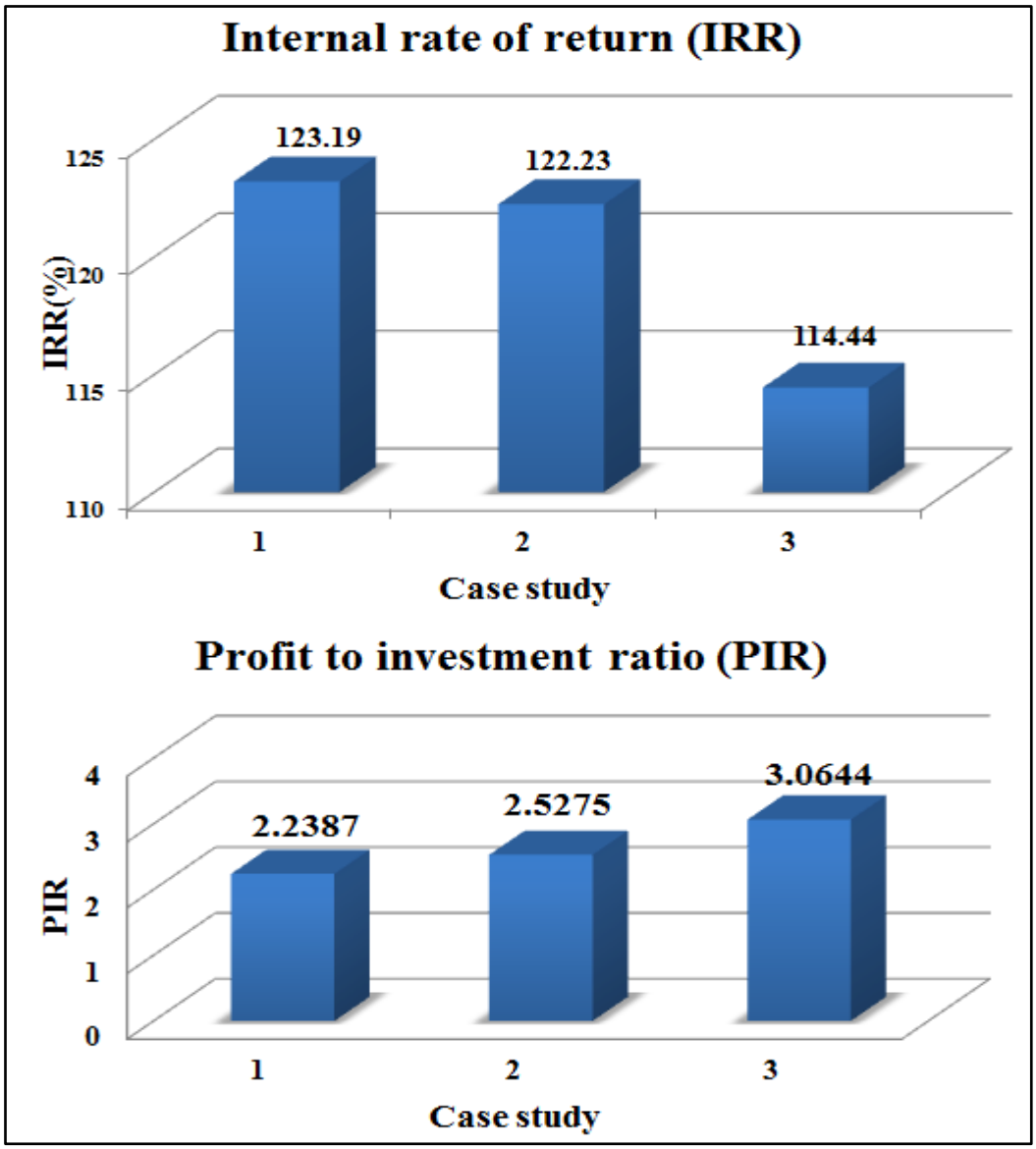

Figure 3. Summary of economics evaluation results

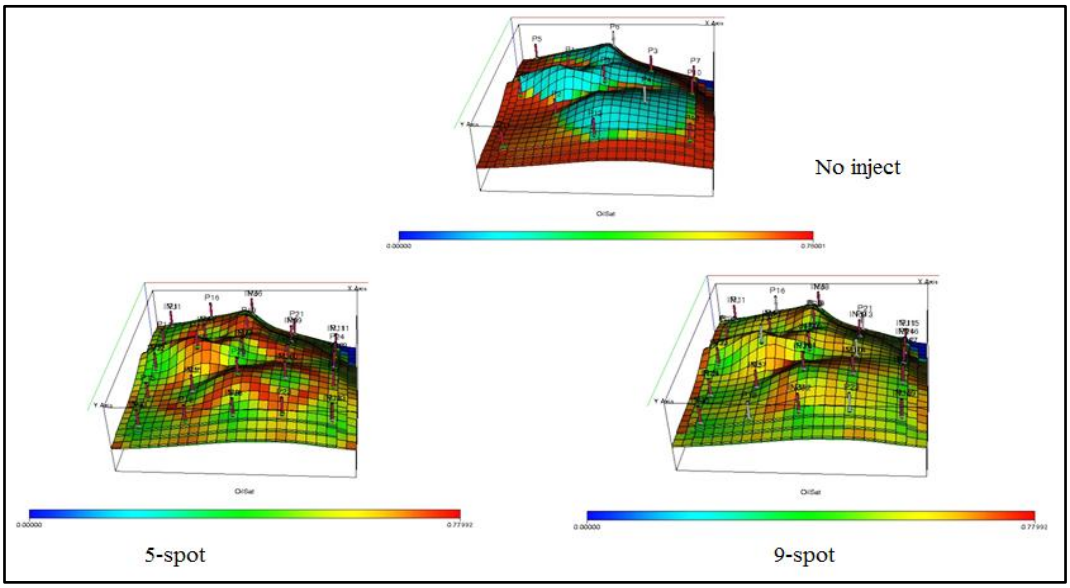

Figure 4. Oil saturation after 20 years production of all case studies

Table 1. Reservoir and fluid properties

Parameter	Properties
Reservoir rock properties:	
Rock type	Unconsolidated Sandstone
Porosity	19 - 29 %
Permeability	100 - 227 md
Average k_v/ k_h	0.1
Reservoir Fluid properties:	
Oil gravity	35.1°API
Gas gravity	0.881
Bubble point pressure	150 psi
Initial reservoir pressure	900 psi
Reservoir temperature	170°F
Water-oil contact depth	2,700 ft
Datum depth	2,600 ft
Density of water	62.428lb/ft^3
Water compressibility @900 psi	2.654x 10^6/psi
Viscosity of water	0.366 cp
Viscosity of oil	2.3-8.2 cp
Viscosity of gas	0.0128-0.018 cp
Salinity	0.00016 fraction
Surface condition:	
Standard temperature	60°F
Standard pressure	14.7 psi

Table 2. Case study

Case	Flood pattern	Number of oil product well before/after water inject well	Number of water inject well	Year to inject	Product rate (bbl)	Inject rate (bbl)
1	No inject	13/13	0	No	400	0
2	5-spot	13/4	9	4th	400	400
3	9-spot	25/6	19	4th	400	400

Table 3. Summary of reservoir simulation results

Case	Flood pattern	Total Oil Production (bbl)	Recovery factor RF (%)
1	No inject	5,869,049	21.24
2	5-spot	8,703,102	31.50
3	9-spot	10,216,367	36.98

Table 4. Economic evaluation parameters

Expenditure Cost Detail	All Case Study
Oil price (US$/bbl)	100
Income tax (%)	50
Inflation rate (%)	5
Discount rate (%)	10
Exchange Rate (THB/US$)	30
Sliding scale royalty (%)	
Production level (bbl/day)	
0-2,000	5
2,000-5,000	6.25
5,000-10,000	10
10,000-20,000	12.5
>20,000	15
Drilling and completion production well (MMTHB/well)	10
Drilling and completion injection well (MMTHB/well)	10
Facility costs of water injection well (MMTHB/well)	10
Maintenance costs of water injection well (THB/unit/month)	200,000
Operating costs of production well (THB/bbl)	600
Operating cost of water injection (THB/bbl)	10

*MMTHB = Million Bath

Table 5. Economic results summary of all case studies

Case study	Profit after income tax	Internal rate of return (IRR)	Profit to Investment ratio (PIR)
1	2,910,366,540	123.19%	2.2387
2	3,285,729,286	122.23%	2.5275
3	3,983,766,732	114.44%	3.0644

*MMUS$ = Million US Dollar

VI. CONCLUSION

The reservoir simulation results indicated that the water flooding technique can increase oil recovery efficiency by comparing with the natural flow of Maesoon oil field.Result from the computer reservoir simulation tests indicated that the oil recovery could be raised up to approximately 10 to 20 percent with depended on water injection rate and water well distributions. Result from the comparison studies found that the water injector pattern gave more oil production was 9-spot pattern. This pattern could give the maximum recovery factor as 36.98 percent. Result from the economics potential analysis was also indicated that the 9-spot water injector pattern could give the maximum internal rate of return and profit to investment ratio as well. Oil saturation after 20 years production of all case studies shown in Figure 4.

VII. Acknowledgements

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