Oil Production Efficiency Of Marginal Fields In The Phitsanulok Basin By Simulation Model

Nawatnimnual*, Kriangkraitrisarn And Akkhapunwannakomol

Running head:Production Efficiency of Marginal Oil Fields in the Phitsanulok basin by Simulation Model

Abstract: *Reservoir models of marginal oil fields in the Phitsanulok basin had been constructed using the computer software"Eclipse 100".The objective of this research is to determine the oil reserves. Four final well reports and 1well testing report are used for the reservoir simulation.* **Theresultsof***the* **simulation are used** *for* **commercial** *evaluation***. The factors** *of* **internal rate of return, profit investment ratio, and net present value are determined for** *a* **petroleum economic evaluation. The factors** *in the* **sensitivity study are oil inplace and oil price. There are** *3* **siz***es* **of** *simulated reservoir. Resevoir model 1 is base case. Reservior model 2 and 3* **are assumed for** *the* **sensitivity study** *(Reservoir model 2 and 3 are bigger size of the base case***50 and 100** *%, respectively). R***eservoir model 3** *is the* **upper portion between** *the* **marginal and middle oil field.** *R***eservoir** *model 1* **has oil inplace of 451,626 barrels.** *M***odel***s* **2 and 3 ha** *ve* **oil inplace of 677,596 and 903,133 barrels***,* **respectively. From** *the* **simulation** *results***, model 1 has** *a* **reserve of 83,387 barrels (percent recovery of 18.46) giving** *an* **internal rate of return (IRR) of 0.55** *%* **(after 10***%* **discounted)***; m***odel 2 has** *a* **reserve of 128,157 barrels (percent recovery of 18.91) giving** *an* **IRR of 14.32***%* **and model 3 has** *a* **reserve of 172,375 barrels (percent recovery of 19.08) giving** *an* **IRRof 20.71***%.*

Keywords: *Marginal petroleum field, Phitsanulok basin, reservoir simulation, economic evaluation*

I. Introduction

Petroleum energy is so essential to human lives and represents a significant part of the cost of production for the agricultural, industrial, and transport sectors; it is vital to the economy of the nation. Thailand has a problem with increasing of oil prices and spends a large amount of money for oil importing. To decrease oil imports, Thailand should provide petroleum which is produced in the country. A marginal petroleum field is a field which economics do not meet acceptable rates of return (Yuvanasiri, 2005). It cannot generate profit under the condition of oil price or/and other factors.Thailand has a problem with increasing of oil prices and spends a large amount of money for oil importing. To decrease oil imports, Thailand should provide petroleum which is produced in the country. The Phitsanulok basin (1,482,600 acres in the central plain) is the Thailand onshore basin (Narin, 2009). A magnetic and seismic survey was conducted in 1979. Pratu Tao A-01 was the first exploration well spudded in 1981. The reservoir rock is consolidated sandstone. The Phitsanulok basin is an interesting area because it has not only a large petroleum reservoir such as the Sirikit oil field but many marginal oil reservoirs have been discovered and cannot be developed into production fields. The objective of this research is to determine the oil reserves of the reservoirs from simulation. The results of production testing are used for commercial evaluation. For a petroleum economic evaluation, oil in place and oil price are the factors in a sensitivity study.

II. Materials and Methods

Materials

1) Geology of the study area The Phitsanulok Basin is developed as an asymmetric half - graben, due to East-West extension along the Western Boundary Fault System, with associated sinistral strike-slip movement on Uttradit and Ping Fault Systems to the north and southwest respectively.The lithostratigraphic units were deposited in five main environments within a fluvio-lacustrine depositional system (Sattayarak, 1992). The geological complexity is a product of the multi-phased structural history and the interaction between faulting and deposition through time.The most volumetrically significant source rocks are lacustrine claystones of the Chum Saeng Formation.The fluvio-lacustrine Tertiary fill of the Phitsanulok Basin offers numerous opportunities to develop potential reservoir rock and seal. The main reservoir formations are LanKrabu (LKU) and Pratu Tao (PTO) formations.

2) Data input for reservoir simulationThe task of reservoir simulation is to prepare the input data for simulation. Four final well reports and 1well testing report in the area are used for the reservoir simulation. The parameters thatare used for reservoir simulation are divided into 3 groups.(1)Fluid data are obtained from well head fluid sample analysis. (2) Rock data and (3) reservoir properties data are obtained from field studies and core analysis.The data of porosity and permeability are assumed homogenously on each layer. The model input parameter description follows the main input section data of the simulator, grid section, PVT section, initialization section and schedule section, respectively. The data are shown in Tables 1 to 3

3) Petroleum economic evaluation dataThe economic assumption is that the oil price is constant over the production period. The increasing rate of capital expenditure comes from the increasing price of machinery and equipment used in the oil industry, and is given at 5% per year. The operating cost is escalated at 5% each year. The production region is under the fiscal regime of Thailand III (Coordinating Committee for Geoscience Programs in East and Southeast Asia, 2009).The conditions of Thailand III can be summarized as follows:

- Income tax 50%
- Royalty 5-15% (under sliding scale)
- Special remuneratory benefit (SRB) 0-75% (depending on revenue of a year per one meter of well depth)

The royalty sliding scale is shown in Table 4 and assumptions of economic evaluation are given in Table 5.

III. Methods

1) Reservoir simulationReservoir modeling exists within the context of the reservoir management function (Fanci, 2001). The reservoir simulation model is a mathematical model to describe the physical behaviors of the process (Crichlow, 1977). Reservoir simulation is the way to describe quantitatively the flow of multiple phases in a heterogeneous reservoir having a production schedule determined not only by the properties of the reservoir. Basically, the model requires that the field under study be described by a grid system, usually referred to as cells or grid blocks. Each cell must be assigned reservoir properties to describe the reservoir properties.This study used the Eclipse 100 simulator with a total of 5,000 grid blocks ofsimulated primary production scenarios. Some data are the confidential documents. To avoid the effect of well position so the models are square monocline reservoirs. The models are divided into 8 layers (7 sands and 1 shale). The shale is non-reservoirlayer. The thickness total 8 layer is44.5 ft. The radius of the reservoir is 600 ft.(from the production testing report).The initial structural surface data is prepared by Suffer

Version 7.0 and the results of the reservoir structure from the reservoir simulation are shown in Figure 1.

2) Petroleum economic evaluationThe objective of this section is to determine the economic parameters that are used to analyze the project investment possibility including the internal rate of return (IRR), profit investment ratio (PIR), and the net present value (NPV).The petroleum economic evaluations are calculated using Microsoft Excel's spreadsheet. Oil in place and oil price are the factors of the sensitivity study which are varied to generate the trend as mentioned. The price of oil is assumed to 60, 70, 80, 90 and 100 US dollar/barrel.

IV. Results and Discussions

In terms of reserve determination, the reservoir model 1 (oil in place of 451,626 barrels) has a reserve of 83,387 barrelsor a recovery percent of 18.46. The reservoir model 2 (oil in place of 677,596 barrels) has a reserve of 128,157 barrels or a recovery percent of 18.91. The reservoir model 3 (oil in place of 903,133 barrels) has a reserve of 172,375 barrels or a recovery percent of 19.08.From the production models, the initial oil production rate is 200 STB/d (maximum rate for production unit). The commercial minimum oil production rate is correlated from the other marginal onshore Thailand fields at about 20 STB/d. The initial production rate of reservoir model 1 is maintained for 26 days. After that, the oil production rate rapidly declines to 21.33 STB/d at the end of the 5th year (end of production). The initial production of reservoir models 2 and 3 is maintained at 200 STB/d for 40 and 66 days, and the production rate rapidly declines to 20.48 and 21.11 STB/d at the end of the 8th and 10th years, respectively. The specific data of the model from the reservoir simulation are shown in Table 6 and the oil production rates of reservoir models 1 to 3 are shown in Figures 2 to 4.

In terms of petroleum economic evaluation, the reservoir model 1 gives IRR (after 10% discounted) of 0.55%, PIR of 0.0066, and NPV of 0.79 million baht. The reservoir model 2 gives IRR of 14.32%, PIR of 0.2480, and NPV of 29.76 million baht. The reservoir model 3 gives the IRR of 20.17%, PIR of 0.4348, and NPV of 52.17 million baht. The payout time of the reservoir models are 5, 4, and 3 years, respectively. The results are shown in Table 7. The factor of IRR, PIR and NPV will increase with oil in place and oil price. The results of the sensitivity study of oil in place and oil price give the trends of the economics that are affected from the factors shown in Figures 5 and 6.

V. Conclusions and Recommendations

Reservoir simulation is the way to describe quantitatively the flow of multiple phases in a heterogeneous reservoir having a production schedule.

Commercially at the oil price of 80 US dollar/bbl, the minimum reserves of a marginal oil field in the Phitsanulok basin should not be as in reservoir model. For the bigger reservoir can give more the reserve and net profit. The oil production rate rapidly declines after the start of the production at 200 bbl per day for 26 - 66 days. An increase of oil price conducts a marginal field development.

The data of this reservoir simulation are limited. The values of the porosity and permeability in the same layer are assumed to be homogeneous. The accuracy of the reservoir simulation depends on the data. The models are the simple structural model. More complex structure of the models will improve accuracy and decrease uncertainly of simulation. For the future, historical matching can reduce the errors. The research is useful in the prediction of the future of the petroleum business of marginal oil fields in the Phitsanulok basin.

VI. Acknowledgement

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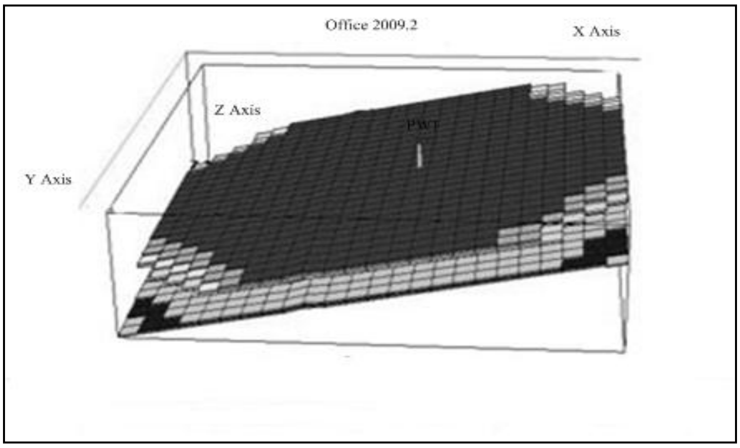

Figure 1. Oblique view of structural model

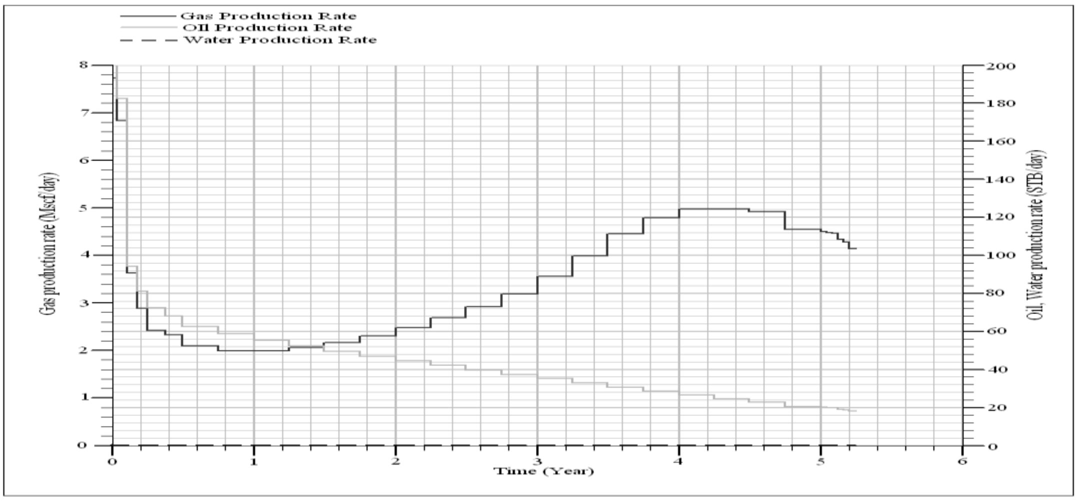

Figure 2. Gas, Oil, and Water production rate of reservoir model 1

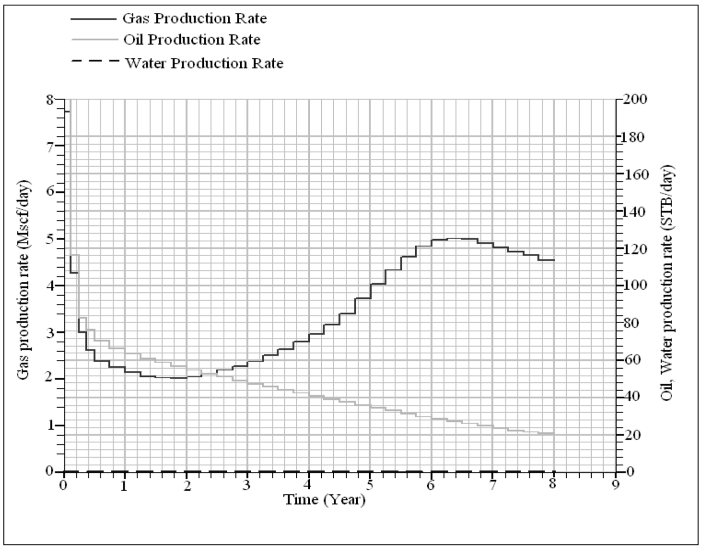

Figure 3. Gas, Oil, and Water production rate of reservoir model 2

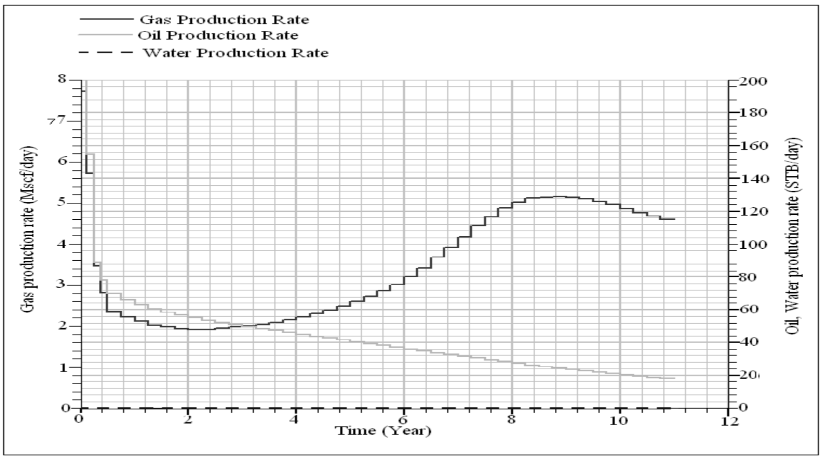

Figure 4. Gas, Oil, and Water production rate of reservoir model 3

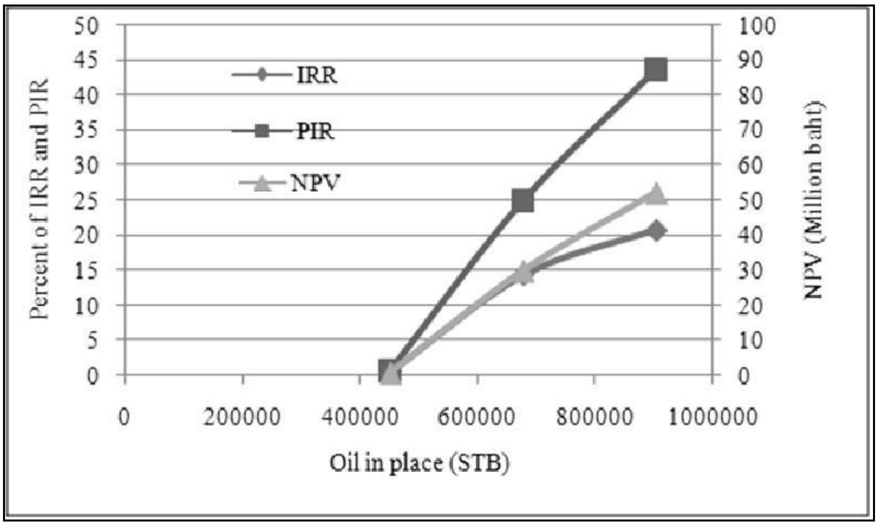

Figure 5. IRR, PIR and NPV from oil in place sensitivity

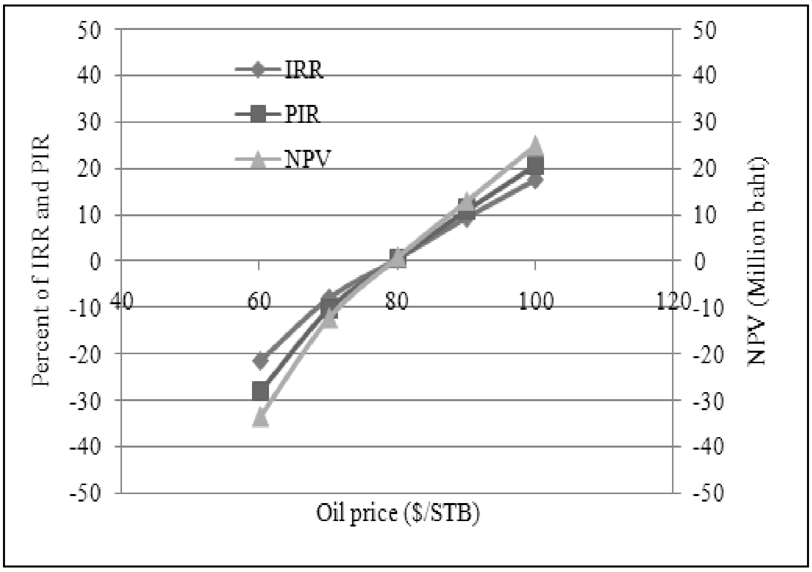

Figure 6. IRR, PIR and NPV from oil price sensitivity

Table 1. Fluid properties data

Property	Unit	Value
Oil viscositiy	cp	27.5
Water viscosity	cp	0.2964
Oil density	API	29.4 - 32.0
Water density	lb/cuft	62.4279
Gas gravity	fraction	0.712
Water compressibility	/psi	3.80E-06
Oil compressibility	/psi	5.77E-06
Oil formation volume factor	rb/STB	1.0461 - 1.0516
Water formation volume factor	rb/STB	1.02203
Solution gas - oil ratio	MSCF/STB	0.0009658 - 0.0386144
Oil Corey exponent	-	2
Water Corey exponent	-	2.8
Gas Corey exponent	-	2.8

Table 2. Rock properties data (Porosity and permeability)

Layer	Formation	Thickness (ft)	Porosity (ø), %	Permeability (k), md
1	Sand	4.80	18.5	131.51
2	Sand	4.80	18.2	106.8
3	Sand	4.80	18	85.45
4	Sand	4.80	17.8	68.36
5	Shale	8.35	-	-
6	Sand	5.65	17.1	43.75
7	Sand	5.65	16.8	35
8	Sand	5.65	16.5	28

Table 3. Reservoir properties data

Property	unit	Value
Initial pressure	psi	1,645
Oil-water contact	ft	3,715
Bubble point pressure	psi	314
Formation temperature	˚c	60.56
Reservoir thickness	ft	21.5
Well radius	ft	0.354
skin factor	Dimensionless	0
water salinity	ppm	50,000
Residual oil saturation	fraction	0.25
Connate water saturation	fraction	0.35
Residual gas saturation	fraction	0.07
end point of water relative permeability	fraction	0.35
end point of oil relative permeability	fraction	0.90
end point of gas relative permeability	fraction	0.93

Table 4.Royalty sliding scale

Production level (STB/d)	Rate (%)
0 - 2,000	5.00
2,000 - 5,000	6.25
5,000 - 10,000	10.00
10,000 - 20,000	12.50
> 20,000	15.00

Table 5. Assumption parameters of petroleum economic evaluation

List	Unit	Value
Concessioncost	baht	10,000,000
Geological and Geophysical exploration cost	baht	10,000,000
Drillingcost	baht	50,000,000
Wellcompletioncost	baht	50,000,000
Oilproductioncost	baht/barrel	800
Tangiblecost	%	20
Intangiblecost	%	80
OilPrice	USdollar/barrel	80
Exchangerate	baht/USdollar	32
Escalationfactor	%	5
Discountfactor	%	10

Table 6. Specific data of model from reservoir simulation

Property	Unit	Reservoir model 1	Reservoir model 2	Reservoir model 3
Oil in Place	bbl	451,626	677,596	903,133
Reserve	bbl	83,387	128,157	172,375
recovery	%	18.46	18.91	19.08
Oil production rate	STB/d	200	200	200
Production life time	year	5	8	10
Number of well	well	1	1	1
Number of cell	cell	5,000	5,000	5,000
$i \times j \times k$	cell	25 × 25 × 8	25 × 25 × 8	25 × 25 × 8
Total area	acre	33	41	48

Table 7.Results of petroleum economic evaluation

Reservoirmodel	Royalty (Millionbaht)	Income TAX (million baht)	IRR (%)	Net profit (Million baht)	PIR (Fraction)
1	12.03	16.68	0.55	0.79	0.0066
2	19.58	29.76	14.32	29.76	0.2480
3	26.36	52.17	20.71	52.17	0.4348