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Uncertainty in Oil Reservoir Properties Deterministic and Stochastic Methods of Reserves Estimation

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Abstract: ***Risk and uncertainty in the industry of oil and gas are very important issues that have major impact in oil industry. This due to the fact that the value of risk and uncertainty in projects with portfolio worth of several million dollars, have also value of worth millions of dollars. During the process of project approval and development in oil industry, risk and uncertainty have been taken in serious consideration by the engineers and they have achieved considerable success. Uncertainty in oil industry has its impact in resource and reserves estimation, because the information we need to use, reservoir data properties, production data, geophysic data etc, have always in some degree some uncertainty. While risk and uncertainty in oil resource estimation are never eliminated, what is very important to us is their evaluation.***

Keywords: uncertainty, oil, methods, stochastic.

1. Introduction

The two established volumetric methods for Oil Reserves are deterministic and Stochastic, (Dermimen, 2005). In case of deterministic method, mathematical formulas are used to estimate oil volumes in a reservoir; each parameter is presented with a single value. An improved deterministic value is scenario approach, where we can produce three values for each parameter, low, best and high value. The stochastic method considers the fact that each parameter can't be presented with a single value, but it should be included in an interval and it fits a best probability distribution. The results from stochastic estimation will be summarized by a CDF (cumulative probability function) of Reserves, commonly known as expectation curve (WADSLEY, 2011). We will use both methods, deterministic and stochastic in estimating reserves in the case of Driza oilfield.

1.1 Oil Original in Place, (OOIP): Methods of Recovery:

Oil recovery methods can be divided into three main groups of interest:

Primary Methods, Secondary methods, Tertiary methods.

During the primary process of recovery, the oil is forced out of the petroleum reservoir in the surface by existing natural pressure of the fluid trapped in the reservoir. Energy of primary recovery can be solution-gas drive, gas-cap expansion, gravity drainage, water drive or processes or their combination.

With time and continuing oil recovery, declining reservoir pressure will make more difficult to get the hydrocarbons to the surface. In these cases it becomes necessary to increase pressure on the artificial reservoir to increase oil production. Primary method, as a method of natural producing of oil is at end. By primary method, only 5-10% of the original oil in place can be recovered from the reservoir.

Secondary method will be implemented by injecting water or gas in the reservoir to increase reservoir pressure to force the remaining oil to the surface.

Tertiary (third) recovery will be implemented with the help of thermal or not procceses, using chemical liquids etc. Oil production methods of the second and third will reach approximately 20- 50% of the amount of oil in place (Speight, JG 2009).

2. Uncertainty in Reservoir Data

Uncertainty comes from various sources of measurement error, errors of mathematical models, incomplete data, errors in measurement, bias, deviations of data, missing data, etc.

All measurements in the field or in the laboratory have a degree of inaccuracy in their values, which may be a consequence objective measurement errors or human means. This type of error can be reduced to some extent by using more accurate instruments or adult human efforts, but it will never be eliminated. However, what really matters, in terms of errors occurring is the assessment of uncertainty and reducing errors.

Speaking statistically, we will always have some samples (campions) from the oilfield data (well logs, water analyses, gjeophysics, etc) and we will have to produce some conclusions about all the oilfield. In geological terms, from collected partial geological, engineering data we have to draw conclusions for all the oilfield.

In the past 10-15 years, stochastic model of reserves estimation and Monte Carlo simulation have been widely accepted and have been very useful in oil industry. This method takes into account the uncertainty of the values of each parameter and finally, the reserves.Therefore, the stochastic approach is more convenient for reserves evaluation.

Stochastic methods will produce a probability distribution function for each parameter and at the end, a probability distribution function for reserves. According to the central limit theorem the sum of probability distributions, regardless of their type will produce a normal distribution and the product of probability distributions, regardless of their type will provide lognormal distribution. The Reserves will suit best lognormal distribution.

3. Resources and Reserves

Classifications of Reserves: (SPE 2011)

Reserves are quantities of oil petroleum which are anticipated to be commercially recovered from known accumulations from a given date forward under defined conditions. Reserves are subdivided into Proved, Probable and Possible categories.

Proven Reserves are those reserves claimed to have a reasonable certainty (normally at least 90% confidence) of being recoverable under present economic and political conditions, with the present technology and state regulations. It is known by specialists as P90 or 1P.

Probable Reserves are those reserves claimed to have a reasonable certainty (normally at least 50% confidence) of being recoverable under existing economic and political conditions, with the present technology and state regulations. It is known by specialists as P50 or 2P.

Possible Reserves are those reserves claimed to have a reasonable certainty (normally at least 10% confidence) of being recoverable under existing economic and political conditions, with present technology and state regulations. It is known by specialists as P10 or 3P.

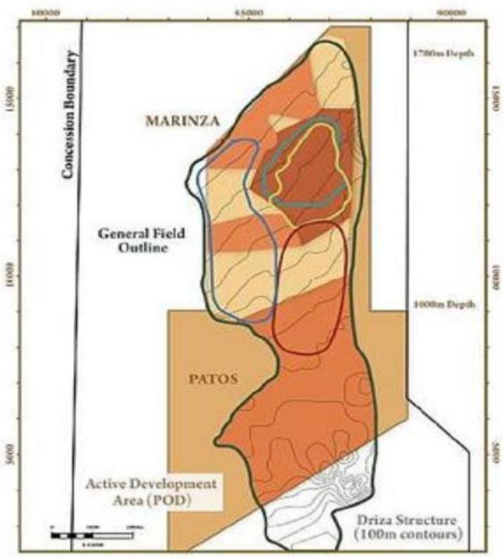
3.1 Reservoir Characterisation

There are numerous parameters to use in order to estimate oil reserves, the most important parameters, those used in volumetric formula are:

- Vertical thickness or layer thickness. Usually reservoir rock is divided in layers, each of them is characterised geometrical such as area, net pay thickness and other geological parameters.
- Oilfield area, is the surface of layer or sum of reservoir layers areas.
- Pore volume is the discrete void within a rock reservoir, which can contain air, water, hydrocarbons. The pore volume can be effective when they are connected or ineffective when they are isolated and oil or water can't go through them.
- Porosity is the percentage of pore volume or void space within rock that can contain fluids. Total porosity is the total void space in the rock whether or not it contributes to fluid flow. Effective porosity is the interconnected pore volume in a rock that contributes to fluid flow in a reservoir. It excludes isolated pores. Thus, effective porosity is typically less than total porosity.
- Oil saturation is the fraction of rock pore volume occupied by oil. Water Oil saturation is the fraction of rock pore volume occupied by water, $S_w = 1 - S_o$.
- Oil density is the mass per unit of volume. Density is typically reported in g/cm^3 (of reservoir rocks) in the oil field.
- Formation Volume Factor is oil and dissolved gas volume at reservoir conditions divided by oil volume at standard conditions. Oil formation volume factors are almost always greater than 1.0 because the oil in the formation usually contains dissolved gas that comes out of solution in the wellbore with dropping pressure.
- Permeability indicates the ability for oil and gas to flow through rocks. High permeability means that fluids move rapidly through rocks. Permeability is affected by the pressure in a rock. The unit of measure is called the darcy, named after Henry Darcy (1803-1858).

Driza Oilfield

The Data Driza oilfield, in Albania, was discovered in 1939 and started the production in 1940. It is one of the biggest onshore oilfield of Albania. It is situated near the village Driza, south of city of Fier. Driza is part of the large oilfield of Marinza, the largest onshore oilfield in Europe, together with Gorani. Driza reservoir contains the majority of the OOIP and Reserves, Figure 1.



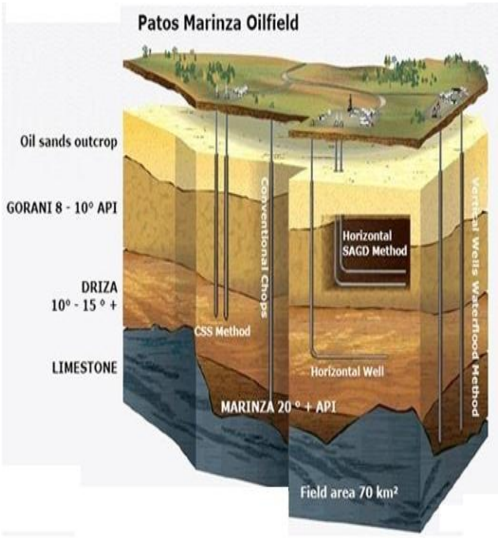


Figure 1: Patos- Marinza oilfield and Driza. (http://www.bankerspetroleum.com/albania)

Table 1: Driza Oilfield. Partial data.

wells	area m2	thickness m	porosity	oil sat	density	b
Dr1	2865555	24.5	0.12	0.29	0.89	1.2
Dr2	3254106	44	0.11	0.4	0.91	1.2
Dr3	2969857	29	0.15	0.3	0.93	1.2
Dr4	2655546	48	0.13	0.28	0.85	1.2
Dr5	2184568	55	0.1	0.25	0.85	1.2
Dr6	1863332	62	0.12	0.42	0.9	1.2
Dr7	2858734	24	0.11	0.29	0.83	1.2
Dr8	3254136	44	0.08	0.4	0.81	1.2
Dr9	2969857	29	0.11	0.3	0.83	1.2
Dr10	2655546	26	0.06	0.35	0.8	1.2
Dr11	2865555	24	0.13	0.29	0.8	1.2
Dr12	3154136	44	0.08	0.4	0.93	1.2
Dr13	3254841	29	0.13	0.3	0.91	1.2
Dr14	2655546	48	0.08	0.35	0.91	1.2
Dr15	2184568	55	0.14	0.25	0.79	1.2
Dr16	1863332	62	0.15	0.27	0.88	1.2
Dr17	2865555	24	0.15	0.29	0.83	1.2
Dr18	3254136	44	0.13	0.4	0.92	1.2
Dr19	2969857	29	0.14	0.3	0.93	1.2
Dr20	2655546	48	0.08	0.35	0.85	1.2
Dr21	2184568	32	0.11	0.25	0.86	1.2
Dr22	1863332	62	0.13	0.42	0.88	1.2
Dr23	2865555	24	0.15	0.29	0.85	1.2
Dr24	3322136	26	0.12	0.4	0.85	1.2
Dr25	3254841	29	0.16	0.38	0.93	1.2
Dr26	2655546	48	0.11	0.35	0.85	1.2
Dr27	2184568	32	0.13	0.25	0.87	1.2
Dr28	1863332	62	0.14	0.42	0.86	1.2
Dr29	2865555	24	0.15	0.29	0.83	1.2
Dr30	2917706	44	0.13	0.4	0.92	1.2
Dr31	2969857	29	0.14	0.3	0.93	1.2
Dr31	2655546	31	0.08	0.35	0.93	1.2
Dr33	2184568	32	0.09	0.25	0.86	1.2
Dr34	2655546	48	0.08	0.35	0.85	1.2
Dr35	2259439	32	0.14	0.25	0.79	1.2
Dr36	1863332	62	0.11	0.42	0.88	1.2
Dr37	2865555	24	0.15	0.29	0.83	1.2
Dr38	3054136	44	0.13	0.4	0.92	1.2
Dr39	2969857	46	0.14	0.3	0.92	1.2
Dr40	2655546	48	0.08	0.35	0.85	1.2
wells	area	thickness	porosity	oil sat	density	1.2

Table 2: Parameters Properties and their PDF's.

Parameters	PDF type	PDF parameters		
		min	best	max
Area	Triangular	1863300	2679400	3322100
Net pay thickness	Triangular	24	40	62
Porosity	Triangular	6%	12%	16%
Oil saturation	Triangular	25%	33%	42%
Density	Triangular	79%	87%	93%
Formation factor	Constant	1.2	1.2	1.2

Volumetric formula for Reserve Estimation is:
$Q = S * h * m * So * Yn * 1 / b$ (1) where:

Q - Oil Reserves (ton)
S - Oilfield area (m^2)
h - Net pay thickness (m)
m - Porosity ratio (%).
So - Oil saturation (%)
Yn - Density of oil ($\frac{kg}{m^3}$)
b - Formation Volume Factor

4. Methods of Reserves Estimation

4.1 Simple deterministic method

The deterministic method (one value) is the simplest; each parameter is represented by only one value which can be the mean or the mode. From the volumetric formula, using simply office 2007, excel, we have the value of Oil Reserves at about 27 million tonnes.

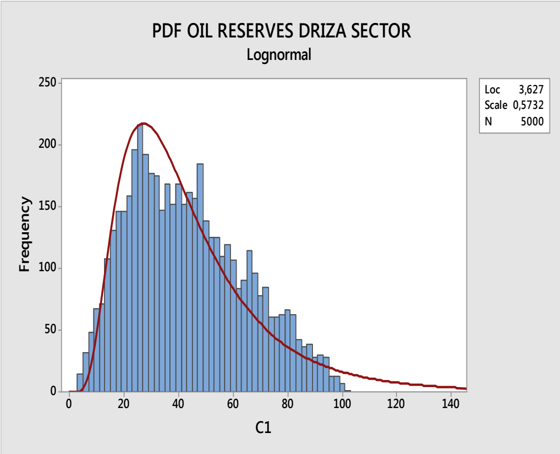
4.2 Deterministic method, scenario approach

This method provides three values for each parameter, "low scenario", "best scenario", "high scenario". The low scenario is the minimum value for each parameter, the best scenario is the average value or the most used value for each parametr and the high scenario is the maksimum value for each parameter. From the excel table, we have these results:

Q "low scenario" = 2 million tonnes.
Q "best scenario"= 26 million tonnes
Q "high scenario"= 103 million tonnes.

4.3 Stochastic method

Anyway, almost all the parameters are assumed to have triangular distribution, except formation volume factor which is a constant in this case. Some parameters may have other distributions fit best, like normal or lognormal distribution. In this case, we have chosen triangular distribution as a simple one. To generate the distribution for the Reserves, we used Minitab software, number of iterations 5000, figure 3.



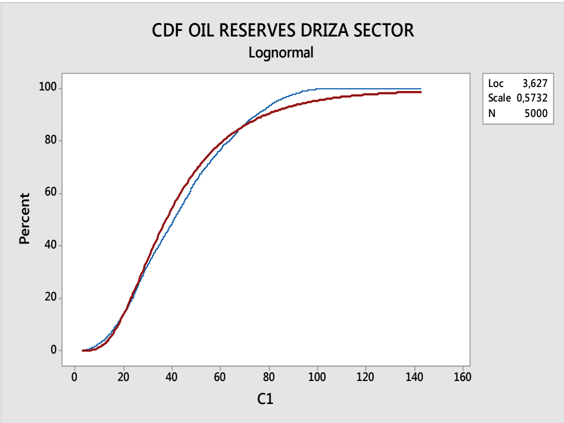


Figure 3: PDF and CDF of Reserves

5. Conclusions

- Simple deterministic method of reserve estimation is very difficult to be accurate, because one value can't represent all the data.
- The scenario method, with three values, is a much better and a more accurate method to express reserve estimation. The more realistic value is "the best" value. Anyway, extreme values are most unrealistic because it is almost impossible to happen at the same time extreme values af all the parameters. The extreme values need some truncation, so it could be more realistic to work with a smaller "high" value and "larger "low value".
- Stochastic method considers all the interval of parameters values, and the probability distribution function for each parameter. Most of the parameters fit triangular distribution, some fit normal distribution or lognormal distribution or uniform distribution. It depends from geologic characteristics, type of data collected, etc.
- We need all the data we can collect to have the most accurate result in reserve estimation. Before using the data, they need cleaning to avoid outliers, extreme values, impossible values etc.
- According to the central limit theorem the sum of probability distributions, regardless of their type will produce a normal distribution. The product of probability distributions, regardless of their type will provide lognormal distribution.
- From the result, we may say that; The oil reserves will be 15 million tonnes, with probability at least 90%, or 1P, or 90%.

The oil reserves will be 40 million tonnes with probability at least 50%, or 2P, or P50%.

The oil reserves will be at least 90 million tonnes, with probability 10%, or 3P, or P90%.

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