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Probabilistic assessment methodology for continuous-type petroleum accumulations

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Abstract

The analytic resource assessment method, called ACCESS (Analytic Cell-based Continuous Energy Spreadsheet System), was developed to calculate estimates of petroleum resources for the geologic assessment model, called FORSPAN, in continuous-type petroleum accumulations. The ACCESS method is based upon mathematical equations derived from probability theory in the form of a computer spreadsheet system.

Keywords: Probabilistic assessment methodology; Continuous-type; Petroleum accumulations

1. Introduction

The purpose of this report is to explain the development of an analytic probabilistic method and spreadsheet software system called Analytic Cell-based Continuous Energy Spreadsheet System (ACCESS), which was originally published in Crovelli (2000). The ACCESS spreadsheet can be used to calculate estimates of the potential additions to reserves of oil, gas, and natural gas liquids (NGL) in a continuous-type assessment unit, within a total petroleum system. The ACCESS method is based upon mathematical equations derived from probability theory. In this report, the geologic assessment model is defined first; the analytic probabilistic method is discussed next; and finally, the spreadsheet ACCESS is described.

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2. Geologic assessment model

The FORSPAN geologic assessment model is explained in detail in Schmoker (1999), along with the input-data form to record data required by the FORSPAN model. The seven sections of the input-data form, which is completed by the geologist for each assessment unit of a continuous accumulation, are

- assessment unit identification information,
- characteristics of assessment unit,
- number of untested cells having potential for additions to reserves in the next 30 years (hereafter shortened to "number of potential untested cells"),
- total oil or gas recovery per cell,
- average coproduct ratios for untested cells,
- selected ancillary data for untested cells, and
- allocations of potential additions to reserves to land entities.

The geologic assessment model for an assessment unit consists of the following components extracted from the input data provided by the geologist.

A. A set of four assessment-unit probabilities:

1. charge
2. rocks
3. timing
4. access

B. A set of nine random variables for an oil assessment unit or a similar set for a gas assessment unit:

1. assessment-unit area (acres)
2. untested percentage of assessment-unit area (%)
3. percentage of untested assessment-unit area having potential for additions to reserves in the next 30 years (hereafter shortened to "potential percentage of untested assessment-unit area") (%)
4. area per cell of untested cells (acres)
5. total recovery per cell (million barrels of oil [mmbo] or billion cubic feet of gas [bcfg])
6. ratio of coproduct A
7. ratio of coproduct B
8. percentage allocation to parcel (or land entity) (%)
9. percentage allocation to offshore portion of parcel (%).

The assessment-unit area, untested percentage of assessment-unit area, potential percentage of untested assessment-unit area, and area per cell of untested cells are used to estimate the number of potential untested cells.

C. A set of three descriptive parameters provided by the geologist for each of the nine given random variables:

1. minimum (F_{100} fractile)
2. median (F_{50} fractile)
3. maximum (F_0 fractile).

3. Analytic probabilistic method

The geologic assessment model FORSPAN (Schmoker, 1999) is a description of a complex probability problem that needs to be solved for the estimates of potential additions to reserves. The method derived herein, called ACCESS, is a system that solves the problem. That is, the model FORSPAN poses the problem, and the method ACCESS offers a solution. Simply stated, ACCESS is a quantitative solution of the data provided in FORSPAN.

The nine given random variables are assigned probability distributions as probability models that are based on the descriptive parameters (F_{100}, F_{50}, and F_0). That is, each given random variable is assigned a probability distribution with the specified descriptive parameters of minimum, median, and maximum. The ACCESS method does not depend upon the specific assignment of probability distributions in that many assignments could be accommodated by modifications of ACCESS. The assignment of a particular probability distribution is an operational decision. The following probability distributions were assigned to the set of nine given random variables for an oil assessment unit or for a gas assessment unit.

1. Assessment-unit area: median-based triangular distribution
2. Untested percentage: median-based triangular distribution
3. Potential percentage of untested area: median-based triangular distribution
4. Area per cell: median-based triangular distribution
5. Total recovery per cell: truncated shifted lognormal distribution
6. Ratio of coproduct A: median-based triangular distribution
7. Ratio of coproduct B: median-based triangular distribution
8. Percentage allocation to parcel (or land entity): median-based triangular distribution
9. Percentage allocation to offshore portion of parcel: median-based triangular distribution.

The mathematical equations for the median-based triangular distribution are derived from probability theory (Crovelli, 1999). The basic probability theory of the triangular distribution can be found in Law and Kelton (1991). The probability theory of the lognormal distribution is given in Aitchison and Brown (1957).

A probabilistic method was derived that combines the given random variables of the geologic assessment model (FORSPAN) to determine parameters (especially, the mean, standard deviation, F_{95}, F_{50}, and F_5) of new random variables of interest, which are functions of the given random variables. The new random variables of interest are the following measures of potential additions to reserves.

- Oil in oil assessment unit
- Gas in oil assessment unit
- NGL in oil assessment unit
- Gas in gas assessment unit
- Total liquids in gas assessment unit.

A probabilistic method is required to compute the estimates in the form of parameters (especially, the mean for a point estimate, and fractiles F_{95} and F_5 for an interval estimate) of a probability distribution. An analytic probabilistic method is a probabilistic method that uses mathematical equations from probability theory to obtain the estimates of the potential additions to reserves in an assessment unit. The ACCESS method is an analytic probabilistic method that was developed by deriving the necessary mathematical equations based upon conditional probability theory and laws of expectation and variance. Three key features of ACCESS are the following.

- ACCESS relates the input and output parameters with mathematical equations.
- ACCESS computes the means, standard deviations, minimums, and maximums exactly.
- ACCESS computes the estimates instantaneously.

For example, in the case of gas in a gas assessment unit, the following relationships are developed for the random variables.

N: number of potential untested cells
X: total recovery per cell (bcfg)
Y: gas in gas assessment unit (bcfg)

$$Y = \sum_{i=1}^{N} X_i$$

The random variable Y is equal to the sum of a random number N of random variables X_i (total recoveries per cell). The mean and standard deviation of Y can be derived from the theory of conditional probability and conditional expectation (Ross, 1993). Parameters of particular interest for gas in a gas assessment unit are the mean (μ_Y), standard deviation (σ_Y), minimum [Min(Y)], and maximum [Max(Y)]:

$$\mu_Y = \mu_N \mu_X$$

$$\sigma_Y = \sqrt{\mu_N \sigma_X^2 + \mu_X^2 \sigma_N^2}$$

$$\mathrm{Min}(Y) = \mathrm{Min}(N)\mathrm{Min}(X)$$

$$\mathrm{Max}(Y) = \mathrm{Max}(N)\mathrm{Max}(X)$$

Many of the mathematical equations for parameters of the new random variables of interest in the ACCESS method are derived using conditional probability theory (Crovelli, 1992). The number of potential untested cells and the total recovery per cell are combined probabilistically to obtain the estimates of potential additions to reserves in an assessment unit.

4. Spreadsheet system

Given the geologic assessment model (the FORSPAN model), the analytic probabilistic method is used as the basis for a spreadsheet probability system called Analytic Cell-based Continuous Energy Spreadsheet System (ACCESS). ACCESS consists of a series of 54 panels in the spreadsheet. A panel is a set of approximately 11 columns of related calculations. Because the total number of columns in ACCESS is 600 columns, ACCESS is constructed as a workbook with four worksheets called Cond (Conditional), Unc1 (Unconditional-1), Unc2 (Unconditional-2), and Numb (Number). Cond is comprised of Panels 1–22, Unc1 has Panels 23–34, Unc2 has Panels 35–46, and Numb has Panels 47–54. Worksheet Cond is linked to the worksheet Numb. Worksheets Unc1 and Unc2 are linked to the worksheet Cond. The topics included in the worksheets Cond, Unc1, Unc2, and Numb are the following.

- Worksheet Cond: input data from the data form (Panels 1–4), probability distribution calculations (Panels 5–10), and conditional (unrisked) resource estimates (Panels 11–22).

- Worksheet Unc1: Unconditional-1 resource estimates (Panels 23–34), which are risked using the geologic (charge, rocks, and timing) probability of the assessment unit.
- Worksheet Unc2: Unconditional-2 resource estimates (Panels 35–46), which are risked using both the geologic and the access probabilities of the assessment unit. The "geoacc" probability is the product of the geologic probability and the access probability.
- Worksheet Numb: input data (Panel 47) and probability distribution calculations (Panels 48–54) for the number of potential untested cells.

A probability system is an orderly collection of random variables logically related in terms of their probability distributions and parameters. In the spreadsheet probability system ACCESS, the computed estimates (Panels 11–46) of potential additions to reserves are grouped into nested categories.

The first grouping is by type of risking:

- conditional (unrisked) estimates
- Unconditional-1 (risked) estimates
- Unconditional-2 (risked) estimates.

Each type of risking has various areas:

- assessment unit
- parcel (or land entity)
- offshore portion of parcel.

Each area has various commodities:

- oil in oil assessment unit or gas in gas assessment unit
- gas in oil assessment unit or liquids in gas assessment unit
- NGL in oil assessment unit or oil in gas assessment unit
- total in oil assessment unit or total in gas assessment unit.

Each commodity has various parameters:

- mean
- standard deviation
- fractiles (F_{100}, F_{95}, F_{75}, F_{50}, F_{25}, F_5, and F_0).

The primary estimates are the mean, median (F_{50}), and fractiles F_{95} and F_5.

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