A New Probabilistic Approach to Proved Reserves Estimation in Mature Fields

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Outline

- Reserves Estimation Framework
- Conventional Deterministic Approach
- New Probabilistic approach to Reserves Evaluation in Mature Fields
- Case Study
  - Block UNI: Field Development Plan and Reserves Estimation
- Conclusions
Reserves Estimation Framework

The volume of existing hydrocarbons can be classified and categorized following PRMS guidelines in two main factors: Degree of technical uncertainty (X axis) and Opportunity of commerciality (Y axis).

Resources and Reserves Calculation Procedures

- Decline curve analysis and Material Balance Estimations are the preferred methods to calculate reserves in Brown Fields.

Oil Project Maturity and Availability of Information

Decline curve analysis and Material Balance Estimations are the preferred methods to calculate reserves in Brown Fields.
### Conventional Deterministic Approach:

**Deterministic Decline Curve Analysis**

<table>
<thead>
<tr>
<th>Case Type</th>
<th>Decline Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Case</td>
<td>Armónica</td>
</tr>
<tr>
<td>Base Case</td>
<td>Hiperbólica</td>
</tr>
<tr>
<td>Low Case</td>
<td>Exponencial</td>
</tr>
</tbody>
</table>

**Deterministic Field Production Profile**

Companies usually assess three scenarios of performance

![Deterministic Field Production Profile](image)

**New Probabilistic Approach - Guidelines:**

- It is recommended to be used for providing consistency and confidence to proved reserves estimation in mature fields.

- Three deterministic scenarios (Low, Base and High) were conceived based on expert opinion to initialize the performance model.

- Ranges of uncertainty and statistical distribution functions of the decline rate (Di) and “b” exponent were estimated.

- Rank correlation factors need to be carefully defined by expert opinion in order to set dependency between b and D.

- Probabilistic production profiles were obtained by applying Monte Carlo Simulation; an expectation curve of proved reserves is eventually built and conventional low, base and high scenarios can be extracted to deterministic cash flow analysis.

- For undeveloped proved reserves, the methodology can be applied in the same way by estimating a type curve for each field and/or reservoir. In addition, a hyperbolic model is associated to this type curve to be treated under probabilistic approach by applying Monte Carlo Analysis.

- Total proved reserves are obtained by adding corresponding PDP and PUD production profiles.
New Probabilistic Approach:

Flowchart - Holistic Probabilistic Model

1. Evaluation of the Production and Pressure History
2. Performance Method Selection: MBE or DCA
3. Verification of the Productive behavior with Dynamic Reservoir Model
4. Built a Type Curve for each Field and/or Reservoir
5. Assigning PDFs for Model Parameters
6. Production Forecasting under Uncertainty

With the production history and using a decline curve analysis (DCA) software, we plot three scenarios of declination (2 hyperbolic and 1 exponential).

Probabilistic density functions are chosen to model uncertainty in decline curve parameters accordingly to historical production performance and expert opinion.

The Monte Carlo method is applied, then the simulation is done for every month until 2027 (A hyperbolic decline model is used).
**Case Study: Block UNI**

### Model Inputs
- Using the production history and a decline curve analysis software, three decline scenarios are plot (2 hyperbolic and 1 exponential). Each decline scenario yields corresponding b and D parameters with a Qi = 76.9 bpd.

- **Hyperbolic Hyperbolic b > 1**
  - Year: 2014
  - b = 0.86
  - D = 1.87%

- **Exponential**
  - Year: 2027
  - b = 0
  - D = 2.37%

- **Hyperbolic b > 1**
  - Year: 2014
  - b = 1.42
  - D = 1.36%

- Beta-pert distributions were used to model b and D under uncertainty.
- Monte Carlo simulation was applied monthly until 2027; probabilistic production profiles and cumulative curves were developed.

### Dependency Di and b

\[ N_x = \frac{q_i}{1 - bD} \left( \frac{1}{q_i^{1-D}} - 1 \right) \]
Case Study: Block UNI

Probabilistic Production Profile – Base Curve of the Block UNI

- Nine (9) producing wells from Ostrea Fm. were used to recover proved developed reserves (PD).

Probabilistic vs. Deterministic Production Forecasting

The best way to evaluate the uncertainty is using the Probabilistic Approach.
Case Study: Block UNI

Probabilistic Production Profile – Additional Work Program of the Block UNI

- Five (5) infill wells were agreed to be drilled to Ostrea Fm. to produce proved undeveloped reserves (PUDs).

Case Study: Block UNI

Probabilistic Production Profile – Total Proved Reserves of the Block UNI

- Fourteen (14) developed wells were used to forecast total proved reserves (PT).
**Case Study: Block UNI**

**Probabilistic Production Profile – Cumulative Production of the Block UNI**

- From 200 to 300 MSTB of oil would be recovered in an interval confidence of 80%.

**Conclusions**

- It is recommended to be used for providing consistency and confidence to proved reserves estimation in mature fields.

- The methodology allows creating a parametric analytic model based on production history and reservoir behavior. This production profile is used to forecast a “band” of proved recoverable volumes under a confidence interval.

- Dependency between model inputs should be set in order to provide consistency to forecasting probabilistic production profiles.

- To estimate proved undeveloped reserves is recommended first to build a “type curve” by reservoir (or at least by well) using analogy principles; then, this type curve should be converted to a “proxy” analytical model (using both/either DCA and/or MBE) to be run under probabilistic approach by Monte Carlo simulation.

- A probabilistic cash flow analysis is the next step to evaluate the profitability of the project. A probabilistic production profile should be the input to make a reliable cash flow analysis for the project.