Petroleum Resources Classification & Reserves Estimation
**Resources (Recoverable Resources)**
Petroleum which are anticipated to be commercially recovered from known accumulations from a given date forward

- **Discovered Resources**
  Total discovered deliverable quantities based on in place volume and recovery factor

- **Undiscovered Resources**
  Total estimated quantities to be recovered from accumulations that remain to be discovered

- **Reserves**
  Anticipated to be commercially recovered from known accumulations from a given date forward

- **Potential Resources**
  Not commercially producible at present

- **Hypothetical**
  Mapped prospects

- **Speculative**
  Not yet been mapped
Reserves
Petroleum which are anticipated to be commercially recovered from known accumulations from a given date forward

Proved Reserves
Estimated with reasonable certainty to be commercially recovered

Unproved Reserves
Less certain to be recovered than proved reserves

Probable reserves
More likely than not to be recovered

Possible reserves
Less likely than likely to be recovered

Developed Reserves
Expected to be recovered from existing wells

Undeveloped Reserves
Expected to be recovered with additional capital investment
## Reserves Estimation

<table>
<thead>
<tr>
<th>Developed Areas</th>
<th>Existing Producing Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Infill Wells</td>
</tr>
<tr>
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<td>Booster Compression</td>
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Reserves Estimation

Calculation Parameters

• Performance Reserves
• Volumetric Reserves

Method

• Deterministic
• Probabilistic
Performance-Based Reserves Calculation

**Deterministic**
- Material Balance
- Decline Curved Analysis
- Simulation

**Probabilistic**
- Apply ranges of performance-based parameters
- Statistically combined the parameters to obtain a range of reserves and their probabilities
Volumetric Reserves Calculation

**Deterministic**

\[
\text{Vol (std. cond.)} = \frac{\text{Area} \times \text{Thickness} \times \phi \times (1-\text{Sw}) \times \text{RF}}{\text{FVF}}
\]

RF = Recovery Factor; 40-70% for gas
5-25% for oil

FVF = Formation Volume Factor

**Probabilistic**

- Same formula
- Apply range of parameters
- Obtain ranges of possible outcomes and their associated probabilities
Applying Statistics in Reserves Estimation

Probabilistic estimate is very useful to form an uncertainty range of and estimation.

Its implication is “what the safe side of the estimate and what the outrageous one are”

If statistical method is to be used, each reserve category should be assessed on different basis to reflect its inherent different level of confidence in data from which it is derived.

Criteria in assessing level of confidence is qualitatively spelled out in SPE/WPC definitions.
Reserves Estimation Methods

Existing Producing Wells

- Performance Reserves
  - Material Balance
  - Decline Curve Analysis

- Volumetric Calculation
  - Performance-based
Reserves Estimation Methods

Example: Chevron Offshore Thailand

Undeveloped areas

Subsurface Data
- Seismic
- Core
- Log
- RFT

P5/50/95
- Area
- Col Height
- net pay
- Porosity
- Saturation

3 Point OGOP/OOIP

P10/50/90
- Condensate Yield
- Primary Recovery
- Secondary Recovery
- Geologic Risk

In-house Software (Crystal Ball)
Example Probabilistic Reserves
Performance-Based
Volumetric Reserves Estimation

Parameters measured from real performance

1. Net Pay (ft)
2. Recovery (MMscf/ft, BBL/ft)

Analogous Groups
- Group A
- Group B
- Group C

Prospects
Performance-Based Volumetric Reserves Estimation

*Example: Unocal Thailand*

- High Confidence Recoveries
- Significant Depletion
- Change from Volumetric to Performance Control
- Acquire Performance Data
- Volumetric Reserves Calculation
- Calculated Areas
- Mean of Inferred Areas Based on Geologic Analogies
- Normalized to line Pressure
Performance-based Reserve Calculation

- Plan conceptual platform location
- Group wells by geological features
- Fill high-confidence well data in each analogous group of conceptual wells
- Apply constraints
- Establish reserve distributions
- Apply risk factors
<table>
<thead>
<tr>
<th>Well</th>
<th>Pay Distribution (FT)</th>
<th>Rec. Distribution (MMCF/FT PAY)</th>
<th>Reserves IN BCF</th>
<th>Risk</th>
<th>Risked Reserves (Bcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref. to Map</td>
<td>Grp.*</td>
<td>P10</td>
<td>P18</td>
<td>P50</td>
<td>P82</td>
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<td></td>
<td>Mean</td>
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<td>71</td>
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<td>Green</td>
<td>56</td>
<td>65</td>
<td>95</td>
<td>139</td>
</tr>
</tbody>
</table>

**Mean * Risk = Risked Reserves**
Pay Distribution

LogNormal Probability Distribution

Swanson = 150.97
Mean = 152.20
Slope = 0.27
P10 = 56.85
P50 = 125.84
696 Wells drilled in B-10, 11, 12, 13, 12/27

Net Pay drilled

[Graph showing net pay drilled in feet]
696 Wells drilled in B-10, 11, 12, 13, 12/27

Net Pay drilled

feet

1000

100

10

10
LogNormal Probability Distribution

Swanson = 18.05
Mean = 18.84
Slope = 0.42
P10 = 3.38
P50 = 11.79

Sum of Mean
Not Every Mean is equal

Which one is the most confident?

- Mode
- Geometric Mean
- Median

Probability

Value

10th percentile

90th percentile
Not Every Mean is equal

Example from 696 Well Drilled

<table>
<thead>
<tr>
<th>Method</th>
<th>Value</th>
<th>Over P50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometric</td>
<td>115.18</td>
<td></td>
</tr>
<tr>
<td>P50</td>
<td>115.18</td>
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<tr>
<td>Median</td>
<td>128.00</td>
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</tr>
<tr>
<td>Arithmetic</td>
<td>139.91</td>
<td>21.5 %</td>
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</tbody>
</table>

Swanson’s Rule

\[
\text{Mean} = 0.3 \times P10 + 0.4 \times P50 + 0.3 \times P90
\]

When \( P50/P10 < 5 \)
Locating Conceptualized Platforms

Delineation well result \( \rightarrow \) Log & RFT

Amplitude Anomaly map & Well tie

Estimate gas&oil volume to justify the setting
Analogous Well Data

- source
- migration
- trap
- reservoir
- Seal

Constraints

- Anomaly map
- Infill well
- Specific Geological Elements
Reserves Distribution

Volume

Percentile

P10 reserve = P50netpay * P50recovery
P10 reserve = P18netpay * P18recovery
P90 reserve = P82netpay * P82recovery