SPE DISTINGUISHED LECTURER SERIES

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RESERVES MANAGEMENT
AND AUDITABILITY
CRITICAL REQUIREMENTS IN TODAY’S OIL & GAS INDUSTRY

T HARRISON
Santos Ltd.
Agenda

• Reserves and resources – what are they?
• From production forecasts to reserves
• Uncertainty and risk
• SPE/WPC/AAPG resource framework
• Workflow and audit trail
• 2007 Revisions to SPE/WPC/AAPG System
Reserves

- Reserves are remaining quantities of hydrocarbons to be commercially produced from a known accumulation as of a given date under stated definitions and economic conditions.
Reserves – What are they?

The volume of petroleum expected to be sold from assets in which the entity has an entitlement.
What are resources (and reserves)?

- Resources (and reserves) are...
  - The summation of the future saleable production
  - From a given date forward
  - Up to the economic or contract limit
  - NOT just a volume!

![Bar Chart showing resource distribution over years](chart.png)
Key tests for reserves

- Are the hydrocarbons discovered?
- What entitlement do you have to hydrocarbons?
- Is the project commercial?
- What is the market for the hydrocarbons, especially for gas?
- What commitment is there to develop infrastructure?
- NONE of these tests (directly) mention volume!!!!

Tests are more about “Project Maturity”
From production forecasts to reserves

Sum of existing plus behind pipe production

+ 

Sum of production from future development

To

Technical or economic or contract or legal limit whichever is first
Production forecasts – uncertainties

1. Reservoir consistency/continuity
2. Drive mechanism
3. Water/gas break through
4. Damage/damage removal
5. Suction pressure profile
6. Impact & timing of development
7. Mechanical integrity
8. Fluid composition
9. Metering accuracy
10. Vertical lift
11. IOR impact
12. Market
13. Weather

How do we ever get it right?
Reserves are functions of technology

The Story of Kern River Oil Reserve

- Discovered in 1899.
- After 43 years of operation, it had reserves of 54 million barrels.
- In next 43 years, it produced, not 54 but 730 million barrels.
- At the end of that time, in 1986, it had “remaining reserves” of about 900 million barrels.
- At end 2000 the field had produced 1,760 million barrels

Adelman, 1987
Reserves uncertainties

1. Production forecast uncertainties
2. Price uncertainty
3. Cost uncertainty (both Capex & Opex)
4. Commercial/legal/political uncertainty
## History of reserves definitions

<table>
<thead>
<tr>
<th>Year</th>
<th>Organisation</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1936</td>
<td>American Petroleum Institute (API)</td>
<td>Oil reserves definitions - first use of term &quot;proved reserves&quot;</td>
</tr>
<tr>
<td>1946</td>
<td>American Gas Association (AGA)</td>
<td>Gas reserve definitions</td>
</tr>
<tr>
<td>1946–1979</td>
<td>API &amp; AGA</td>
<td>Published annual 1P U.S. reports of oil, gas and NGL's</td>
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<tr>
<td>1964</td>
<td>Society of Petroleum Engineers (SPE)</td>
<td>Adopted proved reserves definitions similar to API</td>
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<td>1978</td>
<td>U.S. Securities &amp; Exchange Commission (SEC)</td>
<td>Issued definitions for proved reserves</td>
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<td>SPE</td>
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<td>1983</td>
<td>World Petroleum Congresses (WPC)*</td>
<td>Issued expanded definitions for reserves and resources</td>
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<tr>
<td>1987</td>
<td>SPE + WPC</td>
<td>Published independent definitions for 1P, 2P &amp; 3P reserves</td>
</tr>
<tr>
<td>1997</td>
<td>SPE/WPC</td>
<td>Jointly adopt 1P, 2P &amp; 3P reserve definitions – deterministic &amp; probabilistic</td>
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<tr>
<td>2000</td>
<td>SPE/WPC/AAPG</td>
<td>Issue full petroleum resource framework definitions</td>
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<td>2001</td>
<td>SPE/WPC/AAPG</td>
<td>Issue evaluation guidelines for reserves &amp; resources</td>
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<tr>
<td>2007</td>
<td>SPE/WPC/AAPG/SPEE</td>
<td>Combined &amp; updated definitions &amp; guideline for reserve &amp; resources - PRMS</td>
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*World Petroleum Congresses has subsequently been renamed "World Petroleum Council"
There is a RISK that I am going to fall off this cliff.

I am UNCERTAIN how far it is to the bottom!
Consistent approach to assessment of risk and uncertainty for all assets

**RISK ... project maturity**
Will the project go ahead?

**UNCERTAINTY...**
What is the range of estimated recoverable volumes if the project does go ahead?
<table>
<thead>
<tr>
<th>TOTAL PETROLEUM INITIALLY IN PLACE</th>
<th>DISCOVERED INITIALLY IN-PLACE</th>
<th>UNDISCOVERED INITIALLY IN-PLACE</th>
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<tbody>
<tr>
<td>Production</td>
<td>1P PROVED</td>
<td>LOW ESTIMATE (P90)</td>
</tr>
<tr>
<td></td>
<td>2P PROVED + PROBABLE</td>
<td>BEST ESTIMATE (P50)</td>
</tr>
<tr>
<td></td>
<td>3P PROVED + PROBABLE + POSSIBLE</td>
<td>HIGH ESTIMATE (P10)</td>
</tr>
<tr>
<td>Unrecoverable</td>
<td>LOW ESTIMATE (P90)</td>
<td>BEST ESTIMATE (P50)</td>
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**Range of Uncertainty**

- Reserves
- Contingent Resources
- Prospective Resources
Reserves – A sub-set of resources

Prospective Resources – Exploration Potential

Contingent Resources – Sub-Commercial

Commercialised

Reserves – Commercial

Developed

Production – Sales
The work flow – Key elements:

- Production actuals & forecasts
- Geo/engineering analysis
- Development opportunity inventory
- Economic analysis

“The Worktable”
Process framework – the “Worktable”

- Project Audit
- Production Storage
  - Actual
  - Forecast
- Economic Analysis
- Portfolio Analysis
  - Corporate Planning
- Geo - Analysis Performance
- Opportunity Analysis
- Opportunity Inventory
- Reserves
- Reserves Documentation
  - Intranet Site
- Budget
- Project Execution
- Project Initiation
Benefits of the worktable

- Managing assets for value and not just volume
- Ensure the same forecast is used for cashflows, reserves and all planning purposes
- Asset forecasts visible to all levels of company
- Improve data quality and professional’s productivity
Guiding principles

1. Single point ownership of forecasts, reserves and cashflows for each asset

2. Appropriately defined involvement and responsibilities

3. Data standardised: right data in the right place, at the right time, in the right format

4. Allow real time access and roll-ups of asset data

5. Single source data entry and handling – access often
A few general comments

- Reserves must be part of general workflow of asset teams
- Projects, production history, production forecasts, and economic analysis, are all inextricably linked to reserves and portfolio analysis.

**They can and should be a single workflow**
- **the asset value chain**

- Keeps users happy – link systems to facilitate single point data entry – get IT to do the work!
- Internal reserves audit function must be separated from those tasked with meeting company targets
- Good internal reserves audit is better than external reserves audit
- Include credible external expertise in the reserves review process – Reviewers not doers
## Major Changes in Proposed 2007 SPE/WPC/AAPG/SPEE RMS

<table>
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<tr>
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| Combines 4 previous guidance documents into single "Petroleum Resources Management System":  
  - 1997 SPE/WPC Petroleum Reserves Guidelines  
  - 2000 SPE/WPC/AAPG Petroleum Resources Classification and Definitions  
  - 2001 SPE/WPC/AAPG Guidelines for the Evaluation of Petroleum Reserves & Resources  
  - 2005 SPE/WPC/AAPG Glossary of Terms | Separate documents combined, abbreviated and clarified |
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Thank you for your attention

Any Questions?
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Contingent resource to reserves

- Project must be commercial:
  Economics must be run to differentiate technical from commercial
  *Minimal risk of project not proceeding*

- Demonstrate commitment to develop and place on production within reasonable time frame:
  - Project Sanction
  - Plan of Development
  - Gas Sales Agreement/Spot Market

- Reasonable Level of technical uncertainty:
  - Is low side break-even?
  - Is the uncertainty such that the company is unable to commit to go ahead with project?

*If the project does not proceed reserves may need to be de-booked*

LOWER RANGE OF UNCERTAINTY
Prospective resource to contingent resource

- Must have been penetrated by a well
  Adjacent fault blocks – sealing/non sealing – down dip/up dip?

- In general – moveable hydrocarbon must be shown to flow to surface or at least some recovery

- Where log and/or core data exist – may be OK if there is a good ‘geologically comparable’ analogy nearby
  Key words: “Nearby” & “Geologically Comparable”

Note: Commercial/economic analysis of discovery not required for Contingent Resources

LARGE RANGE OF UNCERTAINTY
Tracking Volumetric Uncertainty

<table>
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<tr>
<th>Exploration</th>
<th>Appraisal</th>
<th>Development/Production</th>
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<tr>
<td></td>
<td>Contingent Resources</td>
<td>Reserves</td>
</tr>
<tr>
<td>P10</td>
<td>High Estimate</td>
<td>3P</td>
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<td></td>
<td>Best Estimate</td>
<td>2P</td>
</tr>
<tr>
<td></td>
<td>Low Estimate</td>
<td>1P</td>
</tr>
<tr>
<td>P50</td>
<td>Range of Uncertainty</td>
<td>Field Abandonment</td>
</tr>
<tr>
<td>P90</td>
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NB: Reserves = UR - Production
• Complete Petroleum resource system from Undiscovered to Production
• Incorporates series of ‘gates’ or decision points

**Focal Points for Corporate Governance**

1. **Undiscovered**
   (Prospective Resource) → **Discovered Hydrocarbon**
   (Contingent Resource)

2. **Discovered**
   (Contingent Resource) → **Discovered – Commercial**
   (Reserves)

3. **Unproved Reserves**
   (Probable & Possible) → **Proved Reserves**
   (Proved)

• First two transition points relate to ‘Project Maturity’ – both technical and commercial
• Third transition point relates to ‘Project Uncertainty’ – mainly technical
Attributes of Proved Reserves

**Reasonable Certainty**
- High degree of confidence
- If Probabilistic methods used – 90% chance reserves will exceed estimate
- Fluid contacts or LKH or as indicated by **definitive** geo/eng or performance data
- Undeveloped – within defined area – reasonable certainty formation is laterally continuous & contains commercially recoverable hydrocarbons

**Commercially Recoverable**
- Commitment to go ahead with project
- Evidence of commercial productivity
- Legal entitlement

**Current Economic Conditions**
- Price & cost forecasts based on historical data
- Economic Limit
- Appropriate contract obligations & Government regulations
- PSC Complexities
Attributes of proved + probable reserves

More likely than not to be recoverable
- Middle ground – best estimate
- If Probabilistic methods used – 50% chance reserves will equal or exceed estimate
- Fluid contacts or as indicated by geo/eng or performance data – if no indicative data – half way between LKH & LCC often used

Commercially recoverable
- Commitment to go ahead with project
- Less stringent evidence of commercial productivity
- Legal entitlement

Reasonably improved economic, technical & operating methods
- Reasonably improved Price & cost forecasts
- If fault separated from proved area – included if faulted area higher than proved area
- Appropriate contract obligations & Government regulations
  - PSC Complexities
- PSC Complexities
Attributes of proved + probable + possible reserves

Less likely to be recoverable than 2P reserves
- High Side Estimate – Upside potential
- If Probabilistic methods used – 10% chance reserves will equal or exceed estimate
- Fluid contacts or as indicated by geo/eng or performance data – if no indicative data – LCC often used

Commercially recoverable
- Commitment to go ahead with project
- May not currently be shown to be commercially producible
- Legal entitlement

Reasonably improved economic, technical & operating methods
- Reasonably improved Price & cost forecasts
- If fault separated from proved area – included if faulted area lower than proved area
- Appropriate contract obligations & Government regulations
- PSC Complexities
Developed & undeveloped reserves

**Developed**

- Production from Existing Completions
- Behind pipe if only minor expenditure
- Compression restaging

**Undeveloped**

- New wells/deepening existing wells
- Connections & recompilations
- Additional compression
Aggregation of accumulations

- Probabilistic up to ‘project’ level where project has common sales point
- Arithmetic above project level
- Arithmetic assumes dependant variables & probabilistic assumes independent
- Real World = somewhere between the two
- Project under way to include probabilistic summation in Volts reporting
Aggregation of accumulations continued

- Probabilistic versus arithmetic
  - Probabilistic will tend to over-estimate the low side if there are dependencies between the distributions
  - Arithmetic will tend to under-estimate the low side if the distributions are independent
- Probabilistic methods assume a continuous distribution not three deterministic estimates
- In a probabilistic world the sum of the individual components will not equal the sum of the total
Contingent resources are “contingent” on overcoming a barrier in order to become reserves:

**Development pending:**
Requires further data acquisition and/or evaluation in order to confirm commerciality

**Development on hold:**
Of significant size, but awaiting development of a market or removal of other constraints to development, - may be technical, environmental, or political.

**Development not viable:**
No current plans to develop or to acquire additional data at this time due to limited production potential.
Coal Seam Methane (CSM)

- Classified by same convention as conventional oil & gas reserves:
  - But; CSM reserves more related to volume of coal & ability of coal to liberate gas rather than estimate of recoverable gas in pore spaces as in conventional reservoirs.
- 1P, 2P & 3P limits in CSM fields not defined by conventional contacts (LKG, HKW, LCC) as most coal contains gas absorbed onto coal surface independent of structural location.
- CSM fields located in a variety of structural settings such as anticlines, synclines & monoclines.
- CSM resource comprises volume of gas throughout coal and surrounding strata.