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Incorporating Numerical Simulation Into Your Reserves Estimation Process: A Practical Perspective

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Outline

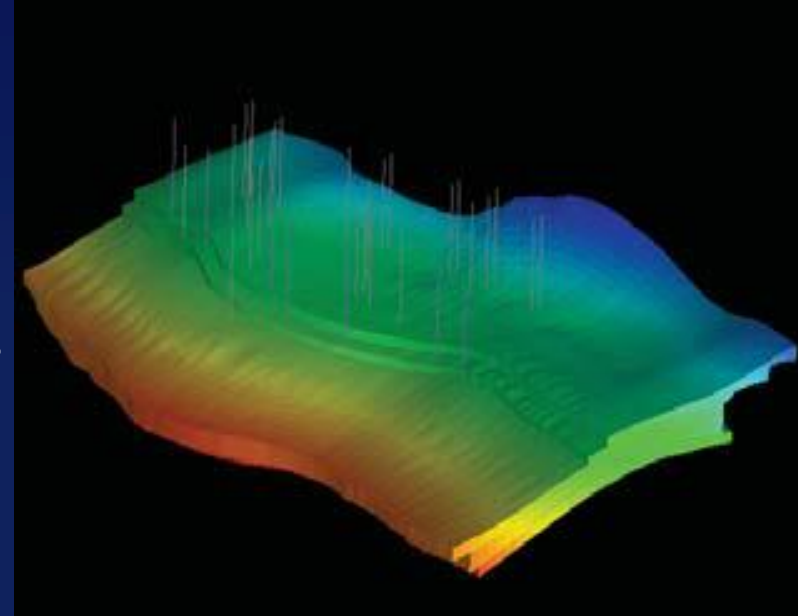
- Introduction
- A Look at Reserves
- Combining Reserves and Simulation
 - Immature Reservoirs
 - Mature Reservoirs
- Examples
- Conclusions

Introduction

- Any estimate of future recovery does not necessarily qualify as an estimate of reserves.
- Specific criteria must be met to qualify estimated recoverable volumes as reserves.
- These criteria are generally defined in the form of “reserves definitions.”

Background on the Subject

- SPE 71430 (2001)
 - Intended to start a dialog
- SPE 96410 (2005)
 - Reviewing History Matches
- SPE 110066 (2007)
 - Case Study Examples



- SPE 71430 “The Adaptation of Reservoir Simulation Models for Use in Reserves Certification Under Regulatory Guidelines or Reserves Definitions”
- SPE 96410 “Reservoir Simulation and Reserves Classifications – Guidelines for Reviewing Model History Matches to Help Bridge the Gap Between Evaluators and Simulation Specialists”
- SPE 110066 “Case Studies Illustrating the Use of Reservoir Simulation Results in the Reserves Estimation Process”

A Look at Reserves



“Estimates of recoverable and marketable quantities can be considered reserves only if commercial or economic.”

Reserves Definitions

- **SPE/WPC/AAPG/SPEE**

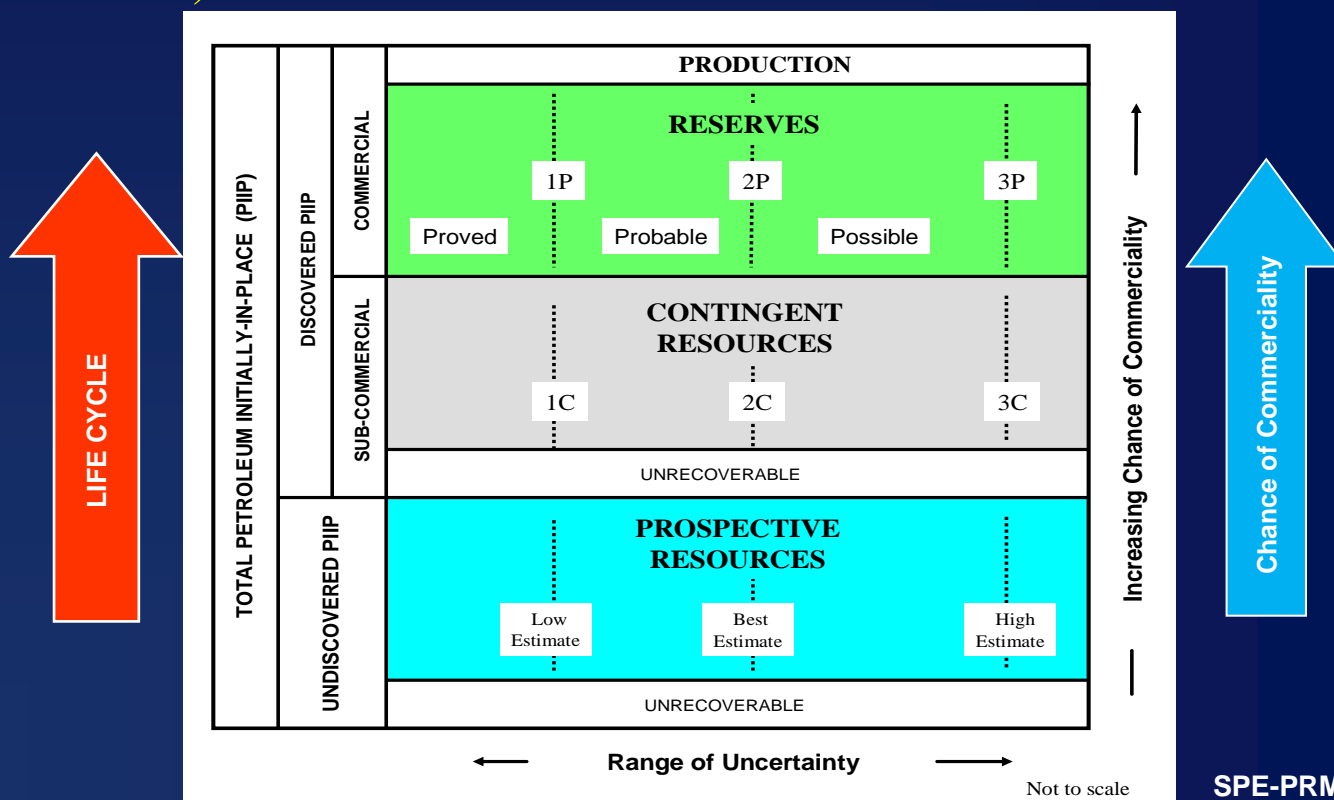
- **Petroleum Resources Management System 2007**, pp. 20 and 21 (PRMS Document)
- Proved, probable, and possible reserves

- **SEC**

- **17 CFR Part 210.4-10**
- Recent revisions effective January 1, 2010
- References:
 - “Modernization of the Oil and Gas Reporting Requirements,” Conforming Version No. 33-8935, pp. 134-147, found at: <http://www.sec.gov/rules/proposed/2008/33-8935.pdf>
 - Federal Register Final Rule, January 14, 2009, pp. 2190-2192, found at: <http://www.sec.gov/rules/final/2009/33-8995fr.pdf>

SPE-PRMS Combines Both Resource Classification vs Categorization

“... projects are “classified” based on their chance of **commerciality** (the vertical axis) and estimates of recoverable and marketable quantities associated with each project are “categorized” to reflect **uncertainty** (the horizontal axis).”



Reference to Simulation with Reserves (SPE-PRMS)

- SPE-PRMS and Reservoir Simulation
 - Recovery can be based on analog field or simulation studies.
 - Reservoir simulation is a “sophisticated form of material balance.”
 - Most reliable when validated with a history match.

*PRMS Document – SPE/WPC/AAPG/SPEE, pp. 20-21
(Petroleum Resources Management System 2007)*

Reference to Simulation with Reserves SEC (2009)

2008 Regulation 210.4-10
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{2008} (25) Reliable technology. *Reliable technology is a grouping of one or more technologies (including computational methods) that has been field tested and has been demonstrated to provide reasonably certain results with consistency and repeatability in the formation being evaluated or in an analogous formation.*

Federal securities laws and the Energy Policy and Conservation Act of 1975.

Note: Exact SEC text shown in *italics* below.

References: "Modernization of Oil and Gas Reporting" conforming version No. 33-8935 found at <http://www.sec.gov/rules/proposed/2008/33-8935.pdf>, the Federal Register version found at <http://www.federalregister.gov/rules/2008/03/31/2008-06959.pdf> and the 1978 version of Regulation S-X 210.4-10 found at <http://www.sec.gov/rules/1978/33-8935.pdf> and the 1978 version of Regulation S-X 210.4-10 found at <http://www.sec.gov/rules/1978/33-8935.pdf>

Disclaimer: This document has been compiled from other SEC documents and should not be construed to be a publication of the SEC. The (Reference Indicator) denotes whether the definition was retained from 1978 or if a 2008 addition or revision. Please note these reference indicators are included for the convenience of the user and are not part of the official SEC document.

(2008 Conforming Version No. 33-8935 Pgs 132-143) (a) Definitions.

(1978) (1) Acquisition of properties. Costs incurred to purchase, lease or otherwise acquire a property, including costs of lease bonuses and options to purchase or lease properties, the portion of costs applicable to minerals when land including mineral rights is purchased in fee, brokers' fees, recording fees, legal costs, and other costs incurred in acquiring properties.

(2008) (2) Analogous reservoir. Analogous reservoirs, as used in resources assessments, have similar conditions (depth, temperature, and pressure) and drive advanced stage of development than the reservoir of interest. In the interpretation of more limited data and estimation of reserves, an "analogous reservoir" refers to a reservoir that is not necessarily in pressure communication with the reservoir of interest.

(1978) (3) Properties with proved reserves. Properties with proved reserves must, in the aggregate, be no more favorable than the reservoir of interest.

(1978) (4) Reasonable certainty. If deterministic methods are used, reasonable certainty means a high degree of confidence that the quantities will be recovered. If probabilistic methods are used, there should be at least a 90% probability that the quantities actually recovered will equal or exceed the estimate. A high degree of confidence exists if the quantity is much more likely to be achieved than not, and, as changes due to increased availability of geoscience (geological, geophysical, and geochemical), engineering, and economic data are made to estimated ultimate recovery (EUR) with time, reasonably certain EUR is much more likely to increase or remain constant than to decrease.

(2008) (25) Reliable technology. Reliable technology is a grouping of one or more technologies (including computational methods) that has been field tested and has been demonstrated to provide reasonably certain results with consistency and repeatability in the formation being evaluated or in an analogous formation.

(2008) (26) Reserves. Reserves are estimated remaining quantities of oil and gas and related substances anticipated to be economically producible, as of a given date, by application of development projects to known accumulations. In addition, there must exist, or there must be a reasonable expectation that there will exist, the legal right to produce or a revenue interest in the production, installed means of delivering oil and gas or related substances to market, and all permits and financing required to implement the project.

(2008) Note to paragraph (a)(26). Reserves should not be assigned to adjacent reservoirs isolated by major, potentially sealing, faults until those reservoirs are penetrated and evaluated as economically producible. Reserves should not be assigned to areas that are clearly separated from a known accumulation by a non-productive reservoir (i.e., absence of reservoir, structurally low reservoir, or



Combining Reserves & Simulation

Reliable results from models can be used for reserves.

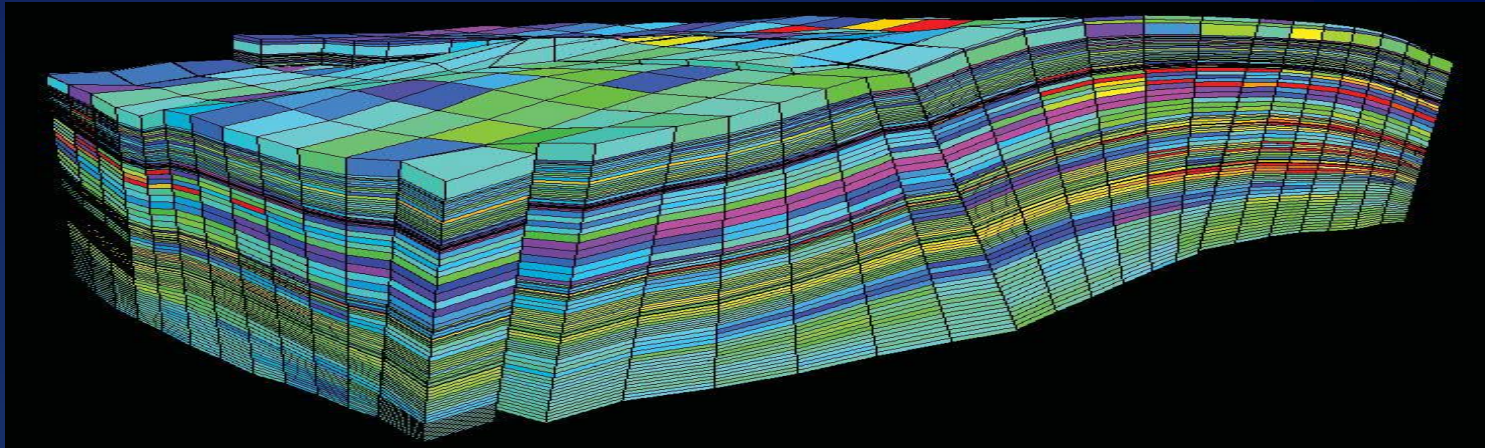
- Verify commerciality*
- Comply with guidelines*

Applying Simulation Results for Estimating Proved Reserves

- Usually, the primary objective of a simulation study is to better understand the reservoir to improve recovery (Proved + Probable – 2P or “most likely”).
- Development plans should be based on 2P or even 3P (Proved + Probable + Possible).

Applying Simulation Results for Estimating Proved Reserves

- It is common that results from a simulation model cannot be directly applied to the proved reserves category, even if they are passed through a cash flow analysis to demonstrate economic viability.



Applying Simulation Results for Estimating Proved Reserves

- Typical models might not be consistent with “proved” guidelines due to:
 - Original oil-in-place (OOIP) beyond “proved”
 - Pressure support or energy
 - Other parameters

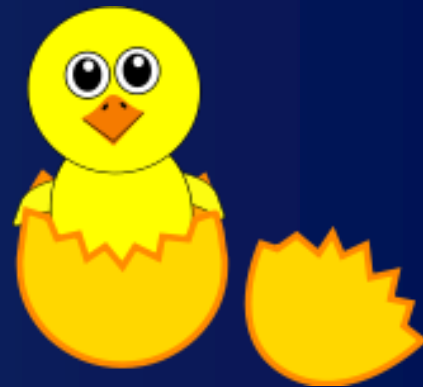


Immature and Mature Reservoirs

- Mature reservoirs contain a period of production history that is modeled or “history matched.”
- Immature reservoirs contain little or no production history and the simulation models have not yet been verified by actual field performance.

Immature Reservoirs

- Description relies primarily on **geophysical** and **geological** data.
- A “history match” of the model to the reservoir is easy to obtain.
 - Few performance points
 - Not very reliable

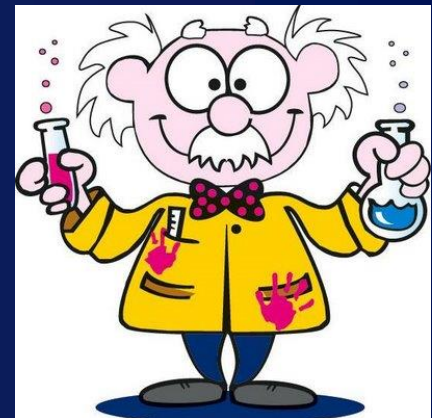


Immature Reservoirs

- Unlikely to be acceptable for proved reserves.
 - “Most likely” OOIP
 - Not reliable
- Models helpful in estimating hydrocarbon recovery efficiency.
 - Sensitivity studies
 - Unless contradicted by analogy data (or experience)

Mature Reservoirs: Validating with a History Match

- Model parameter adjustment
 - Reasonable
 - Non-contradictory
 - Consistent with known geological and engineering evidence
- Sensitivity studies can investigate uncertain parameters.



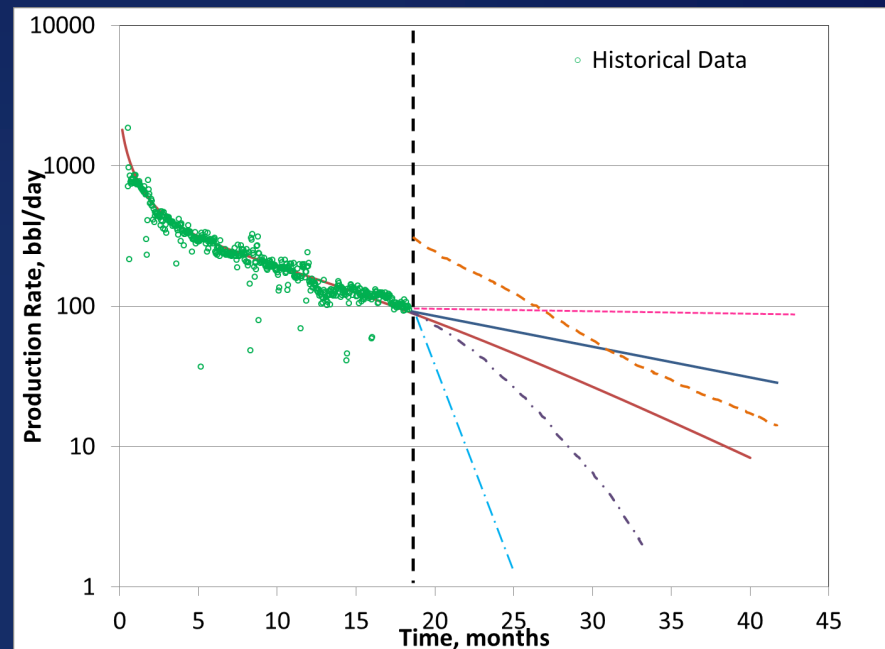
Mature Reservoirs & History Matching Drawbacks

- Non-unique
- Certain parameters may have a limited impact on the history match but may have a dramatic impact on the prediction.
 - Aquifer dimensions
 - Original hydrocarbon in-place!

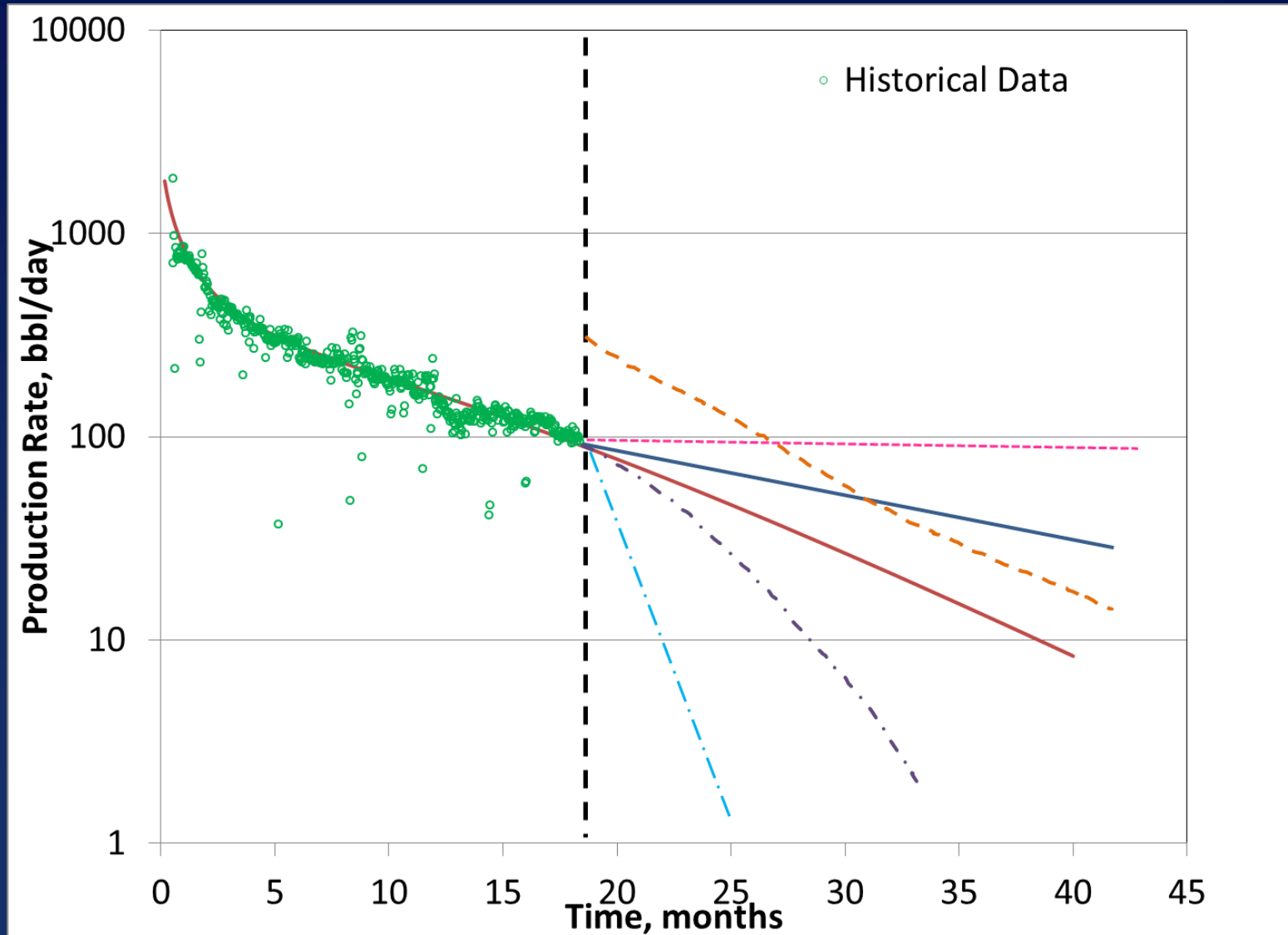
Mature Reservoirs & History Matching

Additional Considerations

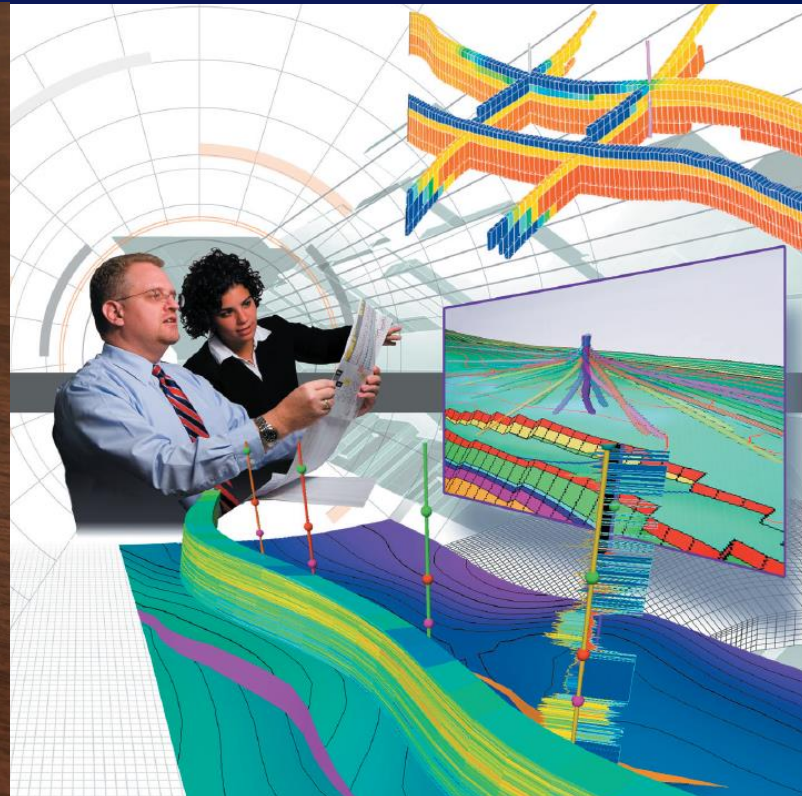
- Recognize situations where there may be changes to the depletion process
- Assess the Transition to Forecast
 - Status quo or “do nothing” case is consistent in rate’s decline



Mature Reservoirs & History Matching Additional Considerations

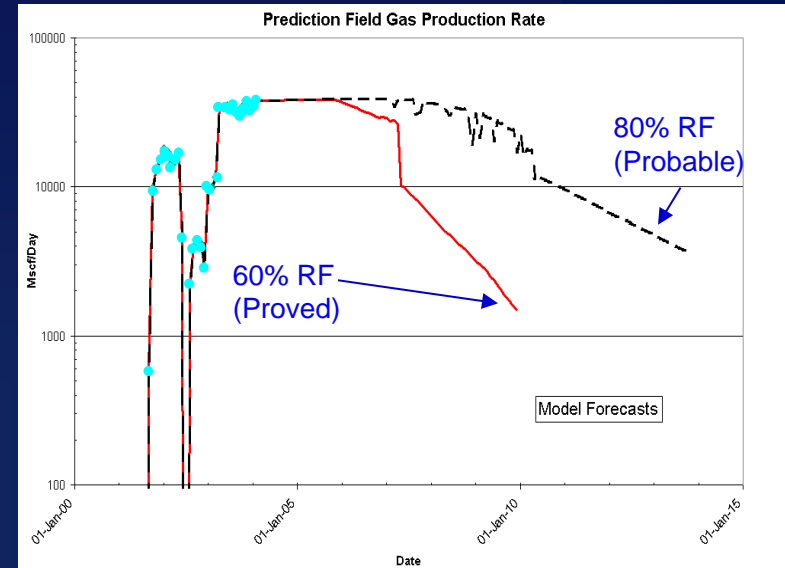
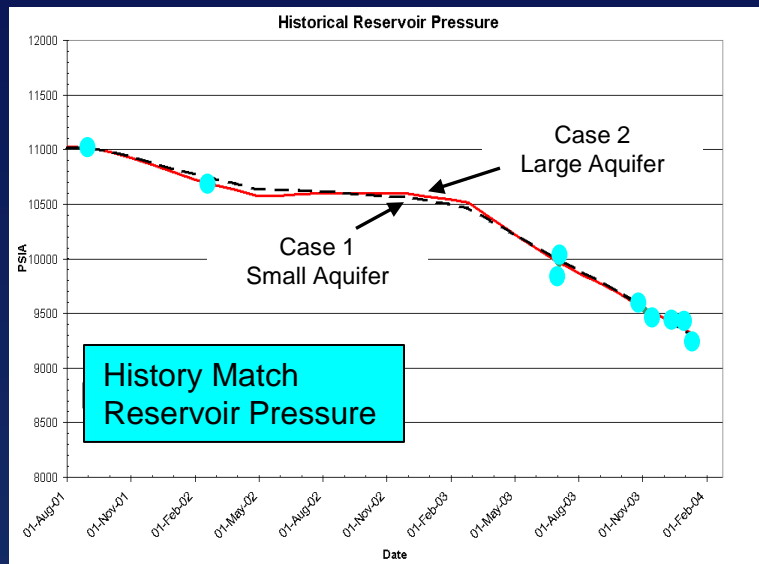


Some Examples



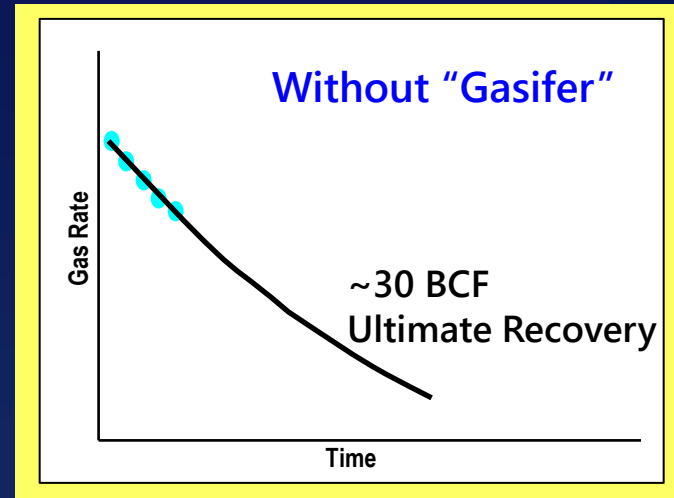
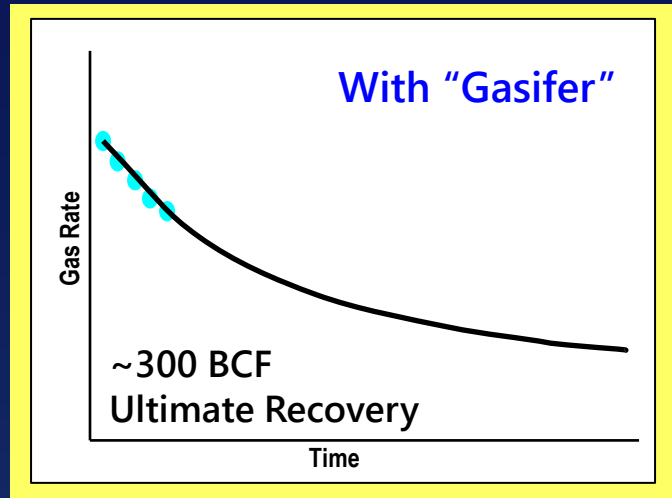
Example 1:

Apply Reservoir Simulation to Assess Geological or Drive Mechanism Uncertainty



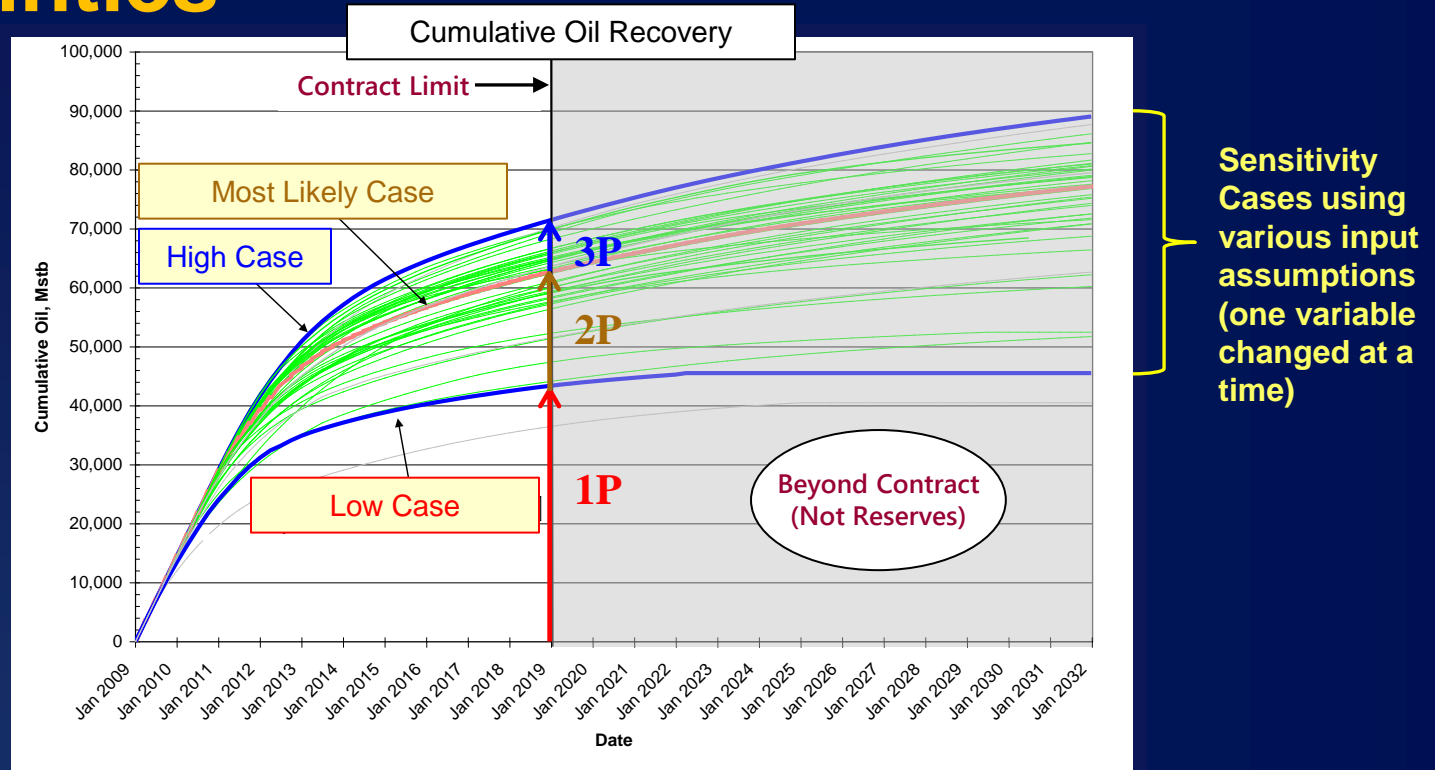
- Two models with different assumptions
- Both have good history match
- Models provide range of expected recovery

Example 2: Misuse of Simulation: The “Gasifer”



- Conclusions not supported by model results
- Easily disputed

Example 3: Reserves Assigned Based on Forecast Uncertainties



- Modeling used to assess field recovery under various operating and input parameter assumptions
- All of the above projected volumes must be demonstrated to have economic or commercial viability before being called “reserves.”

Case Studies Illustrating the Use of Reserves (SPE Paper 110066)

- [SPE Paper 110066](#) (2007) was written to provide examples of incorporating simulation results in the reserves process.

Mature

- Case Study 1 - Modify the simulation results (Mature Reservoir).
- Case Study 2 - Modify so model complies with reserves definitions (Mature Reservoir).

Immature

- Case Study 3 – If the field being evaluated is an Immature Reservoir with no sustained production history, then perform a series of sensitivity studies.

Overall Conclusions

- The **reliability** of the results from a model is strongly dependent on the **understanding of the geology** and the **confidence in all of the parameters** used to construct the model.
 - What is needed?
 - Reasonable assumptions
 - Good history match
 - Good/reasonable forecast
 - Sensitivity cases
 - Documentation/Supporting Information

Final Remarks

- Reliable results from models can be used for reserves.
 - Verify commerciality
 - Comply with guidelines
- Provide significant supporting information.
- For proved reserves, detailed analysis and scrutiny should be applied to “typical models.”



Reliable

Consistent

Reasonably Certain

Repeatable



Thank You!

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