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RYDER SCOTT

Reservoir Simulation in Reserves Analysis

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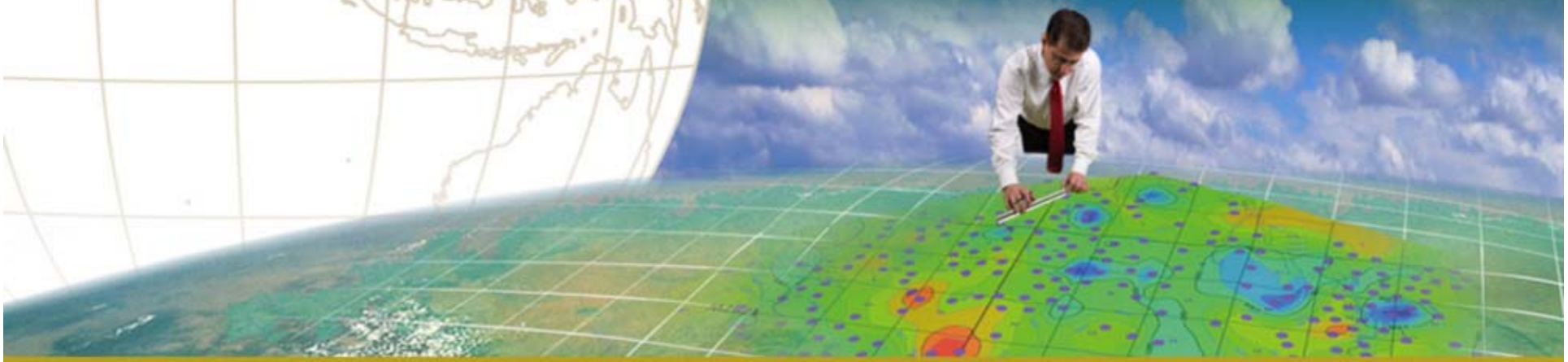


Background Info

- SPE 71430 - 2001 - Palke & Rietz

- “The Adaptation of Reservoir Simulation Models for Use in Reserves Certification Under Regulatory Guidelines or Reserves Definitions”

Outline

- Introduction
- Reservoir Simulation
- Simulation and Proved Reserves
- Immature & Mature Reservoirs (History Matching)
- Reviewing Models
- Conclusions

Introduction

- Regardless of the evaluation methods used, any estimate of future recovery does not necessarily qualify as an estimate of reserves.
- Aside from economic viability, specific criteria must be met to qualify estimated recoverable volumes as reserves.
- These criteria are generally defined in the form of “reserves definitions.”

Prevalence of Reservoir Simulation

- A numerical model that is expected to behave like a particular oil or gas reservoir.
- After the history match is achieved, the model can be “run” to predict future performance.
- Simulation continues to become a more widely used tool.
- Simulation has also been increasingly promoted as a means to estimate reserves.

Limitations of Simulation

- Uniform parameters within grid blocks (possibly very large).
- Average block properties not accurately known.
- Undetected structural features may not be in a model.
- Generally very data intensive.
- History matching tends to be non-unique.

Applying Simulation Results to Estimate Proved Reserves

- Simulation studies are rarely performed with the objective to estimate proved reserves. Usually, the primary objective of a model is to better understand the reservoir to improve recovery (2P).
- Sensible to consider the best estimate of total potential (2P or 3P) when planning.
- Modeling and formulating a development plan based only on proved reserves is likely to reduce overall recovery efficiency.

Applying Simulation Results to Estimate Proved Reserves

- Models built for proved reserves many times are too limited and unrealistic.
- Special circumstances
  - Contentious reserves situations
  - Reserves largely proved

Applying Simulation Results to Estimate Proved Reserves

- It is not just original hydrocarbon in place that may not fit the definition of proved reserves.
- Models may include pressure support from aquifers or rock compressibility that are not “proved.”
- Numerous other parameters would also fall into this category.
- The key is to search for sources of reservoir drive energy that may increase recoveries beyond what would be considered proved.

Applying Simulation Results to Estimate Proved Reserves

- Two approaches to comply with reserves definitions:
  1. Modify the model
  2. Modify the simulation results

Assuming the model and the forecasts are valid

Immature Reservoirs

- Description relies primarily on geophysical and geological data to set reservoir parameters.
- A “history match” of the model to the reservoir is easy to obtain since there are few if any performance points to be matched.
- Because it is so easy to obtain, however, the match is not very meaningful in terms of calibrating and improving the reliability of the model.

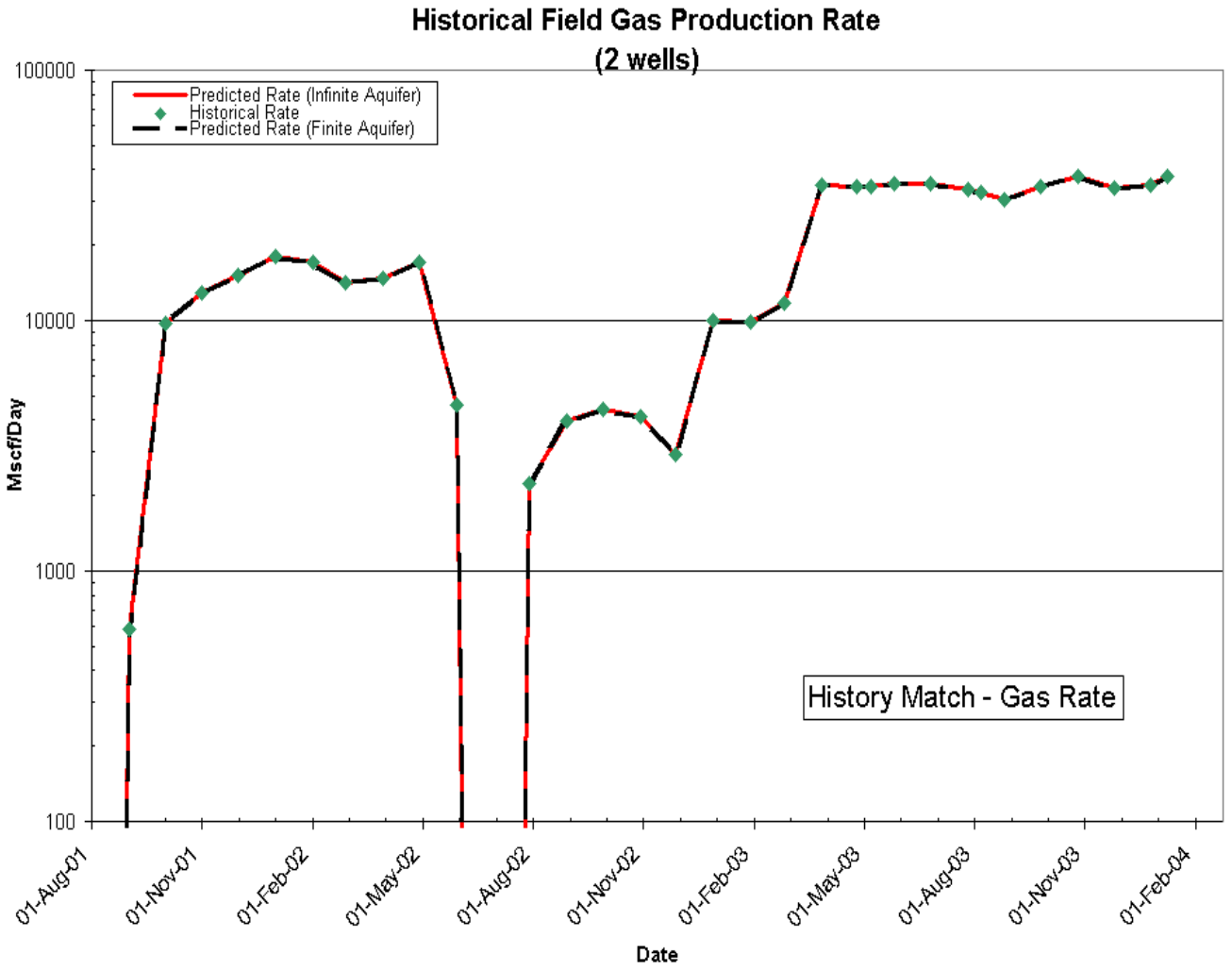
Immature Reservoirs

- Sensitivity studies
- Unless contradicted by analogy data (or experience)
- Remember upward revisions should be (much) more likely

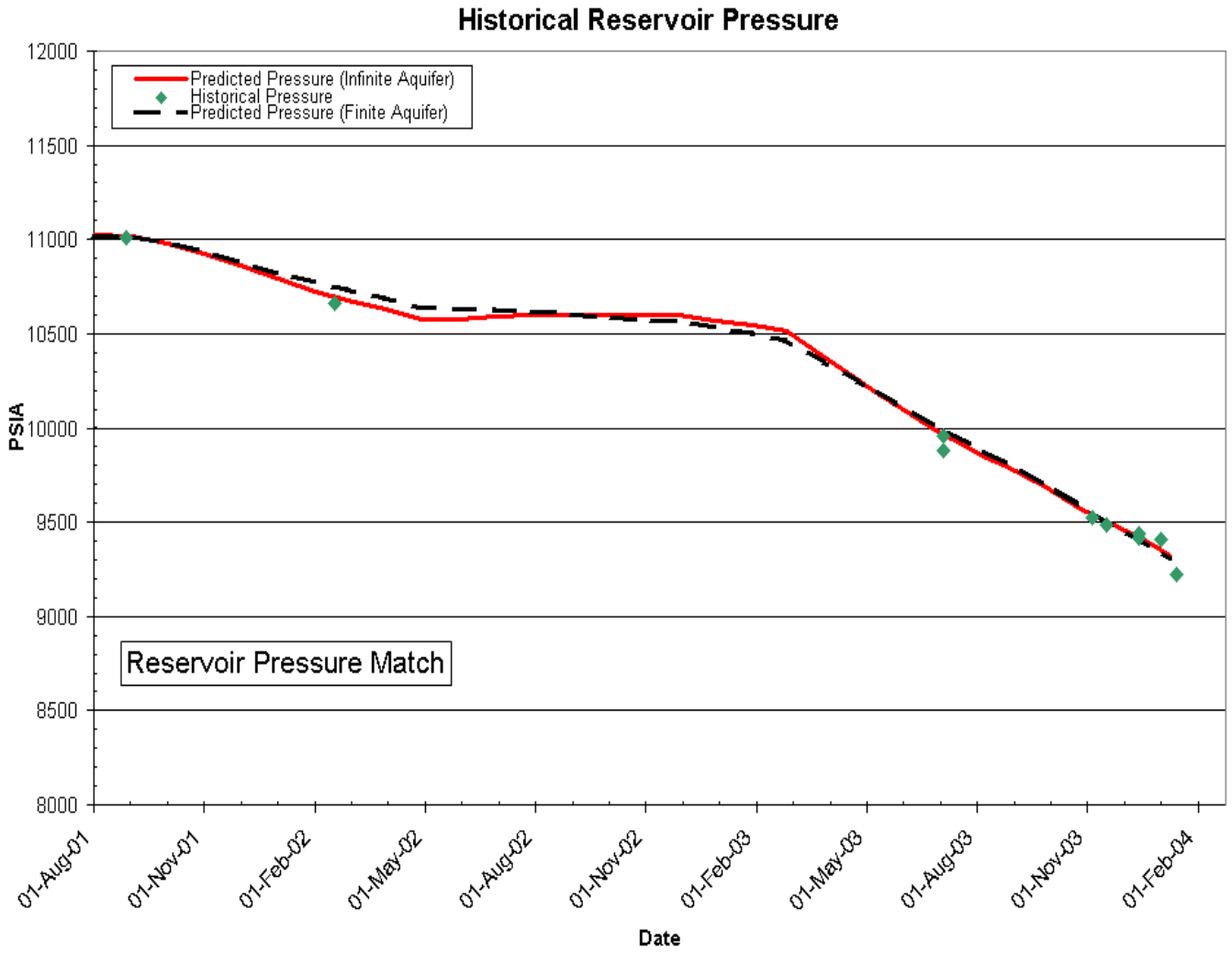
Mature Reservoirs & History Matching

- History match is usually difficult to obtain.
  - Is more meaningful in terms of enhancing model reliability.
- History match is important.
- Should result from logical adjustments.
- Consistent with geological and engineering evidence.
- Uncertain parameters / Sensitivity studies

History Match Example



History Match Example



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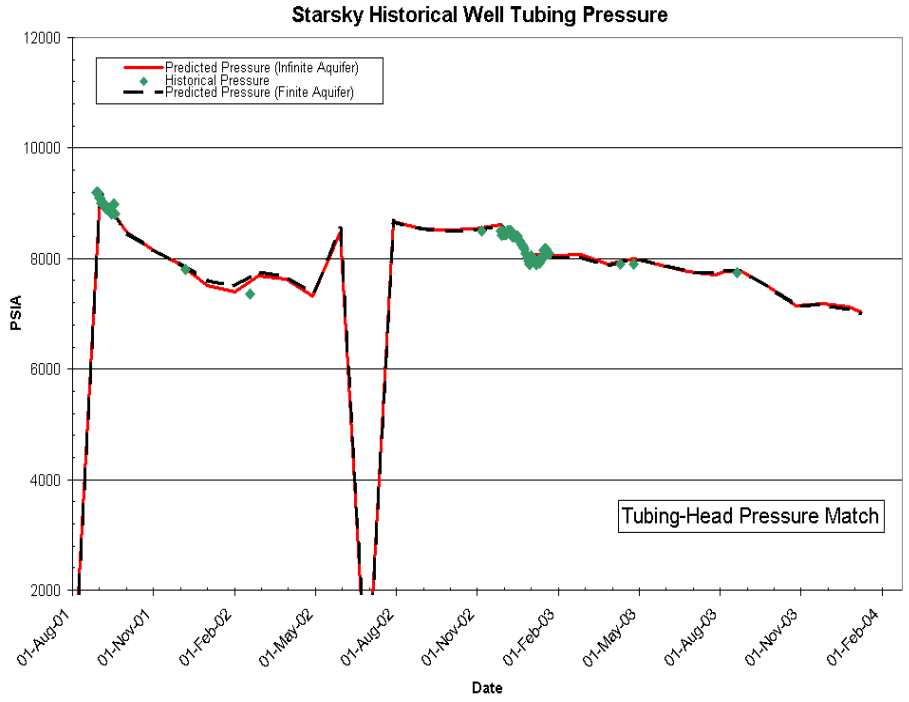

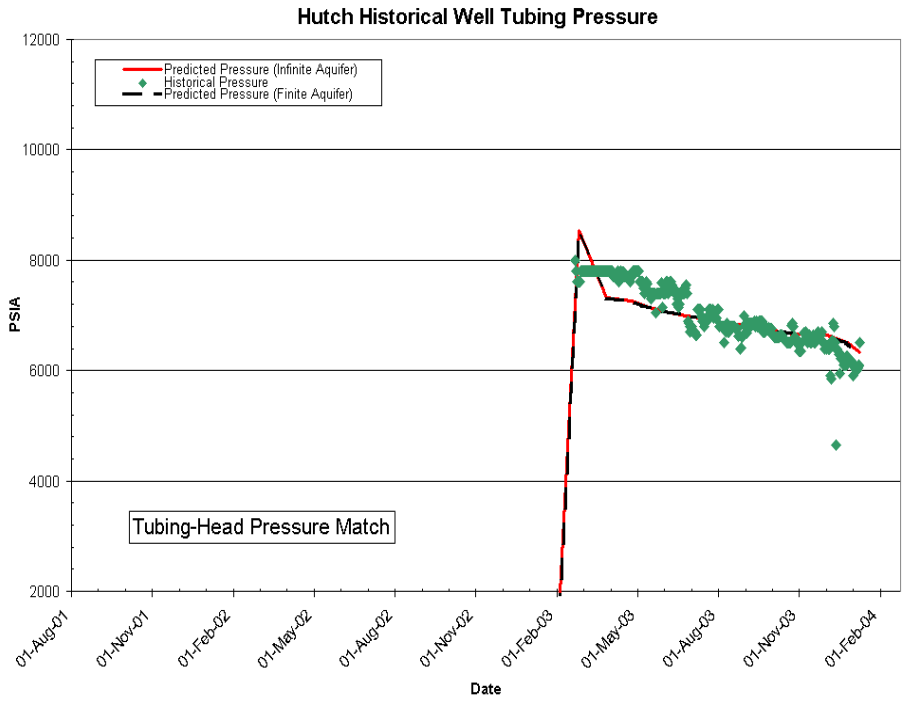

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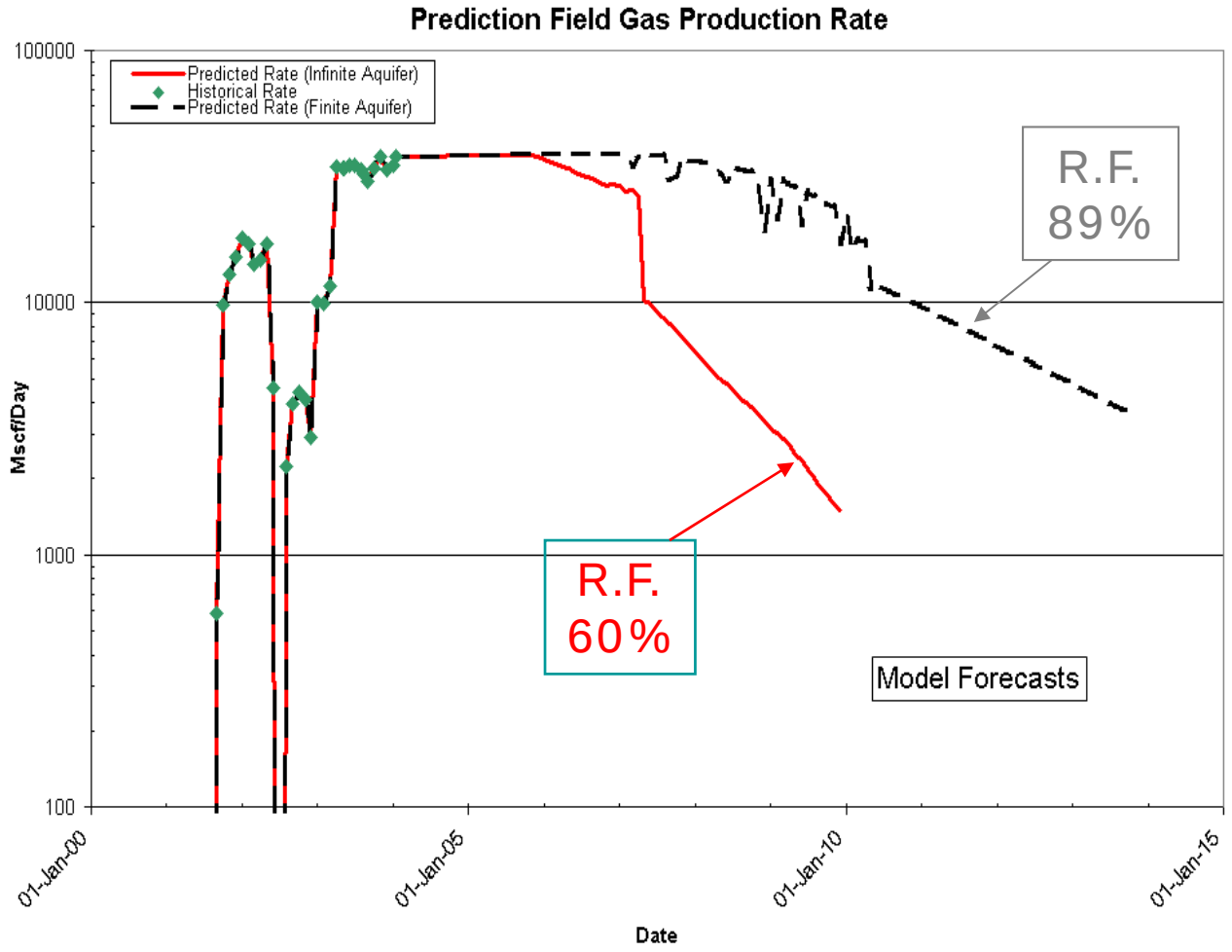


Reviews – Why?

- Decision Relying on Model
  - Production Planning and Scheduling
  - Reserves Estimation
  - Investment Decisions
  - Changes to Field Operations

- Is the Model Appropriate for these Purposes?

Reviews – Why?

- Necessary Because
  - Models are history matched
    - Changes to description are usually part of history matching
  - Controls used during model predictions are “flexible” and largely determine outcome
  - Most decisions are not made by people who are already intimately familiar with the model in question
    - Many times – there is no one available who was involved in the model construction or history matching!
  - Models can become stale and out of date, and no longer fit for purpose
  - Models are INEVITABLY used for purposes beyond those they were designed for

Reviews – How?

- Two main, separate facets of any model require consideration.
- Model Construction:
  - How accurate and detailed is the static model?
    - Does it honor observed data from well control?
    - Are the fluid treatments reasonable?
    - Does the grid have sufficient resolution to address the questions asked?
    - Is the initialization of the model reasonable?
    - Have wells placement and completed intervals been captured correctly?

Reviews – How?

- Two main, separate facets of any model require consideration.
- History Match:
  - Is the history match reasonable?
    - What data was used to match history?
    - How adequate is the match of the simulated values to the observed values?
    - What changes were required to the description during history matching to secure the history match? Are these changes justifiable?
    - How well does the model transition from history to prediction?

Reviews – How?
Tips & Tricks of the Trade

In reviewing history match consider whether changes are reasonable

- Parameters may be adjusted during history matching that have a modest impact on the history, but a significant impact on the prediction
- Simulation software allows changes to be made which may well be unreasonable
- History match changes may be appropriate for certain purposes but not for others
  - Modifying the properties immediately around each well individually
    - May be okay for forecasts of existing wells
    - Probably inappropriate for infill wells

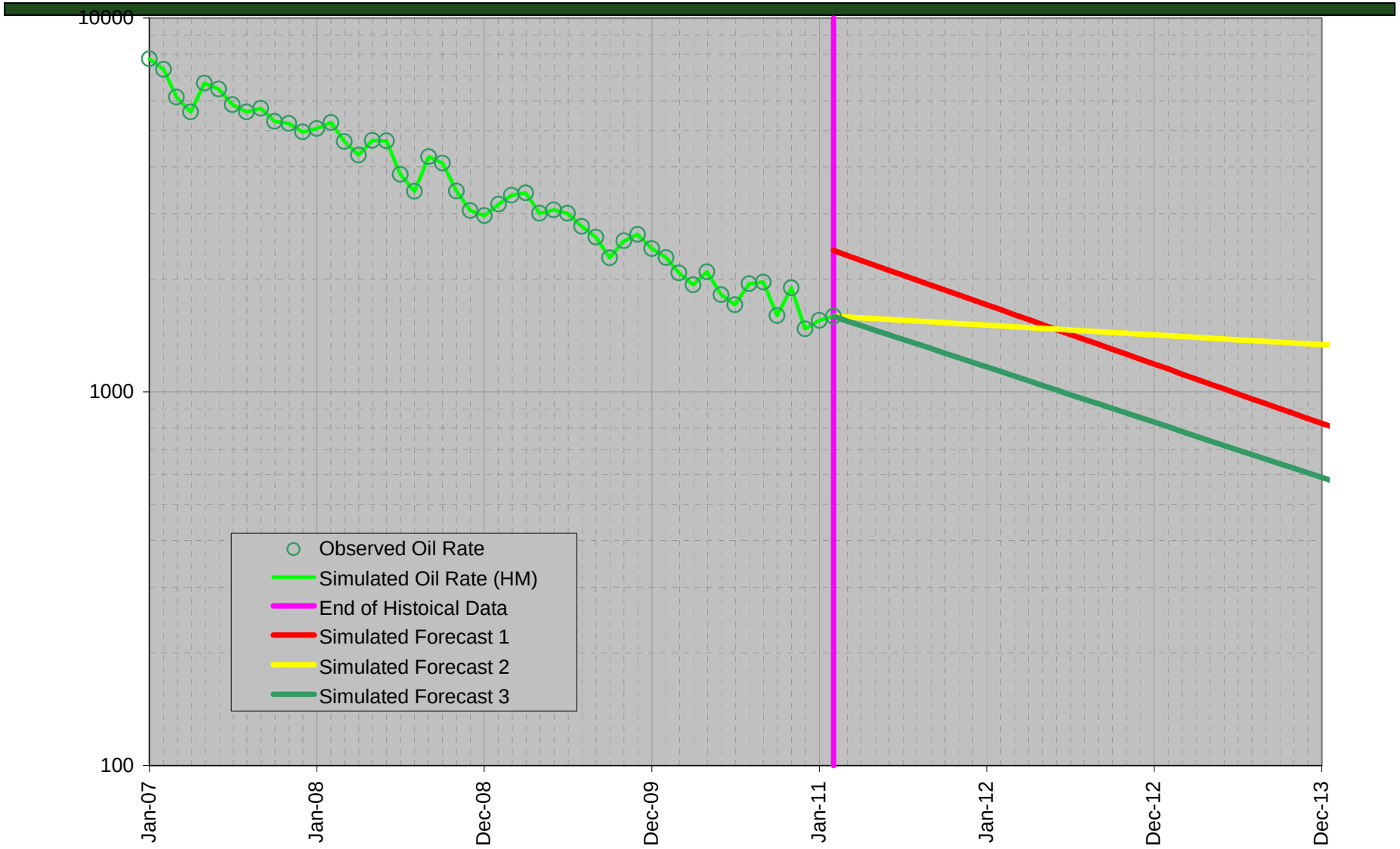
Reviews – How?
Tips & Tricks of the Trade

- Do not be tricked by very good matches of single phases, or cumulative volumes at the end of history
  - It is typical to fix the dominant phase's rate(s) so that the simulator must make those volumes
  - Cumulative volumes at the end of history can be matched while completely missing the boat on trends during history – therefore making the predictions less useful
- Always carefully review how the model transitions from simulation to prediction
- Always carefully review the "reasonableness" of the Status Quo Case

Status Quo Case

- Simulation Modeling has three primary phases:
  - Static Model Construction
  - History Matching/Calibration
  - Prediction
- When prediction starts, the controls imposed on the wells/group/field normally change from controlling on set rates to controlling on set pressures
- Often requires uncalibrated well productivities to be calibrated

Status Quo Case



Reviews – How?
Tips & Tricks of the Trade

- The results of a simulation model should be taken into consideration along with all other data available for the field under review
- The results of a model should not be used to replace good, reliable data or reasonable engineering judgment. Comparisons with traditional analytical techniques should be undertaken to provide the model with a much needed "reality-check"

Ryder Scott Publications

- Several papers by the Presenter and Associates on this topic
- Virtually no literature on the application of simulation results to reserves estimation
- 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"
- SPE 159274
  - "A Novel Simulation Model Review Process"

Questions