Type Well Analysis – Complexities and Analytic Techniques

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Where Are We Today in Type Well Construction?

Problem: Considerable anecdotal evidence suggests optimistic bias in type well construction and application

Solution: Identify and eliminate practices leading to optimistic bias

Why it matters: Many financial decisions based on production forecasts using type wells

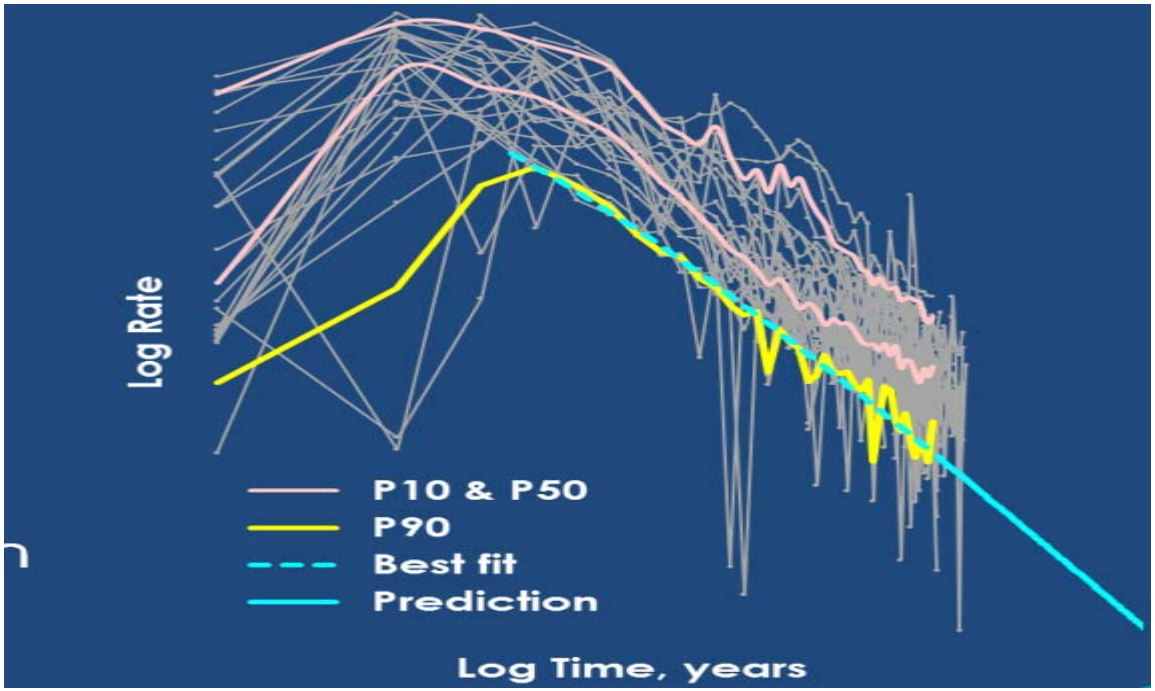
What is a “Type Well”?

- Short term for “typical well production profile”
- Plot of “expected” well production profile
  - Could be “mean” expectation
  - Could be P90, P50, P10 expectations
- Plot based on systematic averaging procedure of production data from wells with relatively longer histories

What's in a Name?

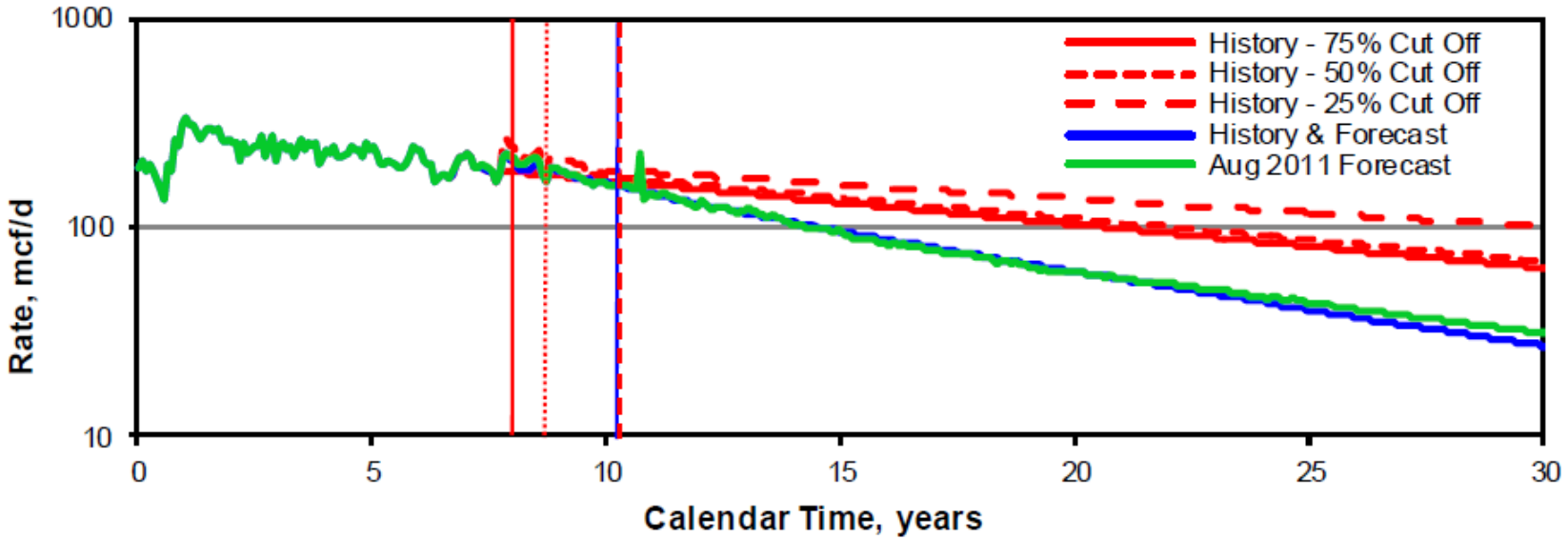
- A rose by any other name would smell as sweet … but … should it be "type well" or "type curve"?
- Name "type curve" dominates
  - **Problem**: *name already taken* (many decades ago, and continuing to present!) for plots of solutions to flow equations to which we compare field data to extract reservoir and completion properties
  - **Solution**: need unique name for our animal … like, perhaps, "type well"

Typical Data Available to Construct Type Well



R. Freeborn, SPE Distinguished Lecture 2016-2017

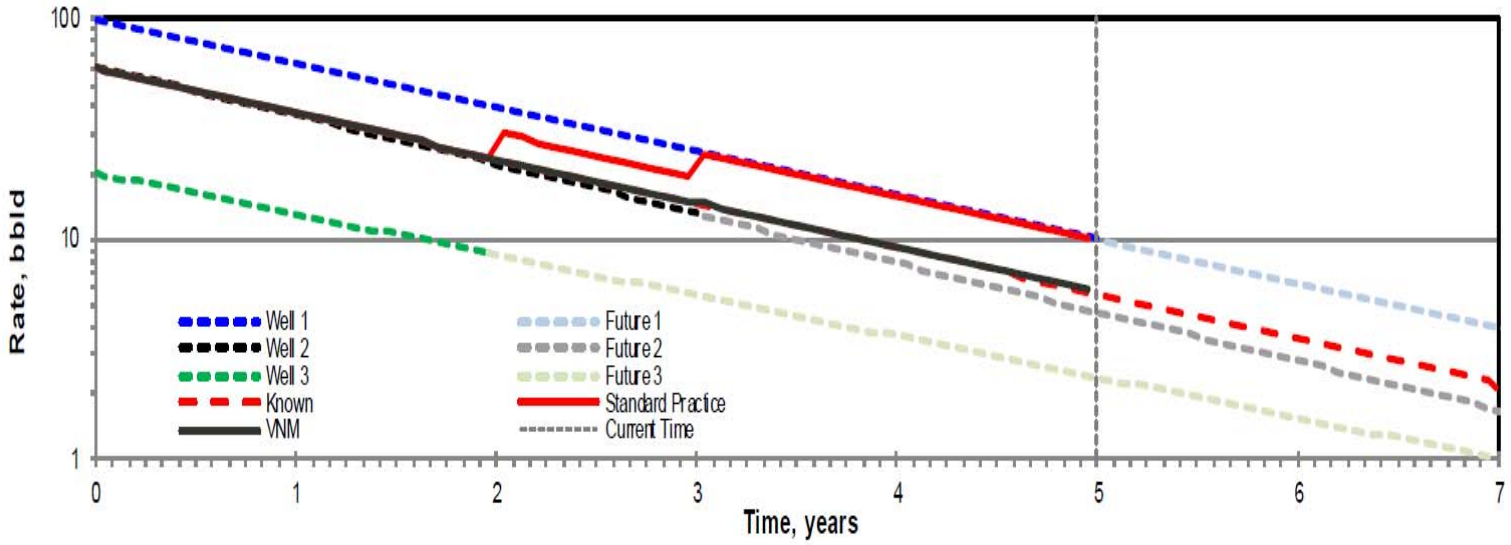
What Happens if We Use Only Historical Data (SPE 158867)?



	EUR mmcf	Error
Aug 2011 Forecast	1466	
10 Years of History		
History & Forecast	1439	-2%
History - 75%	1948	33%
History - 50%	2049	40%
History - 25%	2562	75%

Include Forecasts for Wells with Short Histories? Why?

- Excluding forecasts for wells with short histories ensures bias in type well (***Survivor bias*** – SPE 158867)

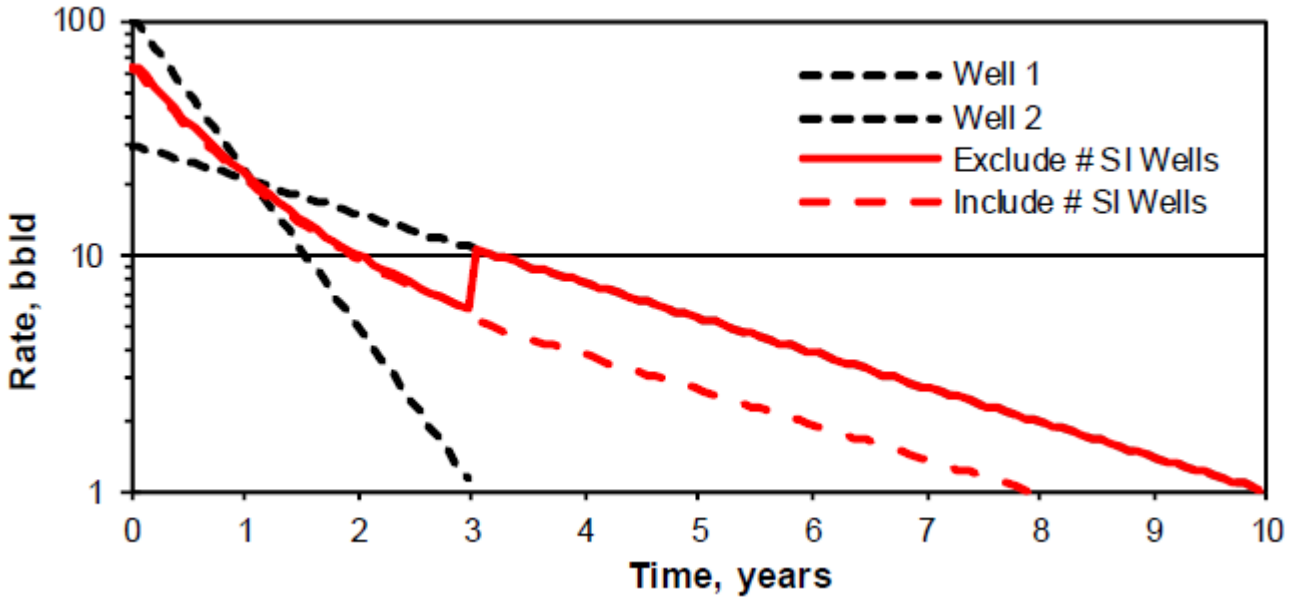


Why Consider Auto-Forecasting?

- Type well construction involves analysis of production histories of 100's or 1,000's of wells
- To achieve objective of including same wells in type well from start to finish, usually need to forecast production for many wells with shorter production histories, and usually need forecasts for all wells to economic limit or expected well life
- Manual forecasting prohibitively time consuming
- Auto-forecasts not foolproof, but rapid manual examination can eliminate unreasonable results
- See SPE 158867 for details

What? Include Abandoned Wells in Well Count with Zero Rate?

- Failure to include abandoned wells with zero rate ensures upward bias in type well (SPE 162631 --*survivor bias*)



Example Workflow for Type Well Construction: State Objective

- Identify objective of type well construction
- Examples
  - Wells with P90, P50, mean, P10 EUR
  - Single production profile with mean 5-year recovery
  - Single production profile with mean 5-year NPV10

Workflow for Type Well Construction: Select Wells

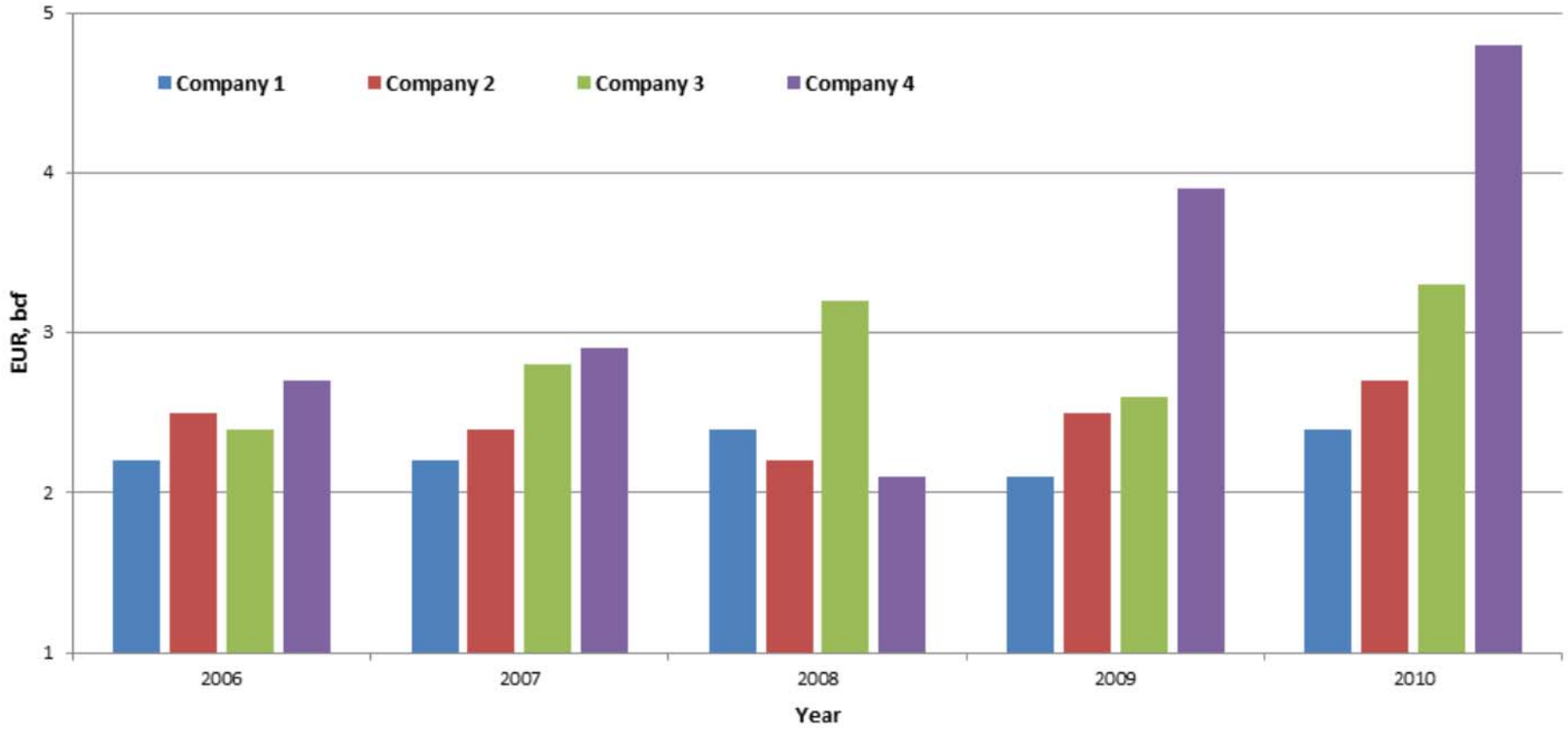
- Usually need ≥200 wells with clearly defined trends, minimum noise
- Place wells into distinct bins
  - When “binning,” need ≥50 wells per bin to ensure statistical confidence
  - Segregate wells by reservoir fluid type (dry gas, retrograde gas, volatile oil, black oil)

Possible Sorting Parameters

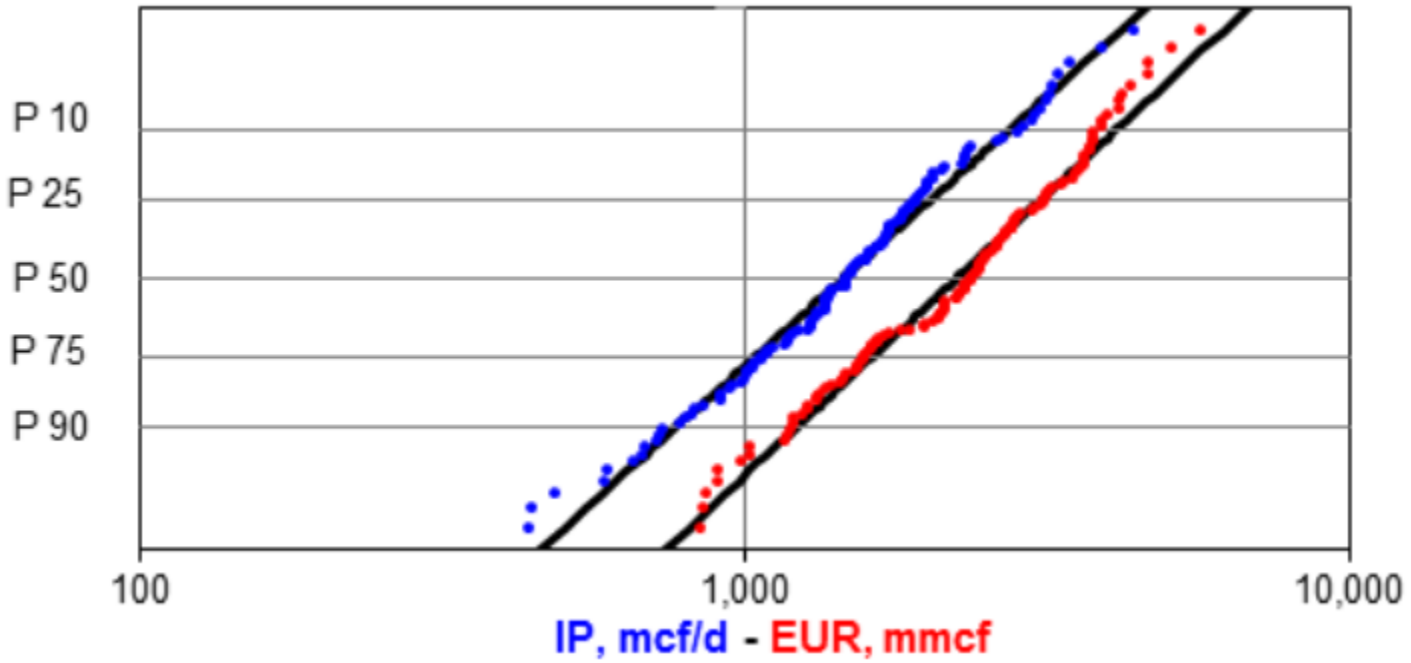
- Geological similarity
- Date of first production (vintage)
- Fracture size and fracture fluid type
- Completion technique
- Well location and spacing
- Operational practices
- Operator

Should We Sort Data by Operator? By Vintage?

Sometimes – SPE 158867 Barnett Study

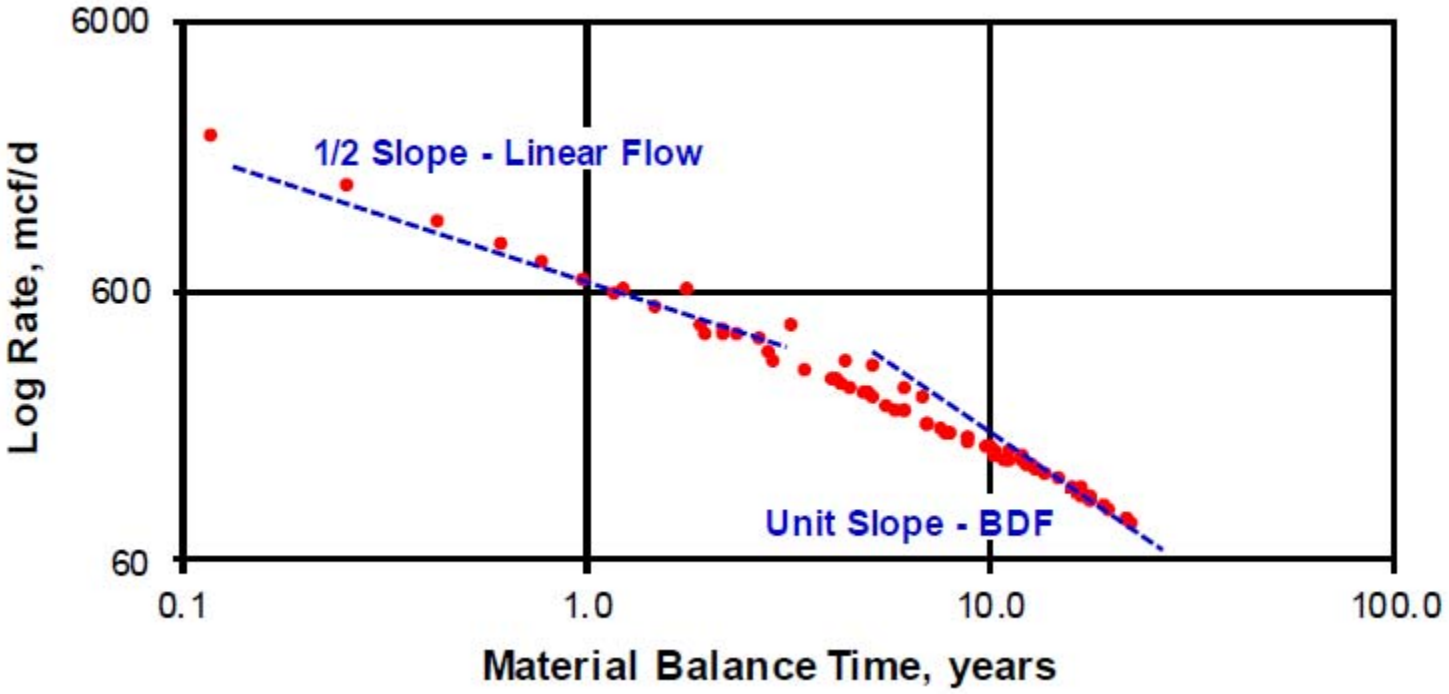


Check for Log-Normal Distribution within Bin

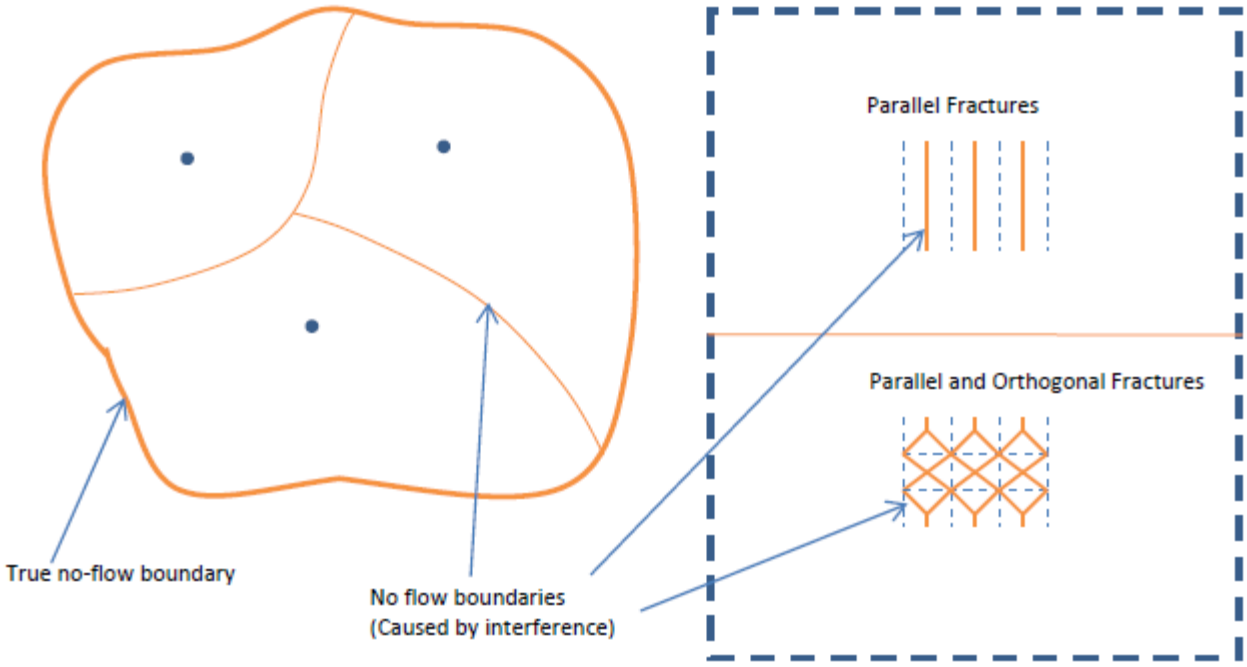


Prepare Diagnostic Plots

- Prepare log-log rate-time (or MBT) diagnostic plots for each well in sample set



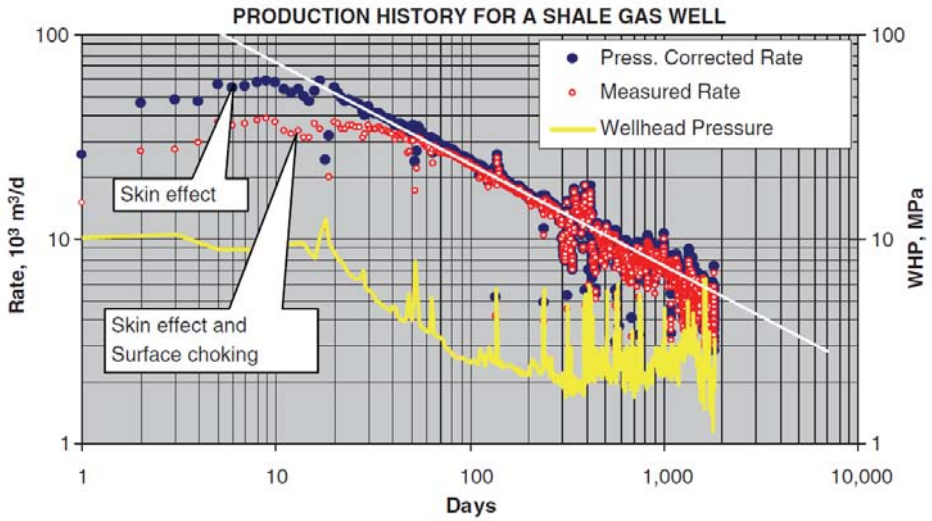
BDF Caused Mostly by Interference (SPE 131787)



Off-Trend Early Data: Develop Separate Type-Well Component

- Develop type well from peak rate forward
- Develop separate add-on segments for early data (important fraction of EUR – can't discard)

(SPE 137748)



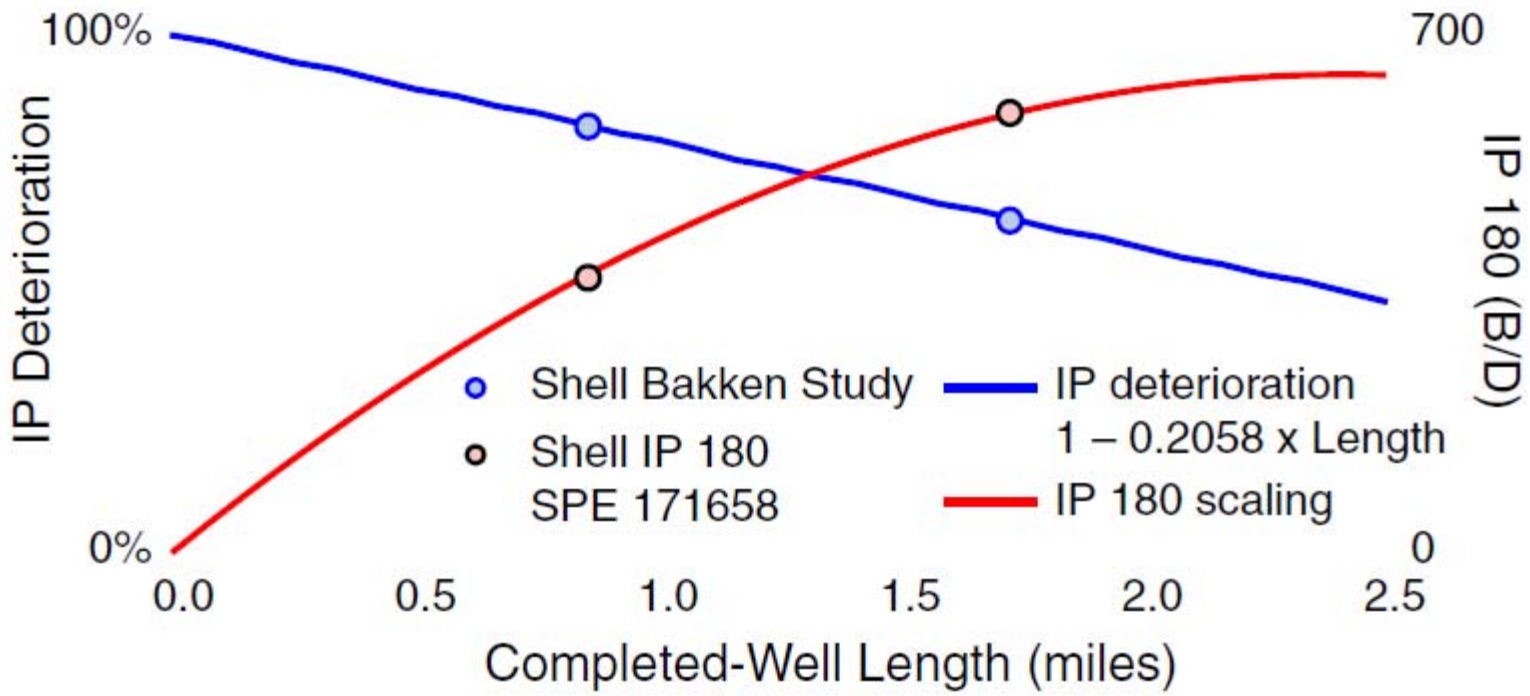
Identify Flow Regimes in Diagnostic Plot

- Early clean-up, choked flow (exclude from fit)
- Transient flow (usually linear)
- Boundary-influenced, boundary-dominated flow

Scale Data as Needed

- Minimize number of separate bins
- Maximize number of wells in each bin
- Example: Could sort by lateral length, but practice could lead to excessive number of bins

Scaling for Well Length (SPE 175967): *Not a Linear Relationship*



Sorting Based on Post-Peak Rate Well Performance

- Factors affecting performance at and following peak rate
  - Permeability-thickness
  - Number of fracture stages
  - Drawdown
- Time to end of linear flow dominated by permeability, fracture spacing
- Could sort wells by one of more of these factors, but need to limit number of bins

Time to End of Linear Flow Can Provide Scaling Factor for Perm

$$d_i = \frac{FS}{2} = \left(\frac{kt}{1896\varphi\mu c_t}\right)^{1/2}$$

Then

$$t_{elf} = \frac{1896\,\varphi\mu c_t\left(\frac{FS}{2}\right)^2}{k} = \frac{C_1}{k}$$

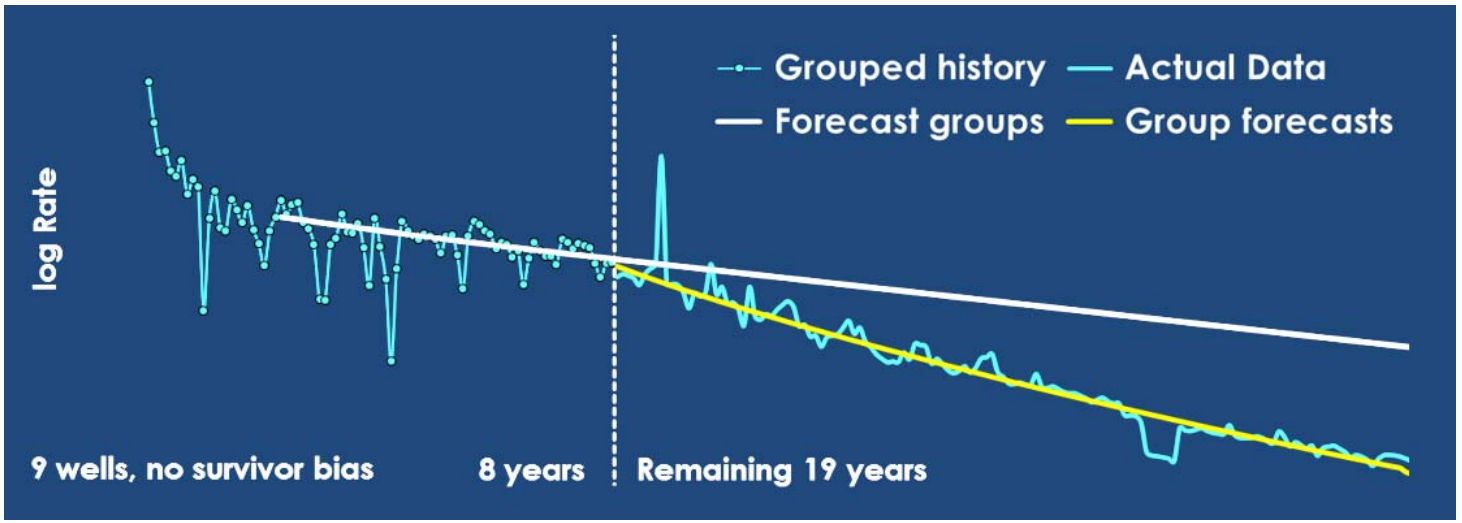
Productivity proportional to *k*, also providing scaling possibilities … see SPE 175967

Construct Type Well Profile for Each Bin to Meet Objectives

- Observe good practices in type well construction
  - Use reliable software, preferably capable of fitting and forecasting with 2-segment Arps decline model or other favorite model
  - Include abandoned wells in well count (with zero rate) to avoid survivor bias
  - Forecast wells with shorter histories to end of history for older wells (again, avoid survivor bias)

Observe Good Practices

- Forecast each well in data set separately, rather than combine all data and then forecast (results can be quite different)



(R. Freeborn SPE Distinguished Lecture, 2016-2017)

Observe Good Practices (Cont'd)

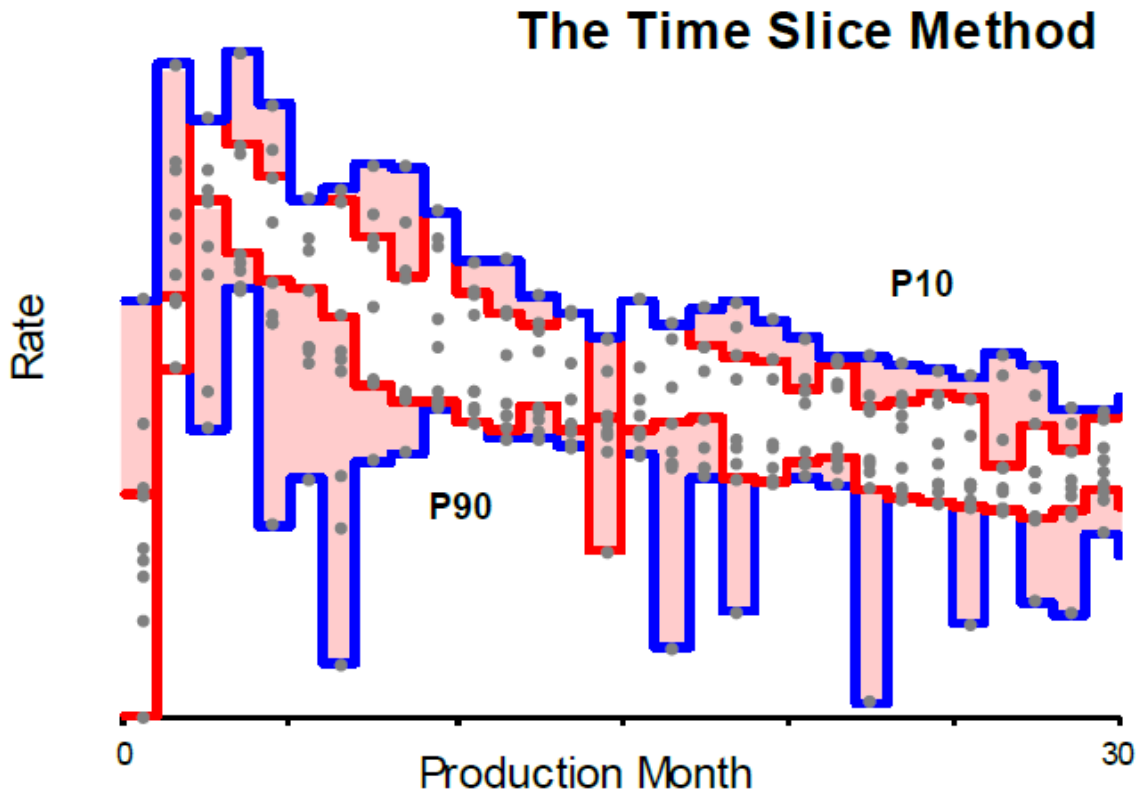
- When preparing personal spreadsheets to implement 2-segment Arps model, preserve smoothness in decline curve
  - Rate at end of transient segment = rate at start of boundary-influenced segment
  - Slopes of decline curve segments (related to decline rate) same at transition point
  - Reset time to zero at start of second segment

Observe Good Practices (Cont'd)

- When selecting production profiles for wells of interest (e.g.,P90, P50, P10), choose actual wells with those probabilities of outcomes (e.g., forecast EUR, 5-year NPV)
- Avoid common, but incorrect "time slice" method
  - Time slice method: Reordering monthly production, largest to smallest, each month, regardless of individual wells involved – production histories for individual wells cross continuously

What's Wrong with Standard Industry (Time Slice) Method?

- P90 too low, P10 too high (SPE 167215)

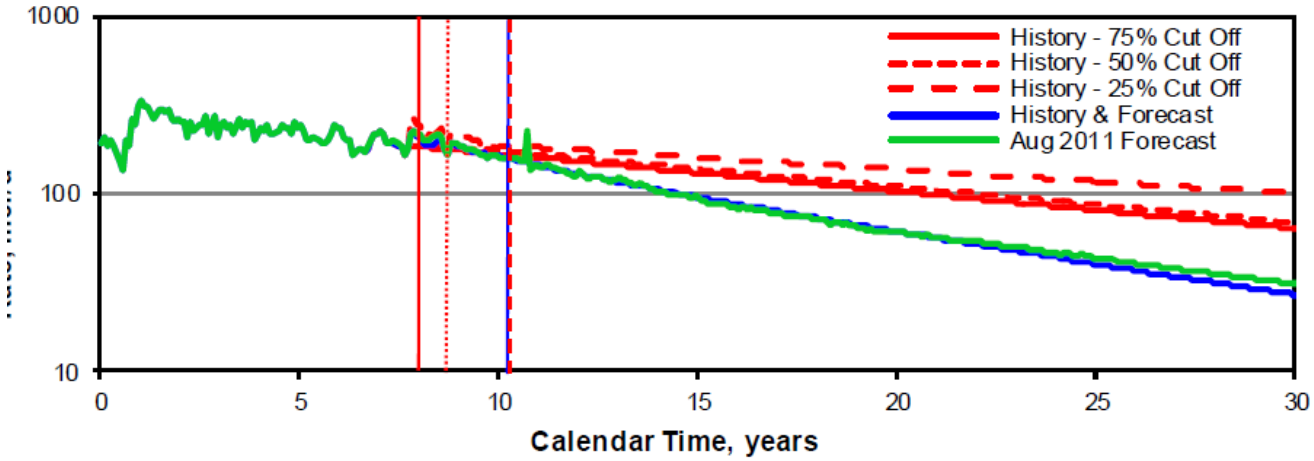


Observe Good Practices (Cont'd)

- To obtain accurate P90, P50, P10 values, use software based on good practices identified in literature to date instead of time slice method
- Example (SPE 175967): Aggregation type wells
  - See paper for details

Workflow for Type Well Construction: Validate Results

- Hindcasting useful
  - For selected wells in area not in sample used to construct type well(s), predict later part of history given earlier part



Summary of Workflow

- Identify objective of type well
- Select wells to use in type well construction, consistent with objective
- Place wells into bins with ≥50 wells
- Scale as needed to normalize well production

Summary of Workflow (Cont'd)

- Observe good practices
  - Forecast each well separately, rather than group and then forecast
  - Avoid survivorship bias
    - Include abandoned wells (with zero rate) in well count
    - Forecast future production for wells with short histories
  - Avoid "time slice" method
  - Validate results

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