SEDA
Statistically Enhanced Decline Analysis Leads to Better Estimates for P10/P90

ENERGY NAVIGATOR

A better way.

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Objectives

Develop a decline method for wells with historical production.

Incorporate producing life in EUR estimates to improve accuracy.

- Combine statistics with a measure of the change in EUR estimates over time to enhance reserve valuation.

Honour reserve definitions.

- Ensure that the quantities actually recovered will equal or exceed the estimate.
- Provide a method to fulfill these certainties without bias.

Improve certainty by including well count (aggregation).

- Develop a method to incorporate the benefits of aggregation to decline analysis.

Problems

Proven + Probable Reserves (50% certainty)

- A production decline is a *best fit* forecast.
- The decline trend hints at the likeliest case (P50), but does not honour its definition, thus failing the certainty criterion.
- Bias may also impact the *best fit* forecast.

Proved / Possible Reserves (90% / 10% certainty)

- The most common reserve category reported is Proved.
- There is no method to ensure the prescribed certainty.

Tweak the P50 — Fit a pessimistic trend

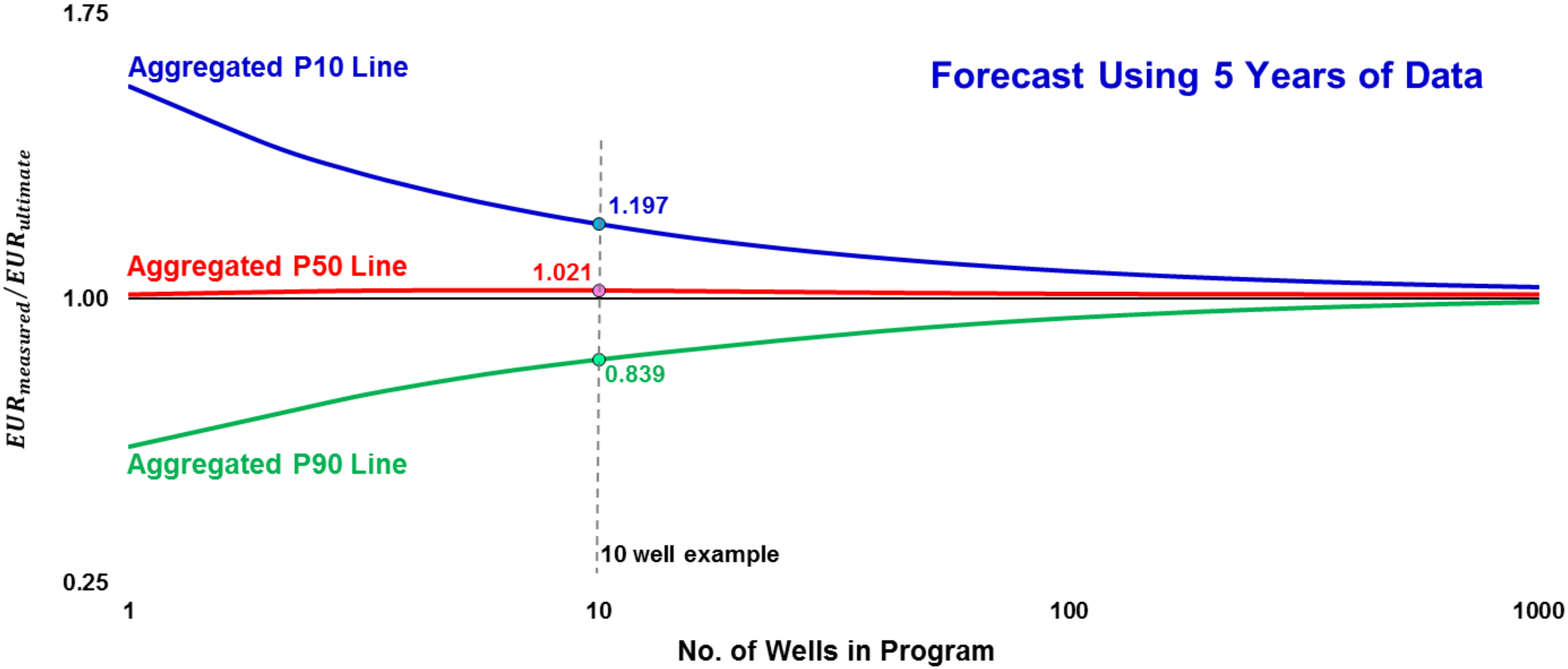
Alter the Arps' exponent — Adjust terminal declines

Specify reserve ratios — Use analogs

…. But mostly we just guess (engineering judgement)!

- Aggregation benefits cannot be realized.
- Declines cannot satisfy reserve definitions.

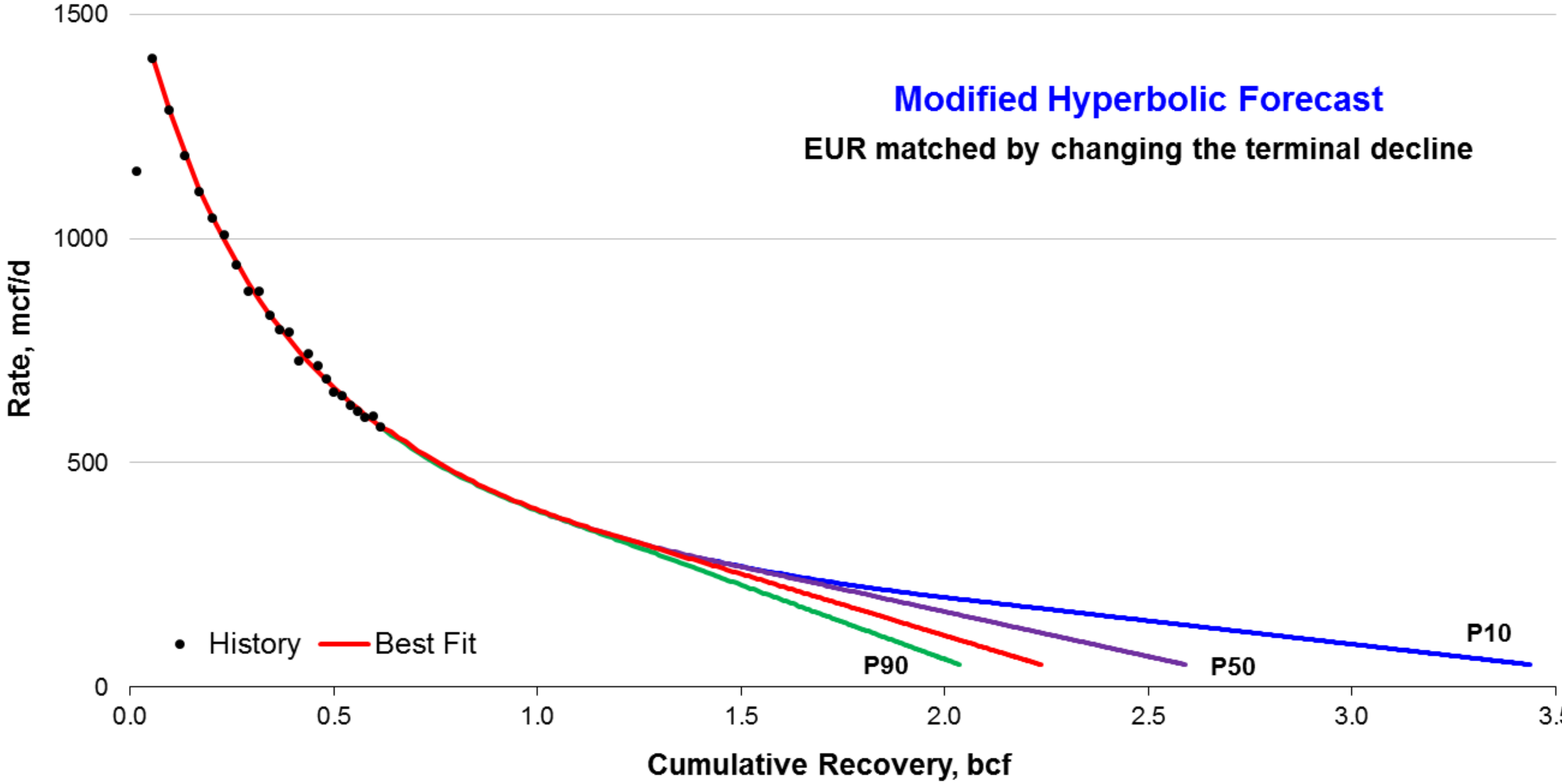
Our Solution - Statistical Enhanced Decline Analysis



Create & Use Trumpet Plot

- Use the best decline and the P50 curve to calculate known EUR
- Use known EUR to calculate P10 & P90 EUR

Our Solution - Statistical Enhanced Decline Analysis



Adjust best decline forecast to match
P10 / P50 / P90 EUR calculated using the Trumpet Plot

Presentation Topics

Forecasting and Statistics

- General comments.
- What do we learn from the statistics?

Aggregation

- The use of Monte Carlo to incorporate aggregation into the Trumpet plots.

How does SEDA work

- An example of the calculation procedure.
- Impact of SEDA on P90.
- Testing the hypothesis. Does the method deliver on its promise?

Wrap Up

- Observations
- Next steps

Forecasting and Statistics

General Comments

849 Barnett Shale wells.

- Early wells with 8 to 14 years of history.

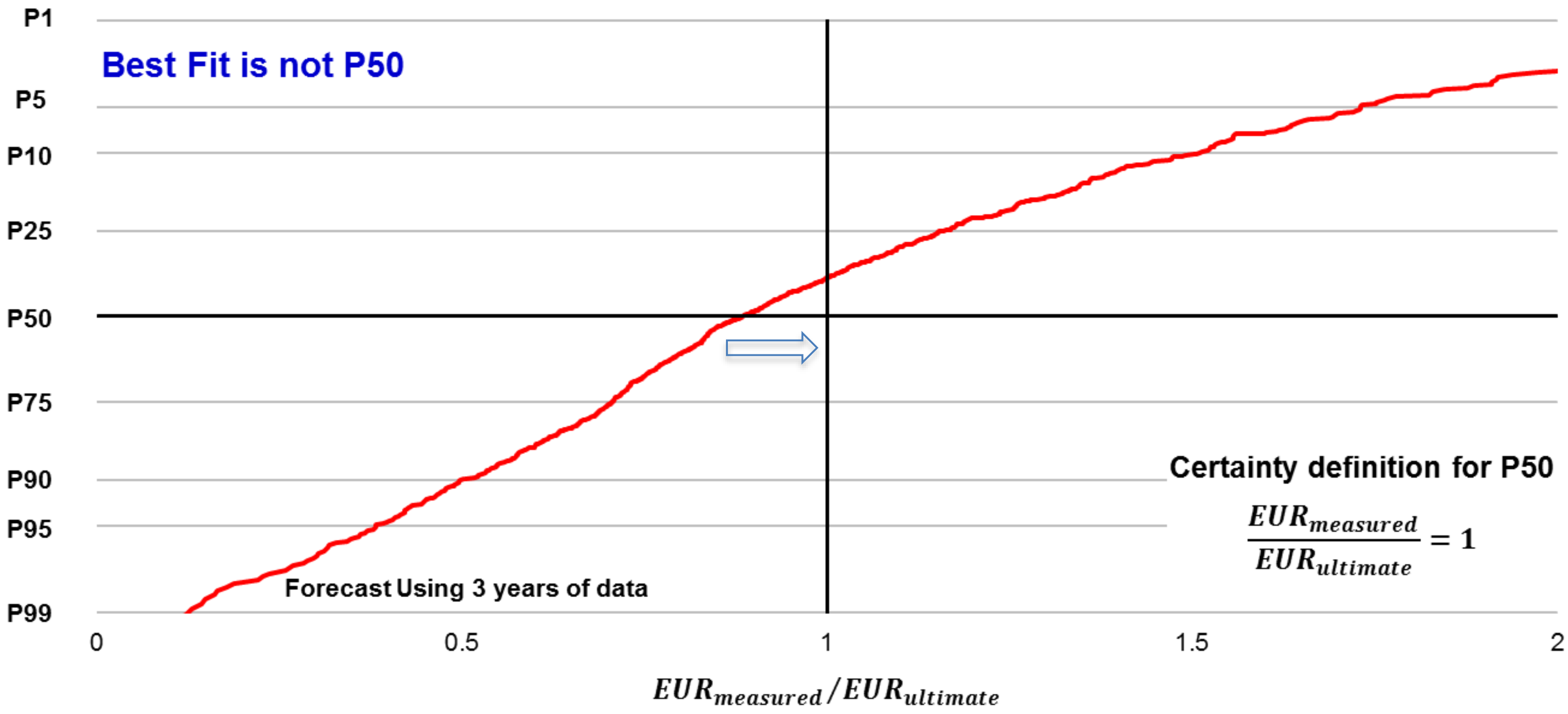
Forecasts

- Automatic forecasts, few manual adjustments were necessary
- 9 forecasts per well at specified time intervals
  0.5 / 1 / 2 / 3 / 4 / 5 / 6 / 7 years and all data
- Analog forecasting used with 0.5 and 1 year of data
- Limiting decline 10% for 2 years 7.5% for 3 years 5% for > 3 years

Consistency

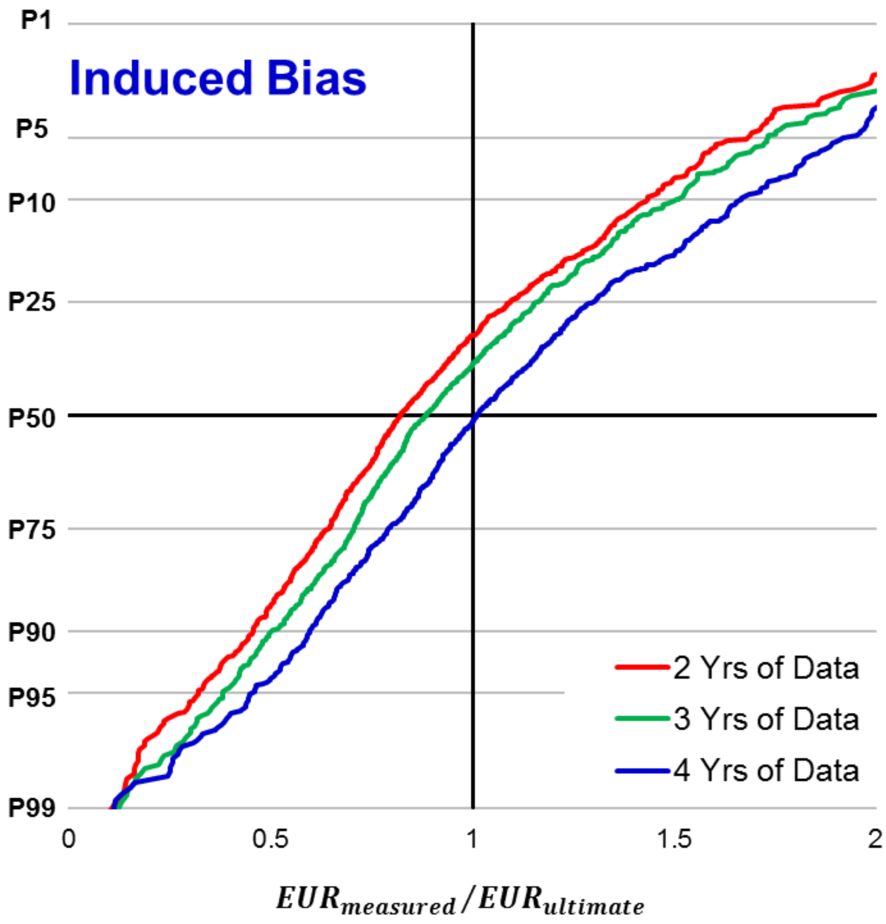
When creating Trumpet plots, forecasting standards are used.
When applying the Trumpet plots, use the same standards.

Revealed from Statistics



- The distribution requires translation to meet P50 certainty.
- The evaluator's best estimate is not always P50.

Revealed from Statistics



Bias reduces from left to right.

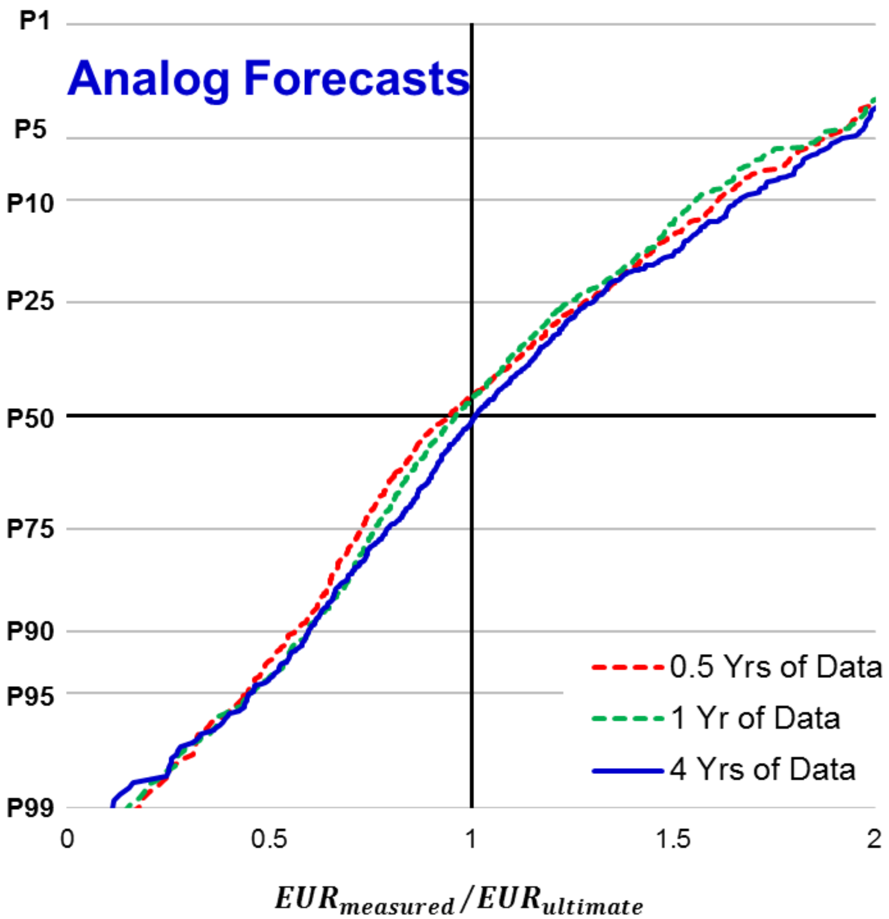
- The evaluator introduced bias by changing the limiting decline over time.

  10% to 7.5% to 5%

- We recommend correcting the bias by requiring that P50 have an EUR ratio = 1.
- Bias correction will result in similar distribution for the 3 years of data shown.

Forecast accuracy is not improving with more data. (slope is constant)

Revealed from Statistics

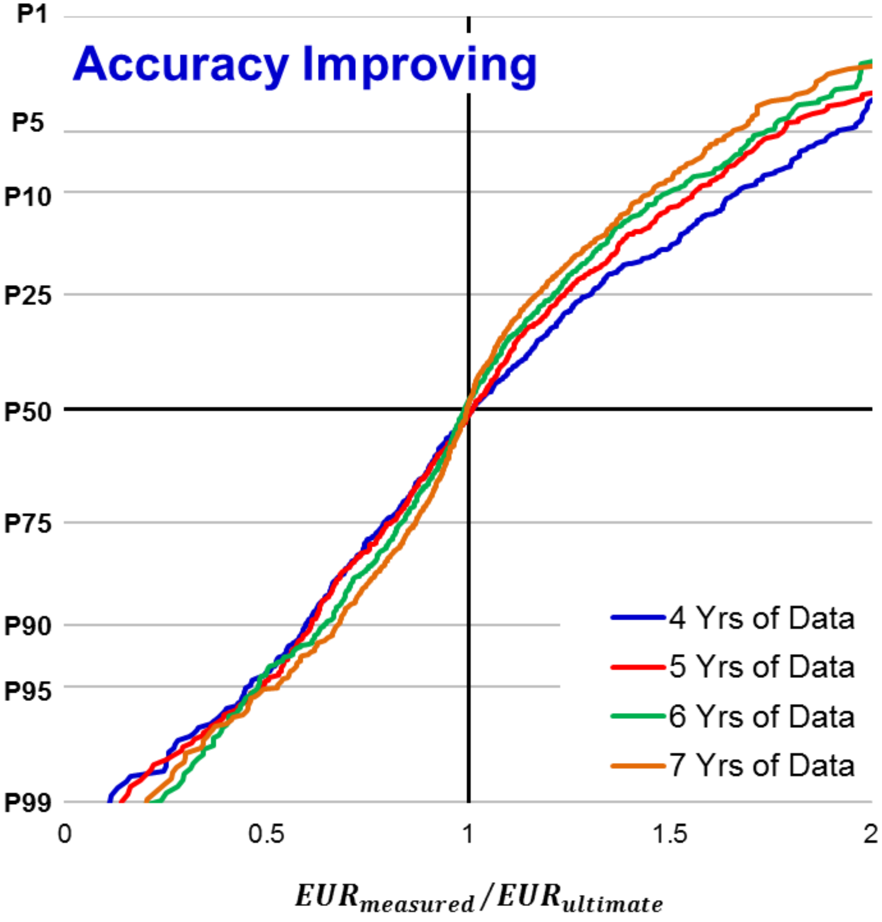


Analog Forecasts (SPE 167215)

- Why?
  - Declines were of low quality for 0.5 and 1.0 years of data (not shown)
  - Best practice is to use Analog Forecasts when there is little data

With less data, analog forecasts are better. (Slope is slightly steeper)

Revealed from Statistics



How much data is needed?

- With 5 years of data the accuracy is starting to improve (steeper slope)
- With 7 years of data the spread in forecast accuracy remains large

  ratio =1.4 P10 to P50

  ratio = 0.6 P90 to P50

Individual well forecasts are not very accurate, even with 7 years of data.

Using Monte Carlo to Incorporate Aggregation

Aggregation

- Used because individual well forecasts are unreliable.
- Evaluate multiple wells as a single entity.
  Calculate EUR ratio for aggregated data.
- Aggregation improves accuracy
  Differences from individual wells tend to cancel out.
  (SPE 158867).
- Use Monte Carlo to create distributions of EUR ratio for randomly selected aggregated well groupings.
- Trumpet plots show EUR ratio distributions for various aggregated well counts.

Aggregation Example – Step 1

5 years of data **Drill: 10 wells**

- Randomly select 10 wells from the single well probability distribution.
- For these 10 wells, calculate the aggregated EUR ratio:

$$EUR\ Ratio = \frac{EUR_{measured}}{EUR_{ultimate}}$$

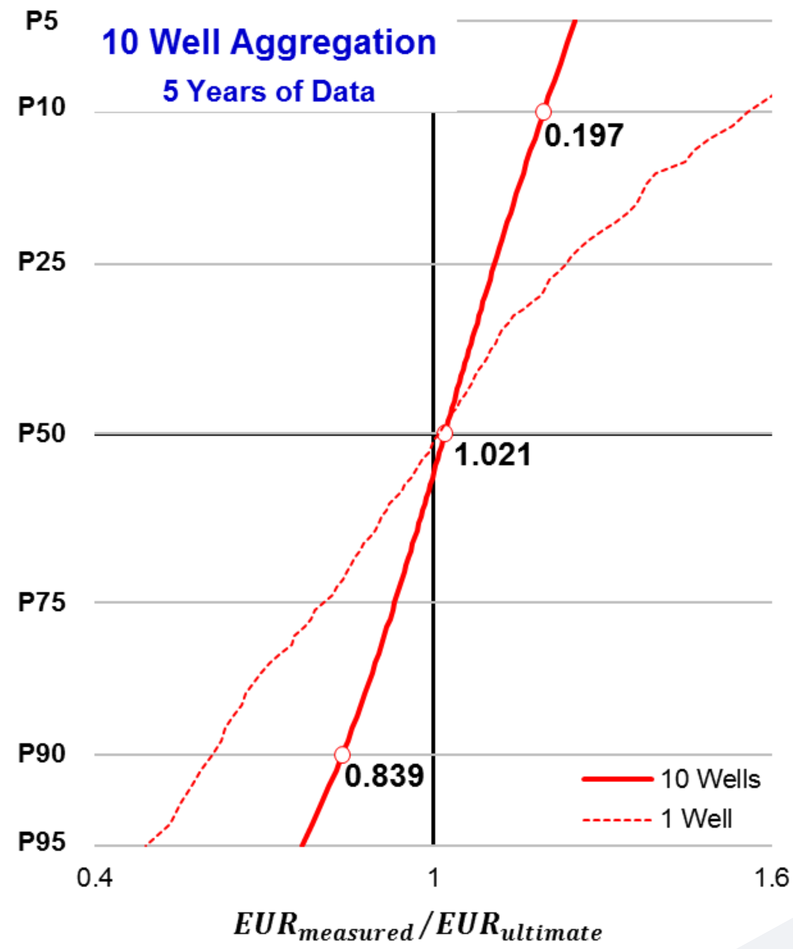
- Repeat the 10 well process for one million trials.

Well	Measured EUR	Ultimate EUR
1	181	206
2	134	145
3	355	429
4	494	374
5	439	545
6	429	1296
7	468	603
8	1209	2000
9	537	709
10	1383	2171
Total	5927	8478
Mean	593	848

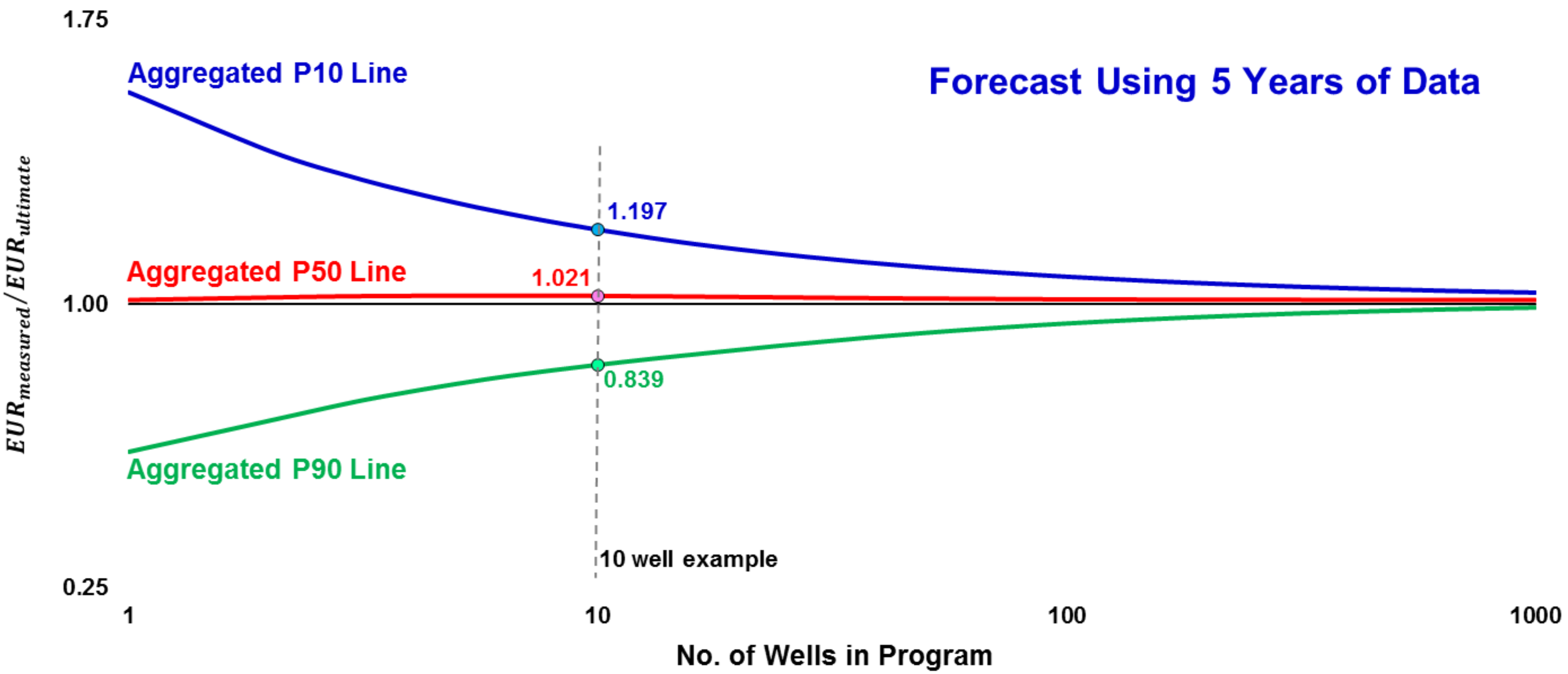
$$\boldsymbol{EUR\ Ratio = \frac{5927}{8478} = 0.699}$$

Aggregation Example – Step 2

- Sort the mean EUR ratio from the million trials.
- Review of the distribution (optional)
  - Assign cumulative probability.
  - Plot the distribution of mean EUR ratio using a probit scale.
- Select the aggregated EUR ratios at the desired probabilities.
- Selected points represent one well aggregation slice on a trumpet chart (to be shown on next slide).



Trumpet Chart – Multi-Well Aggregation



- Aggregation narrows the difference between P10 and P90.
- P10/P90 ratio decreases, accuracy improves.

How Does SEDA Work?
Calculation and Verification

Calculation Procedure

Example Well:	Production history:	5 years
	Aggregation:	Part of 10 well program
	Best fit EUR:	100

From Trumpet Plot: Get EUR ratios

P10 = 1.197 P50 = 1.021 P90 = 0.839

Solve for EURs $EUR\ Ratio = \frac{EUR_{measured}}{EUR_{ultimate}}$

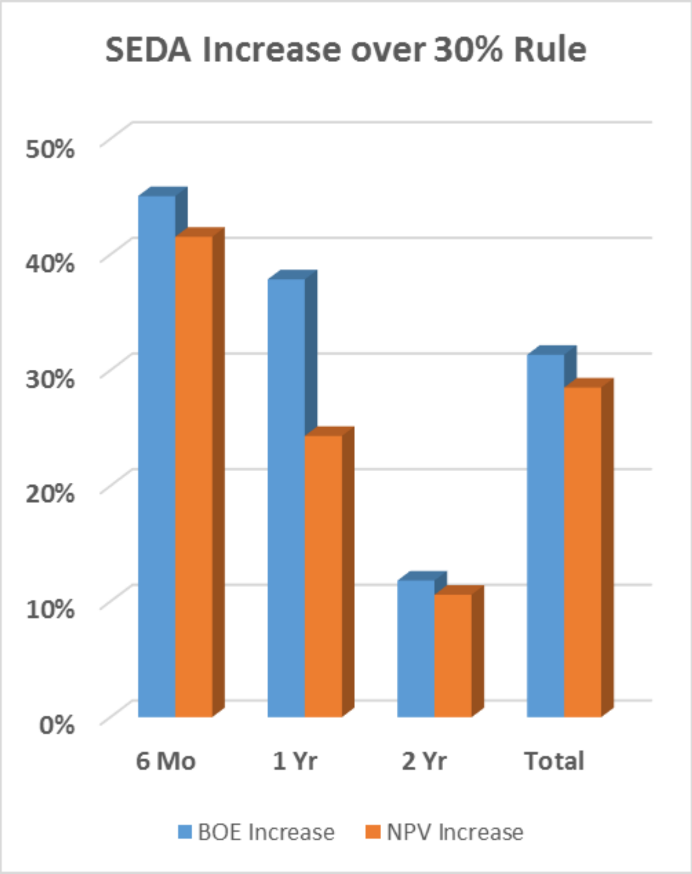
- For P50 EUR $1.0021 = 100/EUR_{ultimate}$ $P50 = 97.9$
- For P90 EUR: $0.839 + (1 - 1.021)^{note} = P90/97.9$ $P90 = 80.1$
- For P10 EUR: $1.197 + (1 - 1.021)^{note} = P10/97.9$ $P10 = 115.2$

note: Adjust P90 and P10 for shift in distribution to correct bias.
Use the sign of the RD determine the denominator.

Impact of SEDA

- 9 random Barnett wells.
- Between 6 months and 2 years of history.
- Evaluated using the following process:
  - Best fit forecast all wells.
  - Scenario 1: Reduce best fit forecast by 30% to adjust for P90 (typical evaluator practice).
  - Scenario 2: Use Trumpet Plots (SEDA) to predict P90 assuming a 100 well aggregation.

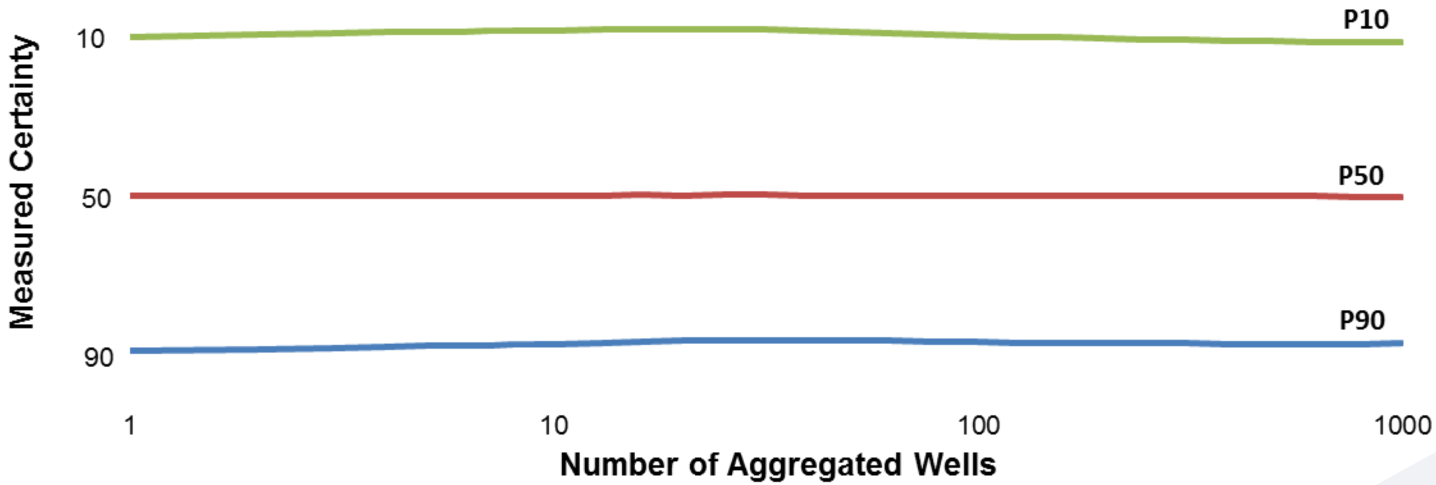
  Common price, costs and lease interests.



- **As shown, the impact of SEDA is dramatic, especially for newer wells.**

Verification

- Tested 100's of data combinations, with a million trials each
  - We varied the number wells in the aggregation
  - Each trial used a different sample of wells
  - The years of data to forecast was randomly chosen for each well
- We counted how many times the certainty definition was honored
- **S**tatistically **E**nhanced **D**ecline **A**nalysis delivers its promise



Workflow

- Use or create a suitable series of Trumpet plots for each project.
- Identify projects suitable for aggregation and count wells.
- For each well in the project.
  - **Best fit to get base forecast & EUR.**
  - **Trumpet plots.**
    - obtain the EUR ratios for P10 / P50 / P9.0
    - interpolate as necessary for mid-years.
  - **Relative Difference equation.**
    - Calculate P50 EUR (adjusts for bias to get ultimate EUR).
    - Calculate P10 & P90 EUR.
    - Adjust the best fit to match new EURs i.e. $b, d_i, d_f, other$
- Your reserve software should easily automate this workflow!

Wrap Up

Observations

- Individual well forecasts have a bias that needs to be corrected.
- Even with 7 years of data, individual well forecasts are not very accurate.
- Forecasts for new wells will be more accurate with Analog Forecasting. (SPE 167215)
- Aggregation increases EUR accuracy.
- It was proved that the distribution of relative difference can be used to estimate P10/P50/P90 from a *best fit* forecast.
- The P10/P50/P90 relative difference range is influenced by the number of wells and the number of months on production.
- **Until now, we have not seen the application of probabilistic methods to estimate deterministic reserves.**

Where Do We Go from Here

- Test SEDA with different plays to confirm the range of applicability.
- Investigate methods to alter the *best guess* decline to match the new EURs.
- Automate the process to generate P90/P50/P10 forecasts from *best guess* declines.
- Need feedback from producers, reserve evaluators and regulators.

Thank You

Questions?