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Two Vital Secrets for Building Accurate Type Wells

Randy Freeborn

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ENERGY NAVIGATOR
A better way.

2

AGENDA

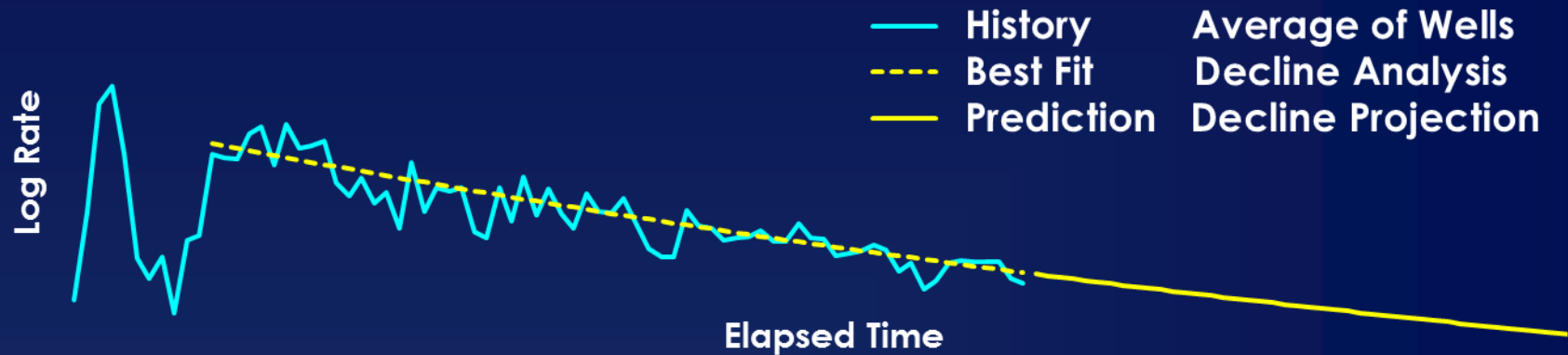|	
TYPE WELL	What is a type well
	The challenge
1st SECRET	All type wells
	3 Inherent Errors
	Case Study
2nd SECRET	Probability type wells
	Time slice method
	Aggregation method
	Comparison
WRAP UP	

TYPE WELL What is a type well?

Rate-time production profile

Shift representative wells to a common start date

Average them to represent new wells

Common method comprised of two parts

- History   average rate until too few wells
- Prediction   projection of best fit of history

TYPE WELL   The Challenge

Dr. Lee, 2015 Reserve Summit

- *SEC's experience (circa 2008)
  type wells exceed results by about 25%.*

2013 Proprietary Research Report

- *Drilling results did not meet the objectives set out
  in 40 of 100 published play specific type wells.*

- *Only 14 of 40 companies consistently met targets.*

Personal Experience

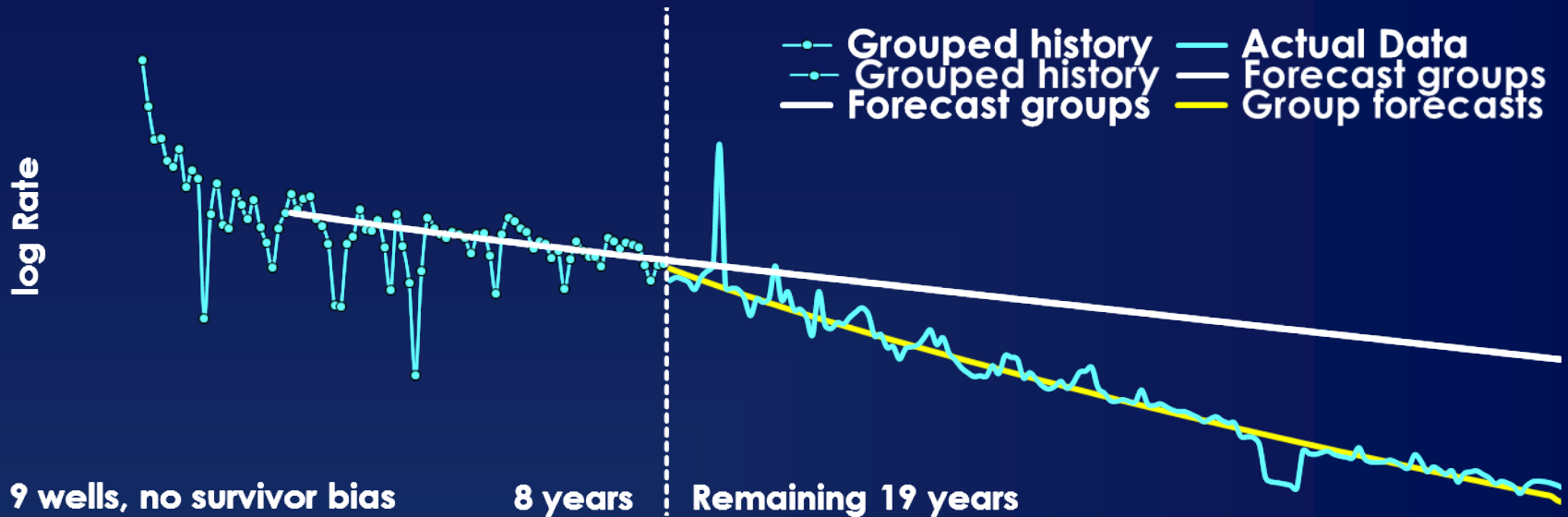- *EUR more likely to be over estimated, as much as 40%.*

Pervasive … Capital Intensive … Errors

1st SECRET

Applies to All Type Well Methods

FORECAST EACH WELL
THEN AVERAGE HISTORY & PREDICTION

3 ERRORS #1 Forecast Groups

Forecast Groups
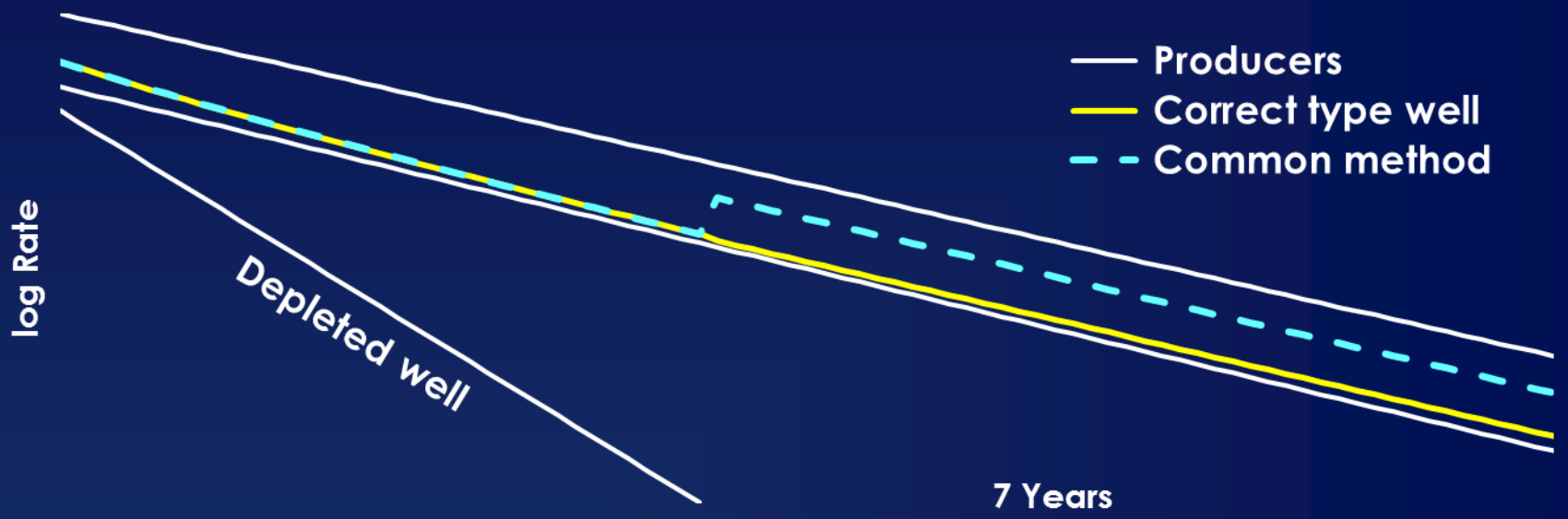
Usually no clear trend
High quality best fit
Bad business decision
Grouping masked a trend

Group Forecasts

New trends are visible
Forecast errors cancel
Accuracy improves
Type well is accurate

3 ERRORS   #2 Survivor bias

Legend:
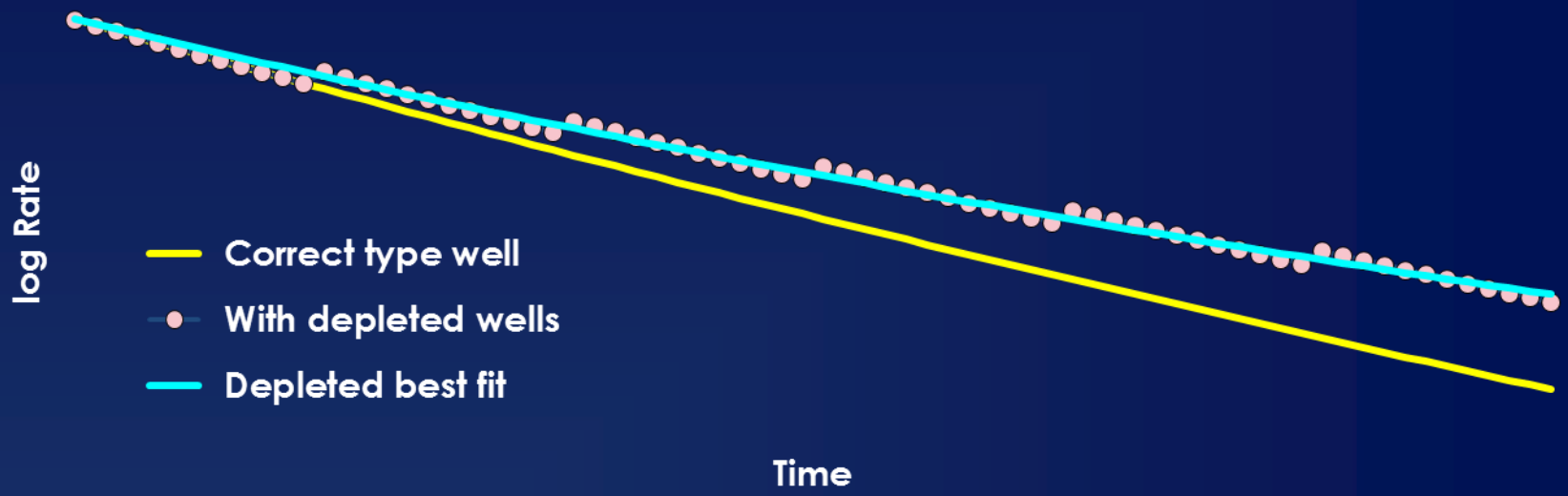- — Producers
- — Correct type well
- – – Common method

log Rate

Depleted well

7 Years

Common method	Depleted rate = type well rate Creates false rate and reserve
Correct treatment	Each well must have a rate

3 ERRORS   #2 Survivor bias

Correct type well — yellow line
With depleted wells — pink dots
Depleted best fit — cyan line
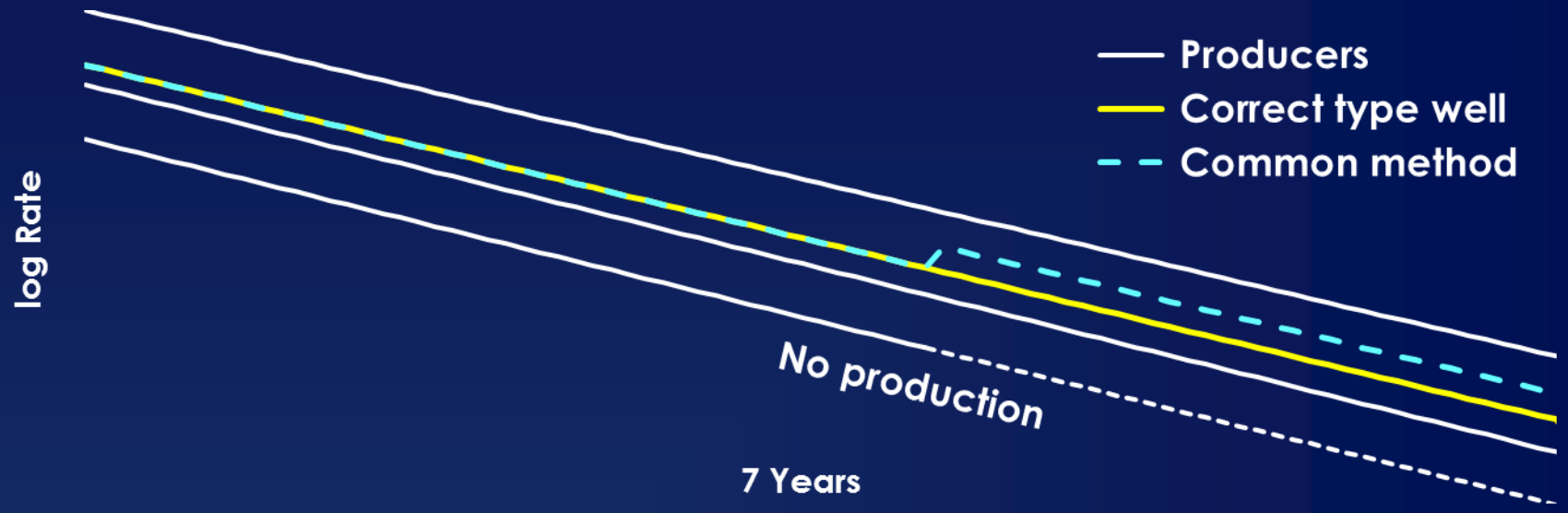
log Rate (y-axis)
Time (x-axis)

Common method   Compounding effect

3 ERRORS   #3 No production

Common method   Well rate = average rate
Best wells drilled first

Correct treatment   Include every well
Use best available forecast

AVOID ALL 3 ERRORS
Forecast, then average history & prediction

3 ERRORS Numerical example

Well	Monthly Production Rate			
	Month 23	Month 24	Month 25	Month 26
1	1200	1100	1000	900
2	1000	900	800	700
3	35	25	no prod	no prod
Field Total	2235	2025	1800	1600
Type Well	2235 / 3 = 745	2025 / 3 = 675	1800 / 2 = 900	1600 / 2 = 800
Drill 3 Wells	3 x 745 = 2235	3 x 675 = 2025	3 x 900 = 2700	3 x 800 = 2400

CASE STUDY 88 Hugoton Kansas wells
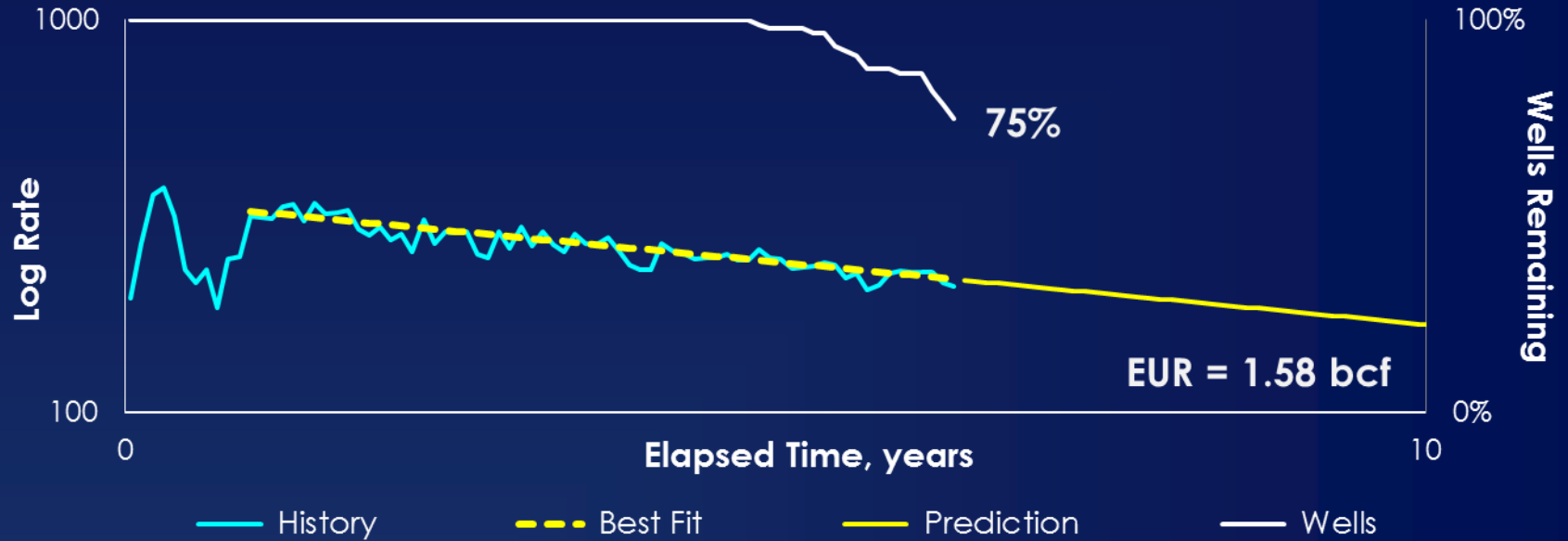
Data truncated   5 years drilling + 5 years producing
Cut off   Stop when too few wells
Type well   Looks reliable
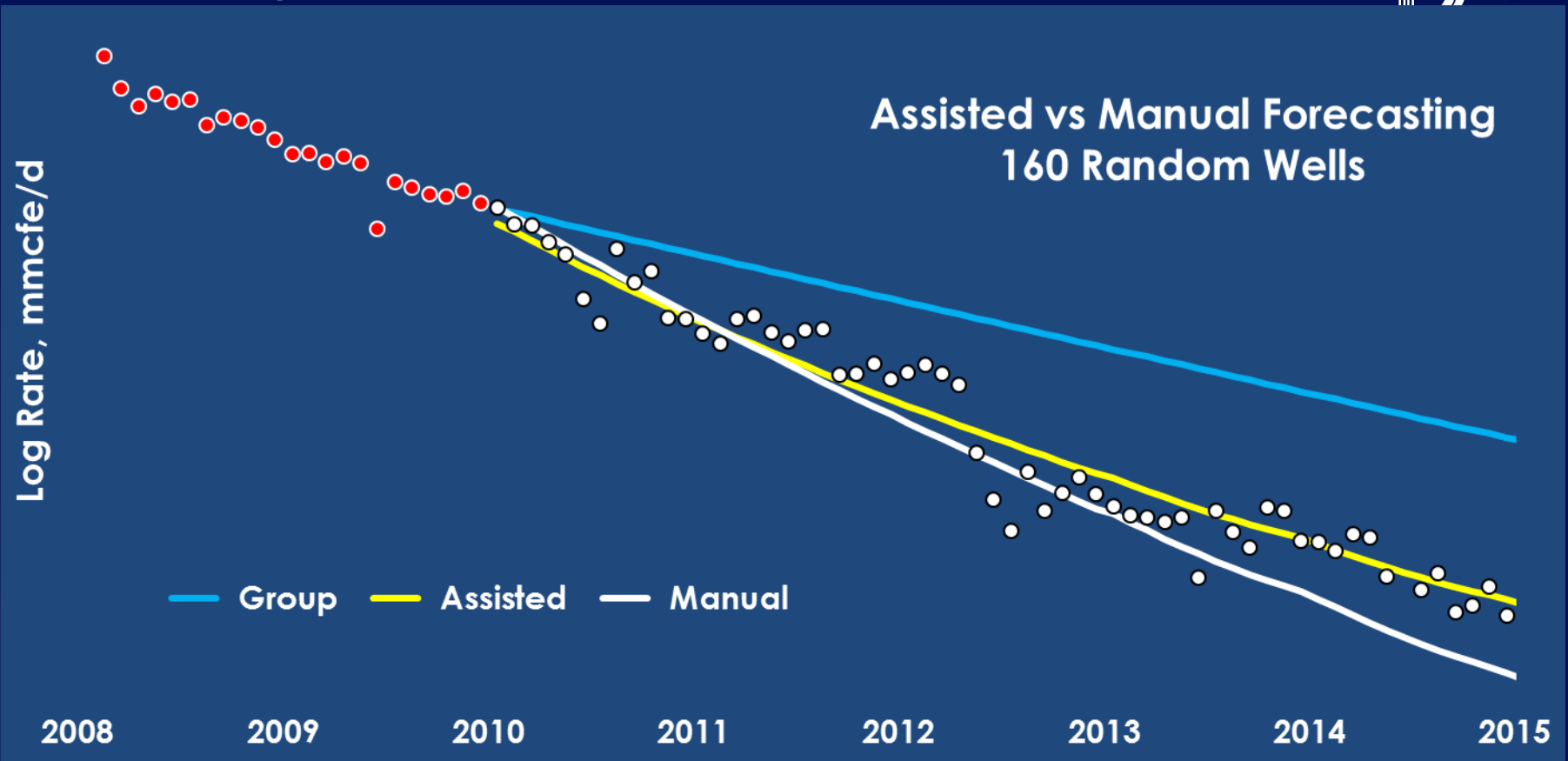
CASE STUDY 88 Hugoton Kansas wells

Legend:
- Data to Nov 2014
- Average history & prediction
- Common method (75% cut off)

Range of common methods

Log Rate · Time, years
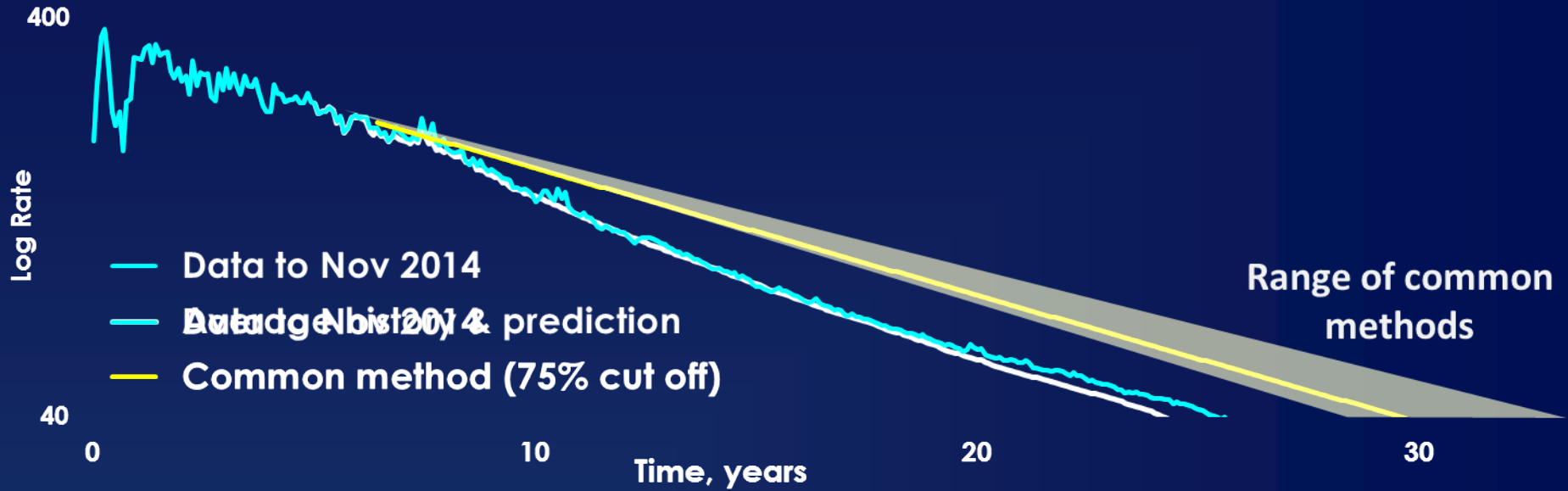
To Dec 1996	History Only Cut Off			History & Prediction	Known Nov 2014
	100%	75%	50%		
EUR, bcf	1.53	1.58	1.74	1.34	1.36
Error, %	13%	16%	28%	-2%	

1st SECRET
average history & prediction

Example #2 – Western Canada Wells

Assisted vs Manual Forecasting
160 Random Wells

Log Rate, mmcfe/d

— Group   — Assisted   — Manual

2008   2009   2010   2011   2012   2013   2014   2015
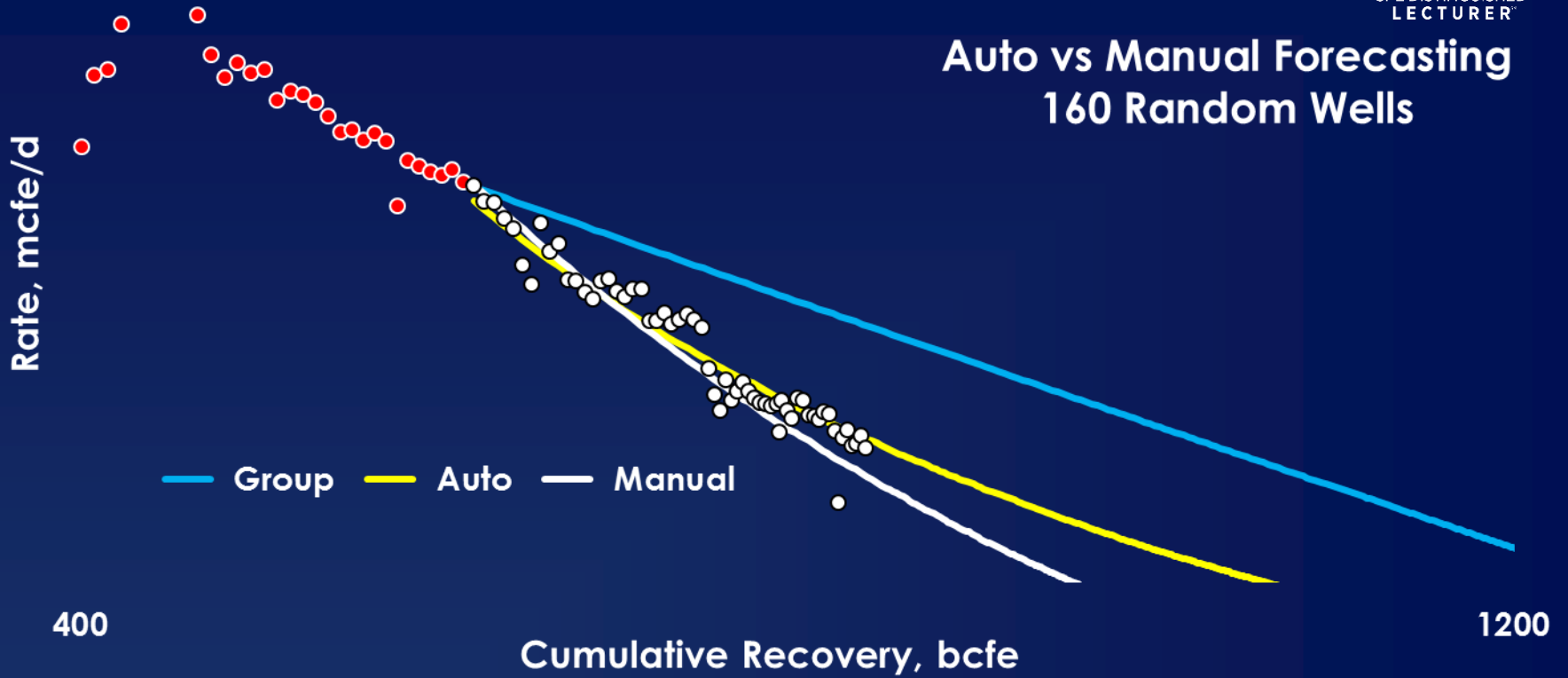
	Group	Assisted	Manual
Volume	+25 %	+1.7%	-2.4%
Time		20 sec	6 hours

Example #2 – Western Canada Wells

Auto vs Manual Forecasting
160 Random Wells

Rate, mcfe/d

Group — Auto — Manual

400

Cumulative Recovery, bcfe

1200

Remaining Reserve, bcfe

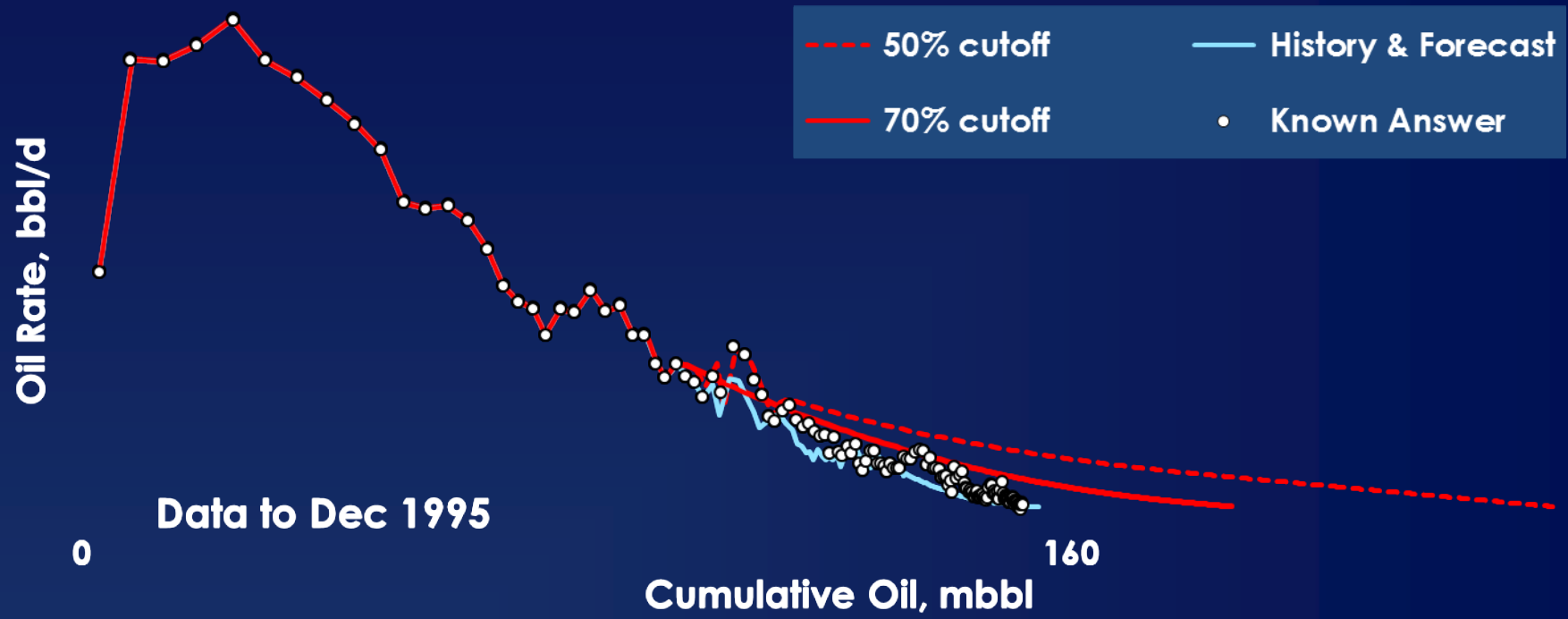| Assist	Manual	Group
576	409	732

EXAMPLE #3 – 26 wells in Winter field
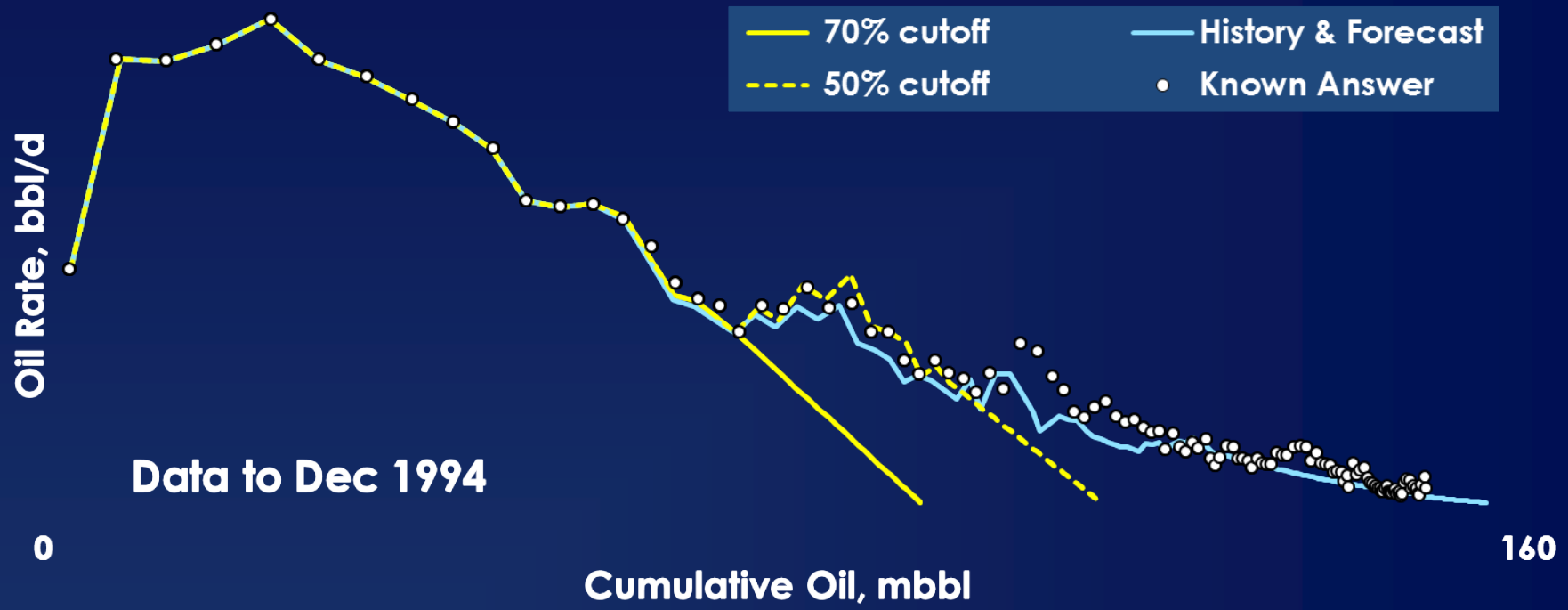
Depleted Cummings oil wells drilled 1988 to 1993
Using history only, forecasts under-estimate recovery
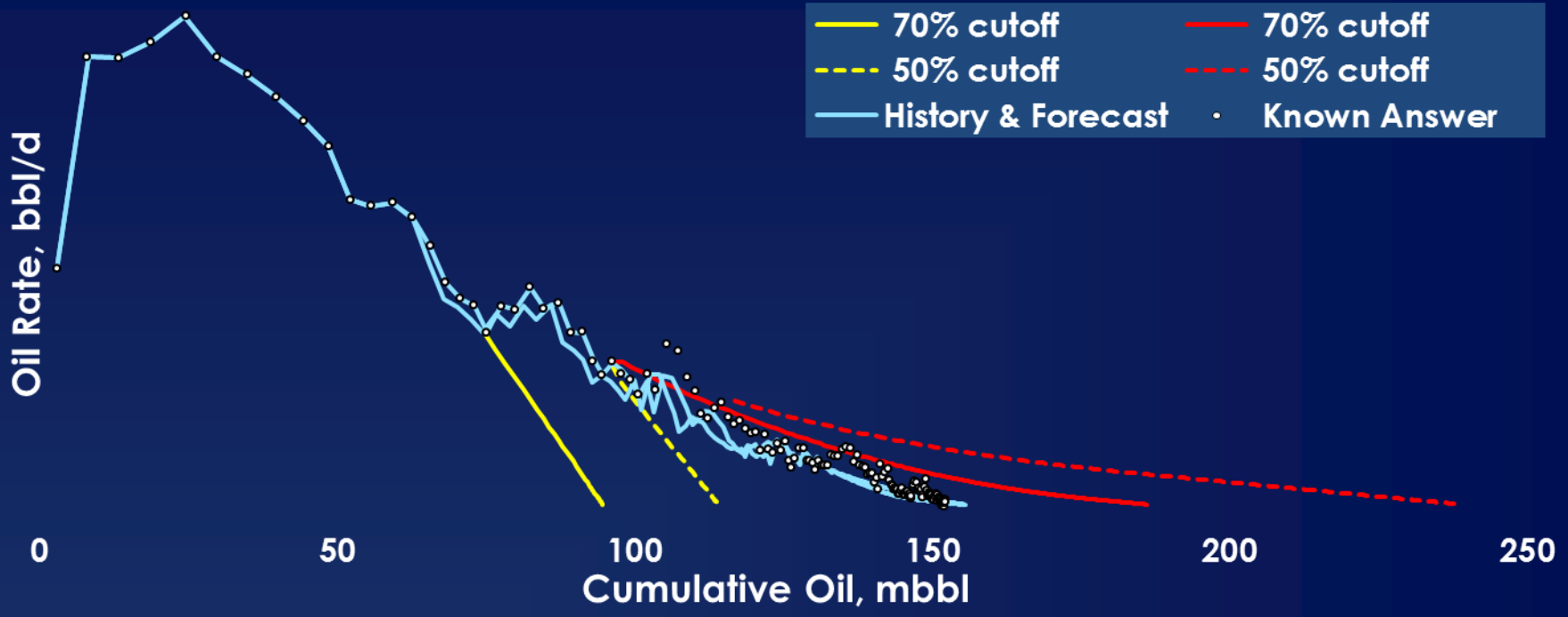With history and forecast, recovery estimate is good

EXAMPLE #3 – 26 wells in Winter field

Legend:
- - - - 50% cutoff
- ——— 70% cutoff
- ——— History & Forecast
- • Known Answer

Oil Rate, bbl/d (y-axis)

Data to Dec 1995

0 ... 160

Cumulative Oil, mbbl (x-axis)

Depleted Cummings oil wells drilled 1988 to 1993
Using history only, forecasts over-estimate recovery
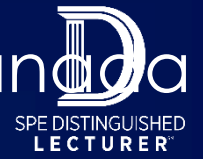With history and forecast, recovery estimate is good

EXAMPLE #2 – 26 wells in Winter field, Canada

Add one more year of data

History only EUR moves from under recover to over

No change to forecast with history and forecast

2nd SECRET

Applies to Probability Based Type Wells

STOP USING THE TIME SLICE METHOD
USE THE AGGREGATION METHOD

Certainty (P10, P50, P90)

What is uncertain?
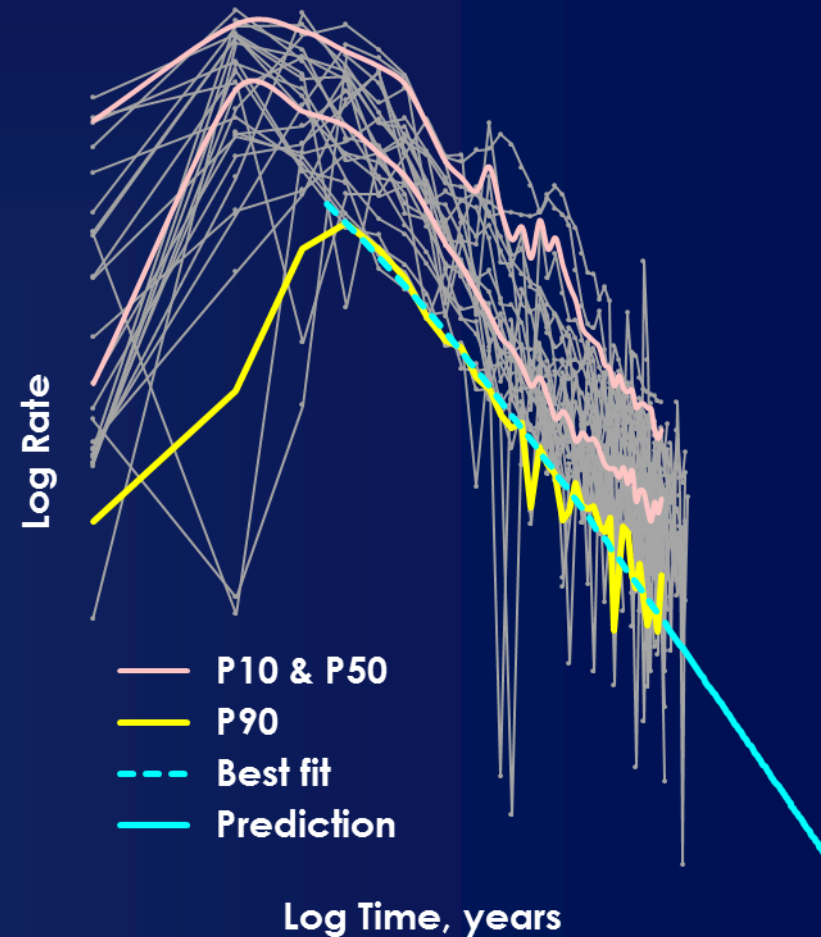*(EUR, Present Value, Cash Flow, …)*

How many wells?

TIME SLICE METHOD

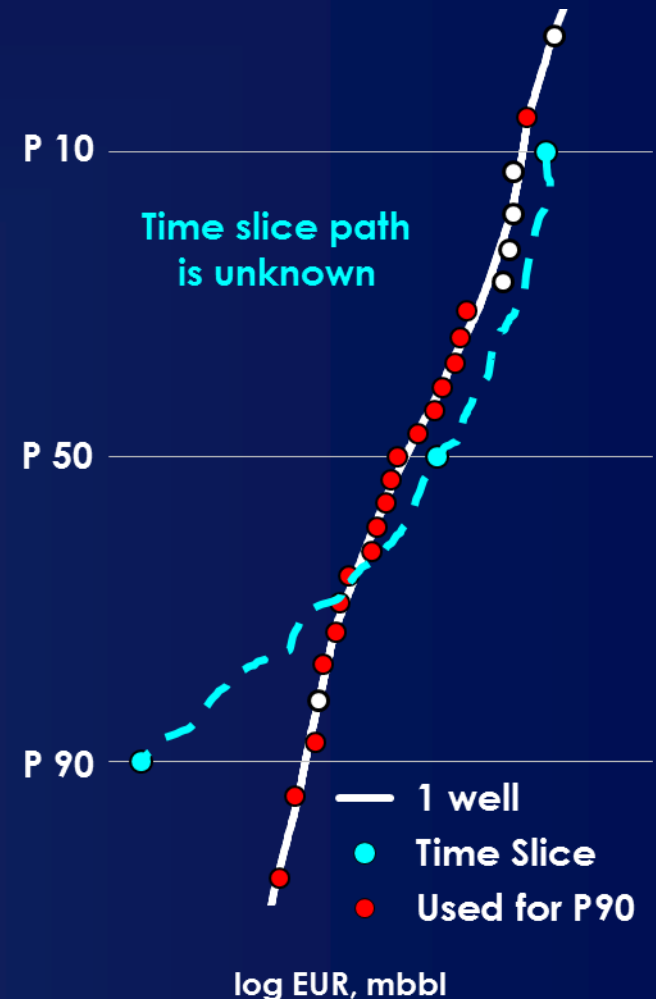Uses only history

Normally P10, P50 or P90

For Each Month

- Sort by rate

- Get the P90 or P50/P10 rate

- Decline to complete

Log Rate

- P10 & P50
- P90
- Best fit
- Prediction

Log Time, years

SPE 62630 & 167215
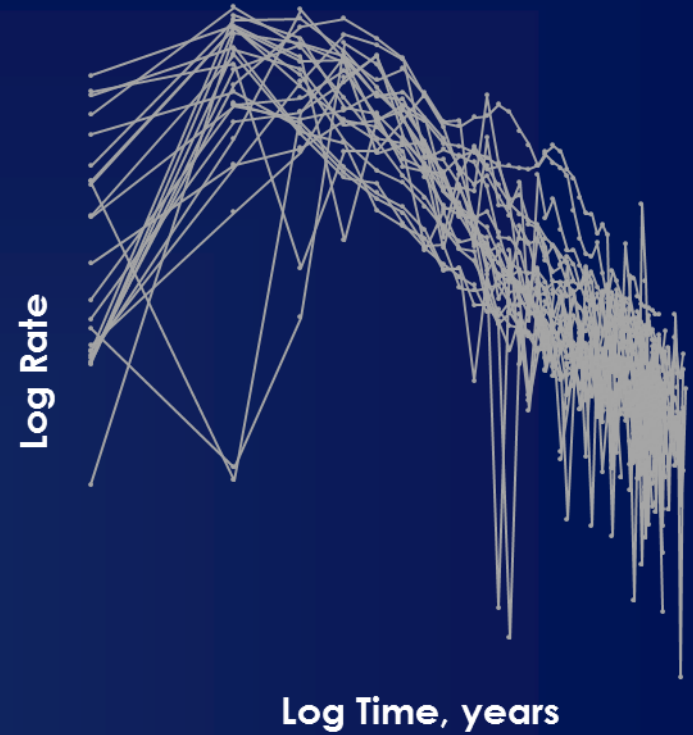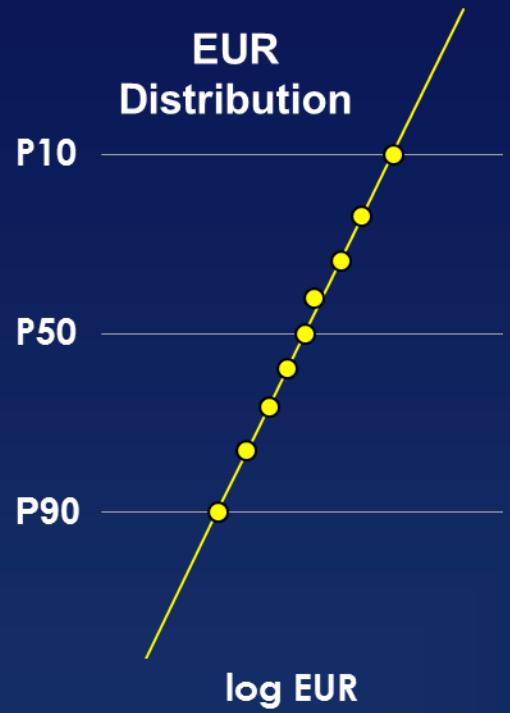
TIME SLICE METHOD

Probability

- What is uncertain? Unknown

- No Aggregation (1 well)

- Rates from the full distribution

- Ignores EUR distribution

P 10

Time slice path is unknown

P 50

P 90

— 1 well
● Time Slice
● Used for P90

log EUR, mbbl

TIME SLICE METHOD

EUR Distribution

P10

P50

P90

log EUR

Log Rate

Log Time, years
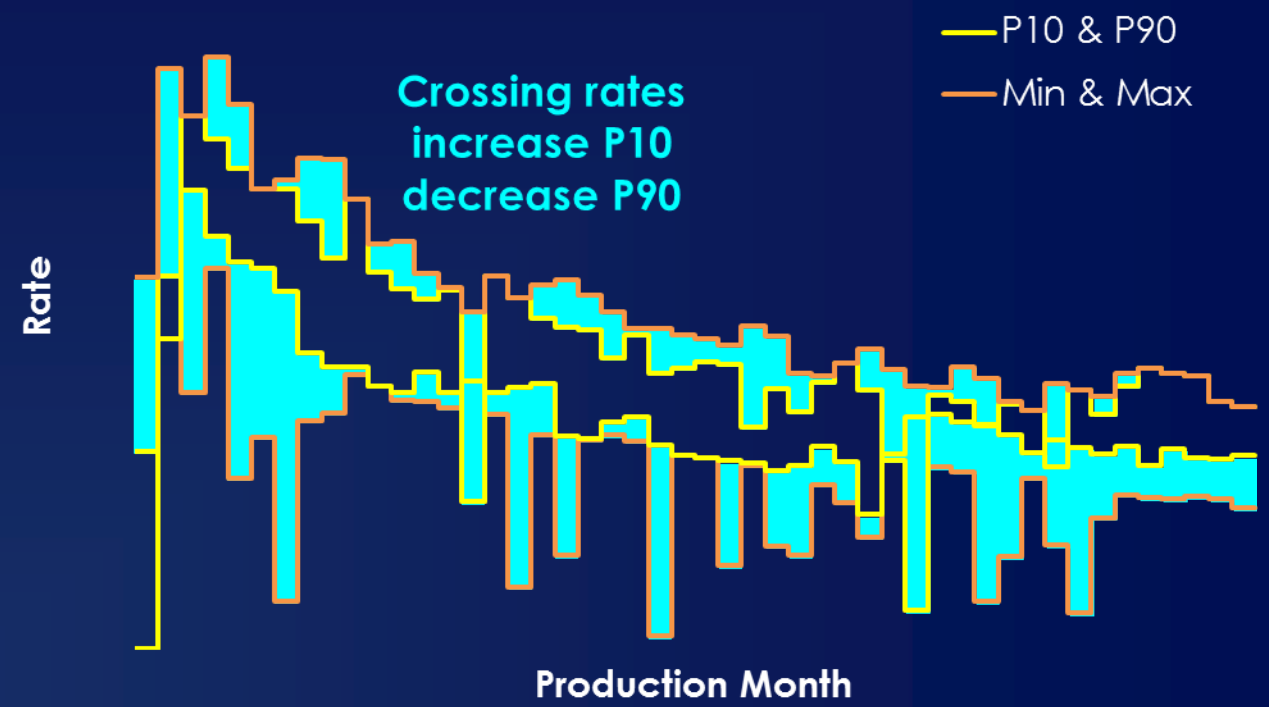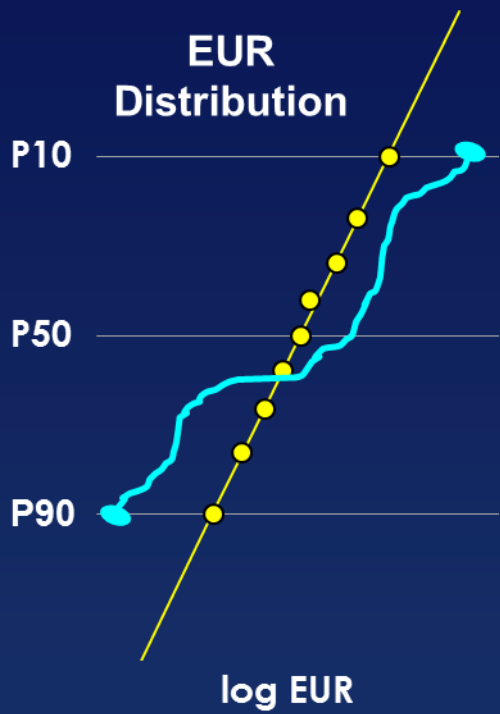
- 9 well example
- Crossing rate/time

There is a P10 & P90 well

Creates additional error

TIME SLICE METHOD

- Shaded area
- P90 low, P10 high

Rate < P90   or   Rate > P10

Where is the EUR right?

SPE 167215

TIME SLICE METHOD

Disadvantages

Probability of what?

- Cannot choose at value , e.g. EUR, NPV
- Type well does not match the EUR

Prone to error

- Errors from using only history
- Crossed rate-time profiles
- Rates selected from all wells and probabilities
- Doesn't represent a defined group of wells

  P90 rates from 19 of 25 wells, P4 to P96

AGGREGATION METHOD

Resolves 4 type well questions

- Which wells to use?

- Should wells have equal weighting?

- How does one account for drill program size?

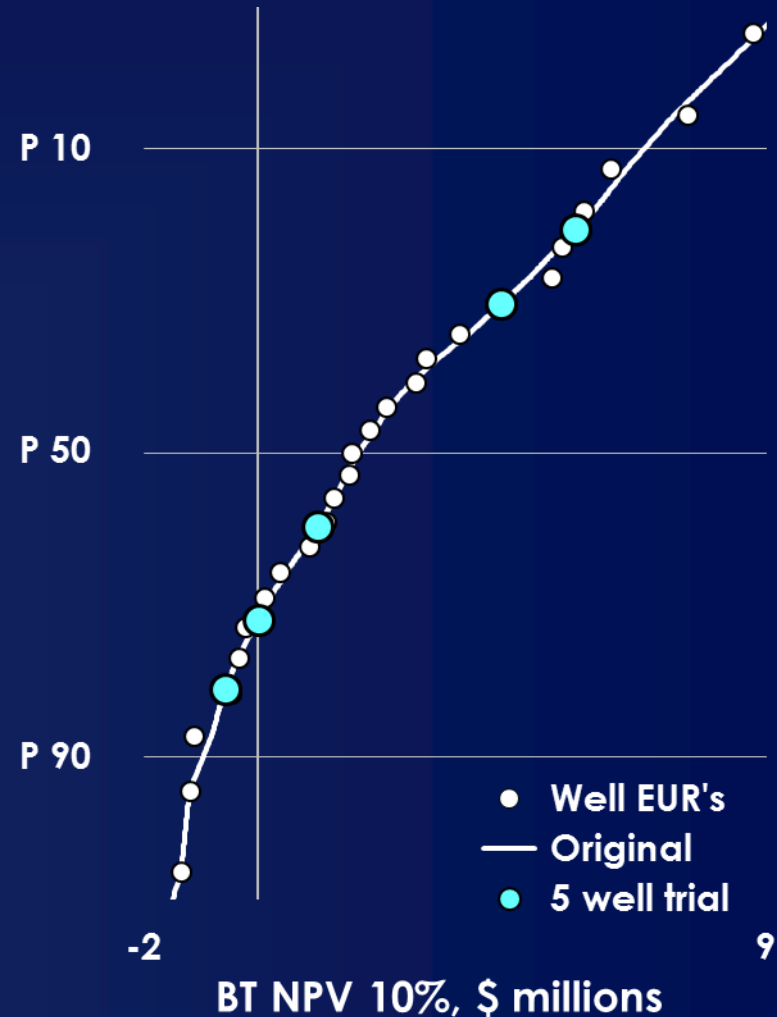- What is the right way to handle probabilities?

The Approach

- Find appropriate weighting factors

AGGREGATION 101

Aggregated Distribution

- Pick 5 random probabilities

- Get values for each

- Average the values

P 10

P 50

P 90

- Well EUR's
- Original
- 5 well trial

-2   9

BT NPV 10%, $ millions

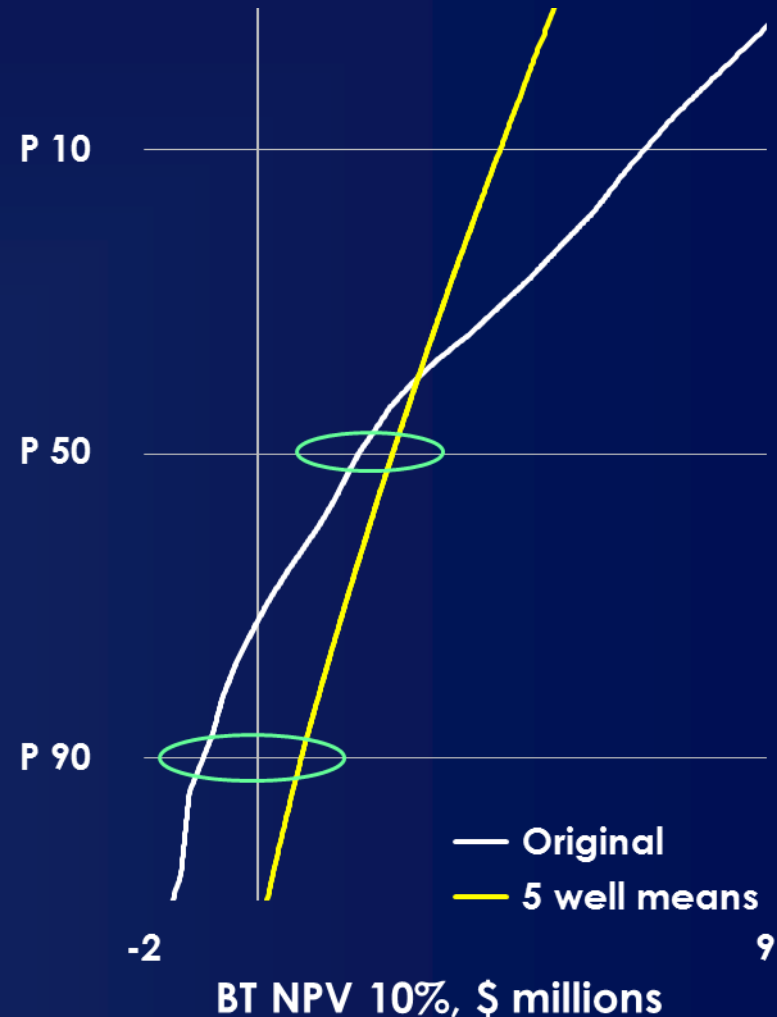27

AGGREGATION 101

Aggregated Distribution

- Pick 5 random probabilities
- Get values for each
- Average the values
- Repeat 100,000 times
- Plot distribution of means

Aggregated Results

- P90 & P50 values increase
- Certainty improves   P10/P90
- P90 economic with 5 wells

P 10

P 50

P 90

— Original
— 5 well means

-2   9

BT NPV 10%, $ millions

AGGREGATION METHOD

Step 1 Get Target EUR (237)

Step 2 Weighting Factor

- Continue 5 well trials
- When mean ~ target
  Tally the selected wells
- Tally more than 1000 trials
- Calculate weighting factor as a % of the total tally

Step 3 Build type well

- Multiply history and prediction by the weighting factor and sum

— Original
— 5 wells

P 10

P 50

target EUR
237 mbbl
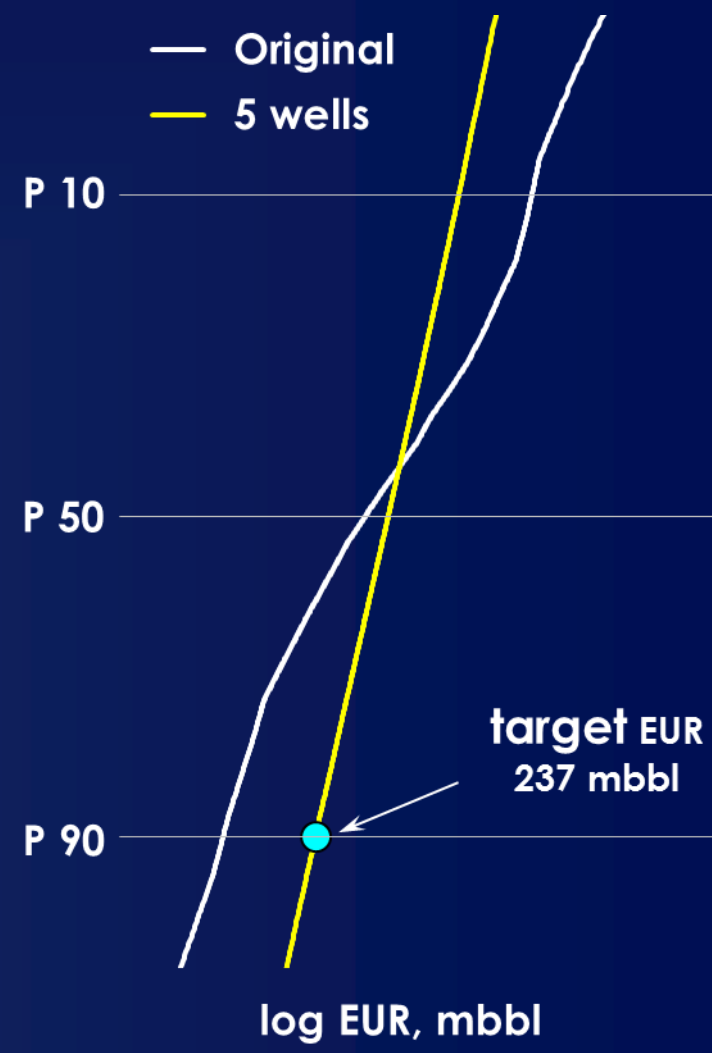
P 90

log EUR, mbbl

AGGREGATION METHOD

Step 1 Get Target EUR (237)

Step 2 Weighting Factor
- Continue 5 well trials
- When mean ~ target
  Tally the selected wells
- Tally more than 1000 trials
- Calculate weighting factor as
  a % of the total tally

Step 3 Build type well
- Multiply history and prediction by
  the weighting factor and sum

Calculate Weighting Factors

Well	EUR	Tally	Weight
8	175	81	8.9%
24	197	69	7.5%
7	203	73	8.1%
25	214	28	3.1%
9	220	67	7.3%
21	241	33	3.7%
5	277	53	5.8%
16	293	25	2.8%
17	326	42	4.6%
3	378	4	0.5%
30	396	7	0.8%
6	434	3	0.3%
		910	100%

AGGREGATION METHOD

Advantages

Designed for new drilling
- *Based on probability of drilling each well*

Properly uses aggregated probabilities

Will use any uncertain parameter

Proper ratios for secondary products
- *Calculated with the correct weighting*

Aggregation
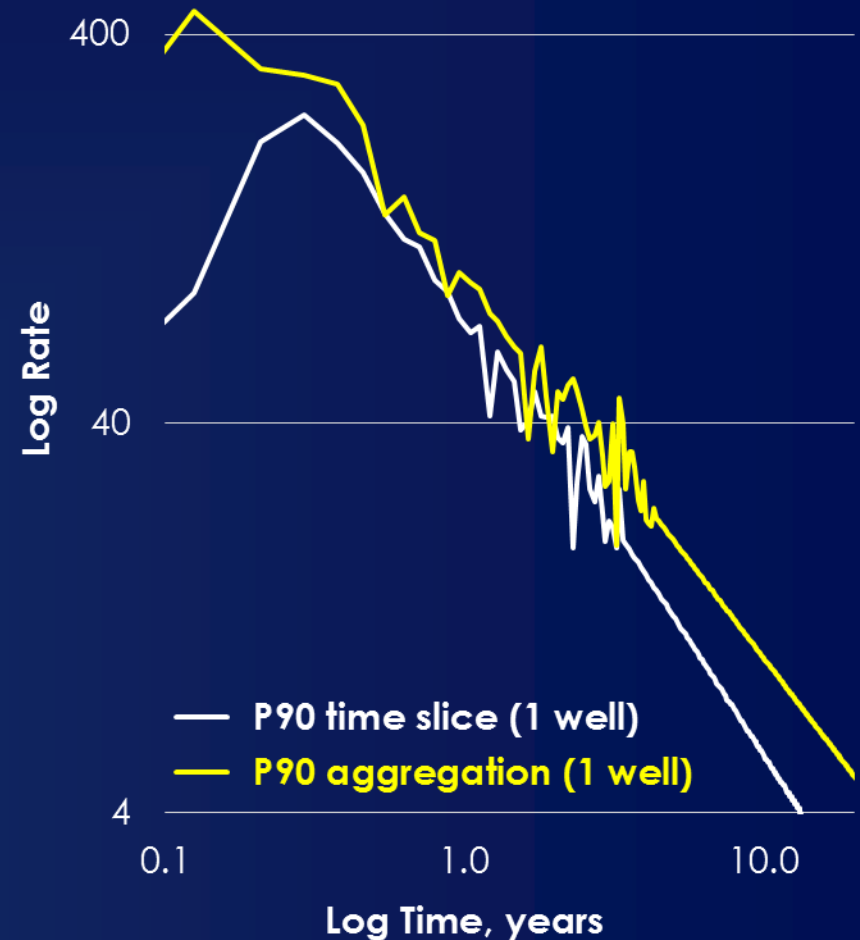- *Increases P90 & P50 reserves*
- *Adds certainty*

COMPARISON   P90 type wells

Time Slice Comparison (1 well)

NPV 10% & EUR	Btax $mm	Atax $mm	EUR mbbl
P90 aggregation	**-0.8**	**-0.9**	**191**
P90 time slice	-3.4	-2.5	111
Difference	2.6	1.7	79

Method is critical

I choose the aggregation method

- P90 time slice (1 well)
- **P90 aggregation (1 well)**

COMPARISON   P90 type wells

Benefit of Aggregation

NPV 10% & EUR	Btax $mm	Atax $mm	EUR mbbl
P90 drill 5 wells	1.1	0.4	237
P90 drilI 1 well	-0.8	-0.9	191
Difference	1.9	1.2	46

— P90 aggregation (1 well)
— P90 aggregation (5 wells)

Log Rate

Log Time, years
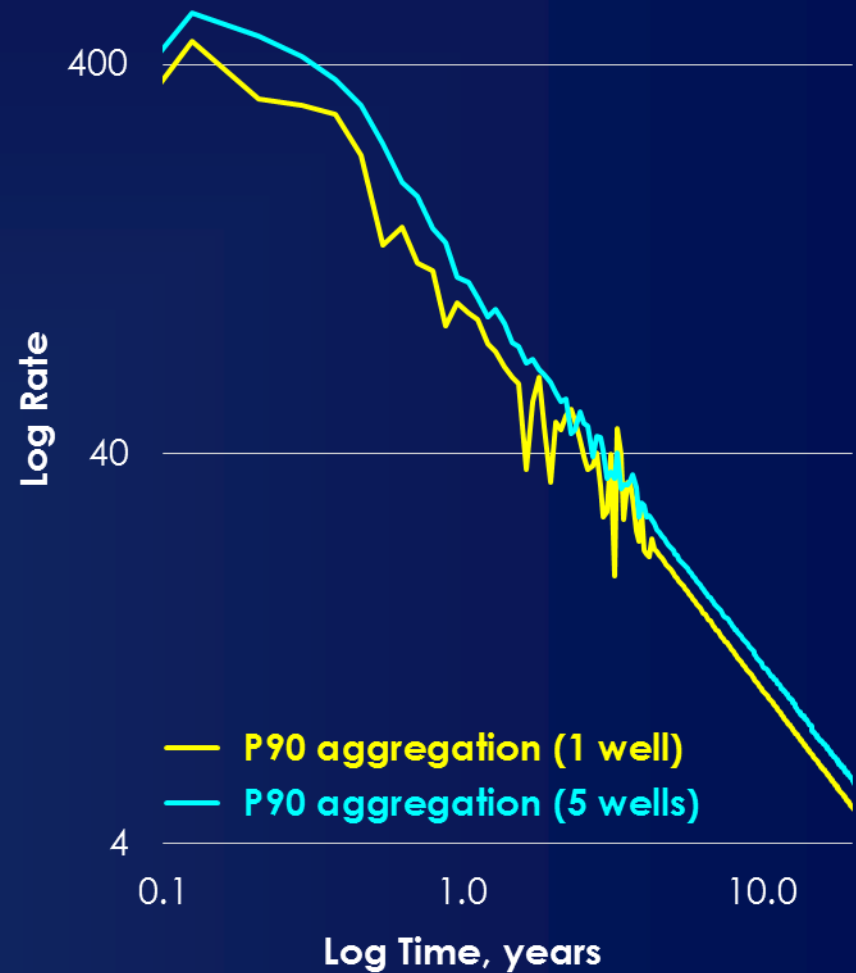
TWO VITAL SECRETS

As a Type Well Builder

☑ Average both history and prediction

☑ Use Aggregation method for new drilling

As a Consumer of Type Wells

☒ Avoid type wells that use only historical data

☑ Type wells should represent
the number and quality of wells you plan to drill