Two Vital Secrets for Building Accurate Type Wells

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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
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
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

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

Common method

Compounding effect

SPE 162630
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
### Numerical example

<table>
<thead>
<tr>
<th>Well</th>
<th>Month 23</th>
<th>Month 24</th>
<th>Month 25</th>
<th>Month 26</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1200</td>
<td>1100</td>
<td>1000</td>
<td>900</td>
</tr>
<tr>
<td>2</td>
<td>1000</td>
<td>900</td>
<td>800</td>
<td>700</td>
</tr>
<tr>
<td>3</td>
<td>35</td>
<td>25</td>
<td>no prod</td>
<td>no prod</td>
</tr>
<tr>
<td><strong>Field Total</strong></td>
<td><strong>2235</strong></td>
<td><strong>2025</strong></td>
<td><strong>1800</strong></td>
<td><strong>1600</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type Well</th>
<th>Month 23</th>
<th>Month 24</th>
<th>Month 25</th>
<th>Month 26</th>
</tr>
</thead>
<tbody>
<tr>
<td>2235 / 3</td>
<td>745</td>
<td>675</td>
<td>900</td>
<td>800</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Drill 3 Wells</th>
<th>Month 23</th>
<th>Month 24</th>
<th>Month 25</th>
<th>Month 26</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 x 745</td>
<td>2235</td>
<td>2025</td>
<td>2700</td>
<td>2400</td>
</tr>
</tbody>
</table>
CASE STUDY  88 Hugoton Kansas wells

Data truncated
Cut off
Type well

5 years drilling + 5 years producing
Stop when too few wells
Looks reliable

EUR = 1.58 bcf
**CASE STUDY**  88 Hugoton Kansas wells

<table>
<thead>
<tr>
<th>To Dec 1996</th>
<th>History 100%</th>
<th>Only Cut Off 75%</th>
<th>Common method (75% cut off)</th>
<th>History &amp; Prediction</th>
<th>Known Nov 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUR, bcf</td>
<td>1.53</td>
<td>1.58</td>
<td>1.74</td>
<td>1.34</td>
<td>1.36</td>
</tr>
<tr>
<td>Error, %</td>
<td>13%</td>
<td>16%</td>
<td>28%</td>
<td>-2%</td>
<td></td>
</tr>
</tbody>
</table>

11st SECRET average history & prediction

Range of common methods

Graph showing log rate vs time with data to Nov 2014 and history & prediction lines.
Example #2 – Western Canada Wells

Assisted vs Manual Forecasting
160 Random Wells

Volume
Group +25 %
Assisted +1.7%
Manual -2.4%

Time
20 sec
6 hours

Log Rate, mmcf/d

Example #2 – Western Canada Wells

Auto vs Manual Forecasting
160 Random Wells

Remaining Reserve, bcf

Assist: 576
Manual: 409
Group: 732

Russell, SPE 167215
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

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
TIME SLICE METHOD

Probability

• What is uncertain? Unknown
• No Aggregation (1 well)
• Rates from the full distribution
• Ignores EUR distribution
• 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?
TIME SLICE METHOD

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

Disadvantages
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
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
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
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

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

<table>
<thead>
<tr>
<th></th>
<th>Btax</th>
<th>Atax</th>
<th>EUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV 10% &amp; EUR</td>
<td>$mm</td>
<td>$mm</td>
<td>mbbl</td>
</tr>
<tr>
<td>P90 aggregation</td>
<td>-0.8</td>
<td>-0.9</td>
<td>191</td>
</tr>
<tr>
<td>P90 time slice</td>
<td>-3.4</td>
<td>-2.5</td>
<td>111</td>
</tr>
<tr>
<td>Difference</td>
<td>2.6</td>
<td>1.7</td>
<td>79</td>
</tr>
</tbody>
</table>

**Method is critical**

I choose the aggregation method.
<table>
<thead>
<tr>
<th>Benefit of Aggregation</th>
<th>Btax</th>
<th>Atax</th>
<th>EUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV 10% &amp; EUR</td>
<td>$mm</td>
<td>$mm</td>
<td>mbbl</td>
</tr>
<tr>
<td>P90 drill 5 wells</td>
<td>1.1</td>
<td>0.4</td>
<td>237</td>
</tr>
<tr>
<td>P90 drill 1 well</td>
<td>-0.8</td>
<td>-0.9</td>
<td>191</td>
</tr>
<tr>
<td>Difference</td>
<td>1.9</td>
<td>1.2</td>
<td>46</td>
</tr>
</tbody>
</table>

![Log Rate vs Log Time, years](image-url)

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