

Calibration of Uncertainty (P10/P90) in Exploration Prospects*

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Abstract

Otis and Haryott (2006) and Haryott and Otis (2009) described a methodology to determine an appropriate P10/P90 (P10-P90 ratio) for both EUR (Estimated Ultimate Recovery) and EUR parameter distributions as a guideline in quantifying uncertainty. The method requires pre- and post-drill data to calibrate a “target” range of P10/P90 that can be used along with an estimate of the high side of the distribution to calibrate the uncertainty of EUR or EUR parameters. The data used in the 2006 analysis were from the Chevron 1989-94 international exploration program and were largely non-amplitude prospects defined by dense 2D seismic data. The 2009 analysis included an expanded sampling that included prospects that were constrained by amplitudes and step-out opportunities that were covered by 3D seismic data. Since then, we have extended the data set with additional wells and conducted additional analyses. Results, some non-intuitive, are shown for each of these samplings and suggest a potential classification, based on structural definition, for a “target” range of P10/P90.

Selected References

Otis, R. and P. Haryott, 2006, How low should you go; a method to calibrate estimates of P99 prospect reserves: AAPG Annual Meeting Abstracts, v. 15, p. 81.

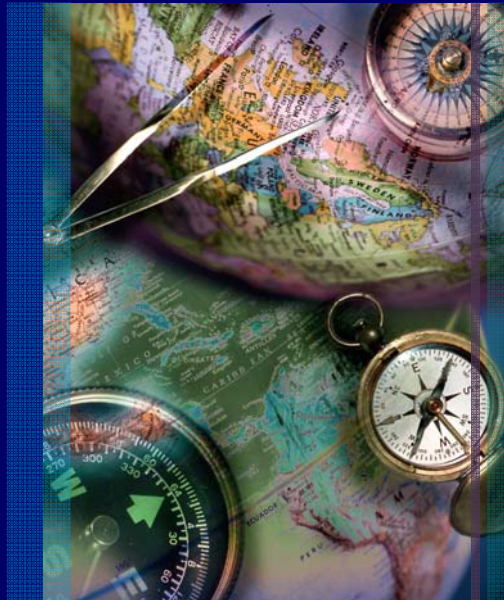
Otis, R.M. and N. Schneidermann, 1997, A process for evaluating exploration prospects: AAPG Bulletin, v. 81/7, p. 1087-1109.

Calibration of Uncertainty (P10/P90) in Exploration Prospects

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Acknowledgement

**Thanks to Chevron Corporation for use of
data in the development of this presentation**

Uncertainty

The **Uncertainty** in a distribution is typically characterized by the **variance** or **standard deviation**

For **estimation of EUR** in Exploration, distributions are typically **lognormal** (especially those that dictate the uncertainty in EUR, e.g., area or average net pay)

For lognormal distributions, **Uncertainty** is best expressed as **P10/P90**, where P10 is exceeded only 10% of the time

The Uncertainty is **dependent** on available **data** and the **accuracy or quality** of those data

Presenter's notes: Uncertainty is present throughout our business. Estimates of exploration prospect resources and many of the variables used to estimate those resources are lognormal (e.g., area, net pay) and the uncertainty is best expressed with the ratio of the P10 (high) of the distribution divided by the P90 (low). This ratio uniquely determines the more traditional standard deviation or variance, but is more easily understood when describing uncertainty in exploration resource estimation.

Why?

Observation suggests that **uncertainty may be consistent** from prospect to prospect **in similar exploration settings**

Differing opinions were abundant on the **appropriate P10/P90**, but most were based on a wide variety of experience; few, if any, were validated with data

We wanted to see a **“data supported”** process that would allow a company to develop their own **“appropriate P10/P90”**, calibrated by drilling results

Presenter's notes: Observations by the authors suggest a consistency in uncertainty (P10/P90) for resource estimates and estimates of resource variables. Our analysis is consistent with this observation for several different classes of prospects. To our knowledge, this is the only “data-supported” process that allows a company to assess the “appropriate” P10/P90 to use for both estimating resource variables and reality-checking resource estimates.

Assumptions

Estimates of EUR, Area and Average Net Pay can be characterized by lognormal distributions

Lognormal distributions can be defined by two pieces of independent information (e.g., two points or Pvalues, one Pvalue and a slope)

- Industry standard is P10 (reasonable upside) and P90 (reasonable downside)
- Use the extreme upside and downside of P01 and P99
- Estimate a Pvalue (P01) and the uncertainty (P10/P90)

Presenter's notes: Assumptions for our approach are listed in this slide. Note that because lognormal distributions are linear on log probability plots, they can be determined either by two points (e.g., P90 and P10) or a point and a slope (e.g., P01 and P10/P90).

Observations

The P01 (extreme high side) of most distributions is probably the best constrained Pvalue

- Field size distributions can use the largest field in the trend
- Area distributions can use the closing contour on structures and reservoir extent on stratigraphic traps
- Average Net Pay distributions can use a high N/G and the thickest reservoir with appropriate averaging

P10/P90 appears to be fairly consistent for different prospect categories

Presenter's notes: If only one point on the distribution can be easily constrained, the point and slope approach may provide better estimates of distributions.

Finding An “Appropriate” P10/P90

The Process

Compile your “history” – zones require two independent values to **define the predrill distribution** and the **post drill mean**

Estimate the **P01** from each **predrill distribution**

Assign a **common P10/P90** to all zones and see where the **post drill mean** result falls on the resulting **pre drill distribution**

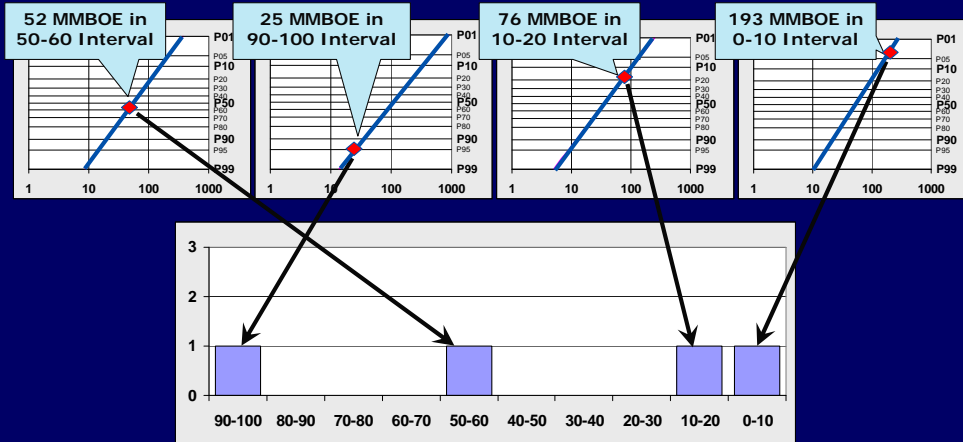
Evaluate results using the **percentile histogram** method from Otis and Schneidermann (1997)

Do this for **several P10/90s** and see which one is “**most appropriate**”

Otis & Haryott, 2006

Presenter's notes: The process was originally documented by Otis & Haryott, 2006.

Percentile Histograms

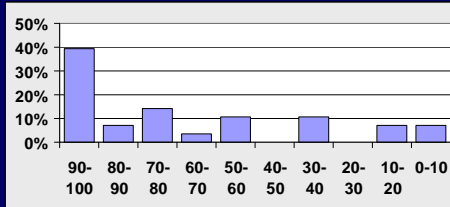


Each percentile interval has a 10% probability

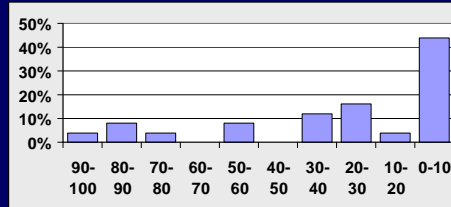
If the post-drill result from each predrill distribution is random, the result is a **uniform** distribution

Presenter's notes: This slide illustrates the process for compiling percentile histograms

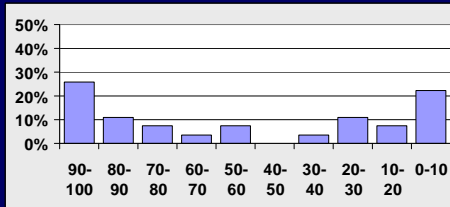
Diagnostics



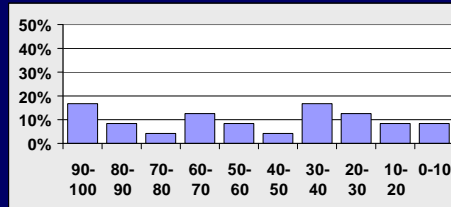
Heavy on the Downside
Too Optimistic



Heavy on the Upside
Too Pessimistic



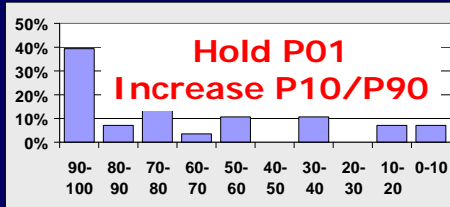
Heavy on both Up - and Downsides
Need To Widen Ranges



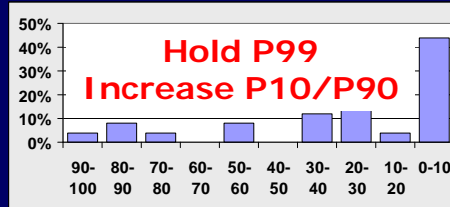
Uniform Distribution
Acceptable

Presenter's notes: Diagnostics for problems related to P01 and P10/P90 as parameters.

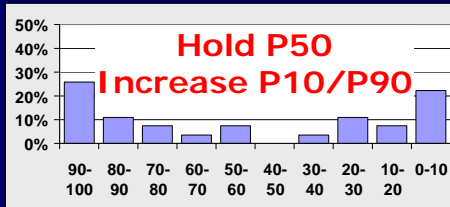
Remedies



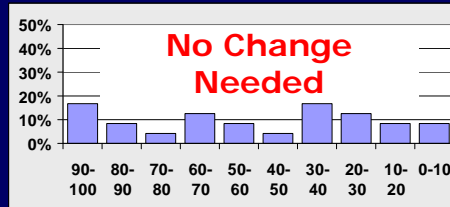
Heavy on the Downside
Too Optimistic



Heavy on the Upside
Too Pessimistic



Heavy on both Up - and Downsides
Need To Widen Ranges



Uniform Distribution
Acceptable

Presenter's notes: Ways to correct problems related to P01, P50 and P10/P90 as parameters used to estimate lognormal distributions.

Otis and Haryott - 2006

Based on **early 90s** pre and post drill reviews of prospects generally defined by moderate to dense **2D seismic**

Results:

- EUR P10/P90 averaged about 8 and ranged from 5 to 10
- Area P10/P90 ranged from 3 to 4
- Average gross pay ranged from 6 to 8

Otis & Haryott, 2006

Presenter's notes: Summary of results from AAPG presentation by Otis & Haryott, 2006.

Objectives of this Project

Continue investigation reported by Otis & Haryott (2006), where most zones were covered by 2D seismic (early 90s)

Extend data set to include:

- DHI (Direct Hydrocarbon Indicator) zones
- Delineation or step-out zones
- Other Exploration zones (non-amplitude zones, most covered by 3D seismic)

Establish “appropriate” P10/P90 for these different categories and revisit the early 90s data

Presenter's notes: The objective of this effort is to extend the results from 2006 to include different classes of prospects that were not included in the original analysis.

Let's Look at Some Data

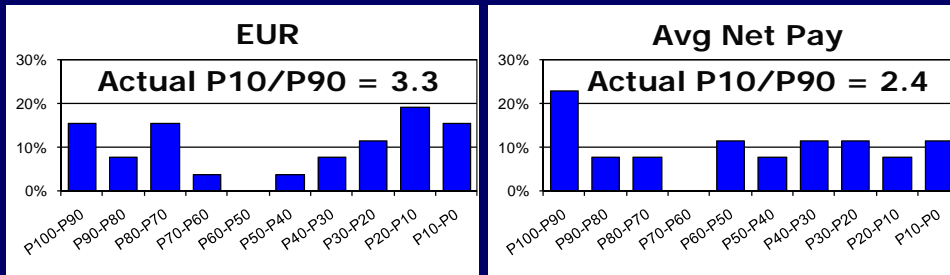
A sample from Chevron exploration wells drilled between 2002 and 2008 (82 discovery zones utilized)

- DHI zones with good structural conformance (26 zones)
- Delineation or step-out zones (25 zones)
- Other exploration zones (31 zones)

Examined P10/P90 for EUR, Area and Average Net Pay

DHIs w/ Structural Conformance

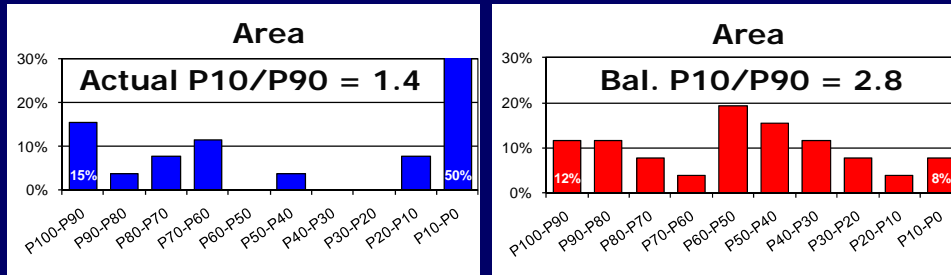
EUR and Average Net Pay



- Pre-drill estimates of EUR and Average Net Pay are acceptable
- EUR P10/P90 ranges from 3 to 5
- Average Net Pay P10/P90 ranges from 2 to 3

Presenter's notes: When DHIs were examined, estimates of EUR and average net pay seemed to reflect the correct amount of uncertainty. Appropriate ranges for Chevron were determined.

DHIs w/ Structural Conformance Area



- Both **P01** and **P10/P90** need to be **increased**
- Increasing P10/P90 **from 1.4 to 2.8** while keeping the low side about the same **balances histogram**
- Results seem **counter intuitive** because of expected area resolution from good structural conformance – however, actuals indicate many optimistic outcomes

Presenter's notes: Estimation of Area uncertainty appeared to be too narrow and a larger P10/P90 was needed, despite excellent structural conformance. This result seemed counter-intuitive; so additional analysis was needed.

New Tool (?)

Calculate: Post Drill Mean/Pre Drill P50

- Gives the percentage increase (or decrease) in the Pre Drill P50 to achieve the actual Mean Outcome

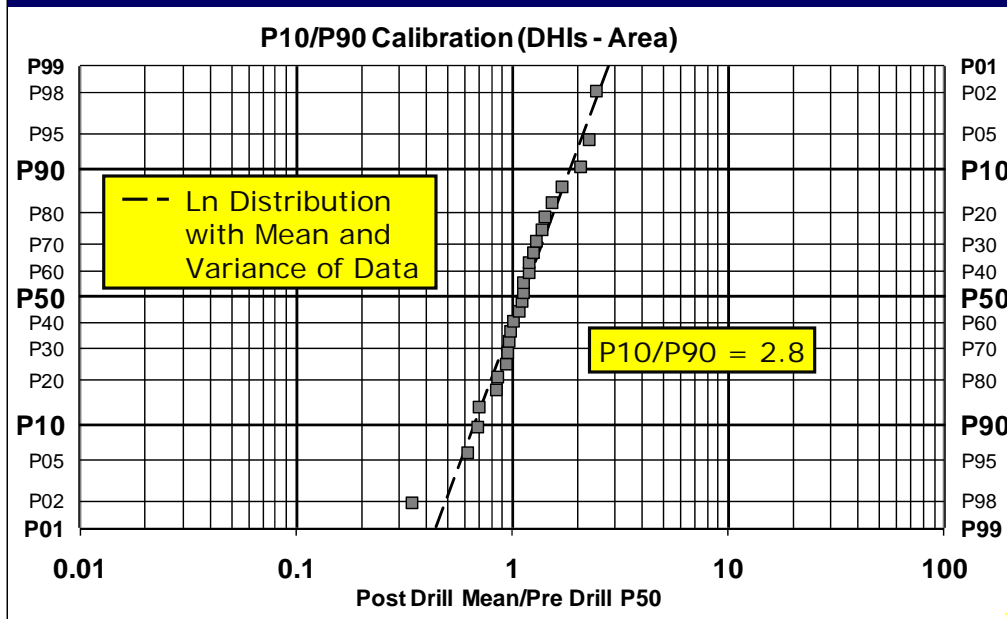
Plot results as a log-probability plot to see the variability of actual outcomes relative to the Pre Drill P50

- Results should plot as a straight line with about half of the values above P50 (1.0 on the plot) and half below
- The slope of a best-fit line should give a first pass approximation of the sample's P10/P90

Presenter's notes: A second tool was used to assess this result for Area. This tool is a log probability plot of the ratio of the post-drill mean and the pre-drill P50. This approach allows the distribution of results (expressed by the mean) to be compared to the pre-drill P50. Thus, we would expect half the results to fall above the P50 (ratio greater than 1.0) and half below (ratio less than 1.0). The slope of this curve should express the post-drill uncertainty, or P10/P90, of actual results compared to the pre-drill forecasts.

DHIs

Post Drill Mean/Pre Drill P50 - Area



Presenter's notes: The slope of this curve should predict the “appropriate” P10/P90 for the variable examined. In this case, the Area P10/P90 for DHIs with excellent structural conformance should be about 2.8. Note the consistency of results and the straight-line character of this curve.

Observations - DHIs

DHIs with good structural conformance are well defined and technology is available to accurately predict EUR while reducing uncertainty – P10/P90 ~ 4 balances histogram

Although DHIs conceptually define a clear Area, considerable uncertainty remains, especially on the upside, (P10/P90 between 2 and 3)

- Note: A P10/P90 of 2 yields a P90-P10 range about the P50 of $\pm 40\%$; P10/P90 of 3 yields $\pm 75\%$

Average Net Pay is well defined with P10/P90 between 2 and 3

Observations – P10/P90

	Amplitude (DHIs)	Delineation	Other Expl. 3D Seismic	Early 90s 2D Seismic
EUR	~4	~7	~8	~10
Area	2 - 3	~3	~4	~3.5
Avg Net Pay	2 - 3	~3.5	~4	~5

Presenter's notes: Because of time constraints, this table summarizes results from similar analyses of delineation (or exploitation) drilling, other exploration prospects using primarily 3D seismic and the early 90s prospects (primarily 2D seismic), reported in Otis & Haryott, 2006.

We would like to report that a closer look at the delineation data suggest a P10/P90 ratio of 4-6 is more appropriate for EUR than the reported ~7.

Summary – P10/P90

Very little difference is observed among Delineation, Other Exploration zones (3D seismic) and the Early 90s zones (2D seismic) for Area and Net Pay – there are **basically two categories** of uncertainty: **DHIs** with good conformance to structure and **all other prospects** (including marginal DHIs)

Uncertainty in **DHIs** is clearly reduced for both **Area and Average Net Pay** with P10/P90 ranging between **2 and 3** resulting in an **EUR P10/P90** of **~4**

In **all other prospects**, both **Area and Average Net Pay** P10/P90 ranged between **3 and 5** resulting in an **EUR P10/P90** between **7 and 10**

Finding An “Appropriate” P10/P90

Because each company has a different portfolio, there are no hard rules – each company will need to determine it independently

To do this, *each company needs a “history” of consistent estimates of predrill distributions and post-drill actual results to use for calibration and the discipline to make learning a part of the assessment*

Otis & Haryott, 2006

Presenter's notes: Finally, we wish to point out that the process and tools presented here should be used by companies to develop their own guidelines for the “appropriate” P10/P90. The numbers reported here are valid only for the data used. Other companies use different strategies, different tools and different decision-making processes, all of which render the numbers reported here as inappropriate for most companies.



**Thank You
For Your Attention**

