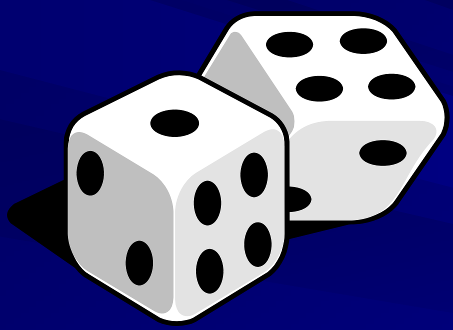
Society of Petroleum Evaluation Engineers

Monograph 3-

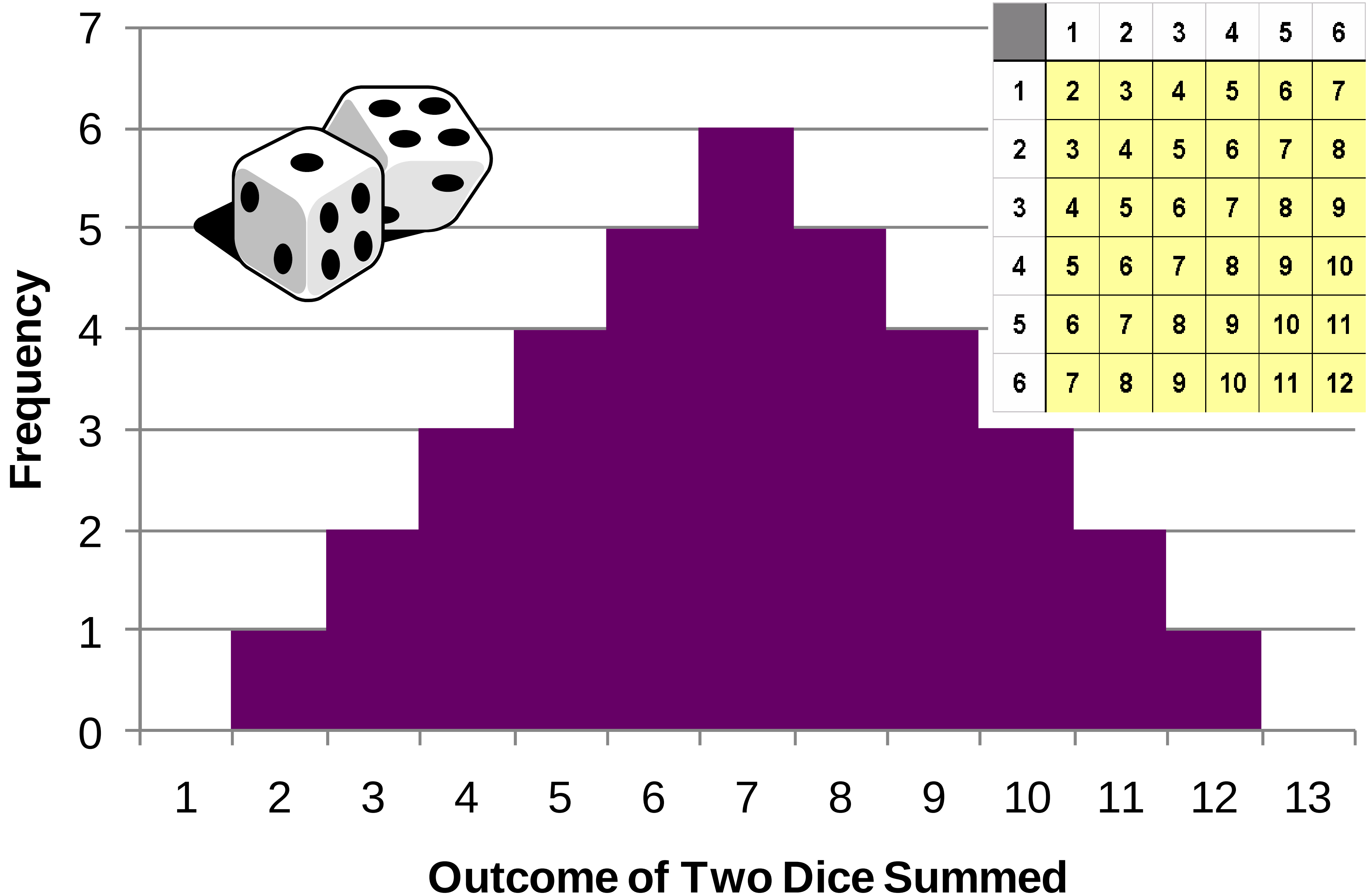
Chapter 2

“Statistics-A Brief Lesson”

Sum of Independent Distributions

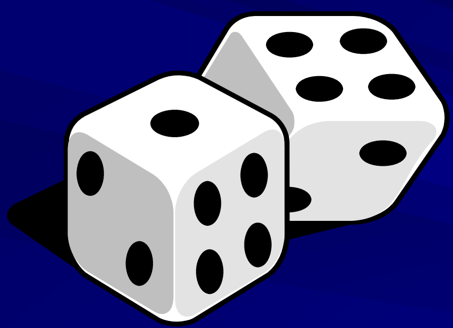


Sum of Independent Distributions

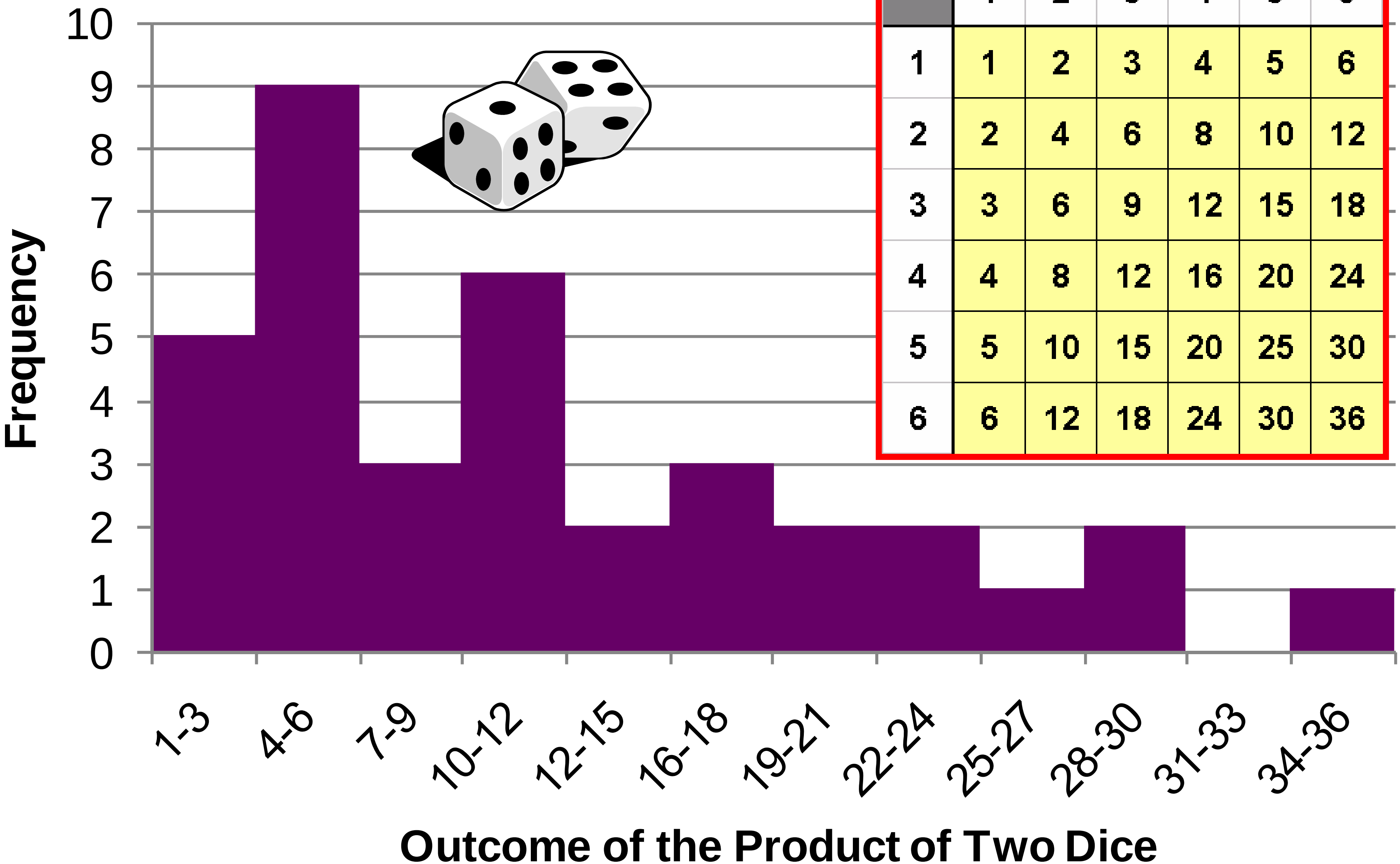


	1	2	3	4	5	6
1	2	3	4	5	6	7
2	3	4	5	6	7	8
3	4	5	6	7	8	9
4	5	6	7	8	9	10
5	6	7	8	9	10	11
6	7	8	9	10	11	12

Product of Independent Distributions

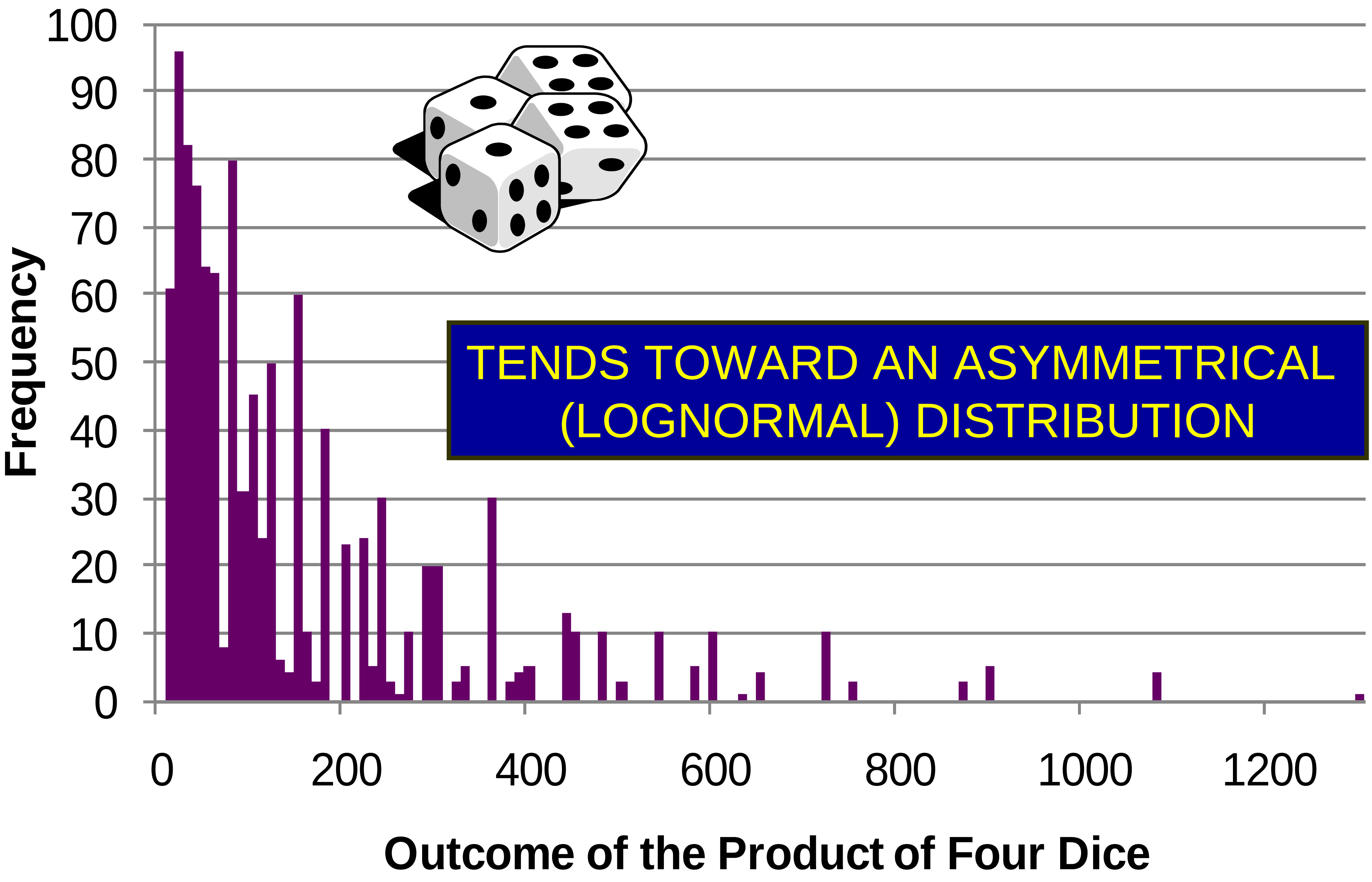


Two Dice Roll : Outcomes Multiplied



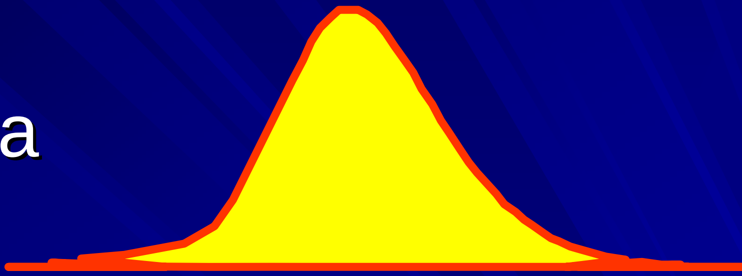
	1	2	3	4	5	6
1	1	2	3	4	5	6
2	2	4	6	8	10	12
3	3	6	9	12	15	18
4	4	8	12	16	20	24
5	5	10	15	20	25	30
6	6	12	18	24	30	36

Product of Independent Distributions



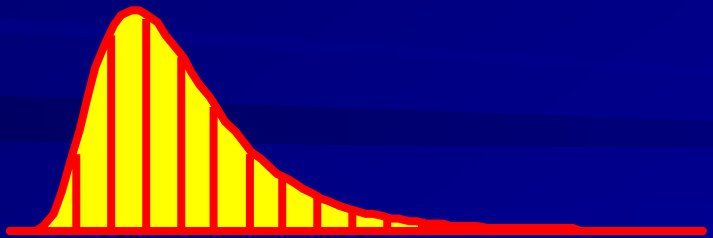
Central Limit Theorem

SUM of a group of independent random variables tends towards a NORMAL DISTRIBUTION

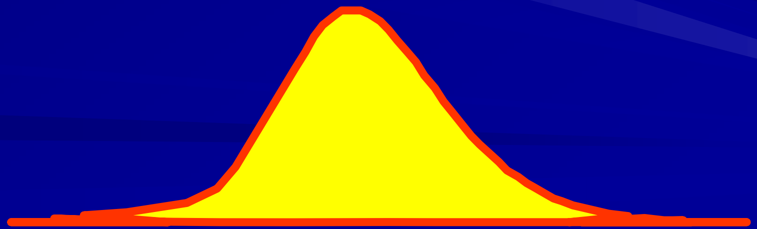


Linear Scale

PRODUCT of a group of independent random variables tends towards a LOGNORMAL DISTRIBUTION

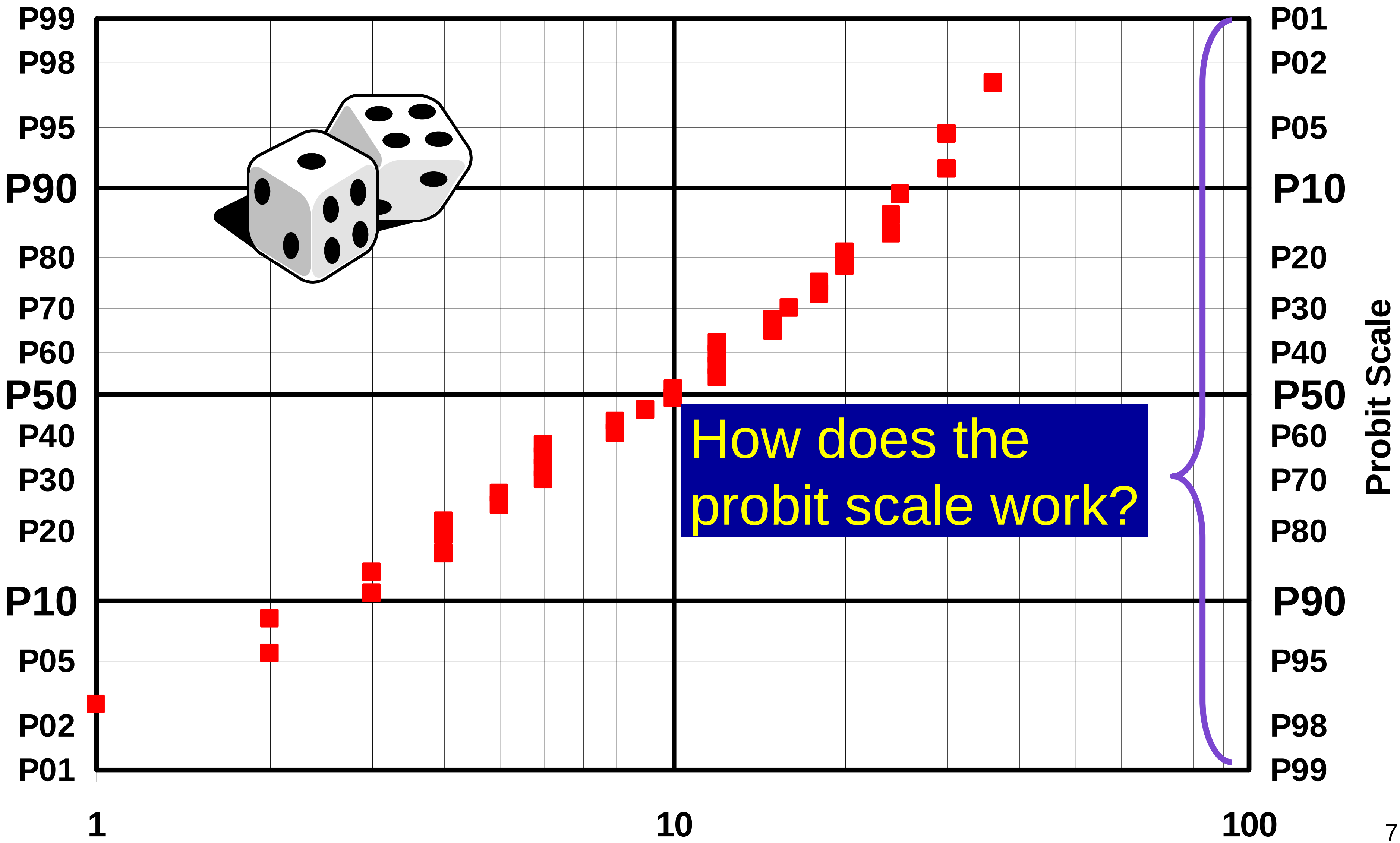


Linear Scale



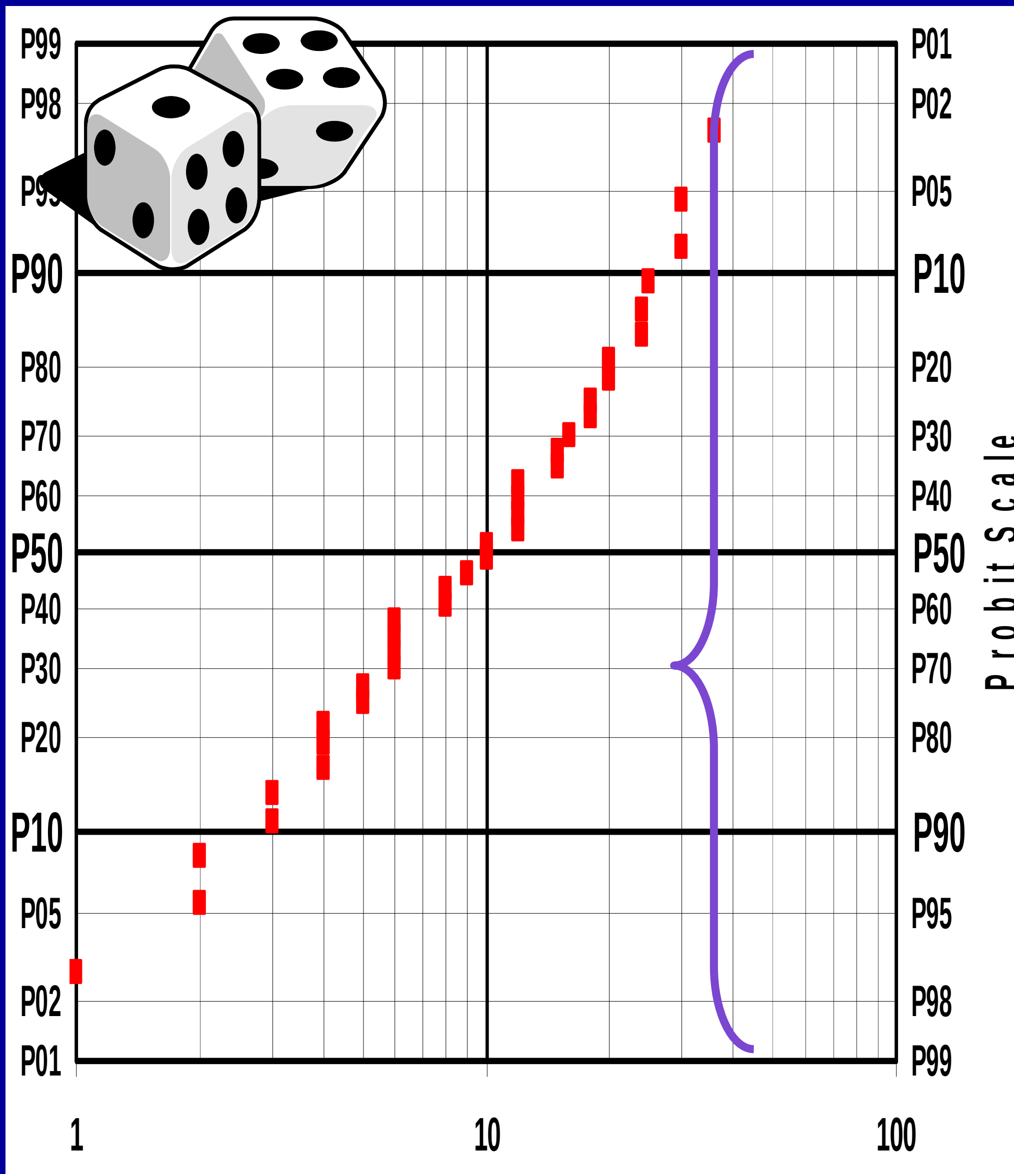
Log Scale

Cumulative Probability Plot
Product of Faces of Two Dice

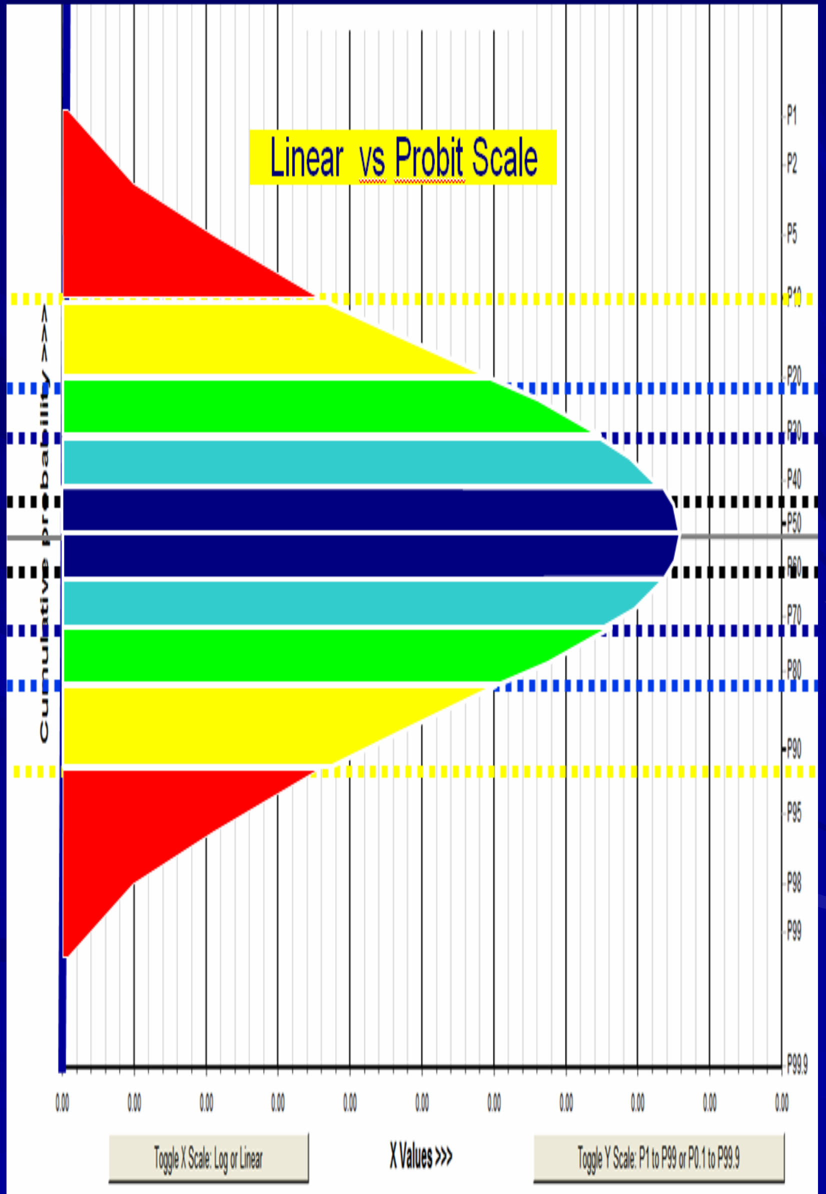


How does the probit scale work?

Cumulative Probability Plot
Product of Faces of Two Dice



Understanding the Cumulative Probability Plot
Y Axis



Plotting Conventions

- Definitions: % >= ('GE') or % <= ('LE')
- Evolving preference: % >= ('GE')
  - Explorers think in terms of large discoveries
  - Consistent with SEC / SPE / WPC / AAPG guidelines
  - Commercial threshold truncations easier to apply
  - Less confusing for decision makers

In a Greater Than convention:

- P10 is the larger number
- P90 is the smaller number

Exercise PB-4: Production Rate Distribution

Production Rate (Mcfd): 850, 2500, 570, 1100, 160, 333, 1333

Using the mid-point approach, build a field size distribution on log probability paper:

a. Arrange all fields by size, largest first and assign Rank
b. Determine the Percentile Values

n = 7; Percentile = 100/n * (Rank – 0.5)

c. Tabulate Field Sizes with %tiles
d. Plot the data pairs

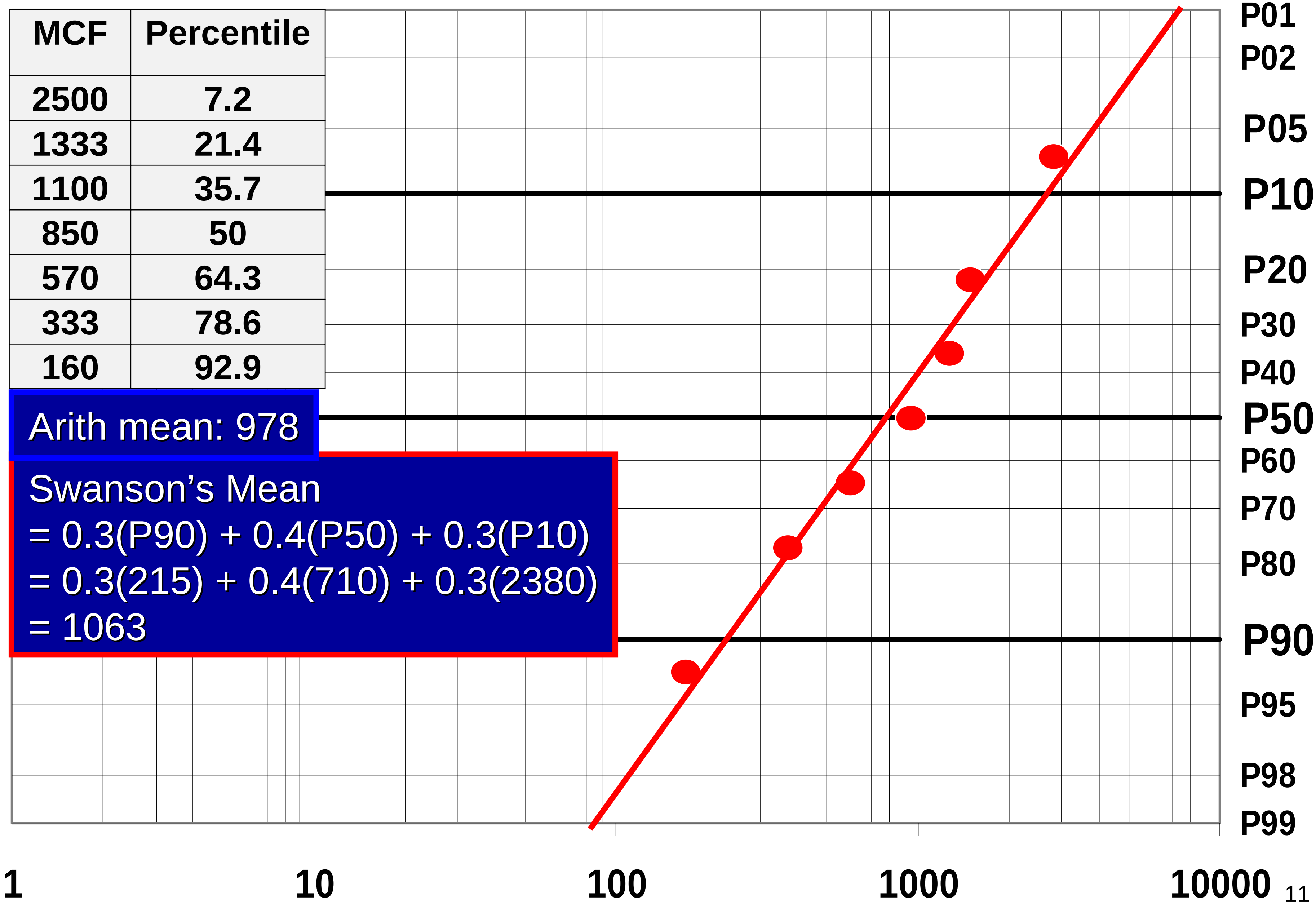
MCFD	Rank	%tile
2500	1	7.2
1333	2	21.4
1100	3	35.7
850	4	50
570	5	64.3
333	6	78.6
160	7	92.9

Rank Order the Rates & Determine the Percentile

MCF	Percentile
2500	7.2
1333	21.4
1100	35.7
850	50
570	64.3
333	78.6
160	92.9

Arith mean: 978

Swanson's Mean
= 0.3(P90) + 0.4(P50) + 0.3(P10)
= 0.3(215) + 0.4(710) + 0.3(2380)
= 1063



Aggregation

POWERFUL ASSETS

What if you have drilled 100 wells in a resource play, where the mean EUR is 3.5 BCF and the range is between 1 and 6 BCF *- - -*

Will you bet your house, that the next well (you only get one chance) drilled in the resource play will be equal to, or greater than the average 3.5 BCF per well?

Not likely?
Why not?

What EUR would you be willing to Bet and be <u>reasonably certain</u>.

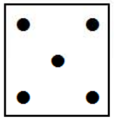
Chesapeake ENERGY

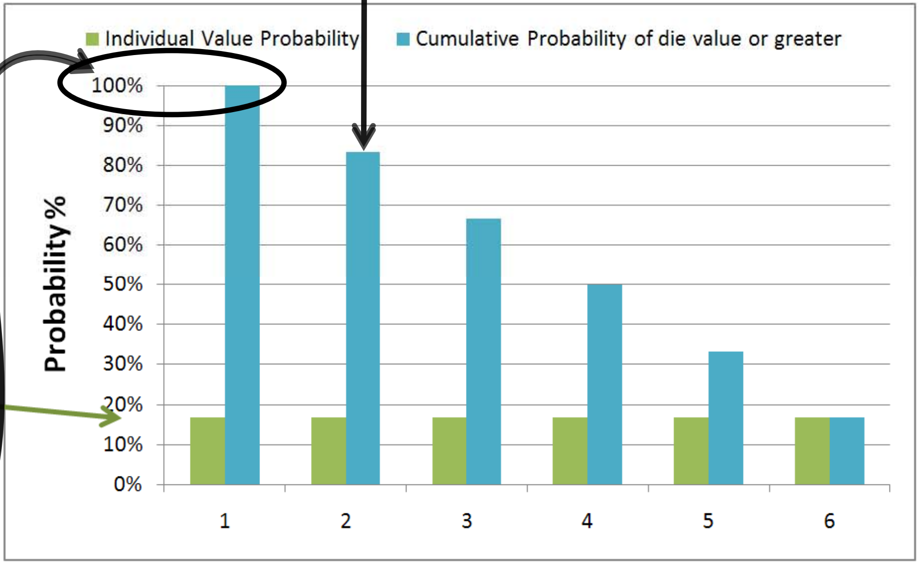
Aggregation -- One Die Distribution

Chance of rolling a 1 or 2 or 3 etc. is 83%

Chance of rolling a 2 or Greater is 83%

	1	2	3	4	5	6	AVG 3.5
Die Values							
Frequency	1/6	1/6	1/6	1/6	1/6	1/6	
Probability %	17%	17%	17%	17%	17%	17%	
Cum Frequency	100%	83%	67%	50%	33%	17%	

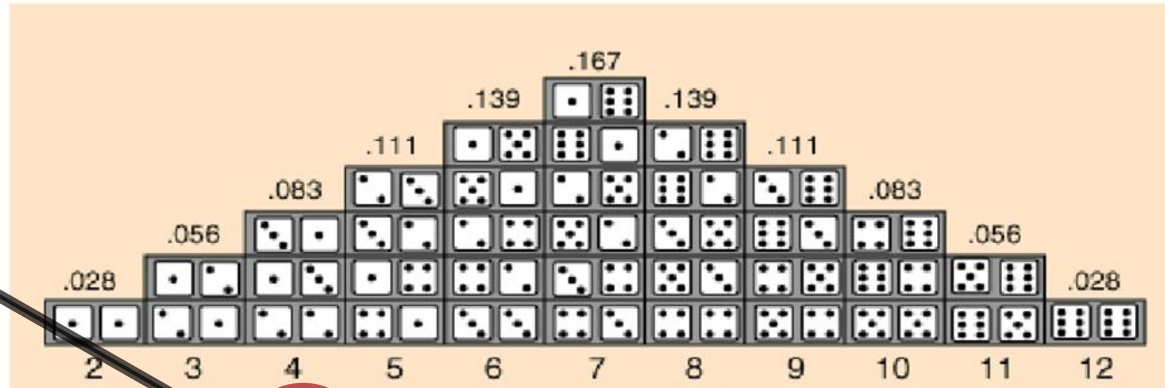




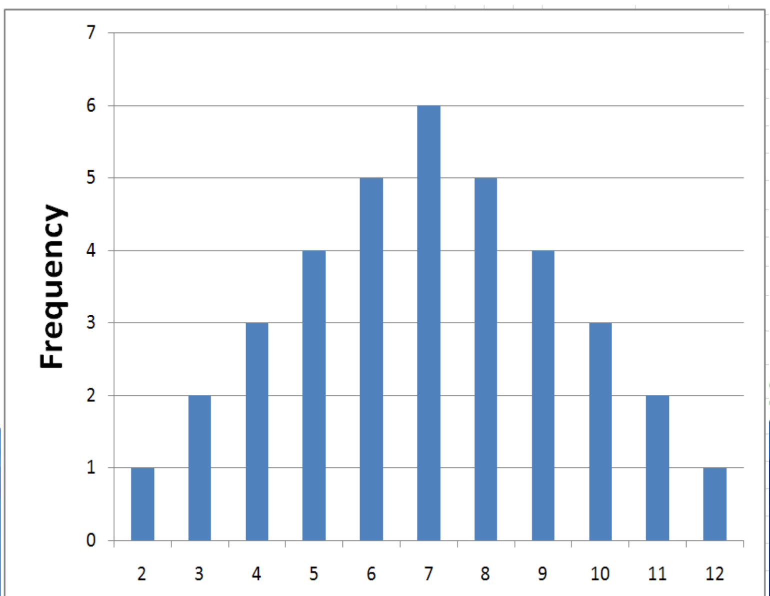
Chesapeake ENERGY

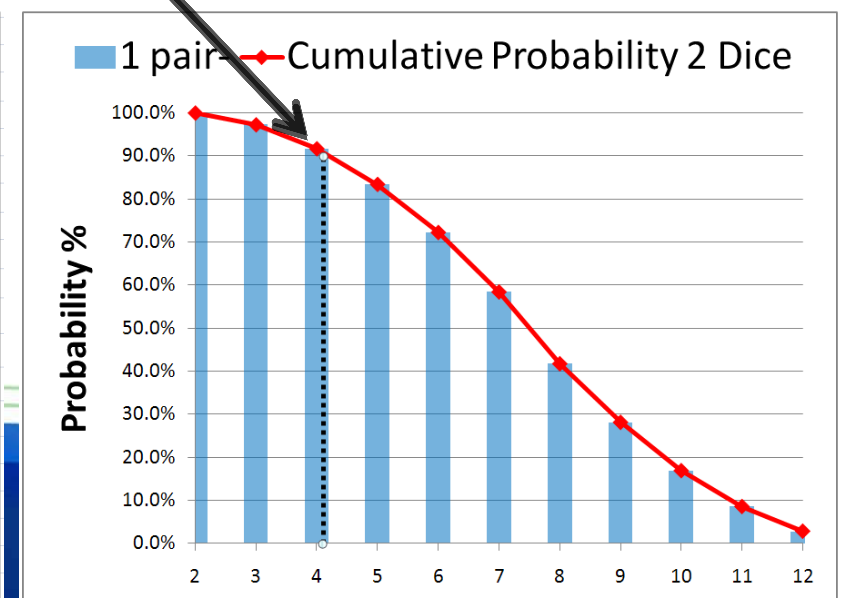
Aggregation Example - Two Dice Distribution

Criteria = 2



Possible Dice Values	2	3	4	5	6	7	8	9	10	11	12
Frequency	1	2	3	4	5	6	5	4	3	2	1
Cum Frequency	1	3	6	10	15	21	26	30	33	35	36
Cum Probability	100%	97.2%	91.7%	83.3%	72.2%	58.3%	41.7%	27.8%	16.7%	8.3%	2.8%

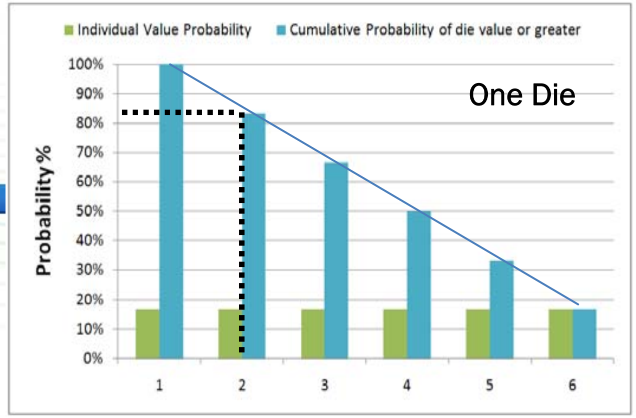




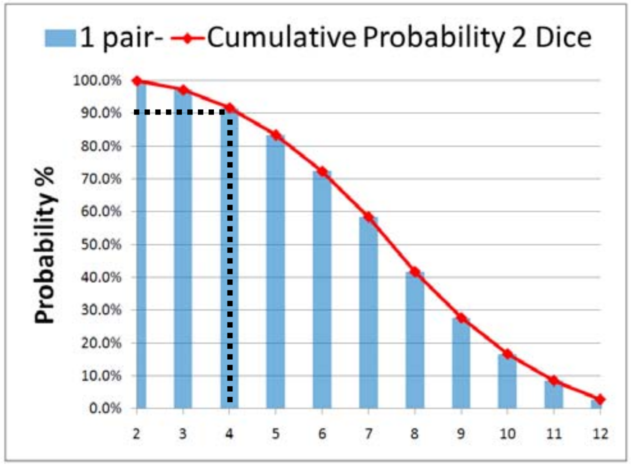
Chesapeake ENERGY

Aggregation and Probability

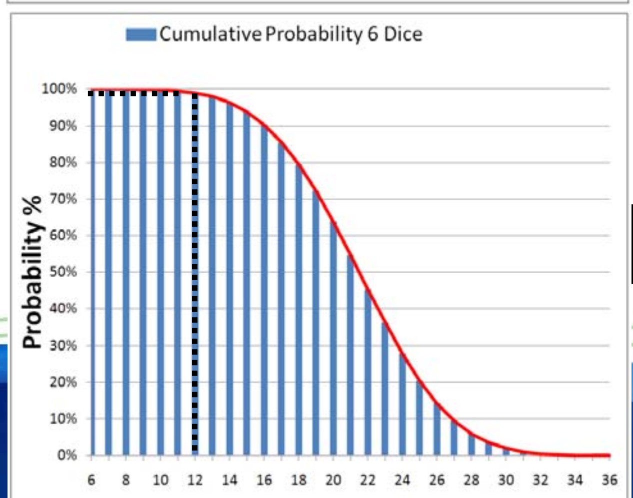
If we hold the criterion value per Die at 2 or Greater, What happens to the Probability (confidence)



~P83% for value of 2 or Greater



~P90% for 2 Dice X 2 Dice = 4



~P99.8% 2 X 6 Dice = 12

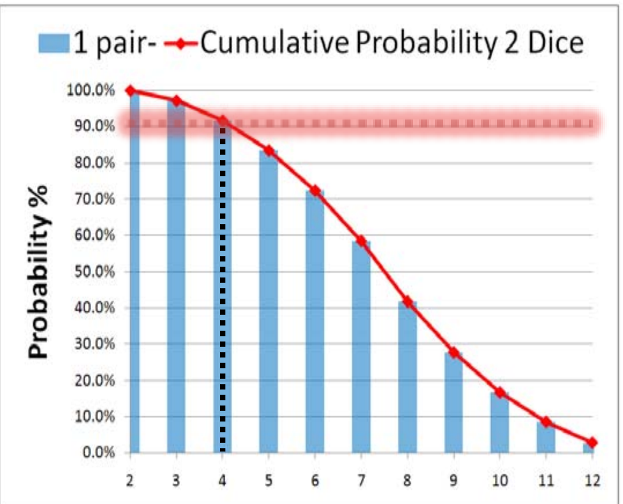
CONCLUSION:
confidence criterion must change with added distributions, otherwise "high confidence" becomes increasingly conservative

POWERFUL ASSETS

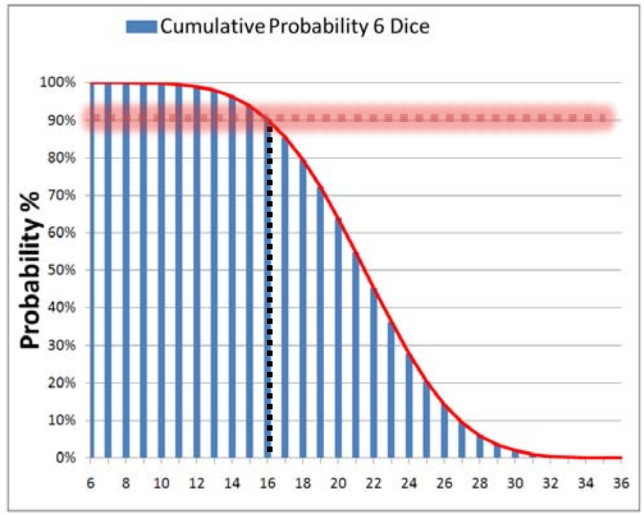
Chesapeake ENERGY

Aggregation – What is the P90 Equivalent of One Die for various sample sizes

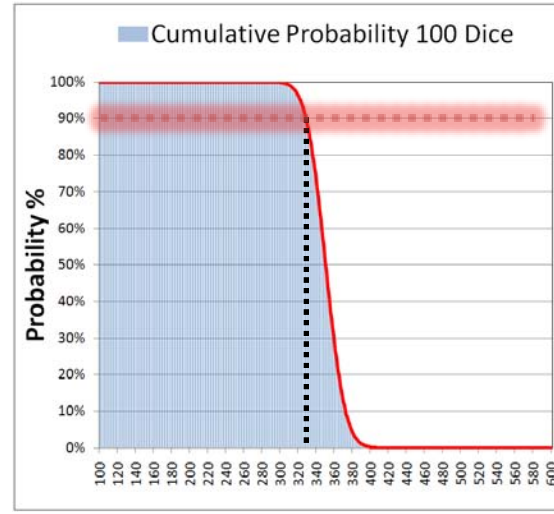
The correct question: What value represents the P90 or Proved of various Distributions?



4.2 & 2 Dice =2.1 per Die



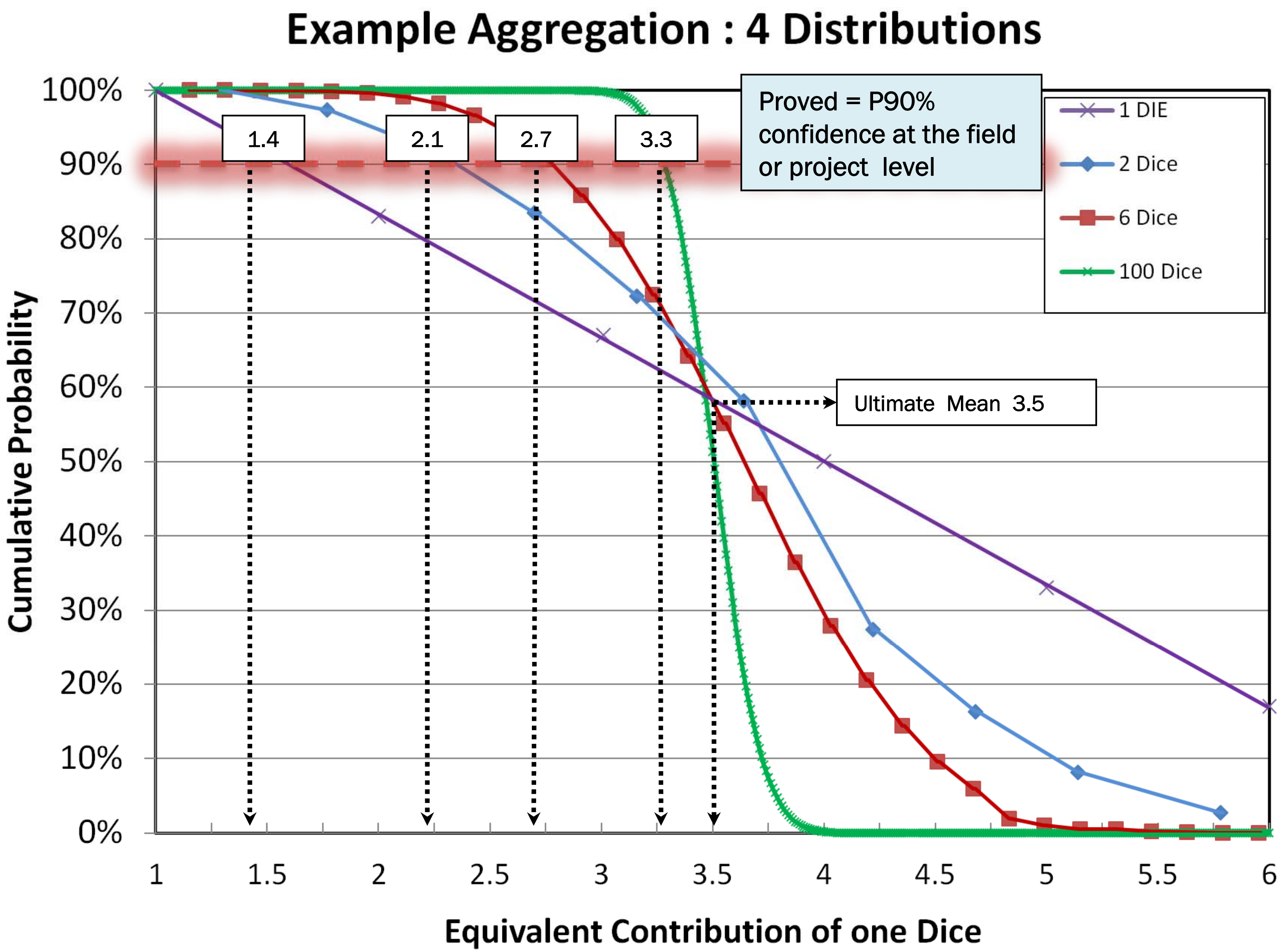
16.1 & 6 Dice =2.7 per Die



330 & 100 Dice =3.3 per Die

Chesapeake ENERGY

P90 comparison for 1, 2, 6, and 100



Aggregation: Proved?

POWERFUL ASSETS

FIELD PDP Performance Information:

Existing Wells	100
AVG EUR	3.5
Range of EUR	1-6
P10/P90	4

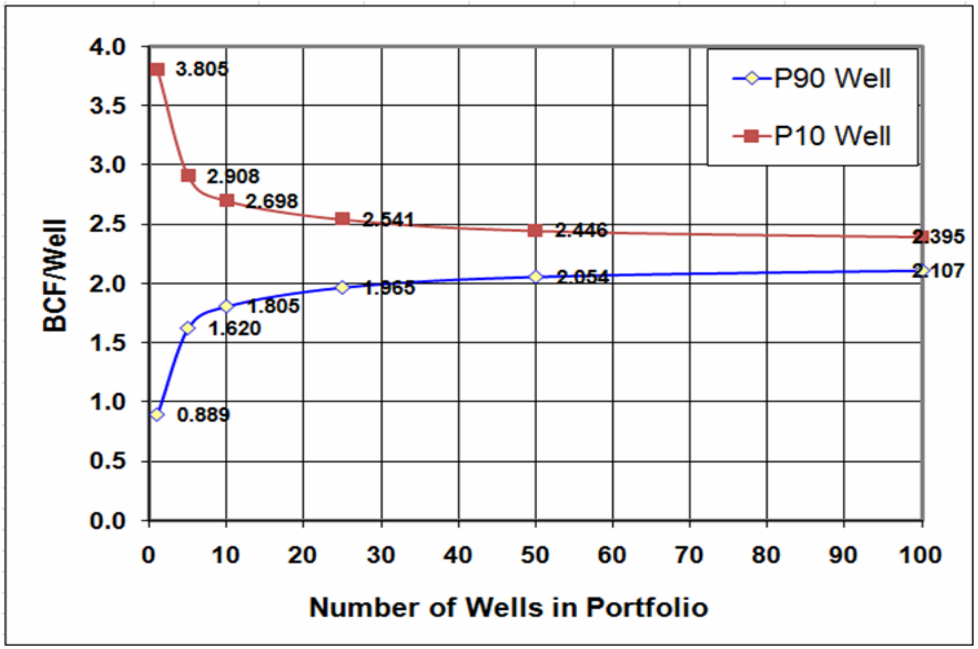
What can be booked as Proved for each case?

PUD Locations	1	2	6	100
EUR per well	1.4	2.1	2.7	3.3

Chesapeake ENERGY

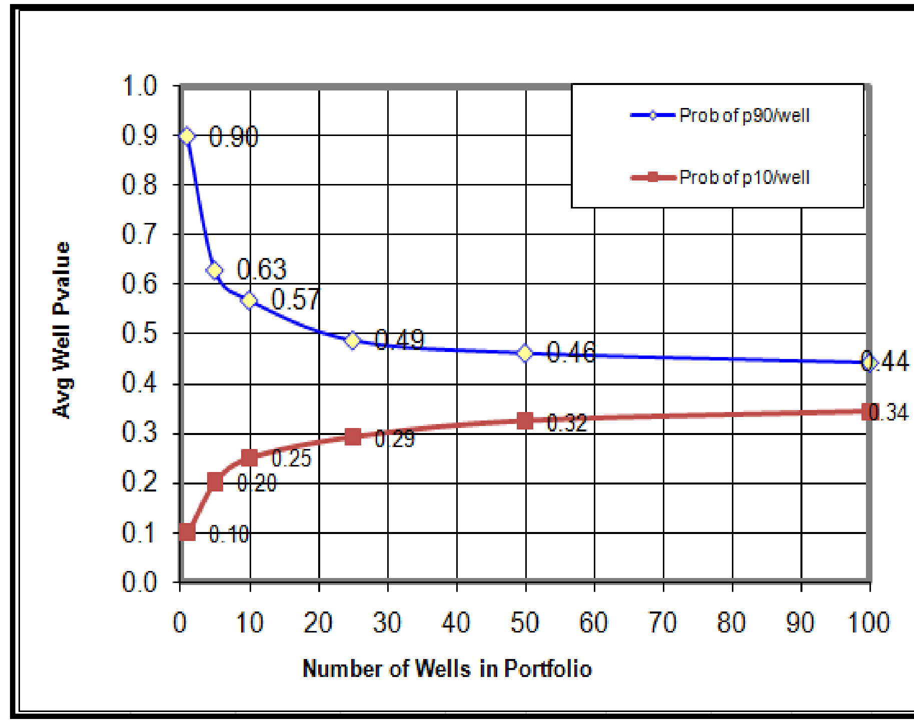
Aggregation Happens Quickly

P90 Bookable value for various portfolio well counts where the mean is 2.2



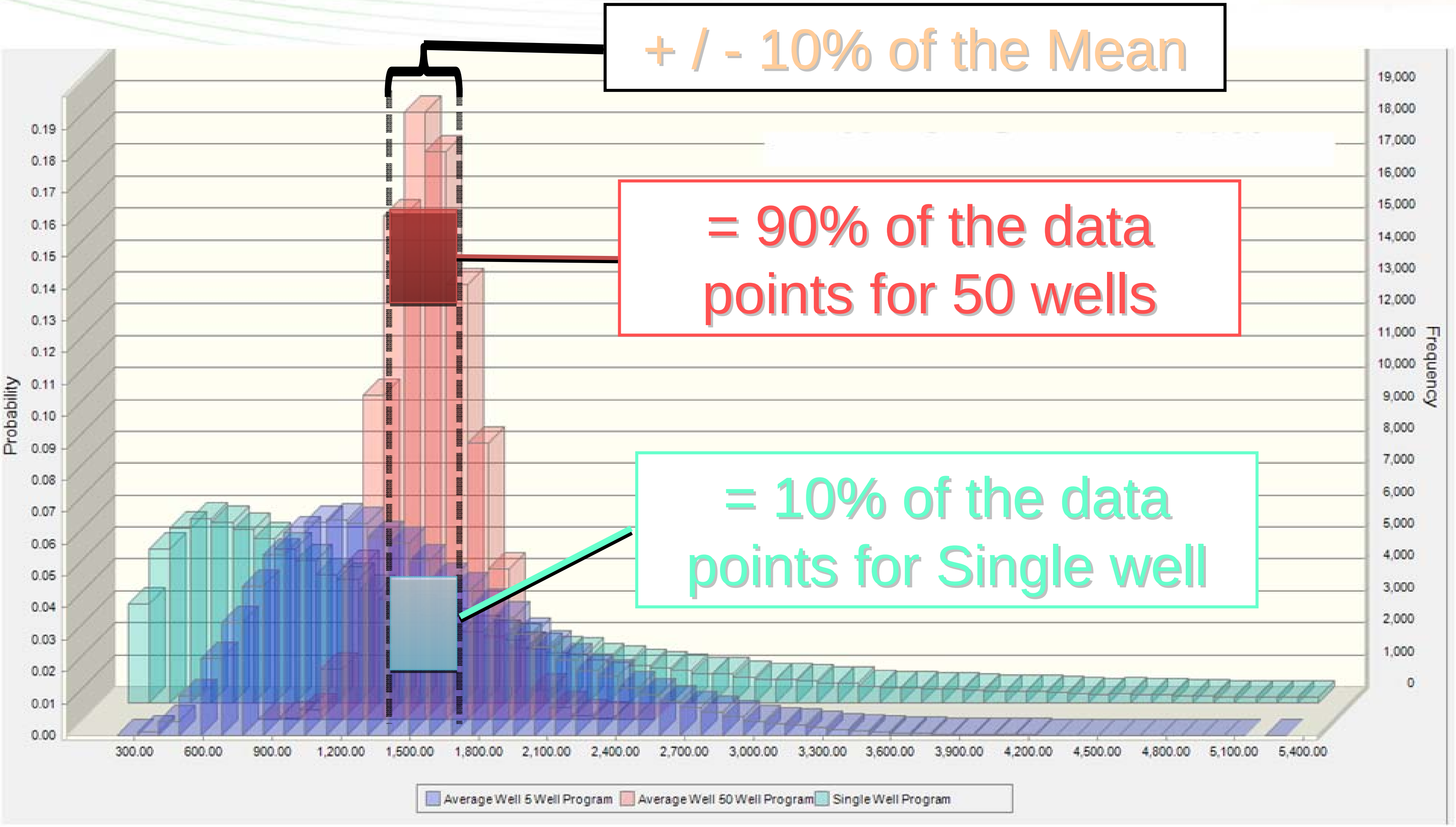
— Monte Carlo simulated P10 and P90 for different Portfolio well counts

Probability that a P90 well would book at for various portfolio well counts



Chesapeake ENERGY

Aggregation Histograms
Variability around the Mean



Aggregation impact of 1, 5 and 50 wells on a P_{10}/P_{90} ratio of 10 Type Curve

The P^ Approximation Concept

- A simple first approximation of the Aggregated portfolio P90 of a large number of PUD locations, which will be represented by the same Type Curve, is the P^ of the distribution.

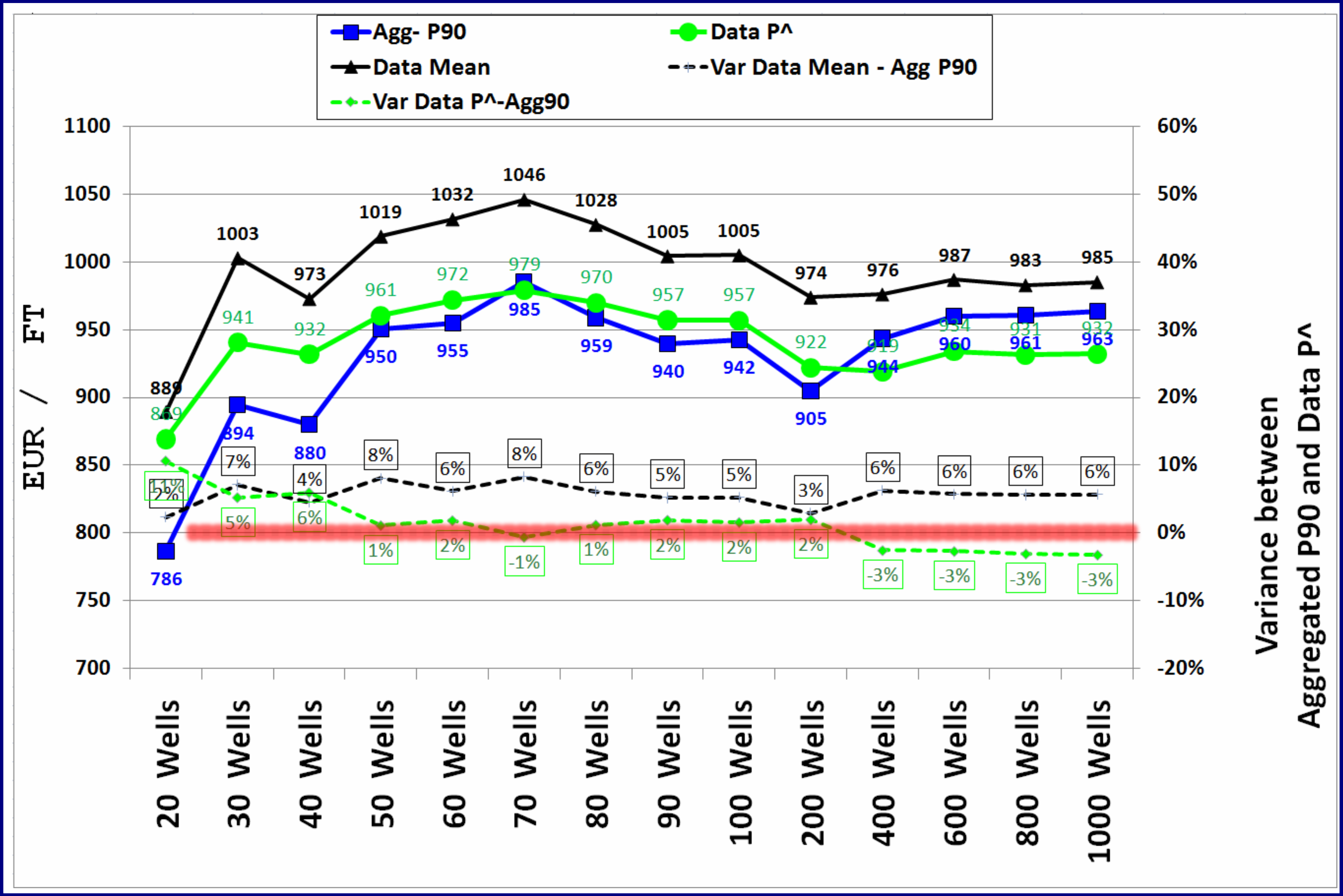
- Where: $\boldsymbol{P\hat{} = (P_{50}+P_{Mean})/2}$

- P^ is a good approximation method for well counts in excess of 30.

- P^ is slightly optimistic for well counts less than 70 to 100 for a P10/P90 Ratio of 4 to 8 respectively.

- P^ is slightly pessimistic for well counts in excess of 70 to 100 for a P10/P90 Ratio of 4 to 8 respectively.

P^ as a Proxy For The Aggregated P90



P^ as a Proxy For The Aggregated P90

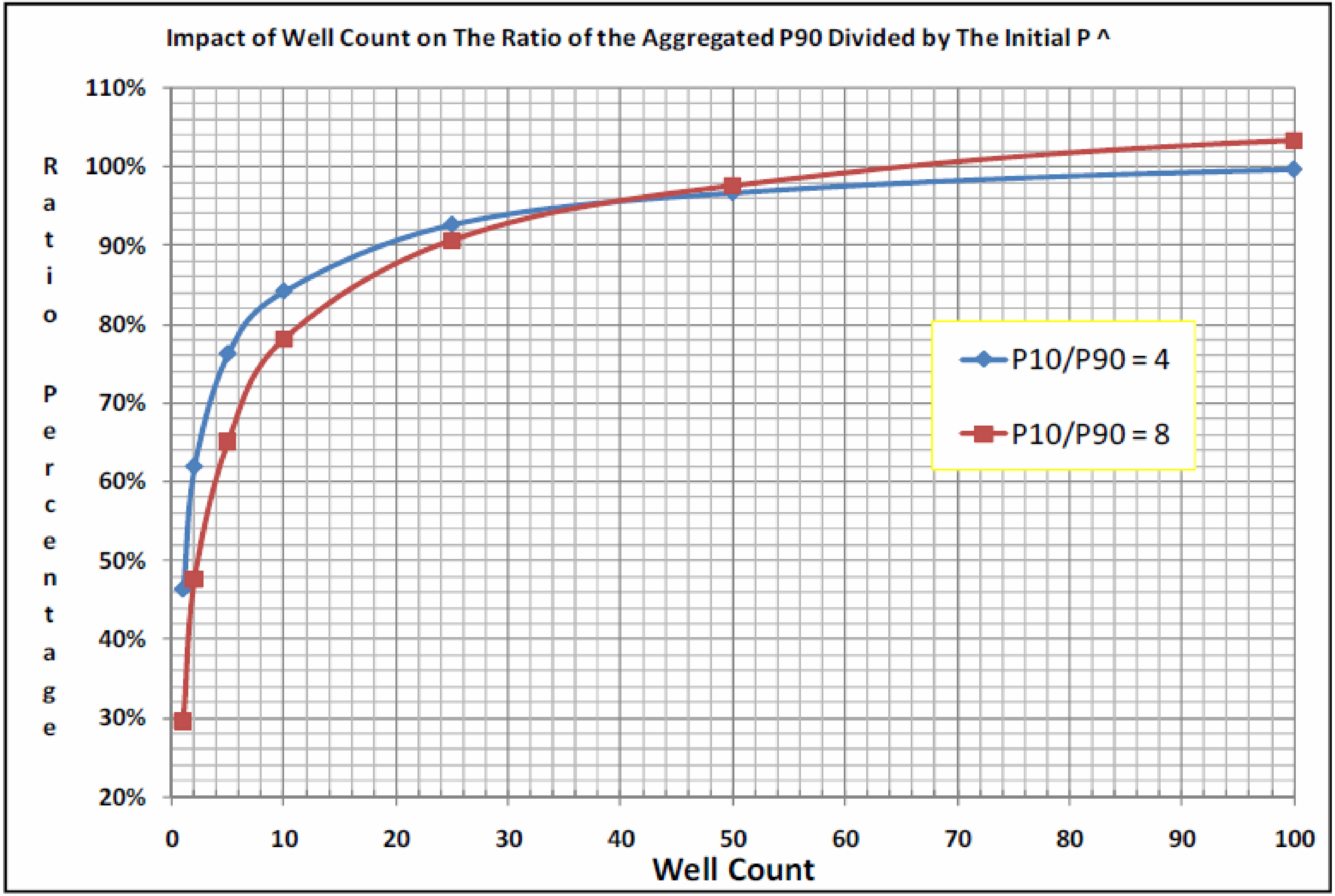
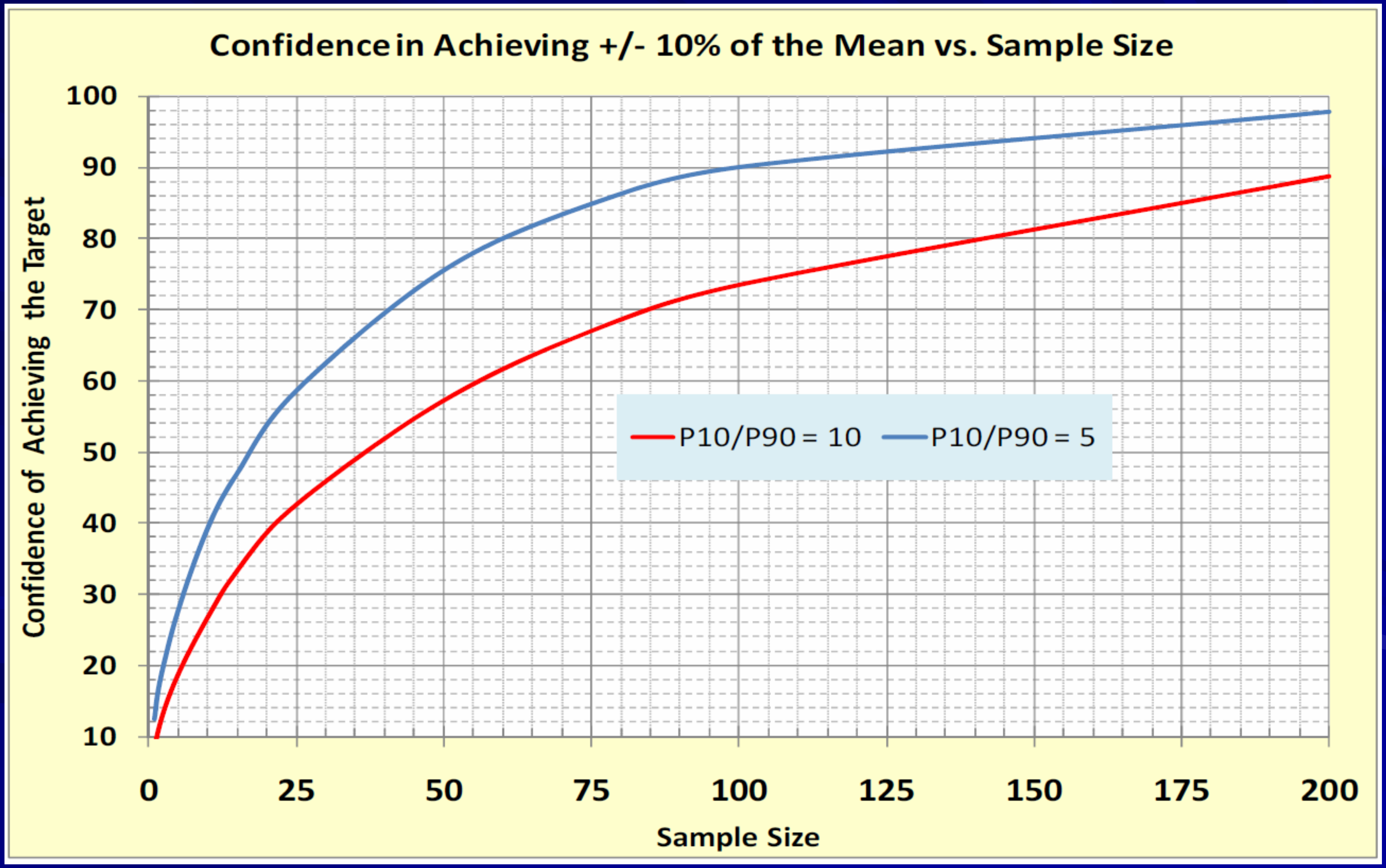


Fig. 2.31 – Ratio of Aggregated P_{90} / P^ Vs. Well Count

Confidence in Achieving +/- 10% of the Mean as a function of Sample Size



What Distributions Are Horizontals Wells?

- Lognormal for each stage

- Tending towards Normal as we add stages
  - However each zone impacts the total results are partially dependent

- Deviations from Normal and Lognormal at both extremes.
  - High end due to extensive pre-existing fracture networks
  - High end due to no flow boundaries
  - Low end due to multiple stages of fracturing; hence an unlikely very poor outcome