Capturing Uncertainty in Prospect Economics*

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Abstract

This paper presents a procedure to describe prospects' uncertain outcomes in investment-decision-friendly terms. Oil and gas investment results are uncertain prior to drilling and producing. This uncertainty has been the focus of excellent papers over the years. However, published approaches usually stop before answers are translated into cash flow. The presented procedure forecasts prospect performance based on a probabilistic distribution of well performance rather than volumetric calculation. By estimating future well performance, cash flows can be forecast providing results in investment decision friendly terms. Using historic production data, examples are presented of data type to use, how to create a performance probability distribution, and how to understand the results. The presented procedure is not complicated, is intuitive to petroleum professionals, and should increase the quality of investment decisions. It can answer that questions like, "What is the likelihood of this investment having an IRR of greater than 15%" or "What is the likelihood of capital requirements of $10 million or more?" Any economic input can be described as a probability function and sampled during simulation making this approach very robust. Such a program can be built on a personal computer with commercially available software and can be very simple or very complex, depending on a user's needs. However, most commercially available economic programs do not provide for this functionality. A very important benefit of this procedure is that it expands the prospect conversation. Because inputs are related to well performance, reservoir, drilling, and completion engineers and geoscientists all have contributions to make. Such a discussion may identify new trends or best practices. While this procedure offers attractive benefits, it does present a number of challenges, notably, how a probabilistic distribution of results are to be used in making decisions. The discomfort, but not the inability, in dealing with this unfamiliar output may be a main reason management does not require this type of analyses! The presented procedure offers a means to improving the investment decision process and, consequently, the decisions made. This process drives technical investigation, encourages cooperative communication, and contributes to the success of exploration and production companies.

References Cited

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Petroleum Resources Management System, 2007, Sponsored by Society of Petroleum Engineers (SPE), American Association of Petroleum Geologists (AAPG), World Petroleum Council (WPC), and Society of Petroleum Evaluation Engineers (SPEE), 47 pp.

Poston, S.W., and B.D. Poe, Jr, 2008, Analysis of Production Decline Curves: Society of Petroleum Engineers, Richardson, TX, ISBN: 978-1-55563-144-4, 175 pp.

Capturing Uncertainty in Prospect Economics

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Outline

- Disclaimers
- Context
- The Problem(s)
- Introduction
- "Another Way"
- Simple Example
- The Tool
- More Realistic Examples
- Conclusions

Disclaimers & Challenges

- I am NOT AN EXPERT at
  - Decline Curve Analysis
  - Statistics
  - The software I was using (it became profoundly clear!)
- This presentation is an IDEA!
  - Not the final word
  - Intended to stimulate a discussion
- The Challenge
  - Offer a better solution
  - Fix this one
  - ***But do SOMETHING!***

Context

- Job of a generating petroleum geologists consists of
  1. Identifying attractive opportunities
  2. Characterizing their risks and uncertainties so financial decision makers can make the best possible decisions
- Geologists do not need to cede ownership of this most important function to others

The Problem(s)

- Tools commonly available for addressing uncertainty are
  - not able to be translated into cash flow
  - Are passive – they don't lead to something you can work to improve

- Attempts to capture and manage uncertainty often met with
  - Resistance/Rejection
  - Disinterest
  - Laziness ?

"You can't really know" is seen as acceptable treatment of uncertainty

Introduction

- Uncertainty – the lack of certainty; the unknown nature of future outcomes
- Uncertainty about what?
  - All "variables" - Porosity, Area, Recovery Factors, IP's, Declines, Prices, Reserves, Revenues and Expenses, Schedules
- Will focus on the uncertainty of upstream capital investment
- Recommend: "The Known, the Unknown and the Unknowable" by Ralph Gomory, June 1995, *Scientific American*

MAGNITUDE OF UNCERTAINTY

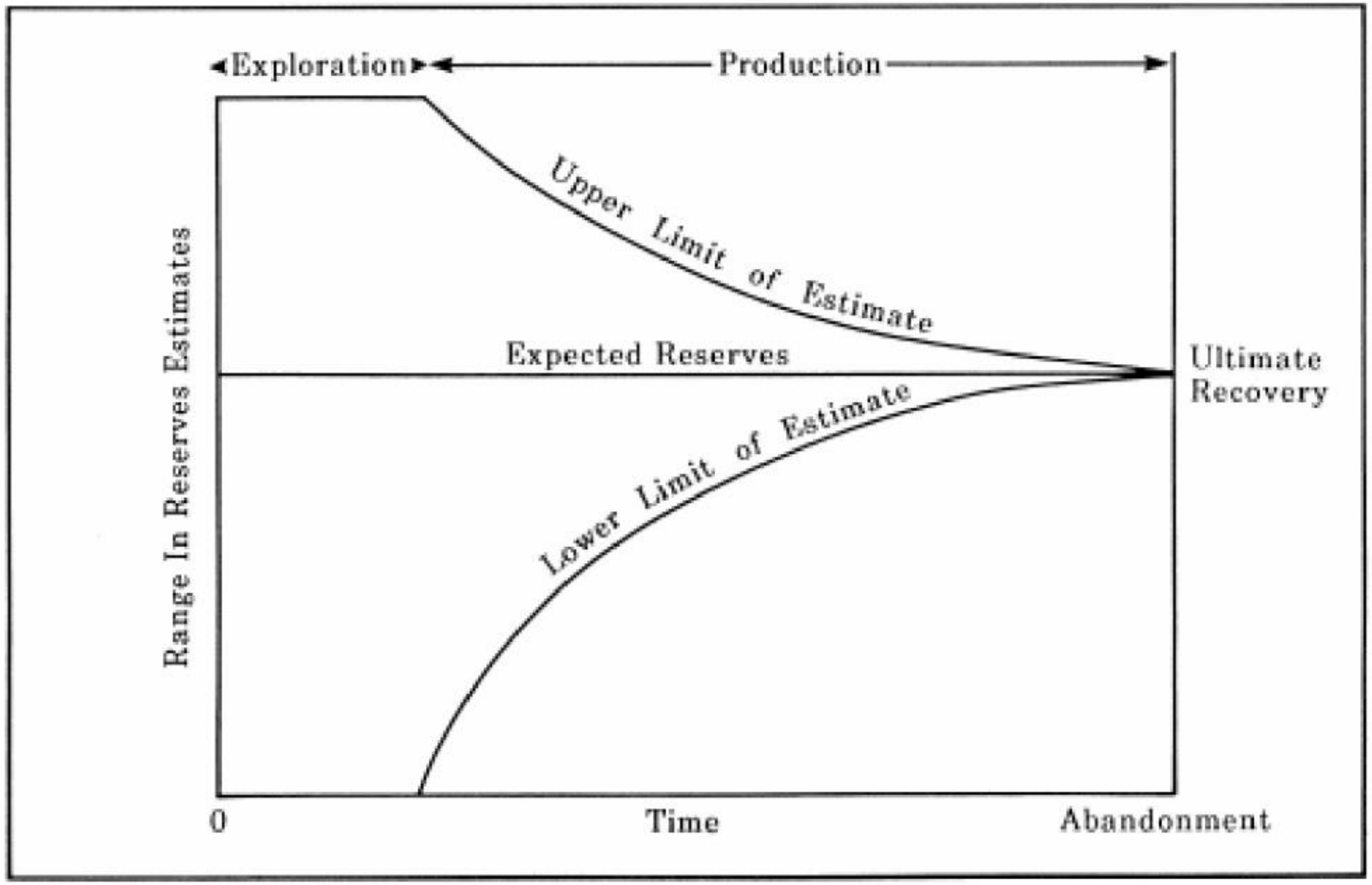


Figure 1: Magnitude of uncertainty in reserves estimates

After Petroleum Reserves Estimation Methods, 2004 [PDF document]. Retrieved from http://large.stanford.edu/courses/2013/ph240/zaydullin2/docs/petrobjects.pdf

- UNCERTAINTY +

+ RISK –

Likelihood of actually producing

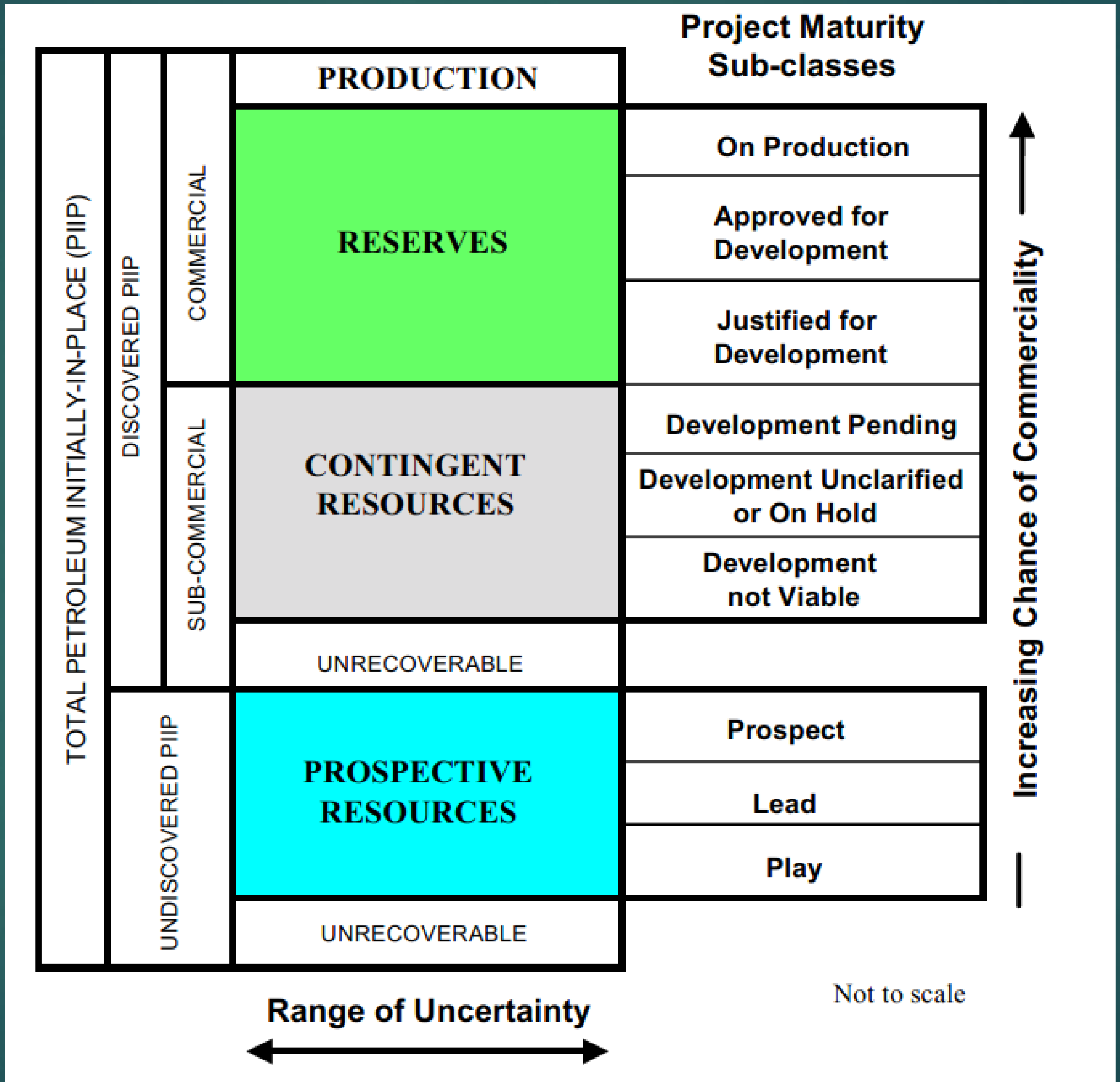


Figure 2-1: Sub-classes based on Project Maturity.

Modified after: Petroleum Resources Management System, 2007, **Sponsored by SPE, AAPG, WPC, & SPEE**

Current State of the "Uncertainty" Art

- Use distributions of inputs to calculate volumetric distribution of reserves

$$P(A) * P(H) * P(RF) = P(Reserves)$$

- Quite simple and elegant
- Adds value in learning
- We stand on the shoulders of great educators/men

It's Good but ....

.... it stops at Reserves

Reserves provide no insight into

- Timing or Rate Uncertainty
- Likelihood of Production

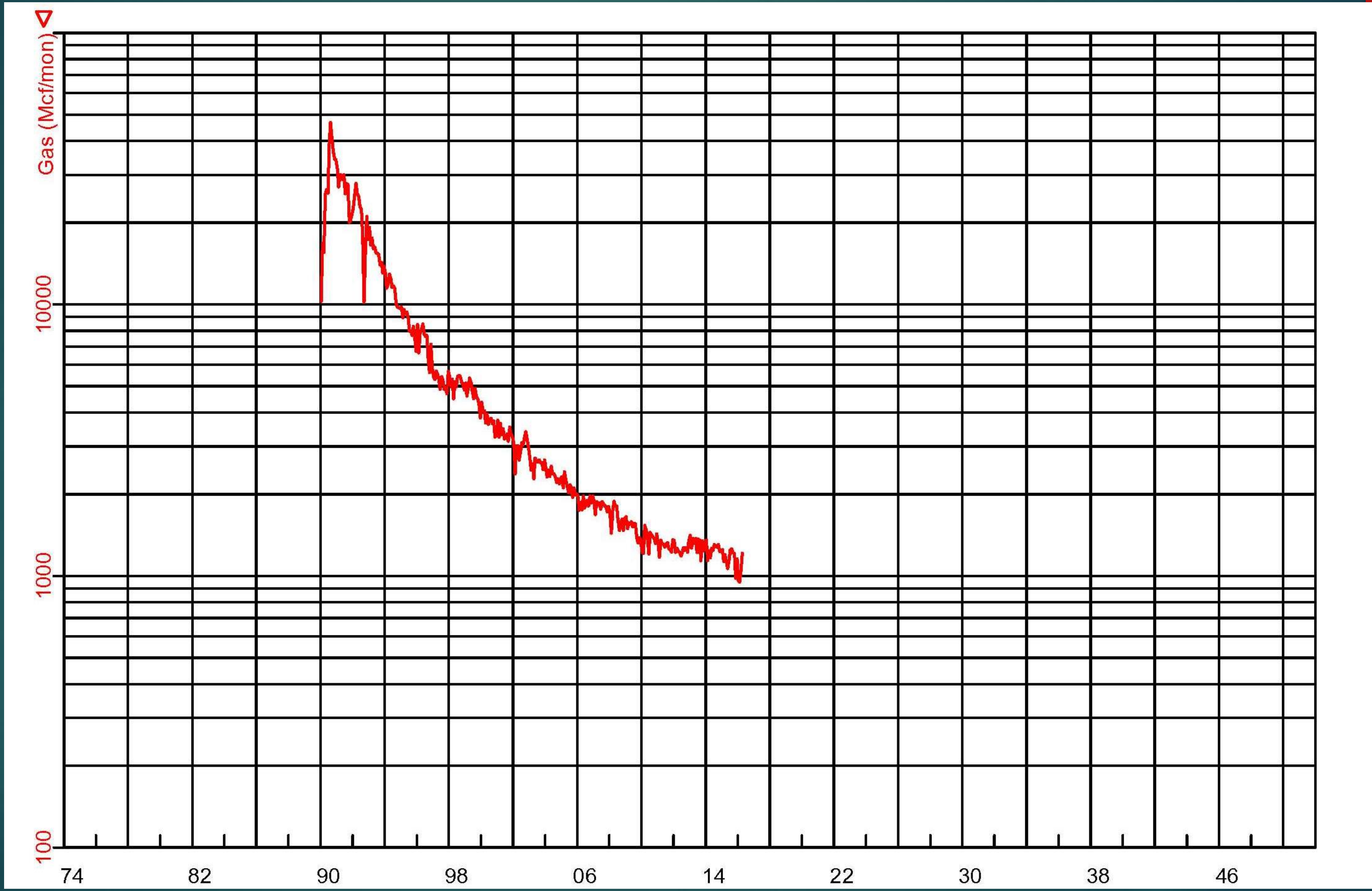
Another Way

- Capture _performance_ uncertainty from historic wells

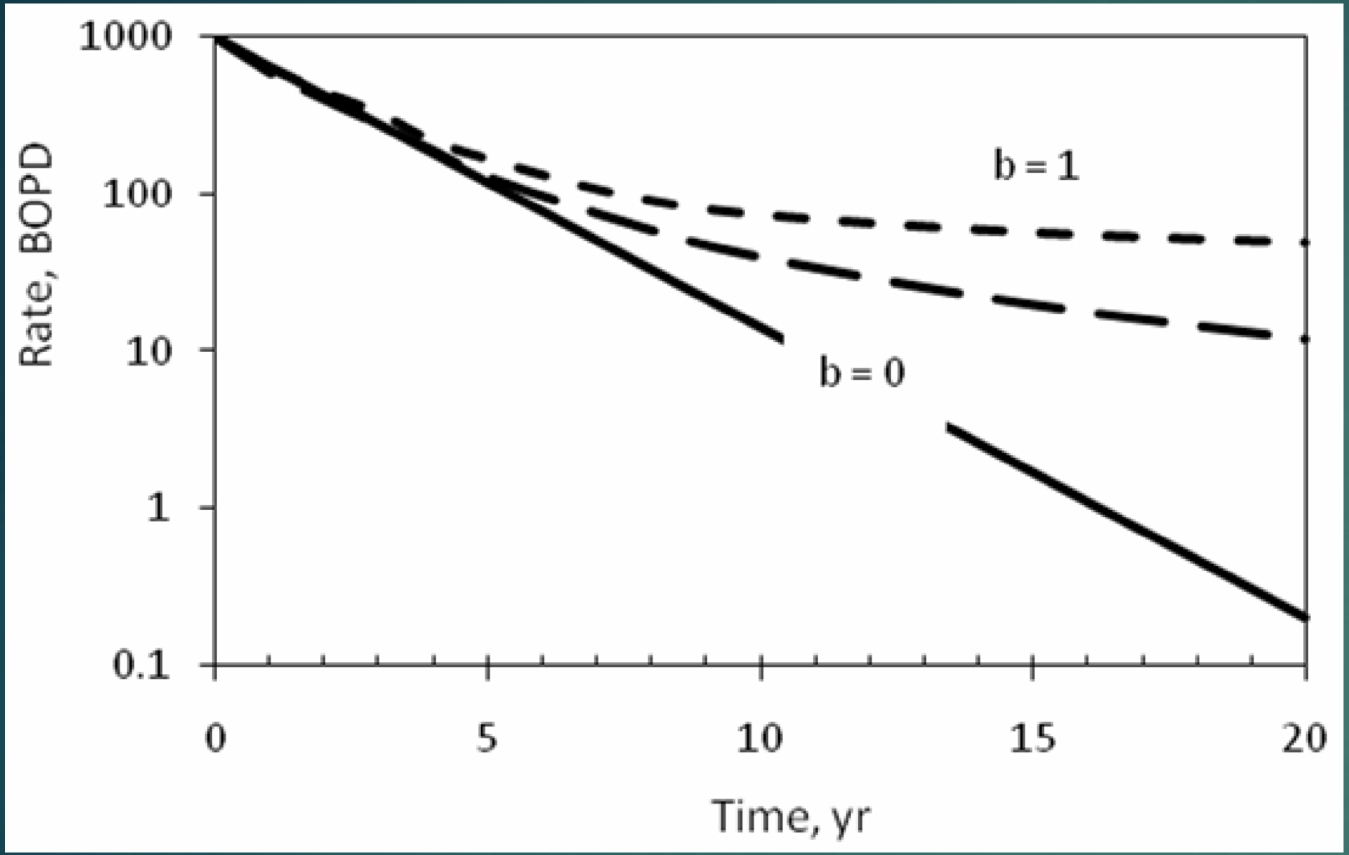
Replace Volumetric Measures for Well Performance Measures

- Describe uncertain future by simulation

Historic Well Performance



Decline Curves



All of these require **rate**, **decline**, “b” and **time**. “**b**” reflects the degree of curvature which is a function of the rate and time.

The Arps Equations

	$b = 0$	$0 < b < 1$	$b = 1$
D	$\frac{\ln(q_1 \square q_2)}{t}$	$D_1\left(\frac{q_2}{q_1}\right)^{\frac{1}{b}}$	$D_1\frac{q_2}{q_1}$
q	$q_1\exp(-Dt)$	$\frac{q_1}{(1+btD_1)^{\frac{1}{b}}}$	$\frac{q_1}{(1+bD_1)}$
Q_p	$\frac{q_1 - q_2}{D}$	$\frac{q_1}{D_1(1-b)}\left[1 - \frac{q_2}{q_1}\right]^{1-b}$	$\frac{q_1}{D_1}\ln(1 + D_1 t)$
t	$\frac{\ln(q_1 \square q_2)}{D}$	$\frac{\left(\frac{q_1}{q_2}\right)^b - 1}{bD_1}$	$\frac{q_1 - q_2}{D_1 q_2}$

b=0 Exponential
0<b<1 Hyperbolic
b=1 Harmonic
B=1+ ? Resource plays

Poston, Steven W. Decline Curves. [PDF document]. Retrieved from http://docslide.us/documents/decline-curves-by-stephenposton.html

Arps Decline Curve Equation

General Case

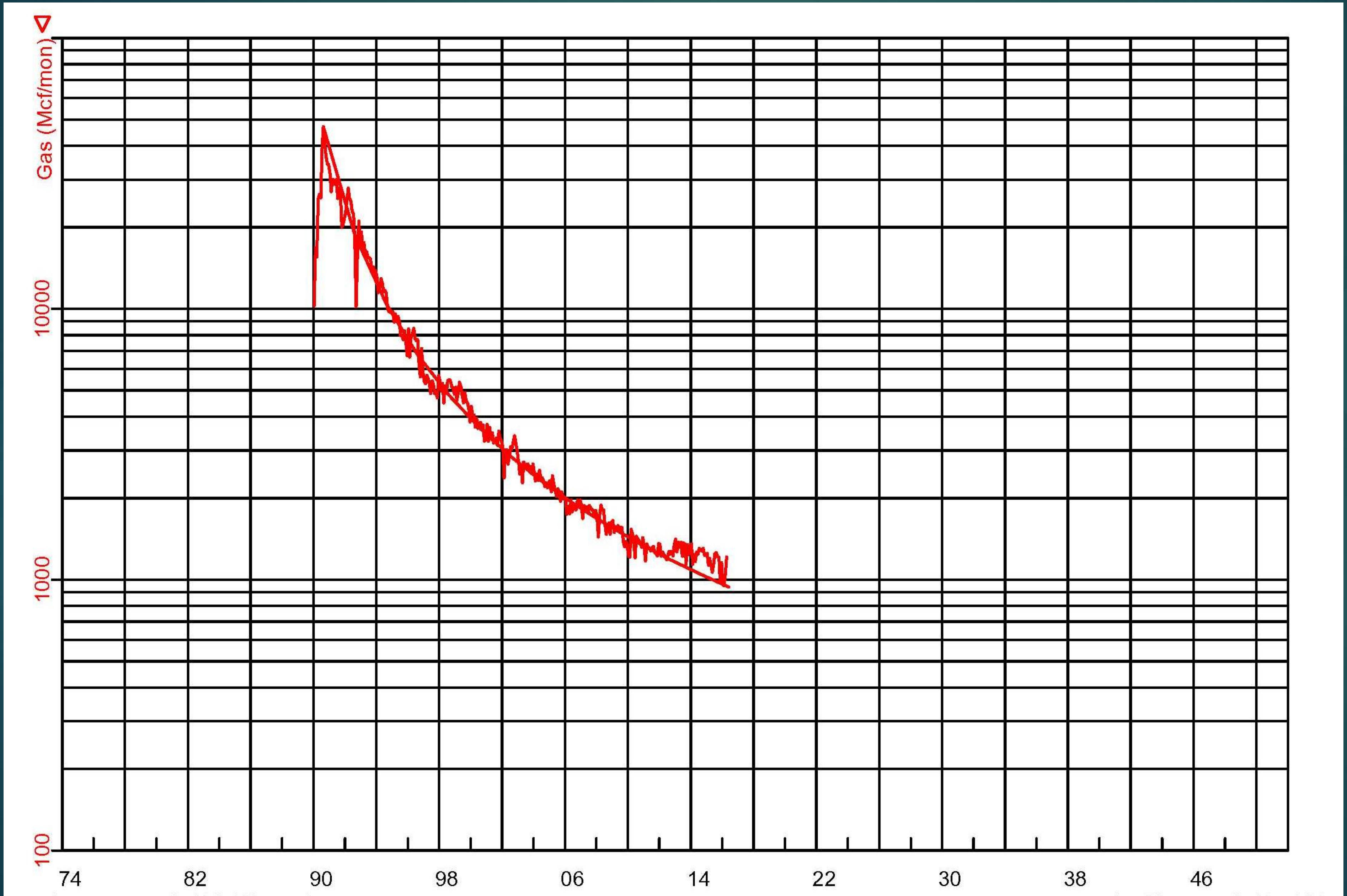
$$q_t = q_i / (1+bD_it)^{1/b}$$

D_i = the initial decline rate
q_i = the initial flow rate
b = the Arps decline curve constant or exponent
t = time in question

Can calculate the rate at time "t" with $\leq$ 3 unknowns

Use these inputs to calculate volumes

Example 1



$Q_i = 47{,}073$

$D_i = 45.77$

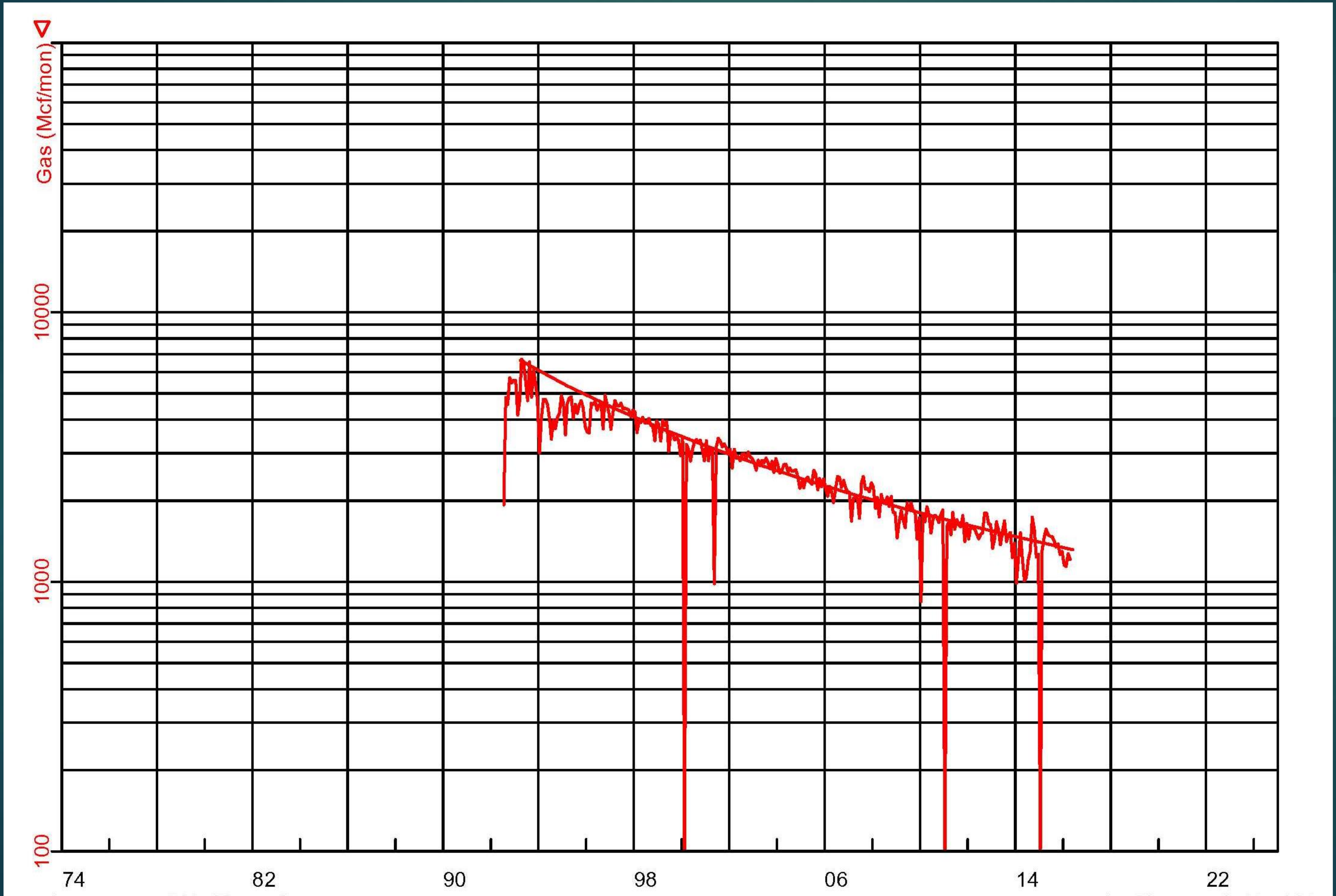
$b = 0.6$

Example 1 - Economics

- Production Profile: Example 1
- CAPEX: $400K
- WI: 100%
- NRI: 75%
- Price: $2.50/mcfg
- STX + AdVal: 8% +1¢/mcfg
- OPEX: $1,500/mo

- **Results**
  - Gross Gas: 1,837 MMCFG
  - Net Cash Flow: $2,273 M
  - PV10: $1,425 M
  - IRR: 167%

Example 2



Q_i = 6,624

D_i = 11.11

b = 0.6

Distribution of Values for Evans Sand

Example	Qi	D_i	b
1	15,188	52.40	-
2	8,240	60.00	1.30
3	14,960	32.62	-
4	24,077	90.00	0.80
5	4,845	90.56	1.30
6	8,850	64.49	1.00
7	10,283	28.91	1.50
8	2,936	83.62	1.00
9	21,526	85.46	1.20
10	6,624	11.11	0.60
11	8,349	60.00	1.50
12	47,073	45.77	0.60
13	12,570	80.00	0.80
14	3,278	76.41	0.60
15	12,600	50.79	-
16	2,990	57.08	0.49
17	1,538	32.49	-

Another Way

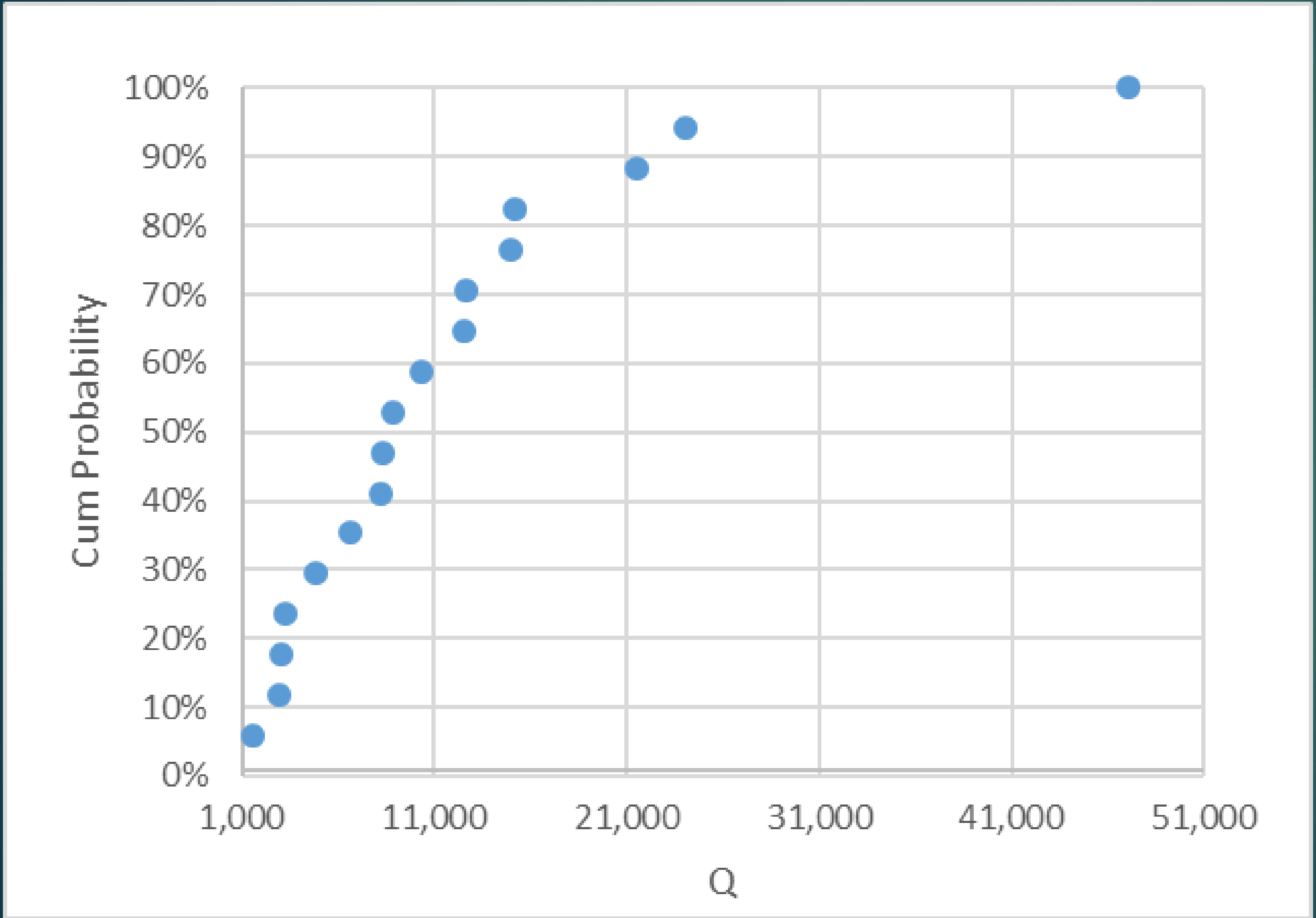
<u>Replace static</u> values **<u>with distributions</u>** of values

$$q_t = q_i / (1+bD_i t)^{1/b} \rightarrow$$

$$P(q_t) = P(q_i) / (1+P(b)P(D)_i t)^{1/P(b)} \rightarrow$$

Distribution of Time Series of Production → Volumes → CFs

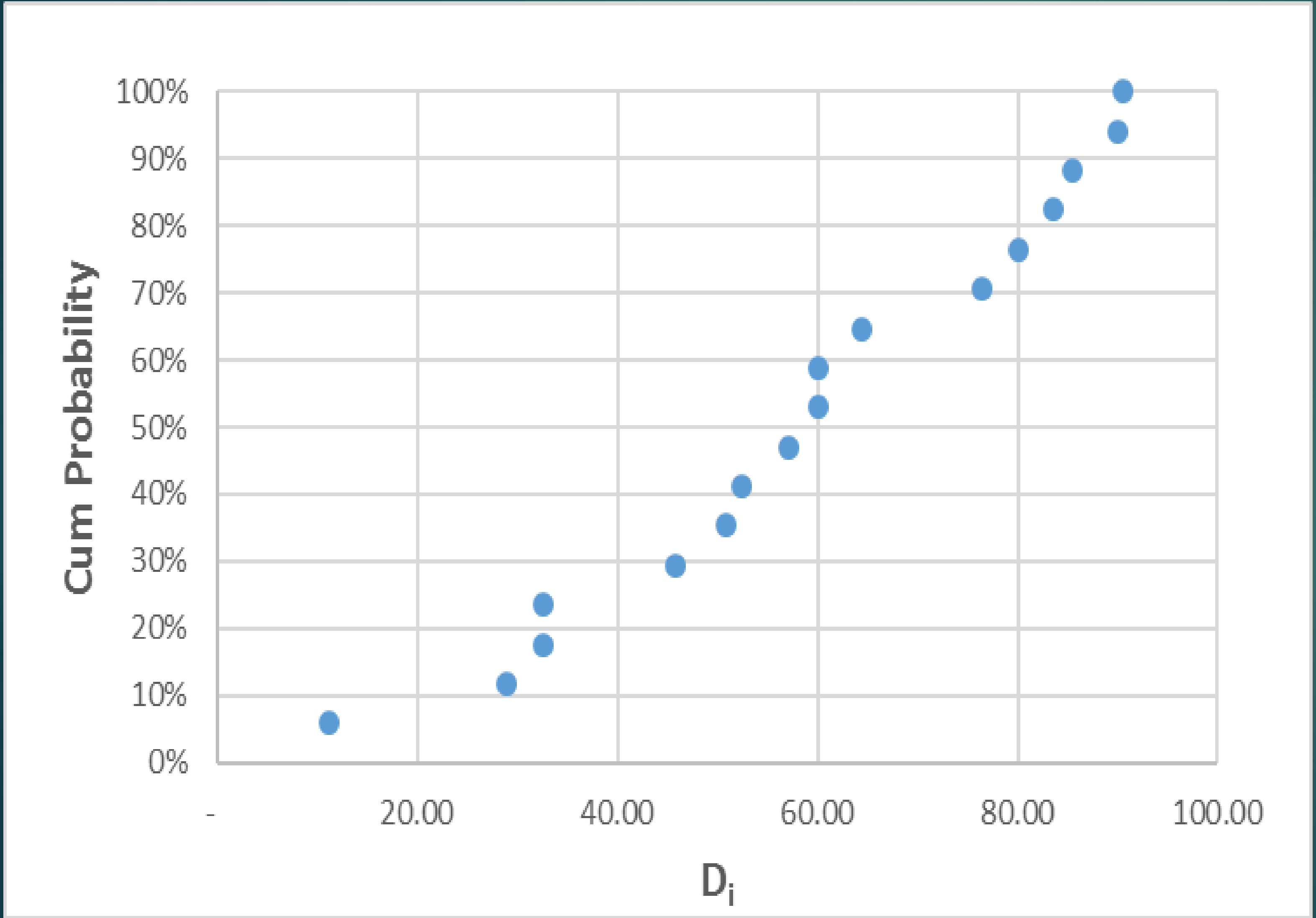
Distribution of **Q**



Whatever type of distribution best fits the data!

Best Fit for this Distribution is an <u>Exponential Distribution</u>

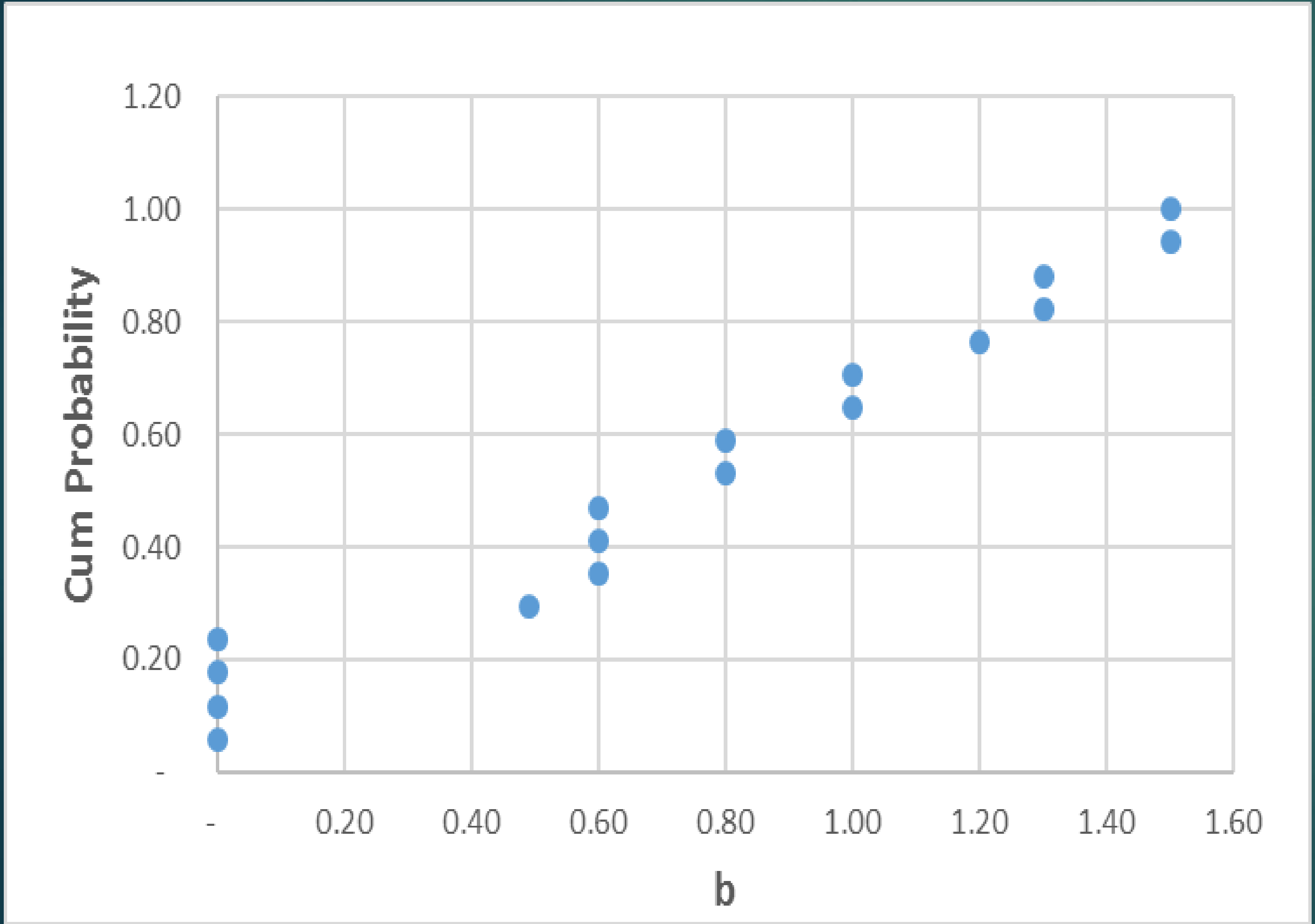
Distribution of **D**



Whatever type of distribution best fits the data!

Best Fit for this Distribution is a <u>Triangular Distribution</u>

Distribution of **b**



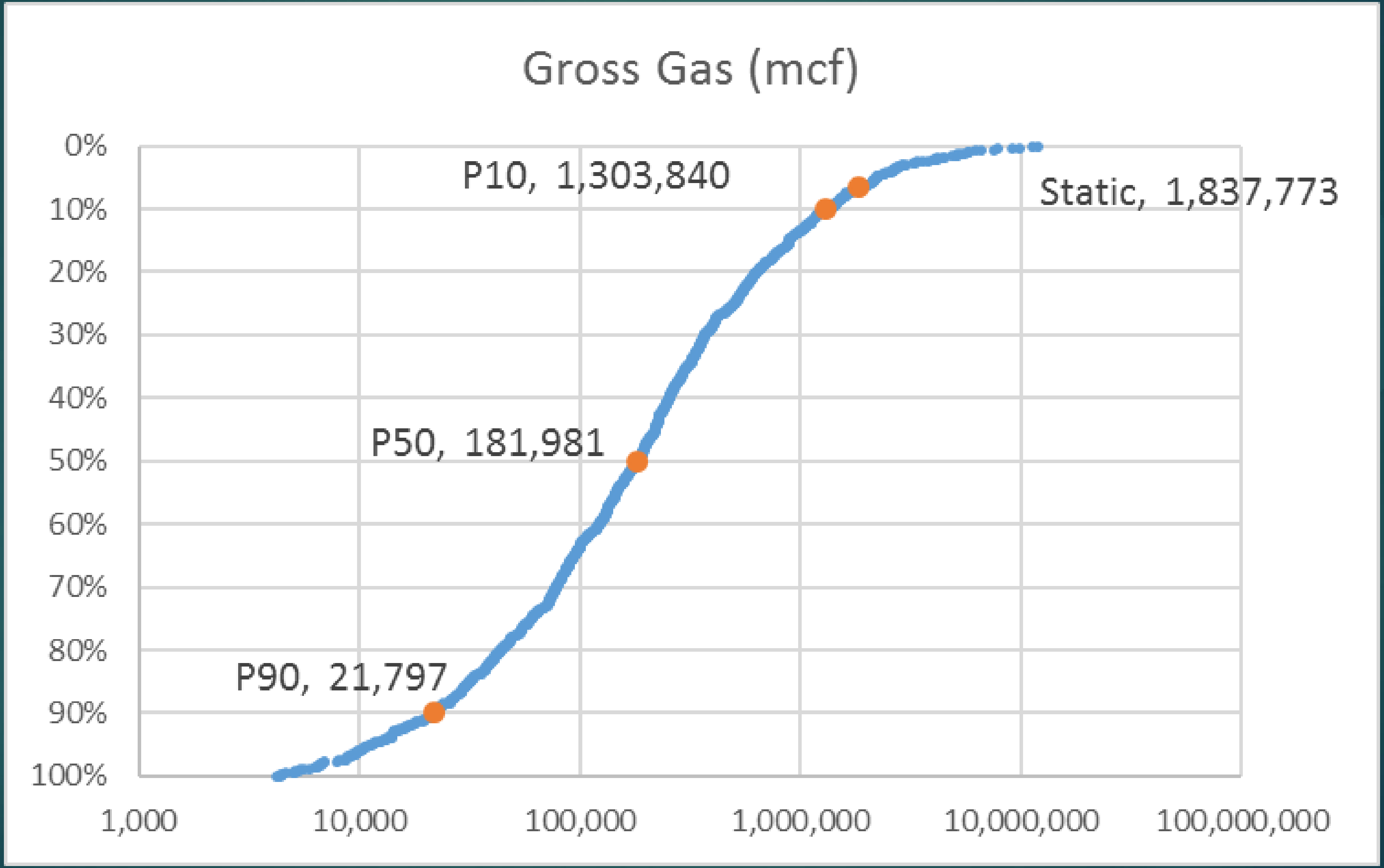
Whatever type of distribution best fits the data!

Best Fit for this Distribution is a <u>Uniform Distribution</u>

A Word about the Tool

- Excel Spreadsheet
  - Simple algorithms – complex relationships
  - Lots of logical and other functions
  - Complexity from built in flexibility
  - Complexity from pushing Excel functions to their limits
- Build the spreadsheet with static inputs in mind
- Use an Excel Add-In <u>to substitute distributions for static values</u>
  - @RISK add-in (by Palisade Corp.)
- Probably better software for this than Excel but that’s what I had and know how to use

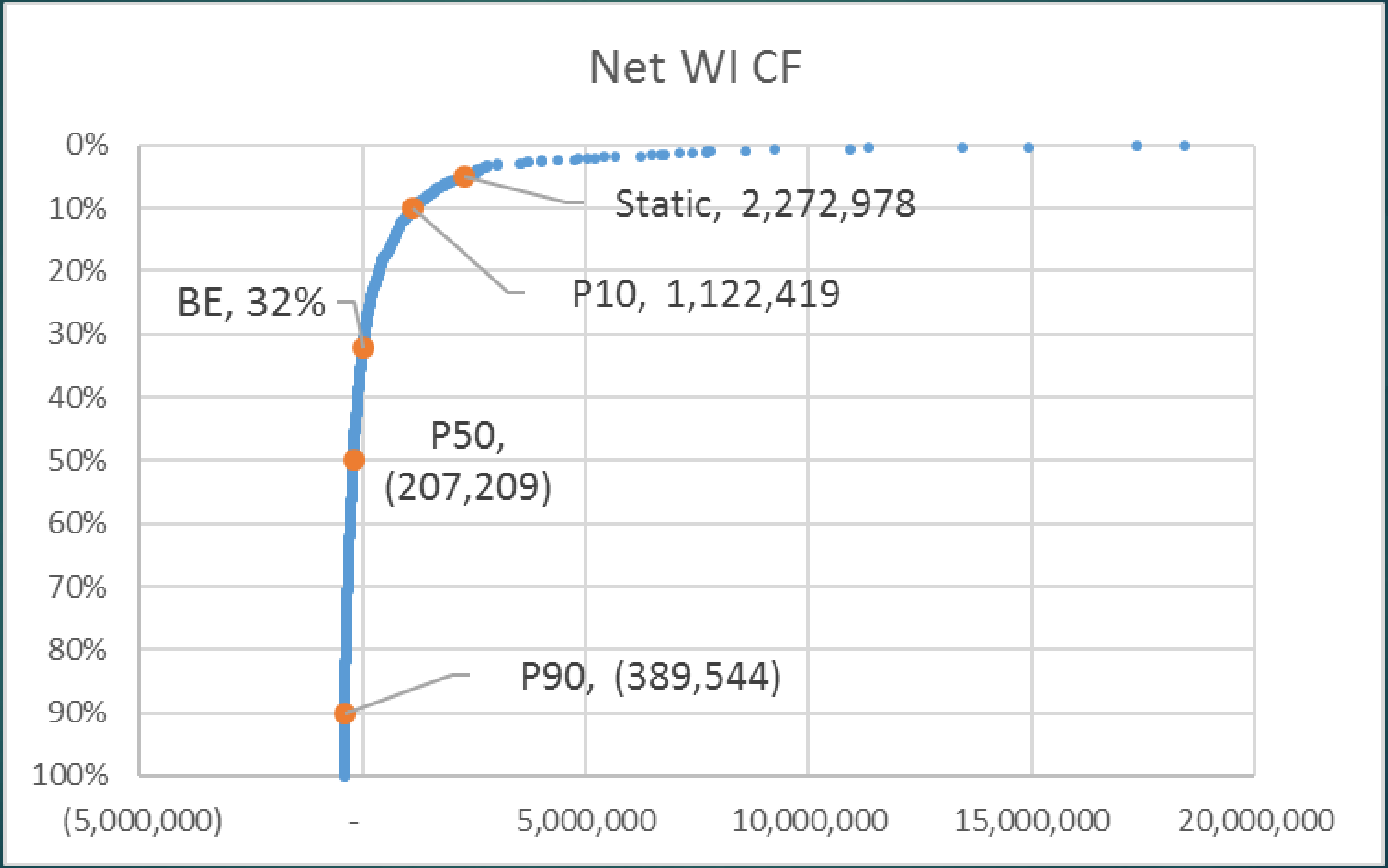
Results from Distributions



Log scale

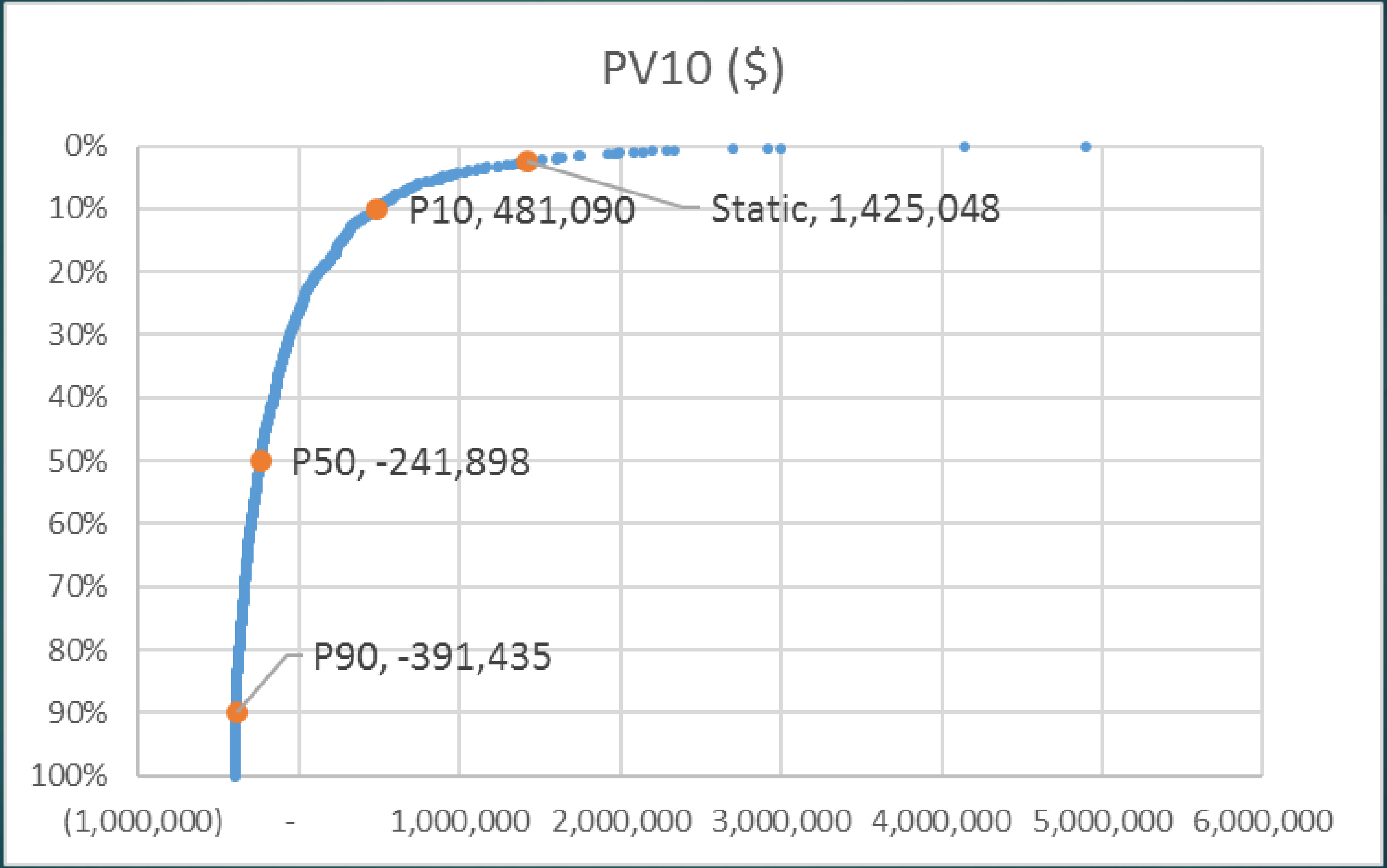
Lognormal distribution

Results from Distributions



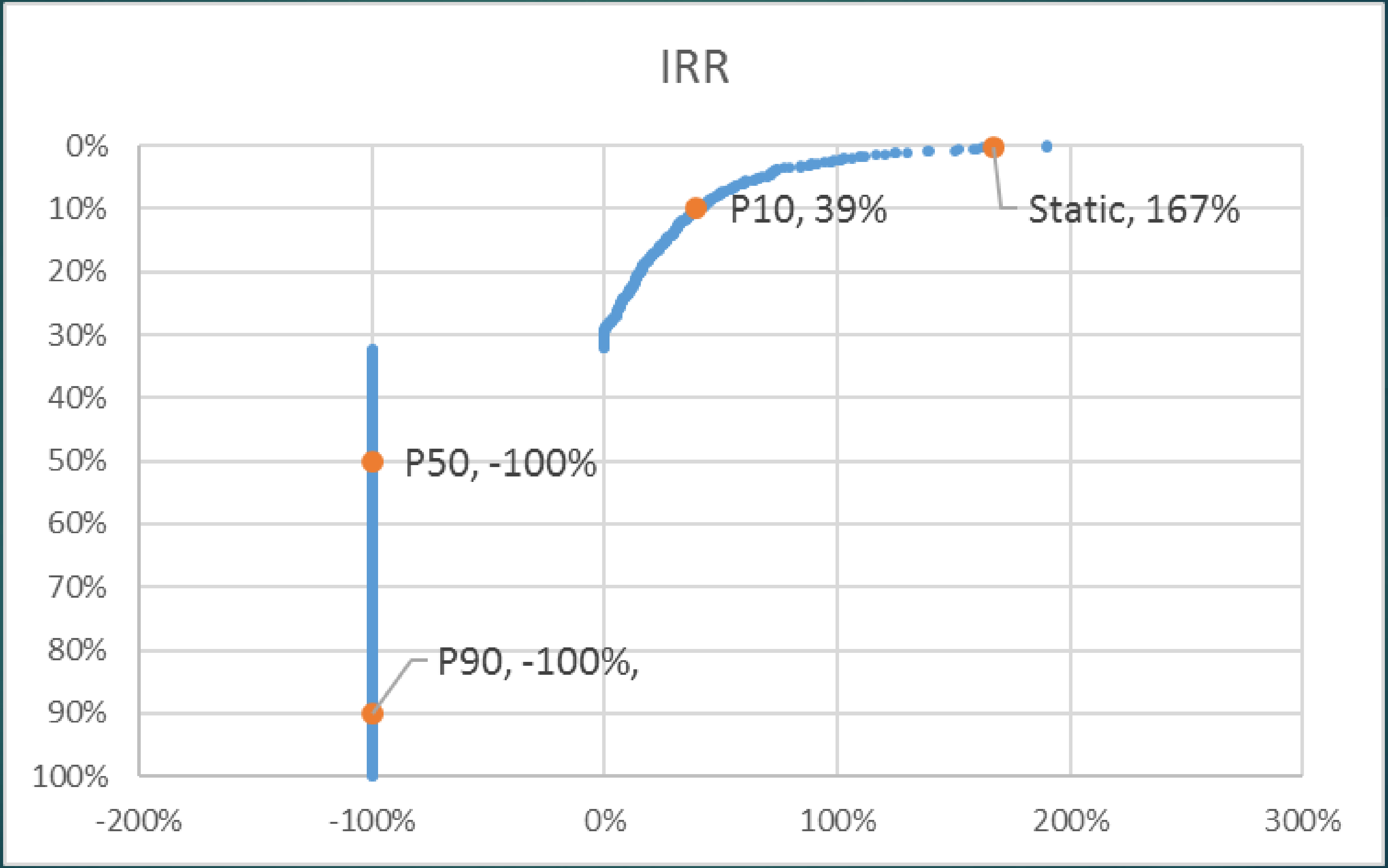
Lognormal distribution

Results from Distributions



Lognormal distribution

Results from Distributions



Summary of Results !! ??

	P(90)	P(50)	P(10)	Static
Gross Gas (MMCFG)	22	182	1,304	1,837,773
Net WI CF	-389,544	-207,209	1,122,419	2,272,978
PV10	-391	-207	1,122	1,425,048
IRR	-100%	-100%	39%	167%
Payout (mos)	1,398	1,398	21	11

A Significant Challenge

- More information <u>does not simplify things</u>
- Traditional static decision processes don’t work
- There is no “right” answer to handling
- Figure out what you are comfortable with and use that
- There are portfolio tools that can help decision making

More Realistic

- Initial Example was simple – to communicate the process
  - No dependencies
  - Only one decline period
  - Only one well (& 1 CAPEX)
  - Did not consider Ps
  - Only one Prospect

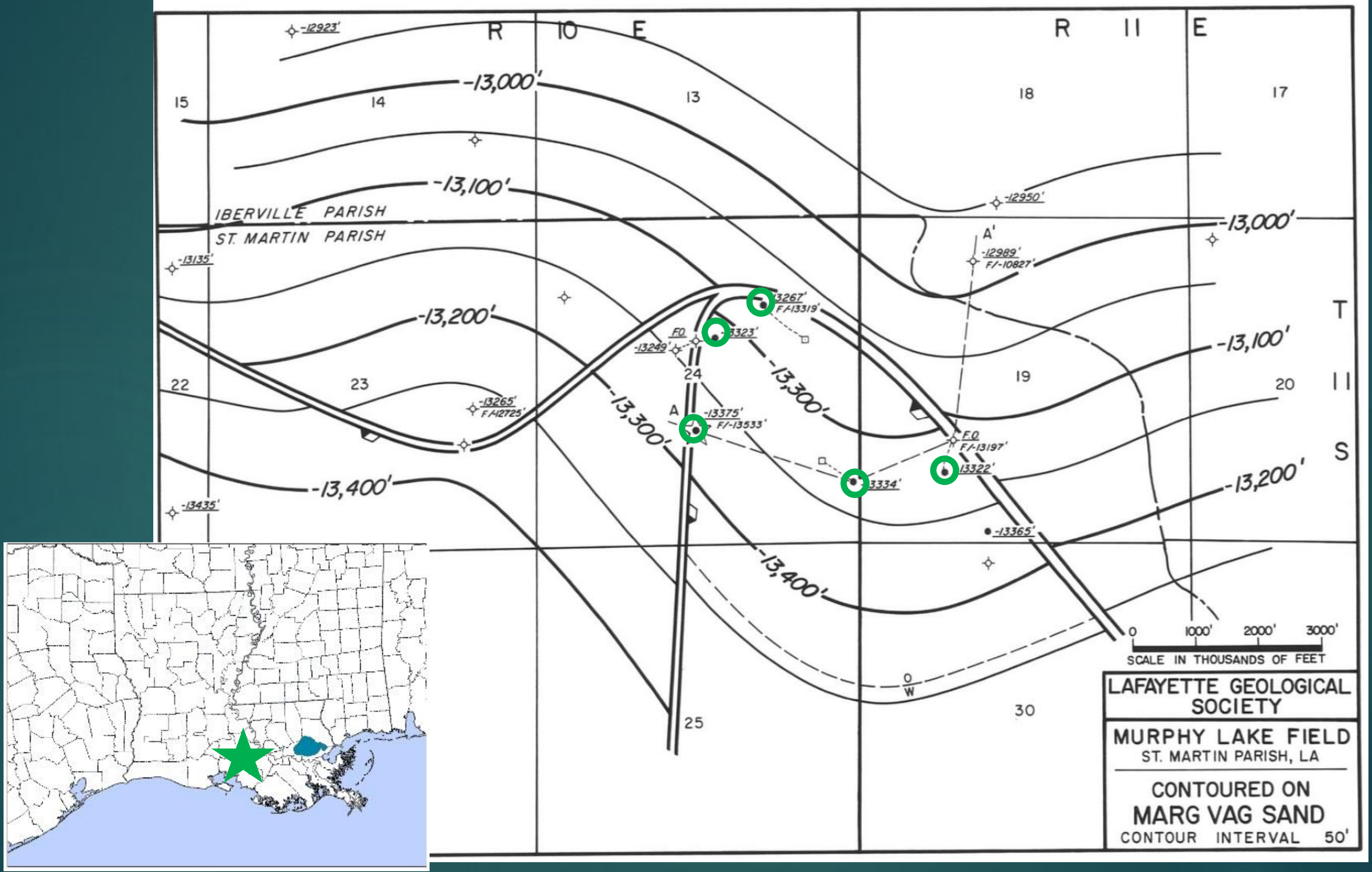
Example 3 (No dependencies; Only one decline period; Only one well (& 1 CAPEX); Did not consider Ps)

Example 4 (Only one Prospect)

- All of the above simplifications can be addressed using the same tools!

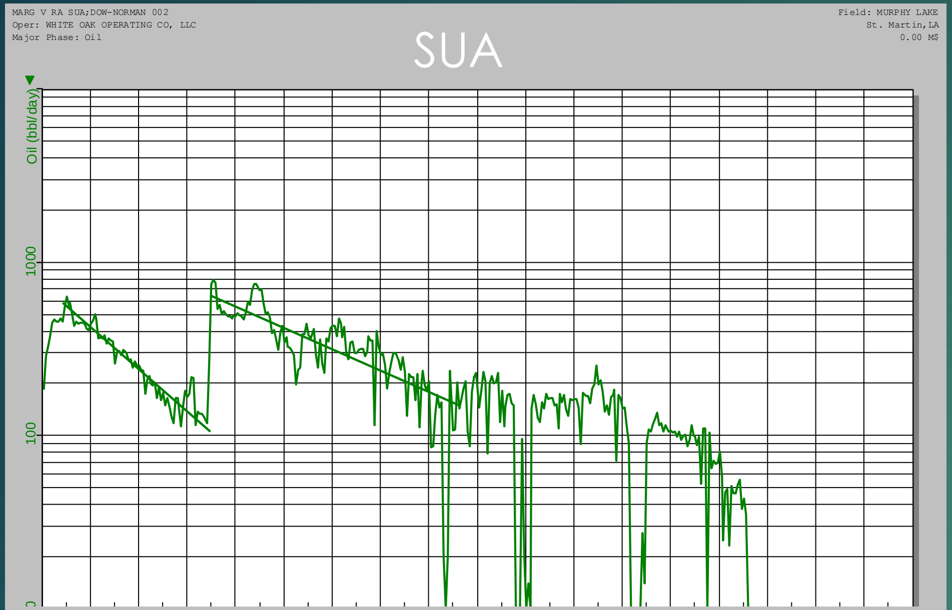
Example 3 – Murphy Lake Field

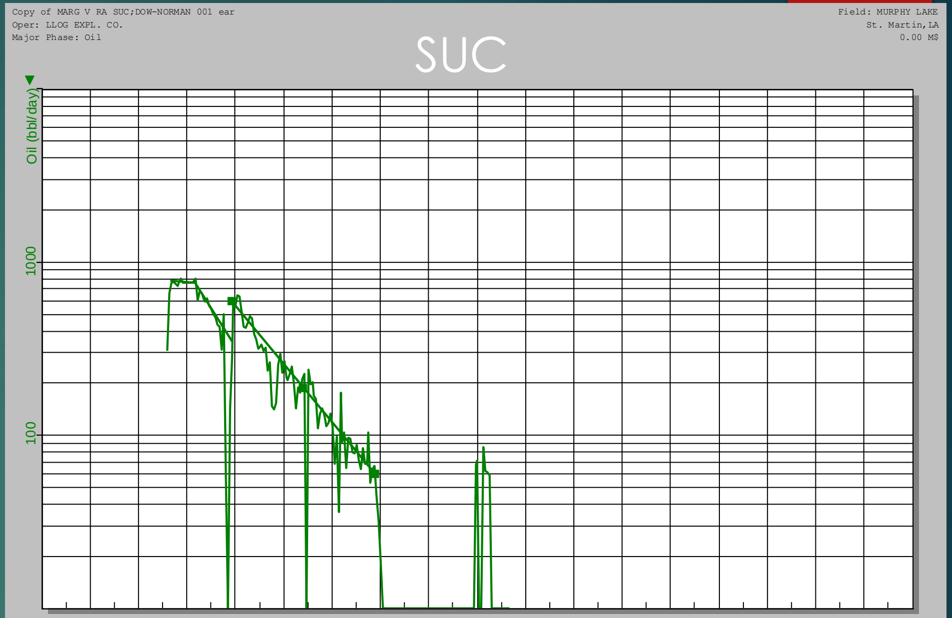
Structure map, Marg vag sand, Murphy Lake field, St. Martin Parish, Louisiana.

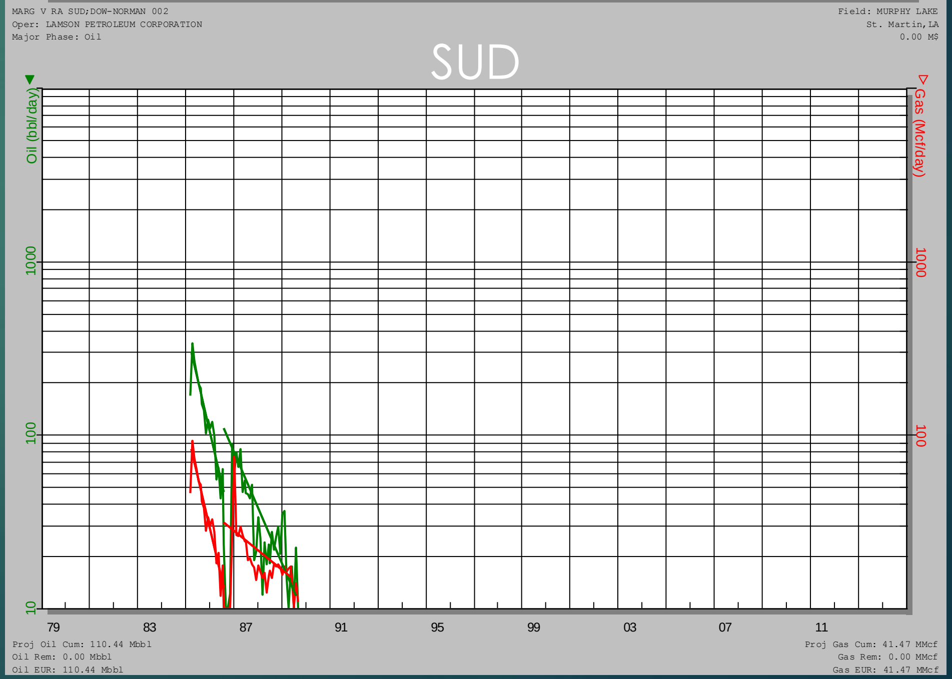


Naumann, Roy L; 1989. Murphy Lake Field. In Typical Oil & Gas Fields of Southwestern Louisiana: Volume III, 1989

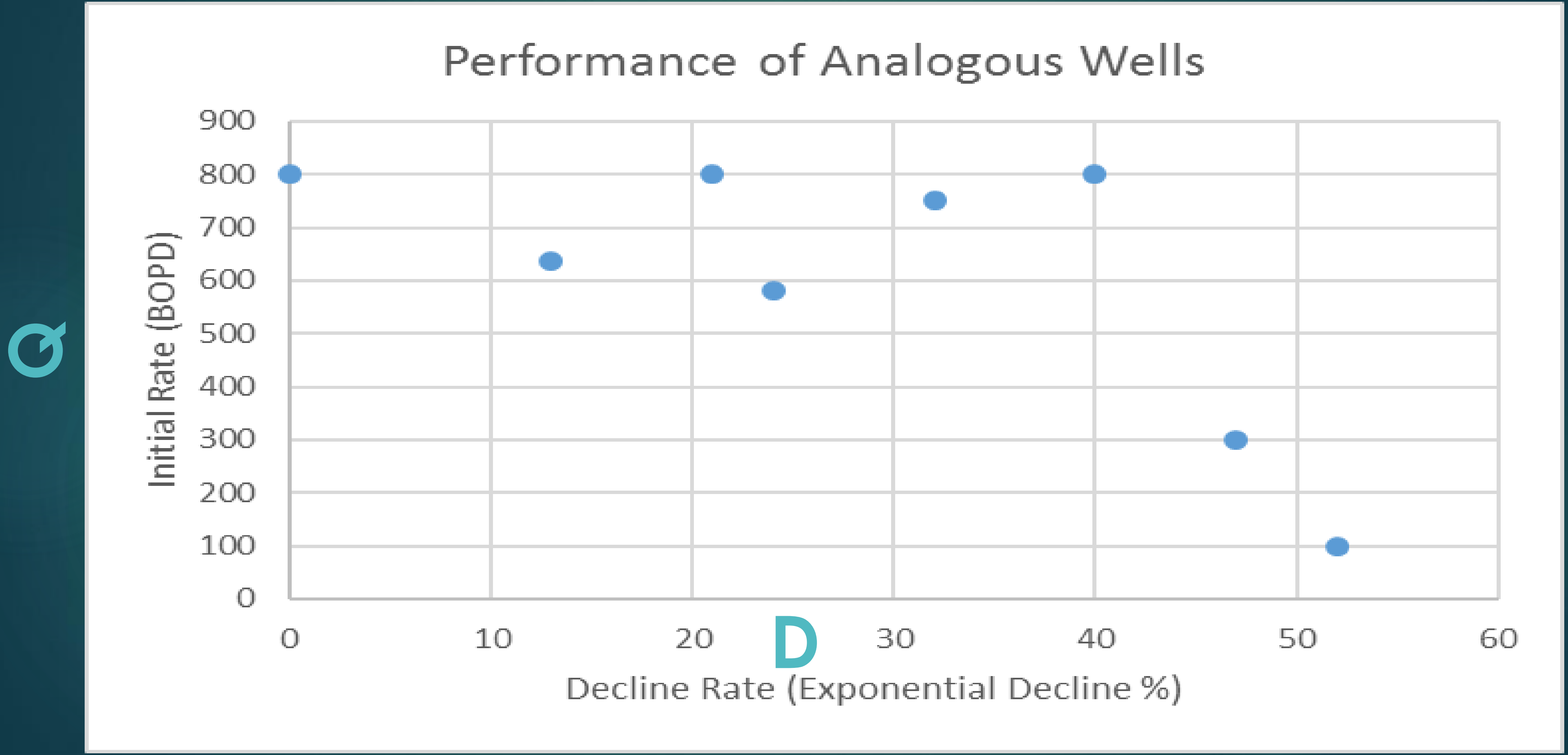
Production Profiles



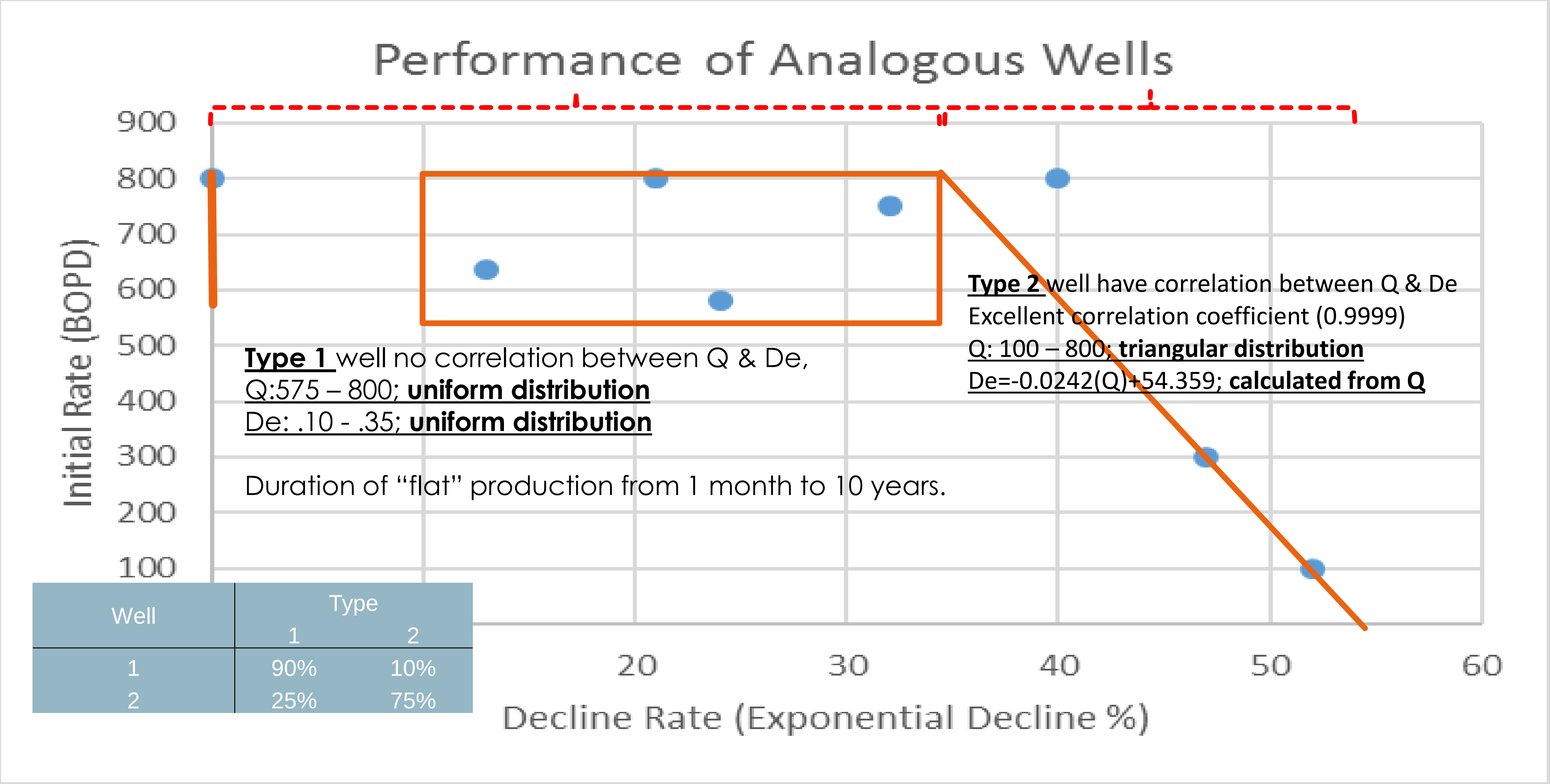




Production Profile Attribute



Production Profile

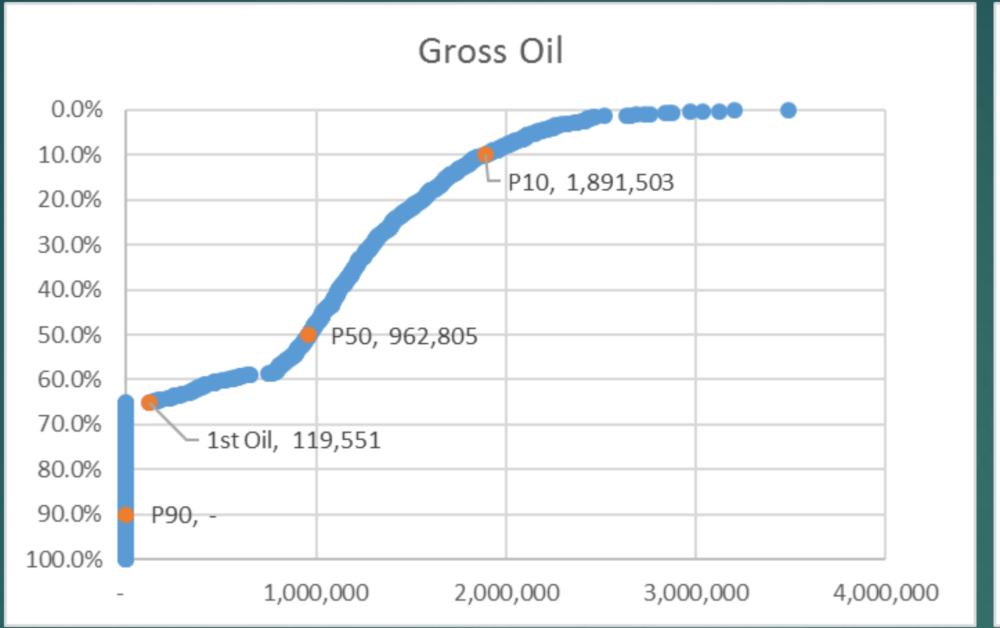


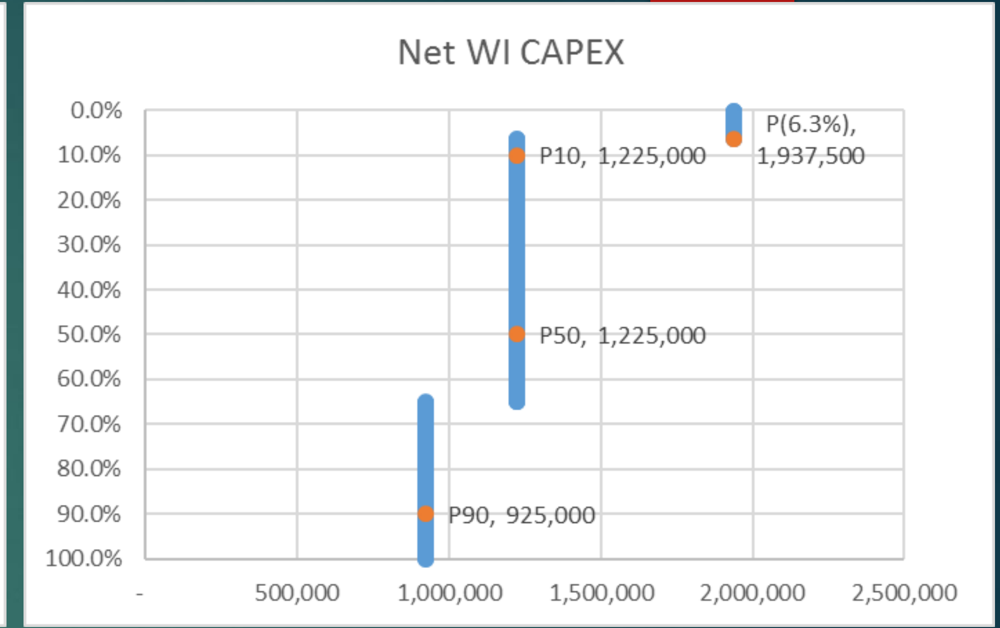
Well	Type	
	1	2
1	90%	10%
2	25%	75%

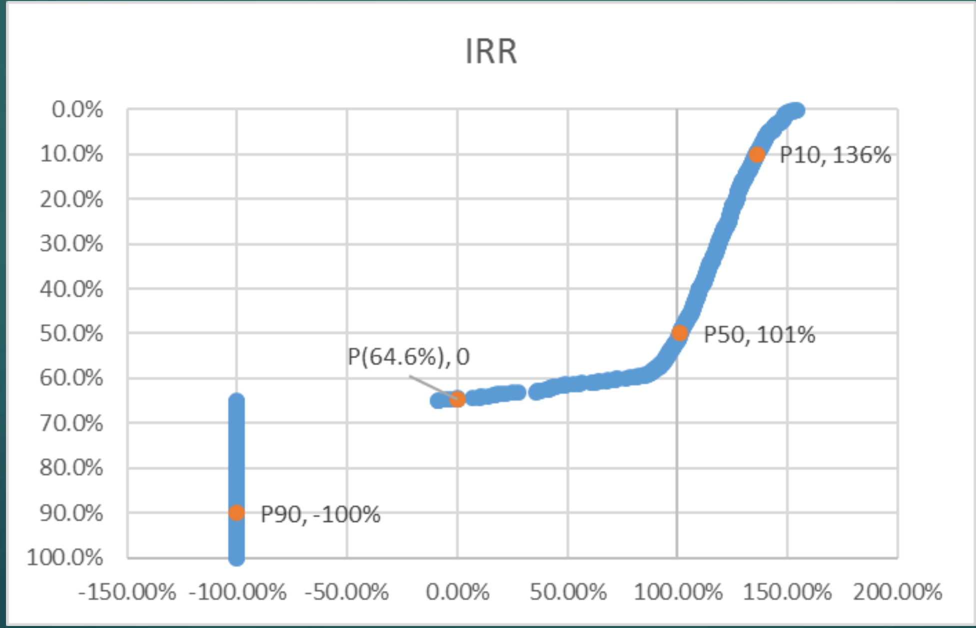
Example 3 Results

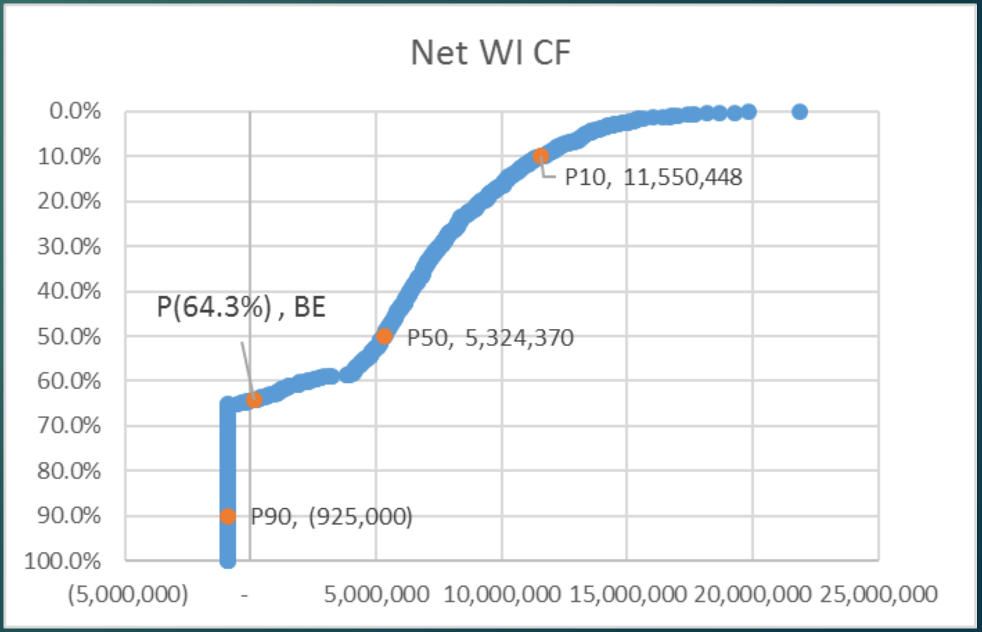
2 Possible Wells

Pse = 65%
Psd = 100%







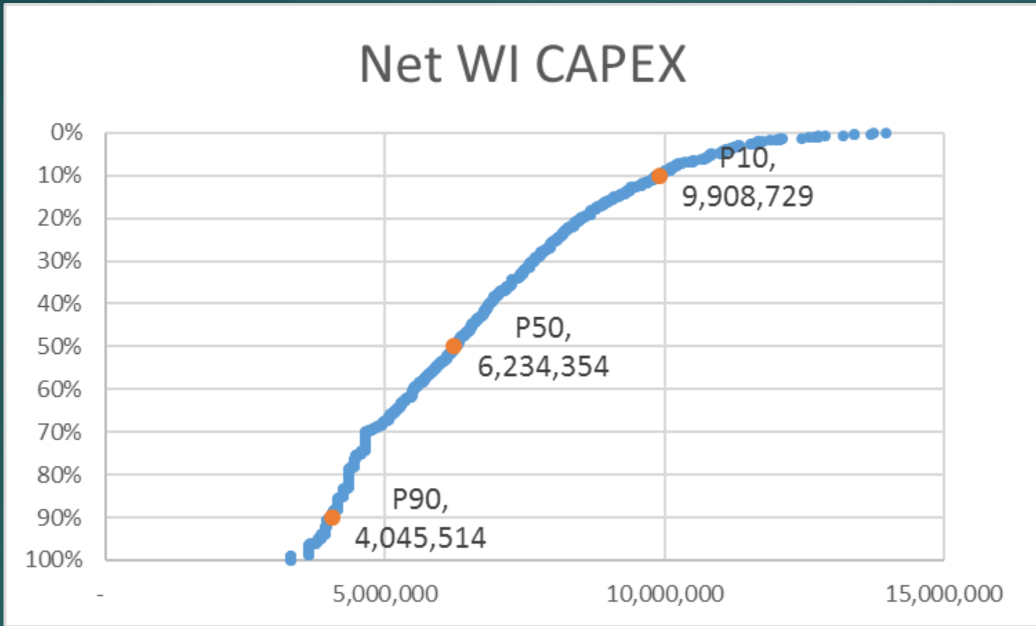


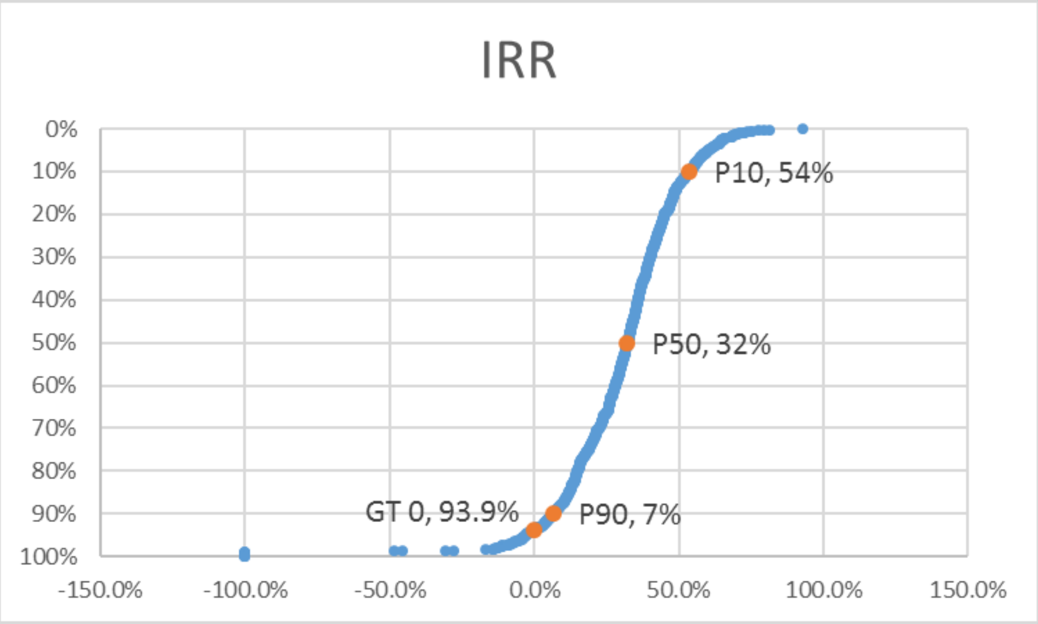
Example 4 - Portfolio - Results

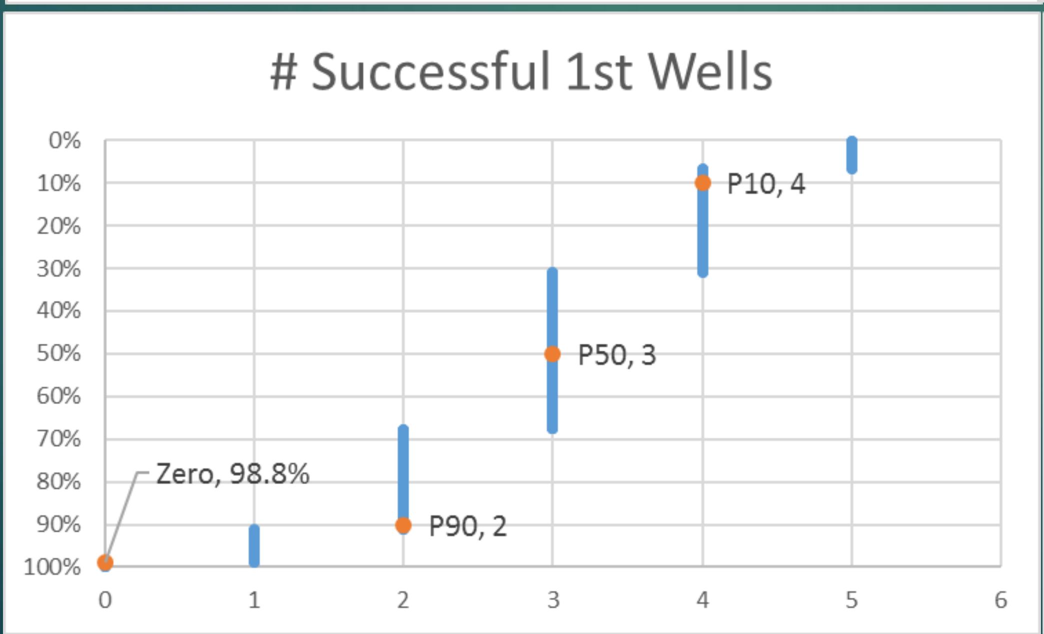
5 Prospects

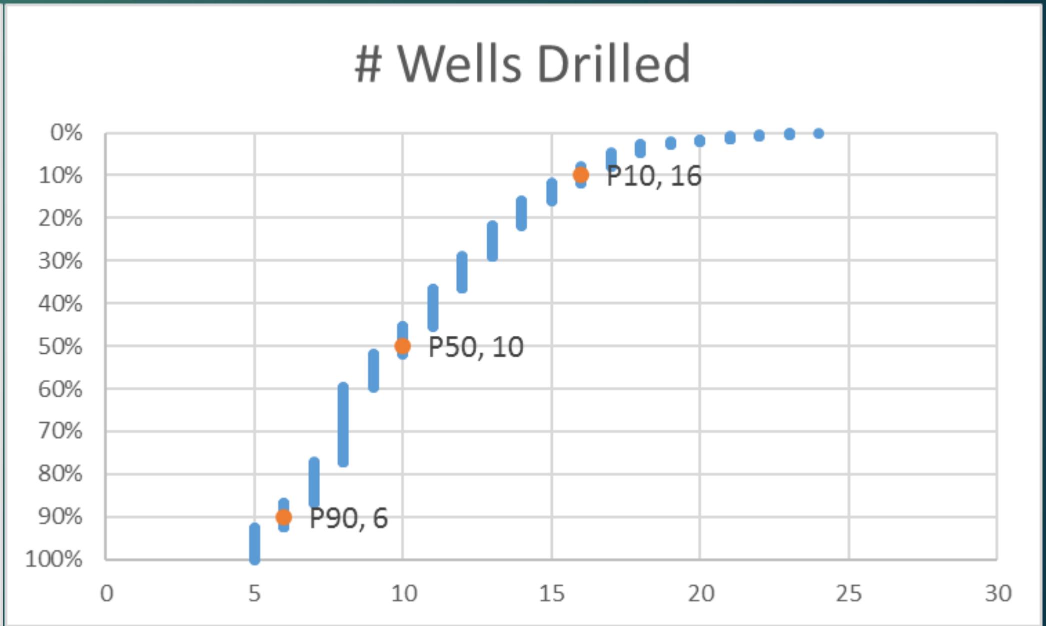
#wells Pse/Psd

2	65%/95%
2	65%/100%
10	40%/80%
9	45%/90%
4	80%/85%









Conclusions

- Uncertainty – it's everywhere and it's important – ignoring it does not help!
- This process is simple and intuitive
- It *will* complicate SIMPLE decision making
- The data is already widely available

Conclusions (cont)

- This <u>process is an exploration tool</u> – it helps understand the reservoir
  - *Production performance is the reservoir talking to you through a translator (wellbore, completions, etc.)*
  - Interpret what it's saying
  - Identify new trends or subtrends, whether geological or operational

- Communications tool – expert input from other disciplines

Conclusions (cont)

- Source of experts' accountability – including its uncertainties and risks
- Future well performance is informed by historic performance not prisoner to it – consider resource plays
- The tools are here – will they be used? Will they be demanded?