Midland Basin Wolfcamp Resource Assessment Using Well Spacing Normalized Recovery per Section

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- Responsible for acreage development, production optimization and data analytics.
- 20 years of unique expertise in Engineering and geoscience domains.
- Areas of focus include business development, inter-discipline integration ,analytical reservoir performance analysis and optimization, completion design, petrophysics, data analytics and machine learning.
- Previous experience: Vencer Energy (VP Subsurface) ,Marathon Oil Company (Upstream Technology/IPT) ,Scala Energy LLC (Technical Advisor), Schlumberger (Petroleum Engineer) , Halliburton (Wireline Engineer)

Talk Outline

- Well spacing - “Nightmare on Wall Street”
- SPEE Monograph 3 Methodology
- Spacing Pilot examples
- Proposed Methodology
- Martin County example
- Conclusion/discussion

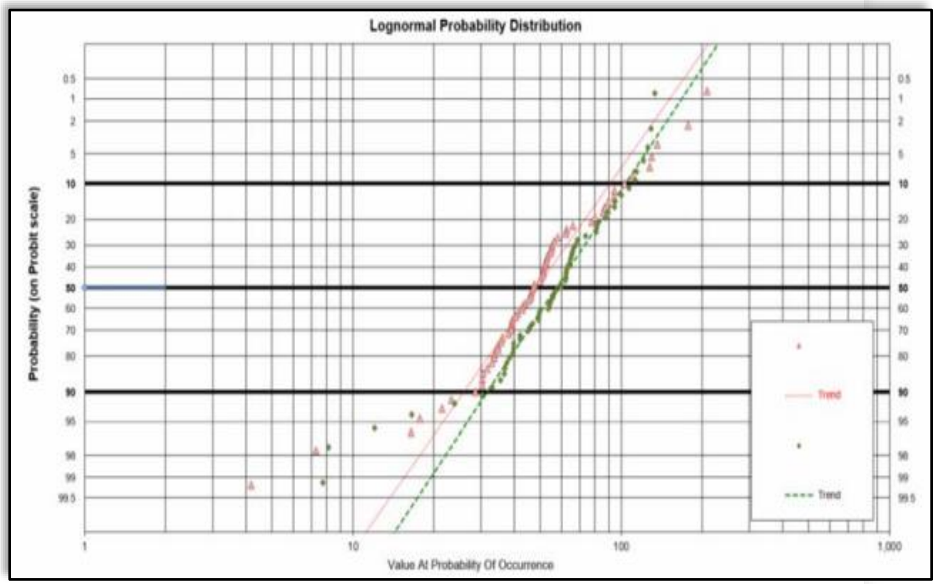
Well Spacing – A constant “thorn” in the “unconventional flesh”

- Misunderstanding of long term well performance
  - For years decisions were bolstered by the parent well performance.
  - Companies have been scrutinized for overly optimistic forecasts
  - The missed projections ranged anywhere between 25-60% (WSJ,2019)
  - Potential downsides, from damaging hits to older parent wells to production from new child wells falling short of the old wells
- Led to over capitalization in full field development plan assumptions
- Missed economic assumptions hurt investor value, leading to distrust throughout the industry

SPEE Monograph 3 Methodology

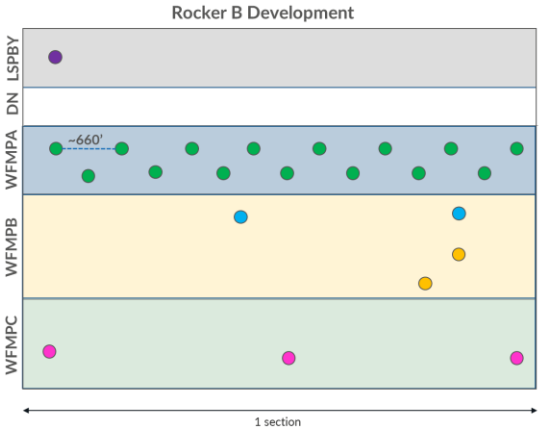
from SPE 206362 Xia et. al.

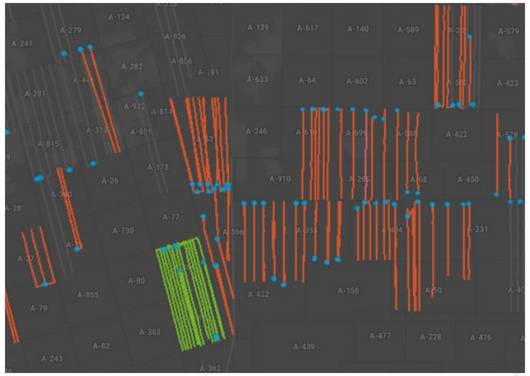
- Well performance is an independent observation - Co-variance ignored
- Focuses on statistical distributions of analogy well technical recoverable resources (TRR) and building type wells to represent probabilities (using Probit plot)
- 50% chance of its TRR being higher or lower than each distributions intersection with the P50 line
- Provides lacks clear guidance for dealing with spacing or stacking scenarios . So, what about expected TRR for tightly spaced development?

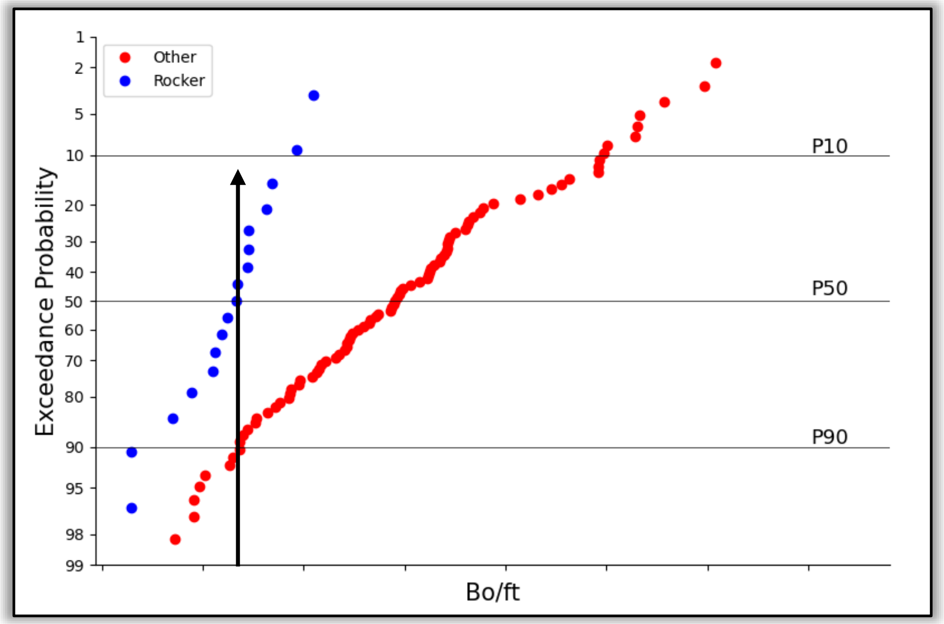


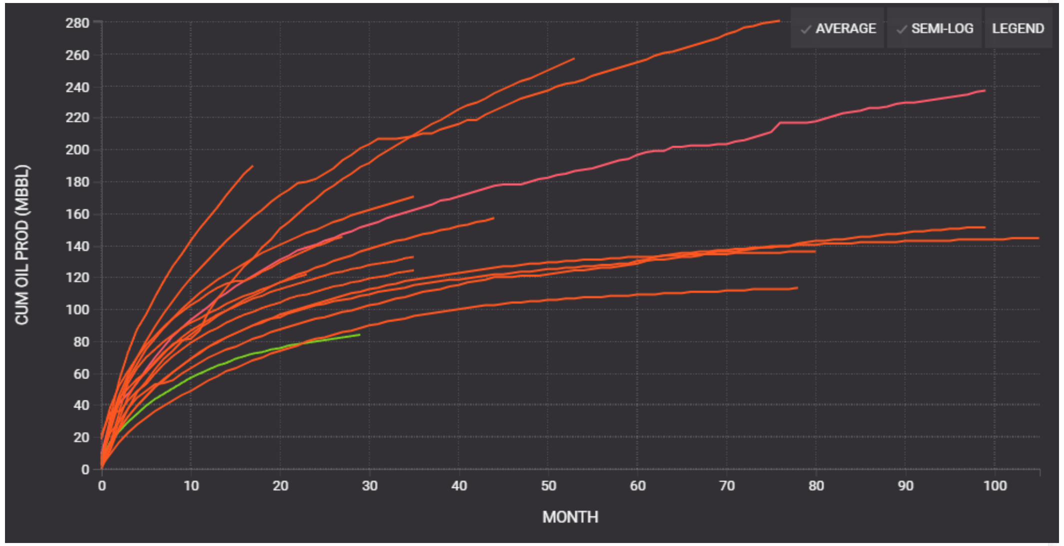
Permian Case Studies– Rocker “B” DSU –Sable Permian (2017)

- Sable Permian LLC brought on 17 infill wells (13 in Wolfcamp A and B) at the Rocker “B” 20-21 DSU in Reagan County, situated in the Southern Midland Basin, in 2017 and 2018



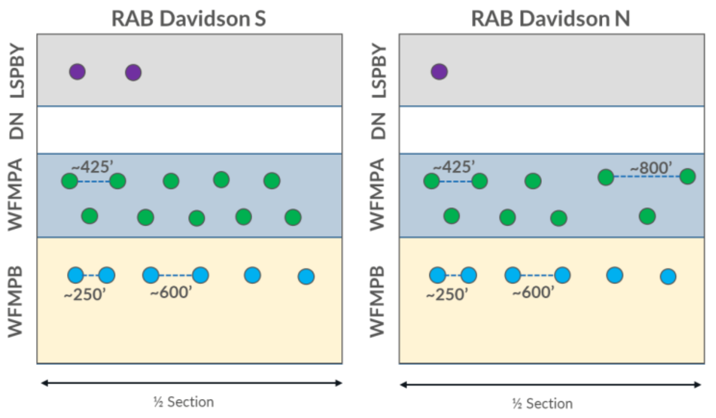


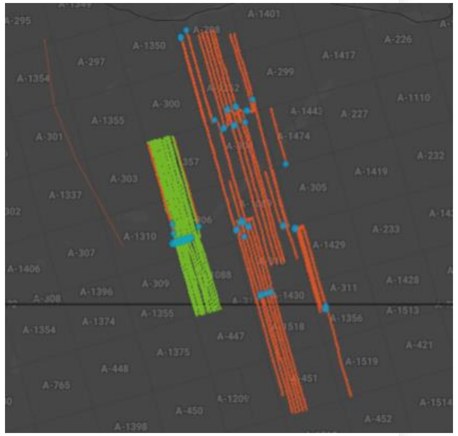


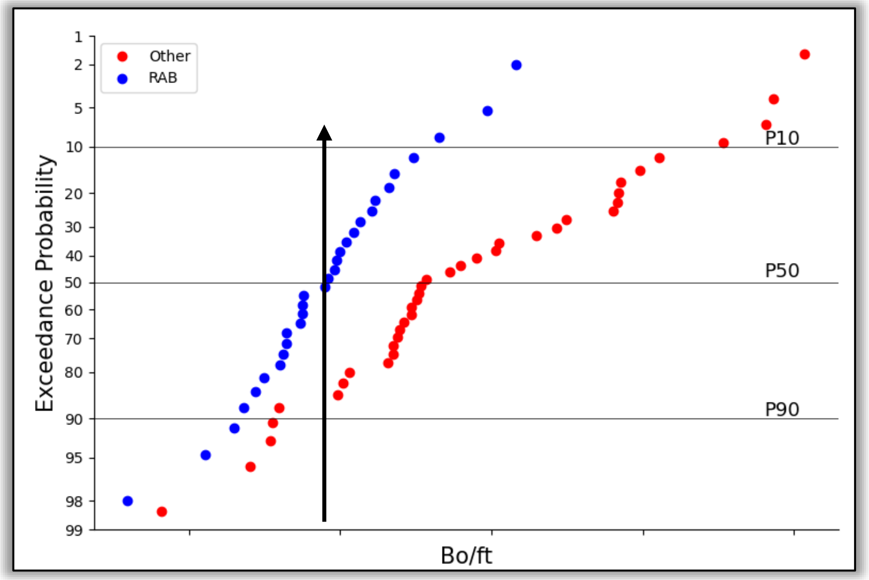


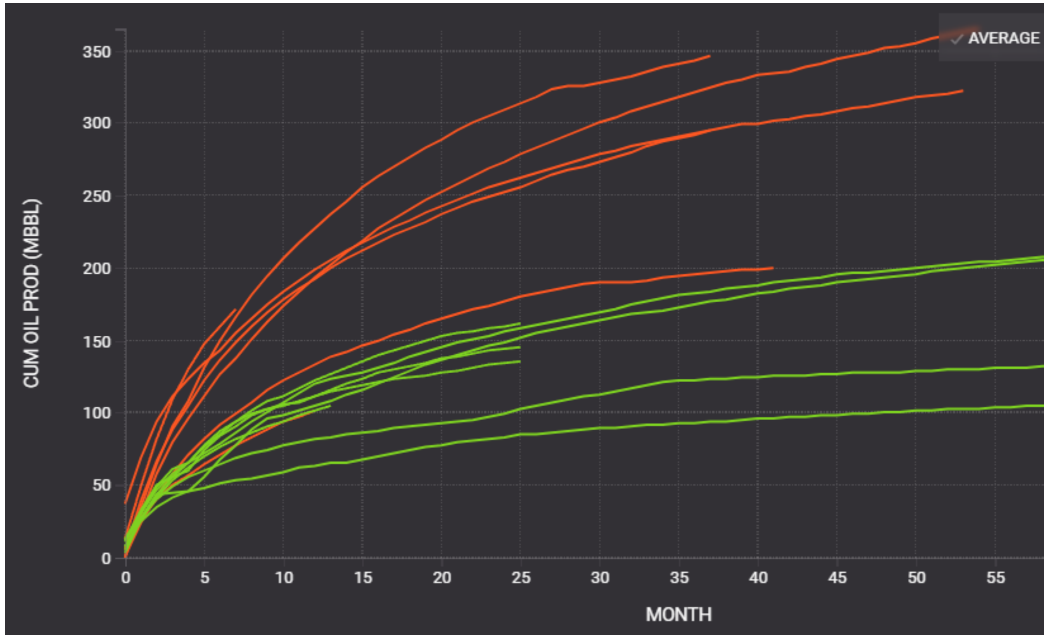
Permian Case Studies– RAB Davidson DSU – Encana (2016)

- “… the company’s biggest cube development to date, 33 wells drilled from one location in West Texas are each on track to pump about 300,000 barrels of oil over 30 years. That is about half the amount of oil Encana said a typical well would pump in late 2017…” (Olsen, B. 2019, WSJ)



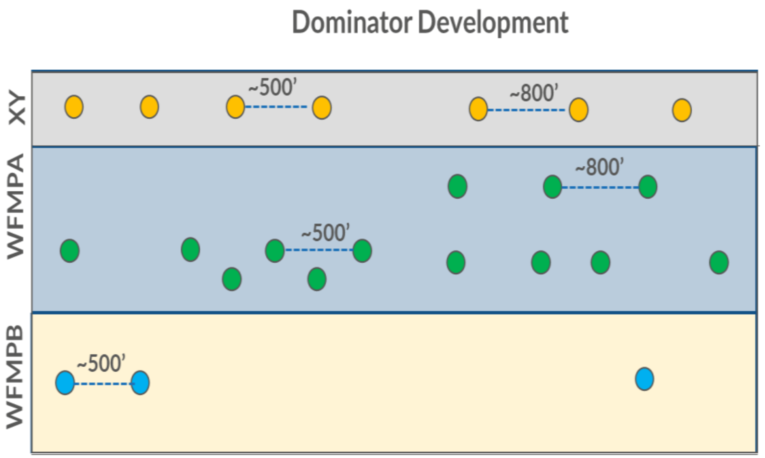


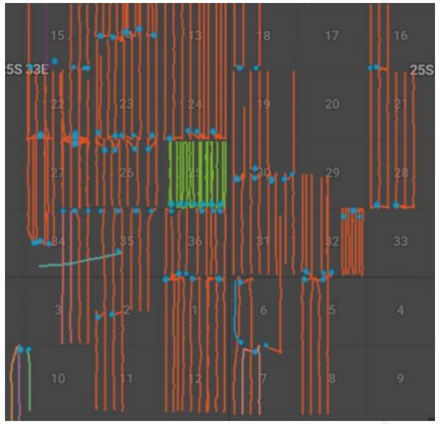


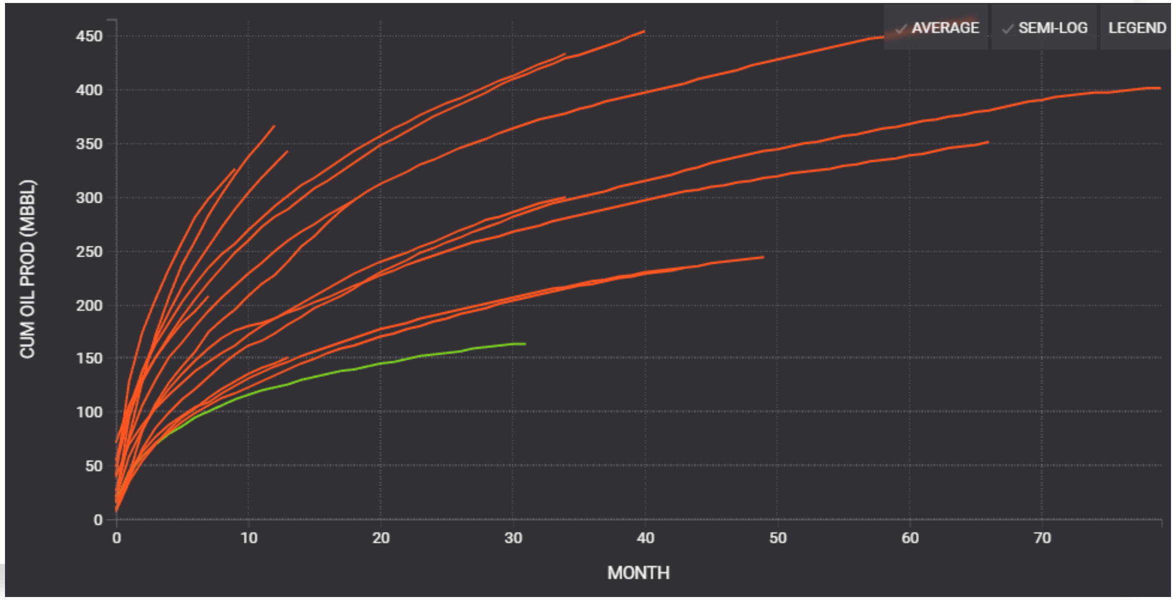


Permian Case Studies– Dominator Concho (2019)

- ❑ At 30-months online, the four 2018 Concho Wolfcamp A and B wells, drilled outside of the Dominator DSU, averaged 92 mbbl/1000-ft wells versus the 23 Dominator 2019 average of 37 mbbl/1000-ft.
- ❑ "Independently developed type curves show that the Dominator wells are now on pace to fall short of initial estimates, maybe by as much as 45%." (T.Jacobs, JPT)



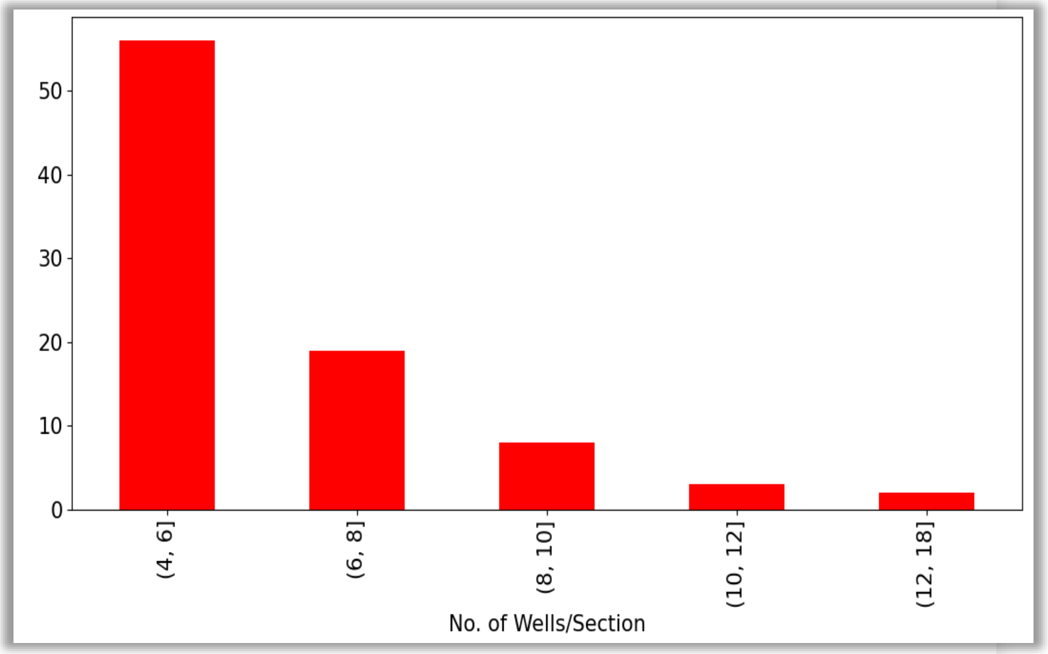




So, What happened?

- Lack of sufficient full section/cube development experiments
- Industry understanding and approach to SRV determination still insufficient
- While Type Curve forecasting methodologies improved, the optimum number of wells concepts still relied on SRV determination and volumetric recovery factors

Martin County (WCA &WCB) - 2022



Well Recovery as a Function of Well Spacing

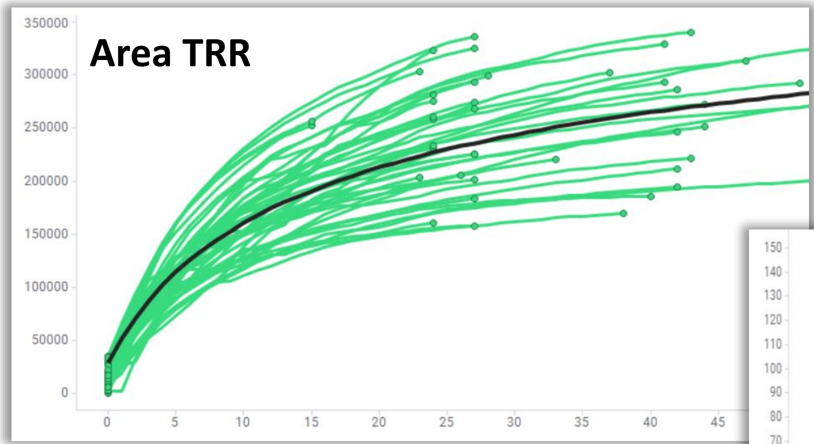
Industry Approach	Pros	Cons
TC Development using SPE Monograph 3	Reasonable estimate when fully developed section wells are scarce	Well performance is not an independent observation
Volumetric Analysis to justify recovery	Inclusive of geology and petrophysics	Recovery Factor uncertainty
Numerical Simulation from RTA results of parent well	Confidence in history matched numerical model	Too many knobs
Trust thy neighbor	Succeed if they succeed	Fail if they fail

Despite the extreme variability in initial production due to the whole spectrum of analogy variables, there exists a strong correlation between spacing and performance.

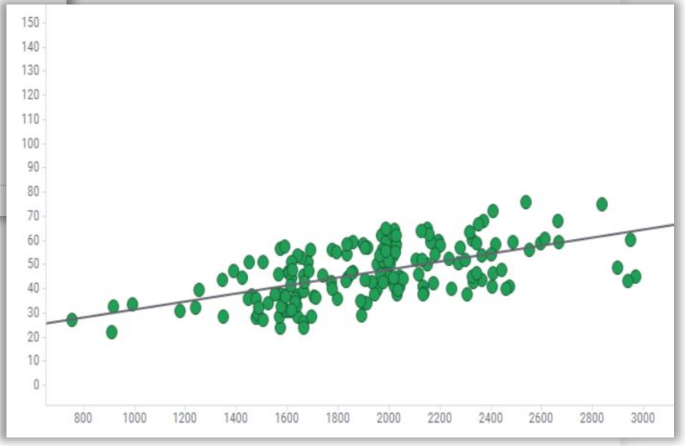
The proposed methodology is an extension of the idea that spacing can trump other analogy variables

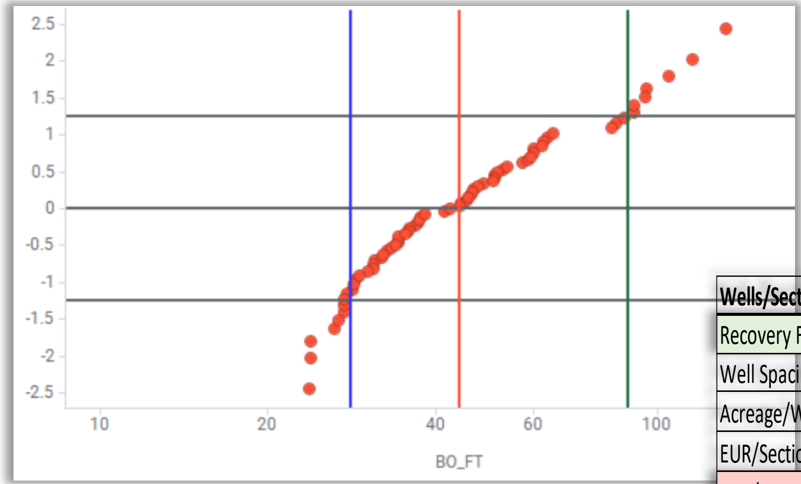
Typical Workflow

- Decline wells – establish individual well TRR and subsequently area TRR (High/Base/Low cases)
- Apply completion uplift if evident from data analysis
- Check if number of wells proposed is justified by volumetrics



Completions uplift





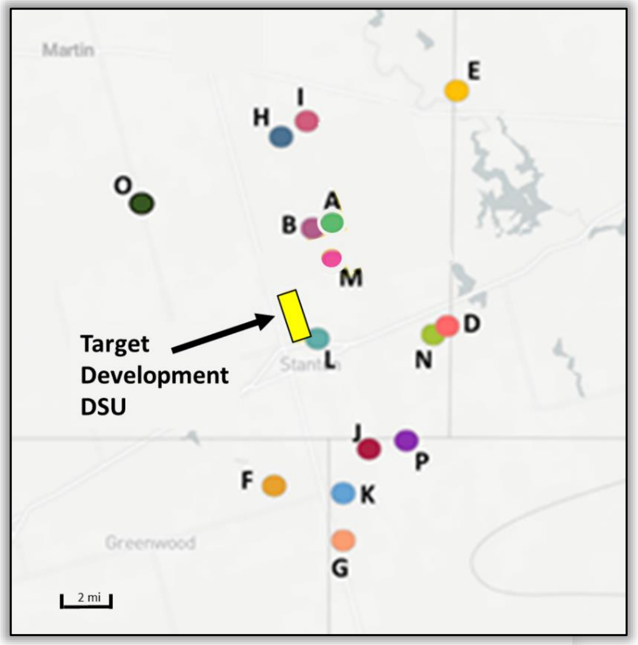
High/Base/Low Cases

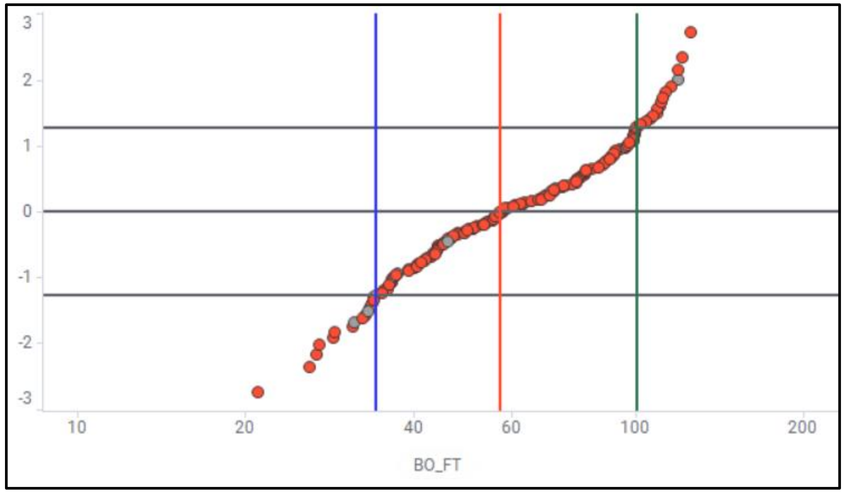
Wells/Section	4	6	7	8
Recovery Factor (Oil)	3.2%	4.7%	5.5%	6.3%
Well Spacing (ft)	1320	880	754	660
Acreage/Well	160	107	91	80
EUR/Section (STBO)	1,020,000	1,530,000	1,785,000	2,040,000
EUR/Section (MCFG)	3,400,000	5,100,000	5,950,000	6,800,000
Recovery Factor (Gas)	5.3%	7.9%	9.2%	10.5%
EUR/Section (STBW)	1,840,000	2,760,000	3,220,000	3,680,000
Recovery Factor (Water)	3.0%	4.5%	5.2%	6.0%

Volumetric Justification

Proposed Methodology

- Decline wells – establish individual well TRR and subsequently area TRR (High/Base/Low cases)
- Identify and compute DSU recovery/section
- The High Case is only 1.7x the Low Case which shows that normalizing TRR bo/ft by WPS provides a relatively narrow range. P10/P90 =1.6 (Rarely seen according to SPEE Monograph 3)





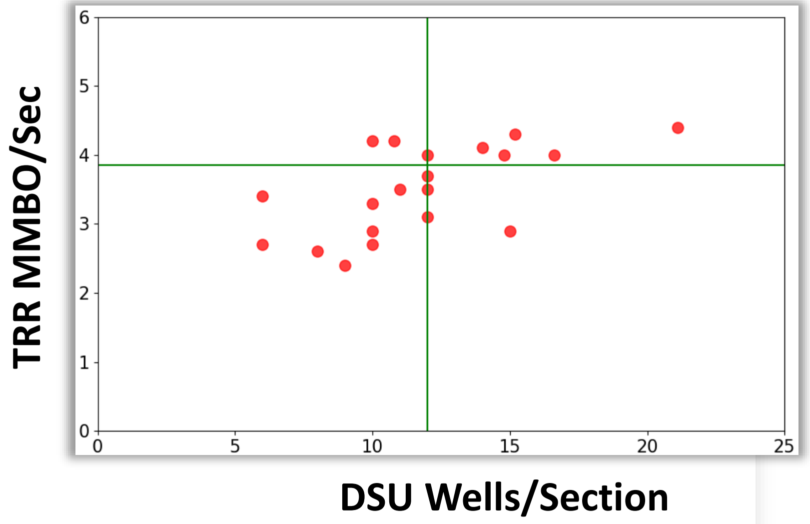
Production Data Source/ Well Landings	Offset Analogy Cube	Wells/ Mile	MMBO TRR Per Sq-Mi	MMCF TRR Per Sq-Mi	TRR Avg bo/ft	TRR Avg BCF/1KFT
Proprietary WC A/B	DSU A	17	3.97	21,153	47	0.25
	DSU B	15	2.87	24,542	38	0.33
Public WC A/B/LB	DSU C	21	4.40	45,015	42	0.43
	DSU D	15	4.31	24,685	57	0.33
	DSU E	15	3.99	31,514	54	0.43
	DSU F	12	3.96	11,095	66	0.18
	DSU G	11	3.53	7,869	64	0.14
	DSU H	10	2.68	26,977	54	0.54
	DSU I	10	2.85	15,237	57	0.30
	DSU J	10	3.26	6,593	65	0.13
	DSU K	10	4.23	28,780	85	0.58
	DSU L	9	2.36	7,332	52	0.16
Public WC A Only	DSU M	6	3.41	7,977	114	0.27
	DSU N	11	4.23	4,229	79	0.08
	DSU O	6	2.66	7,947	89	0.26
	DSU P	6	4.29	4,545	143	0.15

Individual wells – P10/P90 =2.94

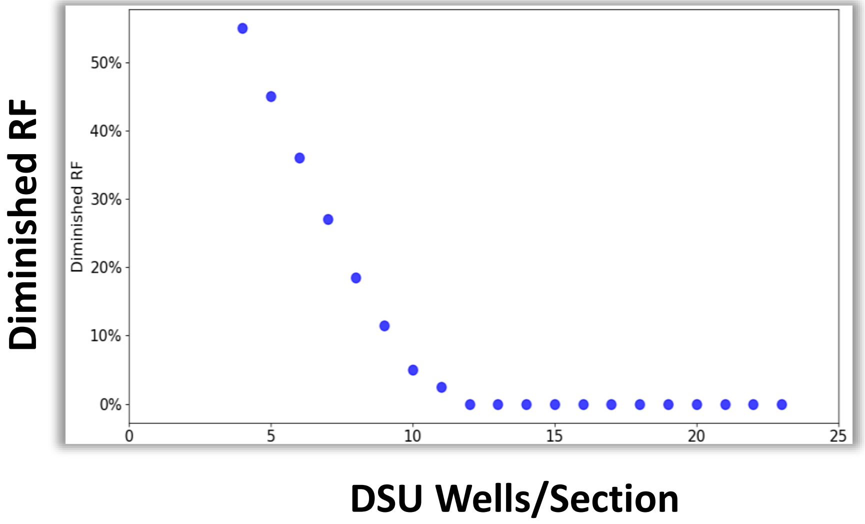
DSU Analysis – P10/P90 =1.6

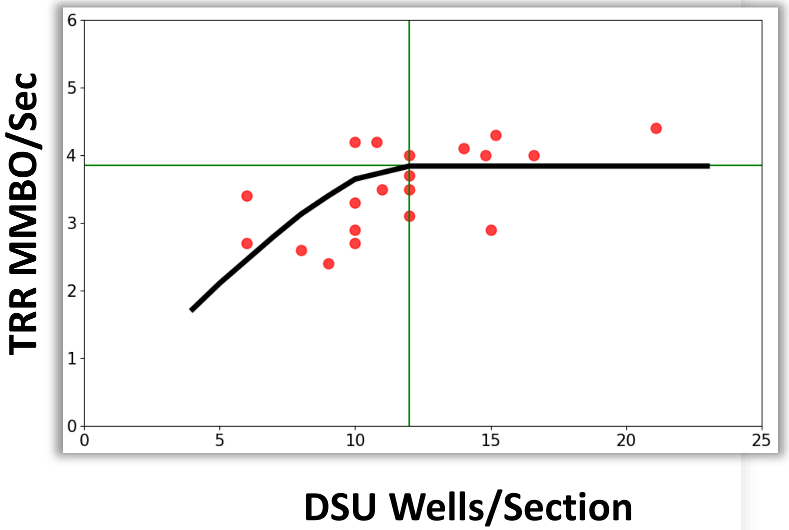
Diminished Recovery Factor

- Identify the inflection plateau and optimum WPS beyond which no significant increase in TRR
- Review unit wells and two- and three-well pad results for the WC A and WC B results in the area.
- Once we have established a typical parent TRR, then we compare its expected TRR against actuals recoveries of a denser spacing tests to establish diminished recovery factors.



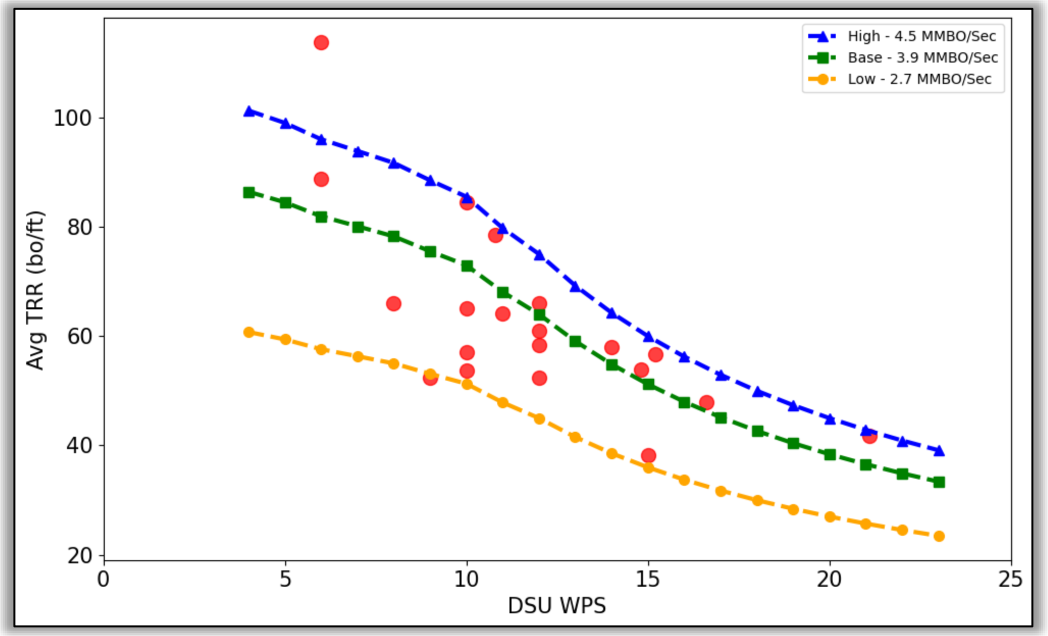
If 10 wells ~ 50 bo/ft
1 well ~ 100 bo/ft
Diminished RF for 1 well = 80%





Well Spacing Normalized Recovery per Section

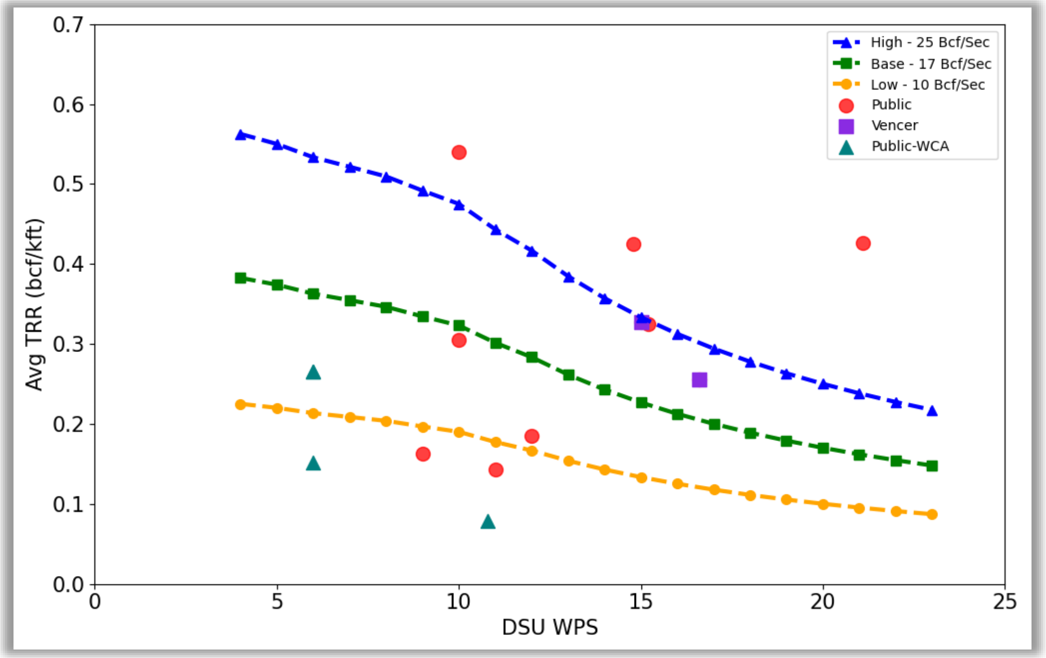
- Wolfcamp A and B is seeing a diminished overall recovery factor (RF) compared to a DSU drilled with enough wells to access all the Wolfcamp A and B oil.
- The modeling shows a 29% TRR bo/ft reduction per well going from 11 to 16 WPS in the WC A & B combined



Wells/Mile Assumed	Diminished RF%	Ideal Base Case TRR (Bo/ft)	Base Case after Dim. RF (Bo/ft)	Ideal Low Case TRR (Bo/ft)	Low Case after Dim. RF (Bo/ft)	Ideal High Case TRR (Bo/ft)	High Case after Dim. RF (Bo/ft)
4	55%	192	86	135	61	225	101
5	45%	154	84	108	59	180	99
6	36%	128	82	90	58	150	96
7	27%	110	80	77	56	129	94
8	19%	96	78	68	55	113	92
9	12%	85	76	60	53	100	89
10	5%	77	73	54	51	90	86
11	3%	70	68	49	48	82	80
12	0%	64	64	45	45	75	75
13	0%	59	59	42	42	69	69
14	0%	55	55	39	39	64	64
15	0%	51	51	36	36	60	60
16	0%	48	48	34	34	56	56

Well Spacing Normalized Recovery per Section

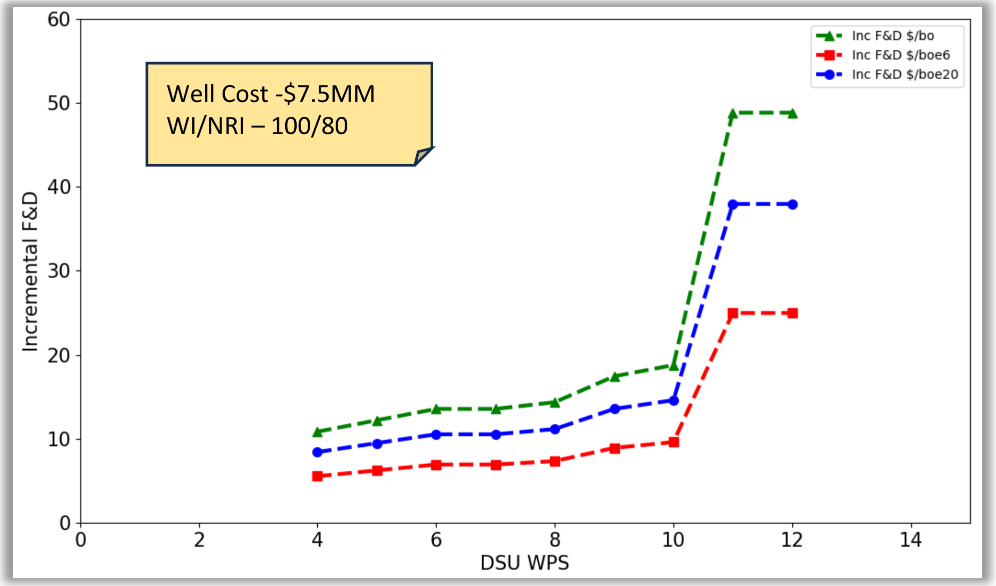
- The shallower, Wolfcamp A landed only DSUs are seeing less gas resource per square mile than the DSUs which include deeper WC B and WC B Lower wells.
- A wider range of gas TRR per section results than oil is possibly to due poorer quality public gas allocated production



Wells/Mile Assumed	Diminished RF%	Ideal Base Case TRR (bcf/kft)	Base Case after Dim. RF (bcf/kft)	Ideal Low Case TRR (bcf/kft)	Low Case after Dim. RF (bcf/kft)	Ideal High Case TRR (bcf/kft)	High Case after Dim. RF (bcf/kft)
4	55%	0.85	0.38	0.50	0.23	1.25	0.56
5	45%	0.68	0.37	0.40	0.22	1.00	0.55
6	36%	0.57	0.36	0.33	0.21	0.83	0.53
7	27%	0.49	0.35	0.29	0.21	0.71	0.52
8	19%	0.43	0.35	0.25	0.20	0.63	0.51
9	12%	0.38	0.33	0.22	0.20	0.56	0.49
10	5%	0.34	0.32	0.20	0.19	0.50	0.48
11	3%	0.31	0.30	0.18	0.18	0.45	0.44
12	0%	0.28	0.28	0.17	0.17	0.42	0.42
13	0%	0.26	0.26	0.15	0.15	0.38	0.38
14	0%	0.24	0.24	0.14	0.14	0.36	0.36
15	0%	0.23	0.23	0.13	0.13	0.33	0.33
16	0%	0.21	0.21	0.13	0.13	0.31	0.31

Incremental Finding and Development Cost

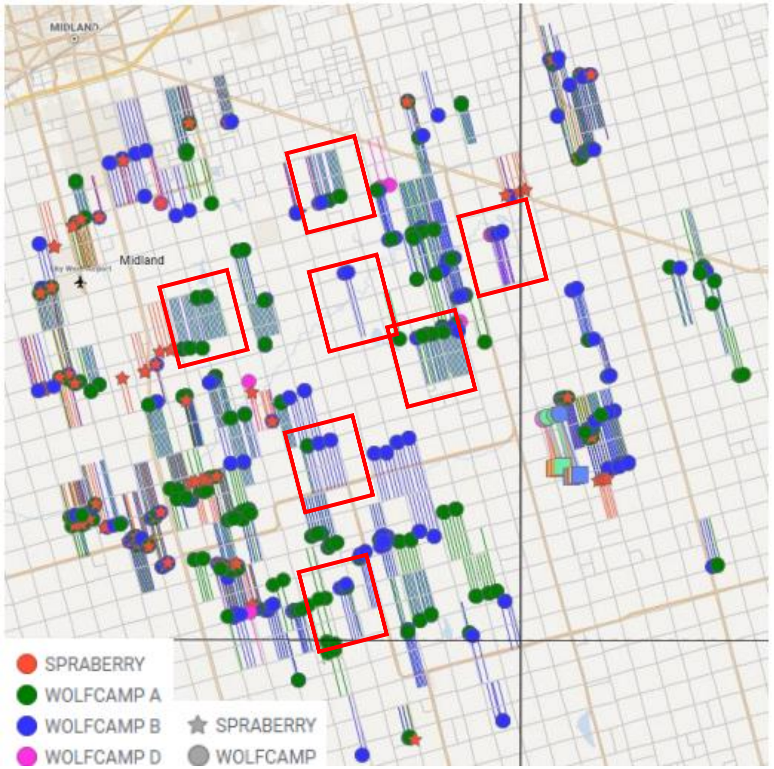
- Base Case normalized curves, it is possible to calculate the incremental gas and oil TRR for each well added to a DSU development plan.
- Reviewing incremental F&D is a check for "last well" economics for a planned DSU
- Within an attractive project there can be some high-cost wells.
- F&D is not the only metric worth reviewing for last well economics—internal rate of return (IRR) and incremental net present value (NPV) should also be studied
- F&D depends on Diminished RF

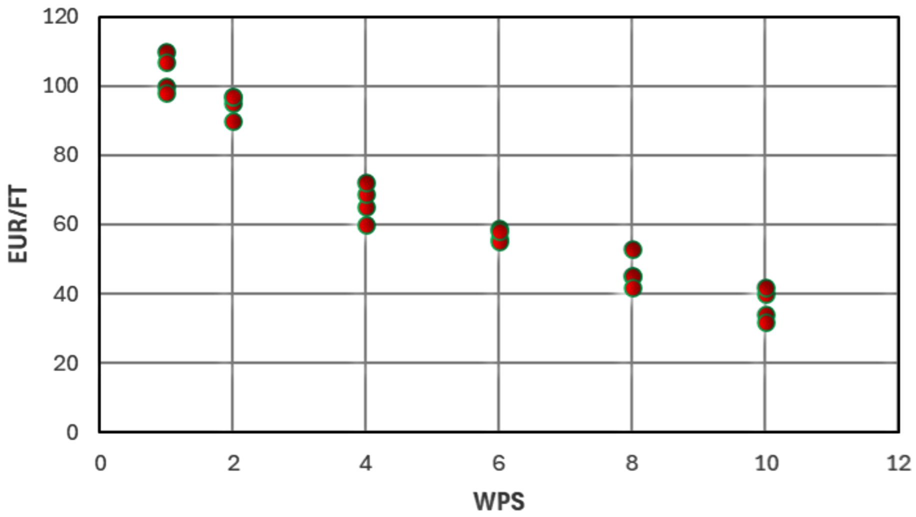


Wells per Mile	Total 10k Well Gross Oil, MMBO	Total 10k Well Gross Gas, BCF	Total Net CAPEX, (100% WI)	Incremental Net CAPEX, (100% WI) MM$	Incremental Net Technical Oil (80% NRI), MMBO	Incremental Net Technical Gas (80% NRI), BCF	Incremental Net F&D, $/bo	Incremental Net F&D, $/boe6	Incremental Net F&D, $/boe20
4	3.46	19.8	30	30.0	2.76	15.84	10.9	5.6	8.4
5	4.22	24.2	37.5	7.5	0.61	3.52	12.2	6.2	9.5
6	4.92	28.2	45	7.5	0.55	3.17	13.6	6.9	10.5
7	5.61	32.1	52.5	7.5	0.55	3.17	13.6	6.9	10.5
8	6.26	35.9	60	7.5	0.52	2.99	14.4	7.3	11.2
9	6.80	38.9	67.5	7.5	0.43	2.46	17.4	8.9	13.6
10	7.30	41.8	75	7.5	0.40	2.29	18.8	9.6	14.6
11	7.49	42.9	82.5	7.5	0.15	0.88	48.8	25.0	38.0
12	7.68	44.0	90	7.5	0.15	0.88	48.8	25.0	38.0
Total				*90*	*6.14*	*35.20*	*14.6*	*7.5*	*11.4*

Discussions

Standard industry practice is observing sections with different well spacing and evaluating the EUR as a function of WPS

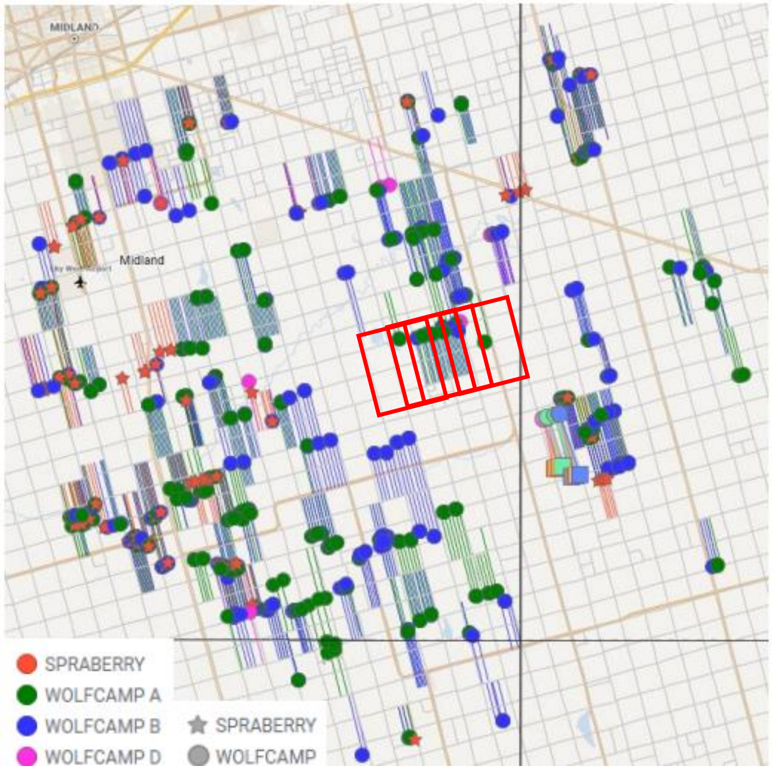


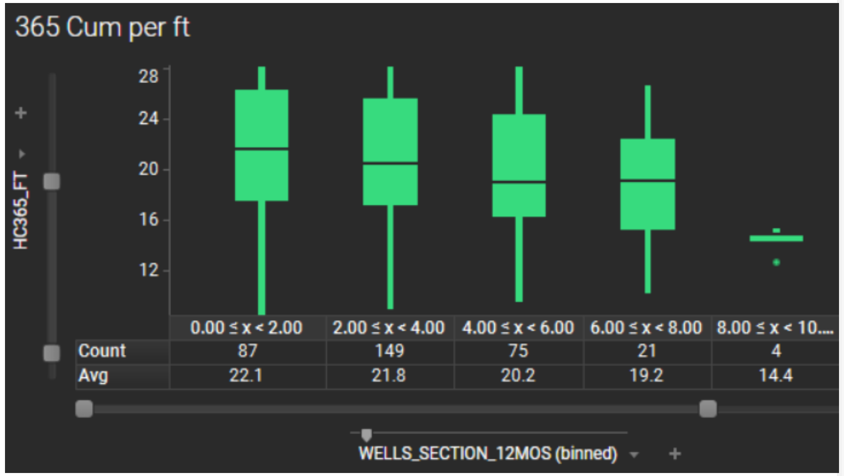


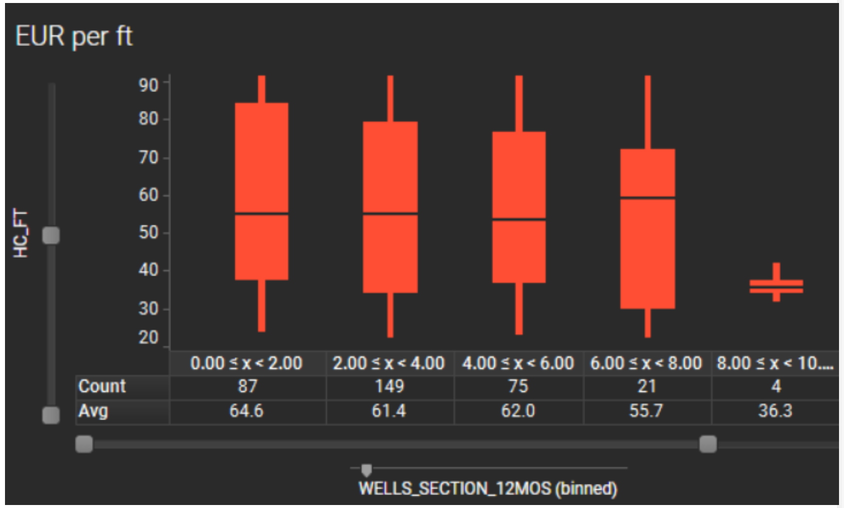
- Changing geology – Is it analogous?
- A potential issue with this method is the timing factor, as not all wells were drilled simultaneously.
- Also does not account for the influence of boundary wells, which may be unbounded or depleted.

Discussions

An innovative method used was having a moving "section" window around each well and evaluating the number of wells around each subject well in the first 12 months or total number of wells in the "section" box.







Conclusions

- Individual well TRR estimates should be verified against DSU level analogy TRRs.
- Our Martin County example shows, at dense well spacing, differences in stimulation designs, landing targets, and parent-child and reservoir heterogeneity between DSUs are less significant than WPS.
- The 1.6 P10/P90 ratio for Wolfcamp A and B TRR per section in the Martin County example shows that evaluating DSU level data has lower variance than typically seen reviewing individual well TRRs.
- At wider well spacing, diminished recovery factor limits the overall DSU TRR while individual well TRR increase.
- Overall project F&D can be low even when “last well drilled” incremental F&D is high.

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