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Engineering Perspective of the Oil Industry – What is the Correct Inter-well Spacing?

-- Prepared by: Stan S. Valdez, P.E., Rob J. Quigley, Tori Najvar, Austin Beckendorf, Adam Taberner
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Contents

Introduction

- Inter-well spacing and Parent / Child well interactions have increasingly become a more publicized issue in our industry.
- Two early 2019 Wall Street Journal articles "sounded the alarm" regarding well performance as a function of spacing, and they have cited separate issues associated with the "Parent" and "Child" well performance as horizontally developed resource plays enter mature stages of development. The names and dates of these articles follow:
  - *"Fracking's Secret Problem – Oil Wells Aren't Producing as Much as Forecast"* (January 2, 2019)
  - *"Shale Companies, Adding Ever More Wells, Threaten Future of U.S. Oil Boom"* (March 3, 2019)
- These articles have made statements and conclusions that have stoked the concerns of oil and gas investors related to potentially systemic over-optimistic reporting of oil and gas reserves and economic returns associated with horizontal drilling inventories in unconventional resource plays.
- The articles provide fodder for the debate of numerous topics that will not be addressed herein, however, regarding the impacts of well spacing on a well's ultimate recovery, the articles are quoted as follows:
  - *"EUR estimates from many companies were grounded on two assumptions: that they could pack wells closer together, squeezing more value from the land they leased, and that they could replicate their best early wells. The results to date suggest those assumptions were often wrong."* (1)
  - *"… shale companies in recent years have touted bunching wells in close proximity, greatly increasing the number of wells drawing on a promising reservoir. The added wells would produce as much as older ones, many drillers believed, allowing them to extract more oil overall while maintaining strong returns from each well."* and *"Newer shale wells drilled close to older wells are generally pumping less oil and gas than the older wells, according to early corporate results. Engineers warn the new wells could produce as much as 50% less in some circumstances."* (2)
- As resource plays mature, the remaining wells will necessarily have closer inter-well spacings and will contend with depleted regions around existing older wells. The purpose of this talk is to address the reality of well spacing and Parent Child issues and provide a framework for analyzing these interactions more rigorously to help operators and investors determine "the correct spacing".

(1) "Fracking's Secret Problem – Oil Wells Aren't Producing as Much as Forecast" (January 2, 2019)
(2) "Shale Companies, Adding Ever More Wells, Threaten Future of U.S. Oil Boom" (March 3, 2019)

Discussion of Parent / Child Interactions and Inter-well Spacing on Individual Well Performance

Engineering Perspective of the Oil Industry –
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Factors Affecting Fracture Geometry and Stimulated Rock Volume

Reservoir Properties

- **Stress** - In-Situ Stress Orientation and Magnitude (σ_x, σ_y, σ_z)
- **Rock Properties** - Mechanical Rock Properties
  - Elasticity (Young's Modulus)
  - Shear strength
  - Anisotropy
- **Geologic discontinuities** - bedding planes, joints, faults, etc.
- **Contrast in elastic properties** - of stacked benches or geologic sequences

Completion Variables

- **Density of Fractures** – Stage and cluster spacing, limited entry perforations influence number of fractures initiated along a wellbore.
- **Carrier Fluids** – fluid types (e.g. slickwater / cross-linked gel, etc.)
- **Pump Rate** – High vs. Low rate
- **Total Pad Volume**
- **Total Proppant Pumped**
- **Proppant Type** – white sand, high strength…
- **Landing Depth** – relative to target interval

Frac Geometry / SRV

- **X_f (ft)** – normalized fracture half length
- **H (ft)** – fracture height
- **CLL (ft)** – Completed Lateral Length
- Proppant Transport and "Propped" SRV
- Fracture Aperture
- Fracture Permeability
- Enhanced Permeability Zone

Frac Geometry and Parent / Child Relationships (Part 1 of 4)

SPE-191799-MS (Defeu et al. 2018) – Delaware Basin Example

- Defeu et al. (2018) presented numerical simulation results from a 5,000’ horizontal well in the Delaware Basin that was completed with 27 stages, 97 clusters of 2-ft each, and completed with 450,000 lbm of total proppant per stage or 2,400 lb/ft of proppant density. A dynamic model was calibrated by history matching the aforementioned “Parent” well as well as an offset child well. This integrated model illustrates the changes in pressure and stress orientation as a direct result of voidage from un-constrained production.
- **Figure 1 -** below shows the modeled pressure depletion around a Parent well at different points in time. The Orange color represents initial pressure of 8,500 psi. After 36 months, the pressure is modeled to reach 5,500 psi, or a 33% drop in pressure. Please note that the pressure boundaries are relatively close to the “Initial” frac geometry; that there was moderate pressure depletion away from the “tip” of the induced fracture system.
- **Figure 2** – Stress magnitude and orientation changes in response to pressure depletion (Ajisafe et al. 2017, Gakhar et al. 2017, Xu et al. 2017, Defeu, et al. 2018). Figure 2 below was generated using the finite element method (“FEM”) to solve for the magnitude and orientation of stresses. The blue area indicates the initial minimum stress of 10,000 psi. After 36 months (and pressure depletion from the reservoir simulation), the minimum stress is predicted to be reduced to 8,200 psi, or by 18% around the entire wellbore.

Pressure Depletion of SRV over time

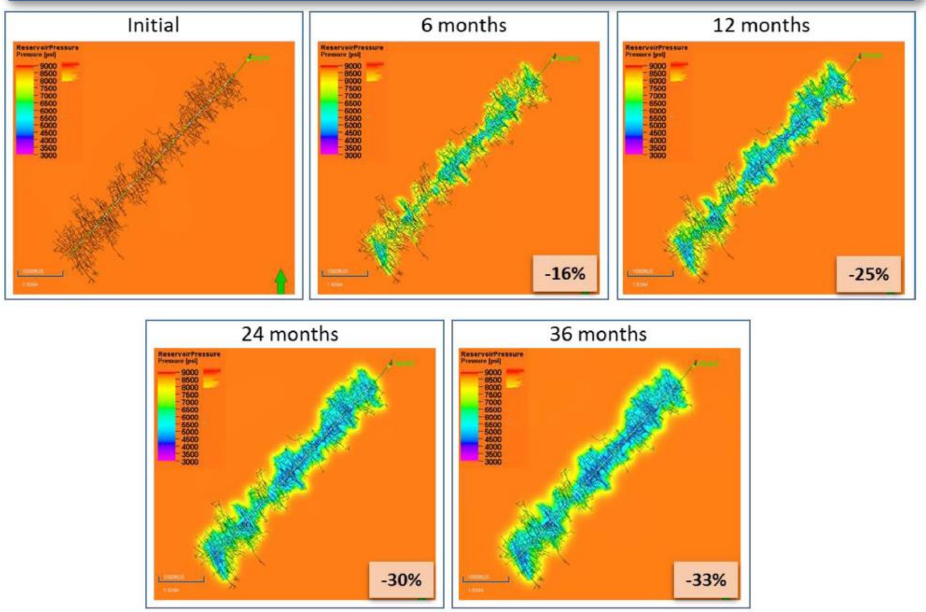


Figure 1 – Reservoir Pressure depletion around a Parent well – top view at the wellbore layer. (Defeu et al. 2018)

Stress Realignment as a Function of Pore Pressure Depletion

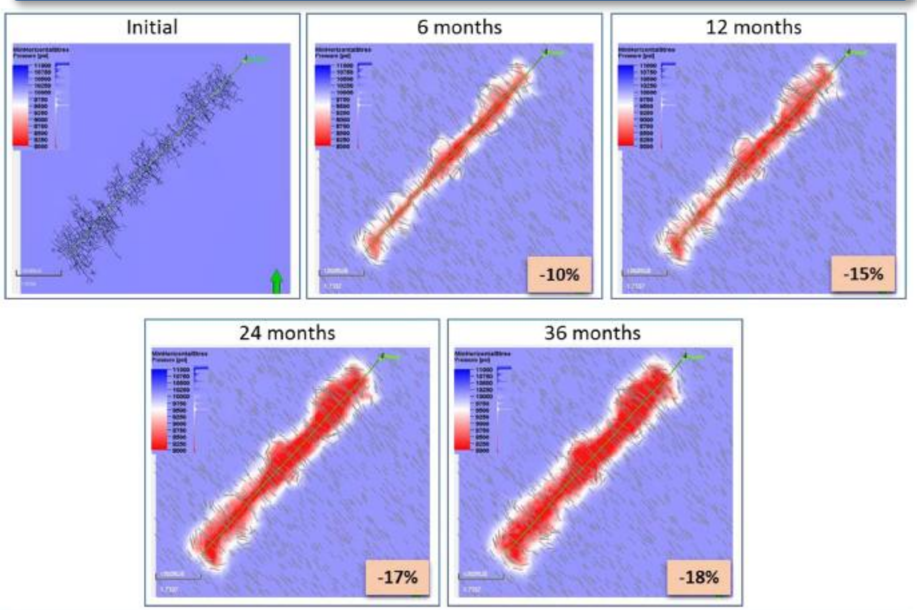


Figure 2 – Maximum horizontal stress change reorientation around Parent well due to pressure depletion – top view at the wellbore layer (Defeu et al. 2018)

Frac Geometry and Parent / Child Relationships (Part 2 of 4)

SPE-191799-MS (Defeu et al. 2018) – Delaware Basin Example

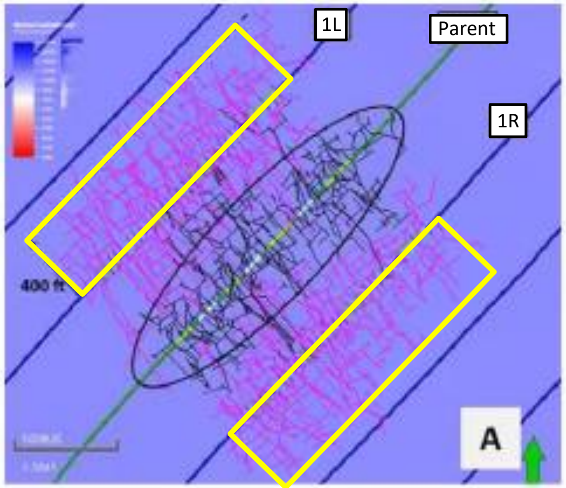


Figure 3 – Parent and Child fracture geometry if "co-developed" at t=0. (Modified from **Defeu et al. 2018**)

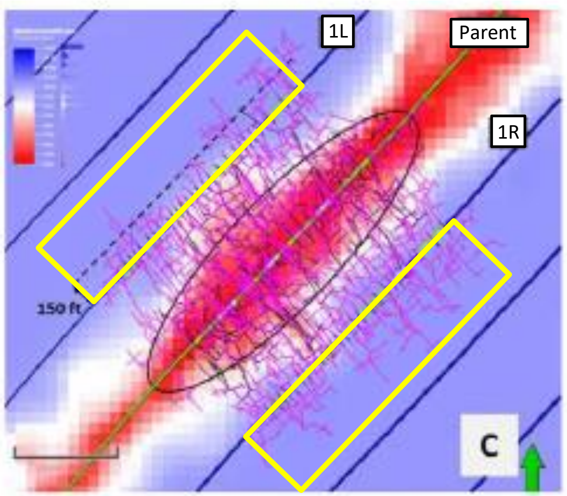


Figure 4 – Parent and Child fracture geometry if Child wells completed at t=12 months (Modified from **Defeu et al. 2018**)

- The authors then modeled the resulting fracture geometry of two "offset" or "child" wells at different time steps and at different spacings from the original Parent well to observe the various degradation impacts.
- The illustrations at left show three (3) total wells drilled parallel to each other. The "Parent" well is in the middle of two "offset" or "child" wells. Each of the offset wells is drilled 480 feet away from the parent well on either side of the Parent. The Child wells are annotated in the illustrations as "1L" and "1R".
- **Figure 3 –** In the first example, all three wells are completed at the same time, or nearly the same time. The fracture geometries for each well (1L, Parent and 2R) are also illustrated; the Parent well fractures are colored "black", while the offset well fractures are colored "pink". The yellow boxes were placed on top of the figure to show the extent of the child well fractures on the "outbound" edge of the wells. The distance of this box is approximately 400' from the centerline of the offset wells.
- **Figure 4** – The authors also modeled what fracture geometry would look like if the Parent well were allowed to produce for 12 months. Figure 4 at left includes color fill that indicates pressure depletion around the Parent well, where the lavender color represents original reservoir pressure and the red color indicates areas of depletion. Once pressure depletion and stresses have reoriented, Figure 4 illustrates that the fracture geometry from the two offset wells (1L and 1R) grow asymmetrically toward the Parent well. The yellow boxes show significantly less fracture density, and an equivalently shorter frac half-length on one side of the wellbore. The figure also indicates frac growth into the original Parent well.

Frac Geometry and Parent / Child Relationships (Part 3 of 4)

URTeC: 2431182 (Gakhar et al. 2016) – Eagle Ford Example

- The authors of URTeC: 2431182 (Gakhar et al 2016) prepared a similar simulation exercise focused on wells drilled in the Lower Eagle Ford shale. Similar to the previous example, the simulation includes a 5,000' lateral length, with 100 perforation clusters at 1 ft. long and 0.42 in. diameter perforation holes at 6 shots per foot. The well was frac'd with a cross-linked gel system at a pump rate of 50 bbl/min with proppant volumes of 279,000 lbm per stage.
- The Parent well in this scenario was allowed to "produce" for 400 days before the offsetting child well was completed. **Figure 5** below shows the resulting unconventional fracture model ("UFM") simulation results for child wells at 3 different offset distances (400', 600' and 800'). The 400' model shows very asymmetric fracture network development skewed toward the pressure sink created by the Parent well, while the 800' example shows much less interaction

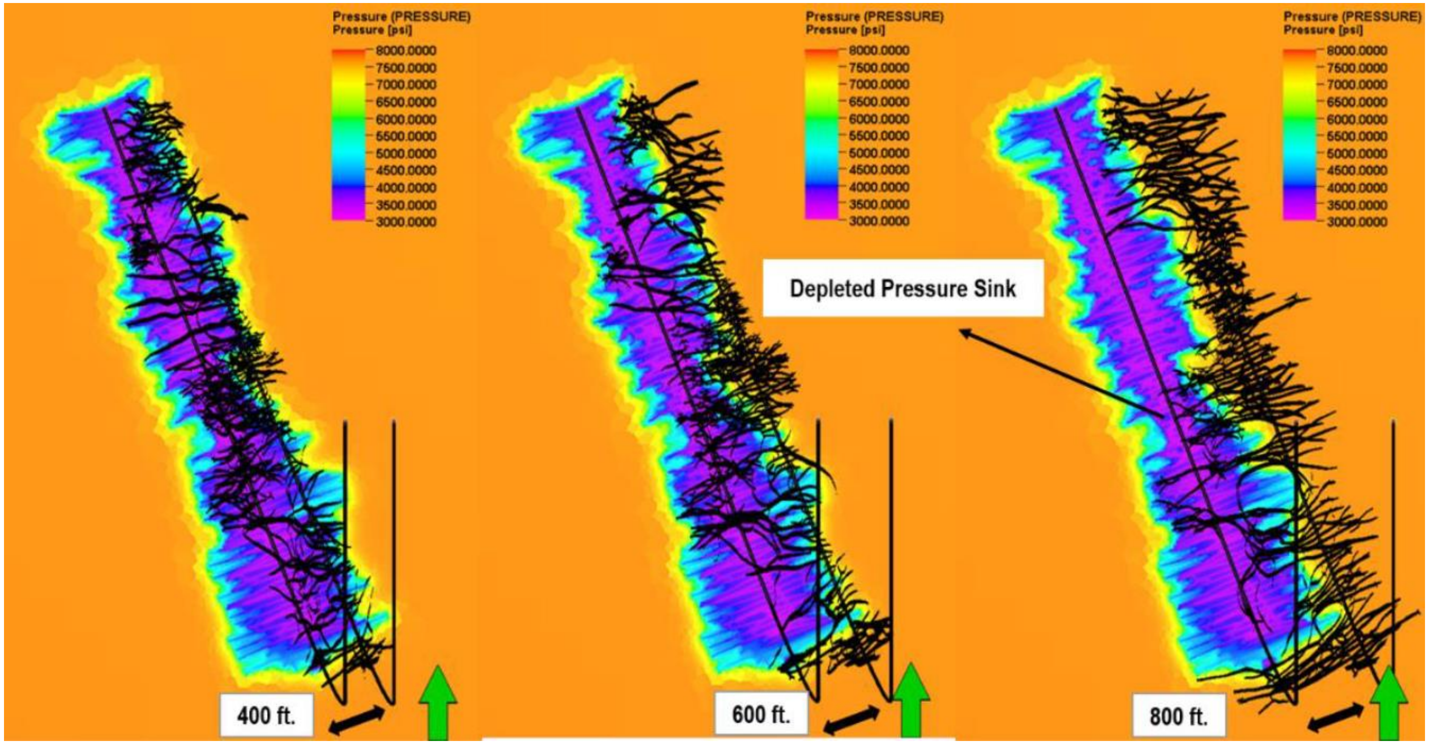


Figure 5 – Parent and Child fracture geometry at t=400 days and at various inter-well spacings (Gakhar et al. 2016)

Frac Geometry and Parent / Child Relationships (Part 4 of 4)

Combined SPE-191799-MS (Defeu et al. 2018) / URTeC: 2431182 (Gakhar et al. 2016)

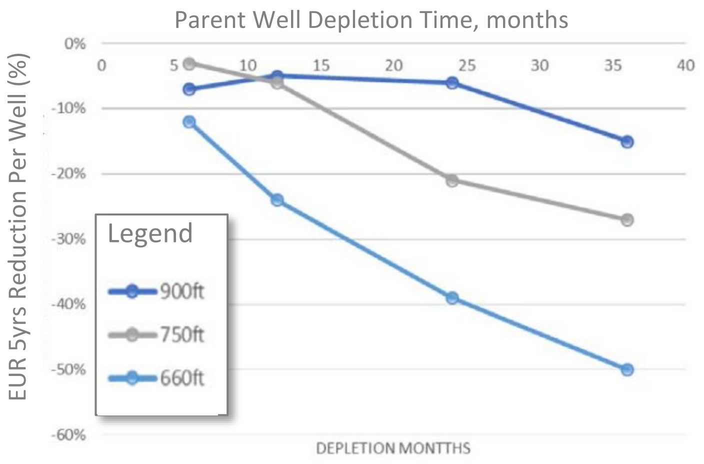


Figure 6 – Child well performance (as measured by percent reduction in 5-year cumulative production) as a function of 1) depletion time of the Parent; and 2) inter-well spacing. (Modified from **Defeu et al. 2018**)

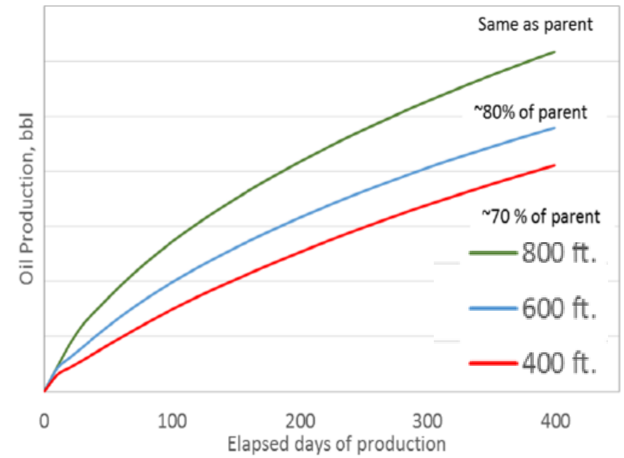


Figure 7 – Child well performance (relative to the Parent well) as a function of inter-well spacing (Modified from **Gakhar et al. 2016**)

- **Figure 6** above shows the Child well degradation in the Delaware Basin as a function of spacing as well as time between when the Parent well first comes on line and when the Child commences first production. Not surprisingly, degradation increases as spacing tightens between the Parent and Child, but timing also plays a key role.
  - Virtually no degradation is observed between the 900 ft and 750 ft spaced wells at approximately 1 year, however the tightly spaced 660 ft well sees slightly over 20% 5-year EUR degradation.
  - At approximately 2 years, significant degradation is observed in the 750 ft and 660 ft spaced wells
  - At approximately 3 years, all spacing groups observe significant degradation.
- **Figure 7** similarly summarizes degradation of the Child well relative to the Parent well performance over the period of approximately one year. This Eagle Ford example shows virtually no degradation for 800-ft spaced wells after one year, but approximately 30% degradation is observed in the 400-ft wells. Please note that full life EUR's may be larger than early time differences caused by altered b-factors. Additional analysis regarding b-factors is provided in the Appendix portion of this talk.

Impact of Inter-well Spacing on Well Performance

URTeC: 2695433 (Rafiee et al. 2017)

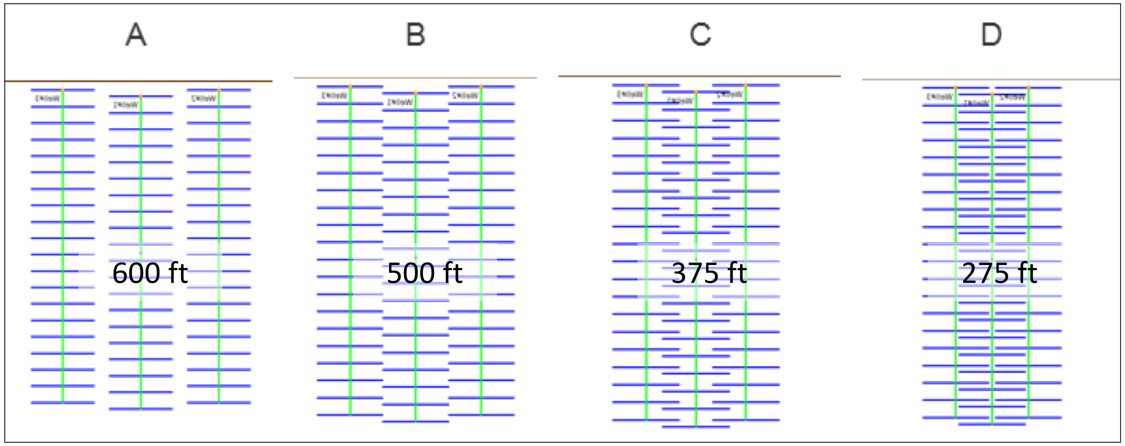


Figure 8 – Numerical simulation set up for well spacing sensitivity: Case A 600 ft spacing; Case B 500 ft spacing; Case C 375 ft spacing; Case D 275 ft spacing. (Modified from **Rafiee et al. 2017**)

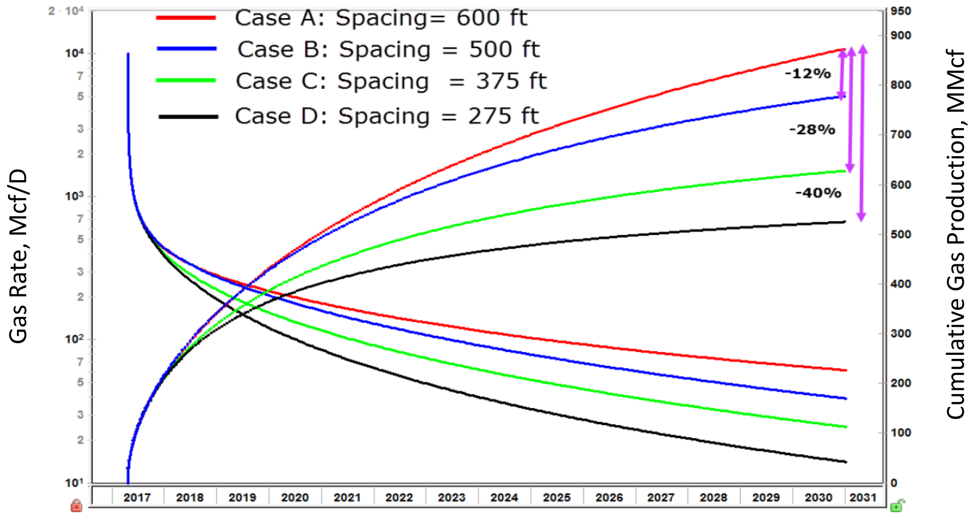


Figure 9 – Resulting decline profiles and cumulative gas vs. time profile for 4 spacing cases. Assumes 10nD matrix reservoir permeability. (Modified from **Rafiee et al. 2017**)

- The authors of URTeC: 2695433 prepared numerical simulation with 20 clusters spaced at 50 feet apart in the Eagle Ford Shale.
- Four inter-well spacing sensitivities were prepared, as shown on **Figure 8** to the left. Inter-well spacings ranged from 600 feet to 275 feet.
- The resulting rate profiles and cumulative production plots are shown on **Figure 9** at left.
- It is interesting to note that the cumulative production from all four scenarios result in very similar cumulative production after 12 months, and that meaningful divergence between the cases occurs later in time.
- No difference is really observable (between the 600 ft and 500ft case) until nearly 4 years.

Well Spacing Framework for Type Well Analysis

Engineering Perspective of the Oil Industry –
What is the Correct Inter-well Spacing?

Well Spacing Framework for Type Well Analysis

- **Need for more rigorous classification of Type Wells** - Over the course of a resource play's development, initial delineation wells are often "Parent" wells that don't compete for reserves in a material way from offsetting wells that are closely spaced, and they don't typically tap into depleted reservoir zones.
  - Parent wells can misrepresent future wells – As plays develop and remaining drilling inventory will either be "co-developed" or infill or offset existing wells, the original Parent wells may not represent future drilling performance very well.
  - Wells chosen for Type Wells should be as analogous as possible to future drilling locations. While there is a lot of attention paid to "analogous" completions, and choosing only wells that were completed with the latest "generation" of frac design, there is both analytical and empirical evidence that spacing and timing should also be considered in Type Well selection.
- **Proposed Methodology and Work Flow** – To select wells that best represent future drilling, the proposed methodology could be employed:
  - Spacing – measure the distance to the nearest well on either side of a given wellbore. Assign the nearest side distance (in the case of only bound on one side) and the average distance (for wells bound on two sides) to each well.
  - Timing and Spacing Designations for Child Wells – The literature review indicates that Parent / Child interaction is most acute at tighter well spacings and with longer production times associated with the Parent well. Timing and Spacing should be a user-defined term that is specific to play or basin relationships. For example, a Parent well in the Eagle Ford may be defined by no wells within 1,000 feet; however a Delaware Basin Parent well may be defined by a larger spacing of 1,500'. Additionally, the user should define the appropriate timing difference between a Parent and Child well. Previous analysis has shown little to no impact for Parent well production less than 12 months, so the user may define a Child well as a well that directly offsets an existing well where the original well has produced for no less than 18 months.
  - Completions – clearly completions drive well performance and wells should be sorted appropriate for vintage or completion design.

Proposed Sub-Classification System

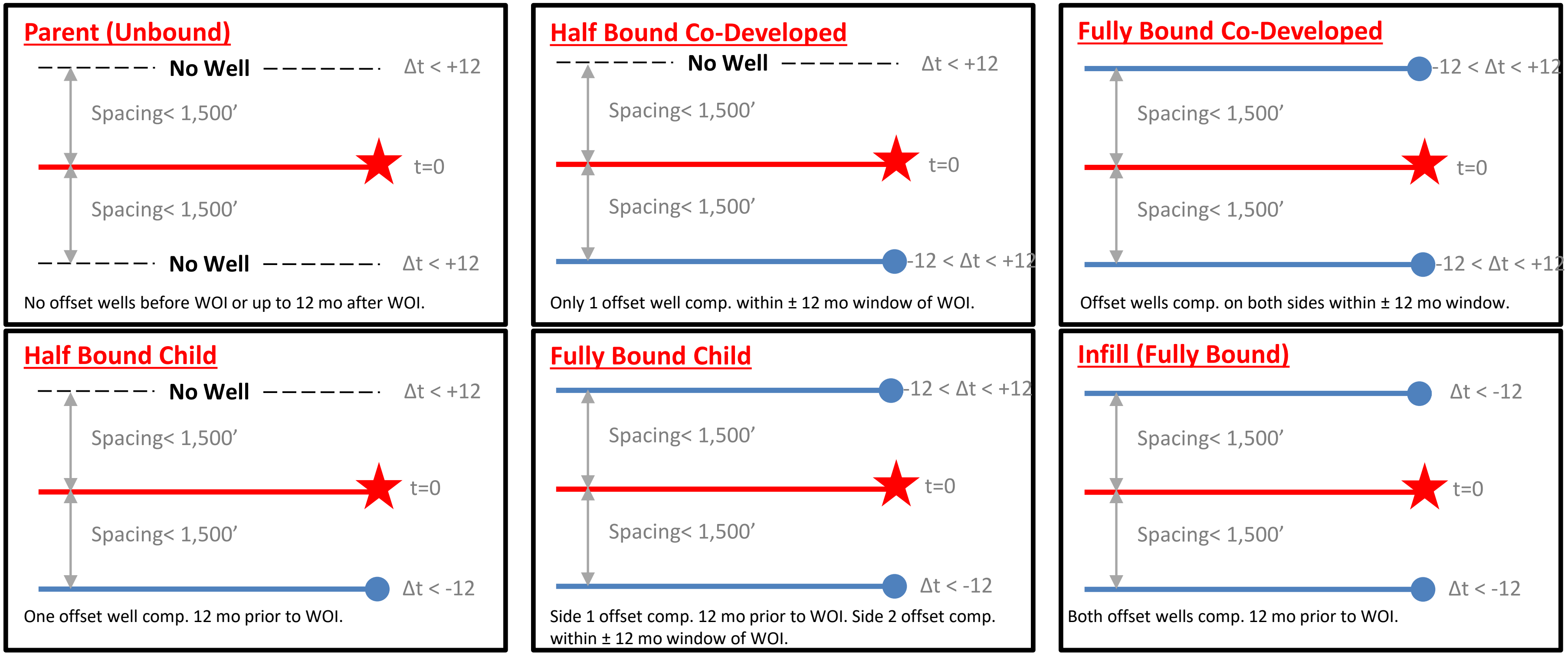


Figure 10 – Proposed Sub-classification convention

Legend
- ★ = Well of Interest ("WOI")
- ● = Offset Well
- Δt = Months between Comp. Date of WOI and Comp. Date of Offset Well

Bounding Terminology

- **Fully Bound ("FB")**: Wells completed on both side of WOI before or up to 12 months after of the WOI's completion date. Includes FB Co-Dev, FB Child, and Infill.
- **Half Bound ("HB")**: Side 1 of WOI has well completed before or up to 9 months after the WOI completion date. Side 2 of WOI has NO WELLS completed before or up to 12 months after the WOI completion date. Includes HB Co-Dev and HB Child.
- **Unbound ("UB")**: WOI has NO WELLS completed on either side before or up to 12 months after of the WOI's completion date. Only Parent wells.

Timing Designation Terminology

- **Parent**: NO WELLS on either side of WOI. Always considered UB.
- **Co-Developed ("Co-Dev")**: Completed at the same time (within ±12 month window) of offsetting well. Can be either FB or HB.
- **Child**: WOI that is directly offset to a well that existed at least 12 months prior to the WOI. Can be either FB or HB.
- **Infill**: Well that is drilled between two pre-existing wells (both offset wells completed more than 12 months before the WOI completion date). Always considered UB.

Example Classification System (Part 1 of 3)

2015 – Two "Parent" wells completed 1,760' Apart

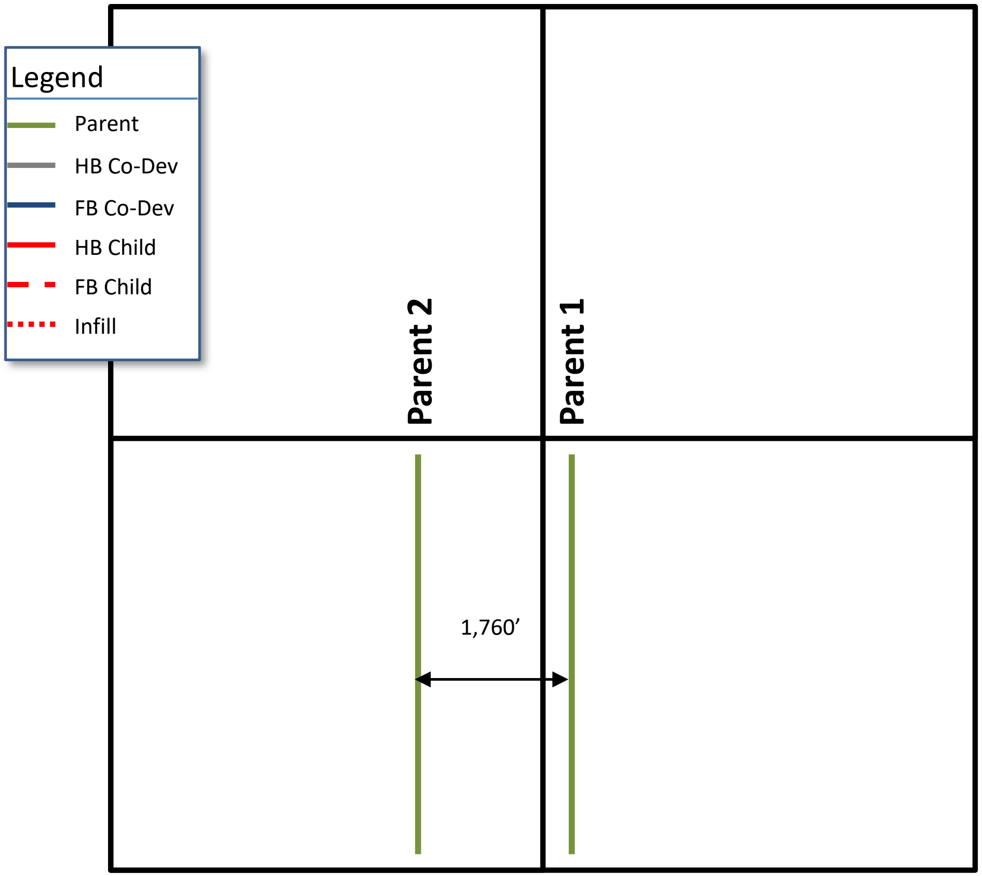


Figure 11 – Example: 2 Parent wells completed simultaneously

- 2015 Drilling Year
- 2 Wells Drilled
- Both Parent Wells
  - Spacing criteria for a Parent wells is no less than 1,500' on either side.
  - Spacing criteria is valid for 12 months
  - (Wells can be infilled later, and Parent will still be a "Parent").

Example Classification System (Part 2 of 3)

2017 – One "Infill" Well Completed in Between Original Parent Wells

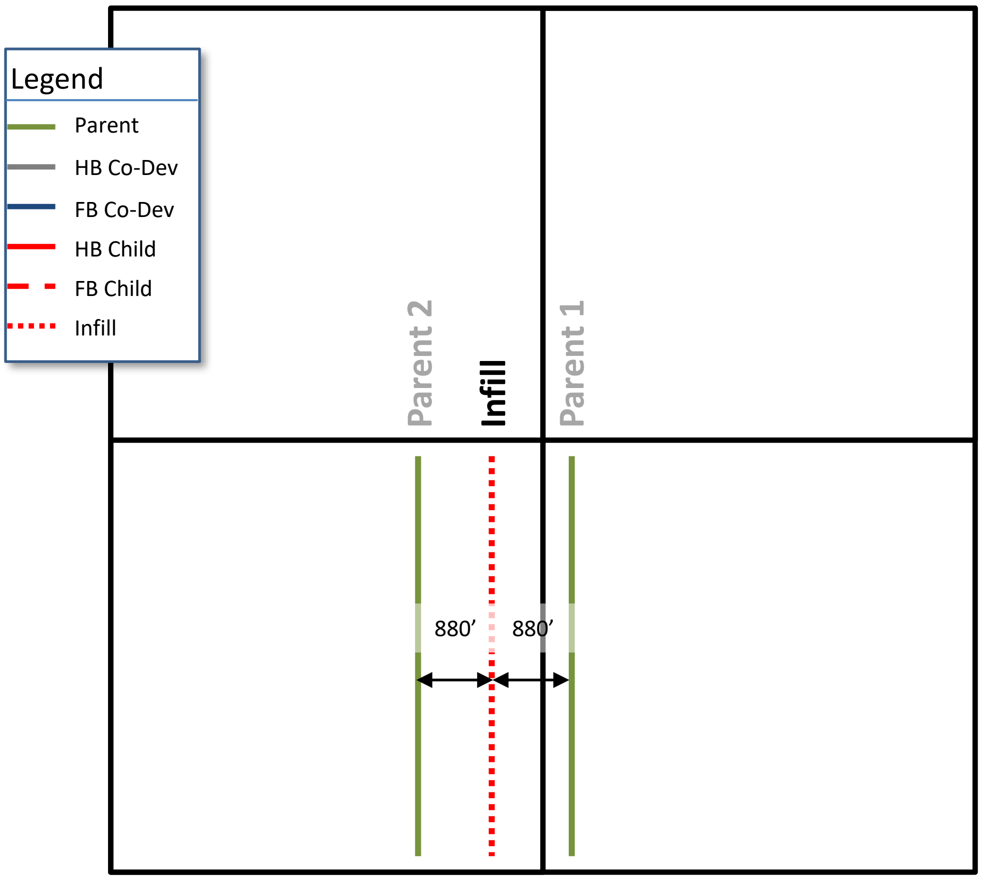


Figure 12 – Example: Infill well completed 24 months after Parent wells

- 2017 Drilling Year (+24 months)
- 1 Well Drilled in the middle of the original Parent wells.
- "Infill" Classification
  - Spacing criteria for an infill well is that it must be bound by an existing well by less than 1,500' on both sides. (In this case, the Infill is bound by 880' on either side)
  - Infill also requires that bounding wells must have produced for at least 12 months. (In this case, both Parent wells were drilled 24 months prior)
  - Original Parent wells are still classified as "Parents"

Example Classification System (Part 3 of 3)

2018 – 5-Well Pad Completed Offset to "Parent 1"

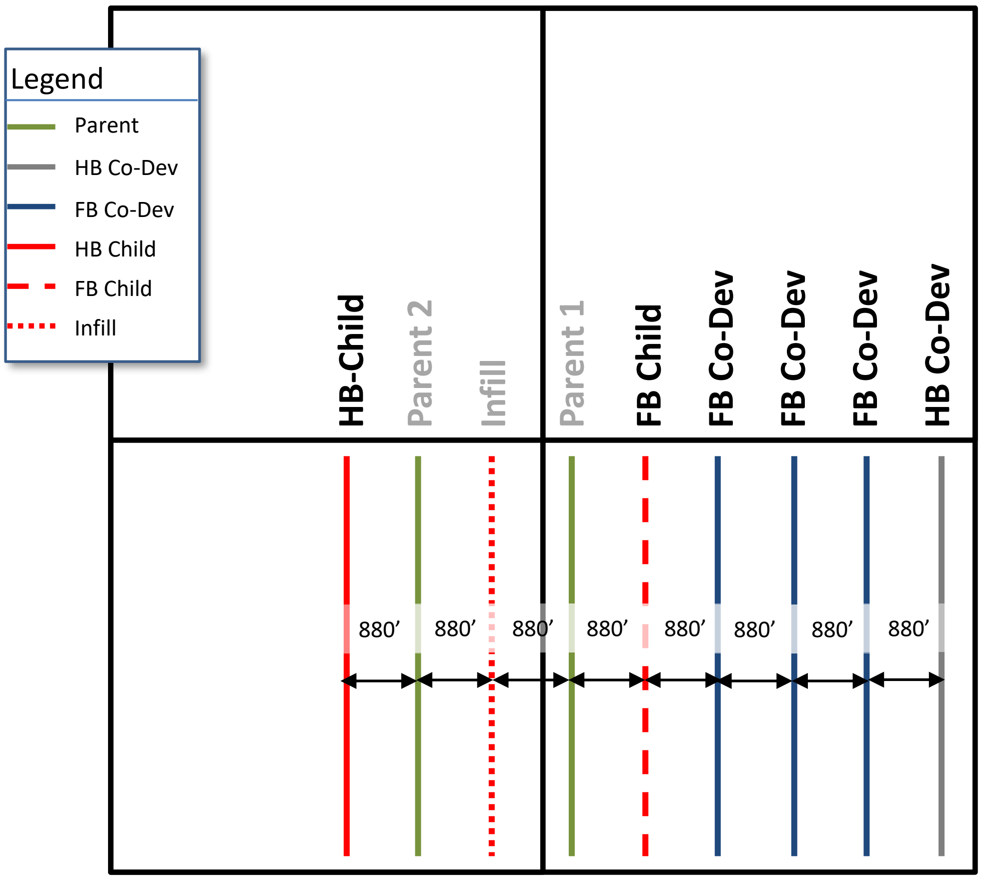


Figure 13 – Example: Additional offset wells to include single HV-Child and a 5-well pad that includes 1 FB Child, 3 FB Co-Dev's and 1 HB Co-Dev

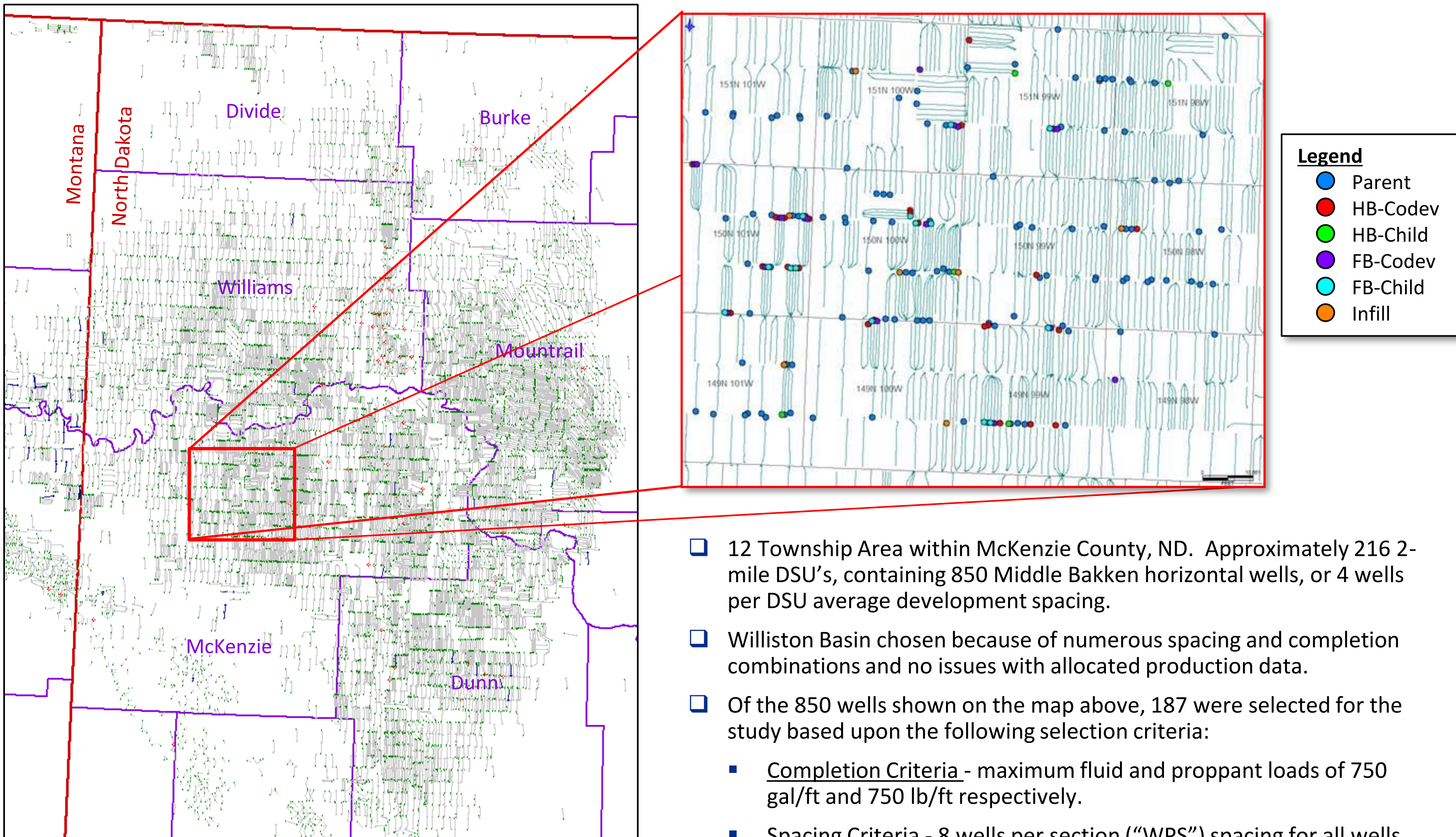
- 2018 Drilling Year (+36 months from Parent 1)
- FB Child – This well is a "child" well because on one side, it directly offsets a Parent well that has produced for more than 12 months.
  - This well is NOT an infill because it was "Co-developed" on one side, and a child on the other.
  - This well IS a fully bound well; i.e. this will compete for reserves with both of its nearest offsets.
- FB Co-Dev – The next 3 wells are "Fully Bound" and since they all came on line less than 12 months from one another, they are considered "Co-Developed".
- HB Co-Dev – The last well on the far right, is only bound on one side, so it is "Half Bound". Since it's nearest offset came on line less than 12 months of this well, this well is considered a "Co-developed" well (and not a "Child" well).

Case Study – Well Performance as a Function of Timing

Engineering Perspective of the Oil Industry –
What is the Correct Inter-well Spacing?

Case Study – Well Performance as a Function of Timing

8 Wells per Section ("WPS") - McKenzie County, ND



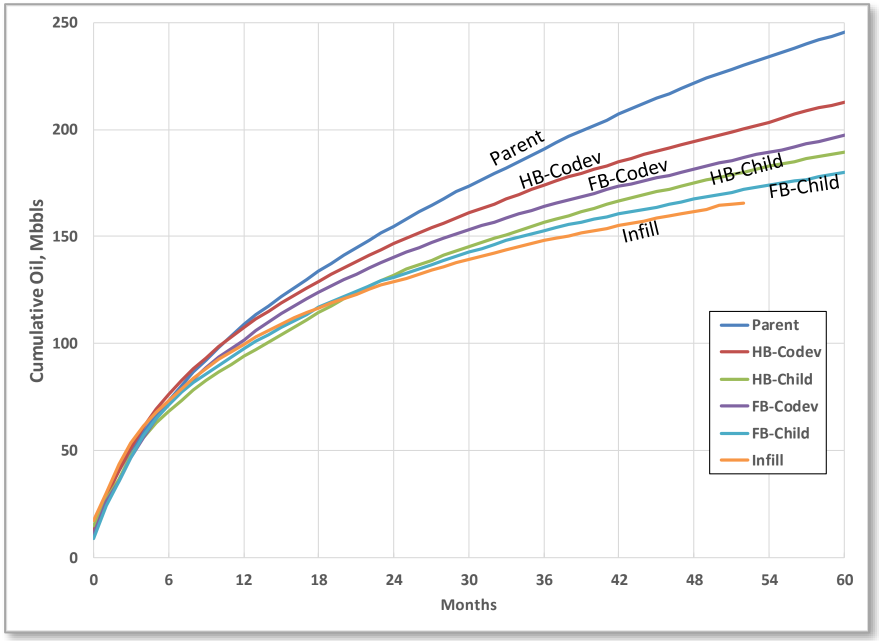
Source Data: I.H.S.

- 12 Township Area within McKenzie County, ND. Approximately 216 2-mile DSU's, containing 850 Middle Bakken horizontal wells, or 4 wells per DSU average development spacing.
- Williston Basin chosen because of numerous spacing and completion combinations and no issues with allocated production data.
- Of the 850 wells shown on the map above, 187 were selected for the study based upon the following selection criteria:
  - Completion Criteria - maximum fluid and proppant loads of 750 gal/ft and 750 lb/ft respectively.
  - Spacing Criteria - 8 wells per section ("WPS") spacing for all wells except Parent wells

Case Study – Well Performance as a Function of Timing

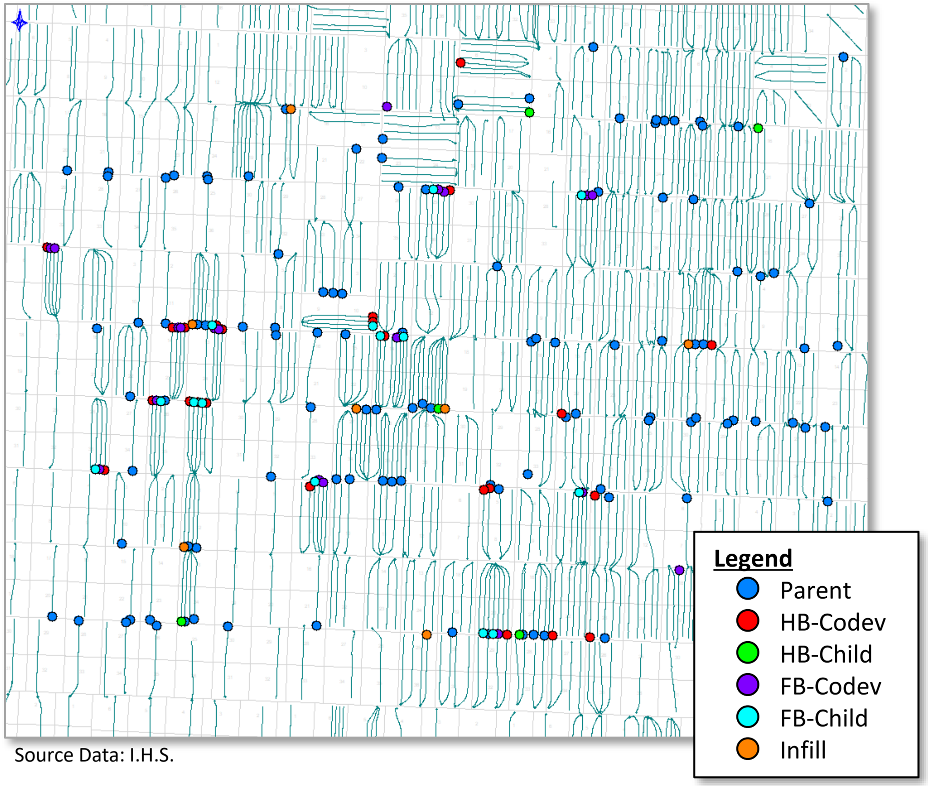
12-Township Area – 8 WPS – McKenzie County, ND

Cumulative Oil vs. Time (8 WPS)



- Parents and Infill wells typically form the bookends of well performance (for well sets bucketed in similar spacing, completion and lateral length groups).
- Near term results can be deceiving – little difference in first 6 months, but Parent wells are ~25% high to Infills after 36 months.
- Half Bound Co-Dev wells perform similar to Parent wells in early time (virtually no difference after 12 months, and ~10% difference after 36 months).
- HB-Child, FB-Codev and FB-Child wells tend to perform similarly. (See next page)

Locator Map



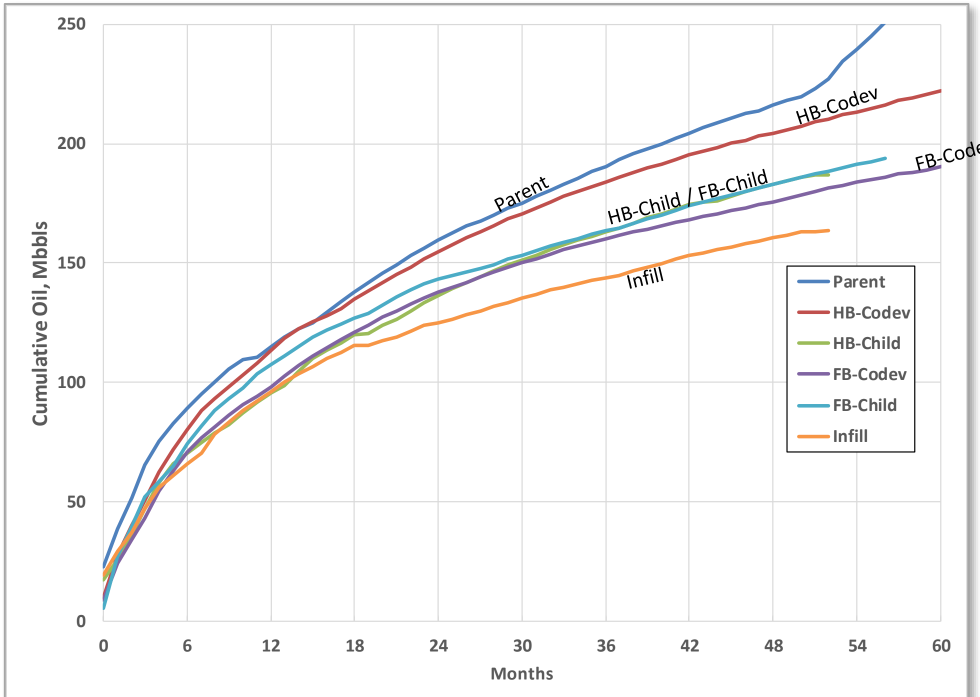
Source Data: I.H.S.

Well Statistics	Timing Designation					
	Parent	HB-Codev	HB-Child	FB-Codev	FB-Child	Infill
Avg. CLL, ft	9,133	9,285	9,506	9,299	9,424	9,256
Avg. Proppant, lb/ft	355	357	373	368	398	373
Avg. Fluid, gal/ft	303	301	279	327	327	276
Avg. Spacing, ft	1,670	630	631	655	636	640
Well Count	111	25	7	19	14	11

Case Study – Well Performance as a Function of Timing

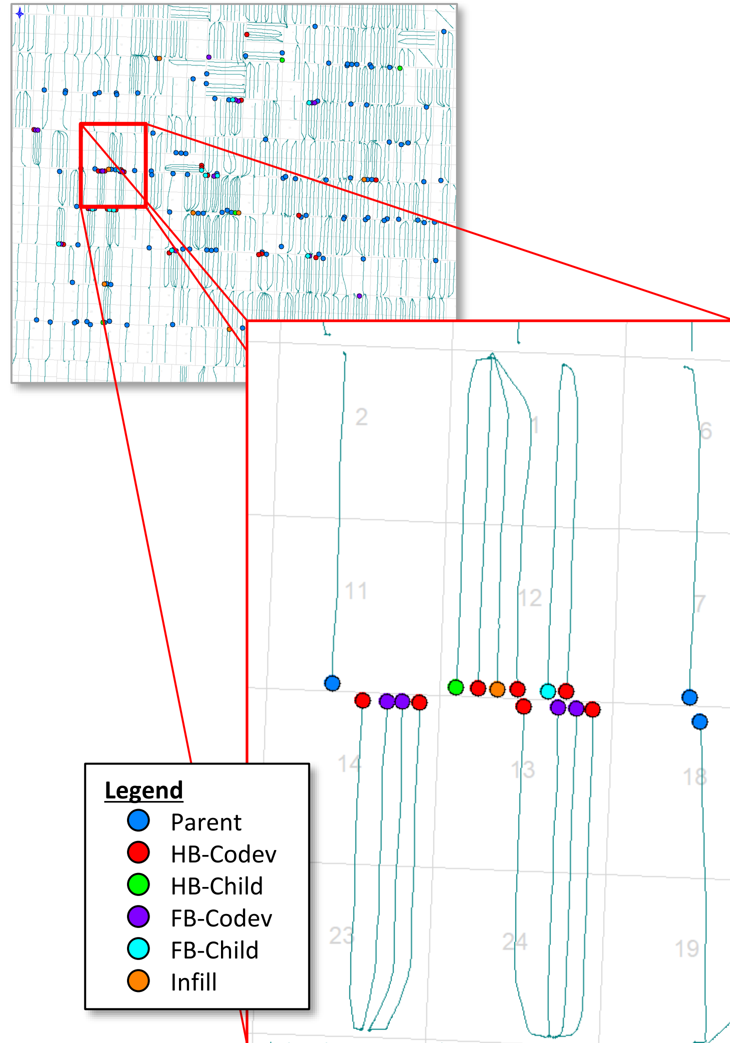
3-Pad Example – 8 WPS – McKenzie County, ND

Cumulative Oil Plot, Mbbl



Source Data: I.H.S.

Locator Map



Well Statistics	Timing Designation					
	Parent	HB-Codev	HB-Child	FB-Codev	FB-Child	Infill
Avg. CLL, ft	9,535	9,389	9,447	9,487	9,479	9,416
Avg. Proppant, lb/ft	394	409	396	392	410	398
Avg. Fluid, gal/ft	392	384	289	356	355	358
Avg. Spacing, ft	3,193	669	657	615	772	556
Well Count	1	7	1	4	1	1

Case Study – Well Performance as a Function of Spacing

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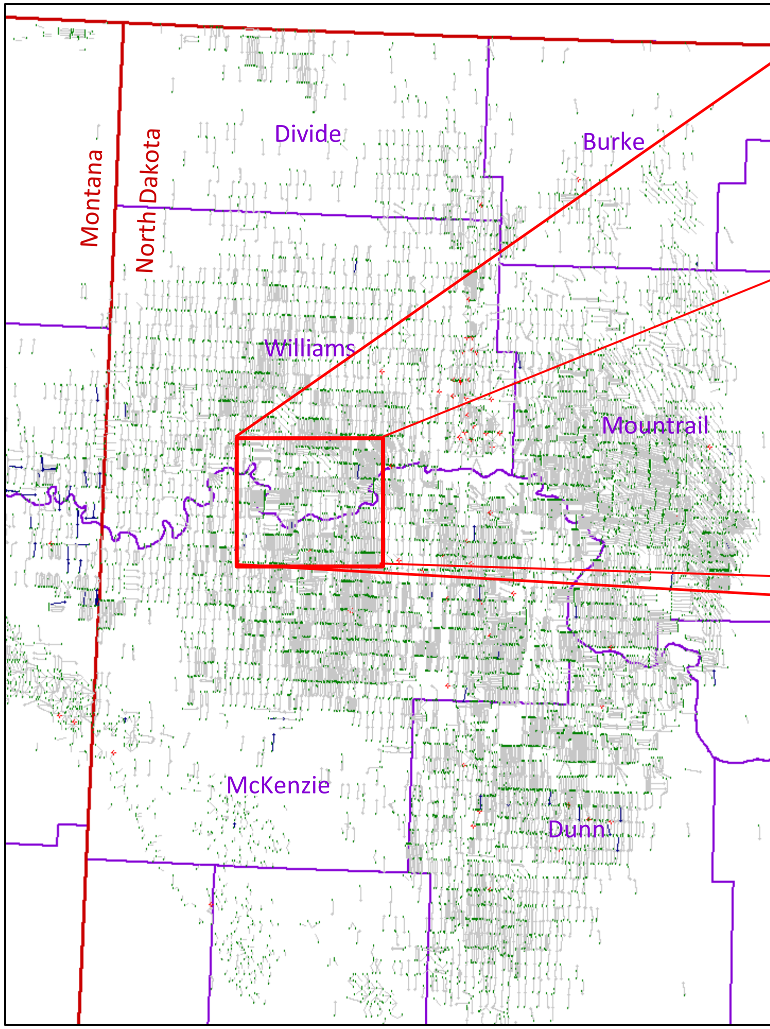
Case Study – Well Performance as a Function of Spacing

FB-CoDev Wells Only / McKenzie County, ND



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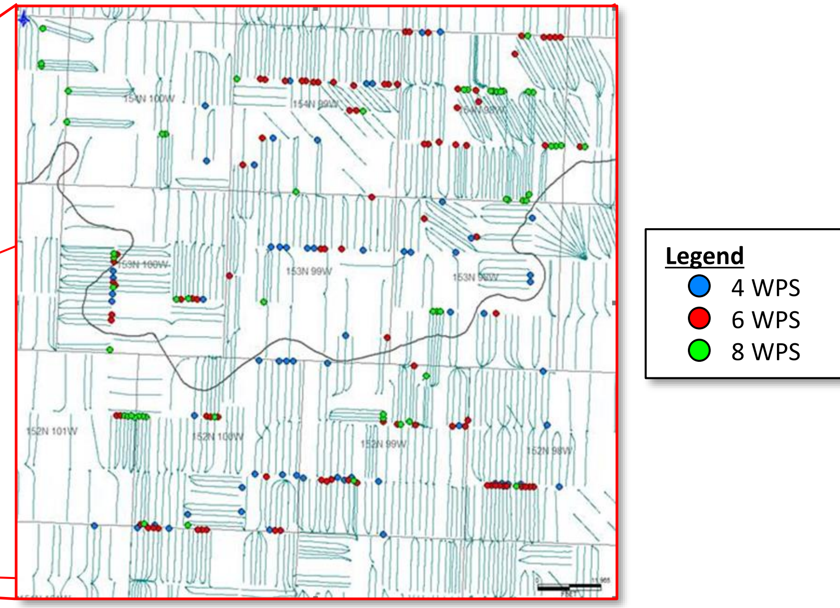
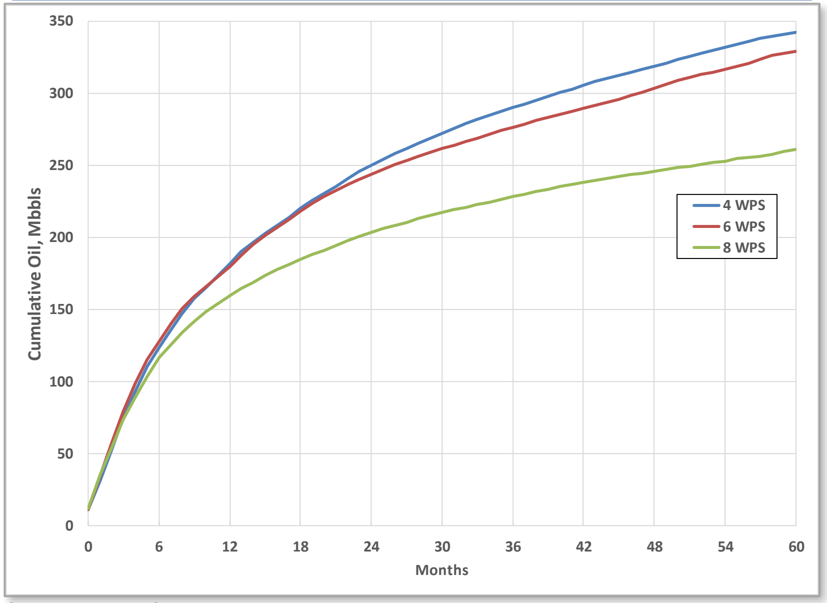


- Approximately 9 Township Area located on the border of McKenzie and Williams Counties, ND.
- Williston Basin chosen because of numerous spacing and completion combinations and no issues with allocated production data.
- For this study, only **Fully Bound Co-Developed** wells were used.
- Wells were sorted into groups that contained similar completions and lateral lengths and located in similar areas for the purpose of removing as many well performance variables as possible.
- Once well groupings were achieved, well performance was observed as a function of inter-well spacing.

Case Study – Well Performance as a Function of Spacing

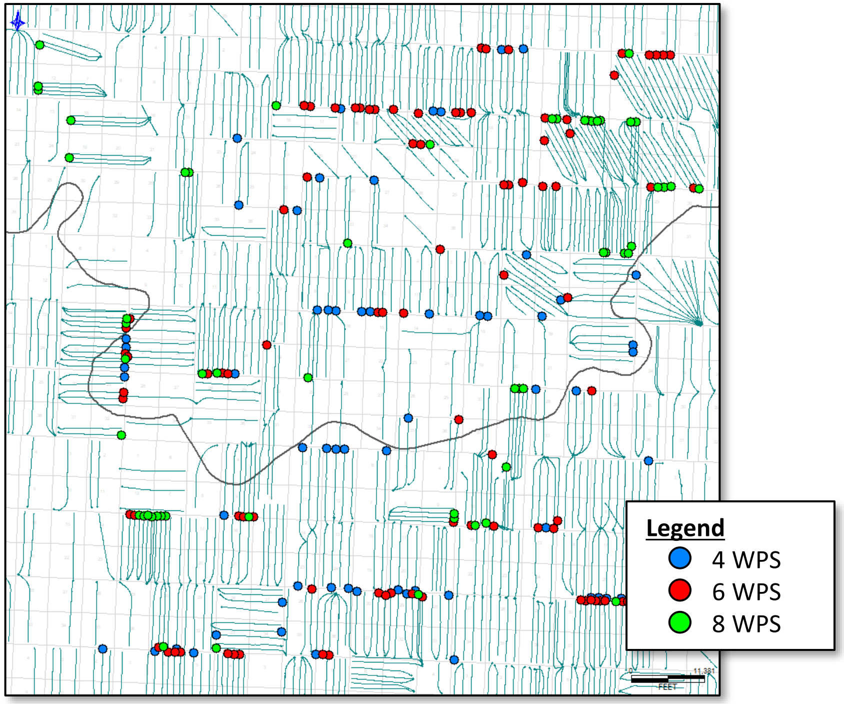
9 Township Area / FB-CoDev Wells Only / ~800 lb/ft

Cumulative Oil vs. Time



Source Data: I.H.S.

Locator Map

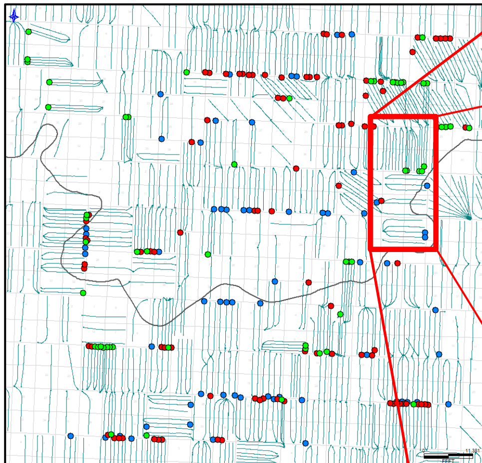


- Wells grouped into groups consisting of similar inter-well spacing (i.e. 4, 6 and 8 WPS)
- Very little performance difference between 4 WPS and 6 WPS. Virtually identical for first two years.
- Material difference observed in tighter spaced wells.
- No Parent / Child impacts affecting well performance because all wells are "Fully Bound Co-Developed".

Well Statistics	Spacing Designation		
	4 WPS	6 WPS	8 WPS
Avg. CLL, ft	9,490	9,322	9,725
Avg. Proppant, lb/ft	746	834	811
Avg. Fluid, gal/ft	917	883	883
Avg. Spacing, ft	1,232	888	635
Well Count	63	91	56

Case Study – Well Performance as a function of Spacing

Focus Area / FB-CoDev Wells Only / ~400 lb/ft



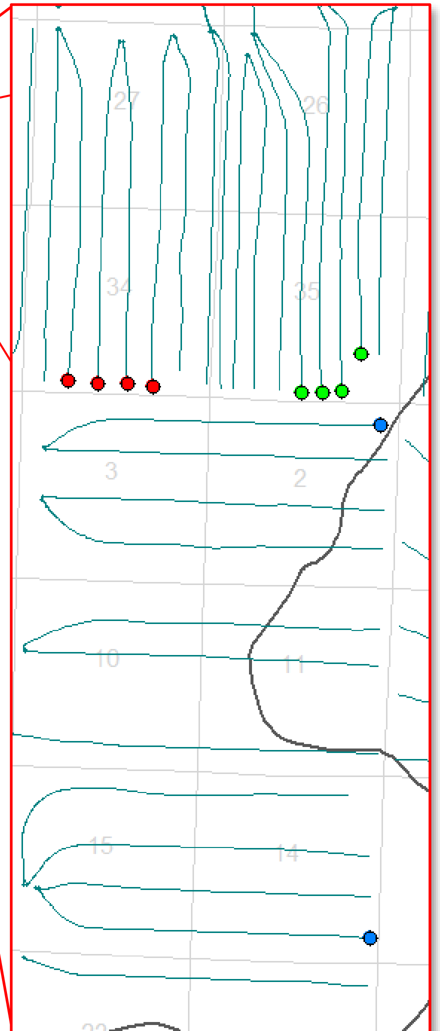
Source Data: I.H.S.

Legend

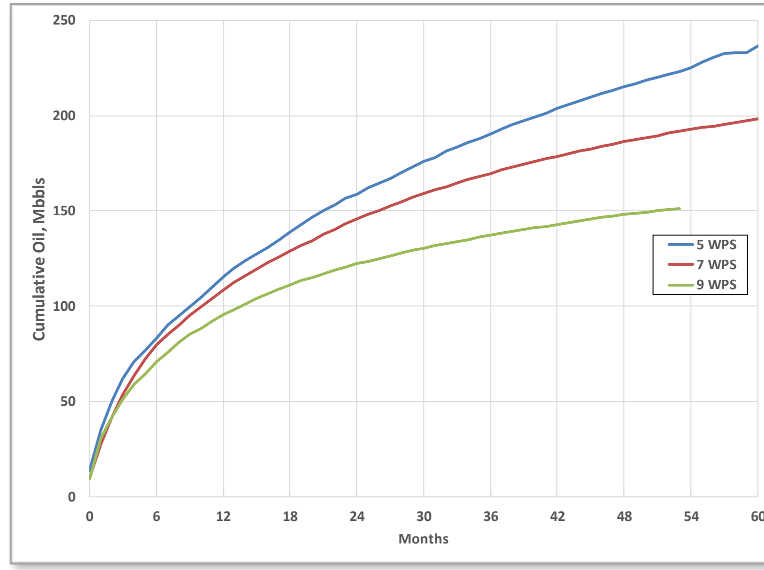
- 5 WPS (blue)
- 7 WPS (red)
- 9 WPS (green)

Well Statistics	Spacing Designation		
	5 WPS	7 WPS	9 WPS
Avg. CLL, ft	9,010	9,055	9,014
Avg. Proppant, lb/ft	356	381	483
Avg. Fluid, gal/ft	299	374	405
Avg. Spacing, ft	1,091	768	632
Well Count	2	4	4

Locator Map



Cumulative Oil vs. Time



- Similar well performance trends observed on a more "focused" area comprised of several drilling units.
- Interesting to note that the "focused" well set is materially less stimulated than the 9-Township area. Well performance is predictably lower, but the same relationship between spacing still exists.
  - 36-month cumulative oil production associated with the "5WPS" curve is significantly lower than the "8WPS" curve on the previous page which has approximately twice the frac intensity.
  - This relationship can be misleading! Tighter spacings in concert with large stimulations can out-perform widely spaced wells, and give the impression that spacing doesn't really matter…

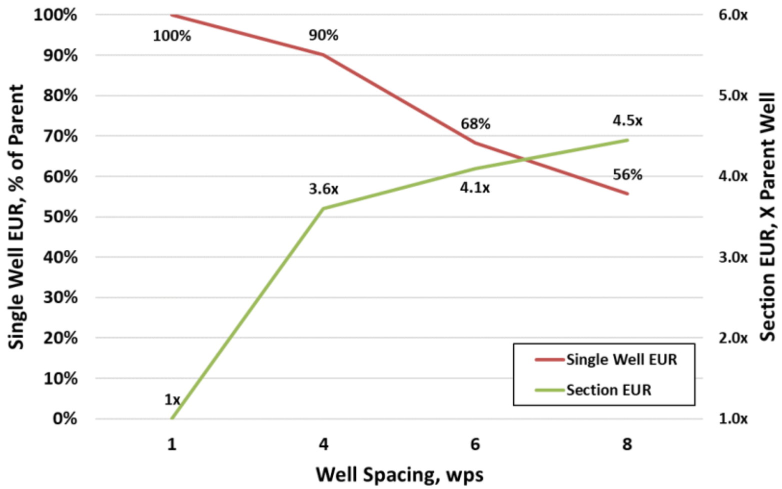
Well Spacing and Optimal Economics

Engineering Perspective of the Oil Industry –
What is the Correct Inter-well Spacing?

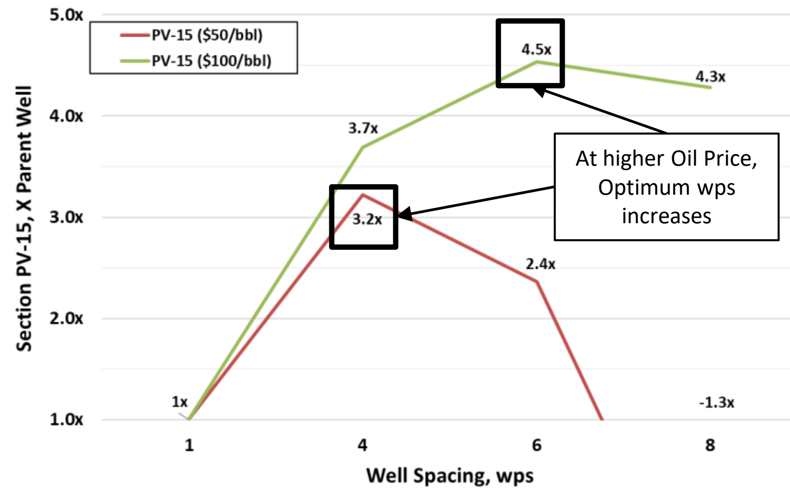
Illustrative Well Spacing and Economics

What is the Right Inter-Well Spacing?

Impact of Spacing on Section EUR



Impact of Spacing on Section Economics



- **What is your objective?** - Ultimately optimal spacing will be derived by balancing numerous variables that drive well performance and economic outcomes. In general, the theoretical "Optimum" well spacing is one that maximizes whatever objective is most important to the operator and / or investor.
- **Single Well Returns or NPV?** - If maximizing return on capital is the primary objective, then wider spacing will result in better single well returns. If maximizing NPV is more important, then operators / investors may be willing to sacrifice single well economic returns.
- **Single Well EUR vs. DSU recovery** - The chart at top left shows single well performance degradation as a function of well spacing (taken from our Case Study work in the Middle Bakken). Coincidently, however, total hydrocarbon is maximized by drilling more wells. Theoretically, this number should flatten at some point (not shown).
- **Rational Economic Decisions** - The chart at top right indicates that the decision to drill 4, 6 or 8 wells per section may vary significantly based on perceived NPV that would be achieved at different oil price levels. Drilling more wells into a higher price environment is a rational decision. Widening spacing in low price environments also makes sense.

Preliminary Results of Vertical Spacing Analysis

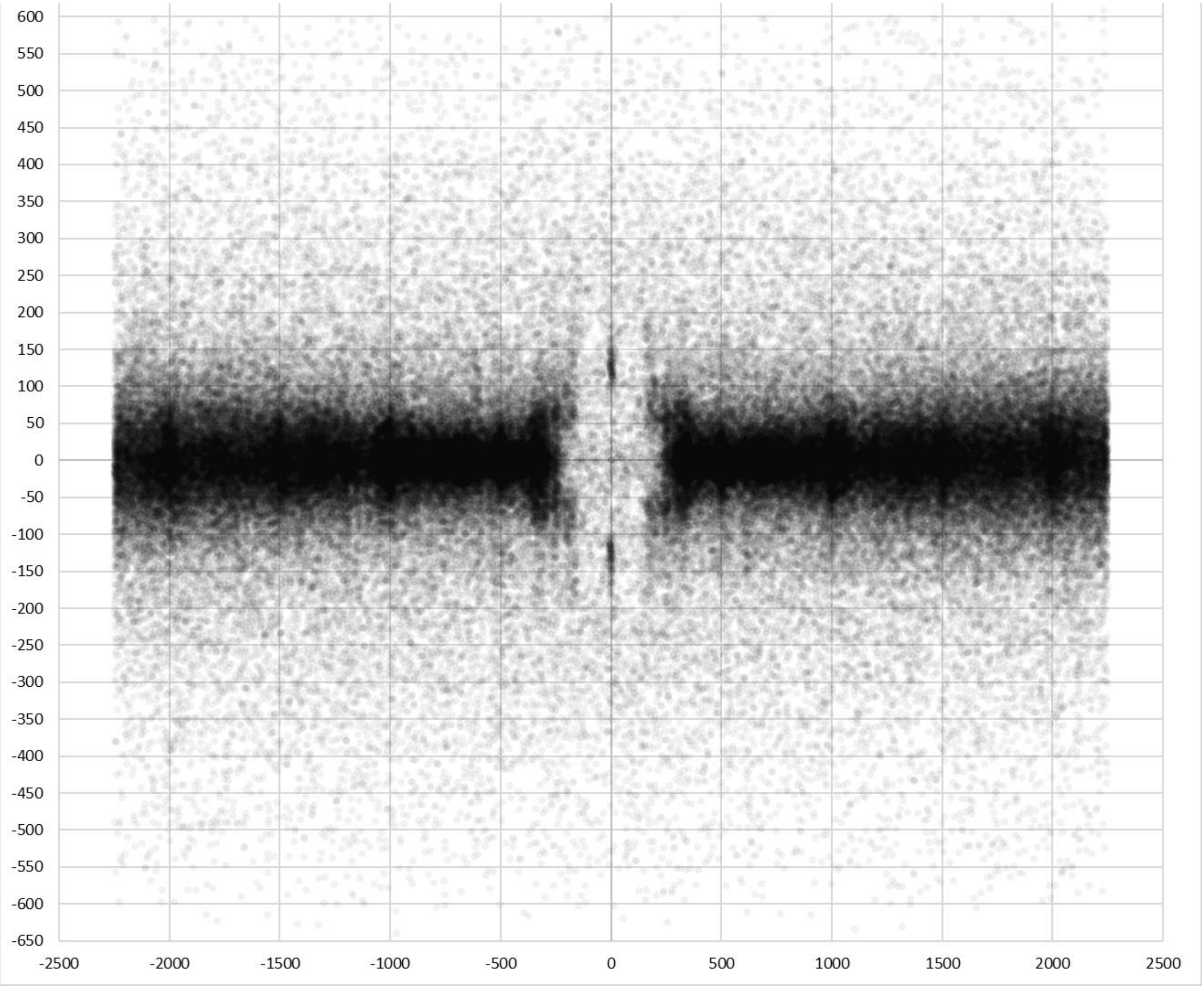
Engineering Perspective of the Oil Industry –
What is the Correct Inter-well Spacing?

Incorporation of Vertical Spacing

- While the proposed sub-classification system makes sense for use in single-bench plays such as the Fayetteville Shale, Barnett Shale and Eagle Ford Shale, it is less applicable to multi-bench targets that span a large vertical distance, such as the Midland and Delaware Basins.
- **Development of 3-D Spacing Tool** - VSO has measured spacings and timings in effort to expand the proposed sub-classification system into a "3-D spacing tool" that incorporates lateral distance, vertical distance and time between completions. Before applying our tool to various well configurations, we hypothesized that vertical distance could be expressed as in terms of a dampened lateral distance or a "quasi" lateral distance. Our initial observations, however, have not supported this hypothesis. We've observed significant liquid and gas phase separation where gas is predominantly produced from shallower wells and liquids are predominantly produced from deeper wells (most notably in the DJ Basin). We've also observed that numerous well sets drilled within close lateral and vertical distance from one another tend to behave (from a production perspective) similar to one another (most notably in the Wolfcamp A, Wolfcamp XY and Third Bone Springs in the Delaware Basin).
- **VSO Current Methodology** - For now, we continue to use the sub-classification system presented herein, but we group certain benches where we believe those benches to be producing as a single flow unit. For example, we commonly group the three Niobrara benches in the DJ Basin together, and we group the WCA, XY and TBSPG together in the Delaware where we think these benches are communicating. Adequate vertical offset (for example greater than 500 feet) provides sufficient reason to exclude wells from data sets.
- **Composite Gun Barrel Diagrams** - The following three slides show "composite" gun-barrel diagrams of three different basins. These diagrams were generated using our 3-D spacing tool for the purpose of illustrating "single-bench" nature of the Eagle Ford Shale, compared to the relatively tight but vertically differentiated DJ Basin, compared to the vast vertical distances targeted in the Midland Basin. The tool essentially looks at all of the offsets for each producing well in the basin and posts the offsetting location of all wells within a 2,500' "radius" of each well. Essentially this display is what you would get if you overlaid each individual gun barrel diagram (in each basin) on top of each other.

“Composite” Gun Barrel Diagram

Eagle Ford Shale



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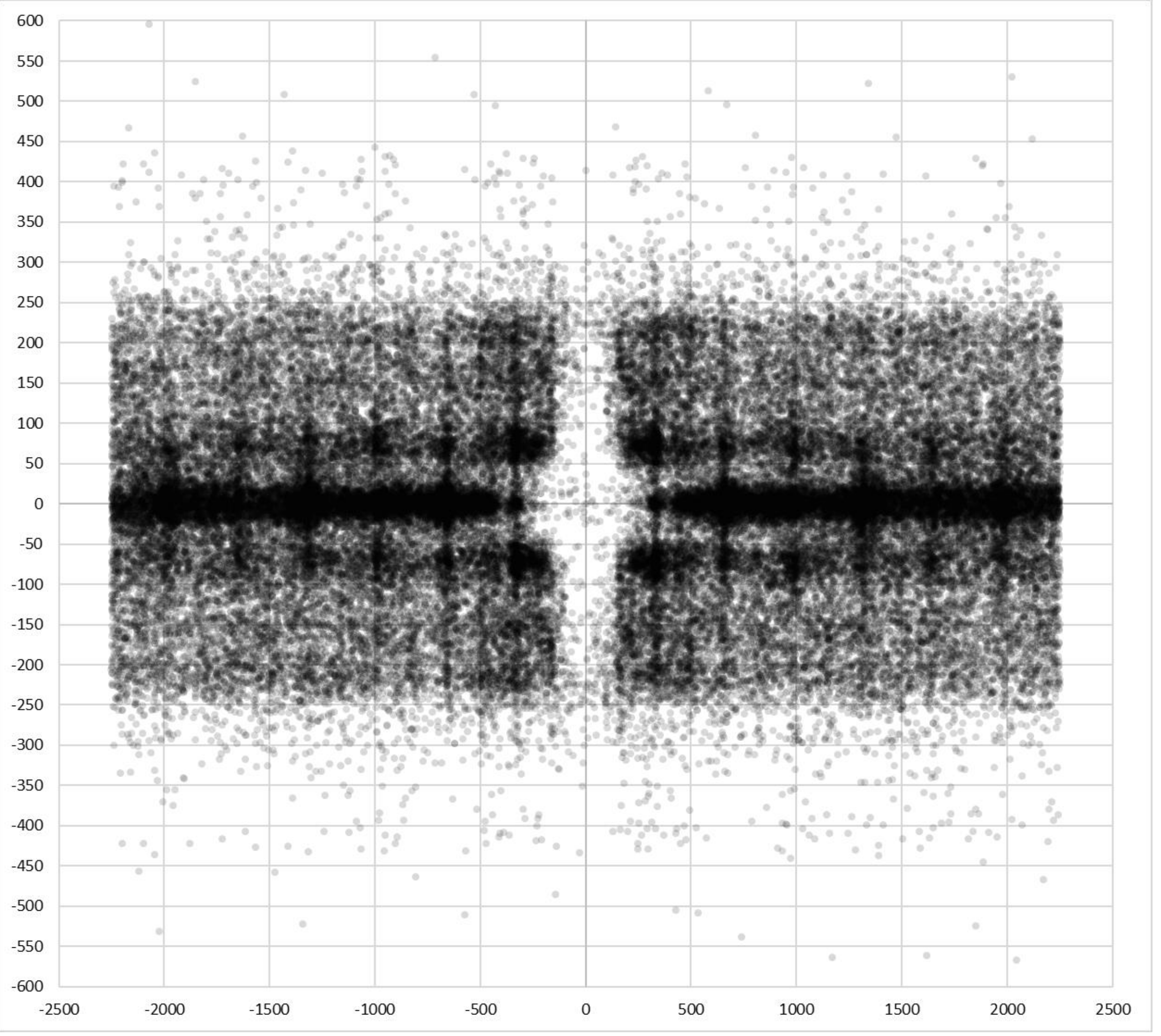
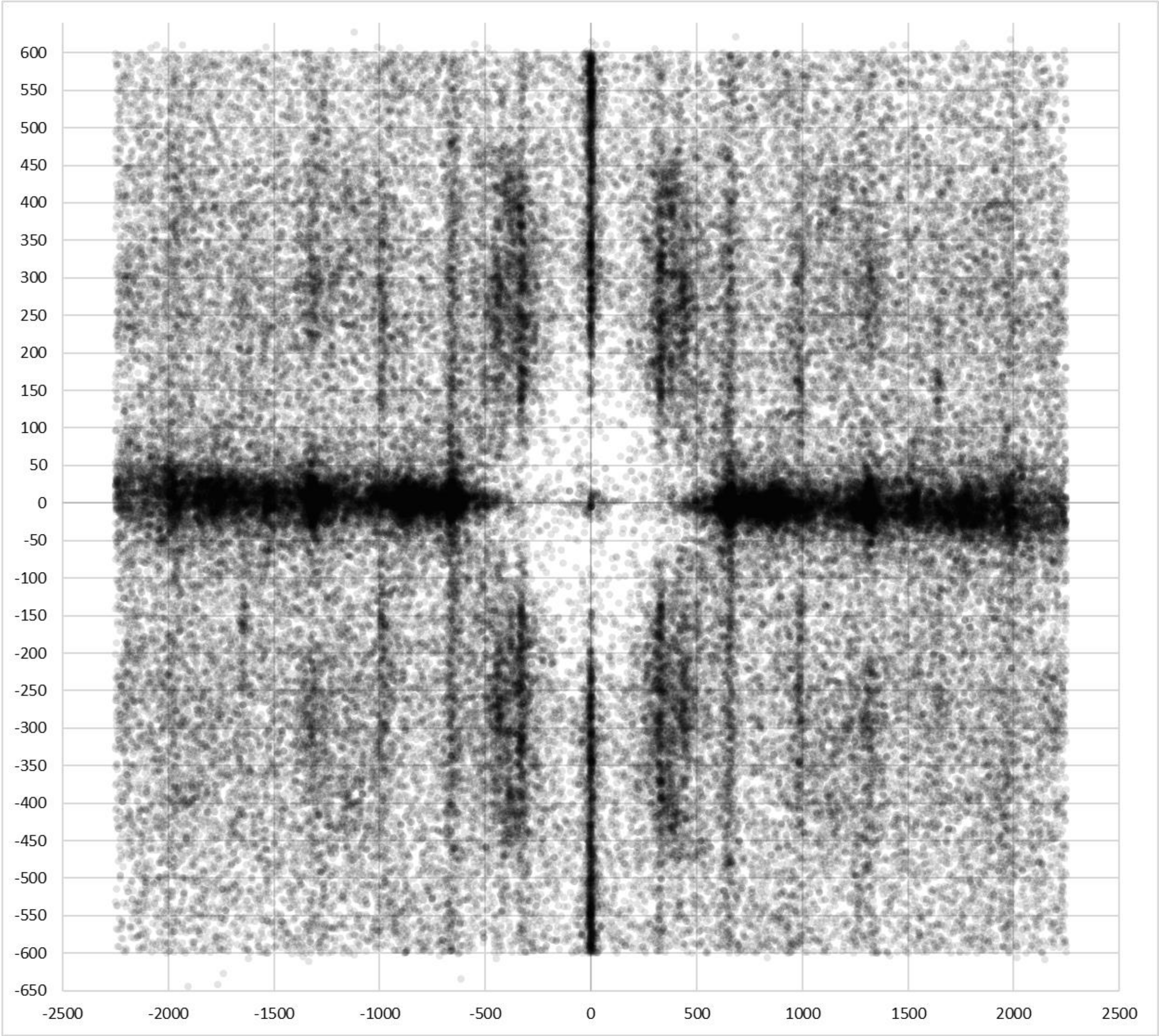
"Composite" Gun Barrel Diagram

DJ Basin



“Composite” Gun Barrel Diagram

Midland Basin



Appendix

Engineering Perspective of the Oil Industry –
What is the Correct Inter-well Spacing?

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Impact of Inter-well Spacing on Well Performance

URTec: 2695433 (Rafiee et al. 2017)

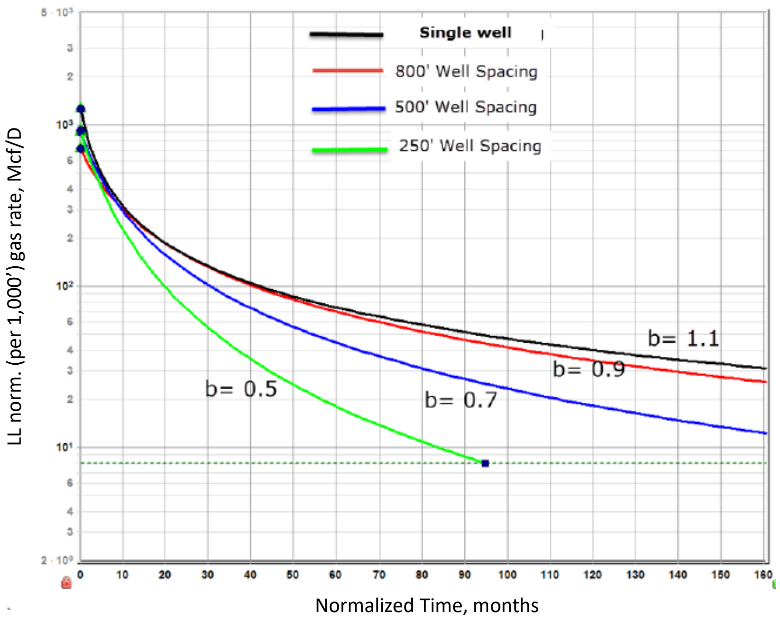

Figure 14 – Decline curve analysis from groupings of wells at different spacing indicate similar initial rates, but higher declines and lower b-factors associated with tighter-spaced wells. (Modified from **Rafiee et al. 2017**)