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Enhanced understanding improves "child well" performance

In U.S. shale fields, operators are attempting to improve infill well performance. In the Eagle Ford, child wells now account for about 75% of new completions. Infill drilling is ramping up in the Permian, which hosts half of all U.S. drilling.

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Fig. 1. Outlines of 10 unconventional plays selected for the parent/child well interaction study.

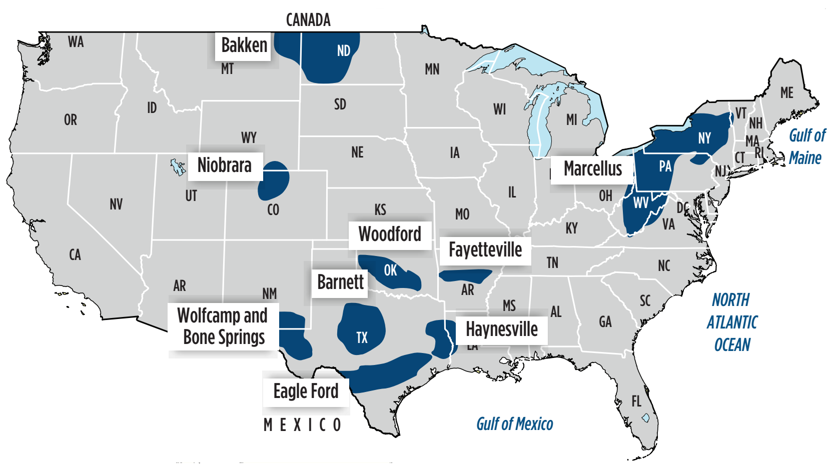


Table 1. Fracture hit breakdown across five major unconventional plays.

	Bakken	Eagle Ford	Haynesville	Woodford	Niobrara
Positive hit - Long term	17%	9%	20%	2%	0%
Positive hit - Short term	33%	14%	38%	2%	6%
Positive hit total	50%	24%	58%	4%	6%
No change	35%	36%	24%	32%	38%
Negative hit total	15%	41%	19%	64%	56%
Negative hit - Short term	7%	13%	5%	20%	19%
Negative hit - Long term	6%	17%	5%	41%	31%
Shut-in post offset hit	2%	10%	9%	3%	6%
Instances included	649	1,210	366	259	32
Original No. of instances	827	1,561	449	283	49
Instances with invalid data	178	351	83	24	17

The transition to infill development in the shale fields has been challenging, and production rates are highly variable and unpredictable. This is due to depletion effects of the parent well that can cause fracture hits and interwell communication among child and parent wells (SPE 174902). In reservoirs with significant depletion caused by parent wells, predicting performance of new infill wells can be difficult. Although operators expect infill wells to perform comparably to, or better than, existing parent wells, the reality is that infill wells often produce below established offset parent well decline curves. This scenario adversely impacts future reserve estimates and, ultimately, field economics.

BASIN STUDIES

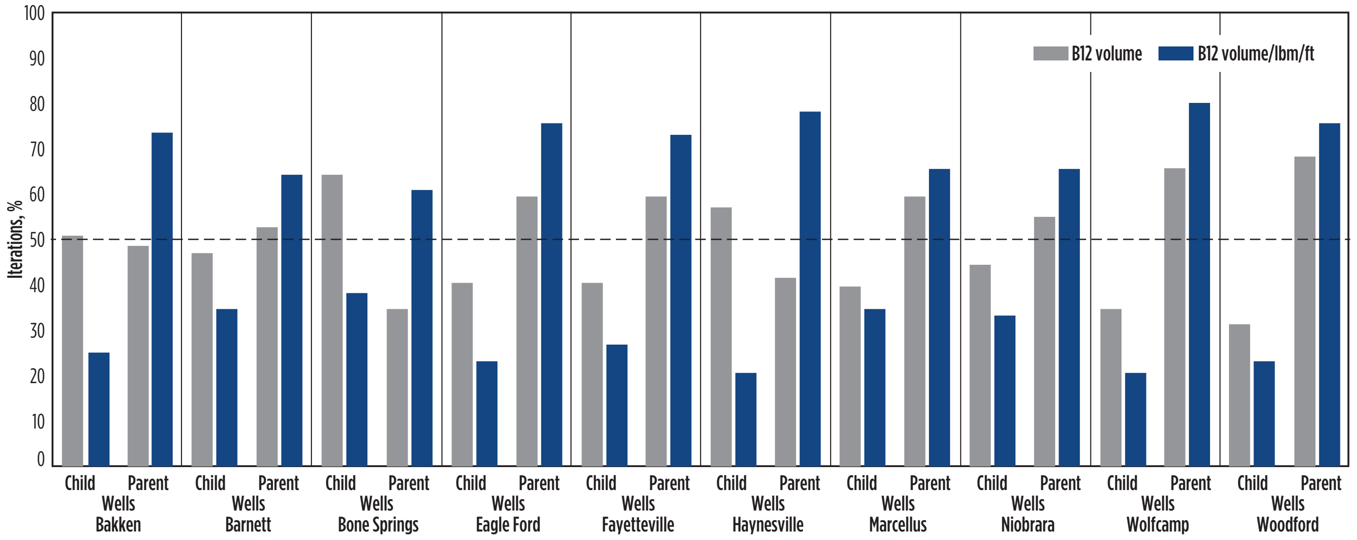
To increase the understanding of the output relationship between parent and child wells, the service provider studied 3,000 fracture hits across five major unconventional plays, Table 1. The analysis was performed to better understand parent well challenges in each individual field (SPE 180200). The study determined that fracture interference had different effects in different basins, in terms of severity and whether the interference was positive or negative to parents. In most cases, fracture hits on existing parent wells resulted in a positive or no change of trend in the production of the parent well. However, in the Woodford and Niobrara, fracture hits on existing parent wells resulted in a negative or no change trend in the parent well. The Eagle Ford was split, with an approximate 50/50 chance that a fracture hit will be positive or negative to parent well production.

INFILL PERFORMANCE

Historically, there has been little research on basin-wide trends for infill well performance, on average, compared with their corresponding parent wells. To better understand child well performance issues, the service company conducted a comprehensive study in 2017 (SPE 189875) across 10 major U.S. unconventional plays, including Bakken/Three Forks, Barnett, Bone Springs, Eagle Ford, Fayetteville, Haynesville, Marcellus, Niobrara, Wolfcamp and Woodford, Fig. 1.

The study used public data from IHS Enerdeq, reported through late 2016, to design a spatial, statistical approach with key production indicators, to evaluate the difference in production performance between the original parent well and new child wells. While the study was not intended to present a specific protocol for accurately predicting infill well production, it does use a logical workflow that provides scientific-based inferences on production performance of infill wells versus pre-existing parent wells. The conclusions present alternative strategies and

Fig. 2. The study suggests longer laterals and larger frac volumes are required in offsets to achieve production rates similar to parent wells.



technologies that may increase the potential of underperforming infill wells.

The study examines the effects of reservoir depletion and fracture behavior on infill production. These factors have become increasingly important, as operators push the envelope of unconventional development to maximize return on investment. Fluctuating commodity prices and service costs, and the economics of single-well versus pad drilling, must be considered when calibrating expectations.

Statistical moving-window workflow. To consistently evaluate infill/parent well production, a statistical moving-window workflow was implemented to study thousands of wells in a relatively short time-span. The approach analyzes each well, compared to all surrounding wells, within a specified three-dimensional radius to enable evaluation in three directions. Distances between wells were measured from the midpoints of laterals, as identified from public deviation survey data. This method takes into account different landing zones for the laterals, especially in plays with thick or stacked pay intervals, such as the Permian's Bone Springs and Wolfcamp.

Each moving-window iteration included a preexisting parent well and new child well(s) within a specified radius. Parent wells were defined as having a minimum of two years of production history with at least one child well that produced a minimum of one year. These cutoffs were implemented to allow adequate time to observe depletion effects. A 1,000-ft radius was studied primarily for each moving window, followed by 1,000-1,500-ft, 1,500-2,000-ft and 2,000-2,500-ft radii, to investigate changing effects with distance. For wells with thick or stacked pay, a 100-ft limit was assumed in the depth direction, even though vertical communication may be shorter or longer, depending on fracture height, vertical permeability or fracture conductivity.

A best, consecutive 12-month volume (B12) was calculated for every well as a comparative tool for each iteration. For dry gas basins, a B12 gas volume was calculated, and for oil basins, a B12 oil volume was determined. A B12 boe volume was calculated for basins with significant gas and oil production.

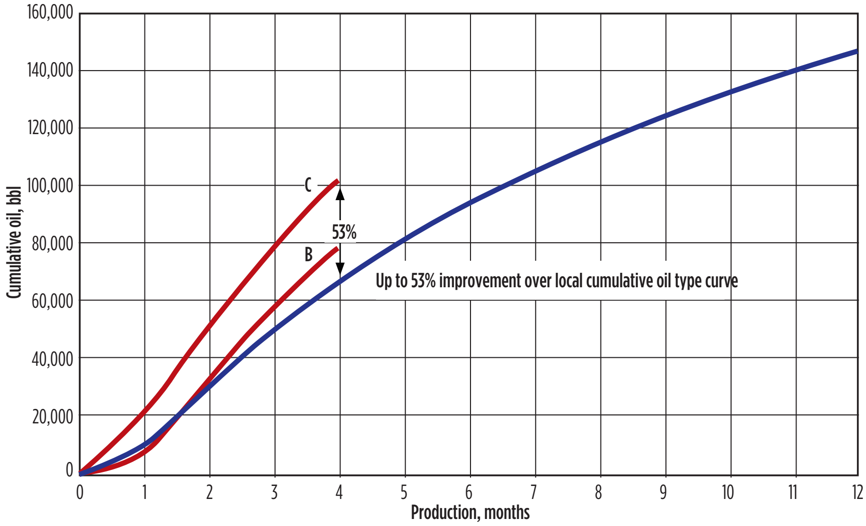
The parent well B12 volumes were compared to the average B12 volumes of the child well(s) in each iteration, and then compared at different distances. To adjust for other possible drivers, production was normalized by total proppant pumped and lateral length for each iteration, as these were accessible through public sources. Only producing wells with reported lateral lengths and total proppant volumes were included in the data set, to ensure an accurate comparison when looking at raw versus normalized volumes.

The study assumed that the geology and reservoir properties in each moving window were the same. Also, because the information is not available in public sources, the study did not consider all completion components, such as open-hole versus cased-hole, number of stages, perforation cluster spacing and fluid type, differences in flowback, production practices or artificial lift techniques. Additionally, production indicators used as the comparative tool in the analysis were not intended to, and should not be used to, directly correlate with differences in expected reserve volumes.

Trends across basins. Despite reservoir heterogeneity and variations in the number of iterations, ranging from 31 for the Bone Springs to 1,661 for the Eagle Ford, the study identified key trends across each specific basin, **Fig. 2.** The depletion effects from parent wells and intercommunication between child wells can result in lower-than-expected production from child wells. A first glance at a basic B12 production comparison indicates there is an approximately 50% chance that a child well will outperform a parent well. However, adjusting production for available completion information suggests that larger proppant volumes and longer laterals in child wells may be necessary to achieve similar production rates to the parent wells, which can have negative economic implications for operators.

Using 1,000 ft as the radius of investigation, parent well B12 production slightly outperforms child well(s) in seven plays (Eagle Ford, Fayetteville, Haynesville, Marcellus, Niobrara, Wolfcamp and Woodford), while in the Bakken and Barnett formations, there is roughly an equal chance that the parent well will outper-

Fig. 3. Fracture geometry service increases child well production, up to 53%.



form the offset. However, when normalizing B12 production lateral length and proppant volume, parent wells outperform child wells 70% to 80% of the time. These trends strengthen the implication that operators have been successful at increasing the potential of infill wells by pumping larger treatment sizes; however, it may increase the risk of detrimental fracture hits on parent wells while increasing the costs associated with child well completions.

Two of the biggest drivers behind poor child well performance are the depletion effects of the parent well and the interwell communication between offsets, as they compete for the same resources. One would expect that the child wells further from the parent well would be better performers; however, this was difficult to conclude from the evaluation, because it was masked by the effect of the interwell communication between child wells.

PERMIAN BASIN

With increased infill drilling in the Permian basin, operators will soon be encountering the above outlined issues. One of the examples is the Bone Springs, which flagged 31 parent/child well sets. Here, the situation is unique, in that child wells perform better than parent wells 65% of the time on a non-normalized basis at 1,000-ft radius. Normalized proppant volumes reflect the same trends as in other plays, meaning that a given proppant concentration doesn't deliver as much oil in the child well as it did in the parent well. However, because proppant loading increased, likely leading to improved child well performance, child well production on a non-normalized basis is on par with, or better than, that of the parent wells across the data set.

At first glance, the distances between parent and child wells doesn't appear to be as significant in the Permian as in the other basins. However, this may be because there are fewer iterations, and therefore less data for evaluating parent versus child wells, or because the average well spacing between child wells is larger than in the other basins. It is important to note that the completion design has improved continuously in the Bone Springs since 2012, so each generation of wells—regardless of child or parent—performs better than the previous generation. The Bone Springs is fairly new compared to other basins; therefore, the depletion effects aren't as severe, and major child development hasn't begun.

Well performance numbers are flipped at 1,000-ft spacing in the Wolfcamp play, which has 82 parent/child sets. Parent wells perform better than the child wells 66% of the time when non-normalized, and nearly 80% of the time when production is normalized with proppant volumes and lateral length. Time, an indicator of depletion, appears to play an important role, because after more than 24 months between child well and parent well drilling, there is a significant drop in child well production versus parent well production. As in the Bone Springs, proppant volume increases over time in the Wolfcamp likely account for production improvements observed in the parent wells.

IMPROVING THE ODDS

Engineering experts are working on technologies and best practices that mitigate the effects of depletion and interwell communication on child well performance. They also are improving reservoir models to better account for the real impact of infill wells to fully understand critical timing, spacing, and job sizes, to solve these dynamic challenges related to field development planning in unconventional basins. The following strategies are suggested to improve infill development campaigns:

- From a purely technical standpoint, drilling and completing all wells in a given area at the same time would be ideal, but is economically and operationally unrealistic, given production requirements for holding leases in U.S. unconventional plays. However, completing wells next to each other on lease boundaries to equalize the drainage patterns could minimize the depletion effect when infill wells are completed. It is also important to recognize that timing of the infill drill will impact the child well performance, so job designs and even well spacing will need to change, as time to infill drilling changes. Completing the well closest to the parent well and then working outward from there also could reduce the potential negative impact caused by parent well depletion on non-adjacent child wells.
- Optimizing completion designs by modeling the depletion effects can be a viable predictive tool for infill drilling, and proppant volumes and well spacing can be adjusted accordingly to maximize the return on capital deployed, as operators don't want to over- or undercapitalize an area.
- Additionally, the use of near-wellbore and far-field chemical diversion techniques can help increase child well production while limiting interwell communication. In the Eagle Ford, the Broadband Shield* fracture-geometry control service has been successful in encouraging fracture propagation in new undrained rock of child wells, while reducing negative fracture hits on the parent wells. **Figure 3** shows a 15%-to-50% increase in child well production when using BroadBand

Shield service versus the average of the other child wells in the area (URTeC 2670497).

- In some cases, refracturing the parent well before completing the offset child wells can boost production in both the parent and child wells.
- Enhanced oil recovery (EOR) also may increase production in both the parent and child wells. EOR applications using natural gas injection have delivered positive production results in the Eagle Ford for EOG; nevertheless, the technique needs further testing in the unconventional sector. WO

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