



RYSTAD ENERGY

# EFFECT OF SAND TYPE ON WELL PRODUCTIVITY

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12 May 2020



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RYSTAD ENERGY

# Rystad Energy report represents an objective analysis of sand type impact on well productivity

## Background

Wisconsin Industrial Sand Association (WISA) is a group of sand producers with significant exposure to the oil and gas industry onshore North America.

Early in the shale revolution, Northern White Sand (NWS) was the preferred option in frac operations among oil companies. However, in recent years, most of the active basins in North America has seen a growth in the use of locally sourced sand, i.e. in-basin sand. NWS is generally perceived to be of higher quality and thus a key question is whether change of sand type will affect well productivity.

## Rystad Energy Report

Rystad Energy is a global energy consultancy with comprehensive data and a deep industry knowledge in the upstream oil and gas sector, with a specific focus on North America land. Rystad Energy has a relatively even distribution of client groups, including oil companies, service companies (including sand producers) and financial companies/investors.

The scope of this report is to perform an objective analysis on the operators that have switched away from NWS to see whether there has been an impact on their respective well productivity.

The report is structured in three main parts:

1. Executive summary highlighting all the main findings and briefly describing methodology
2. Methodology description with more details
3. Rich basin-by-basin review with detailed case study descriptions

# Contents

Executive summary

Methodology

Basin overview

Permian Midland

Permian Delaware

Eagle Ford

Haynesville

SCOOP/STACK

This study is an update to a study previously delivered in December 2019, in which the wells for each case study have remained identical but with the most recent production figures

### New metrics

- In order to better visually highlight the effects of proppant on well productivity, Rystad Energy has introduced the production per ton metric in the updated study.
- Production normalized for proppant pumped per well is a close proxy to revenue per ton, highlighting the economic gains or losses seen after switching to in-basin sand.
- The latest injection of data for each case study in the update also allows us to analyze longer-term IP rates where we did not have a large enough sample size in the previous report.
- The economic analysis now looks at the observed changes in IP270, rather than IP90, after switching to in-basin sand.

### Definition of case study classifications

- By comparing the average IP270 rate in the quarters immediately following in-basin sand adoption to the quarters immediately preceding adoption, Rystad Energy has classified each of the case studies as either showing *no impact*, *light impact*, or *impact*.
- **No impact** cases demonstrate increases in average IP270 in the quarters following in-basin sand adoption compared to the quarters prior to adoption.
- **Light impact** cases show signs of production declines after switching to in-basin sand, however, average IP270 rates decline less than the allowable degradation caused in the first year of switching to in-basin sand required to wipe out the cost savings of the switch.
- Finally, cases classified as **impact** show clear signs of productivity declines after switching to in-basin sand where average IP270 rates have declined further than the allowable first year degradation.

# Study shows impact on short and long term productivity for six out of seven Permian cases

**We have analyzed case studies across North America with Permian having the most relevant data**

- Rystad Energy has looked at the following basins for this update of the study – Permian (Midland and Delaware), Eagle Ford, SCOOP/STACK, Haynesville.
- The Permian Basin has seen the highest penetration of in-basin sand historically and hence the study has a high number of cases with sufficient data from that basin.
- Overall, Rystad Energy has studied a total of 15 operator cases across the major North American basins, of which 8 have sufficient data to be studied in detail and included in this updated report. Only operator case studies with high confidence of sand type usage and timing of shift to in-basin have been analyzed.
- The report mainly covers wells drilled up until the end of the second quarter of 2019.

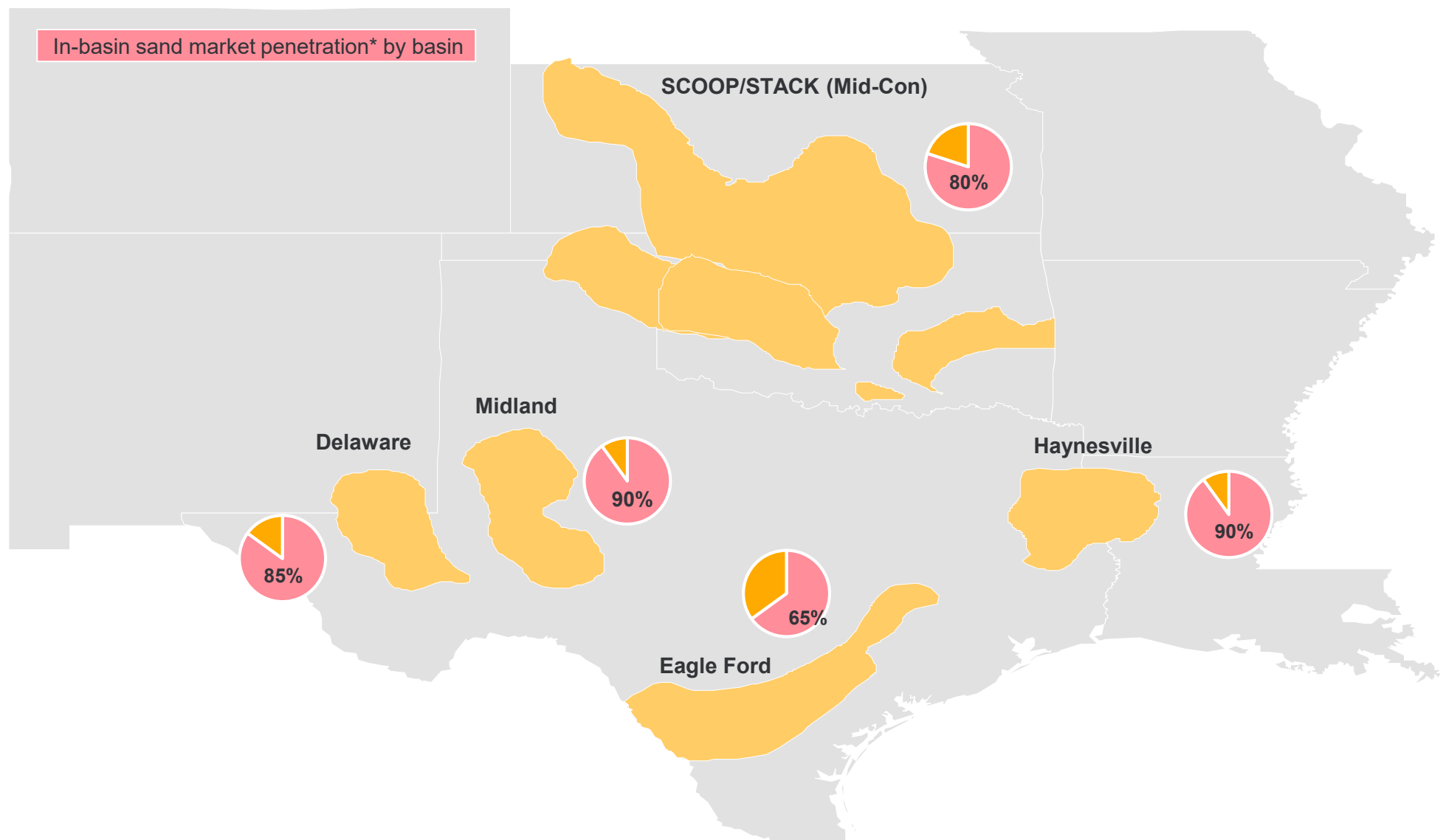
**6 out of 7 cases in the Permian exhibit reduced productivity**

- Rystad Energy has analyzed 4 operator case studies in the Midland and 3 operator case studies in the Delaware where there was sufficient data to understand impact on well productivity due to shift to in-basin sand from northern white sand.
- 6 out of 7 Permian case studies exhibit reduced well productivity following switch to in-basin sand, as classified as either light impact or impact outlined in the previous slide.
- Short-term IP rates are holding up in certain case studies following switch to in-basin sand, while latest injection of data points towards declines in longer-term IP rates.

**In-basin sand adoption is still in an early phase and operators should monitor longer term well production**

- In-basin sand adoption is still in an early phase in most major basins; outside the Permian, very few case studies have been identified with significant data to analyze well production impact.
- Permian results suggest there is impact on productivity, though for three of the identified cases the reduced production does not outweigh likely cost savings.
- Operators should monitor well results over a longer period of time to fully understand impact of in-basin sand adoption and whether they are optimizing value creation with the choice of sand type.

# In-basin sand has captured a higher market share across the selected basins since 2018



\*Indicative market penetration based on both reported numbers and primary intelligence (i.e. conversations with various market participants)  
Source: Rystad Energy research and analysis

# How to analyze impact of sand type? Rystad Energy approach uses operator case studies

## Data sampling a challenge due to inconsistent data reporting

- The starting point for the analyses is to review public sources to capture what sand type has been used in different wells, i.e. using the FracFocus Chemical Disclosure Registry. However, there is incomplete reporting in FracFocus which makes the analysis more challenging.
- Using operator communication and primary research, the sand type for more wells can be identified, e.g. looking into companies with clear announcements around shift to in-basin sand.
- Only operator case studies with high confidence of sand type usage and timing of shift to in-basin have been analyzed.

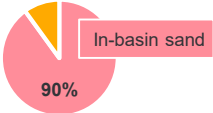
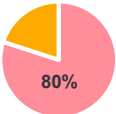
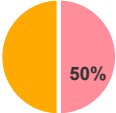
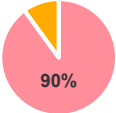
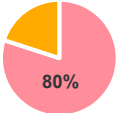
## Operator approach chosen in order to control for several parameters

- It is critical to do an apples-to-apples comparison to understand the impact on well productivity after a switch from northern white sand to in-basin sand as multiple parameters may impact well production, e.g. lateral length, proppant intensity, target formation, acreage quality, well spacing and more.
- The approach used in the study revolves around case studies by operator and formation which ensure that most of those variables are controlled for during the analysis.
- Operator cases with too much noise are not included, e.g. significant experimentation in well designs or if the operator switched acreage focus at the time of shift to in-basin.

## Well productivity and economic impact analyzed to do a proper value assessment







- For the identified operator case studies, trends in well productivity can be analyzed, e.g. reviewing produced oil after 3 months (IP90), 6 months (IP180), 9 months (IP270) and 12 months (IP360).
- In this update, we compare productivity normalized for both lateral lengths and the proppant used.
- The main value proposition of in-basin sand is reduced up front well costs. As such, for operators to consider northern white, any negative impacts from using in-basin sand must be greater than the cost saving. Hence an economic analysis is performed to estimate how big the impact must be in order for northern white sand to provide more value, i.e. estimating the allowable degradation in well productivity.

# Permian demonstrating impact on well production following in-basin sand adoption

Basin	Penetration of in-basin sand	Impact on well productivity	Comments
Midland	 90%	<b>Impact</b>	The in-basin sand adoption happened in early 2018. Three out of four cases analyzed show an impact in average IP270 rates after switching to in-basin sand.
Delaware	 80%	<b>Impact</b>	The in-basin sand adoption happened in early 2018. There are early indications of reduced productivity in two of the three case studies analyzed, however it is not clear if production declines have been driven purely from a change in sand type.
Eagle Ford	 50%	<b>Too early to tell</b>	In-basin sand was available in the Eagle Ford in late 2017. However, most mines came on early to mid 2019 and hence it is still too early to understand impact of in-basin sand on well productivity.
Haynesville	 90%	<b>No impact</b>	In-basin sand adoption began to take off in January 2018. The data analyzed thus far for one operator shows no signs of impact on well productivity. Some in-basin sand used in the Haynesville is similar to northern white sand quality, which may explain lack of impact.
SCOOP/STACK	 80%	<b>Too early to tell</b>	Well productivity per foot has been deteriorating in SCOOP/STACK prior to in-basin sand adoption; most in-basin mines became active early-to-mid 2019 and hence it is too early to assess impact of in-basin sand on well production.









All Permian Basin case studies except one show either an impact or light impact in well productivity after switching to in-basin sand

Basin	Case	Well Count (NWS)	Time Frame Assessed (NWS)	IP270 (NWS)	Well Count (In-Basin)	Time Frame Assessed (In-Basin)	IP270 (In-Basin)	Observed Change in IP270	Allowable Degradation (Year 1)	Impact Assessment
Midland	Midland Operator A	46	4Q17 – 2Q18	15,892	133	3Q18 – 2Q19	15,075	-5.1%	-6.8%	 Light Impact
	Midland Operator B	30	3Q17 – 2Q18	18,296	117	2Q18 – 2Q19	16,731	-8.6%	-6.0%	 Impact
	Midland Operator C	32	3Q18 – 4Q18	17,848	43	4Q18 – 2Q19	16,320	-8.6%	-7.1%	 Impact
	Midland Operator D	16	1Q18 – 2Q18	13,239	33	3Q18 – 2Q19	12,304	-7.1%	-8.8%	 Light Impact
Delaware	Delaware Operator A	61	2Q17 – 3Q18	19,420	81	3Q18 – 2Q19	18,180	-6.4%**	-6.1%	 Light Impact
	Delaware Operator B*	31	3Q18 – 4Q18	31,806	31	1Q19 – 2Q19	27,980	-12.0%	-4.3%	 Impact
	Delaware Operator C	62	1Q18 – 4Q18	29,482	60	4Q18 – 2Q19	31,516	+6.9%	-5.6%	No Impact

\*Delaware Operator B has both in-basin and NWS wells in NWS well count bucket for timeframes between 3Q18 and 4Q18; sand type is unknown for wells in 3Q18 and 4Q18  
\*\*Change in production per lateral foot is slightly greater than allowable degradation, but production per ton is increasing, hence light impact (see also next page for more commentary)  
Source: Rystad Energy research and analysis

Cases with impact have seen IP rates decline since adopting in-basin sand;  
Other well design factors and mesh size uncertainty make it difficult to be definitive

Basin	Case	Well productivity impact	Vertical depth and max treatment pressure	Comment
Midland	Midland Operator A	 Light Impact	8,700' 8,700 PSI	All IP rates show declines in productivity since switching to in-basin sand, however average IP270 still remains below the allowable degradation limit hence only ' <i>light impact</i> '.
	Midland Operator B	 Impact	9,200' 8,000 PSI	Midland Operator B is showing an ' <i>impact</i> ' in well productivity once switching to in-basin sand; IP270 rates have declined further than the allowable degradation.
	Midland Operator C	 Impact	7,800' 9,200 PSI	Midland Operator C has been classified as a case with ' <i>impact</i> ' from switching to in-basin sand; Average IP270 rates have declined slightly less than the allowable degradation.
	Midland Operator D	 Light Impact	7,600' 8,400 PSI	Well spacing is a large contributor to decreasing IP rates since 2016; recent injection of data shows declines in productivity remain below allowable degradation. Any increases in productivity may be driven by increasing proppant intensities and well spacing.
Delaware	Delaware Operator A	 Light Impact	10,700' 10,200 PSI	IP90 and IP180 have remained relatively stable since switching to in-basin sand when normalized for lateral length, while longer term IP rates show decline close to the allowable degradation; Productivity significantly increases when normalized for proppant intensity, making it difficult to draw a definitive conclusion.
	Delaware Operator B	 Impact	10,900' 10,900 PSI	Delaware Operator B production has been declining since before in-basin sand adoption and continues post adoption. This may be due to increasing laterals or finer mesh sand grades, however, no definitive conclusion can be determined.
	Delaware Operator C	No Impact	11,100' 9,700 PSI	Delaware Operator C is front-loading its production schedule and hence there is no impact on short-term well productivity. Injection of latest data also shows significant increases in longer-term IP rates.
Haynesville	Operator	No Impact	11,900'	For the identified case there has not been any impact on well productivity since in-basin sand adoption for all well productivity metrics.

Source: Rystad Energy research and analysis

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# Productivity benchmarking of wells based on thorough operator specific assessments

## Overview of methodology

1) Choose operators with high confidence on sand type\*

2) Isolating operator controls for important parameters

3) Benchmarking well productivity

Operator A

Operator B

Operator C

Operator D

Operator E



*Proppant intensity*



*Lateral length*



*Design*



RYSTAD ENERGY  
*ShaleWellCube*






- *In-basin still in early phase*
- *Limited production data on relevant wells*

The methodology applied for this research is three-fold:

- 1) Identifying operators with high confidence on sand type
- 2) Isolating operator, by basin, control for acreage and the most important well design parameters – proppant intensity, lateral length, frac types etc.
- 3) Well productivity for comparable samples with different sand types is benchmarked with use of Rystad Energy's proprietary database ShaleWellCube

# Frac forms with sand type references are the primary data source for sand type identification

Sand type identification: An example of a frac form that contains a sand type reference	Comment																																																																																																																								
<div> <div> <div>Hydraulic Fracturing Fluid Product Component Information Disclosure</div> <div>  <div>   </div> </div> </div> <div> <div>Hydraulic Fracturing Fluid Composition:</div> <div> <div>100 MESH <b>REGIONAL</b> CRYSTALLINE SILICA</div> <table> <tr> <th>Trade Name</th><th>Supplier</th><th>Purpose</th><th>Ingredients</th><th>Chemical Abstract Service Number (CAS #)</th><th>Maximum Ingredient Concentration in Additive (% by mass)**</th><th>Maximum Ingredient Concentration in HF Fluid (% by mass)**</th><th>Comments</th></tr> <tr> <td>WATER</td><td>SM ENERGY</td><td>CARRIER/BASE FLUID</td><td></td><td></td><td></td><td></td><td></td></tr> <tr> <td>100 MESH REGIONAL</td><td>US SILICA COMPANY</td><td>PROPPING AGENT</td><td>WATER</td><td>7732-18-5</td><td>100.00000</td><td>50.00252</td><td>None</td></tr> <tr> <td></td><td></td><td></td><td>CRYSTALLINE SILICA</td><td>14808-60-7</td><td>99.99999</td><td>6.42032</td><td>None</td></tr> <tr> <td></td><td></td><td></td><td>ALUMINUM OXIDE</td><td>1344-28-1</td><td>1.00000</td><td>0.06436</td><td>None</td></tr> <tr> <td>40/70 WHITE</td><td>US SILICA COMPANY</td><td>PROPPING AGENT</td><td></td><td></td><td></td><td></td><td></td></tr> <tr> <td></td><td></td><td></td><td>CRYSTALLINE SILICA</td><td>14808-60-7</td><td>99.90000</td><td>2.75897</td><td>None</td></tr> <tr> <td></td><td></td><td></td><td>ALUMINUM OXIDE</td><td>1344-28-1</td><td>1.00000</td><td>0.02762</td><td>None</td></tr> <tr> <td>WTW-931</td><td>IMPERATIVE</td><td>BIOCIDE</td><td>Proprietary</td><td>Proprietary</td><td>100.00000</td><td>0.02762</td><td>None</td></tr> <tr> <td>GS ME-350</td><td>ACE COMPLETIONS</td><td>SURFACTANT</td><td></td><td></td><td></td><td></td><td></td></tr> <tr> <td></td><td></td><td></td><td>WATER</td><td>7732-18-5</td><td>90.00000</td><td>0.01911</td><td>None</td></tr> <tr> <td></td><td></td><td></td><td>ETHYLENE OXIDE/PROPYLENE OXIDE COPOLYMER</td><td>9003-11-6</td><td>10.00000</td><td>0.00212</td><td>None</td></tr> <tr> <td></td><td></td><td></td><td>ISOTRIDECANOL, ETHOXYLATED</td><td>9043-30-5</td><td>6.00000</td><td>0.00127</td><td>None</td></tr> <tr> <td></td><td></td><td></td><td>ALCOHOL</td><td>58609-68-7</td><td>5.00000</td><td>0.00106</td><td>None</td></tr> <tr> <td></td><td></td><td></td><td>AMINE SULFONATE</td><td>26836-07-7</td><td>5.00000</td><td>0.00106</td><td>None</td></tr> </table> </div> </div> </div>	Trade Name	Supplier	Purpose	Ingredients	Chemical Abstract Service Number (CAS #)	Maximum Ingredient Concentration in Additive (% by mass)**	Maximum Ingredient Concentration in HF Fluid (% by mass)**	Comments	WATER	SM ENERGY	CARRIER/BASE FLUID						100 MESH REGIONAL	US SILICA COMPANY	PROPPING AGENT	WATER	7732-18-5	100.00000	50.00252	None				CRYSTALLINE SILICA	14808-60-7	99.99999	6.42032	None				ALUMINUM OXIDE	1344-28-1	1.00000	0.06436	None	40/70 WHITE	US SILICA COMPANY	PROPPING AGENT									CRYSTALLINE SILICA	14808-60-7	99.90000	2.75897	None				ALUMINUM OXIDE	1344-28-1	1.00000	0.02762	None	WTW-931	IMPERATIVE	BIOCIDE	Proprietary	Proprietary	100.00000	0.02762	None	GS ME-350	ACE COMPLETIONS	SURFACTANT									WATER	7732-18-5	90.00000	0.01911	None				ETHYLENE OXIDE/PROPYLENE OXIDE COPOLYMER	9003-11-6	10.00000	0.00212	None				ISOTRIDECANOL, ETHOXYLATED	9043-30-5	6.00000	0.00127	None				ALCOHOL	58609-68-7	5.00000	0.00106	None				AMINE SULFONATE	26836-07-7	5.00000	0.00106	None	<ul style="list-style-type: none"> <li>▪ The primary source of data for sand type identification are well frac forms submitted by operators to FracFocus, a database containing frac fluid chemicals disclosure for more than 150,000 wells fracked in the US.</li> <li>▪ Frac forms contain detailed information on frac fluid products used during fracking, broken down to individual chemicals comprising those products.</li> <li>▪ Rystad Energy performs a thorough cleaning of frac forms that, among other, allows us to identify entries that refer to sand used during hydraulic fracturing.</li> <li>▪ While not a requirement, operators occasionally include references to exact type of sand in either trade or ingredient name referring to sand (e.g. “100 mesh regional”).</li> <li>▪ Rystad Energy developed a methodology that looks for and analyzes such textual markers referring to sand type used.</li> </ul>
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# Examples of textual markers in frac forms that allow for identification of sand type

Examples of entries classified as Northern White Sand		Examples of entries classified as Brown Sand	
<p><i>Reported trade name</i></p> <p>Northern White Sand</p> <p>40/70 <b>WHITE</b></p> <p>Sand, <b>White</b>, 20/40</p> <p>Sand, <b>White</b>, 40/70</p> <p>Sand (20/40) <b>Ottawa</b></p> <p>Sand, <b>White</b>, 100 mesh</p> <p>Sand (40/70) <b>Ottawa</b></p> <p>Sand (30/50) <b>Ottawa</b></p> <p>30/50 <b>WHITE</b></p> <p>Sand, <b>White</b></p> <p>Sand, <b>White</b>, 30/50</p> <p>20/40 <b>White</b></p> <p><b>Ottawa</b> Sand</p> <p>100 mesh <b>White</b> Sand, Area 1</p> <p>40/70 <b>White</b> (Special Order)</p>	<p>Typically, “<i>White</i>”/”<i>Ottawa</i>”/”<i>Northern</i>” and variations of spelling of</p>	<p><i>Reported trade name</i></p> <p>Sand, <b>Brown</b> [SB-4]</p> <p>16/30 <b>Brady</b></p> <p>Sand, <b>Brown</b>, 20/40</p> <p>20/40 <b>Brady</b></p> <p>20/50 <b>Brown</b> Sand</p> <p>Sand <b>Texas Gold</b>, 30/50</p> <p>Sand <b>Texas Gold</b>, 100M</p> <p>Sand <b>Texas Gold</b>, 40/70</p> <p>40/70 <b>Brown</b> Sand</p> <p>40/70 <b>Brady</b></p> <p>40/70 <b>TG</b></p> <p>12/20 <b>Brady</b> Sand</p> <p><b>Brown</b> Sand</p> <p>Sand, <b>Brown</b>, 16/30</p> <p>Sand, <b>Brown</b></p>	<p>Typically, “<i>Brown</i>”/”<i>Brady</i>”/”<i>Texas Gold</i>” and variations of spelling of</p>
Examples of entries classified as In-Basin Sand		Examples of entries with no reference to exact sand type	
<p><i>Reported trade name</i></p> <p>100 MESH <b>REGIONAL</b></p> <p>40/70 <b>REGIONAL</b></p> <p><b>West TX</b> 100 Mesh</p> <p><b>West TX</b> 40/70</p> <p><b>Regional</b> Sand</p> <p><b>Permian</b> 100 Mesh</p> <p>40/70 <b>Permian</b></p> <p><b>Permian</b> 40/70</p> <p><b>STX</b>-40/70</p> <p>40/70 <b>REGIONAL</b> SAND</p> <p><b>PERMIAN</b> 100M</p> <p><b>Permian</b>-100 MESH</p> <p><b>STX</b> 100 MESH</p> <p>Sand <b>Regional</b></p> <p><b>STX_</b> 100 MESH</p>	<p>Typically, “<i>Regional</i>”/”<i>Permian</i>”/”<i>West TX</i>”/”<i>STX</i>”, and variations of spelling of</p>	<p><i>Reported trade name</i></p> <p>Sand</p> <p>Sand (Proppant)</p> <p>Silica Sand</p> <p>CRC SAND</p> <p>100 mesh sand</p> <p>Sand (50/140)</p> <p>100 MESH</p> <p>Crystalline Silica Quartz</p> <p>CRC SAND PREMIUM</p> <p>Sand (40/70)</p> <p>FRAC SAND</p> <p>Sand (20/40)</p> <p>SAND (WHOLE GRAIN)</p> <p>20/40 Sand</p> <p>Sand (30/50)</p>	<p>No textual markers allowing for identification of sand type based on trade/ingredient names alone</p>

## Pure in-basin sand providers appearing on frac forms improve in-basin sand wells coverage

Sand type identification: An example of a frac form that contains a pure in-basin sand provider

## Comment

## Hydraulic Fracturing Fluid Product Component Information Disclosure



100 MESH SAND SUPPLIED BY  
**ATLAS SAND COMPANY**

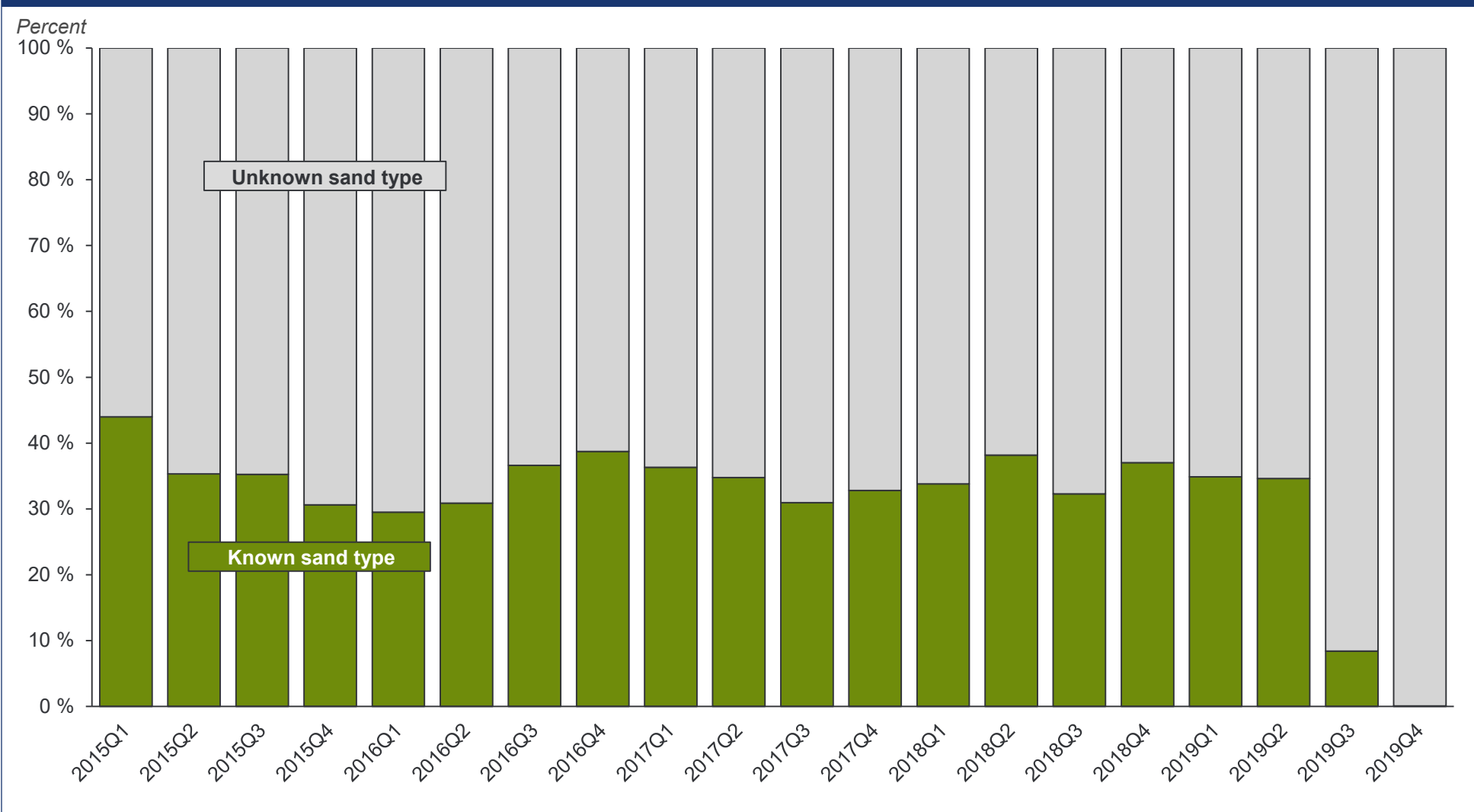
### Hydraulic Fracturing Fluid Composition:

Trade Name	Supplier	Purpose	Ingredients	Chemical Abstract Service Number (CAS #)	Maximum Ingredient Concentration in Additive (% by mass)**	Maximum Ingredient Concentration in HF Fluid (% by mass)**	Comments
WATER	XTO ENERGY	CARRIER/BASE FLUID					
			WATER	7732-18-5	100.00000	88.03734	None
100 MESH SAND	ATLAS SAND COMPANY	PROPPING AGENT					
			QUARTZ	14808-60-7	97.00000	10.30381	None
40/70 RCS	SANTROL PROPPANTS	PROPPING AGENT					
			CRYSTALLINE SILICA (QUARTZ)	14808-60-7	97.00000	1.14793	None
			PHENOL-FORMALDEHYDE NOVOLAK RESIN	9003-35-4	5.00000	0.05917	None
			HEXAMETHYLENETETRAMINE	100-97-0	1.00000	0.01183	None
CS-15	ACE COMPLETIONS	CLAY STABILIZER					
			WATER	7732-18-5	100.00000	0.01967	None
			MAGNESIUM CHLORIDE	7791-18-6	100.00000	0.01967	None
			CHOLINE CHLORIDE	67-48-1	100.00000	0.01967	None
BF-200	ACE COMPLETIONS	HIGH PH BUFFER					
			WATER	7732-18-5	85.00000	0.01769	None
			POTASSIUM HYDROXIDE SOLUTION	1310-58-3	30.00000	0.00624	None

- Among many attributes appearing on a frac form, provider of a given product and its associated chemicals is listed in a form.
- We look at suppliers appearing on frac forms and check those against a list of known pure in-basin sand providers.
- An example of such companies would be Atlas Sand who a pure Permian in-basin sand provider, Black Mountain who have in-basin sand mines in the Permian, Eagle Ford and Mid-Con, Preferred Sands (Permian, Eagle Ford, and Mid-Con), and Vista Sands (Permian and Eagle Ford).
- Although exact sand type used may not be explicitly mentioned in a frac form (as in example to the right, i.e. “100 MESH SAND”, with no reference to sand type), this sand was supplied by Atlas Sand, who is pure in-basin sand provider.
- In turn, we can tag this entry as Permian In-Basin with high degree of confidence.

Identifying proppant type from public disclosures is a challenge; only 30% to 40% of wells drilled post 2015 have a known proppant type

Fraction of wells\* with known sand type, 2015 – 2019 YTD by completion quarter



\* Includes all wells drilled in Permian, Eagle Ford and SCOOP/STACK, known sand type refers to wells where sand type can be identified with high confidence  
Source: Rystad Energy ShaleWellCube



# We analyze communication from players to further improve in-basin sand coverage

Examples of communication from E&P companies addressing in-basin sand adoption*	Comment
<p><b>Operator, Financial and Operating Results</b></p> <p>The company communicated in their investor presentation that they have fully switched over to in-basin sand from northern white sand, and thus saw a certain amount of cost savings due to the shift.</p> <p><b>Operator, Financial and Operating Results</b></p> <p>The company communicated in their earnings results that they tested in-basin sand and have now decided to fully utilize in-basin sand in their well designs.</p>	<ul style="list-style-type: none"><li>• We further analyze communication from major E&amp;P companies with an intention of identifying the timeline when the company switched to in-basin sand completely, and as such, allowing us to tag corresponding completed wells as in-basin with high degree of confidence despite “unknown” tags from public disclosures.</li><li>• As an example, one operator explicitly communicated in their earnings of full adoption of in-basin sand in the Midland Basin</li><li>• An operator communicated over earnings results that they began utilizing in-basin sand on all of their completions during a certain time period.</li><li>• In some cases, whenever explicit communication on in-basin sand adoption is not available, we use other, secondary indications, e.g. sand costs savings provided by an operator in earnings results suggests full adoption of in-basin sand with high degree of confidence.</li></ul>

Source: Rystad Energy research and analysis; Company reporting

# For the identified cases, key metrics are analyzed to assess well productivity

## Metrics

## Description

## Examples from case studies

### Input parameters

- It is highly critical to do an apples-to-apples comparison to understand the impact on well productivity after a switch from northern white sand to in-basin sand.
- Different parameters like lateral length, proppant intensity, formation, well spacing etc. impact well production, and hence these variables have to be controlled when assessing impact of in-basin sand usage on well production.
- Designing case studies by operator and formation ensures most of the above variables are controlled for during the analysis.

Midland Operator A has exhibited relatively flat proppant intensities and lateral length since switch to in-basin sand

**Midland Operator A**

- Midland Operator A proppant intensities have fluctuated very little since 2Q 2017.
- Despite a large dip in lateral lengths in 3Q 2018, Midland Operator A has held fairly steady laterals since switching to in-basin sand.
- Recent quarters have seen a modest uptick in lateral lengths.

**Proppant intensity distribution by vintage quarters (H2 wells)**

Proppant per foot

Observed per foot

Median Average

1Q16 2Q16 3Q16 4Q16 1Q17 2Q17 3Q17 4Q17 1Q18 2Q18 3Q18 4Q18 1Q19 2Q19

**Lateral length distribution by vintage quarters (H2 wells)**

Observed feet

Median Average

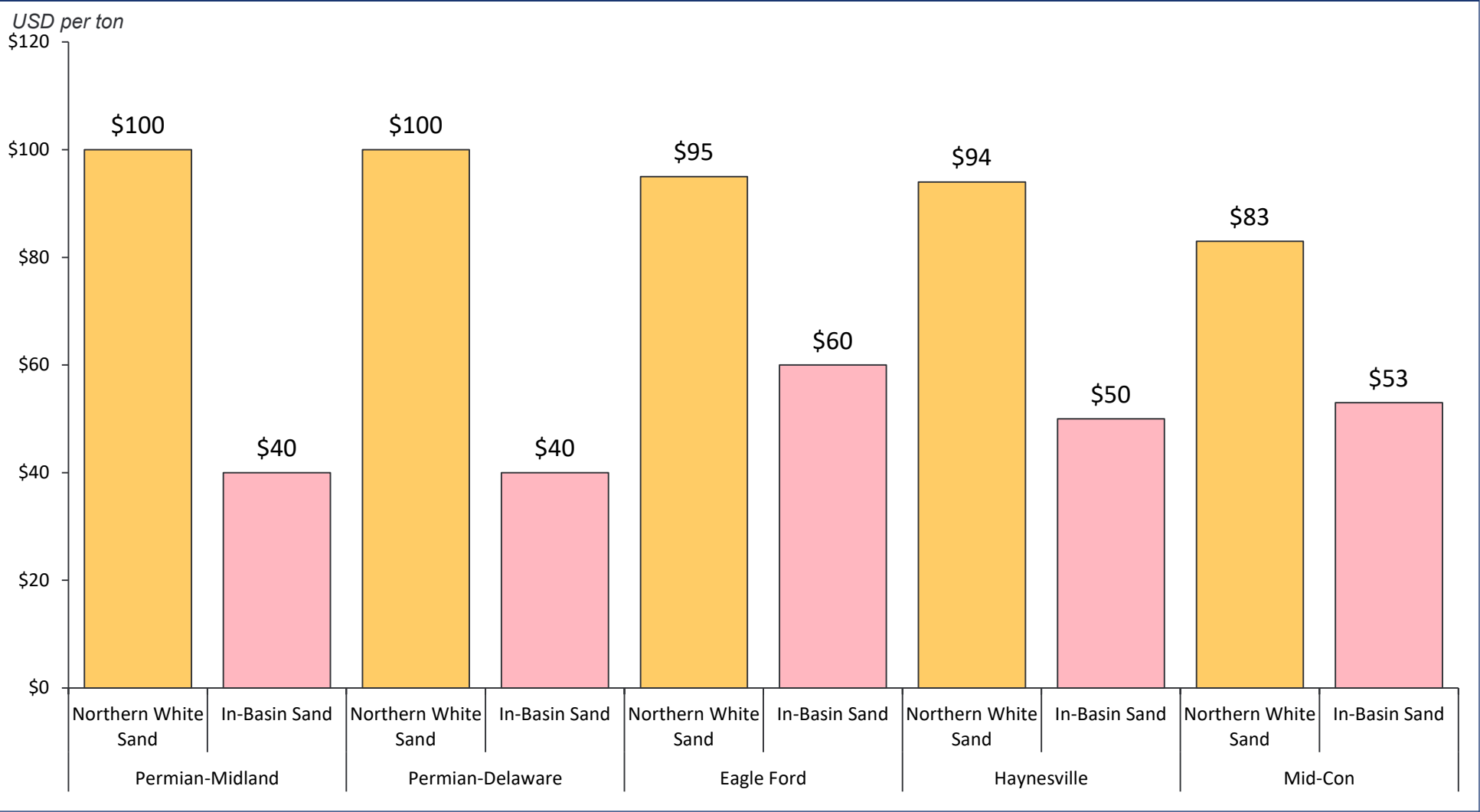
1Q16 2Q16 3Q16 4Q16 1Q17 2Q17 3Q17 4Q17 1Q18 2Q18 3Q18 4Q18 1Q19 2Q19

Note: Only wells with at least 80% completion light oil content have been included in the analysis.  
Source: Wood Mackenzie, Wood Mackenzie

Source: Rystad Energy research and analysis

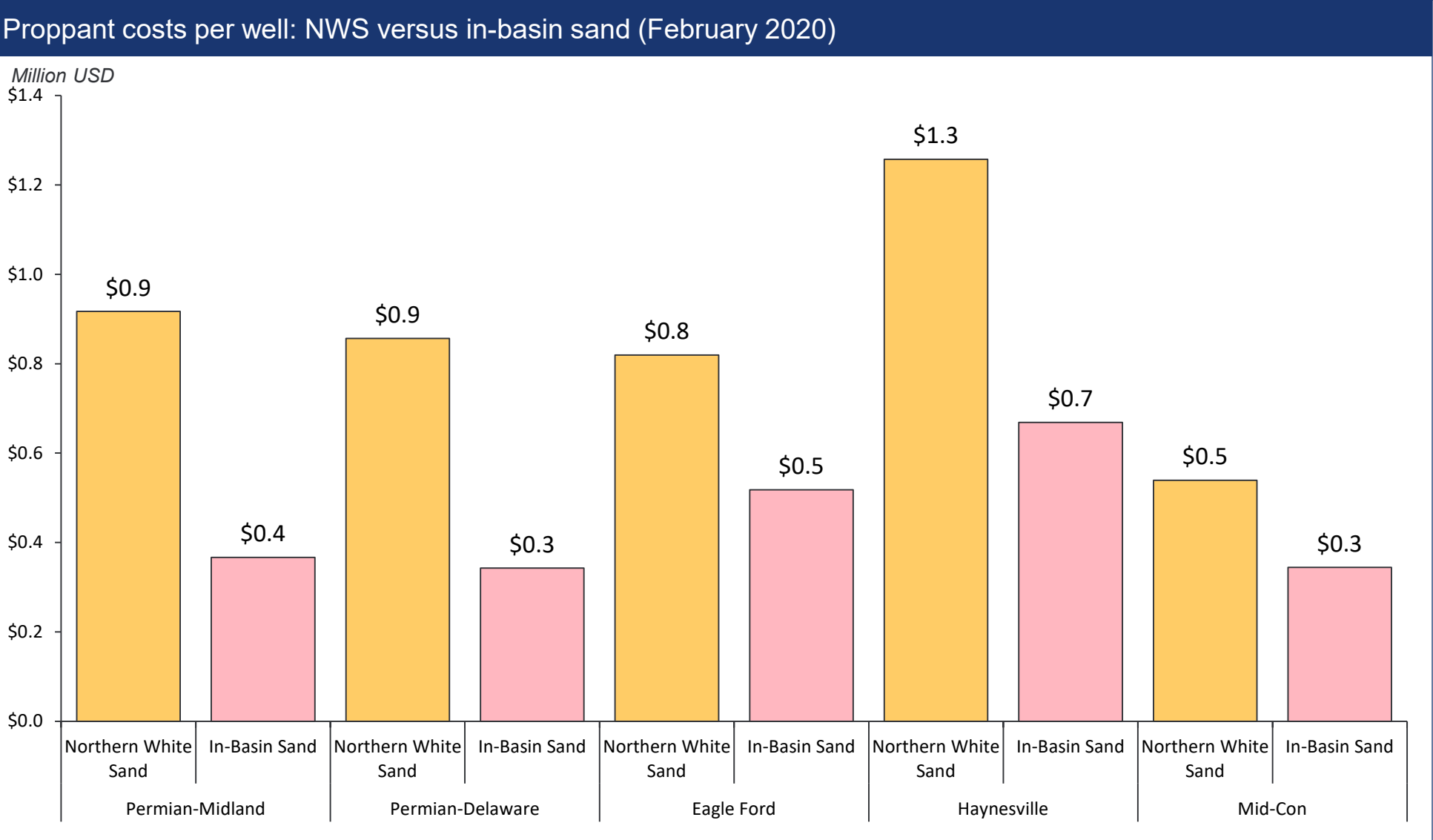
In-basin sand prices have dropped in the Permian; hence widening the gap between NWS and in-basin delivered sand prices

Delivered sand prices: NWS versus in-basin sand (February 2020)



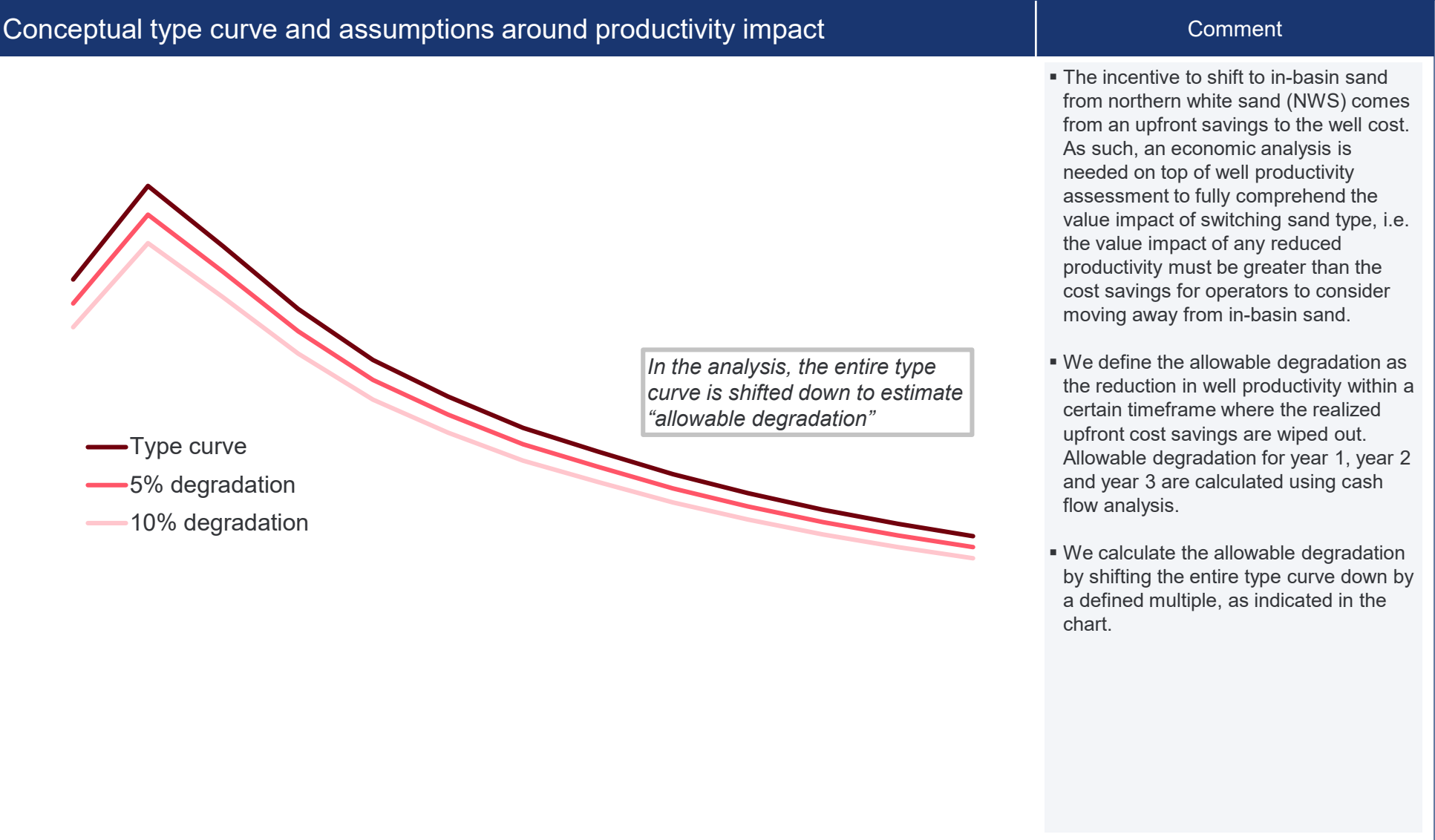
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

The Haynesville has the highest proppant cost among all major shale plays and stands to benefit the most from shifting to in-basin sand



Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# Economic analysis needed to assess productivity impact versus cost savings



Source: Rystad Energy research and analysis

# Example of economic analysis output for Midland Operator B and assumptions used (1/3)

## Midland Operator B: Economic Model Parameters

Parameters	NWS	In-Basin	Actuals
Lateral length	9,867	9,867	9.463
Proppant intensity	1,602	1,602	1,593
D&C cost (\$)	\$7.1 MM	\$6.8 MM	\$6.7 MM
Oil price, \$ per bbl	\$50.00	\$50.00	\$50.00
Gas price, \$ per boe	\$6.00	\$6.00	\$6.00
Cost savings per ton	\$40	\$40	\$40

### Step 1 in the economic analysis - Input parameters

- The realized cost savings from switching to in-basin sand varies by operator and is dependent on amount of frac sand pumped in their well design.
- After controlling for operator and geography, a typical northern white sand well is created for each operator using data from Rystad Energy's proprietary database ShaleWellCube (see example above).
- Assuming a \$40 per ton differential between NWS and in-basin sand, realized savings for each operator chosen in the case study is calculated keeping the well design (lateral length, proppant intensity and other factors) the same.
- Further sensitivity analysis, e.g. around cost savings per ton, can be performed in the Excel based model that has been provided separately.

Well Count (NWS)	Time Frame Assessed (NWS)	IP90 (NWS)	Well Count (In-Basin)	Time Frame Assessed (In-Basin)	IP90 (In-Basin)	Observed Change in IP90
30	3Q17 – 2Q18	6,336	117	2Q18 – 2Q19	5,750	-9.2%

\* CFCF difference is defined as the difference between cumulative net cash flow from a northern white sand and in-basin sand well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# Example of economic analysis output for Midland Operator B and assumptions used (2/3)

## Midland Operator B: Economic Model Parameters

### Step 2 in the economic analysis – Calculate allowable degradation

- Allowable degradation is the reduction in well productivity within a certain timeframe where the realized upfront cost savings are wiped out. This impact is calculated based on net present value (NPV) of cash flows using 10% discount rate for Year 1, 2 and 3. Allowable degradation in Year 1 relates to the necessary negative impact that is needed in order to make up for the cost savings in the first year of production. Similarly, the same applies to Year 2 and Year 3.
- We also highlight the difference in cumulative free cash flow (CFCF), which is defined as the difference in cash generated in year 1, year 2 and year 3 between a typical northern white sand well and an in-basin sand well. It is calculated under different degradation scenarios in each case study to highlight the direct impact on cash flows.
- WTI oil price scenarios for \$40/bbl, \$50/bbl and \$60/bbl price strips are run to understand how allowable degradation varies under different oil prices. The results are compared against both NPV and CFCF for Year 1, 2 and 3, though discounting the cash flows have limited impact compared to the pure CFCF.

## Midland Operator B: Allowable degradation

Year	Allowable Degradation	Total cost savings	CFCF Difference* Year 1	CFCF Difference Year 2	CFCF Difference Year 3
1	-6.0%	\$316K	\$331K	\$501K	\$614K
2	-4.1%	\$316K	\$226K	\$342K	\$419K
3	-3.4%	\$316K	\$189K	\$287K	\$351K

## Midland Operator B: Observed degradation

Well Count (NWS)	Time Frame Assessed (NWS)	IP90 (NWS)	Well Count (In-Basin)	Time Frame Assessed (In-Basin)	IP90 (In-Basin)	Observed Change in IP90
30	3Q17 – 2Q18	6,336	117	2Q18 – 2Q19	5,750	-9.2%

\* CFCF difference is defined as the difference between cumulative net cash flow from a northern white sand and in-basin sand well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# Example of economic analysis output for Midland Operator B and assumptions used (3/3)

## Midland Operator B: Economic Model Parameters

Parameters	NWS	In-Basin	Actuals
Lateral length	9,867	9,867	9,463
Proppant intensity	1,602	1,602	1,593
D&C cost (\$)	\$7.1 MM	\$6.7 MM	\$6.7 MM

**Step 3 in the economic analysis – Comparison against observed change in IP270**

- Finally, the observed changes in well productivity for the timeframes described in the table are compared to the calculated allowable degradation to assess whether switch to in-basin sand from northern white sand has had an economic impact.
- In the updated analysis, we compare the allowable degradation with the observed change in IP270, i.e. cumulative production after 270 days (9 months). We had previously studied the changes in IP 90 due to sample size constraints, however given the latest injection of data we now have enough production data to study the longer term IP270 rate.

1	-7.7%	\$395K	\$414K	\$397K	\$750K
2	-5.2%	\$395K	\$278K	\$428K	\$536K
3	-4.3%	\$395K	\$229K	\$352K	\$441K

## Midland Operator B: Observed degradation

Well Count (NWS)	Time Frame Assessed (NWS)	IP270 (NWS)	Well Count (In-Basin)	Time Frame Assessed (In-Basin)	IP270 (In-Basin)	Observed Change in IP270
30	3Q17 – 2Q18	18,296	117	2Q18 – 2Q19	16,731	-8.6%

\* CFCF difference is defined as the difference between cumulative net cash flow from a northern white sand and in-basin sand well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis



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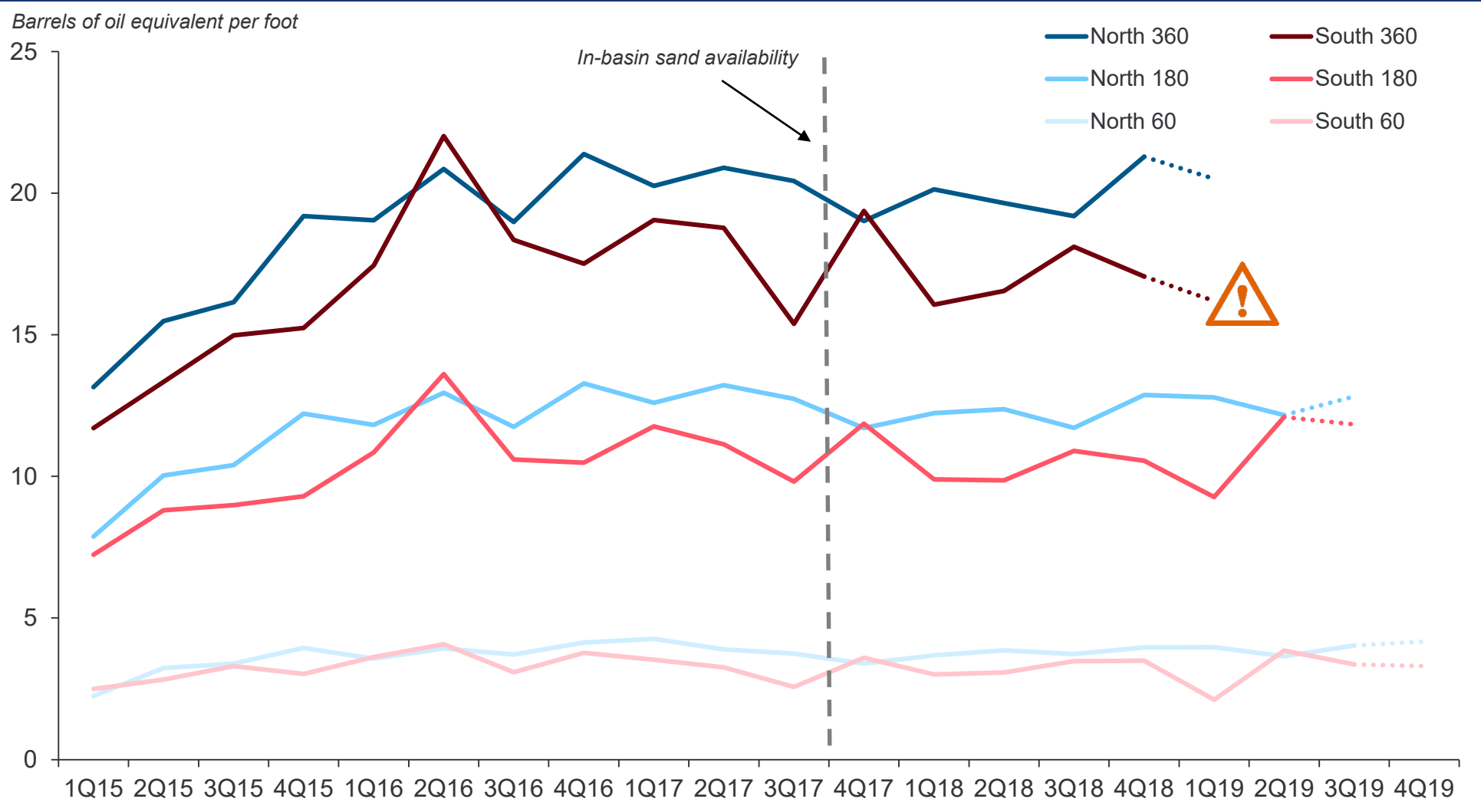
Eagle Ford

Haynesville

SCOOP/STACK

# Latest data suggests potential degradation in full year IP rate in Midland South

Permian-Midland: Median cumulative 2-stream production by production start year-quarter and sub-basin



Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

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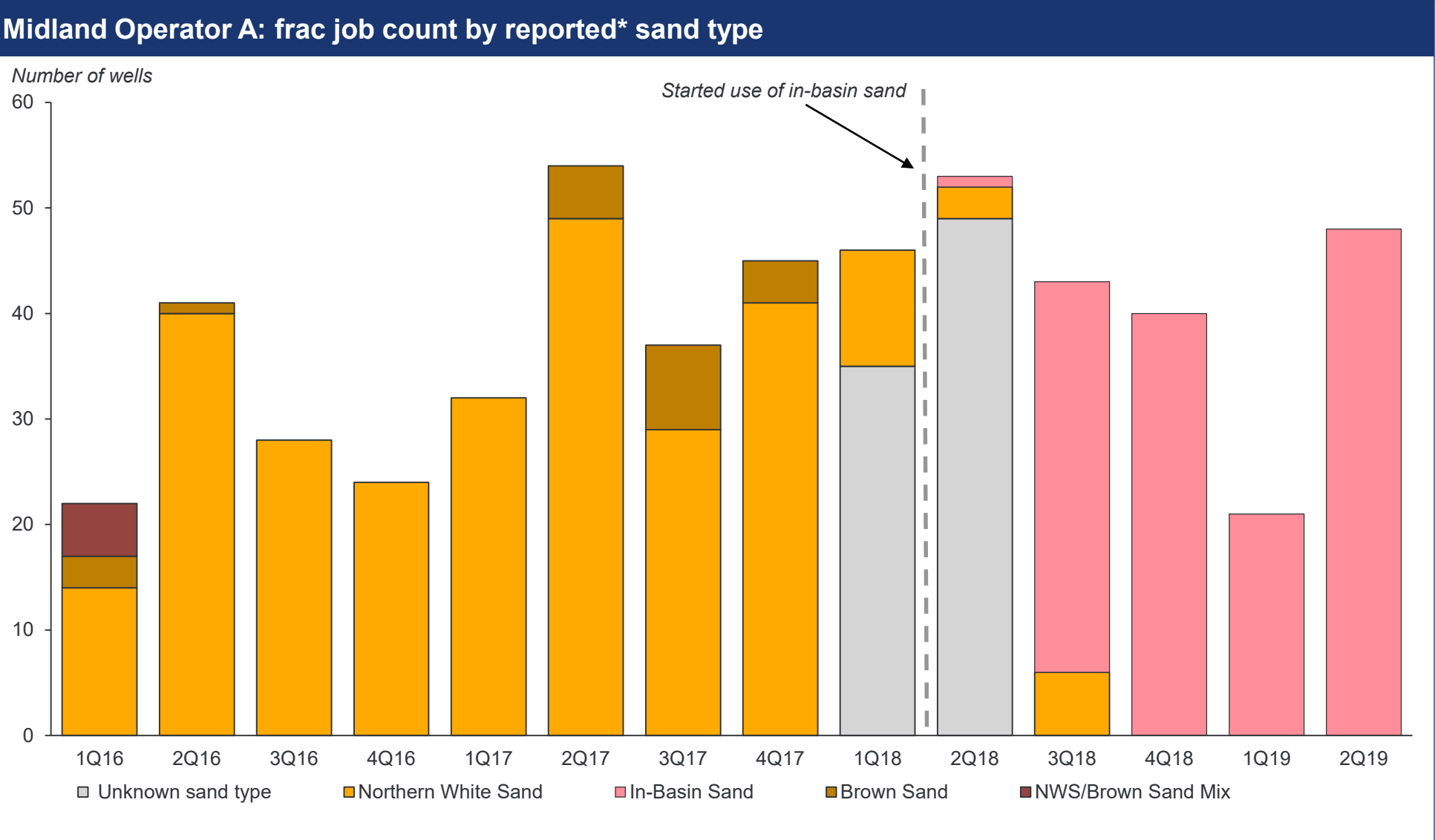
Permian Delaware

Eagle Ford

Haynesville

SCOOP/STACK

# Midland Operator A started using in-basin sand in the Midland in 2Q18



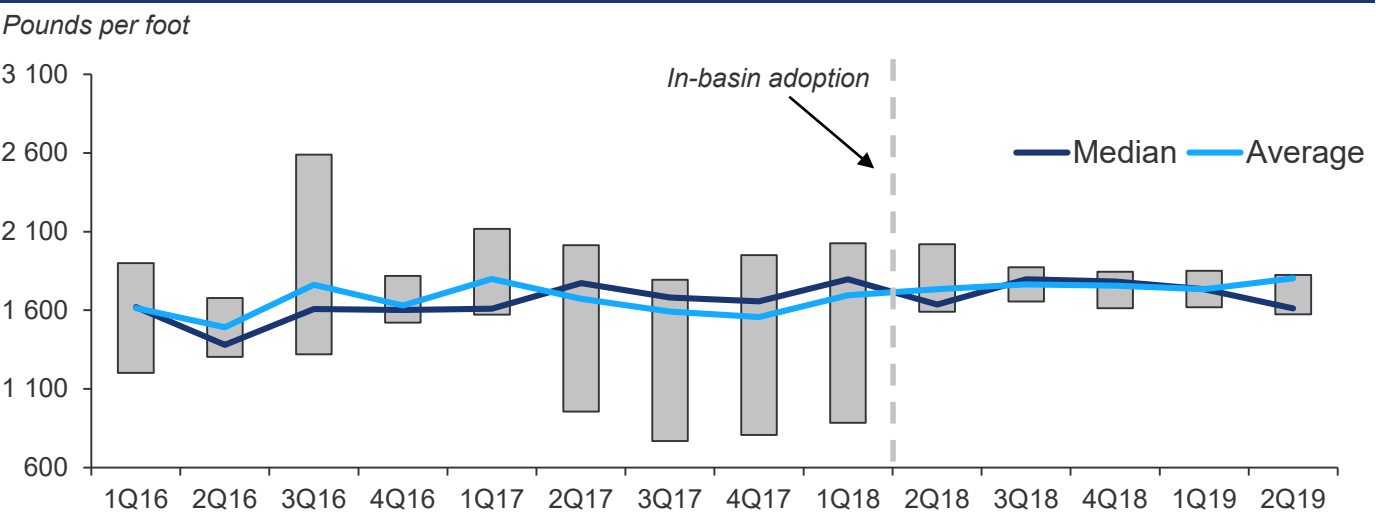
\*From Midland Operator A investor presentation. Based on Rystad Energy's analysis of chemical ingredient and trade names reported to FracFocus Chemical Disclosure Registry  
Source: Rystad Energy ShaleWellCube, Midland Operator A investor presentation, Rystad Energy research and analysis

# Midland Operator A has exhibited relatively flat proppant intensities and lateral length since switch to in-basin sand

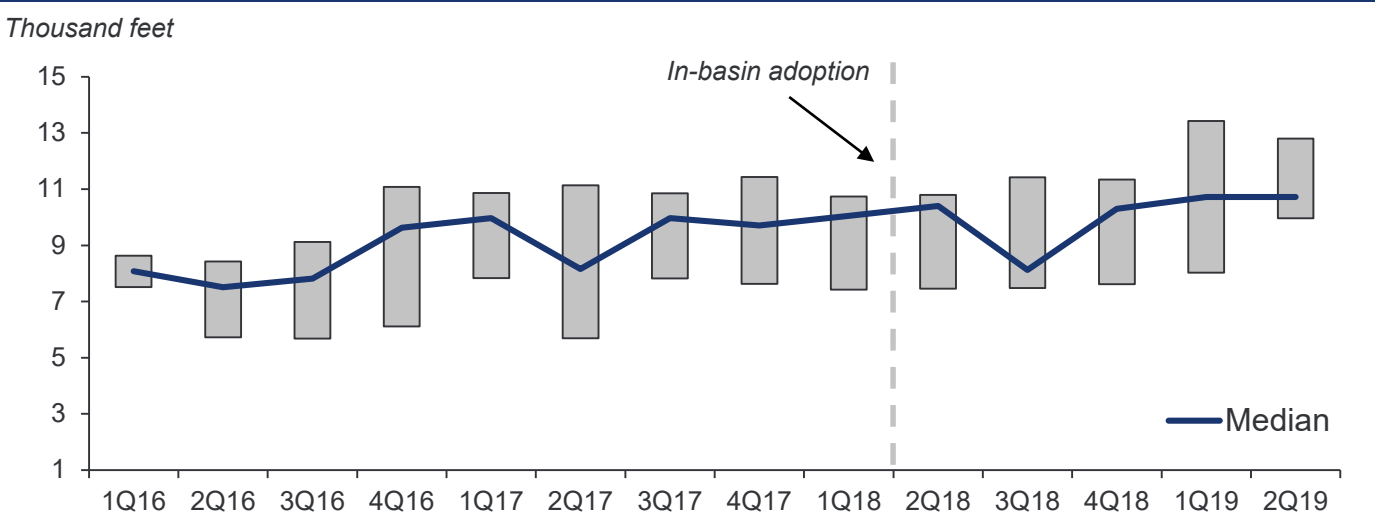
## Midland Operator A

- Midland Operator A proppant intensities have fluctuated very little since 2Q 2017.
- Despite a large dip in lateral lengths in 3Q 2018, Midland Operator A has held fairly steady laterals since switching to in-basin sand.
- Recent quarters have seen a modest uptick in lateral lengths.

### Proppant intensity distribution by vintage quarters (HZ wells)



### Lateral length distribution by vintage quarters (HZ wells)

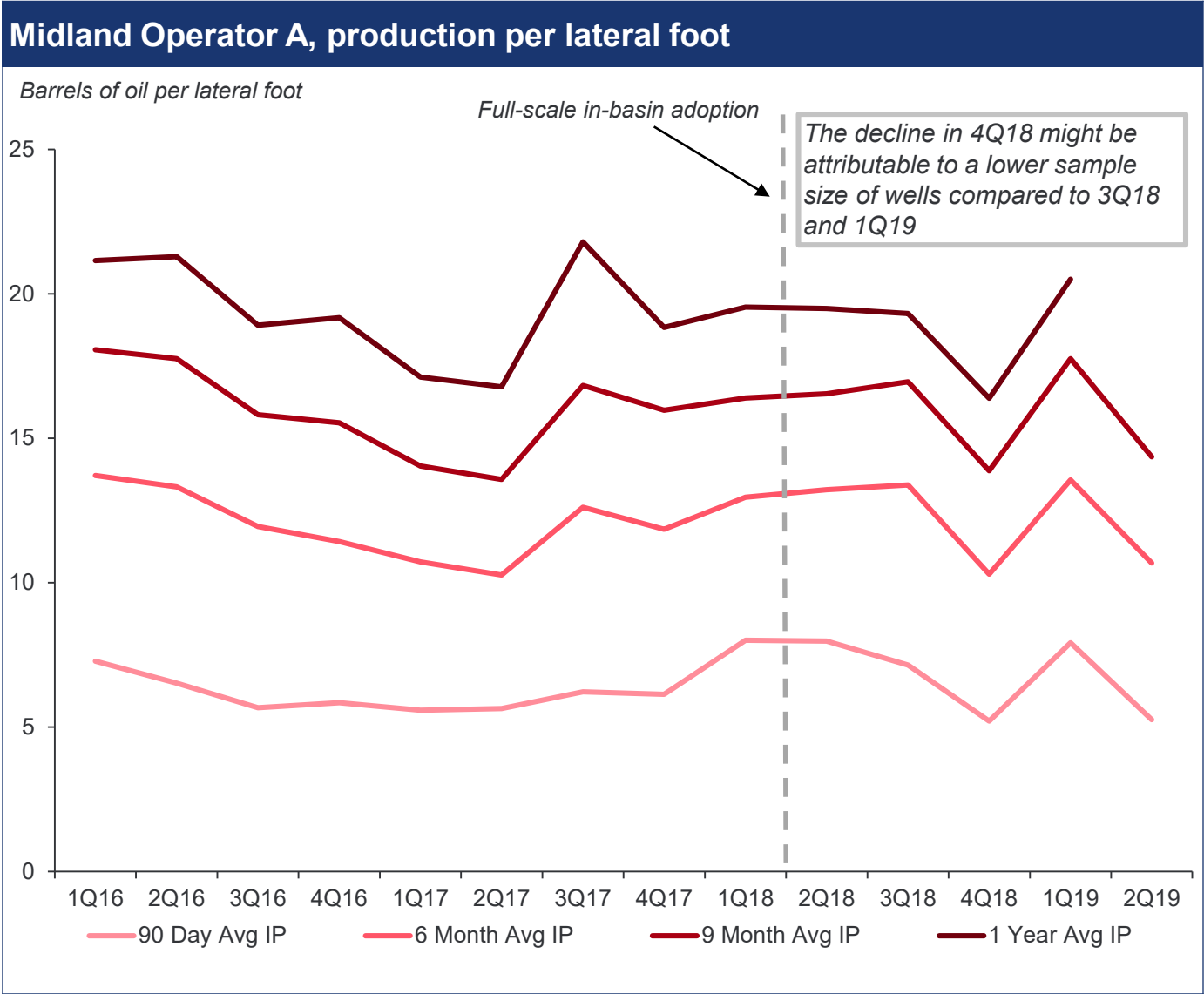


Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# Midland Operator A is seeing a decline in well productivity after switching to in-basin sand

## Midland Operator A

- All IP rates for Midland Operator A have exhibited a decline since switching to in-basin sand.
- Poor sample size in 4Q 2018 may be causing sudden and severe drop in production, however overall trend suggests some impact once switching completely to in-basin sand.
- Despite decreases in productivity, average IP270 degradation still remains below allowable degradation (see economic analysis), hence Midland Operator A has been classified as 'light impact'.

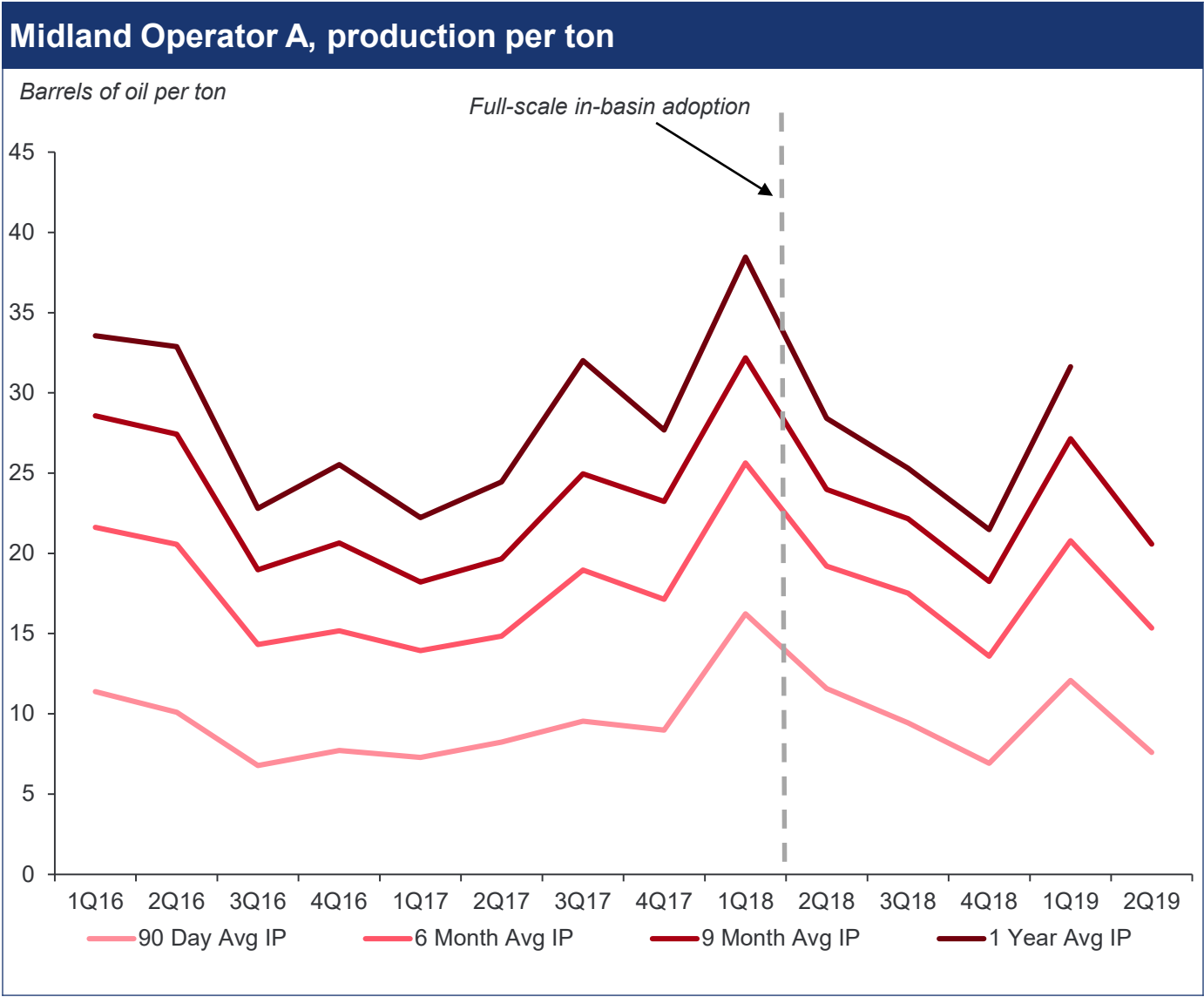


Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

Midland Operator A exhibits impact on productivity once switching to in-basin sand; declines in production immediately following switch to in-basin followed by modest recovery

Midland Operator A

- Proppant intensity and lateral length have remained relatively stable since switching to in-basin sand, while production per ton of proppant has declined in the quarters immediately following the switch.
- Decline in barrels per ton proppant is more profound than barrels per lateral length.



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

Midland Operator A observed degradation of 5.1% in average IP270 remains less than the allowable first year degradation of 6.8% therefore determining '*light impact*' of case

### Midland Operator A : Economic Model Parameters

Parameters	NWS	In-Basin	Actual In-Basin
Lateral length	9,658	9,658	9,806
Proppant intensity	1,661	1,661	1,786
D&C cost (\$)	\$7.5 MM	\$7.1 MM	\$6.9 MM
Oil price, \$ per bbl	\$50.00	\$50.00	\$50.00
Gas price, \$ per boe	\$6.00	\$6.00	\$6.00
Cost savings per ton	\$40	\$40	\$40

### Midland Operator A : Allowable degradation

Year	Allowable Degradation	Total cost savings	CFCF Difference* Year 1	CFCF Difference Year 2	CFCF Difference Year 3
1	-6.8%	\$321K	\$334K	\$462K	\$543K
2	-5.1%	\$321K	\$248K	\$343K	\$404K
3	-4.4%	\$321K	\$216K	\$299K	\$352K

### Midland Operator A : Observed degradation

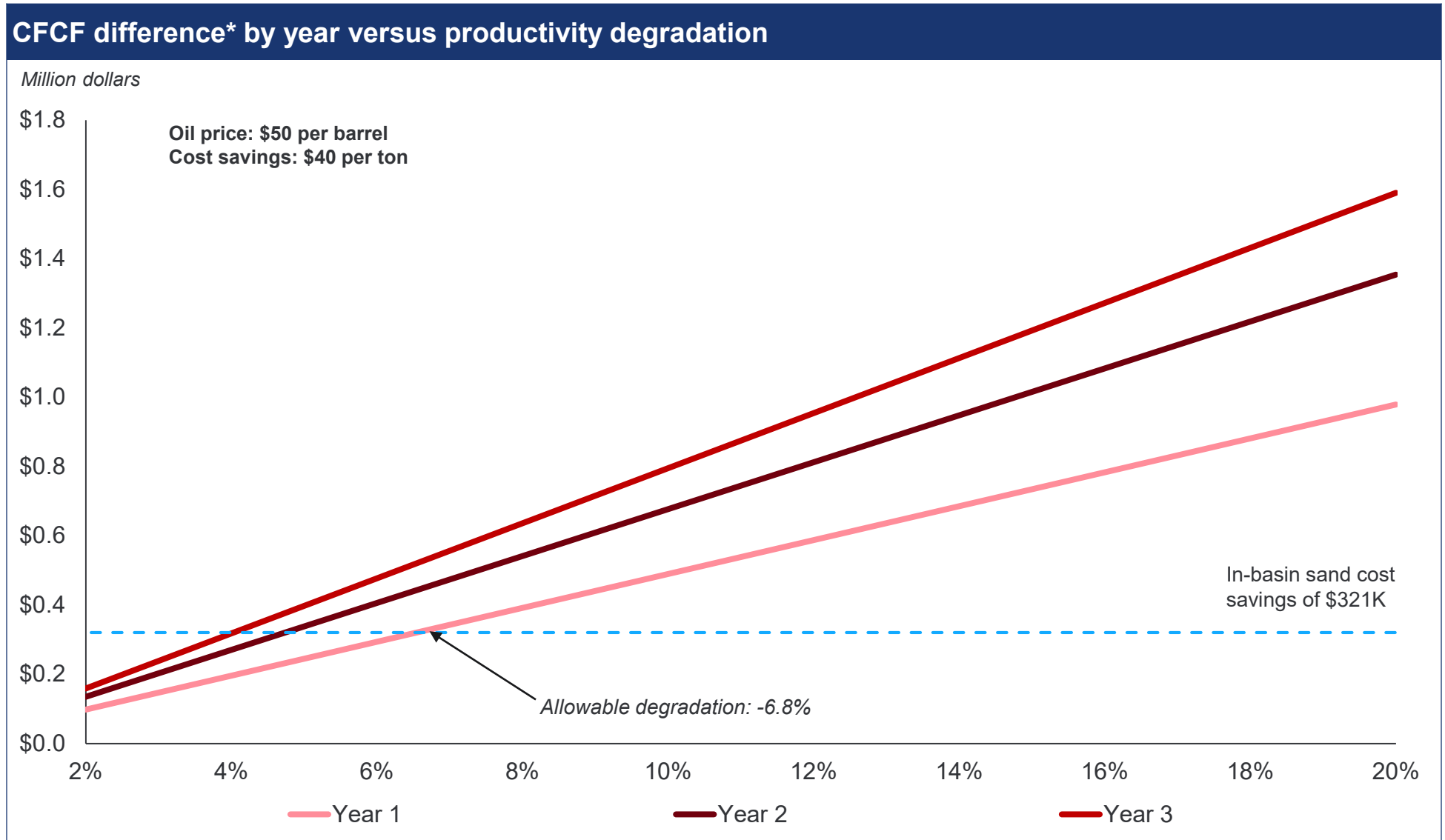
Well Count (NWS)	Time Frame Assessed (NWS)	IP270 (NWS)	Well Count (In-Basin)	Time Frame Assessed (In-Basin)	IP270 (In-Basin)	Observed Change in IP270
46	4Q17 – 2Q18	15,892	133	3Q18 – 2Q19	15,075	-5.1%

\* CFCF difference is defined as the difference between cumulative net cash flow from a northern white sand and in-basin sand well

Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis



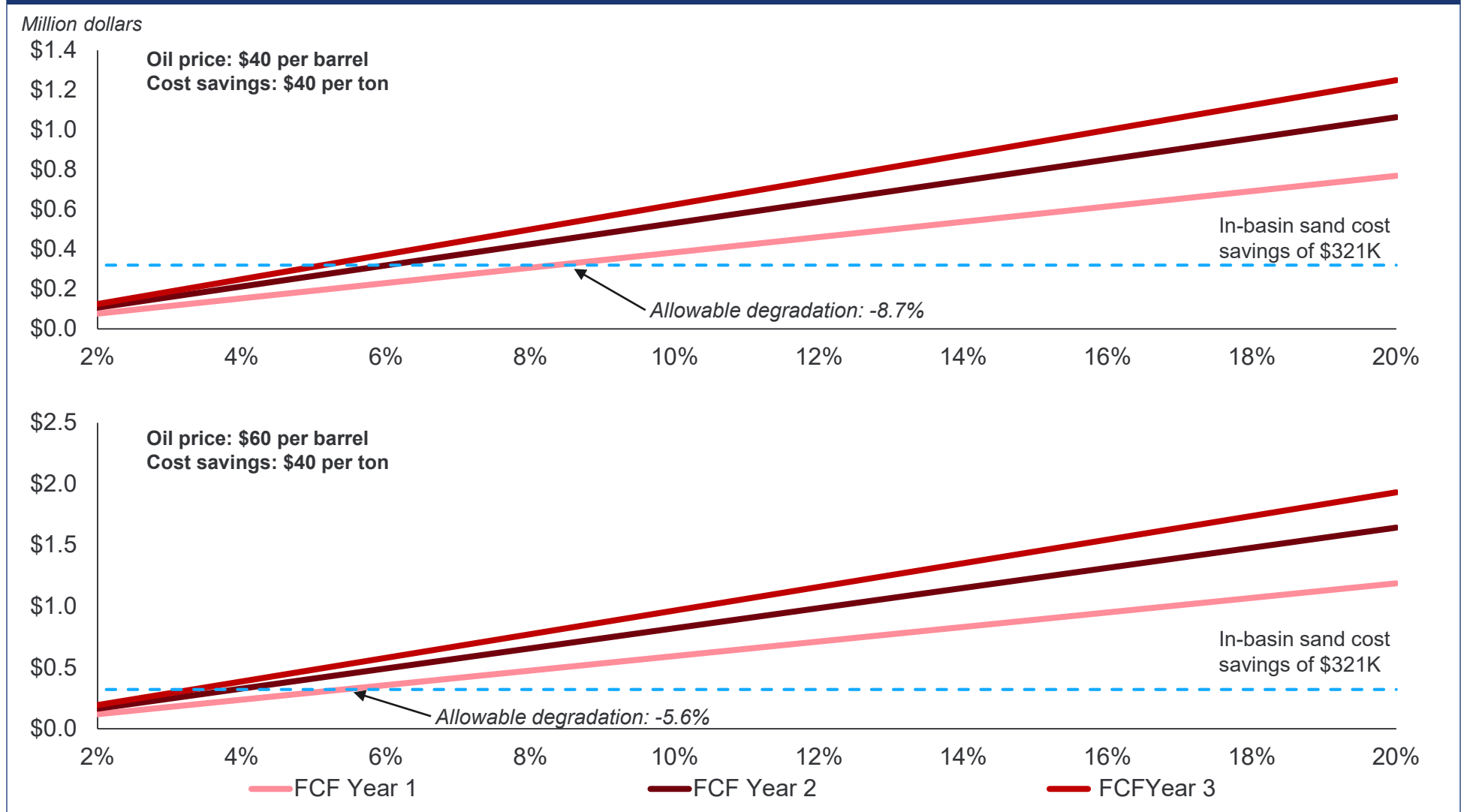
# CFCF difference would exceed cost savings in Year 1 at a degradation greater than 6.8%



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis; CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

**\$40 per bbl oil price results in an additional 3.1% allowable degradation from \$60 oil assuming in-basin sand cost savings of \$40/ton**

### CFCF difference\* by year versus productivity degradation



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis; CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

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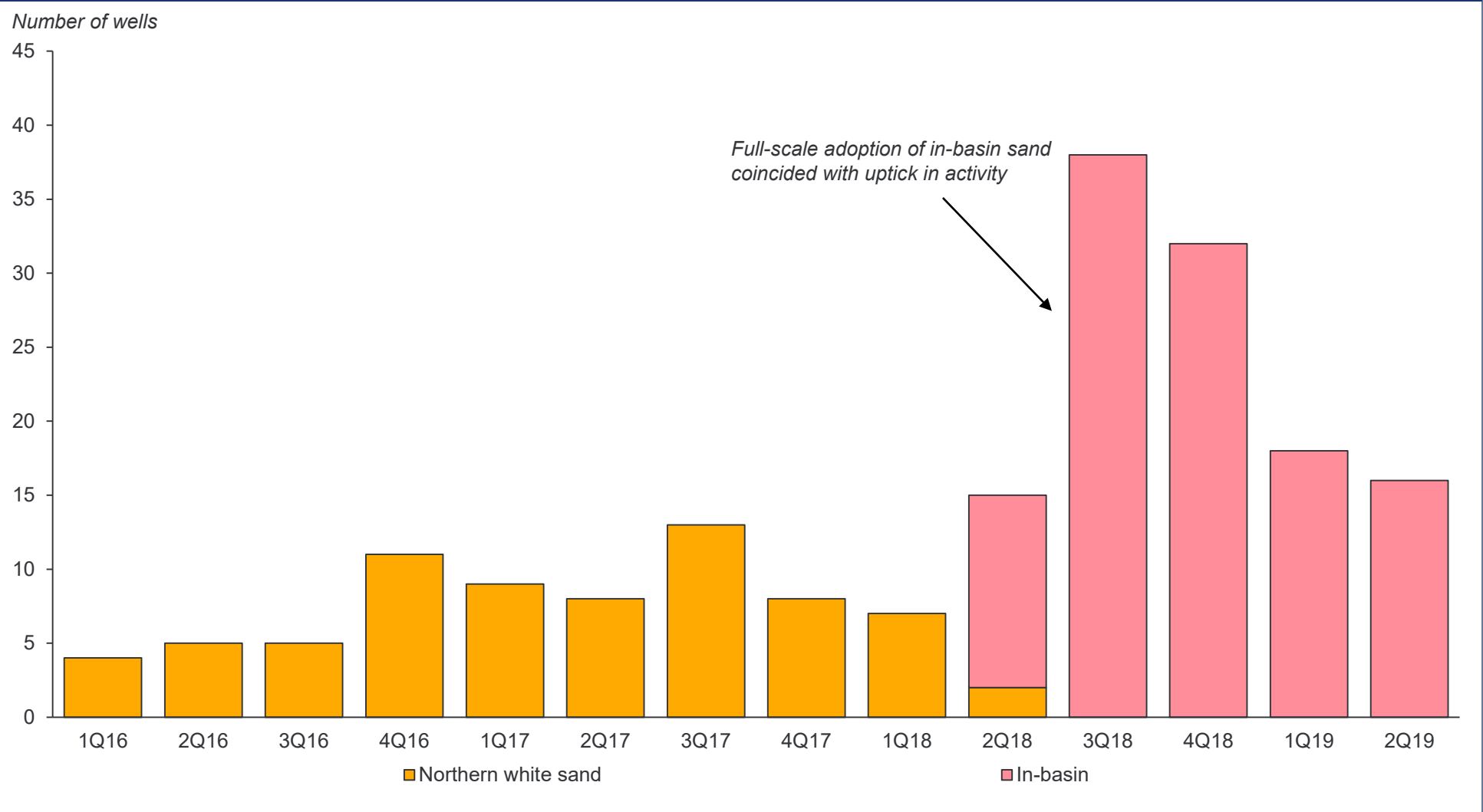
Eagle Ford

Haynesville

SCOOP/STACK

# Full scale adoption of in-basin sand for Midland Operator B happened in 3Q18

Midland Operator B: frac job count by reported\* sand type



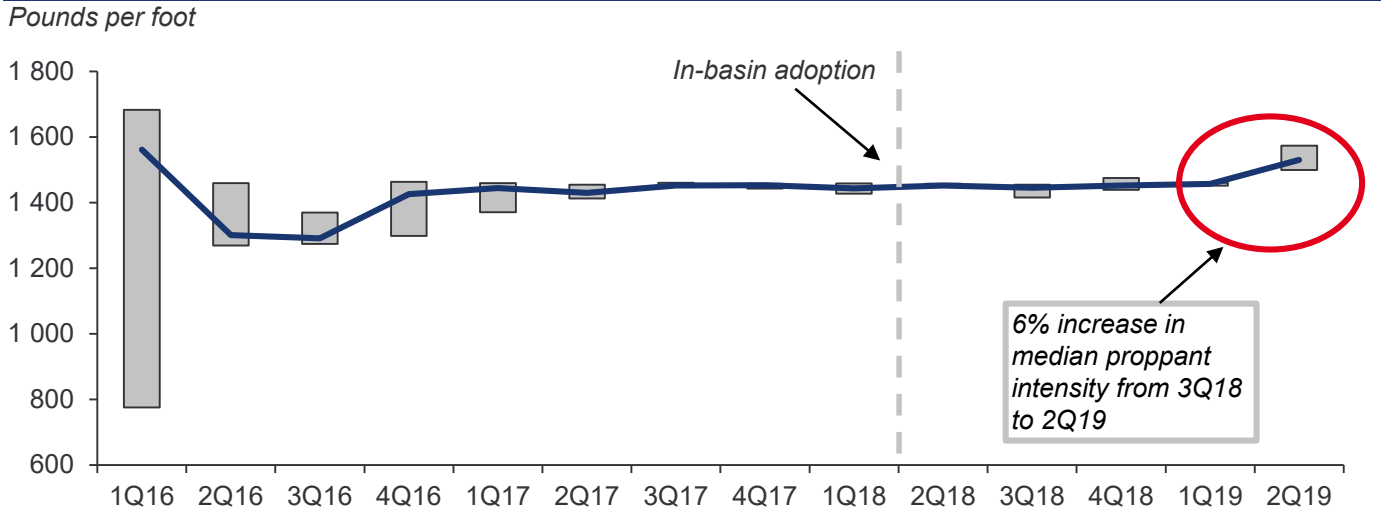
\*Based on Rystad Energy's analysis of chemical ingredient and trade names reported to FracFocus Chemical Disclosure Registry  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

Proppant intensity levels have remained steady after switch to in-basin sand except for a 6% increase seen in 2Q19; lateral lengths have shown increased variability

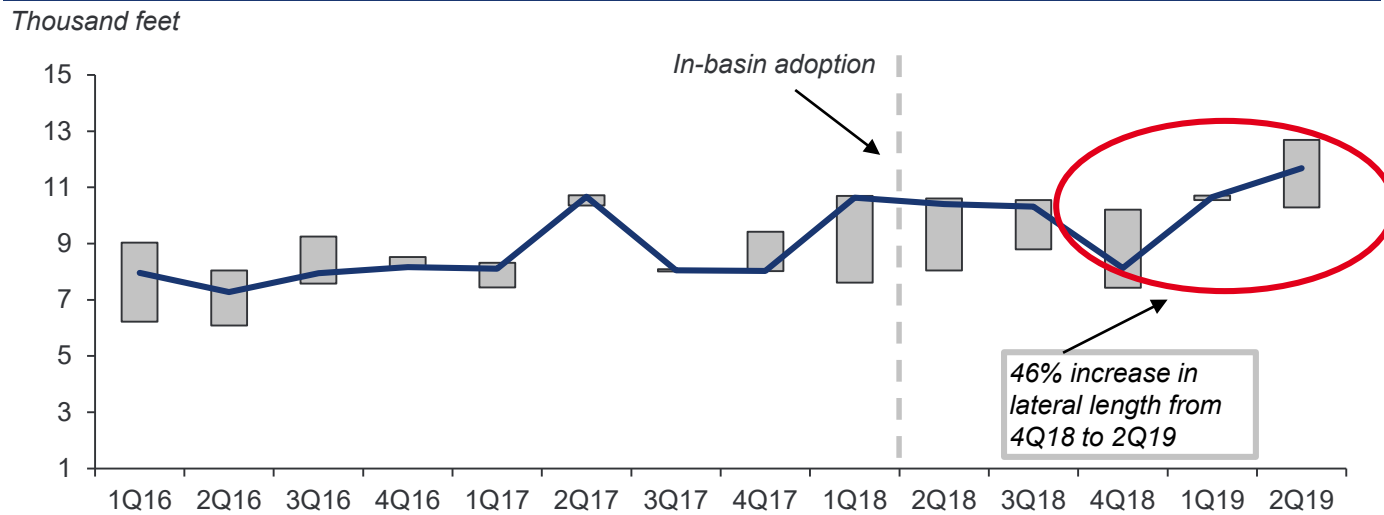
Midland Operator B

- Since switching to in-basin sand, Midland Operator B has kept proppant intensity levels relatively flat until 2Q19, which has seen a 6% spike from 3Q18.
- Lateral lengths have shown increased variability since switching to in-basin sand, with a dramatic 46% increase from 4Q 2018 to 2Q 2019.

Proppant intensity distribution by vintage quarters (HZ wells)



Lateral length distribution by vintage quarters (HZ wells)

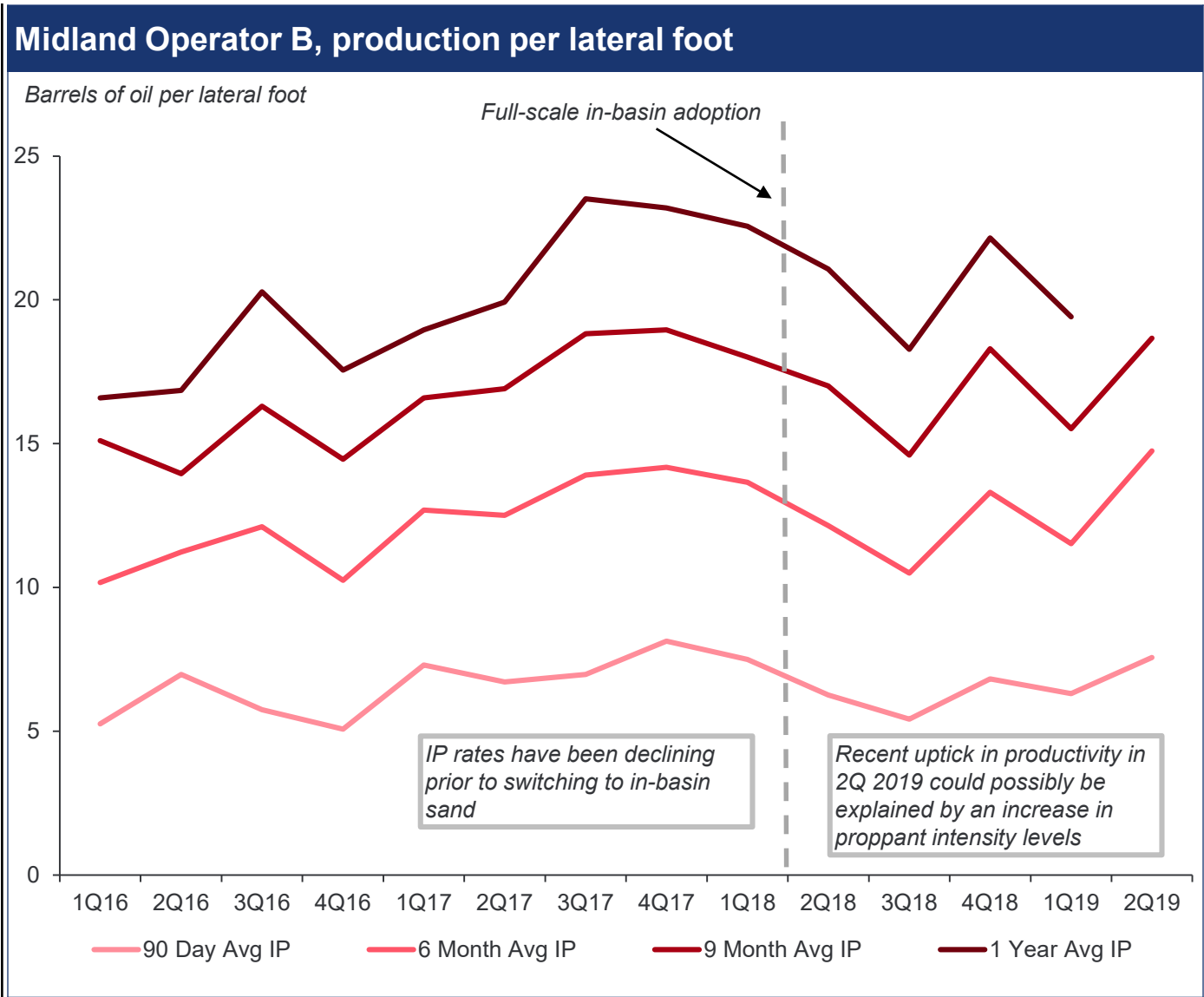


Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

Midland Operator B is seeing an impact on well productivity, though subsequent up and down trend makes it more challenging to draw conclusions

Midland Operator B

- All IP rates for Midland Operator B have been declining since late 2017 up until 3Q18.
- This trend could be due to a shift to finer mesh sand; however, mesh size data isn't available in the public domain to make a definitive conclusion.
- Since switching to in-basin sand, IP rates have continued to decline before showing signs of recovery from 4Q18.
- Midland Operator B has been classified as a case study showing a “*impact*” from switching to in-basin sand.



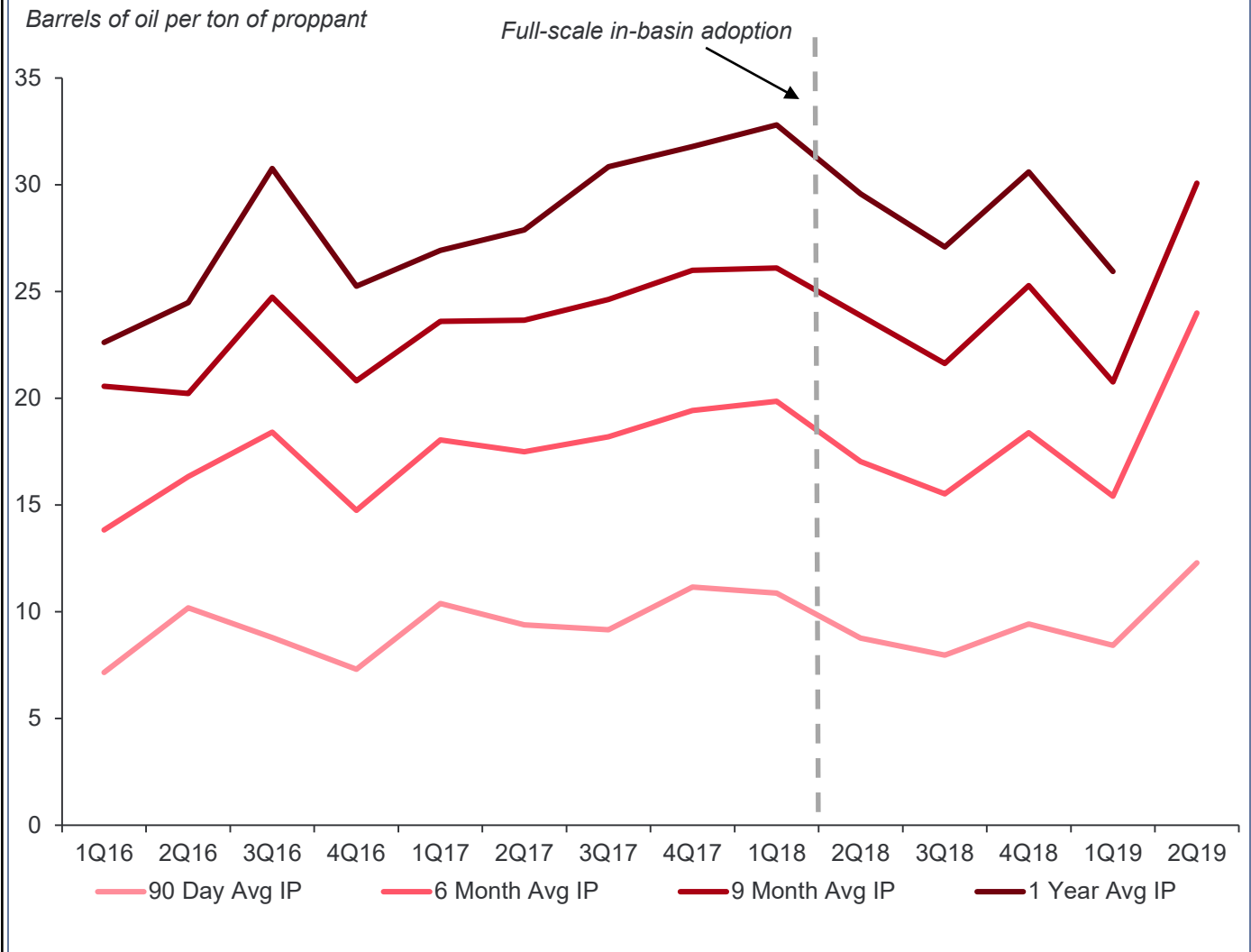
Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

Production per ton has been declining since switch to in-basin sand;  
Uptick seen in 2Q19 could be due to increased proppant intensity and lateral lengths

## Midland Operator B

- Production per ton of proppant pumped signals a significant increase in IP rates in 2Q19, stronger indication than barrels per foot, though there was a clear declining trend in the preceding quarters.
- During 2Q19, Midland Operator B increased both proppant intensity and lateral lengths.
- The Midland Operator B case study has been classified as having “*impact*” due to decreasing production per ton after switch to in-basin sand.

### Midland Operator B, production per ton



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

Observed degradation of 8.6% greater than allowable degradation of 6.0%, assuming in-basin sand cost savings of \$40/ton

### Midland Operator B: Economic Model Parameters

Parameters	NWS	In-Basin	Actuals
Lateral length	9,867	9,867	9.463
Proppant intensity	1,602	1,602	1,593
D&C cost (\$)	\$7.1 MM	\$6.8 MM	\$6.7 MM
Oil price, \$ per bbl	\$50.00	\$50.00	\$50.00
Gas price, \$ per boe	\$6.00	\$6.00	\$6.00
Cost savings per ton	\$40	\$40	\$40

### Midland Operator B : Allowable degradation

Year	Allowable Degradation	Total cost savings	CFCF Difference* Year 1	CFCF Difference Year 2	CFCF Difference Year 3
1	-6.0%	\$316K	\$331K	\$501K	\$614K
2	-4.1%	\$316K	\$226K	\$342K	\$419K
3	-3.4%	\$316K	\$189K	\$287K	\$351K

### Midland Operator B : Observed degradation

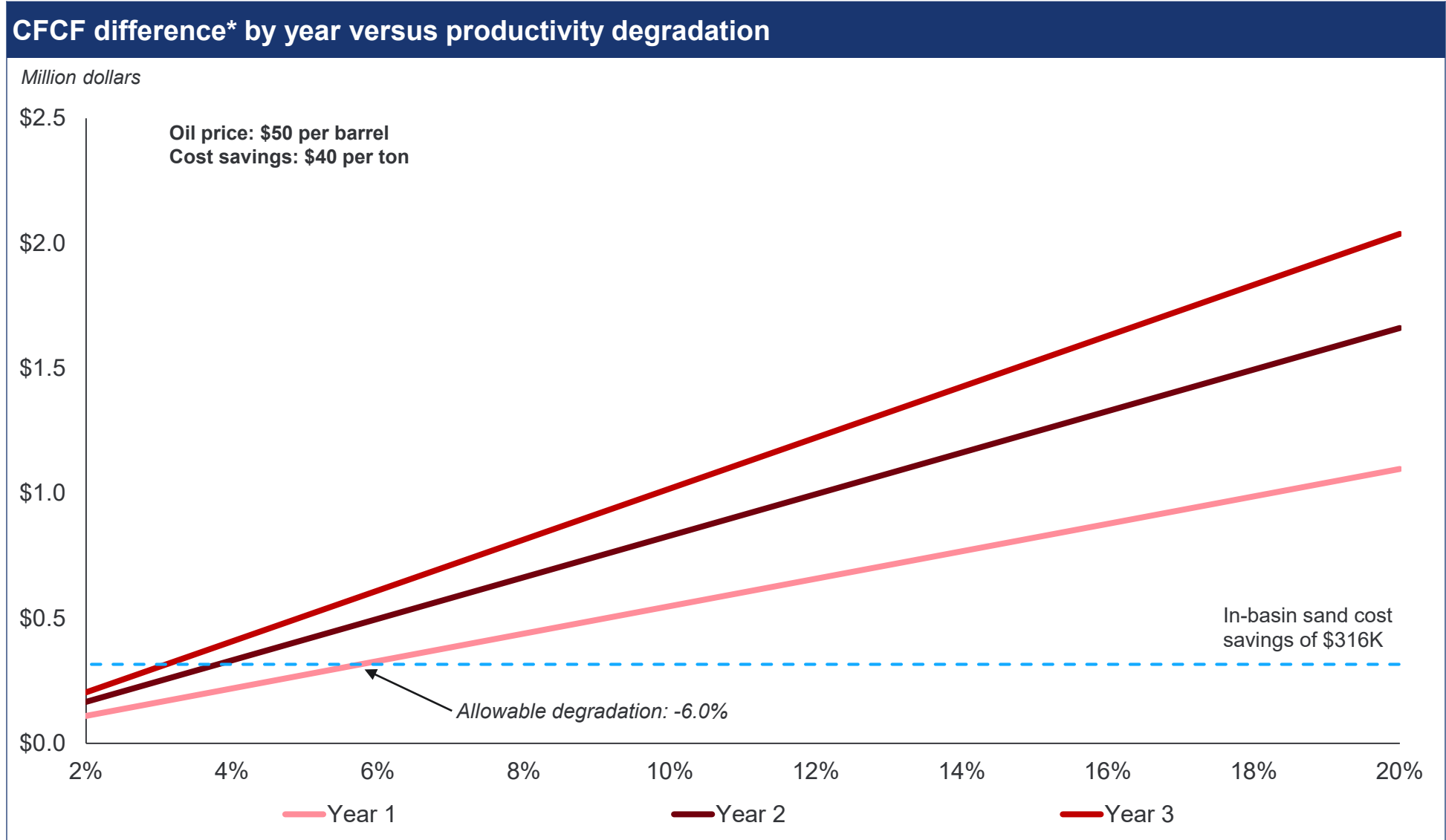
Well Count (NWS)	Time Frame Assessed (NWS)	IP270 (NWS)	Well Count (In-Basin)	Time Frame Assessed (In-Basin)	IP270 (In-Basin)	Observed Change in IP270
30	3Q17 – 2Q18	18,296	117	2Q18 – 2Q19	16,731	-8.6%

\* CFCF difference is defined as the difference between cumulative net cash flow from a northern white sand and in-basin sand well

Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis



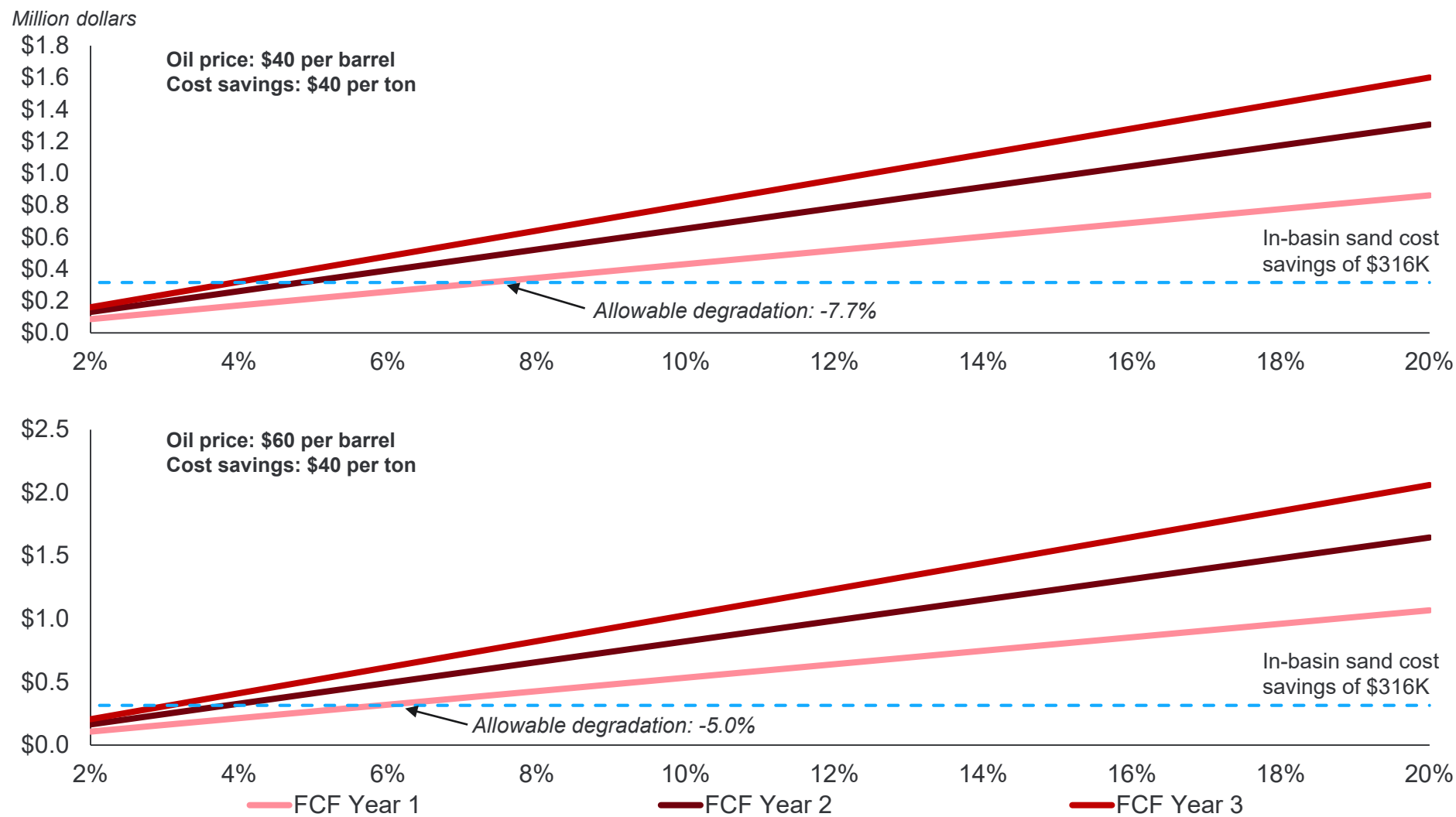
CFCF difference would exceed cost savings in Year 1 at a degradation greater than 6.2%



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis; CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

\$40 per bbl oil price results in 2.7% allowable degradation, close to observed productivity drop, with cost savings from in-basin sand of \$40/ton

## CFCF difference\* by year versus productivity degradation



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis; CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

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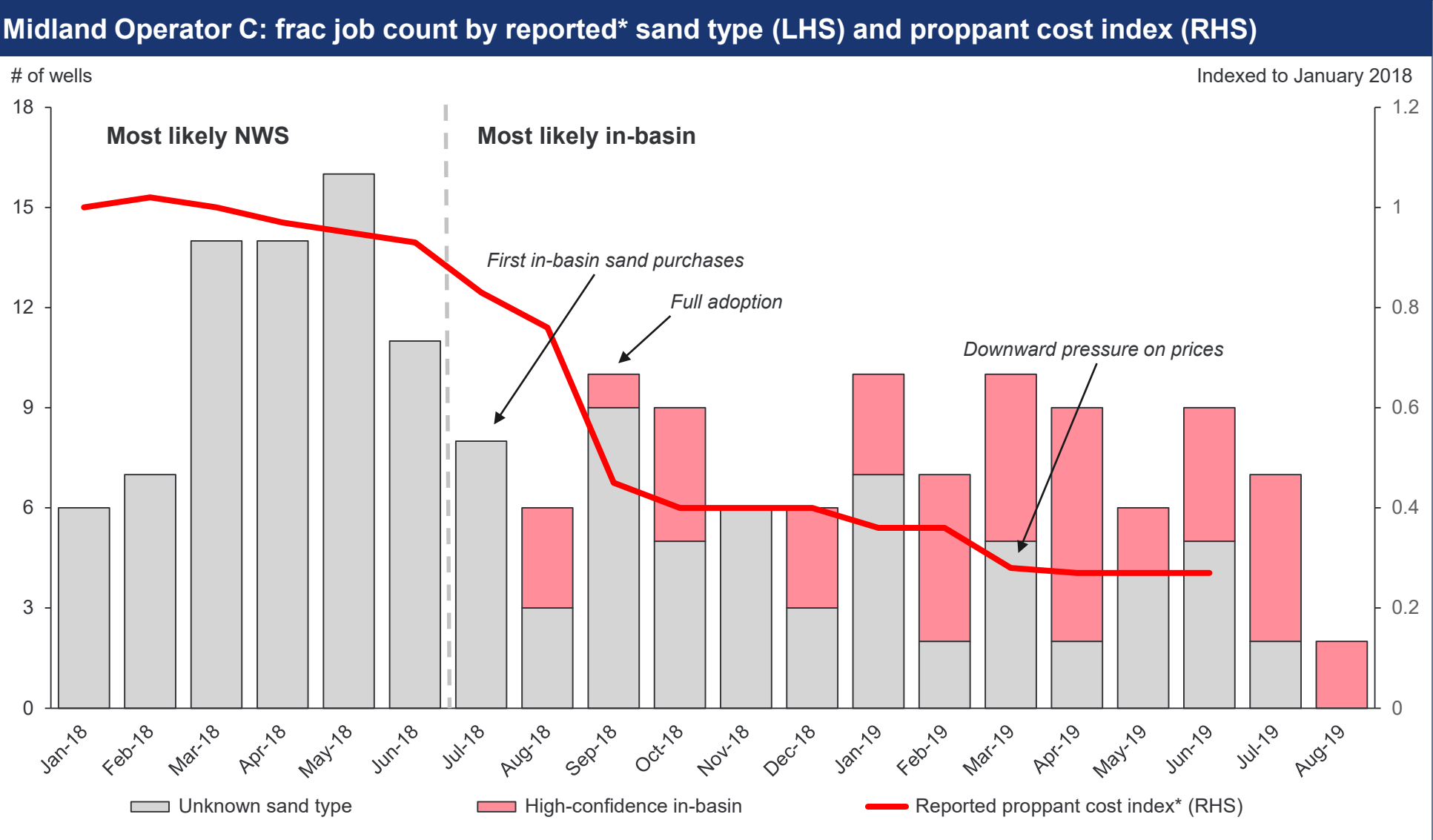
Permian Delaware

Eagle Ford

Haynesville

SCOOP/STACK

# Midland Operator C completed full in-basin sand adoption in September 2018

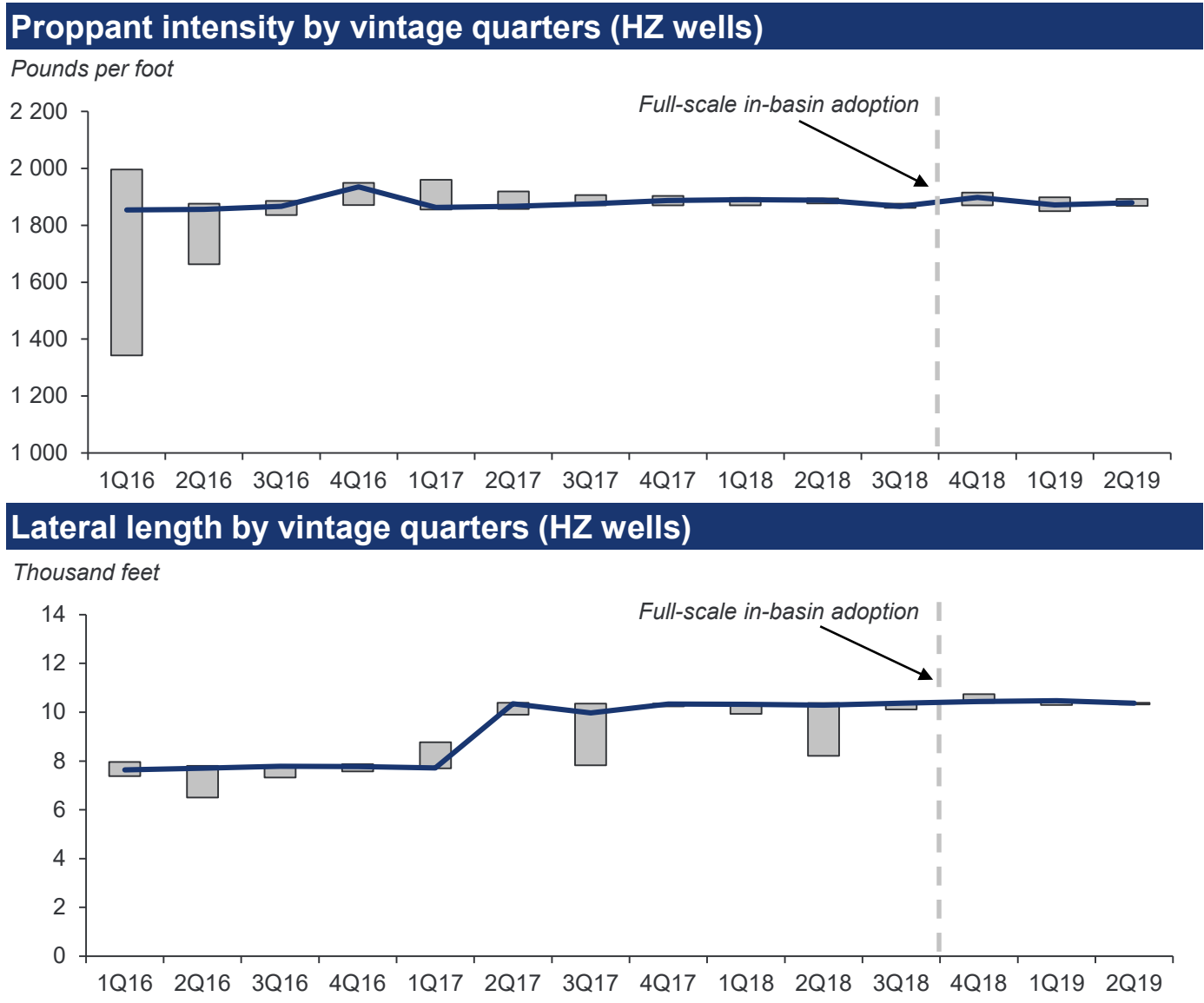


\*From Midland Operator C's investor presentation. Based on Rystad Energy's analysis of chemical ingredient and trade names reported to FracFocus Chemical Disclosure Registry  
Source: Rystad Energy ShaleWellCube, Midland Operator C investor presentation, Rystad Energy research and analysis

# Midland Operator C has kept lateral length and proppant intensity flat since switching to in-basin sand

## Midland Operator C

- Proppant intensity levels for Midland Operator C have held pretty steady between 1,850 and 1,900 pounds per foot before and after the switch to in-basin sand.
- Lateral lengths have shown very little variability and has remained at ~10,000 feet since 2Q17.

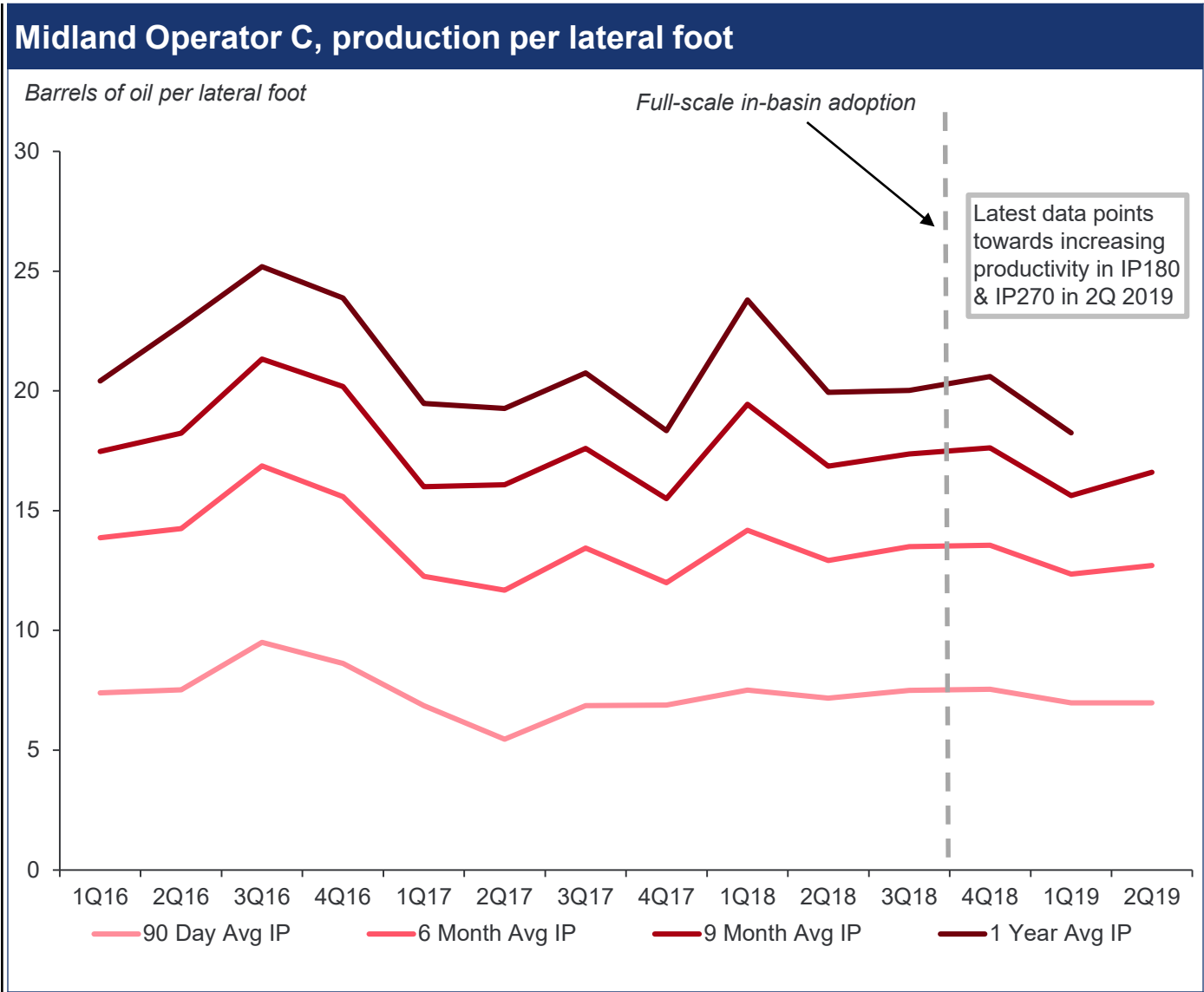


Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# Midland Operator C has seen an impact on productivity since switching to in-basin sand

## Midland Operator C

- Lateral lengths have stayed remarkably stable since 2Q17, even once switching to in-basin sand, while production normalized for lateral length has declined immediately following the switch.
- Recent data for 2Q19 suggests a modest increase in productivity, although still not recovering to levels seen prior to switching to in-basin sand.
- Therefore, Midland Operator C has been classified as a case with 'impact' from switching to in-basin sand .

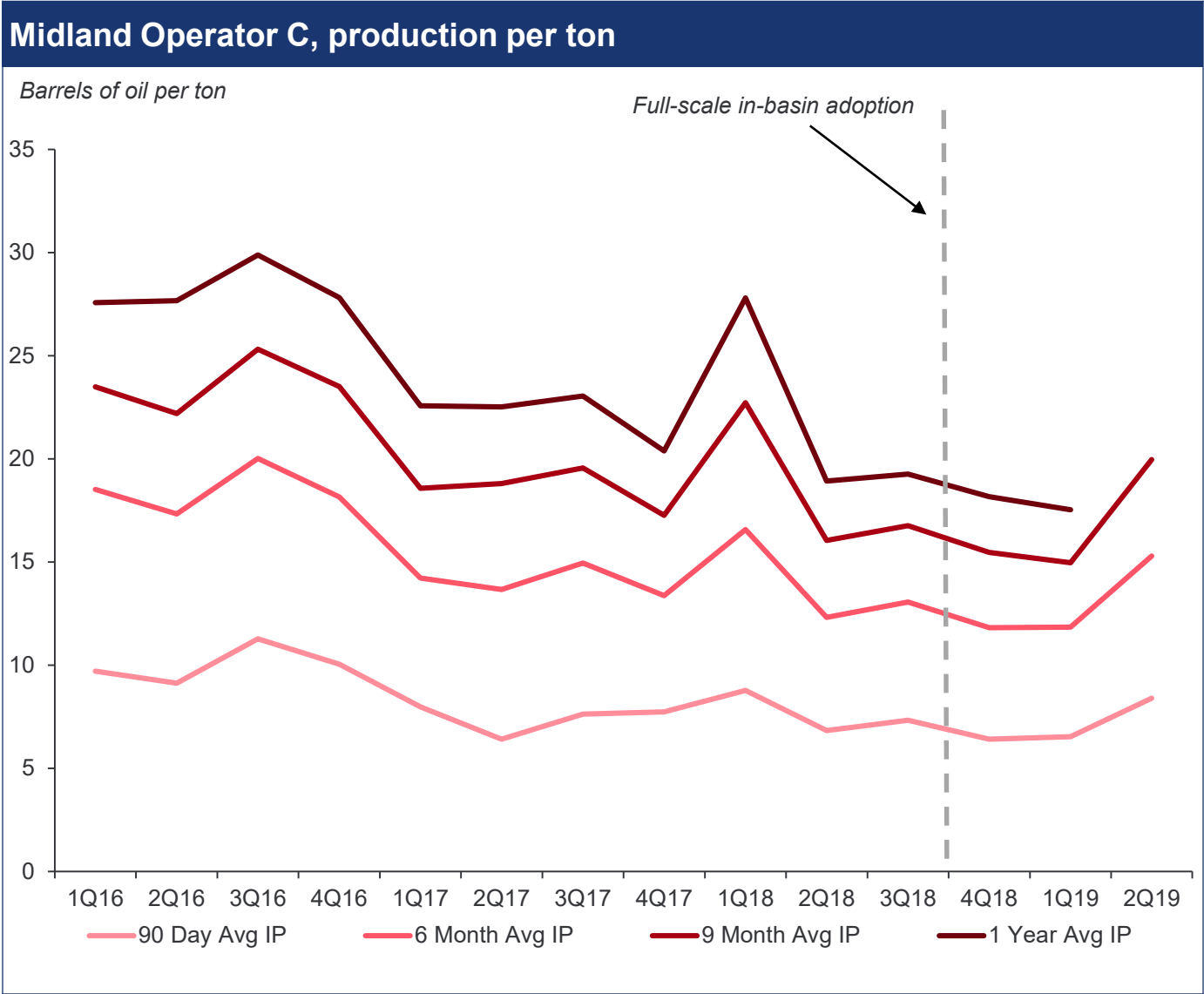


Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# Productivity per ton proppant more volatile, but clear drop from older vintages

## Midland Operator C

- Despite proppant intensity levels remaining flat since the point of full-scale in-basin sand adoption, production per ton of proppant immediately declined after the switch.
- The production per ton is more volatile than production per lateral foot, e.g. steeper drop from older vintages, but also stronger increase seen in the 2Q19 vintage.
- The 2Q19 observation makes it harder to draw firm conclusions, but Midland Operator C has still been identified as a case with 'impact' from switching to in-basin sand.



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

Midland Operator C observed degradation of 8.6% is greater than the allowable degradation of 7.1%

### Midland Operator C: Economic Model Parameters

Parameters	NWS	In-Basin	Actuals
Lateral length	10,288	10,288	11,119
Proppant intensity	1,890	1,890	2,421
D&C cost (\$)	\$7.9 MM	\$7.5 MM	\$7.1 MM
Oil price, \$ per bbl	\$50.00	\$50.00	\$50.00
Gas price, \$ per boe	\$6.00	\$6.00	\$6.00
Cost savings per ton	\$40	\$40	\$40

### Midland Operator C : Allowable degradation

Year	Allowable Degradation	Total cost savings	CFCF Difference* Year 1	CFCF Difference Year 2	CFCF Difference Year 3
1	-7.1%	\$389K	\$405K	\$558K	\$653K
2	-5.3%	\$389K	\$302K	\$416K	\$487K
3	-4.7%	\$389K	\$264K	\$364K	\$426K

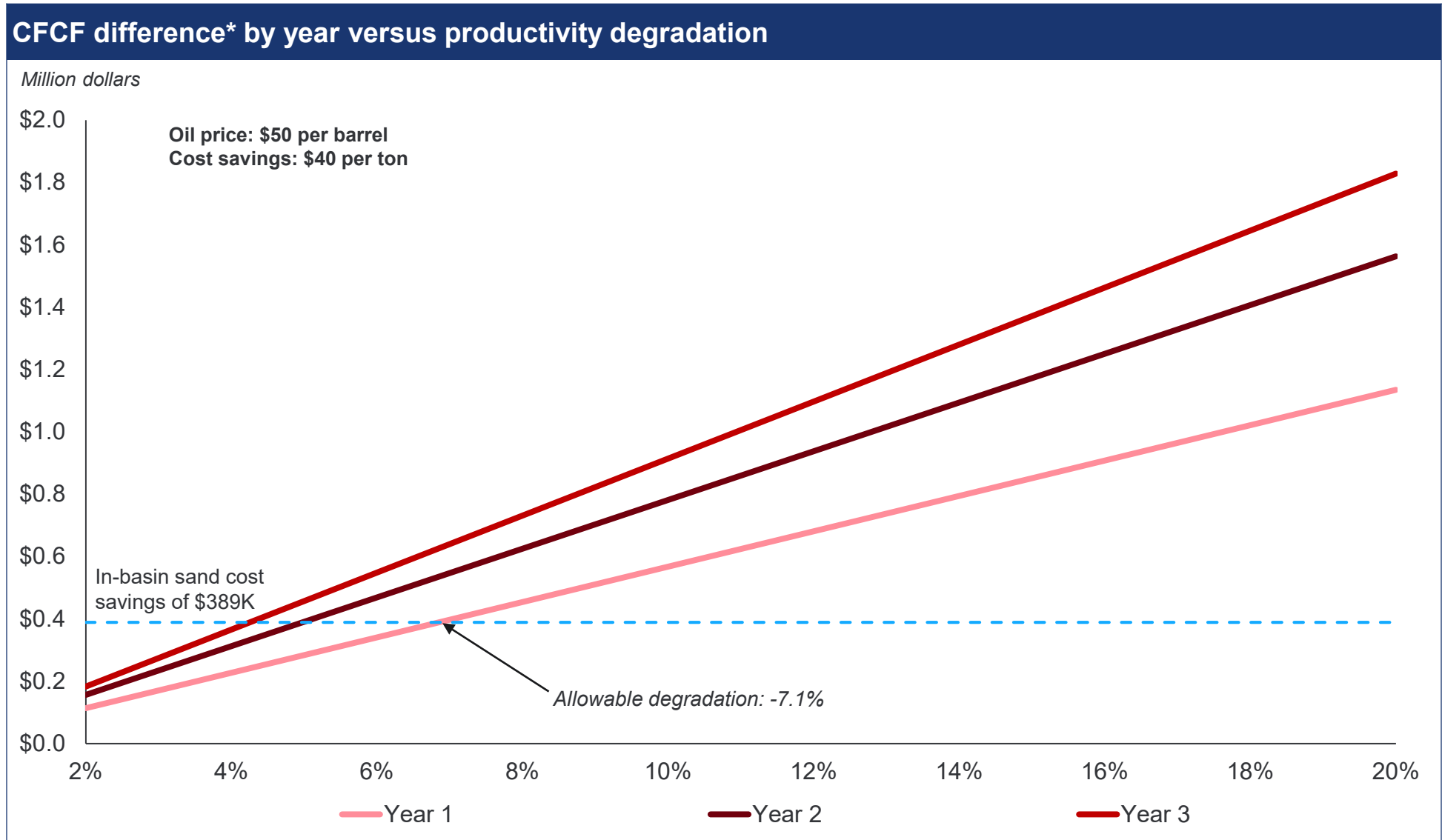
### Midland Operator C : Observed degradation

Well Count (NWS)	Time Frame Assessed (NWS)	IP270 (NWS)	Well Count (In-Basin)	Time Frame Assessed (In-Basin)	IP270 (In-Basin)	Observed Change in IP270
32	3Q18 – 4Q18	17,848	43	4Q18 – 2Q19	16,320	-8.6%

\* CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis



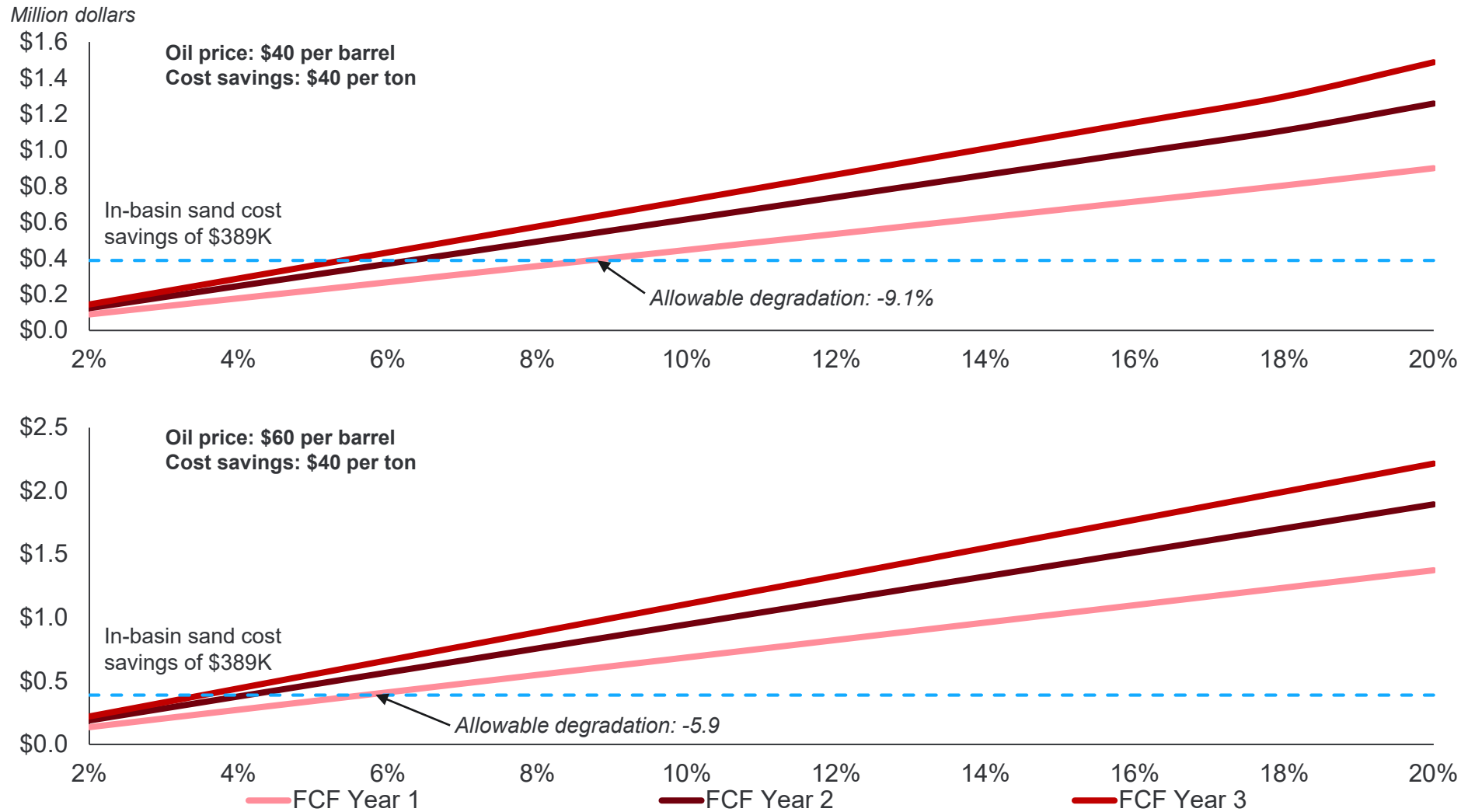
# CFCF difference would exceed cost savings in Year 1 at a degradation of 7.1%



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis; CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

\$40 per bbl oil price results in an additional 3.2% allowable degradation from \$60 oil assuming in-basin sand cost savings of \$40/ton

### CFCF difference\* by year versus productivity degradation



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis; CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

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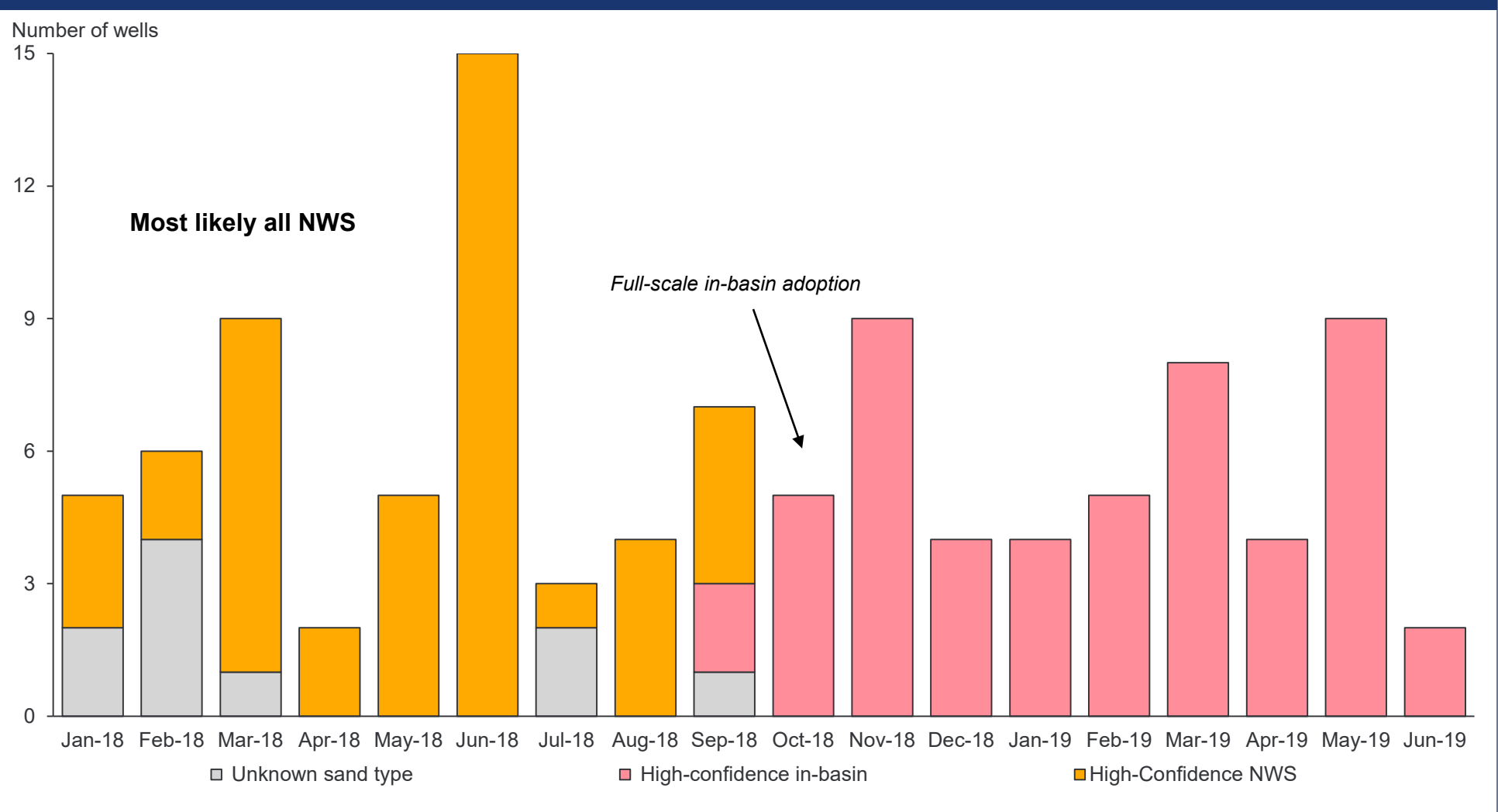
Eagle Ford

Haynesville

SCOOP/STACK

# Midland Operator D completed full in-basin sand adoption in October 2018

Midland Operator D: frac job count by reported\* sand type (LHS)

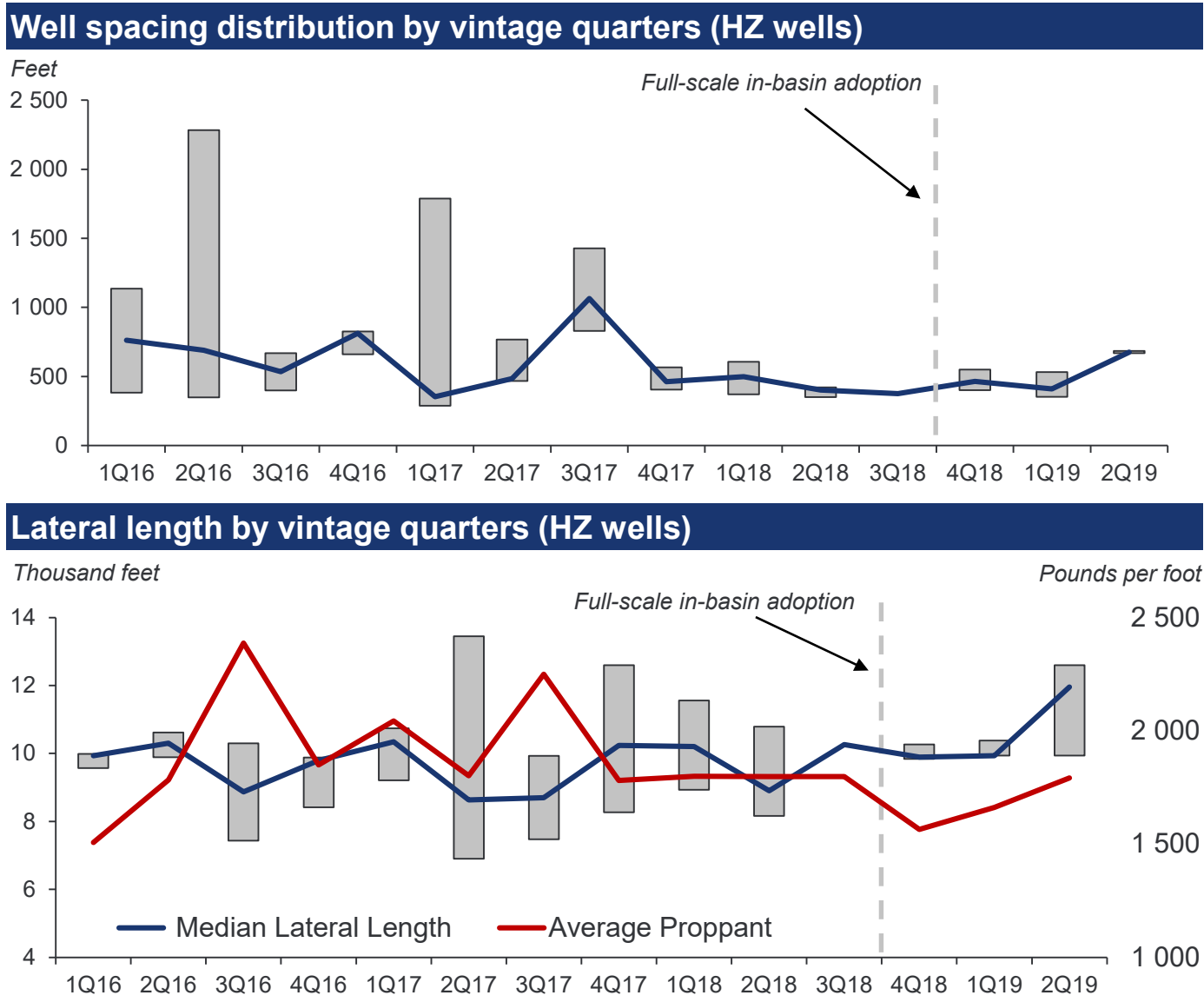


\*From Midland Operator D's investor presentation. Based on Rystad Energy's analysis of chemical ingredient and trade names reported to FracFocus Chemical Disclosure Registry  
Source: Rystad Energy ShaleWellCube, Midland Operator D investor presentation, Rystad Energy research and analysis

# Midland Operator D has increased all well design parameters since switching to in-basin sand

## Midland Operator D

- Midland Operator D has consistently pointed towards closer well spacing as a smoking gun for production declines seen since mid-2016.
- Lateral lengths started increasing in 3Q 2018, before in-basin adoption, with 2Q 2019 increasing sharply after the complete switch to in-basin sand.
- Well spacing has sharply risen in 2Q 2019 returning to levels not seen since 2017.
- Proppant intensity levels dropped immediately following in-basin sand adoption but have since been recovering.

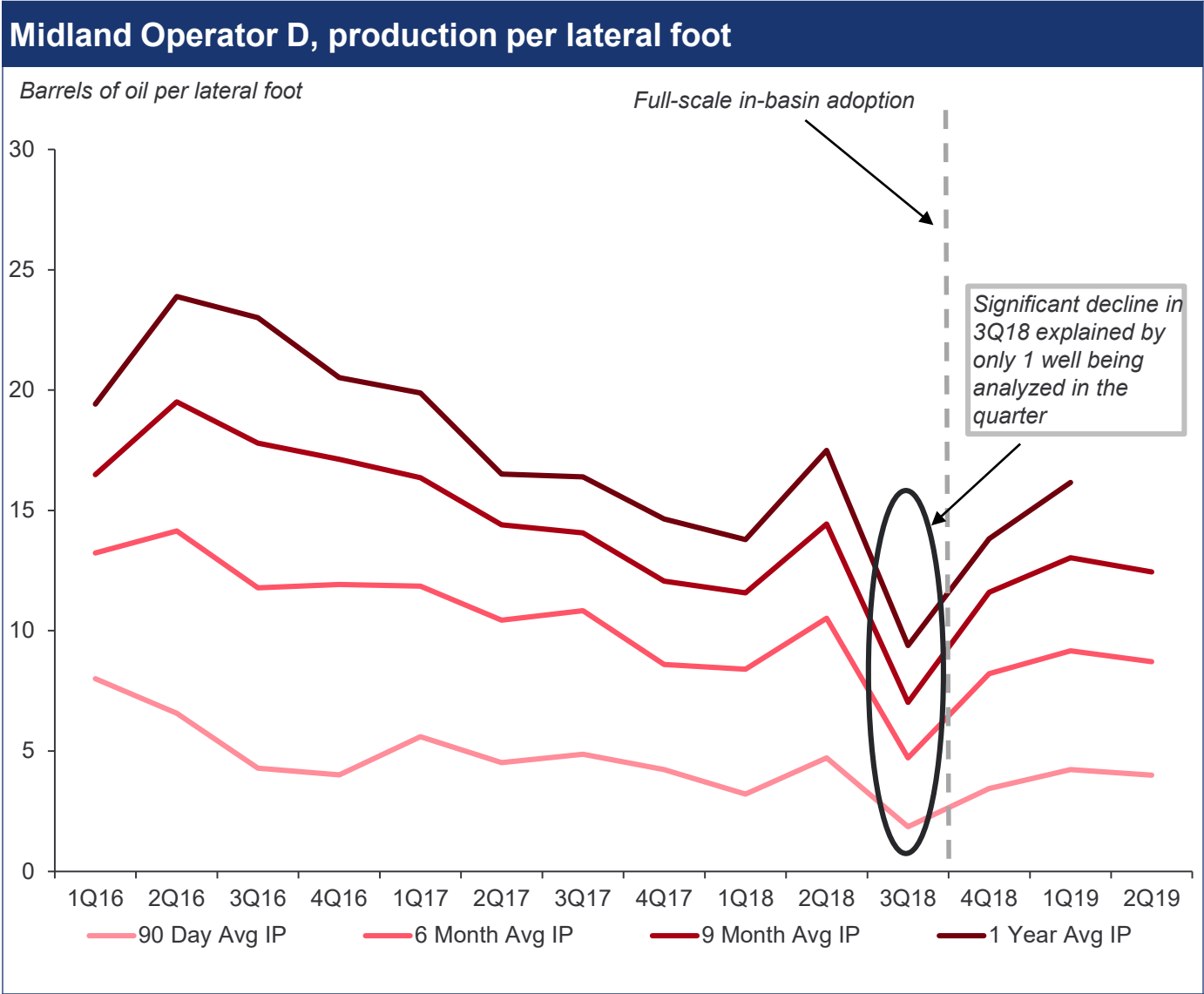


Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# Midland Operator D exhibits some impact on productivity following the switch to in-basin sand

## Midland Operator D

- Since the adoption of in-basin sand Midland Operator D has seen a decline in overall productivity once normalized for lateral length, however still within the allowable degradation limit (see economic analysis).
- Increases in productivity following in-basin sand adoption may be attributed to Midland Operator D increasing their well spacing and proppant intensity during this same time period.
- Despite decreases in productivity, average IP270 degradation still remains below allowable degradation, hence Midland Operator D has been classified as 'light impact'.

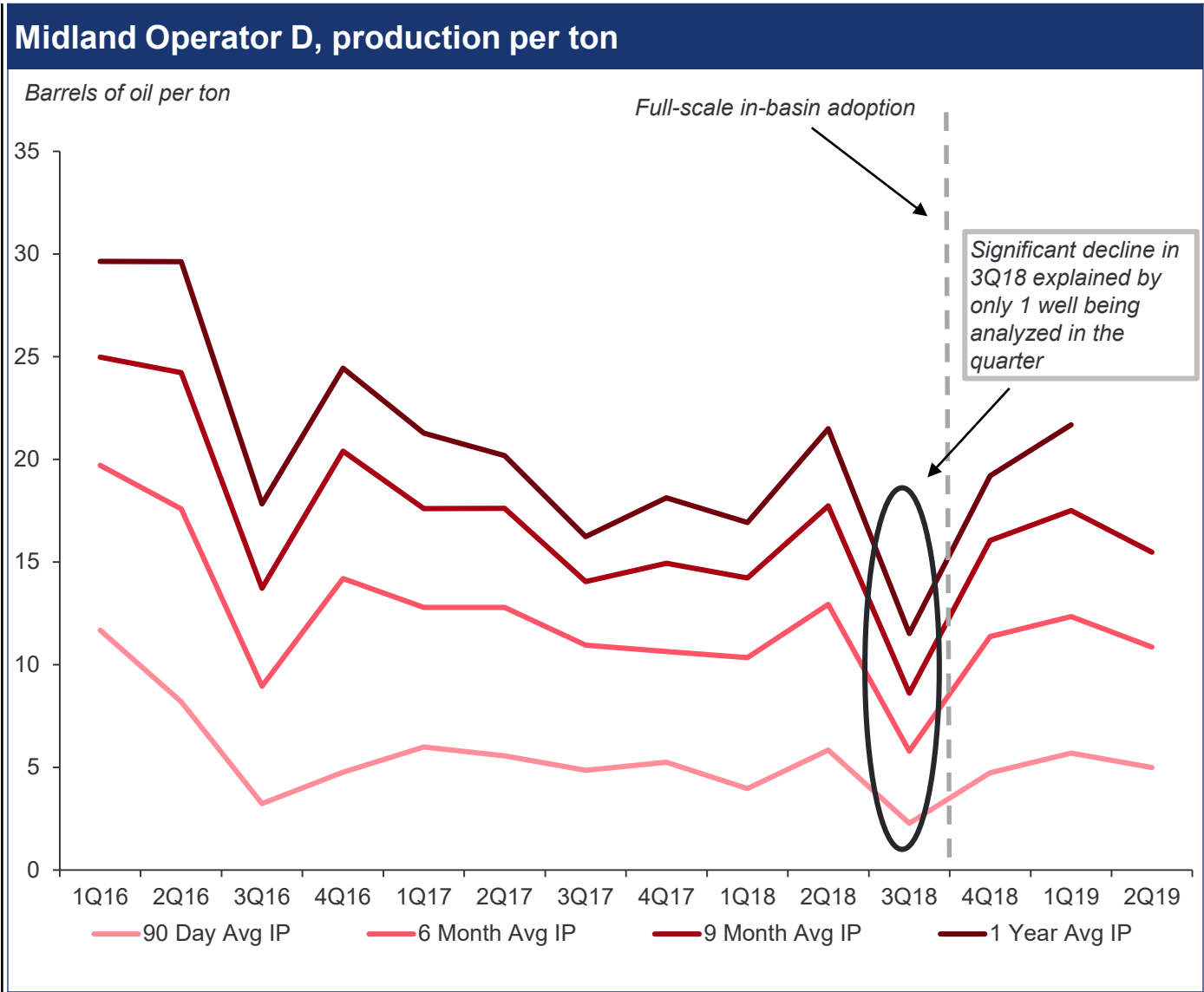


Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# Production per ton proppant seeing similar trends for Midland Operator D case

## Midland Operator D

- Since switching completely to in-basin sand, Midland Operator D has seen an overall decline in production per ton of proppant as proppant intensity levels rise.
- Trends and changes are similar to production per foot, despite the lateral lengths having more variability than proppant loading.



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

Midland Operator D exhibits a 7.1% decline in IP270 following switch, below the 8.8% allowable degradation

Midland Operator D: Economic Model Parameters

Parameters	NWS	In-Basin	Actual In-Basin
Lateral length	8,905	8,905	10,634
Proppant intensity	1,806	1,806	1,682
D&C cost (\$)	\$7.2 MM	\$7.0 MM	\$6.7 MM
Oil price, \$ per bbl	\$50.00	\$50.00	\$50.00
Gas price, \$ per boe	\$6.00	\$6.00	\$6.00
Cost savings per ton	\$40	\$40	\$40

Midland Operator D : Allowable degradation

Year	Allowable Degradation	Total cost savings	CFCF Difference* Year 1	CFCF Difference Year 2	CFCF Difference Year 3
1	-8.8%	\$329K	\$343K	\$480K	\$566K
2	-6.4%	\$329K	\$253K	\$353K	\$417K
3	-5.6%	\$329K	\$219K	\$306K	\$362K

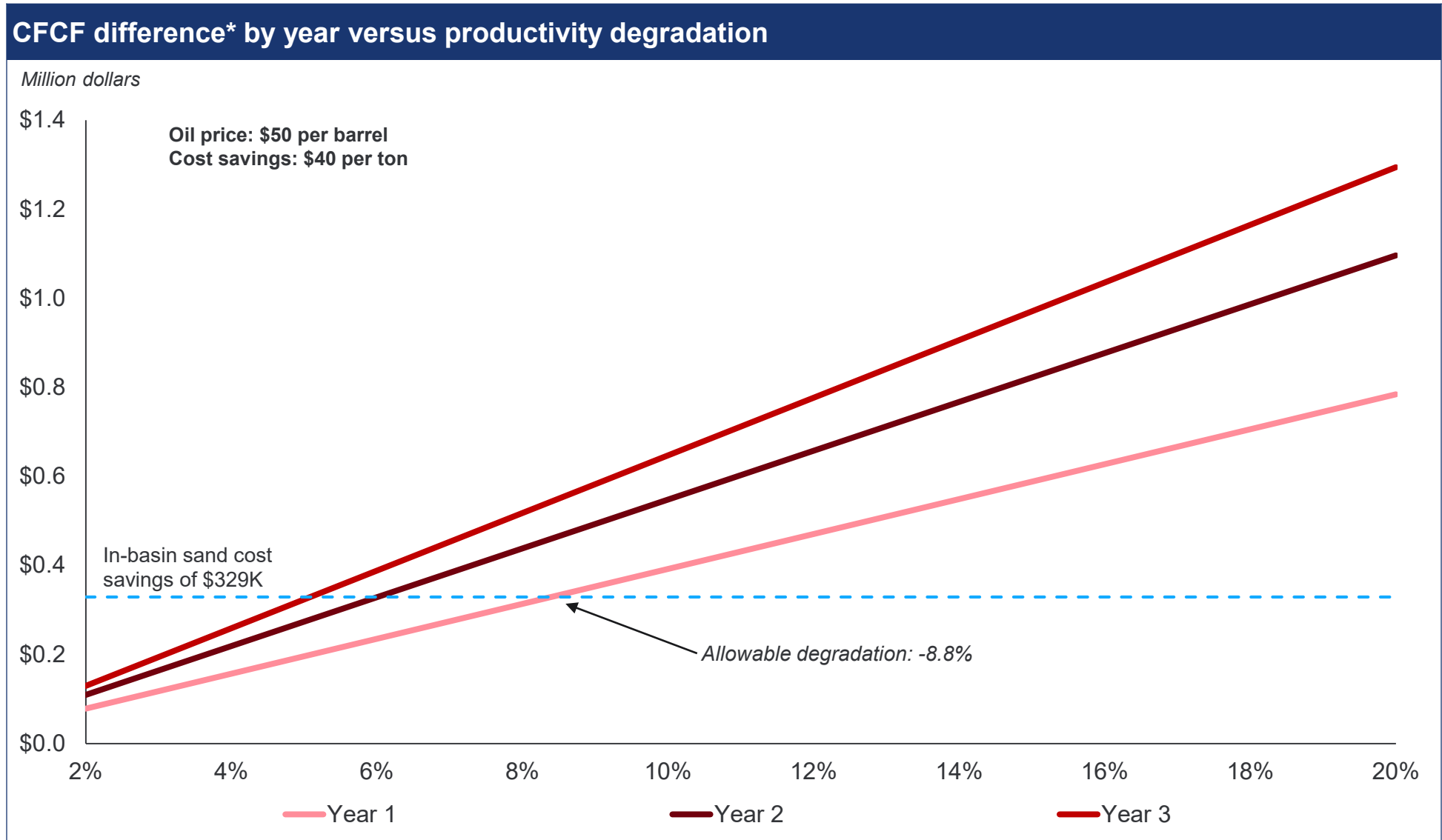
Midland Operator D : Observed degradation

Well Count (NWS)	Time Frame Assessed (NWS)	IP270 (NWS)	Well Count (In-Basin)	Time Frame Assessed (In-Basin)	IP270 (In-Basin)	Observed Change in IP270
16	1Q18 – 2Q18	13,239	33	3Q18 – 2Q19	12,304	-7.1%

\* CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis



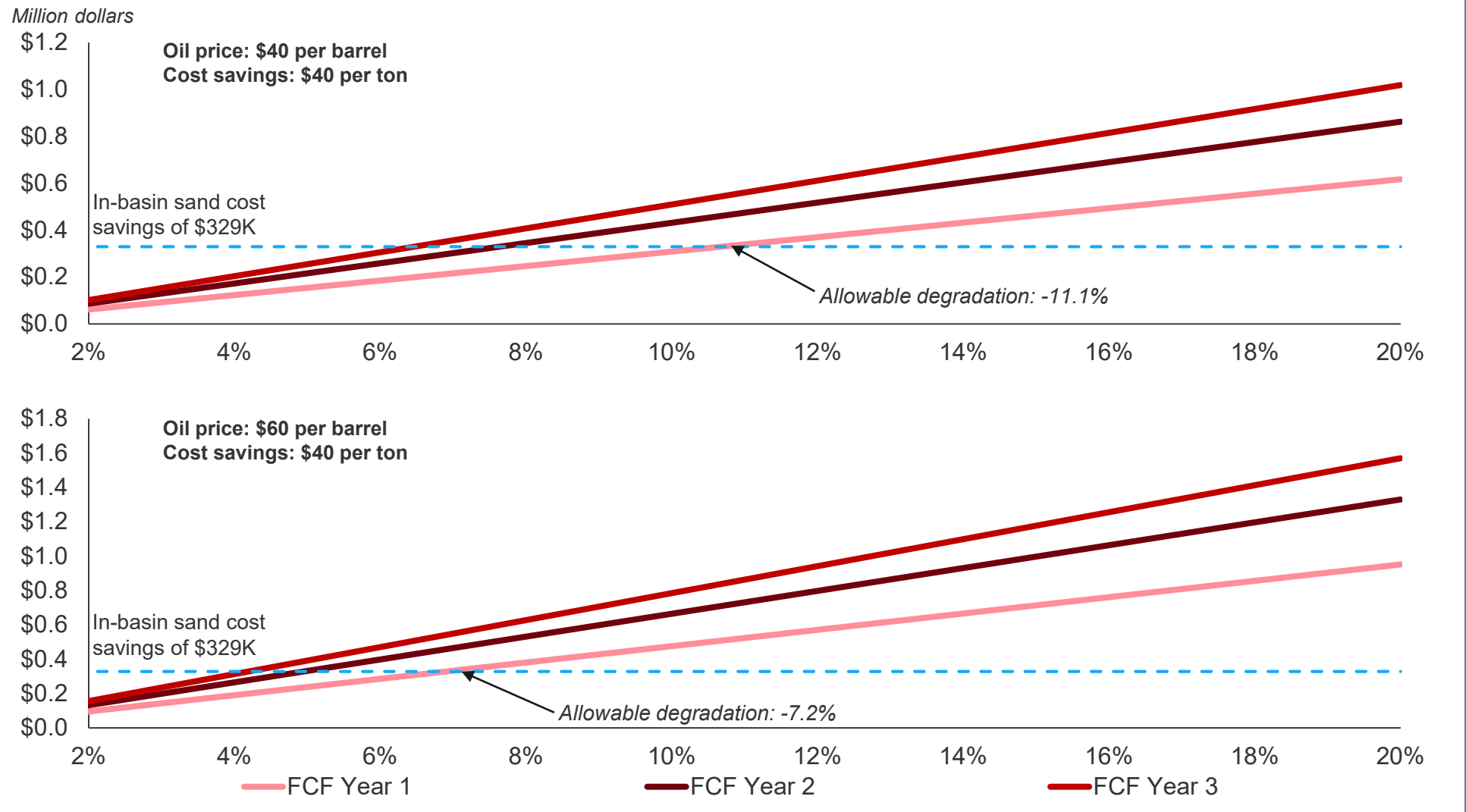
# CFCF difference would exceed cost savings in year 1 at a degradation of 8.8%



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis; CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

**\$40 per bbl oil price results in an additional 3.9% allowable degradation from \$60 oil with in-basin sand cost savings of \$40/ton**

### CFCF difference\* by year versus productivity degradation



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis; CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

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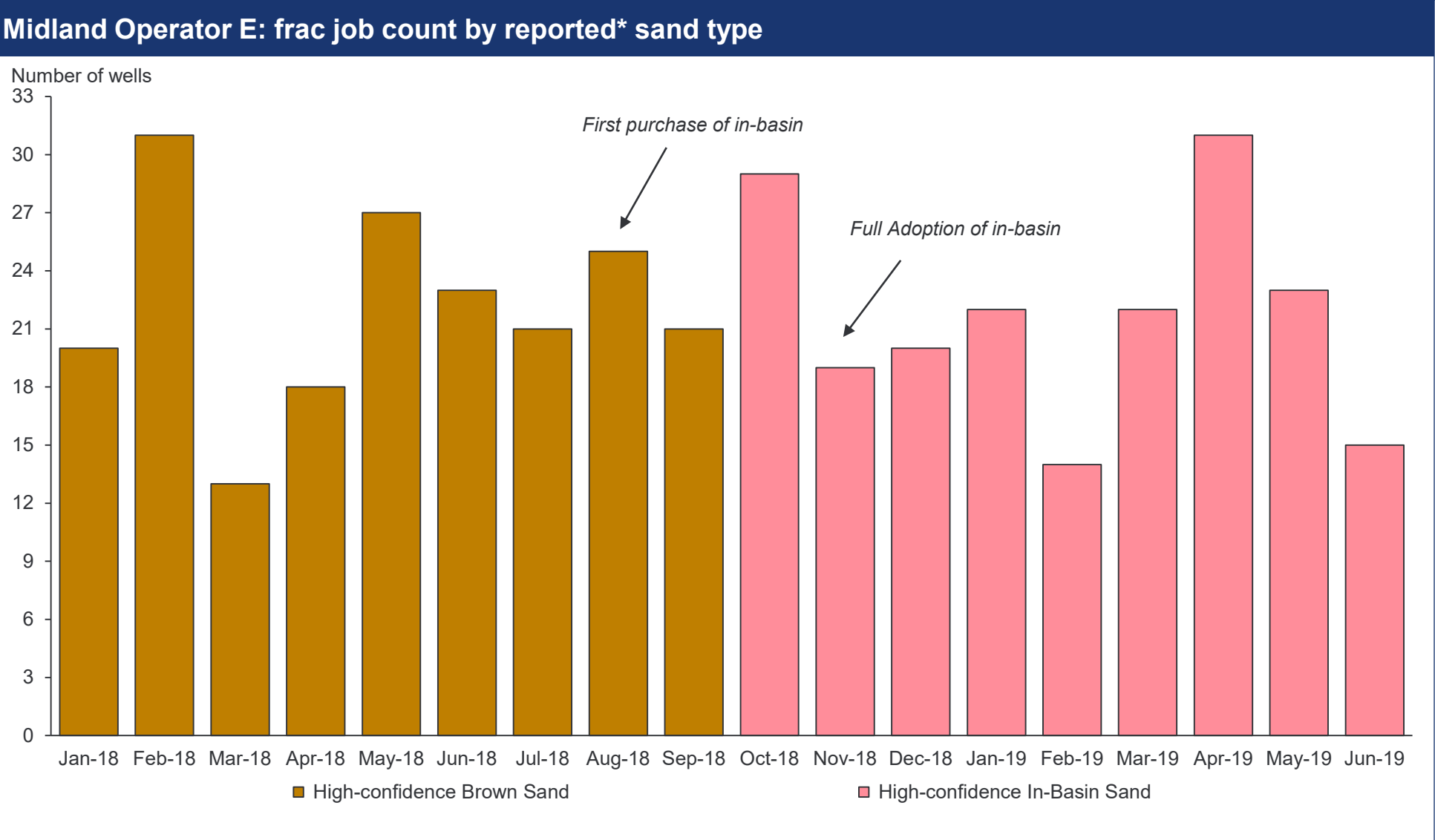
Permian Delaware

Eagle Ford

Haynesville

SCOOP/STACK

# Midland Operator E began moving away from brown sand to in-basin sand in 4Q18

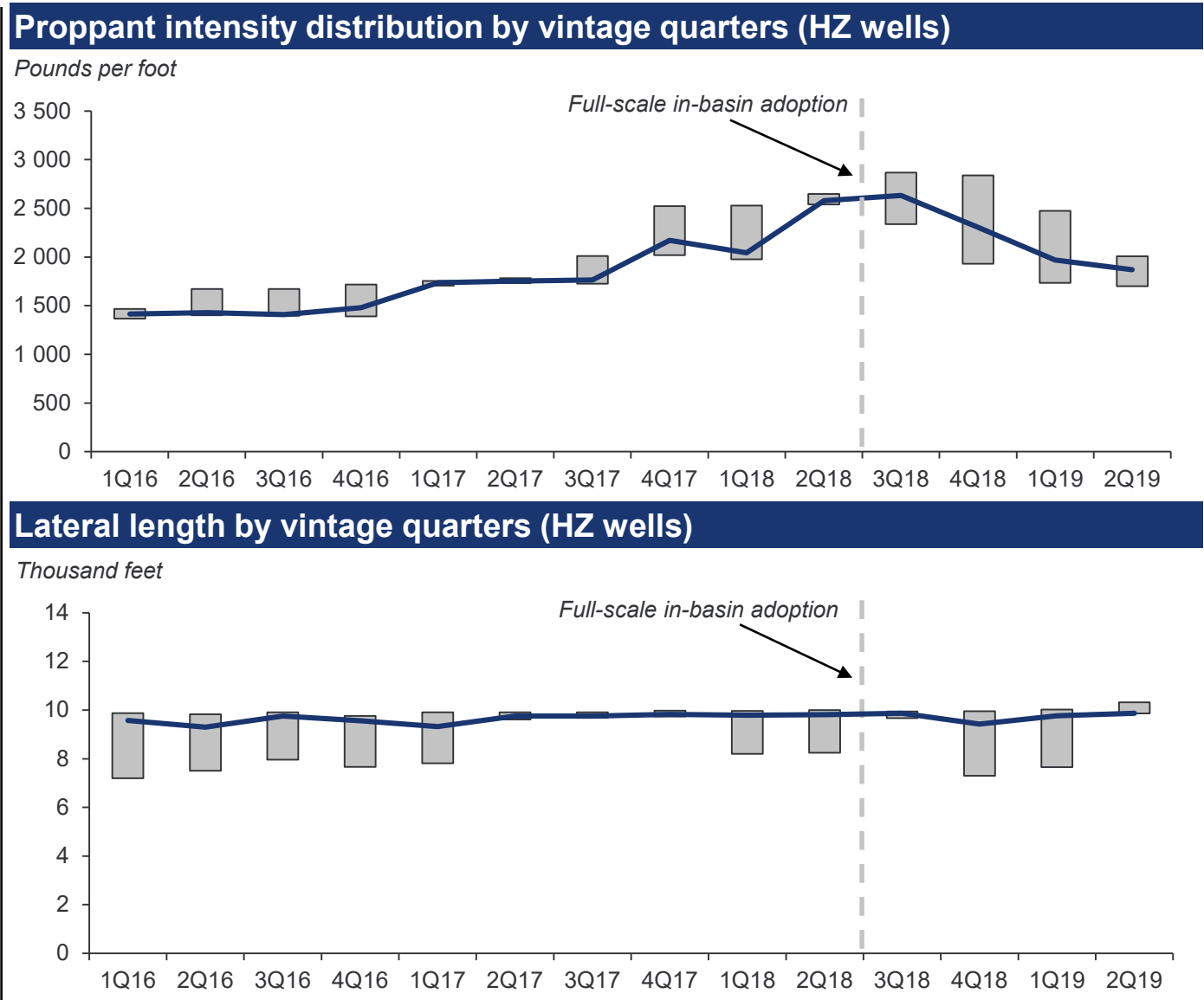


From Midland Operator E investor presentation \*Based on Rystad Energy's analysis of chemical ingredient and trade names reported to FracFocus Chemical Disclosure Registry  
Source: Rystad Energy ShaleWellCube, Midland Operator E investor presentation, Rystad Energy research and analysis

# Midland Operator E has significantly reduced proppant intensities since switching to in-basin sand

## Midland Operator E

- After years of increasing proppant intensities, Midland Operator E has drastically reduced proppant loading since switching to in-basin sand
- Lateral lengths have remained very stable over the last several years right around 10,000 feet

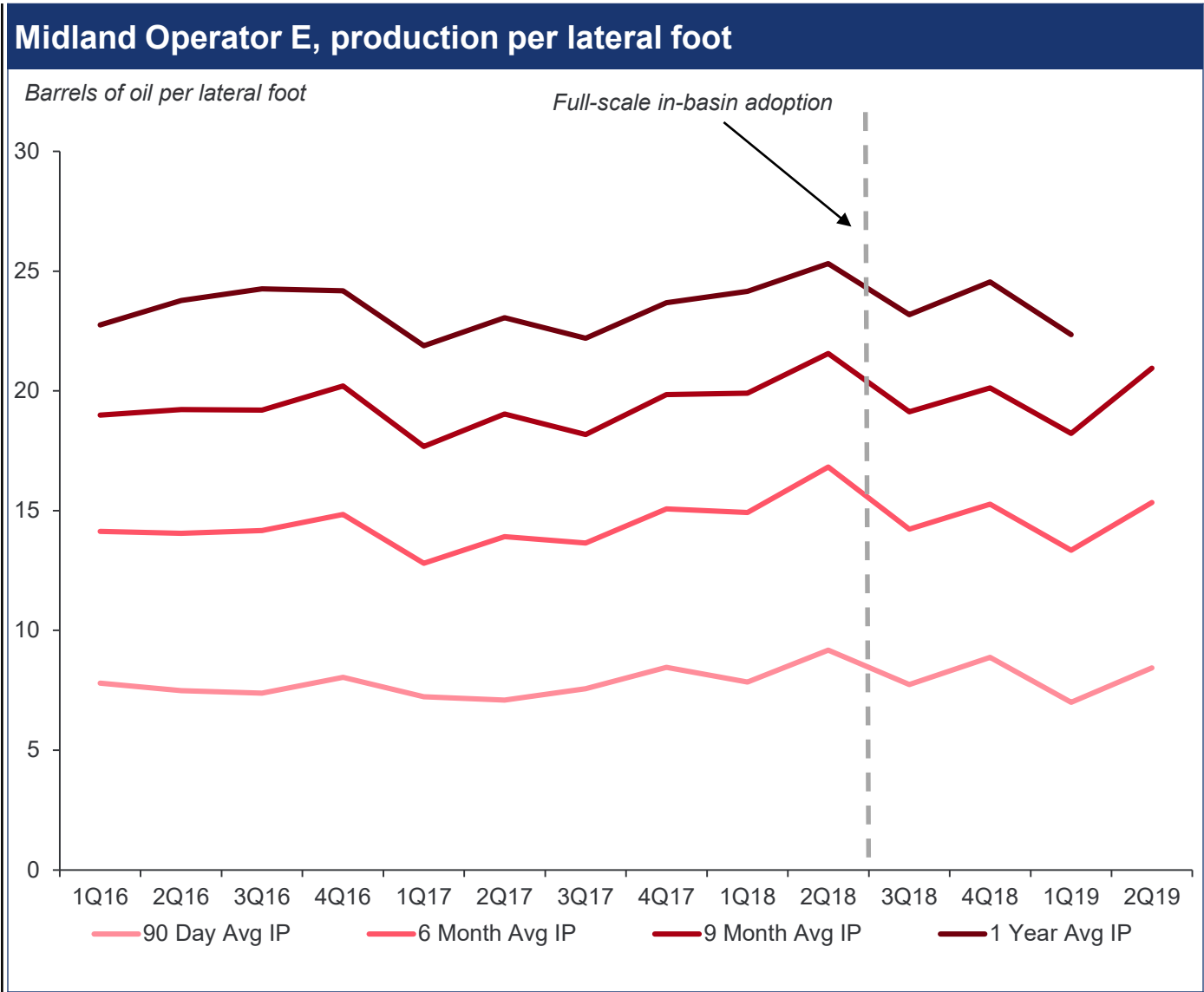


Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# Midland Operator E has seen limited productivity impact since switching from brown to in-basin sand

## Midland Operator E

- Production per lateral foot has exhibited similar quarterly fluctuations once switching completely to in-basin sand as experienced prior.
- Productivity has only moderately declined immediately following switch to in-basin sand despite significant reductions in proppant intensity levels.
- Midland Operator E has been classified as a case with '*no impact*' from switching to in-basin sand, although being compared to brown sand.

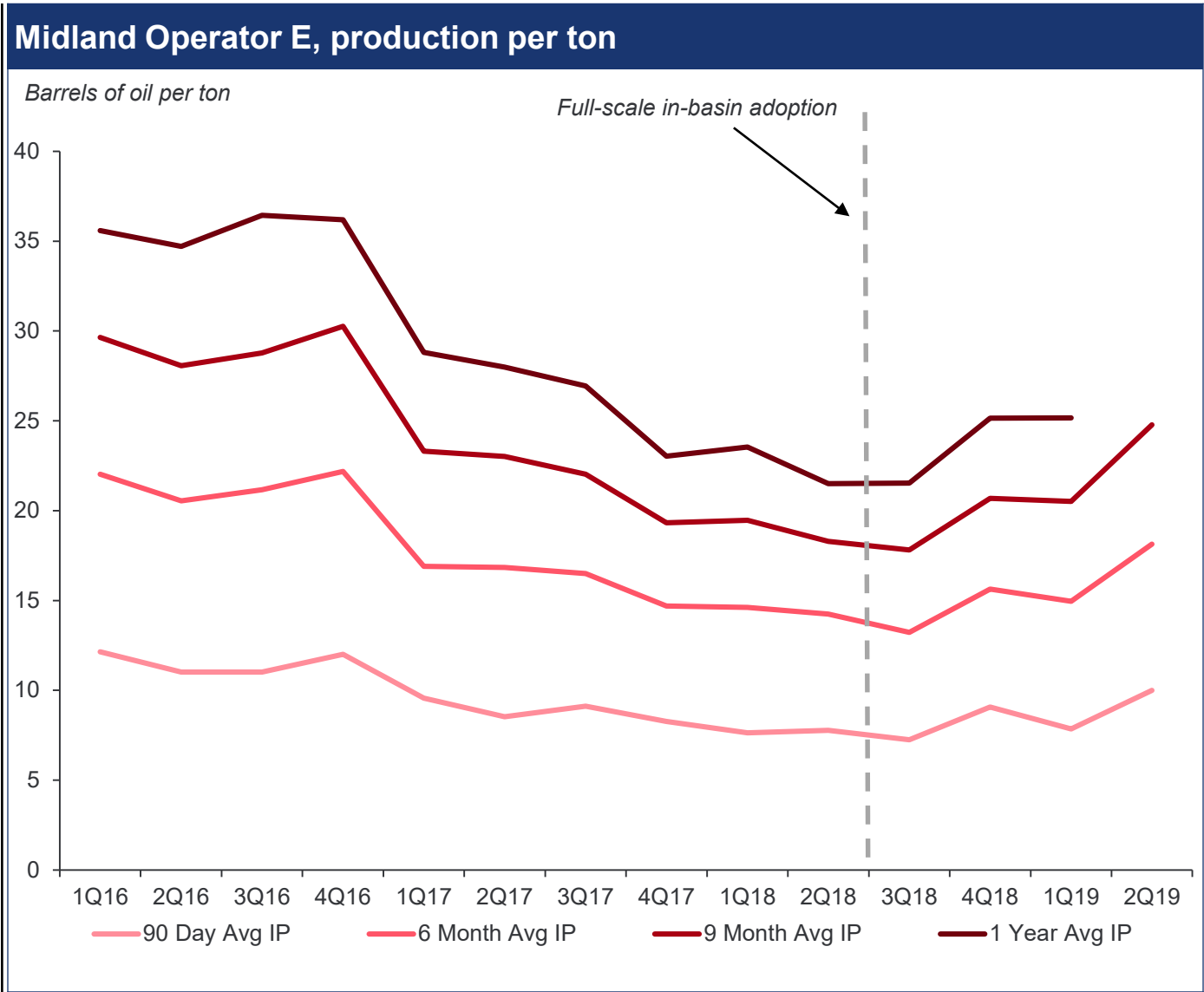


Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# Normalized by proppant use, productivity metric shows different trends, but same conclusion

## Midland Operator E

- Normalizing production by ton proppant shows a steeper drop in productivity before the switch to in-basin sand, compared with the lateral length normalization.
- Since the full-scale adoption of in-basin sand Midland Operator E has significantly reduced proppant intensities, which helps explain why production per ton has been increasing during the same period.
- The resulting combination of reduced proppant cost through lower intensities and rising production results in significant increases in margin per ton of proppant.
- Though productivity is not back to peak output from older vintages, it still tops the latest pre-switch vintages.



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

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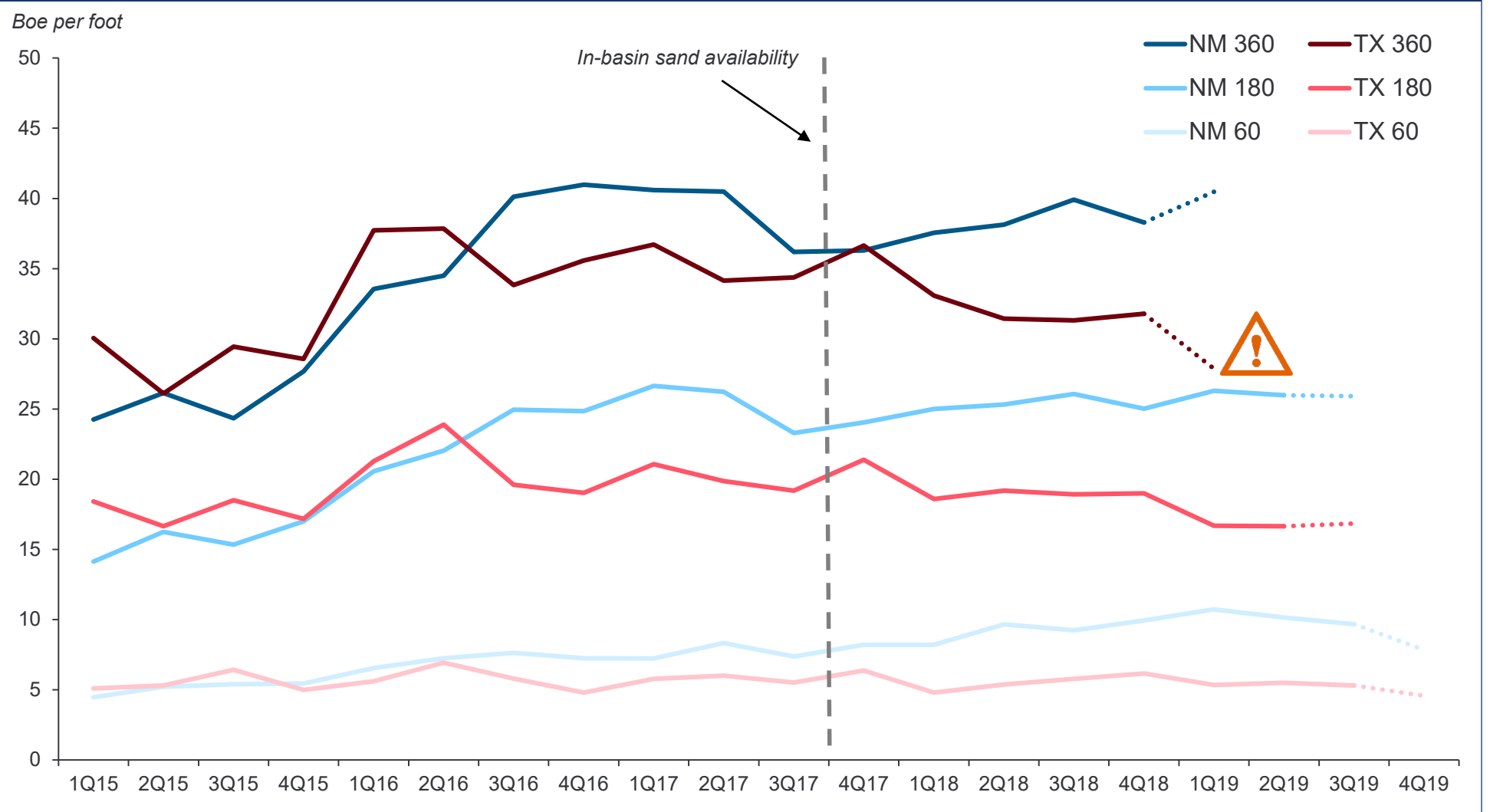
Haynesville

SCOOP/STACK



# Latest data indicates continued degradation in Delaware Texas longer term IP rates

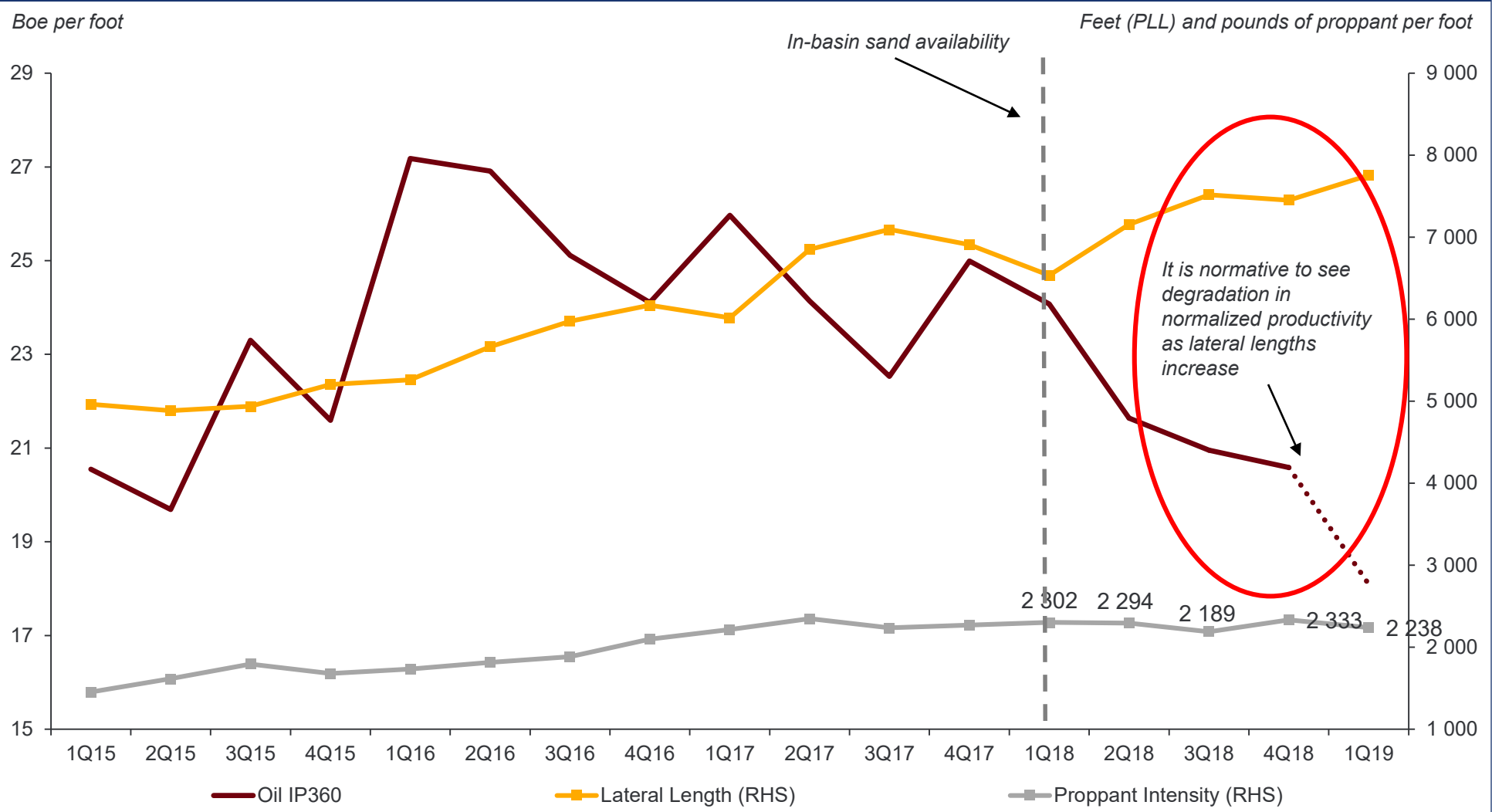
Permian Delaware: Median cumulative 2-stream production by production start year-quarter and sub-basin



Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

Recent degradation observed in the oil stream of Reeves and Loving counties paired with a steady increase in lateral length during this period

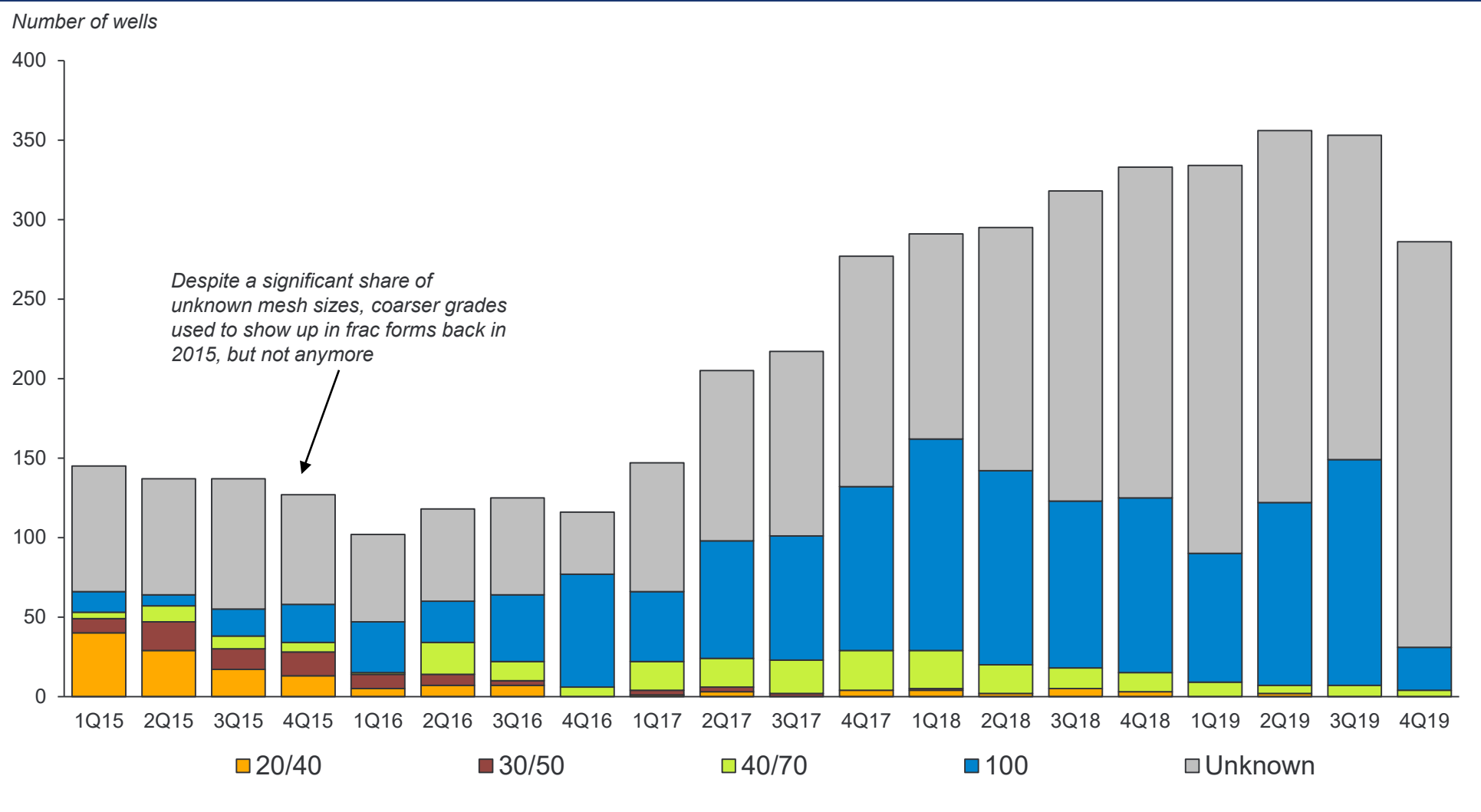
Loving and Reeves counties: average cumulative oil IP360 and key well design metrics



Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

There could be an increase in finer grades usage as 20/40 and 30/50 sand grades are not showing up like they used to post 2015

Loving and Reeves counties: wells fracked, by mesh size



Source: Rystad Energy research and analysis

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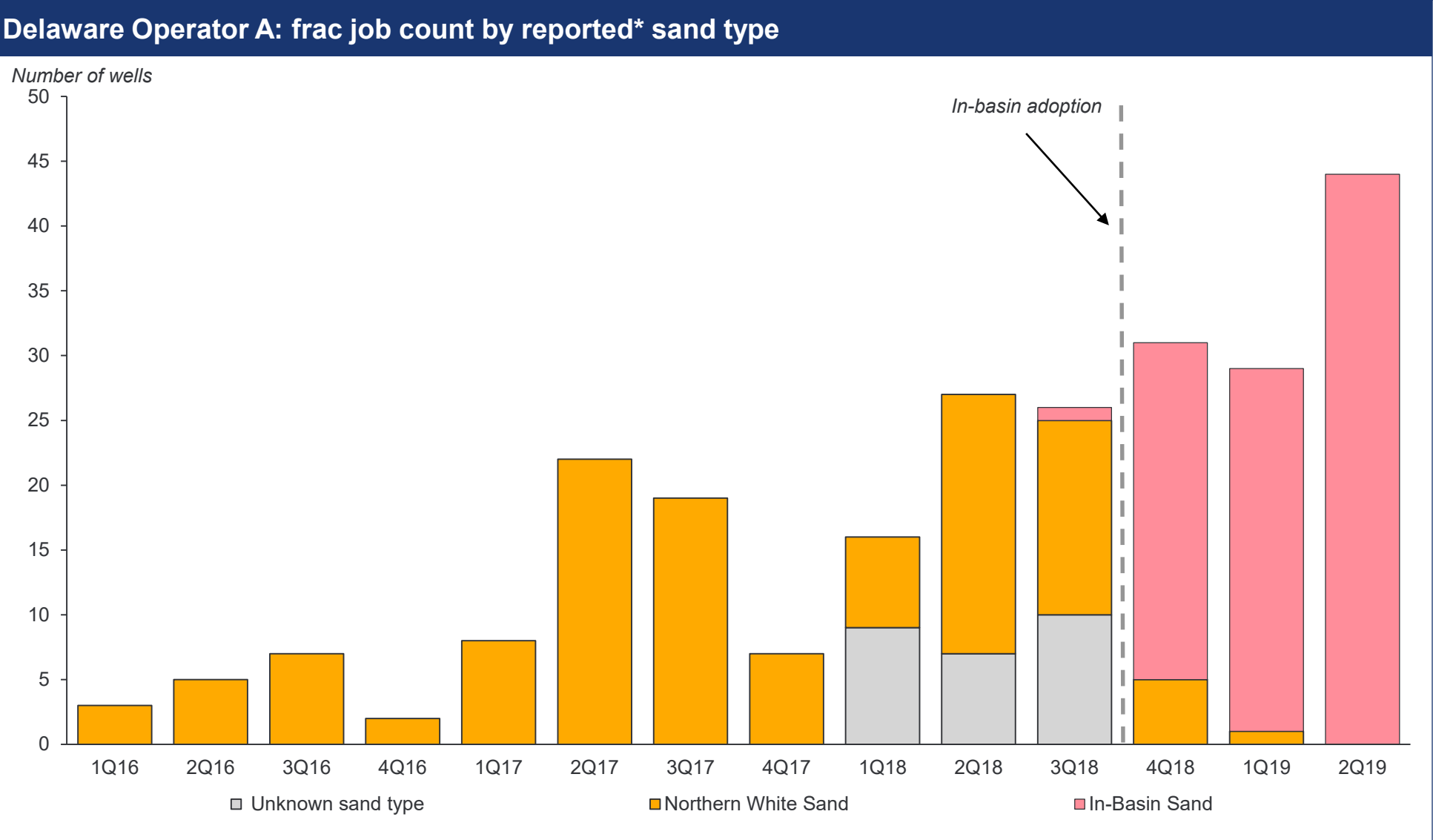
Case: Delaware Operator C

Eagle Ford

Haynesville

SCOOP/STACK

# Delaware Operator A started using in-basin sand from 3Q18

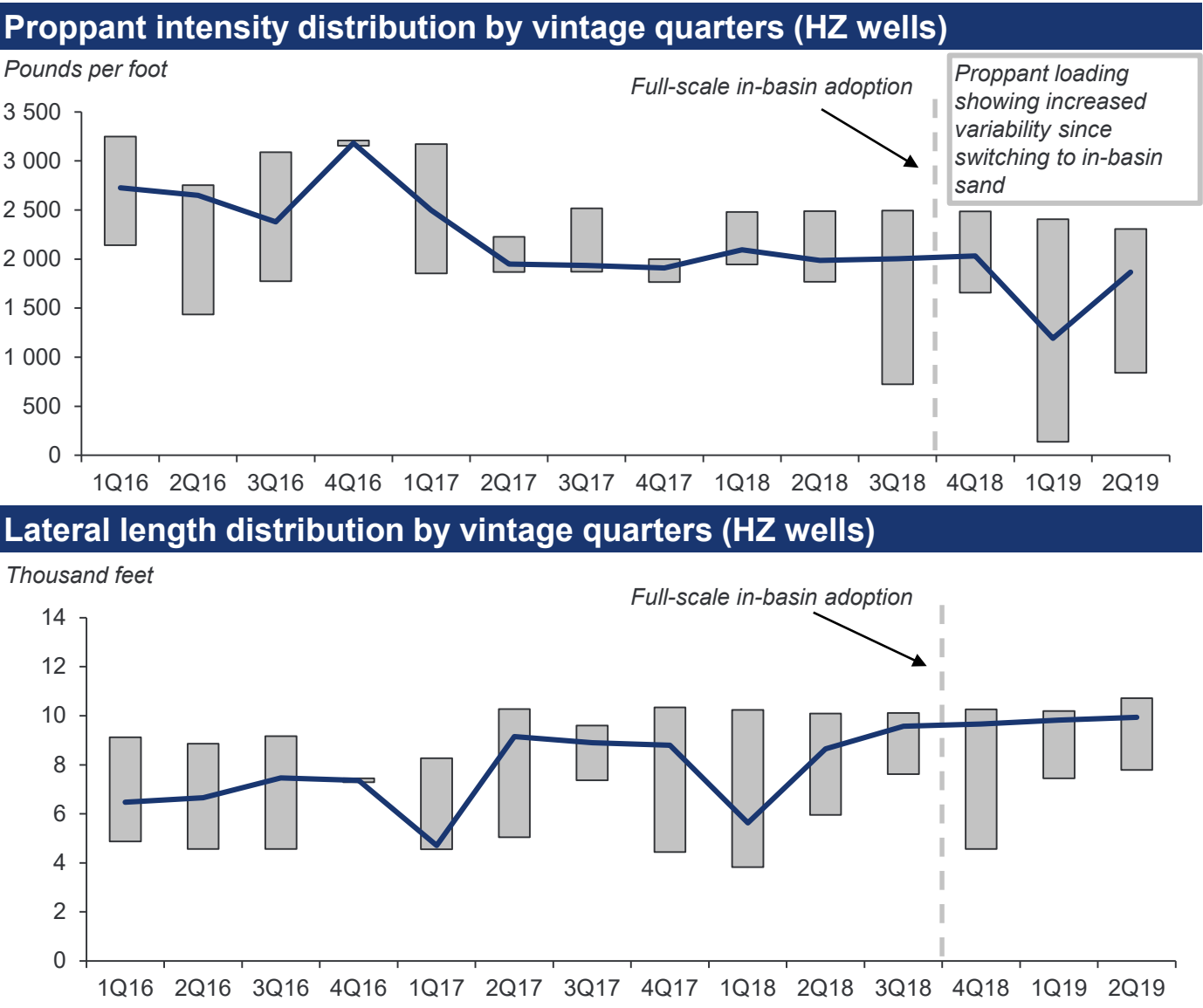


\*From Delaware Operator A's investor presentation. Based on Rystad Energy's analysis of chemical ingredient and trade names reported to FracFocus Chemical Disclosure Registry  
Source: Rystad Energy ShaleWellCube, Delaware Operator A's investor presentation, Rystad Energy research and analysis

# Proppant intensities have shown increased variability since switching to in-basin sand while lateral lengths have remained consistent

## Delaware Operator A

- Lateral length has remained steady at around 10,000 feet since switching to in-basin sand.
- Overall, proppant intensity has decreased since switching to in-basin sand, but the variability has increased during this time.

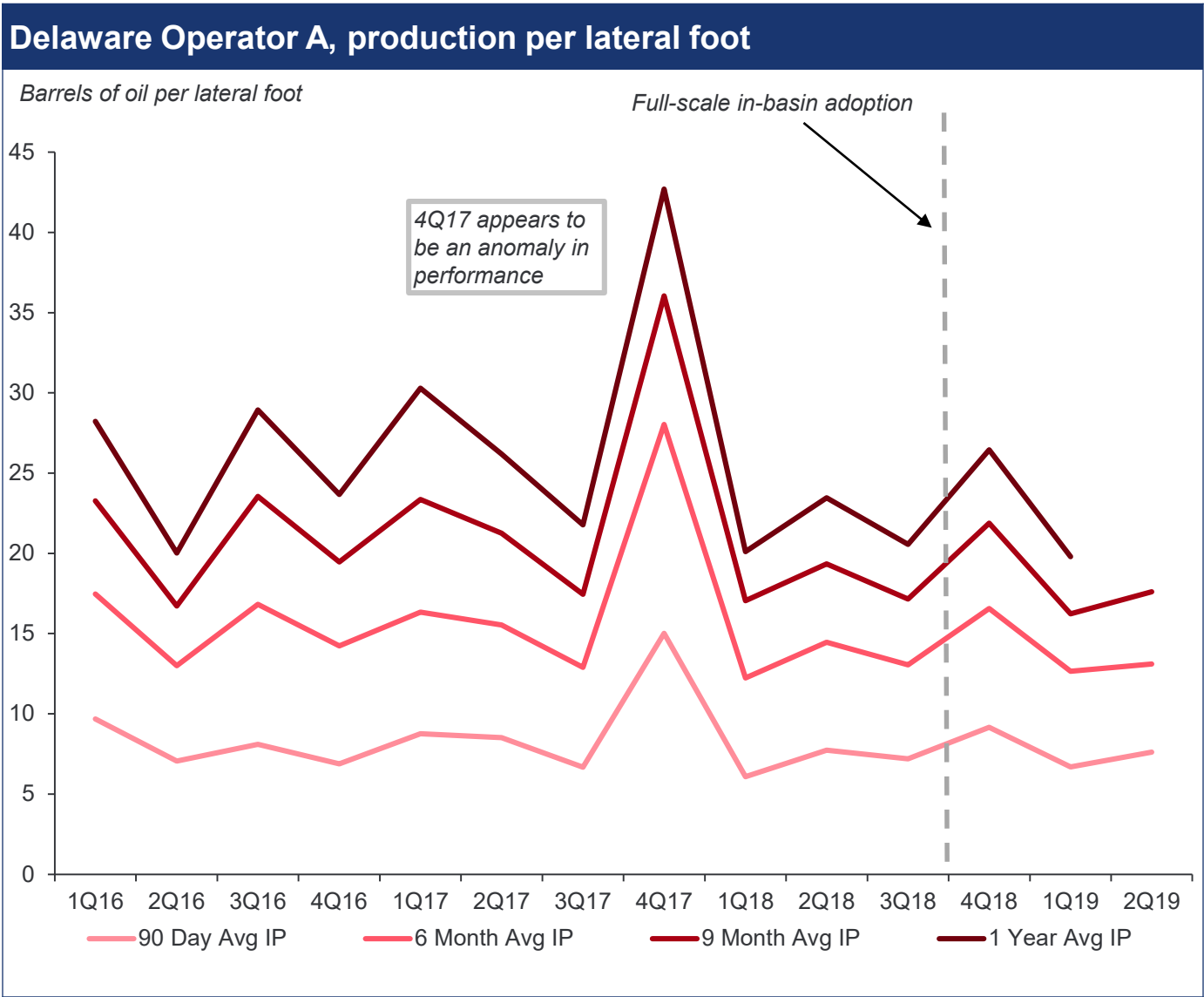


Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# Delaware Operator A exhibits some decline in productivity since switching to in-basin sand due to declines in longer term IP rates

## Delaware Operator A

- Despite stable lateral lengths, production per lateral foot has seen a reduction following complete adoption of in-basin sand.
- Longer-term IP rates have seen a greater impact on productivity since switching to in-basin sand, compared to relatively flat production per lateral foot for IP90 and IP180.
- Delaware Operator A has been classified as a case with '*light impact*' from switching to in-basin sand as we do observe some decline.

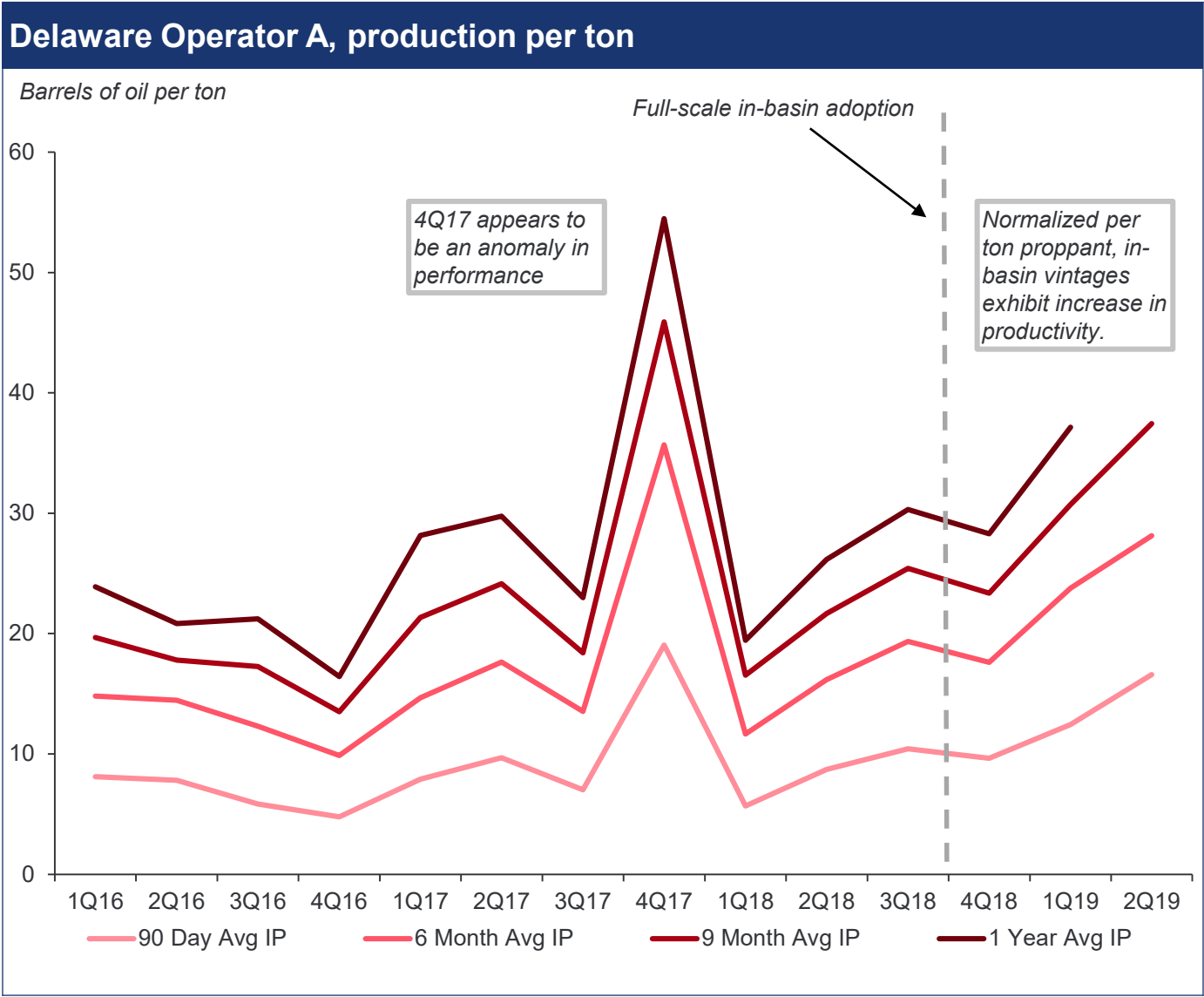


Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# Production per ton shows different trends, likely driven by higher proppant loading variability

## Delaware Operator A

- Proppant intensity variability has increased since switching to in-basin sand, which may explain the increases shown in all IP rates once normalized for proppant.
- In addition to increased variability, the overall proppant loading has slightly declined since the switch to in-basin, thus yielding an *increase* in productivity, which is the opposite trend of the production per foot metric, thus making the case less conclusive.



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis



Delaware Operator A average IP270 per foot declined 6.4% once switching completely to in-basin sand, slightly greater than the allowable degradation of 6.1%

Delaware Operator A: Economic Model Parameters

Parameters	NWS	In-Basin	Actual In-Basin
Lateral length	8,174	8,174	9,000
Proppant intensity	1,987	1,987	1,905
D&C cost (\$)	\$8.8 MM	\$8.5 MM	\$8.5 MM
Oil price, \$ per bbl	\$50.00	\$50.00	\$50.00
Gas price, \$ per boe	\$6.00	\$6.00	\$6.00
Cost savings per ton	\$40	\$40	\$40

Delaware Operator A : Allowable degradation

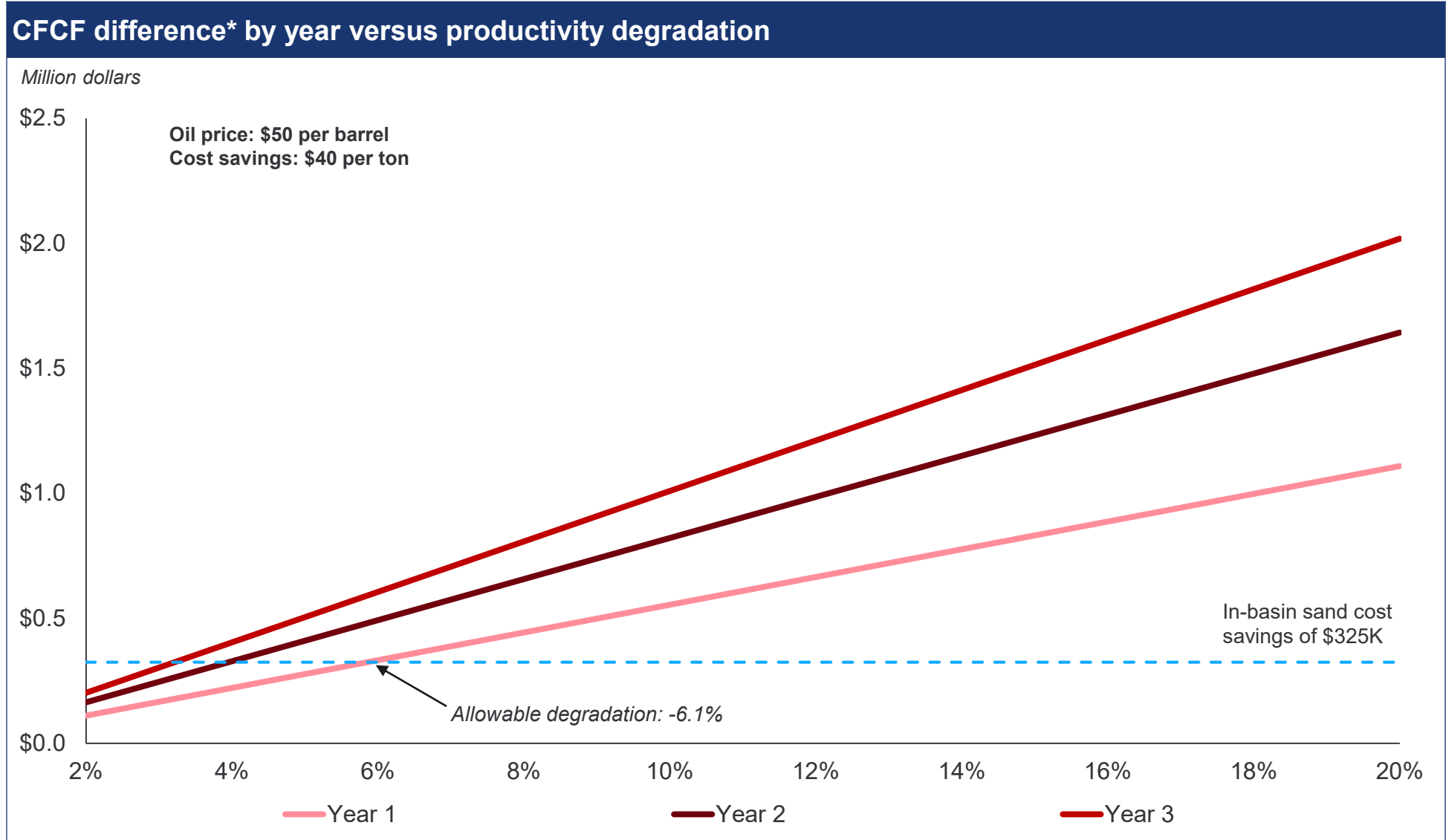
Year	Allowable Degradation	Total cost savings	CFCF Difference* Year 1	CFCF Difference Year 2	CFCF Difference Year 3
1	-6.1%	\$325K	\$339K	\$503K	\$618K
2	-4.3%	\$325K	\$236K	\$350K	\$430K
3	-3.6%	\$325K	\$198K	\$293K	\$360K

Delaware Operator A : Observed degradation

Well Count (NWS)	Time Frame Assessed (NWS)	IP270 (NWS)	Well Count (In-Basin)	Time Frame Assessed (In-Basin)	IP270 (In-Basin)	Observed Change in IP270
61	2Q17 – 3Q18	19,420	81	3Q18 – 2Q19	18,180	-6.4%

\* CFCF difference is defined as the difference between cumulative net cash flow from a northern white sand and in-basin sand well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

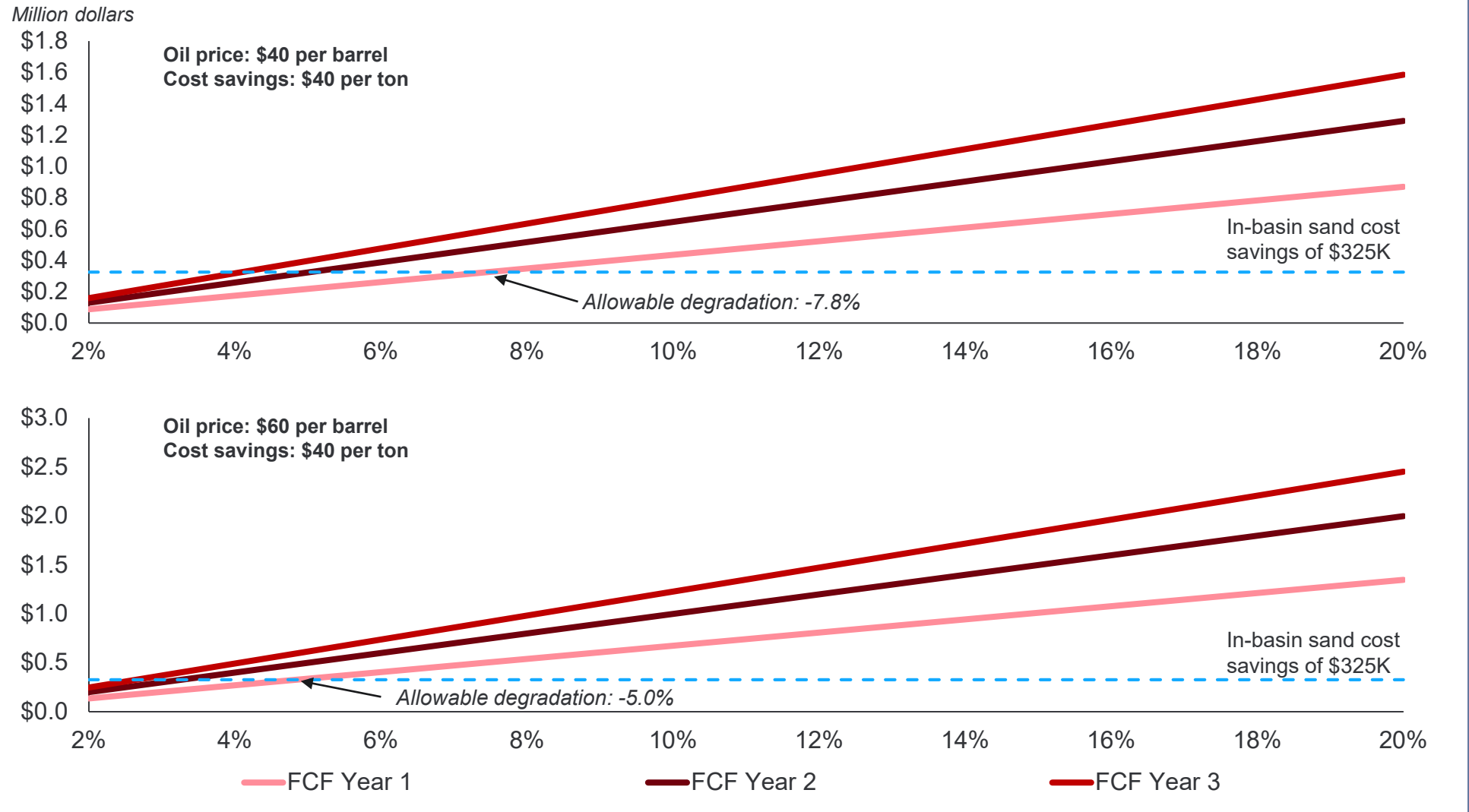
CFCF difference would exceed cost savings in Year 1 at a degradation greater than 6.1%



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis; CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

**\$40 per bbl oil price results in an additional 2.8% allowable degradation from \$60 oil assuming in-basin sand cost savings of \$40/ton**

## CFCF difference\* by year versus productivity degradation



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis; CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

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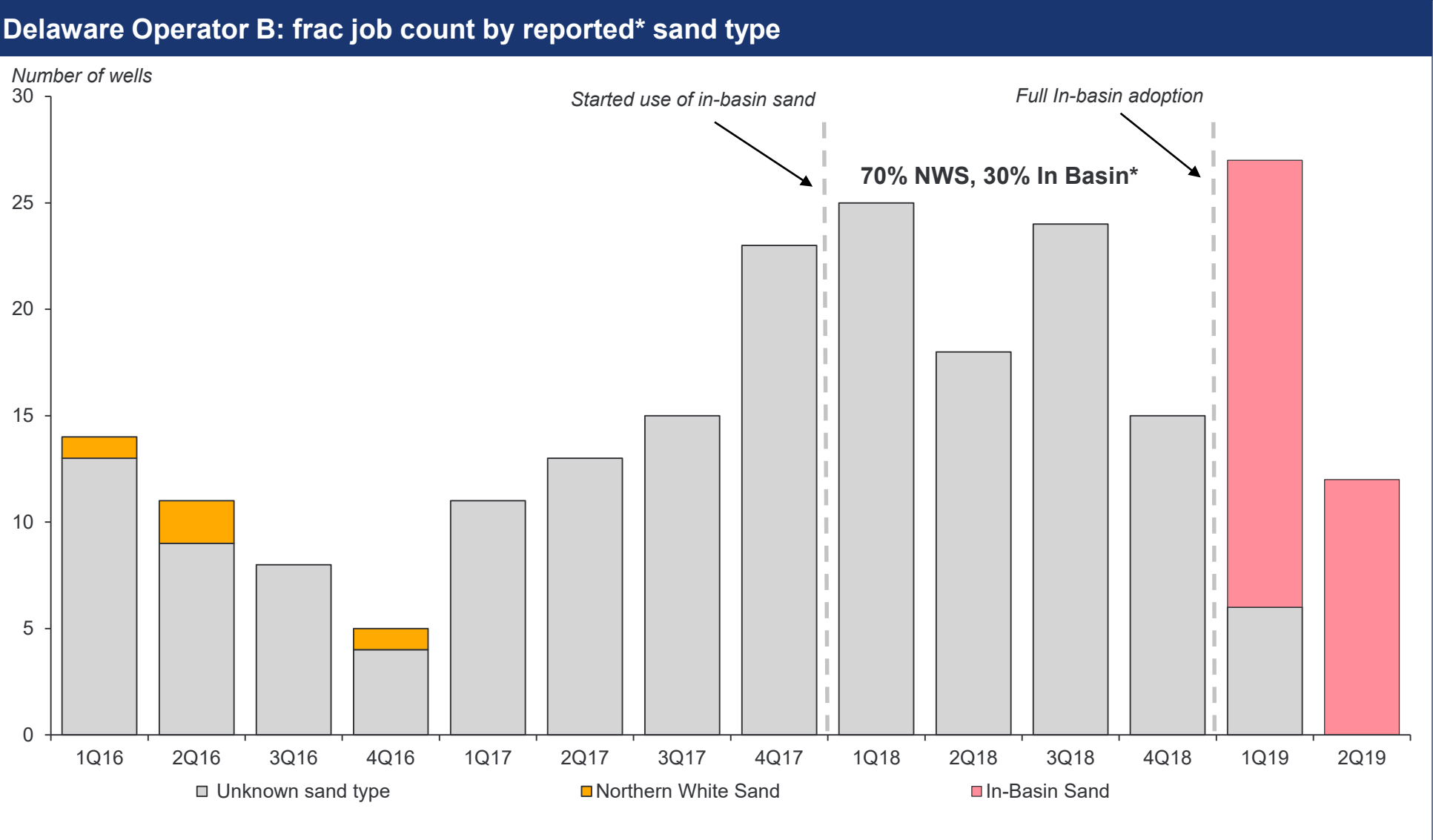
  - Case: Delaware Operator C

- Eagle Ford

- Haynesville

- SCOOP/STACK

Delaware Opreator B fully adopted in-basin sand in 2019 after having tested it throughout 2018

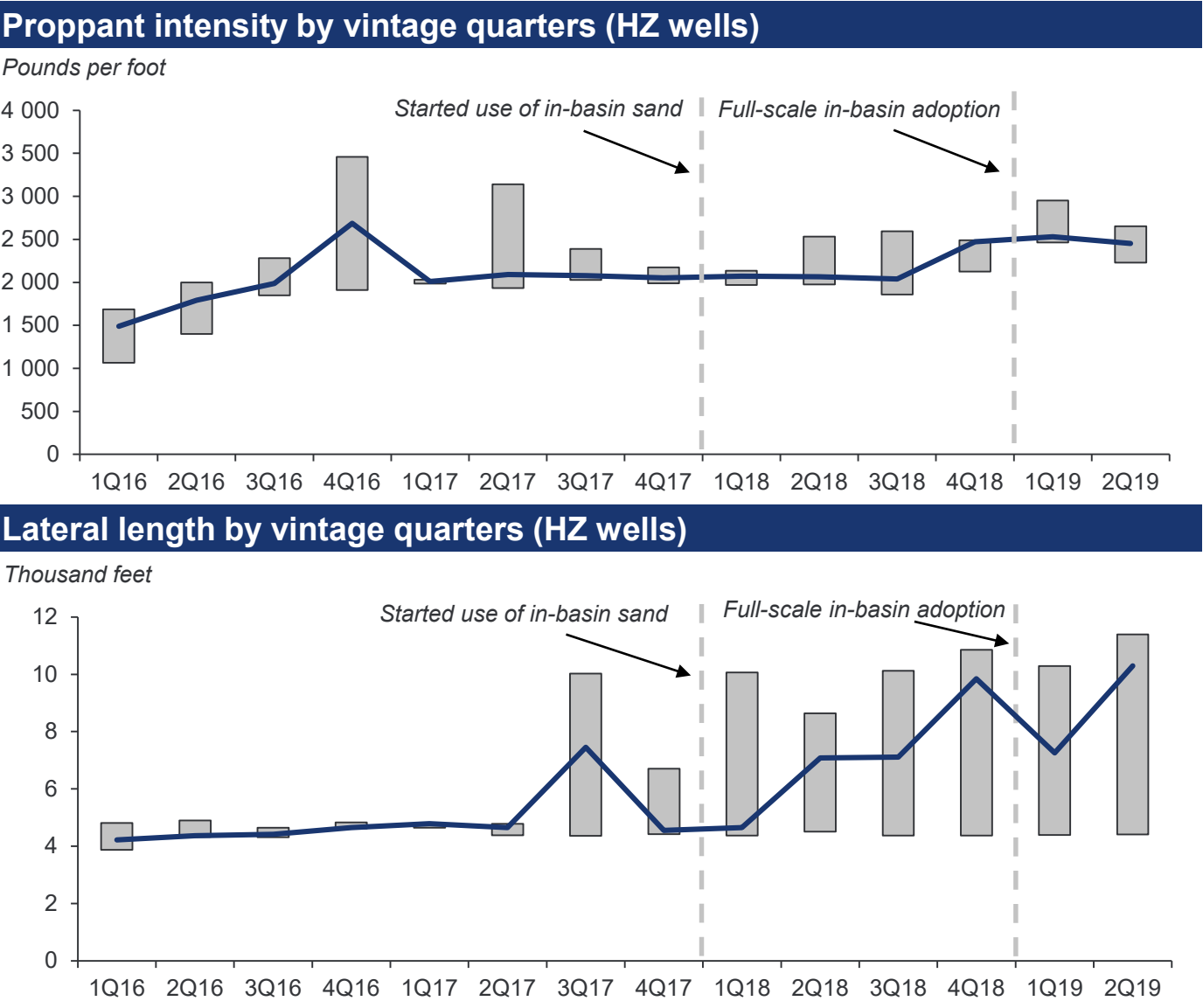


\*From primary intelligence sources. Based on Rystad Energy’s analysis of chemical ingredient and trade names reported to FracFocus Chemical Disclosure Registry  
Source: Rystad Energy ShaleWellCube, primary intelligence, Rystad Energy research and analysis

# Delaware Operator B has increased both lateral lengths and proppant intensity since switching to in-basin sand

## Delaware Operator B

- Delaware Operator B began significantly increasing lateral lengths after the first initial use of in-basin sand, continuing into full-scale adoption
- Proppant intensity levels began increasing around the same time, perhaps in an effort to offset production declines from increasing laterals

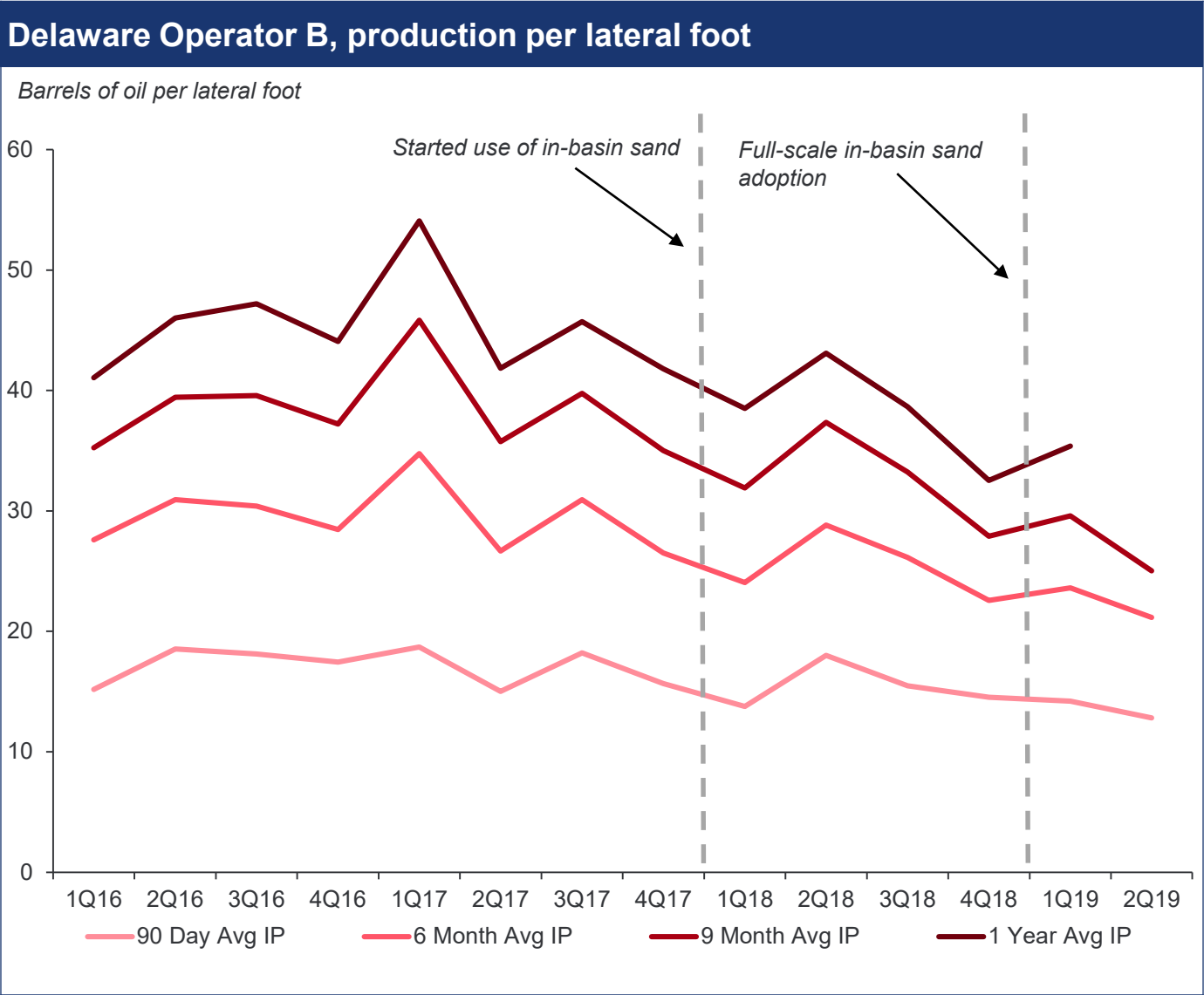


Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

Delaware Operator B exhibits clear decline in productivity, but production declines prior to and after in-basin adoption makes it more challenging to draw firm conclusions

Delaware Operator B

- As expected, production per lateral foot has been decreasing as Delaware Operator B has steadily increased lateral lengths from 3Q 2017
- Given that it is normative to see degradation in normalized production with increasing laterals it is difficult to pin-point the exact cause of production declines after switching to in-basin sand, as the declines started before the switch
- This trend could be due to a shift to finer mesh sand; however, mesh size data isn't available in the public domain to make a definitive conclusion
- Overall though, the decline in productivity is still strong so Delaware Operator B has been classified as a case with 'impact' from switching to in-basin sand

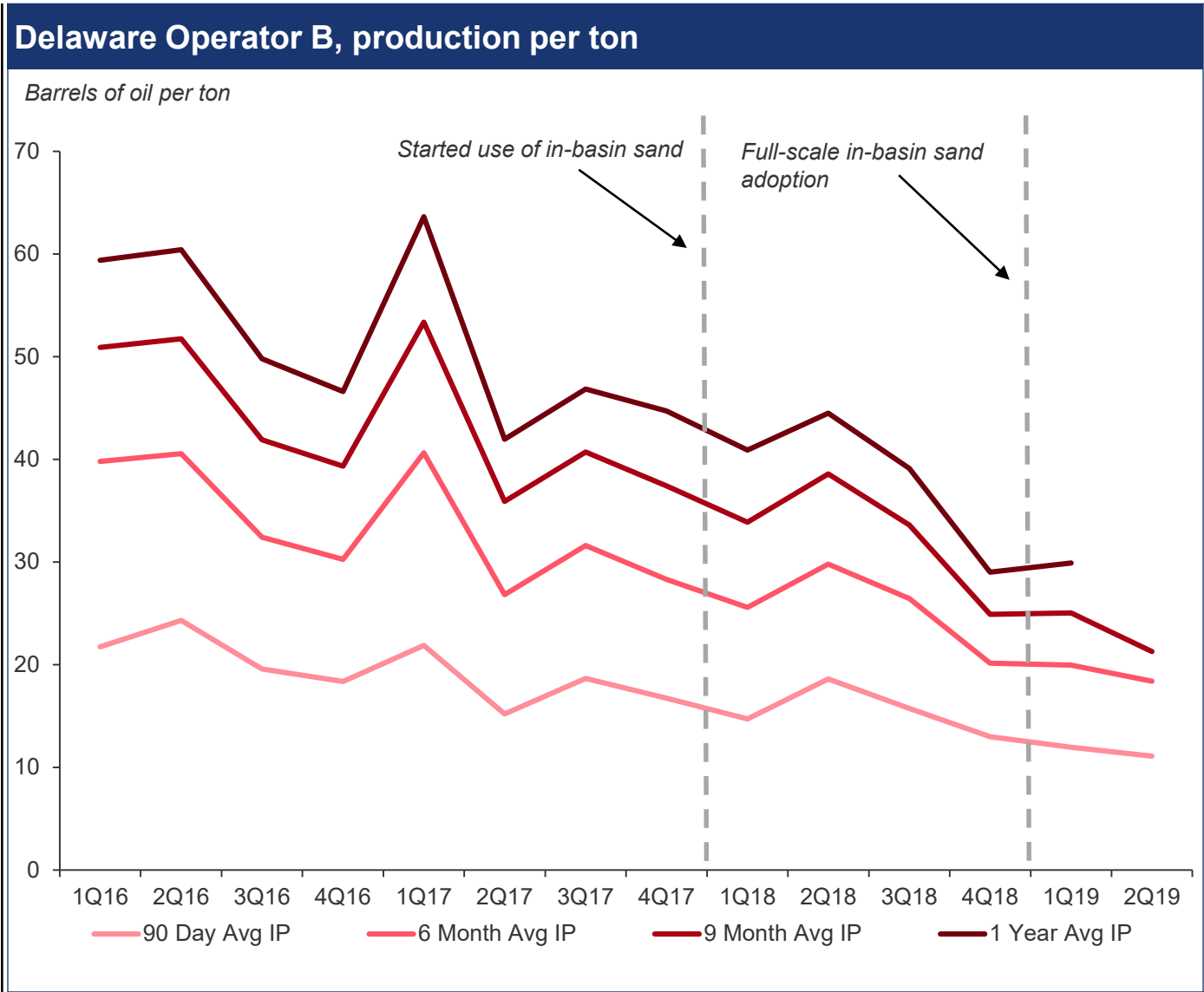


Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# Production per ton across all IP rates shows same trends as productivity per foot

## Delaware Operator B

- Production per ton has been steadily decreasing since 3Q 2017, when Delaware Operator B began significantly increasing lateral lengths, similar to production per lateral foot, though the trend is even clearer.
- From the point of first in-basin usage Delaware Operator B began increasing proppant intensity levels as well, which has not done any material good to stop production declines, but trend could also be due to a shift to finer mesh sand.



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis



Delaware Operator B exhibits a 12.0% reduction in average IP270 once switching completely to in-basin sand, much greater than the allowable first year degradation of 4.3%

#### Delaware Operator B: Economic Model Parameters

Parameters	NWS	In-Basin	Actual In-Basin
Lateral length	4,795	4,795	6,973
Proppant intensity	2,069	2,069	2,580
D&C cost (\$)	\$5.8 MM	\$5.6 MM	\$5.4 MM
Oil price, \$ per bbl	\$50.00	\$50.00	\$50.00
Gas price, \$ per boe	\$6.00	\$6.00	\$6.00
Cost savings per ton	\$40	\$40	\$40

#### Delaware Operator B : Allowable degradation

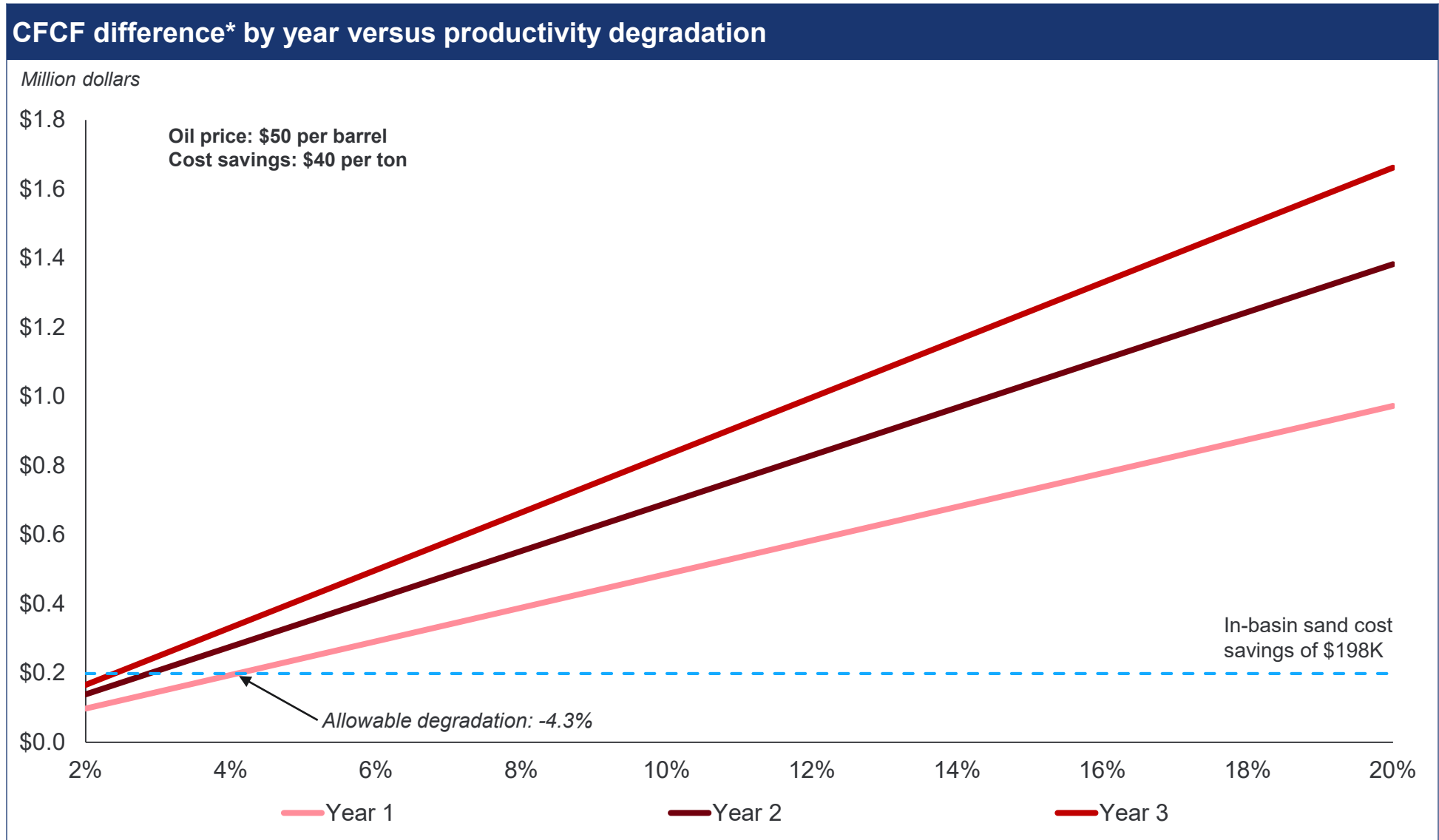
Year	Allowable Degradation	Total cost savings	CFCF Difference* Year 1	CFCF Difference Year 2	CFCF Difference Year 3
1	-4.3%	\$198K	\$207K	\$295K	\$354K
2	-3.1%	\$198K	\$150K	\$213K	\$256K
3	-2.6%	\$198K	\$128K	\$181K	\$218K

#### Delaware Operator B : Observed degradation

Well Count (NWS)	Time Frame Assessed (NWS)	IP270 (NWS)	Well Count (In-Basin)	Time Frame Assessed (In-Basin)	IP270 (In-Basin)	Observed Change in IP270
31	3Q18 – 4Q18	31,806	31	1Q19 – 2Q19	27,980	-12.0%

Note: Only wells with at least 40% cumulative light oil content have been included in the analysis; CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

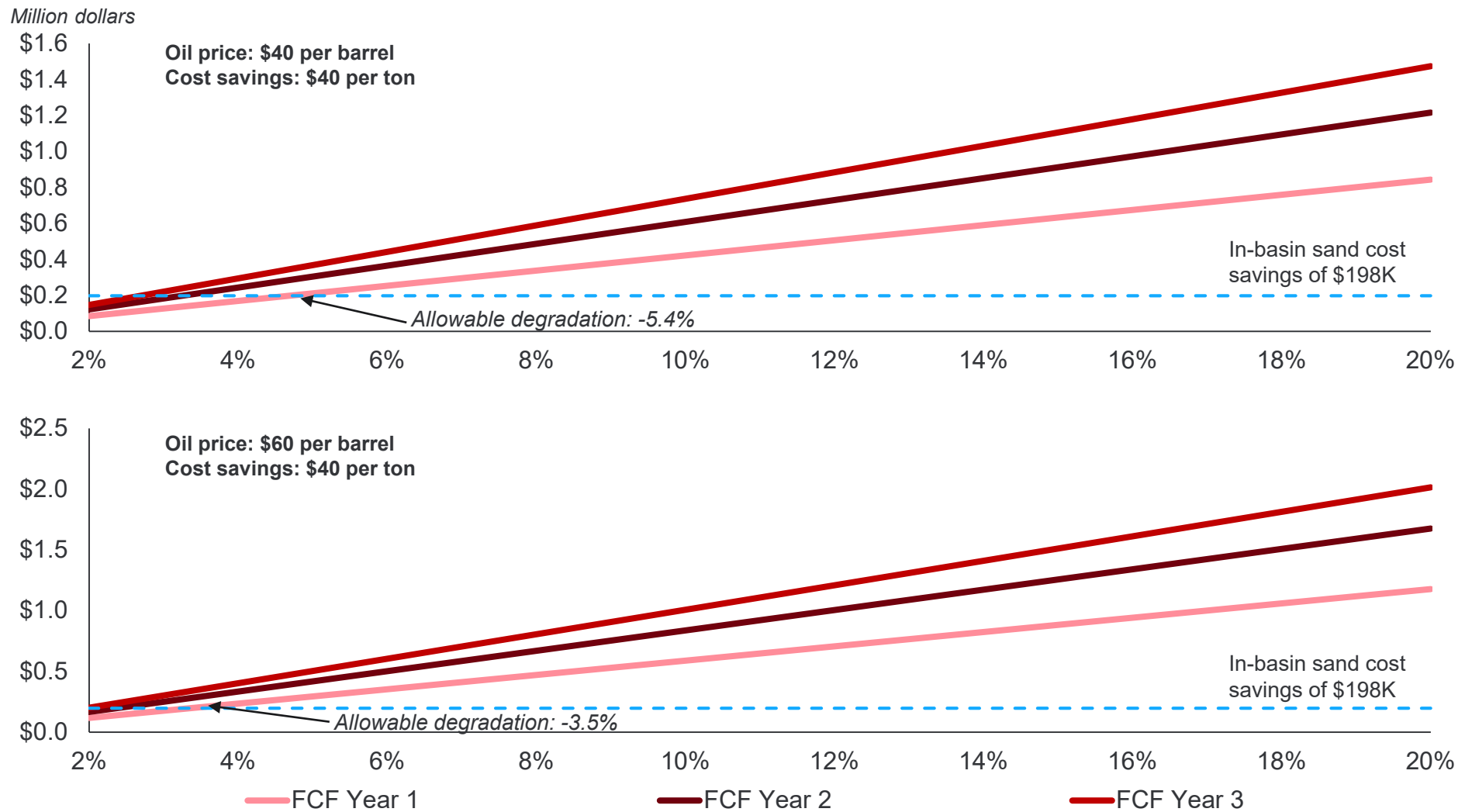
# CFCF difference would exceed cost savings in Year 1 at a degradation greater than 4.3%



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis; CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# Allowable degradation at \$40 per bbl oil still far below observed decline in productivity

## CFCF difference\* by year versus productivity degradation



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis; CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

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Case: Delaware Operator A

Case: Delaware Operator B

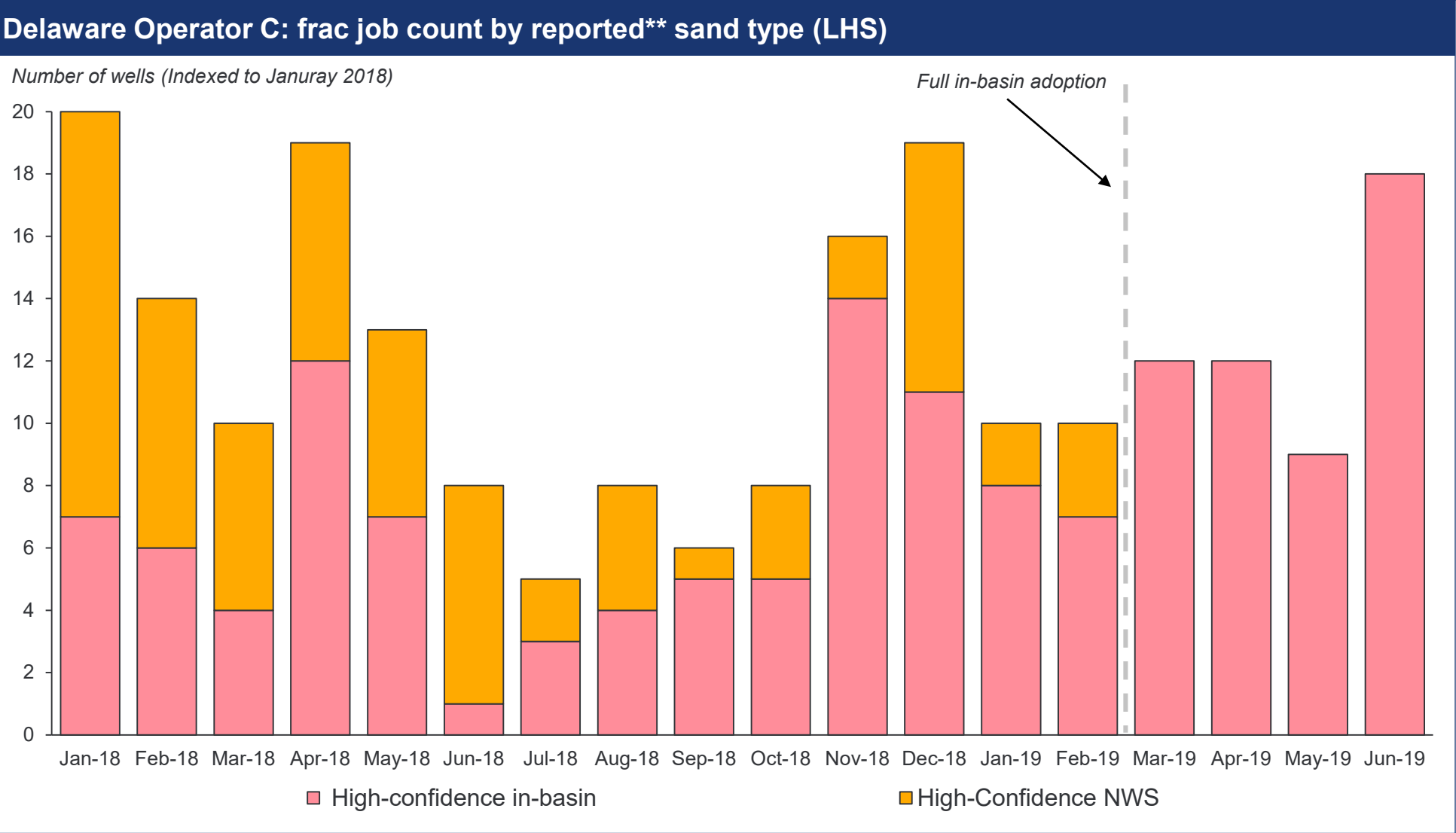
Case: Delaware Operator C

Eagle Ford

Haynesville

SCOOP/STACK

# Delaware Operator C shifted to full-scale in-basin sand adoption from March 2019

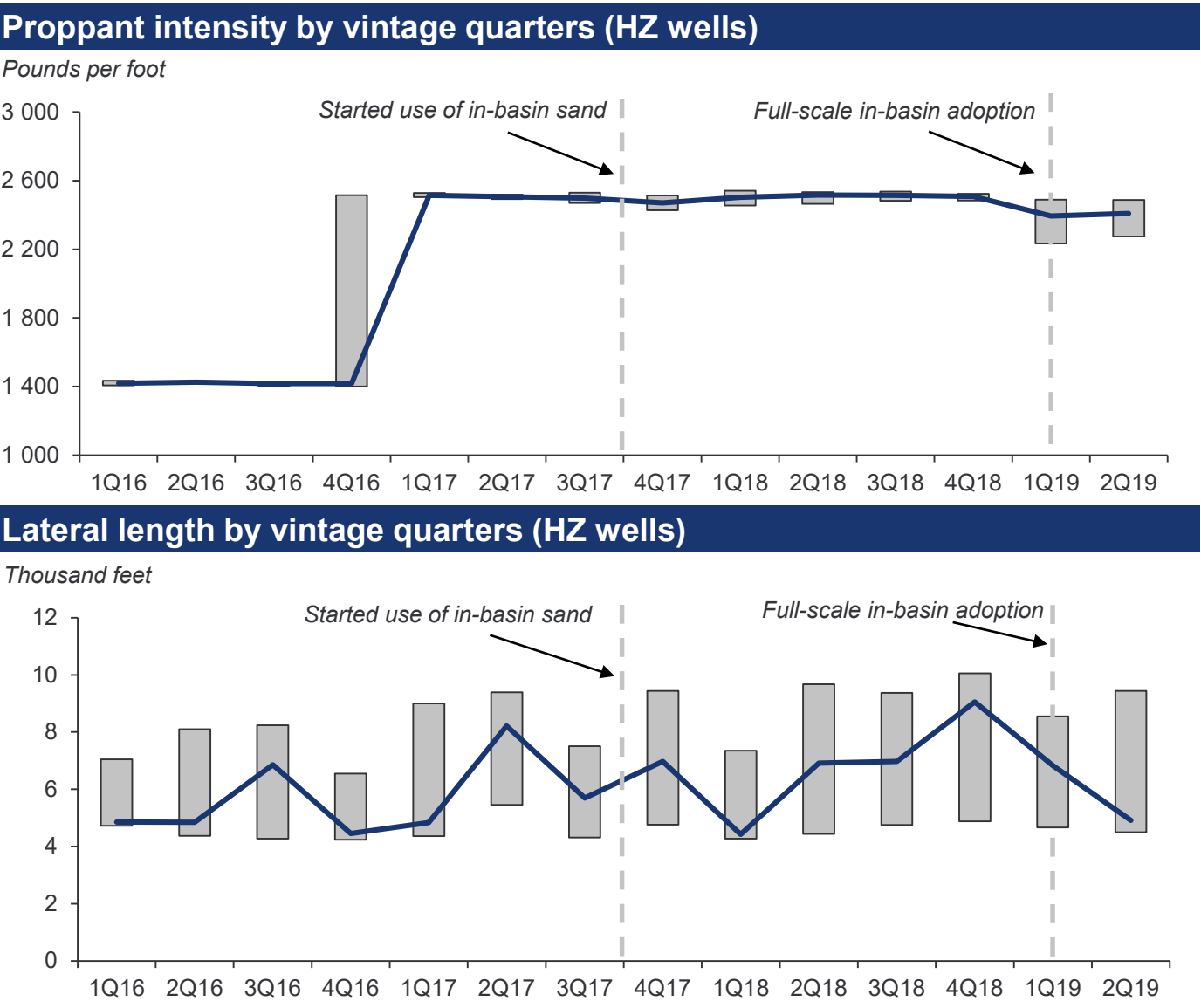


\*From Delaware Operator C's investor presentation  
\*\*Based on Rystad Energy's analysis of chemical ingredient and trade names reported to FracFocus Chemical Disclosure Registry  
Source: Rystad Energy ShaleWellCube, Delaware Operator C investor presentation, Rystad Energy research and analysis

# Delaware Operator C has kept proppant intensity relatively flat since switching to in-basin sand

## Delaware Operator C

- Since complete adoption of in-basin Delaware Operator C has slightly reduced proppant intensity and sharply reduced average lateral lengths.
- Lateral lengths were steadily on the rise from the first use of in-basin sand until 1Q 2019, though the variability has been similar across the whole period.



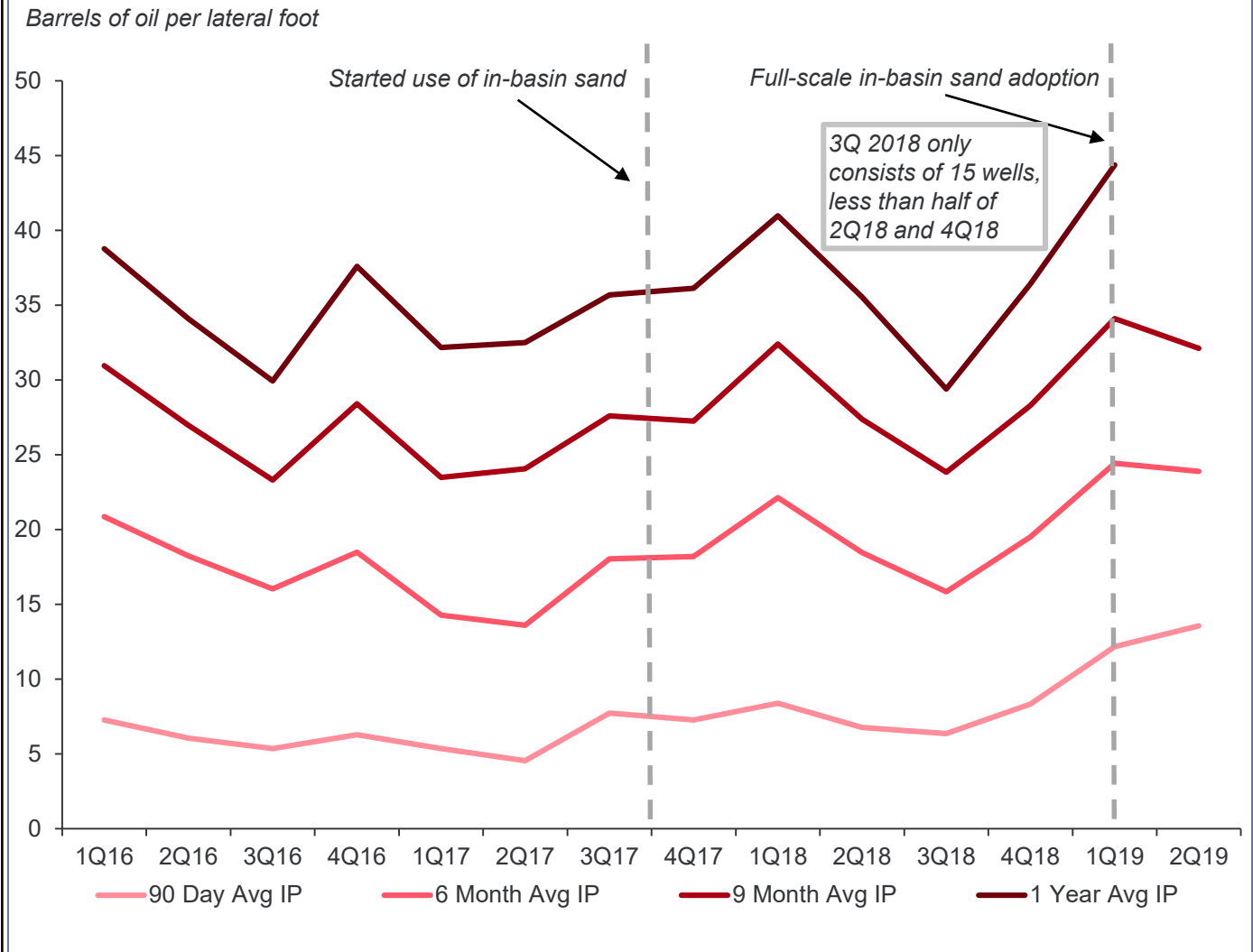
Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# With more production history, Delaware Operator C exhibits no impact on productivity following switch to in-basin sand

## Delaware Operator C

- Since the first use of in-basin sand for Delaware Operator C, there has been an increase in normalized production, despite increasing lateral lengths.
- Amount of well data for 3Q 2018 is less than half that of neighboring quarters, perhaps explaining the sudden contraction in productivity.
- Delaware Operator C is a case that has been classified as '*no impact*' from switching to in-basin sand.

## Delaware Operator C, production per lateral foot

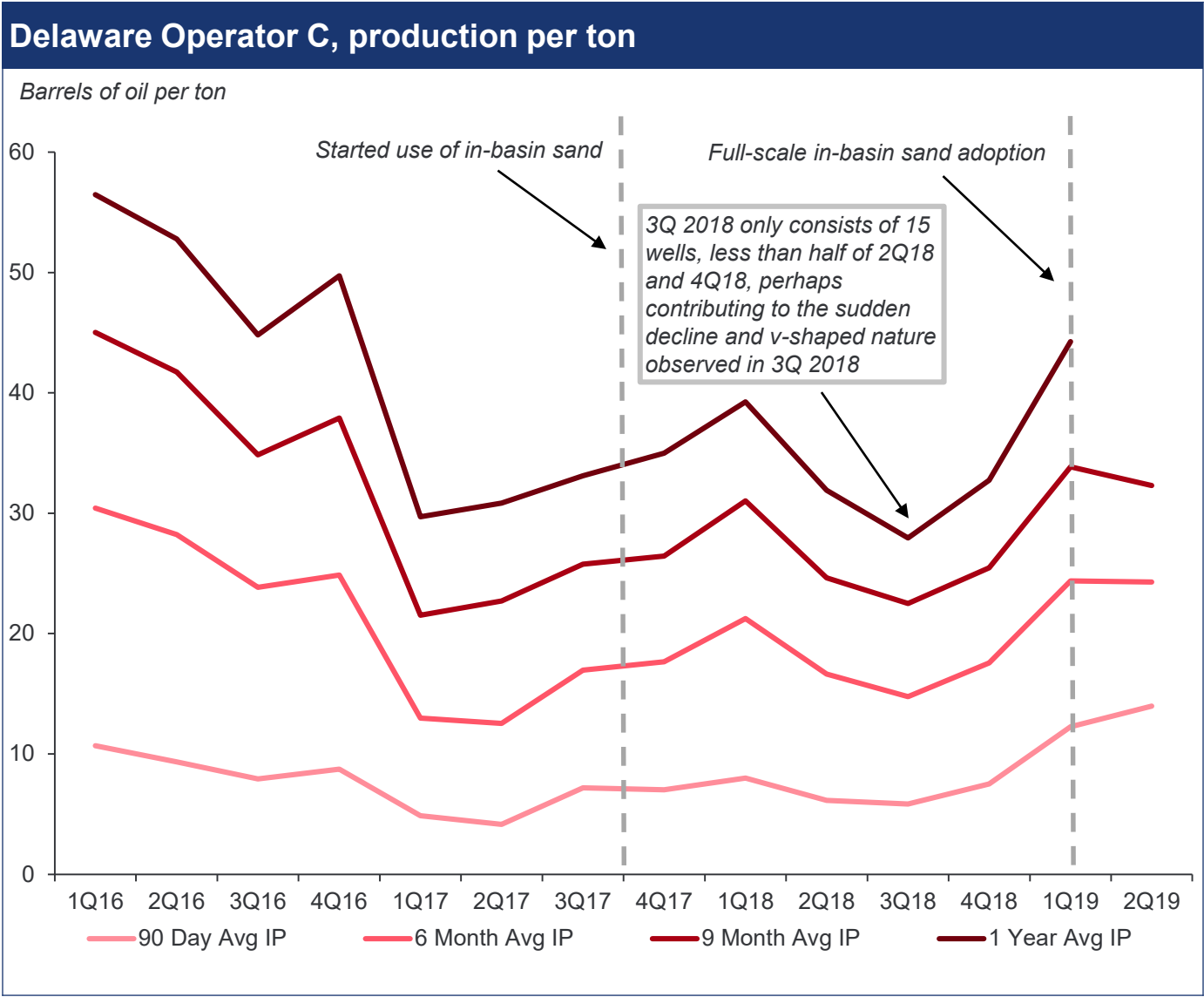


Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# Production per ton also supports the limited productivity impact for Delaware Operator C

## Delaware Operator C

- Production normalized for proppant pumped per well has increased significantly since first adopting in-basin sand, despite proppant intensities staying relatively flat during this period.
- Similar to the production per foot metric, the productivity normalized per proppant also supports the conclusion of no impact from switching to in-basin sand.



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis



Delaware Operator C's allowable degradation assuming \$40/ton cost savings from switching to in-basin sand is 5.6%

### Delaware Operator C: Economic Model Parameters

Parameters	NWS	In-Basin	Actual In-Basin
Lateral length	6,695	6,695	7,208
Proppant intensity	2,499	2,499	2,351
D&C cost (\$)	\$9.1 MM	\$8.8 MM	\$8.6 MM
Oil price, \$ per bbl	\$50.00	\$50.00	\$50.00
Gas price, \$ per boe	\$6.00	\$6.00	\$6.00
Cost savings per ton	\$40	\$40	\$40

### Delaware Operator C: Allowable degradation

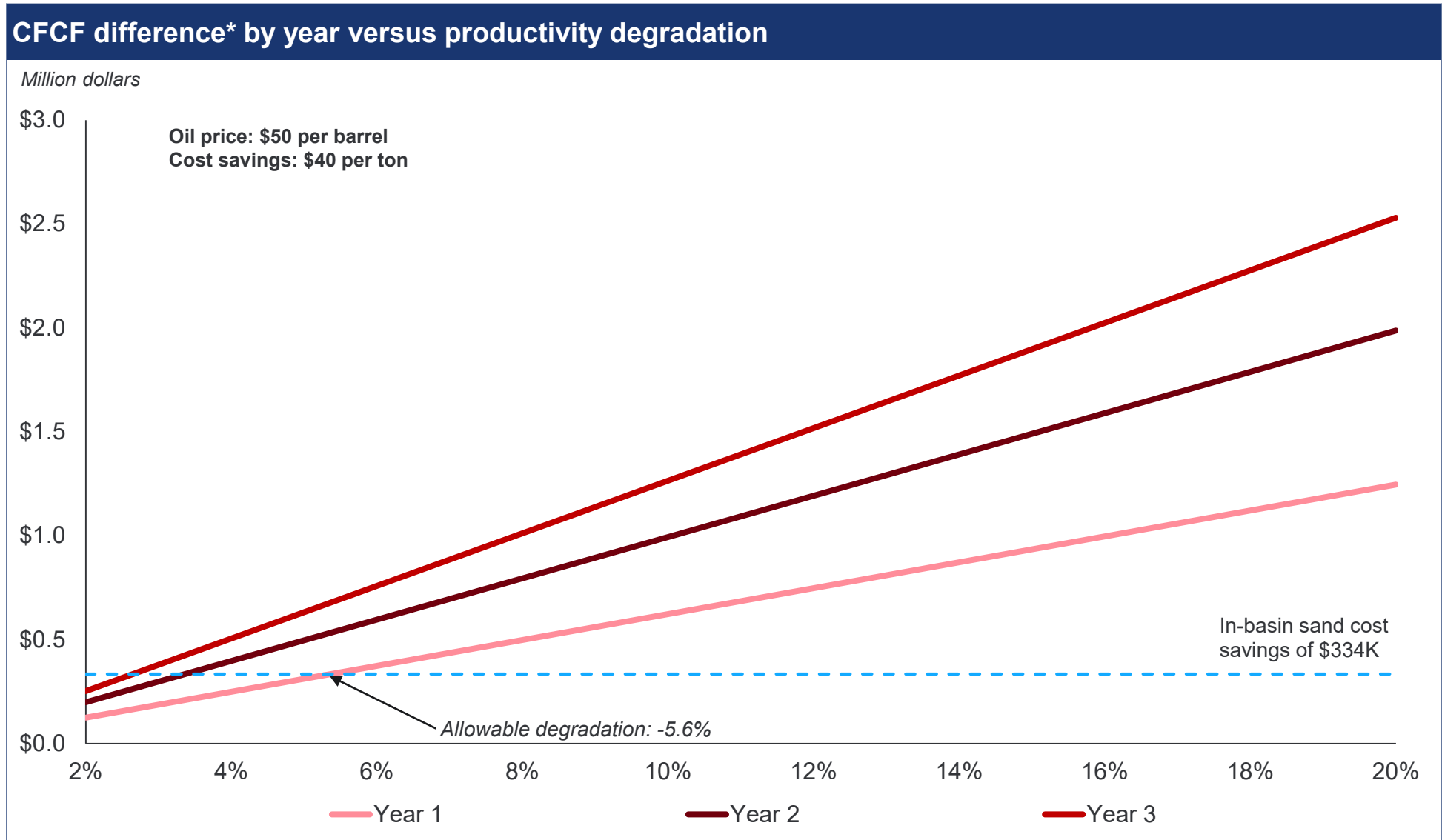
Year	Allowable Degradation	Total cost savings	CFCF Difference* Year 1	CFCF Difference Year 2	CFCF Difference Year 3
1	-5.6%	\$334K	\$351K	\$559K	\$712K
2	-3.7%	\$334K	\$228K	\$363K	\$462K
3	-3.0%	\$334K	\$185K	\$294K	\$375K

### Delaware Operator C : Observed degradation

Well Count (NWS)	Time Frame Assessed (NWS)	IP270 (NWS)	Well Count (In-Basin)	Time Frame Assessed (In-Basin)	IP270 (In-Basin)	Observed Change in IP270
62	1Q18 – 4Q18	29,482	60	4Q18 – 2Q19	31,516	+6.9%

Note: Only wells with at least 40% cumulative light oil content have been included in the analysis; CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

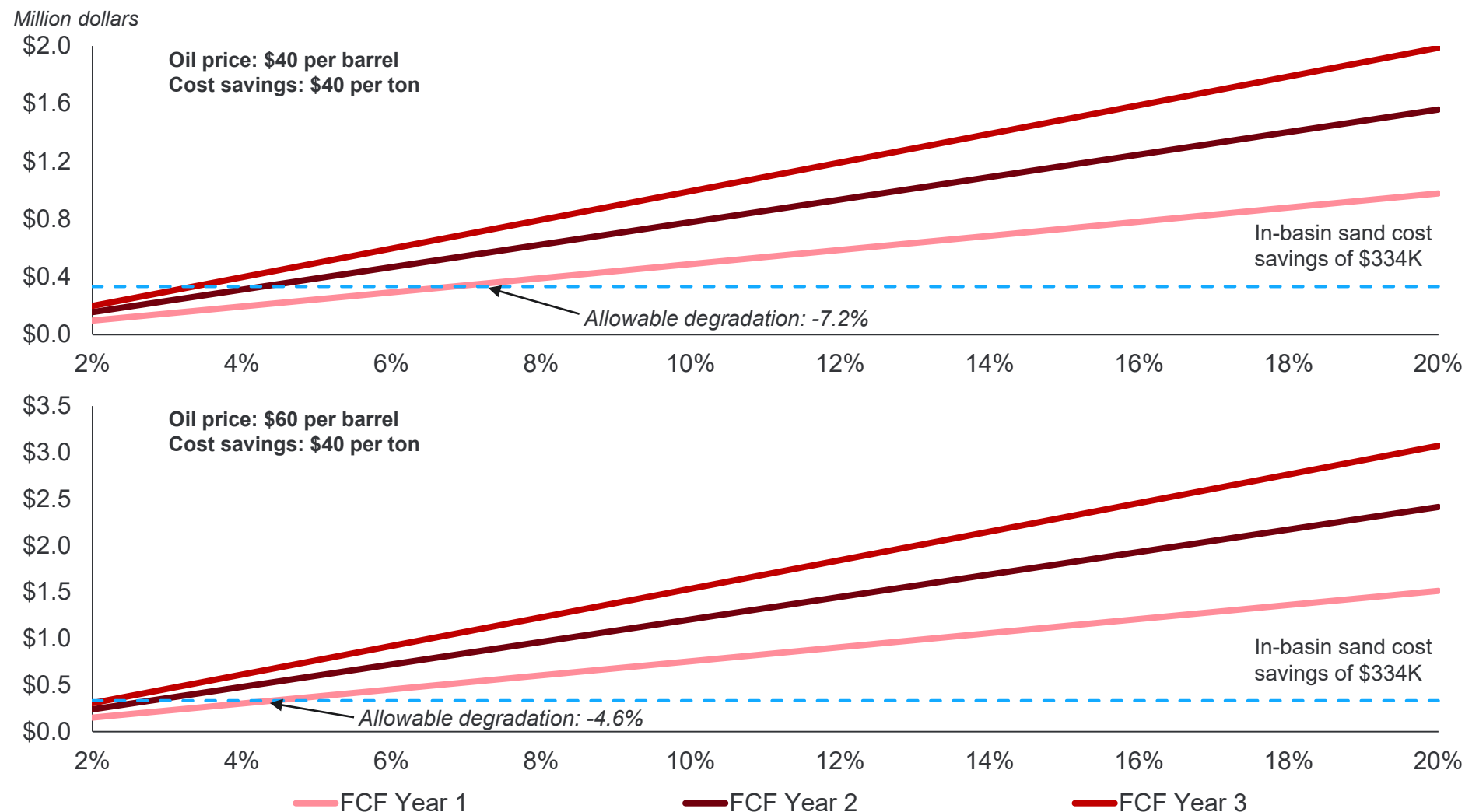
CFCF difference would exceed cost savings in Year 1 at a degradation greater than 7.0%



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis; CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

\$40 per bbl oil price results in an additional 2.6% allowable degradation from \$40 oil

## CFCF difference\* by year versus productivity degradation



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis; CFCF difference is defined as the difference between cumulative net cash flow from a northern white and in-basin well  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

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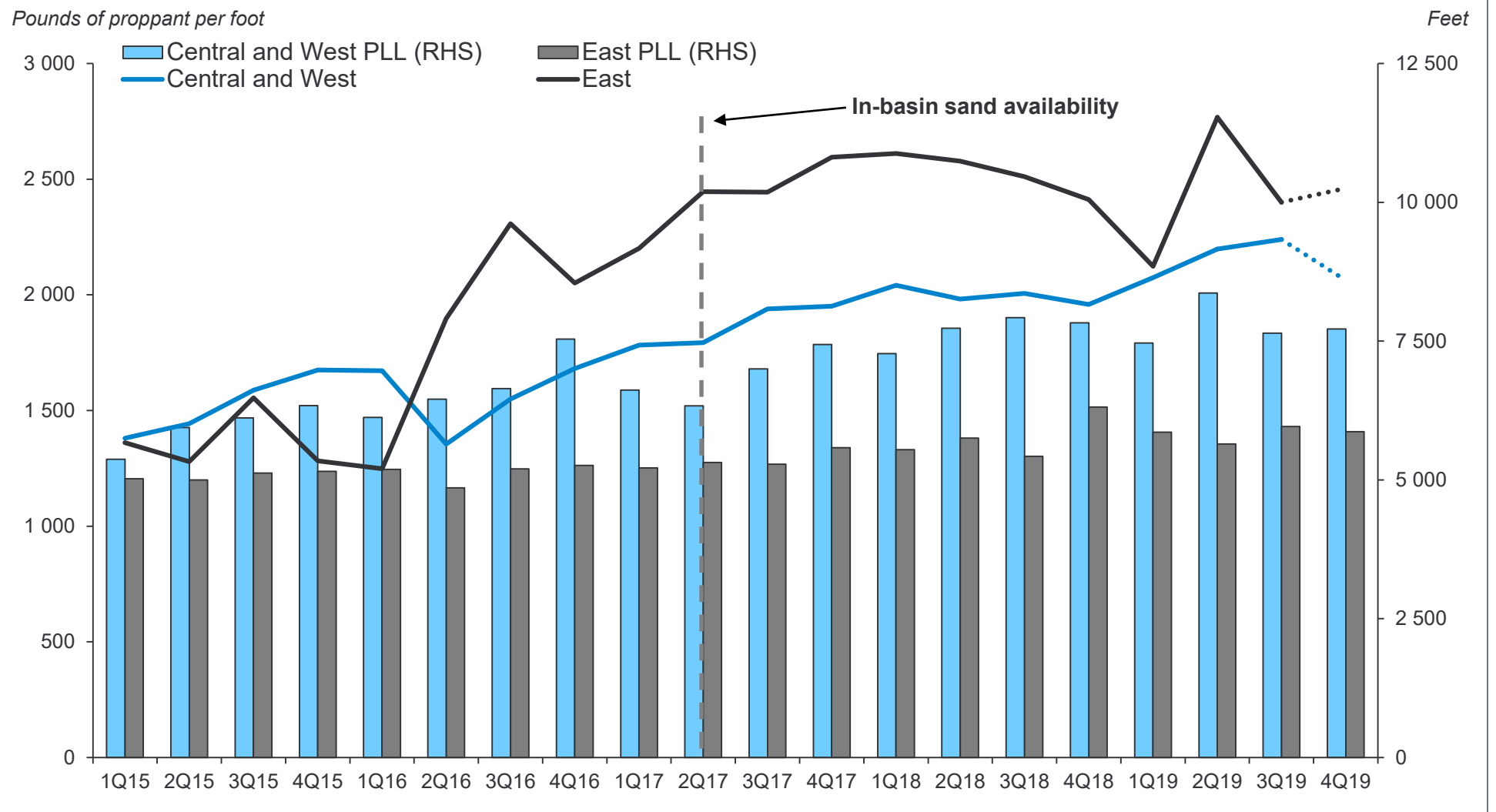
Eagle Ford

Haynesville

SCOOP/STACK

Eastern portion of Eagle Ford remains the most proppant-intensive as wells are shorter  
Comparable evolution of lateral length and proppant loadings across all other areas

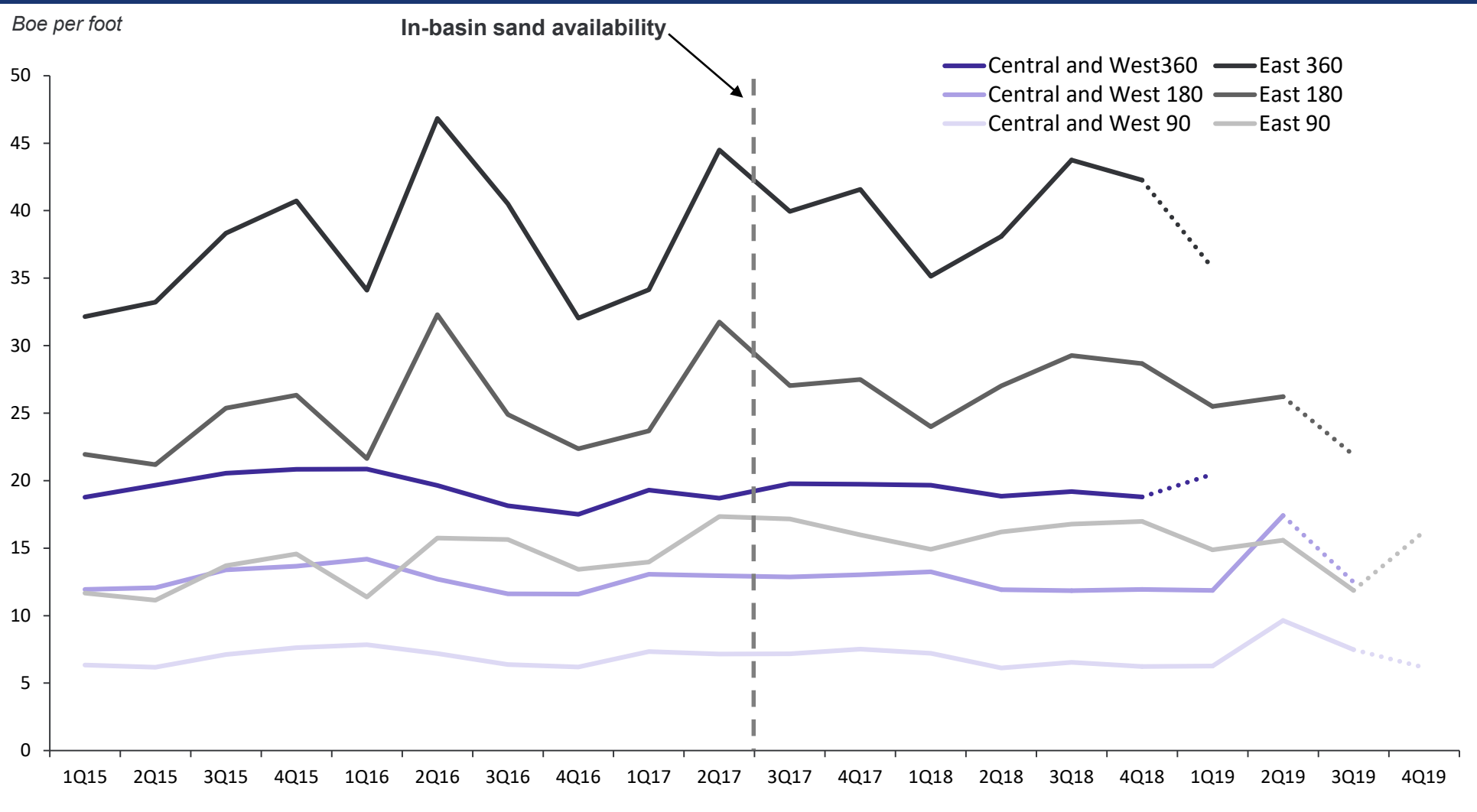
Eagle Ford shale, core\*: Median proppant intensity and perforated lateral length (PLL) by completion quarter



\*Includes the following counties: Atascosa, La Salle, Live Oak, McMullen (Central); De Witt, Gonzales, Karnes, Lavaca (East); Dimmit, Webb (West)  
Source: Rystad Energy research and analysis, Rystad Energy ShaleWellCube

Latest injection of data continues to show limited evidence for impact on Eagle Ford IP rates; Potential impact among longer term IP rates but historically data has been noisy

Eagle Ford shale, core\*: Median cum. 2-stream production by production start year-quarter and sub-basin



\*Includes the following counties: Atascosa, La Salle, Live Oak, McMullen (Central); De Witt, Gonzales, Karnes, Lavaca (East); Dimmit, Webb (West)  
Source: Rystad Energy research and analysis, Rystad Energy ShaleWellCube

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Eagle Ford

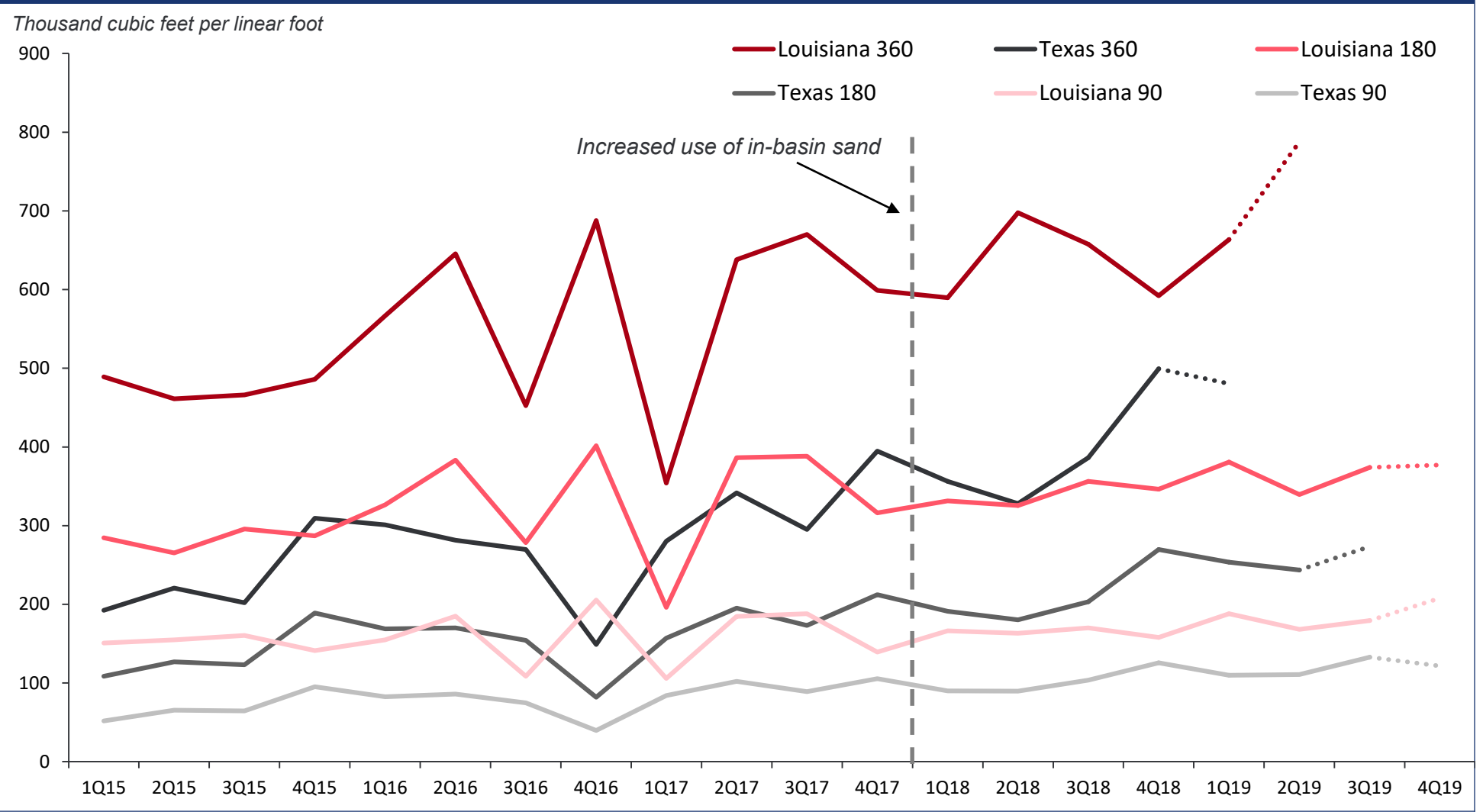
Haynesville

Case: Operator

SCOOP/STACK

# Latest injection of data in the Haynesville signals increases in productivity among all IP rates

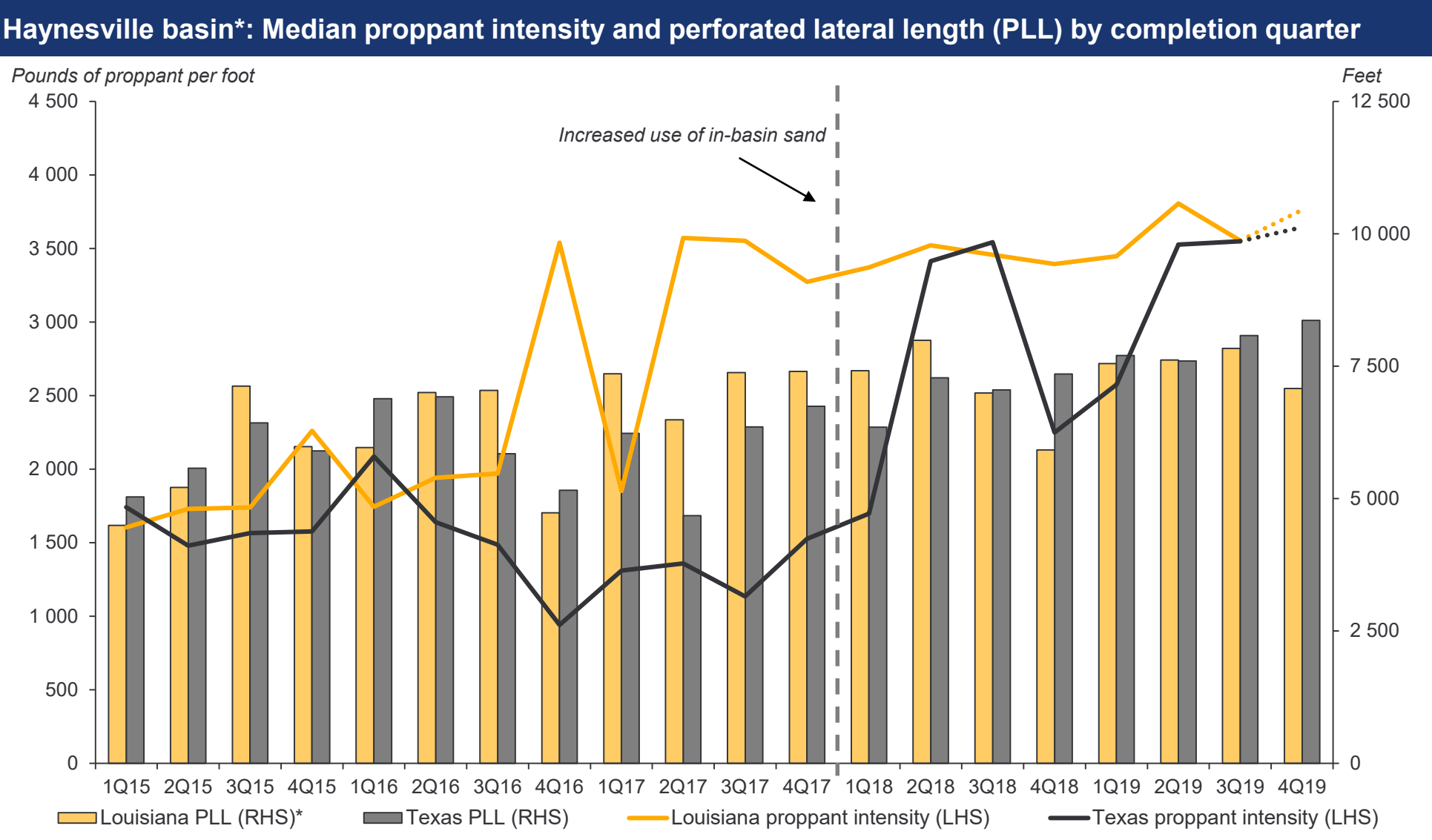
Haynesville basin : Median cumulative gas production by production start year-quarter and area



Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis



Proppant loadings and lateral lengths keep increasing on both the Texas and Louisiana side of the Haynesville border



\*Note: PLL refers to perforated lateral length  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

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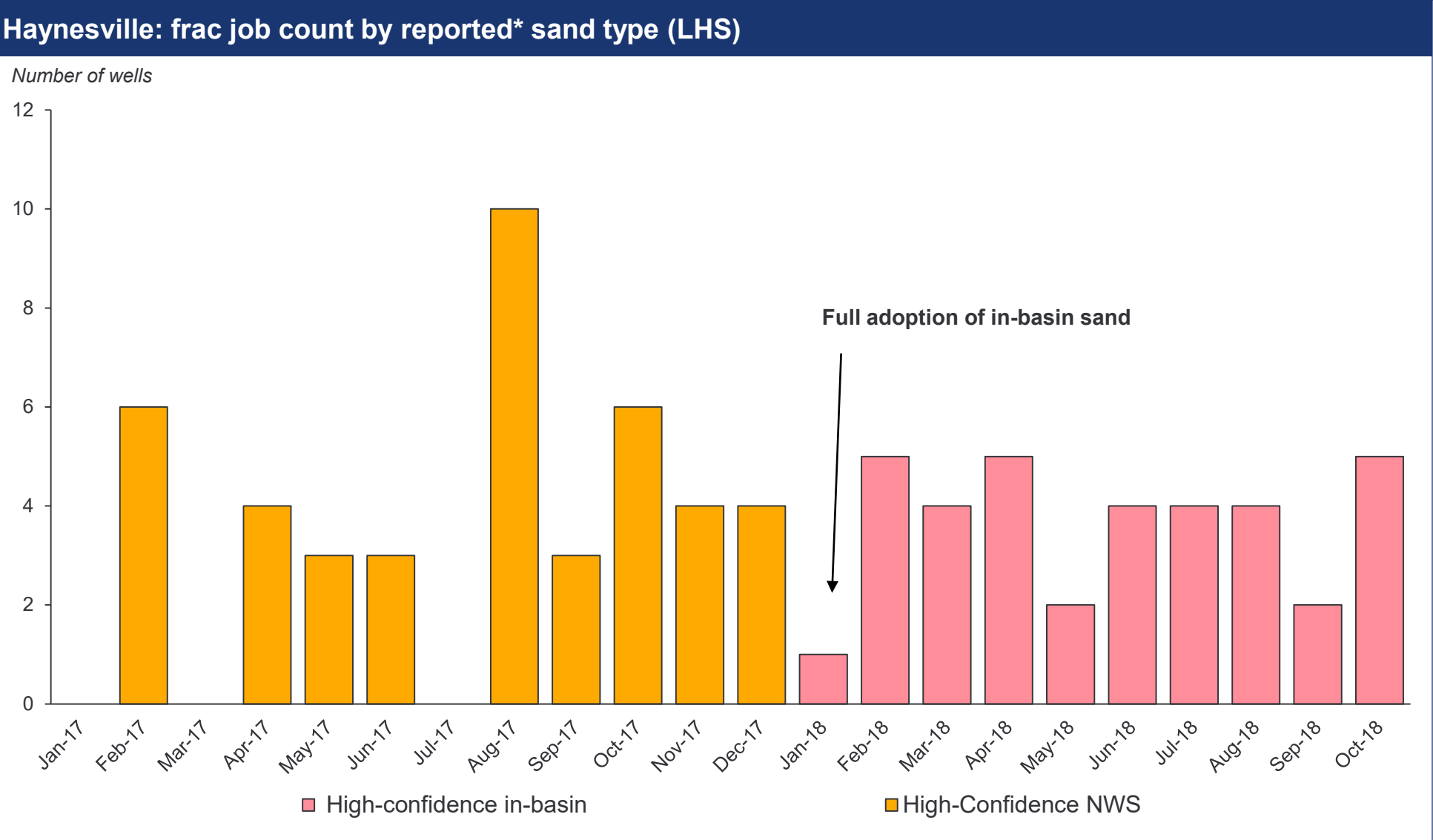
Eagle Ford

Haynesville

Case: Operator

SCOOP/STACK

Full in-basin adoption began for this operator in 1Q18



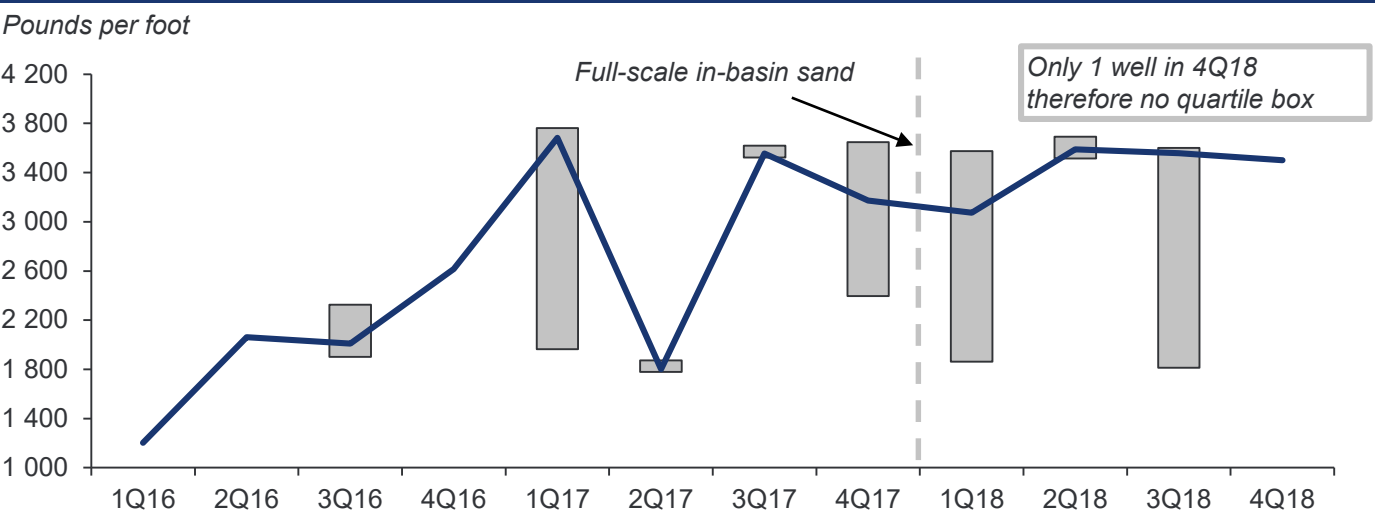
\*Based on Rystad Energy's analysis of chemical ingredient and trade names reported to FracFocus Chemical Disclosure Registry  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

Small sample size contributes to noisy data, however lateral lengths and proppant intensity levels show minimal changes since switching to in-basin sand

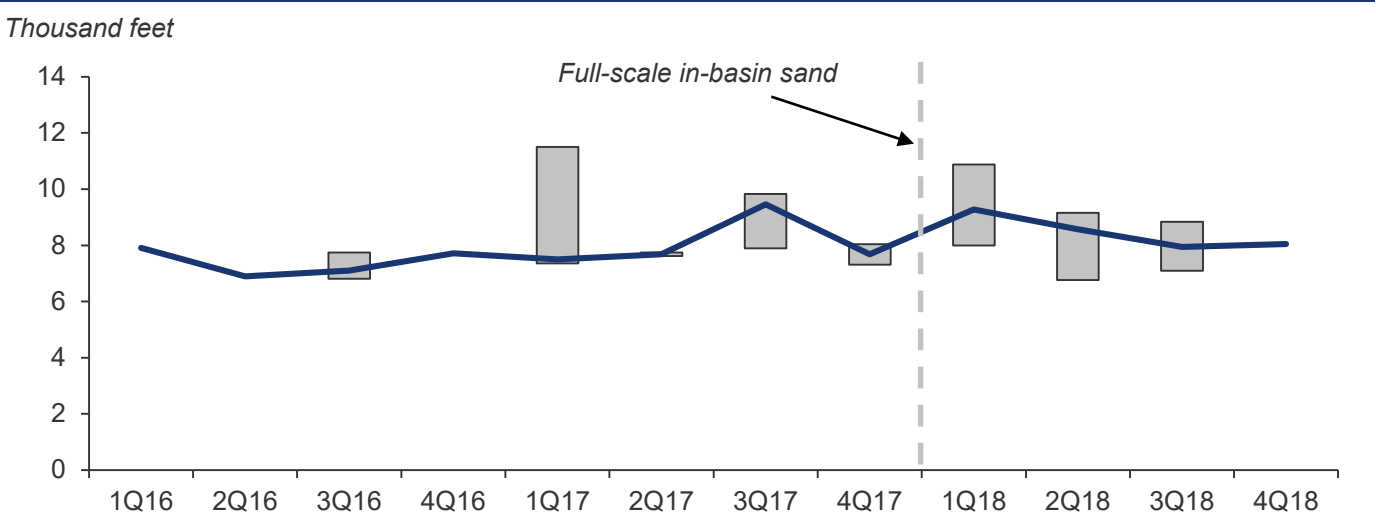
Haynesville Operator

- Proppant intensity data has been historically noisy, with some quarters only containing one well.
- Overall, proppant intensity levels have increased marginally and lateral lengths have stayed relatively stable with modest declines since switching completely to in-basin sand despite noisy and insufficient data.

Proppant intensity by vintage quarters (all wells)



Lateral length by vintage quarters (all wells)

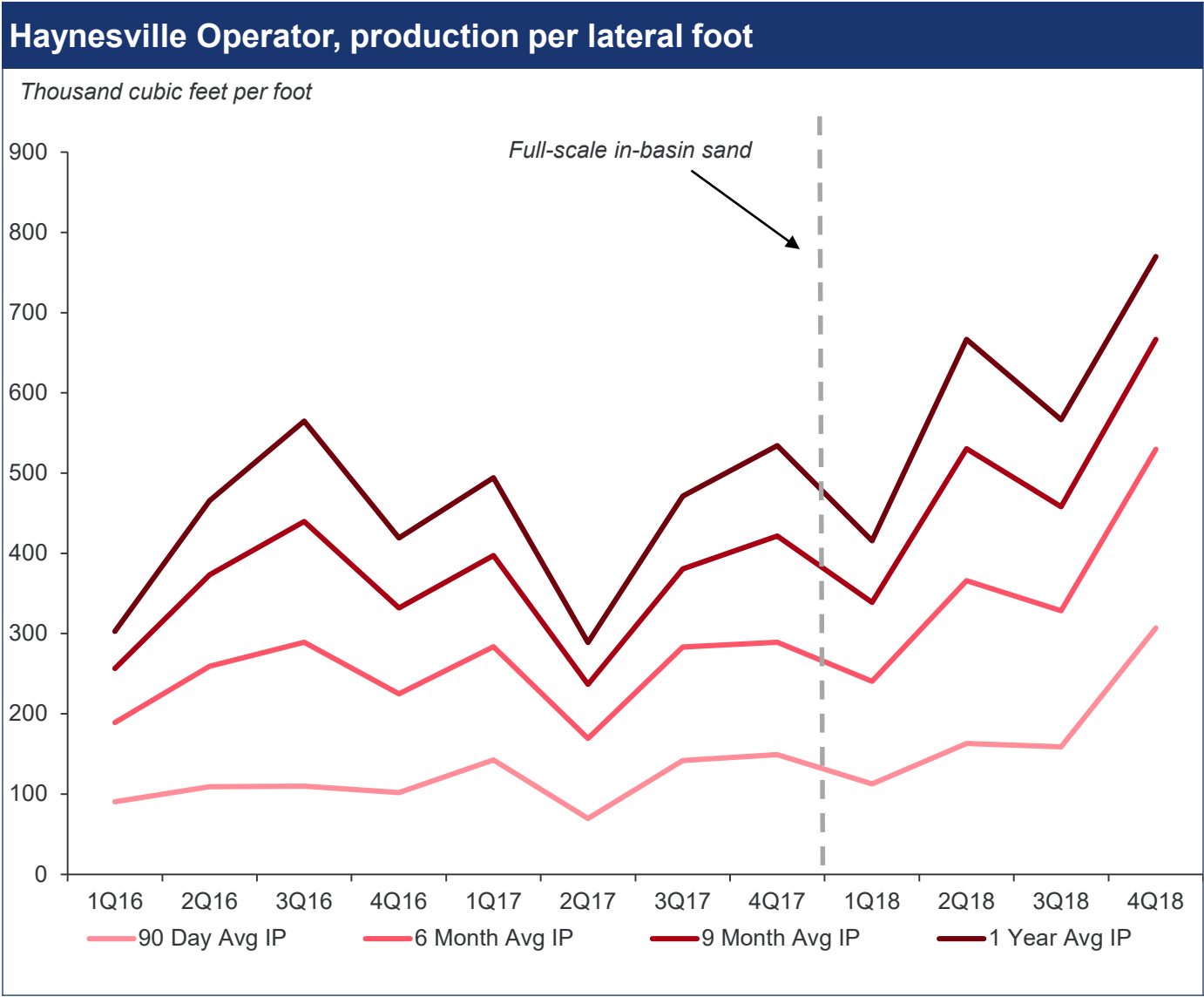


Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# The Haynesville operator has been no impact from from switching to in-basin sand

## Hayneville Operator

- Since complete adoption of in-basin sand this Haynesville operator has experienced significant *growth* in production per lateral foot.
- Quality of in-basin sand in the Haynesville region is more comparable to northern white sand rather than in-basin sand.
- As such, this Haynesville operator has been identified as a case with ‘no impact’ from switching to in-basin sand.

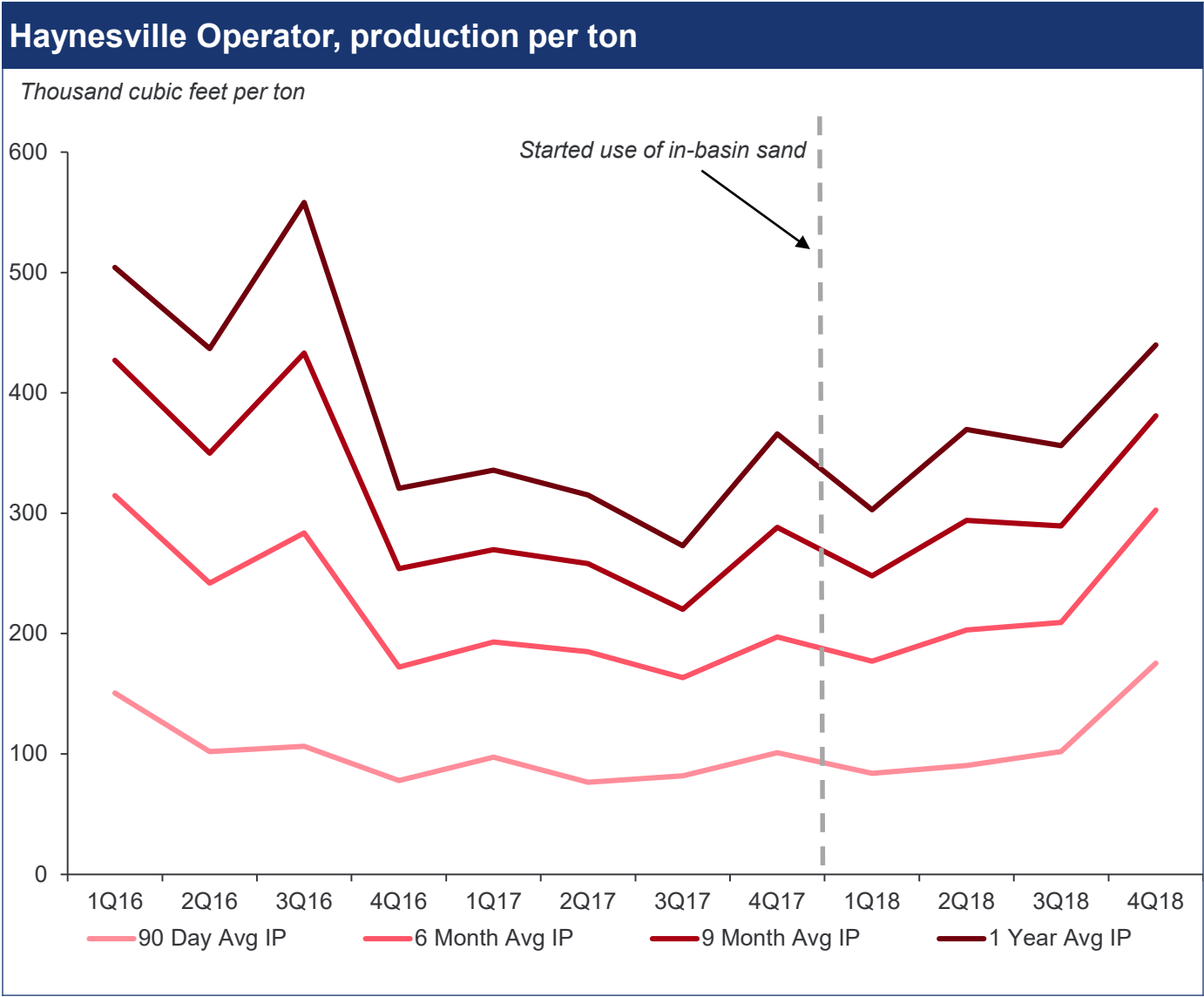


Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

# Productivity trend similar, but not as strong when normalizing for proppant use

## Haynesville Operator

- Proppant intensity levels increased immediately following in-basin sand adoption back to levels seen while utilizing northern white sand.
- Production normalized for proppant has increased significantly since this point, signaling gains not driven purely through increased proppant intensity.
- Given the smaller sample size historically, there is larger variation in the 2016 vintages, more than a year before the switch to in-basin sand.



Note: Only wells with at least 40% cumulative light oil content have been included in the analysis  
Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

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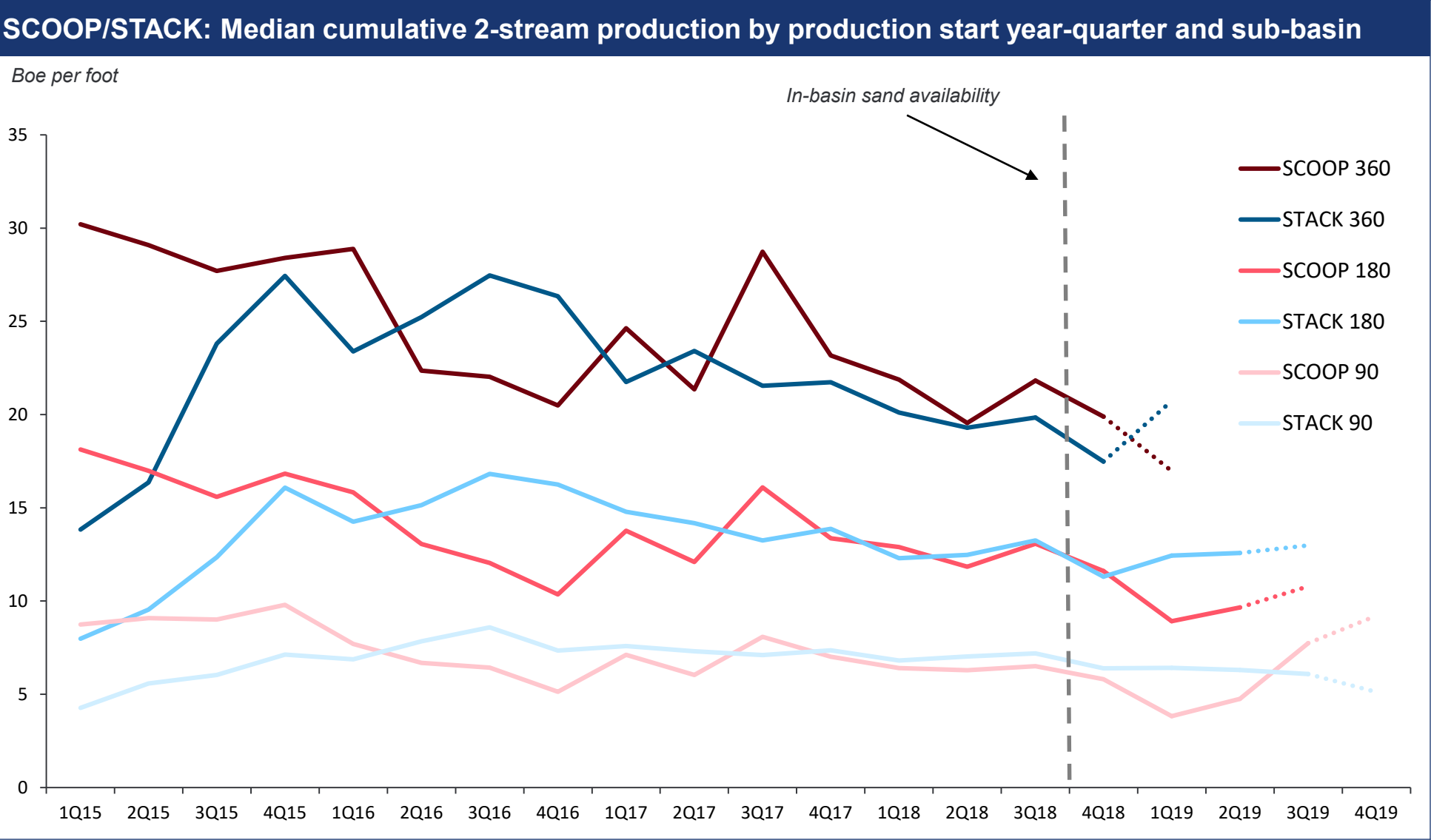
Permian Delaware

Eagle Ford

Haynesville

SCOOP/STACK

# New data shows recovery in SCOOP IP90 and IP180 while IP360 performs worse

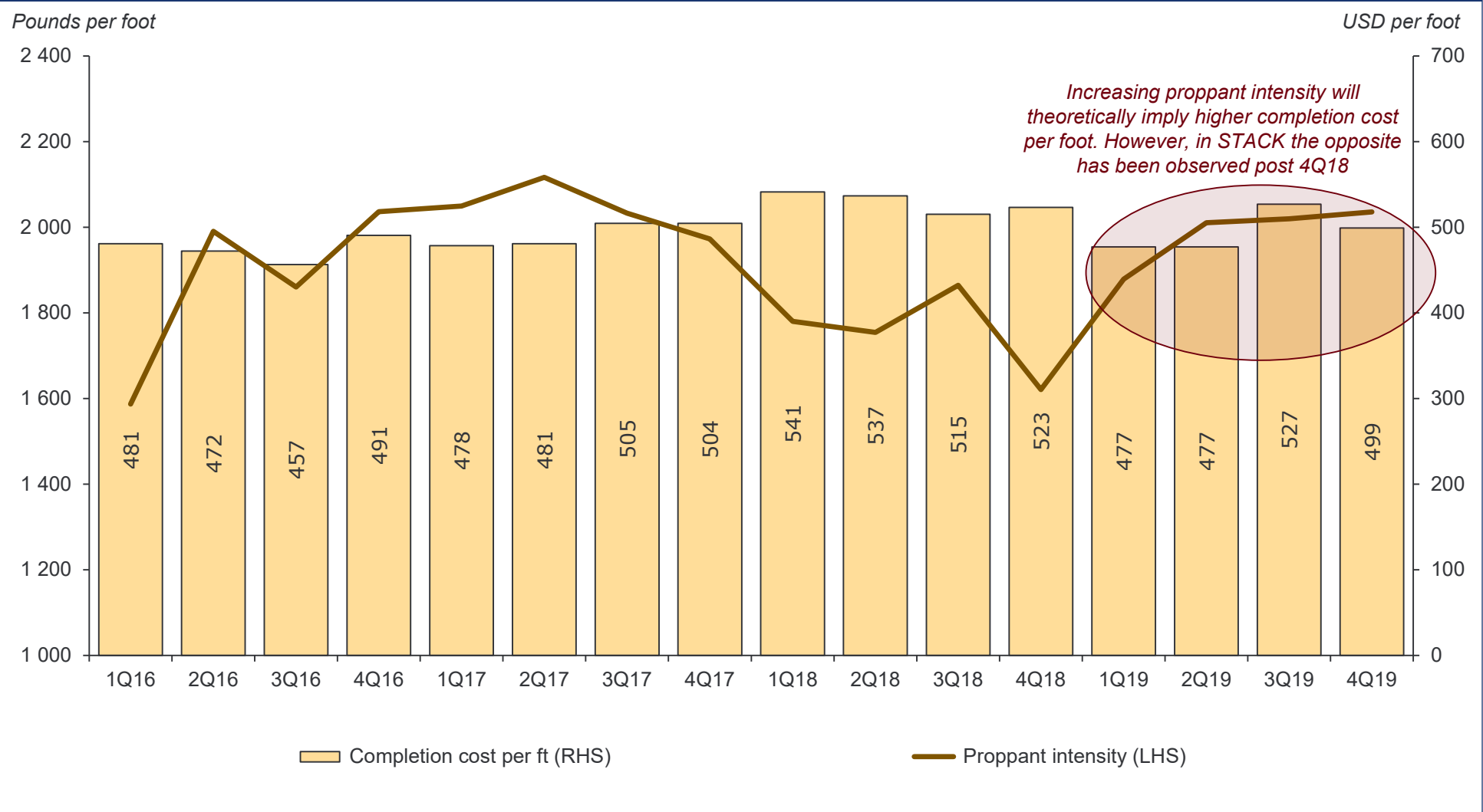


Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis



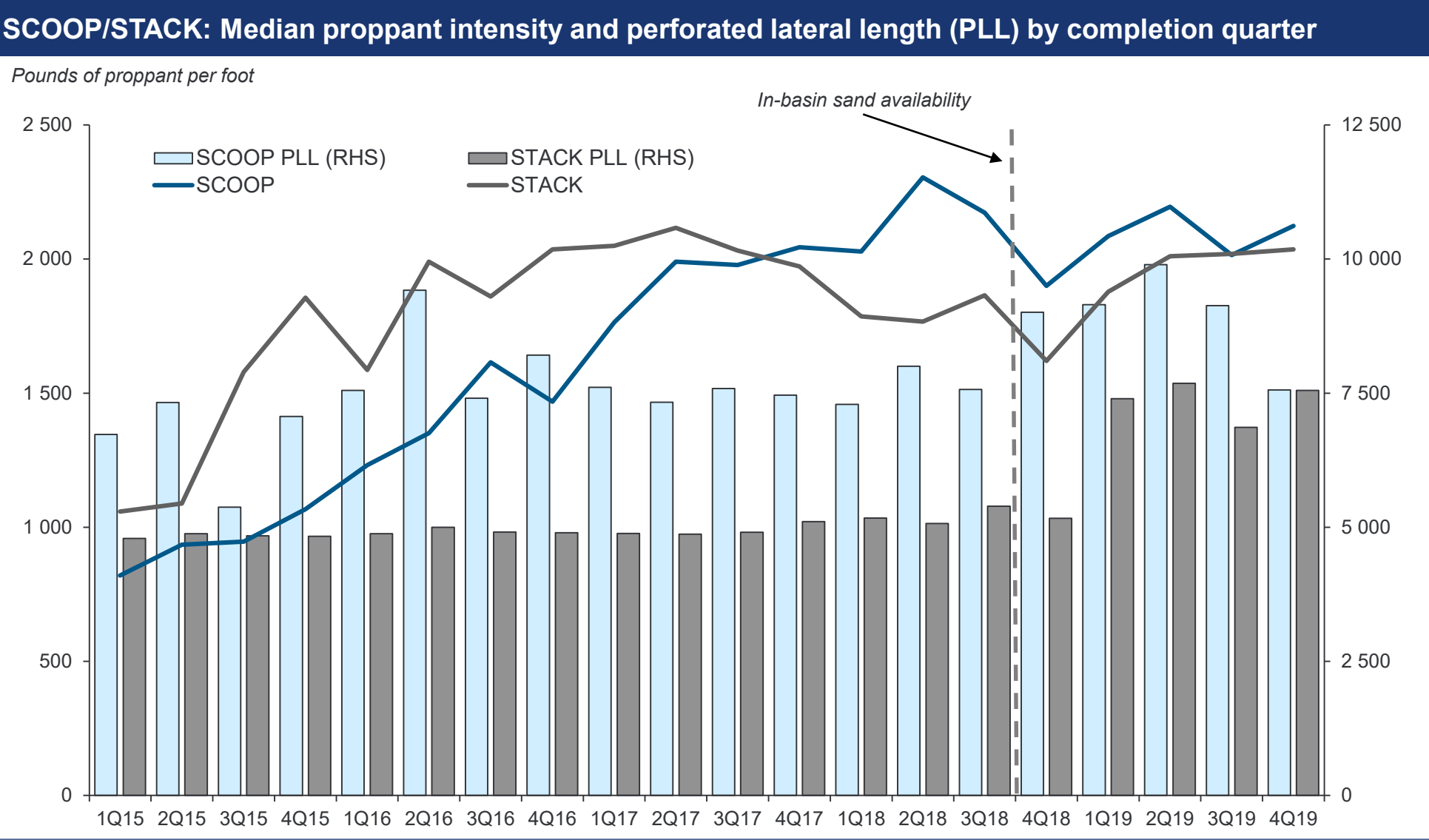
STACK has recently seen increasing proppant intensity levels at reduced cost per foot; this is likely driven by in-basin sand adoption

STACK median proppant intensity and completion cost per foot



Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis

STACK proppant intensity and lateral length increasing since in-basin sand adoption while SCOOP intensity has stayed relatively flat with lateral lengths increasing until 4Q19



Source: Rystad Energy ShaleWellCube, Rystad Energy research and analysis



## RYSTAD ENERGY

Rystad Energy is an independent energy consulting services and business intelligence data firm offering global databases, strategy advisory and research products for energy companies and suppliers, investors, investment banks, organizations, and governments. Rystad Energy's headquarters are located in Oslo, Norway.

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