RYSTAD ENERGY

EFFECT OF SAND TYPE ON WELL PRODUCTIVITY

FINAL REPORT, 7 SEPTEMBER 2022

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This 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 North American onshore oil and gas industry.

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 have seen a growth in the use of locally sourced sand, or 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 deep industry knowledge in the upstream oil and gas sector, with a specific focus on North America onshore. Rystad Energy has a relatively even distribution of client groups, including oil companies, service companies (including sand producers) and financial companies/investors.

This report is the third in a series of studies undertaken to perform an independent analysis of 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 and case overview
3. Case-by-case review and other supporting material

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This is the third study by Rystad Energy on the impact of sand type on productivity
The main approach is to examine operator case studies and estimate allowable degradation

This is the third iteration of Rystad Energy's study of the impact of sand type on well productivity

- Rystad Energy has performed several studies on the impact of sand type on well productivity. The first was released in December 2019 and an updated version was subsequently published in May 2020. Compared to previous iterations of this study, the macro environment has changed considerably with both oil and gas prices remaining firmly elevated. All price outlooks are inherently uncertain, but most analyses point to prices staying significantly above the levels recorded in 2020 going forward.
- The purpose of these studies is to provide an objective and independent view on the impact of sand type on productivity, utilizing Rystad Energy's rich data sets and strong knowledge in the sand space. This iteration focuses on case studies in the Permian Basin – both Midland and Delaware – and analyzes the same wells reviewed in the past, now with more production history. In total, about 800 wells are analyzed.

Operator case studies main approach to study productivity trends

- It is critical to do an apples-to-apples comparison to understand the impact on well productivity after a switch from northern white sand (NWS) to in-basin sand as multiple parameters may impact well production, such as lateral length, proppant intensity, target formation, acreage quality, well spacing and more.
- The study uses operator cases studies which ensure that most of those variables are controlled for in the analysis. Operator cases with too much noise in the data are not included.
- In this updated study, more production data is available and thus the focus is on analyzing one-year (IP360) and two-year (IP720) production trends.

We assess impact of sand type based on actual production data versus estimated *allowable degradation*

- The main value proposition of in-basin sand is reduced upfront well costs. For operators to consider NWS, any negative impact from using in-basin sand must be greater than the cost saving. Hence an economic analysis is performed to estimate how big the production impact must be for northern white sand to provide more value – in other words, estimating the *allowable degradation* in well productivity from wells using in-basin sand.
- We assess the impact of sand type by comparing actual production data against the *allowable degradation*:
  - **No impact**: Operator case studies that do not exhibit any productivity decline following in-basin adoption.
  - **Light impact**: Cases with decline in well productivity that is within the allowable degradation.
  - **Significant impact**: Clear signs of productivity declines that are greater than the allowable degradation.

Source: Rystad Energy research and analysis

Six of seven cases see productivity declines after switching from NWS to in-basin sand Higher commodity prices and more production history enhance the impact

Six out of seven cases see drop in productivity after switching to in-basin sand

- Productivity decline is observed in six of seven cases, which is what the previous studies also showed.
- The decline in productivity for these six cases is clear when considering both the average and median well performance. As such, the aggregated well results are not driven by outliers.
- With more production history included in the analyses, the productivity decline in these six cases is clearer compared to previous studies and the difference generally grows over time – a bigger difference in two-year productivity trends versus one-year trends.

Economic impact on cases more profound given the current macro environment, significant impact on four cases

- With higher commodity prices, the value of potentially lost barrels is much higher, and the estimated *allowable degradation* has gone down significantly across all cases analyzed, generally by more than 50%. As such, smaller productivity declines can wipe out all the cost savings potential compared to the previous studies.
- Four of the seven cases are now seeing a *significant impact* following the switch from NWS to in-basin sand, *one* more compared to the previous studies, while two cases are still tagged as *light impact*. The effect grows when looking at two-year trends and the two *light impact* cases become borderline significant.
- For all the six cases with impact, the whole cost savings from switch to in-basin sand on a cash basis is gone after two years at a $90 per barrel (WTI). For the four cases with *significant impact*, the upfront cost saving is wiped out even under a $50 per barrel assumption.

More transparency is encouraged to avoid value destruction

- For most of the cases studied, operators are losing out on future cash flows following the switch from NWS. The wells included in this study make up about 10% of all wells drilled in the Permian during the period studied. However, due to issues with limited transparency in well reporting, it is hard to comment on how transferable these results are to the broader population of wells.
- As such, a clear recommendation to the industry is to improve reporting of sand type so the broader well population can be studied as this choice can impact future value creation.
- This and the past studies have focused on oil wells. However, with the macro environment changing considerably for gas, the value of the commodity has become much more significant and thus is an additional area to consider when assessing the impact of sand type on well productivity.

Source: Rystad Energy research and analysis

Case studies generally align with the 2020 review for one-year trends, but the impact is more significant in two-year trends as 6/7 cases decline beyond allowable degradation

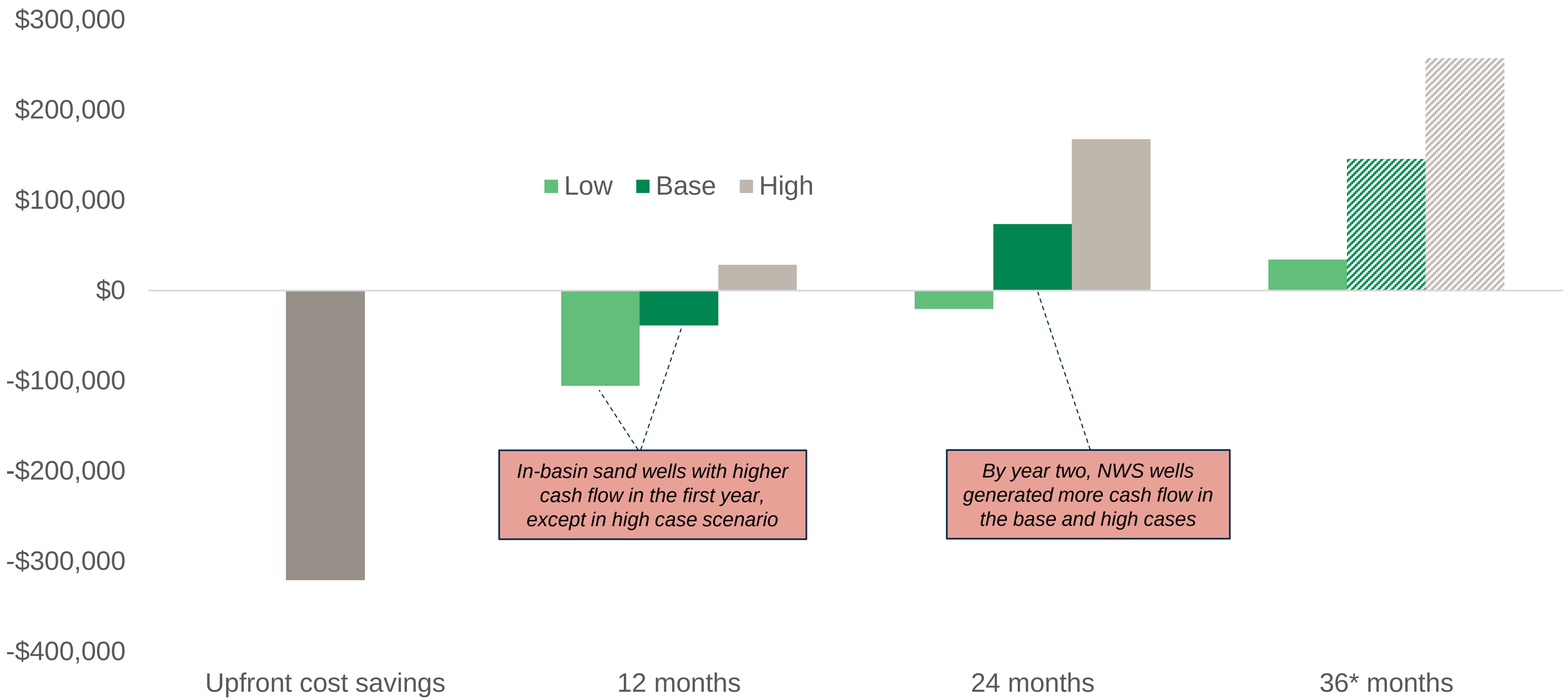
Basin	Case	Well Count	IP 360	IP 720	Impact Assessment
Midland	Operator A	179			Light impact
	Operator B	147			Significant impact
	Operator C	75			Significant impact
	Operator D	49			Light impact
Delaware	Operator A	142			Significant impact
	Operator B	62			Significant impact
	Operator C	122			No Impact

NWS In-Basin Observed Change Allowable Degradation

Note: Allowable degradation assumes an oil price of $90/bbl and $7/MMBtu for gas
Source: Rystad Energy research and analysis

Midland Operator A case study is an example where the upfront cash savings are wiped out as more production history is included

Cumulative free cash flow (CFCF) differences by commodity price scenario
USD



- Operator saved ~$320,000 upfront in switching from NWS to in-basin sand.
- In-basin sand wells still saw savings of ~$106,00 for the low case and ~$39,000 for the base at the end of year 1.
- Operator lost ~$74,000 in the base case and ~$168,000 in the high case by the end of year 2.

*Estimated as not all wells in the set have 36 months production history Low = $70/bbl and $5/MMBtu -- Base = $90/bbl and $7/MMBtu – High = $110/bbl and $9/MMBtu
Source: Rystad Energy research and analysis

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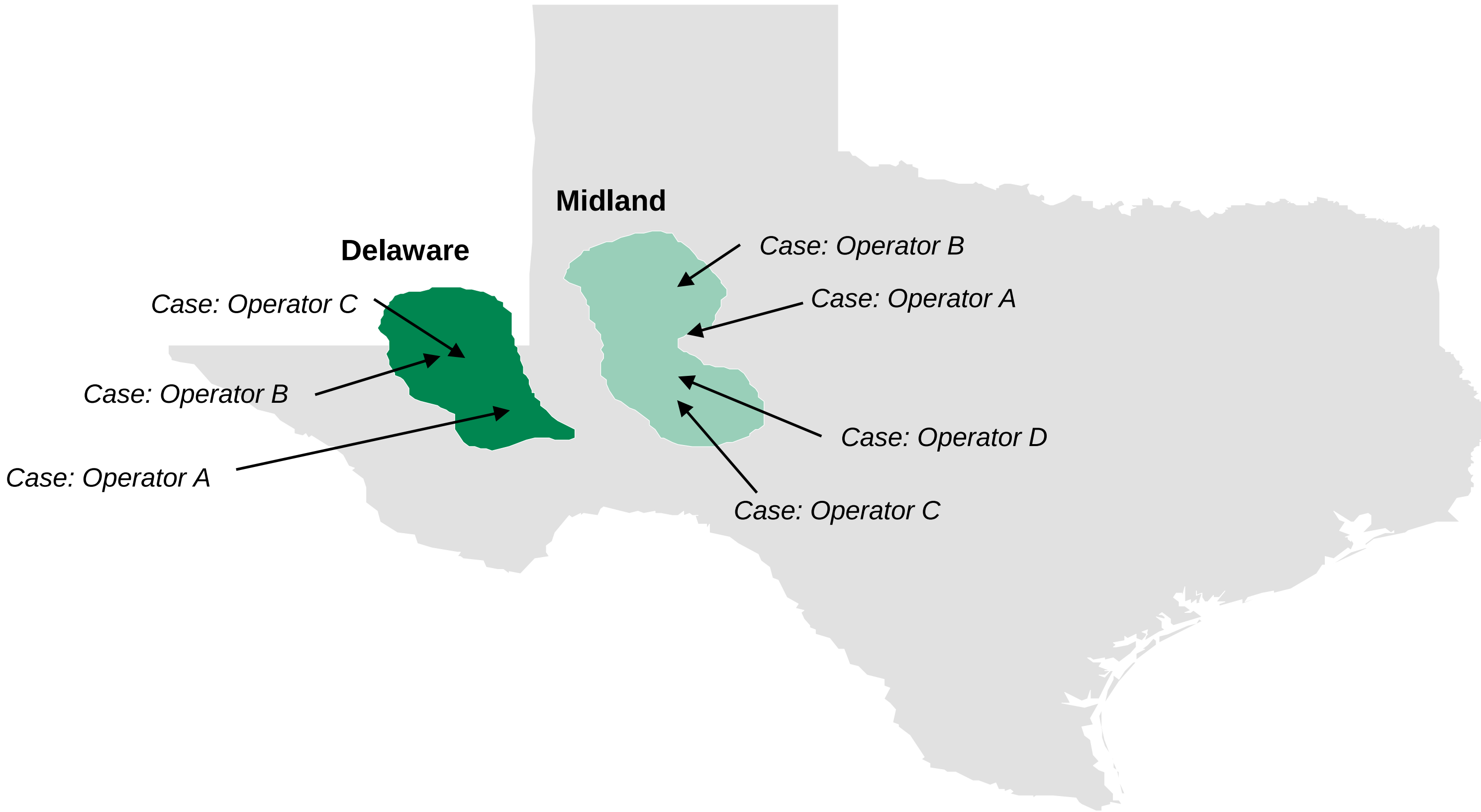
Rystad Energy uses operator case studies to analyze impact of sand type on productivity

Data sampling is a challenge due to inconsistent reporting	• The starting point for the analyses is to review public sources to capture what sand type has been used in different wells, from sources such as the FracFocus Chemical Disclosure Registry. The reporting in FracFocus is, however, incomplete, which makes the analysis more challenging. • Using operator communications and primary research, the sand type for more wells can be identified, by looking at companies that make clear announcements around shifting 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 NWS to in-basin sand as multiple parameters may impact well production, such as lateral length, proppant intensity, target formation, acreage quality, well spacing and more. • The approach used in this exercise revolves around case studies by operator and formation which ensure that most of those variables are controlled for in the analysis. • Operator cases with too much noise are not included – including significant experimentation in well designs or if an operator switched acreage focus at the time of the shift to in-basin sand.
We compare production trends with the *allowable degradation* based on economical analyses	• For the identified operator case studies, trends in well productivity can be analyzed. In this updated study, more production data is available and hence the focus is on one-year (IP360) and two-year (IP720) trends. • The main value proposition of in-basin sand is reduced upfront well costs. As such, for operators to consider NWS, any negative impacts from using in-basin sand must be greater than the cost saving – in other words, the value of potential lost barrels must be greater than the initial cost savings. • Hence, an economic analysis is performed to estimate how big the production impact must be for northern white sand to provide more value – or estimating the *allowable degradation* in well productivity from wells using in-basin sand.

Source: Rystad Energy research and analysis

Map of case studies – focusing on the Permian



Source: Rystad Energy research and analysis

Rystad Energy has analyzed ~800 wells across seven operator case studies for this study
Timestamp of wells spans from 2Q17 to 2Q19

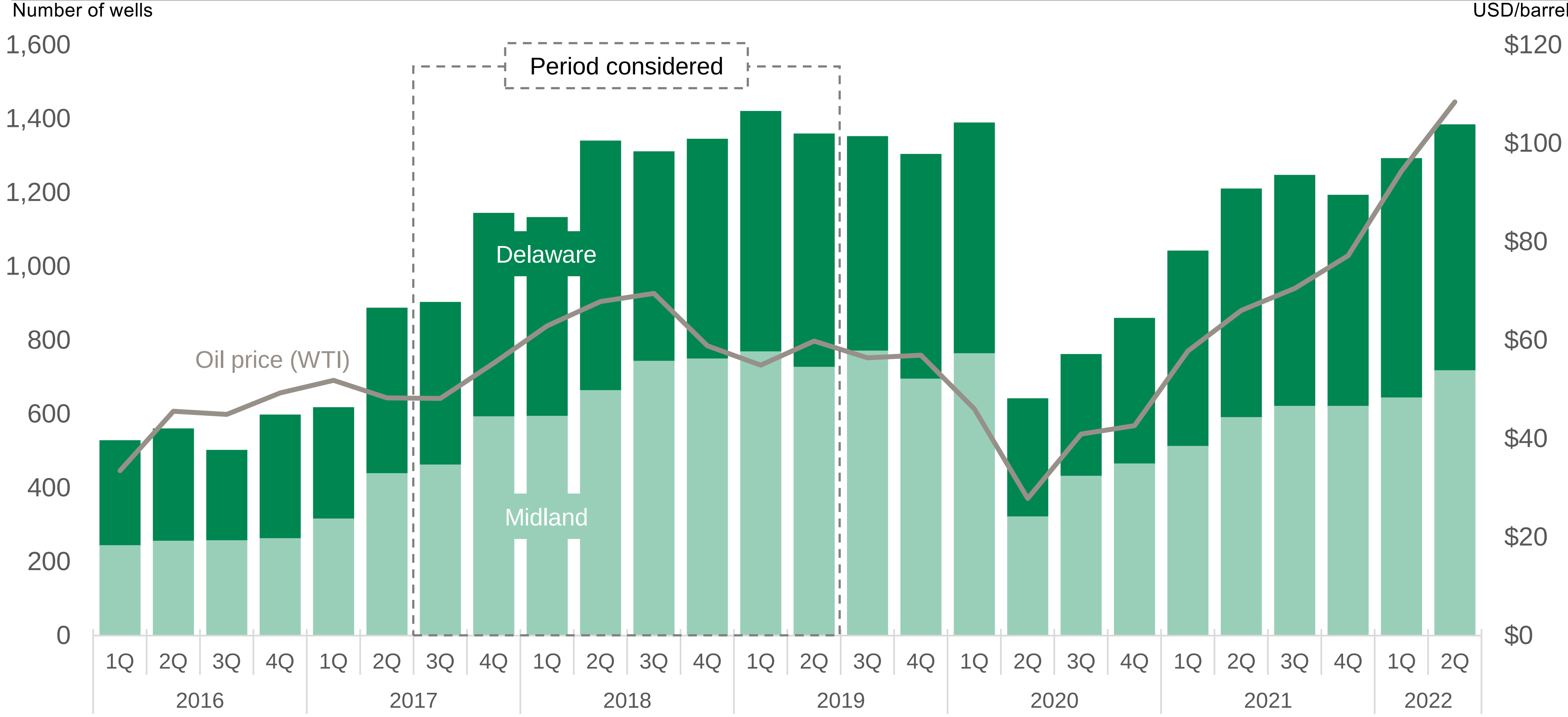
Basin	Case	Wells Count	Time Frame Assessed (NWS)	Time Frame Assessed (In-Basin)
Midland	Operator A	179	4Q17 – 2Q18	3Q18 – 2Q19
	Operator B	147	3Q17 – 2Q18	2Q18 – 2Q19
	Operator C	75	3Q18 – 4Q18	4Q18 – 2Q19
	Operator D	49	1Q18 – 2Q18	3Q18 – 2Q19
Delaware	Operator A	142	2Q17 – 3Q18	3Q18 – 2Q19
	Operator B	62	3Q18 – 4Q18	1Q19 – 2Q19
	Operator C	122	1Q18 – 4Q18	4Q18 – 2Q19
Total		**796** (NWS 298, In-Basin 498)		

NWS In-Basin

Note: time frame refers to time of original well spud
Source: Rystad Energy research and analysis

Data sample has been taken from a period with relatively stable oil price and activity levels suggesting a normative operating environment for operators

Oil price and completed horizontal wells evolution from 2016 to 2022

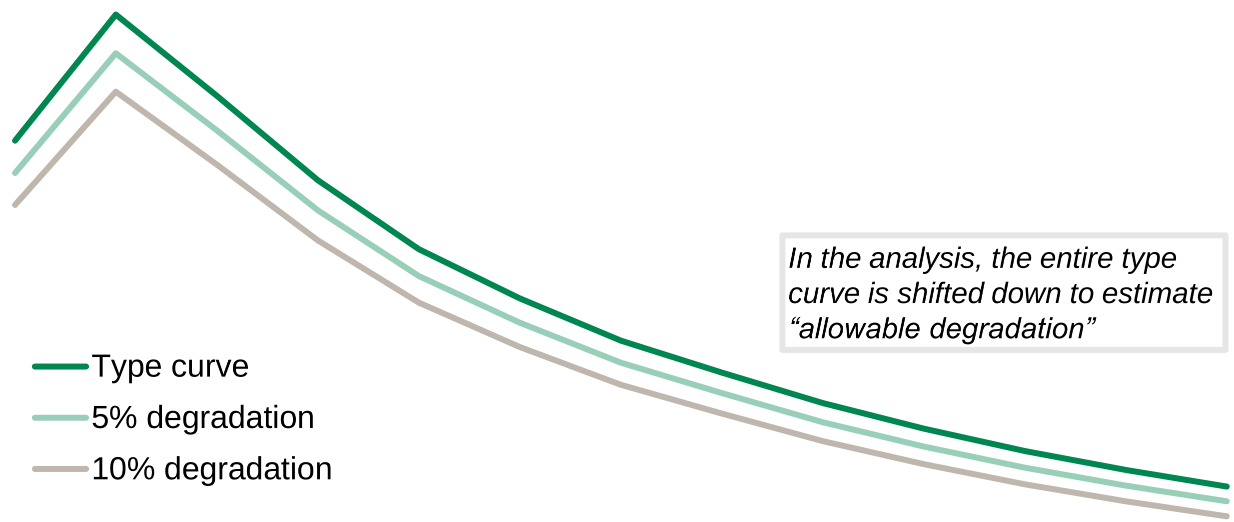


- The chart above shows the development in Permian activity and oil prices following the oil price trough in 2016.
- The data sample used in this study mainly stems from 2Q 2017 – 2Q 2019. During the period, oil prices had recovered somewhat from 2016 and activity levels grew to a steady-state level that persisted until the Covid-19 induced crash in 2020.
- As such, the data used in the study mainly reflects a steady period suggesting that operators did not change their well construction approach.

Source: Rystad Energy research and analysis

Economic analysis is needed to assess productivity impact versus cost savings

Conceptual type curve and assumptions around productivity impact



- The incentive to shift to in-basin sand from NWS comes from an upfront savings in well costs. As such, an economic analysis is needed on top of a well productivity assessment to fully comprehend the value impact of switching sand type – the value impact of any reduced productivity must be greater than the cost savings to consider moving away from in-basin sand.
- We define allowable degradation as the reduction in well productivity within a certain timeframe where the realized upfront cost savings are wiped out. Allowable degradation for year 1, year 2 and year 3 are calculated using cash flow analysis.
- We calculate the allowable degradation by shifting the entire type curve down by a defined multiple, as indicated in the chart.

Source: Rystad Energy research and analysis

The study utilizes three main scenarios based on commodity price permutations

		Gas		
		$5/MMBtu	$7/MMBtu	$9/MMBtu
Oil	$70/bbl	LOW		
	$90/bbl		BASE	
	$110/bbl			HIGH

- Scenarios are constructed around varying commodity price assumptions.
- Oil price is the main driver as the cases in the analysis are primarily oil heavy, but gas price changes are included to capture the variance of wells with more associated gas production.
- The matrix above allows for several permutations, but we end up with three main scenarios. As mentioned, due to the oil-heavy content of the wells studied, gas prices have less of an impact and thus it is less important to cover more scenarios.

Source: Rystad Energy research and analysis

Key changes in assumptions for 2022 study – commodity price is the biggest adjustment, but also utilizing more production history and smaller changes in sand prices

Economic and case specific assumptions

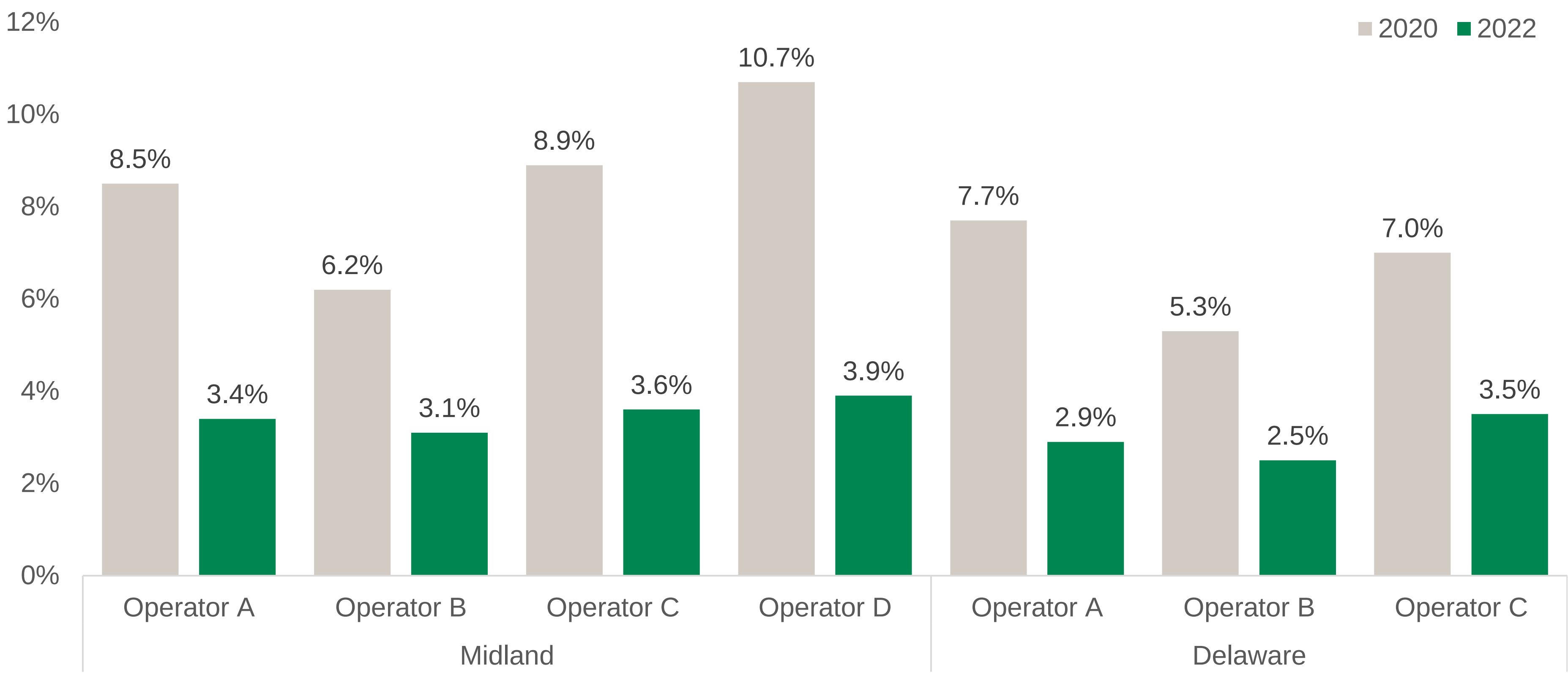
Base assumptions	2020	2022	Comments
Oil price ($/bbl)	50	90	Big changes in the macro environment calls for a revised base oil price.
Gas price ($/MMBtu)	1	7	Gas not really accounted for in previous studies so updating to reflect the changing macro environement.
Cost savings between sand types ($/ton)	50	40	Based on Rystad Energy research, the current tight market situation suggests a lower price difference between NWS and in-basin sand.
Compared observed changes to one-year allowbale degradation	IP270	IP360 and IP720	As more production data is now available, the study can focus on full one-year and two-year trends.

- Other assumptions around standard well design, well costs etc. that go into the economic model are kept unchanged compared to the previous studies. See the appendix for more details.

Source: Rystad Energy research and analysis

New commodity price assumptions have significant impact on allowable degradation, more than 50% reduction in most cases

Base case allowable degradation comparison to previous study
Degradation percentage



- Updated assumptions with higher oil and gas prices generally reduces the allowable degradation significantly.
- For all cases, the drop is at least 50% and, in some cases, greater than that.
- The 2022 base case assumes $90 per barrel for oil and $7 per MMBtu gas.

Source: Rystad Energy research and analysis

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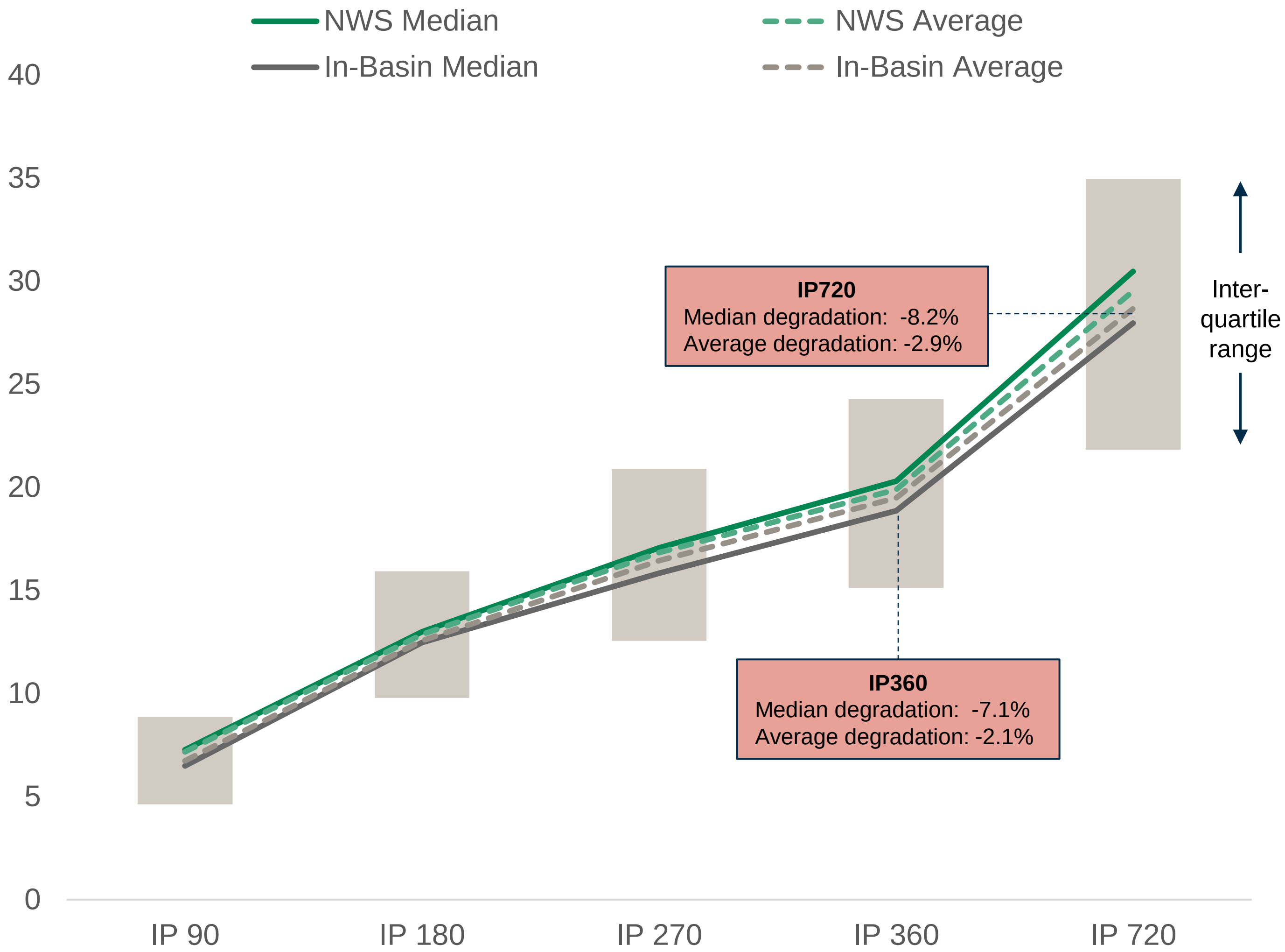
Midland Operator A: In-basin sand wells exhibit decline in productivity, both when comparing average and median production values

Actual IP Averages (in-basin vs. NWS)
Average boe/lateral foot



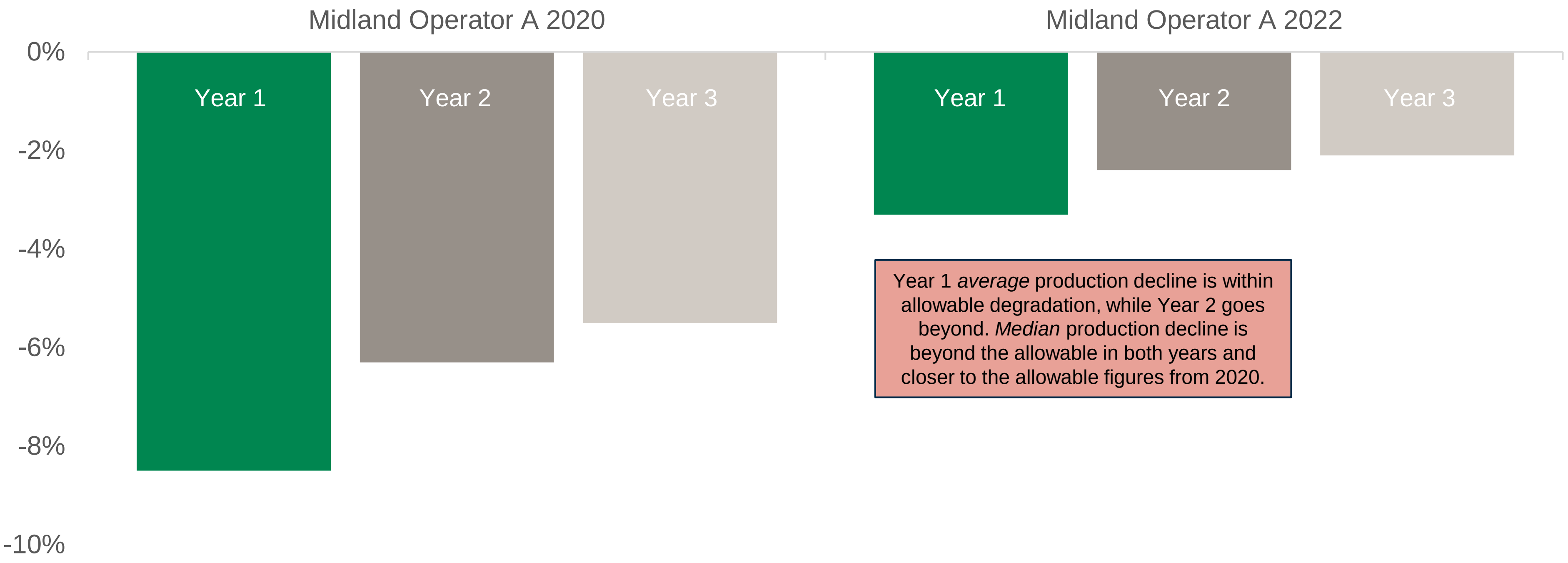
- Midland Operator A in-basin sand wells exhibit an average loss in IP360 and IP720 production of 2.1% and 2.9%, respectively, compared to NWS wells analyzed.
- The median exhibits a stronger degradation in production and the trend increases over time.
- For the economical analyses later in the report the average figures are used to assess overall impact.

Source: Rystad Energy research and analysis

Midland Operator A: Higher commodity price environment pushes Year 1 allowable degradation to 3.4%, thus wiping out upfront cost savings faster when production declines

Comparison of allowable degradation to previous study
Degradation percentage

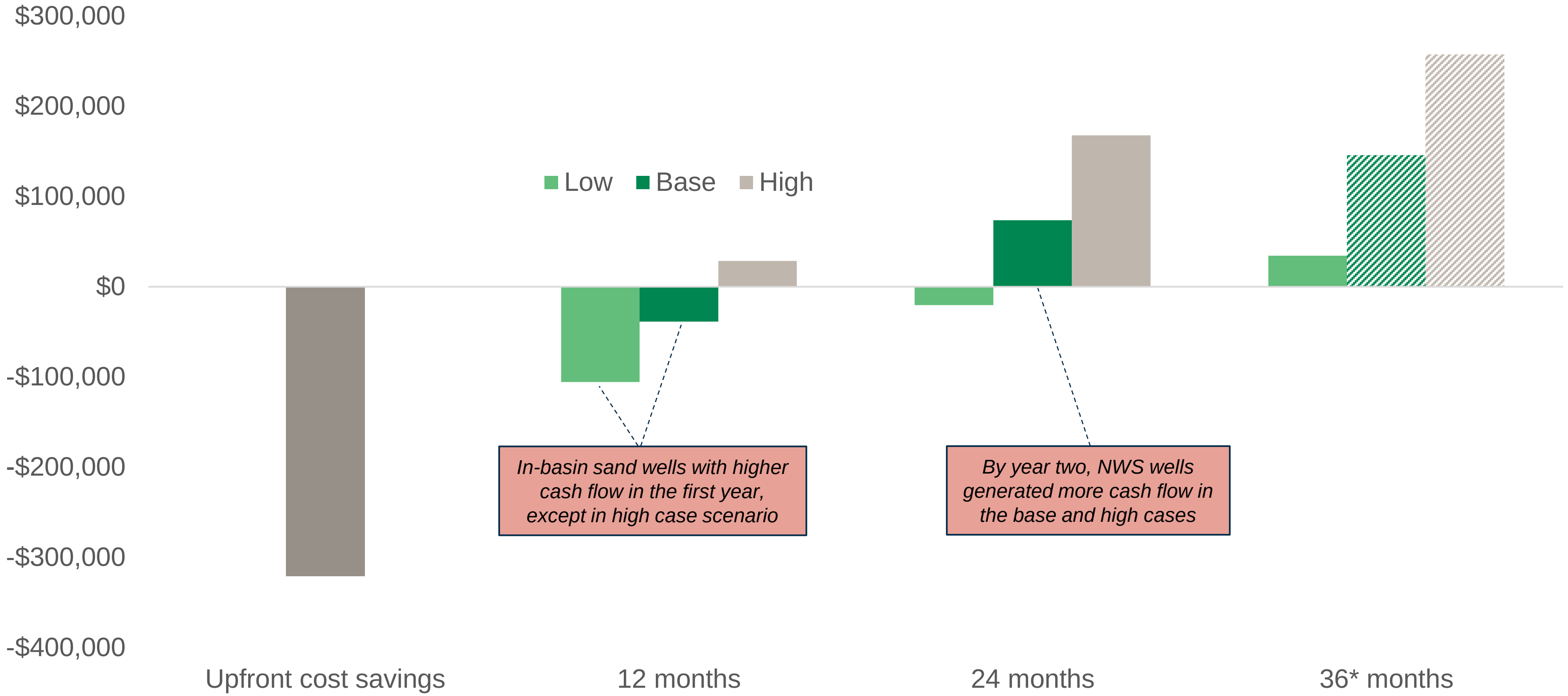
Study Year*	Year 1 Allowable Degradation	Year 2 Allowable Degradation	Year 3 Allowable Degradation
2020 ($50/bbl)	8.5%	6.3%	5.5%
2022 ($90/bbl)	3.4%	2.5%	2.2%



*Note: Study update in 2020 was run under a $50/bbl and $1/MMBtu natural gas price assumption, while the 2022 study is on a $90/bbl and $7/MMBtu price assumption
Source: Rystad Energy research and analysis

Midland Operator A: NWS wells show improved cash flows over time in comparison to in-basin sand wells, cumulative NWS cash flow greater after two years

Cumulative free cash flow (CFCF) differences by commodity price scanario
USD



- Operator saved ~$320,000 upfront in switching from NWS to in-basin sand.
- In-basin sand wells still saw savings of ~$106,00 for the low case and ~$39,000 for the base at the end of year one.
- Operator lost ~$74,000 in the base case and ~$168,000 in the high case by the end of year two.

*Estimated as not all wells in the set have 36 months production history Low = $70/bbl and $5/MMBtu -- Base = $90/bbl and $7/MMBtu – High = $110/bbl and $9/MMBtu
Source: Rystad Energy research and analysis

Midland Operator A: Productivity impact gets significant at $80+ for two-year trends

Difference between allowable and observed average degradation* across multiple sensitivities

		Gas ($/MMBtu)						
		3	4	5	6	7	8	9
Oil ($/bbl)	50	1.9%	1.8%	1.7%	1.6%	1.5%	1.4%	1.3%
	60	1.1%	1.0%	1.0%	0.9%	0.8%	0.8%	0.7%
	70	0.5%	0.5%	0.4%	0.4%	0.3%	0.3%	0.2%
	80	0.1%	0.1%	0.0%	0.0%	-0.1%	-0.1%	-0.1%
	90	-0.2%	-0.3%	-0.3%	-0.3%	-0.4%	-0.4%	-0.4%
	100	-0.5%	-0.5%	-0.6%	-0.6%	-0.6%	-0.6%	-0.7%
	110	-0.7%	-0.8%	-0.8%	-0.8%	-0.8%	-0.8%	-0.9%

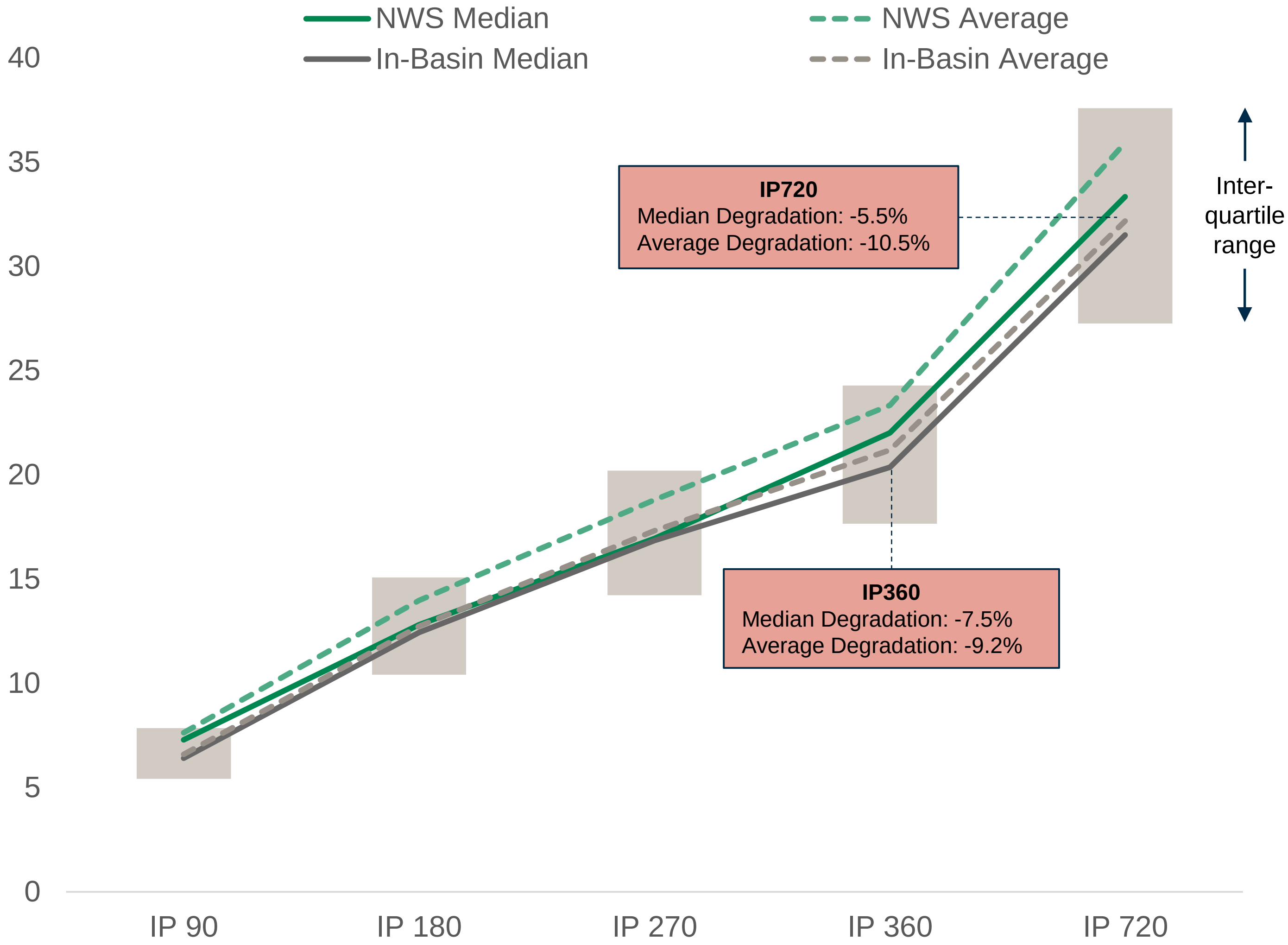
Within allowable degradation | **At allowable degradation** | **Greater than allowable degradation**

- Observed IP720 difference between NWS and in-basin sand wells is at -2.9%.
- The sensitivity analysis shows that the allowable degradation reaches the observed decline in IP720 at $80 per barrel oil and $5/MMBtu gas.

*Note: Negative numbers correspond to significant impact, meaning observed decline exceeds allowable degradation
Source: Rystad Energy research and analysis

Midland Operator B: Median production loss greater than 5%, average loss higher

Actual IP Averages (in-basin vs. NWS)
Average boe/lateral foot



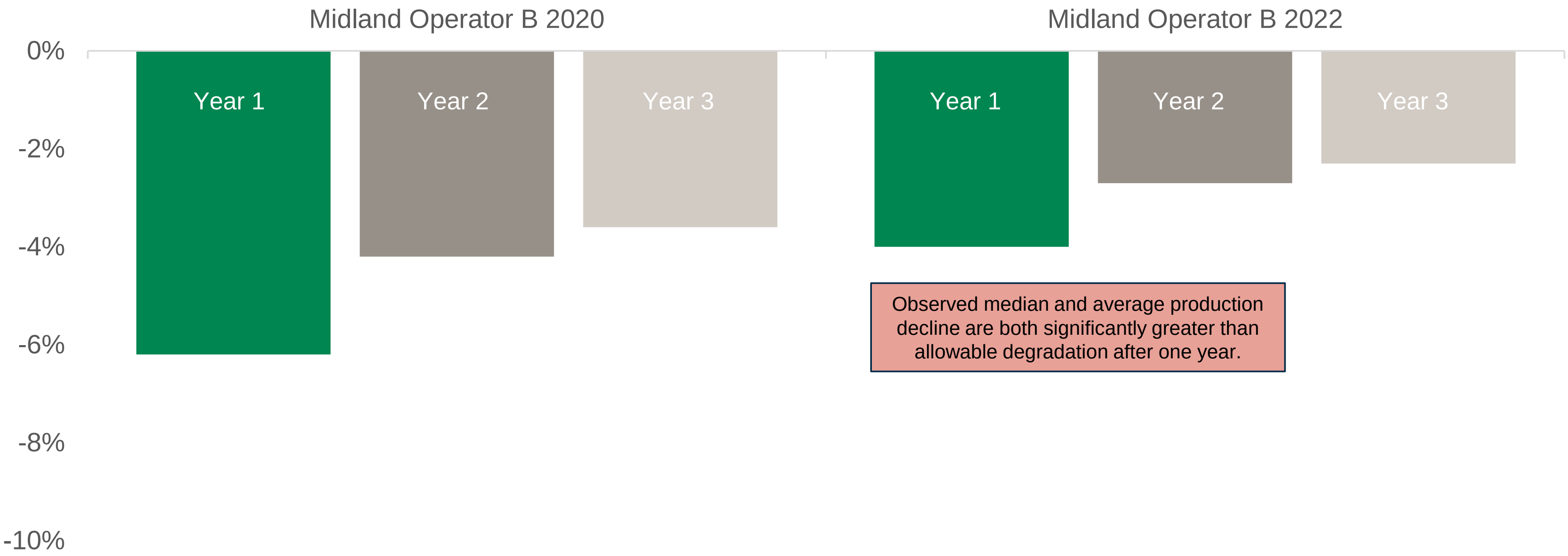
- Midland Operator B in-basin sand wells versus NWS wells exhibited a decline in production of 7.5% and 5.5% for IP360 and IP720, respectively.
- The average exhibits a stronger degradation in production and the trend increases over time, while the median difference is slightly smaller after two years.
- For the economical analyses later in the report, the average figures are used to assess overall impact.

Source: Rystad Energy research and analysis

Midland Operator B: Updated allowable degradation is closer to 3% after one year and declines towards 2% by Year 2, thus wiping out upfront cost savings faster

Comparison of allowable degradation to previous study
Degradation percentage

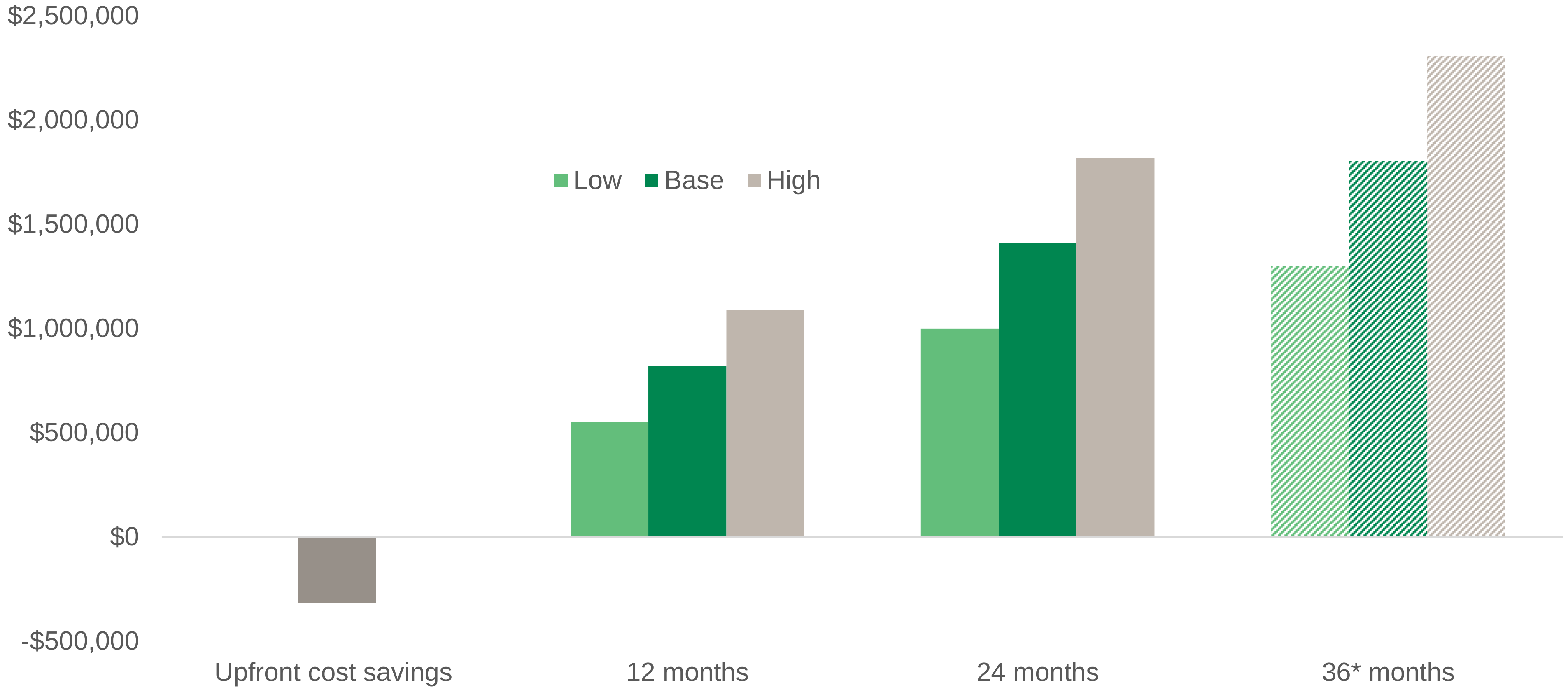
Study Year*	Year 1 Allowable Degradation	Year 2 Allowable Degradation	Year 3 Allowable Degradation
2020 ($50/bbl)	6.2%	4.2%	3.6%
2022 ($90/bbl)	3.1%	2.1%	1.7%



*Note: Study update in 2020 was run under a $50/bbl and $1/MMBtu natural gas price assumption, while the 2022 study is on a $90/bbl and $7/MMBtu price assumption
Source: Rystad Energy research and analysis

Midland Operator B: Upfront cost savings from in-basin sand wiped out in all cases after one year

Cumulative free cash flow (CFCF) differences by commodity price scanario
USD



- Operator saved ~$316,000 upfront in switching from NWS to in-basin sand.
- Operator lost ~$551,000, ~$820,000 and ~$1 million under low, base and high cases, respectively, by the end of year 1 in using in-basin sand.
- Operator lost ~$1 million, ~$1.4 million and ~$1.8 million under low, base and high cases, respectively, by the end of year 2 with in-basin sand.

*Estimated as not all wells in the set have 36 months production history Low = $70/bbl and $5/MMBtu -- Base = $90/bbl and $7/MMBtu – High = $110/bbl and $9/MMBtu
Source: Rystad Energy research and analysis

Midland Operator B: Production decline after two years greater than allowable degradation across all sensitivities, including $50 per barrel oil

Difference between allowable and observed average degradation* across multiple sensitivities

		Gas ($/MMBtu)						
		3	4	5	6	7	8	9
Oil ($/bbl)	50	-6.5%	-6.6%	-6.6%	-6.7%	-6.8%	-6.8%	-6.9%
	60	-7.2%	-7.2%	-7.3%	-7.3%	-7.4%	-7.4%	-7.5%
	70	-7.7%	-7.7%	-7.7%	-7.8%	-7.8%	-7.8%	-7.9%
	80	-8.0%	-8.0%	-8.1%	-8.1%	-8.1%	-8.2%	-8.2%
	90	-8.3%	-8.3%	-8.3%	-8.4%	-8.4%	-8.4%	-8.4%
	100	-8.5%	-8.5%	-8.6%	-8.6%	-8.6%	-8.6%	-8.6%
	110	-8.7%	-8.7%	-8.7%	-8.8%	-8.8%	-8.8%	-8.8%

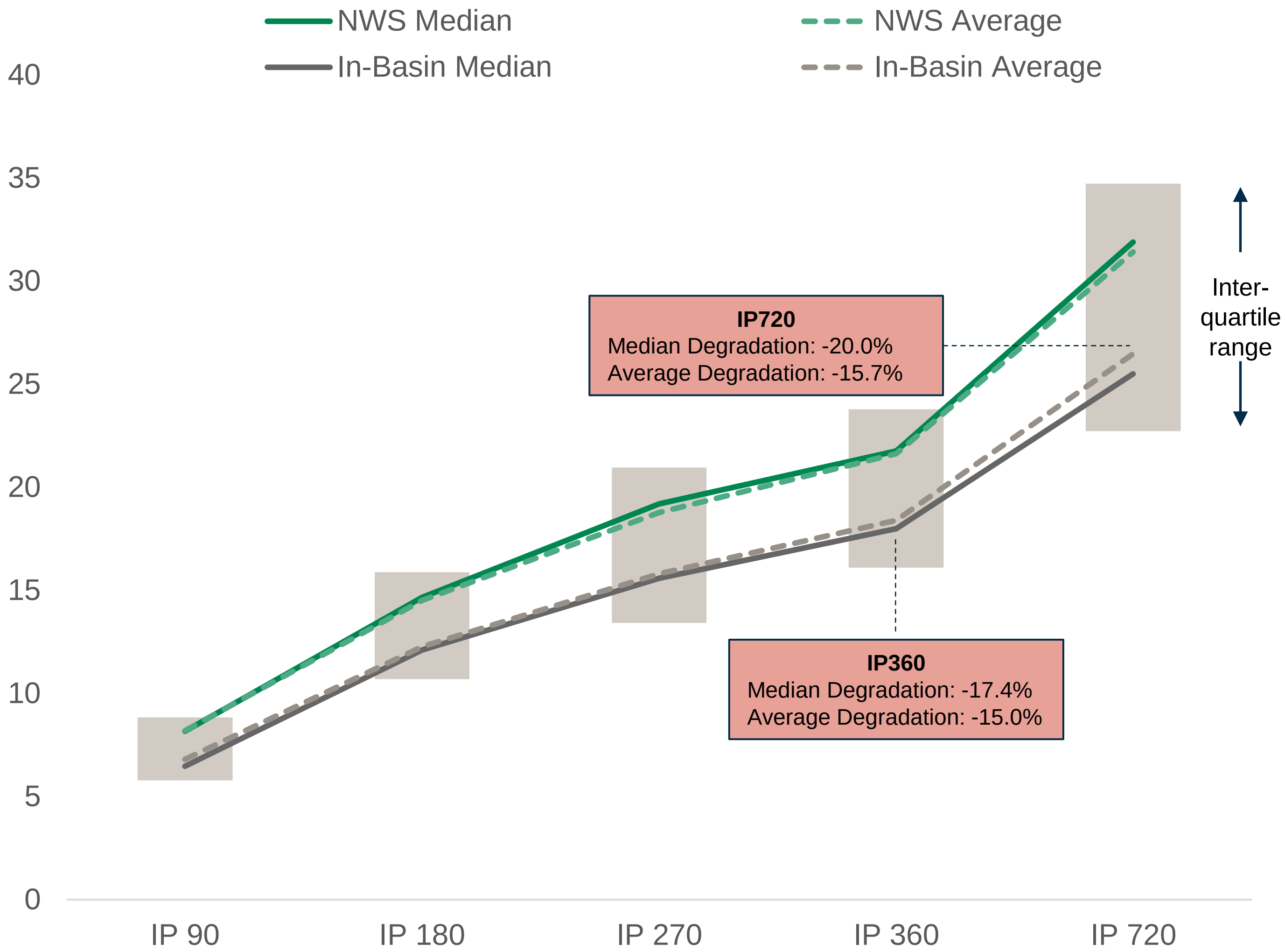
Within allowable degradation	At allowable degradation	Greater than allowable degradation

- Observed IP720 difference between NWS and in-basin sand wells is at -10.5%.
- The decline in production is significantly higher than the allowable degradation and hence it is better to use NWS in all oil and natural gas price scenarios.

*Note: Negative numbers correspond to negative impact, meaning observed decline exceeds allowable degradation
Source: Rystad Energy research and analysis

Midland Operator C: Severe production loss exhibited upon switching to in-basin sand

Actual IP Averages (in-basin vs. NWS)
Average boe/lateral foot



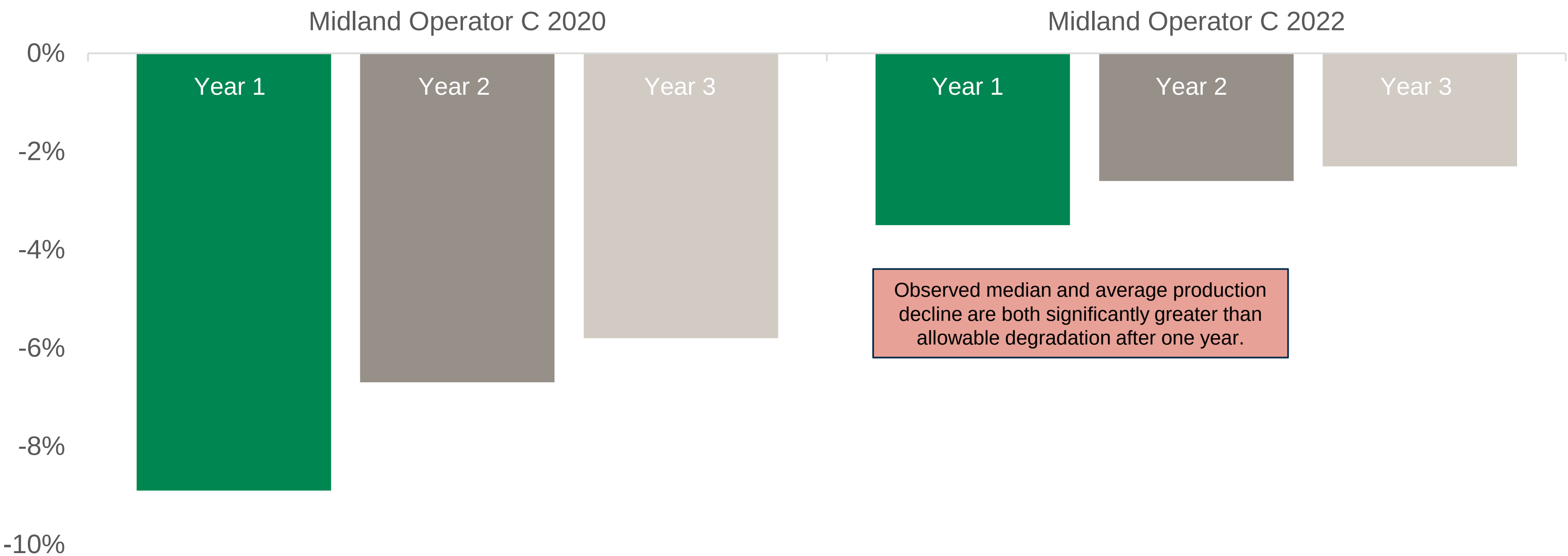
- Midland Operator C in-basin sand wells in comparison to NWS wells exhibit an average loss in IP360 and IP720 production of 15% and 15.7%, respectively.
- The differences are quite similar when analyzing both the median and average production values.
- For the economical analyses later in the report, the average figures are used to assess overall impact.

Source: Rystad Energy research and analysis

Midland Operator C: Updated allowable degradation is cut in half after one year, thus diminishing cost savings faster when production declines

Comparison of allowable degradation to previous study
Degradation percentage

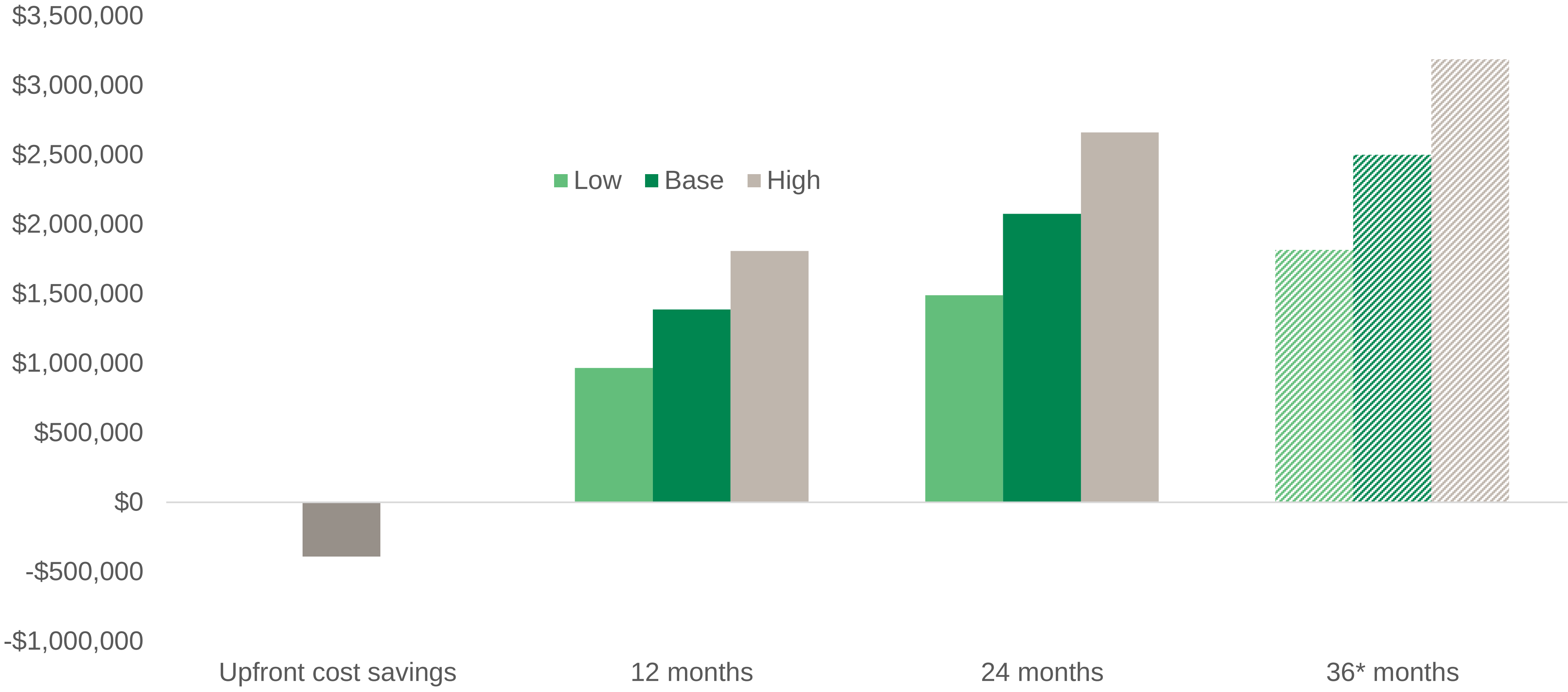
Study Year*	Year 1 Allowable Degradation	Year 2 Allowable Degradation	Year 3 Allowable Degradation
2020 ($50/bbl)	8.9%	6.7%	5.8%
2022 ($90/bbl)	3.6%	2.7%	2.3%



*Note: Study update in 2020 was run under a $50/bbl and $1/MMBtu natural gas price assumption, while the 2022 study is on a $90/bbl and $7/MMBtu price assumption
Source: Rystad Energy research and analysis

Midland Operator C: Upfront cost savings from in-basin sand wiped out in all cases after one year

Cumulative free cash flow (CFCF) differences by commodity price scanario
USD



- Operator saved ~$389,000 when switching to in-basin sand from NWS.
- Operator lost ~$966,000, $1.4 million and $1.8 million under low, base and high cases, respectively, by the end of year 1 with in-basin sand.
- Operator lost ~$1.5 million, ~$2.1 million and ~$2.7 million under low, base and high cases, respectively, by year 2 in using in-basin sand.

*Estimated as not all wells in the set have 36 months production history Low = $70/bbl and $5/MMBtu -- Base = $90/bbl and $7/MMBtu – High = $110/bbl and $9/MMBtu
Source: Rystad Energy research and analysis

Midland Operator C: Production decline after two years greater than allowable degradation across all sensitivities, including $50 per barrel oil

Difference between allowable and observed average degradation* across multiple sensitivities

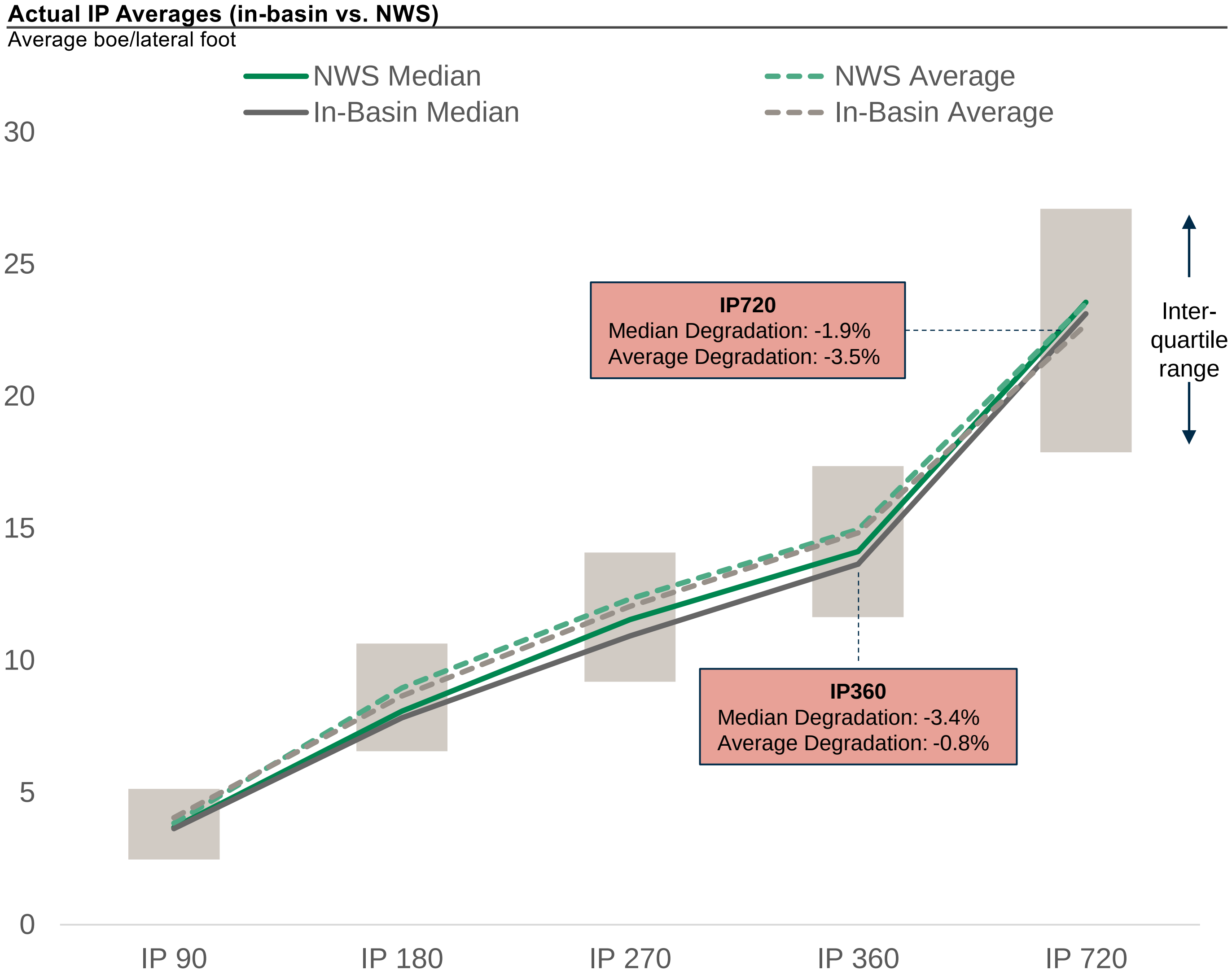
		Gas ($/MMBtu)						
		3	4	5	6	7	8	9
Oil ($/bbl)	50	-6.5%	-6.6%	-6.6%	-6.7%	-6.8%	-6.8%	-6.9%
	60	-7.2%	-7.2%	-7.3%	-7.3%	-7.4%	-7.4%	-7.5%
	70	-7.7%	-7.7%	-7.7%	-7.8%	-7.8%	-7.8%	-7.9%
	80	-8.0%	-8.0%	-8.1%	-8.1%	-8.1%	-8.2%	-8.2%
	90	-8.3%	-8.3%	-8.3%	-8.4%	-8.4%	-8.4%	-8.4%
	100	-8.5%	-8.5%	-8.6%	-8.6%	-8.6%	-8.6%	-8.6%
	110	-8.7%	-8.7%	-8.7%	-8.8%	-8.8%	-8.8%	-8.8%

Within allowable degradation | **At allowable degradation** | **Greater than allowable degradation**

- Observed IP 720 difference between NWS and in-basin sand wells is at -20.0%.
- The decline in production is significantly higher than the allowable degradation and hence it is better to use NWS in all oil and natural gas price scenarios.

*Note: Negative numbers correspond to negative impact, meaning observed decline exceeds allowable degradation
Source: Rystad Energy research and analysis

Midland Operator D: IP360 and IP720 both observed modest declines



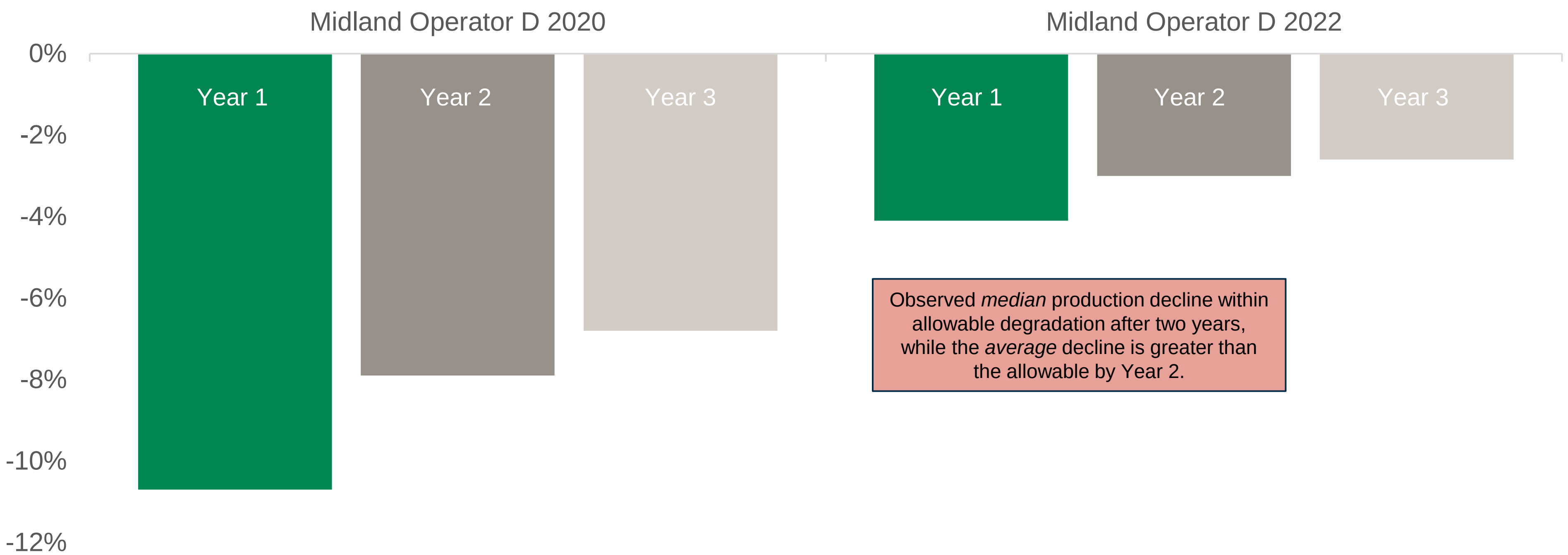
- Midland Operator D in-basin sand wells in comparison to NWS wells exhibited a median decline in production of 3.4% and 1.9% for IP 360 and IP 720, respectively.
- The average decline is stronger after two years while the difference in median performance shrinks.
- For the economical analyses later in the report, the average figures are used to assess overall impact.

Source: Rystad Energy research and analysis

Midland Operator D: Updated allowable degradation is closer to 4% in Year 1 and declines towards 2% by Year 3, thus limiting in-basin cost savings when production declines

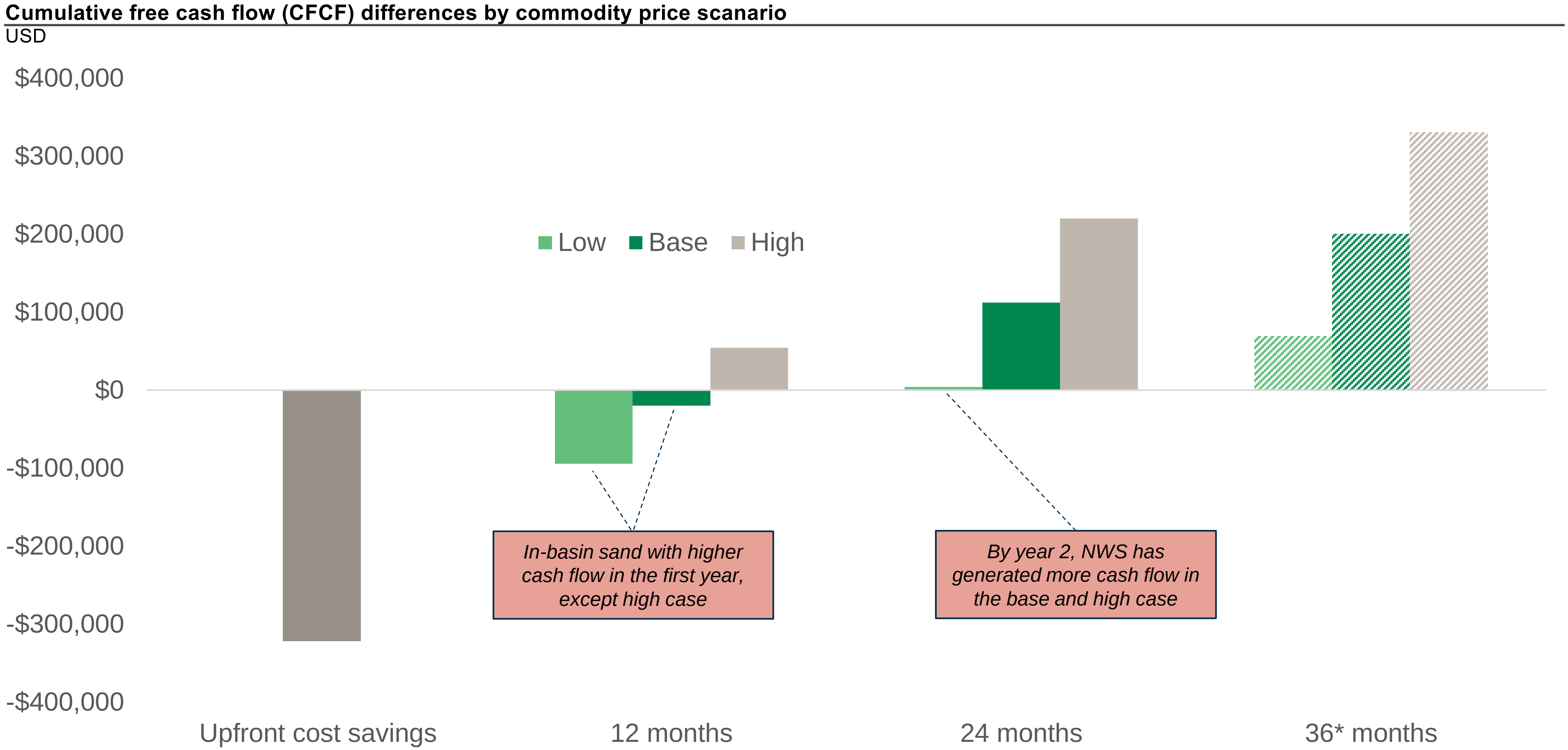
Comparison of allowable degradation to previous study
Degradation percentage

Study Year*	Year 1 Allowable Degradation	Year 2 Allowable Degradation	Year 3 Allowable Degradation
2020 ($50/bbl)	10.7%	7.9%	6.8%
2022 ($90/bbl)	3.9%	2.8%	2.4%



*Note: Study update in 2020 was run under a $50/bbl and $1/MMBtu natural gas price assumption, while the 2022 study is on a $90/bbl and $7/MMBtu price assumption
Source: Rystad Energy research and analysis

Midland Operator D: Upfront cost savings from in-basin sand wiped out by the end of Year 2 in all cases



- Operator saved ~$322,000 when switching to in-basin sand from NWS.
- In-basin sand wells still saw savings of ~$94,000 for the low case and ~$20,000 for the base at the end of year 1.
- Operator lost ~$112,000 in the base case and ~$220,000 in the high case by the end of year 2.

*Estimated as not all wells in the set have 36 months production history Low = $70/bbl and $5/MMBtu -- Base = $90/bbl and $7/MMBtu – High = $110/bbl and $9/MMBtu
Source: Rystad Energy research and analysis

Midland Operator D: Productivity impact gets significant at $70+ for two-year trends

Difference between allowable and observed average degradation* across multiple sensitivities

		Gas ($/MMBtu)						
		3	4	5	6	7	8	9
Oil ($/bbl)	50	2.0%	1.7%	1.5%	1.2%	1.0%	0.8%	0.6%
	60	1.2%	0.9%	0.7%	0.6%	0.4%	0.2%	0.1%
	70	0.5%	0.4%	0.2%	0.1%	-0.1%	-0.2%	-0.3%
	80	0.0%	-0.1%	-0.2%	-0.3%	-0.4%	-0.5%	-0.6%
	90	-0.3%	-0.4%	-0.5%	-0.6%	-0.7%	-0.8%	-0.9%
	100	-0.6%	-0.7%	-0.8%	-0.9%	-1.0%	-1.0%	-1.1%
	110	-0.9%	-1.0%	-1.0%	-1.1%	-1.2%	-1.2%	-1.3%

Within allowable degradation	At allowable degradation	Greater than allowable degradation

- Observed IP720 difference between NWS and in-basin sand wells is at -1.9%.
- The sensitivity analysis shows that the allowable degradation reaches the observed decline in IP 720 at $80 per barrel oil and $3/MMBtu gas.

*Note: Negative numbers correspond to negative impact, meaning observed decline exceeds allowable degradation
Source: Rystad Energy research and analysis

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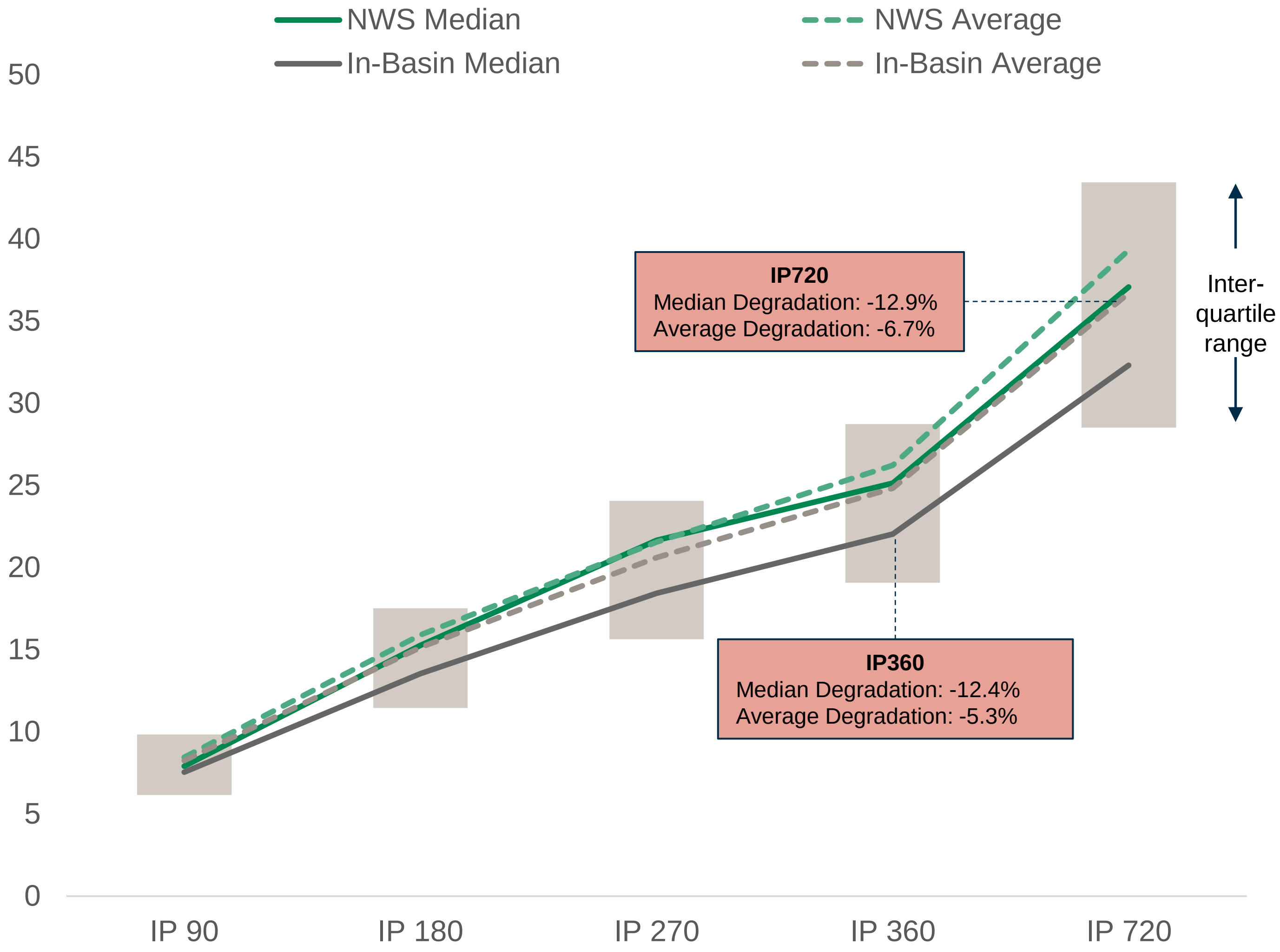
Delaware Operator A: Significant production declines after both one and two years

Actual IP Averages (in-basin vs. NWS)
Average boe/lateral foot



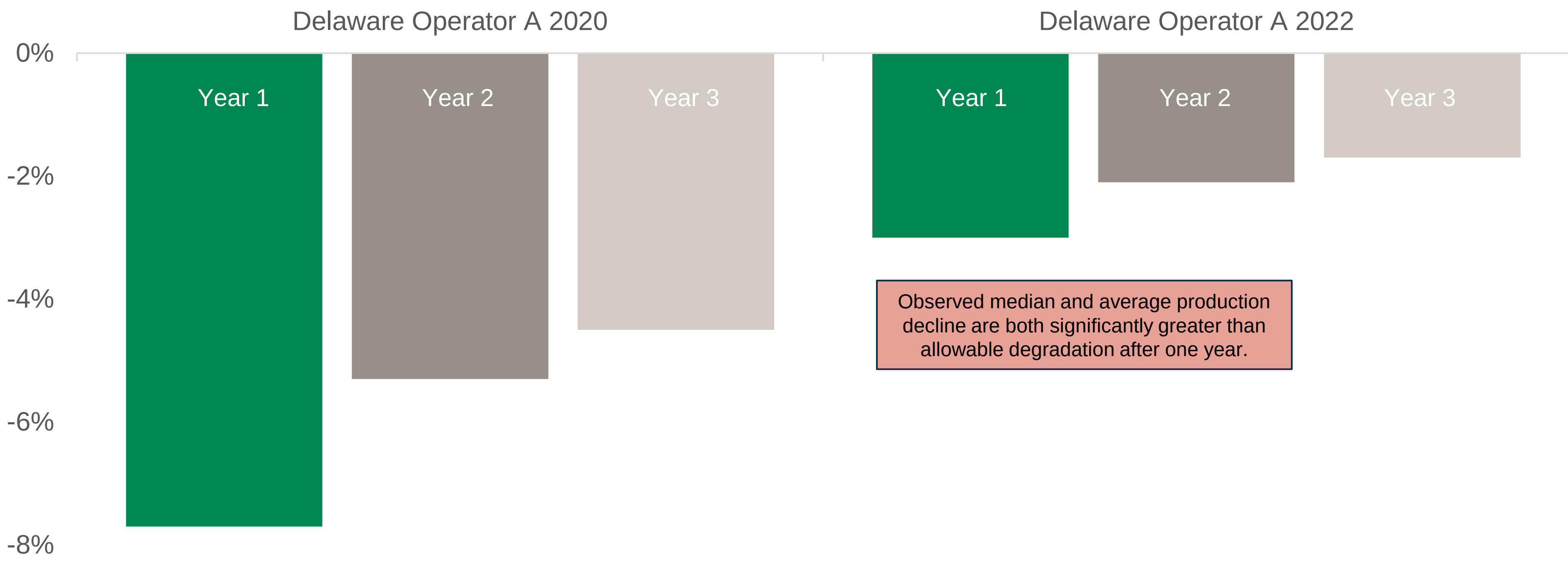
- Delaware Operator A in-basin sand wells exhibit an average loss in IP360 and IP720 production of 5.3% and 6.7%, respectively, compared to NWS wells analyzed.
- There is a bigger difference in the median figure versus the average, but both exhibit clear declines, and the decline increases over time.
- For the economical analyses later in the report, the average figures are used to assess overall impact.

Source: Rystad Energy research and analysis

Delaware Operator A: Updated allowable degradation is closer to 3% in Year 1 and declines towards 2% by Year 3, thus limiting in-basin cost savings when production declines

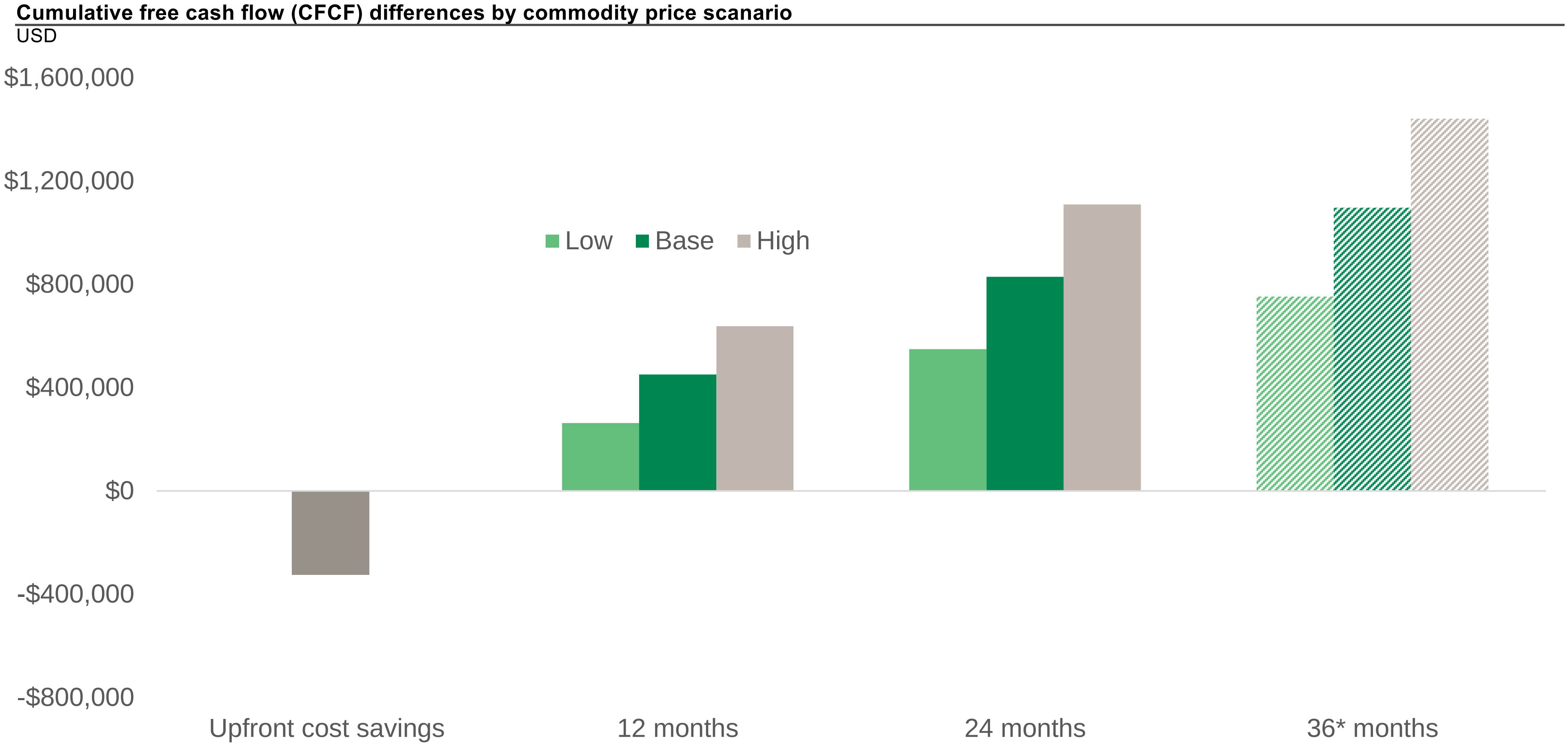
Comparison of allowable degradation to previous study
Degradation percentage

Study Year*	Year 1 Allowable Degradation	Year 2 Allowable Degradation	Year 3 Allowable Degradation
2020 ($50/bbl)	7.7%	5.3%	4.5%
2022 ($90/bbl)	2.9%	2.0%	1.7%



*Note: Study update in 2020 was run under a $50/bbl and $1/MMBtu natural gas price assumption, while the 2022 study is on a $90/bbl and $7/MMBtu price assumption
Source: Rystad Energy research and analysis

Delaware Operator A: Upfront cost savings from in-basin sand wiped out in all cases after one year



- Operator saved ~$325,000 when switching to in-basin sand from NWS.
- Operator lost ~$263,000, ~$451,000 and ~$638,000 under low, base and high cases, respectively, by the end of year 1 using in-basin sand
- Operator lost ~$549,000, ~$829,000 million and ~$1.1 million under low, base and high cases, respectively, by year 2 with in-basin sand.

*Estimated as not all wells in set have 36 months production history

Low = $70/bbl and $5/MMBtu -- Base = $90/bbl and $7/MMBtu – High = $110/bbl and $9/MMBtu

Source: Rystad Energy research and analysis

Delaware Operator A: Production decline after two years greater than allowable degradation across all sensitivities, including $50 per barrel oil

Difference between allowable and observed average degradation* across multiple sensitivities

		Gas ($/MMBtu)						
		3	4	5	6	7	8	9
Oil ($/bbl)	50	-2.8%	-2.9%	-3.1%	-3.2%	-3.3%	-3.4%	-3.5%
	60	-3.4%	-3.5%	-3.6%	-3.7%	-3.8%	-3.9%	-3.9%
	70	-3.9%	-4.0%	-4.0%	-4.1%	-4.2%	-4.2%	-4.3%
	80	-4.3%	-4.3%	-4.4%	-4.4%	-4.5%	-4.5%	-4.6%
	90	-4.5%	-4.6%	-4.6%	-4.7%	-4.7%	-4.7%	-4.8%
	100	-4.7%	-4.8%	-4.8%	-4.8%	-4.9%	-4.9%	-4.9%
	110	-4.9%	-5.0%	-5.0%	-5.0%	-5.0%	-5.1%	-5.1%

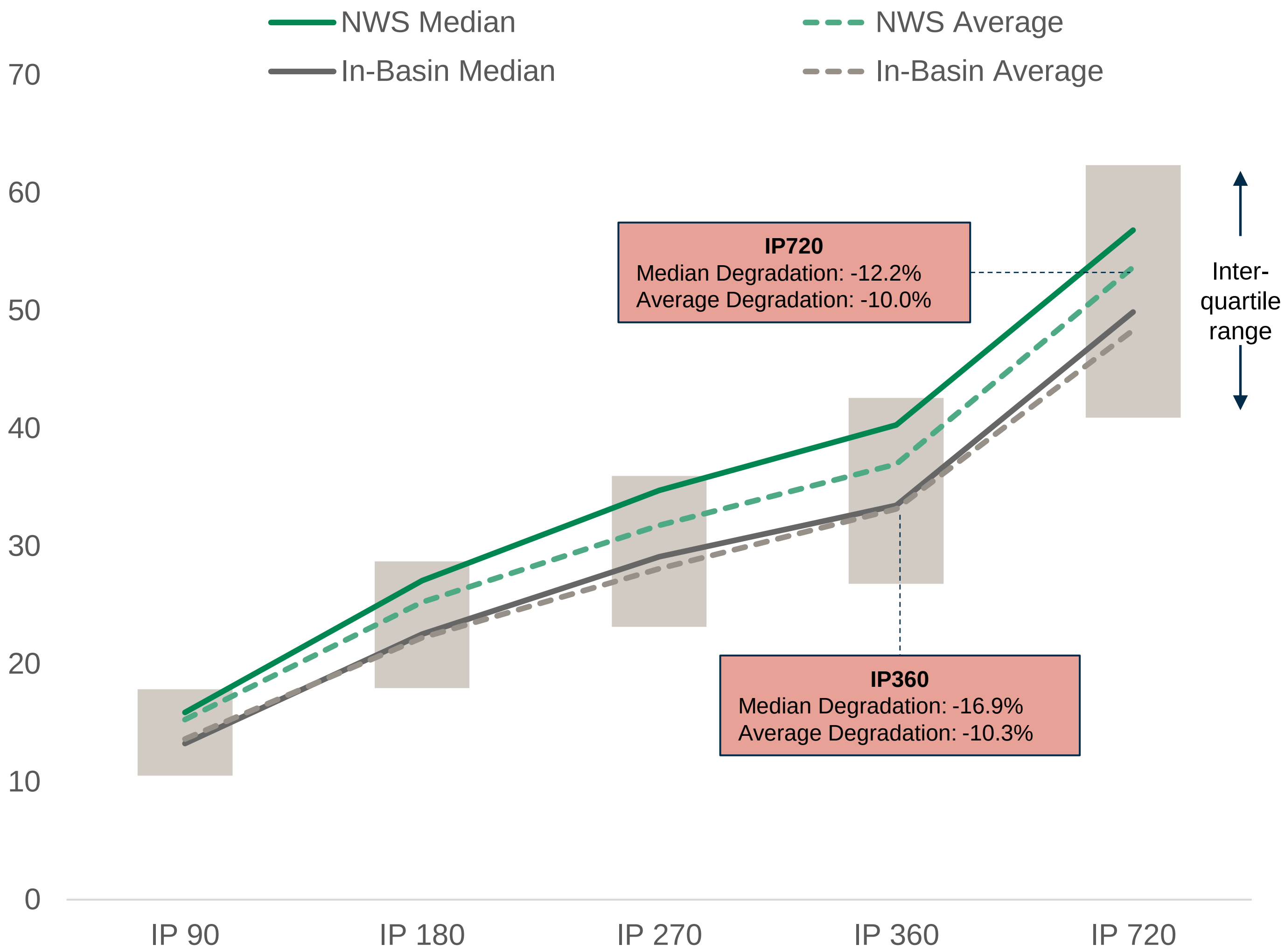
Within allowable degradation | At allowable degradation | Greater than allowable degradation

- Observed IP720 difference between NWS and in-basin sand wells is at -6.7%.
- The decline in production is significantly higher than the allowable degradation and hence it is better to use NWS in all oil and natural gas price scenarios.

*Note: Negative numbers correspond to negative impact, meaning observed decline exceeds allowable degradation
Source: Rystad Energy research and analysis

Delaware Operator B: Strong impact on well productivity when switching to in-basin sand

Actual IP Averages (in-basin vs. NWS)
Average boe/lateral foot



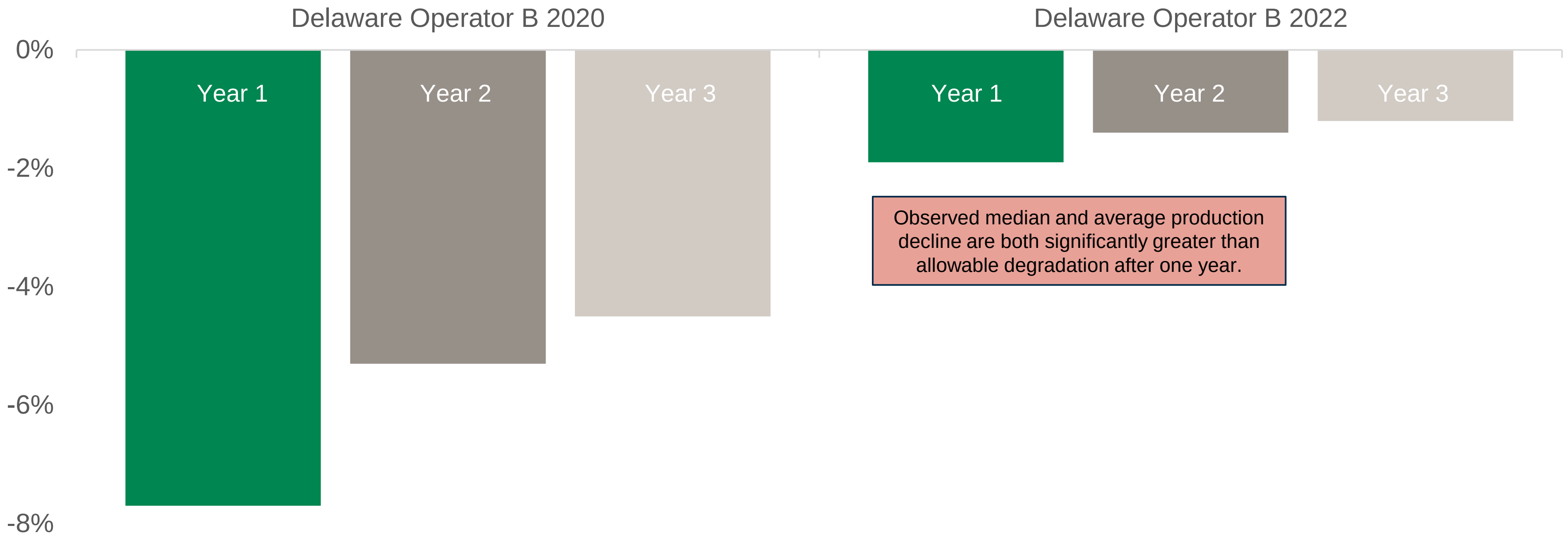
- Delaware Operator B in-basin sand wells exhibit an average loss in IP360 and IP720 production of about 10% compared to NWS wells analyzed.
- The median exhibits a stronger degradation in production, though slightly lower difference after two years.
- For the economical analyses later in the report, the average figures are used to assess overall impact.

Source: Rystad Energy research and analysis

Delaware Operator B: Updated allowable degradation is closer to 2% in year-one and declines towards 1% by year-three

Comparison of allowable degradation to previous study
Degradation percentage

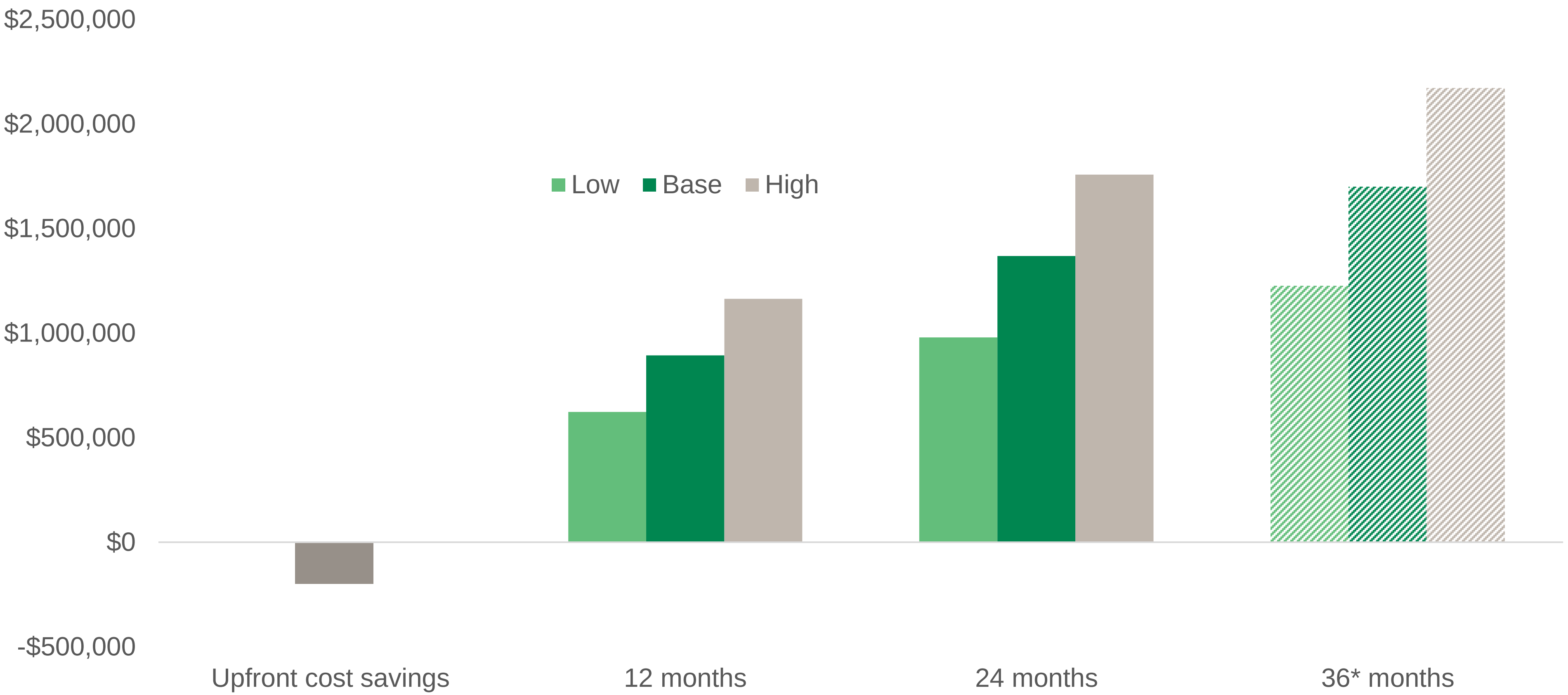
Study Year*	Year 1 Allowable Degradation	Year 2 Allowable Degradation	Year 3 Allowable Degradation
2020 ($50/bbl)	5.3%	3.9%	3.3%
2022 ($90/bbl)	1.9%	1.4%	1.2%



*Note: Study update in 2020 was run under a $50/bbl and $1/MMBtu natural gas price assumption, while the 2022 study is on a $90/bbl and $7/MMBtu price assumption
Source: Rystad Energy research and analysis

Delaware Operator B: Upfront cost savings from in-basin sand wiped out in all cases after one year

Cumulative free cash flow (CFCF) differences by commodity price scenario
USD



- Operator saved ~$198,000 when switching to in-basin sand from NWS.
- Operator lost ~$620,000, ~$894,000 and ~$1.2 million under low, base and high cases, respectively, by the end of year 1 with in-basin sand.
- Operator lost ~$980,000, ~$1.4 million and ~$1.8 million under low, base and high cases respectively by year 2 in using in-basin sand.

*Estimated as not all wells in the set have 36 months production history Low = $70/bbl and $5/MMBtu -- Base = $90/bbl and $7/MMBtu – High = $110/bbl and $9/MMBtu
Source: Rystad Energy research and analysis

Delaware Operator B: Production decline after two years greater than allowable degradation across all sensitivities, including $50 per barrel oil

Difference between allowable and observed average degradation* across multiple sensitivities

		Gas ($/MMBtu)						
		3	4	5	6	7	8	9
Oil ($/bbl)	50	-7.3%	-7.5%	-7.6%	-7.7%	-7.8%	-7.9%	-8.0%
	60	-7.7%	-7.8%	-7.9%	-8.0%	-8.1%	-8.2%	-8.3%
	70	-8.0%	-8.1%	-8.2%	-8.3%	-8.3%	-8.4%	-8.4%
	80	-8.3%	-8.3%	-8.4%	-8.4%	-8.5%	-8.6%	-8.6%
	90	-8.4%	-8.5%	-8.6%	-8.6%	-8.6%	-8.7%	-8.7%
	100	-8.6%	-8.6%	-8.7%	-8.7%	-8.8%	-8.8%	-8.8%
	110	-8.7%	-8.8%	-8.7%	-8.8%	-8.9%	-8.9%	-8.9%

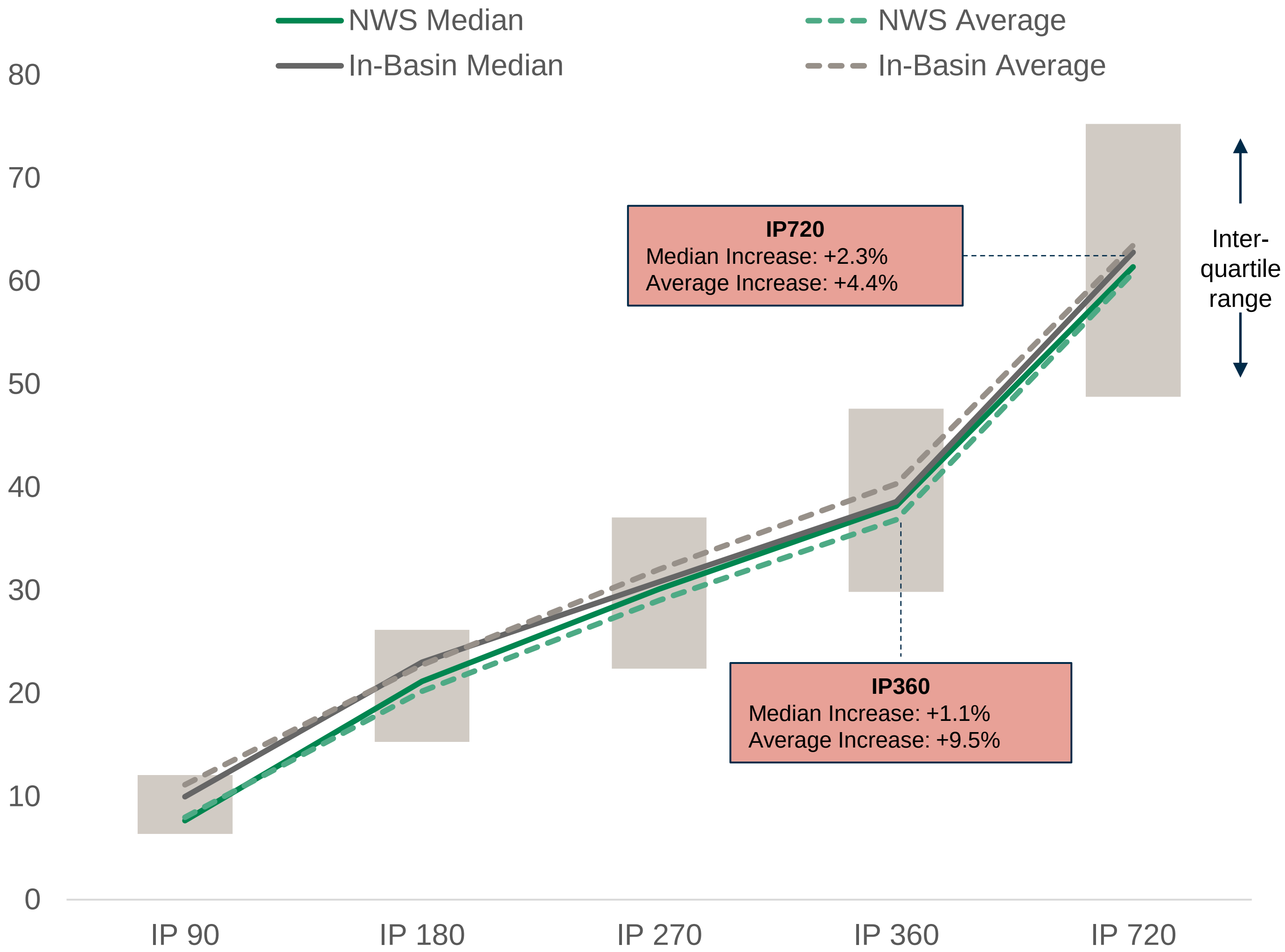
Within allowable degradation	At allowable degradation	Greater than allowable degradation

- Observed IP720 difference between NWS and in-basin sand wells is at -10.0%.
- The decline in production is significantly higher than the allowable degradation and hence it is better to use NWS in all oil and natural gas price scenarios.

*Note: Negative numbers correspond to negative impact, meaning observed decline exceeds allowable degradation
Source: Rystad Energy research and analysis

Delaware Operator C: Wells exhibit increase in productivity upon switching to in-basin sand

Actual IP Averages (in-basin vs. NWS)
Average boe/lateral foot



- Delaware Operator C in-basin sand wells in comparison to NWS wells experienced an increase in production of 1.1% and 2.3% for IP360 and IP720, respectively.
- This is the only example among the seven operator case studies that showed an increase in production upon shifting to in-basin sand
- The analysis doesn't change when comparing the median versus average production values.

Source: Rystad Energy research and analysis

Delaware Operator C: Higher commodity price environment yields lower allowable degradation but less relevant for cases that exhibit production growth

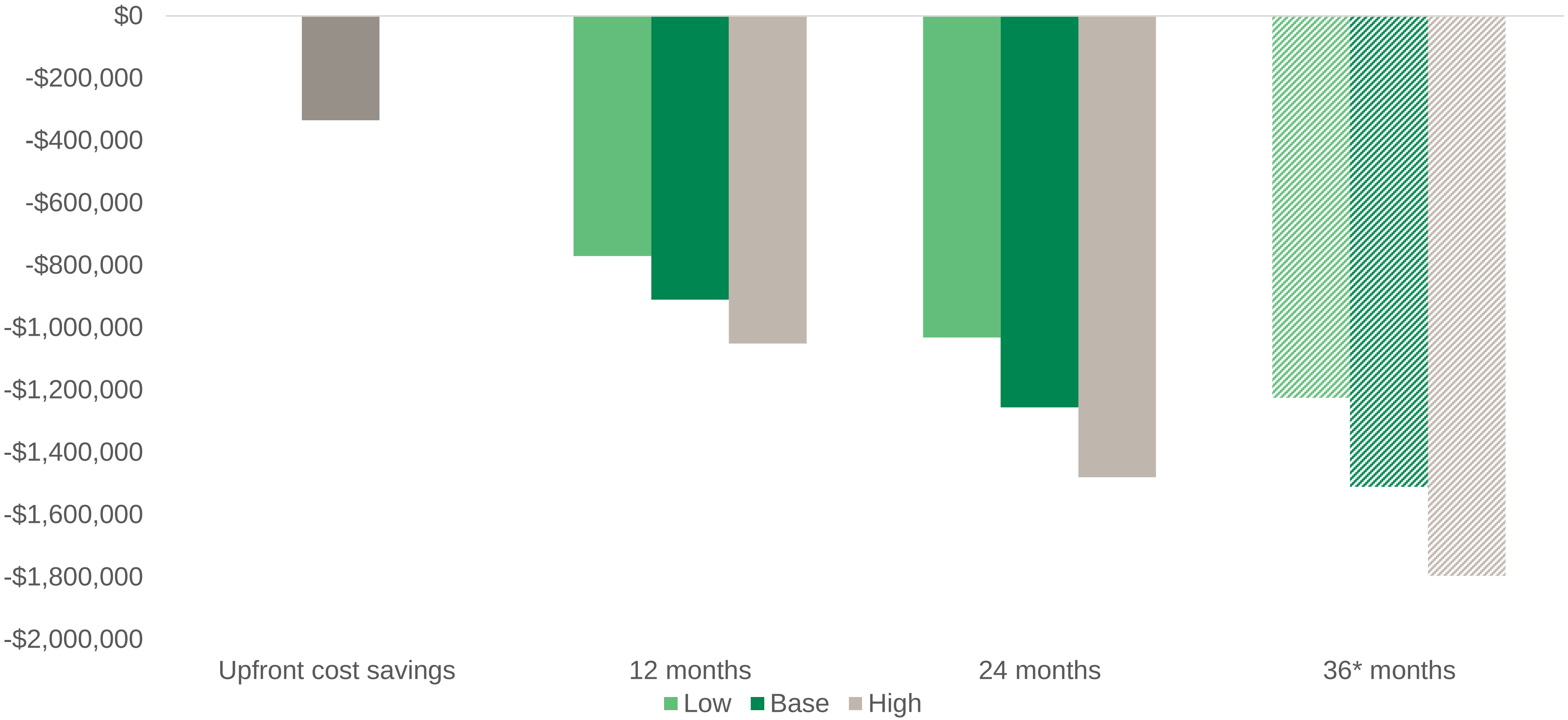
Comparison of allowable degradation to previous study
Degradation percentage

Study Year*	Year 1 Allowable Degradation	Year 2 Allowable Degradation	Year 3 Allowable Degradation
2020 ($50/bbl)	7.0%	4.6%	3.7%
2022 ($90/bbl)	2.7%	1.7%	1.4%

*Note: Study update in 2020 was run under a $50/bbl and $1/MMBtu natural gas price assumption, while the 2022 study is on a $90/bbl and $7/MMBtu price assumption
Source: Rystad Energy research and analysis

Delaware Operator C: Case exhibits productivity gains following switch to in-basin sand and hence cash flow savings will continue to grow from initial upfront cost reduction

Cumulative free cash flow (CFCF) differences by commodity price scenario
USD



- Operator saved an upfront cost of ~$334,000 in switching from NWS to in-basin sand.
- There was no impact on cash flows in any of the 3 years upon switch to in-basin sand.

*Estimated as not all wells in the set have 36 months production history Low = $70/bbl and $5/MMBtu -- Base = $90/bbl and $7/MMBtu – High = $110/bbl and $9/MMBtu
Source: Rystad Energy research and analysis

Delaware Operator C: Case exhibits productivity gains following switch to in-basin sand and hence within allowable degradation in all price scenarios

Difference between allowable and observed average degradation* across multiple sensitivities

		Gas ($/MMBtu)						
		3	4	5	6	7	8	9
Oil ($/bbl)	50	7.8%	7.7%	7.5%	7.4%	7.3%	7.1%	7.1%
	60	7.2%	7.1%	7.0%	7.0%	6.9%	6.7%	6.8%
	70	6.8%	6.8%	6.7%	6.6%	6.6%	6.4%	6.5%
	80	6.5%	6.5%	6.4%	6.4%	6.3%	6.2%	6.3%
	90	6.3%	6.2%	6.2%	6.2%	6.1%	6.0%	6.1%
	100	6.1%	6.1%	6.0%	6.0%	6.0%	5.9%	5.9%
	110	5.9%	5.9%	5.9%	5.9%	5.8%	5.8%	5.8%

Within allowable degradation	At allowable degradation	Greater than allowable degradation

- IP720 observed is 4.4%.
- The sensitivity analysis shows that the operator's wells can leverage in-basin sand in all oil and natural gas price scenarios due to the nature of increasing production recorded upon switching to in-basin sand.

*Note: Negative numbers correspond to negative impact, meaning observed decline exceeds allowable degradation
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

Proppant intensity

Lateral length

Design

RYSTAD ENERGY

ShaleWellCube

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

Source: Rystad Energy research and analysis

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

Hydraulic Fracturing Fluid Product Component Information Disclosure

Frac Focus
Chemical Disclosure Registry

GROUNDWATER PROTECTION COUNCIL

Interstate Oil & Gas Compact Commission

100 MESH ***REGIONAL*** CRYSTALLINE SILICA

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	SM ENERGY	CARRIER/BASE FLUID					
			WATER	7732-18-5	100.00000	90.68292	None
100 MESH REGIONAL	US SILICA COMPANY	PROPPING AGENT					
			CRYSTALLINE SILICA	14808-60-7	99.90000	6.42932	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	68609-68-7	5.00000	0.00106	None
			AMINE SULFONATE	26836-07-7	5.00000	0.00106	None

Comment

- The primary source of data for sand type identification are frac forms submitted by operators to FracFocus, a database containing frac fluid chemicals disclosure for more than 150,000 wells fracked.
- Frac forms contain detailed information on frac fluid products used during fracking, broken down to individual chemicals comprising those products.
- Rystad Energy performs a thorough cleaning of the forms that, among other things, allows us to identify entries that refer to the sand used during fracturing.
- While not a requirement, operators occasionally include references to the exact type of sand in either trade or ingredient name referring to the sand (for example, "100 mesh *regional*").
- Rystad Energy has developed a methodology that looks for and analyzes such textual markers referring to the sand type used.

Source: Rystad Energy research and analysis; FracFocus

Examples of textual markers in frac forms that allow for identification of sand type

Examples of entries classified as Northern White Sand

Reported trade name

Northern White Sand
40/70 ***WHITE***
Sand, ***White***, 20/40
Sand, ***White***, 40/70
Sand (20/40) ***Ottawa***
Sand, ***White***, 100 mesh
Sand (40/70) ***Ottawa***
Sand (30/50) ***Ottawa***
30/50 ***WHITE***
Sand, ***White***
Sand, ***White***, 30/50
20/40 ***White***
Ottawa Sand
100 mesh ***White*** Sand, Area 1
40/70 ***White*** (Special Order)

Typically, "*White*"/"*Ottawa*"/"*Northern*" and variations of spelling of

Examples of entries classified as Brown Sand

Reported trade name

Sand, **Brown** [SB-4]
16/30 **Brady**
Sand, **Brown**, 20/40
20/40 **Brady**
20/50 **Brown** Sand
Sand **Texas Gold**, 30/50
Sand **Texas Gold**, 100M
Sand ***Texas Gold***, 40/70
40/70 ***Brown*** Sand
40/70 ***Brady***
40/70 ***TG***
12/20 ***Brady*** Sand
Brown Sand
Sand, ***Brown***, 16/30
Sand, ***Brown***

Typically, "*Brown*"/"*Brady*"/"Texas *Gold*" and variations of spelling of

Examples of entries classified as In-Basin Sand

Reported trade name

100 MESH ***REGIONAL***
40/70 ***REGIONAL***
West TX 100 Mesh
West TX 40/70
Regional Sand
Permian 100 Mesh
40/70 ***Permian***
Permian 40/70
STX-40/70
40/70 ***REGIONAL*** SAND
PERMIAN 100M
Permian-100 MESH
STX 100 MESH
Sand ***Regional***
STX_100 MESH

Typically, "*Regional*"/"*Permian*"/"*West TX*"/"*STX*", and variations of spelling of

Examples of entries with no reference to exact sand type

Reported trade name

Sand
Sand (Proppant)
Silica Sand
CRC SAND
100 mesh sand
Sand (50/140)
100 MESH
Crystalline Silica Quartz
CRC SAND PREMIUM
Sand (40/70)
FRAC SAND
Sand (20/40)
SAND (WHOLE GRAIN)
20/40 Sand
Sand (30/50)

No textual markers allowing for identification of sand type based on trade/ingredient names alone

Source: Rystad Energy research and analysis; FracFocus

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

Hydraulic Fracturing Fluid Product Component Information Disclosure

FracFocus Chemical Disclosure Registry

GROUNDWATER PROTECTION COUNCIL

Interstate Oil & Gas Compact Commission

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

Comment

- Among the many attributes appearing on a frac form, provider of a given product and its associated chemicals is listed.
- We look at suppliers appearing on frac forms and check those against a list of known pure in-basin sand providers.
- An example would be Atlas Sand, a pure Permian in-basin sand provider, Black Mountain which has in-basin mines in the Permian, Eagle Ford and the 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 an example on the right - “100 MESH SAND”, with no reference to the sand type. This sand was supplied by Atlas Sand, a pure in-basin provider.
- In turn, we can tag this entry as Permian in-basin with a high degree of confidence.

Source: Rystad Energy research and analysis; FracFocus

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