

THE PERMIAN BASIN

Past, Present, and Future

Russell K. Hall
Midland, Texas

THE PERMIAN BASIN

- Geology Overview
- Early History
- Recent Events
- Future Projections

GENERALIZED STRATIGRAPHIC COLUMN FOR THE PERMIAN BASIN REGION

ERA	SYSTEM	SERIES	AGE	NORTHWEST SHELF	DELAWARE BASIN	CENTRAL BASIN PLATFORM	MIDLAND BASIN
PALEOZOIC	PERMIAN	OCHOA	253-245	DEWEY LAKE RUSTLER SALADO	DEWEY LAKE RUSTLER SALADO CASTILE	DEWEY LAKE RUSTLER SALADO	DEWEY LAKE RUSTLER SALADO
		UPPER GUADALUPE	258-253	TANSILL YATES SEVEN RIVERS	LAMAR BELL CANYON RAMSEY / OLDS	TANSILL YATES SEVEN RIVERS	TANSILL YATES SEVEN RIVERS
		MIDDLE GUADALUPE		QUEEN PENROSE	CHERRY CANYON	QUEEN PENROSE	QUEEN GRAYBURG
		L. GUADALUPE		SAN ANDRES	BRUSHY CANYON	SAN ANDRES	SAN ANDRES
		LEONARD	268-258	GLORIETA	1ST BONE SPRING	GLORIETA	SAN ANGELO
				BLINEBRY		CLEARFORK/BLINEBRY	LEONARD
				TUBB-DRINKARD	2ND BONE SPRING	TUBB-DRINKARD	SPRABERRY
				ABO	3RD BONE SPRING	WICHITA - ALBANY	DEAN
		WOLFCAMP	286-268	WOLFCAMP	WOLFCAMP	WOLFCAMP	WOLFCAMP
	PENNSYLVANIAN	VIRGIL	291-286	CISCO	ABSENT	CISCO	CISCO
		MISSOURI	296-291	CANYON	ABSENT	CANYON	CANYON
		DES MOINES	301-296	STRAWN	STRAWN	STRAWN	STRAWN
		ATOKA	306-301	ATOKA / BEND	ATOKA / BEND	ATOKA / BEND	ATOKA / BEND
		MORROW	320-306	MORROW	MORROW	ABSENT	ABSENT
	MISSISSIPPIAN	CHESTER		CHESTER	ABSENT	ABSENT	ABSENT
		MEREMEC	355-320	MEREMEC	BARNETT	BARNETT	BARNETT
		OSAGE		OSAGE	ABSENT	ABSENT	ABSENT
		KINDERHOOK	360-355	KINDERHOOK	KINDERHOOK	KINDERHOOK	KINDERHOOK
	DEVONIAN	UPPER	374-360	WOODFORD	WOODFORD	WOODFORD	WOODFORD
		LOWER	408-374	DEVONIAN	DEVONIAN	DEVONIAN	DEVONIAN
	SILURIAN	UPPER	421-408	UNDIFFERENTIATED SILURIAN	SILURIAN	SILURIAN SHALE	SILURIAN SHALE
		LOWER	438-421		FUSSELMAN	FUSSELMAN	FUSSELMAN
	ORDOVICIAN	UPPER	458-438	MONTOYA	MONTOYA	MONTOYA	MONTOYA
		MIDDLE	478-458	SIMPSON	SIMPSON	SIMPSON	SIMPSON
		LOWER	505-478	ELLENBURGER	ELLENBURGER	ELLENBURGER	ELLENBURGER
	CAMBRIAN		570-505	CAMBRIAN	CAMBRIAN	CAMBRIAN	CAMBRIAN
	PRECAMBRIAN		> 570	PRECAMBRIAN	PRECAMBRIAN	PRECAMBRIAN	PRECAMBRIAN

3

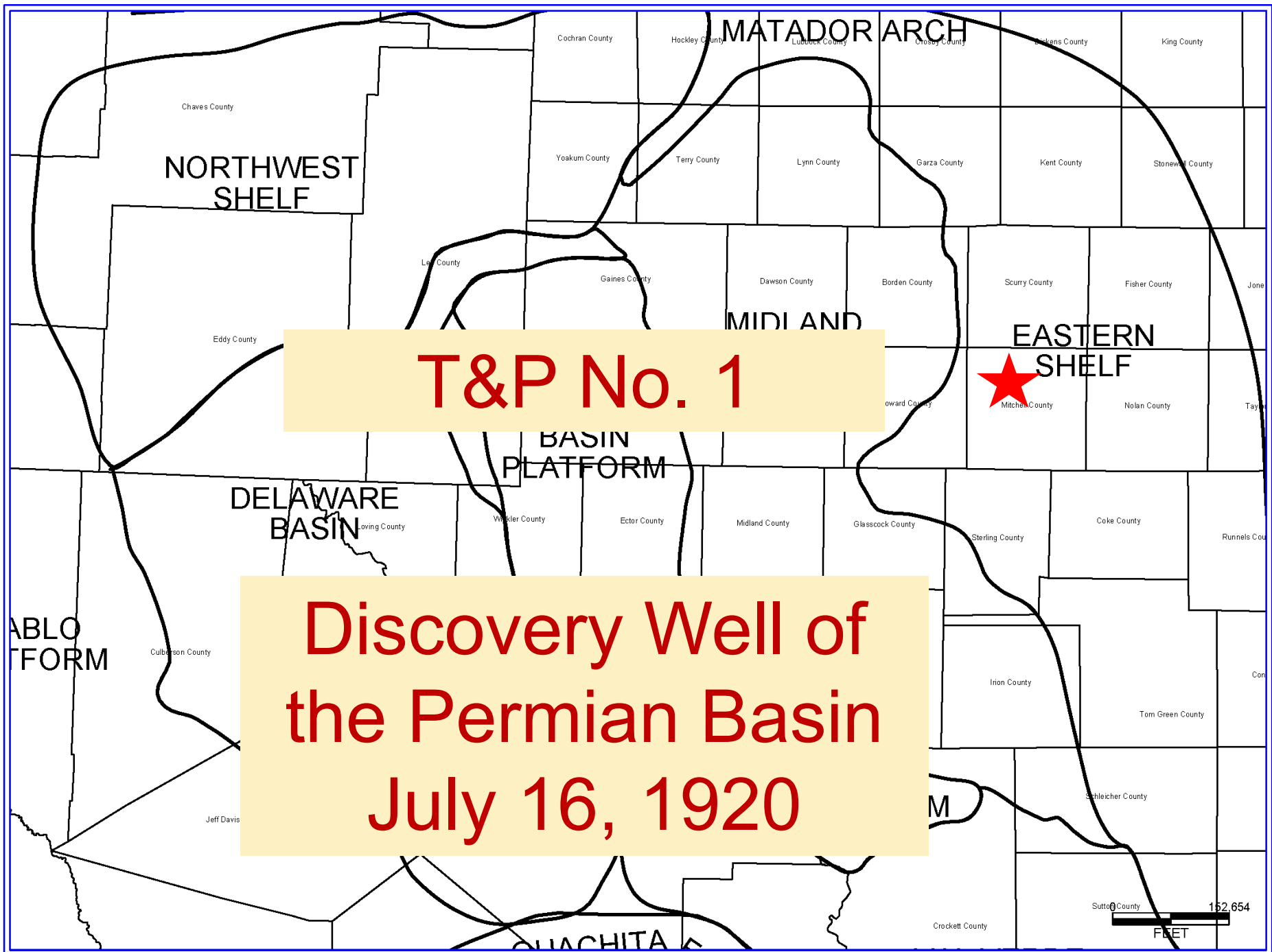
2

1

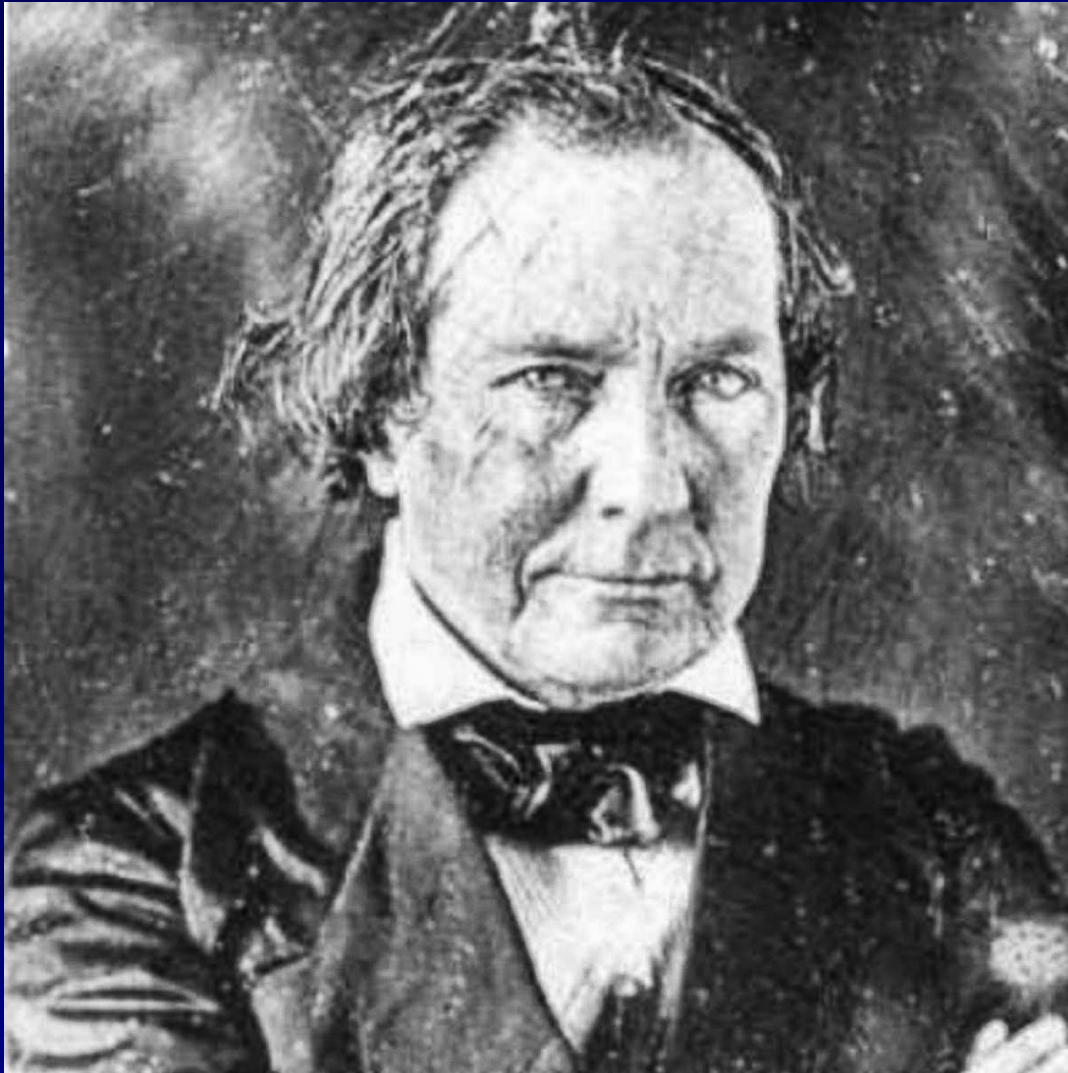
DIVIDED BASINS

MARATHON
OUACHITA
OROGENY

TOBOSA BASIN



Mirabeau B. Lamar - Republic of Texas 2nd President



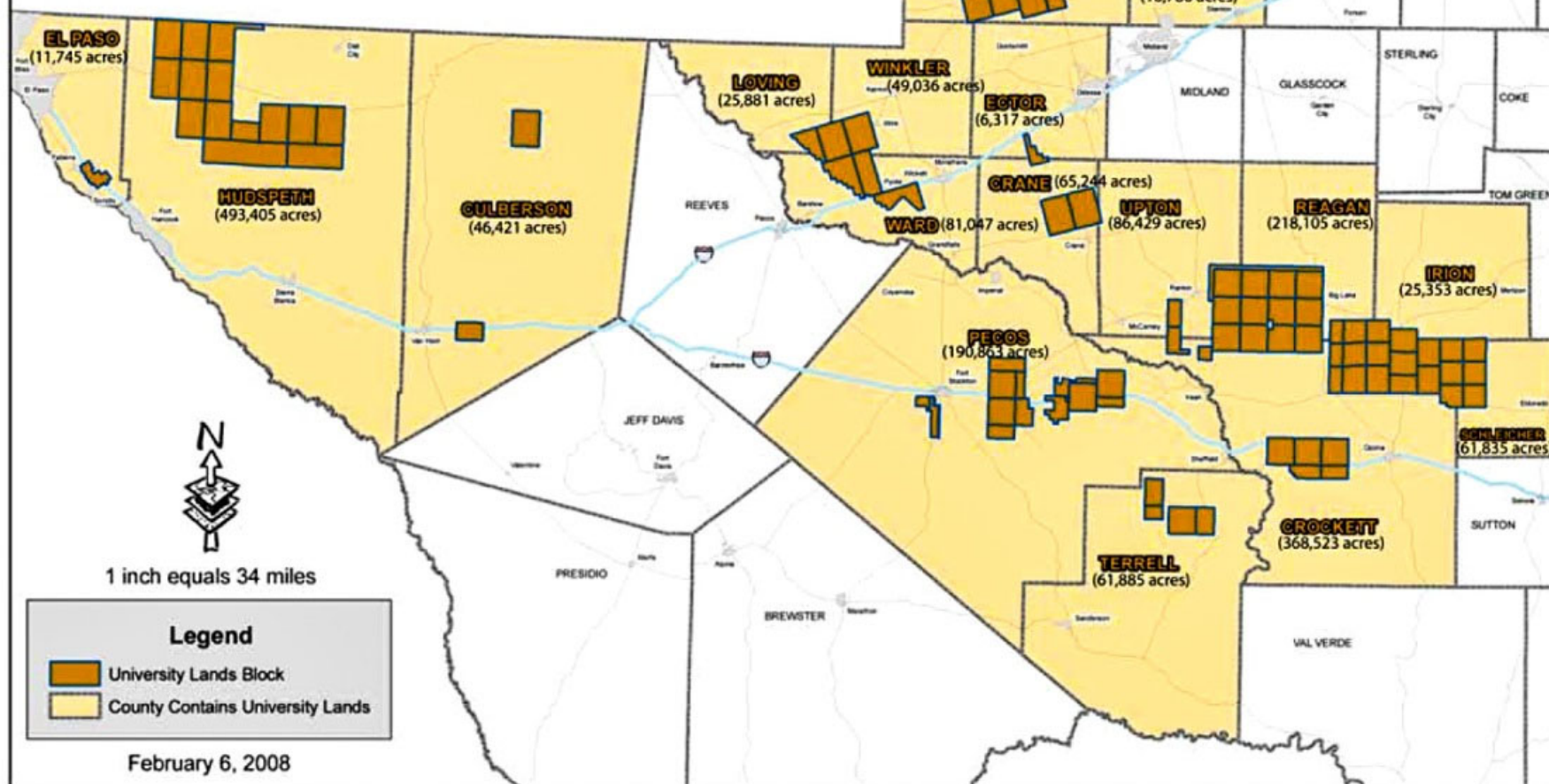
“... Education is the guardian genius of democracy...”

“The influence of education in the moral world is like light in the physical, rendering luminous what was before obscure.”

Considered the Father of Texas Education

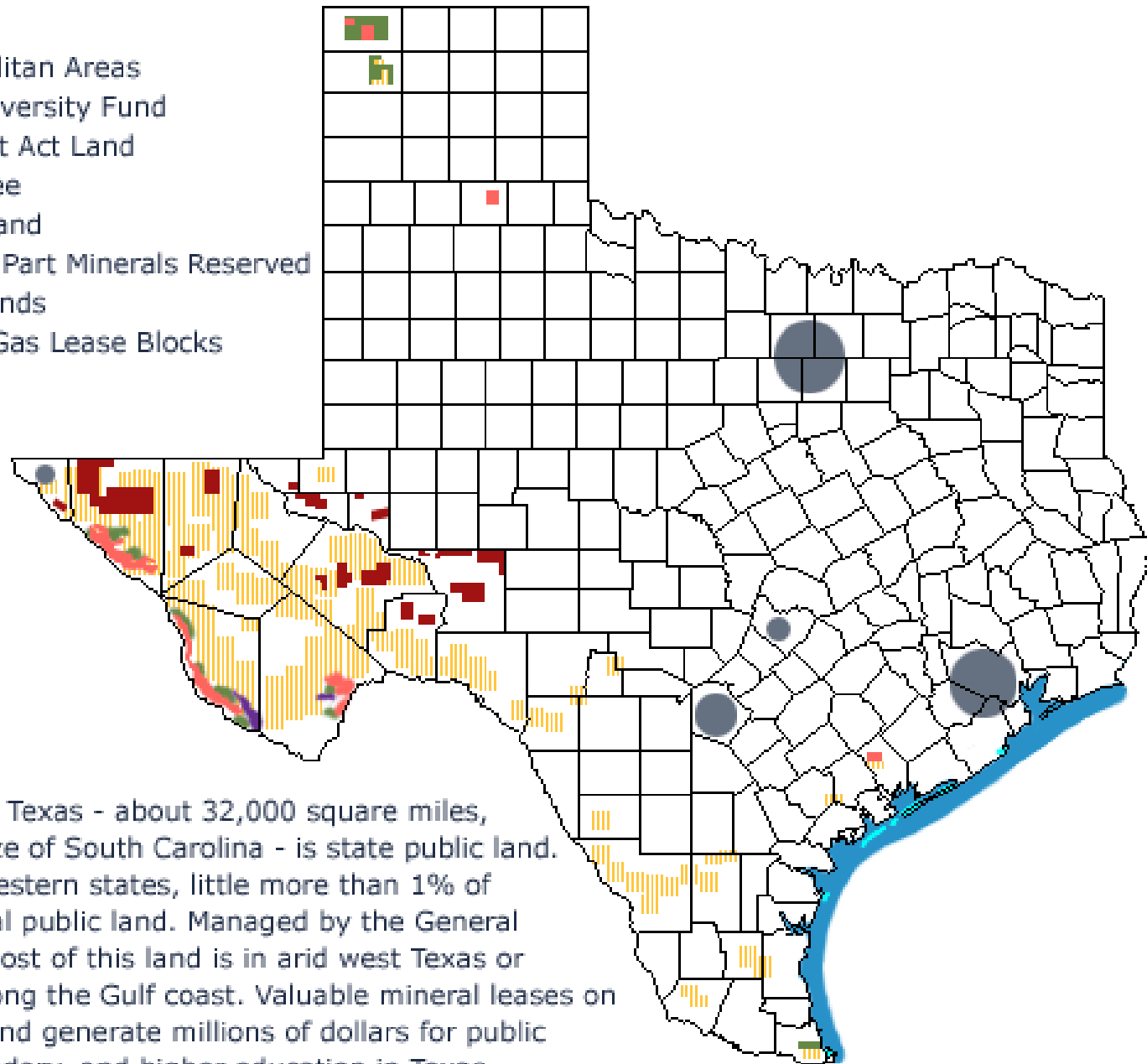


The University of Texas System University Lands Midland, Texas



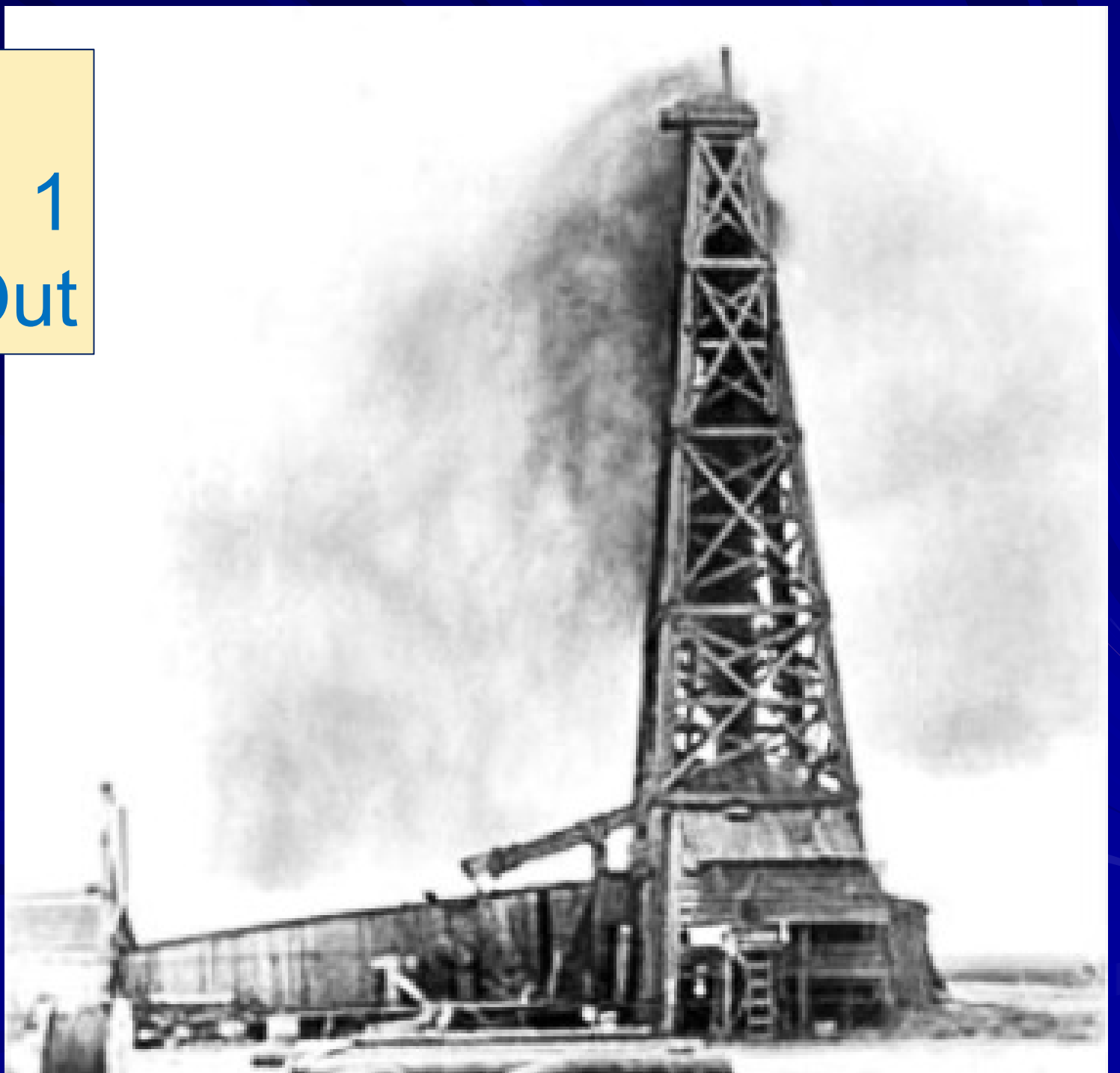
Texas Public Lands

- Major Metropolitan Areas
- Permanent University Fund
- ▨ Relinquishment Act Land
- School Land Fee
- Free Royalty Land
- Surface Sold - Part Minerals Reserved
- Submerged Lands
- State Oil and Gas Lease Blocks

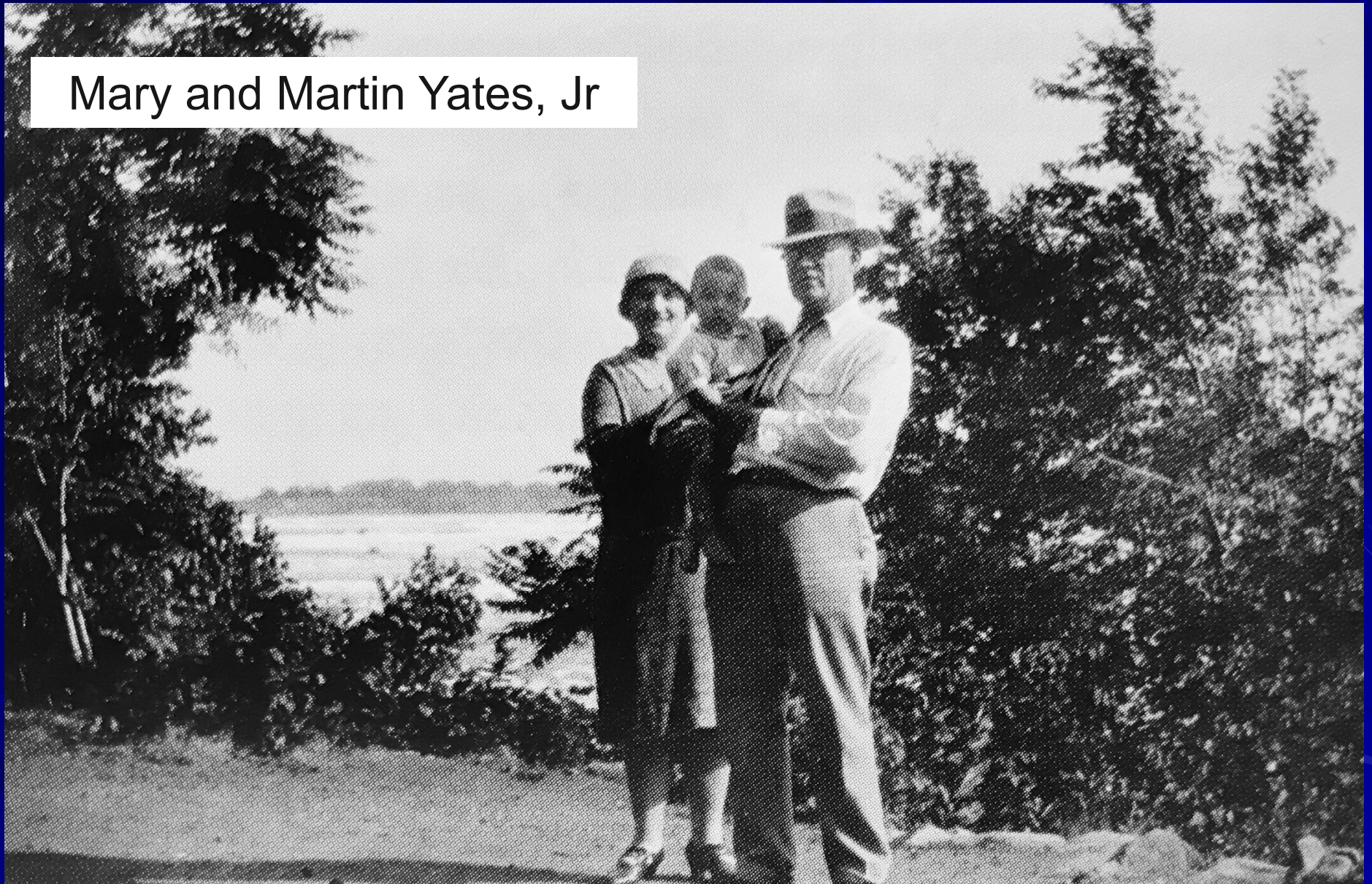


Nearly 12% of Texas - about 32,000 square miles, an area the size of South Carolina - is state public land. Unlike most western states, little more than 1% of Texas is federal public land. Managed by the General Land Office, most of this land is in arid west Texas or submerged along the Gulf coast. Valuable mineral leases on parts of this land generate millions of dollars for public primary, secondary, and higher education in Texas.

Santa
Rita No. 1
Blows Out



Mary and Martin Yates, Jr

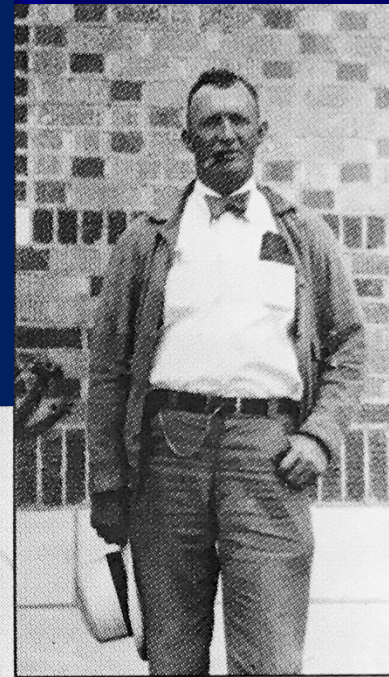


Third Time Is A Charm

Mary Yates Selects Location
of Third Well and Marks It
With Heel of Her Shoe



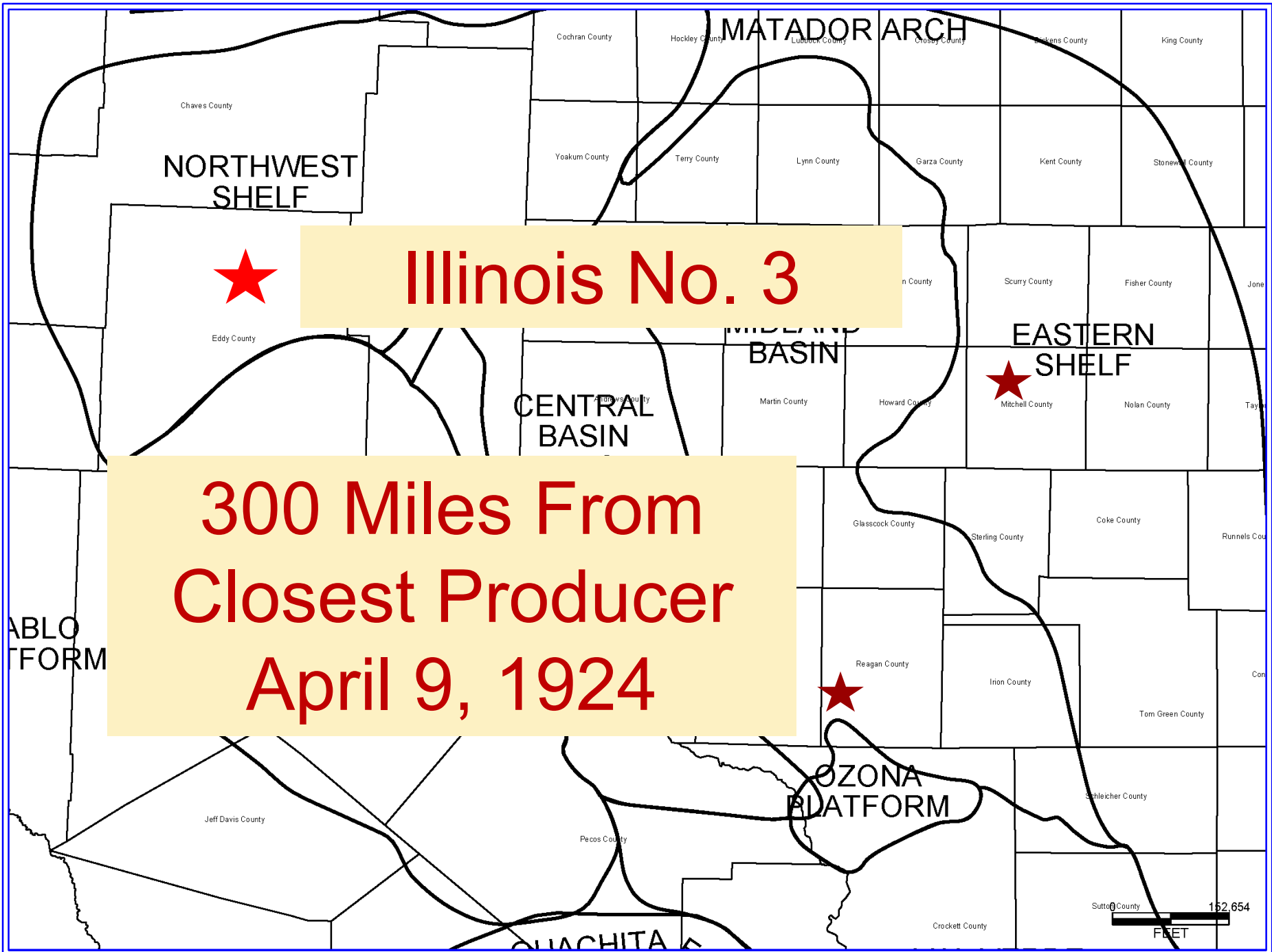
ILLINOIS NO. 3 RIG

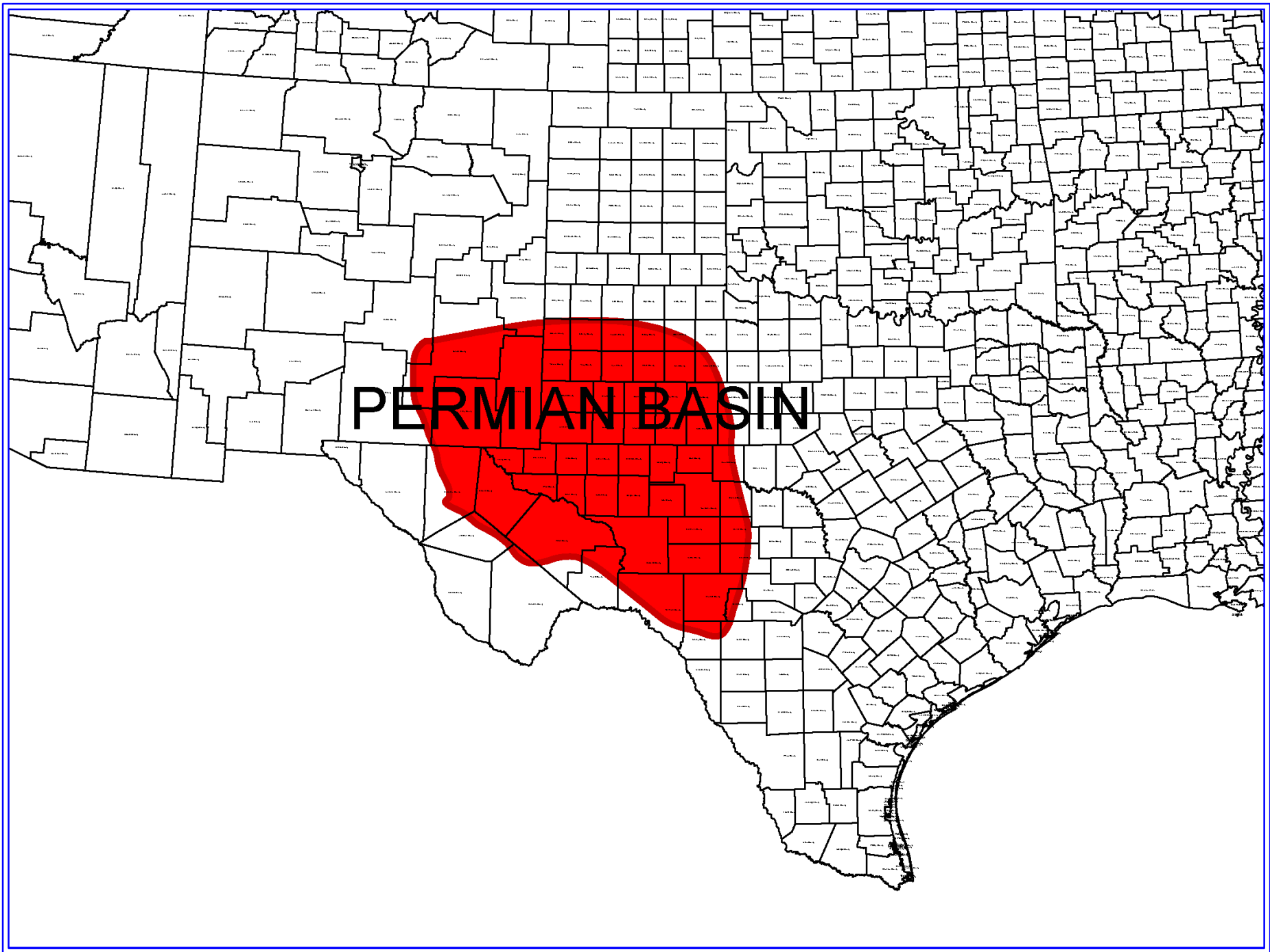


Driller J. W. Berry (above and left), Basil Tigner, Ed Wingfield, and Frank Tigner (l to r)

Illinois No. 3, First
Commercial Oil Well
In New Mexico,
Strikes Oil At 1,947
Feet







This Train Stop Town Was
Named For Its Location
Half Way Between Fort
Worth and El Paso.

Question: What is
Midland, Texas?

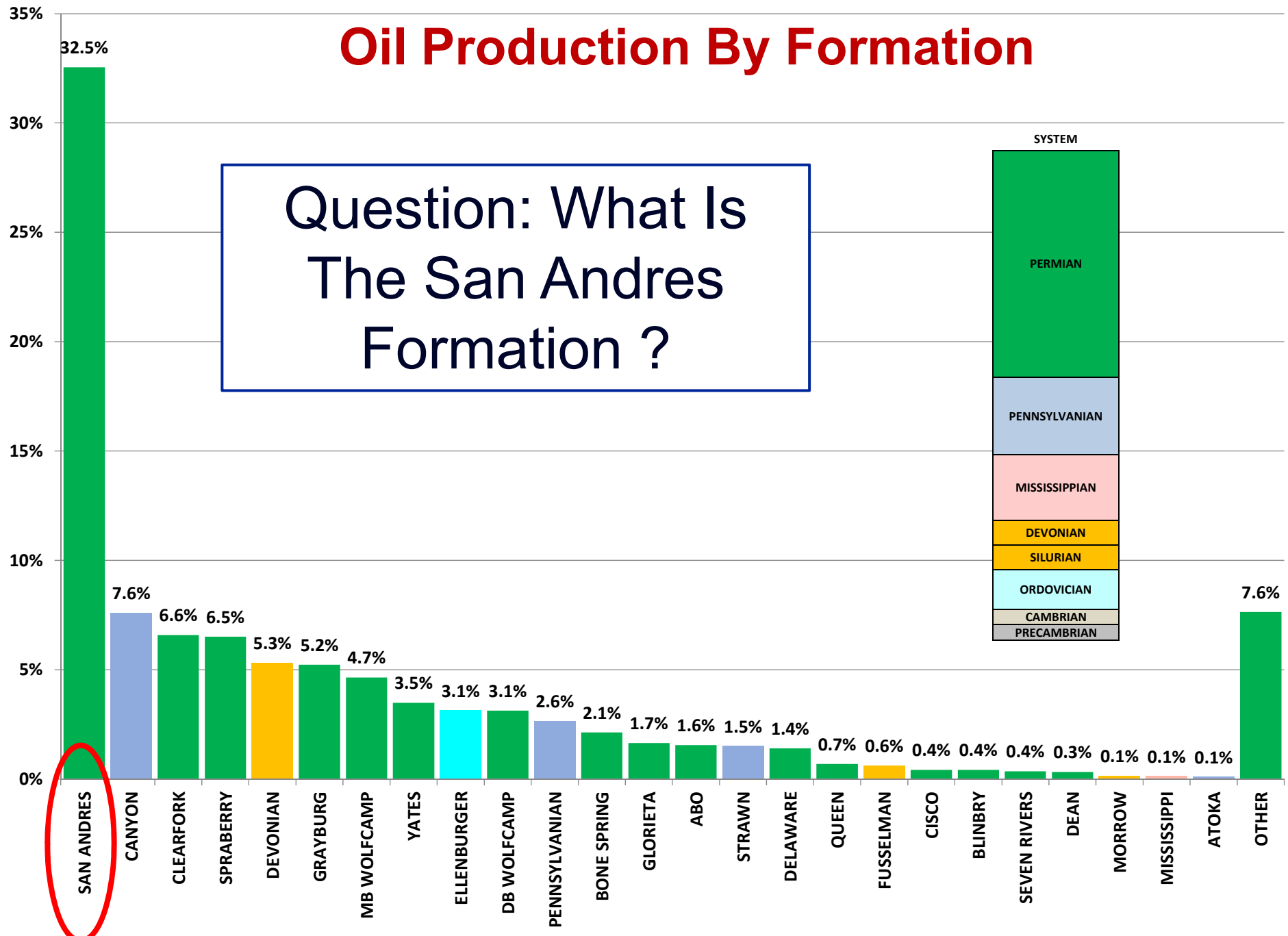


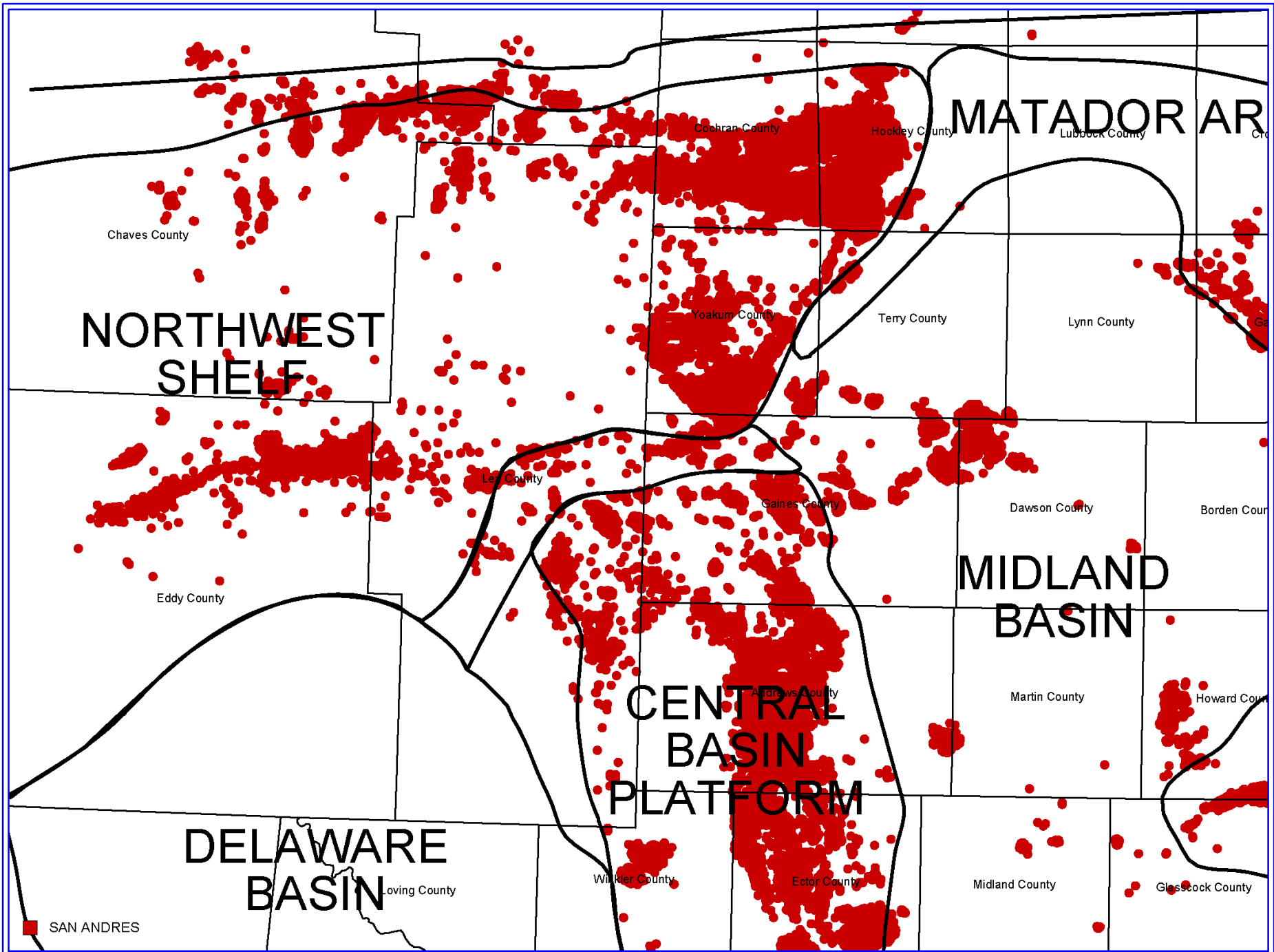
This Formation Has
Produced 12.5 Billion
Barrels Or Nearly 1/3 Of
The Permian Basin's Oil.



Oil Production By Formation

Question: What Is
The San Andres
Formation ?



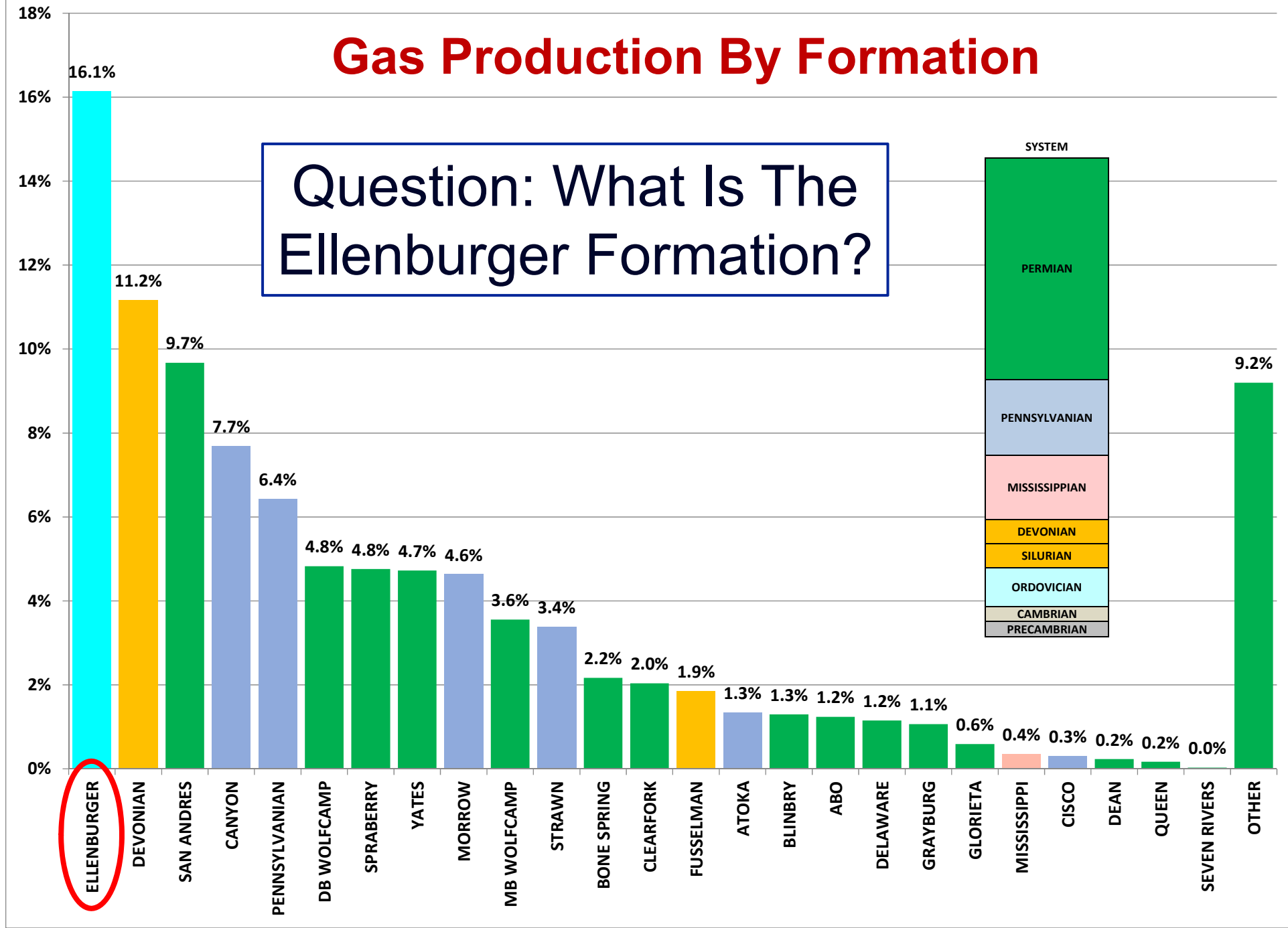


This Ordovician Age
Formation Accounts for
About 1/6 of the Permian
Basin's 128 Tcf Of Gas
Production.



Gas Production By Formation

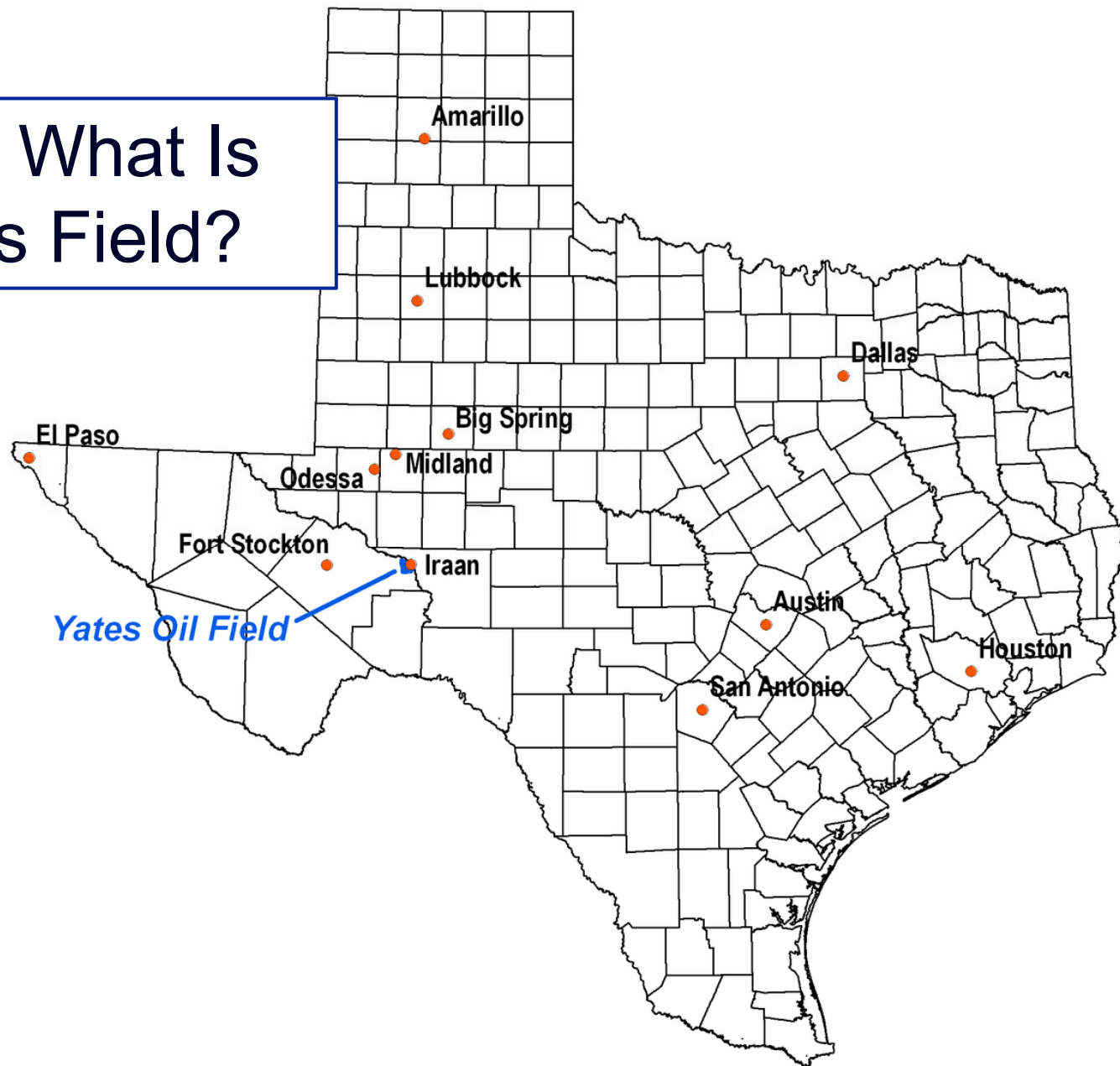
Question: What Is The Ellenburger Formation?



The Record US Single Well
Flow Rate Of 8,528 Barrels
Per Hour Was Observed In
This PB Field.



Question: What Is The Yates Field?



After Antandrus at English Wikipedia

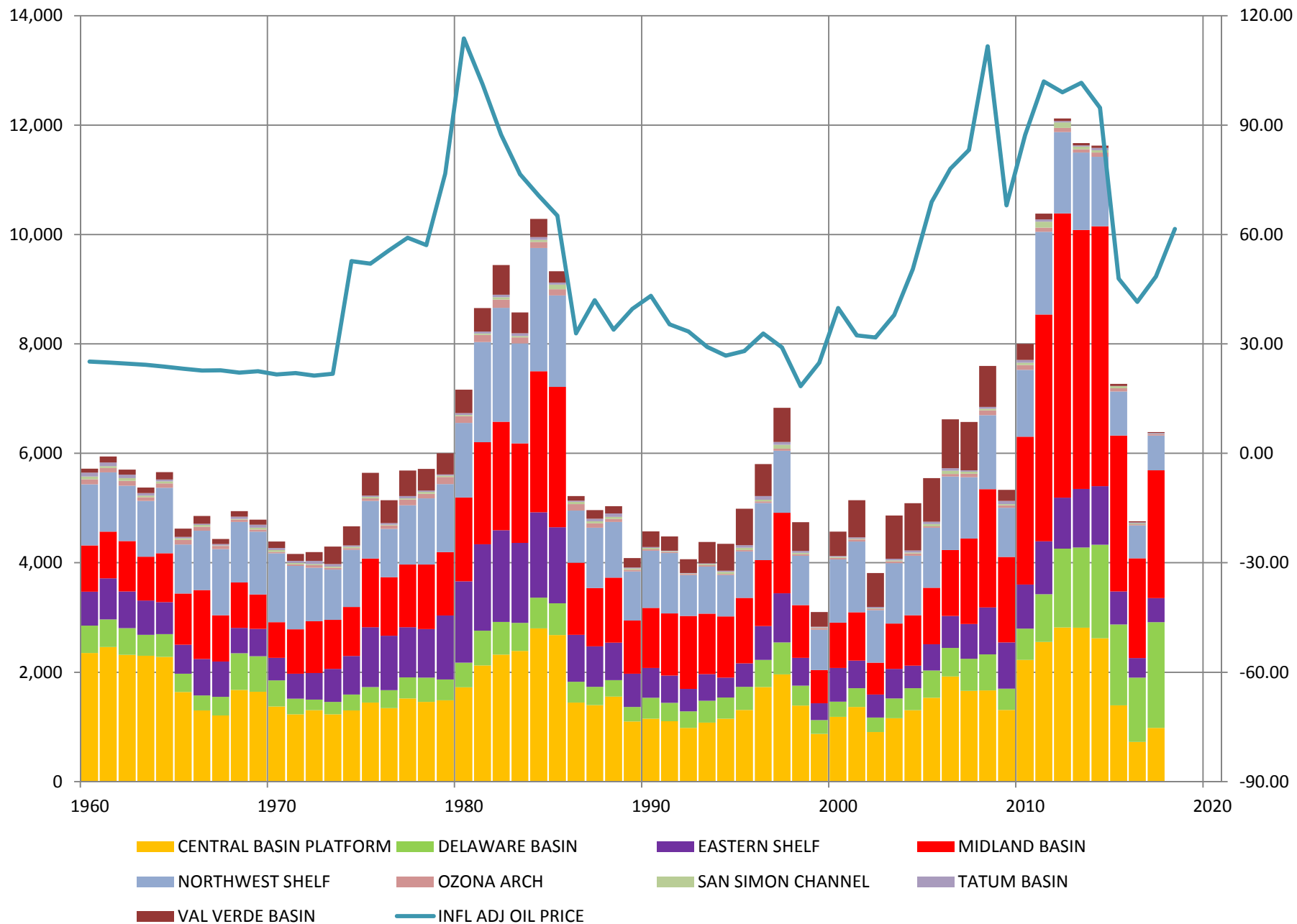
Permian Basin History

1. Permian Basin Discovered (1920)
2. Santa Rita No. 1 (1923)
3. Yates Field Discovered (1926)
4. Deep Drilling of Ellenburger Formation (1930's)
5. Permian Age Carbonate Development – San Andres, Grayburg, Clearfork (late 1930's thru 1940's)

Permian Basin History

6. Waterflooding Of Permian Age Carbonates (1960's thru 1980's)
7. CO₂ Flooding of Permian Age Carbonates (1980's)
8. Majors Move Staff From PB To Houston, Sell Off "Marginal" Assets (1990's)
9. Amoco and Shell Form JV Altura Energy (1997)
10. Oxy Buys Altura for \$3.2 B (2000)

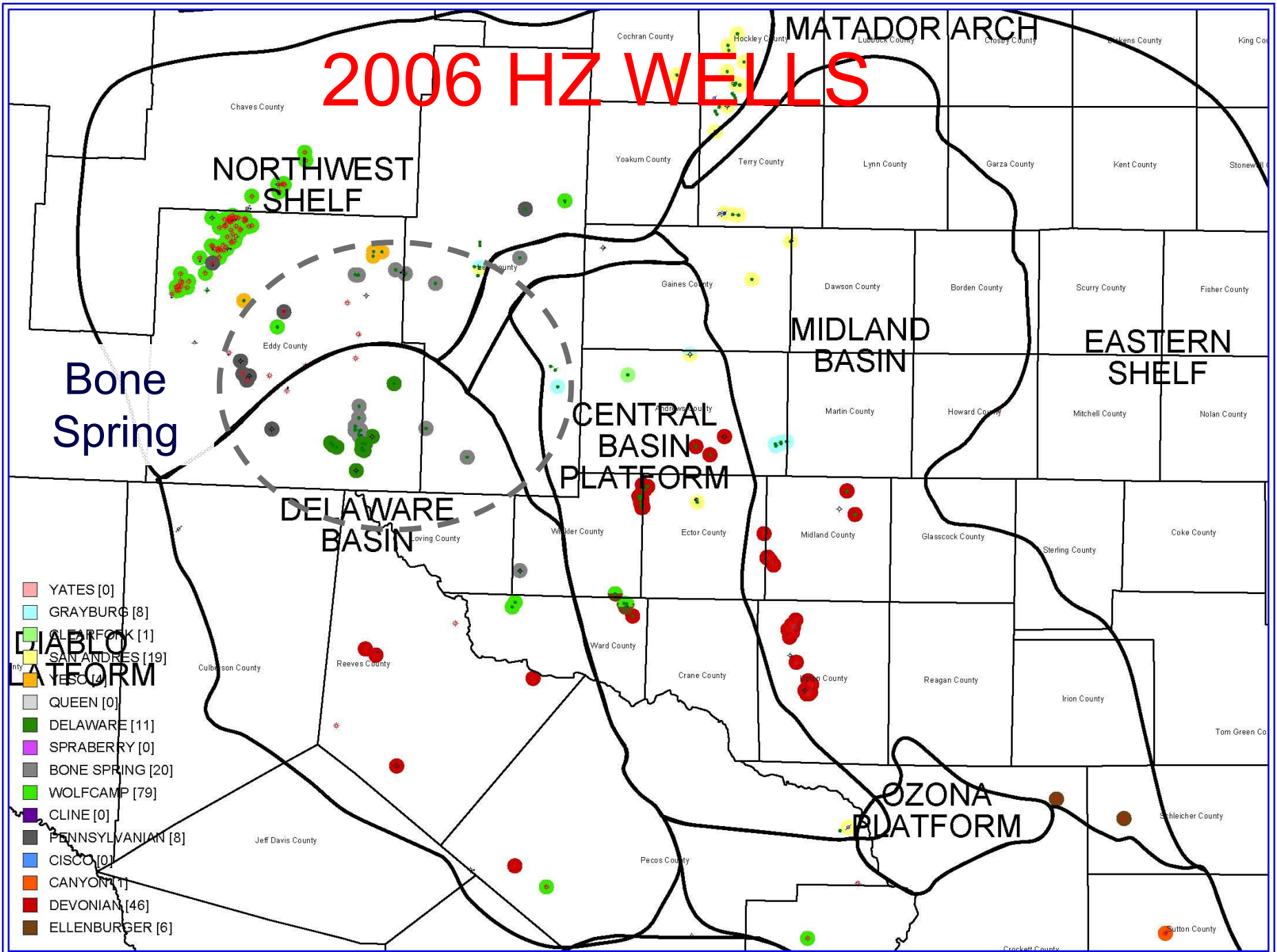
Completions by Basin



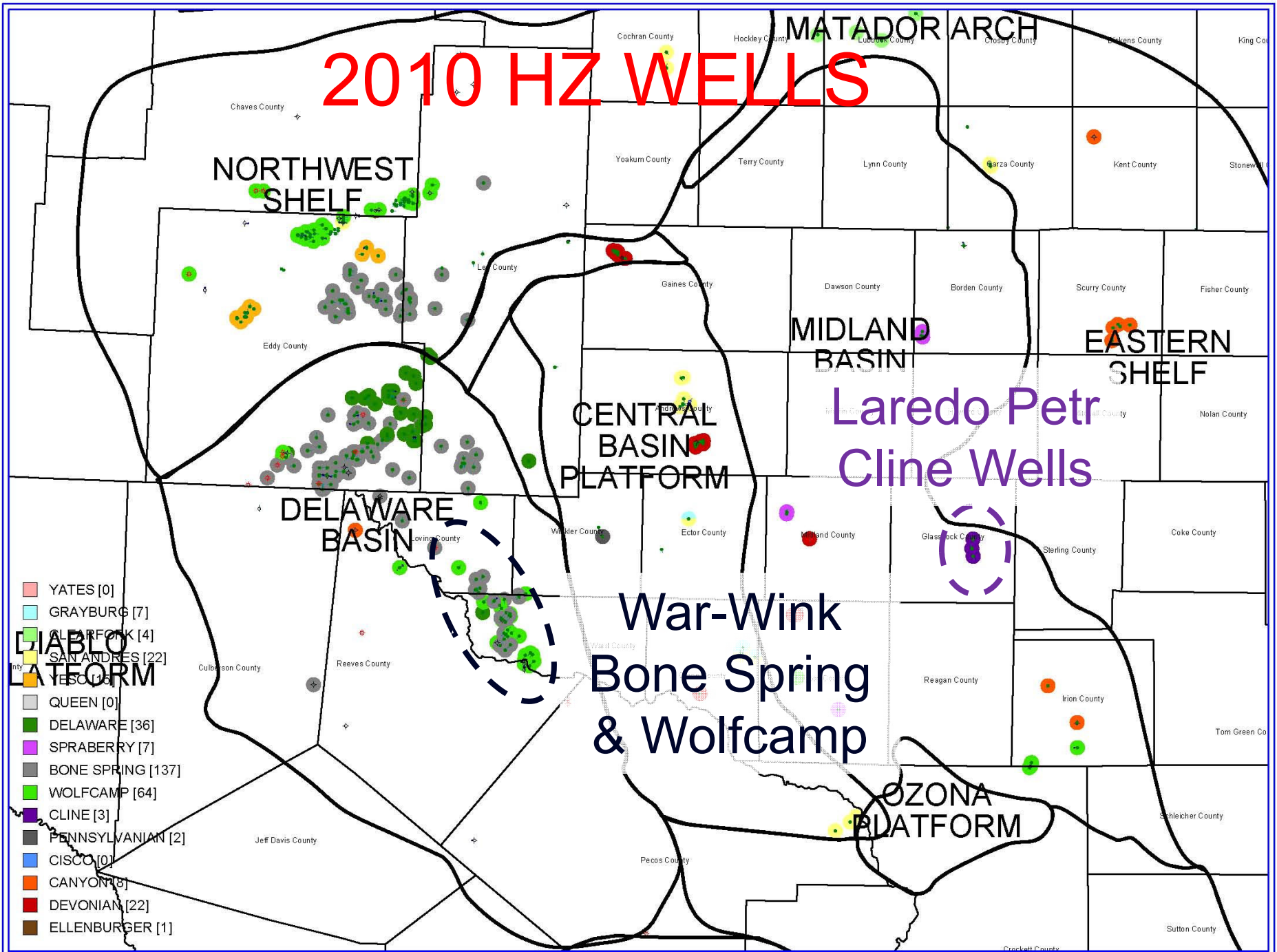
Recent Major Steps

1. Vertical Well – Slick Water Frac of Wolfcamp (1999)
2. Vertical Well – Adding Deeper Wolfcamp Intervals (2003)
3. Horizontal Drilling – DB (2006), MB (2010)
 - a. Identify Formations
 - b. Defend Acreage

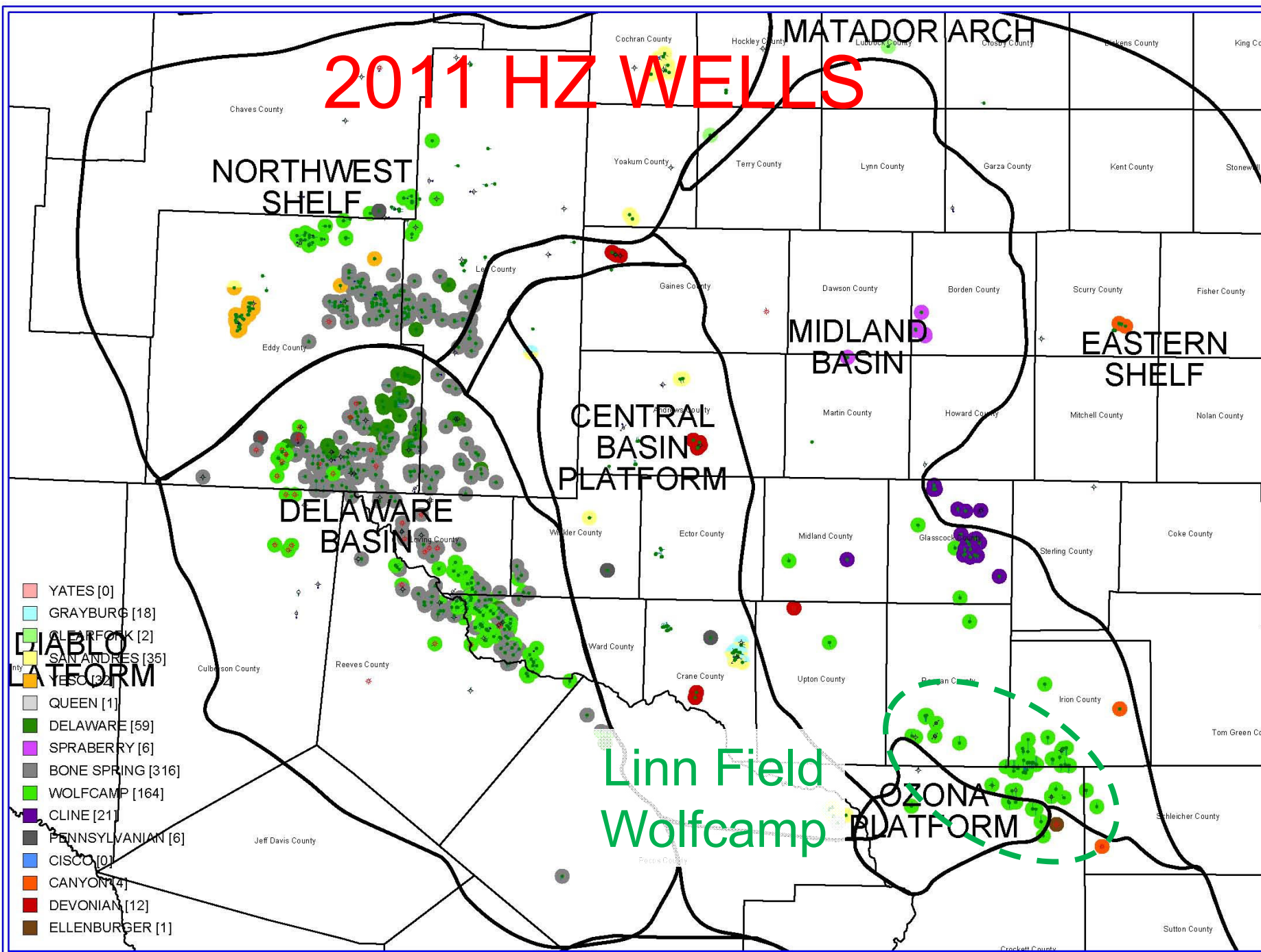
2006 HZ WELLS



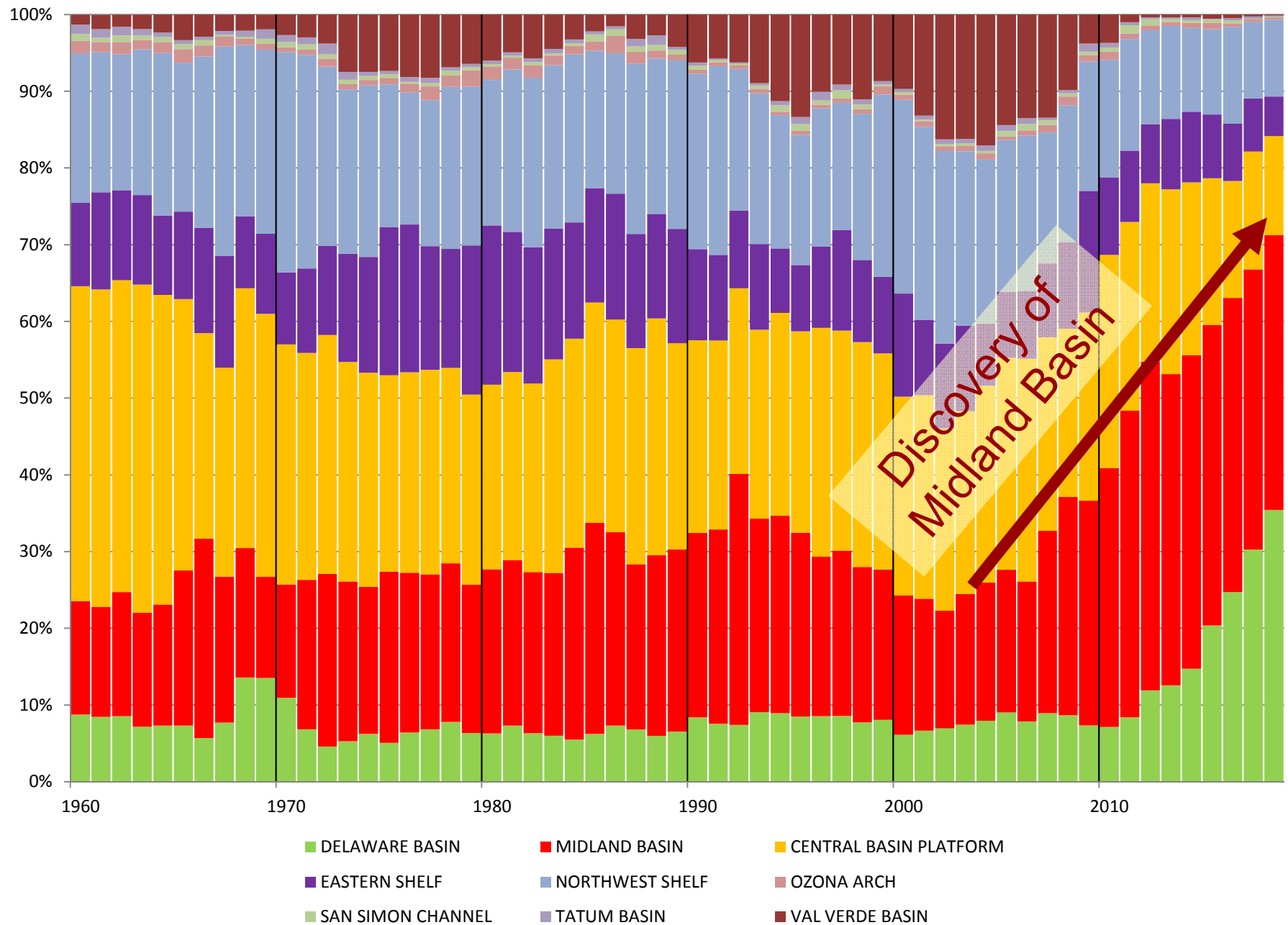
2010 HZ WELLS



2011 HZ WELLS



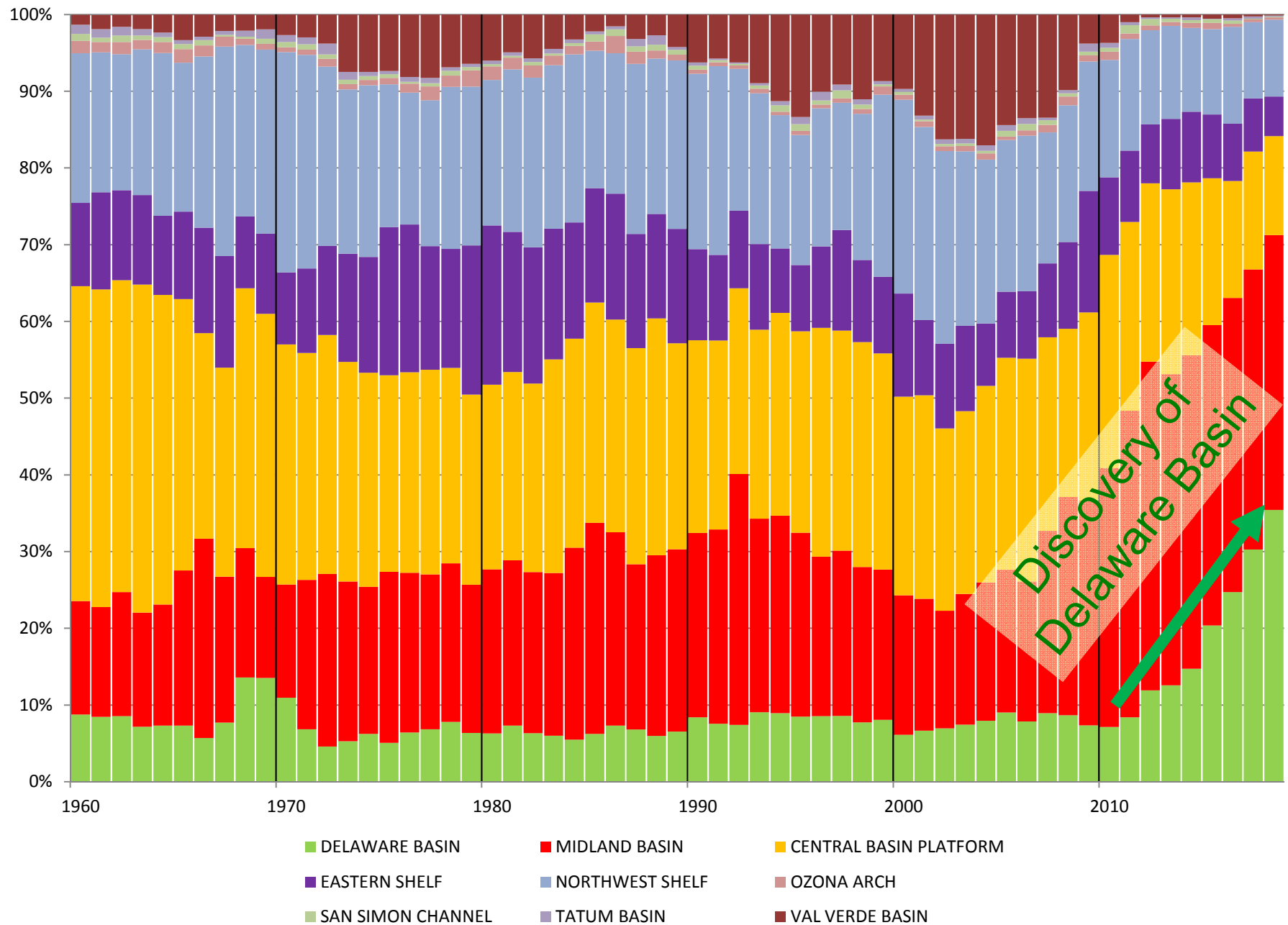
Completions by Basin



Recent Major Steps

4. Phantom Wolfcamp Field – Delaware Basin (2012)

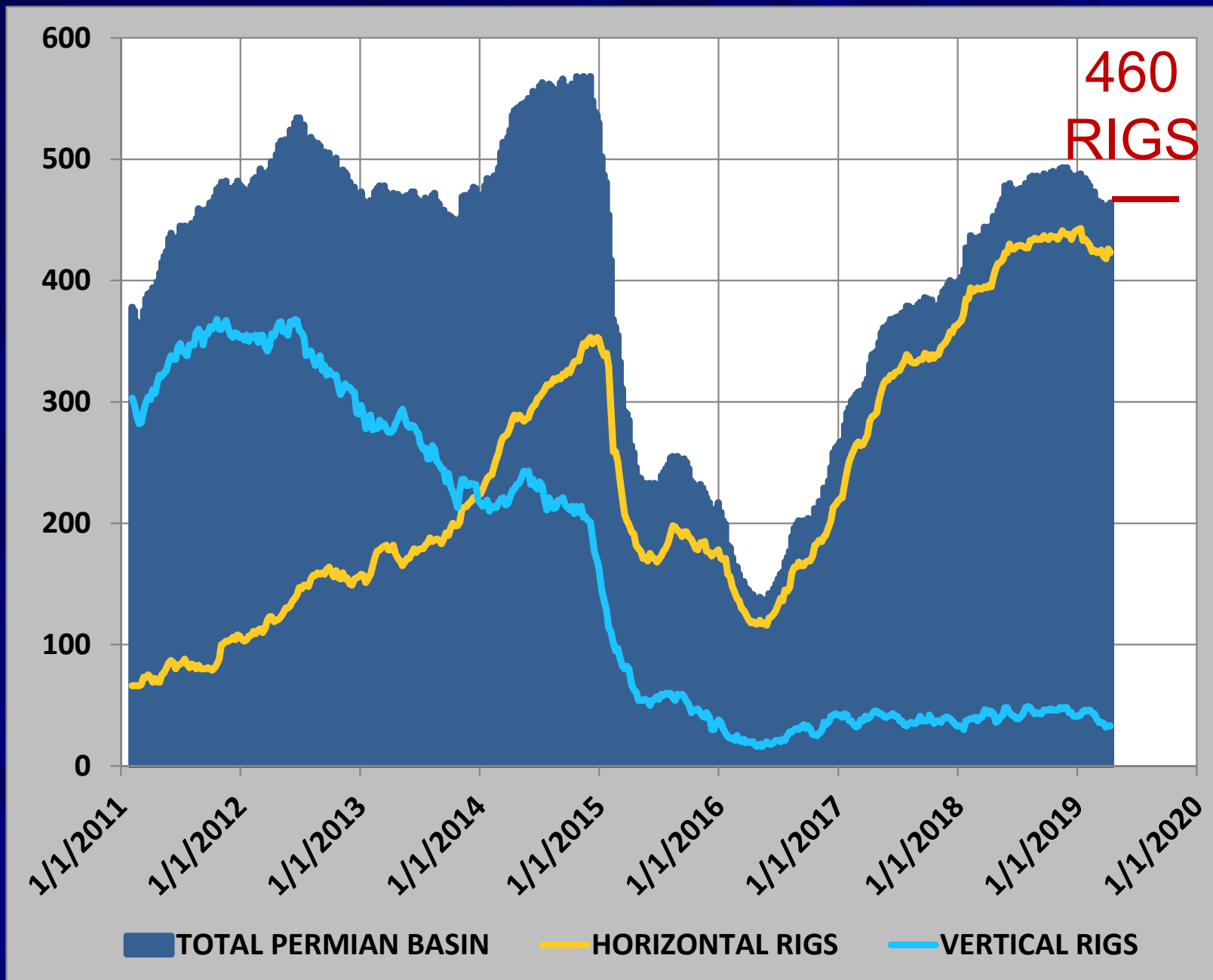
Completions by Basin



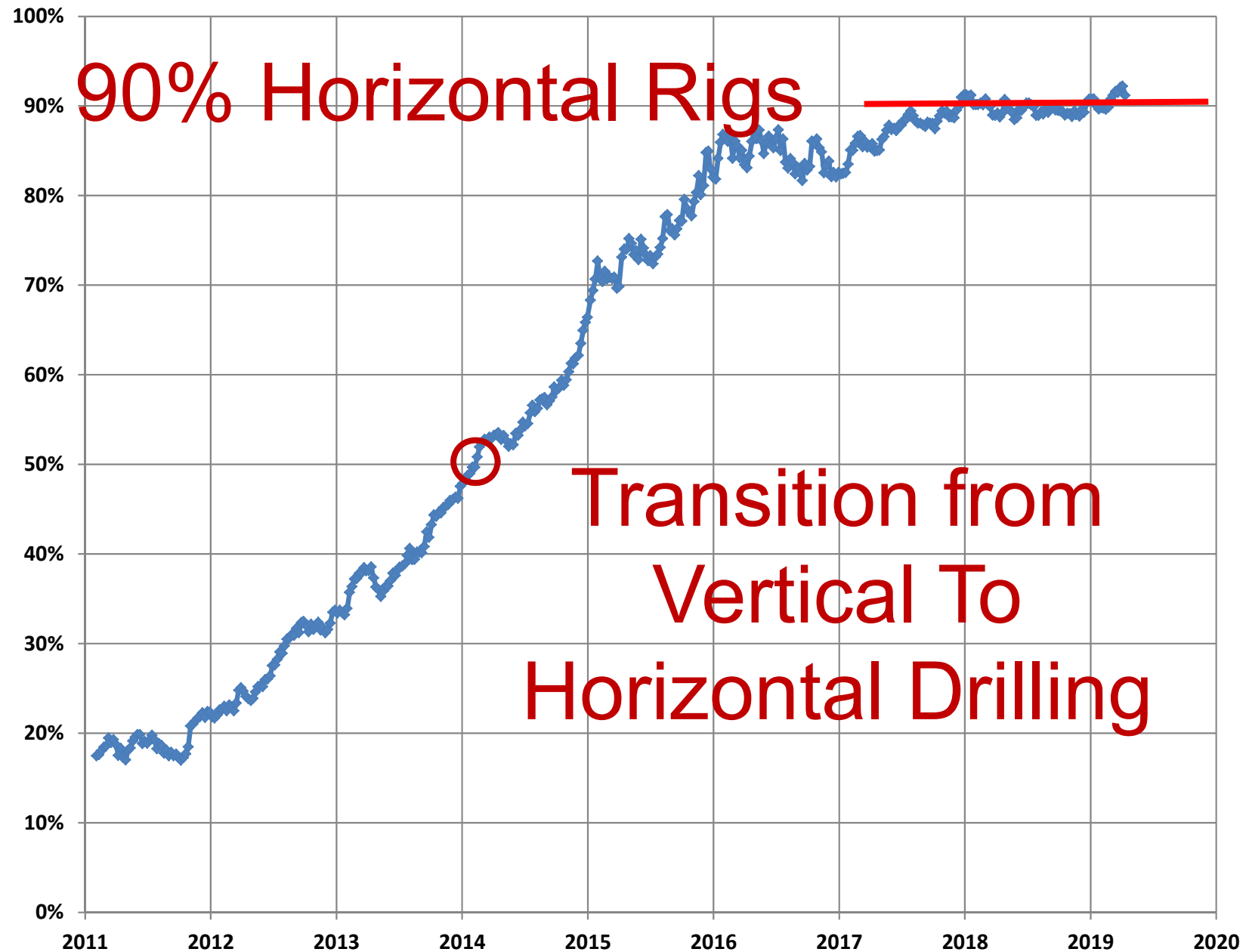
Recent Major Steps

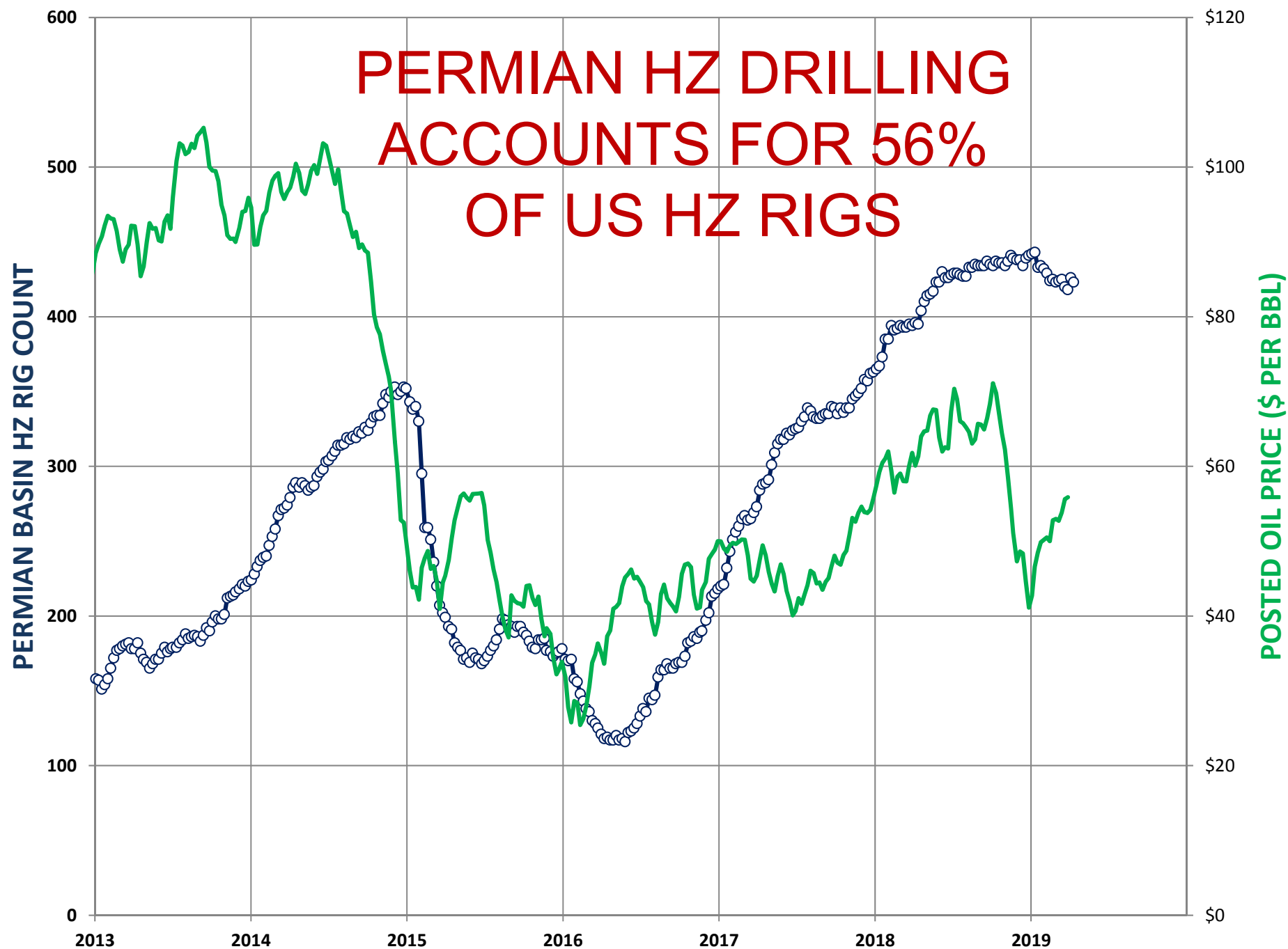
4. Phantom Wolfcamp Field – Delaware Basin (2012)
5. Transition to Horizontal Drilling (2014)

Permian Basin Rig Count



Permian Basin Rig Count

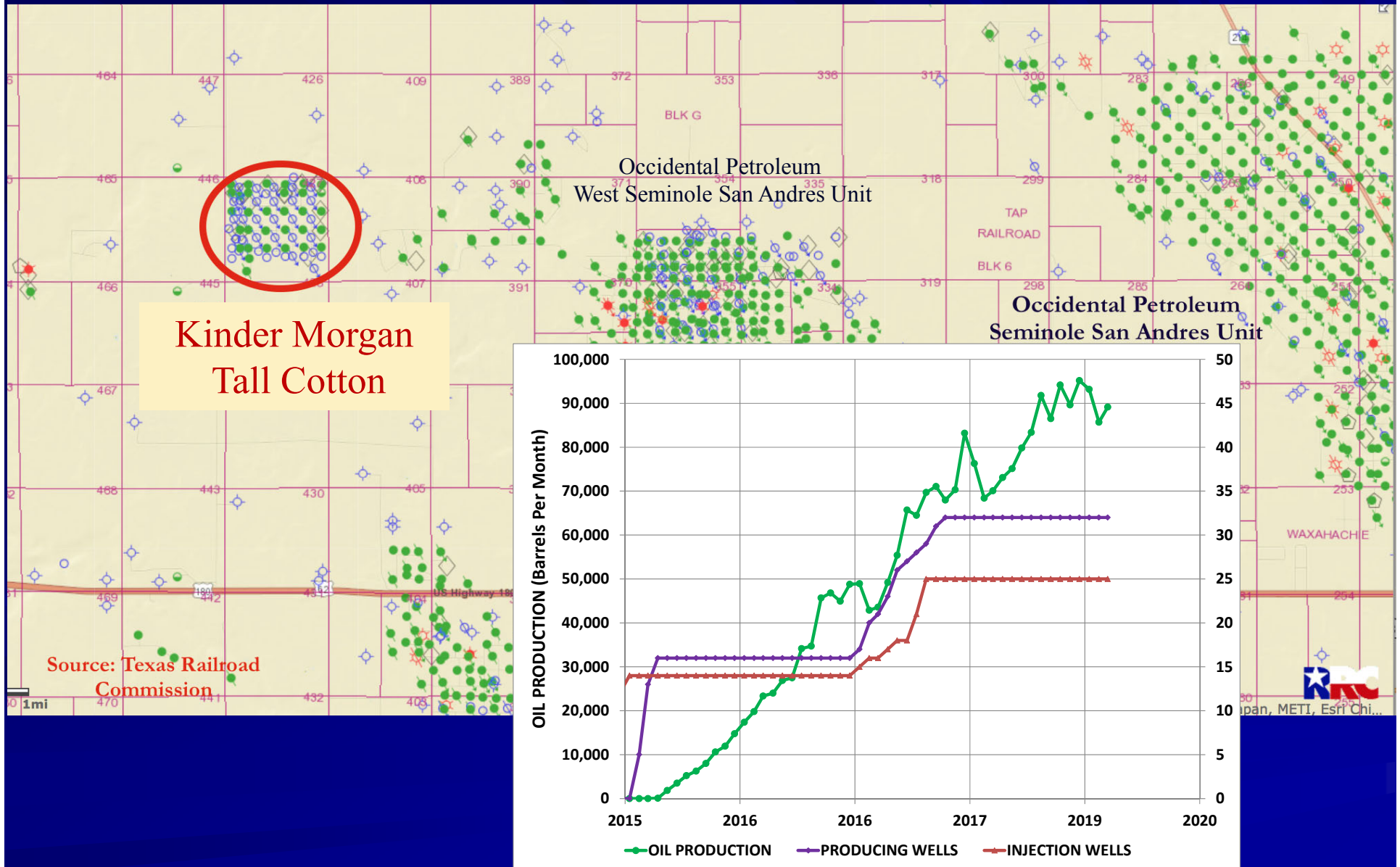




Recent Major Steps

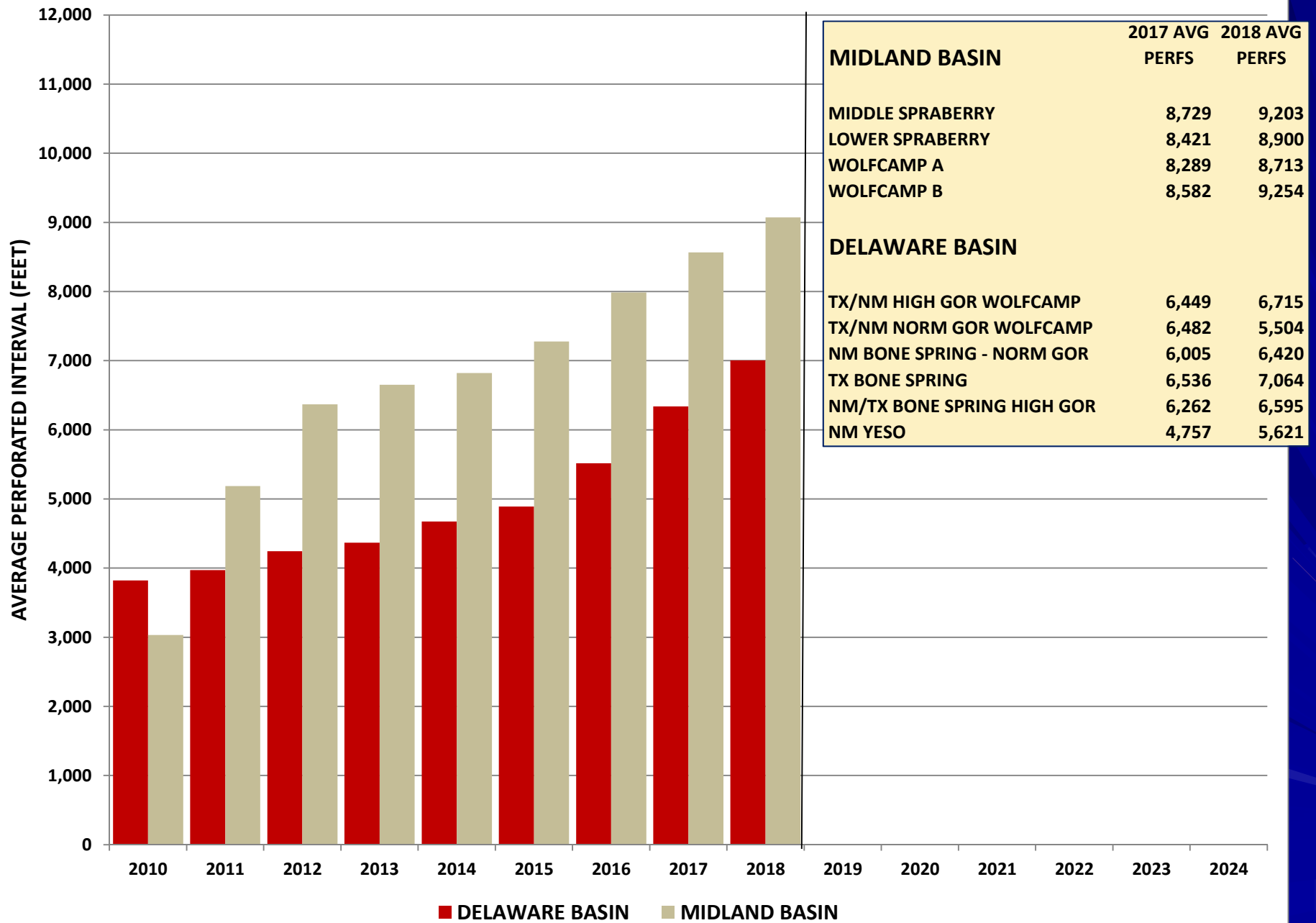
4. Phantom Wolfcamp Field – Delaware Basin (2012)
5. Transition to Horizontal Drilling (2014)
6. Tall Cotton – First ROZ Greenfield (2015)

Tall Cotton – San Andres EOR ROZ Greenfield (Gaines County – NW Shelf)

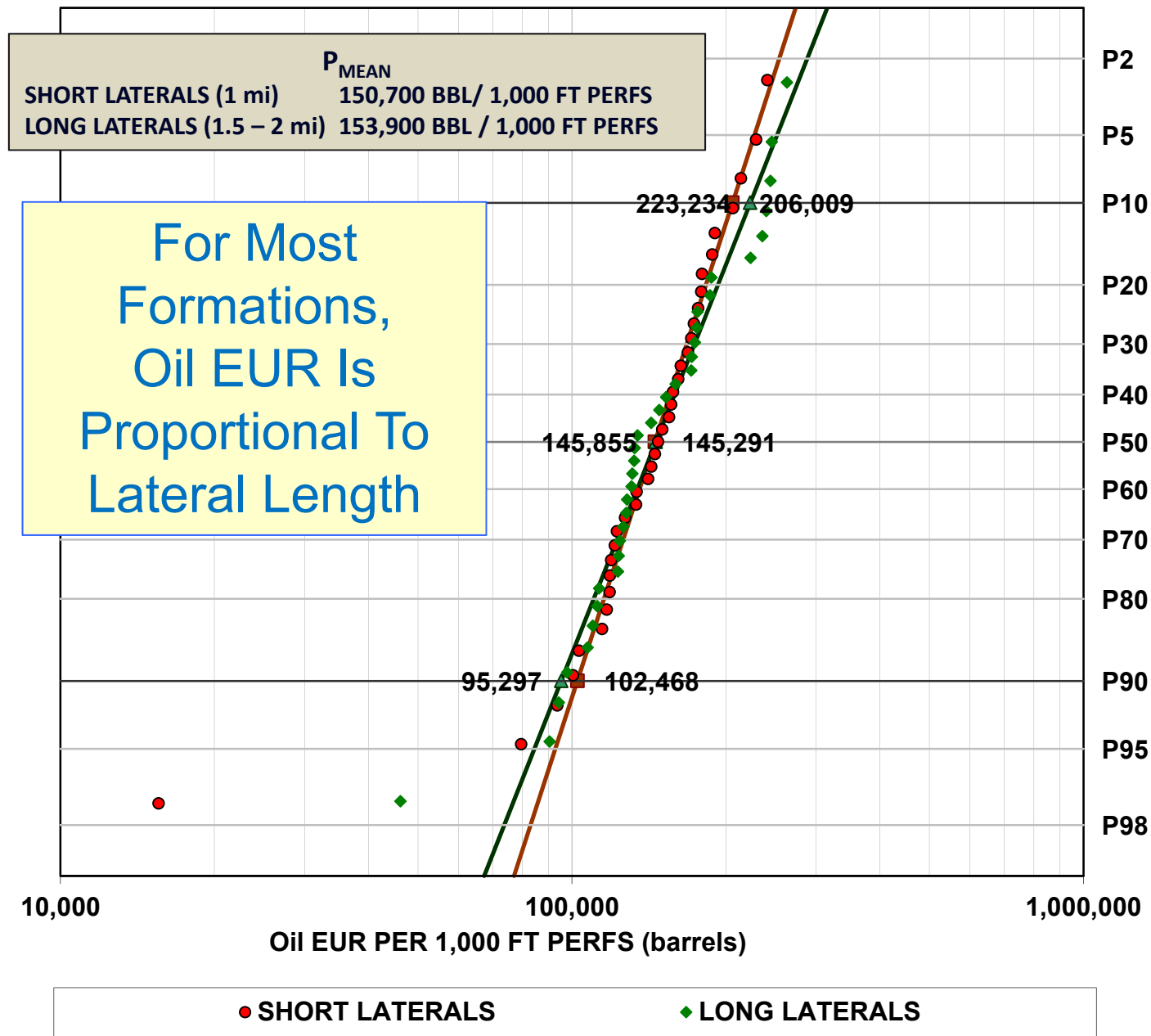


Recent Major Steps

4. Phantom Wolfcamp Field – Delaware Basin (2012)
5. Transition to Horizontal Drilling (2014)
6. Tall Cotton – First ROZ Greenfield (2015)
7. Horizontal Well – Longer Laterals (2016)

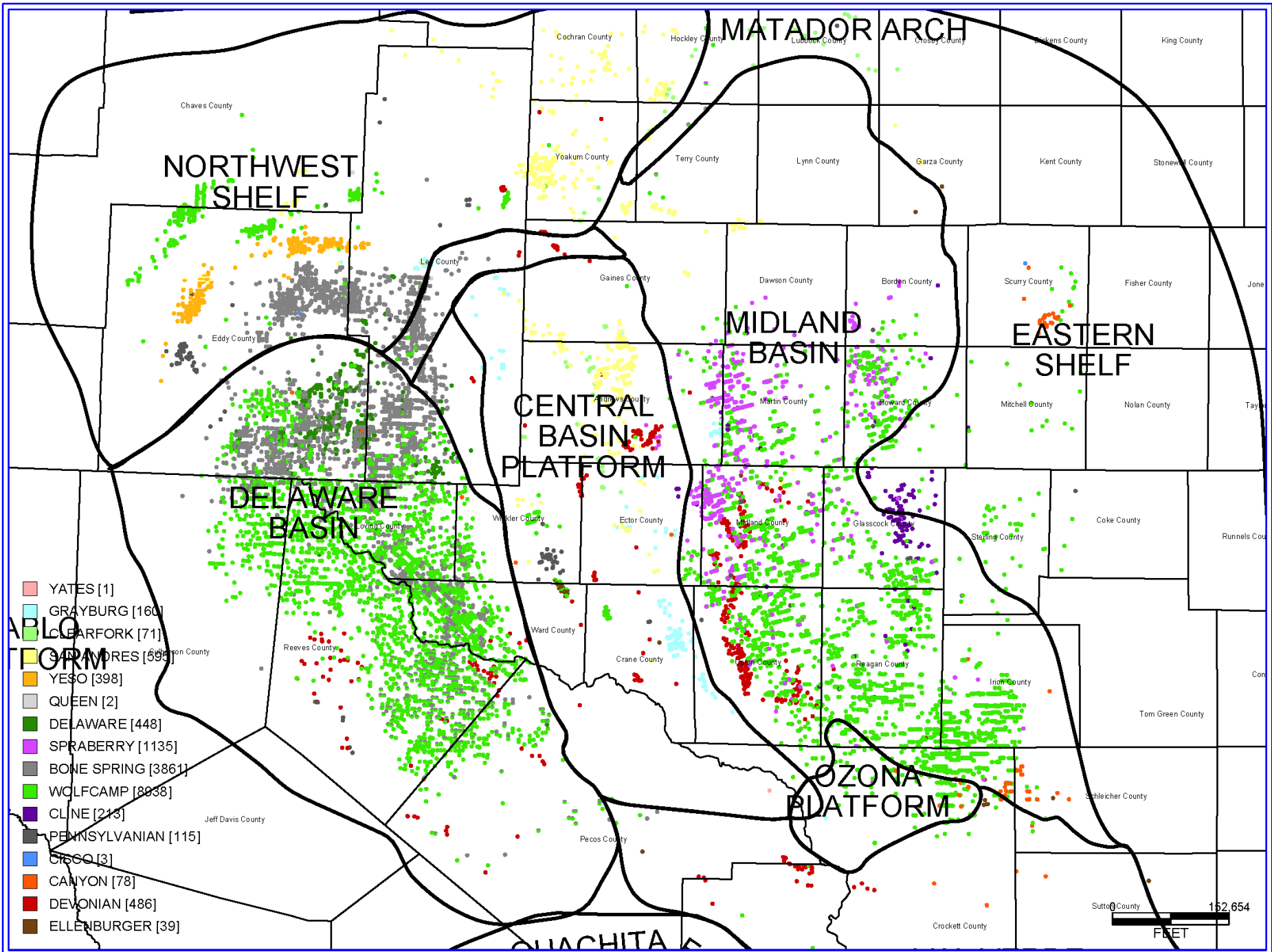


NEW MEXICO - LOW GOR WOLFCAMP



Recent Major Steps

4. Phantom Wolfcamp Field – Delaware Basin (2012)
5. Transition to Horizontal Drilling (2014)
6. Tall Cotton – First ROZ Greenfield (2015)
7. Horizontal Well – Longer Laterals (2016)
8. Extend Delaware Basin Westward (2017)

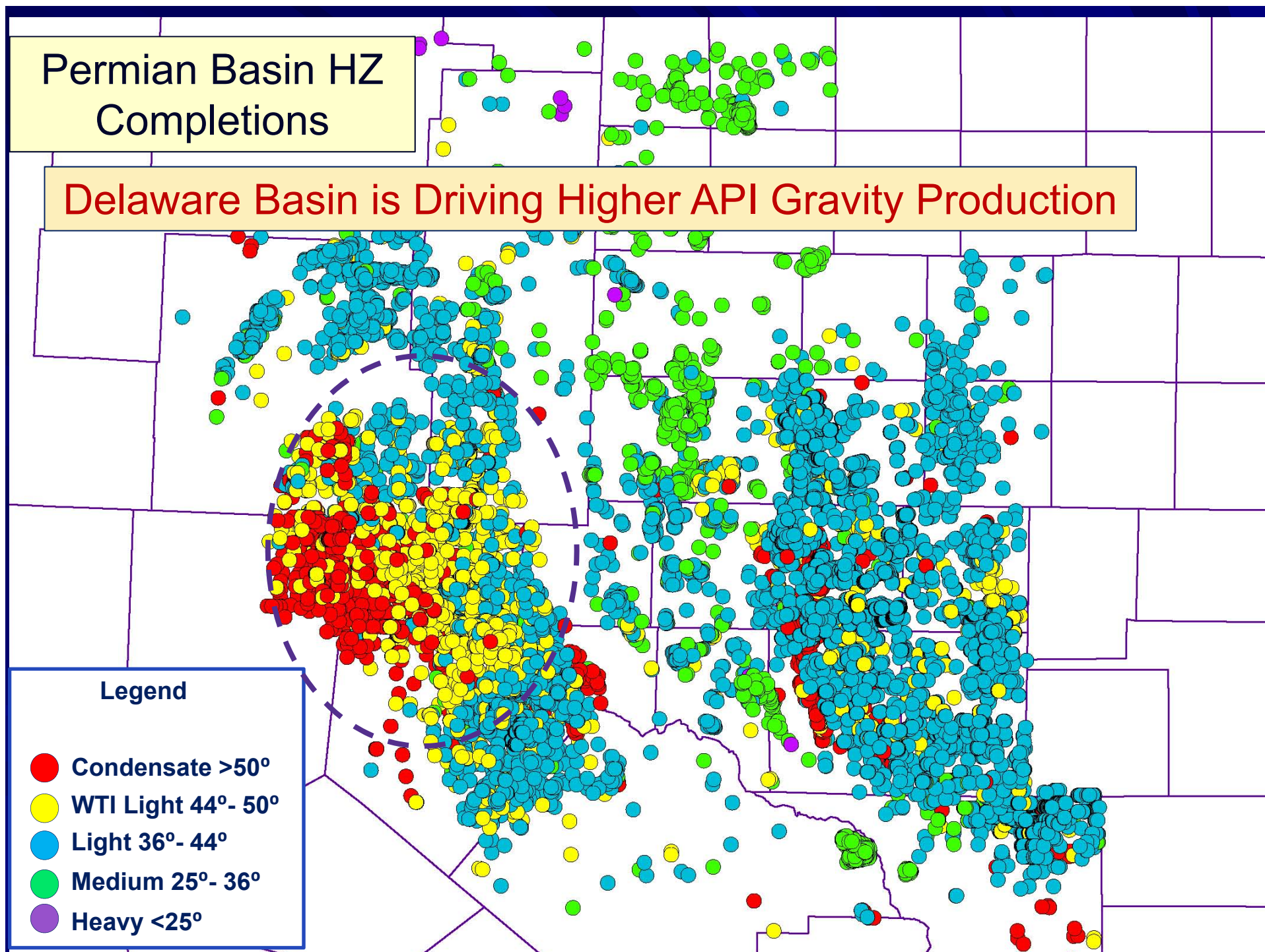


Permian Basin HZ Completions

Delaware Basin is Driving Higher API Gravity Production

Legend

- Condensate $>50^{\circ}$
- WTI Light $44^{\circ} - 50^{\circ}$
- Light $36^{\circ} - 44^{\circ}$
- Medium $25^{\circ} - 36^{\circ}$
- Heavy $<25^{\circ}$



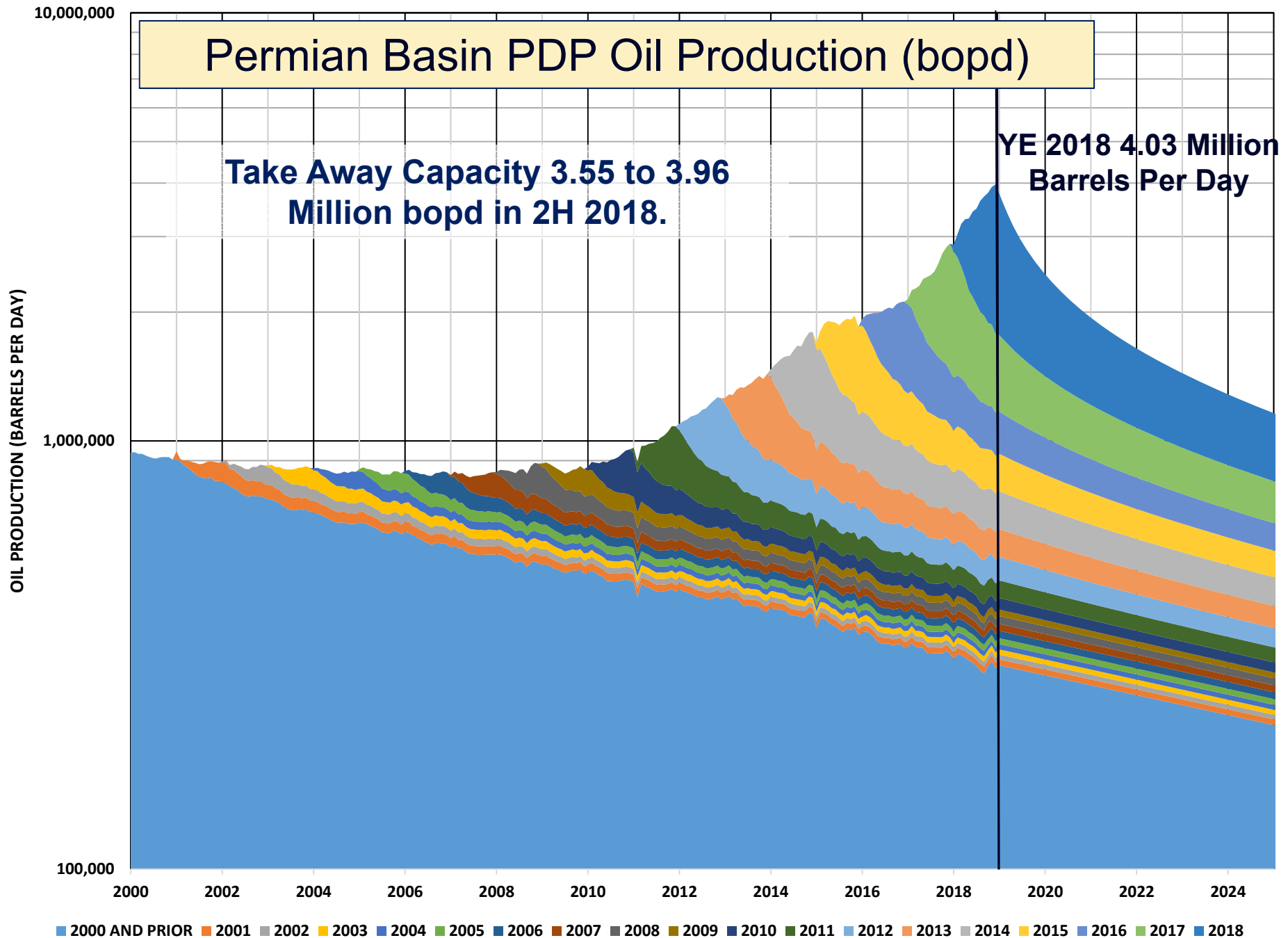
Recent Major Steps

4. Phantom Wolfcamp Field – Delaware Basin (2012)
5. Transition to Horizontal Drilling (2014)\
6. Tall Cotton – First ROZ Greenfield (2015)
7. Horizontal Well – Longer Laterals (2016)
8. Extend Delaware Basin Westward (2017)
9. Permian Basin Production Hits 4 Millions Barrels Per Day (2018)

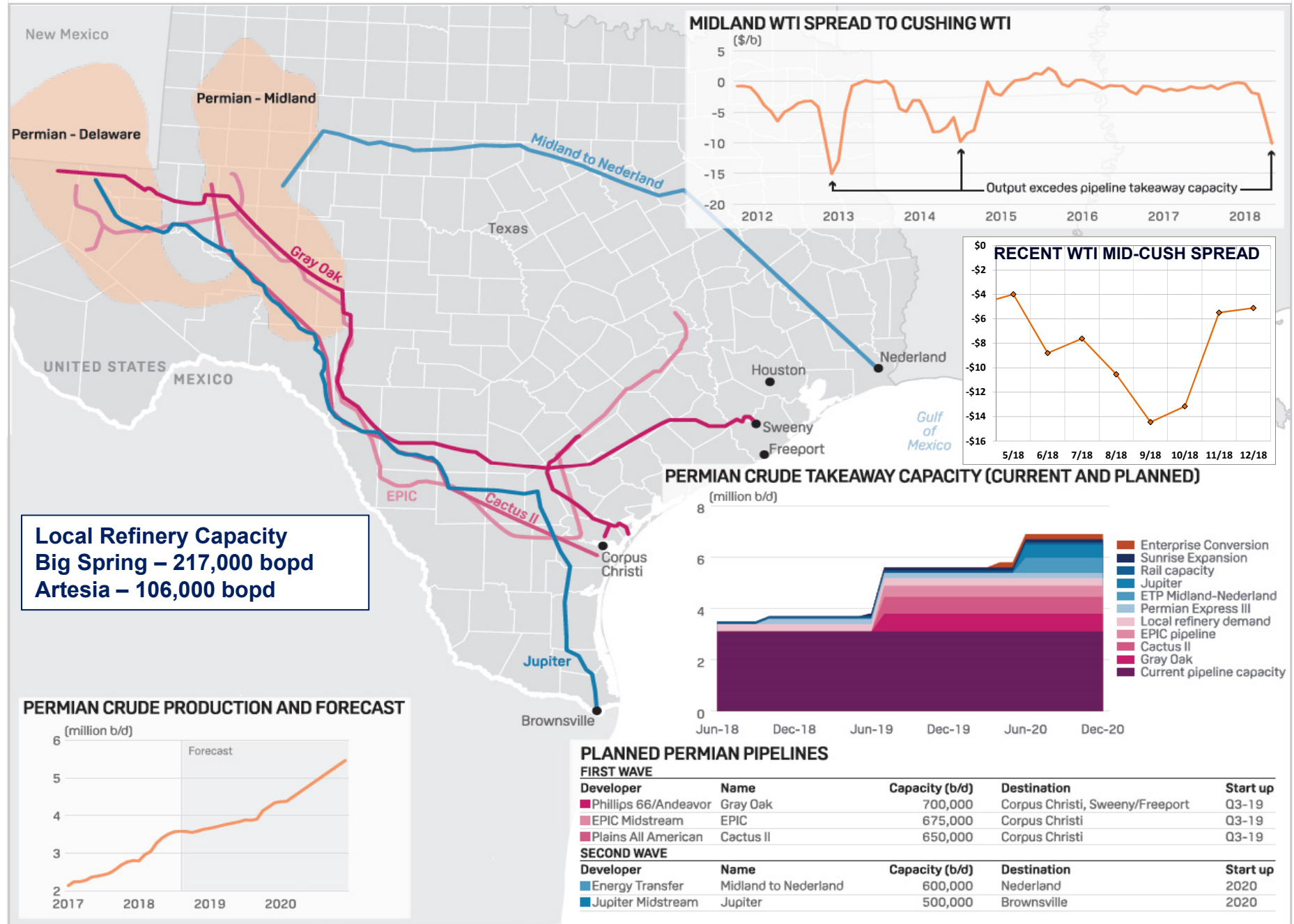
Permian Basin PDP Oil Production (bopd)

Take Away Capacity 3.55 to 3.96
Million bopd in 2H 2018.

YE 2018 4.03 Million
Barrels Per Day



PERMIAN PIPELINE BUILDOUT TO SUPPORT INCREASED PRODUCTION



Source: S&P Global Platts, S&P Global Platts Analytics

Recent Major Steps

10. Transition To Multi-Pay Development (Pad Drilling (2018)

Permian Basin – Speed Bumps

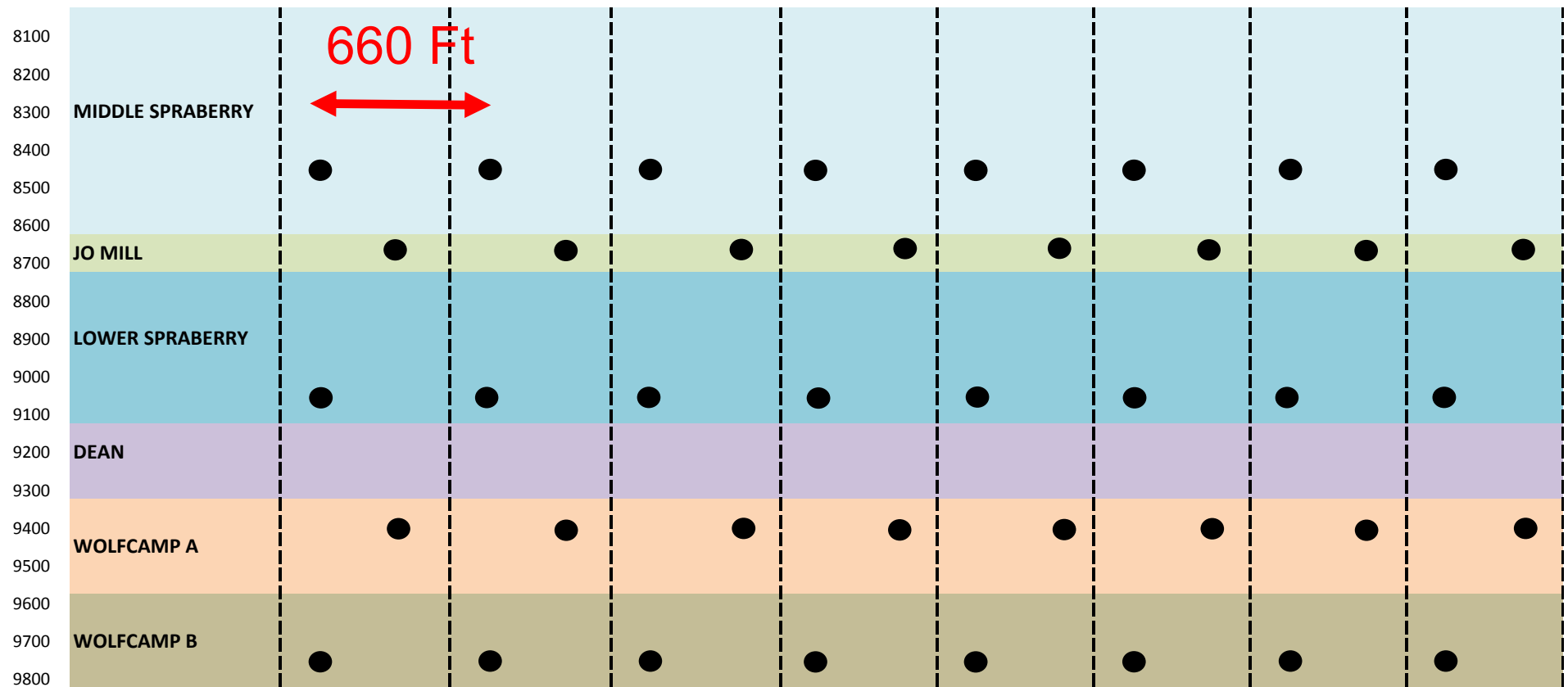
Frac Hits

Permian Basin – Speed Bumps

1 Mile



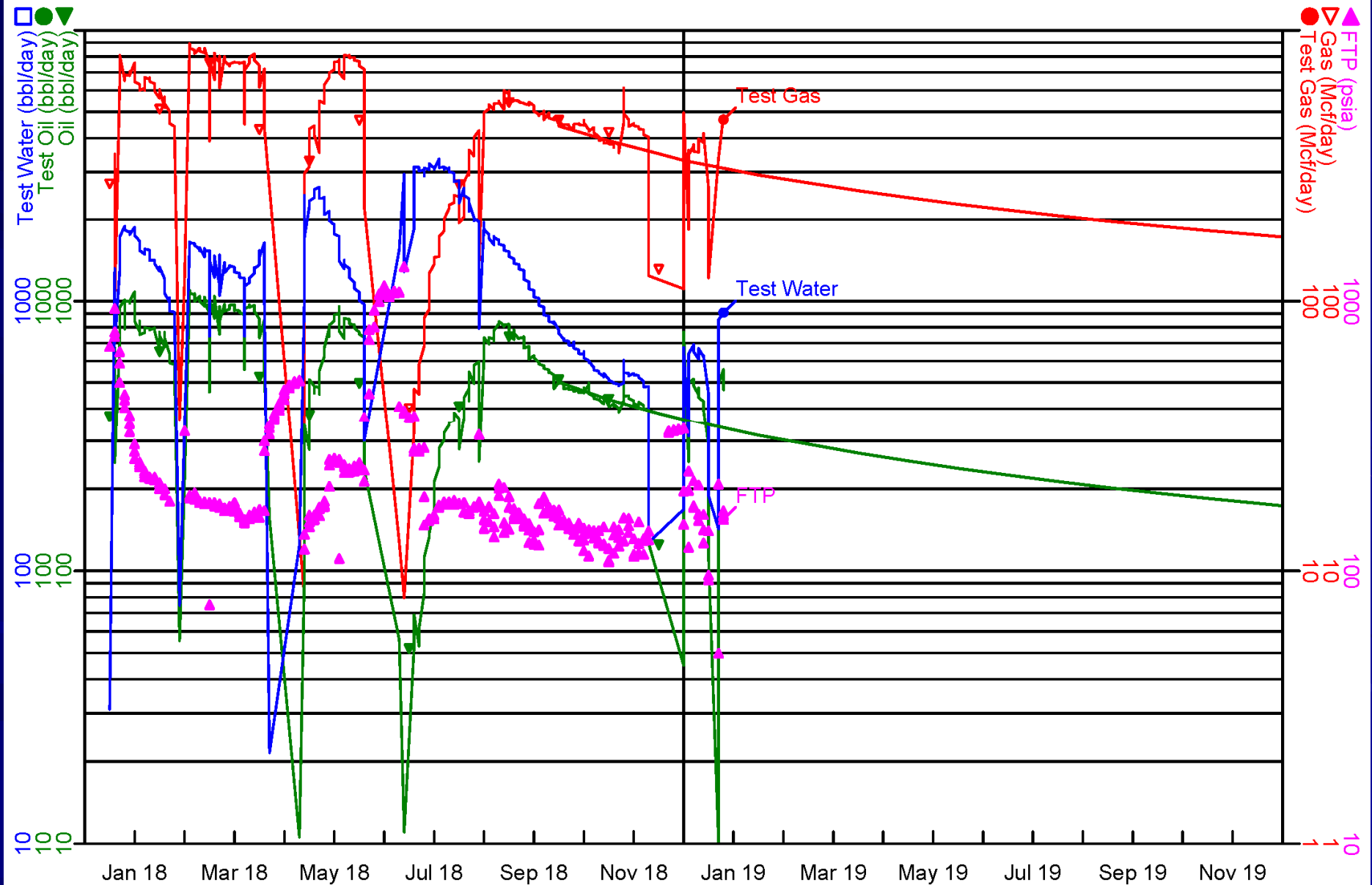
DEPTH FORMATION



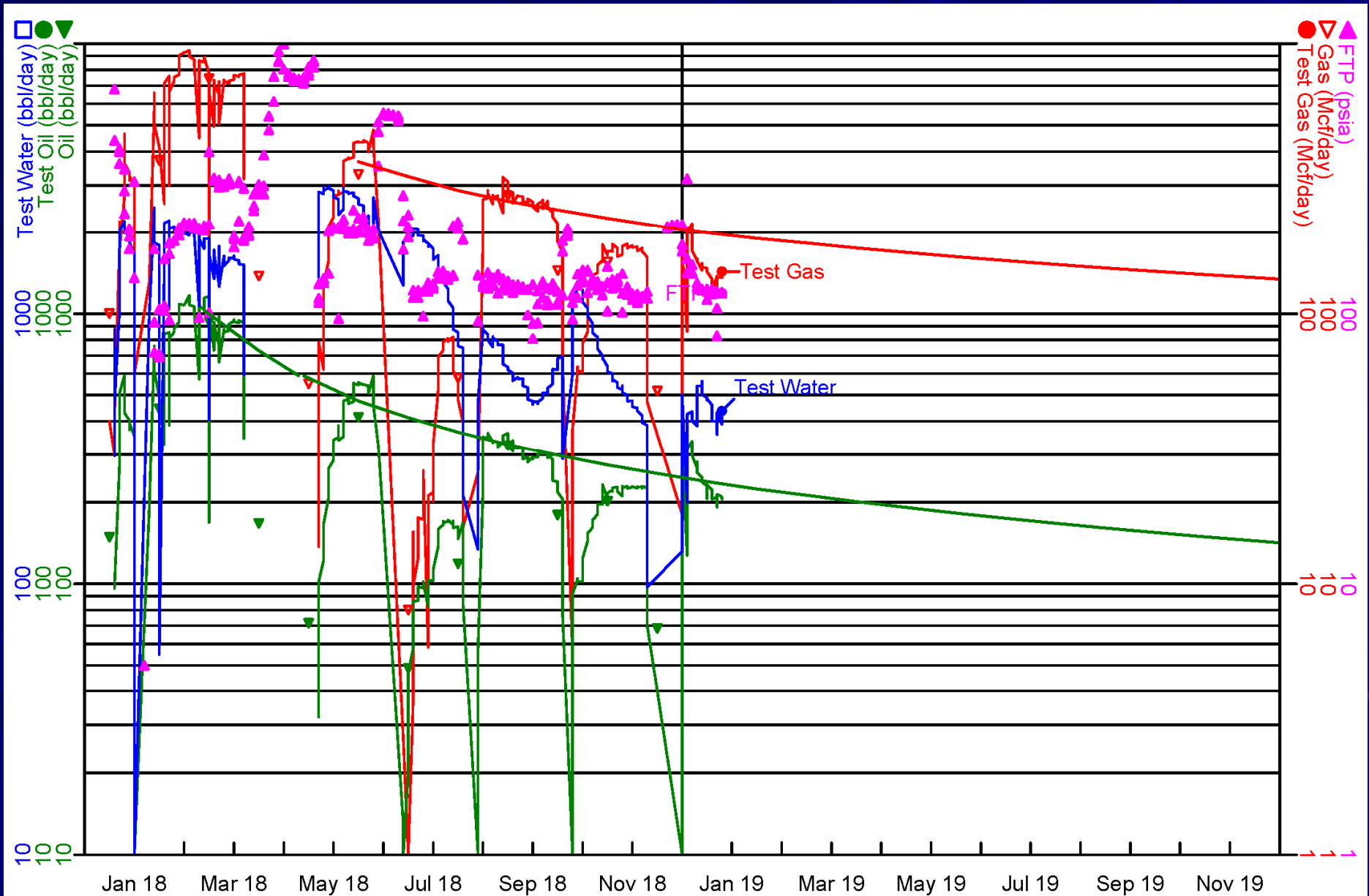
Permian Basin – Speed Bumps

How Do Wells Perform
After A Frac-Hit

MARTIN COUNTY – LOWER SPRABERRY



MARTIN COUNTY – LOWER SPRABERRY

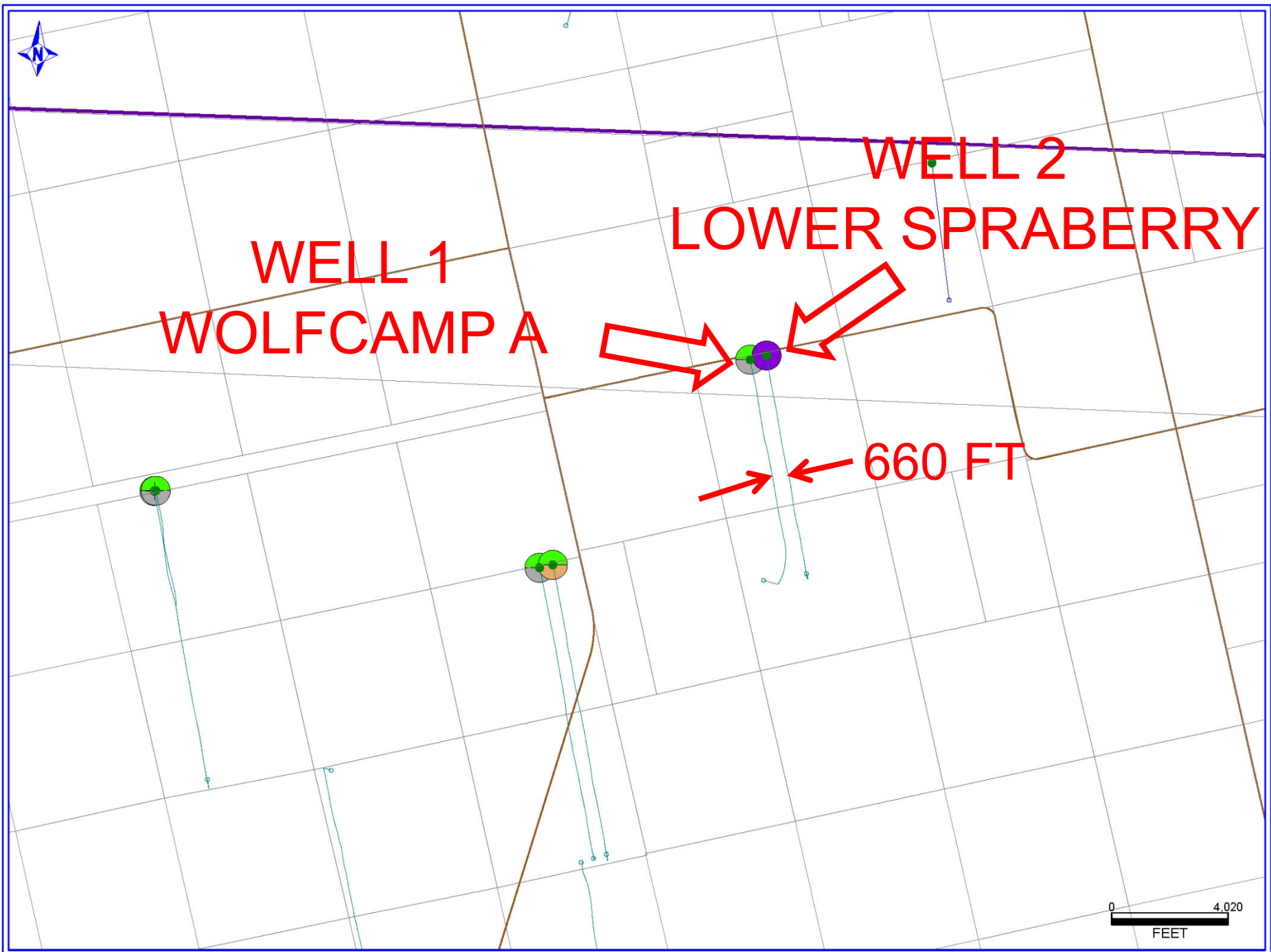


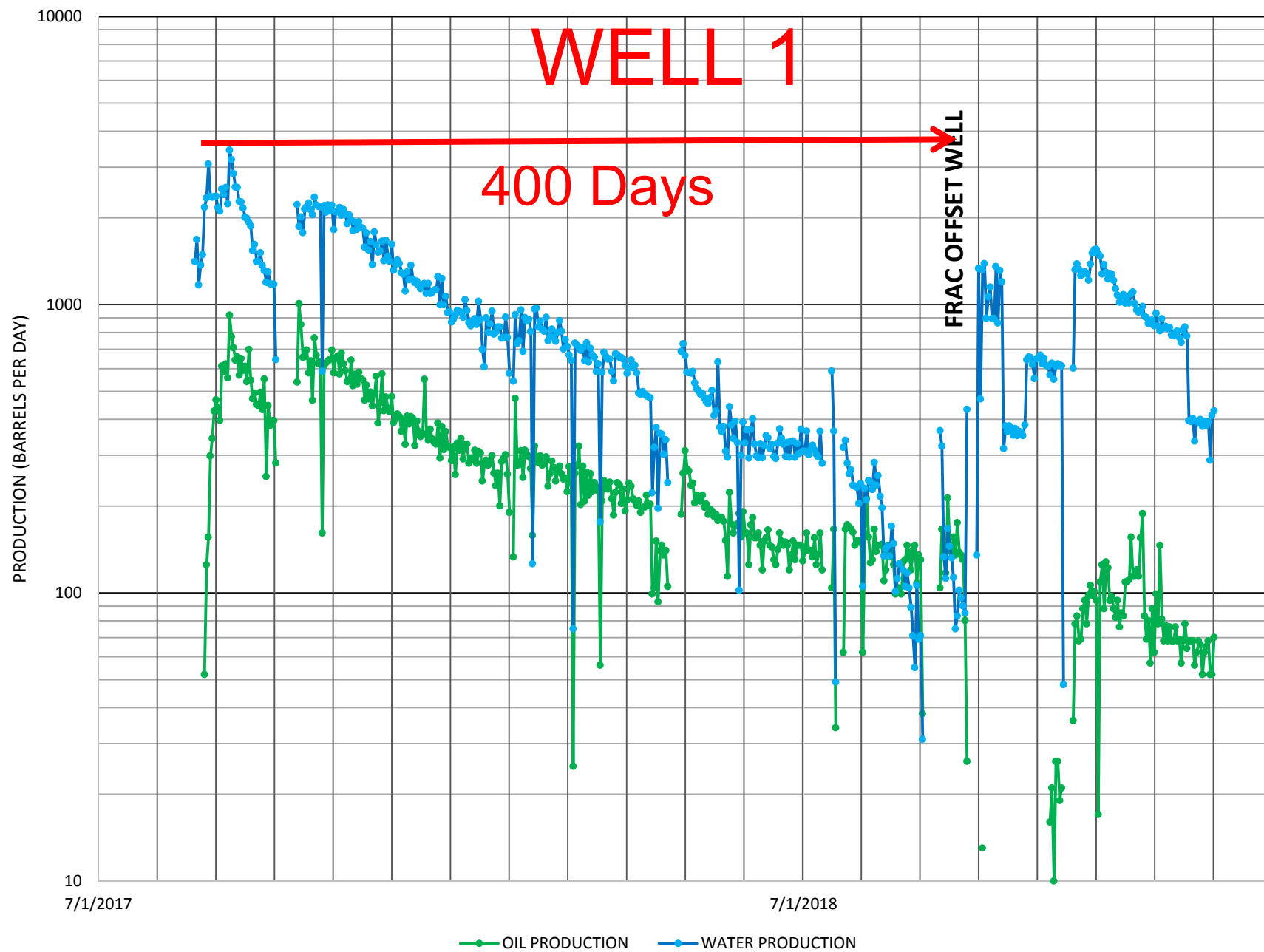
Permian Basin – Speed Bumps

1. About One-Half of Wells Return to Production Volumes Prior to Shut-In
2. About one-Half of Wells Follow Decline Curve Established Prior to Shut-In

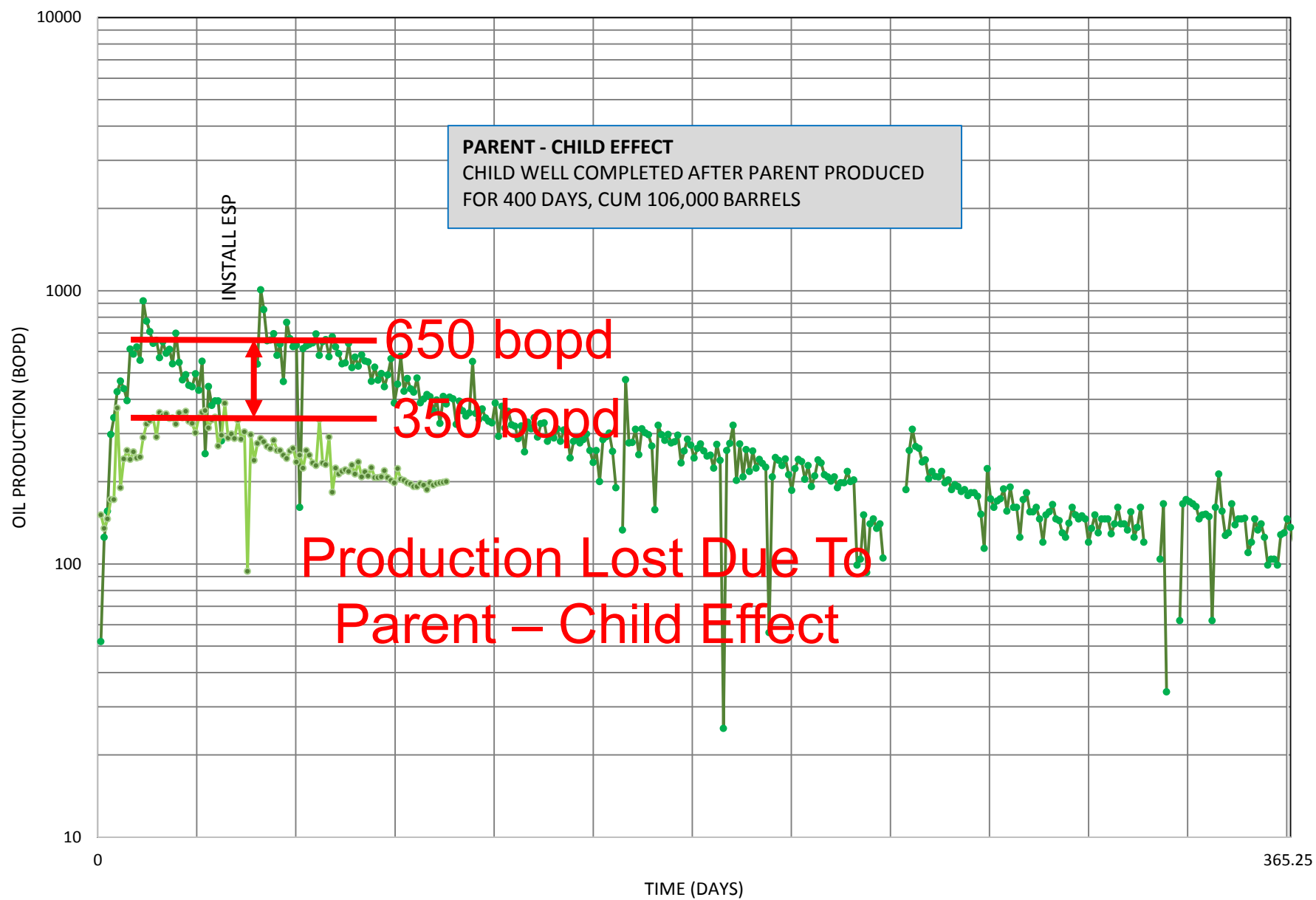
Permian Basin – Speed Bumps

4. Phantom Wolfcamp Field – Delaware Basin (2012)
5. Transition to Horizontal Drilling (2014)
6. Horizontal Well – Longer Laterals (2016)
7. Extend Delaware Basin Westward (2017)
8. Transition to Multi-Pay Development (Pad Drilling) (2017)
9. Child – Parent Deterioration (2018)









Permian Basin – Speed Bumps

1. To Minimize Parent-Child Deterioration, Wells Need to Be Completed Within 6 Months.
2. Spacing Greater Than 800 Ft Greatly Reduces Parent-Child Effect. (After Schlumberger)

Permian Basin – Speed Bumps

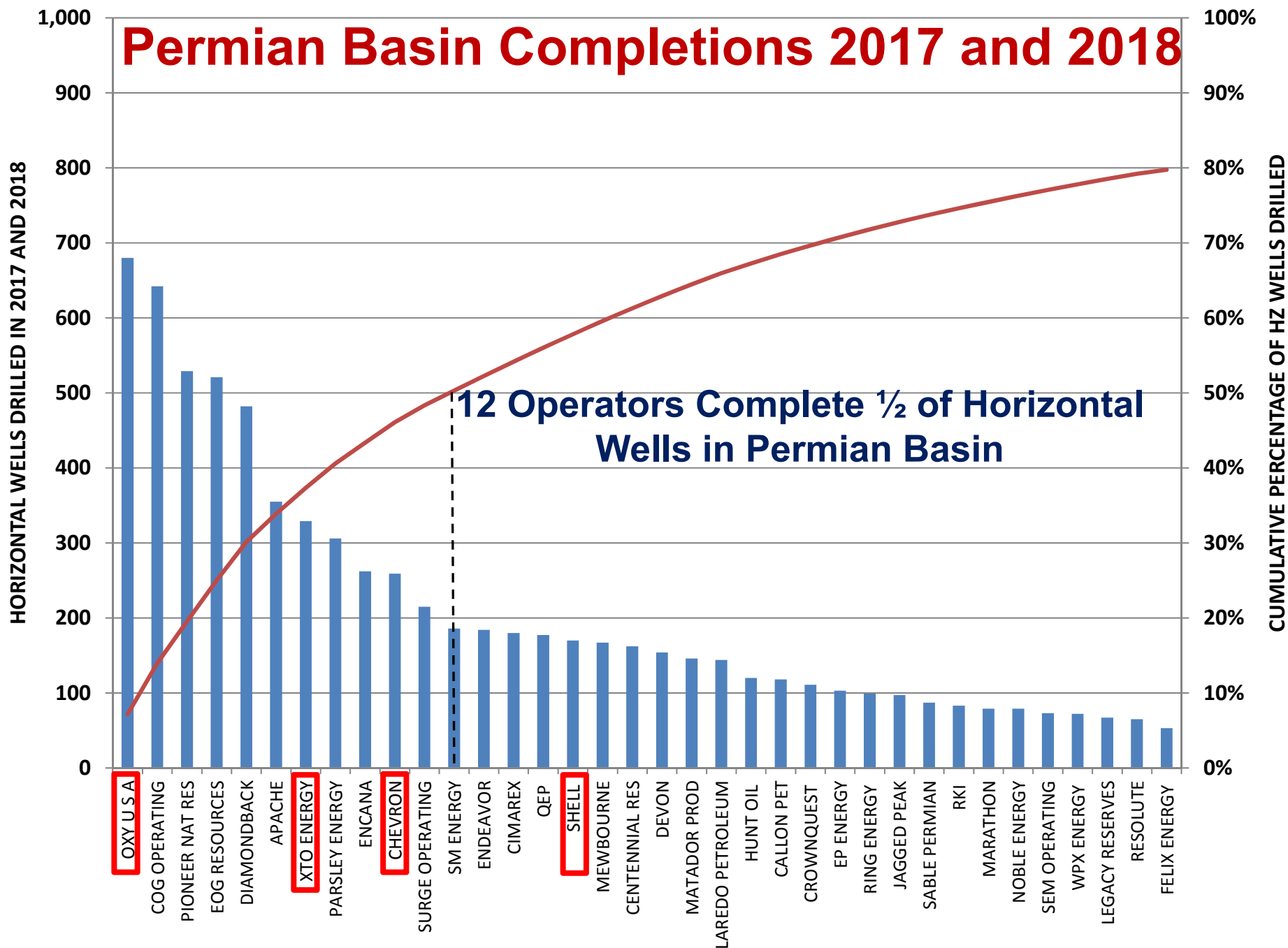
1. Midland Basin – 8,831 Horizontal Completions
2. Delaware Basin – 10,659 Horizontal Completions

The background is a solid dark blue with a pattern of lighter blue diagonal lines that create a sense of depth and movement, radiating from the top right corner.

Permian Basin

The Future

Permian Basin Completions 2017 and 2018



Permian Basin – 50 PE Companies

Admiral Permian Resources	Pine Brook Partners, ARES
Adventure Exploration	Kayne Anderson
AmereDev	EnCap
Atlantic Resources	Denham Capital
Capstone Natural Resources	Lime Rock Management
Carrera	EnCap
Centennial Resources	Natural Gas Partners, Riverstone
Charger Shale	Oak Tree Capital
Chi Energy	Energy Trust Partners
Chisholm Energy	Warburg Pincus
Colgate Energy	Natural Gas Partners
Costilla Energy	Chiron Financial
CrownQuest	Lime Rock Management
Crump Energy Partners	Quantum Energy Partners
Custer & Wright	
Double Point Energy	Quantum Energy Partners
Eagle Permian Partners	Energy Trust Partners
Element Petroleum	ArcLight
Elevation Resources	Pine Brook Partners
EXL Petroleum	Quantum Energy Partners
Five Stones Energy	Energy Trust Partners
Fortuna Resources	Och-Ziff
Forty Acres Energy	Sage Road Capital
Guidon Energy	Blackstone
Hibernia	Natural Gas Partners

Jagged Peak	Quantum Energy Partners
Llano Energy	Sage Road Capital
Mammoth Exploration	
Manzano	Energy Trust Partners
Monadnock Resources	Kayne Anderson
Moriah Henry Partners	Post Oak Energy Capital
OGX	EnCap
PAK Development	Kayne Anderson
Pegasus Resources	EnCap
PetroLegacy	EnCap
Piedra	EnCap
Plantation Holdings	EnCap
Prime Rock Resources	Lime Rock Management
PT Petroleum	Kayne Anderson
Qstar	EnCap
Ridge Runner	Warburg Pincus
Ridglea Energy	Sage Road Capital
Rio	Denham Capital
Riverbend E&P	Kayne Anderson
ROXO	Vortus Investments
Saballo	EnCap
Saber Oil & Gas	Alt Point Capital
Scalla	EnCap
Tall City	Warburg Pincus
Three Rivers Operating	Riverstone Holdings
Windy Cove	Yorktown
Wishbone Energy Partners	Quantum Energy Partners

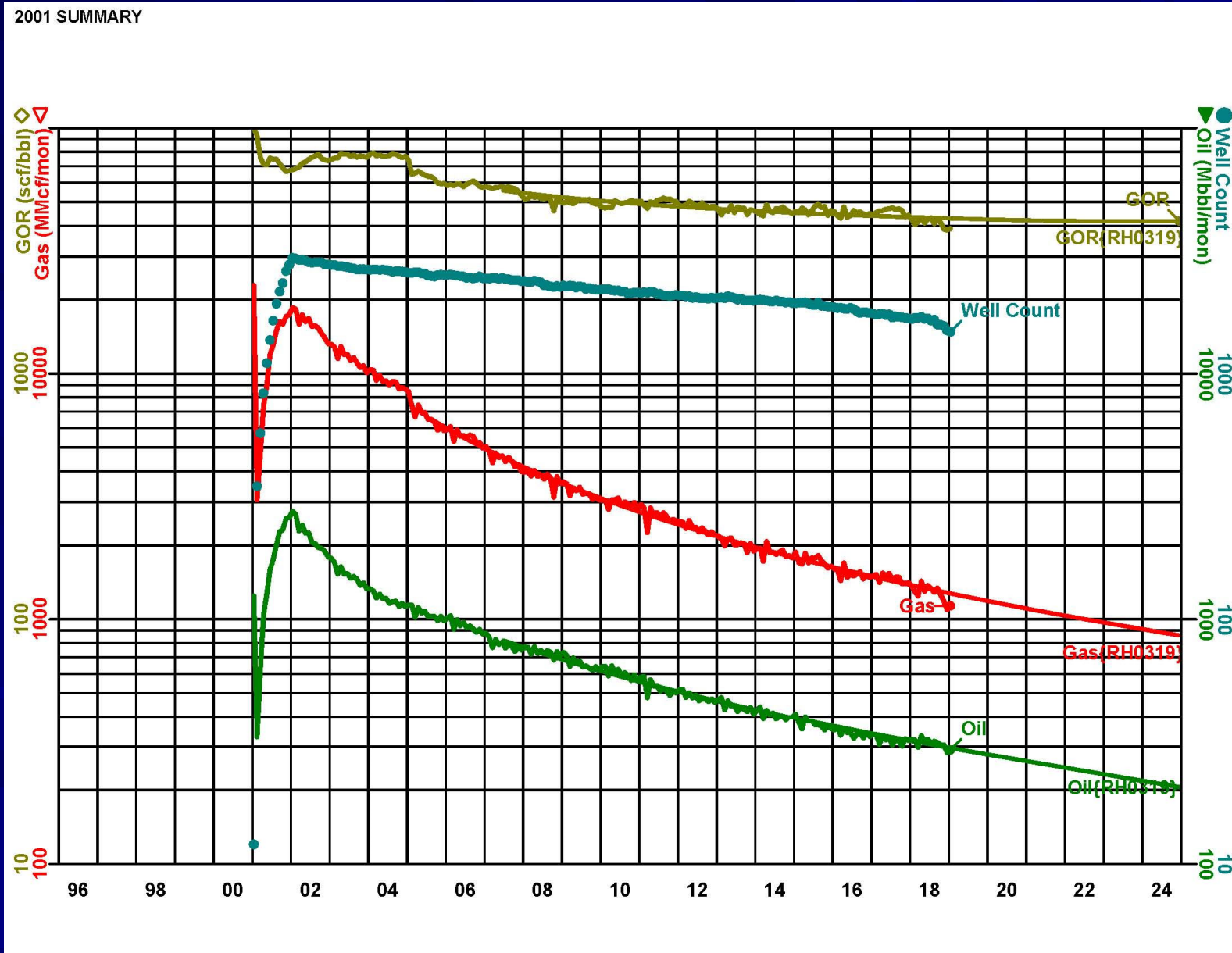
Consolidation of Operators Will Continue

1. Large Majors Seeking To Expand Footprint
2. Wall Street Desires Better Oil E&P Returns
(Lower G&A, CAPEX Below Cash Flow,
Higher Dividends)
3. PE Investors Need Return on Investment

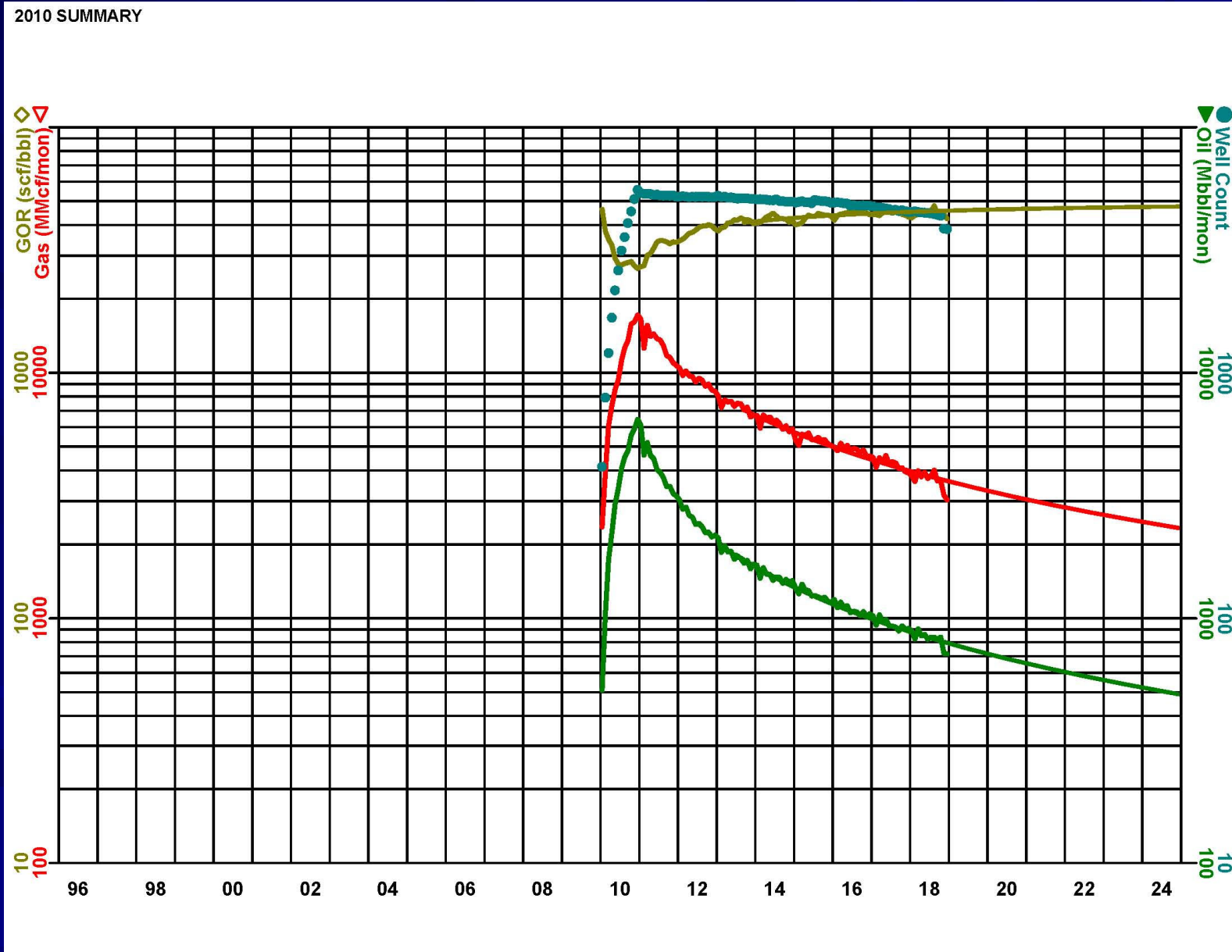
Permian Basin – Projected Production

1. Forecast PDP Production By Year
2. Divide Basin Into Producing Areas
3. Typical Decline Profile For Each Area
4. Project Drilling Rate
5. Project Lateral Length
6. Project Parent-Child Impacts
7. Combine Forecasts

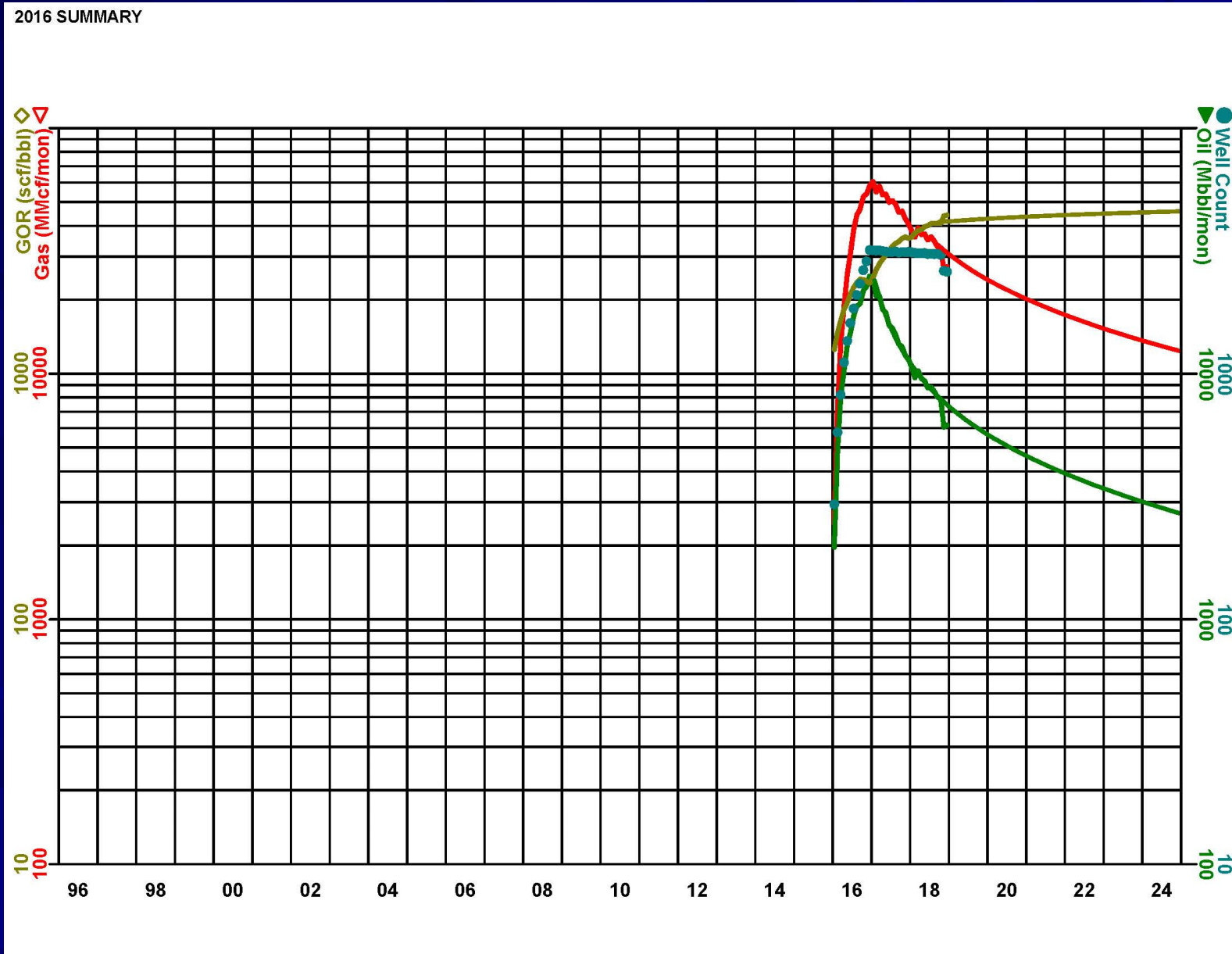
Permian Basin – 2001 PDP Forecast

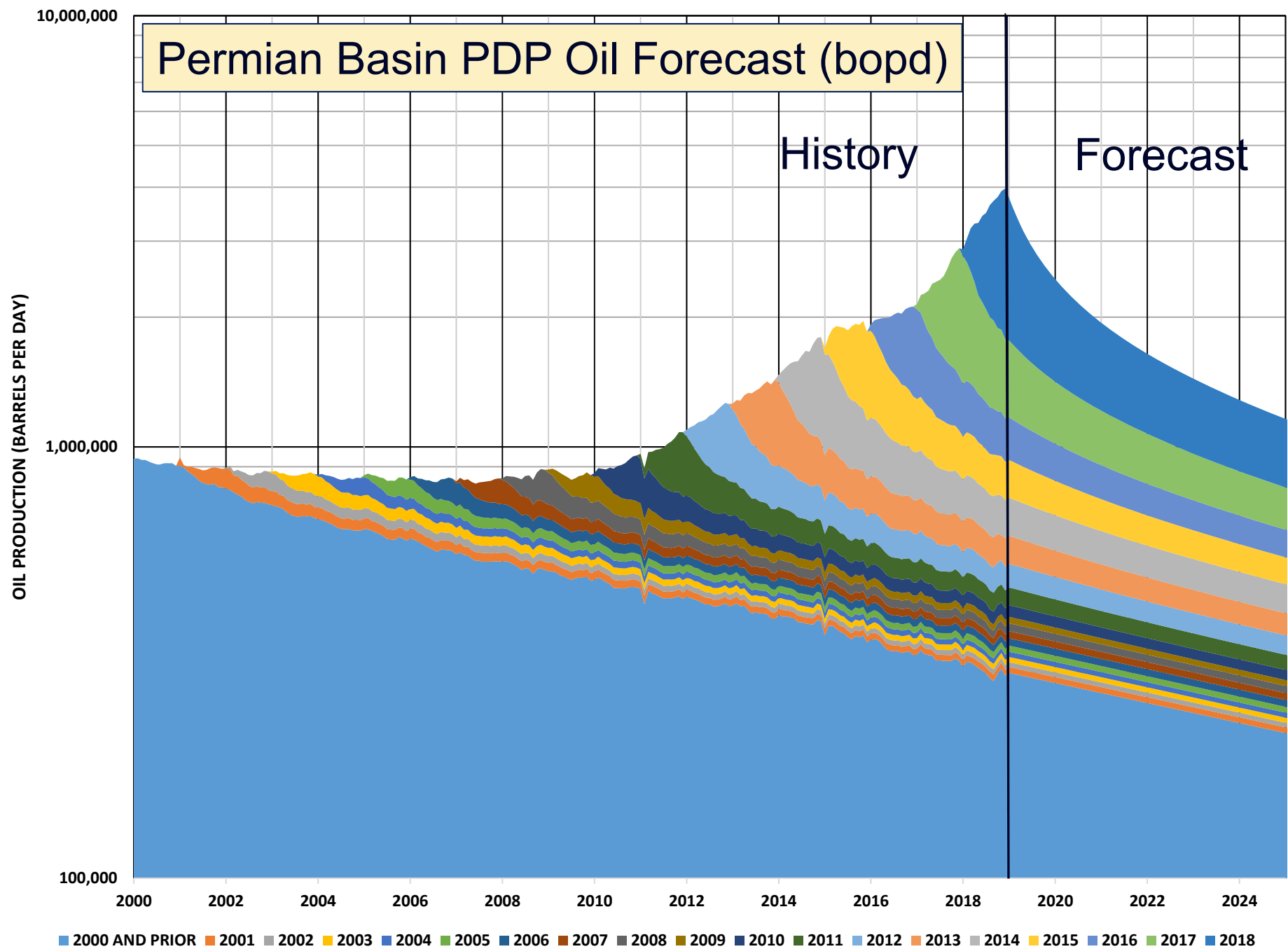


Permian Basin – 2010 PDP Forecast



Permian Basin – 2016 PDP Forecast





Permian Basin – Projected Production

1. Forecast PDP Production By Year
2. Divide Basin Into Producing Areas
3. Typical Decline Profile For Each Area
4. Project Drilling Rate
5. Project Lateral Length
6. Project Parent-Child Impacts
7. Combine Forecasts

Permian Basin – 19 Forecast Areas

MIDLAND BASIN

WOLFCAMP B	34.5%
LOWER SPRABERRY	34.1%
WOLFCAMP A	20.7%
SOUTHERN WOLFCAMP	6.1%
MIDDLE SPRABERRY	2.9%
WOLFCAMP C	0.9%
CLINE	0.8%

DELAWARE BASIN

TX/NM LOW GOR WOLFCAMP	29.0%
TX/NM HIGH GOR WOLFCAMP	24.4%
NM BONE SPRING - NORM GOR	17.1%
TX/NM NORM GOR WOLFCAMP	14.1%
NM/TX BONE SPRING HIGH GOR	8.7%
TX BONE SPRING	3.8%
NM YESO	2.9%

CENTRAL BASIN PLATFORM & NORTHWEST SHELF

CBP MISC	40.0%
NWS SAN ANDRES - TIER 1	25.0%
NWS SAN ANDRES - TIER 2	15.0%
CBP SAN ANDRES	15.0%
CBP BARNETT SHALE	5.0%

**Forecast 1,645 Wells
or 46% of 2017 – 2018
Completions**

Typical Decline Profile – MB Lower Spraberry

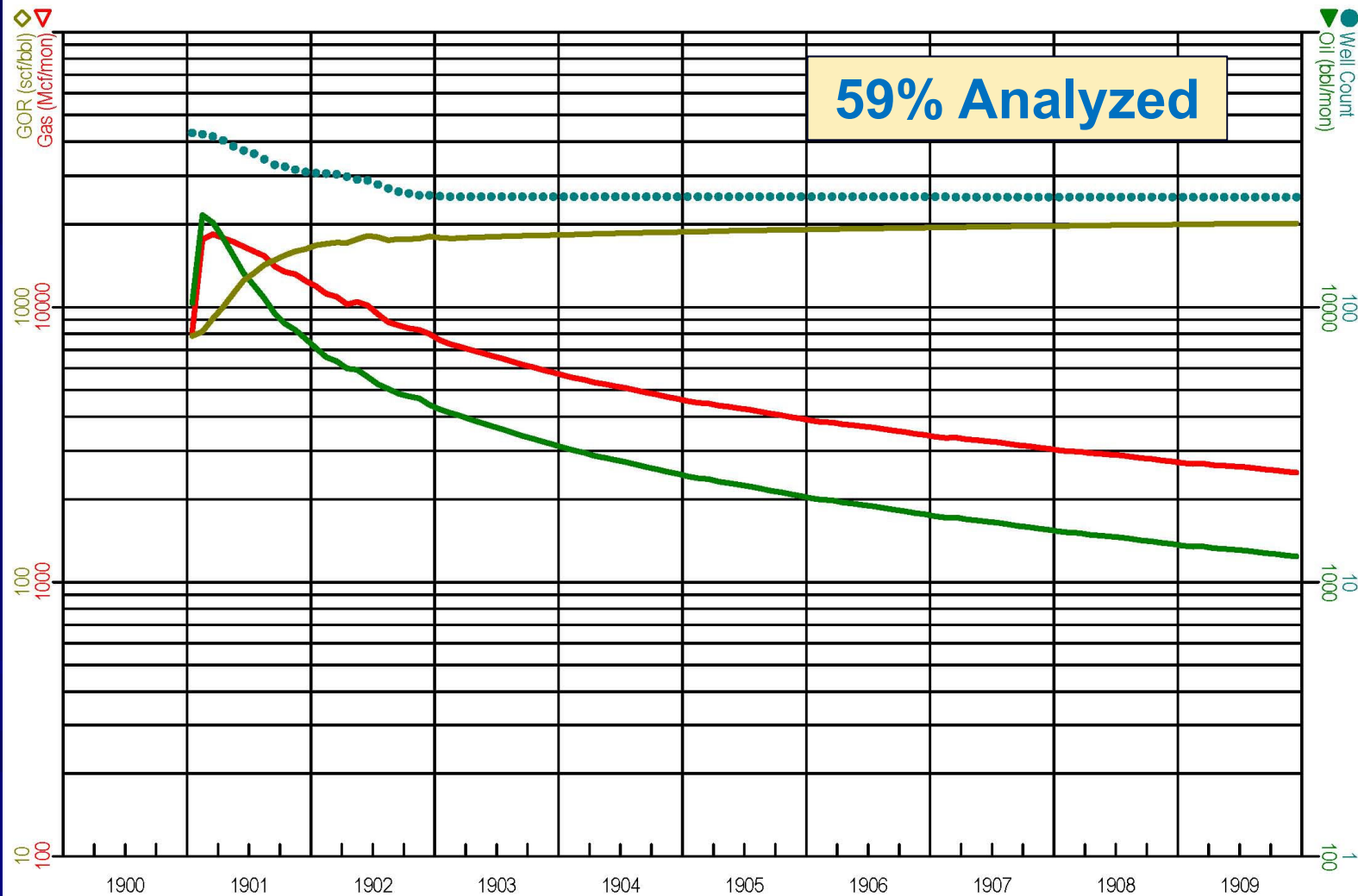
LOWER SPRABERRY 2017 - 2018
Oper: VARIOUS

County,State: VARIOUS,TX

Field: STAF

Reservoir: LOWER SPRABERRY

Normalized to Time Zero and divided by Well #



Oil EUR: 649.56 Mbbl

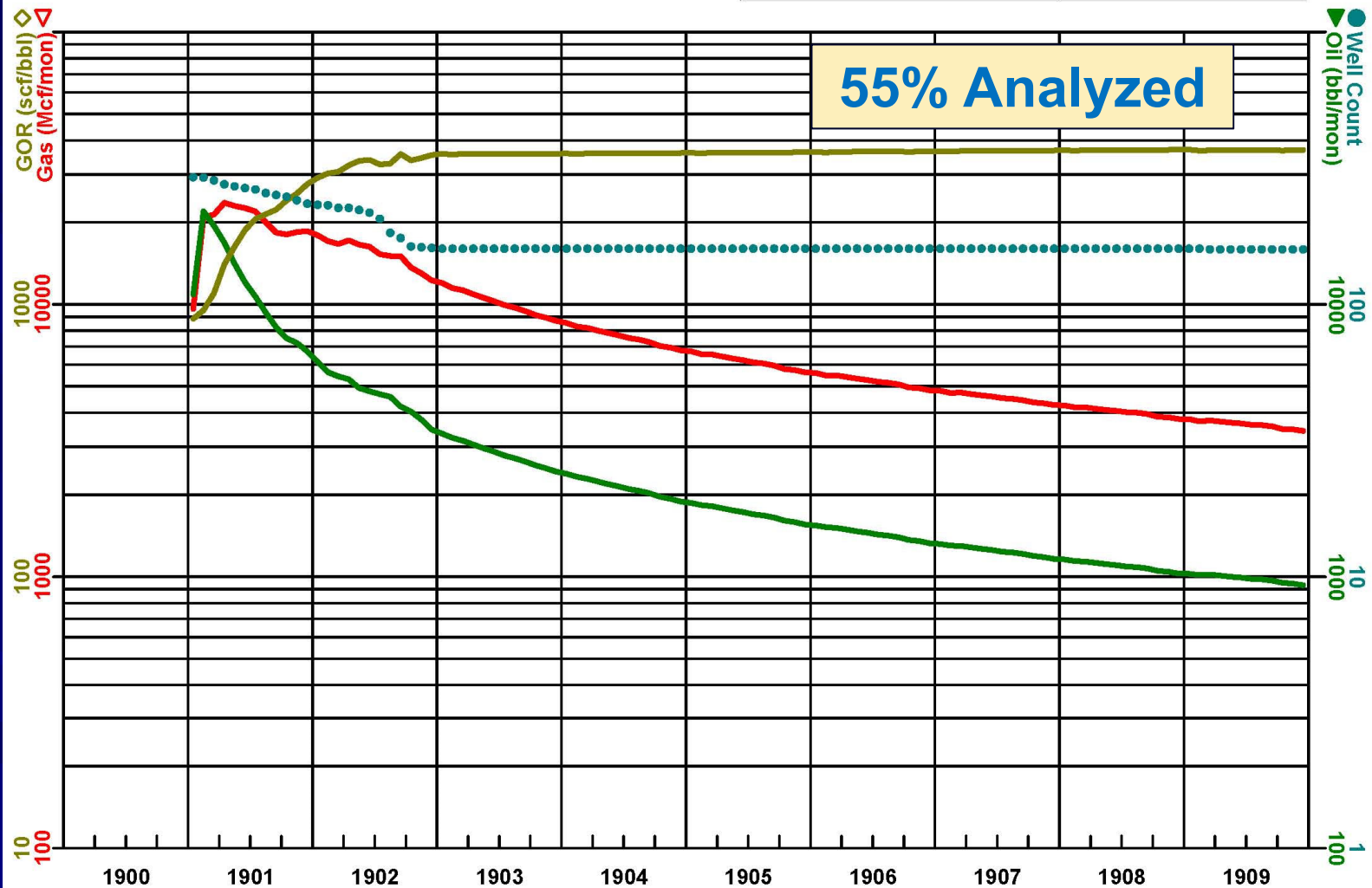
Gas EUR: 1,178.89 MMcf

Typical Decline Profile – MB Wolfcamp B

WOLFCAMP B 2017 - 2018
Oper: VARIOUS

County,State: VARIOUS,TX
Field: STAF
Reservoir: WOLFCAMP B

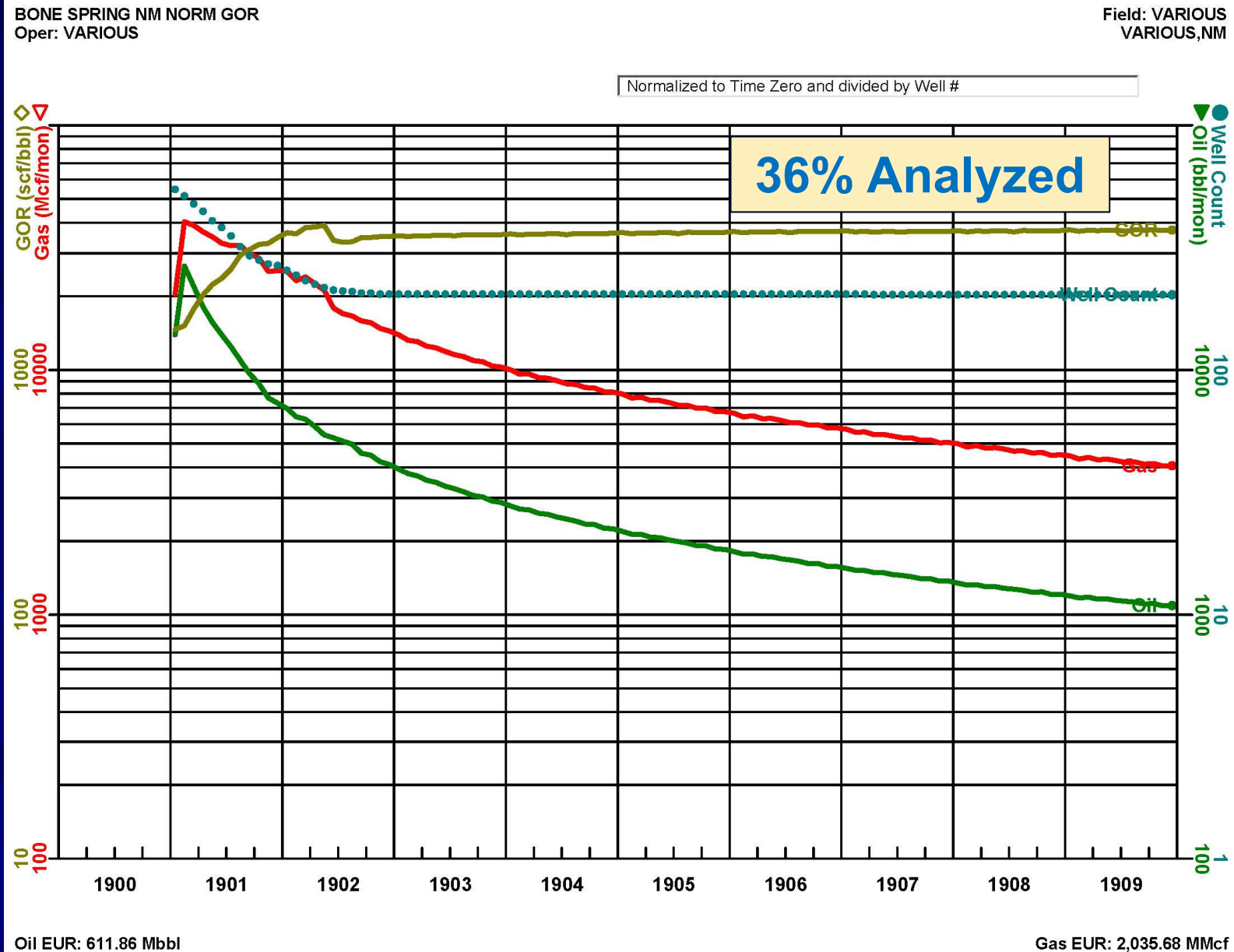
Normalized to Time Zero and divided by Well #



Oil EUR: 525.18 Mbbl

Gas EUR: 1,614.93 MMcf

Typical Decline Profile – NM Bone Spring

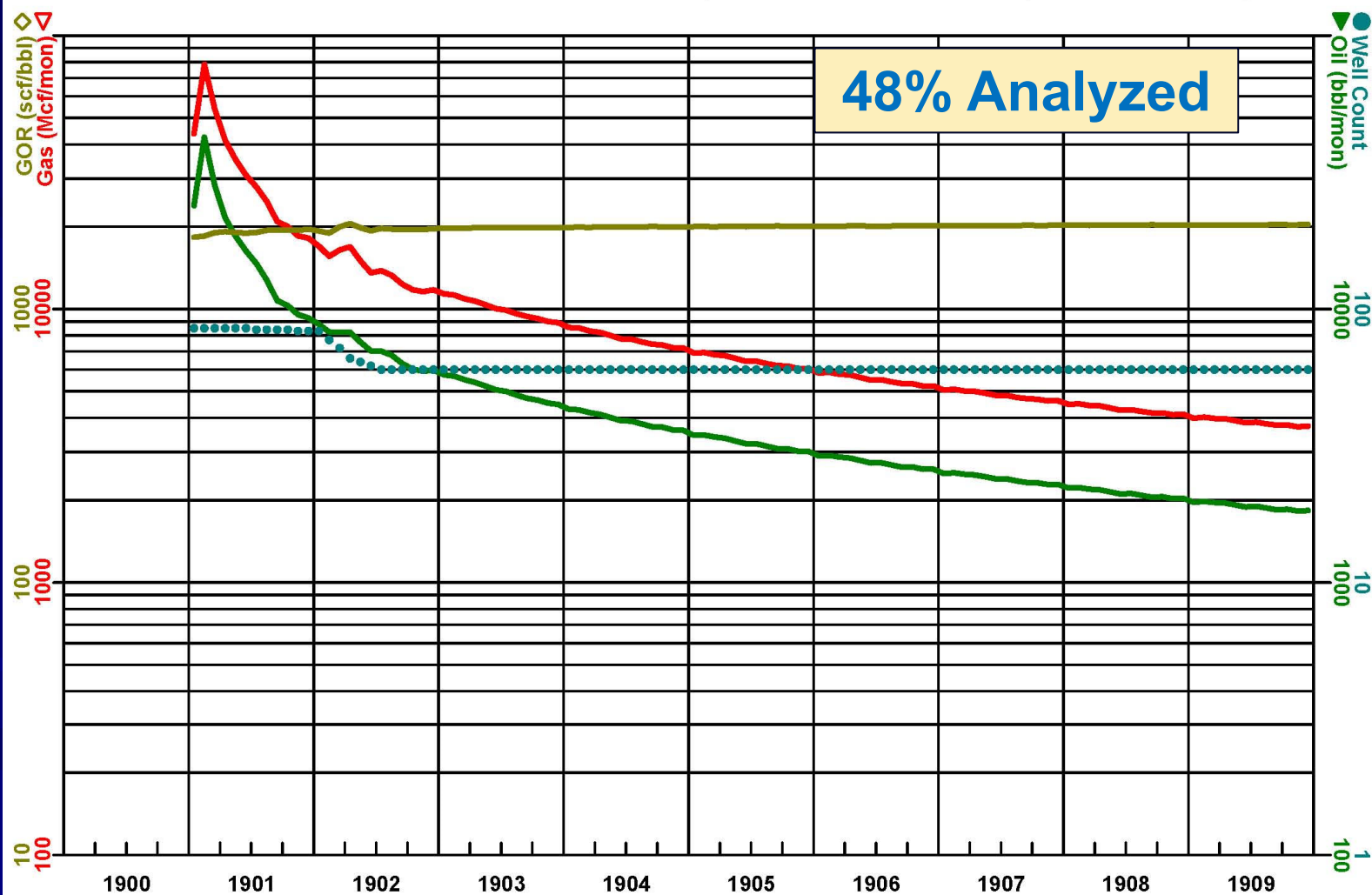


Typical Decline Profile – DB Wolfcamp Low GOR

NM 2017 AND LATER
Oper: VARIOUS

Field: VARIOUS
VARIOUS,NM

Normalized to Time Zero and divided by Well #



Oil EUR: 930.01 Mbbl

Gas EUR: 1,863.06 MMcf

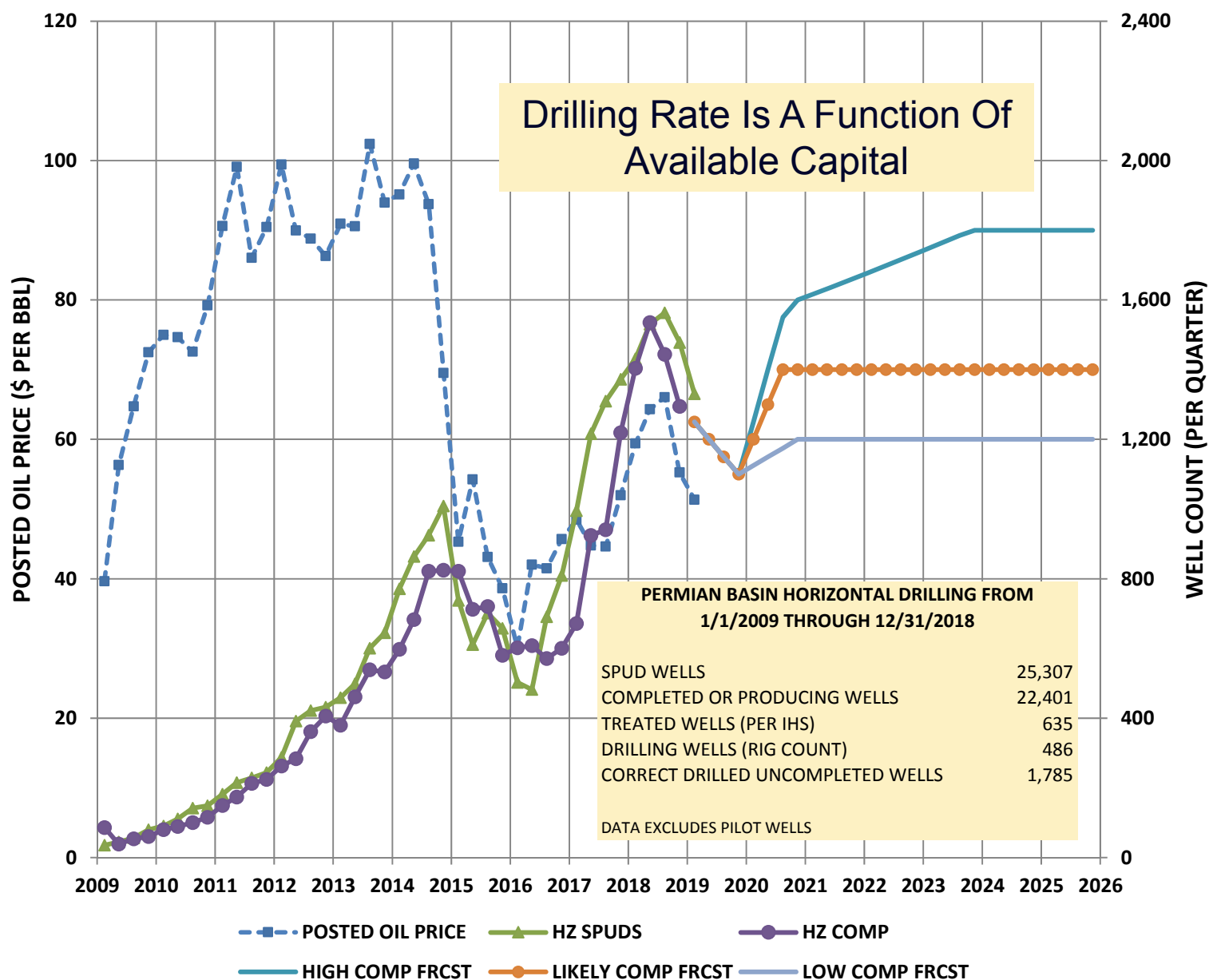
Permian Basin – Projected Production

1. Forecast PDP Production By Year
2. Divide Basin Into Producing Areas
3. Typical Decline Profile For Each Area
4. Project Drilling Rate
5. Project Lateral Length
6. Project Parent-Child Impacts
7. Combine Forecasts

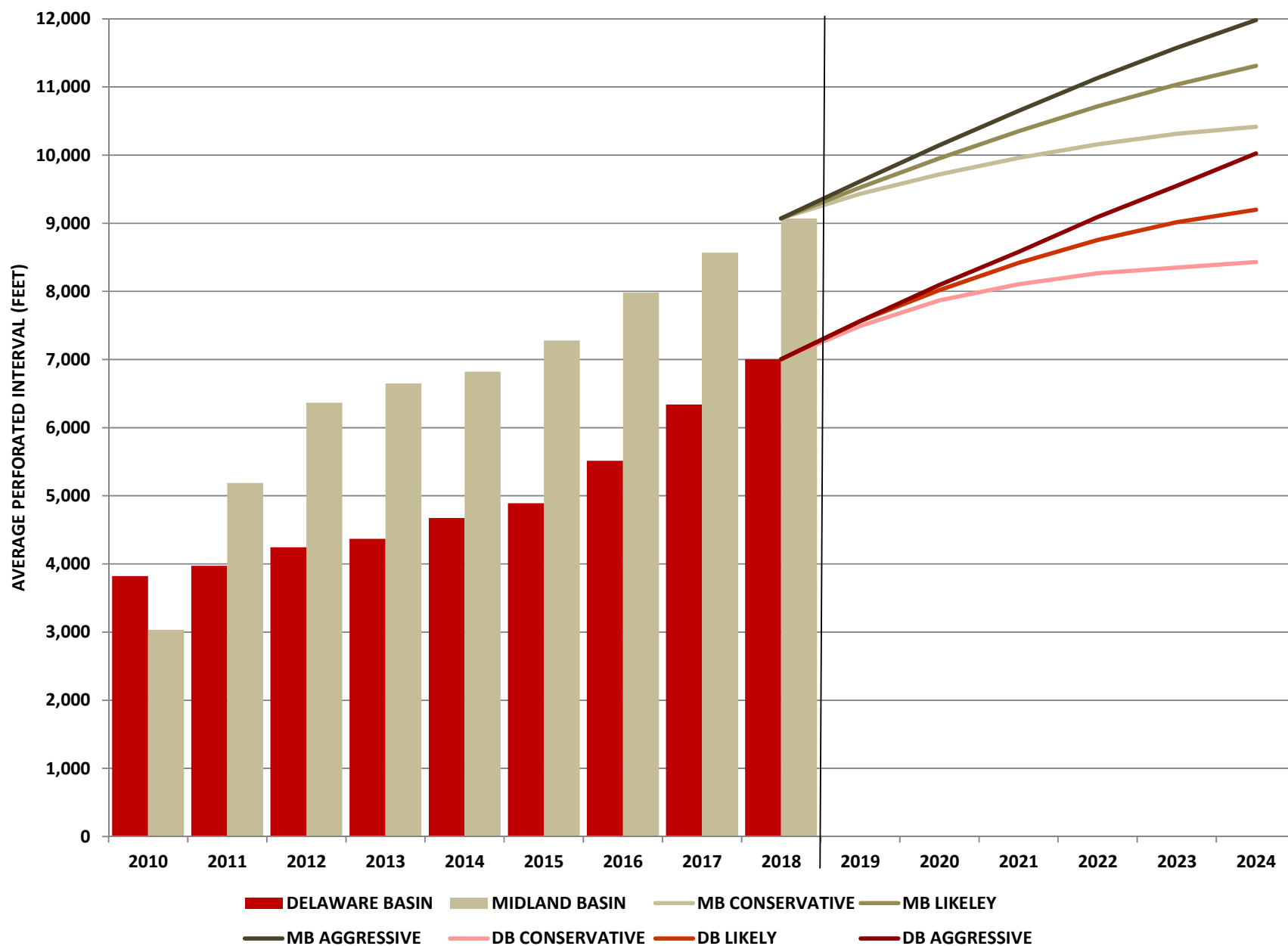
2019 Permian Basin Public Company Trends

1. Decreasing Rig Count !!
2. CAPEX Less Than Cash Flow
3. Pay Down Debt
4. Many Plan To Increase Dividends

Permian Basin – Completion Forecast

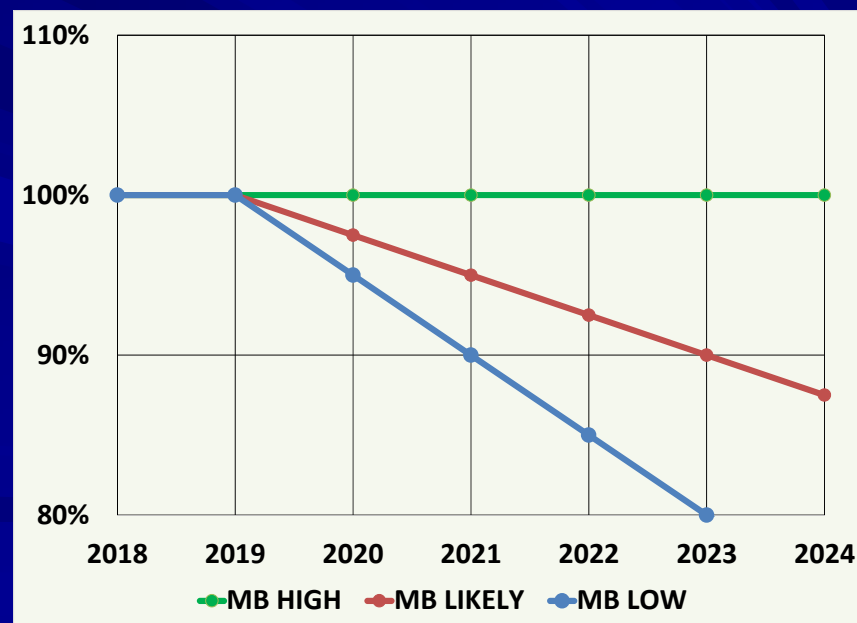
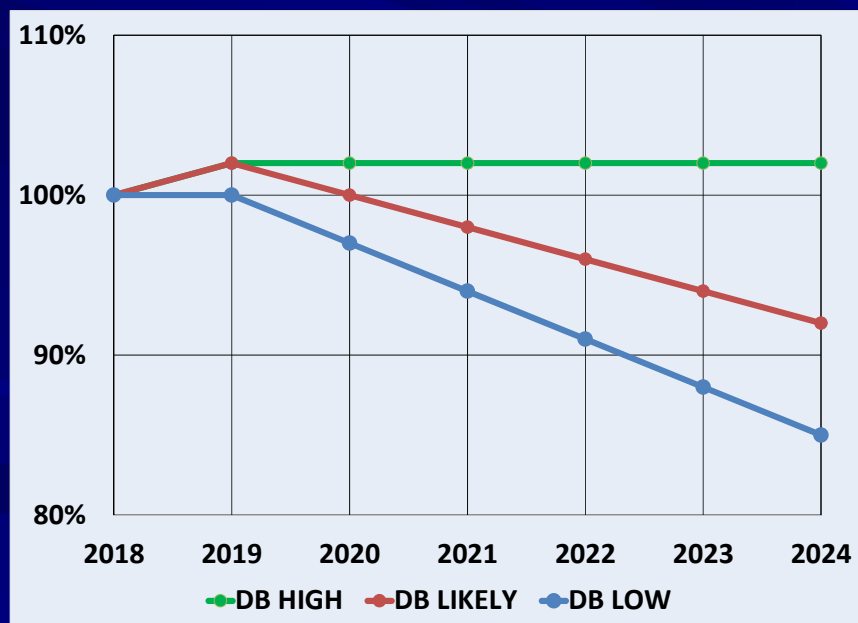


Permian Basin – Lateral Forecast



Permian Basin – Parent-Child Forecast

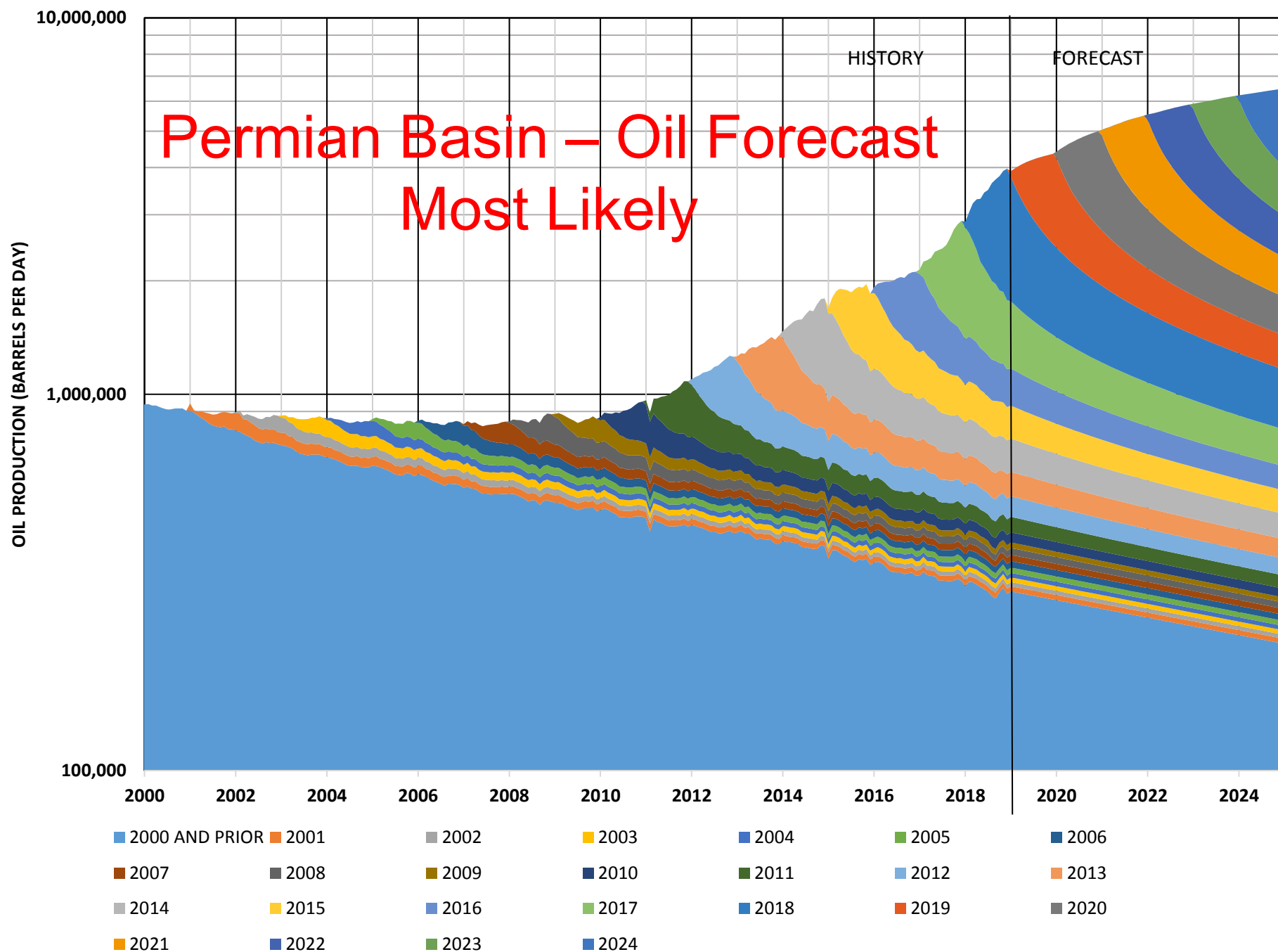
	DELAWARE BASIN			MIDLAND BASIN			CENTRAL BASIN PLATFORM		
	LOW	LIKELY	HIGH	LOW	LIKELY	HIGH	LOW	LIKELY	HIGH
2019	100.0%	102.0%	102.0%	100.0%	100.0%	100.0%	100.0%	102.0%	105.0%
2020	97.0%	100.0%	102.0%	95.0%	97.5%	100.0%	100.0%	104.0%	110.0%
2021	94.0%	98.0%	102.0%	90.0%	95.0%	100.0%	100.0%	106.0%	112.0%
2022	91.0%	96.0%	102.0%	85.0%	92.5%	100.0%	100.0%	108.0%	114.0%
2023	88.0%	94.0%	102.0%	80.0%	90.0%	100.0%	100.0%	110.0%	116.0%
2024	85.0%	92.0%	102.0%	75.0%	87.5%	100.0%	100.0%	112.0%	118.0%



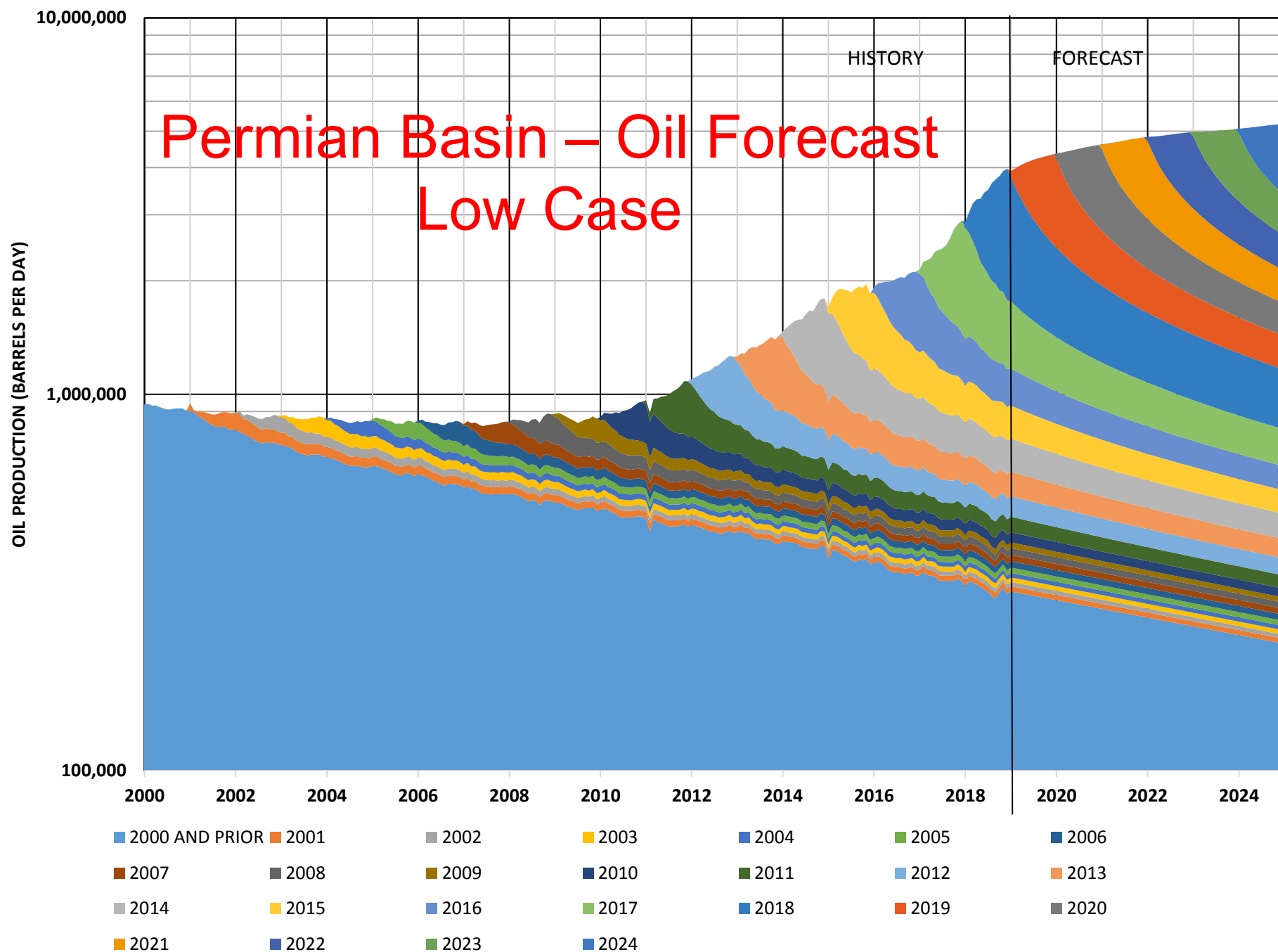
Permian Basin – Projected Production

1. Forecast PDP Production By Year
2. Divide Basin Into Producing Areas
3. Typical Decline Profile For Each Area
4. Project Drilling Rate
5. Project Lateral Length
6. Project Parent-Child Impacts
7. Combine Forecasts

Permian Basin – Oil Forecast Most Likely



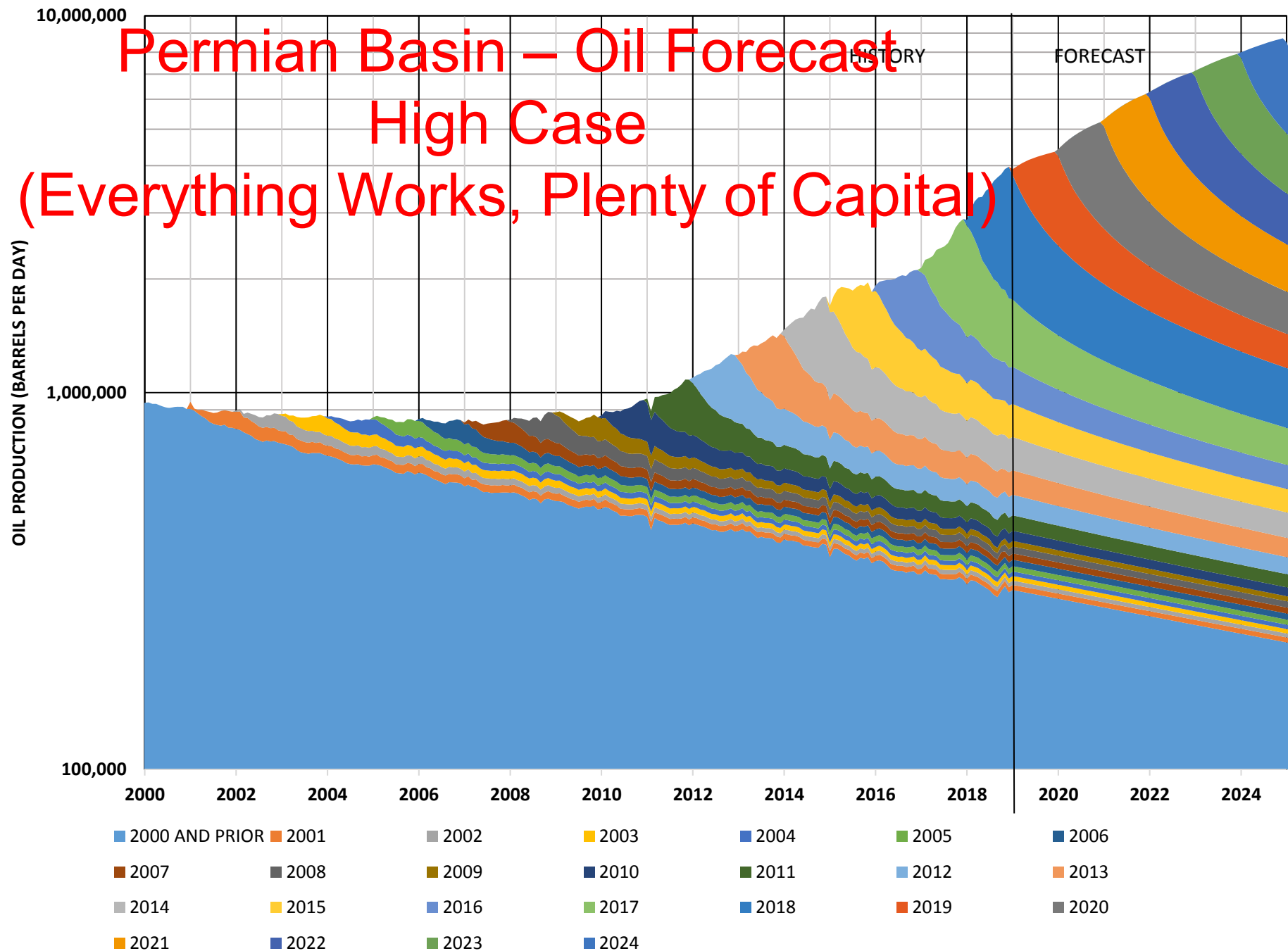
Permian Basin – Oil Forecast Low Case

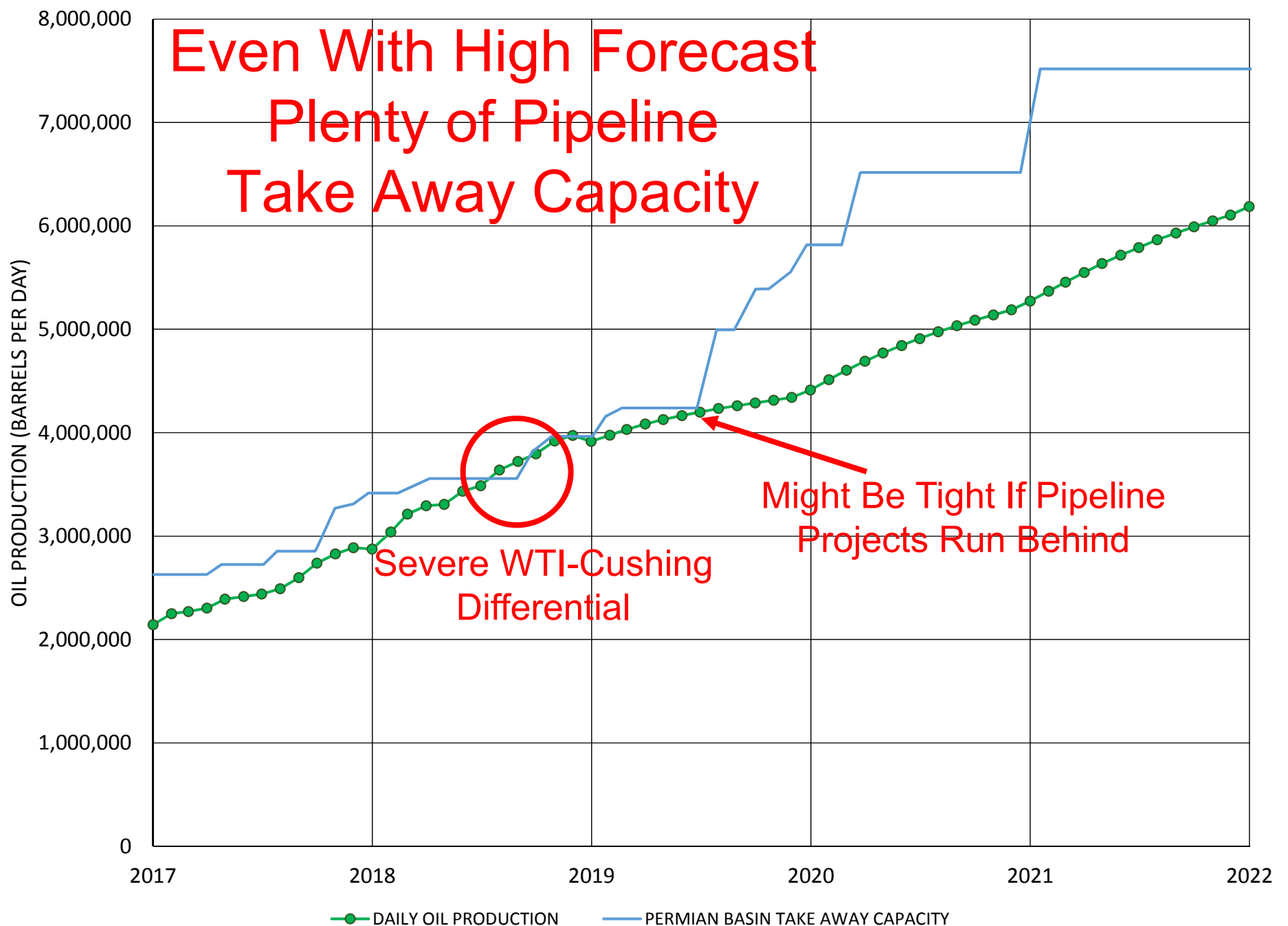


Permian Basin – Oil Forecast

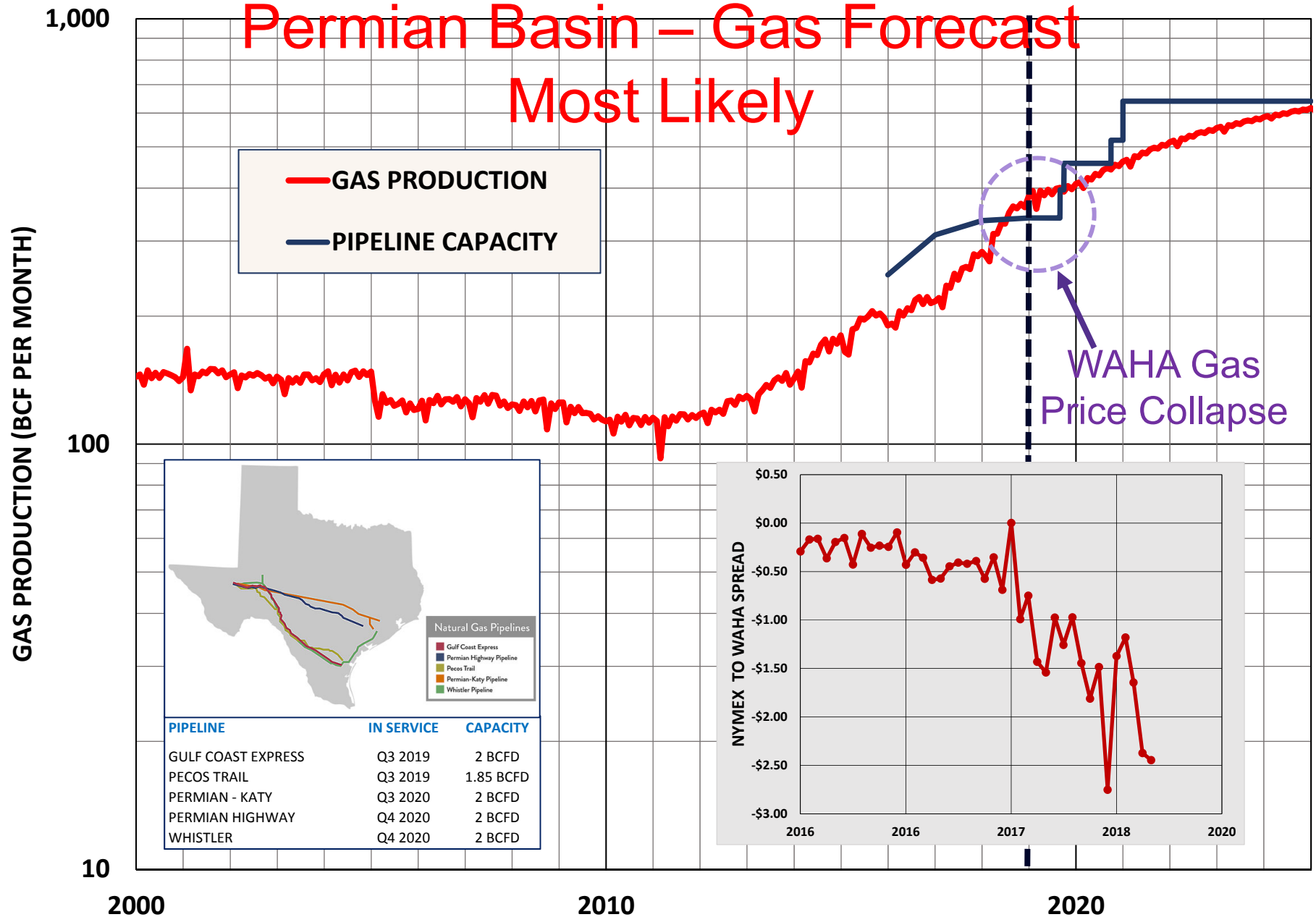
High Case

(Everything Works, Plenty of Capital)





Permian Basin – Gas Forecast Most Likely



THE PERMIAN BASIN

An Surprising Past

An Intriguing Present

A Promising Future

THE PERMIAN BASIN

Past, Present, and Future

Thank You

Russell K. Hall
Midland, Texas