Production Forecasting

Bazean Case

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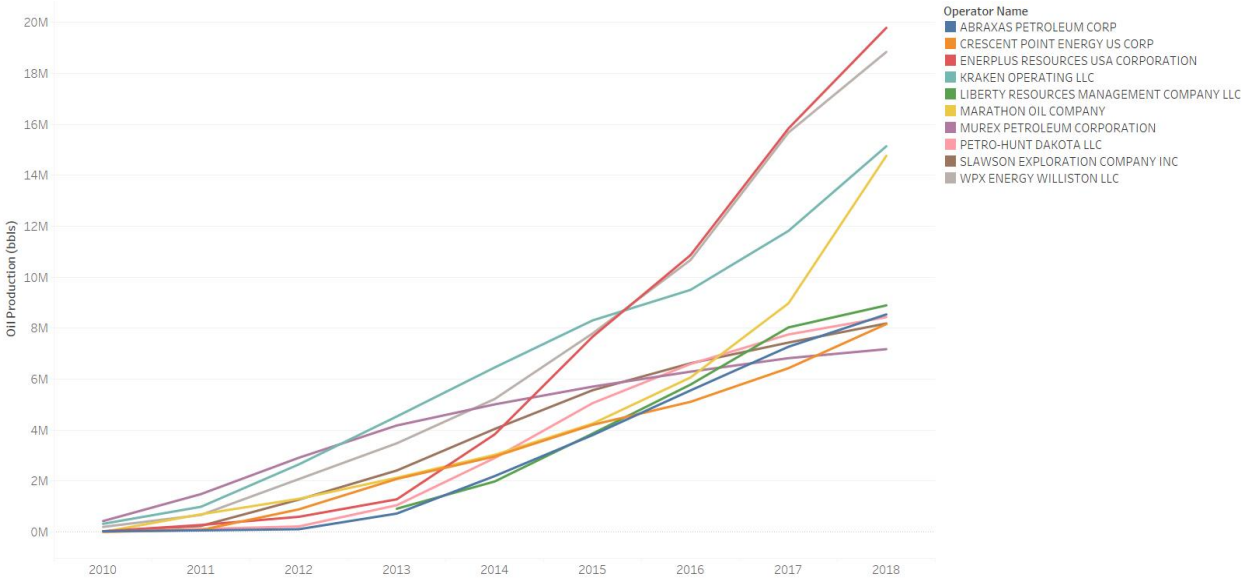
Note:

This document has all necessary figures to stand alone as a solution to the case. However, the solution is enhanced by the accompanying Tableau workbook. To view, please download Tableau Reader at: https://www.tableau.com/products/reader

Summary

Aggregate Historical Production:

Cumulative Production by Operator



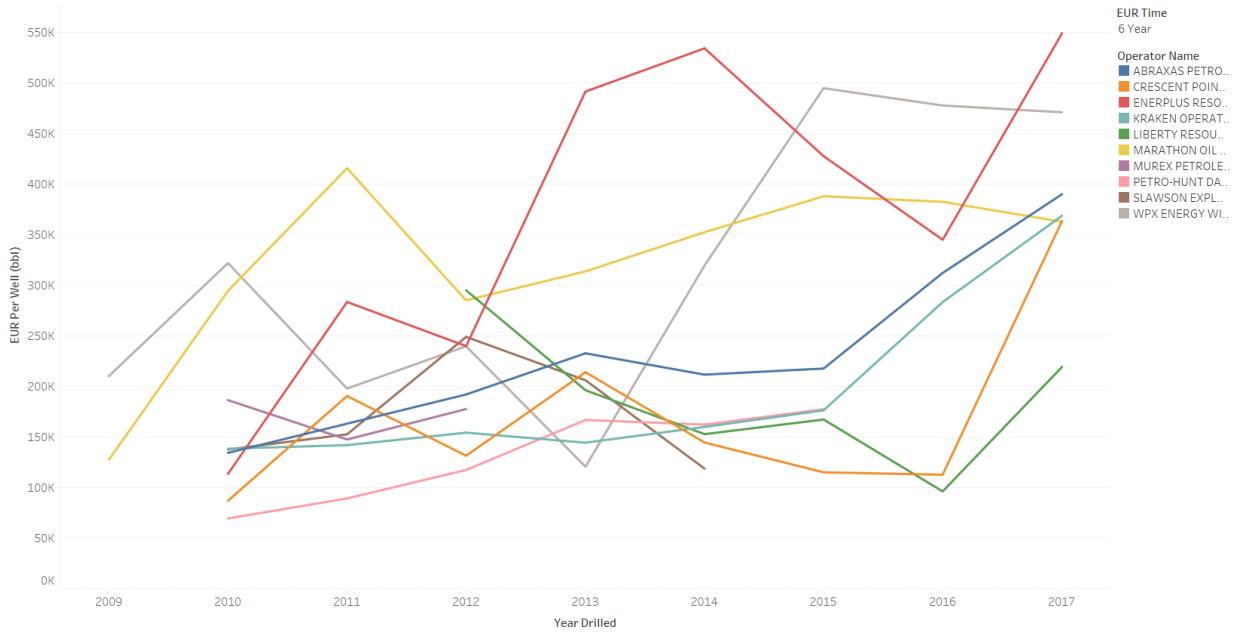
2018 Cumulatives

Operator Name	Oil Production (bbls)	Well Count	Production Per Well (bbls)
ABRAXAS PETROLEUM CORP	8,540,877	42	374,339
CRESCENT POINT ENERGY US C..	8,162,123	74	233,297
ENERPLUS RESOURCES USA CO..	19,790,392	67	600,057
KRAKEN OPERATING LLC	15,142,670	100	266,921
LIBERTY RESOURCES MANAGEM..	8,895,860	56	308,315
MARATHON OIL COMPANY	14,767,455	51	615,290
MUREX PETROLEUM CORPORAT..	7,176,605	40	234,665
PETRO-HUNT DAKOTA LLC	8,433,024	62	224,931
SLAWSON EXPLORATION COMP..	8,185,194	52	249,478
WPX ENERGY WILLISTON LLC	18,843,811	66	521,304

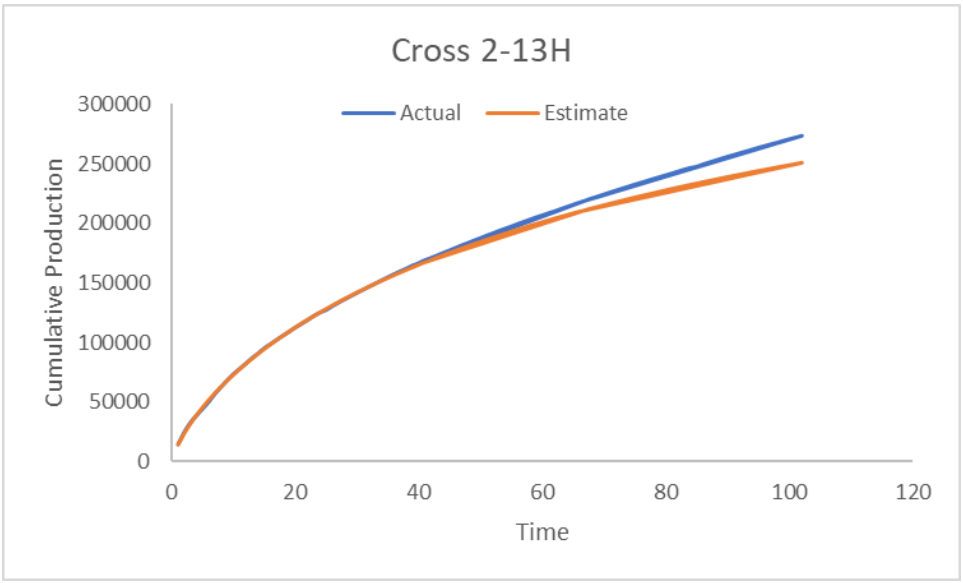
EUR Forecasting:

- Cumulative production of a given well was modeled using a logistic growth model
- EUR was calculated as cumulative production over 6 years
- Enerplus Resources and WPX Energy both had the highest per well EUR of wells drilled in 2017 and showed considerable improvement over wells that were drilled in 2010

Average EUR per Well by Operator



Model Verification on Ideal Well



Historical Aggregate Production

Data:

- Joined ND_PRODUCTION_DATA with ND_WELL_DATA on API
- Default setting is to filter out inactive wells
    - Do not know reason why they are no longer active
    - Total well count only drops from 627 to 610 wells

Aggregate Calculations:

- Grouped wells by operator
- Used monthly production figures found in ND_PRODUCTION_DATA
- Only focused on oil produced
    - Primary reason for these wells is to produce oil
    - Natural gas is also much cheaper than oil and represents a small fraction of the total value of produced material
    - Natural gas in North Dakota also trades at a 30% discount compared to Henry Hub, compared to oil which trades at about the same price as WTI

Notes:

- Enerplus Resources has produced the most oil as of August 2018
    - Most of its production coming after 2013 (Figure 1)
    - Only has the third most wells drilled so its production per well is also the second highest (Figure 2)
- Looking at the map (Figure 2), Enerplus, Marathon and WPX Energy have all drilled wells in a similar location
    - These three companies have the highest production per well
    - Suggests that location has highly productive wells and is a desirable location for future projects

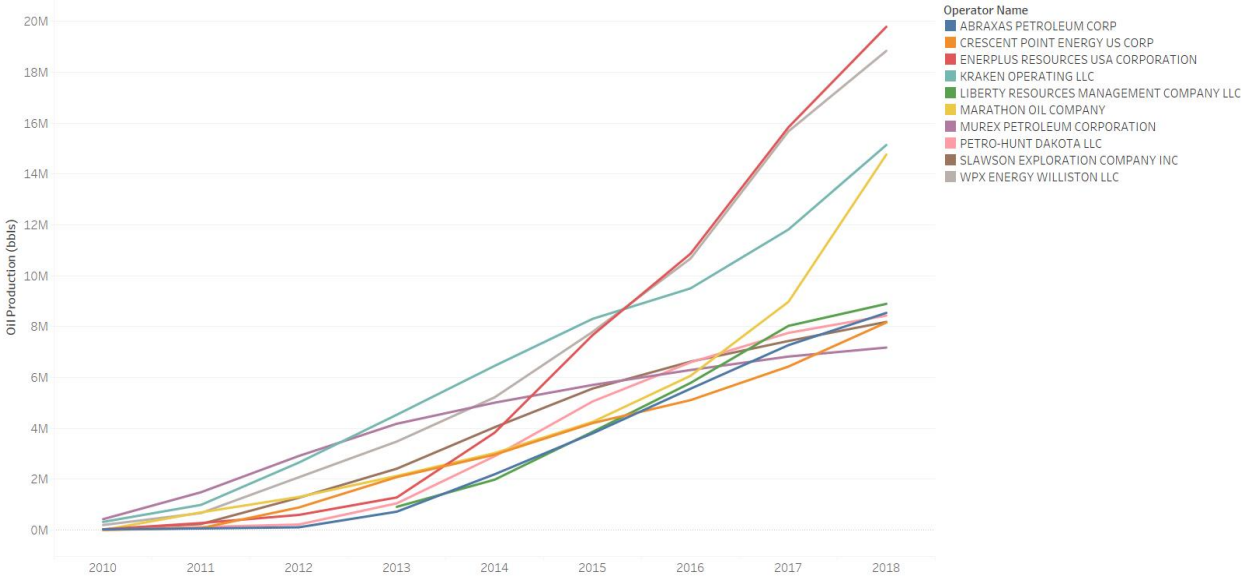


Figure 1: Aggregate Oil Production by Operator

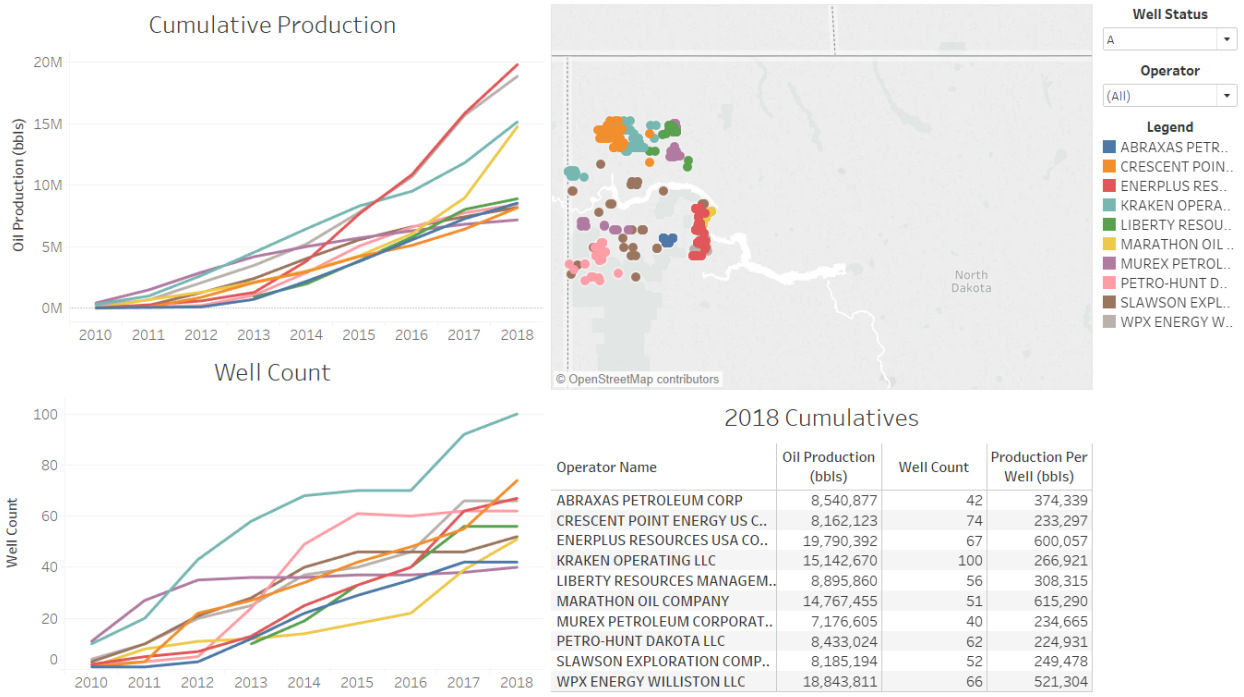


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Figure 2: Historic Production Summary

Production Forecasting

Data:

- Primary source: ND_PRODUCTION_DATA
    - Some descriptive information about each well added from ND_WELL_DATA
    - Raw data set is Forecasting_Data.csv
- Instead of using API, each well was assigned a number
- Removed inactive wells
    - Total number decreases from 627 to 610
- Standardized data by adjusting initial production date to be the maximum production date
    - Further production was reported as months after initial date
    - Maximum production date was taken to be the date of maximum production up to 2 years from the minimum date production data was recorded (Figure 3 and Figure 4)

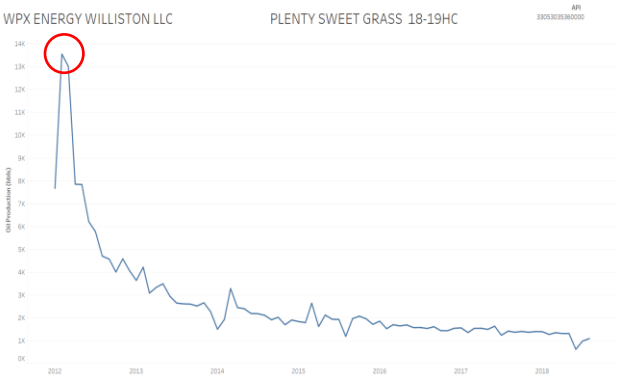

Figure 3: Simple Case for Max Production Date

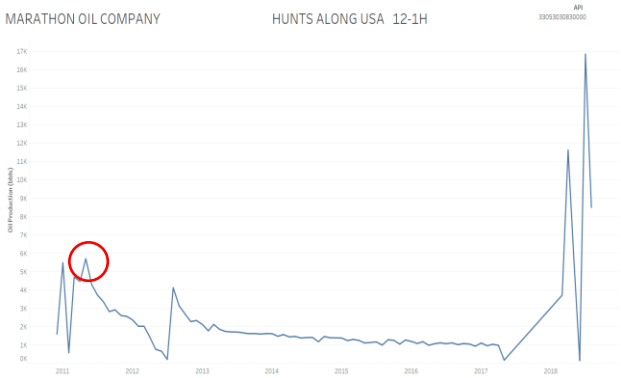

Figure 4: Max Production Occurs after 2 Years

- Required that wells drilled prior to 2017 had a minimum of 12 months of production data and wells drilled after 2017 had a minimum of 6 months of data
    - Not done scientifically, but still provided enough data to build forecasts while not reducing well count too much
    - Well count dropped from 610 wells to 542 wells
- Up to 24 months of data following the initial production date were used to fit the forecasts
    - Many wells were observed to have rework done
    - No reliable method for determining if a spike in production was due to natural causes or rework due to incomplete completions data
    - Value was empirically selected based on quick survey of production history

Model Build and Verification:

- Cumulative production was modeled using a logistic growth model as outlined in *Production Forecasting with Logistic Growth Models* [Clark 2011][1]

$$Q(t) = \frac{Kt^n}{a + t^n}$$

  - $Q(t)$ is the cumulative production
  - K is the carrying capacity of the well
  - t is production time in months
  - a is a constant
- The model was fit using the curve_fit function found in scipy.optimize
  - An initial guess of K=250000, a=25 and n=1 was used for all wells
  - These values were based off typical values observed by Clark et al.
- The model was verified by using a few wells and importing the model constants into Excel
  - Production profiles of the wells chosen can be seen in Figure 6, Figure 8 and Figure 10
    - Figure 6 is an idealized case where the data is relatively clean
    - Figure 8 has a recompletion that could not be cut out
    - Figure 10 has large fluctuations in production
  - Looking at performance in Figure 7, Figure 9 and Figure 11 the model does well for the first three to four years, but then begins to diverge

EUR Estimation:

- EUR was calculated based on 6 years of aggregate production
  - Full Tableau version allows user to select from 2 to 10 years
  - In the idealized case (Figure 7) the model begins to diverge around 5 years
- Horizontal shale wells are expected to deliver the majority of their expected production in the first few years after being brought online
- Due to the limited range of input data, it was not expected that this model would be able to accurately predict long-term cumulative production
- The prevalence of recompletions and rework negates the effectiveness of long-term forecasts

[1] Clark, A. J., Lake, L. W., & Patzek, T. W. (2011, January 1). Production Forecasting with Logistic Growth Models. Society of Petroleum Engineers. doi:10.2118/144790-MS

Notes:

- Based on both 2017 data and overall trends, Enerplus resources and WPX Energy are expected to deliver the most productive wells in the future (Figure 5)
    - Both companies have been drilling wells in the same location (Figure 2)
    - Both Enerplus and WPX have high year to year volatility in EUR per well
    - If Enerplus and WPX are no longer able to drill in their current location, it is possible that they will see a reduction in their EUR per well
- Considering long term trends since 2010, either Abraxas Petroleum and Kraken Operating could be expected to deliver the best performing wells in the future
    - Both companies have had year over year improvements in EUR nearly every year
    - Even though they have been drilling in a less productive regions, their most recent wells are predicted to be more productive than Marathon who is drilling in the same region as Enerplus and WPX
    - If the improvements are expected to continue, investment in Abraxas Petroleum or Kraken Operating could be a good value

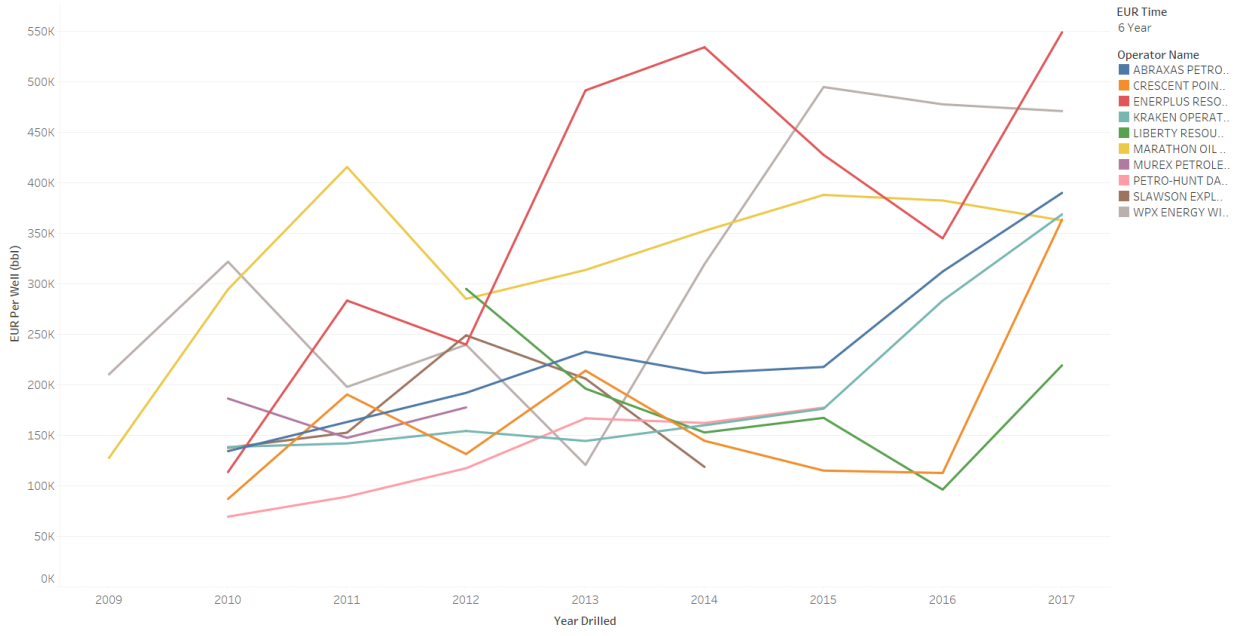

Figure 5: Average EUR Per Well

Figure 6: Idealized Case

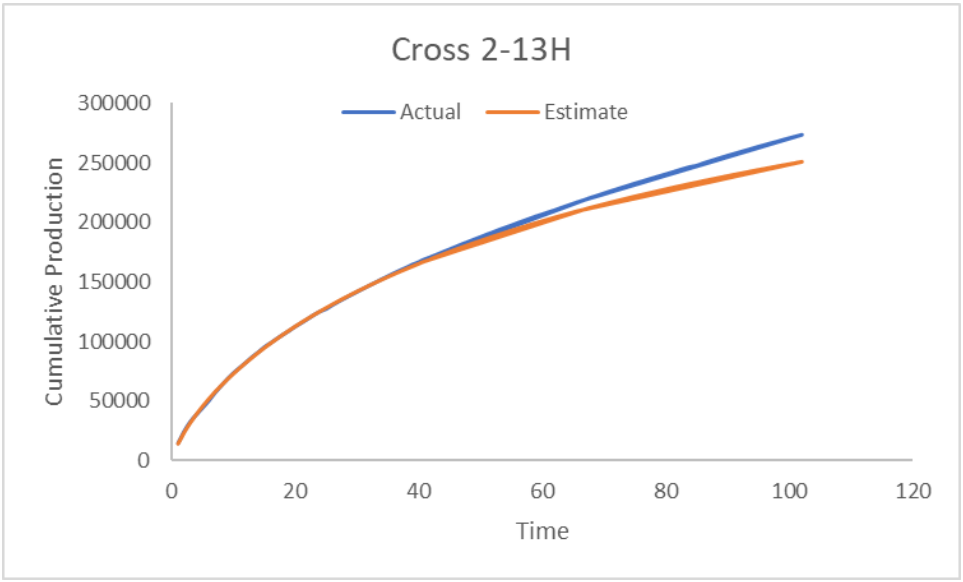

Figure 7: Idealized Case Model Results

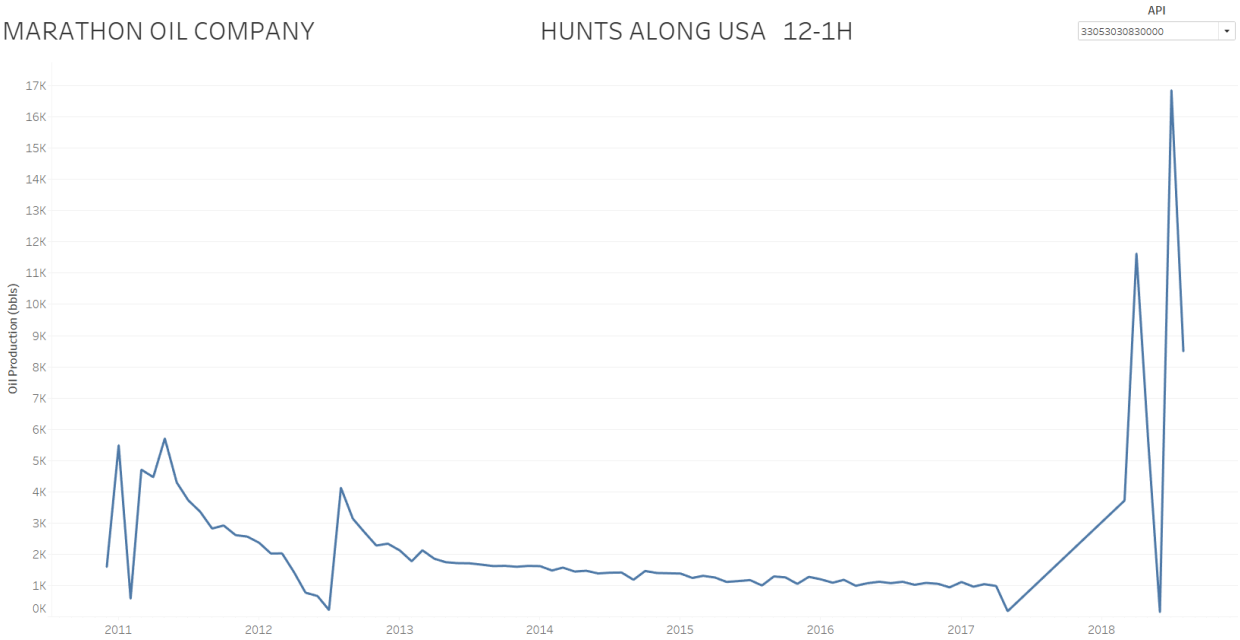

Figure 8: Including Recompletion

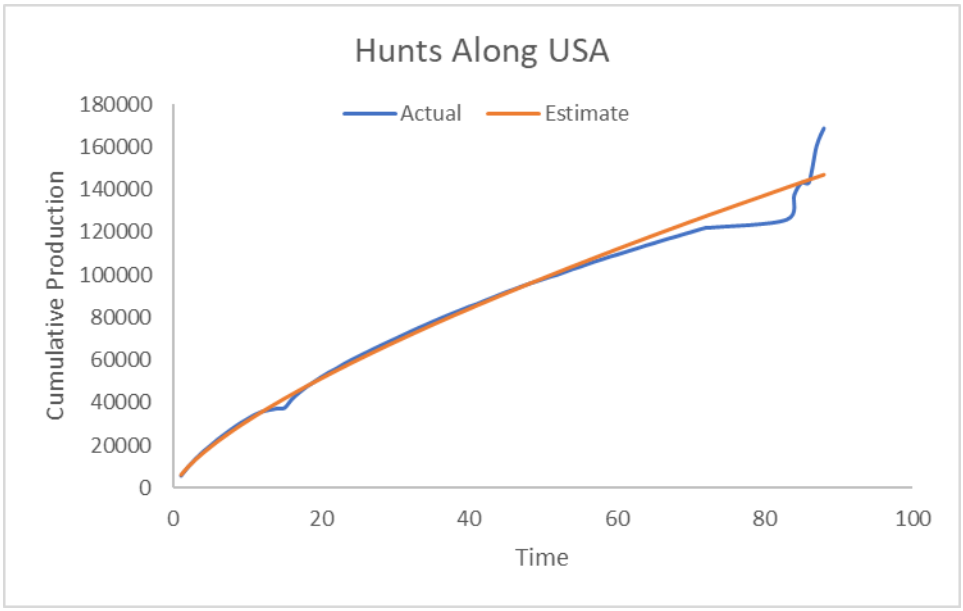

Figure 9: Including Recompletion Model Results

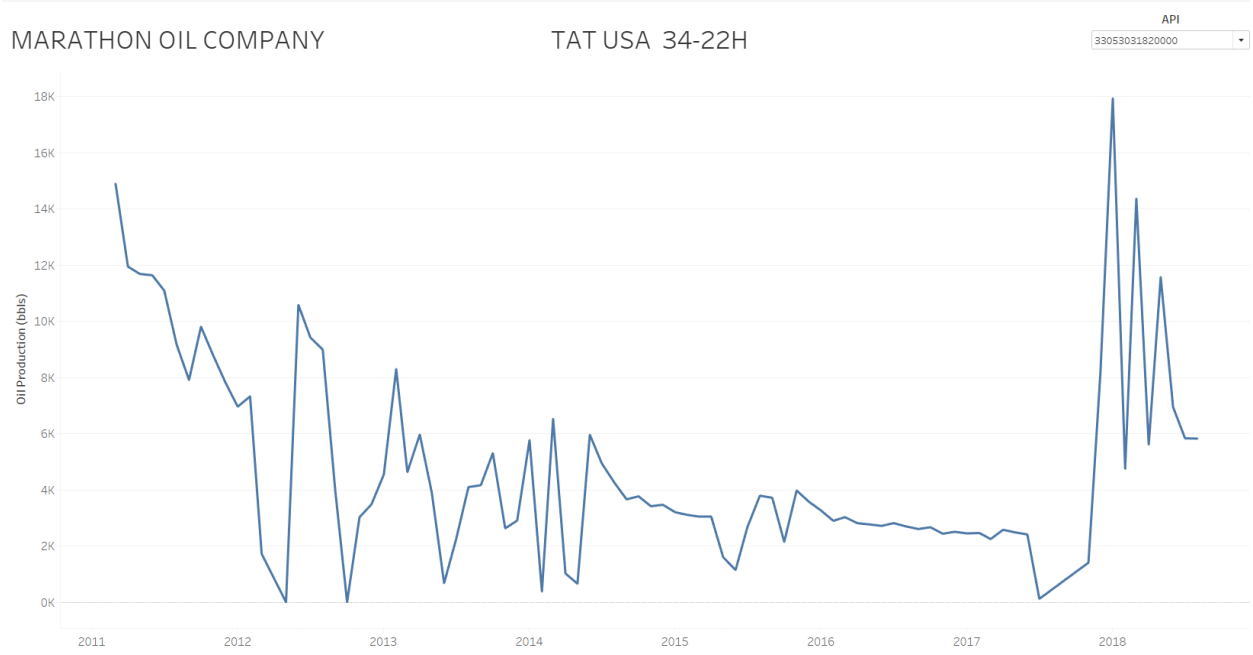

Figure 10: Production Variation

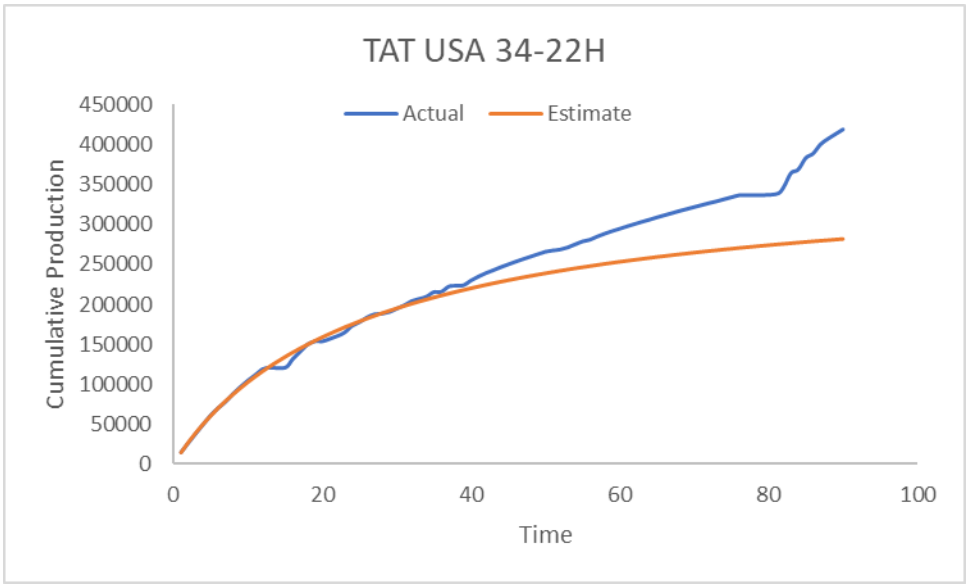

Figure 11: Production Variation