5 FEBRUARY 2025
WHITSON WEBINAR

CONSISTENT EUR FORECAST IN UNCONVENTIONAL RESERVOIRS WITH PRESSURE NORMALIZED RATE

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Shunhua Liu
Oxy

OUTLINE

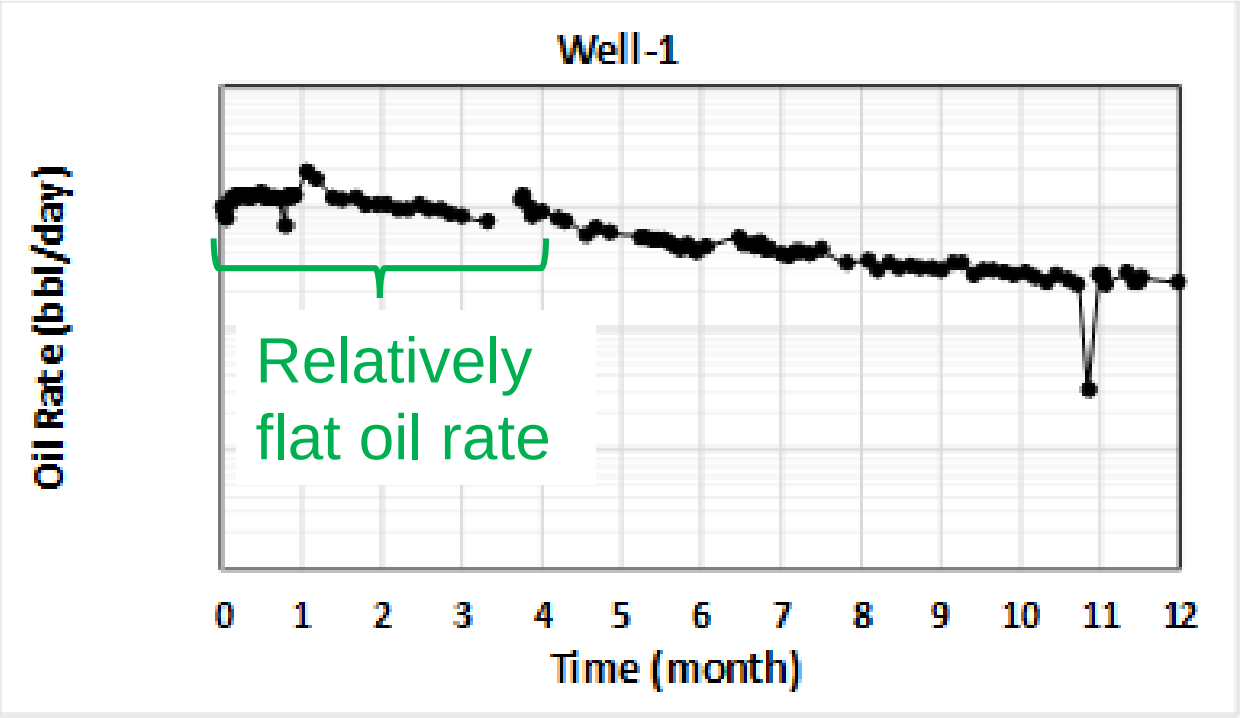
- Motivation

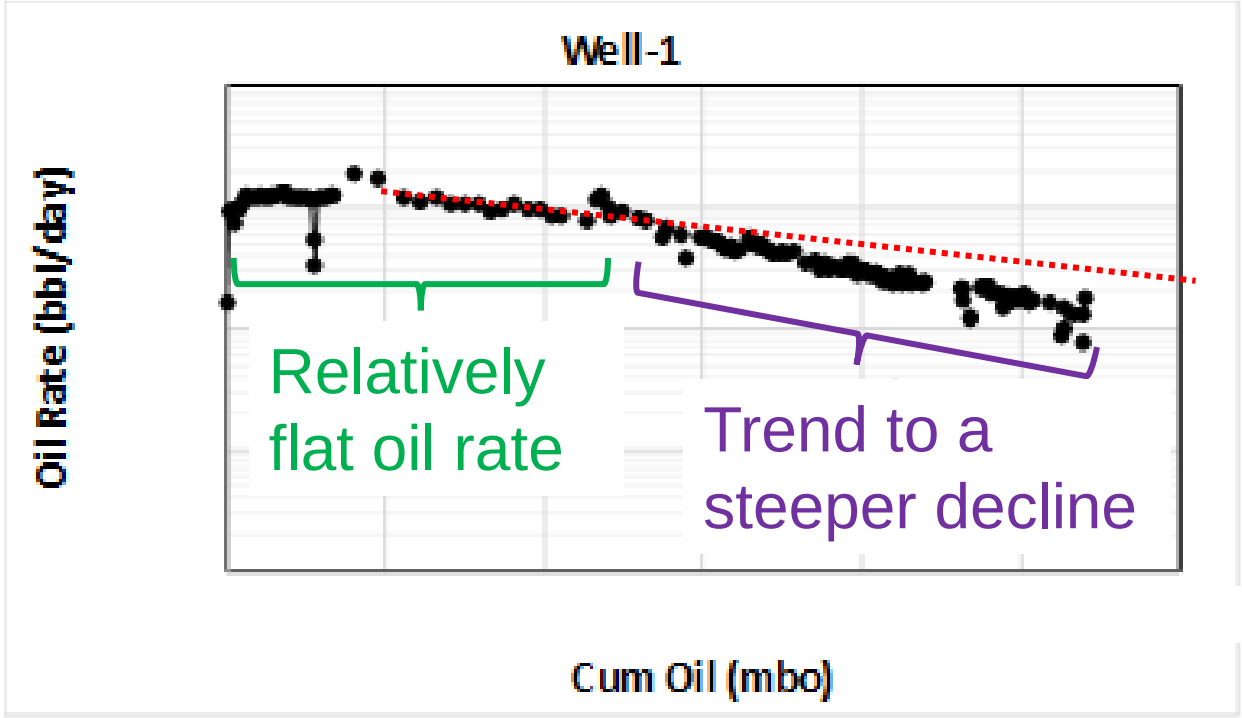
- Pressure Normalized Rate Decline Curve Analysis (PNR DCA) method
  - Forecast Permian unconventional well EUR in 3 months

- Method validation
  - EUR consistency check
  - Reservoir simulation

- Application in all Permian benches

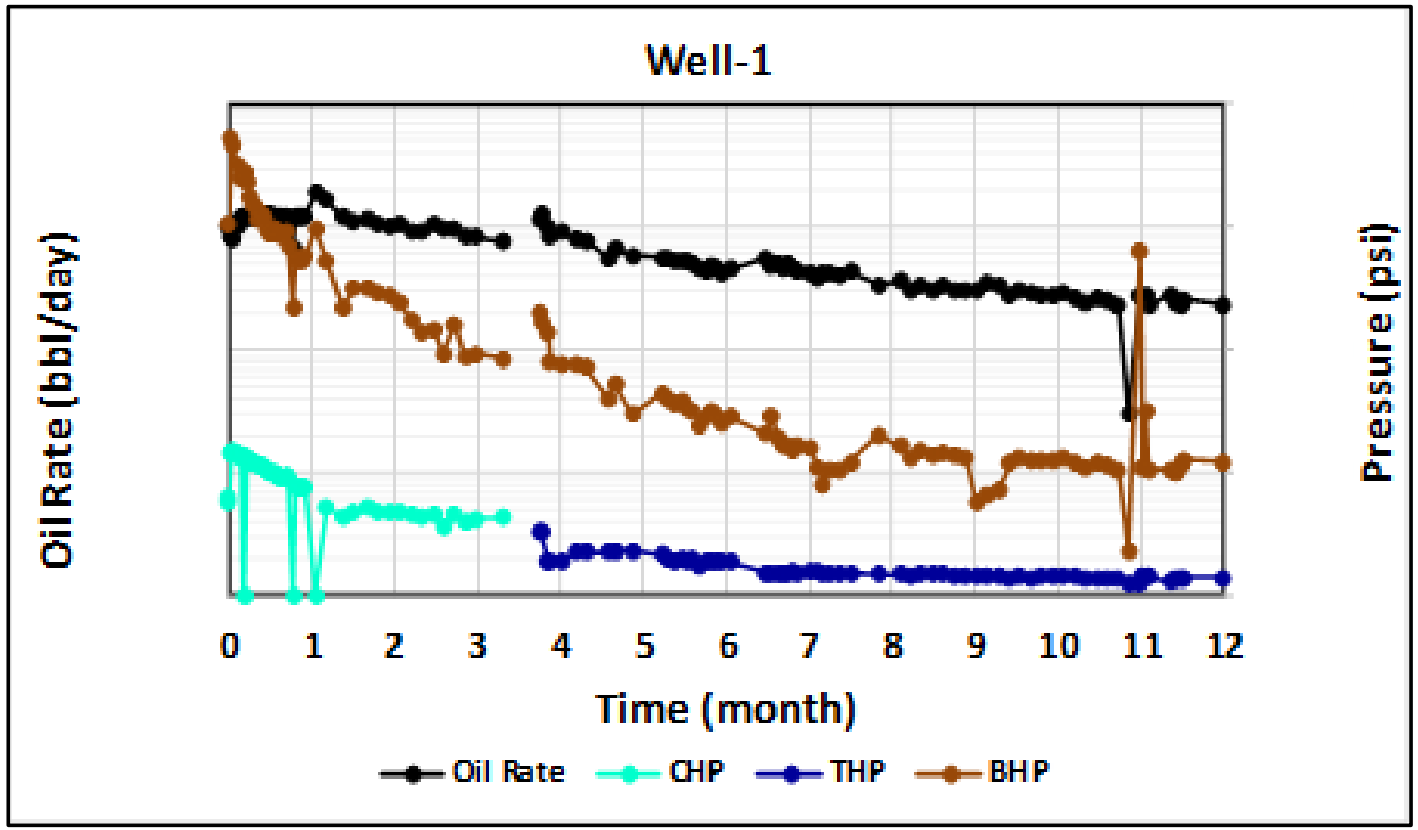
MOTIVATION: DCA CHALLENGES IN FORECASTING UNCONVENTIONAL WELLS





- Oil rate quite flat in early time
- DCA based on early decline trend will over-predict

MOTIVATION: OTHER PRODUCTION LIMITATIONS



- BHP varies
- Except oil rate flat/shallow decline in early time and declining BHP, unconventional well production operation imposes challenges as well
  - Irregular prod curves (operation changes, frac-hit…)

PRESSURE NORMALIZED RATE (PNR) FOR GAS

Back to early unconventional development in 2010

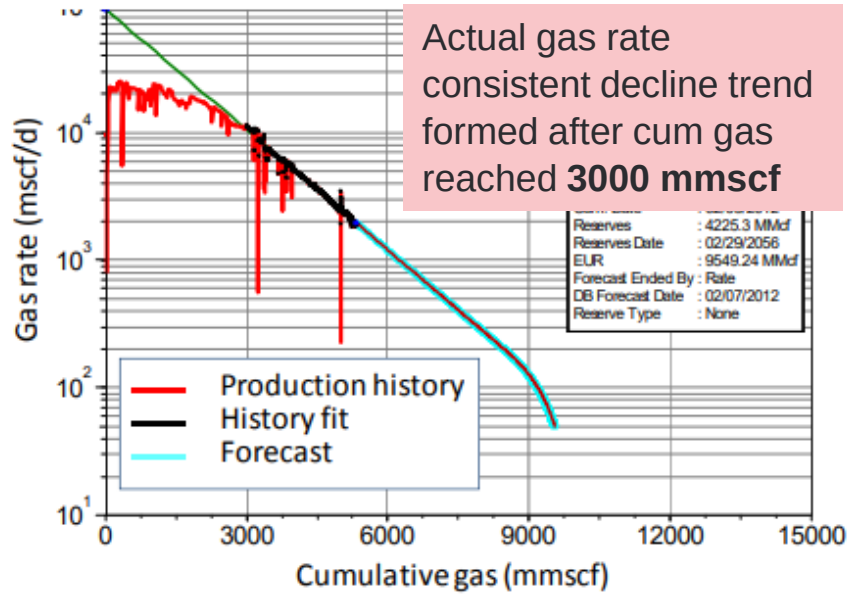
$$J_{gas} = \frac{q}{m(P_i) - m(P_{wf})}$$

Where $m(P) = \int_{P_r}^{P} \frac{2p}{\mu z} dp$

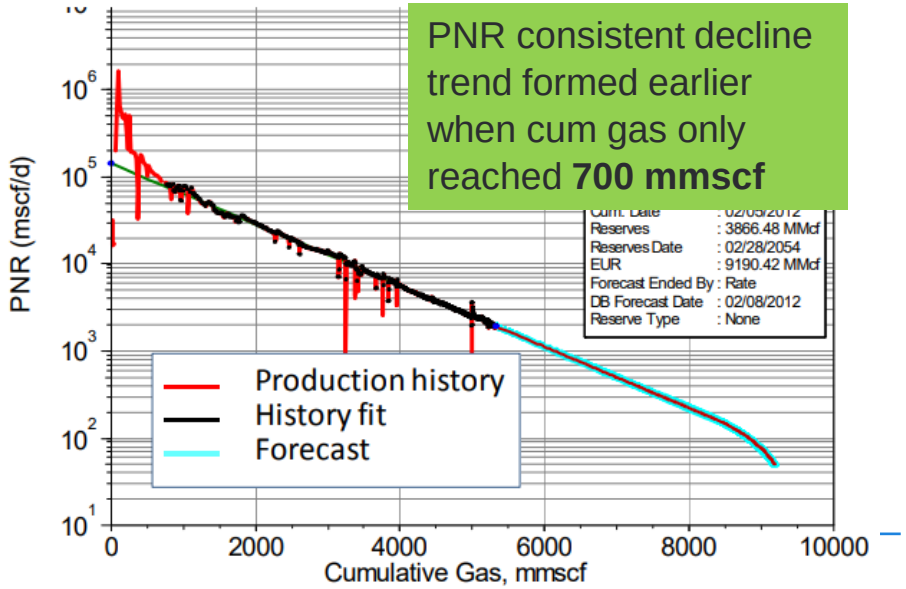
To express in consistent rate units, define pressure normalized rate by multiplying a constant pressure drawdown

$$q_N = \frac{q}{m(P_i) - m(P_{wf})} (m(P_i) - m(P_{wf@abandon}))$$

Xueying Xie, et al., A New Method for Earlier and More Accurate EUR Prediction of Haynesville Shale Gas Well SPE-159273-MS, Oct 2012, https://doi.org/10.2118/159273-MS



Actual gas rate consistent decline trend formed after cum gas reached **3000 mmscf**



PNR consistent decline trend formed earlier when cum gas only reached **700 mmscf**

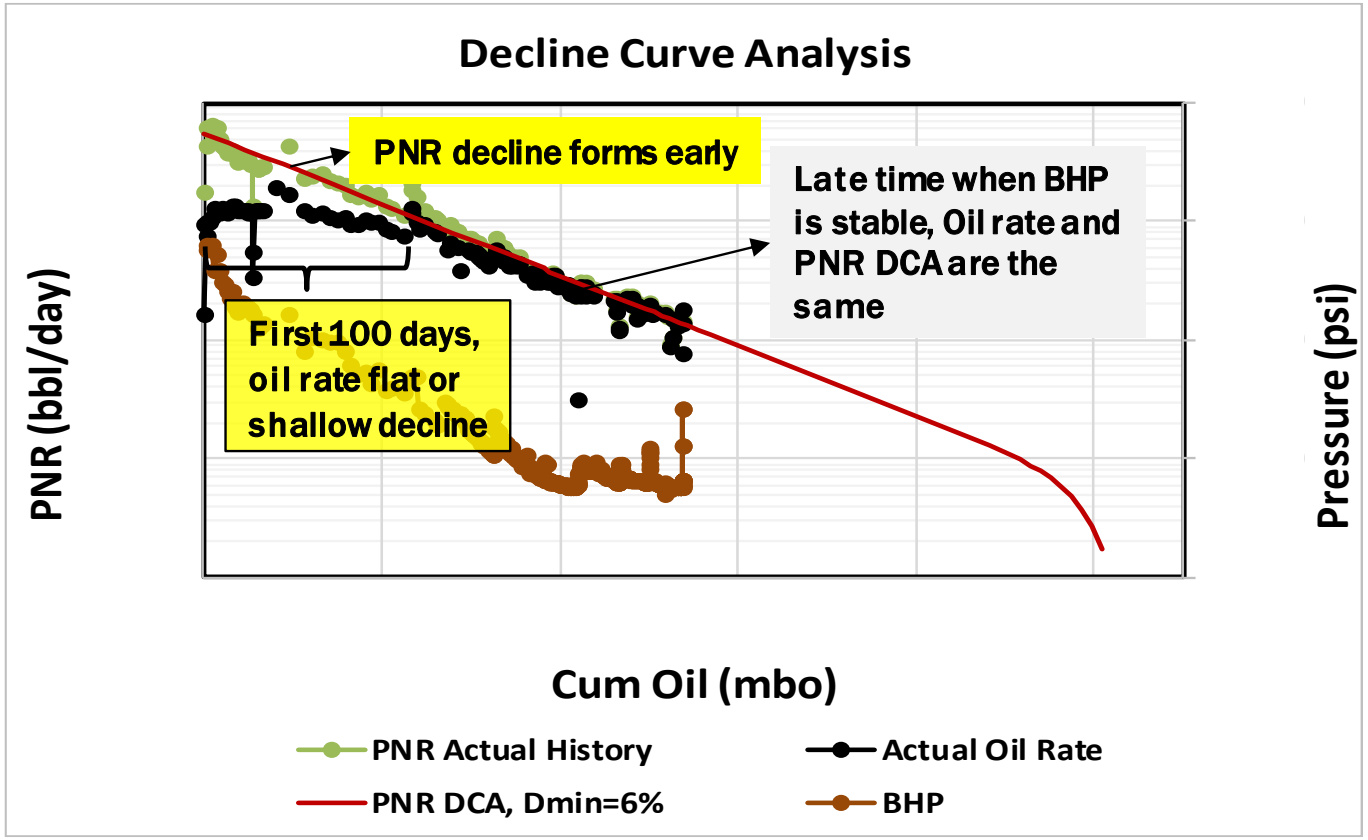
PNR DCA METHODOLOGY FOR PERMIAN OIL WELLS

Xueying Xie and Shunhua Liu,
SPE-215173-MS, Oct 2023,
https://doi.org/10.2118/215173-MS

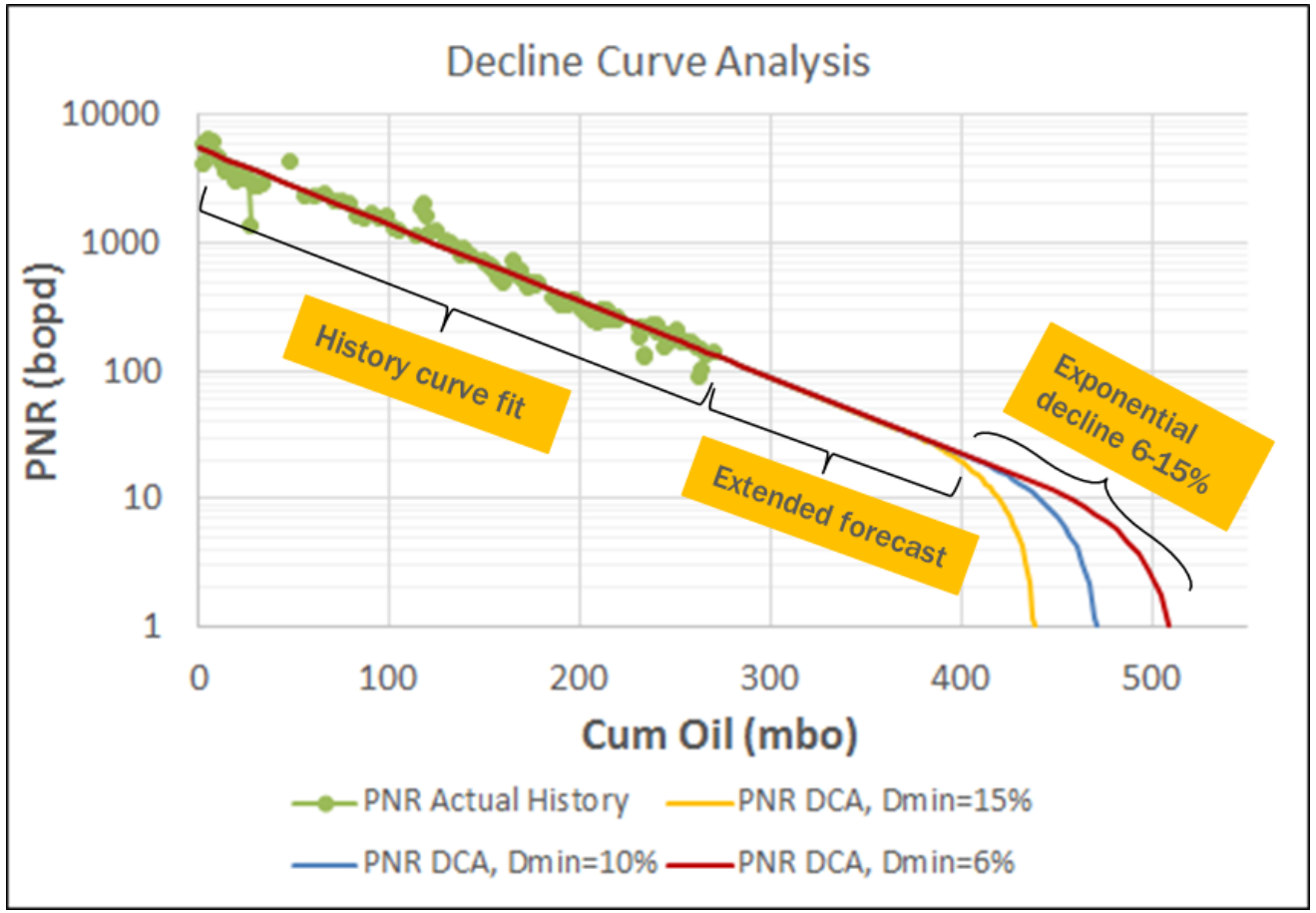
$$q \sim c(P_{re} - P_{BHP}) \frac{1}{B_o} \sqrt{\frac{\varphi c_t}{\mu}} A_c \sqrt{k} \frac{1}{\sqrt{t}}$$

$$PNR = \frac{q}{P_i - P_{BHP}} (P_i - P_{BHP_{min}})$$

- PNR DCA
  - Integrate decline of both rate and pressure
  - Do PNR vs Cum oil DCA
  - Obtain EUR
- PNR decline trend forms earlier
- PNR & actual rate decline trends converge when BHP stable

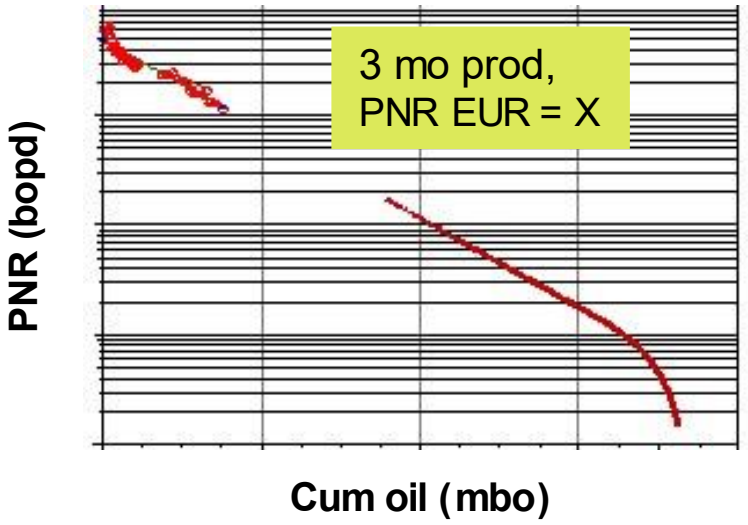


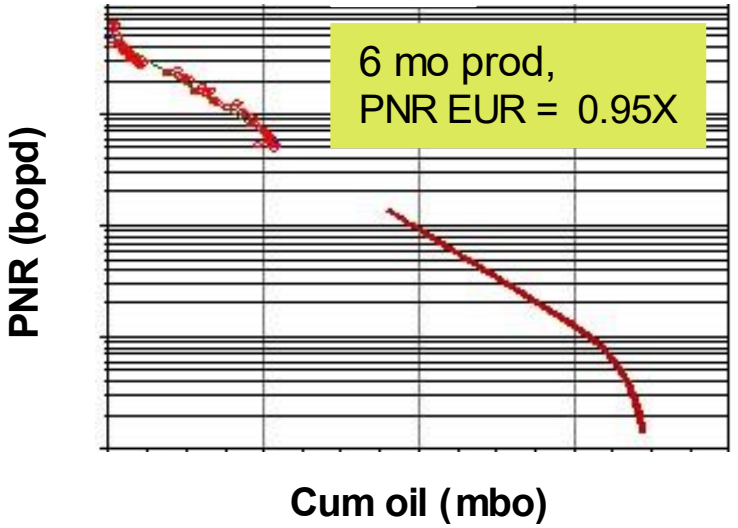
PRESSURE NORMALIZED RATE (PNR) DCA METHODOLOGY

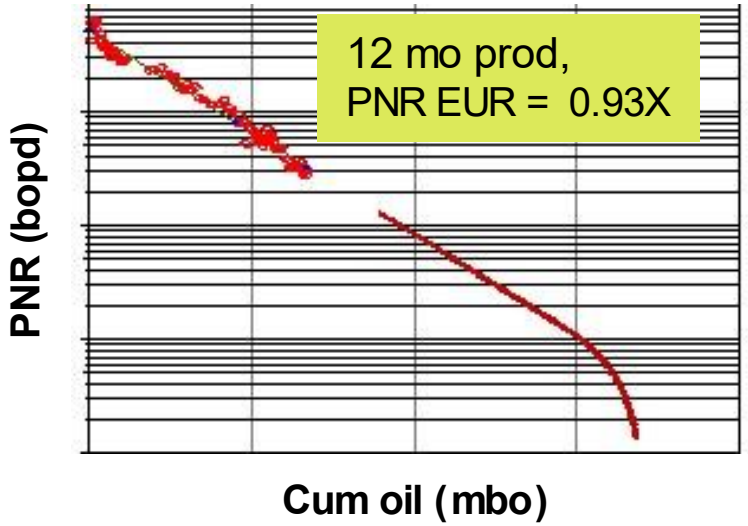


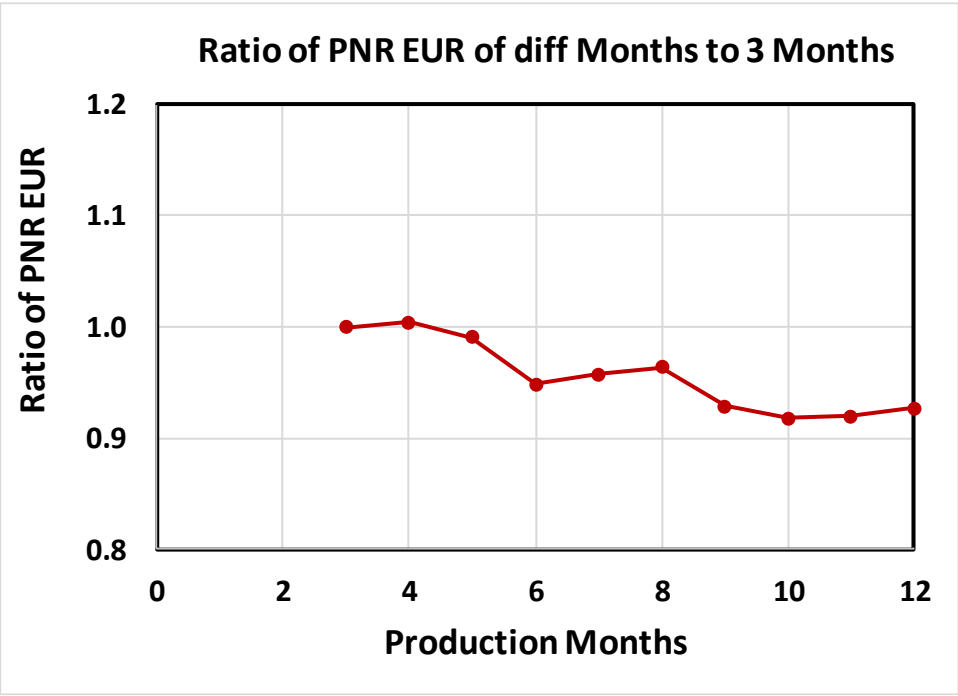
- Pressure normalized rate resolves early time challenges
- Late time has the same uncertainty range as traditional DCA
- D_min can be assumed in a range to obtain EUR uncertainty

VALIDATION: PNR EUR OF ONE 2BSS WELL





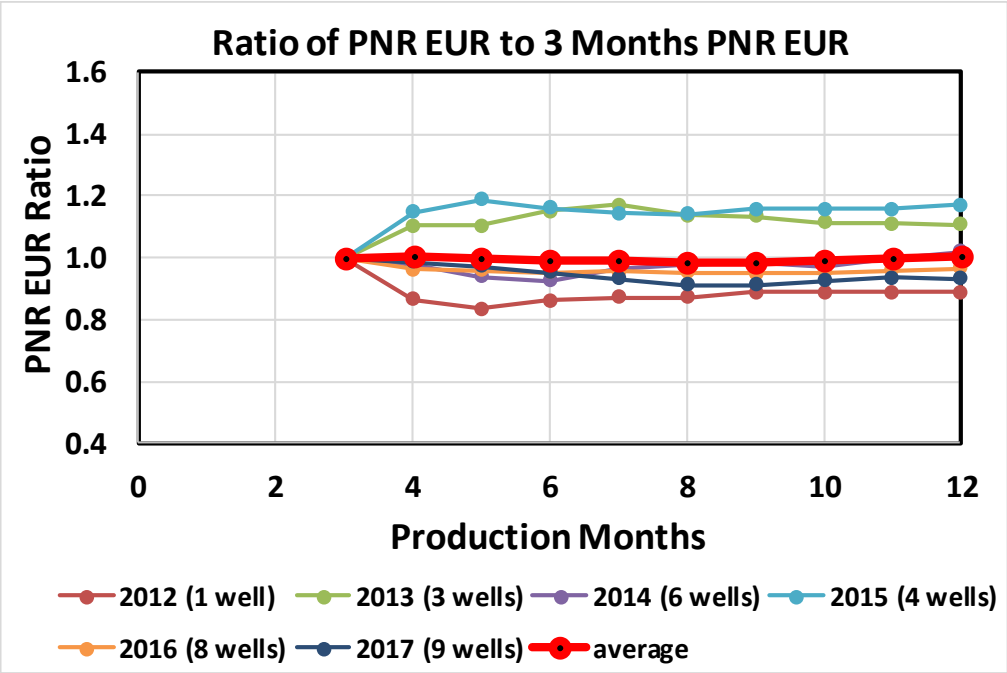


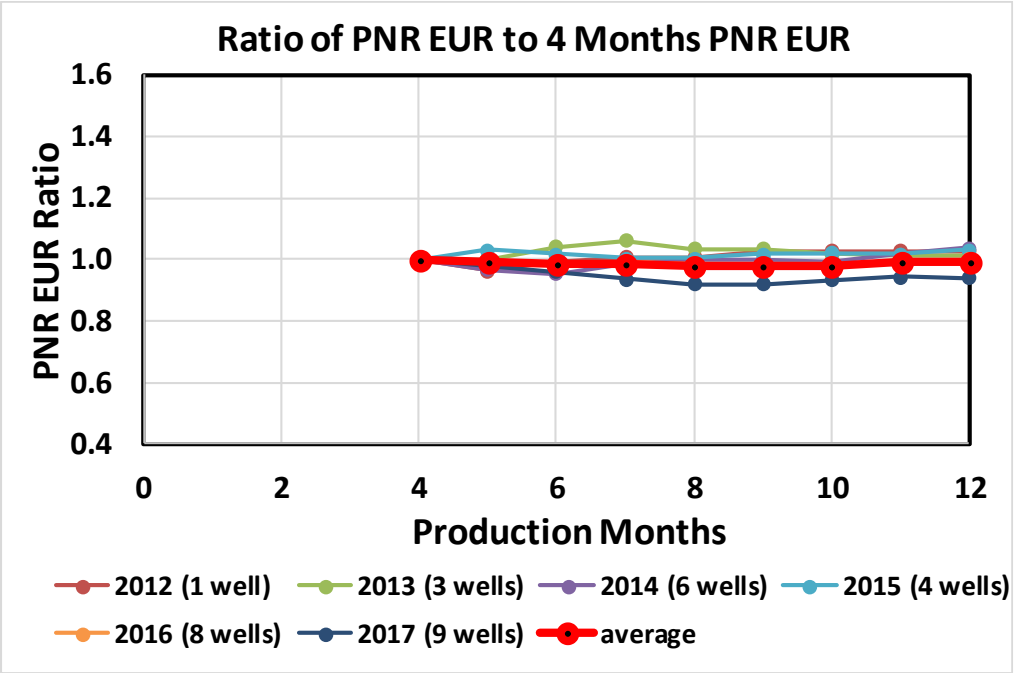


Prod Months	3	6	12
Ratio of PNR EUR to 3 mo PNR EUR	1.0	0.95	0.93

- Predicted EUR variation from 3 to 12 mo is within 7%
- Validate early prediction

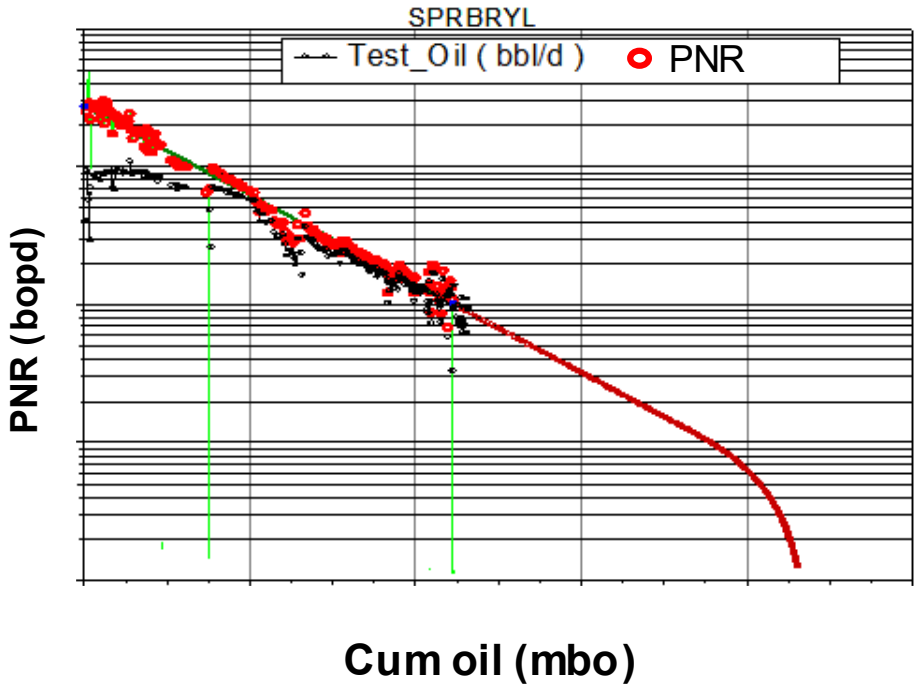
VALIDATION: PNR EUR IN ONE NM FIELD'S 2ND BONE SPRING

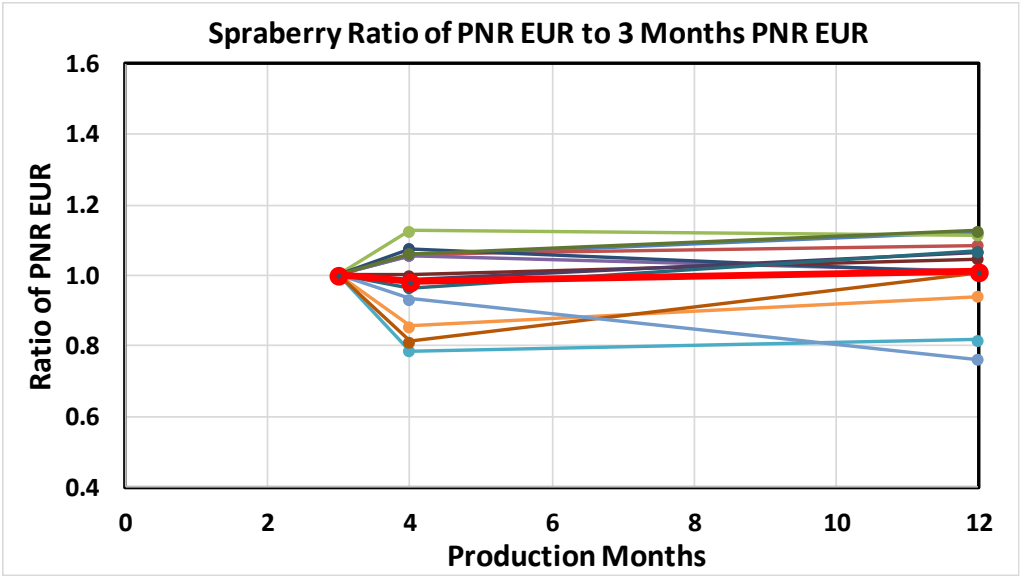




- 3 months production: Reasonable EUR prediction (5-20%)
- 4 months production: Consistent EUR prediction (5%)

VALIDATION: PNR EUR IN TEXAS MIDLAND SPRABERRY

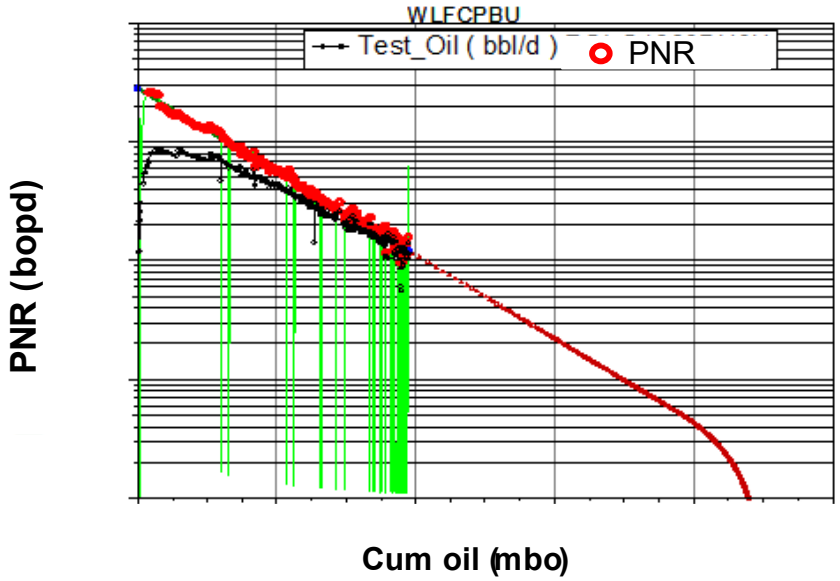


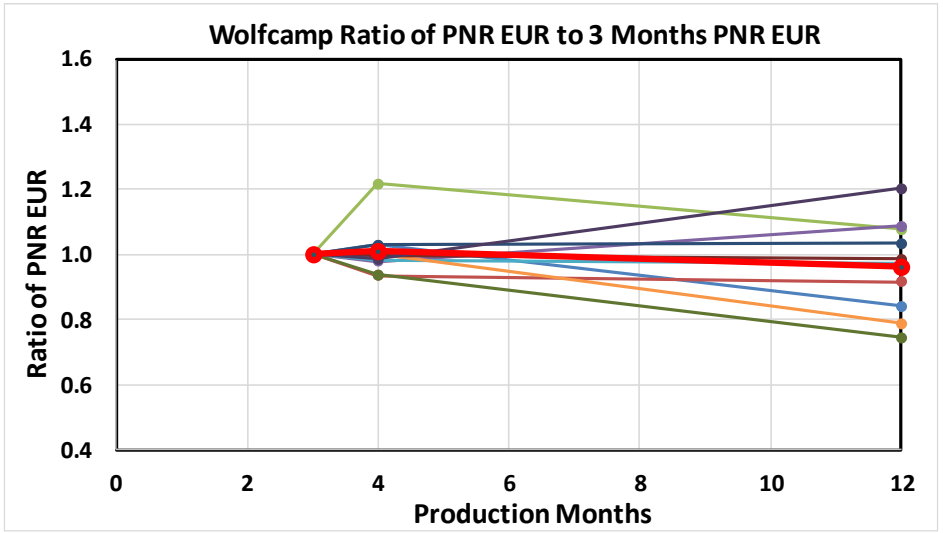


Average of all example wells

- 3 months production: Reasonable EUR prediction (5-20%)
- Some wells under-predicted and some over-predicted → avg EUR stable

VALIDATION: PNR EUR IN TEXAS MIDLAND WOLFCAMP

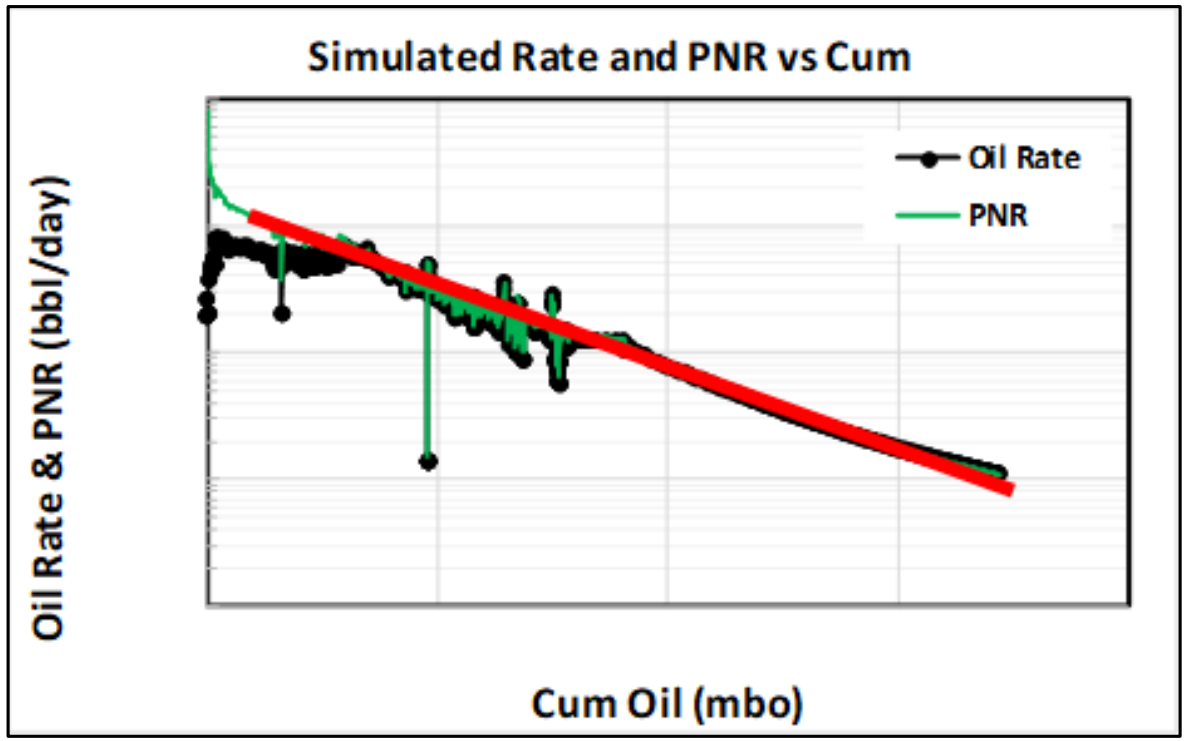




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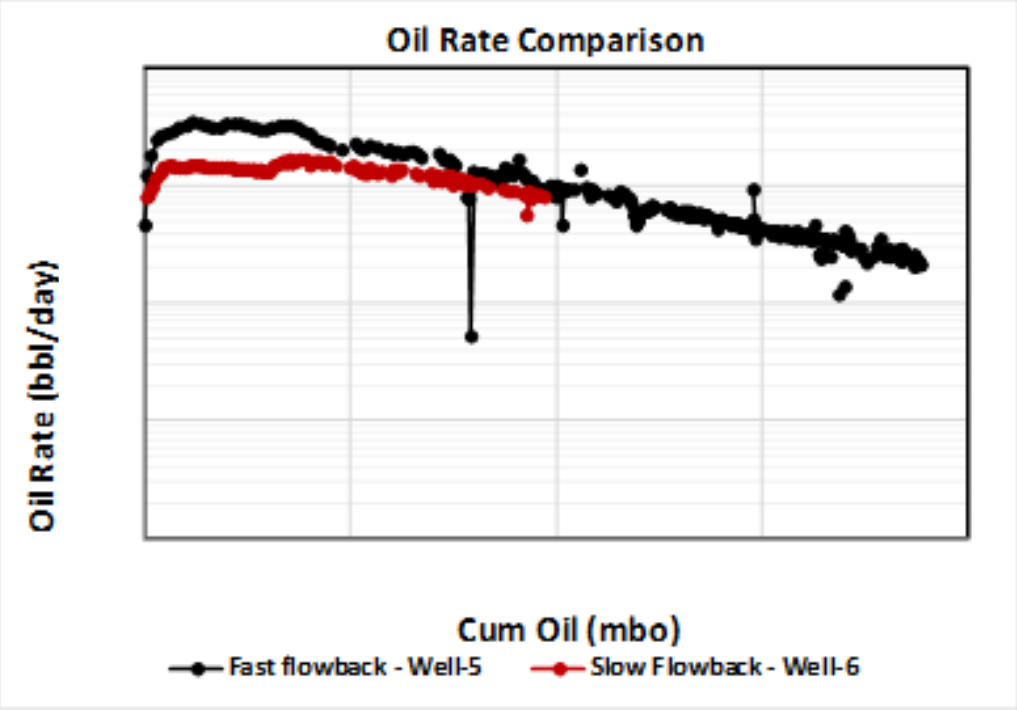
VALIDATION: PNR EUR BY RESERVOIR SIMULATION

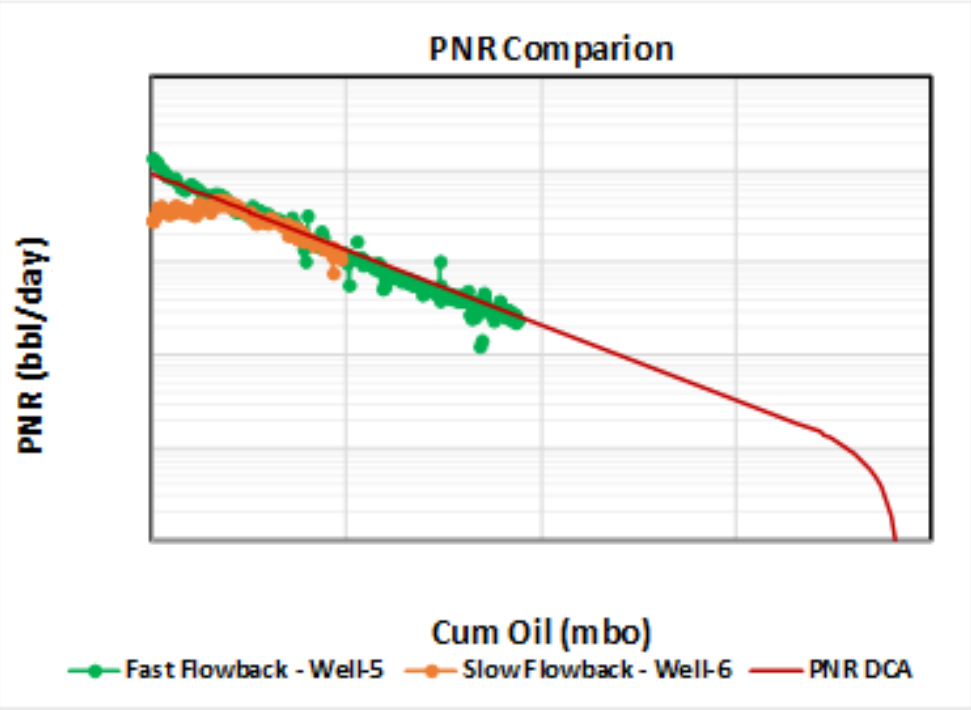


- The simulation model history matches a 2nd Bone Spring well and then forecasts
- Early time: PNR decline trend starts to form from 1 month while oil rate flat in early 4 months
- For the long term: the actual oil rate rate and PNR DCA overlap
- Simulation validates PNR method to forecast EUR

APPLICATION: PERFORMANCE COMPARISON OF DIFFERENT OPERATIONS

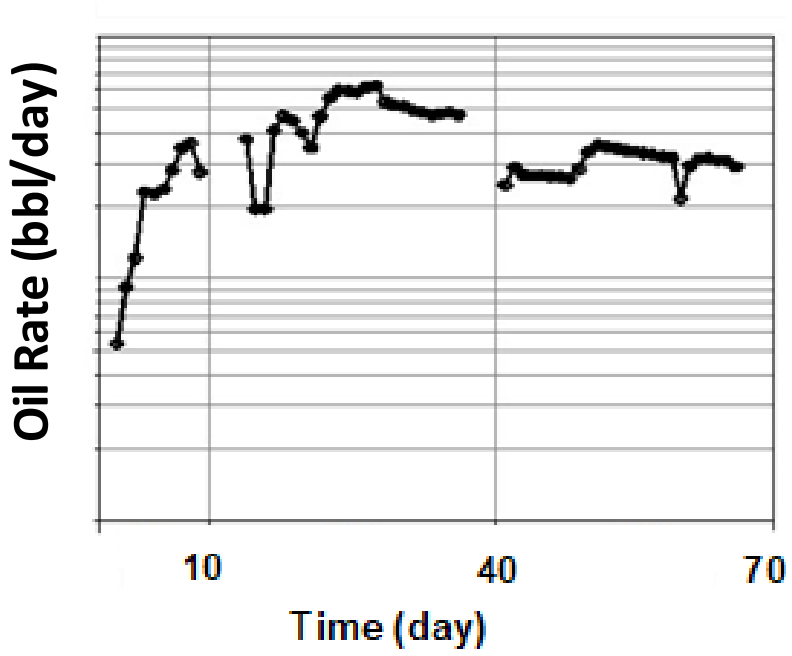
Xueying Xie et. al.
URTEC-2021-5088-MS, July 2021,
https://doi.org/10.15530/urtec-2021-5088.

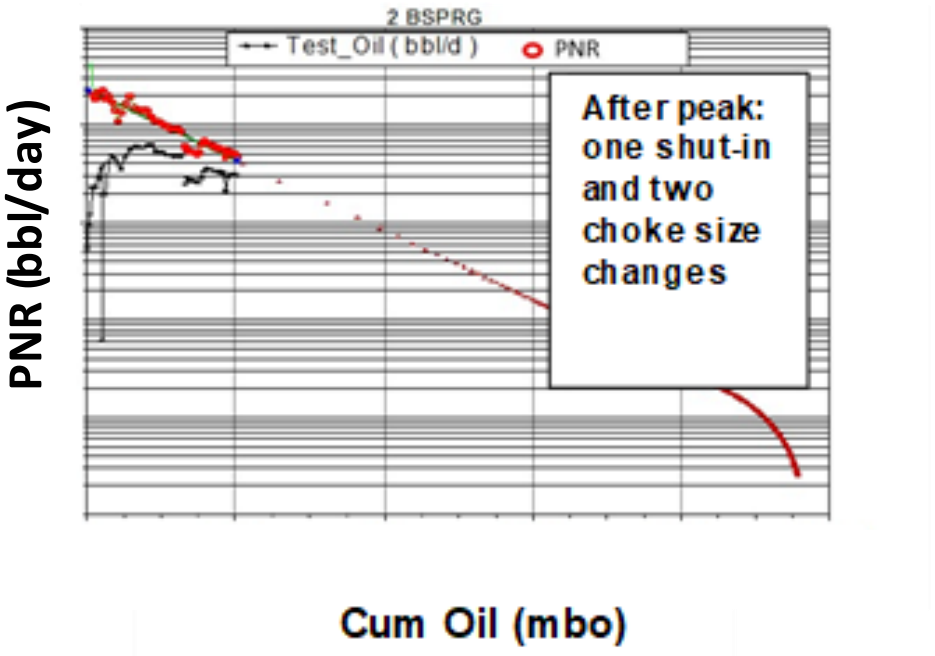




- Different flowback strategies could lead to very different early production rate
- PNR DCA method tremendously speeds up the performance comparison

APPLICATION: PERFORMANCE PREDICTION FOR IRREGULAR PRODUCTION





- Choke changes lead to non-smooth oil decline trend
- PNR smooths the decline trend for a more reliable prediction

SUMMARY

- PNR DCA - A method to forecast unconventional well EUR in 3 months
  - Applicable to multiple fields/benches in Oxy Permian
  - EUR prediction available even when oil rate is flat
  - Smoother decline even with irregular operation

- Validated in developed area wells and by simulation

- Applied to recent develop/operational strategy and appraisal benches
  - Speed up the optimization/prioritize development plan
  - Evaluate appraisal benches early for fast maturation and acreage build-up
  - Provide more reliable and consistent secondary method for reserve forecast

Xueying Xie, Shunhua Liu, Courtney Leiker, Early EUR indicator for Permian Basin Unconventional Resources Based on Hourly Flowback Data, URTEC-3854193-MS, Jun 2023, https://doi.org/10.15530/urtec-2023-3854193