Calgary • Houston • Denver

A New Empirical Analysis Technique for Shale Reservoirs

HE Zhang

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DISCLAIMER

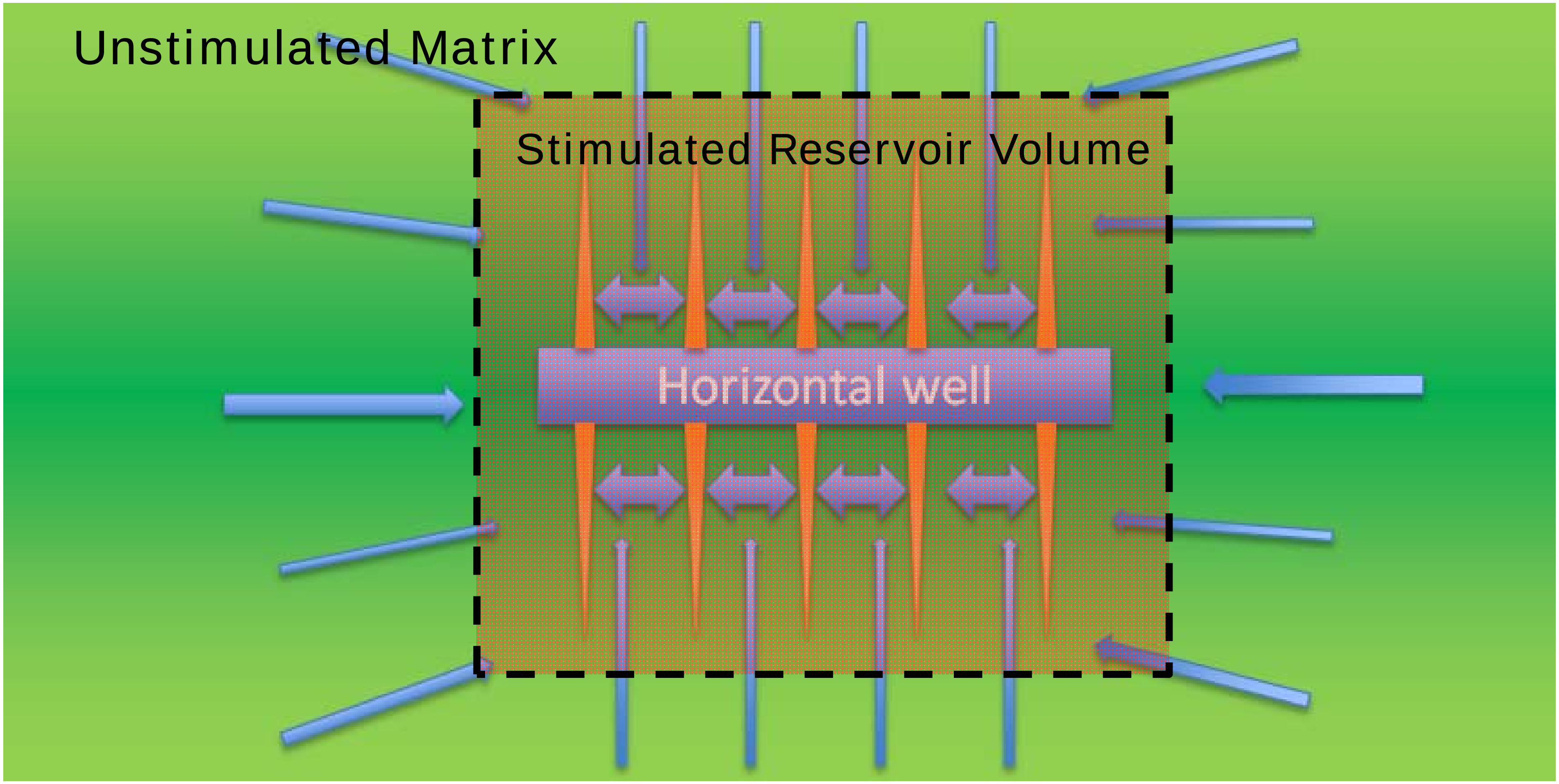
The following presentation covers a topic which is currently in an experimental stage. At this time, Ryder Scott does NOT endorse the method presented here, nor does this presentation represent the opinions of Ryder Scott Company. It solely represents the opinions of the authors.

The method presented here is not used for any reserves work performed by Ryder Scott at this time.

OUTLINE

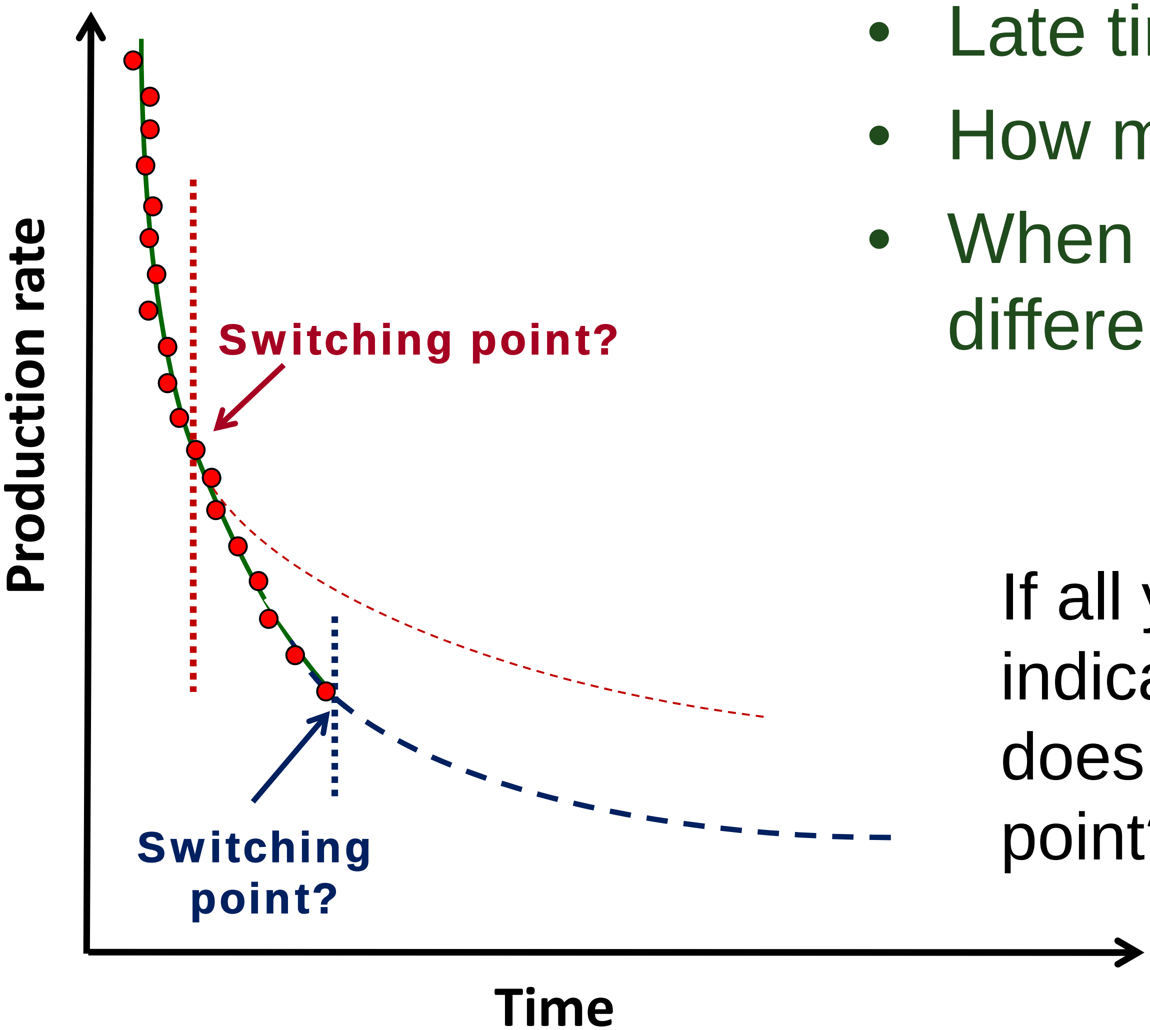
- Introduction
- Quick Review of Models for Decline Curve Analysis
- Experimental Research
- Empirical Extended Exponential DCA Model
- Experimental Results
- Conclusions
- Final Remarks

FLOW REGIMES FOR MULTI-STAGE FRACTURED HORIZONTAL WELLS



The flow mechanism is **completely different** for different flow regimes.

A TYPICAL SHALE GAS/OIL DECLINE CURVE

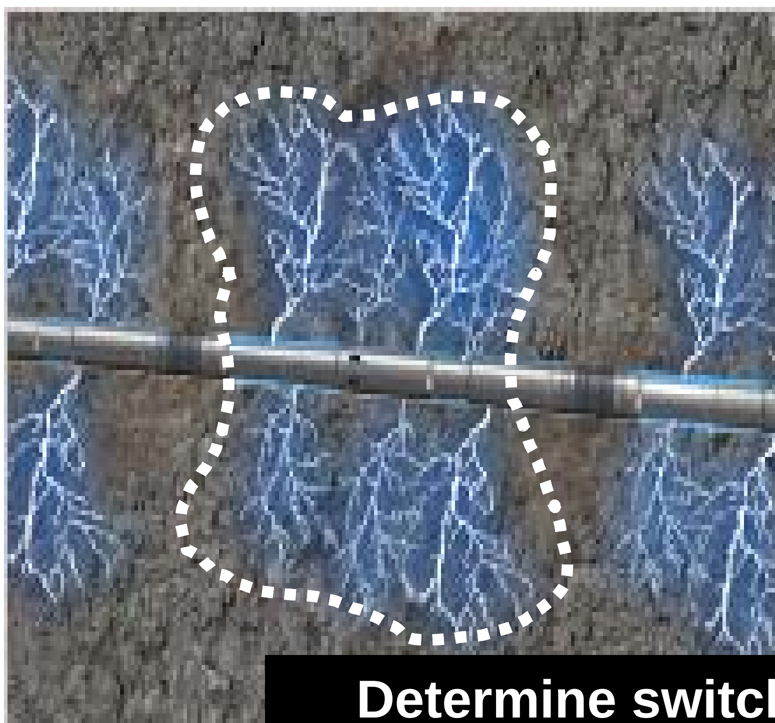


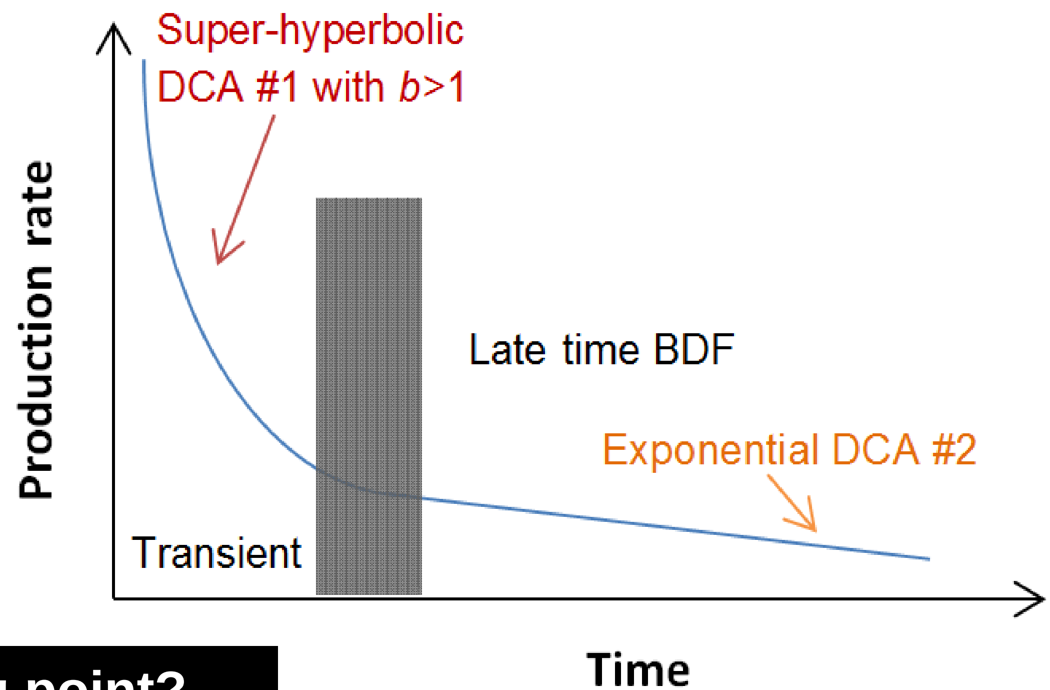
- Early time – sharp decline?
- Late time – flatter decline?
- How many flow regimes?
- When is the switching point of different flow regimes?

If all you have is the data indicated by the markers, how does one determine the switching point?

GROWING DRAINAGE VOLUME

- Initial production is from fractures with insufficient pressure support from tight formation
- Once reaching “initial outer-boundary”, it further drains the extremities of reservoir





Determine switching point?

CURRENT INDUSTRY PRACTICES

- **Most popular approach** in industry at present:
  Hyperbolic with b-factor > 1
  with minimum (exponential) decline

- Other available models:
  - Stretched Exponential Decline Model (SEDM) by Valko (2009)
  - Power Law (Ilk, Blasingame et al. 2008)
  - Duong's method (Duong, 2010)
  - Combination models: various models for early transient flow, then switch to Arps at late time flow period.

SUMMARY OF LITERATURE MODELS

DCA Model	Valid for Transient Flow	Valid for BDF	Need to change parameters?	Good with limited data?	Easy to use, Combine with Economics Software?
Arps -original	No	Yes	Yes	No	Yes
Arps -modified	No	Yes	Yes	No	Yes
Stretched Exponential	Yes	No	No	No	Somewhat
Extended Power Law	Yes	Yes	No	No	No
Duong	Yes	No	No	Yes	No

Cited from J. Lee 2015. SPE Webinar
"*Critique of Simple Decline Models*"

WHY A DIFFERENT APPROACH?

Can another equation

- represent early time and late time data better?
- be easier to use?

EXTENDED EXPONENTIAL DECLINE EQUATION

- Keep the same Exponential form of Arps equation for simplicity

$$q = q_i e^{-at}$$

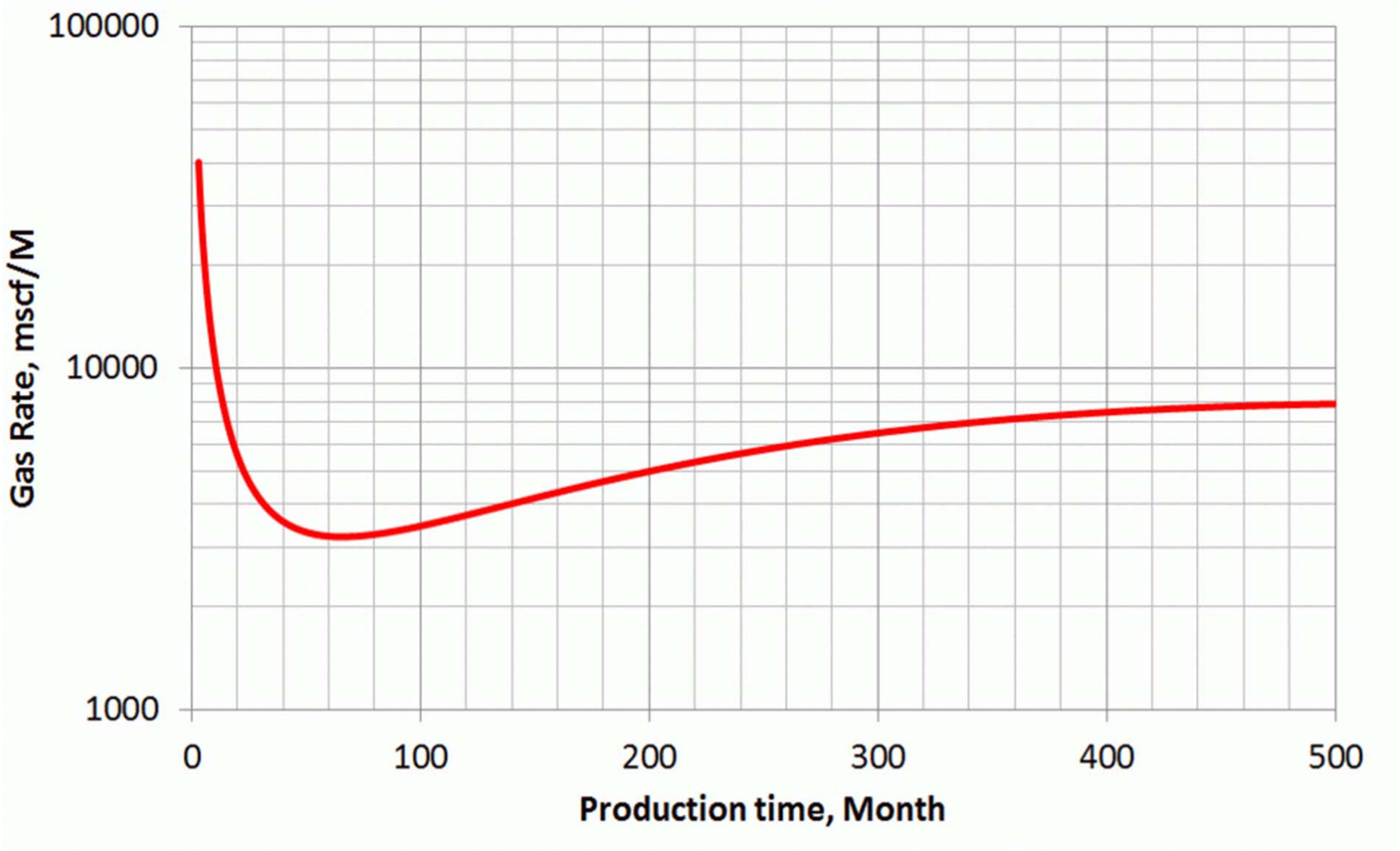
- But exponent a should vary with time

$$a = \beta_l + \beta_e e^{-t^n}$$

β_e is a constant to account for the early (fully-transient) period,
which should be larger than β_l as recommended and observed in field data;
β_l is a constant to account for the late-life period,
presumably to mimic transient to exponential decline;
n is an empirical exponent, with a recommended range of 0 to 0.7;
t is the time in months.

THE BAD NEWS

- Unrealistic forecasts for unconstrained input parameters



As with any unconventional approach, more late-time data is needed to ascertain realistic boundaries of each parameter.

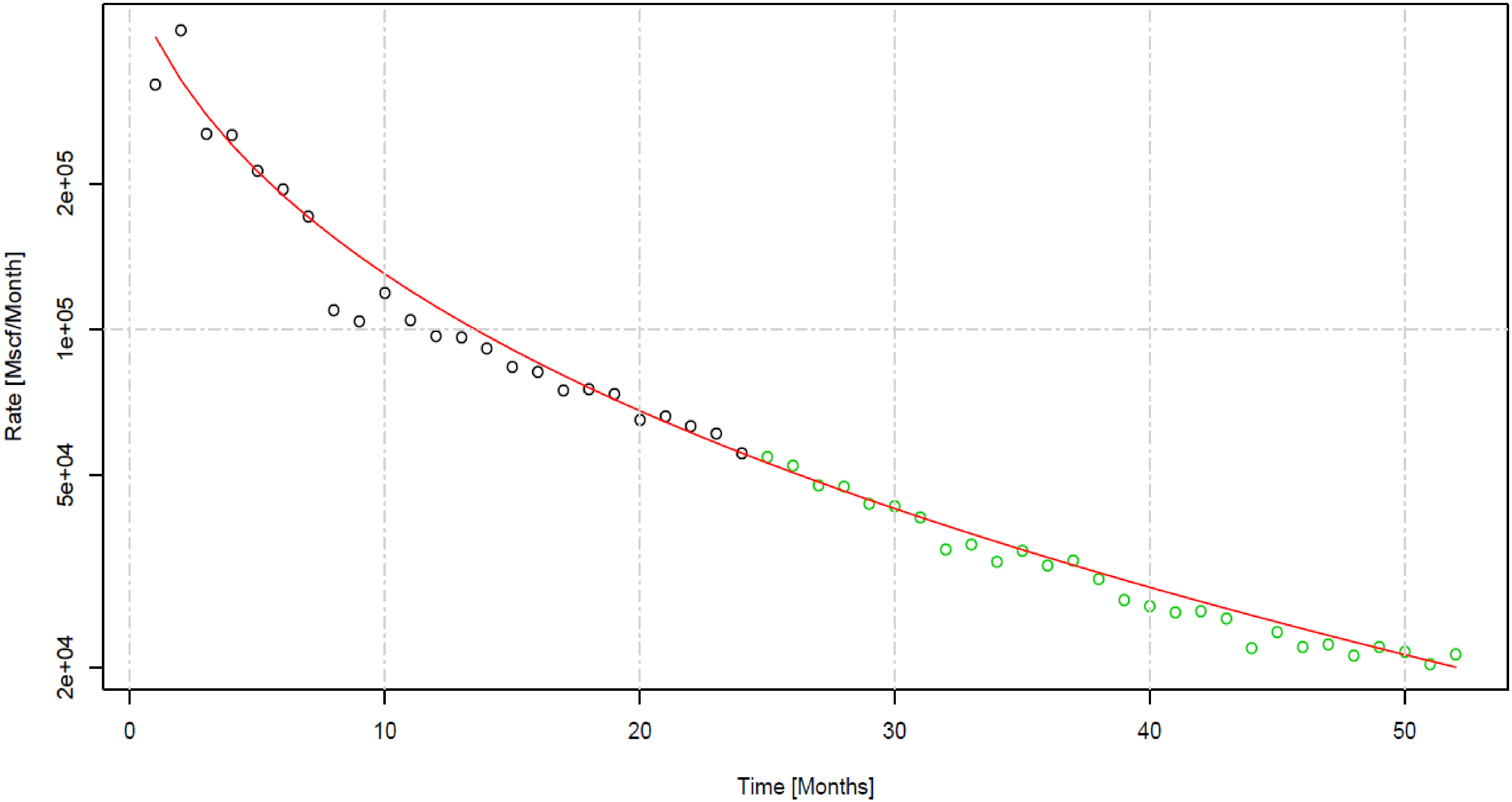
THE GOOD NEWS

- We have tested this with over 2,000 wells with different shale plays. It shows reasonable projections.

- The results of this approach also compare favorably with detailed reservoir simulation models.

- We also used hindcasting to test the predictive power of the model.
  - Manual hindcast tests for over 100 wells in Haynesville where we have established data history.

WELL #1



Rate [Mscf/Month]
2e+05
1e+05
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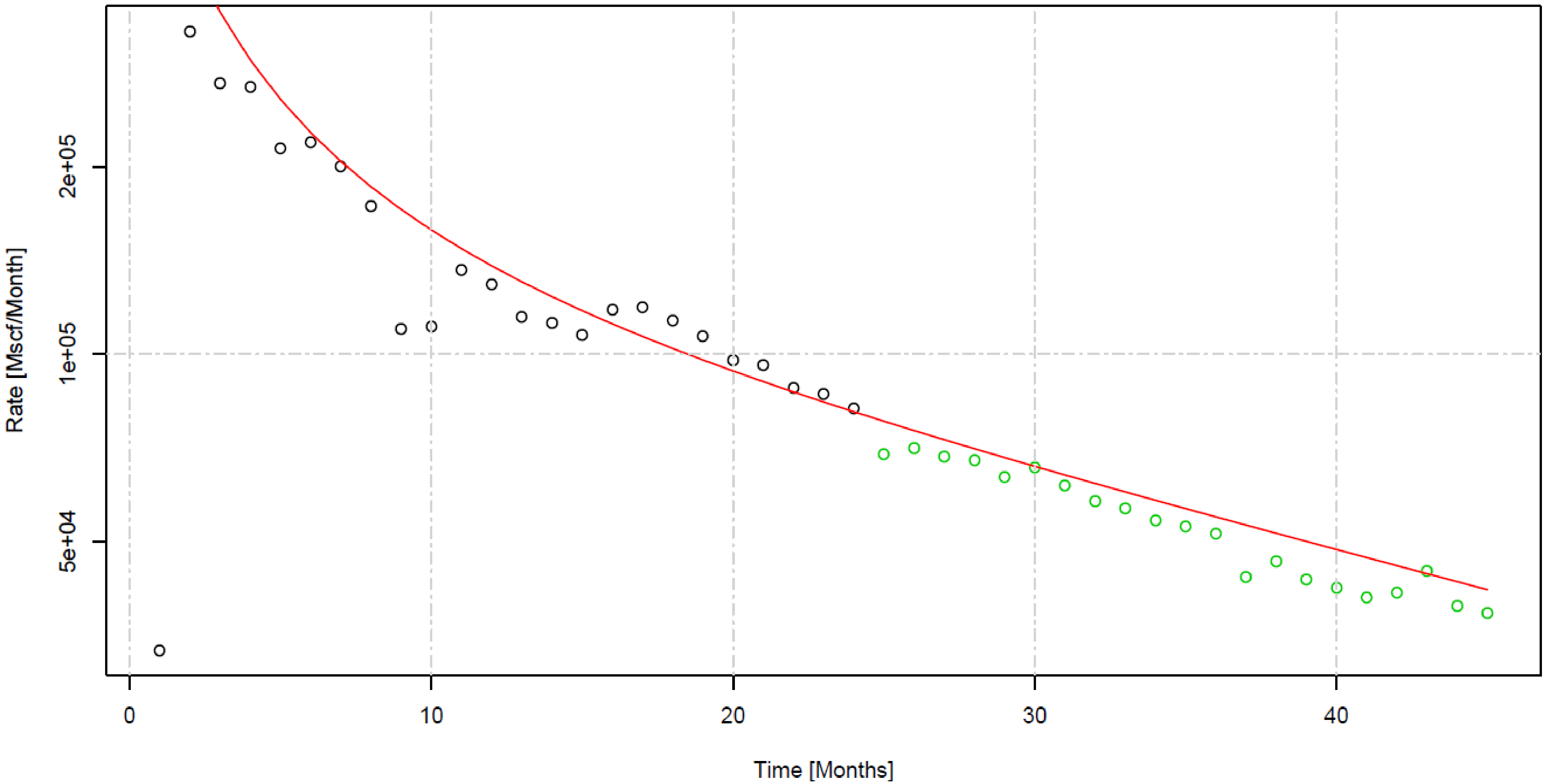
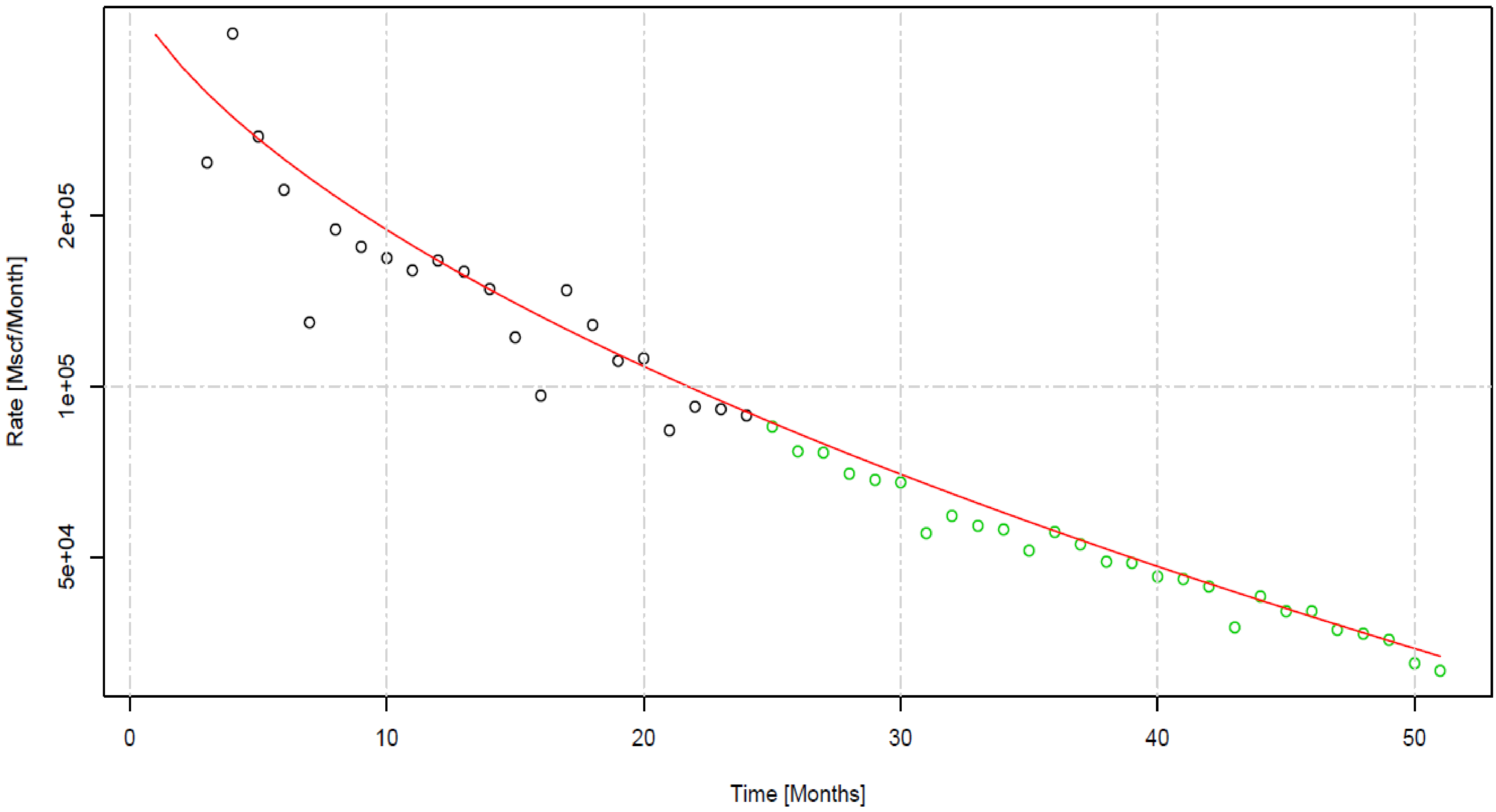
Time [Months]

WELL #2



WELL #3



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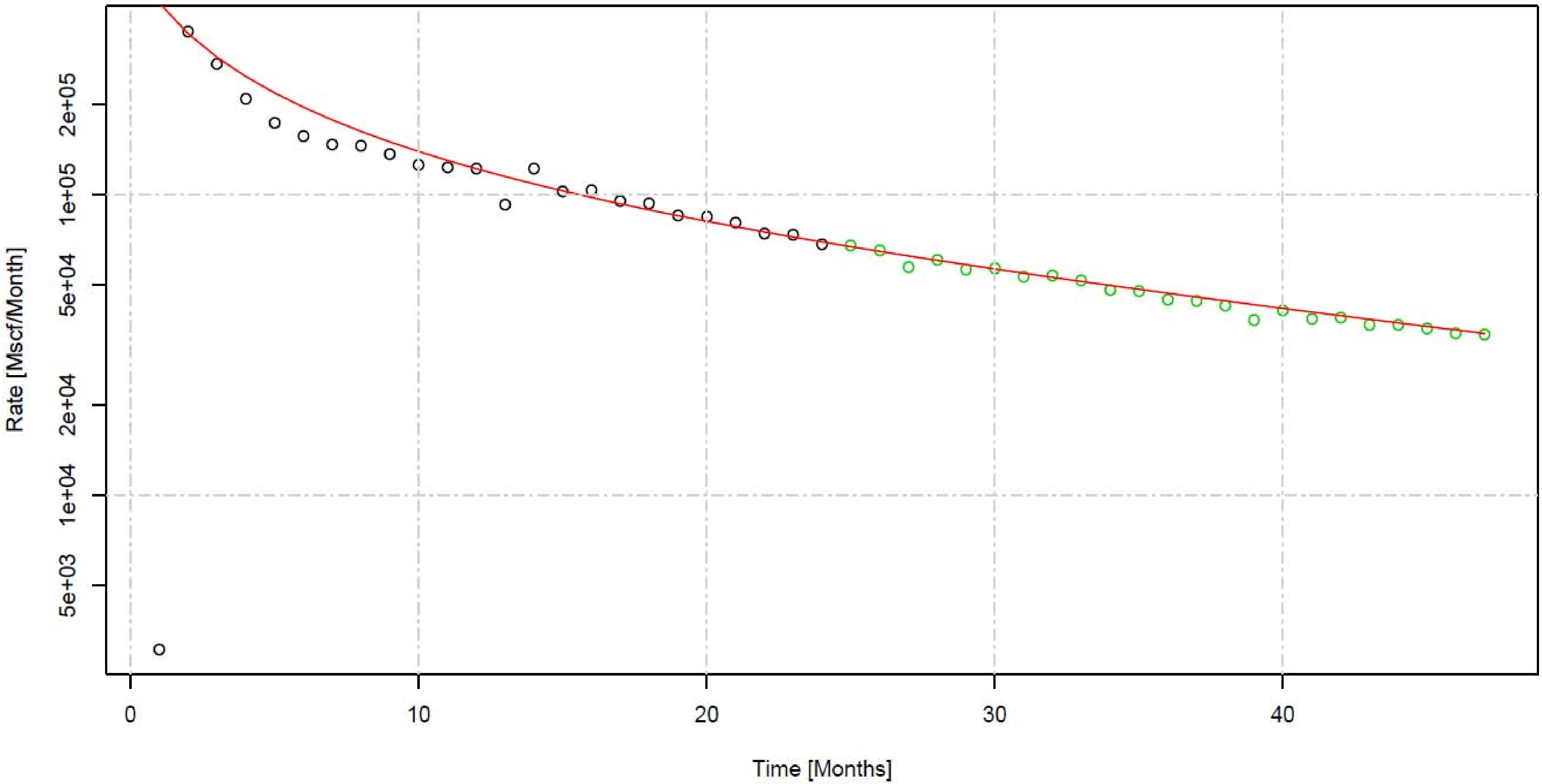

Rate [Mscf/Month]
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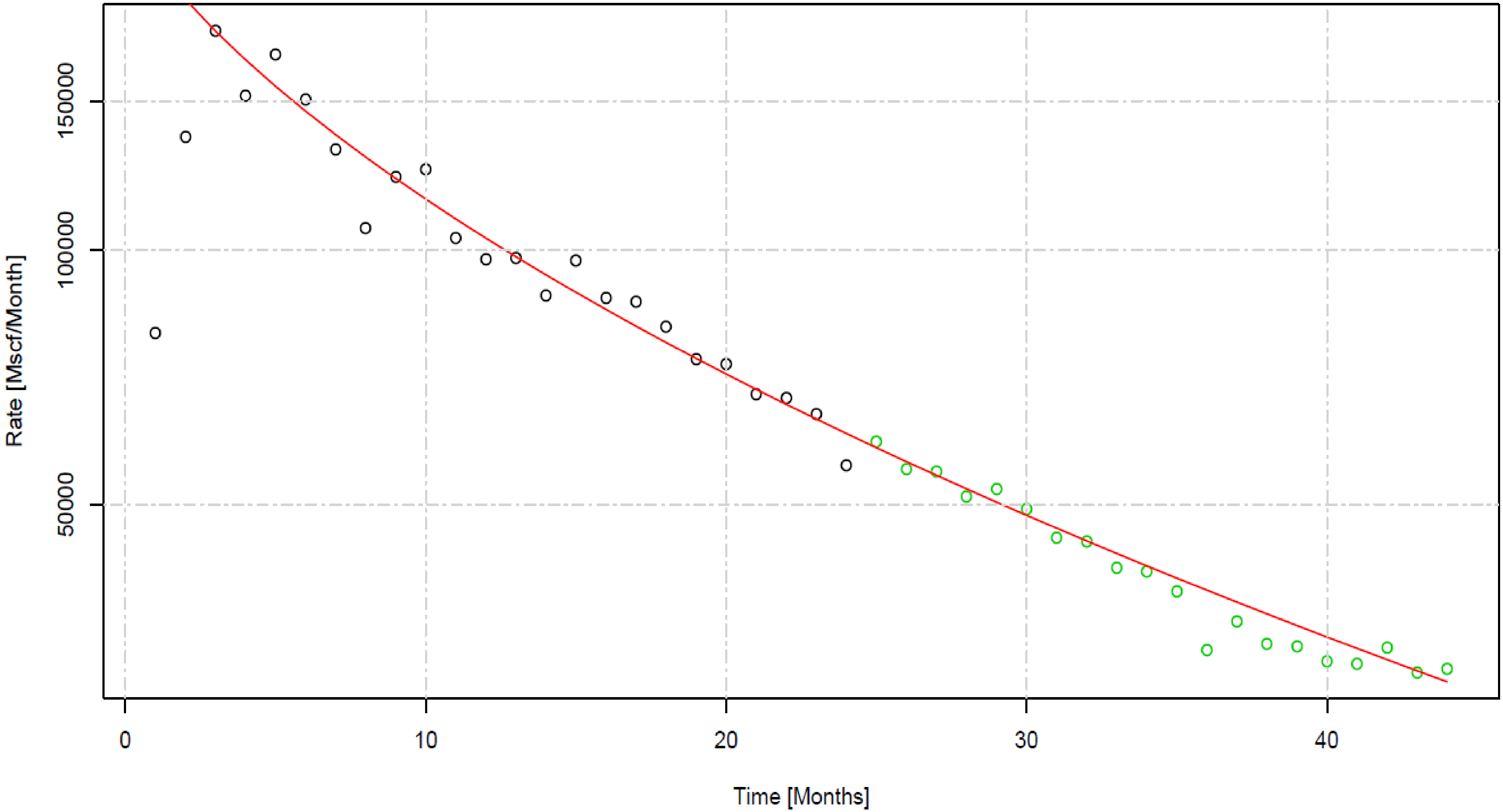
Time [Months]

WELL #5



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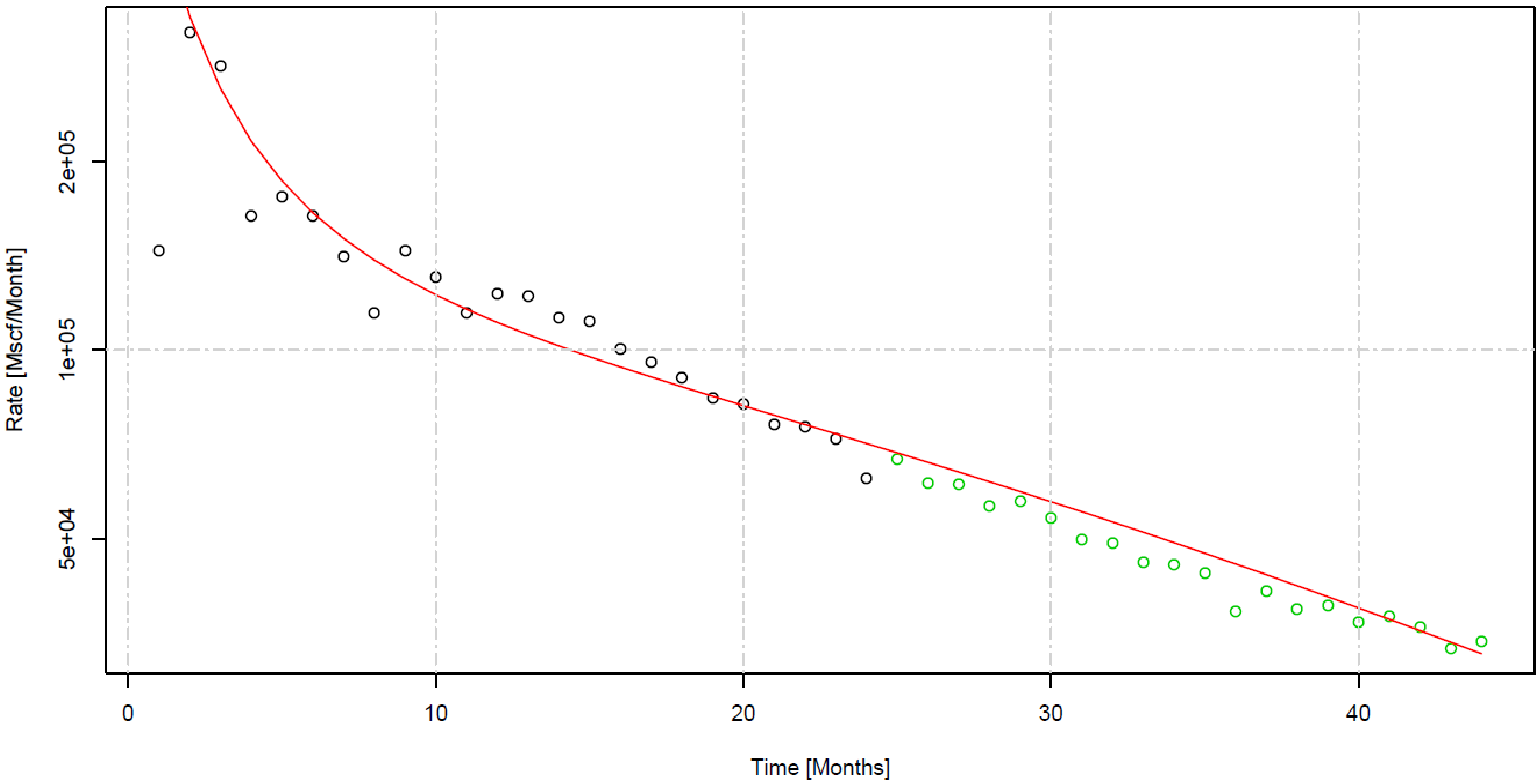

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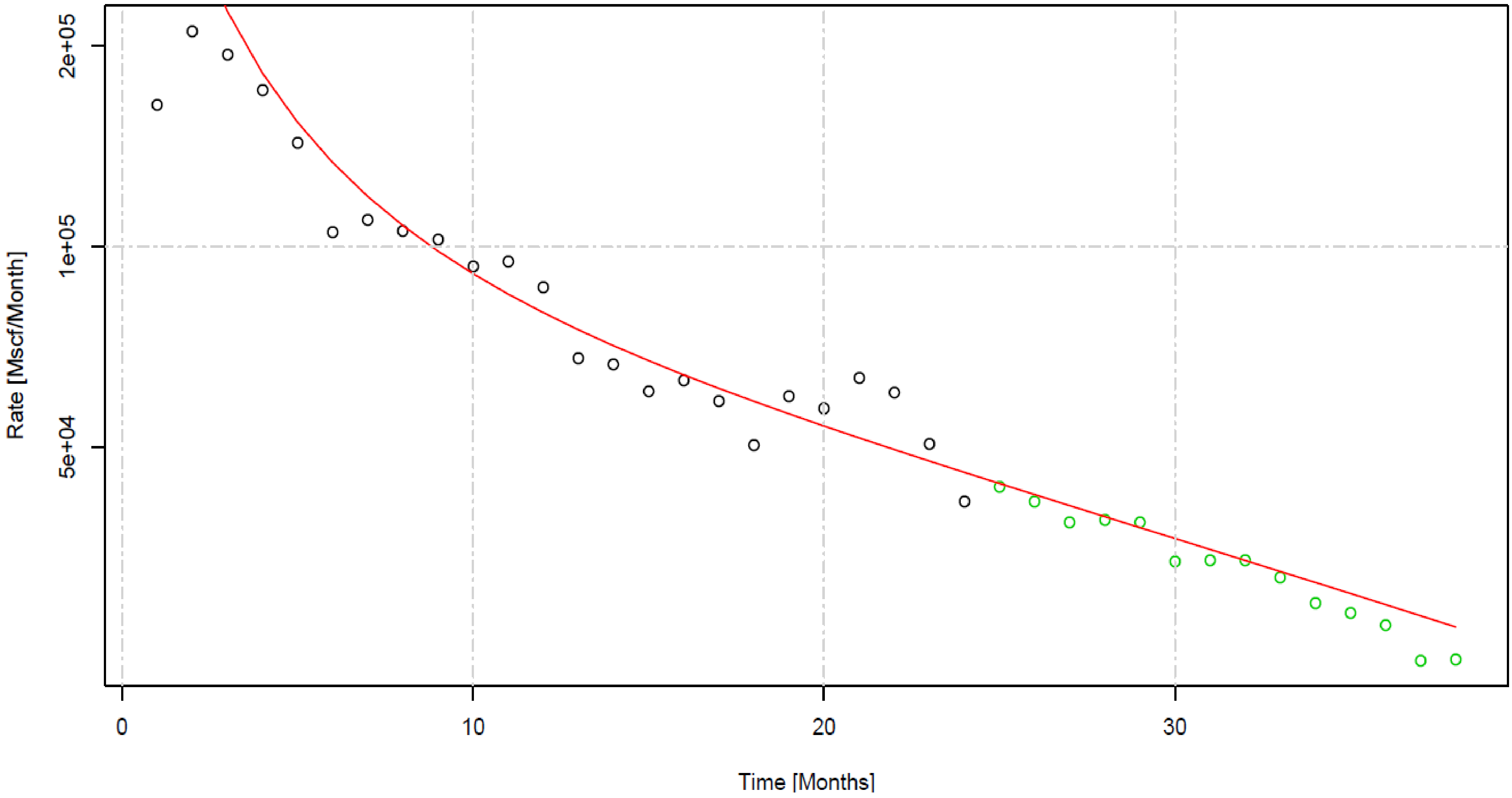
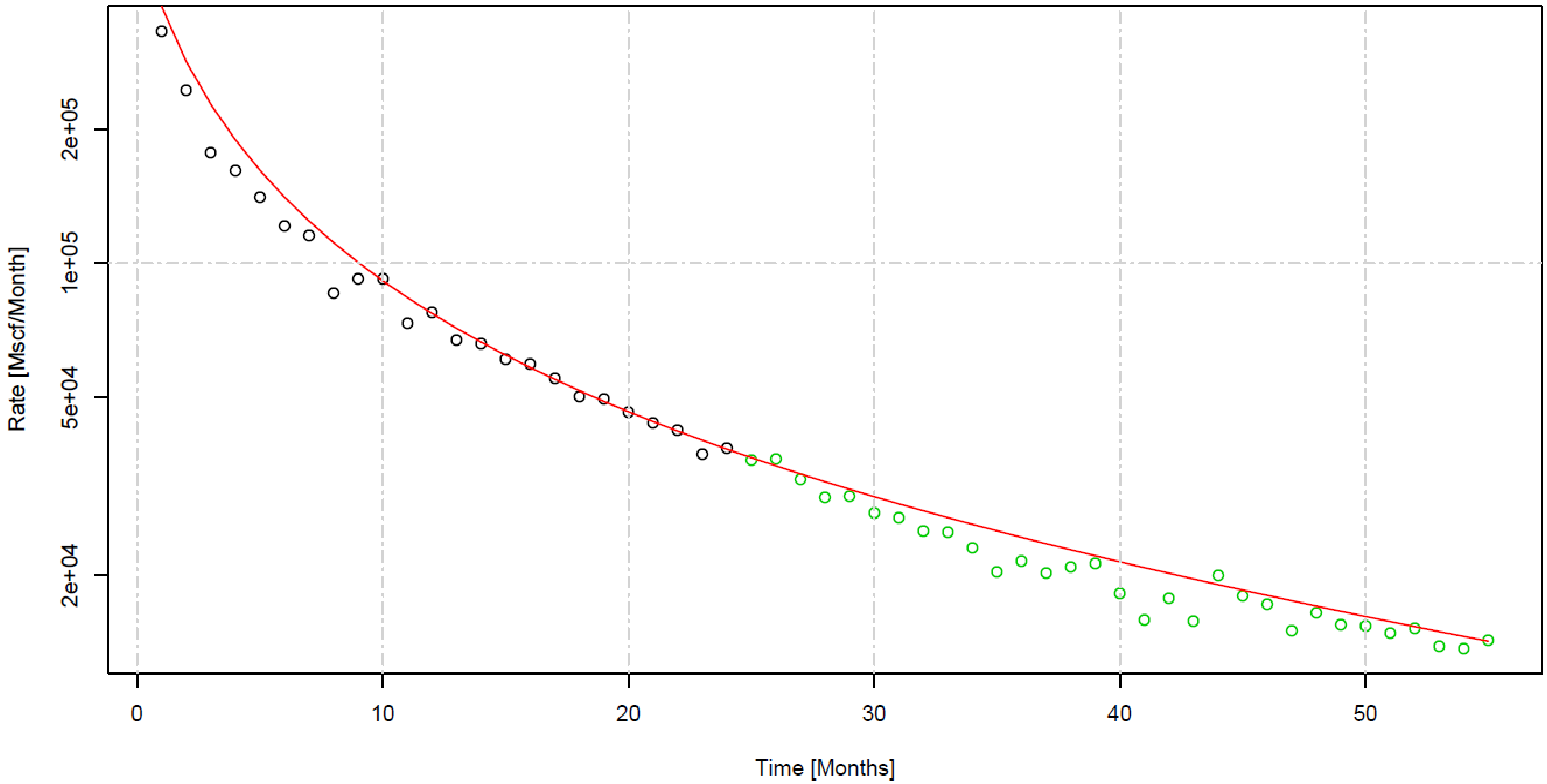


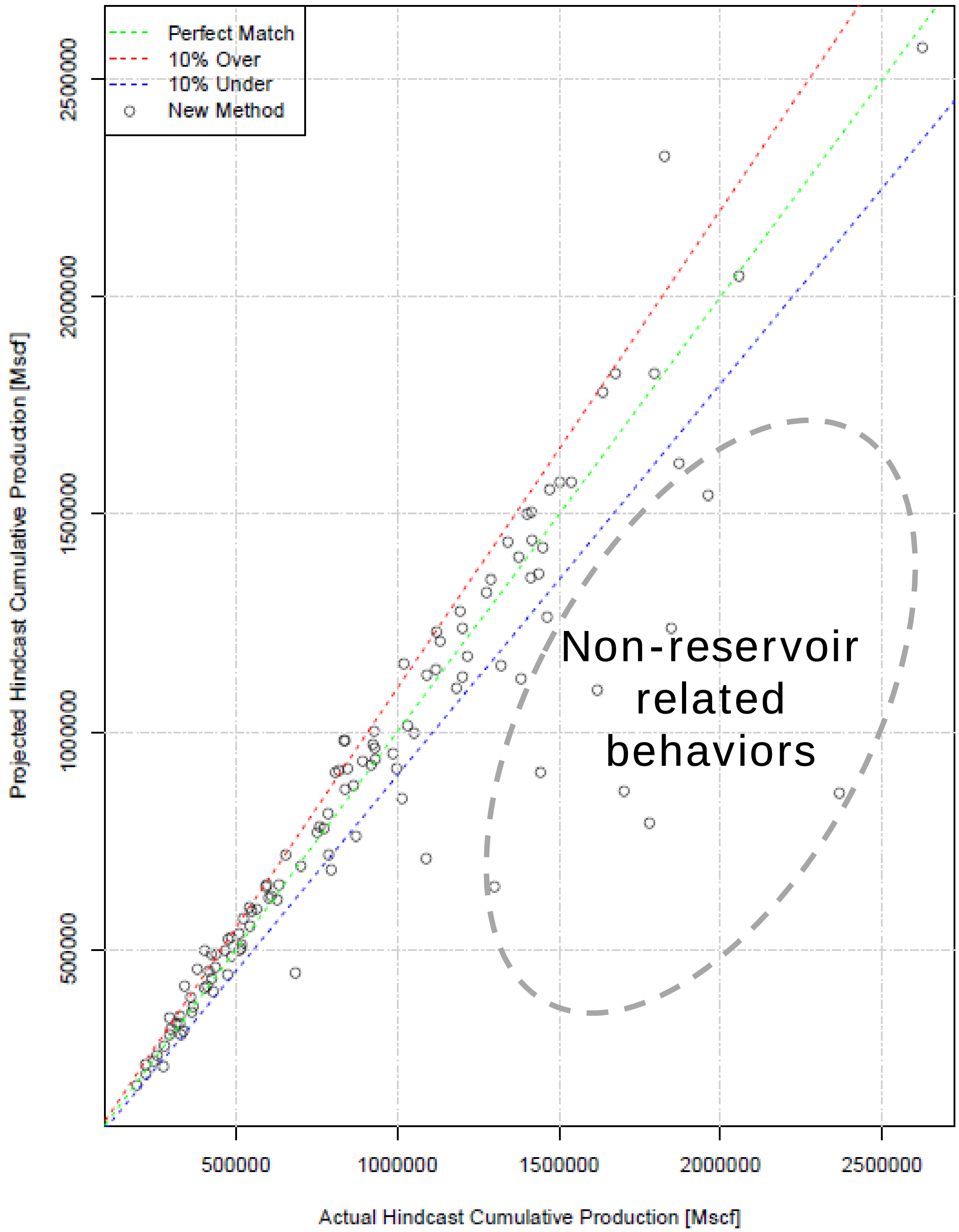
WELL #8



Rate [Mscf/Month]
2e+05
1e+05
5e+04
2e+04
0
10
20
30
40
50
Time [Months]

HINDCAST TESTS

- As expected, forecasts are reasonable (due to the near term of the comparison).
- Generally speaking there was no significant bias (optimistic or pessimistic) in the forecast for the subsequent 1-2 years.



CURRENT UNKNOWNS AND CONCERNS

- Effects of pressure
- Appropriateness of early time data
  - Well clean-up
  - Wellbore storage
  - Curtailed production
- Variations in fluid properties
- Variations in completion techniques
- Appropriate input parameter boundaries
- Influence and relationship of the early-time performance to the late-time

CONCLUSIONS

- This work presented a new form of DCA with three empirical coefficients for shale reservoirs.
- The method is easy to implement in practice.
- It does not require an estimate of the switching point (flow regime changes).
- It is able to project the future production by fitting all of the historical production data from the beginning of the production decline (i.e., it uses the early time data in its forecast).

While we may have found a better and more accurate method for forecasting "unconventionals," we are still in the early-evaluation stage of the process.

FINAL REMARKS

- Early stages of testing
- **NOT** yet considered “reliable” – not being used for forecasting of reserves at Ryder Scott at this time
- Full paper will be presented at ATCE (SPE 175016)
- While we believe the early time data helps improve the overall forecast, we continue to investigate the level of influence the early time data should have on the late time declines.

We welcome anyone to look at the paper and help us to validate the approach.

ACKNOWLEDGMENTS

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- Ryder Scott Company