Status of SPEE Monograph 4
&
The Importance of Transient Flow in Estimating Unconventional Reserves

Denver SPEE chapter luncheon

14 October 2015

John Seidle

MHA Petroleum Consultants

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Or
How I became a modified Arps agnostic.

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Status of SPEE Monograph 4 – Estimating Developed Reserves in Unconventional Reservoirs

- 6 of 10 chapters – final edits in progress
- 4 of 10 chapters – revised drafts due 1 November
- Final manuscript to SPEE 1 December?
- Sister society review?
- Publication 1Q 2016?

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Developed Reserves Historically Estimated with Decline Curves

Decline curve assumptions

1. **Constant bottomhole flowing pressure**
2. **Constant drainage area**
3. **Constant permeability and wellbore condition**
4. **Constant fluid properties**
5. **Well in boundary-dominated flow (BDF)**

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The Problem – Unconventional wells can take years to reach BDF

The Solution – Rate Transient Analysis (RTA)

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The Problem – RTA requires rates and pressures

The Solution – Semi-empirical models

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Current semi-empirical transient flow models

1. Arps
2. Modified Arps
3. Duong
4. Stretched Exponential Decline Model (SEDM)

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These models can accurately forecast future well performance, even when the well is in transient flow.

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Or can they?

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DJ Niobrara horizontal well – four analyses

1. Full history – 4.7 years – The Truth
2. 6 months production data
3. 1 year production data
4. 3 years production data

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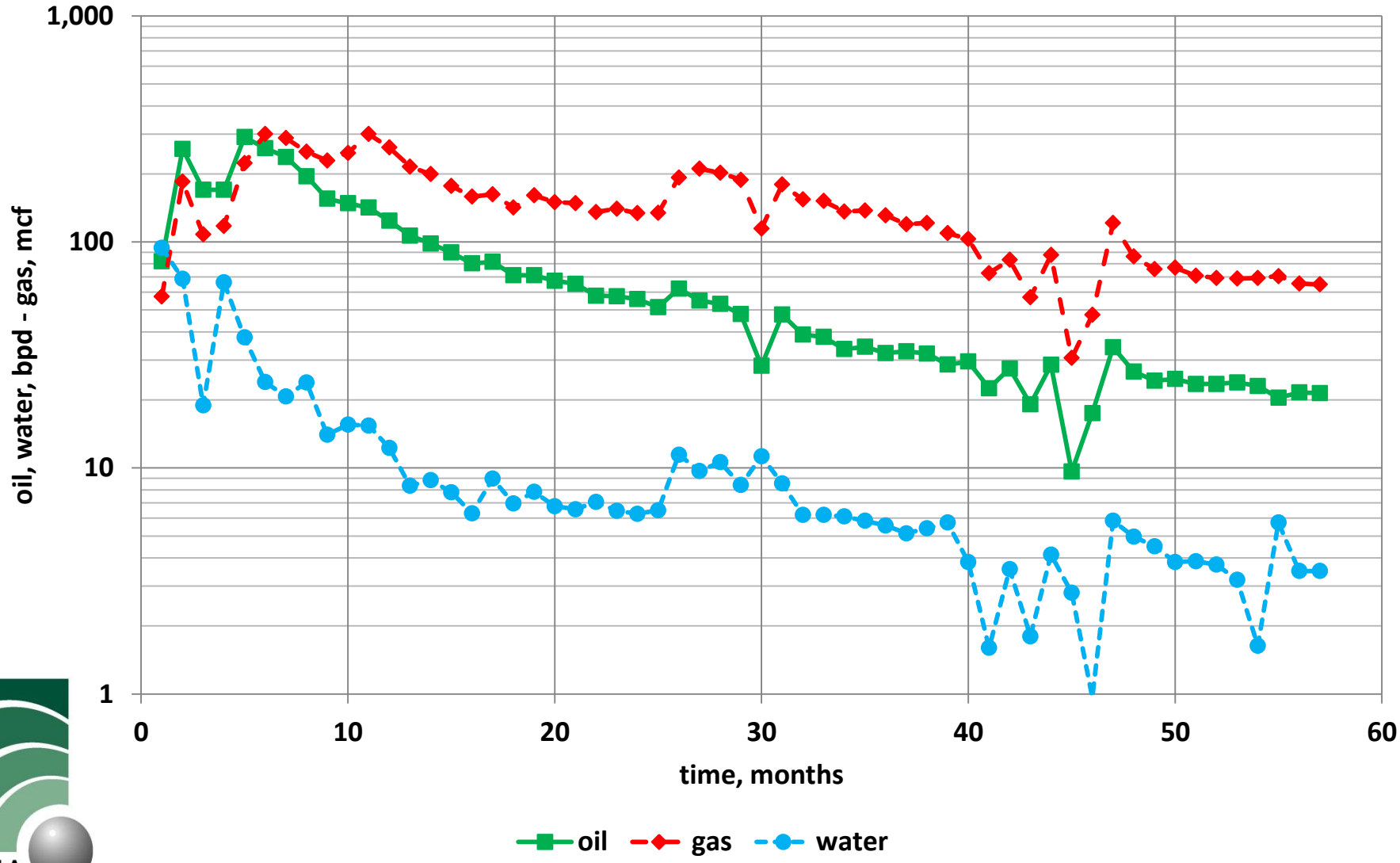
Full history – production data



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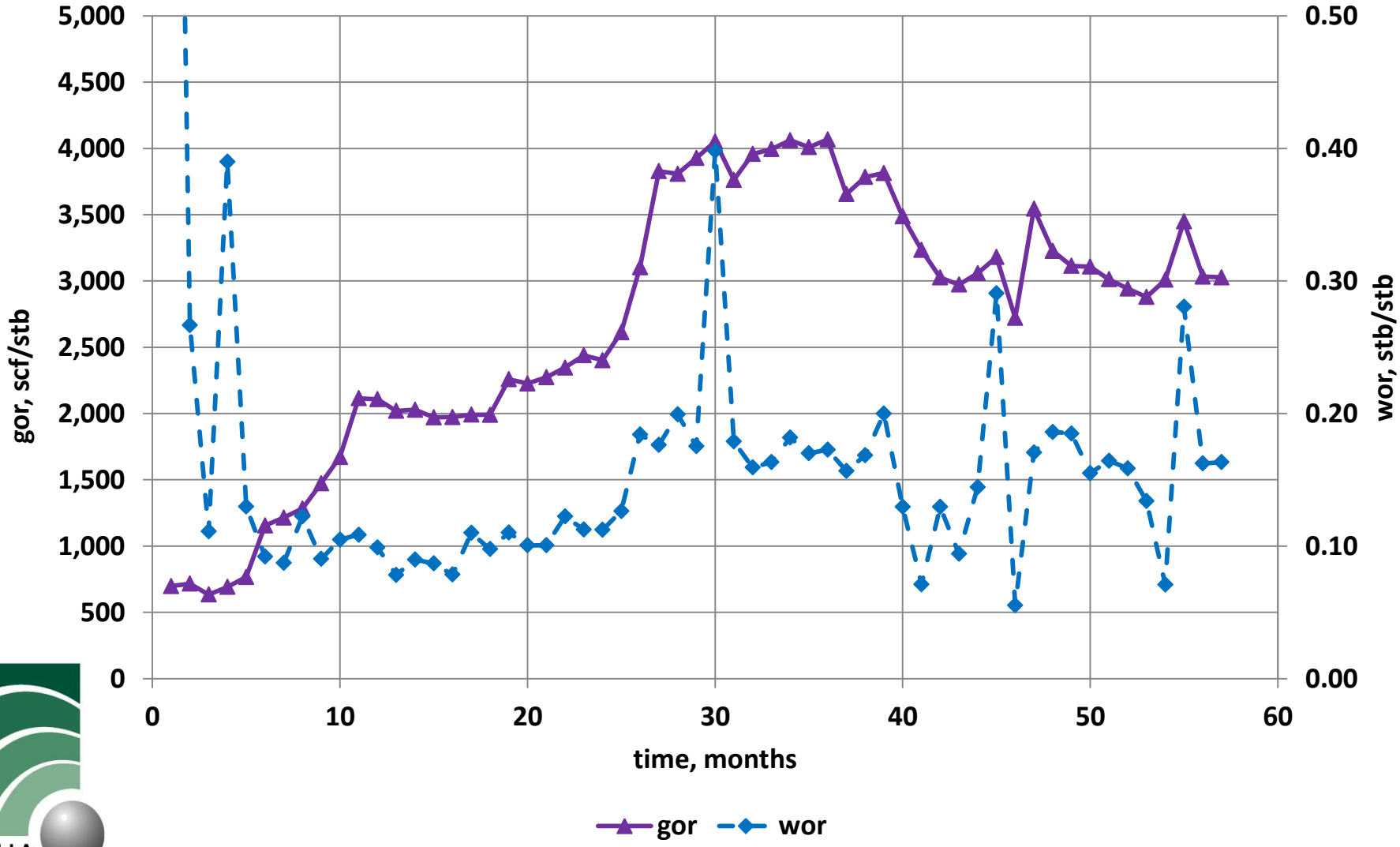
Full history – GOR & WOR plot



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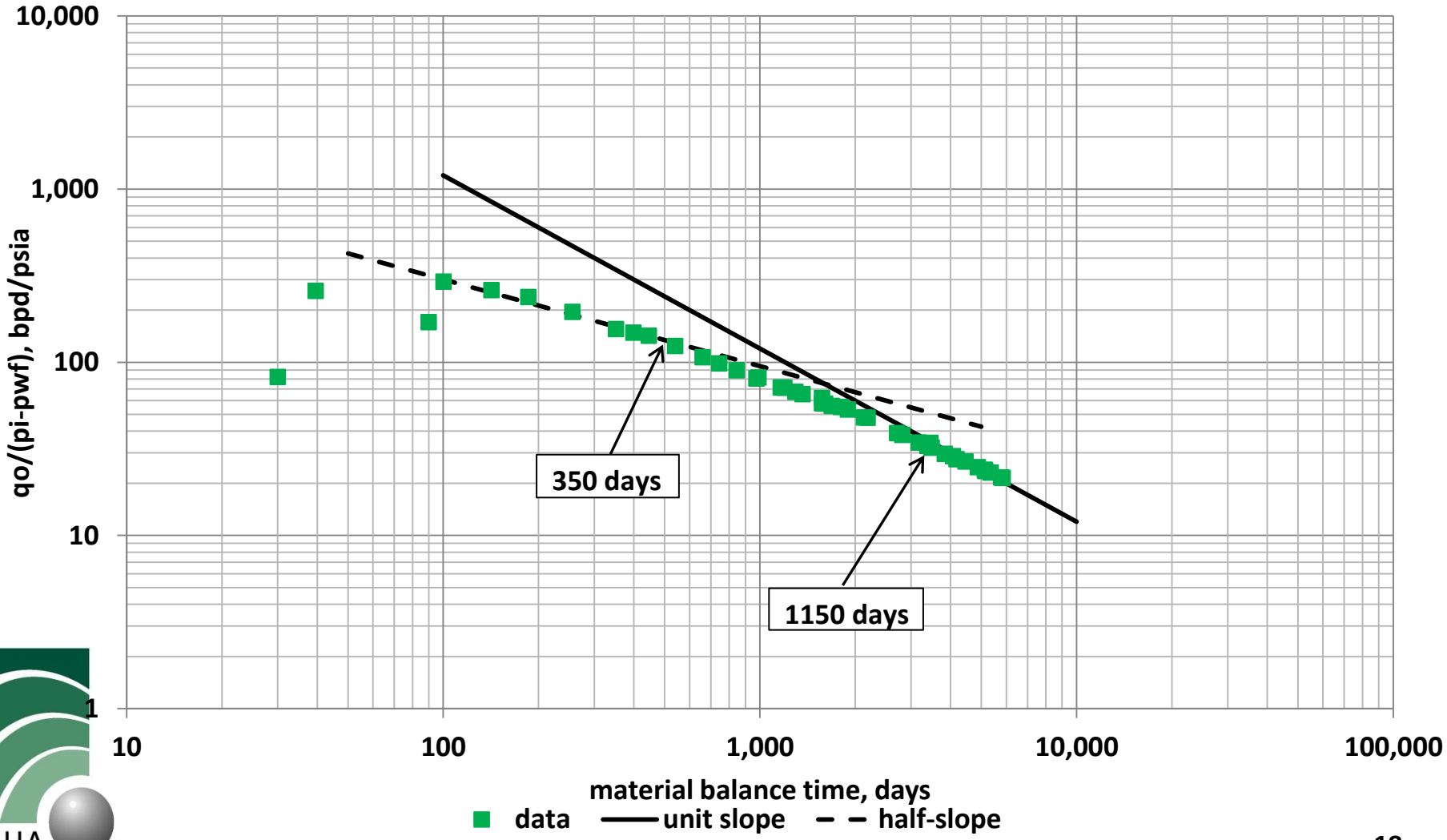
Full history – normalized rate vs material balance time plot



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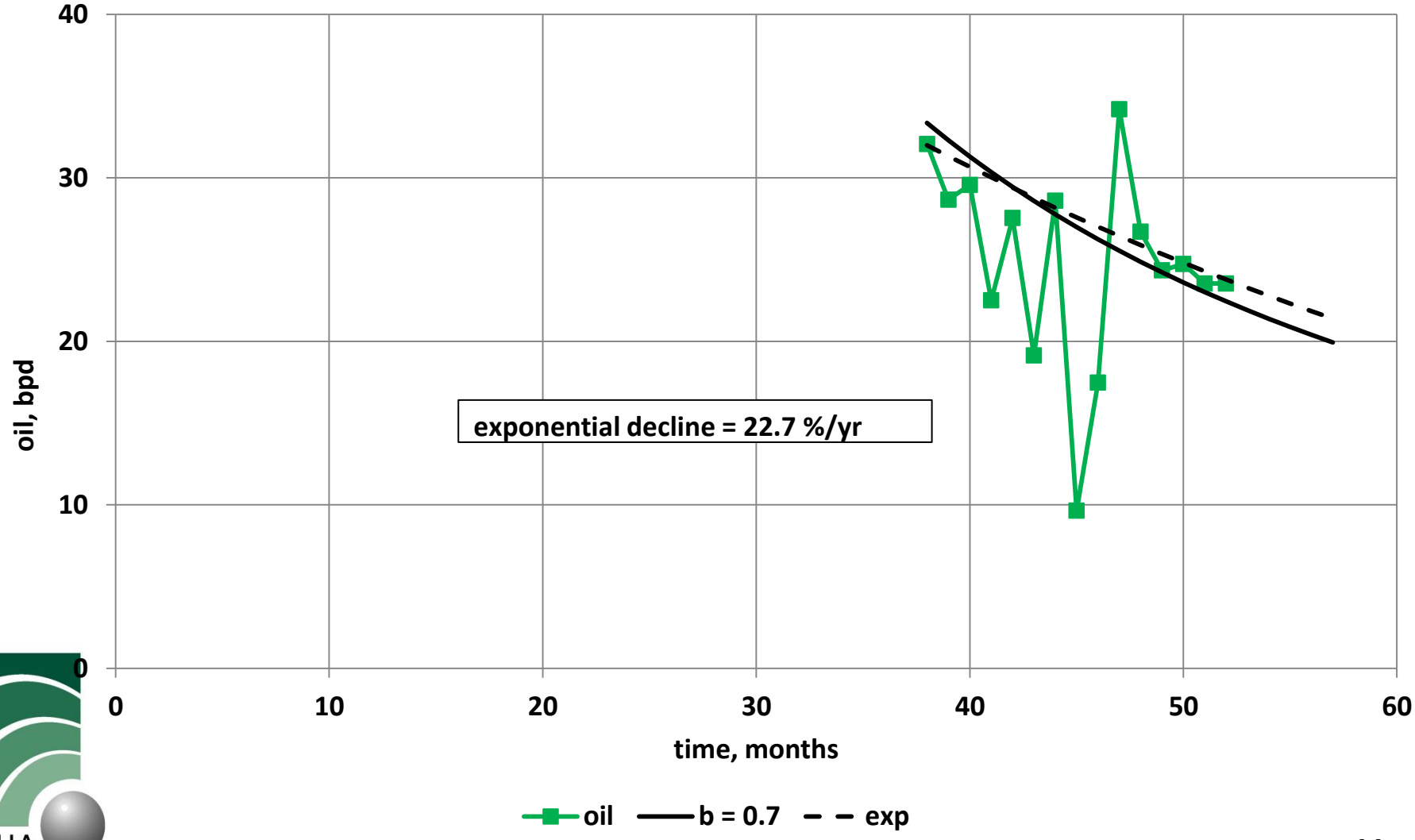
Hyperbolic and exponential declines match boundary dominated flow



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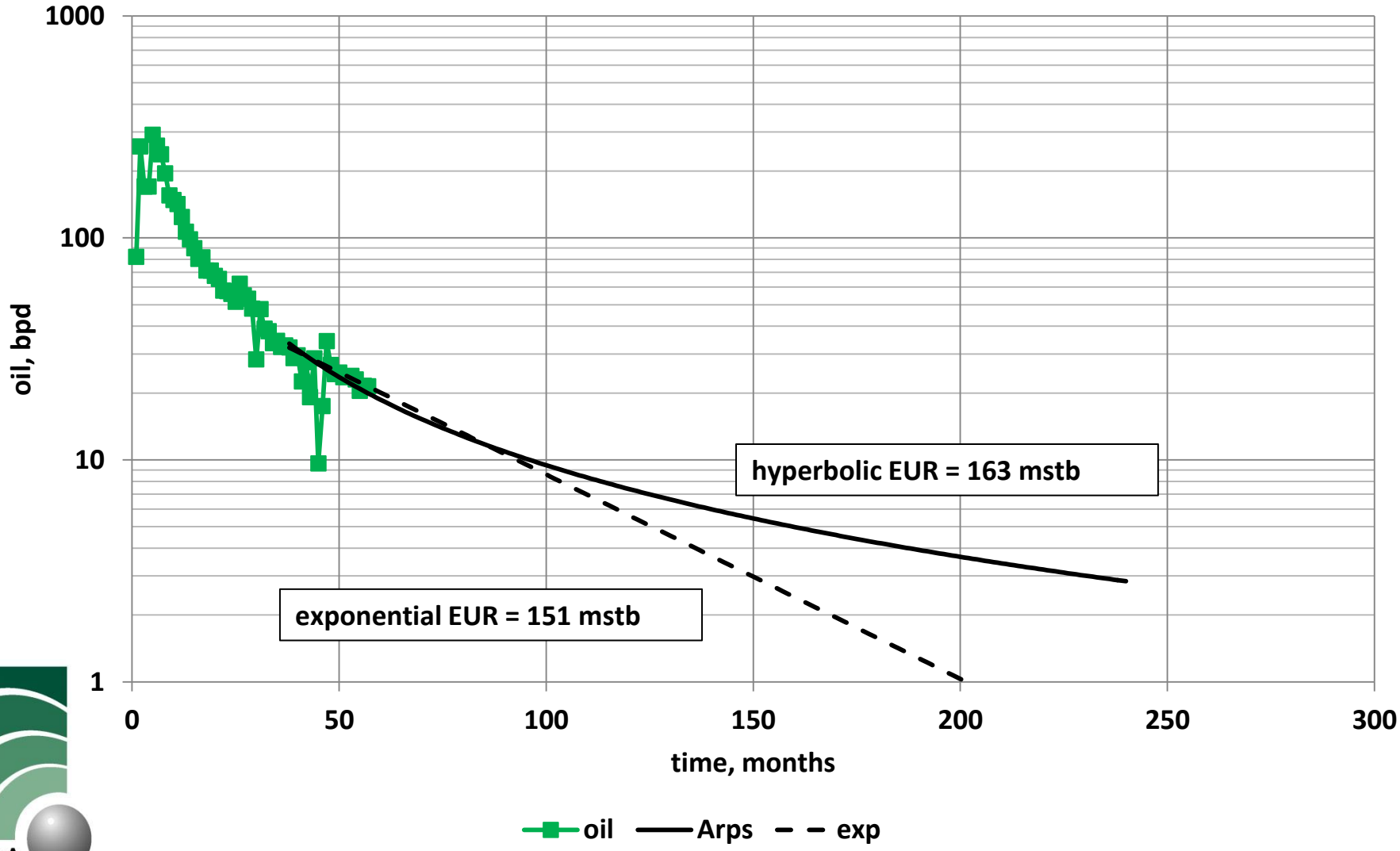
The Truth –
Estimated Ultimate Recovery = 157 mstb



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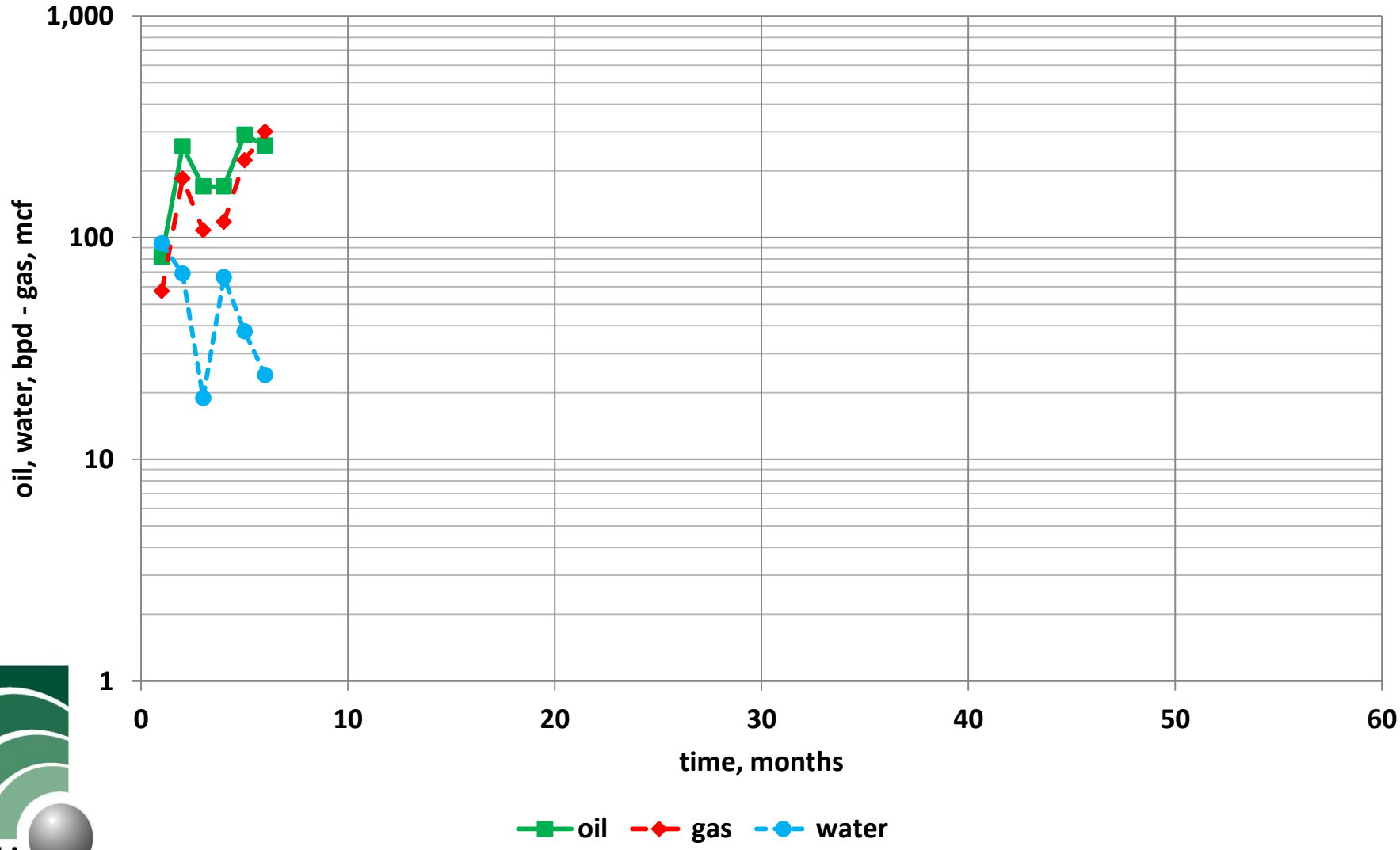
6 months – production data



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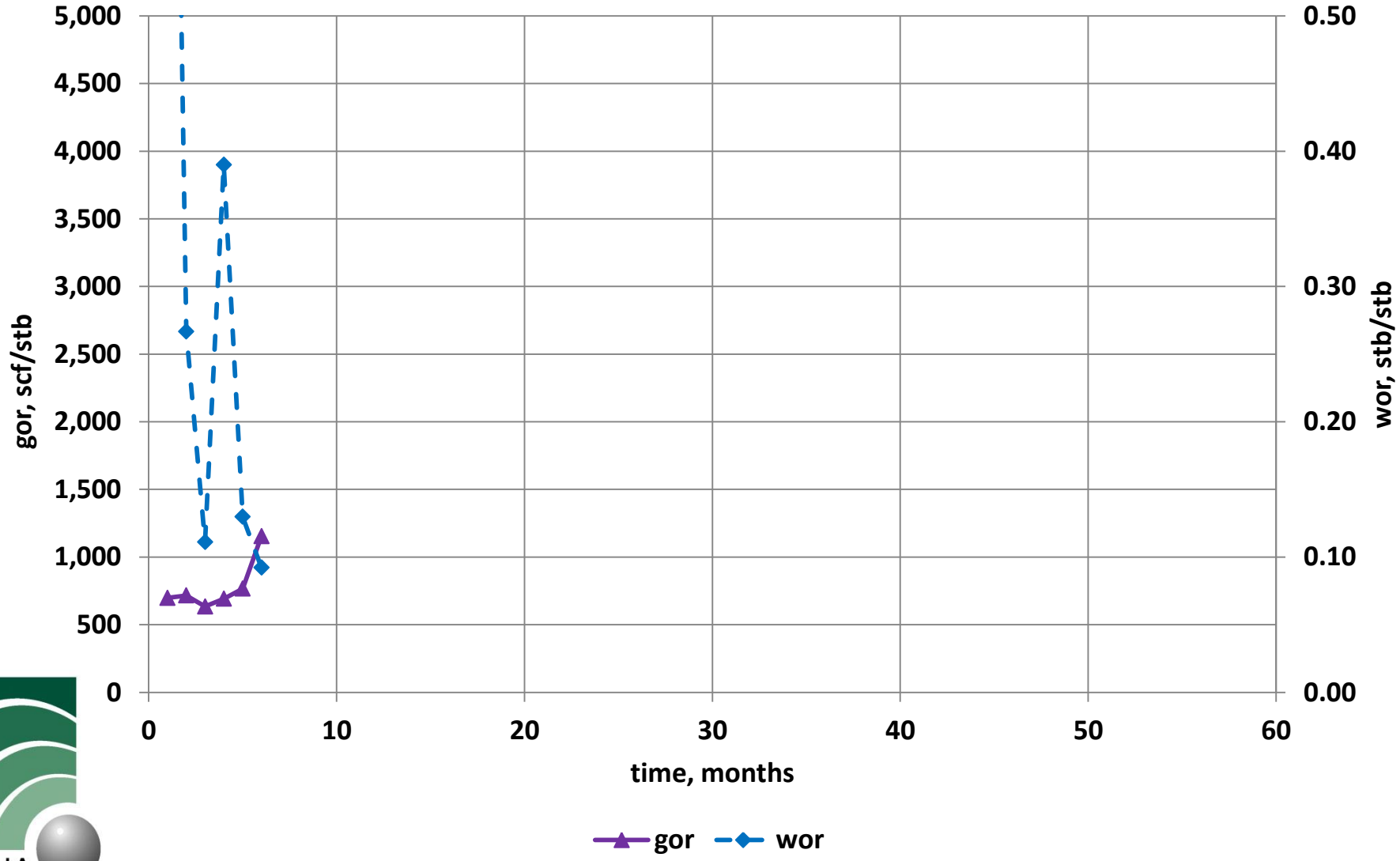
6 months – GOR & WOR plot



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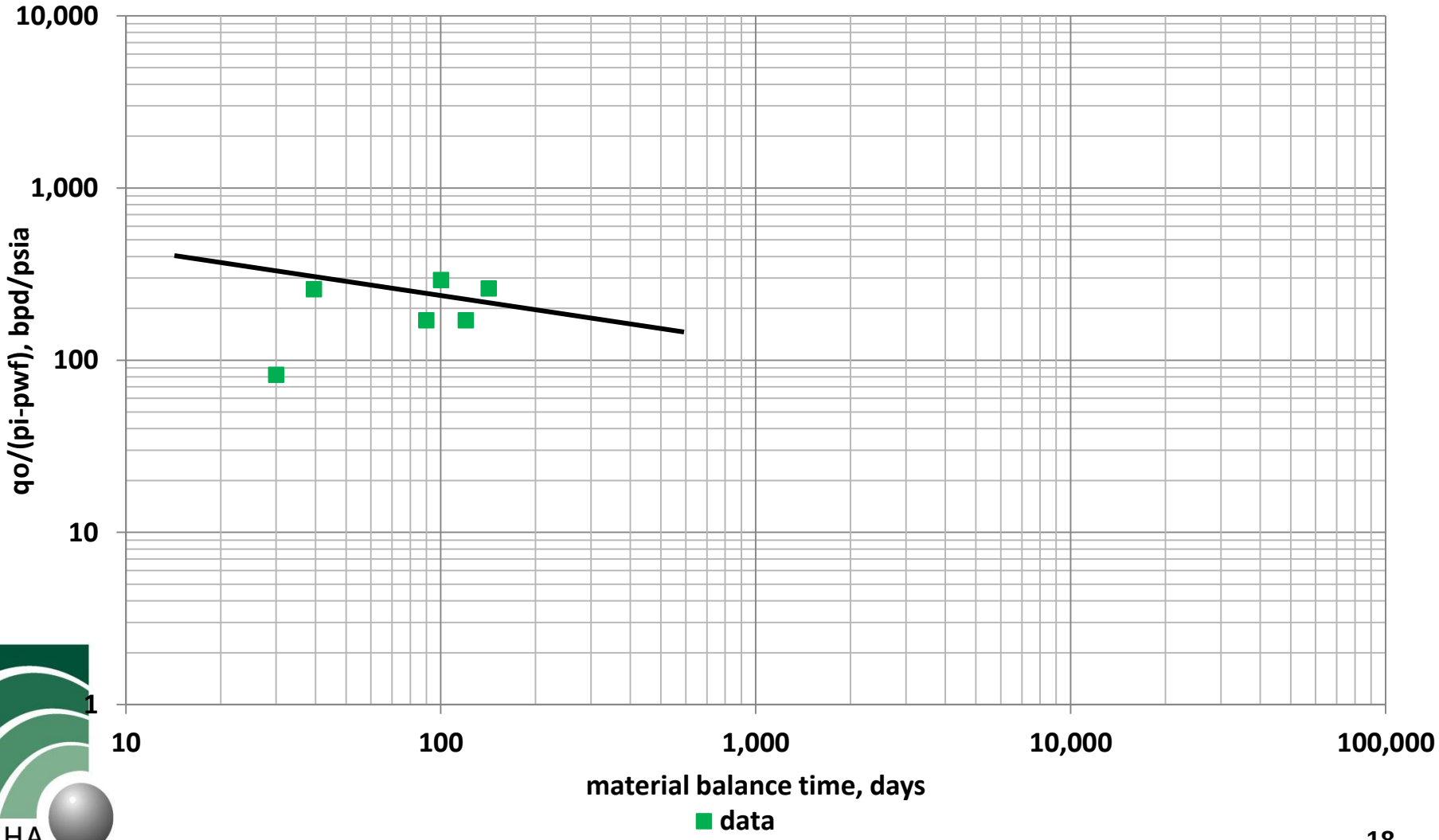
6 months –
normalized rate vs material balance time plot



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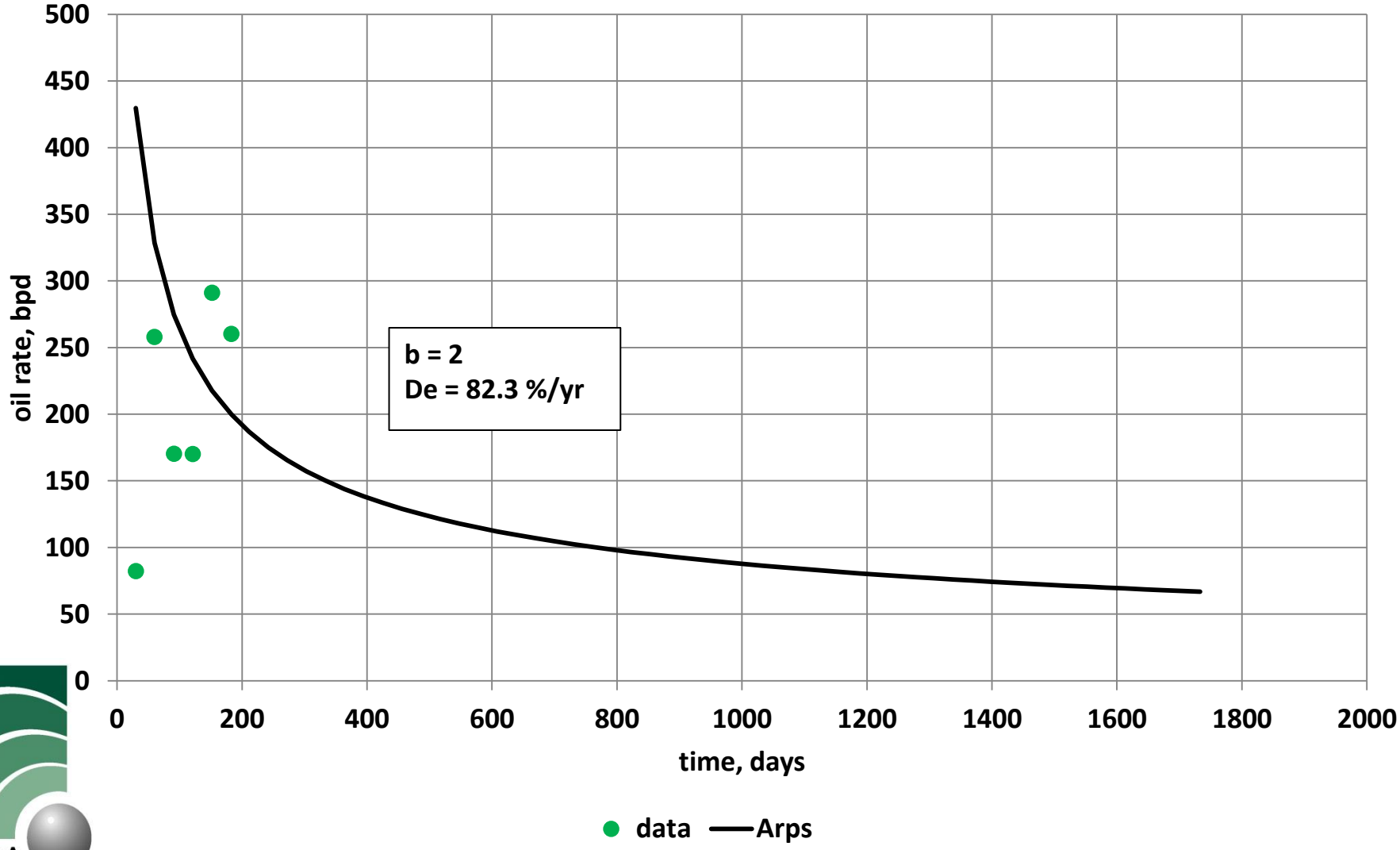
6 months – Arps match & forecast



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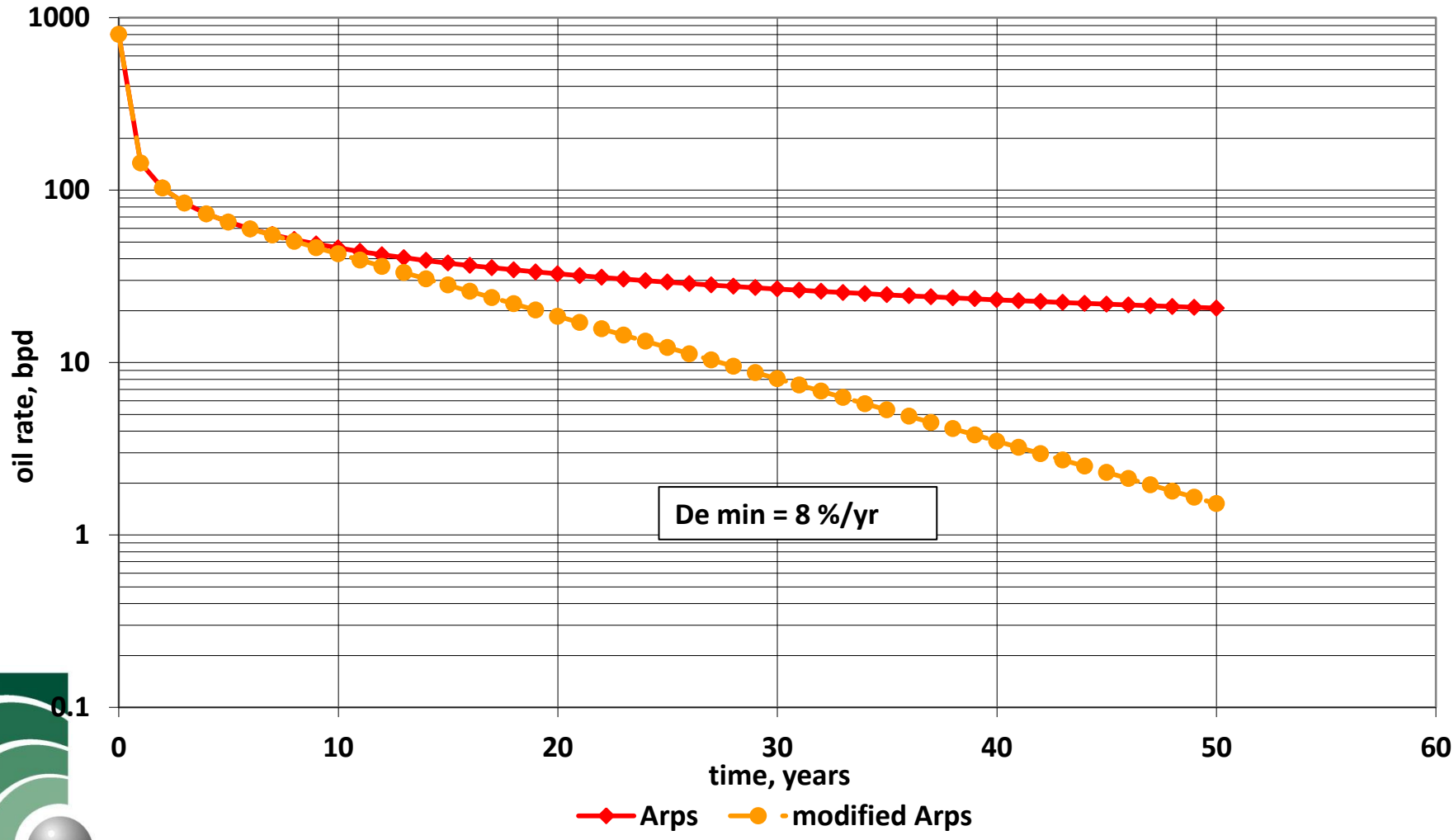
6 months – Arps & modified Arps forecast



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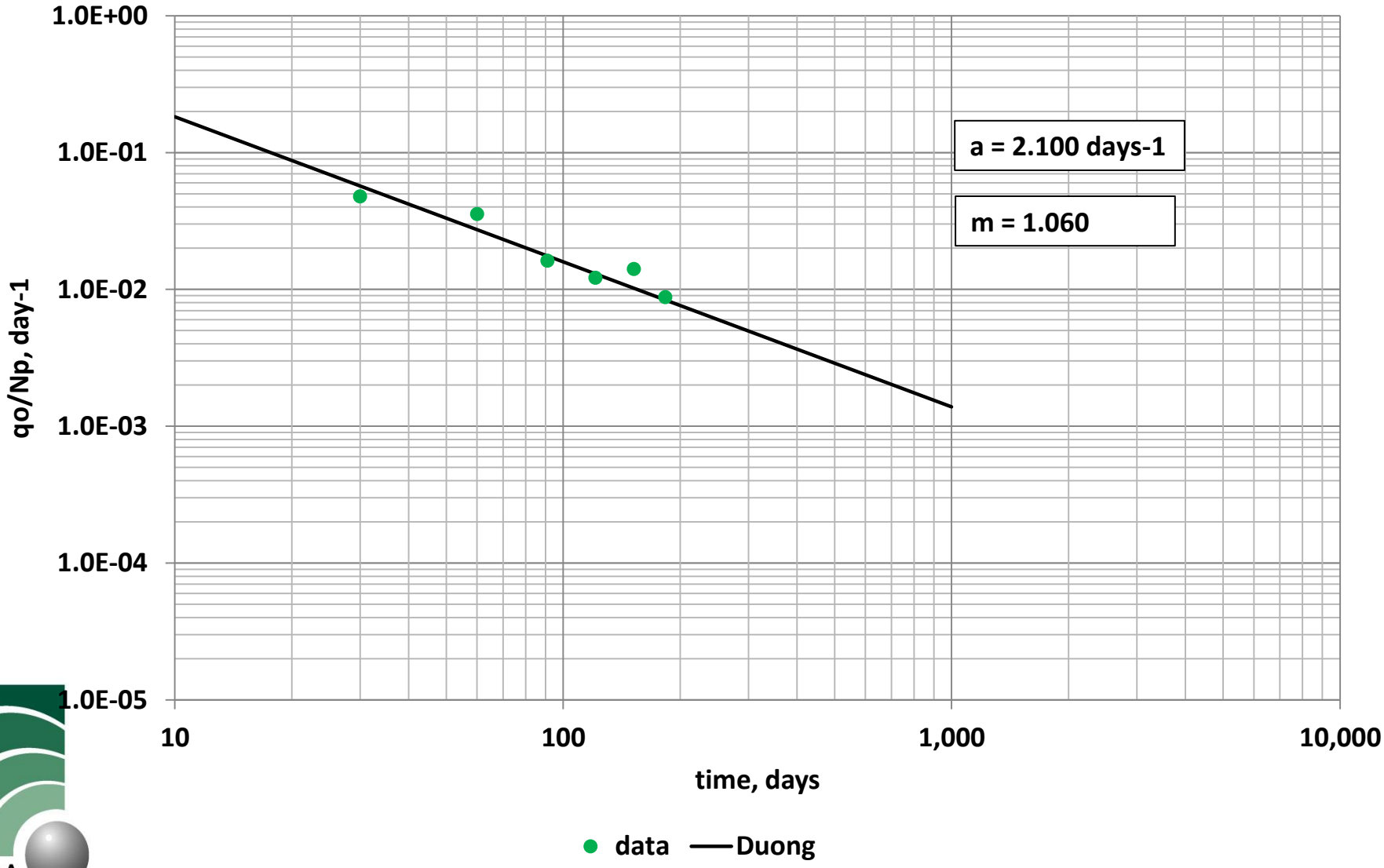
6 months – Duong plot



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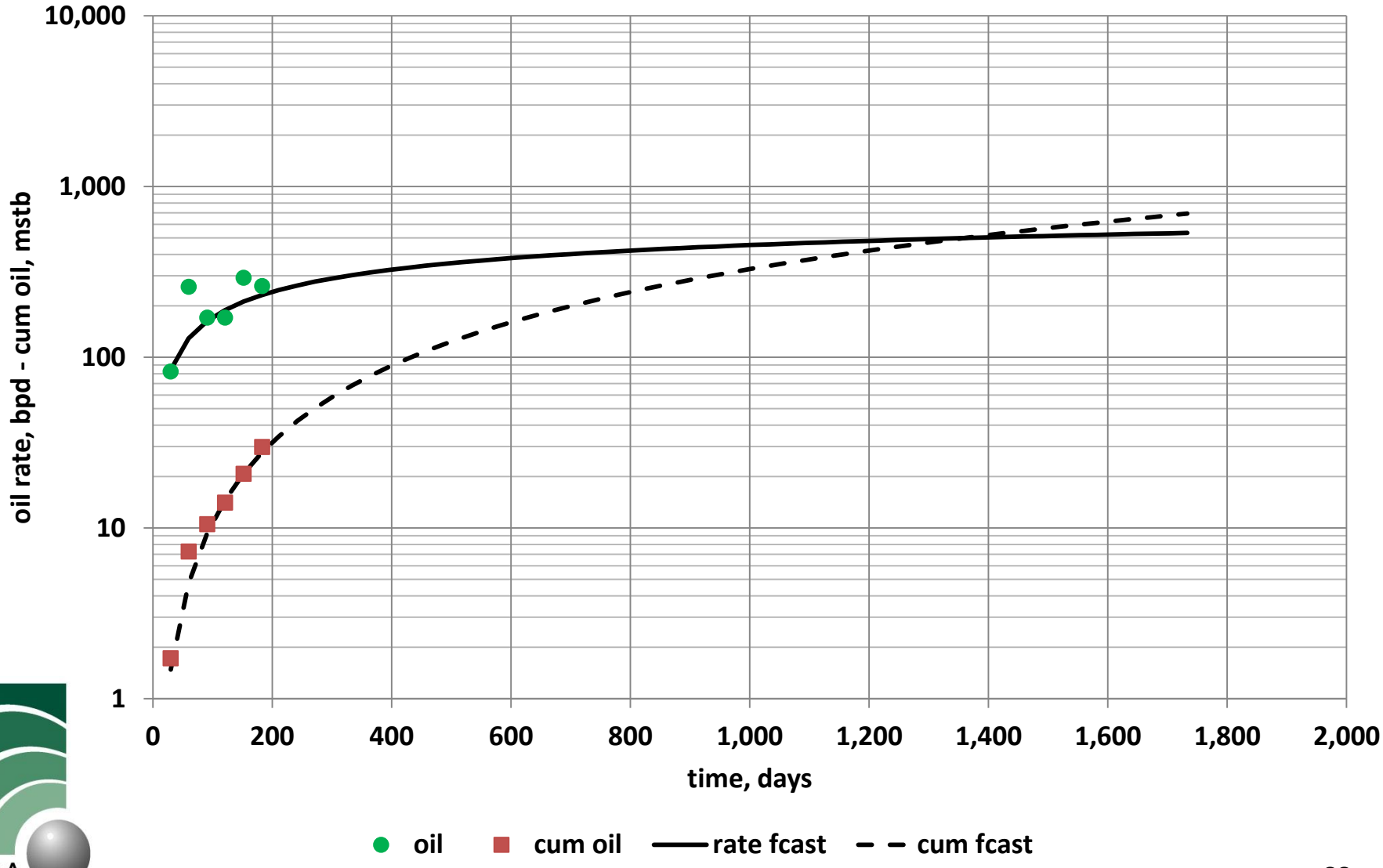
6 months – Duong match & forecast



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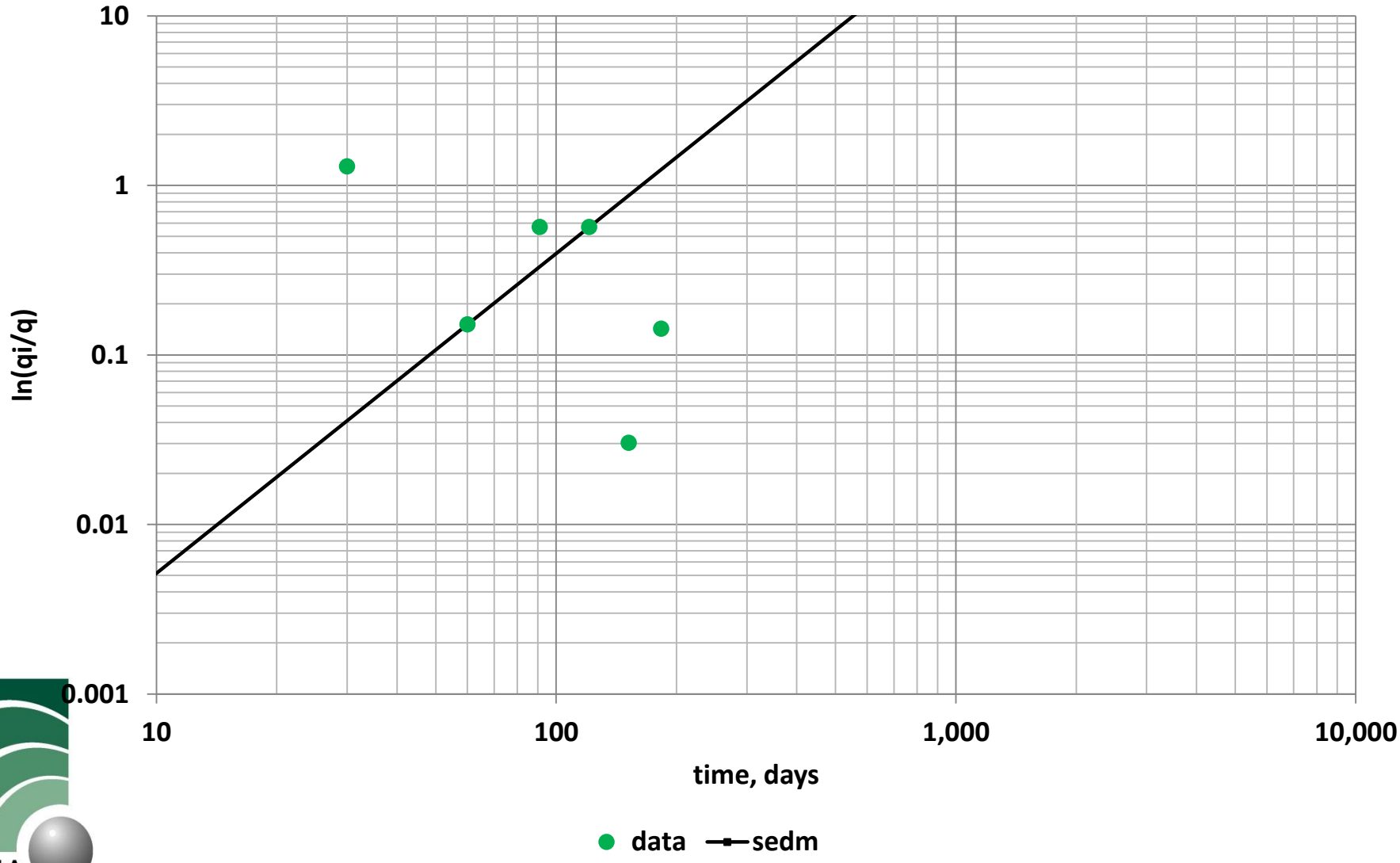
6 months – SEDM plot



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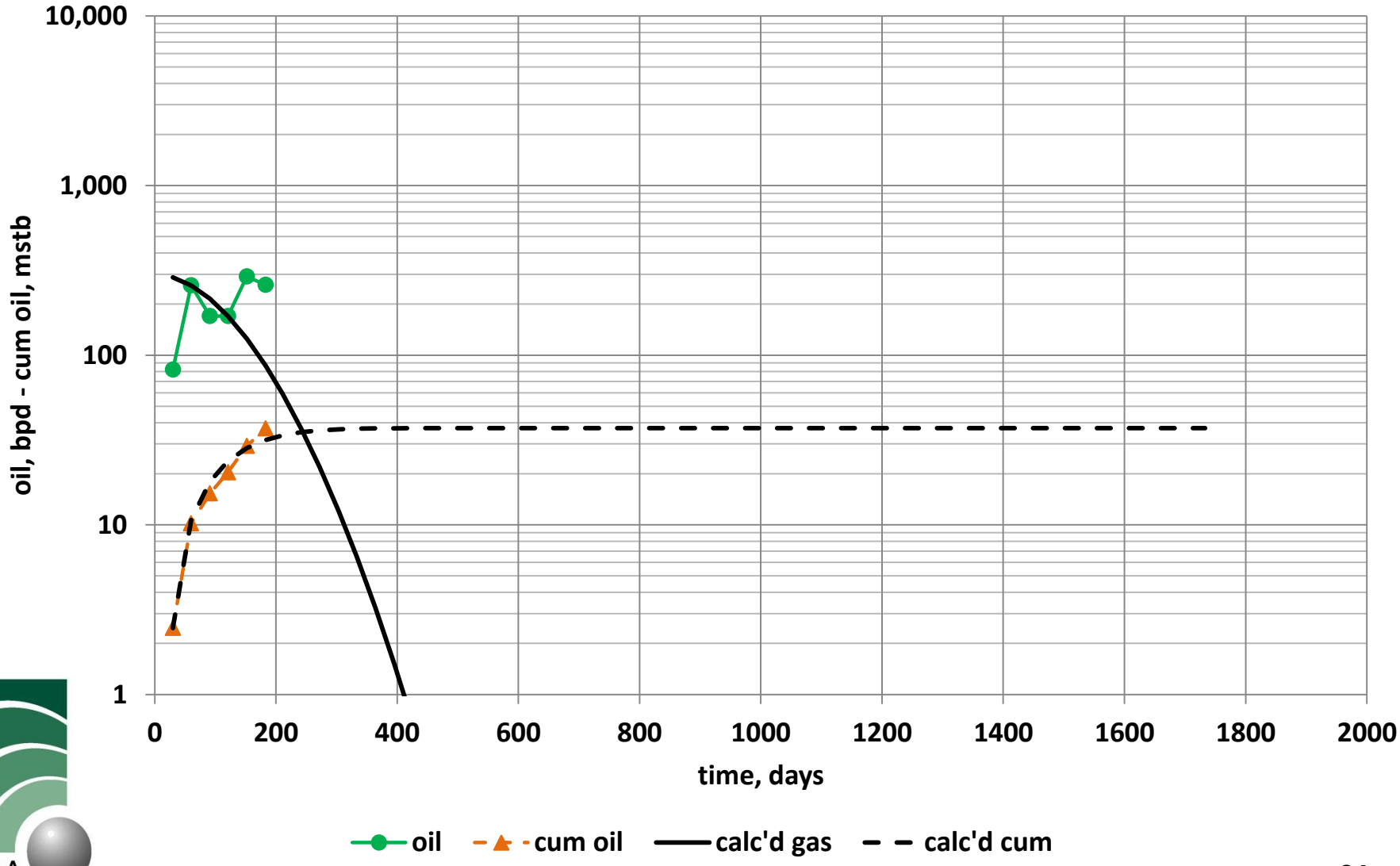
6 months – SEDM match & forecast



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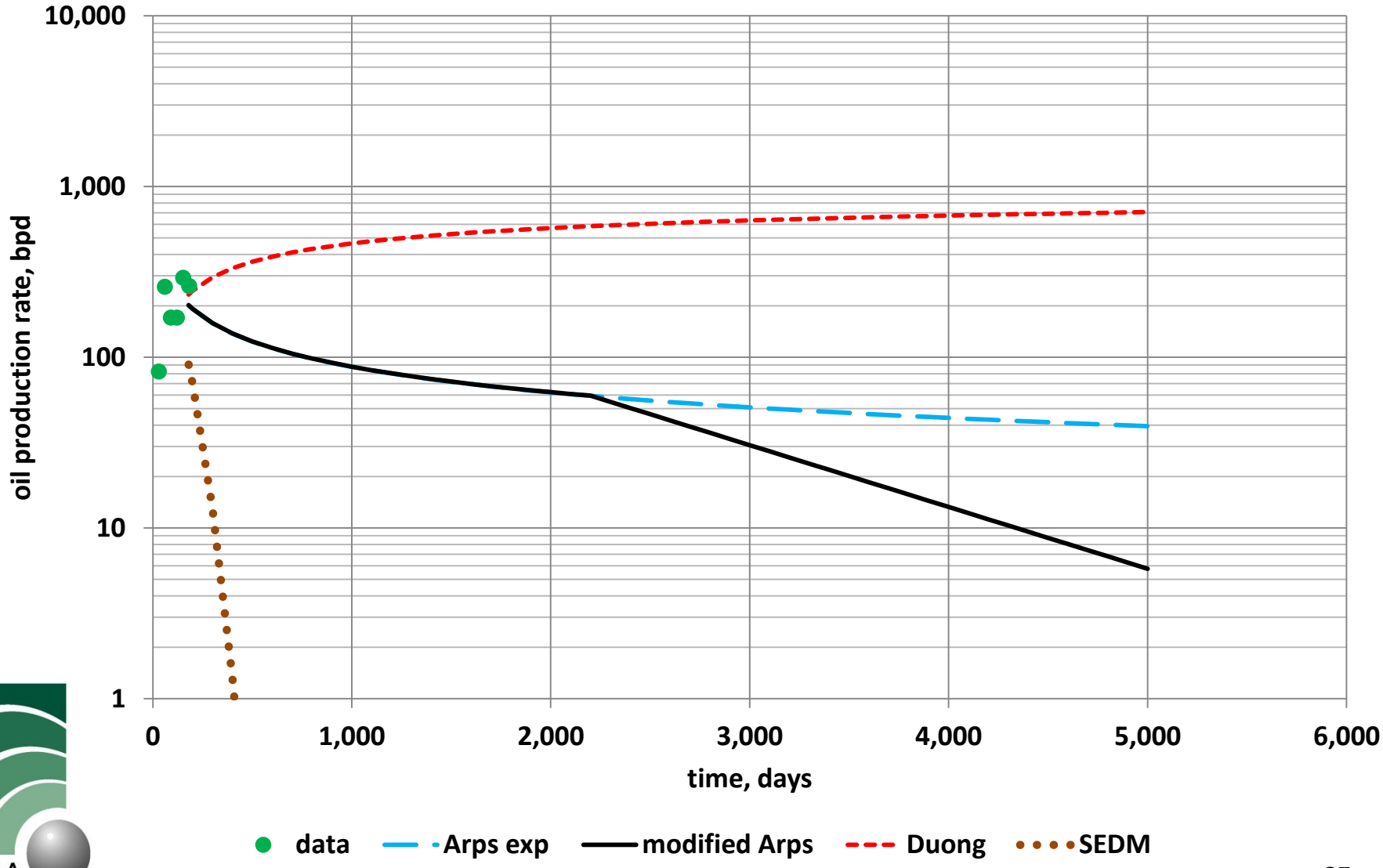
6 months – all models – rate forecasts



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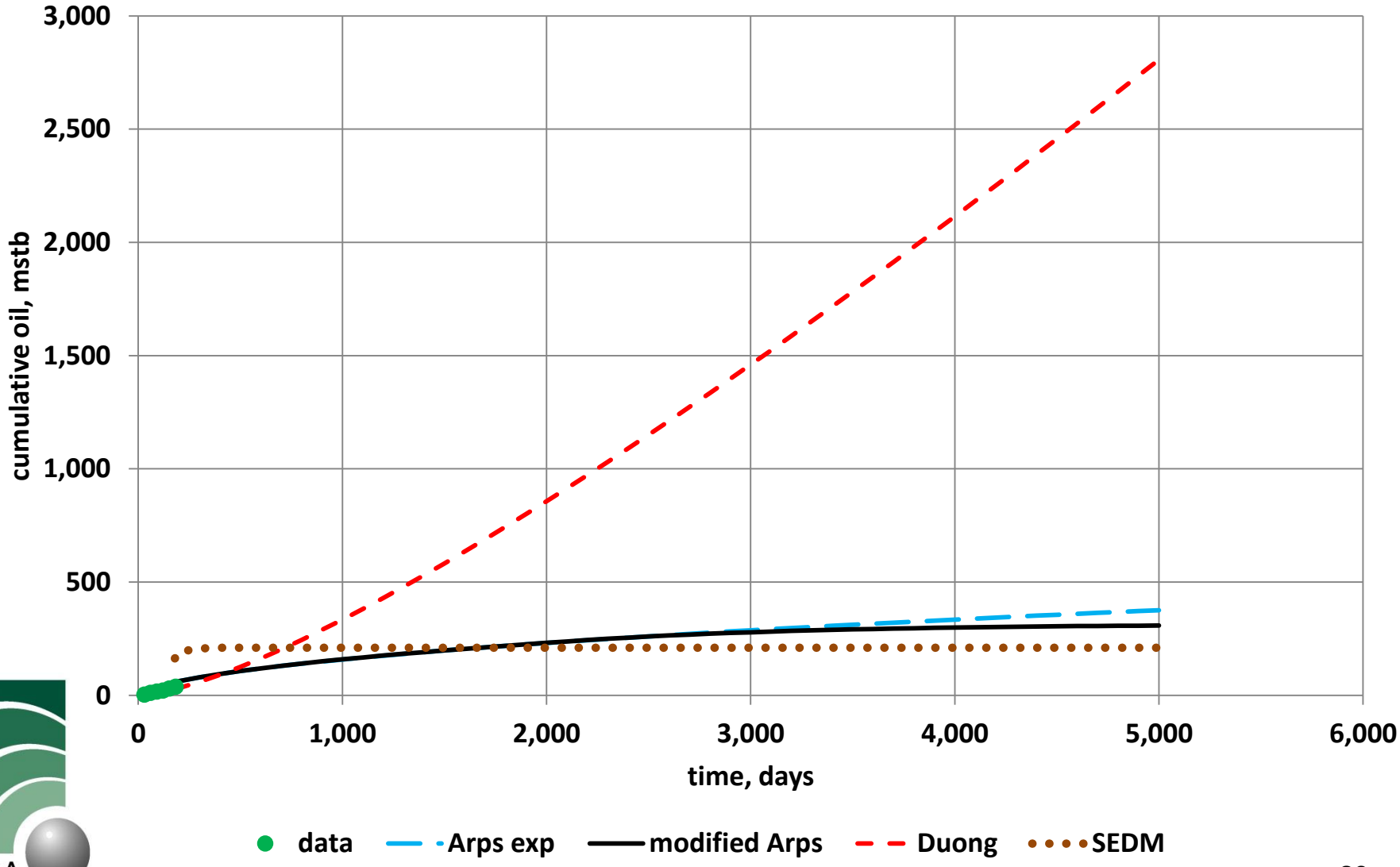
6 months – all models – cumulative forecasts



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6 months – EUR's & lifetimes

model	EUR, mstb	life, yrs
Arps	5,172	2,370
modified Arps	490	42
Duong	fails – rate inc	fails – rate inc
SEDM	43	1
hyperbolic	163	19
exponential	151	14

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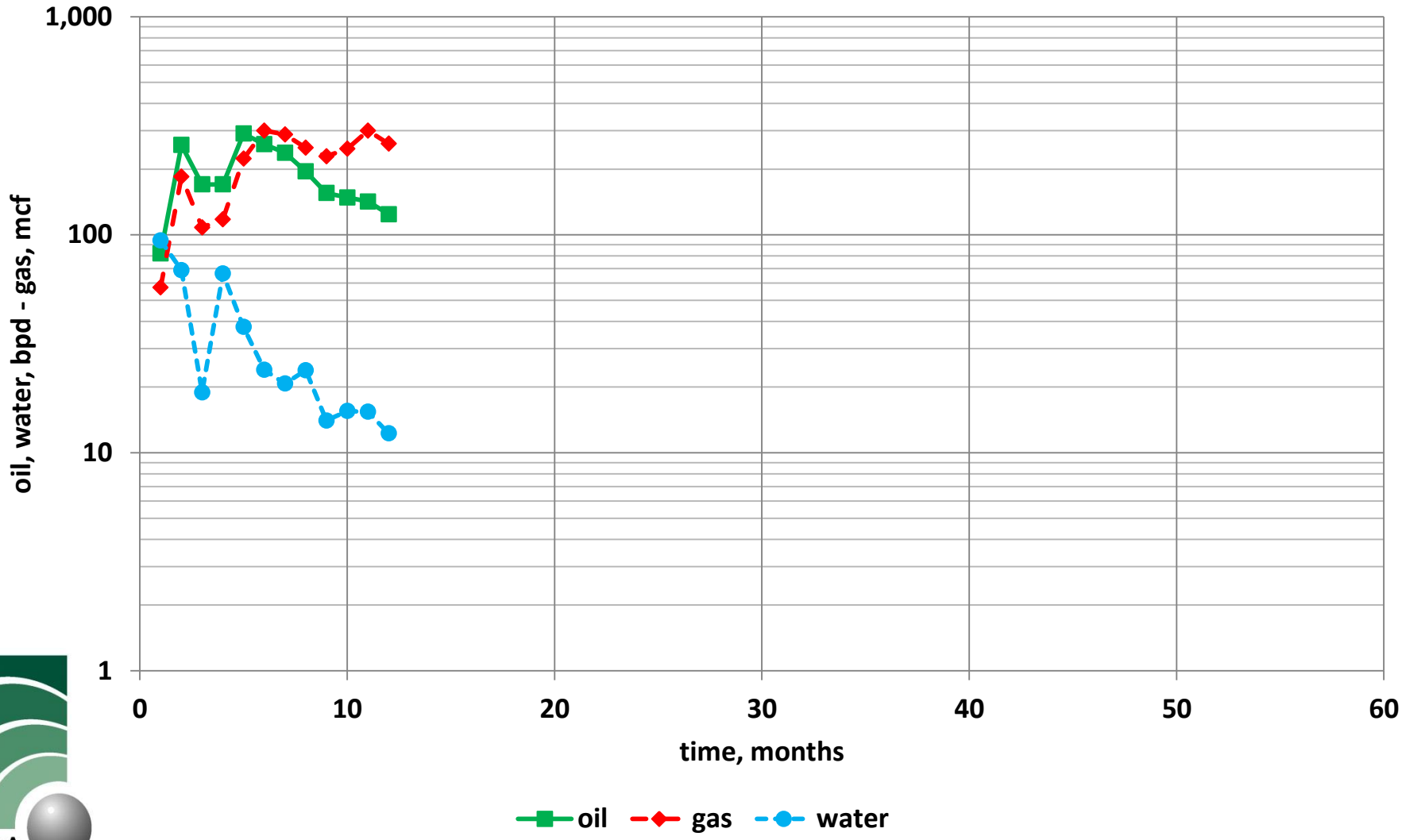
1 yr – production data



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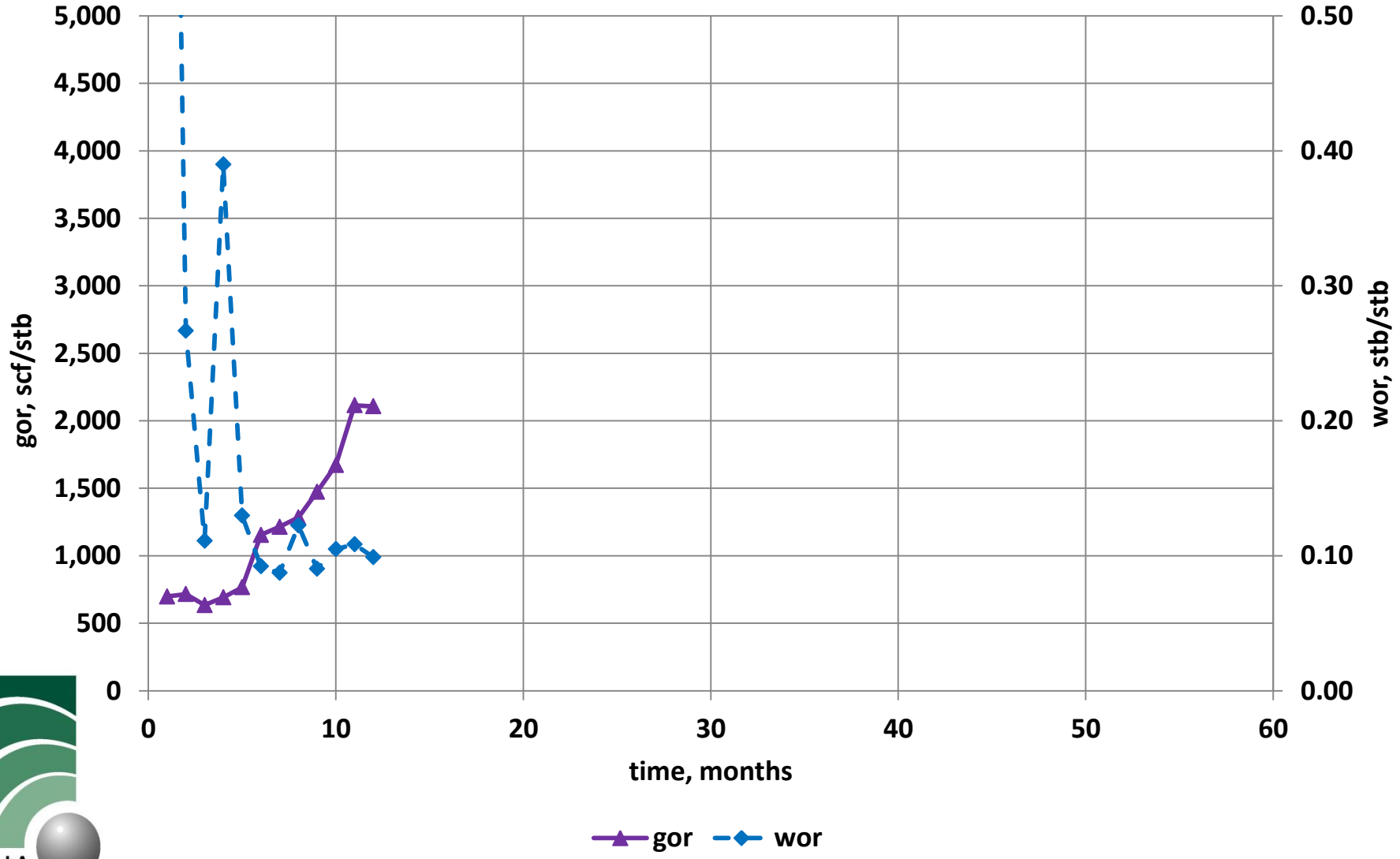
1 yr – GOR & WOR plot



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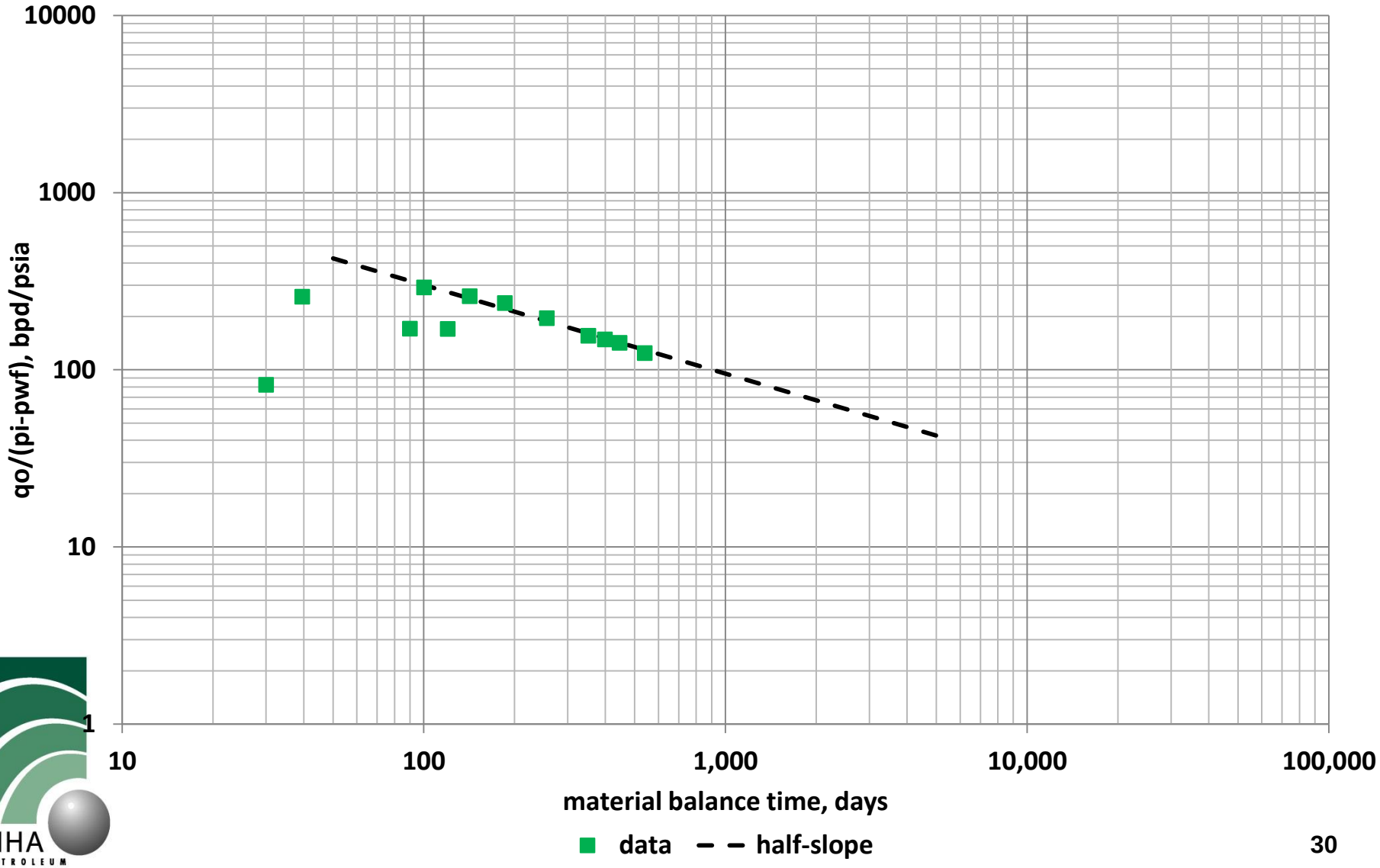
1 yr –
normalized rate vs material balance time plot



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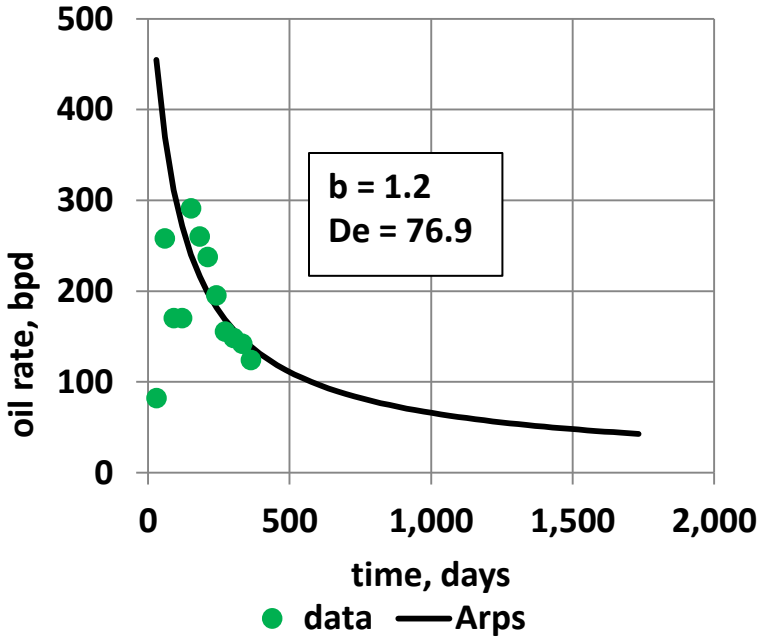
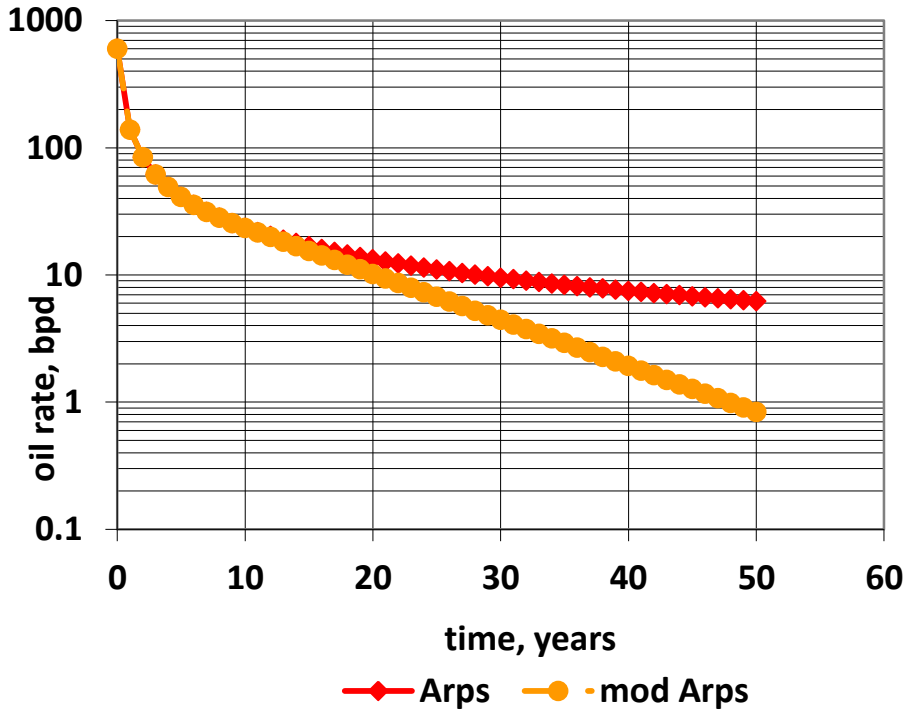
1 yr – Arps & modified Arps





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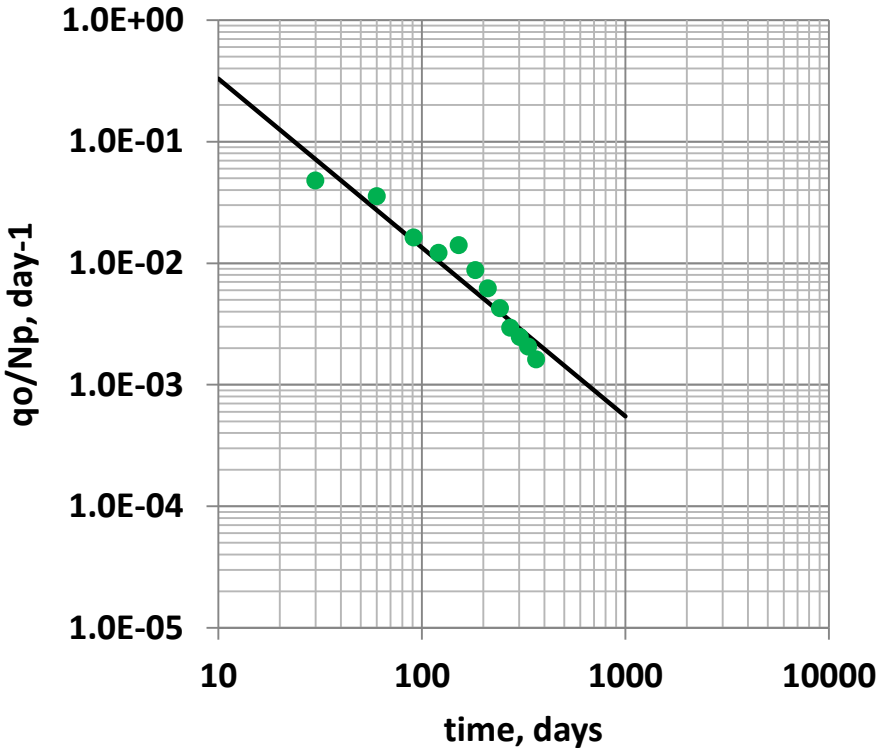
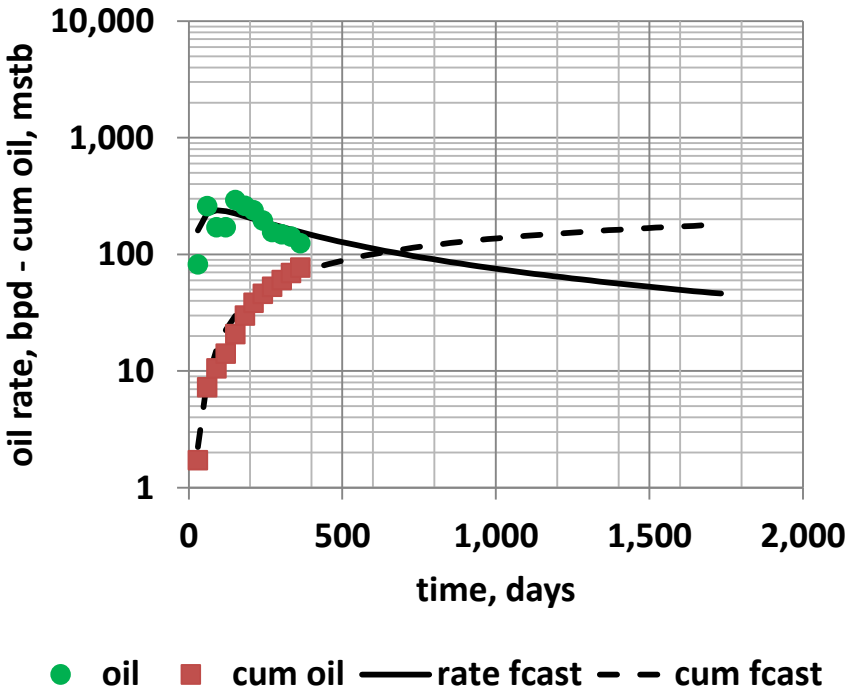
1 yr – Duong plot & match





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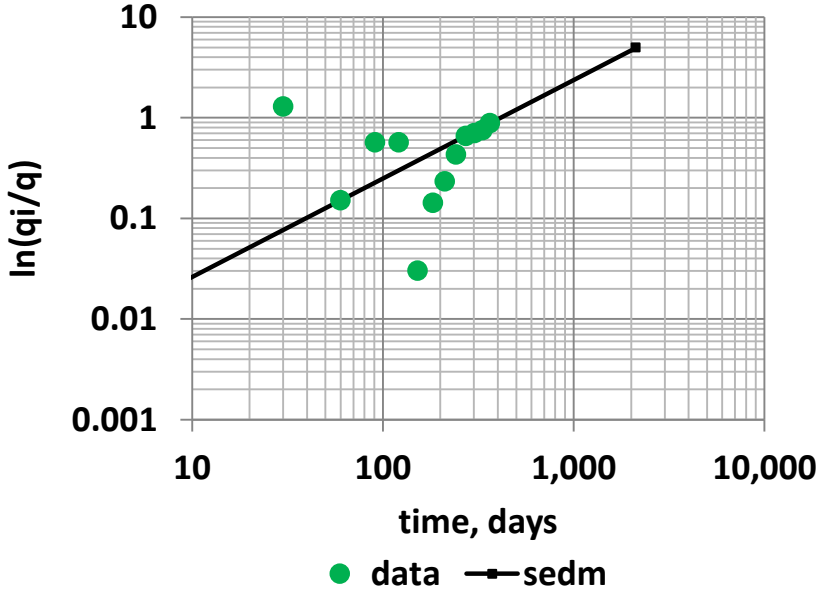
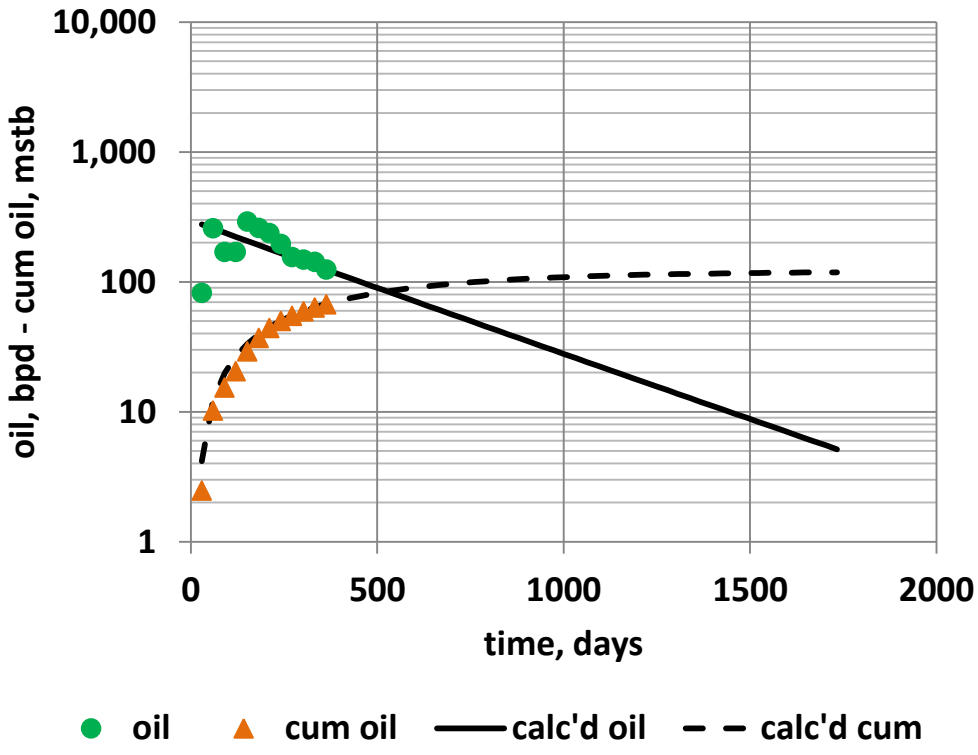
1 yr – SEDM plot & match





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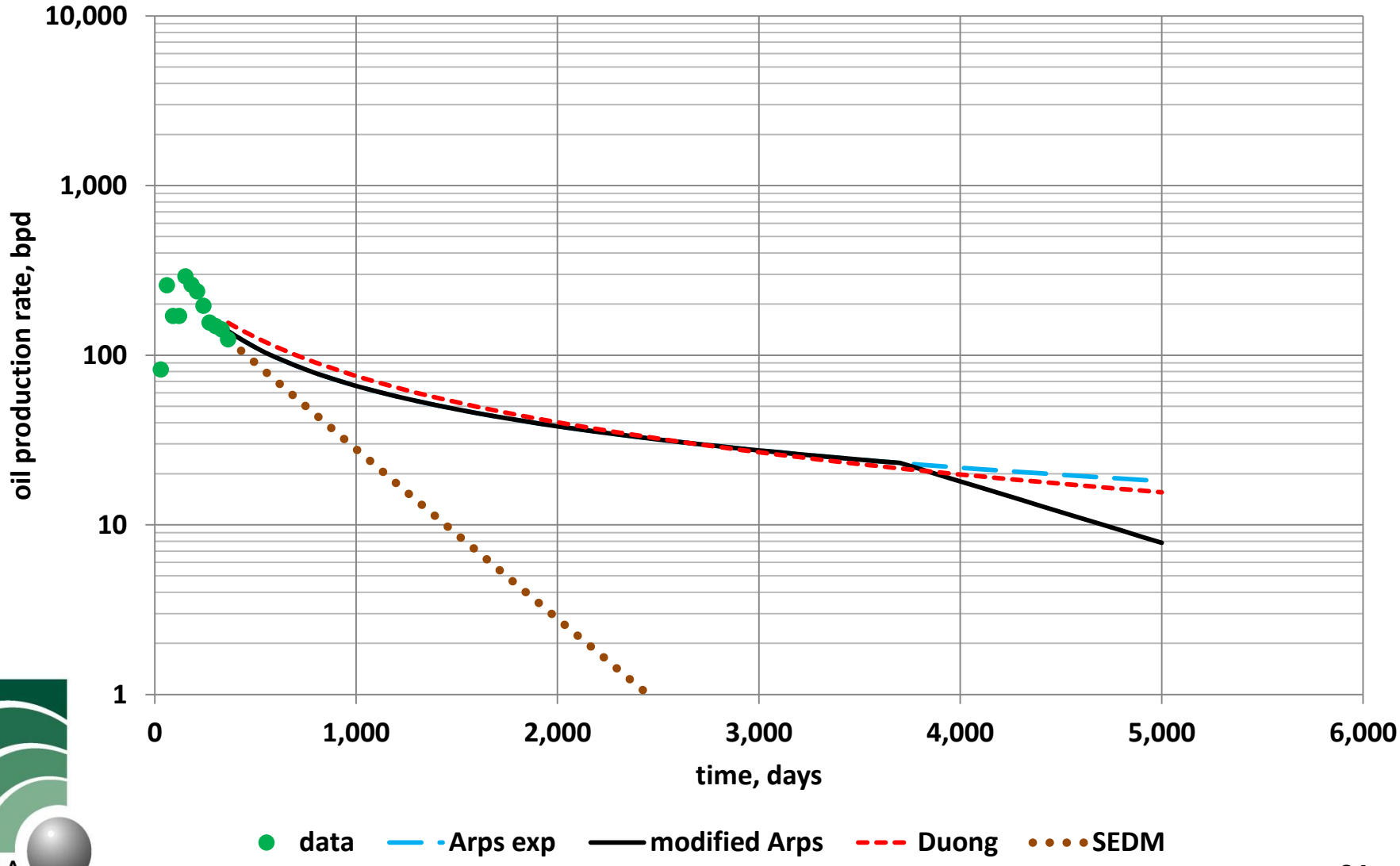
1 yr – all models – rate forecasts



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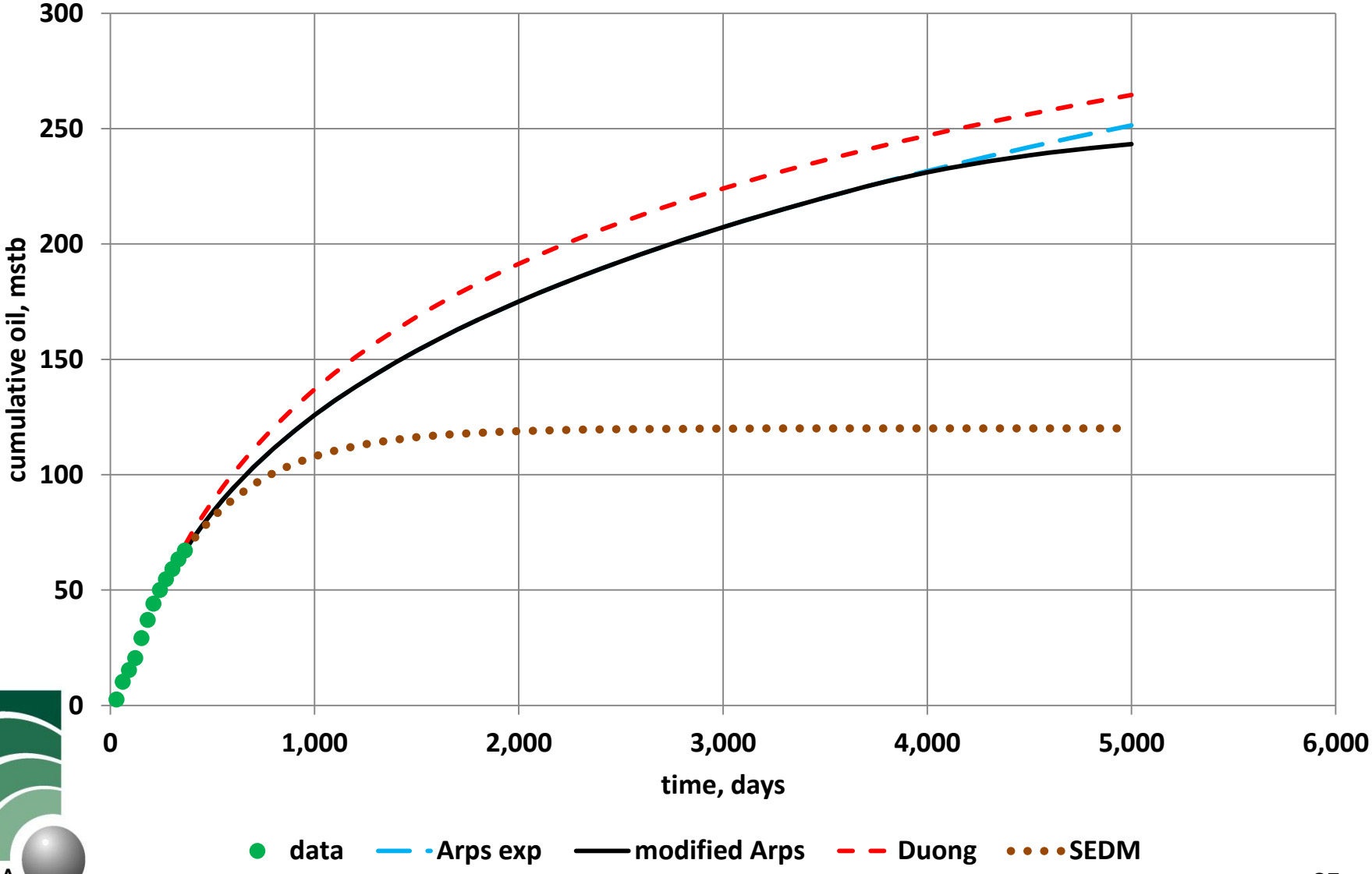
1 yr – all models – cumulative forecasts



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1 yr – EUR's & lifetimes

model	EUR, mstb	life, yrs
Arps	516	120
modified Arps	339	35
Duong	365	57
SEDM	124	5
hyperbolic	163	19
exponential	151	14

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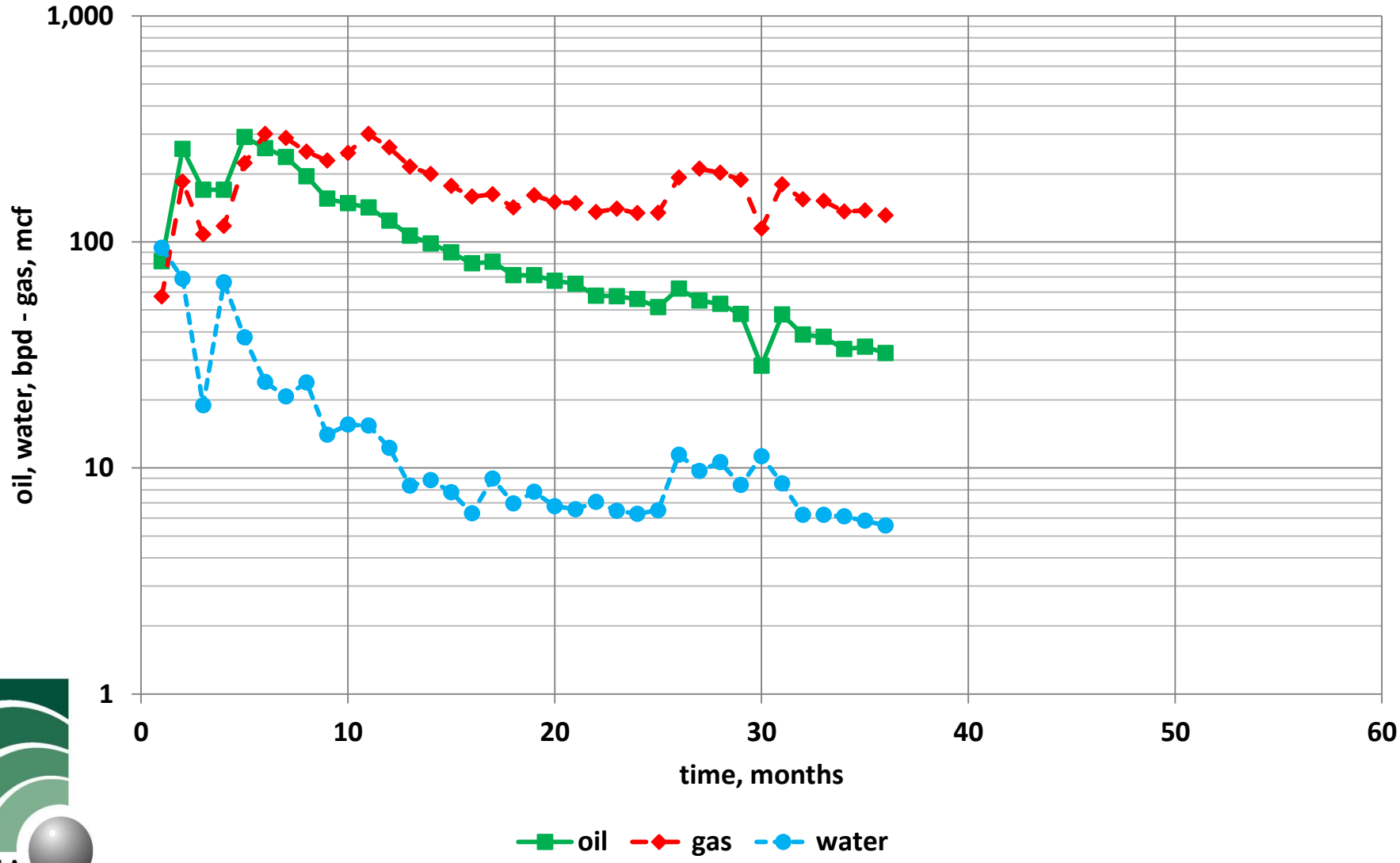
3 yrs – production data



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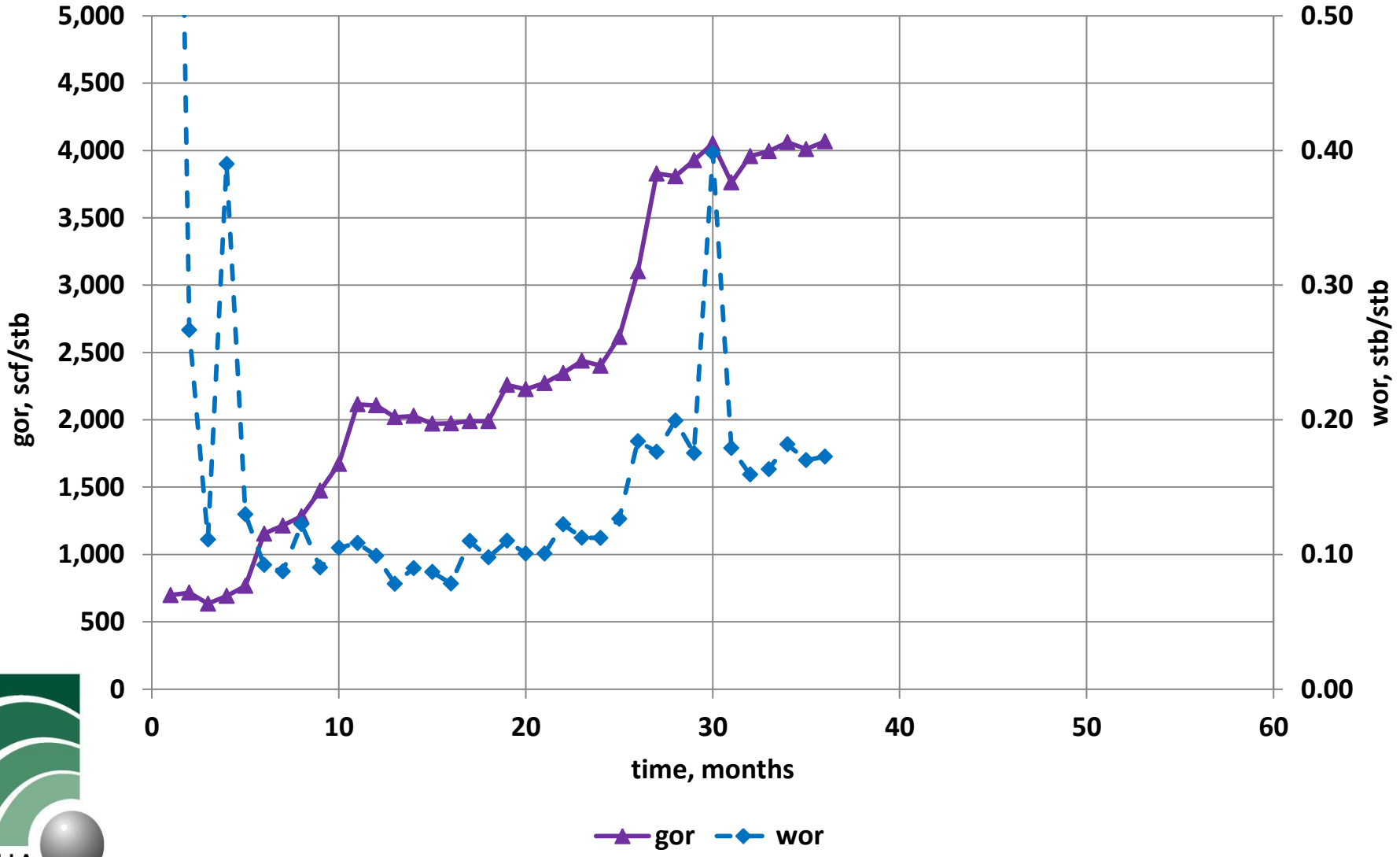
3 yrs – GOR & WOR plot



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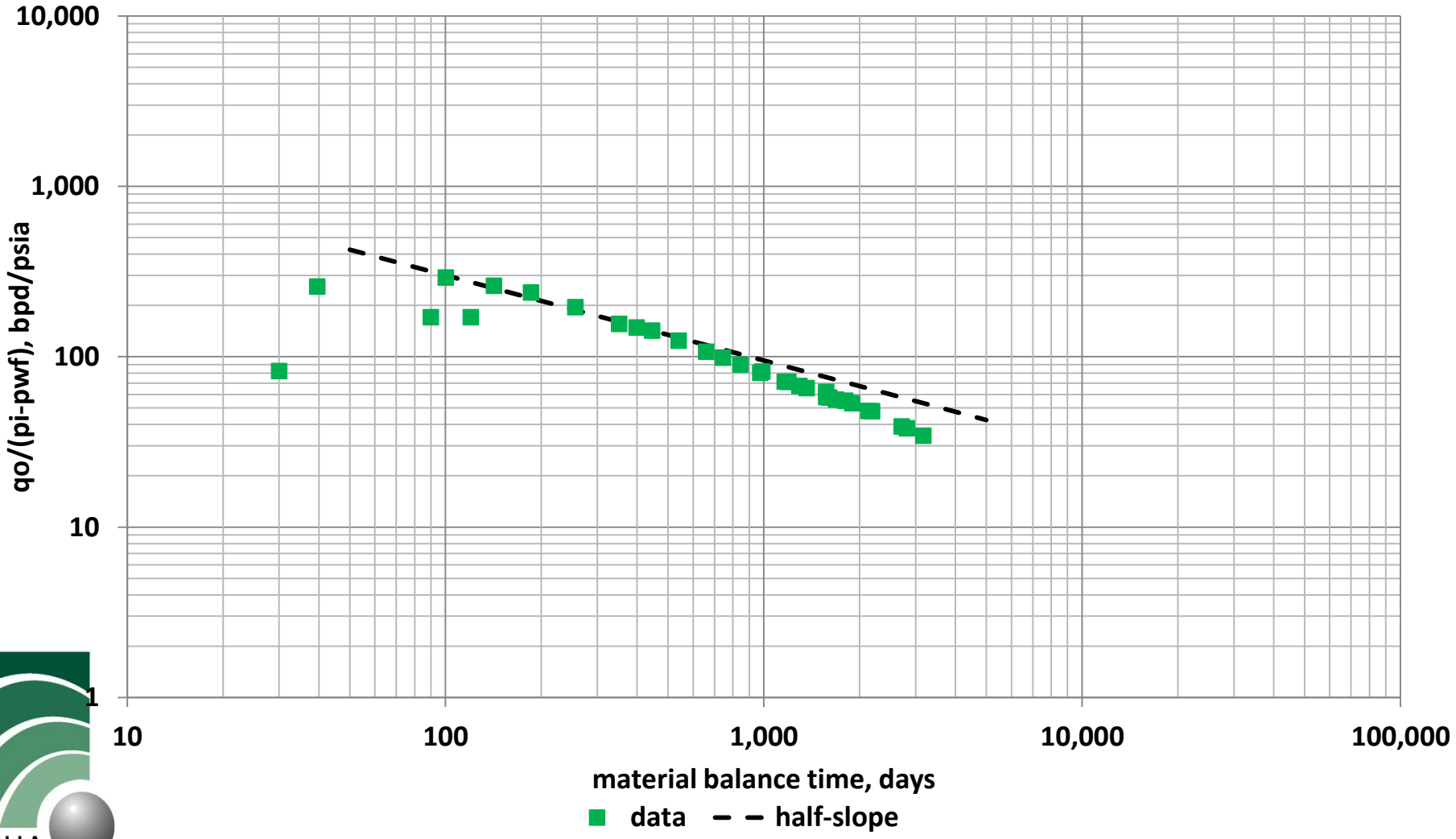
3 yrs –
normalized rate vs material balance time plot



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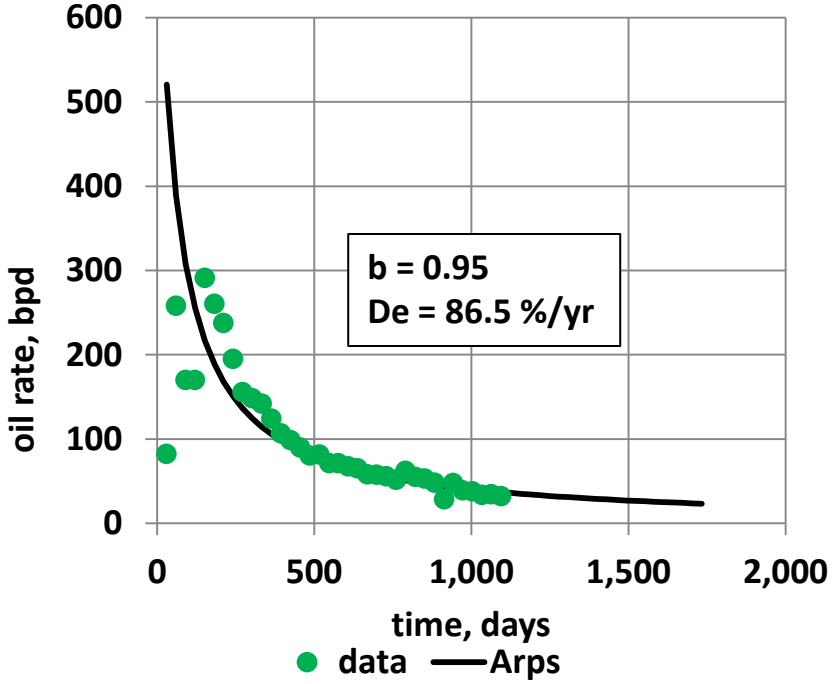
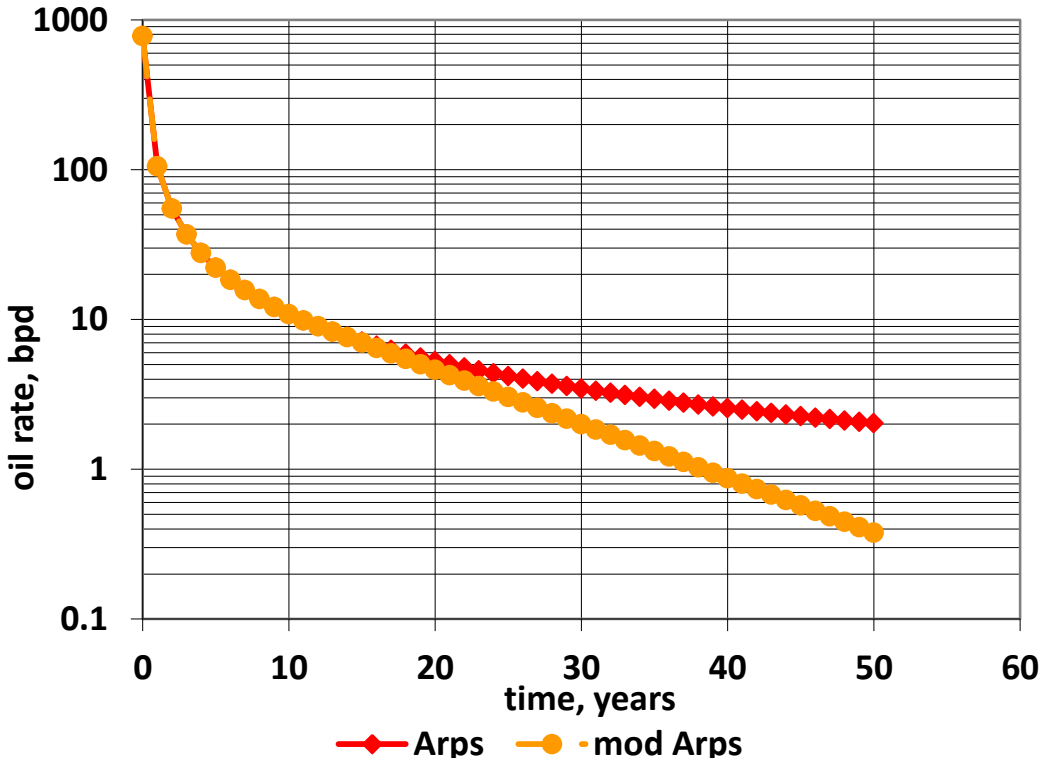
3 yrs – Arps & modified Arps





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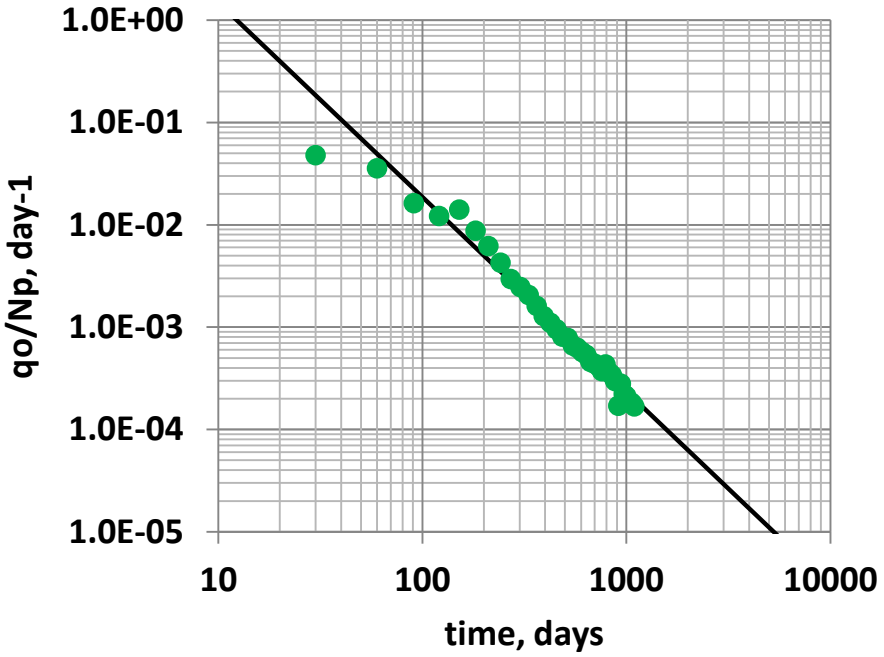
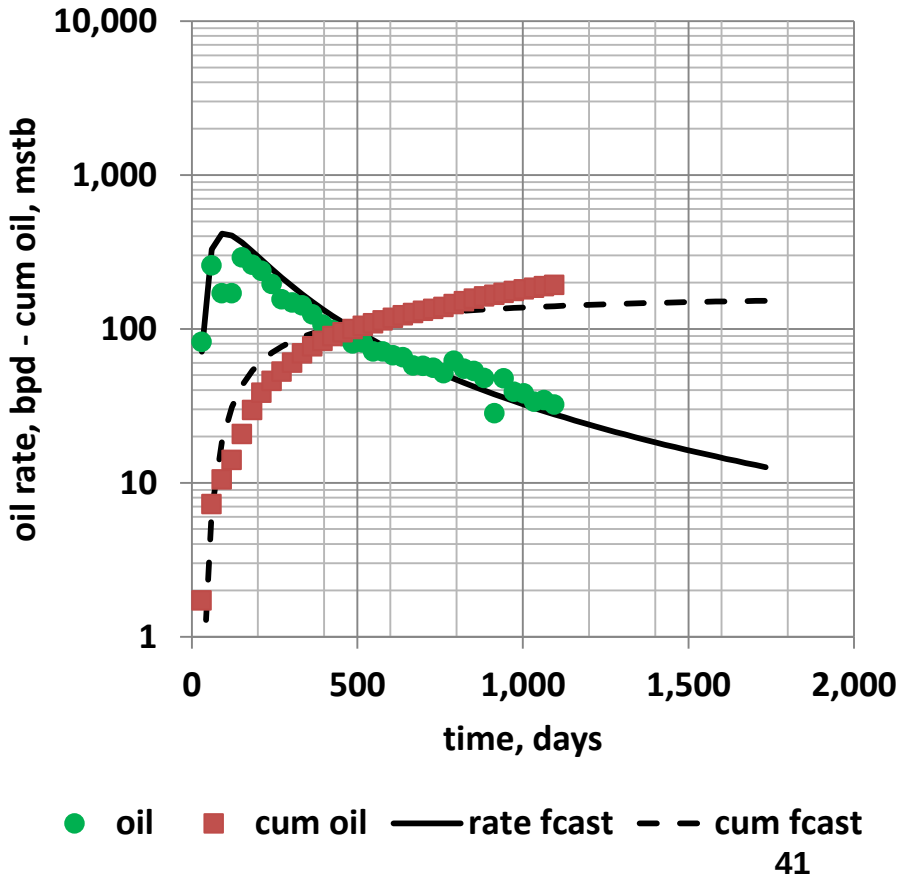
3 yrs – Duong plot & match





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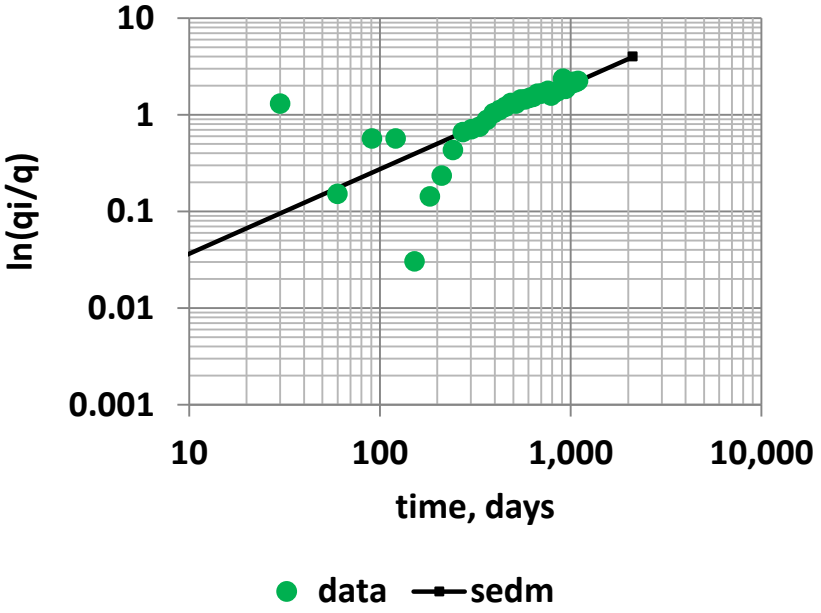
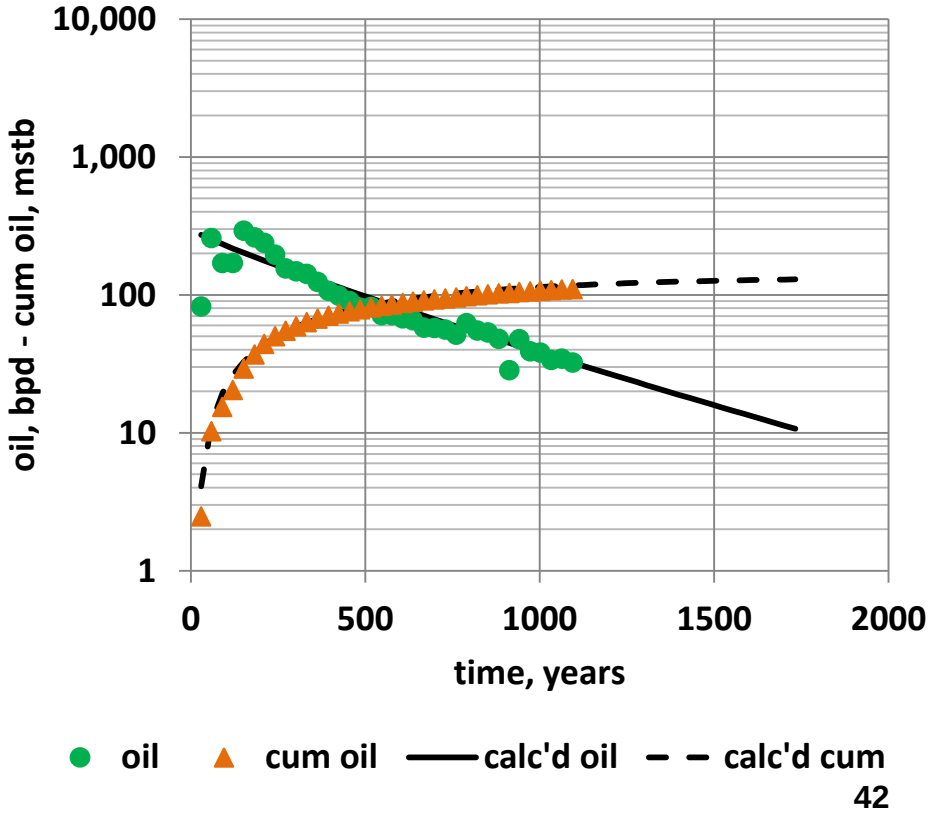
3 yrs – SEDM plot & match





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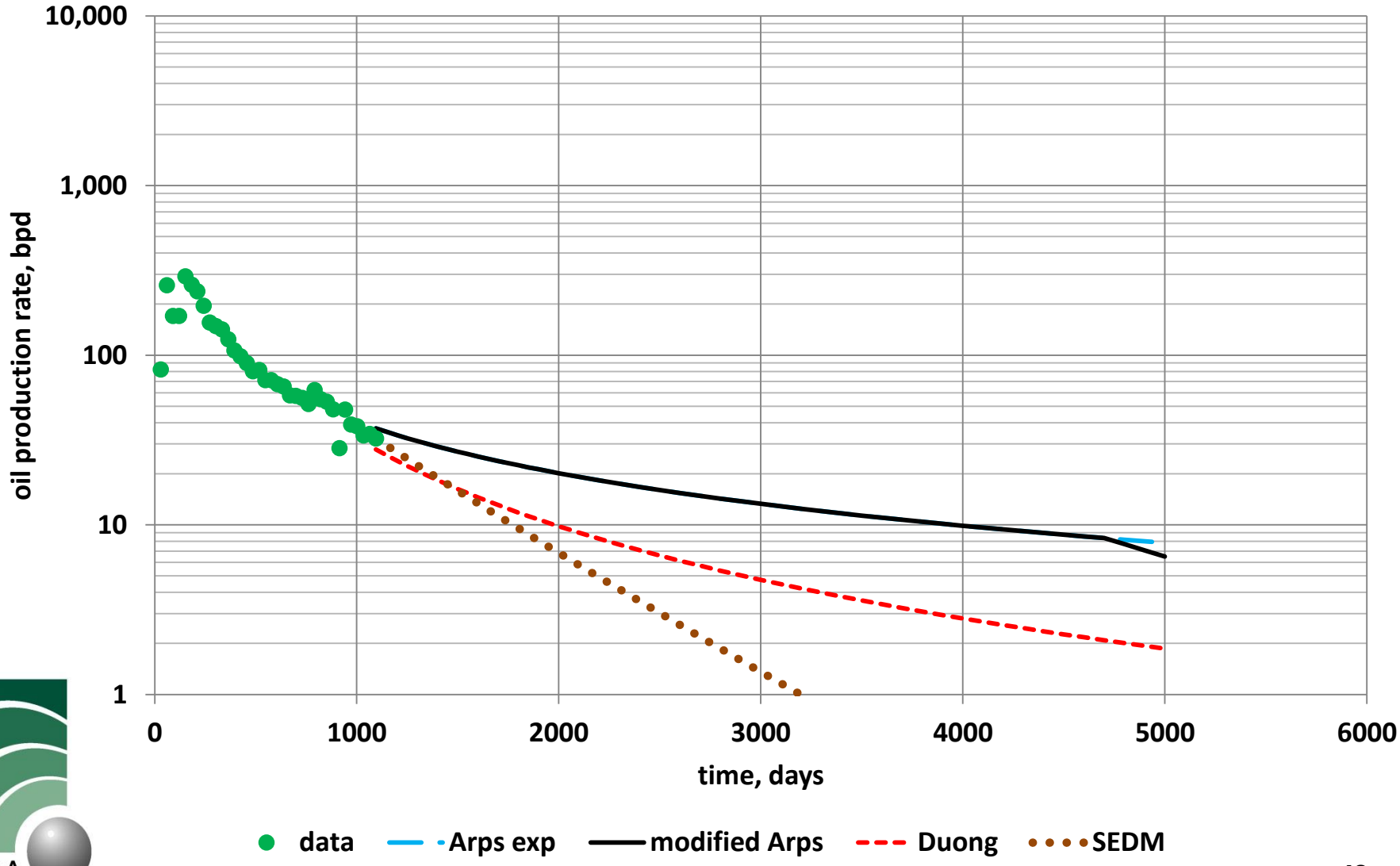
3 yrs – all models – rate forecasts



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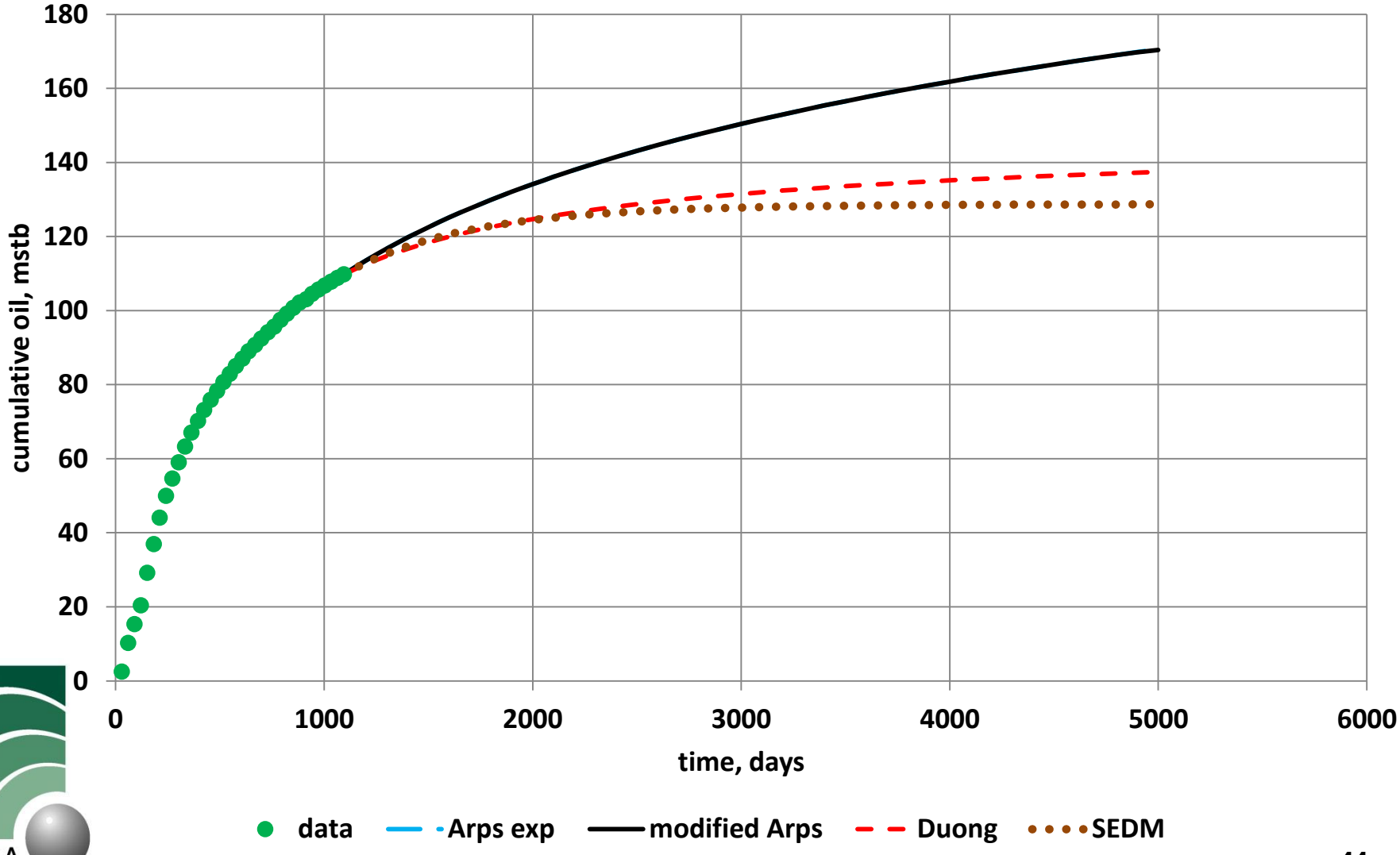
3 yrs – all models – cumulative forecasts



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3 yrs – EUR's & lifetimes

model	EUR, mstb	life, yrs
Arps	230	34
modified Arps	216	25
Duong	166	11
SEDM	139	7
hyperbolic	163	19
exponential	151	14

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Summary

- **Unconventional well rate forecasts often difficult because--**
  - **Multi-year transient flow – DCA problematic**
  - **Only rates, no pressures available – RTA problematic**
- **Solution - semi-empirical models & rates to predict performance**
- **Industry standard is modified Arps method**

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Summary - 2

- Mature DJ Niobrara well performance forecasted with—
  - Arps, modified Arps, Duong, and SEDM methods
  - 6 months, 1 year, and 3 years of production history
- None of the 4 methods considered--
  - Was clearly superior
  - Matched full history EUR
  - Only SEDM gives constant or increasing EUR with time

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Summary - 3

Estimated Ultimate Recoveries (mstb) by method & history interval

Method	6 mons	1 yr	3 yrs
Arps	5,172	516	230
Modified Arps	490	339	216
Duong	na	365	166
SEDM	43	124	139

EUR from current production = 157 mstb

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Recommendations for Unconventional Wells in Transient Flow

- **Continue to use modified Arps method to forecast future performance.**
- **Forecasts with modified Arps method are more accurate if constrained by offset and/or analogous wells—**
  - **Initial decline parameters – qi, b, Di**
  - **Terminal decline rate – De min**

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Thank you!

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