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Production Forecasting in Ultra-Low Permeability Reservoirs: Proposed Methodology

SPEE Central Texas Chapter Meeting

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DISCLAIMER

The comments conveyed herein represent informed opinions of the author about engineering methodology. The applicability of the interpretative guidance provided should be considered on a case by case basis.

Problem

- Extensive development of unconventional resources sheds light on problems with production forecasting and reserves estimation.
- The most used and easy method of production forecasting is Arps methodology in Decline Curve Analysis (DCA), but that method strictly applies only to the boundary dominated flow regime (BDF).
- For BDF, the strict limits of the hyperbolic exponent b are normally taken to be $0 \leq b \leq 1$.
- The ultra-low permeability of unconventional reservoirs (UCR) leads to extremely long transient flow periods, sometimes lasting for years.
- Several proposed forecasting methods have been developed to forecast UCR, but "superhyperbolic" schemes are the most used ($b>1$).

RTA and Production Forecasting

- Rate Transient Analysis (RTA) encompasses several methods of analysis.
  - But more data is required than for Arps
  - Also requires more time
  - When thorough RTA is performed, one well can take a day to analyze
  - RTA is not possible to do in a reasonable time if hundreds or thousands of wells are in the data set
- If groups of similar wells can be identified, RTA can be done on a few wells in each set and good parameters can be estimated.
- This is possible with modern software.

Further Considerations

- One of the methods considered as Advanced DCA is Fetkovich type curve analysis.
  - Note: We will distinguish between type wells (curve shapes generated from averaging well production histories) and type curves (curve shapes based on analytical models)
- Fetkovich type curves were the beginning of the Advanced DCA school.
  - Other type curves have been proposed (Agarwal-Gardner, Blasingame, e.g.)
  - Many of the other curves require pressure data, which is often not available to a reserves evaluator
  - Also use of pressure data extends the time required to analyze wells, as mentioned before

Further Considerations

- The method I discuss today is a work in progress.
- More work is ongoing to improve work flow and validate the ideas.
- There are several references that are useful:
  - IHS Fekete technical notes
  - John D. Wright, Oil and Gas Property Evaluation (Alpha Test Edition), 2013, particularly Chapter 5
  - Bob Bachman, "Production Forecasting for Reserves Determination: A time to re-think old techniques?", Calgary SPE Technical Luncheon, January 10, 2011
  - Michael Golan and Curtis Whitson, Well Performance (2nd Edition, 1991), Chapter 4 in particular
  - Dr. W. John Lee, "Production Forecasting for Unconventional Resources", Class given at SPE ATCE, 2011

Further Considerations

- Useful References (cont.)
  - J. J. Arps, “Analysis of Decline Curves”, SPE 945228 (in One Petro), 1944.
  - Mike J. Fetkovich, Advances in Well Deliverability and Production Forecasting, Dissertation submitted to University of Trondheim for Doctor of Technical Sciences, 1988. (This dissertation contains most of Fetkovich’s and his coauthors’ papers in the area of production forecasting.)
  - There are numerous other papers and books available that address this issue. This is an area of active research.
  - Most of the papers and Mike Fetkovich’s dissertation are available online through Internet searches.
  - Recent research by Boyd Russell and Randy Freeborn (both of Energy Navigator)

General Work Flow

- Obtain production data.
- Import data to desired program. This includes commercial economic programs or analysis programs (ARIES, PhD Win, Fekete Harmony, e.g.)
- Review the data to ensure reasonably smooth production histories (no frequent re-stimulations, for example).
- Autofit the acceptable data to obtain Estimated Ultimate Recoveries (EURs) for the well set. At this stage, the autofits do not have to be excellent or even very good.
- Group the wells by EUR. Since we generally look for low, mid, and high cases, division by thirds is used. Curve shapes may not be the same (poor wells may not have the same decline curve shape as good wells).

General Work Flow (cont.)

- Review the wells in a group. If possible, select two or three wells with reasonably smooth production histories and prepare diagnostic plots or type curve analyses (such as Fetkovich type curves) to estimate length of transient flow.
- Fit the data with appropriate b and D_i values, including transient and BDF periods. This may be the type curve approach or the type well approach, depending on time constraints and data quality.
- Use the b and D_i values obtained from the comprehensive analysis to fit all the wells in the group.
- Modify the fits to obtain acceptable engineering forecasts.
- If any well does not seem to belong to a group, move to another group as required.
- In all cases, review the fits with all available data, which should be done as a routine matter for all reserves estimates.

General Work Flow (cont.)

- This should lead to better forecasts than simply autofitting each individual case. (We hope!)
- Once a field has been analyzed, new wells should be examined with EUR estimates and placed into the appropriate group. One very good principle to follow is that new wells should have a minimum of 90 days of production history that indicate a clear decline trend.
- Review not only the simple statistics of the data set, but also review the spatial statistics of the well set to see if there is a grouping by area of the different groups.
- The map on the following slide shows Group 1 in red, Group 2 in blue, and Group 3 in green. Note that while some wells in Group 3 are mixed in the Group 1 and 2 wells, they largely lie to the north on the fringe of the better area.

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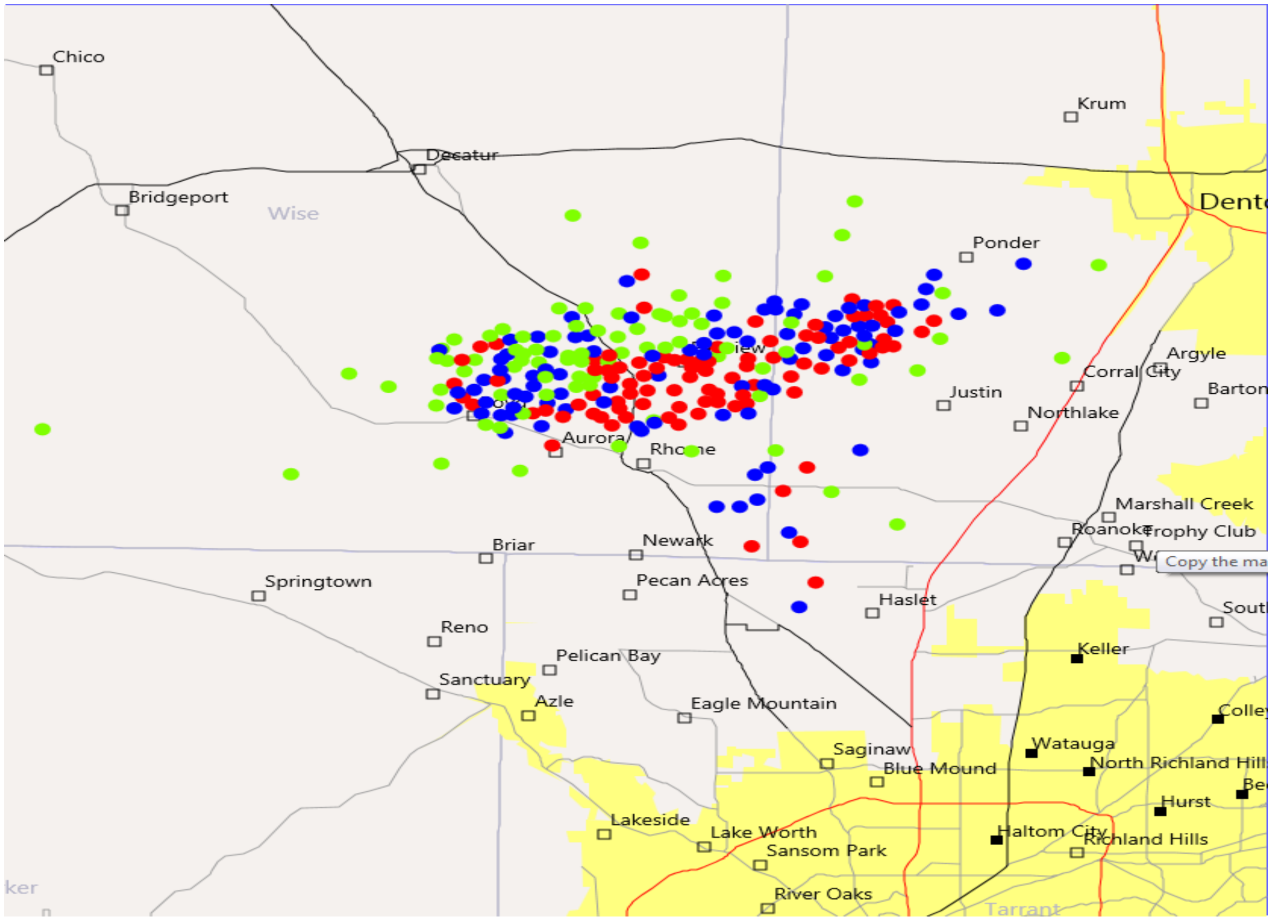
MAP OF WELLS IN DATA SET



Legend:

Group 1 = RED

Group 2 = BLUE

Group 3 = GREEN

Case Example

Barnett Shale Vertical Wells

Barnett Shale Vertical Wells

- Older vertical wells from the Barnett Shale (Newark, East field) were selected and monthly production data downloaded from HPDI. The data set totaled 265 wells.
- The data was uploaded into PhDWin and ARIES.
- Autofit of the data in PHDWin was done on all wells. Some of the fits were not useable as a final product, but they gave a first pass at EURs.
- Two wells were selected from each of the groups (91 wells for the top two groups, 90 for the last group). Diagnostic log-log plots were prepared, and the data was fit to Fetkovich type curves.
- Hyperbolic b exponent and initial decline rate D_i were estimated, and the resulting values were used for the other wells in the group.

Barnett Shale Vertical Wells

- Results were acceptable and improved the overall production forecasting in the well set.
- Example curves for one well (Bryan-Askey GU 1) and the type wells are shown in the following slides.
- Note the shape of the type wells. They are distorted because many of the wells were re-stimulated. More comprehensive analysis will be done in the future to refine the process.
- The curves include the curve fit in PhD Win, the Fetkovich type curve plot from RTA in Fekete Harmony, and an Excel plot showing half slope (transient linear flow model) for much of the second flow period.
- The Excel plot uses first order material balance time as defined by Blasingame (cumulative divided by rate).

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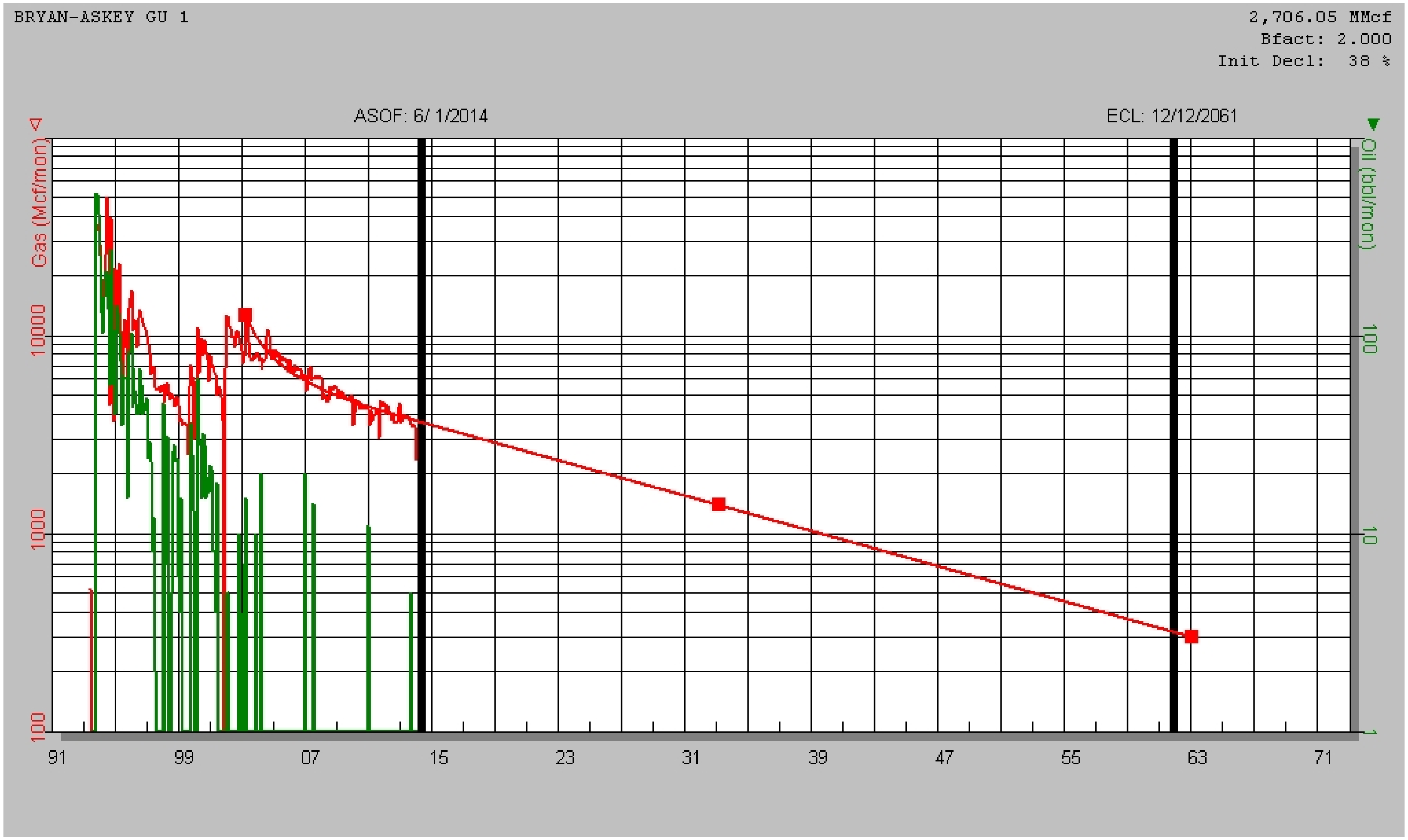
Bryan-Askey GU 1 Plot from PhD Win



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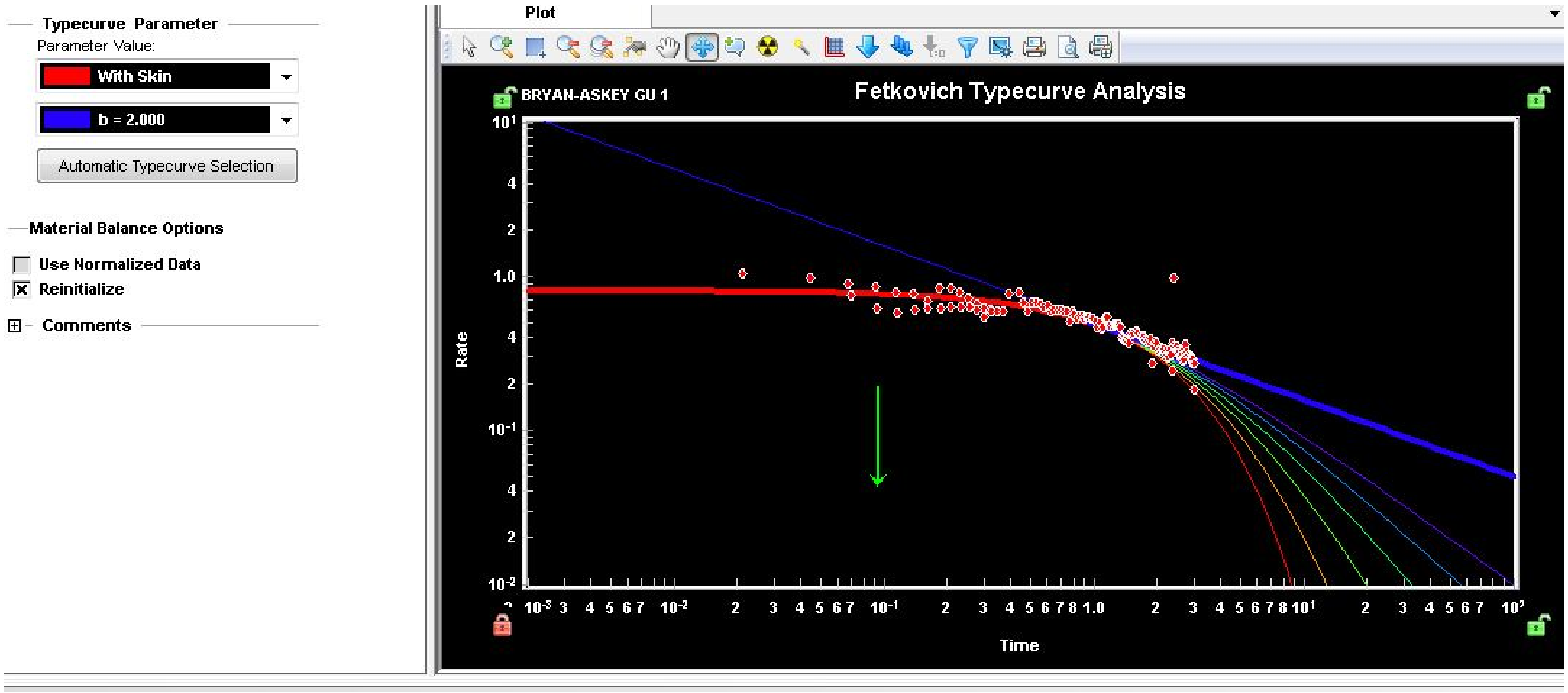
Bryan-Askey GU 1 Fetkovich Plot from Fekete Harmony



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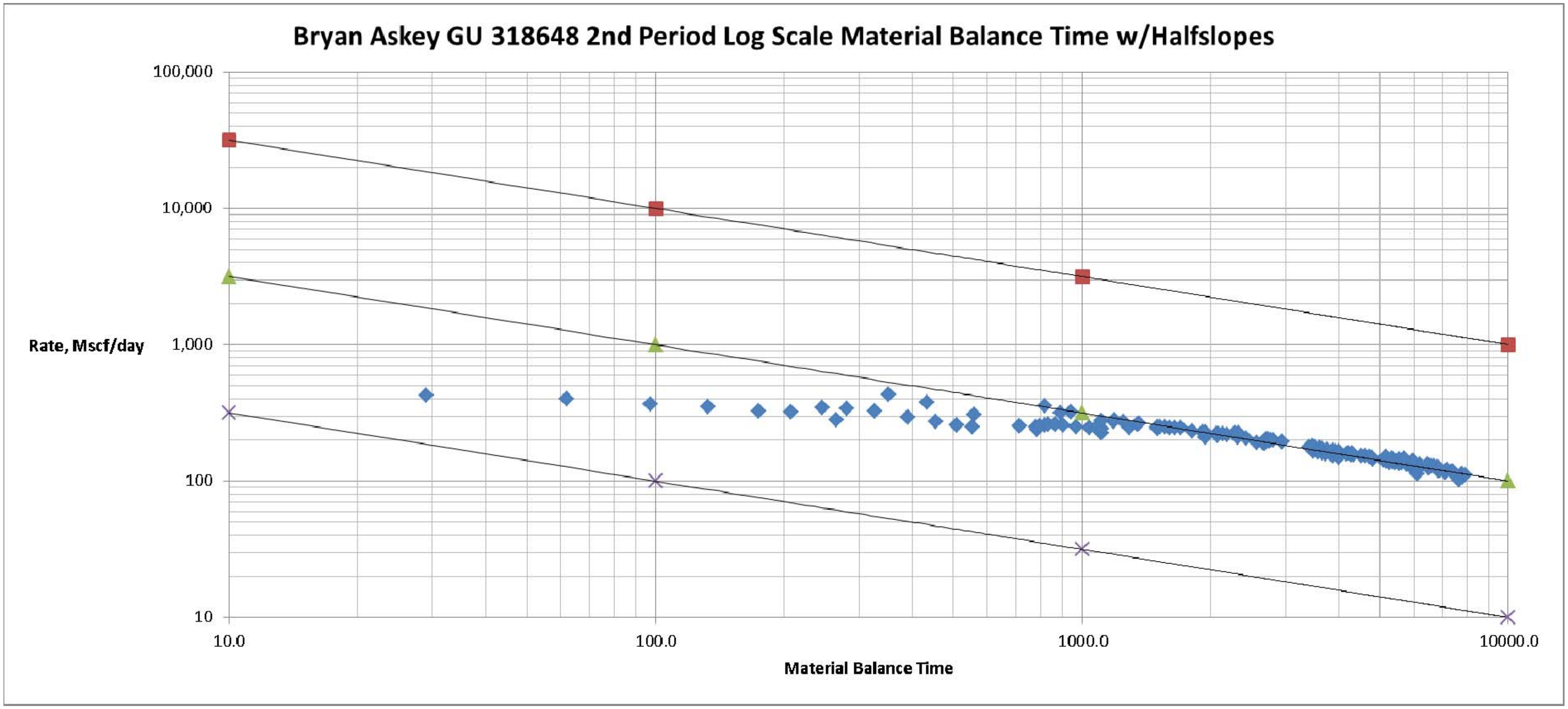

Normal Practice for Type Wells

- In most cases, a group of wells is selected and normalized with respect to time and maximum rate.
- The average curve is calculated using the period where the well count is relatively stable.
- A curve fit is then calculated to estimate decline curve parameters.
- The following plots show such a methodology for the 3 groups of Barnett vertical wells.
- Note the unusual shapes of the curves.
- The initial flow regime displays transient linear flow with a b of 2 for all groups.
- The time to a change to the curve shape is different for the three groups: approximately 4 years for Group 1, 4.5 years for Group 2, and 3.5 years for Group 3. Initial rates and declines and EURs change for each group.

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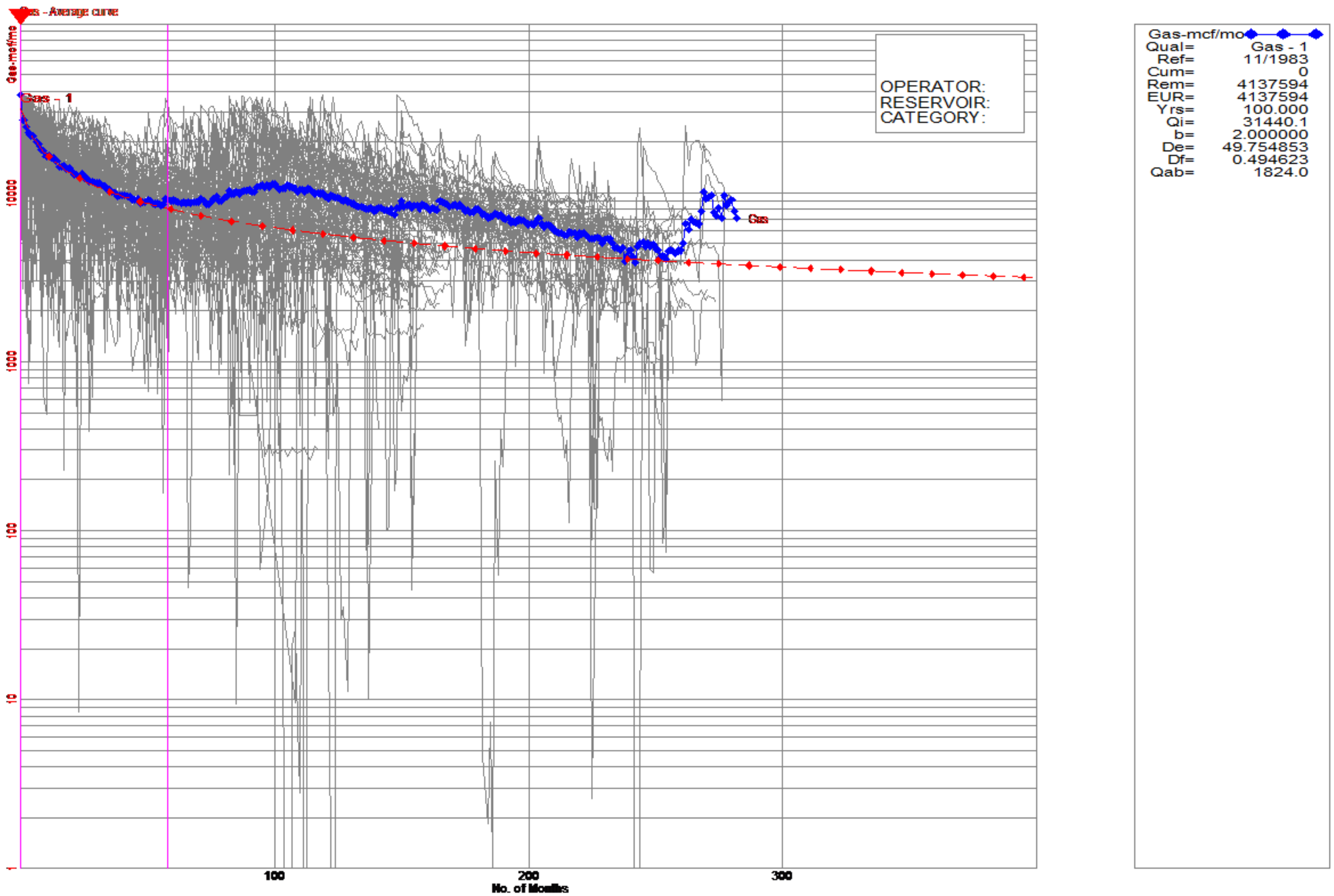
RYDER SCOTT

Barnett Group 1 Wells (High EUR Case)



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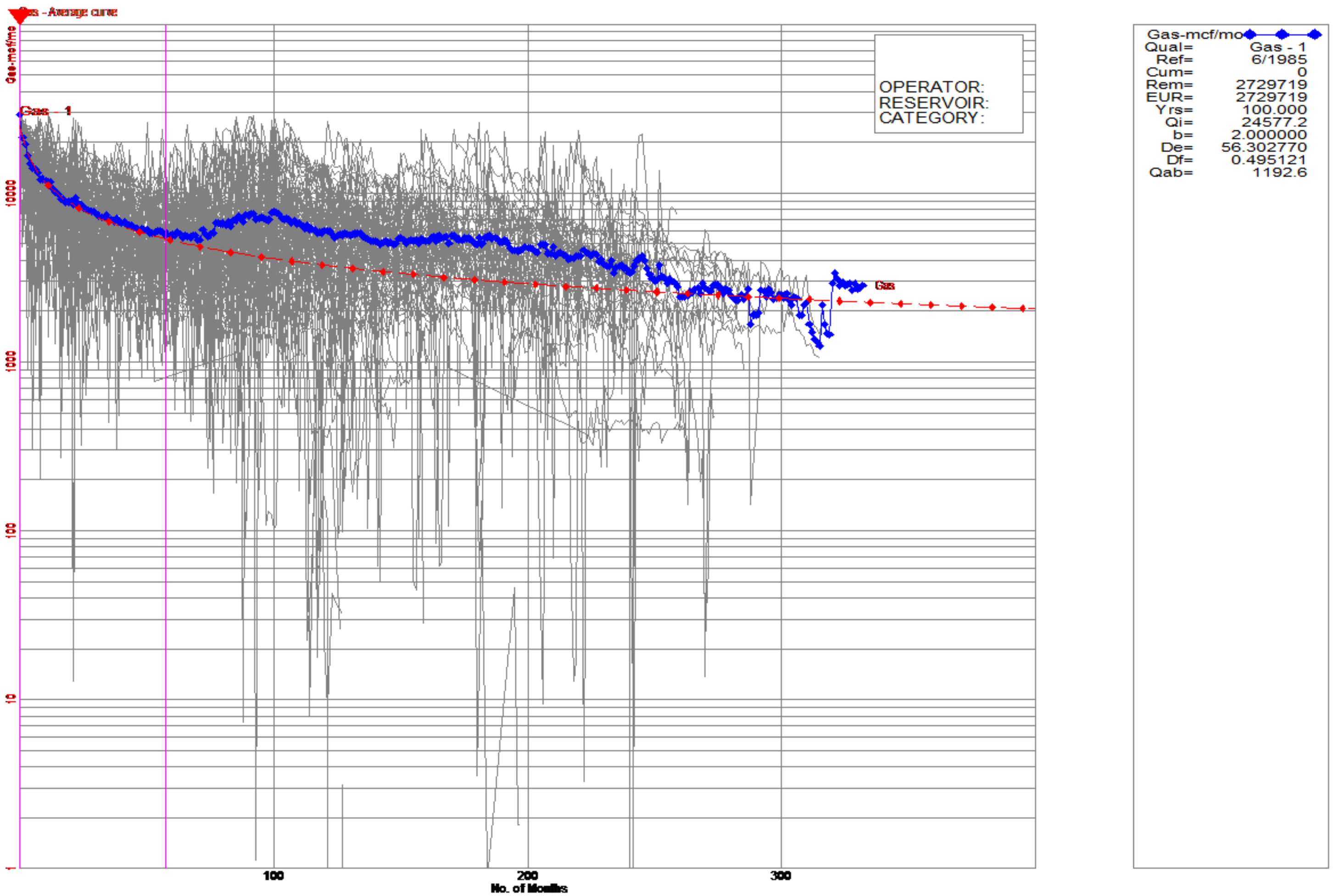
Barnett Group 2 Wells (Middle EUR Case)



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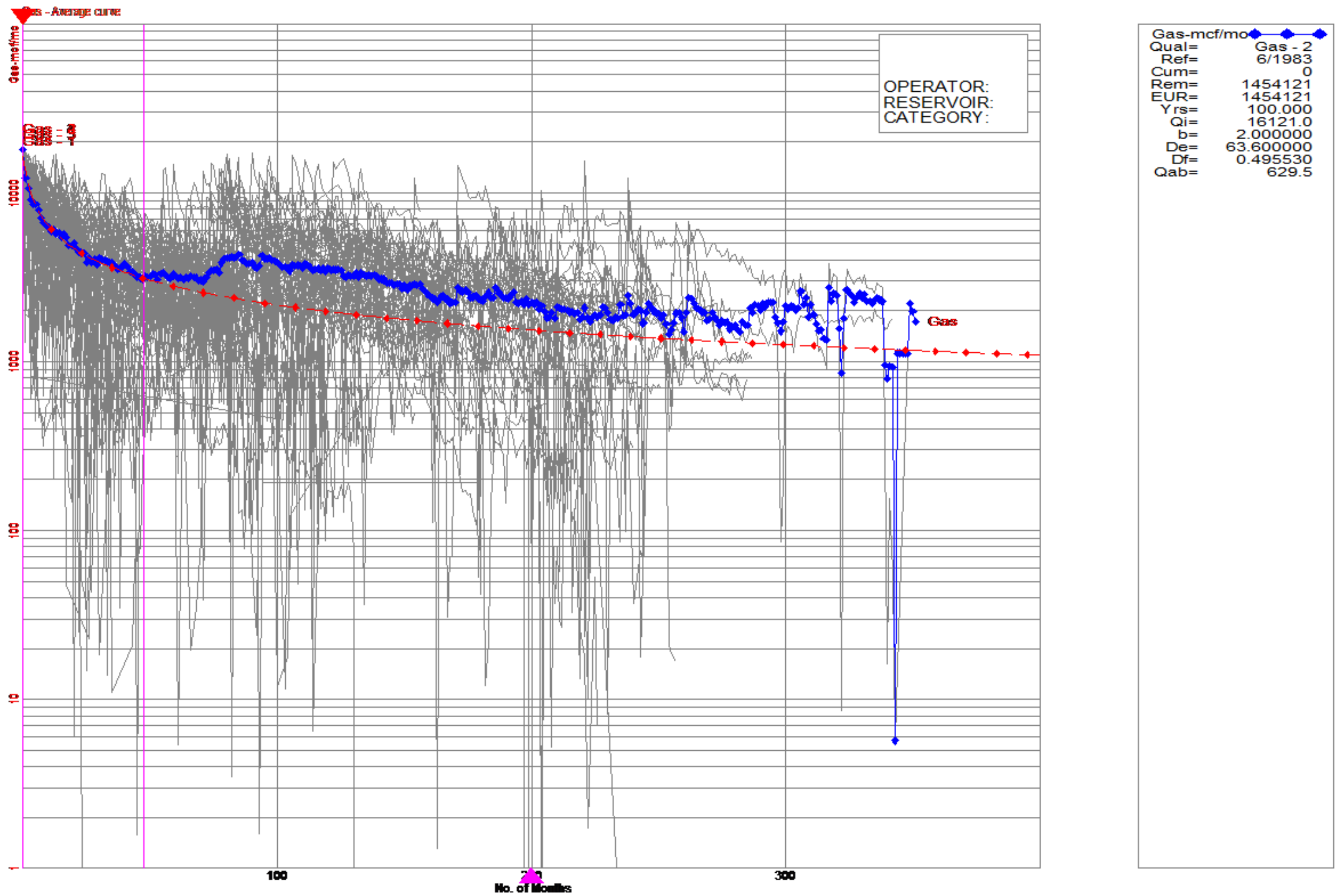
Barnett Group 3 Wells (Low EUR Case)



The Perils of the Normal Practice for Type Wells

- The following two slides show plots from the data. (The Currie-Blasingame spreadsheet, which is distributed freely and generously by Dr. Tom Blasingame, was used to prepare the plots).
- Note that the two wells shown were re-stimulated one or more times.
- The re-stimulations were common practice for the vertical wells in the Barnett.
- Engineering judgment and careful review of the basic data are always necessary to properly interpret the production data.
- The Fetkovich type curve was applied to the last flow period to generate production forecasts for evaluation.
- Although not perfect for gas, other methods generally require pressure data, which was not available in this data set.

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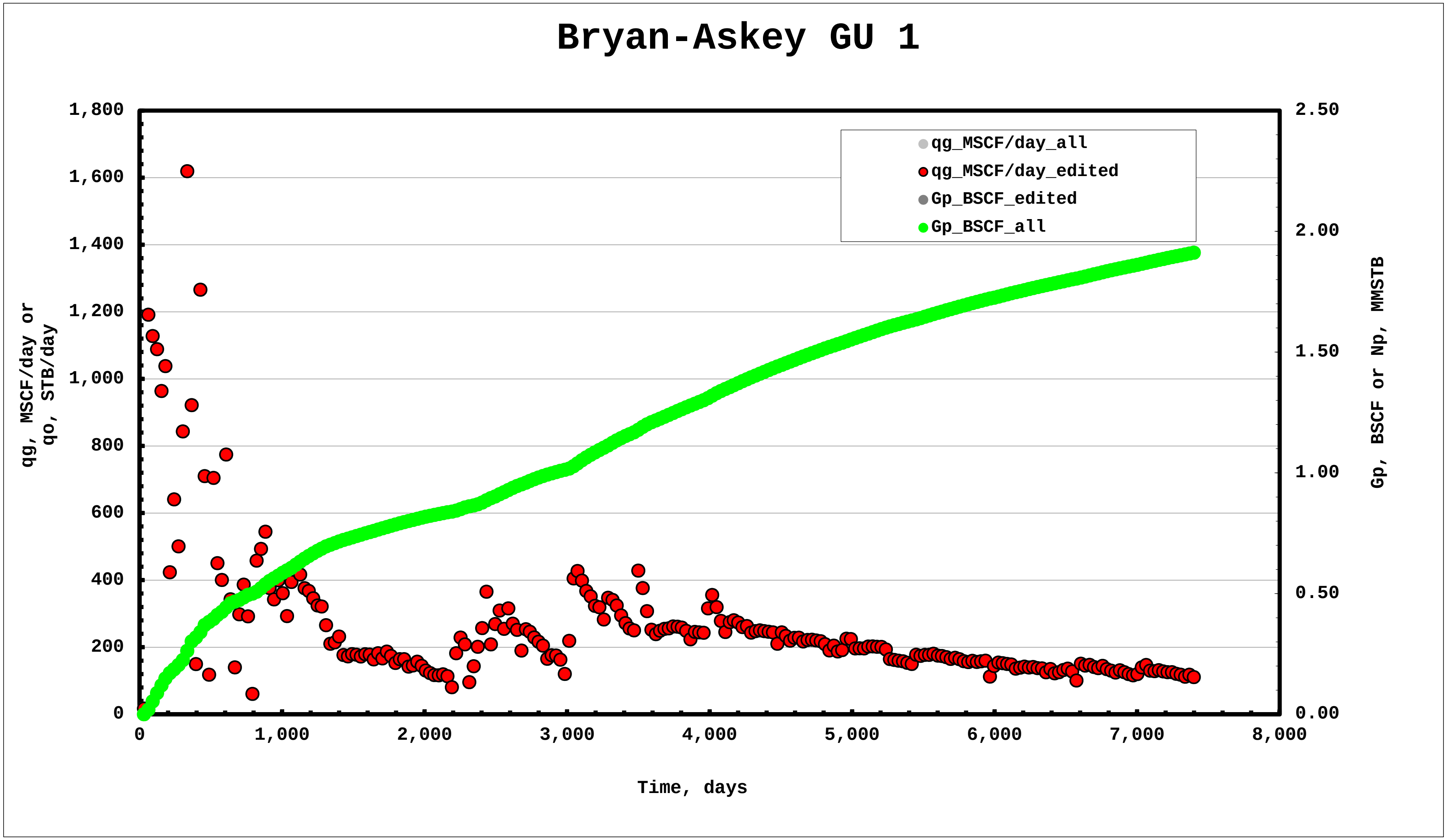

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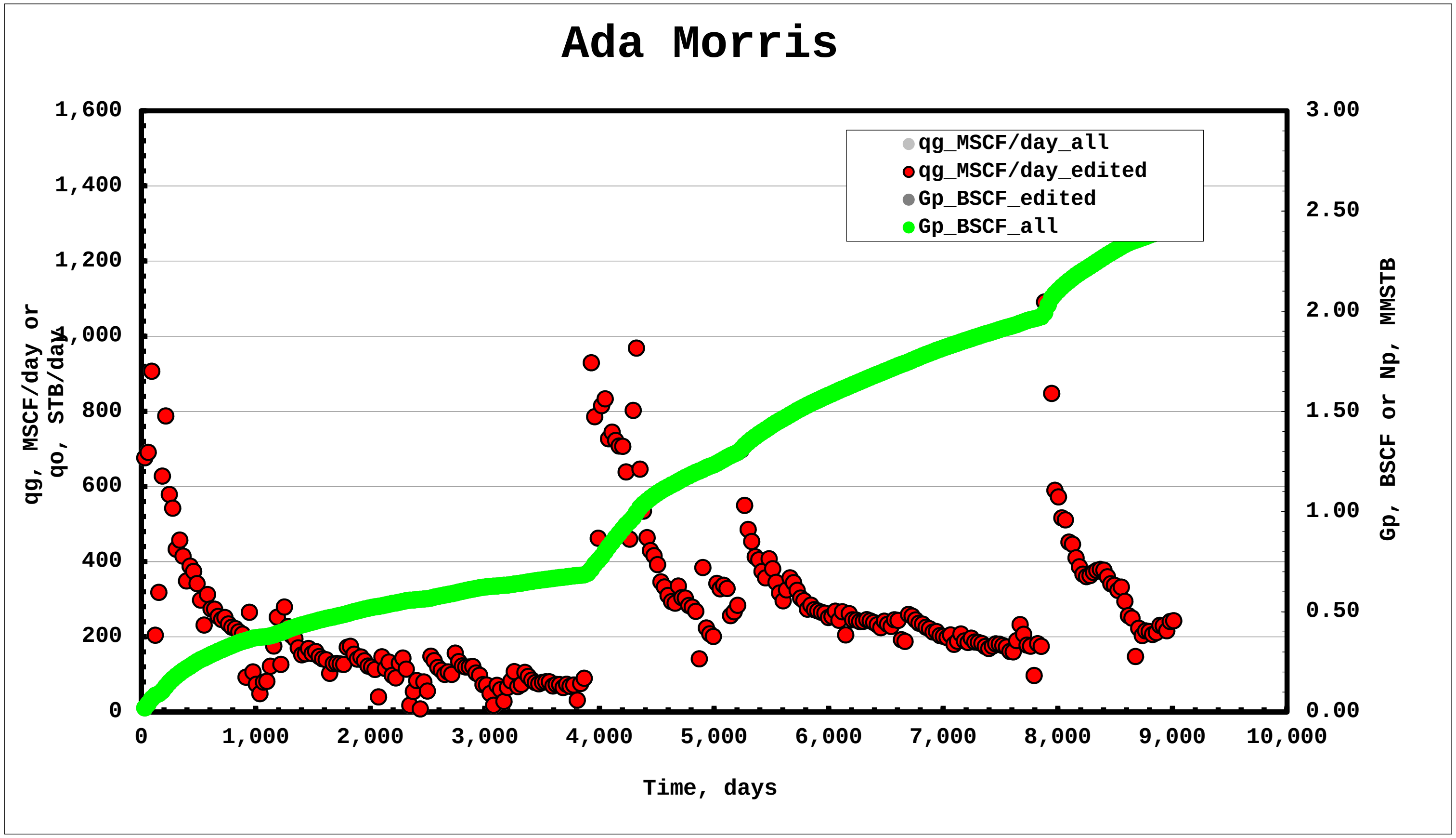

I express my appreciation to Virginia Anderson and Brian Everitt, both of whom were instrumental in helping me to get as far as I have.

Thanks for your attention.

Questions?