8TO. CONGRESO IAPG
Producción y Desarrollo de Reservas
HACIA UN DESARROLLO DE RECURSOS SUSTENTABLE

INSTITUTO ARGENTINO DEL PETROLEO Y DEL GAS
24 · 27 Octubre 2016
Llao Llao Hotel&Resort
Bariloche, Argentina

A Practical Workflow for Performance Prediction of Low Permeability Reservoirs

Steven J. Golko, P.Eng.
Sproule Associates
Calgary, Alberta, Canada

My Goal for Today

- To outline a practical engineering workflow
  - Evaluate unconventional plays developed with horizontal multi-stage fractured wells
  - Efficiency. Consistency. Flexibility.
  - Consistent with the geologic and engineering principles of SPEE's Monograph 4
  - Developed and tested over the past 8 years
- Focus on aspects not readily available in other literature

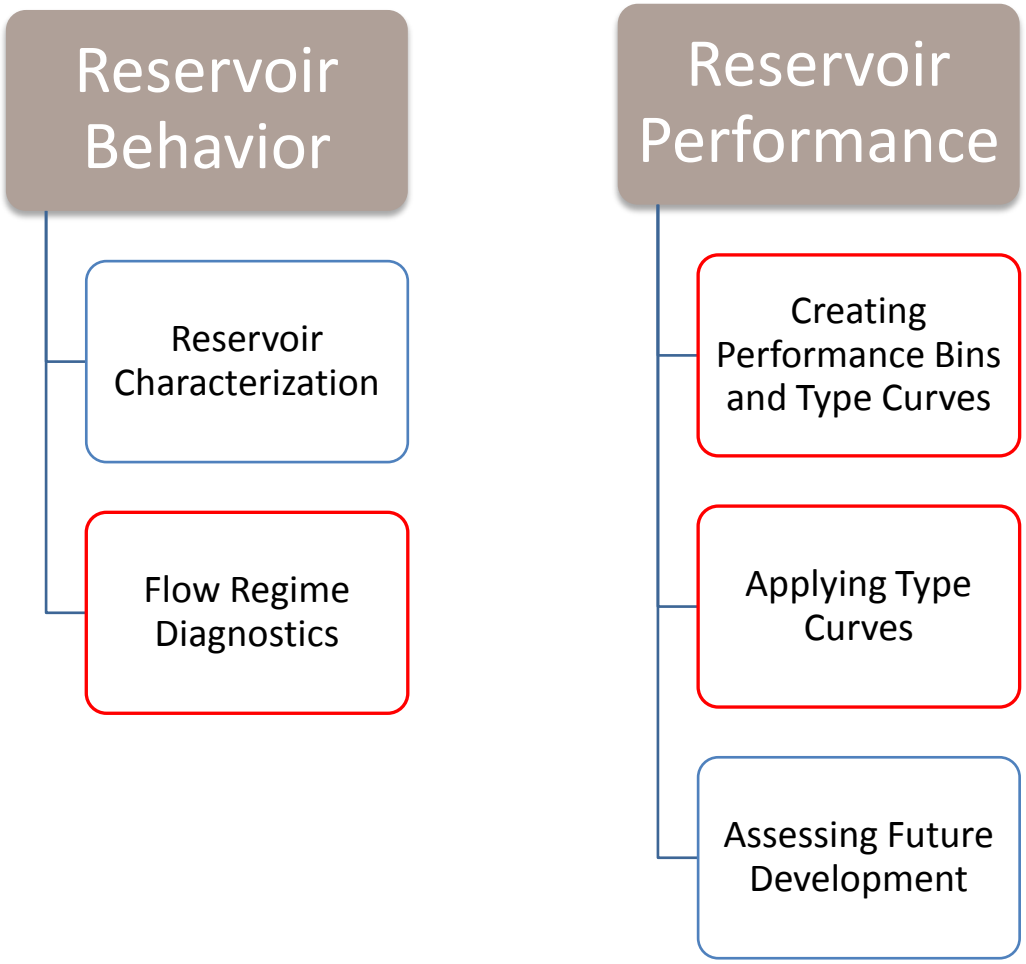
Process Workflow

Case Study -
Montney Shale Gas

Conclusions

PROCESS WORKFLOW

Main Steps


Reservoir Behavior
Reservoir Characterization
Flow Regime Diagnostics
Reservoir Performance
Creating Performance Bins and Type Curves
Applying Type Curves
Assessing Future Development

Workflow Applications

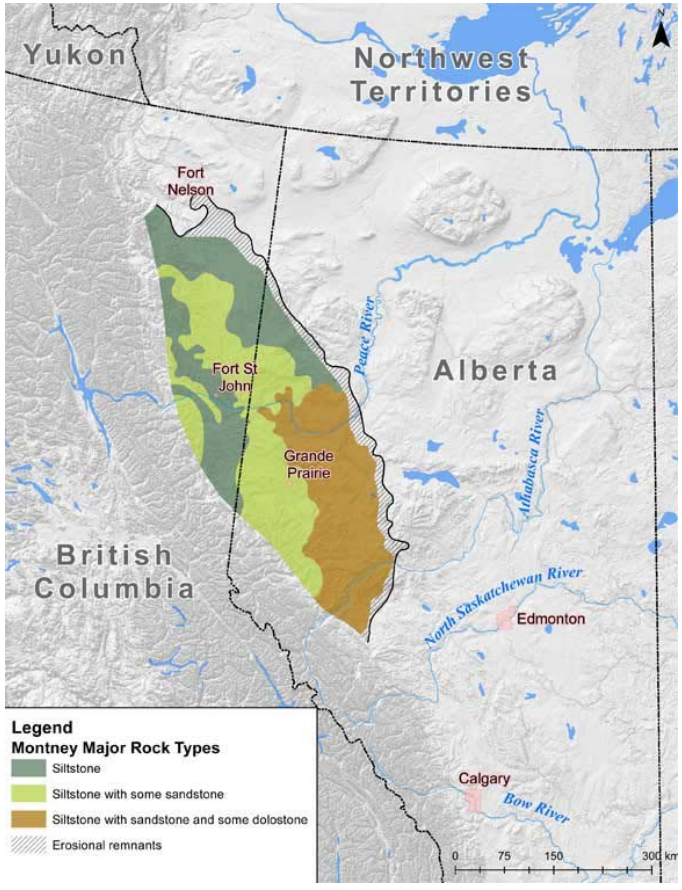
- ✓ Assessing potential acquisitions/bid rounds
- ✓ Assessing new plays
- ✓ Benchmarking competitor wells
- ✓ Corporate budget process
- ✓ Long term business planning
- ✓ Portfolio management
- ✓ Supply studies for infrastructure development
- ✓ Reserves certification

CASE STUDY: MONTNEY SHALE GAS

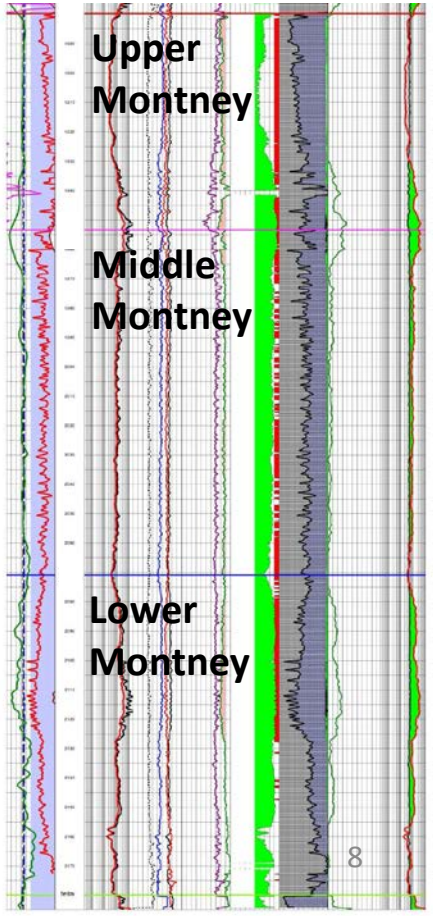
British Columbia, Canada

Reservoir Characterization

British Columbia Montney

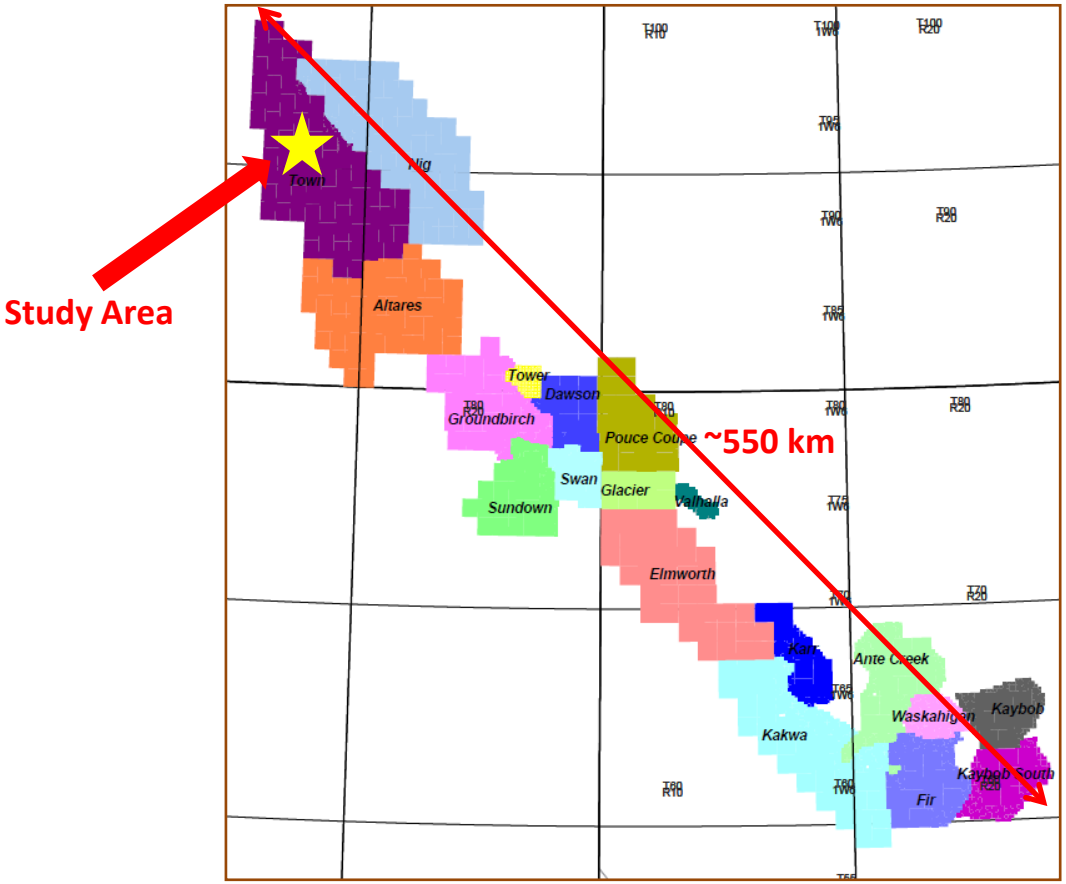


- Divide play into "geologic bins" based on rock and fluid properties
- Lots of literature available on this
- Reservoir characteristics and production performance varies greatly within the Montney



Reservoir Characterization

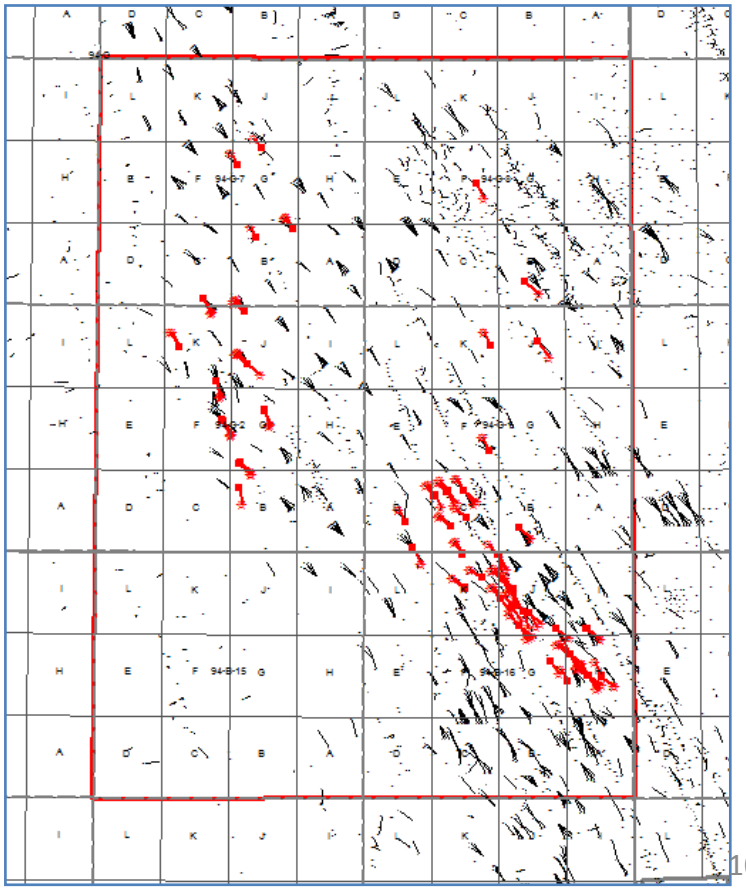
Montney Geologic Bins - Town



Reservoir Characterization

Montney Study Area - Town

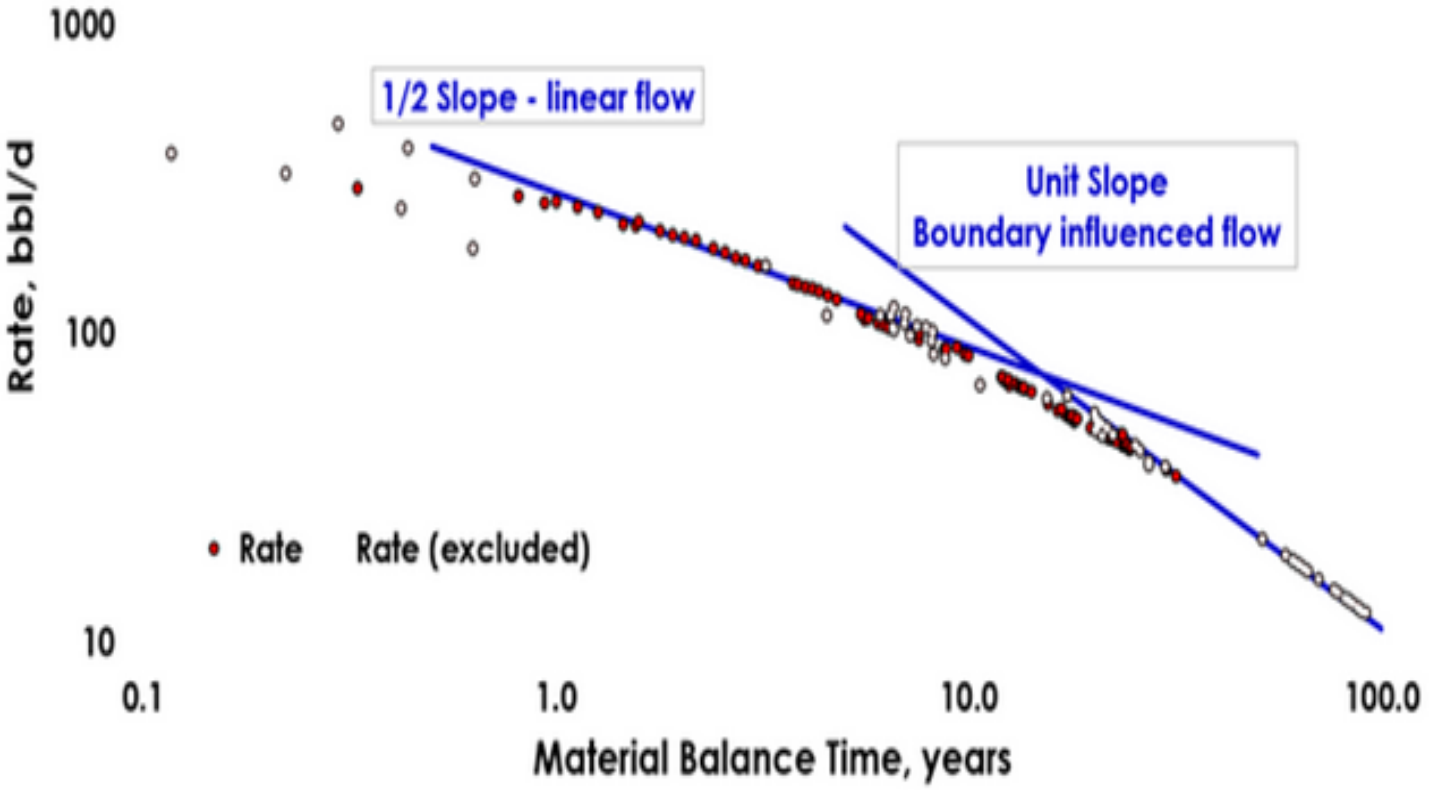
- 109 HZ Montney wells drilled in the study area as of mid-2014 that were used to create the type wells.
- Well Vintage (circa mid-2014):
  - 2009 – 4 wells
  - 2010 – 14 wells
  - 2011 – 28 wells
  - 2012 – 18 wells
  - 2013 – 45 wells
- Avg HZ length ~ 1600 m
- Mostly upper Montney
- Average of 9 slickwater fracs per well, 175t per frac



Flow Regime Diagnostics

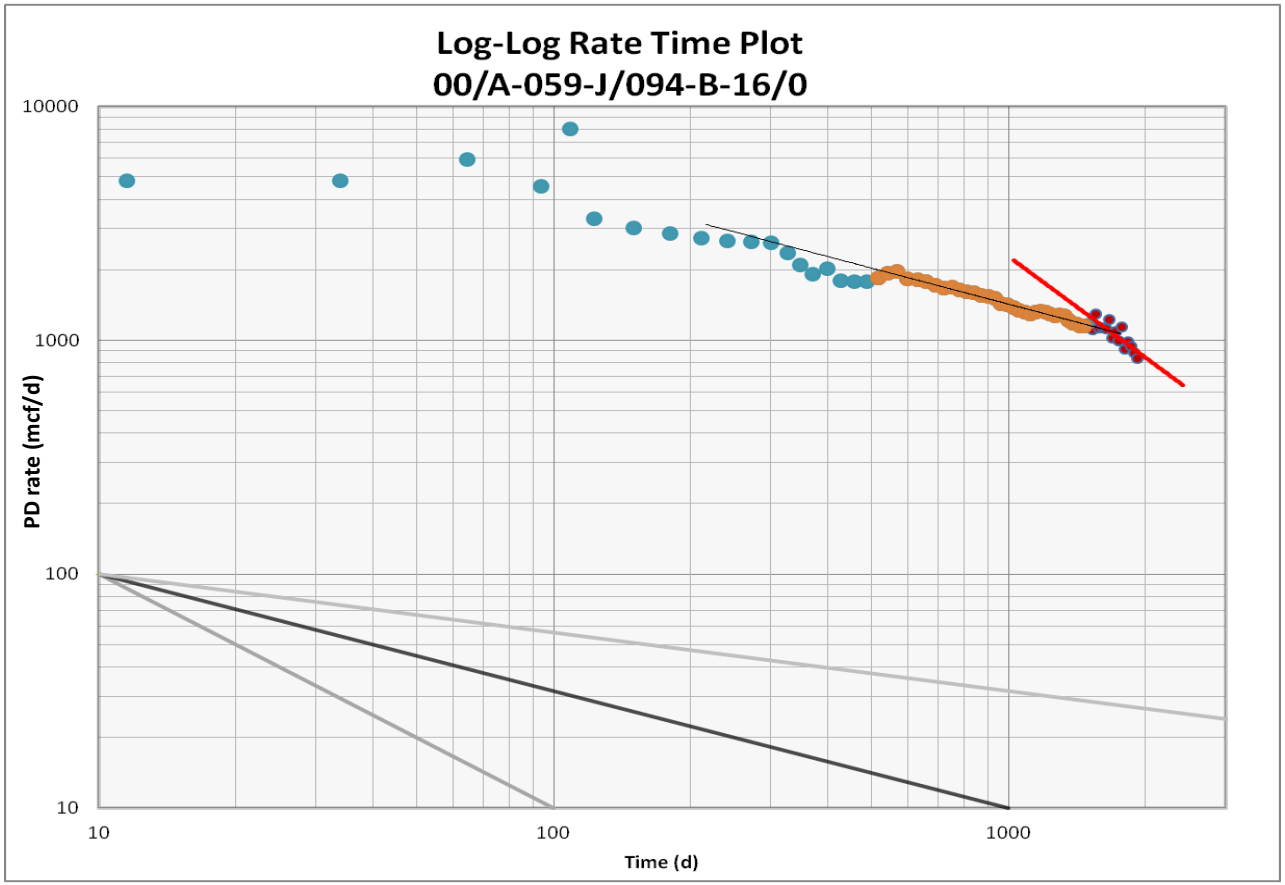
Theory

- b-value of transient segment
- Length of transient segment
- b-value of BDF segment



Flow Regime Diagnostics

Transient Flow -> Boundary Dominated Flow



Transient Segment

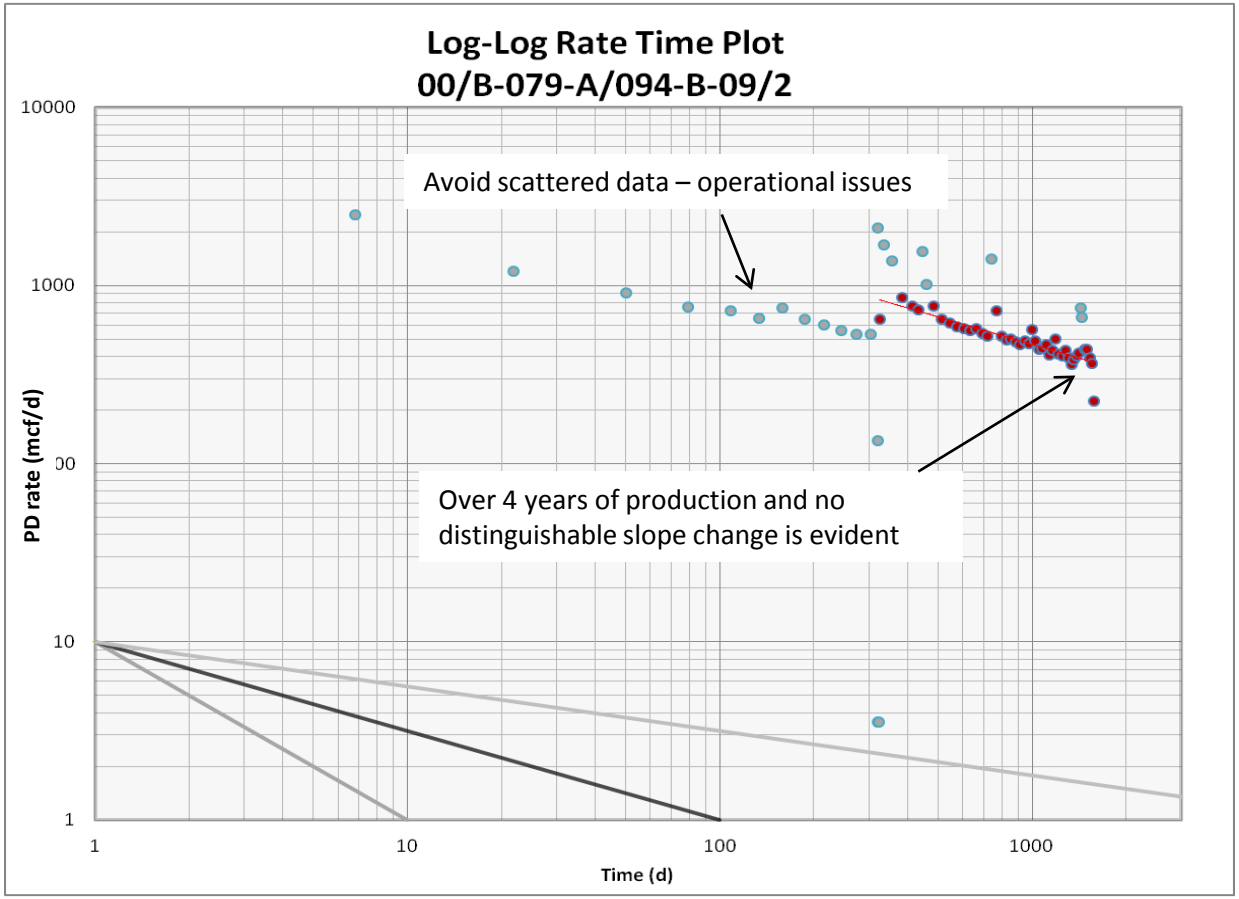
Slope	-0.5117
b	1.95
#producing months	49

BDF Segment

Slope	-1.4363
b	0.7
#producing months	14

Flow Regime Diagnostics

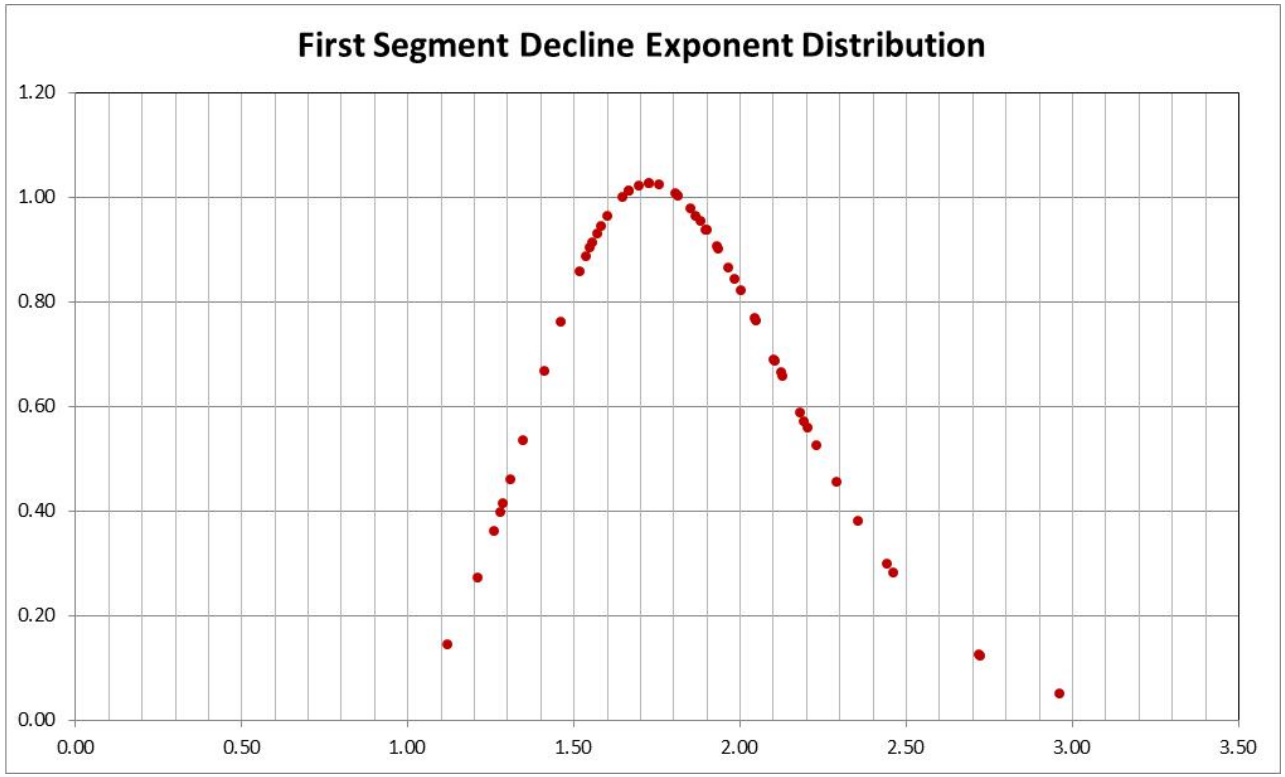
Data Issues



Slope	-0.5118
b	1.95
#producing months	52

Flow Regime Diagnostics

Summary

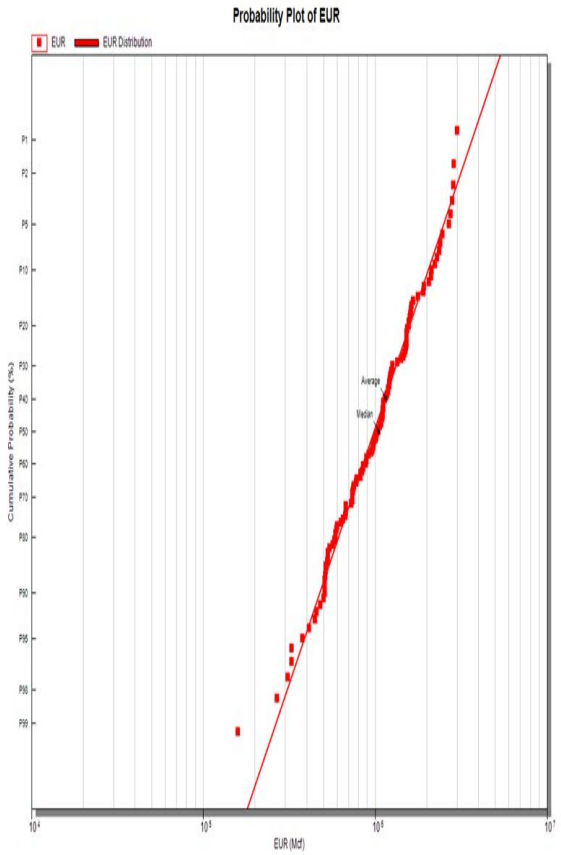


Mean b ~ 1.8

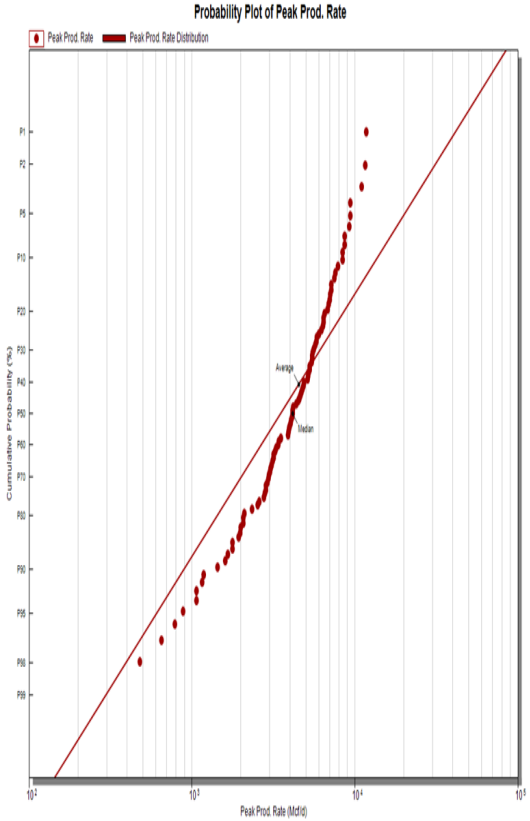
Time to Boundary Dominated Flow = 5 years

52 wells were chosen for the linear flow analysis, as these wells have the cleanest production profiles (highest on-time and no obvious operational issues)

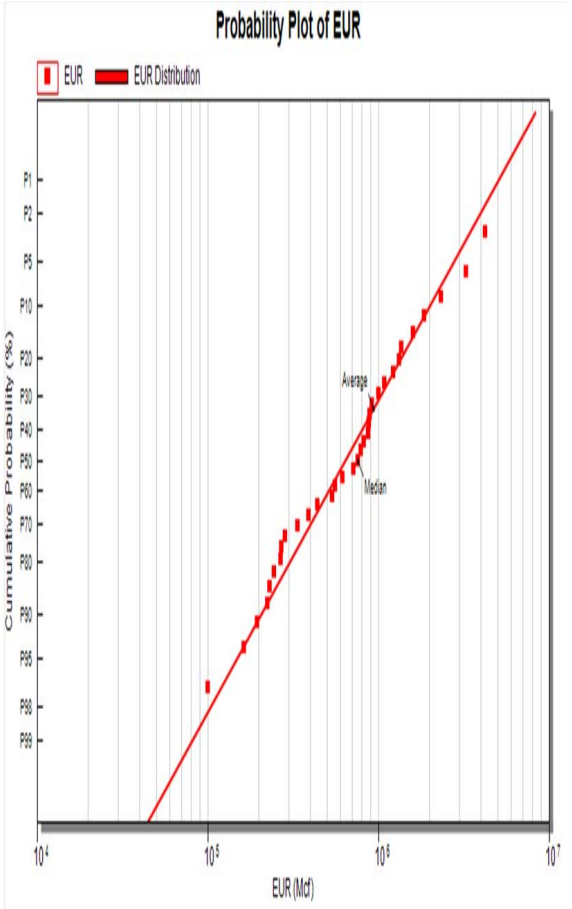
Geologic Binning – Diagnostic Validation



P10/P90 = 4

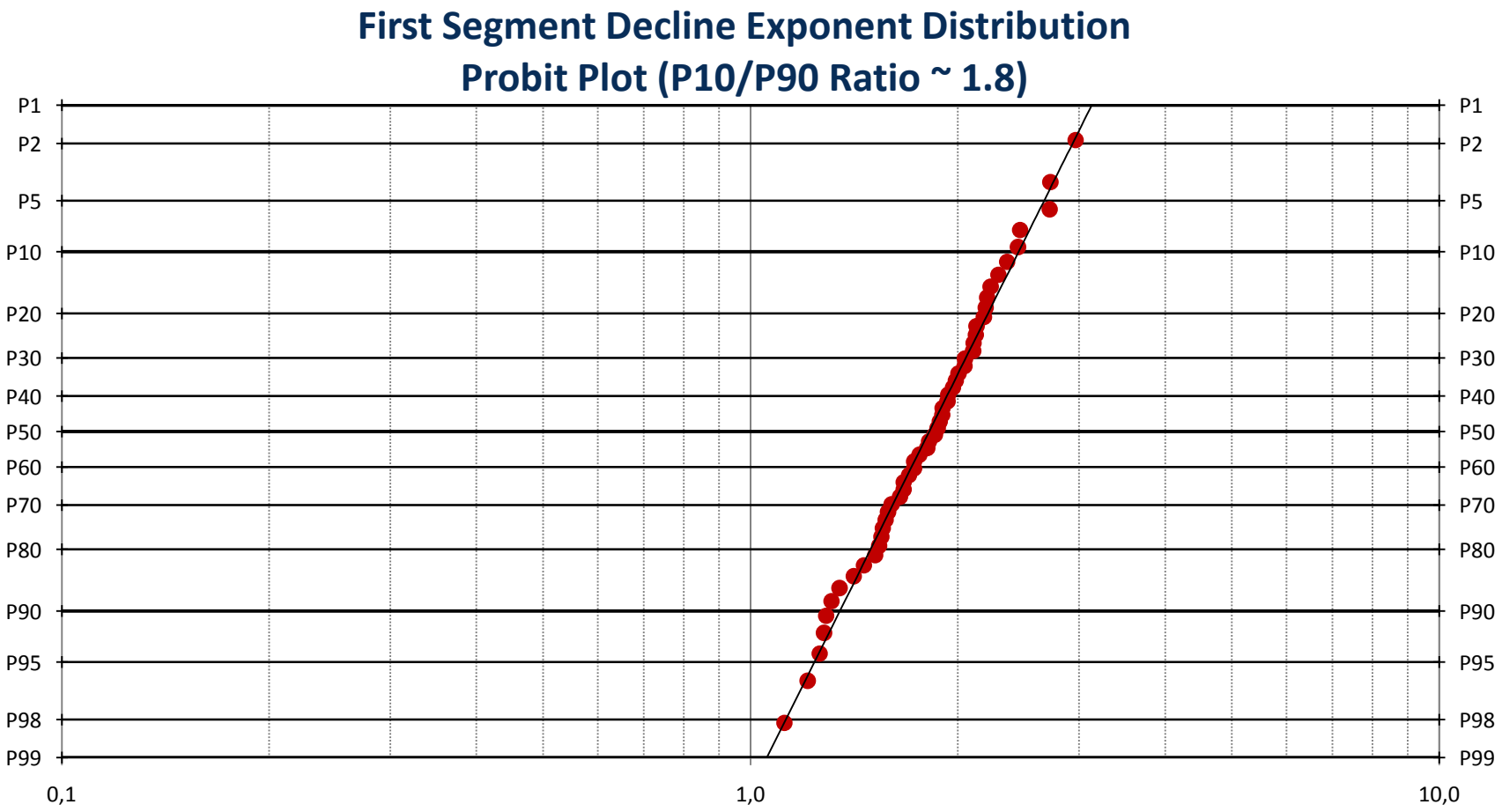


Data does not lie within lognormal distribution



P10/P90 = 10

Geologic Binning – Diagnostic Validation



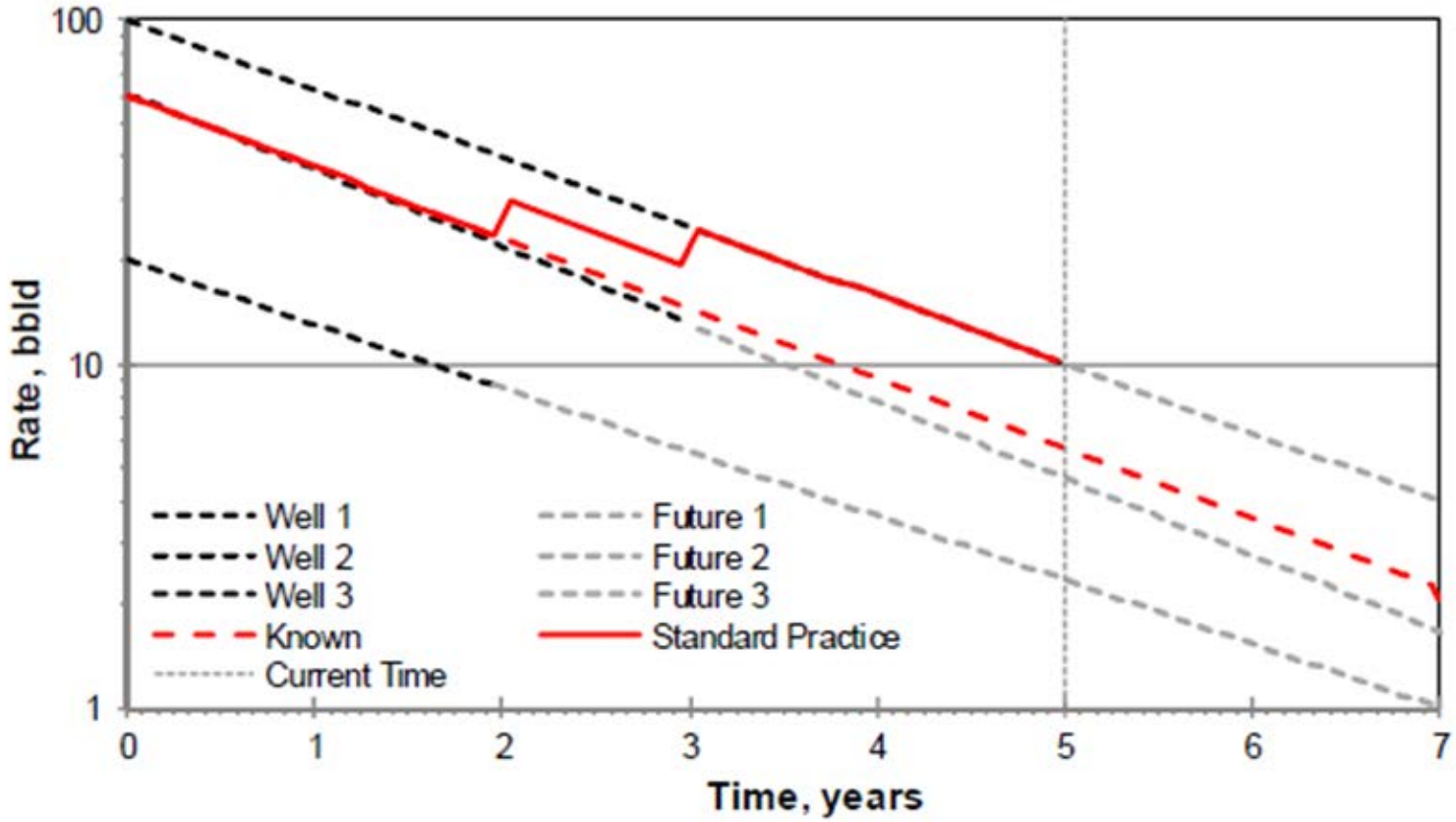
Creating Type Curves

Performance Bins

- Completions constantly changing
- Performance bins account for variability and differences in completions
- Allows for accuracy in forecasting wells away from the “average”
- Use production metrics as proxy for determining performance

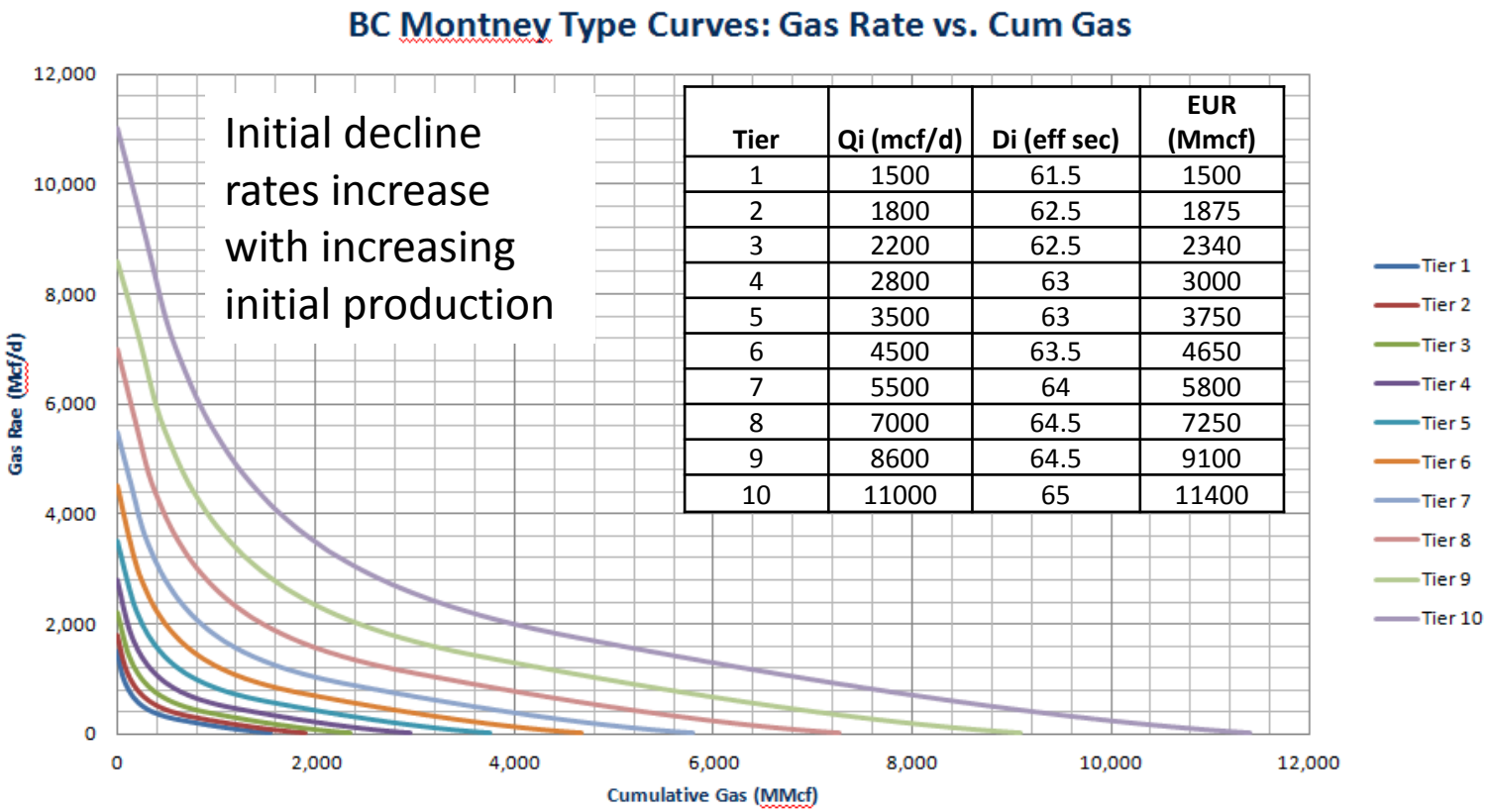
Creating Type Curves

Survivor Bias



Creating Type Curves

Tiers



Tier	Qi (mcf/d)	Di (eff sec)	EUR (Mmcf)
1	1500	61.5	1500
2	1800	62.5	1875
3	2200	62.5	2340
4	2800	63	3000
5	3500	63	3750
6	4500	63.5	4650
7	5500	64	5800
8	7000	64.5	7250
9	8600	64.5	9100
10	11000	65	11400

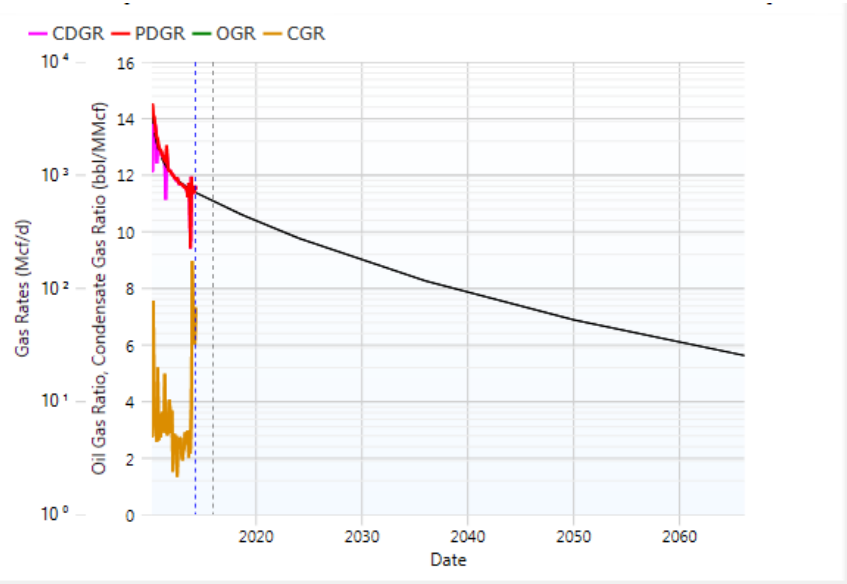
NOTE: Watch out for kinks in type curves!

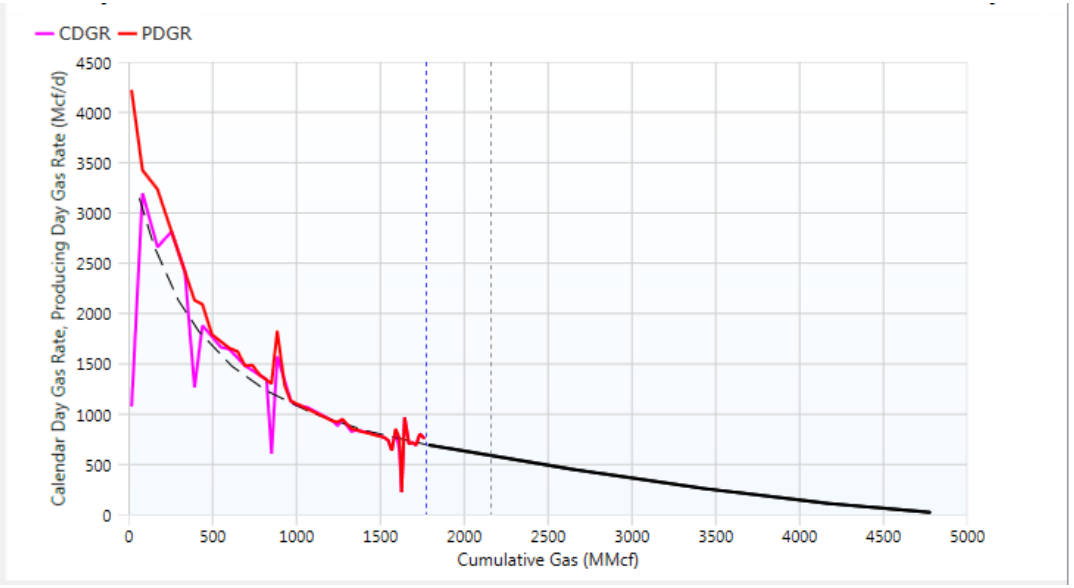
Applying Type Curves

- Use shape and average parameters of type curve generated to fit to historic production profile
- Adjust parameters to fit specific well performance
- This process is highly scalable to the level of detail required

Applying Type Curves

Use auto-forecast tool with average parameters

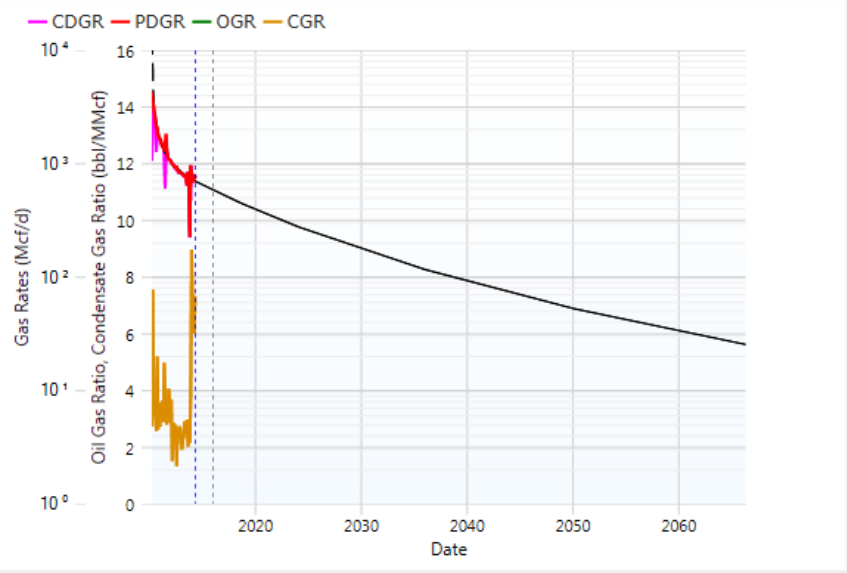


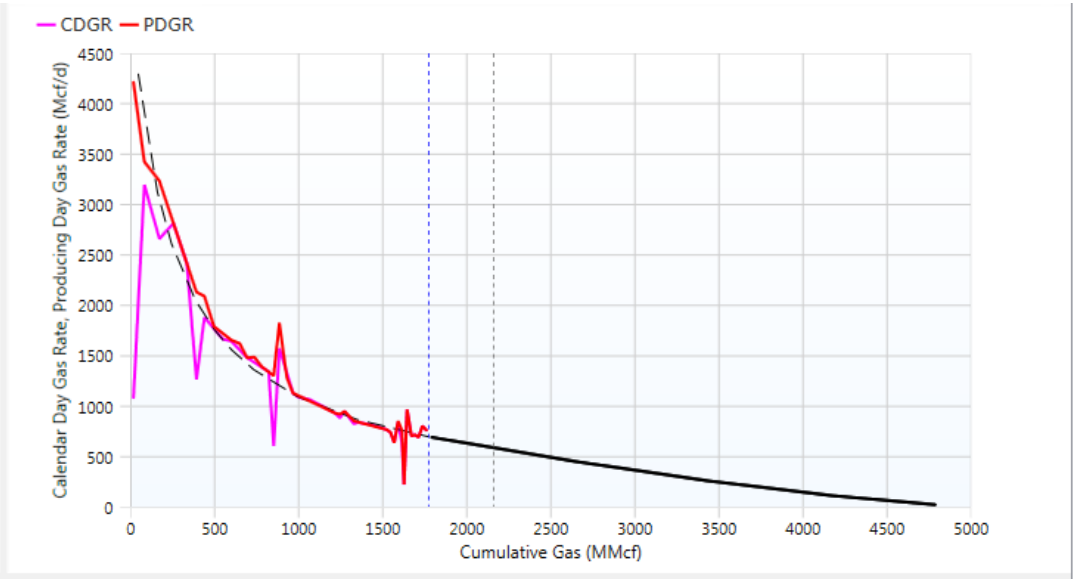


Well A – Decline exponent is higher than the average

Applying Type Curves

Use auto-forecast tool with average parameters

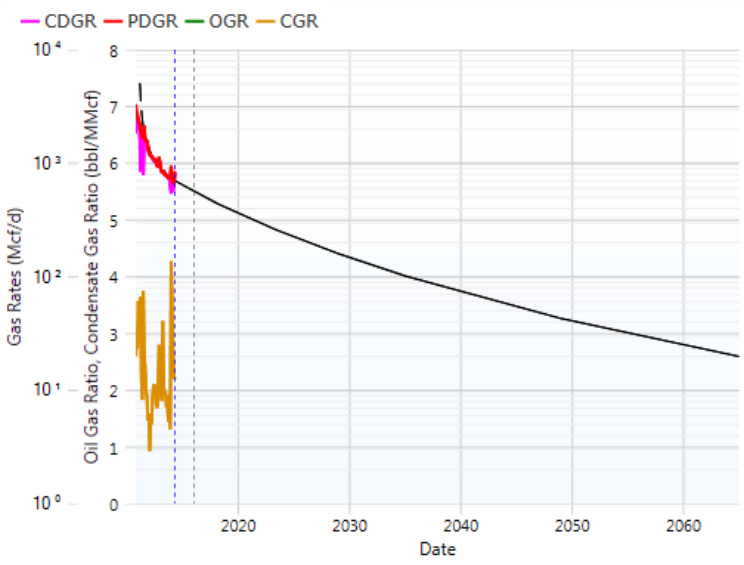


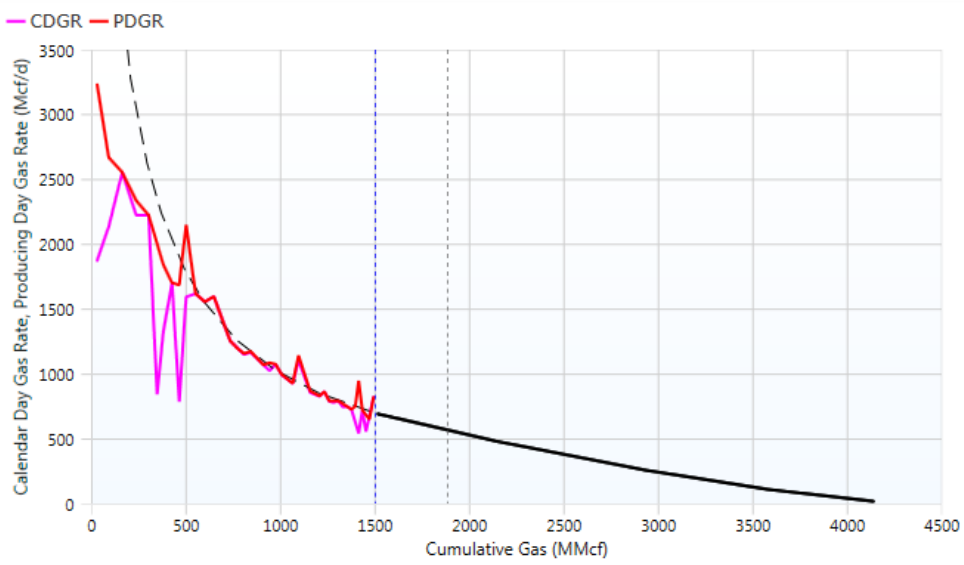


Well A – Decline exponent has been adjusted

Applying Type Curves

Use auto-forecast tool with average parameters

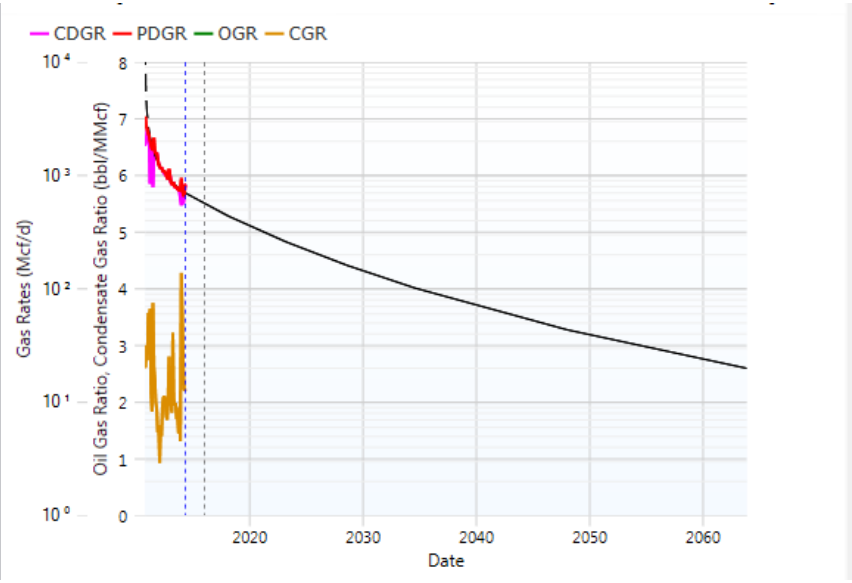


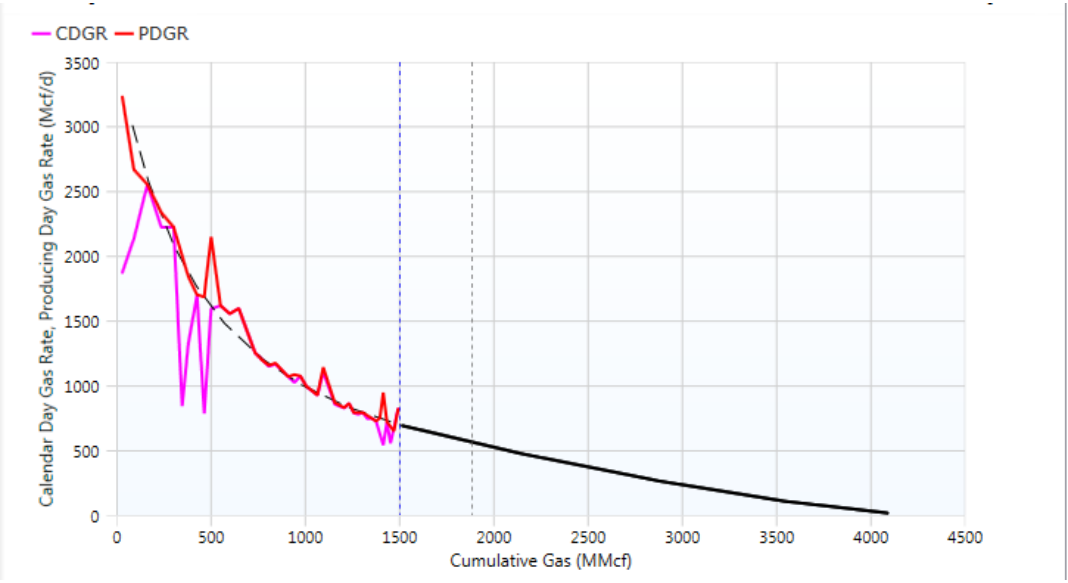


Well B – Decline exponent is lower than the average

Applying Type Curves

Use auto-forecast tool with average parameters

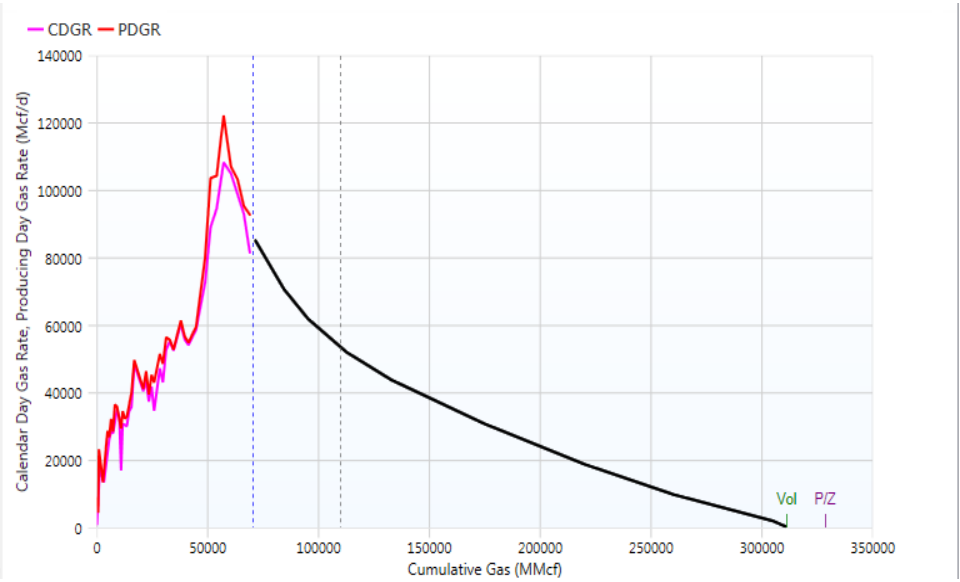




Well B – Decline exponent has been adjusted

Applying Type Curves

Summary forecast for all wells in 2014

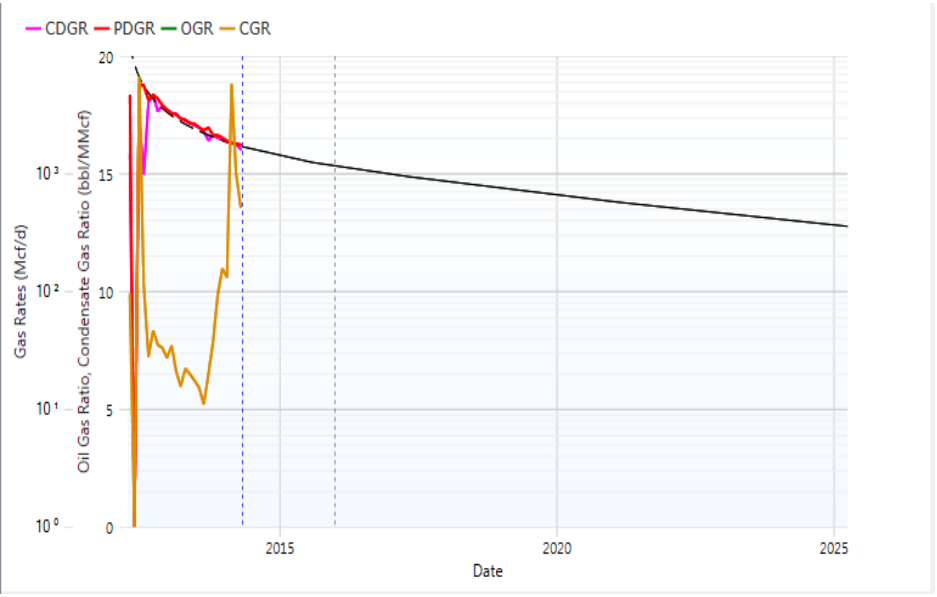


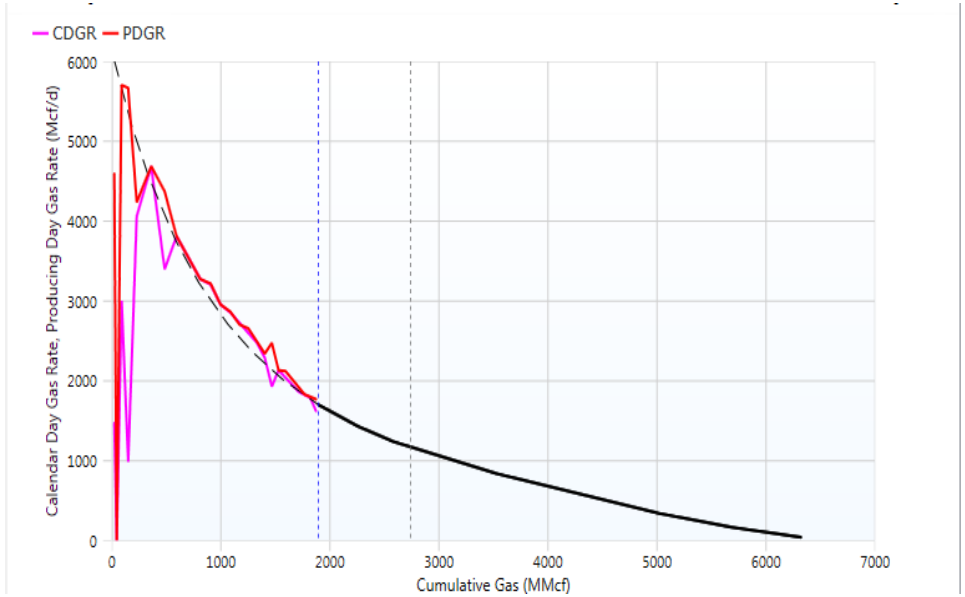
Applying Type Curves

Fast-forward two years to 2016 to see how our forecasts held up

Applying Type Curves

Well C - Forecast in 2014

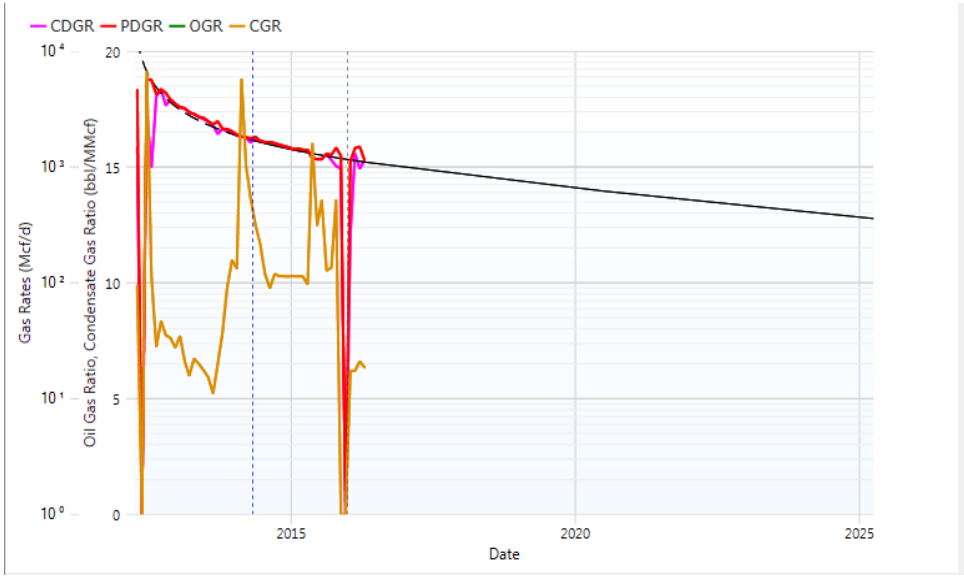


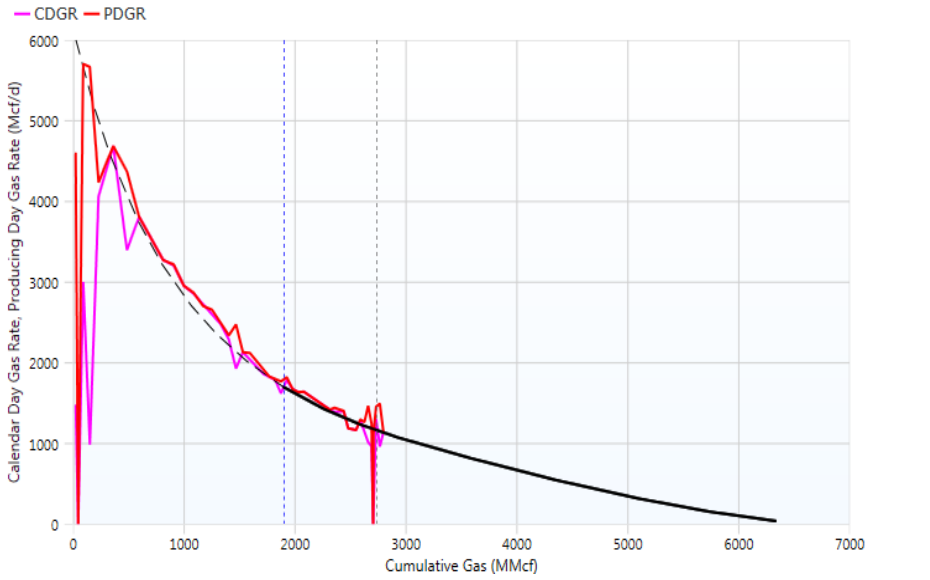


Good back-fit of data

Applying Type Curves

Well C - Production updated to 2016, same forecast

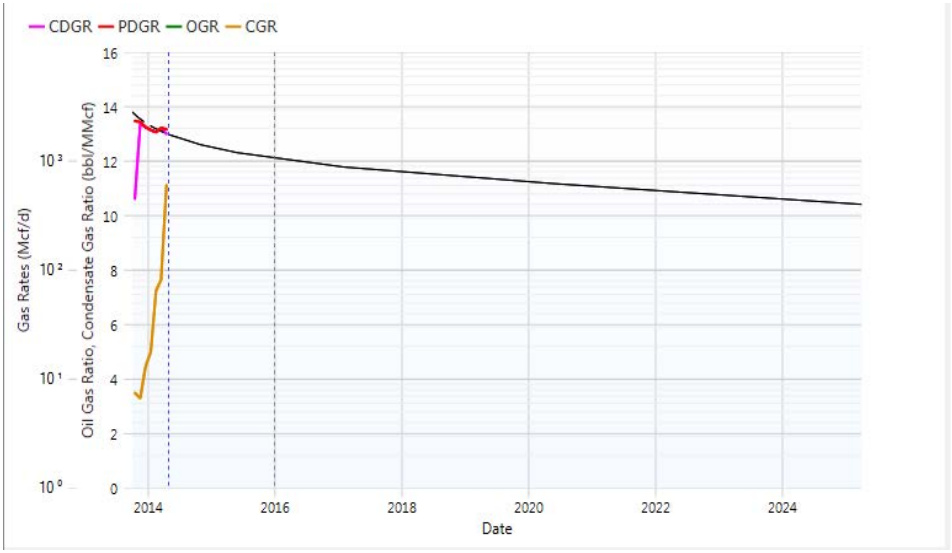


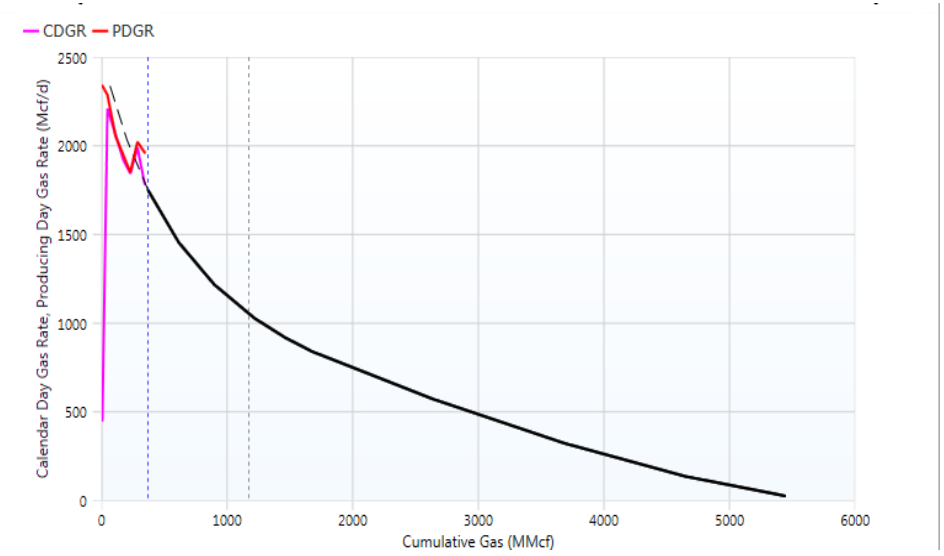


Production on trend

Applying Type Curves

Well D - Forecast in 2014

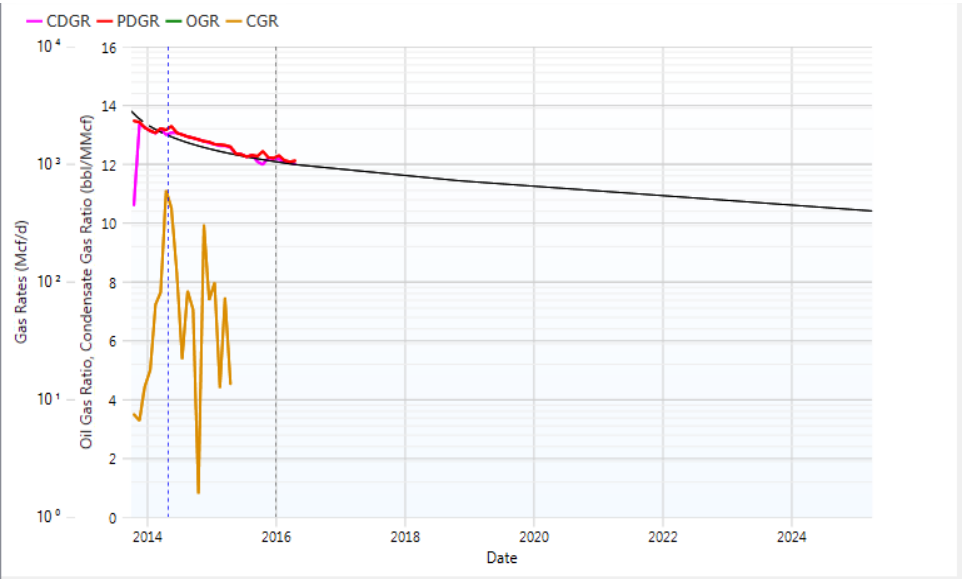


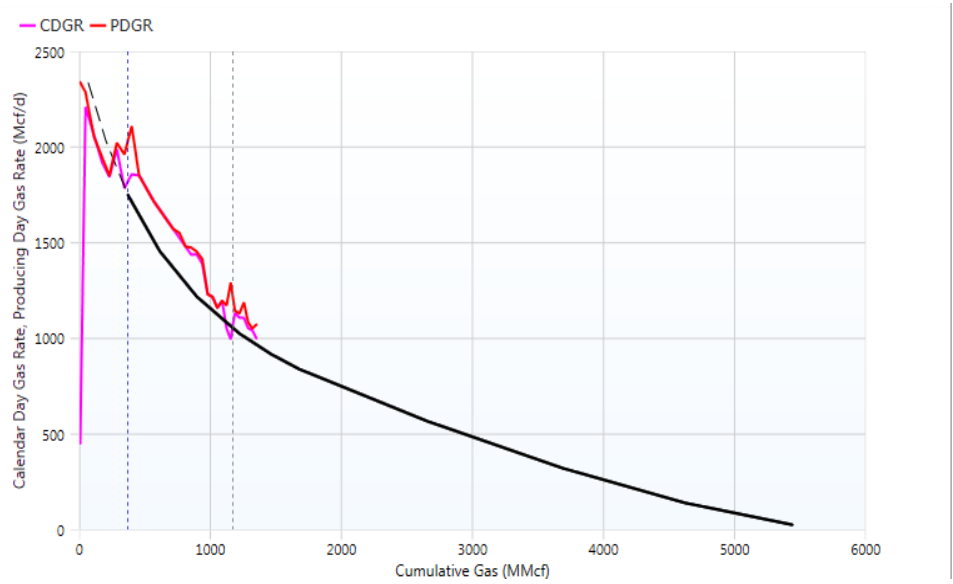


Very little production history to match, average parameters matched to initial rate

Applying Type Curves

Well D – Production updated to 2016, same forecast

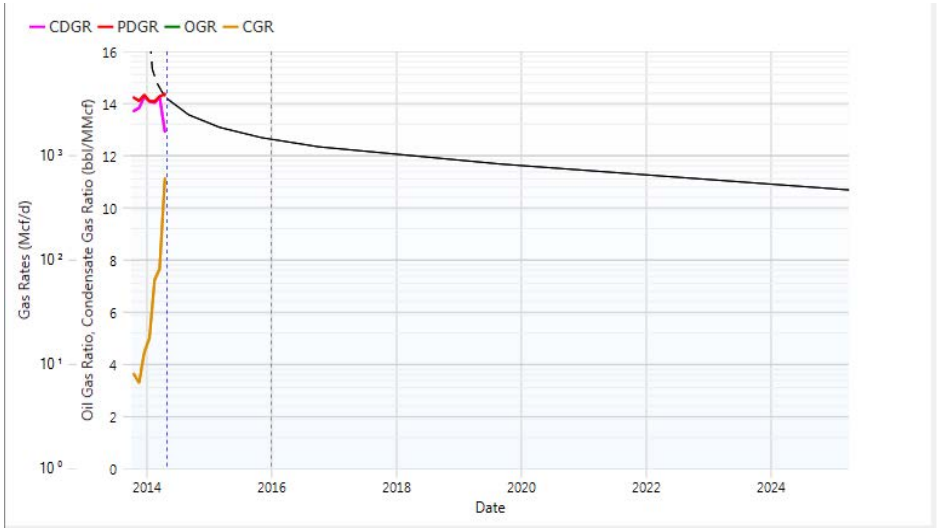


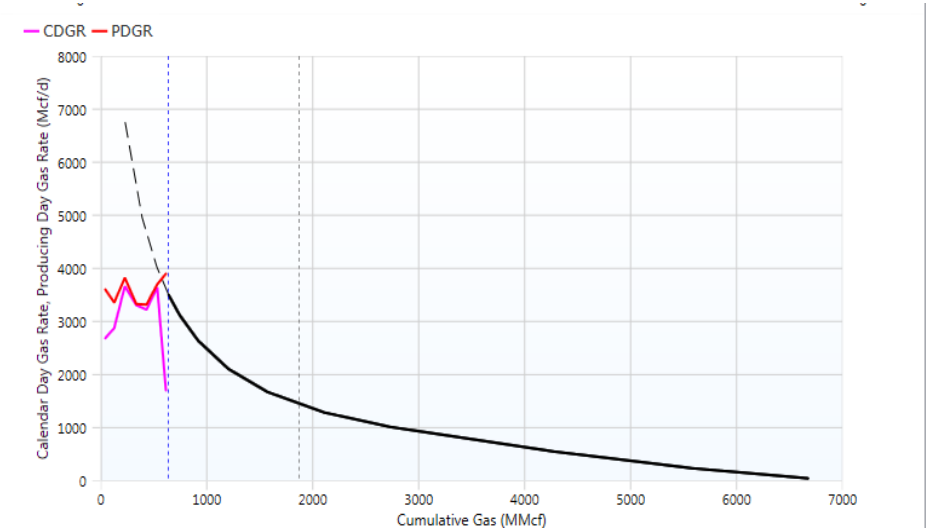


Well produced slightly better than forecast, but with same shape

Applying Type Curves

Well E - Forecast in 2014

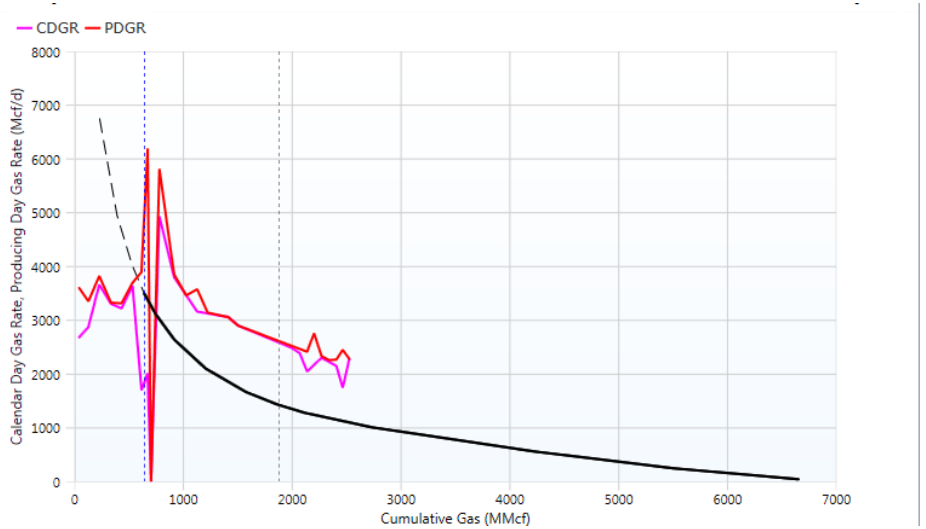




Rate restricted production history – difficult to forecast. Used average parameters from last known rate

Applying Type Curves

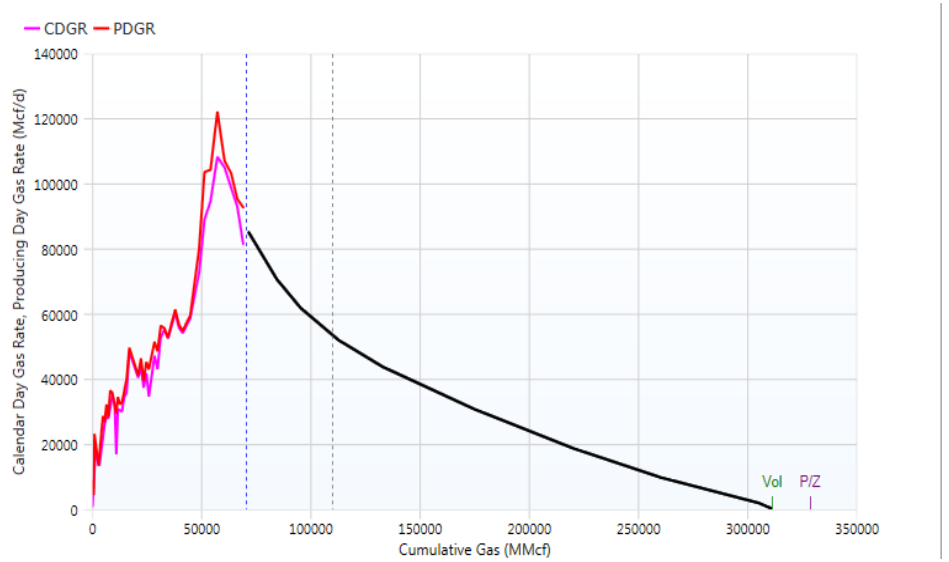
Well E – Production updated to 2016, same forecast



Well continued to produce restricted for several more months before starting to decline. Forecast from 2014 was pessimistic

Applying Type Curves

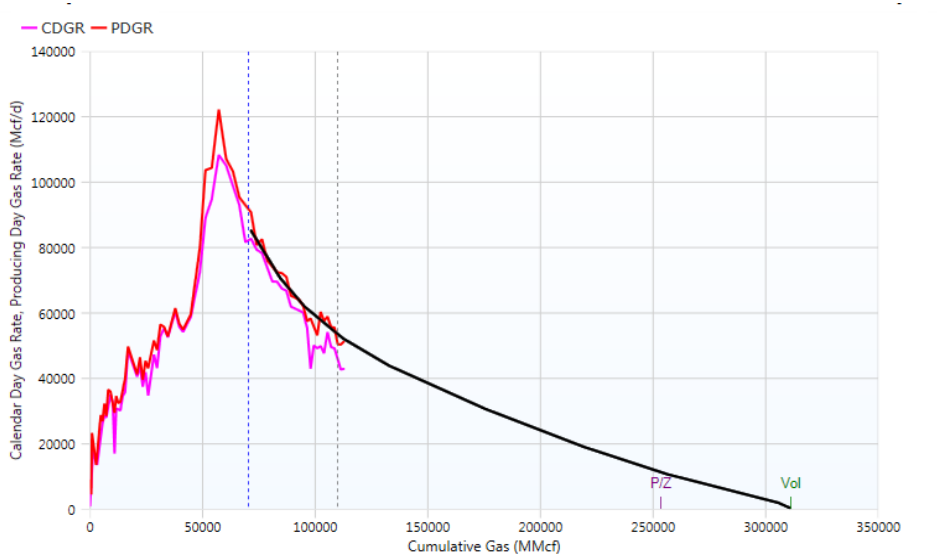
Summary forecast on all wells from 2014



Same plot as before

Applying Type Curves

Production updated to 2016 with 2014 forecasts



Summary forecast on producing-day rate still looks reasonable after two years have passed. There were some on-time disruptions in the field which reduced calendar-day rates below the forecast rates

Assessing Future Development

- Process is highly dependent on the end goal
  - Reserves - Proved, Probable, Possible
  - Contingent/Prospective Resources
  - Potential acquisition
  - Supply study
- Leverage the type curve work done
- Spectrum of type curves available to account for advances in technology

CONCLUSIONS

Review

- **Reservoir Behavior**
  - Reservoir Characterization
  - Flow Regime Diagnostics
- **Reservoir Performance**
  - Creating Performance Bins and Type Curves
  - Applying Type Curves
  - Assessing Future Development

Summary

- Provides framework for a consistent methodology of evaluation
- Flexible, efficient, accurate
- Software adds efficiency, but does not remove the need for sound engineering judgement
- Details of process can and will change as we gain more understanding and insight

and finally…

- No two plays are the same
  - But the general underlying principals apply to all
  - a lot of knowledge can be transferred between plays
- Which means, experience is the single most important factor
- By employing a standard process, decisions can be made knowing that each opportunity has been evaluated using a consistent approach and industry best practices

THANK YOU