Evaluating Shale Gas Wells Using Rate and Flowing Surface Pressure Data

February 6, 2013

Netherland, Sewell & Associates, Inc.

ctucker@nsai-petro.com
214-9695401

OUTLINE

1. Shale Gas Production - What made it possible?
2. Flowing Material Balance - Estimating Contacted OGIP
3. PI Method - Estimating Recoverable Gas

Shale Gas Production
What Made It Possible?

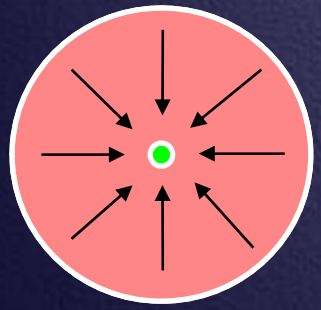
Flow Rate α Permeability x Area / Distance

So which of these three parameters did the industry work on?

How about ALL THREE!

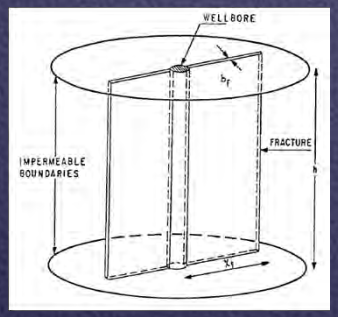
Conventional Reservoir

Good K
Small Area = $2\pi r_w h$
Large Distance
Radial Flow



Tight Gas Reservoir

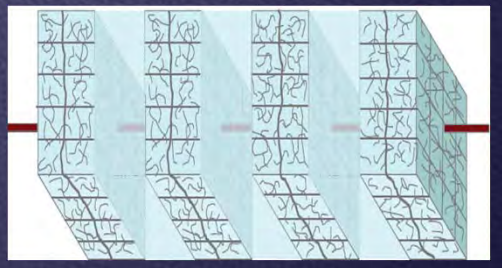
Low K
Increased Area = 2Lh
Large Distance
Linear Transient Flow

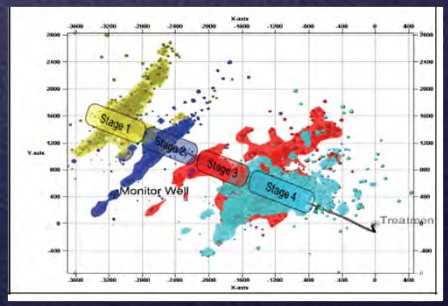


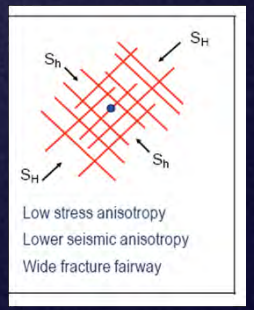
SPE 7490

Shale Gas Horiz Multi-Stage Frac

Enhanced K in SRV
Significantly Increased Area
Significantly Decreased Distance
Complex Flow with Early BDF







SPE 136696 and 145080

Flowing Material Balance

Flowing Material Balance (FMB)

WHAT IS IT?

- Dynamic (performance-based) estimate of contacted OGIP

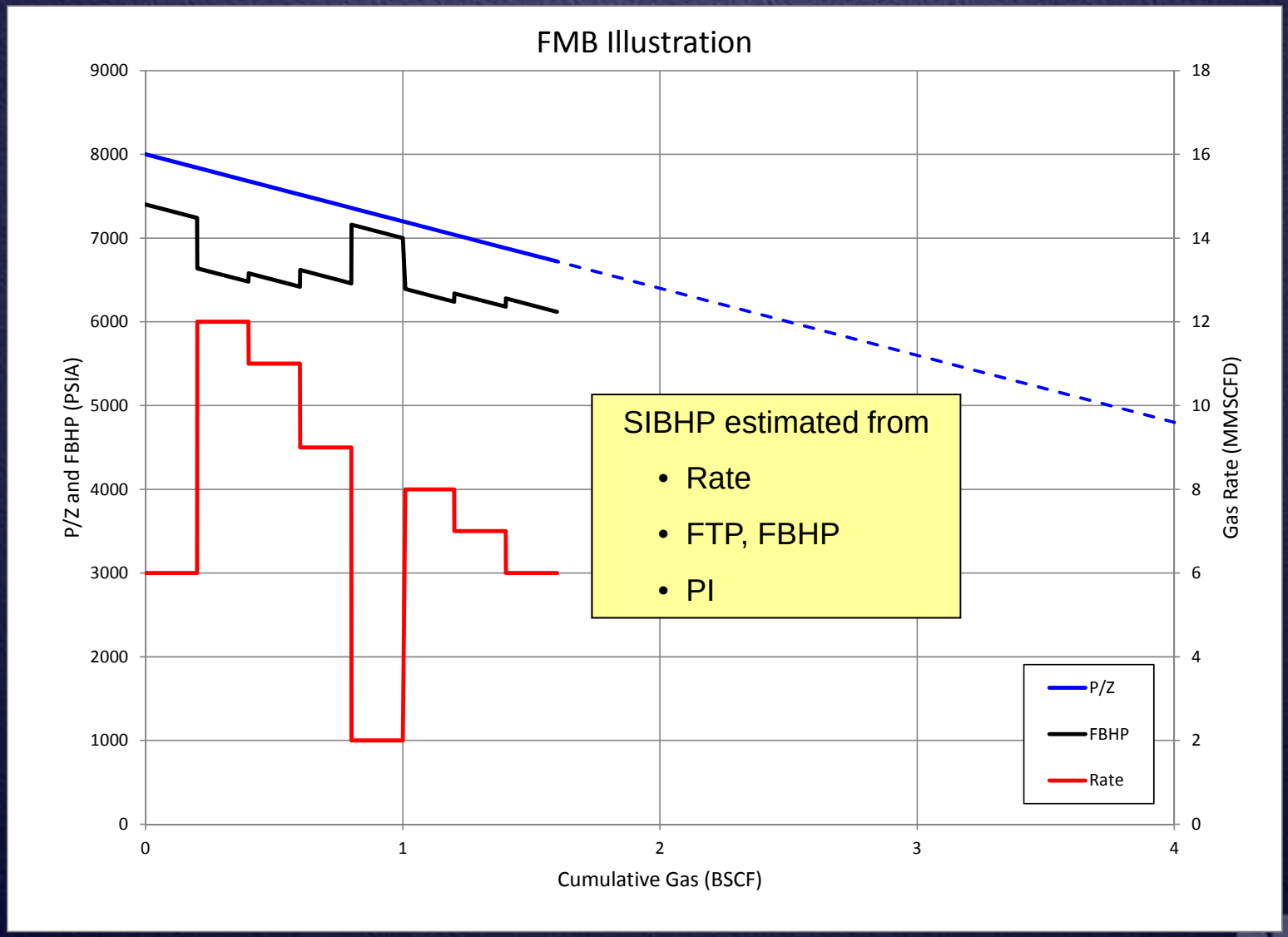
HOW DO WE DO IT?

- Estimate FBHP from rate and flowing tubing pressure
- Estimate SIBHP from FBHP, rate and productivity index (PI)
- Perform gas material balance

DOES IT WORK?

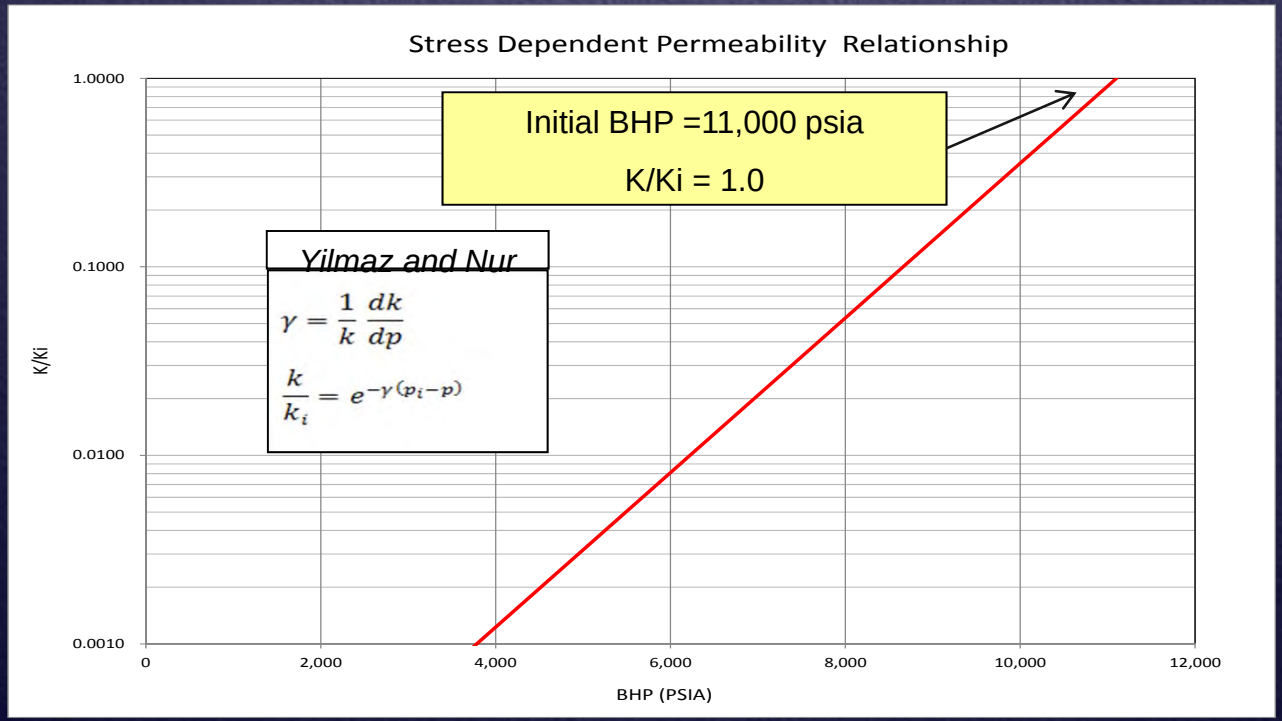
- Have seen very “linear” FMB trends across numerous wells with as little as 3 months of data for the Haynesville (little longer for the shallower plays)
- Estimated connected OGIP volumes appear reasonable
- Estimated RF’s are typically 50-60% of contacted OGIP

FMB – What is it?

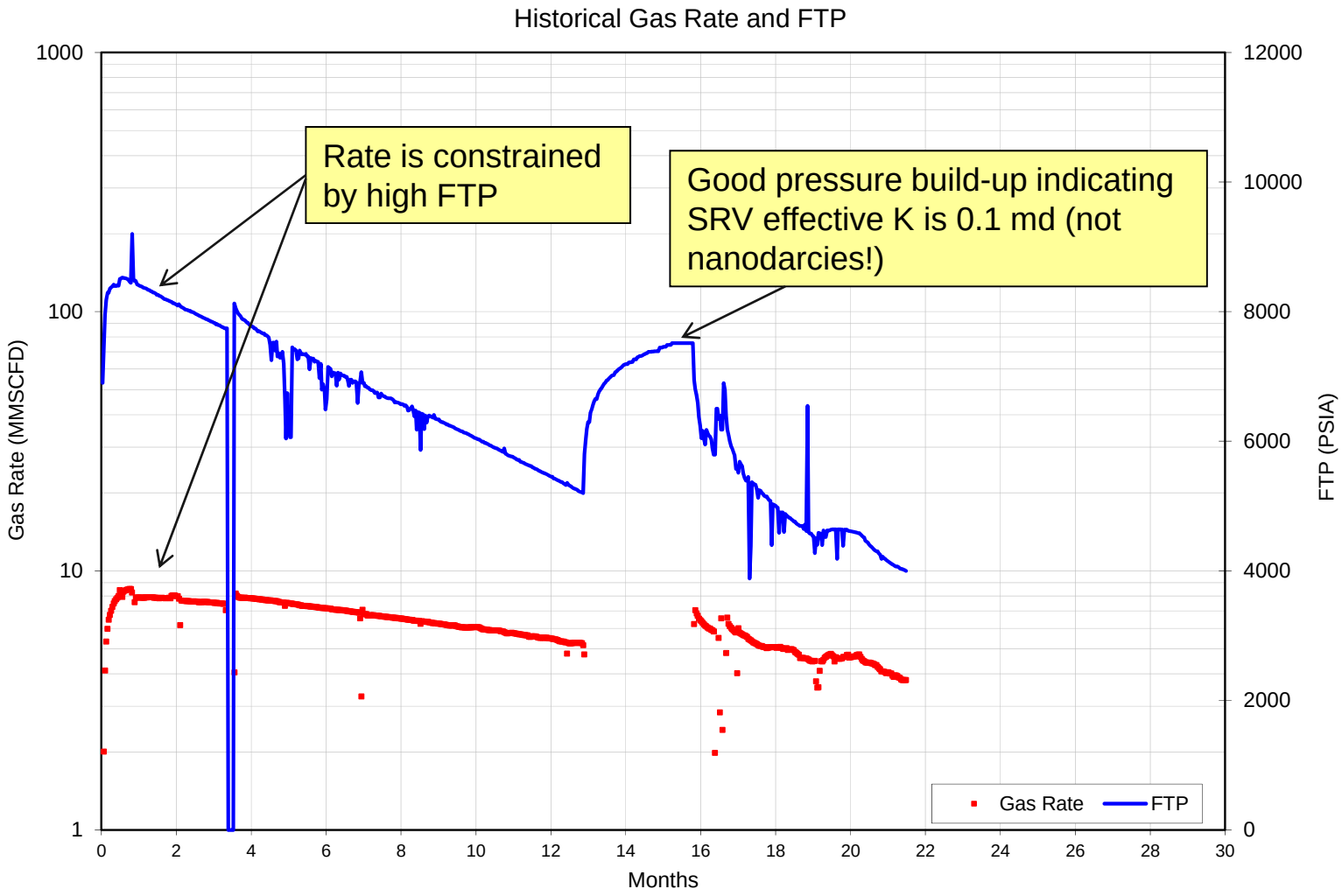


Stress Dependent K

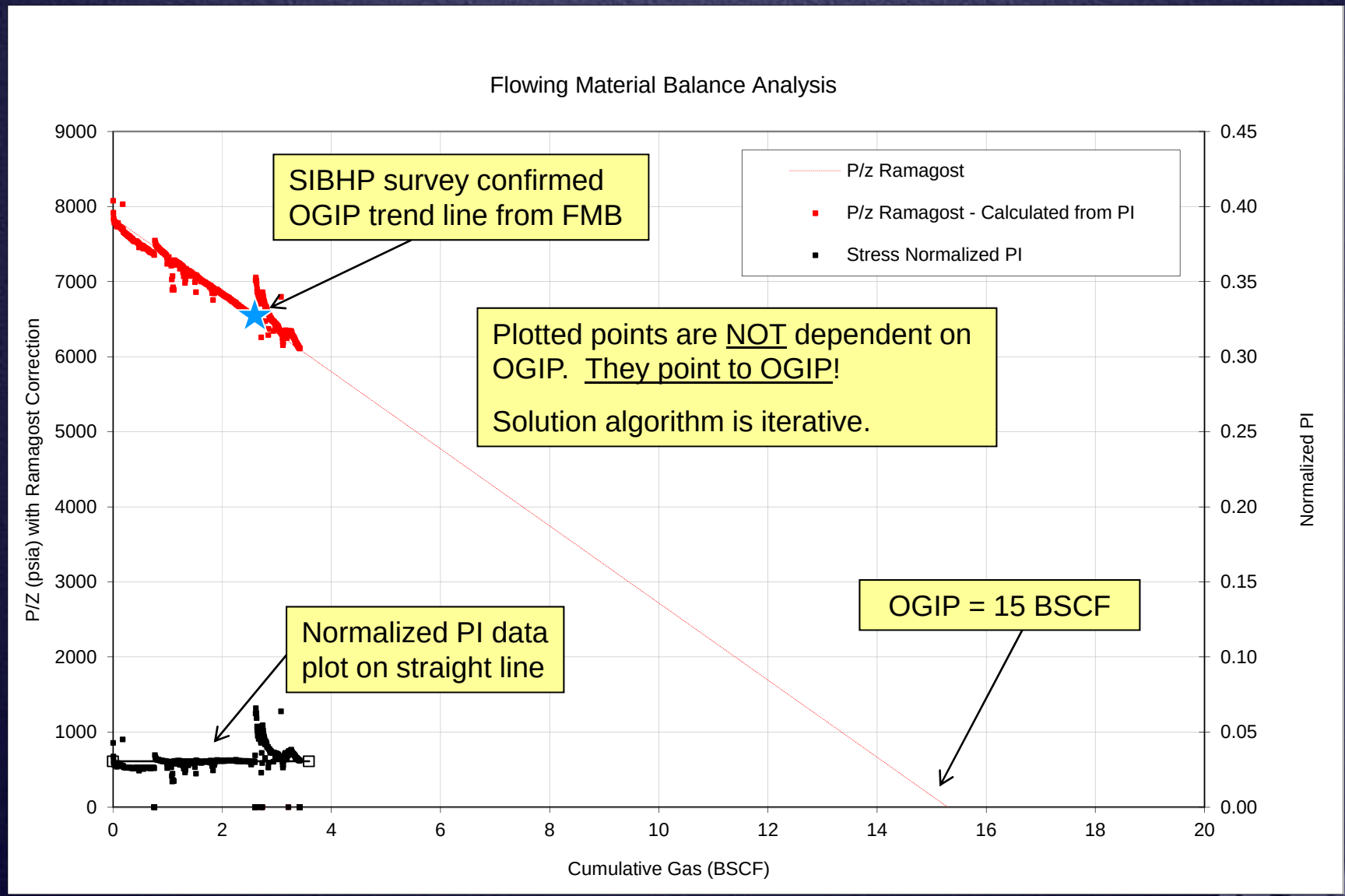
- FMB analysis requires a PI model
- A stress-dependent decline in K is used for shale wells
- Stress dependency must be determined independent of FMB analysis – need SIBHP from subject well or analog



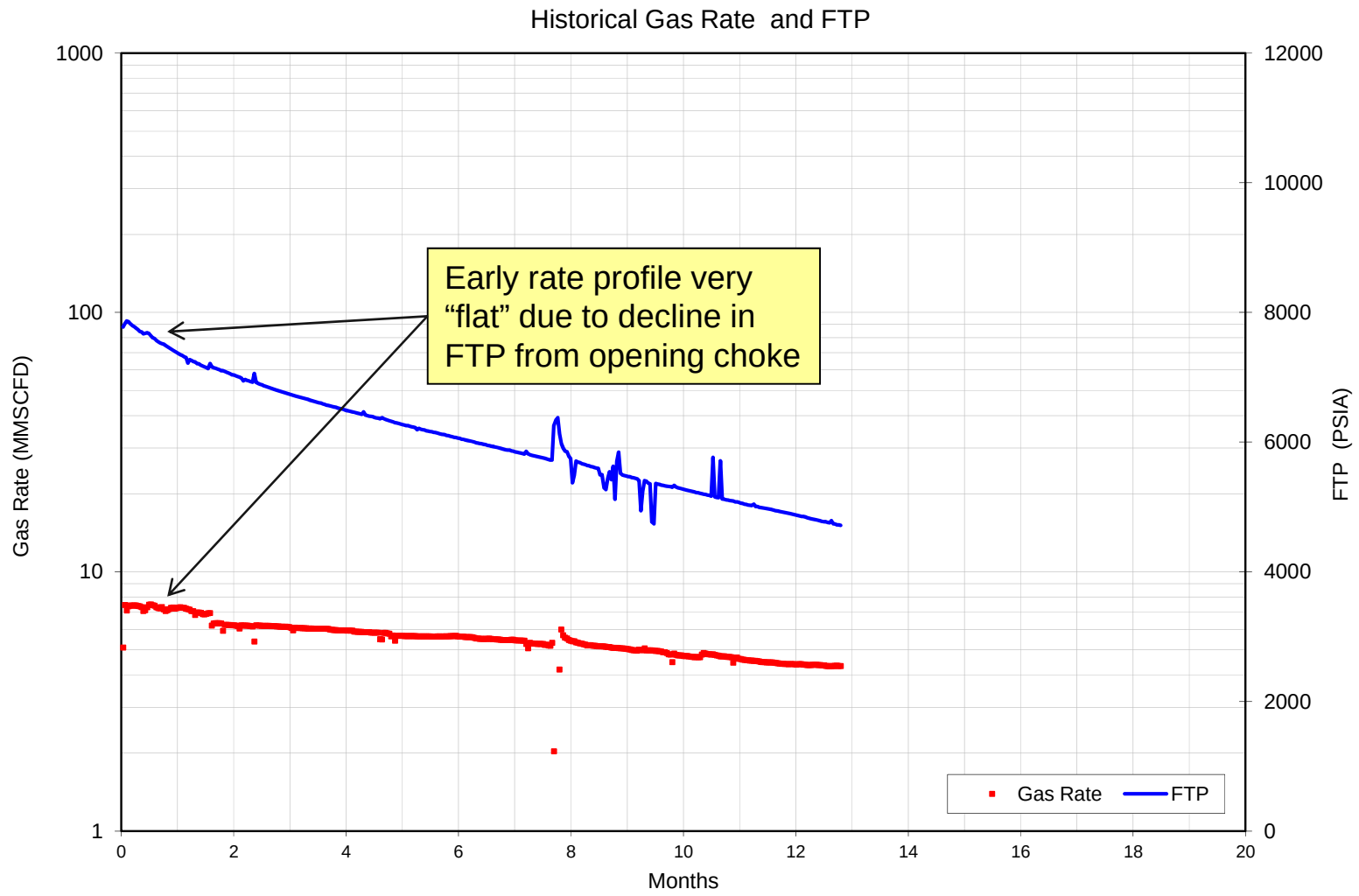
Rate and FTP vs Time – Example 1



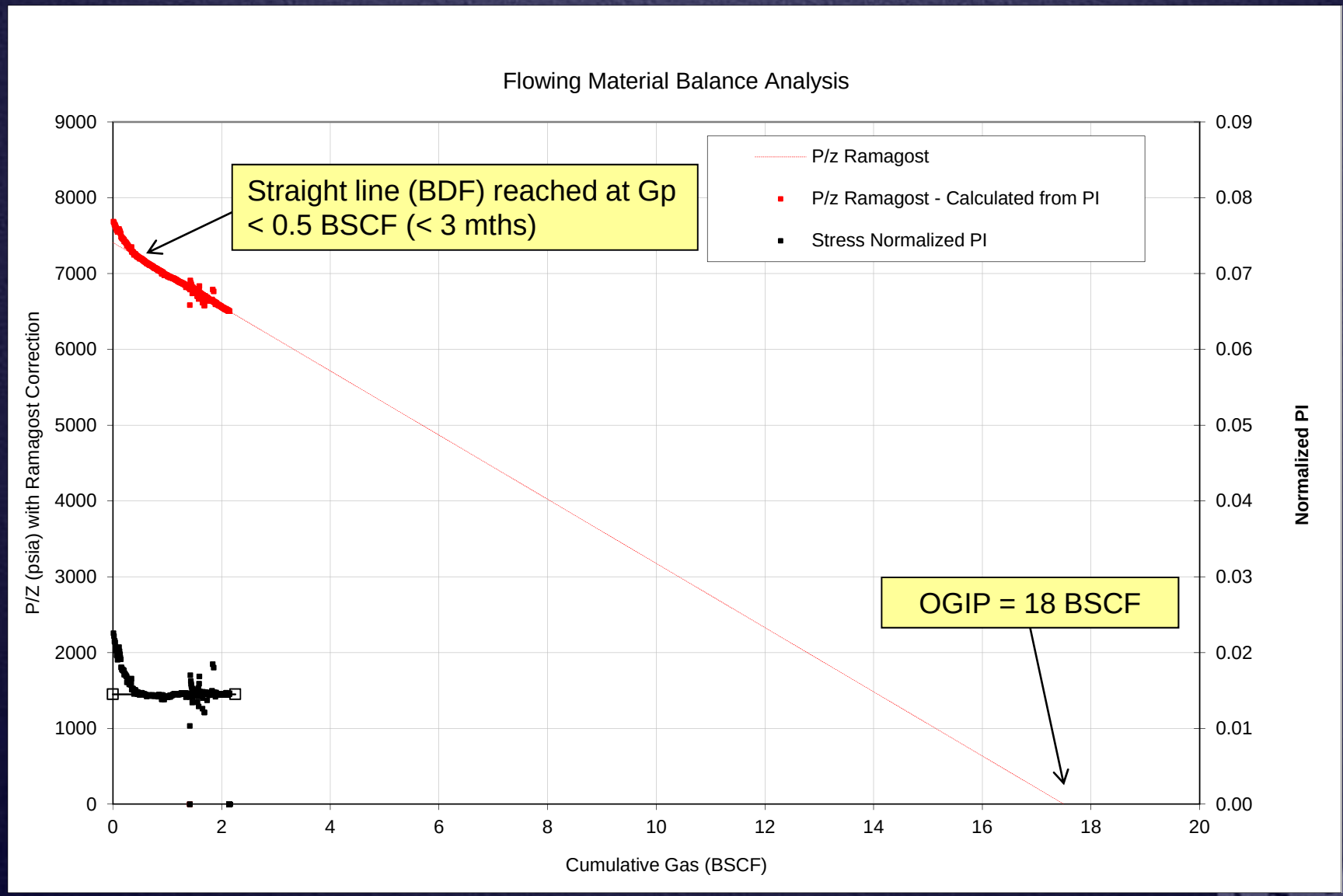
FMB Method – Example 1



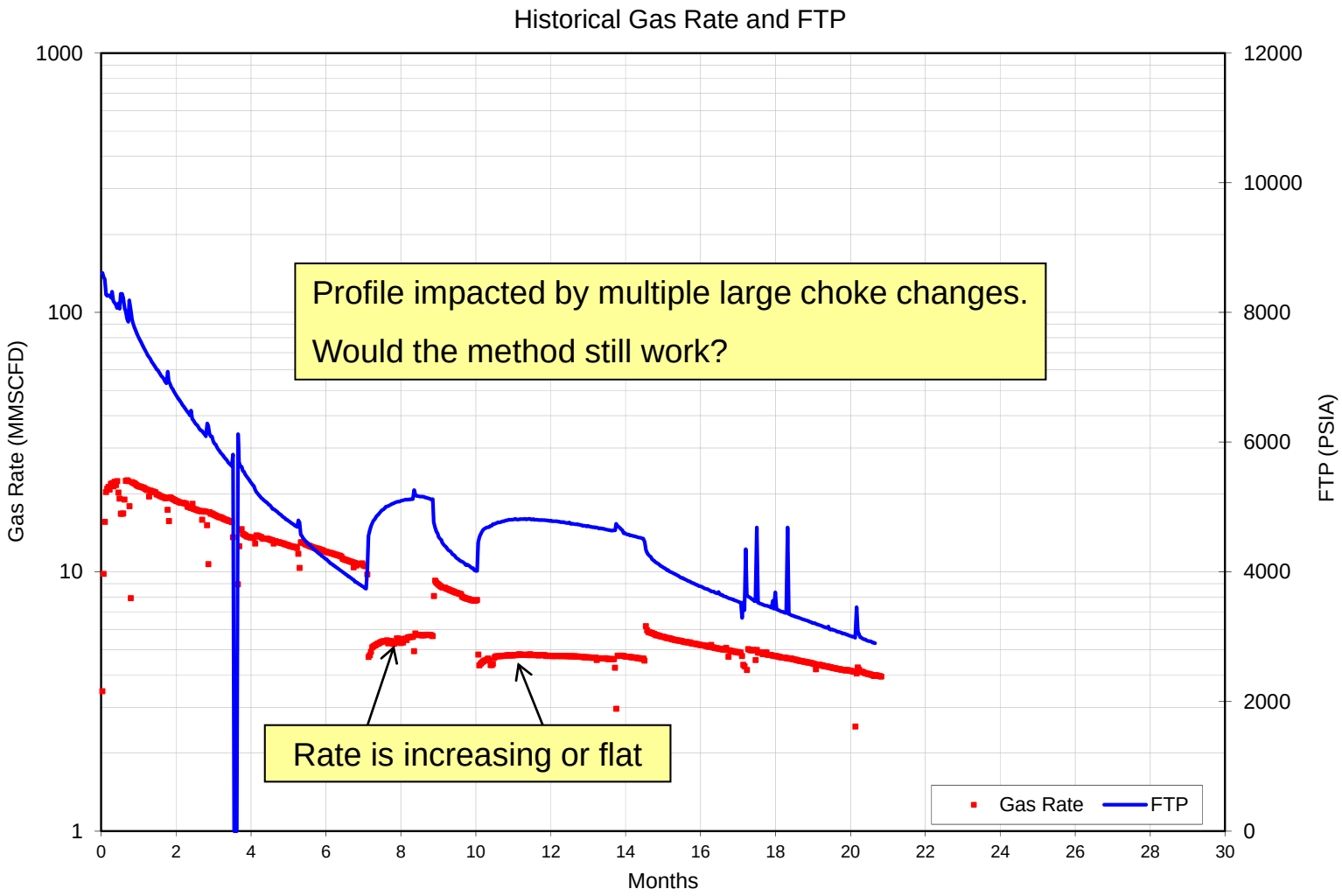
Rate and FTP vs Time – Example 2



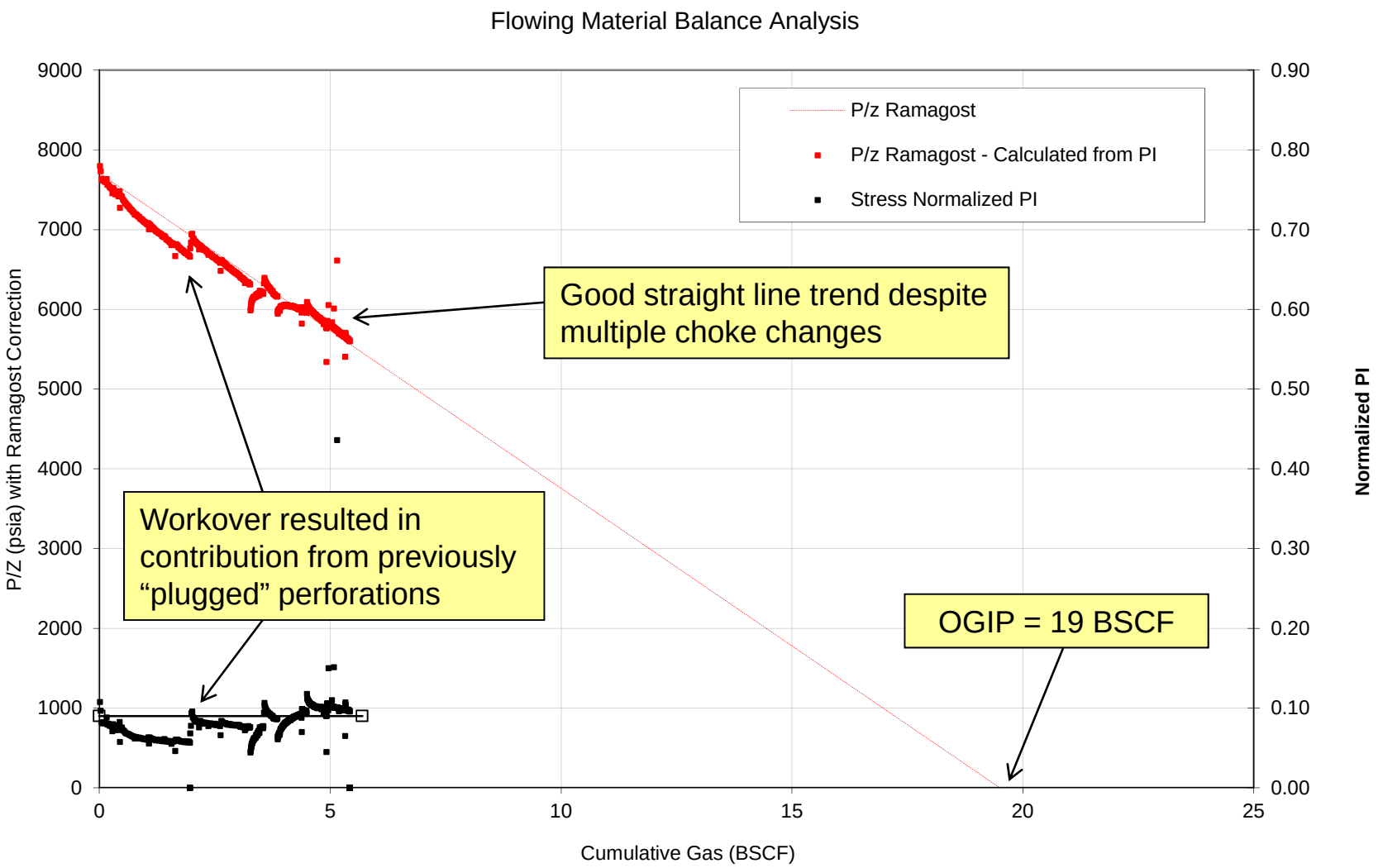
FMB Method – Example 2



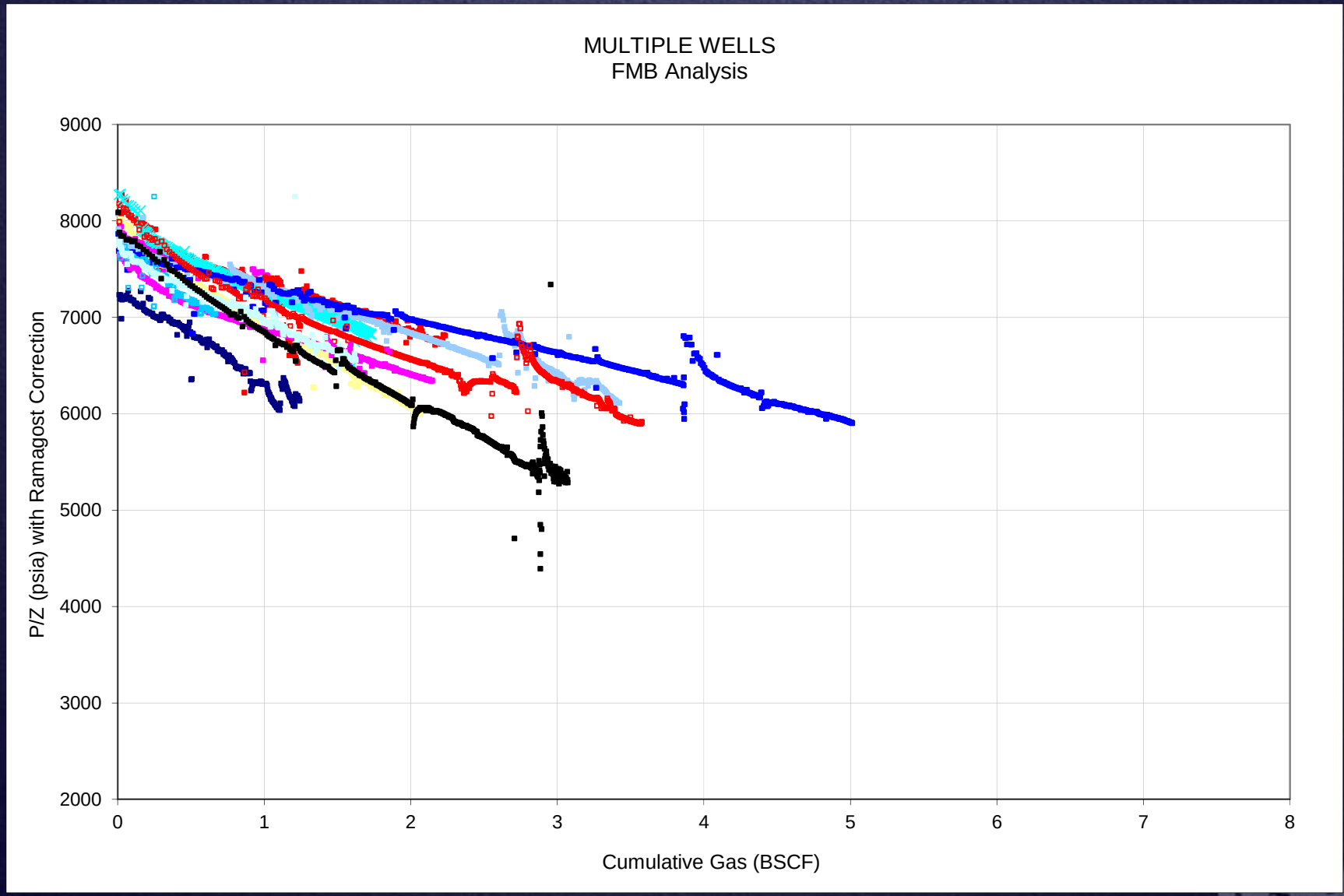
Rate and Pressure – Example 3



FMB Method – Example 3



FMB Method – Multiple Examples



Observations/Questions?

- FMB method seems to work across multiple shale plays including Haynesville, Eagleford, Niobrara and Marcellus
- Is it a surprise the method still works with shallow, normally pressured shale plays?
- FMB trends have thus far remained straight suggesting
  - GIIP is not increasing
  - Negligible contribution from outside of SRV (so far)
  - Free GIIP appears to be key, especially in early years which dominate recovery and NPV
- Will the lines stay straight?
- Will there be material contribution from outside SRV?

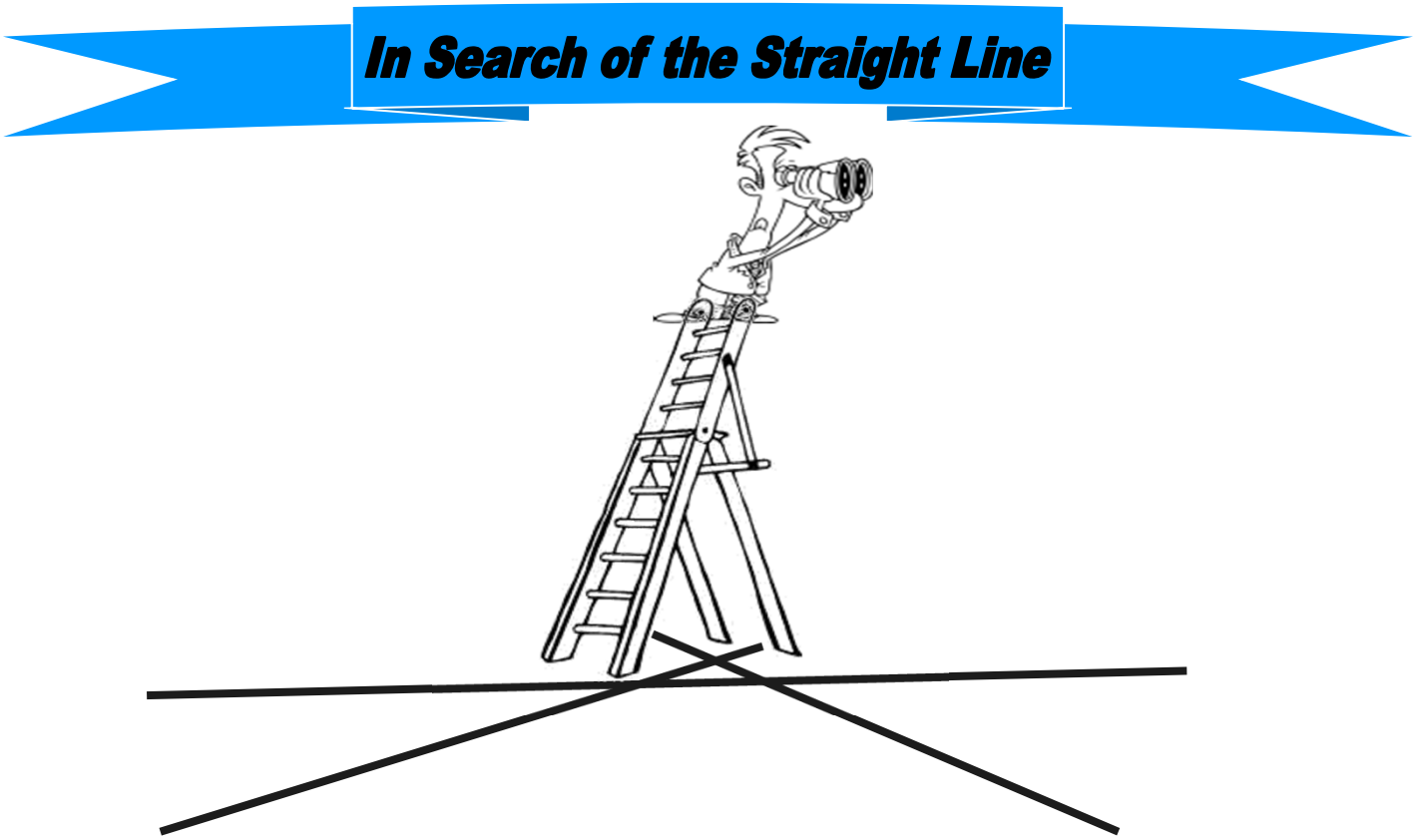
PI Method

The Motivation

- Shale gas wells are often rate-constrained during the early years of production
- Production rates can sometimes be near constant or even increasing as a result of choke changes
- Decline curve analysis methods that rely only on rate data are not reliable in such circumstances
- Thousands of US shale wells need to be analyzed each year. We wanted a simple forecast method that gave reliable estimates.

➢ Was there a straight line out there somewhere?

The Search



STRAIGHT LINES
Sheep, Engineers and Pseudo-Scientist's

"Lets apply a little science to understand why the line is straight so we can more confidently predict the future and avoid any cliffs"
Scott Rees – NSAI CEO, March 2011

The PI Method

Why?

- Restricted rate and variable choke settings prohibit DCA
- Productivity Index (PI) trends are predictable
- Can address future operations (e.g. line pressure impact)
- Diagnostic of problems/issues (e.g. offset interference, well damage etc)
- EUR can be observed directly from the plot

How?

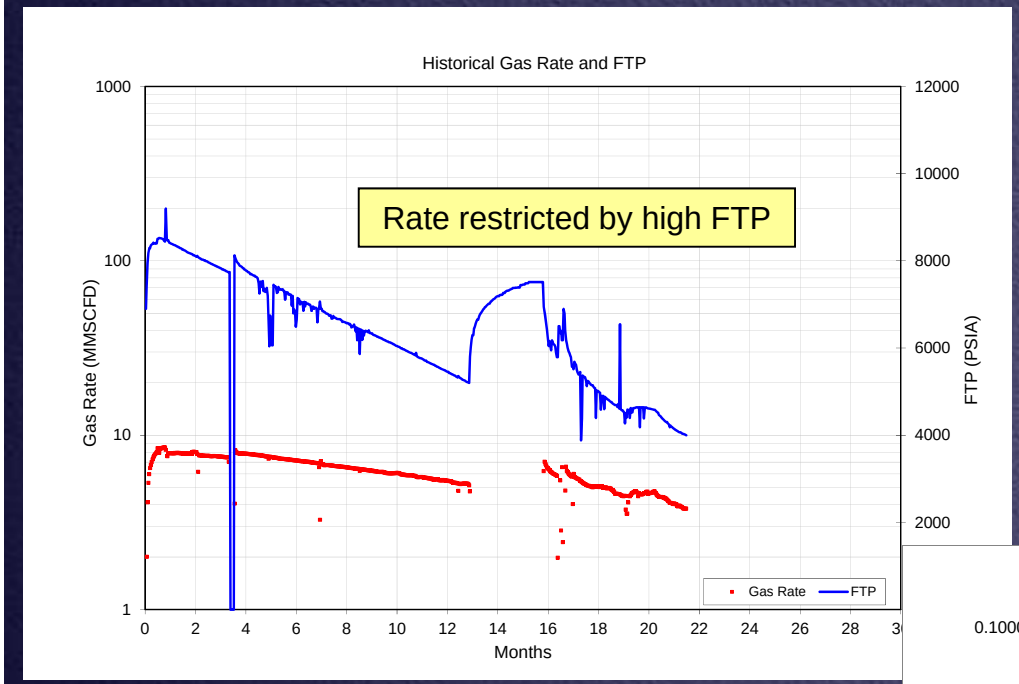
- Convert FTP to FBHP using tubing flow equation
- Calculate PVT properties including Pseudo Pressure m(p)
- Calculate PI as follows

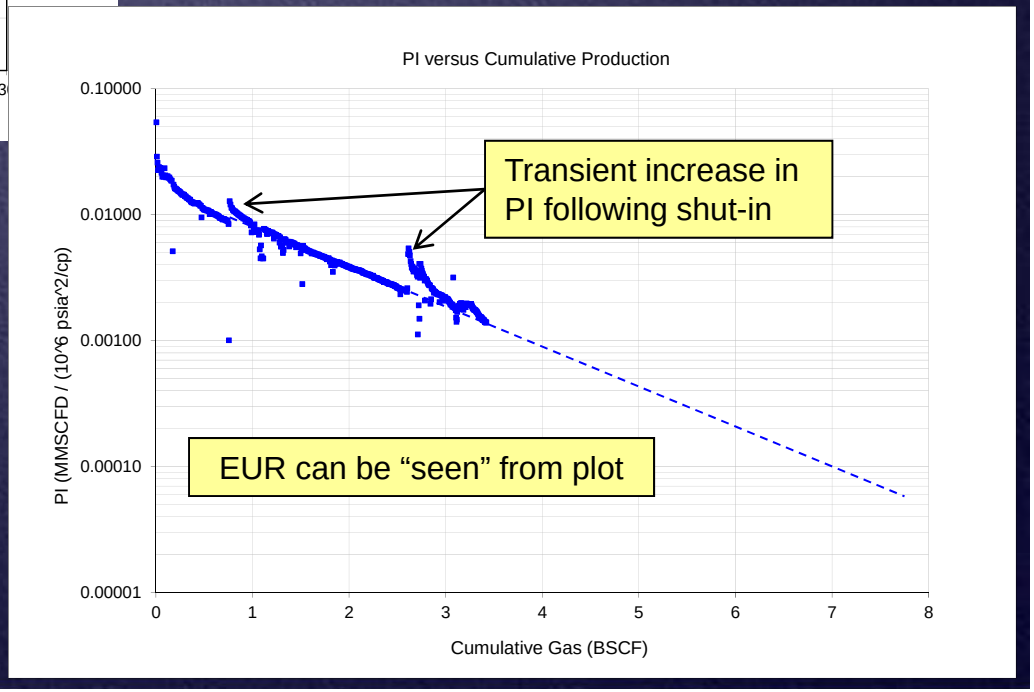
  $PI = Qgas / [m(p_i) - m(p_{wf})]$

$$m(p) = 2\int_{p_m}^{p} \frac{p}{\mu(p)z(p)}\,dp$$

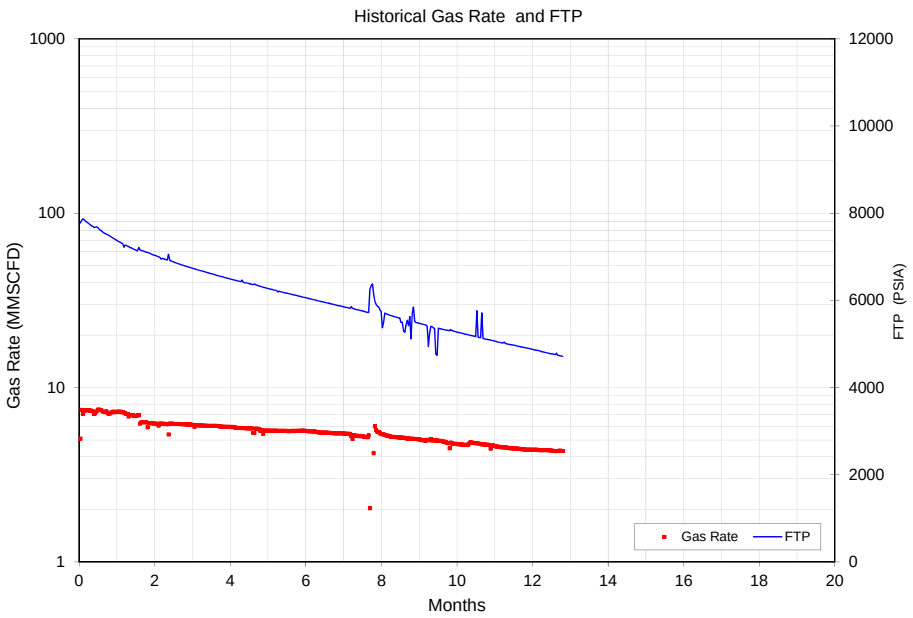
- Plot Log(PI) versus Gp

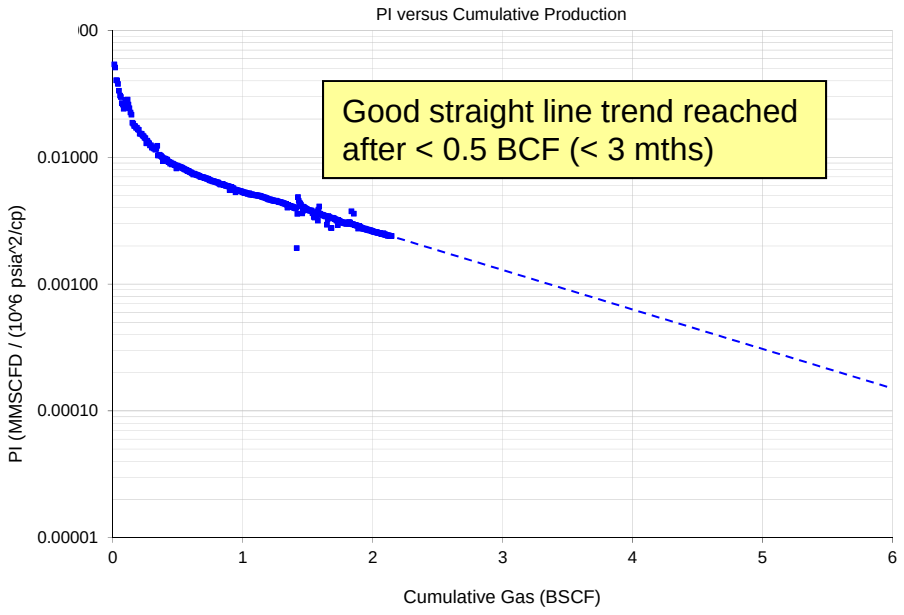
PI Method – Example 1



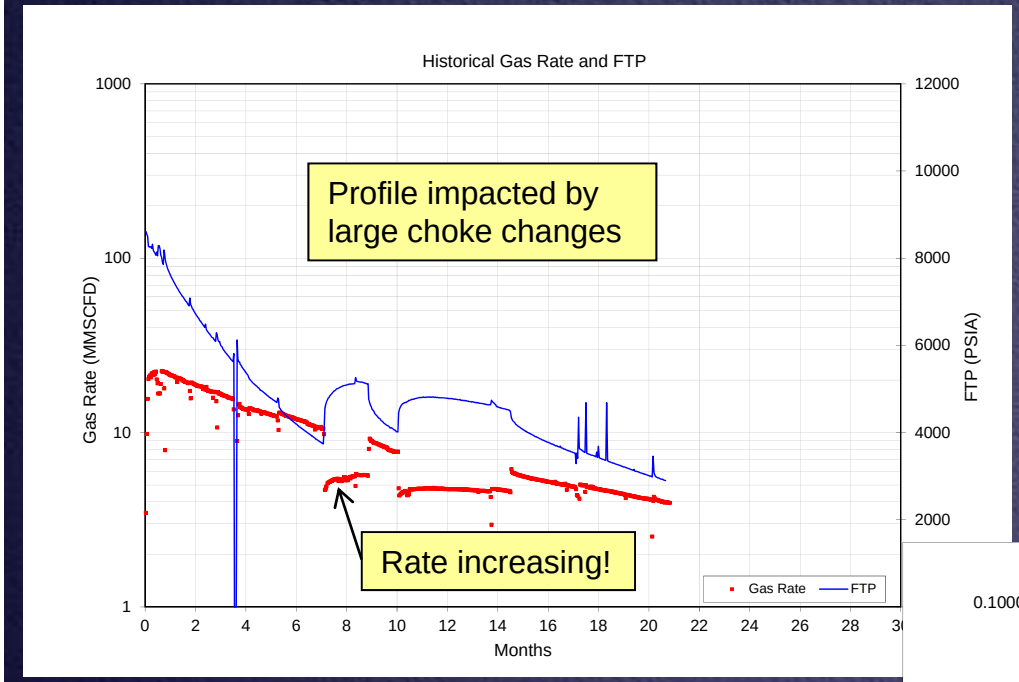


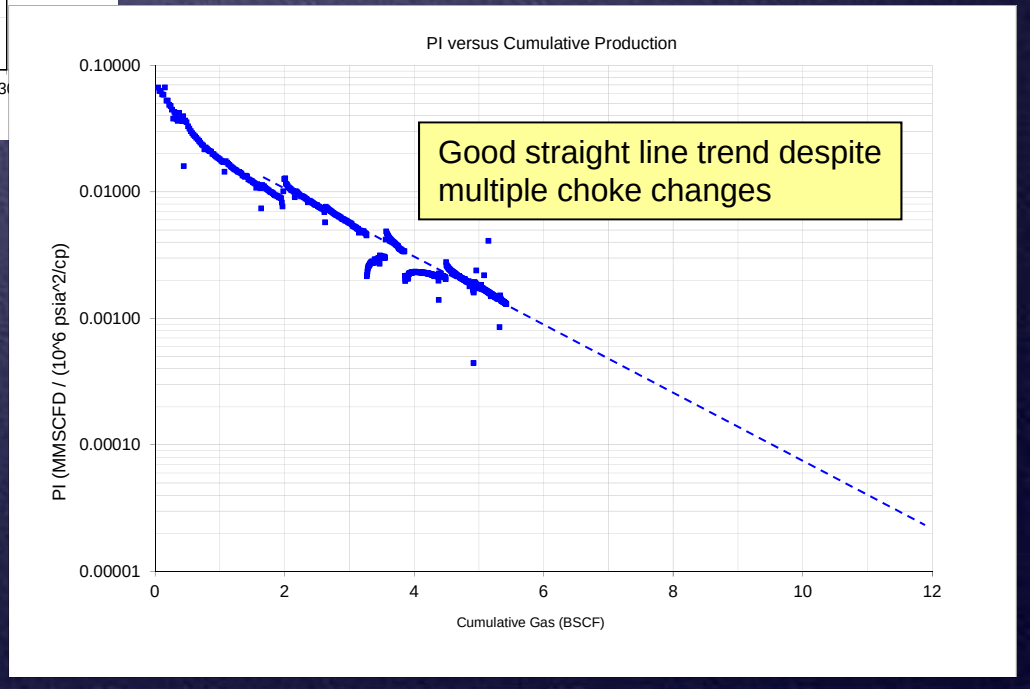
PI Method – Example 2



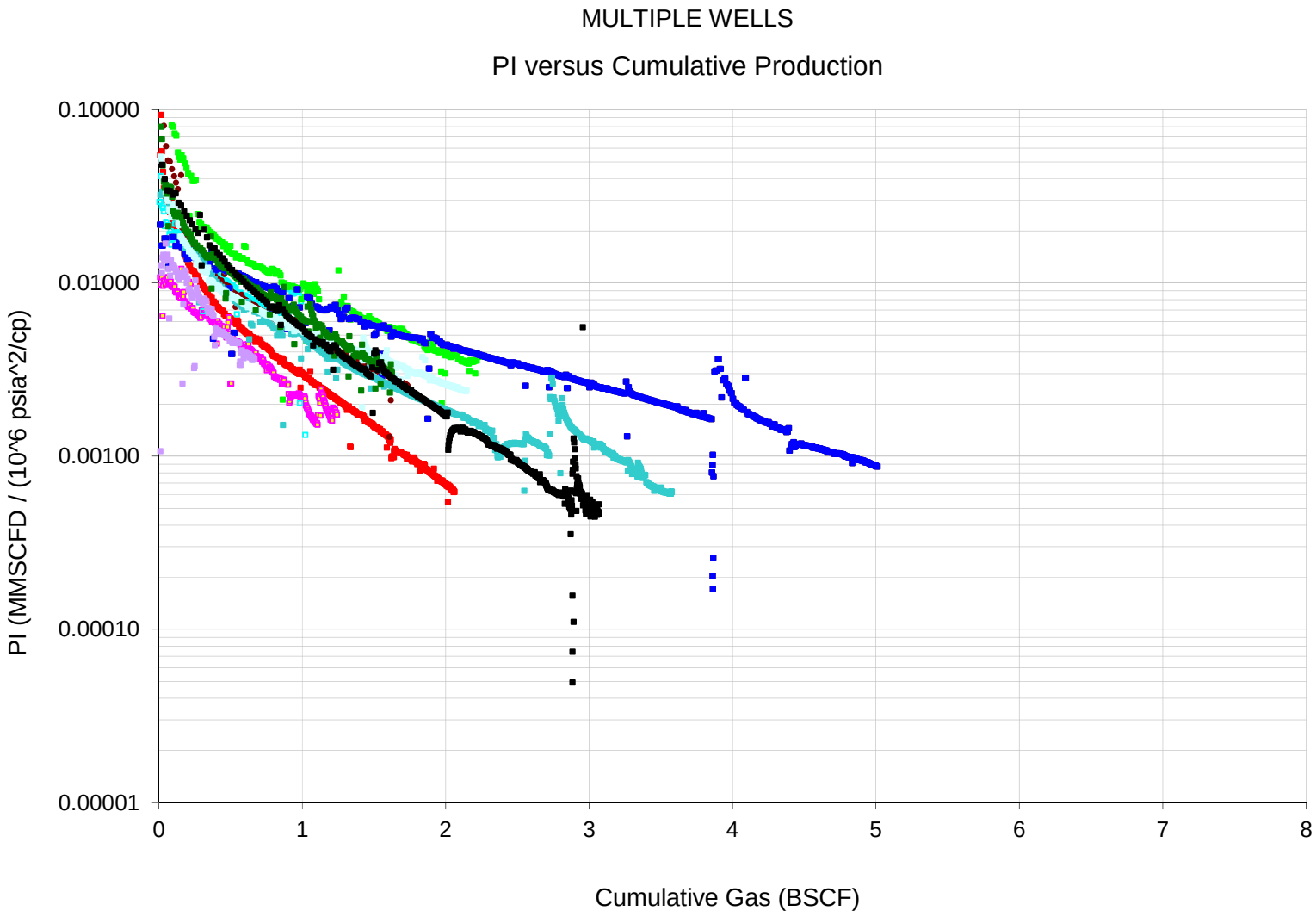


PI Method – Example 3

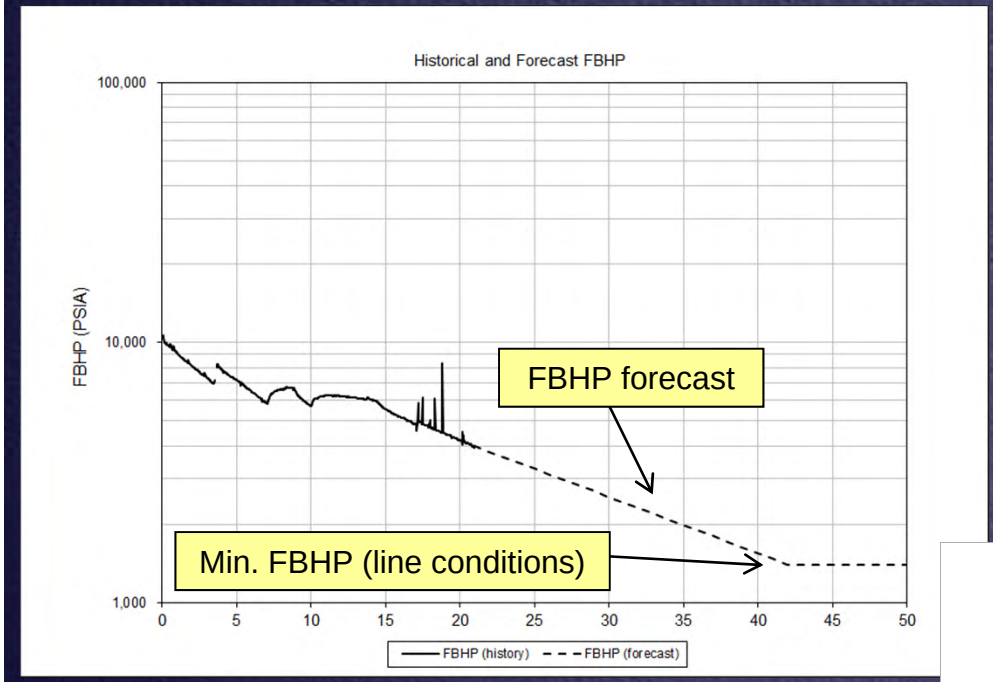


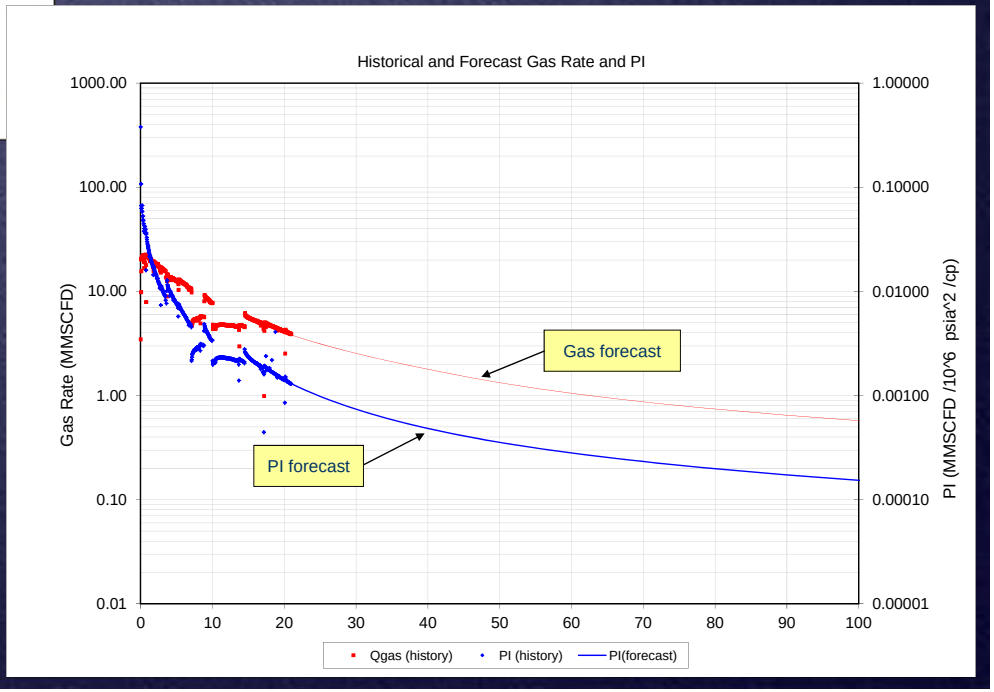


PI Method – Multiple Examples



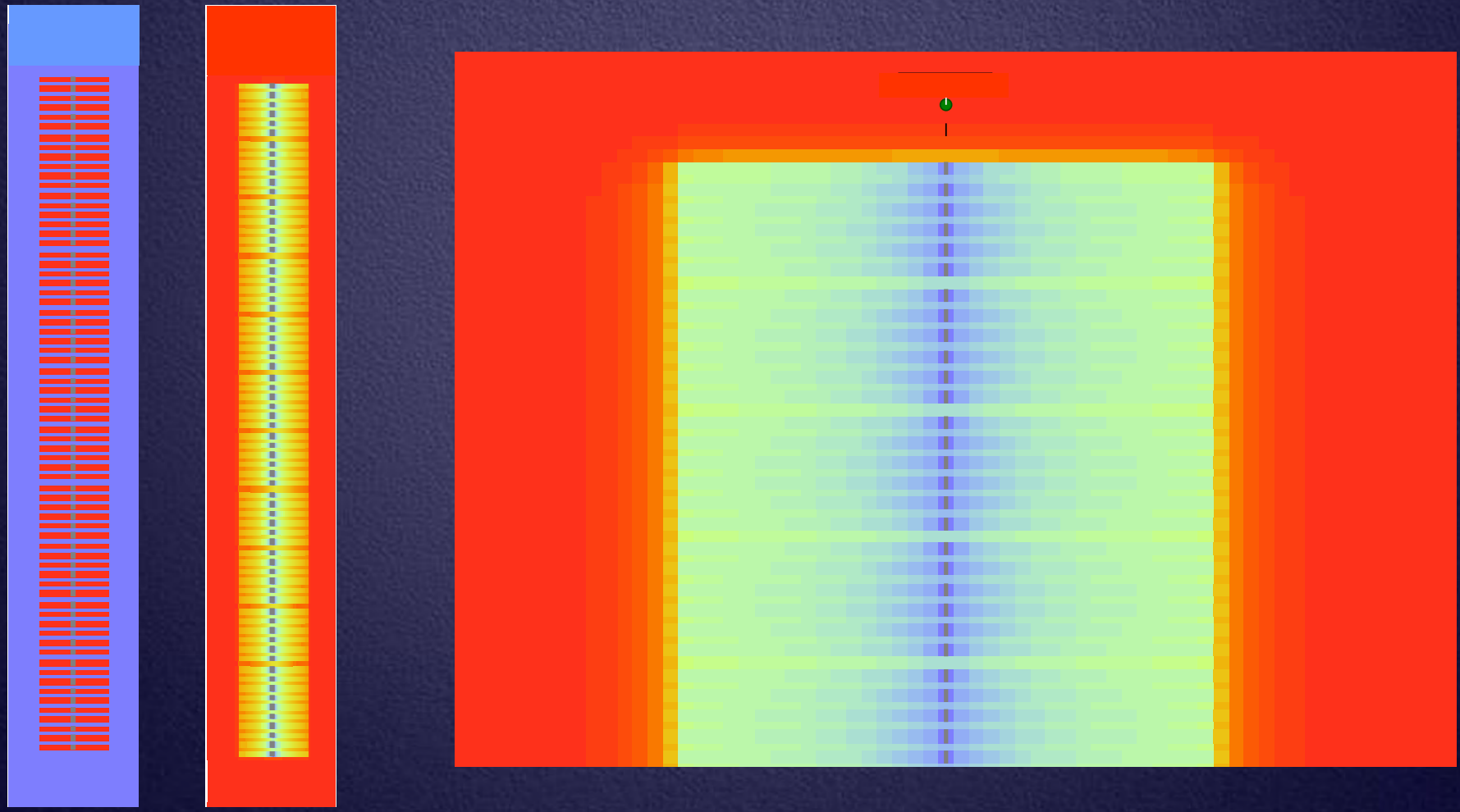
Rate vs Time Forecast – Example 3



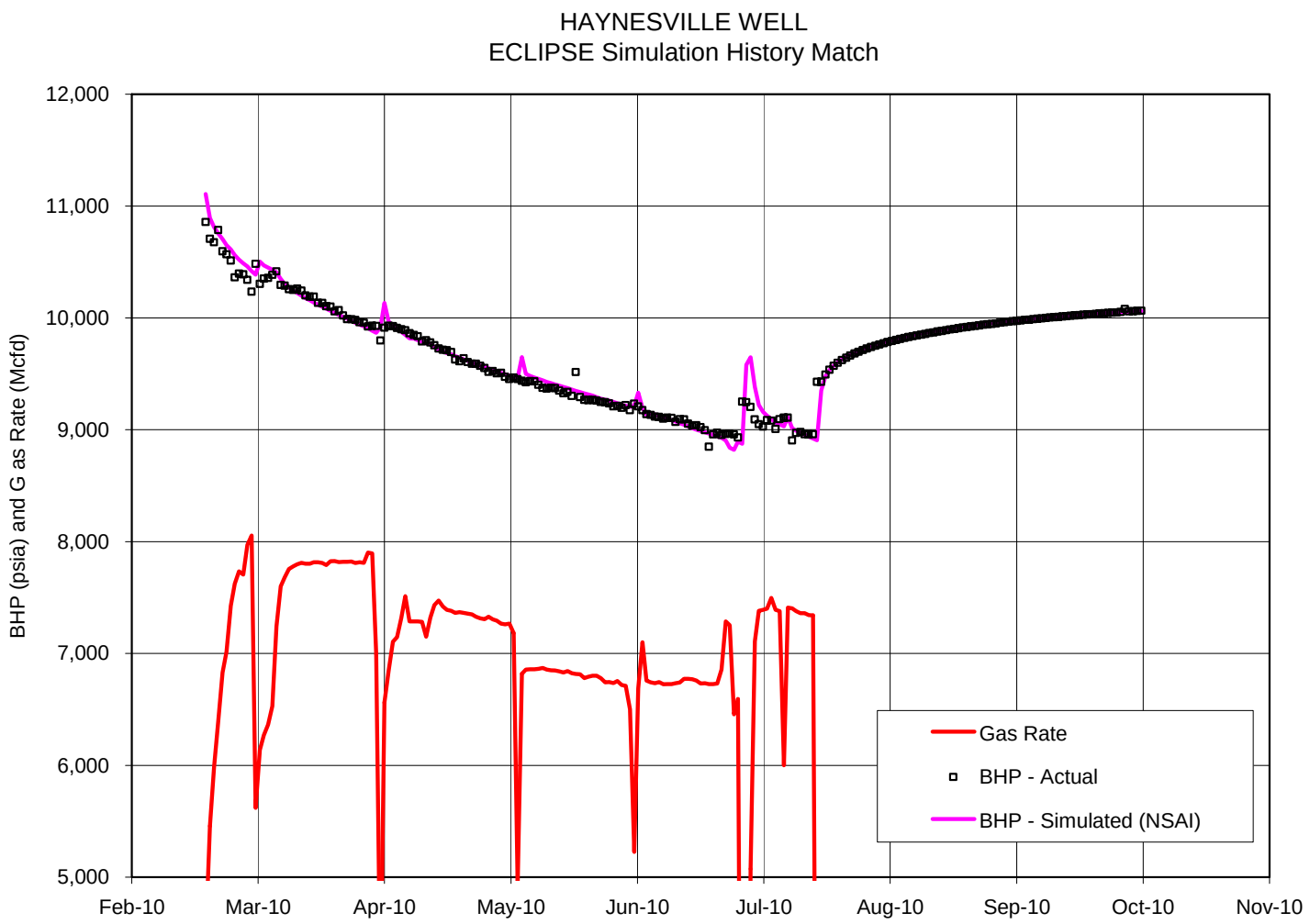


Reservoir Simulation

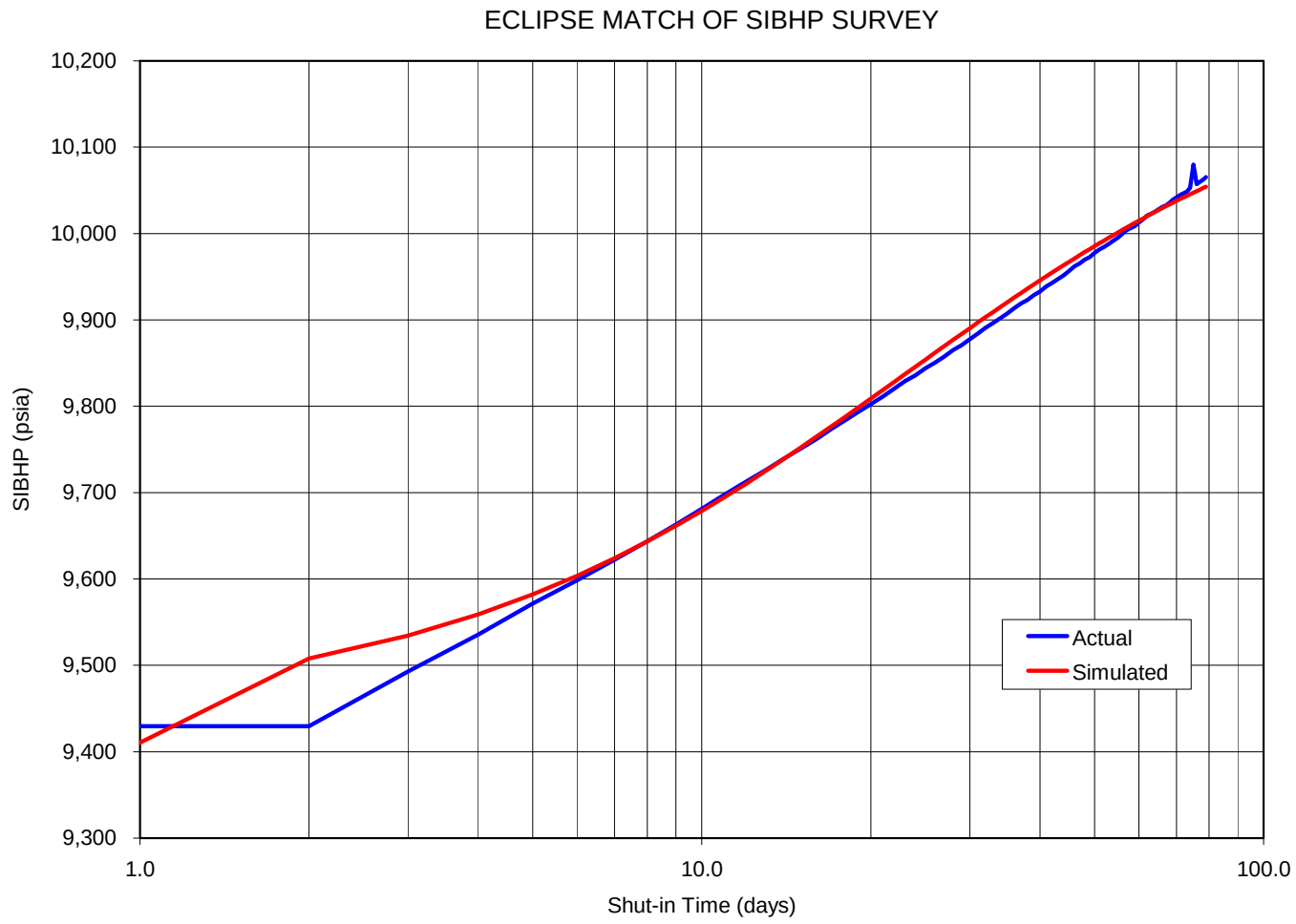
RESERVOIR SIMULATION
K Layout and BHP distribution



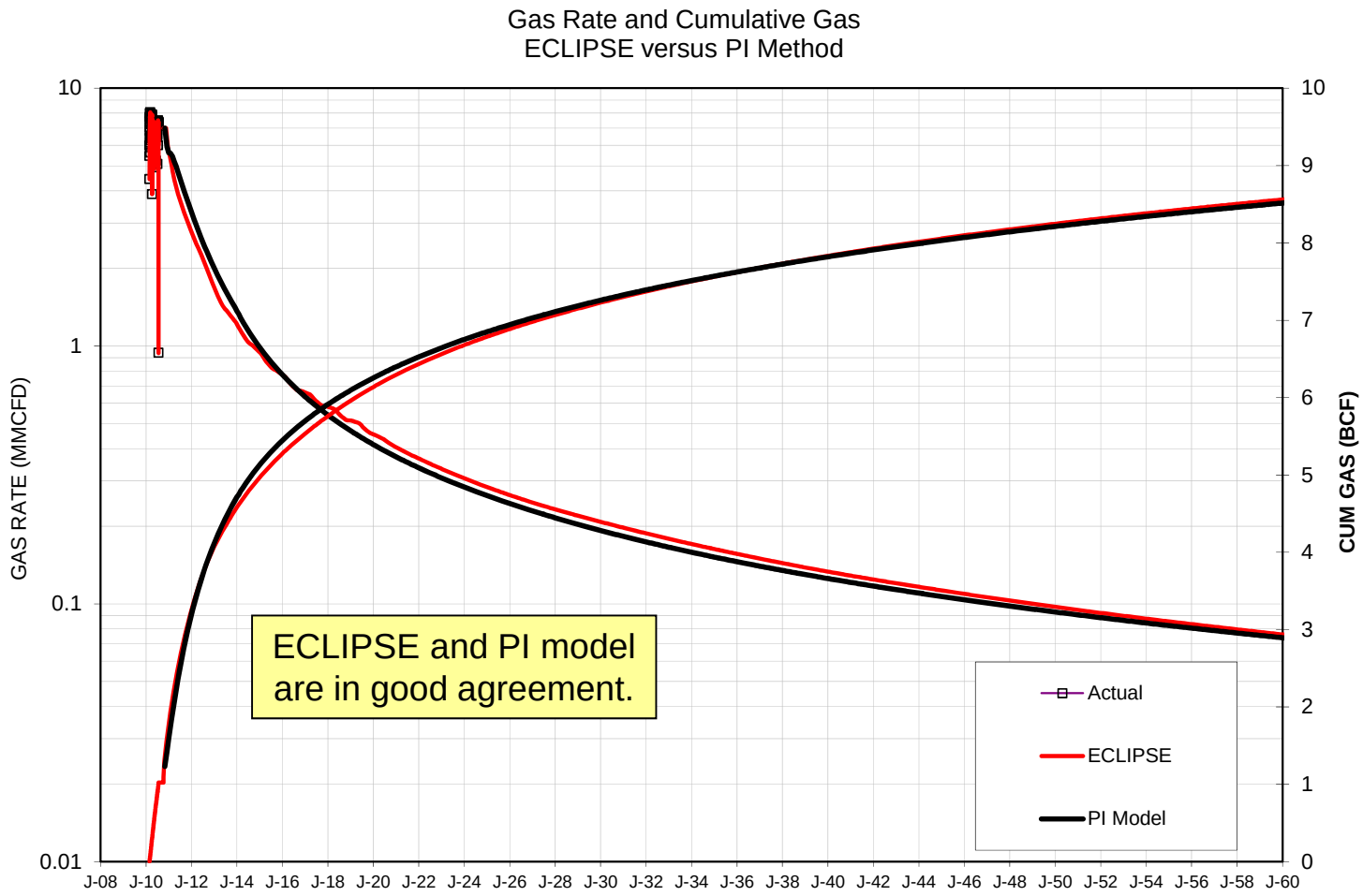
RESERVOIR SIMULATION
BHP Match – Haynesville Well



RESERVOIR SIMULATION
Pressure Build-up Match – Haynesville Well



RESERVOIR SIMULATION
Rate Forecast – Haynesville Well

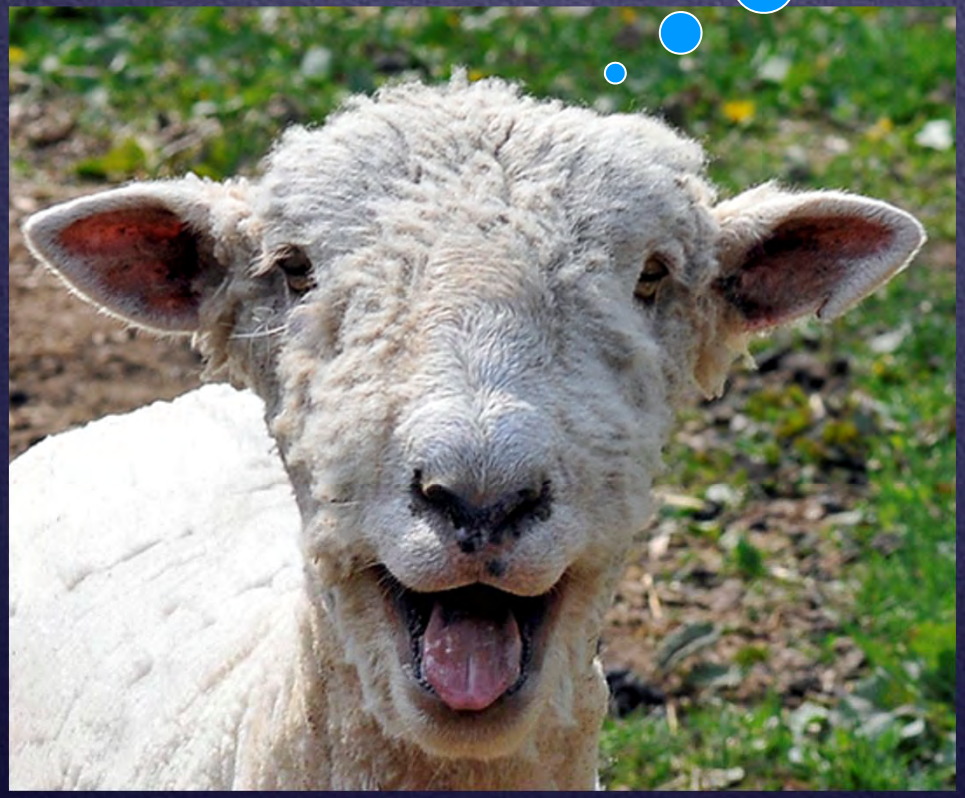


Observations

- PI method seems to work across multiple shale plays including Haynesville, Eagleford, Niobrara and Marcellus
- Method advantages
  - Incorporates both rate and pressure data
  - Simple to implement - only need Rate, FTP and Initial BHP data
  - Provides EUR estimates with limited production history
  - Easy to convert to rate versus time forecast

➢ Will the lines stay straight?

Happiness is a Straight Line!




NSAI
NSAI