

Distinguished Lecturer Program

Primary funding is provided by

**The SPE Foundation through member donations
and a contribution from Offshore Europe**

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Additional support provided by AIME



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Distinguished Lecturer Program
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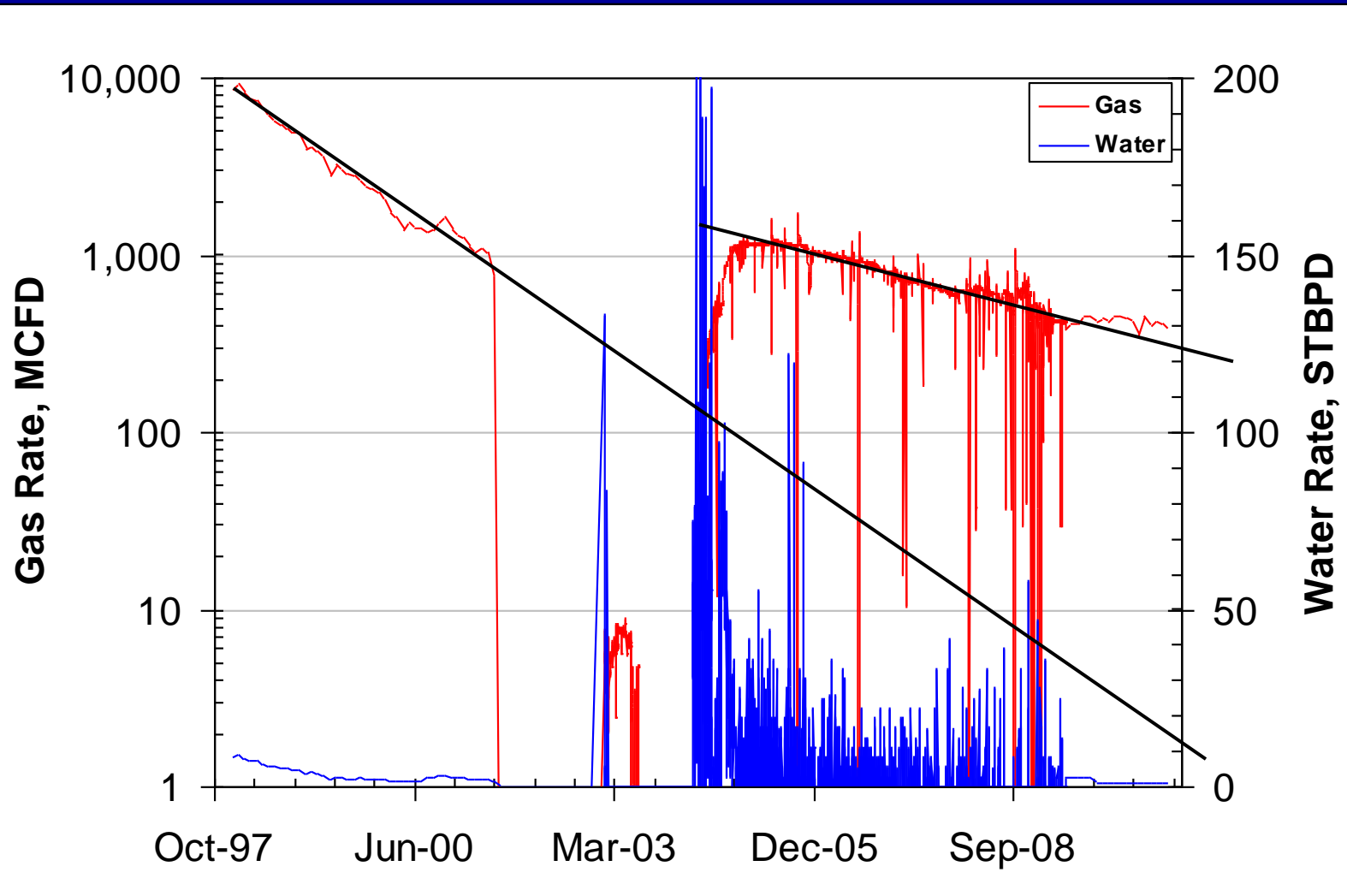
Understanding Liquid Loading Will Improve Well Performance



Marathon Oil
Corporation

Rob Sutton

Example of Successful Deliquification Program



Purpose

Address the following question:

Can complex well geometries affect liquid loading characteristics and well performance?

Terminology

- Critical velocity
- Critical rate
- Static liquid column
- Terrain slugging
- Severe slugging
- Vertical Flow Performance
 - VFP Curves
 - Nodal Analysis

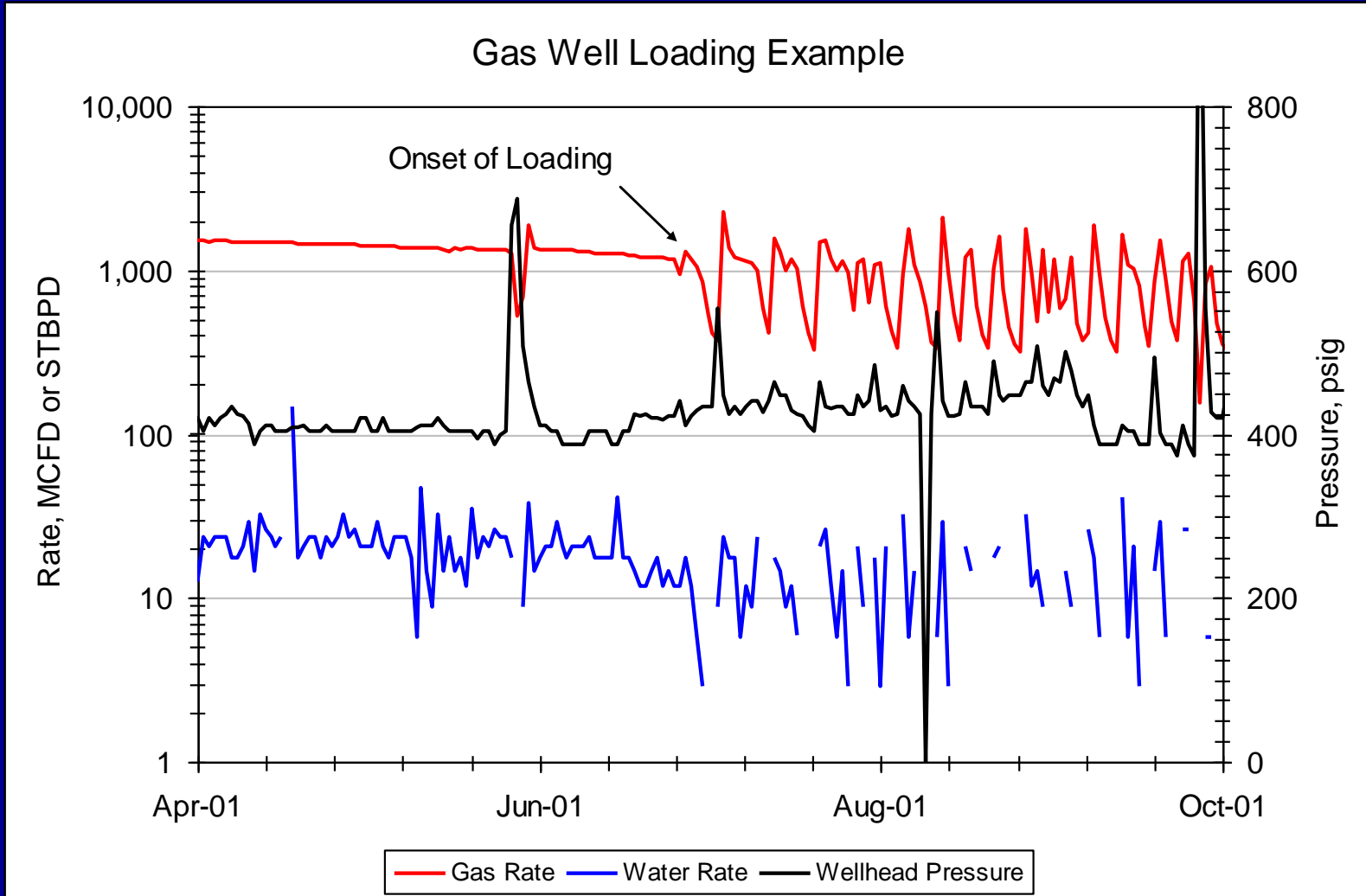
Analysis Techniques

- Vertical flow performance curves
- Critical velocity
- Production graphs
 - Rate vs Time
 - Pressure vs Time
- Flowing pressure surveys
- Acoustic survey

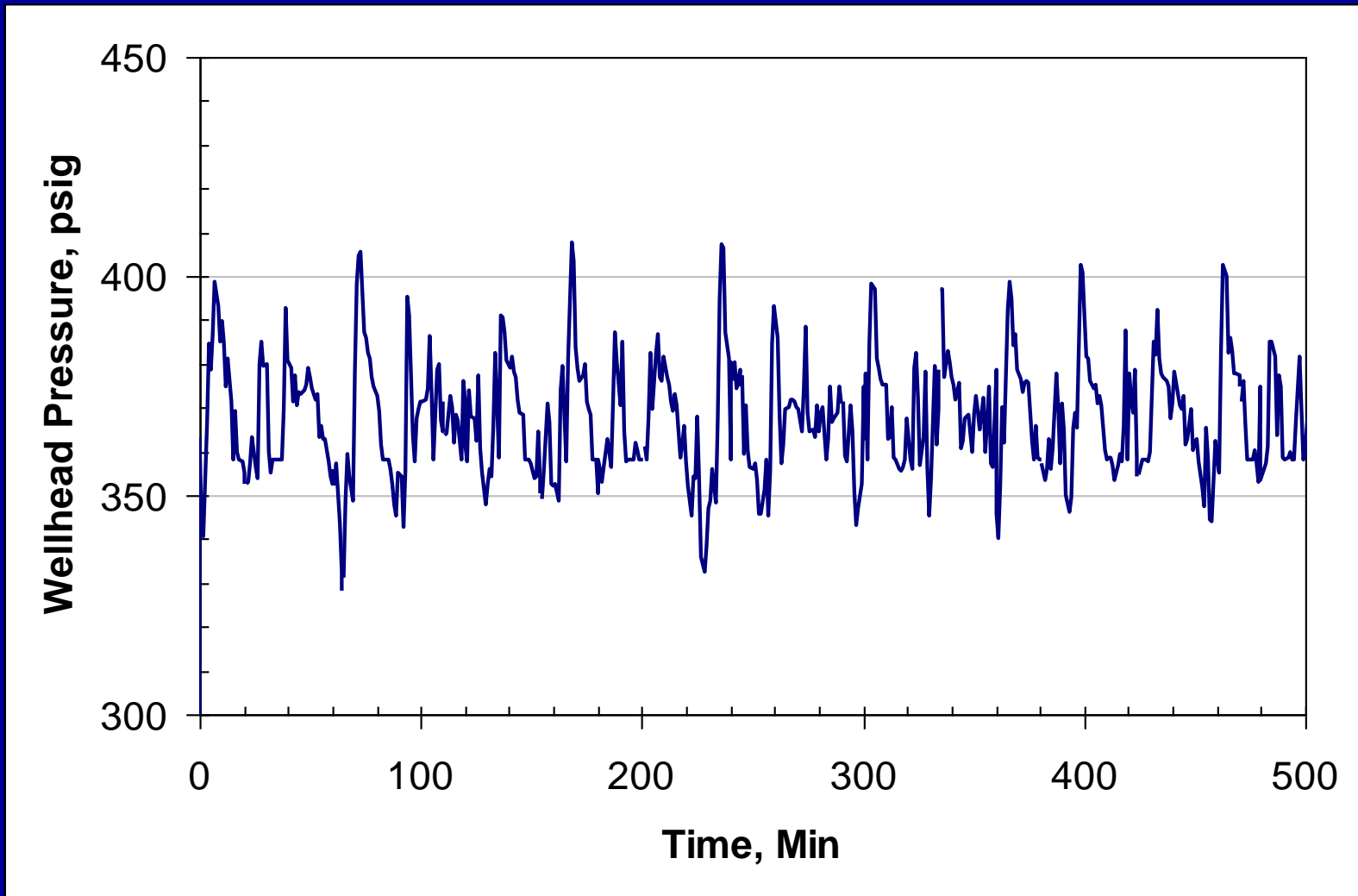
Complications

- Tubing set high above perforations
- Long completion intervals
- Complex well geometries
- Problem recognition

Production Data

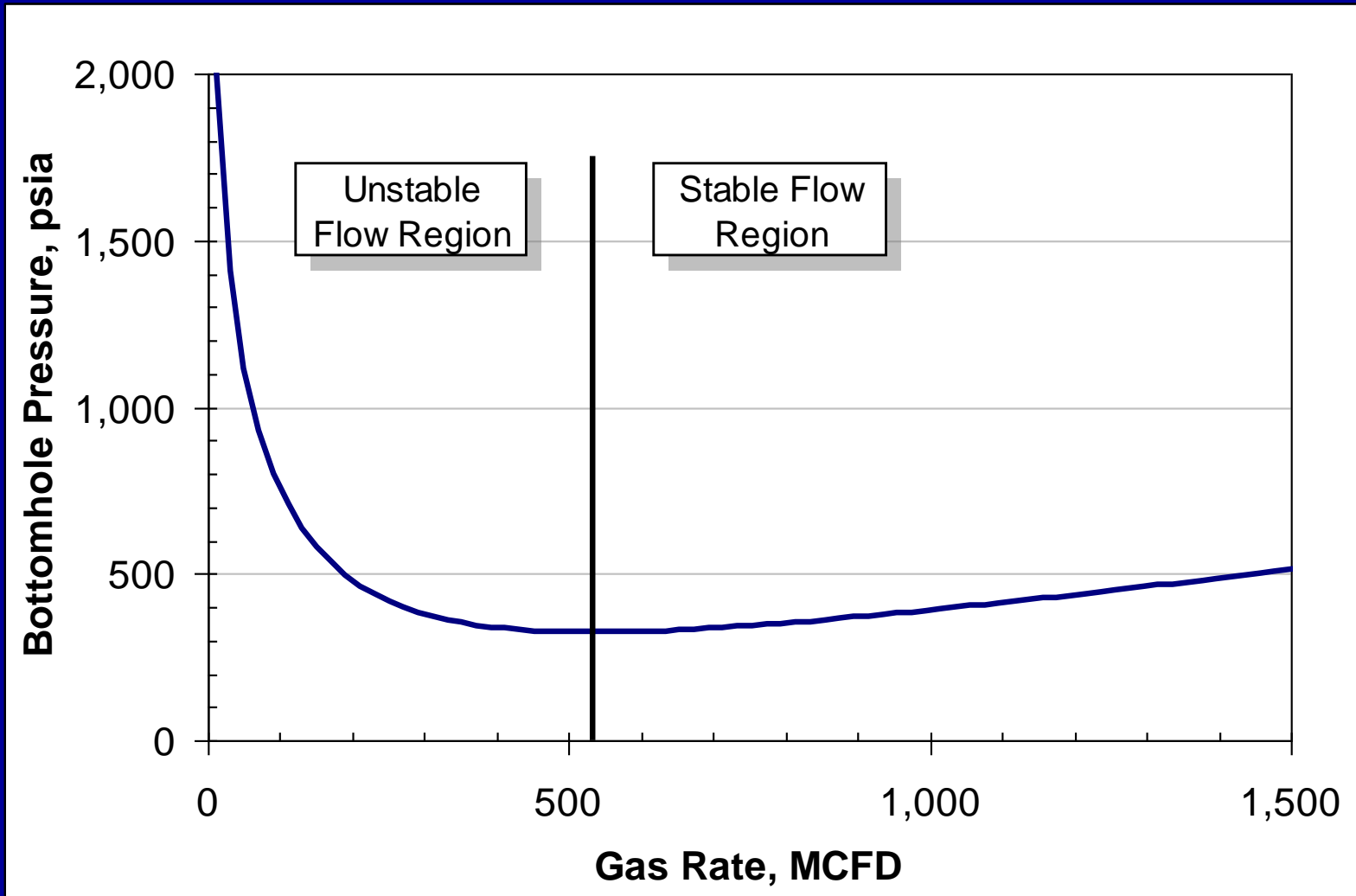


Pressure Data

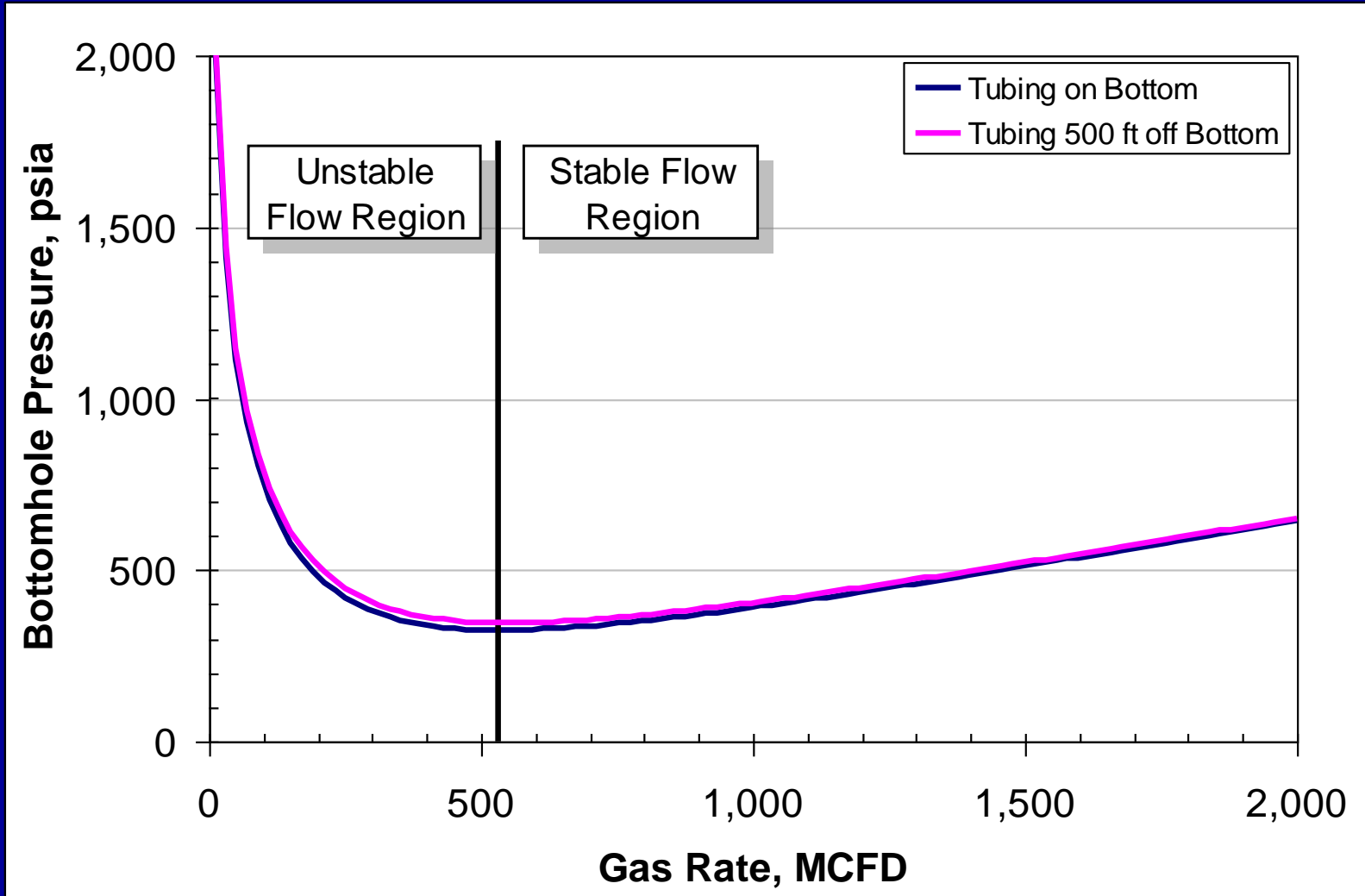


Critical Rate

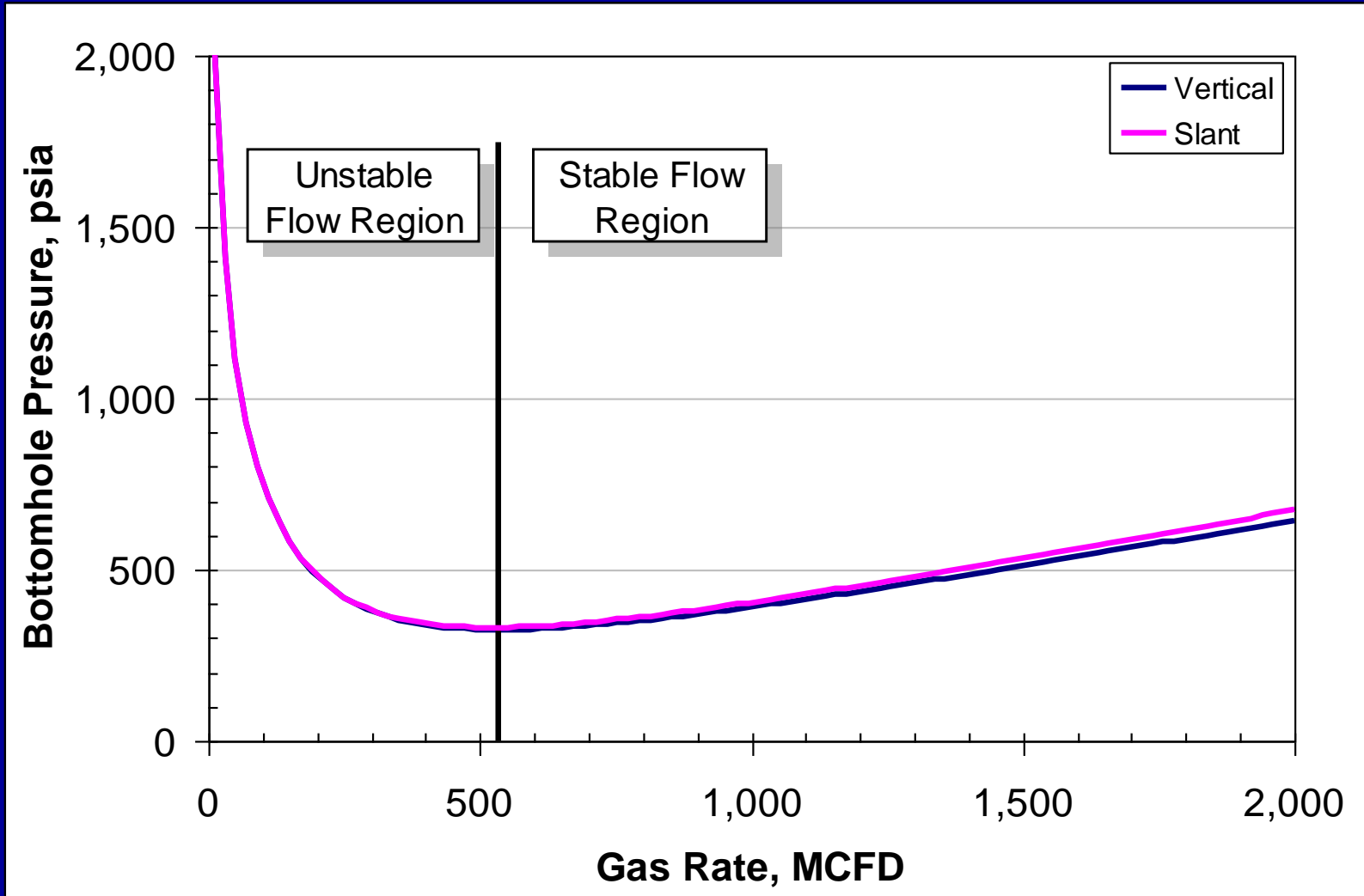
Vertical Flow Performance



Tubing on Bottom vs Tubing Set High



Vertical vs Slant Well Geometry



Unloading Velocity

- Equation derived for vertical well
- Developed from terminal fall velocity
 - Liquid density
 - Gas density
 - Largest liquid droplet
- Frequently termed “critical velocity”

Turner Unloading Velocity

$$v_c = 1.5934 \left[\frac{\sigma (\rho_l - \rho_g)}{\rho_g^2} \right]^{0.25}$$

Without $\pm 20\%$ adjustment
Coleman Equation

where

ρ_g = gas phase density, lbm/ft³

ρ_L = liquid phase density, lbm/ft³

σ = surface tension, dynes/cm

v_c = critical velocity of liquid droplet, ft/sec

Turner Unloading Velocity

$$v_c = 1.5934 \underbrace{\left[\frac{N_{we}}{30} \right]^{0.25}}_{\text{Turner Adjustment}} \left[\frac{\sigma(\rho_l - \rho_g)}{\rho_g^2} \right]^{0.25} \underbrace{\frac{[\sin(1.7(90 - \theta))]^{0.38}}{0.740767}}_{\text{Belfroid et al SPE 115567 Angle Correction}}$$

where

ρ_g = gas phase density, lbm/ft³

ρ_L = liquid phase density, lbm/ft³

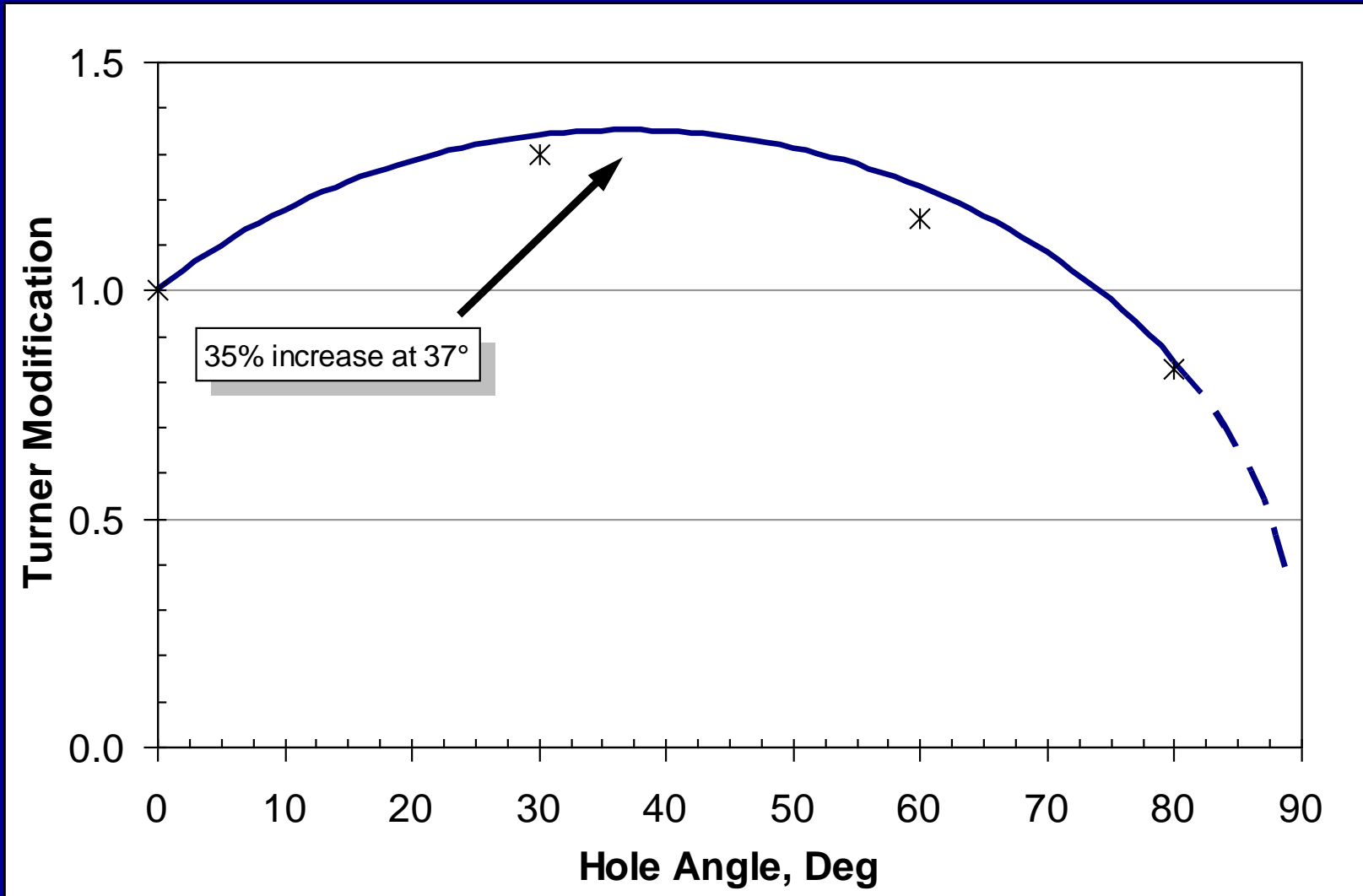
σ = surface tension, dynes/cm

N_{we} = Weber Number (use 60 for original Turner)

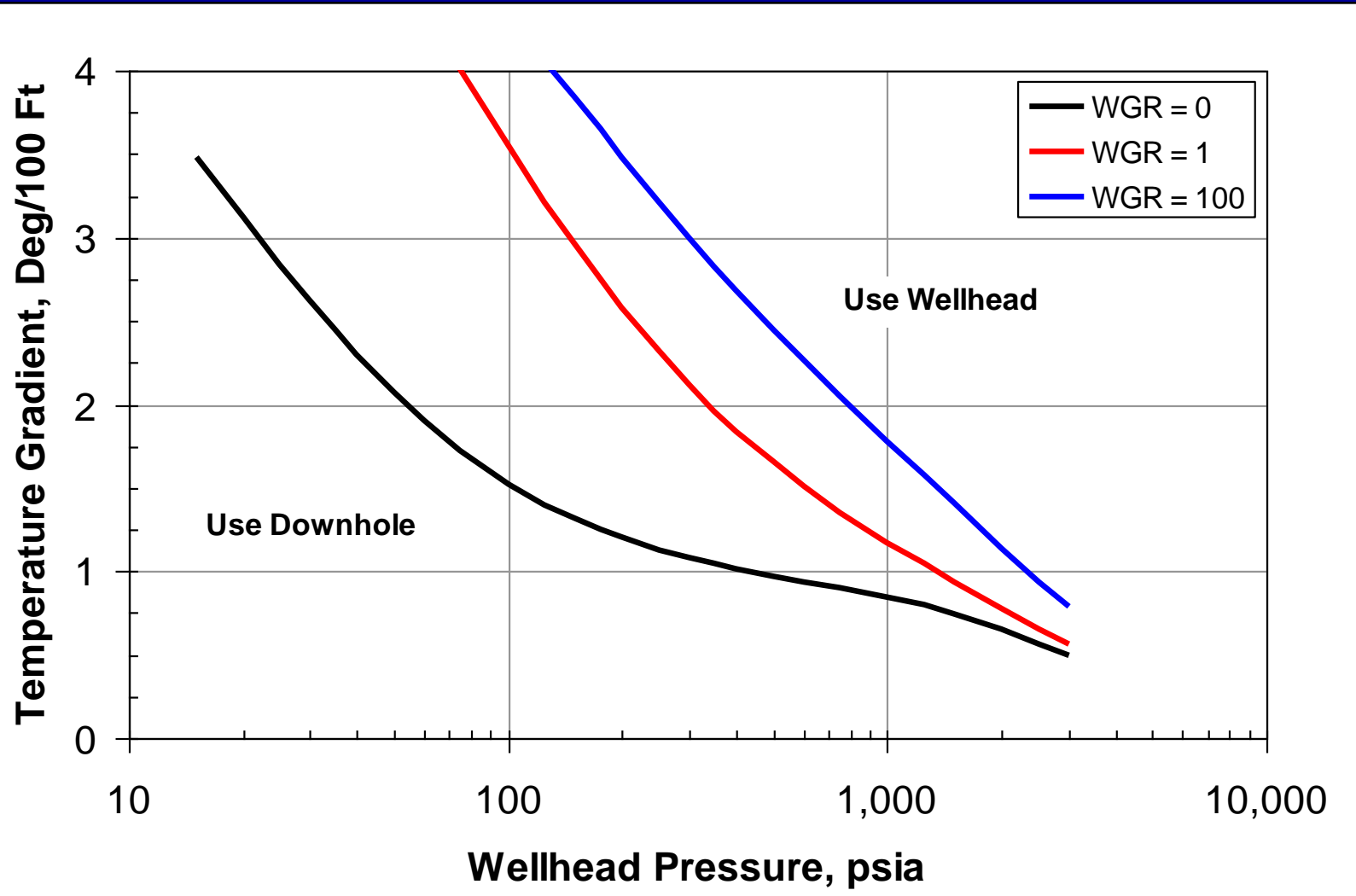
θ = hole angle (Deg from vertical)

v_c = critical velocity of liquid droplet, ft/sec

Well Angle Modification to Turner



Evaluation Point

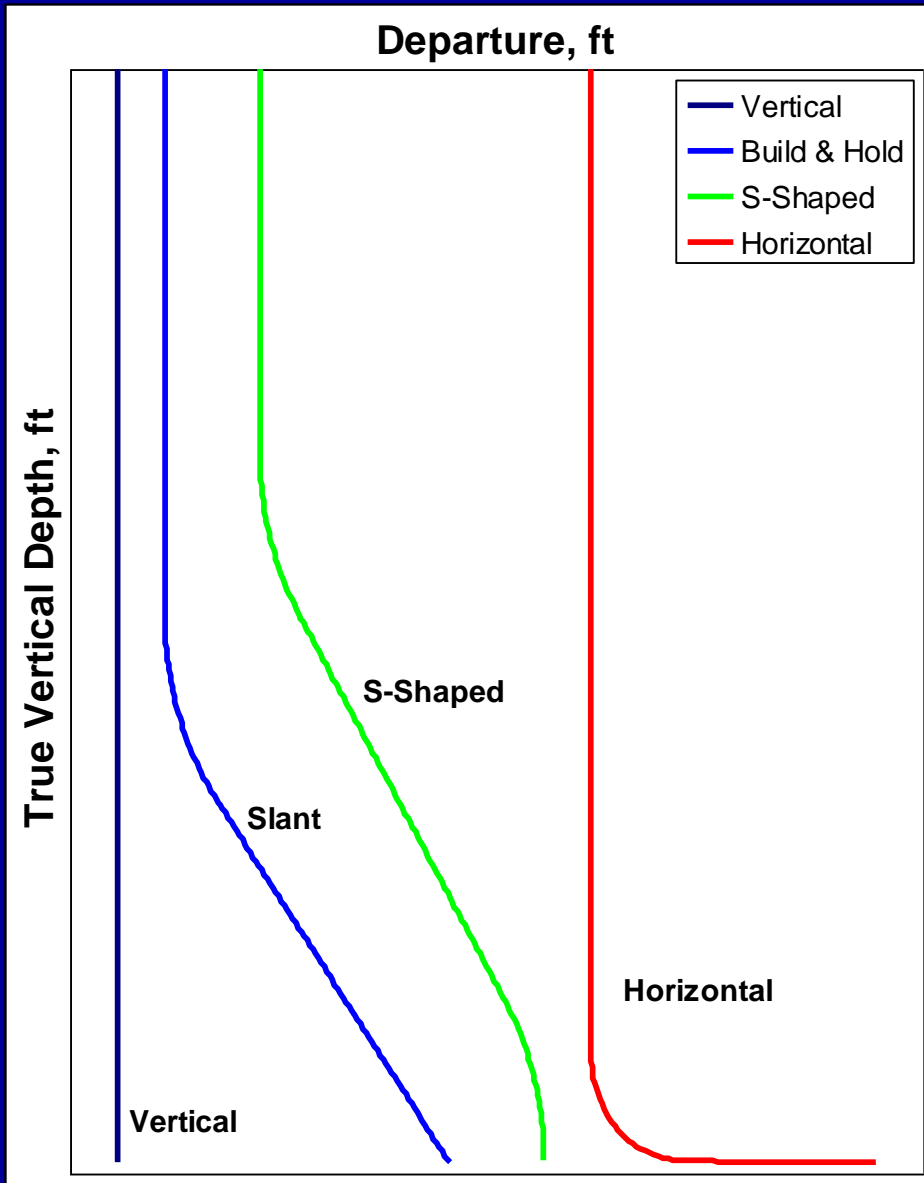


Dtbg = 2.441 in

$\gamma_g = 0.65$

SPE 120625

Assorted Well Profiles

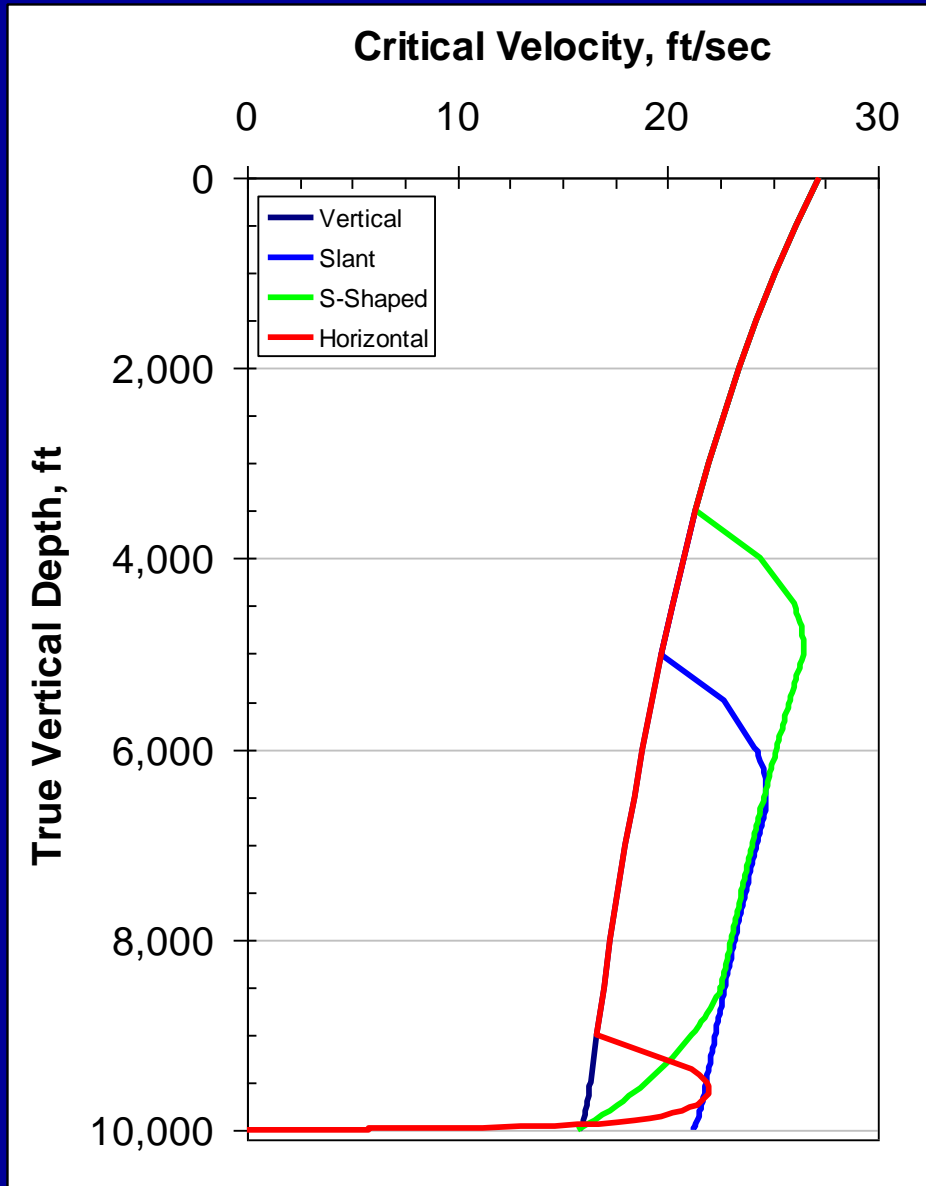


Complex Profiles

- Vertical
- Build & Hold (Slant)
- S-Shaped
- Horizontal

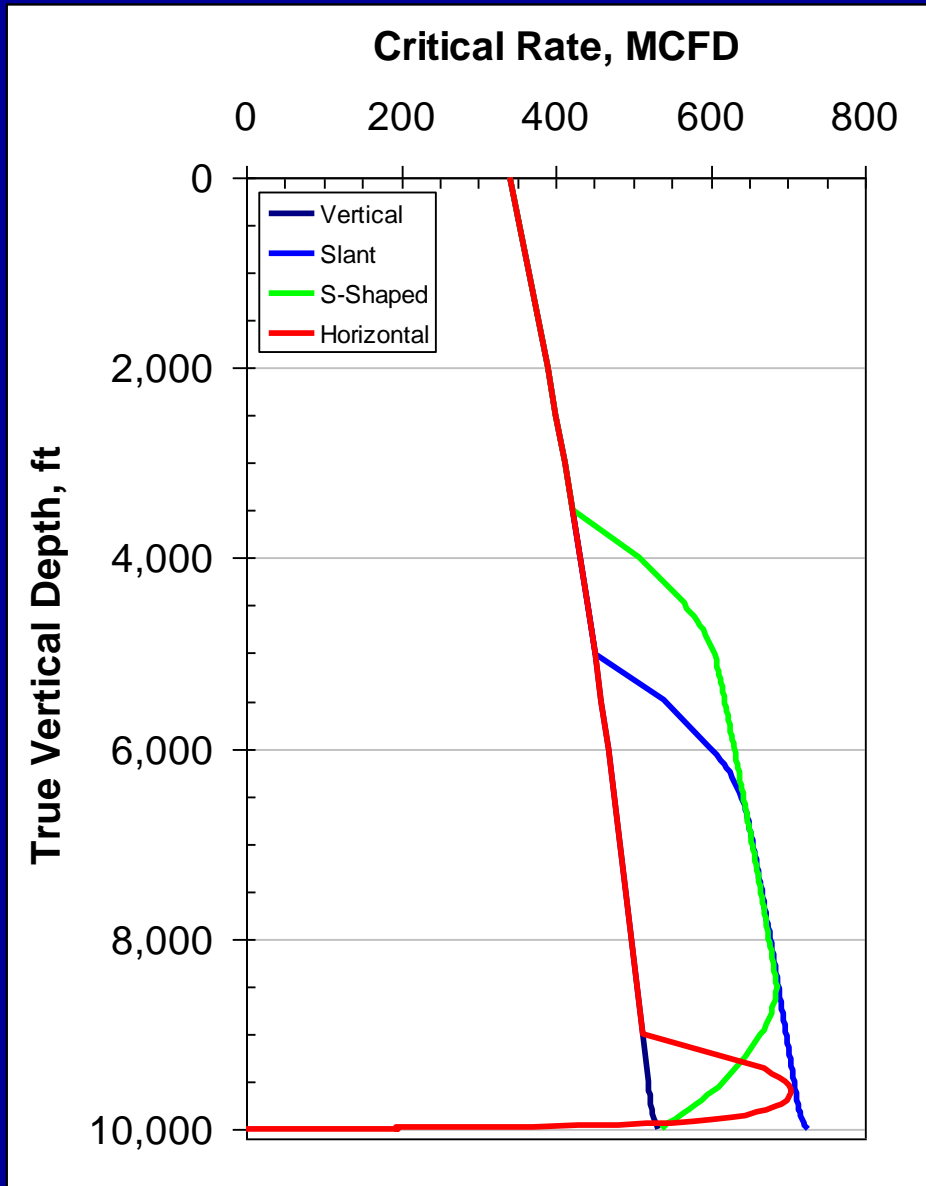
- Complexity increases velocity or rate to unload well

Example Critical Velocity Profiles



- Effects on critical velocity
 - Pressure
 - Temperature
 - PVT
 - Gas gravity
 - Water salinity
 - Hole Angle

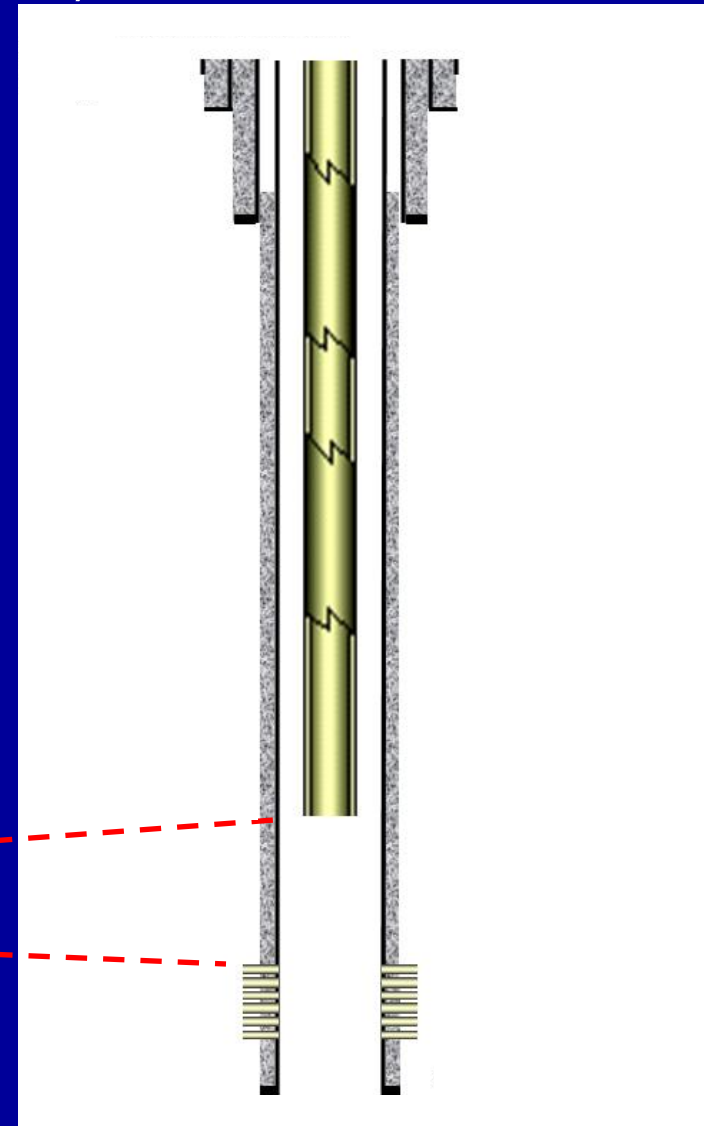
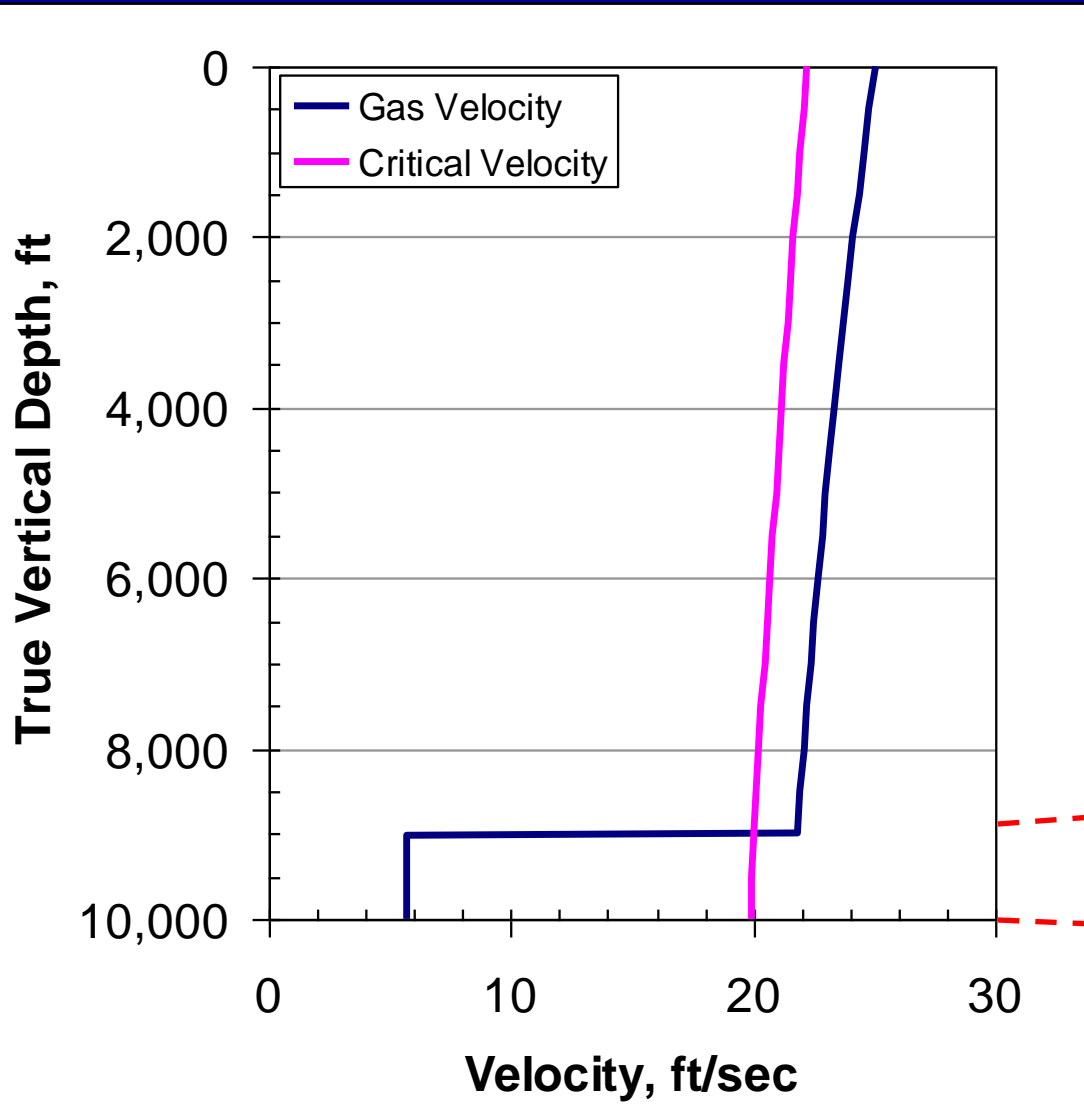
Example Critical Rate Profiles



- Effects on critical rate
 - Pressure
 - Gas gravity
 - Water salinity
 - Temperature
 - PVT
 - Hole Angle
 - Pipe Diameter

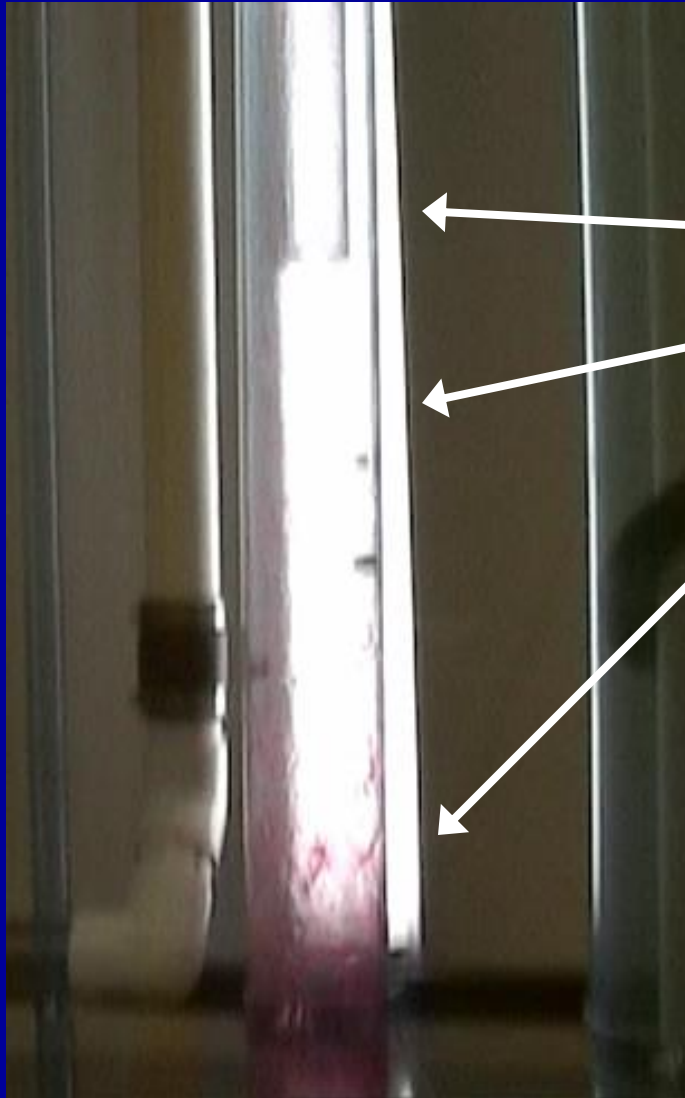
Vertical Well Case

(Variable Tubing Size)

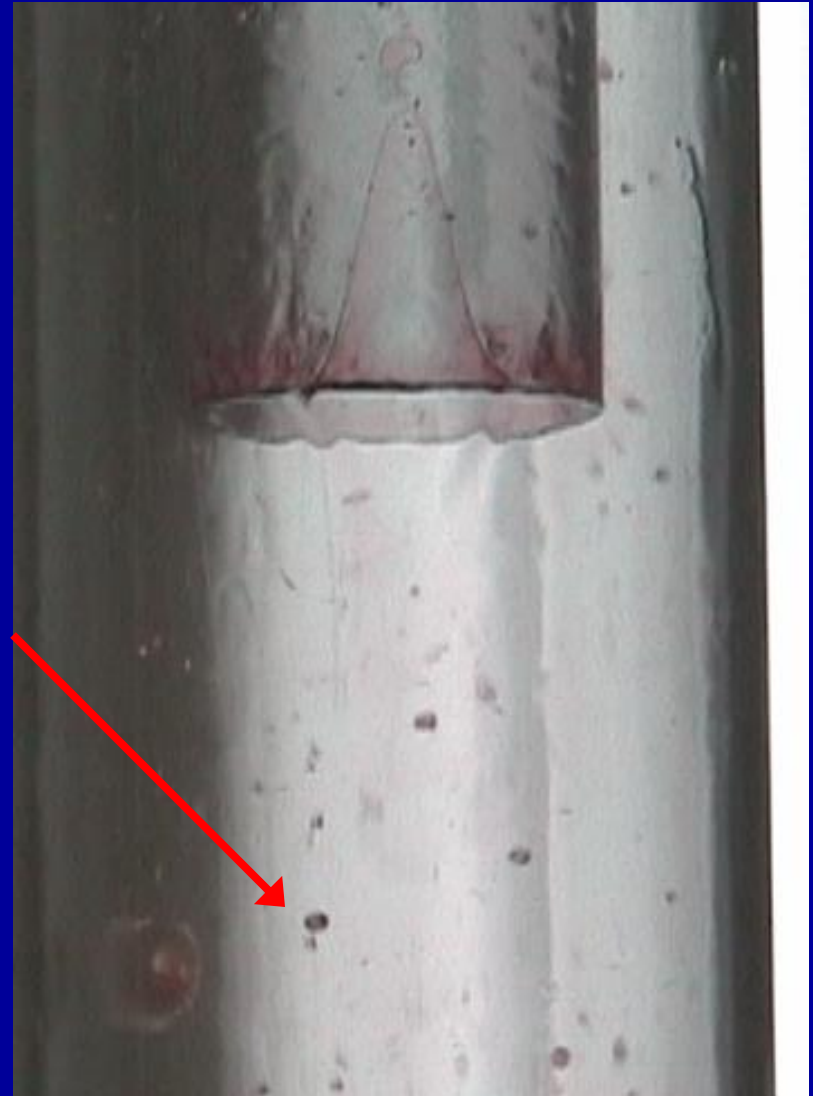


Liquid Loading

Bottom of Vertical Well

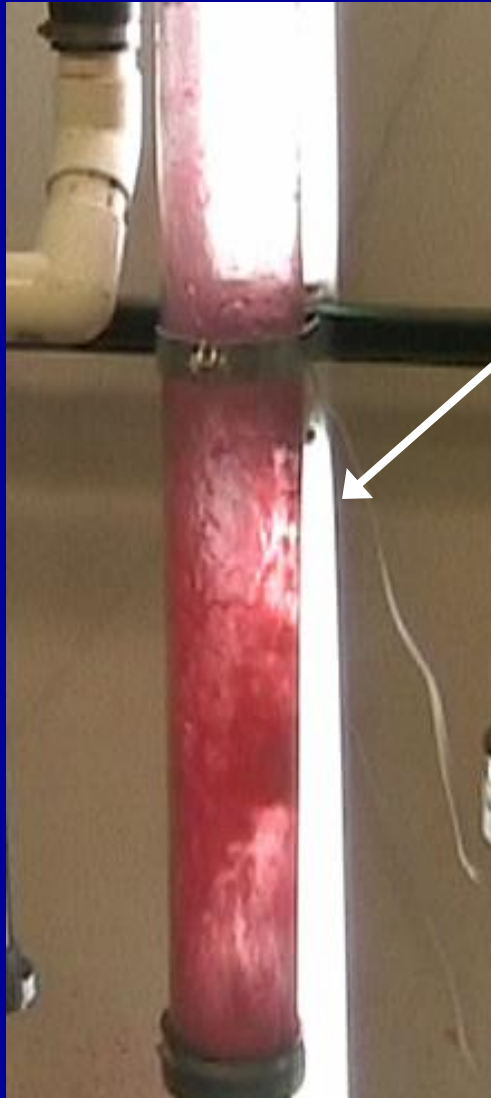


- ← Tubing
- ← Casing
- Gas-cut
- Liquid
- ← Droplets



Liquid Loading

Bottom of Vertical Well

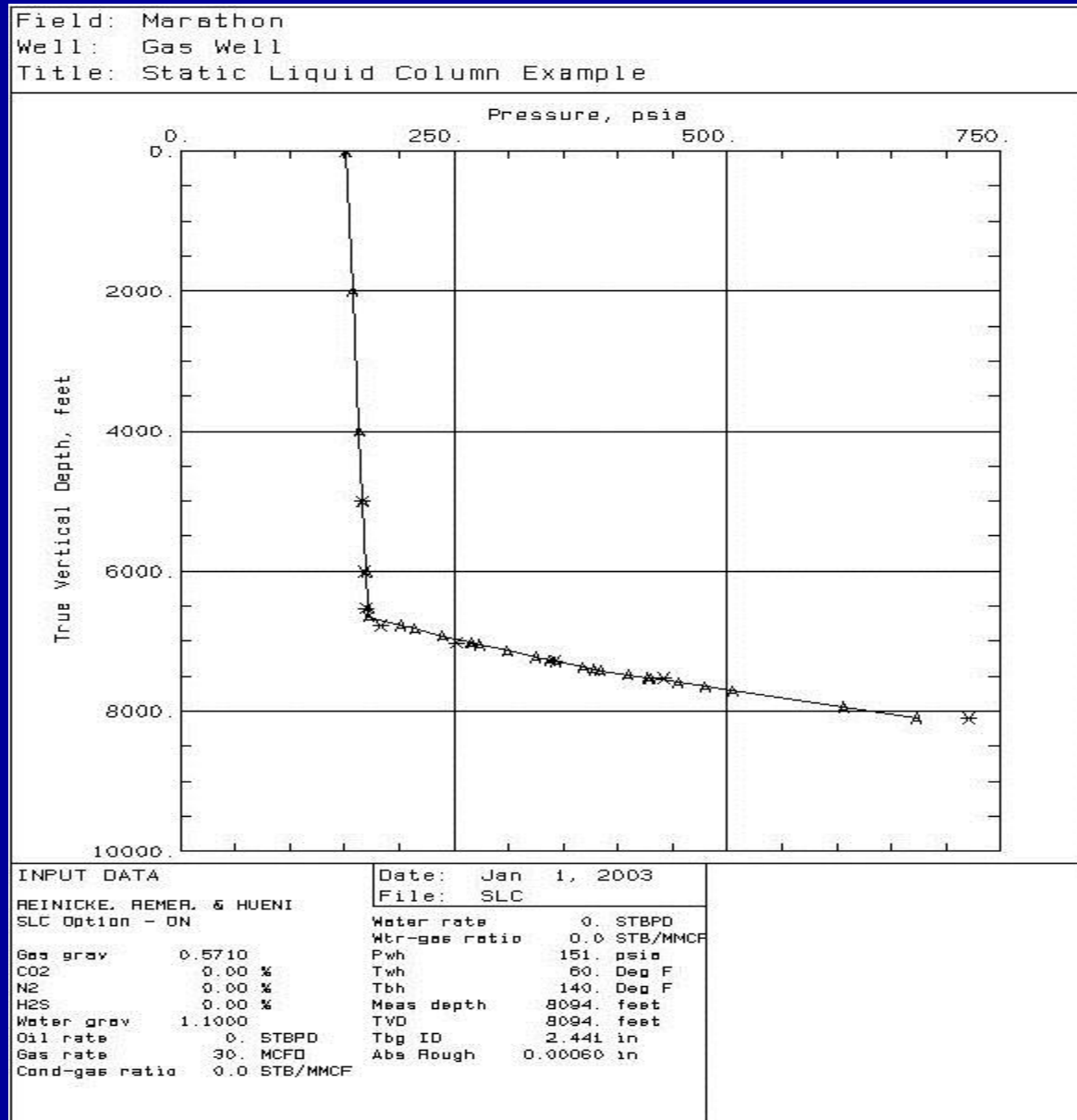


Gas-cut
Liquid

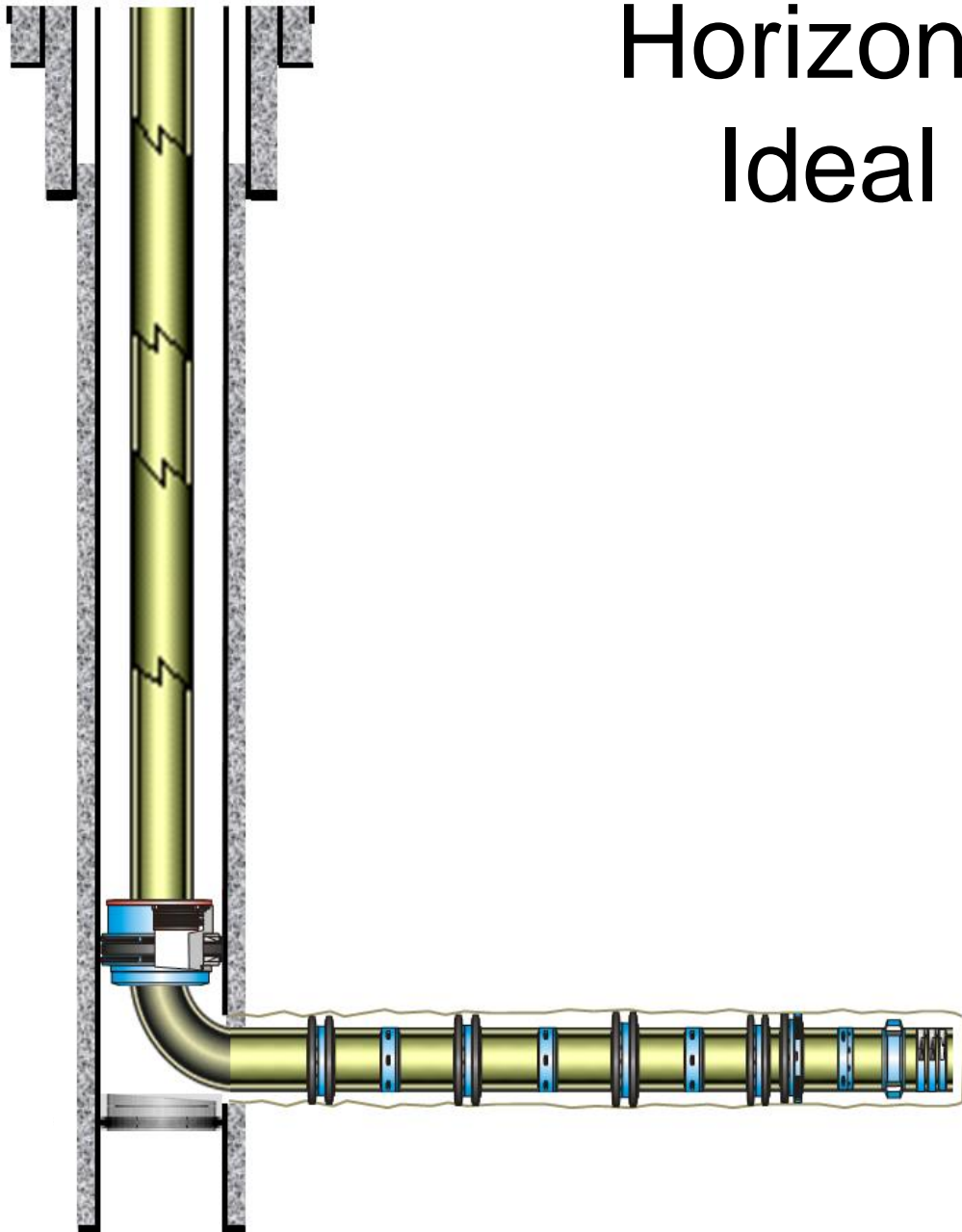
Droplets
variable
size
distribution



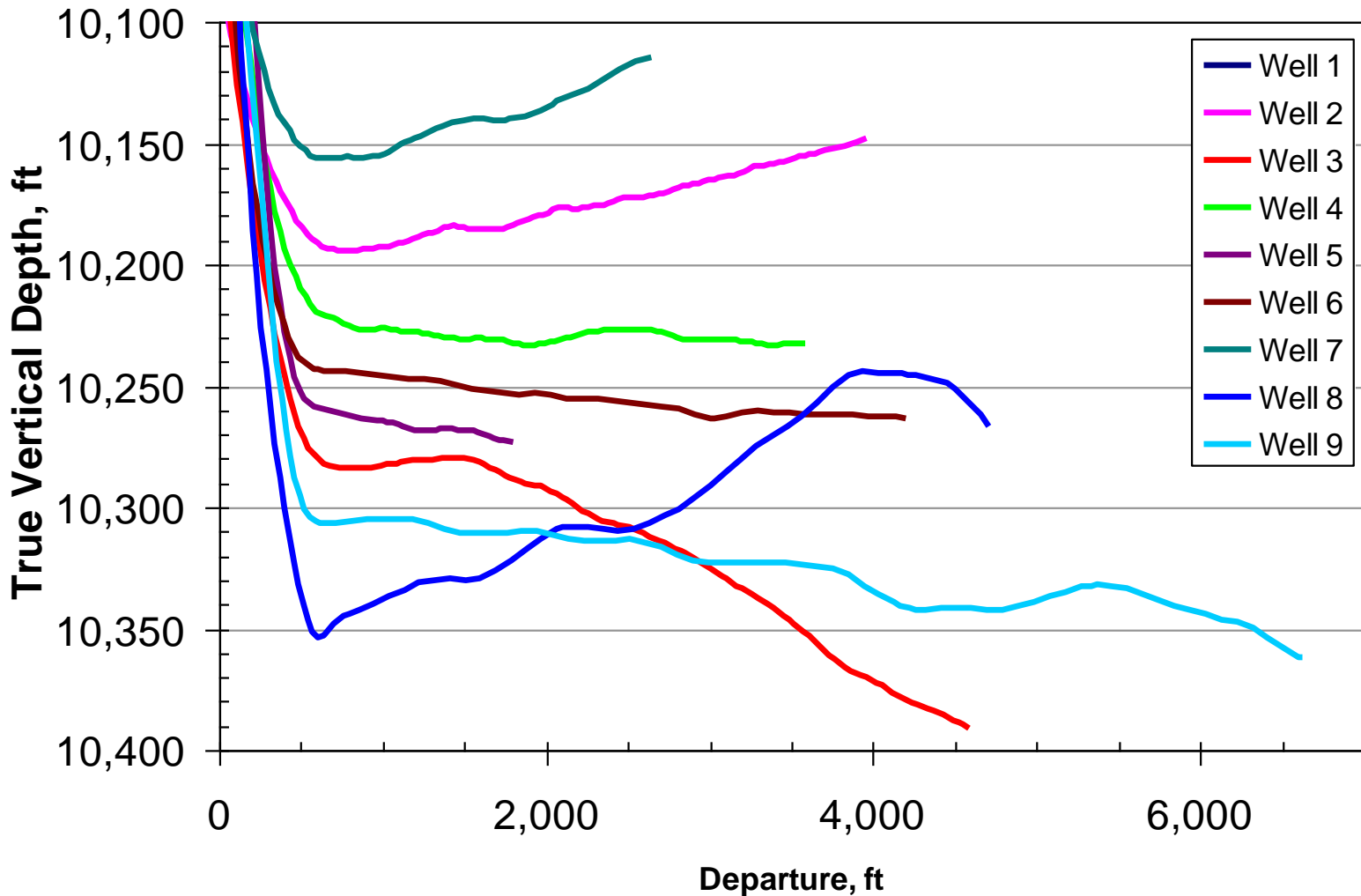
Static Liquid Column Pressure Profile



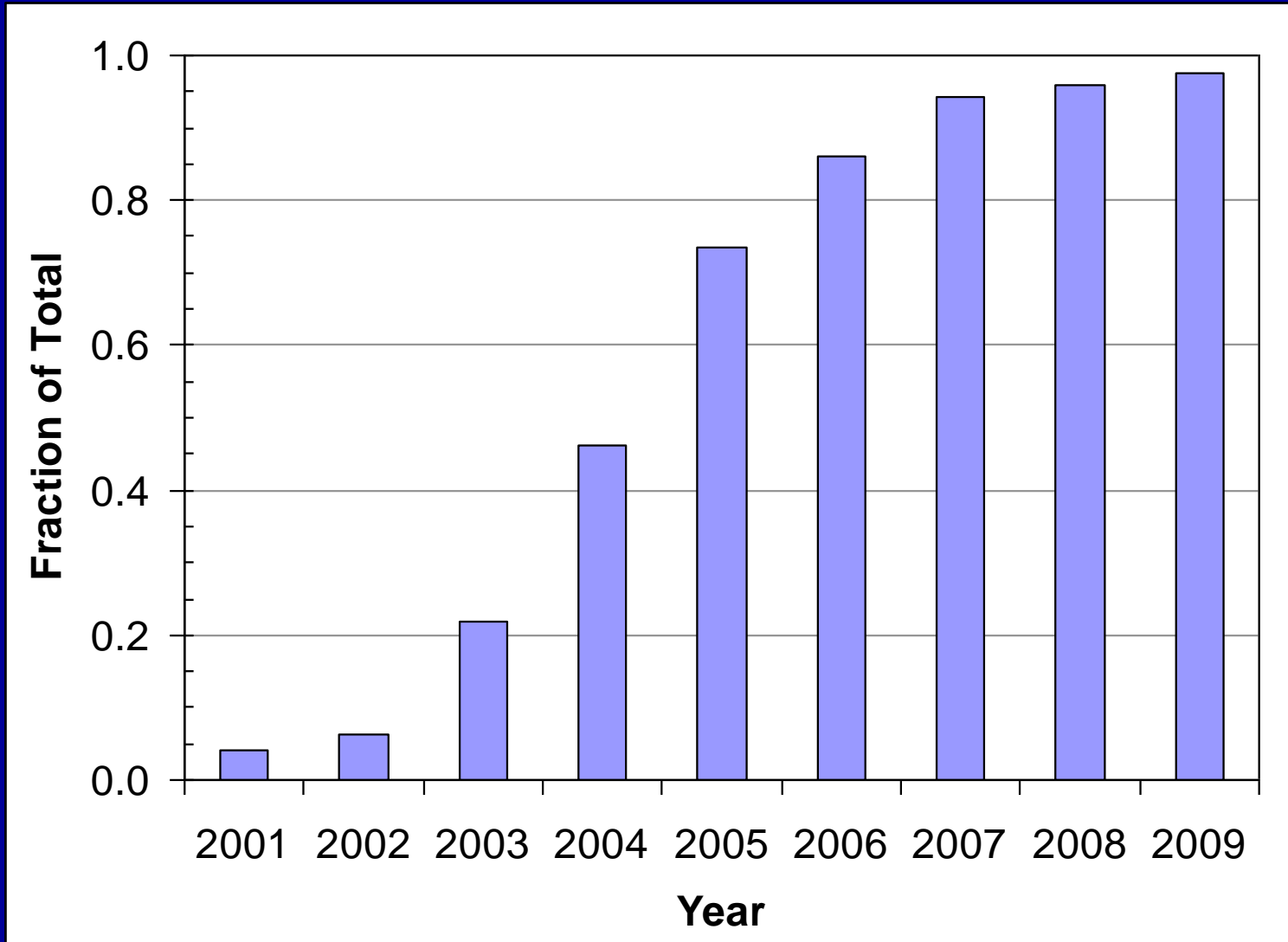
Horizontal Well Ideal Case



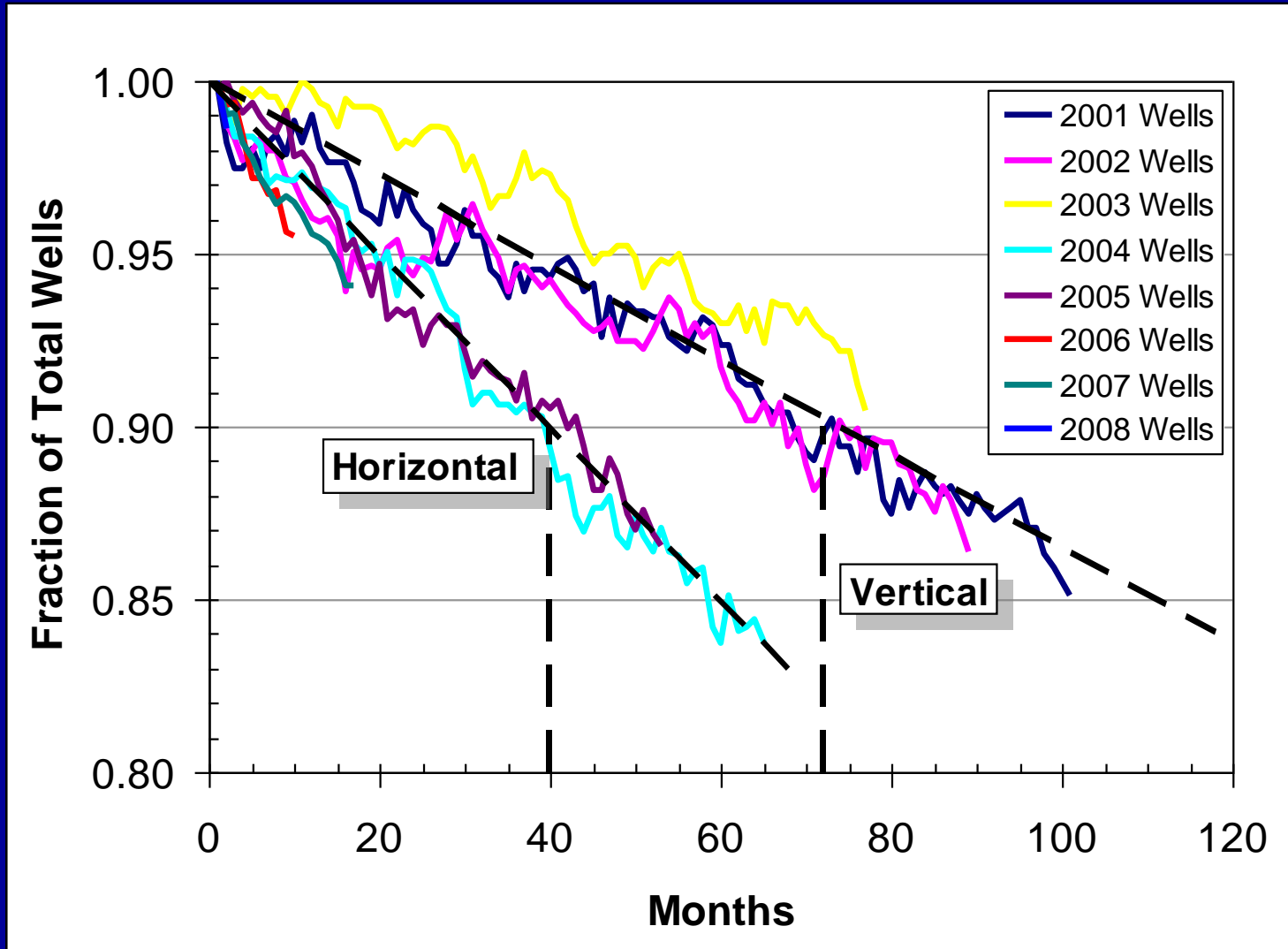
Complex Horizontal Well Profiles



Barnett Shale Horizontal & Vertical Wells

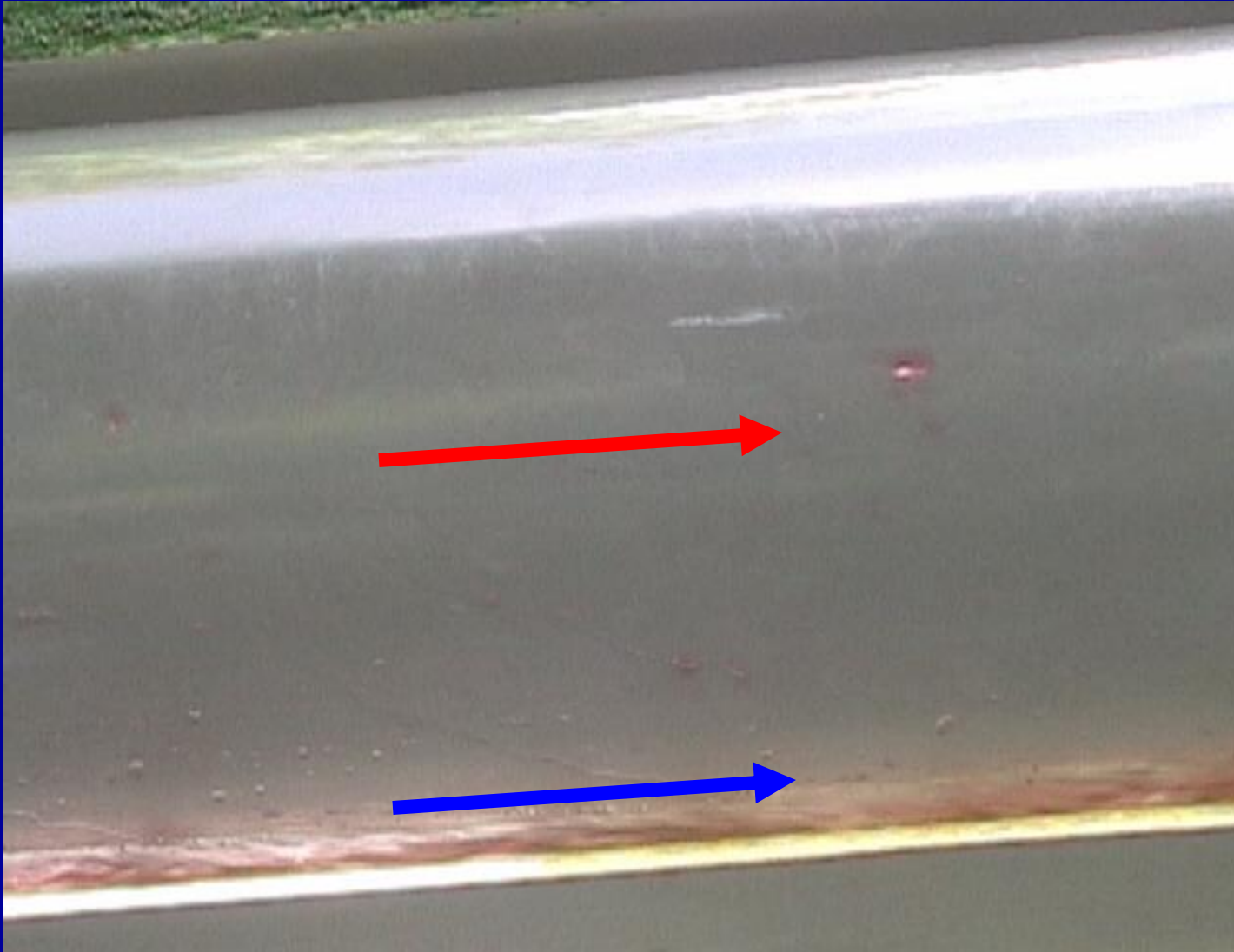


Vertical vs Horizontal Well Attrition



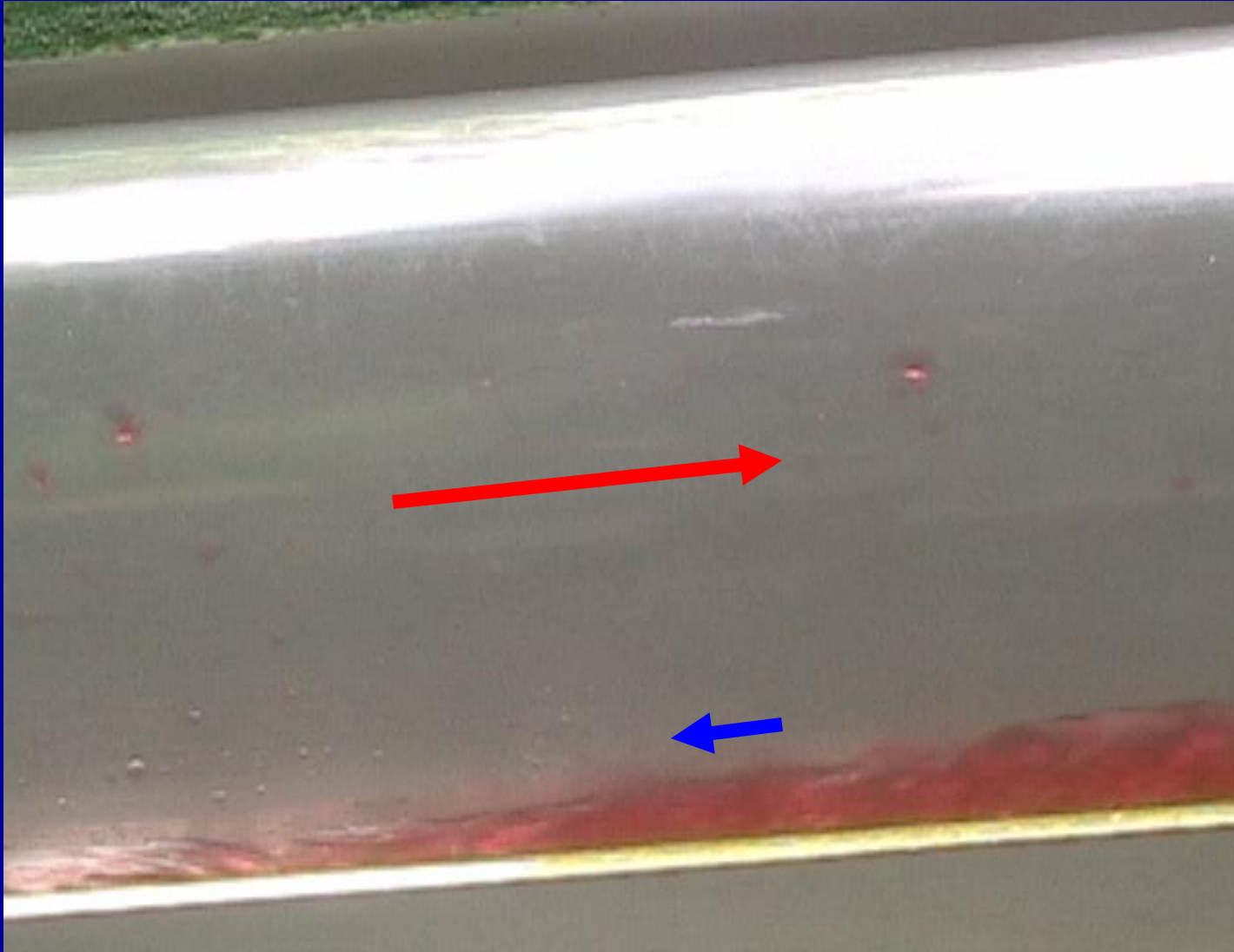
Liquid Loading at 86° from Vertical

4-in Pipe



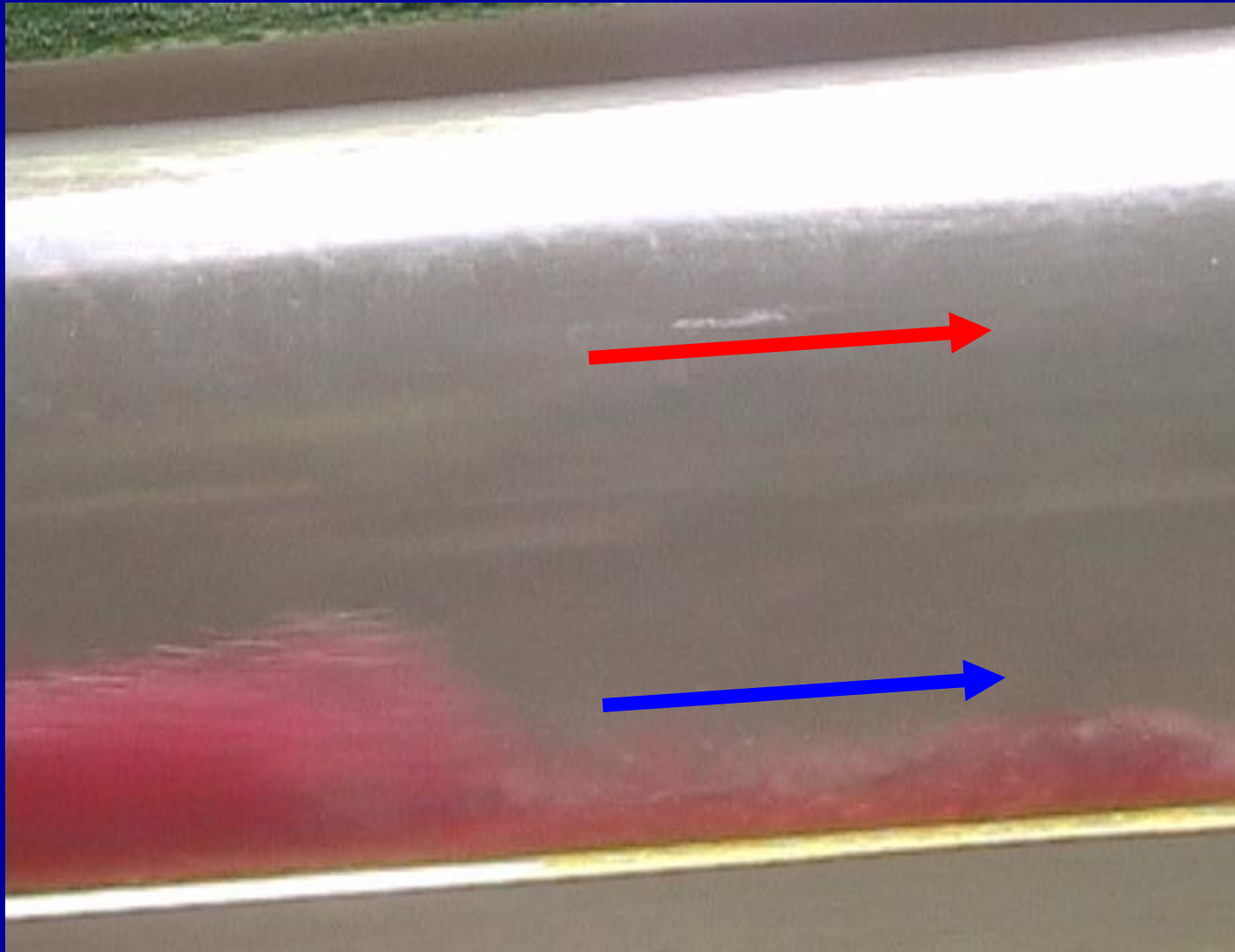
Stratified
flow
pattern

Liquid Loading at 86° from Vertical



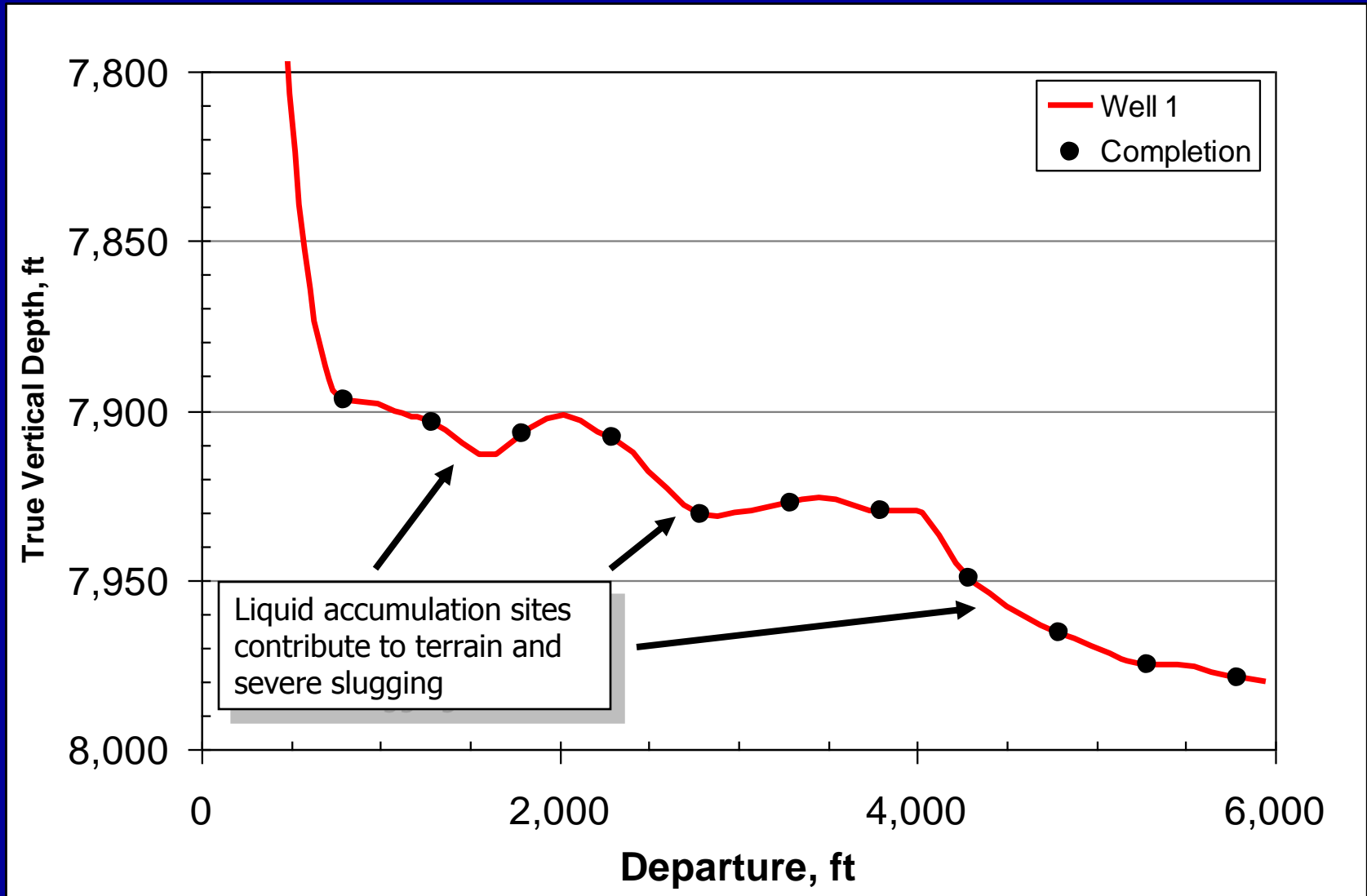
Liquid accumulation at gas velocity less than critical

Liquid Loading at 86° from Vertical

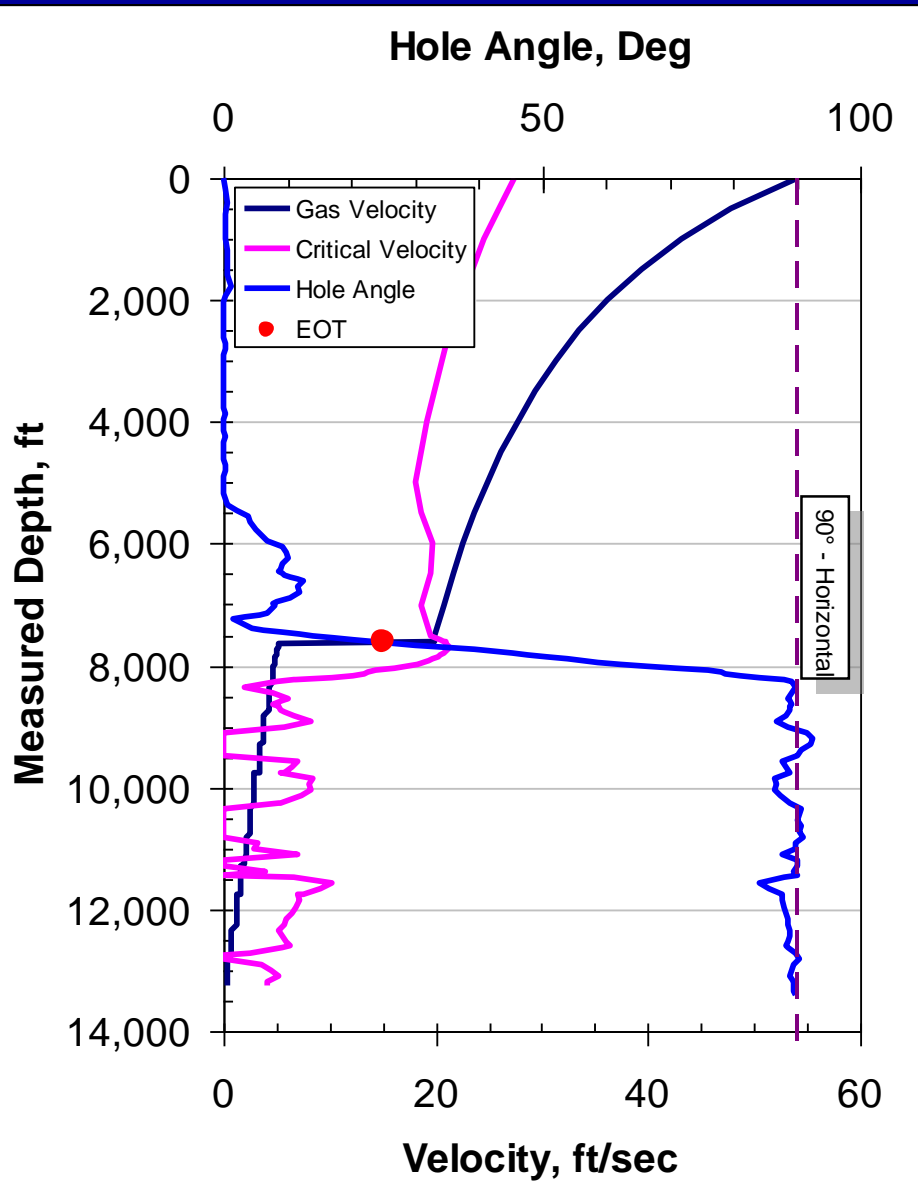


Onset of
terrain
slugging

Example Horizontal Well

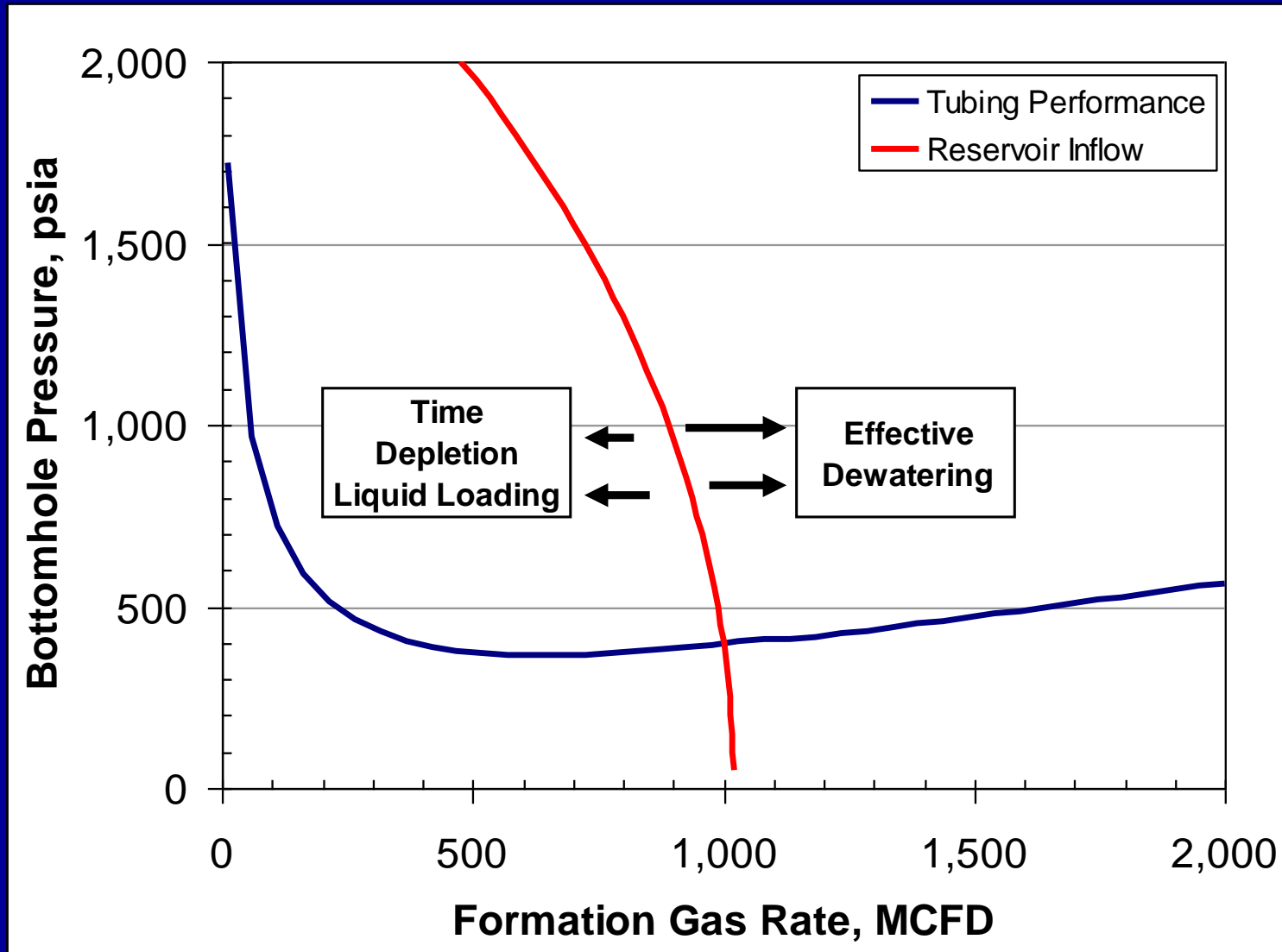


Example Horizontal Well

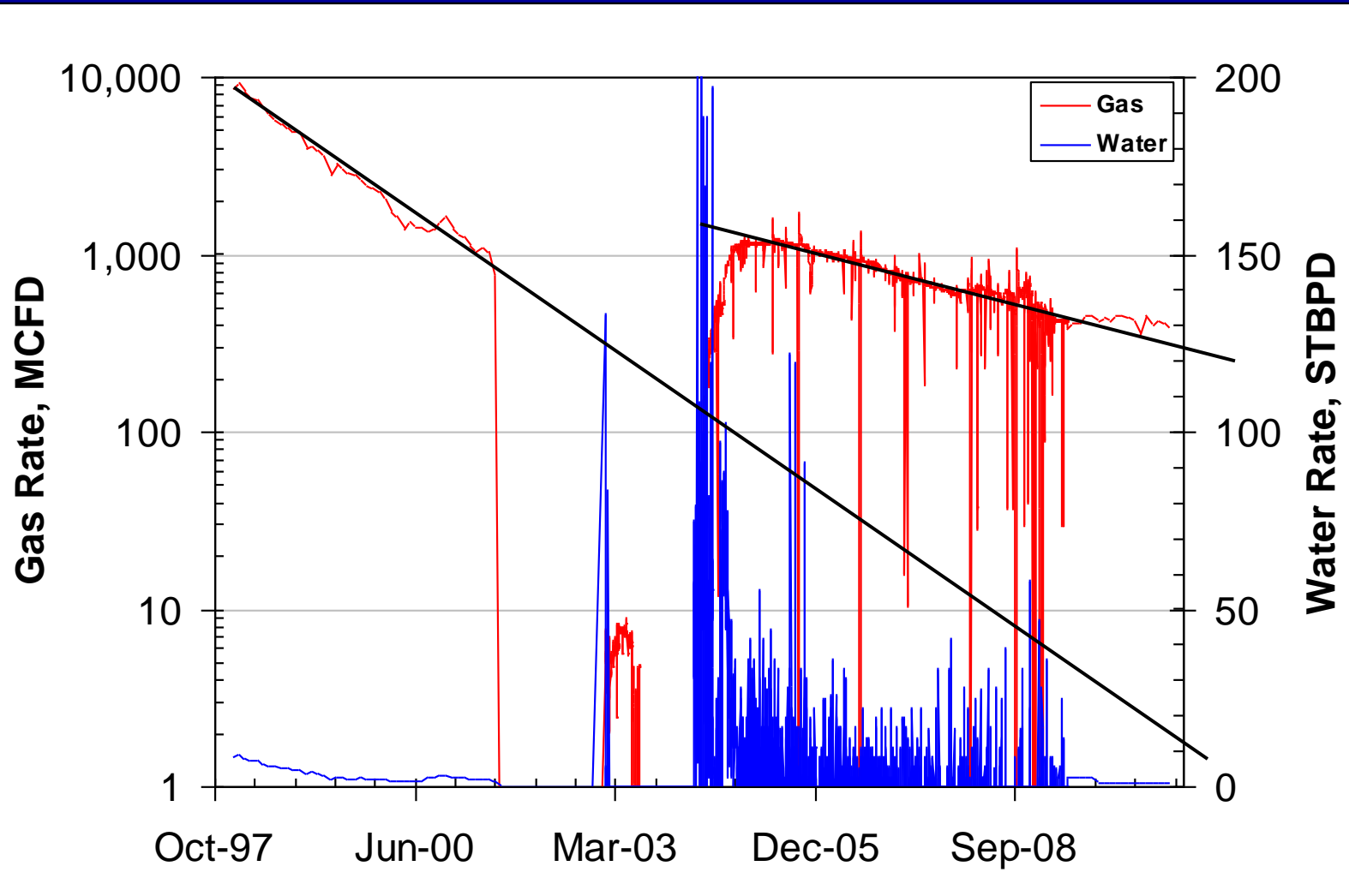


- Velocity profile
- Gas velocity
 - Comparison with critical velocity
- EOT at 25°
 - Shallow
 - Slugging in curve
 - Slugging in horizontal

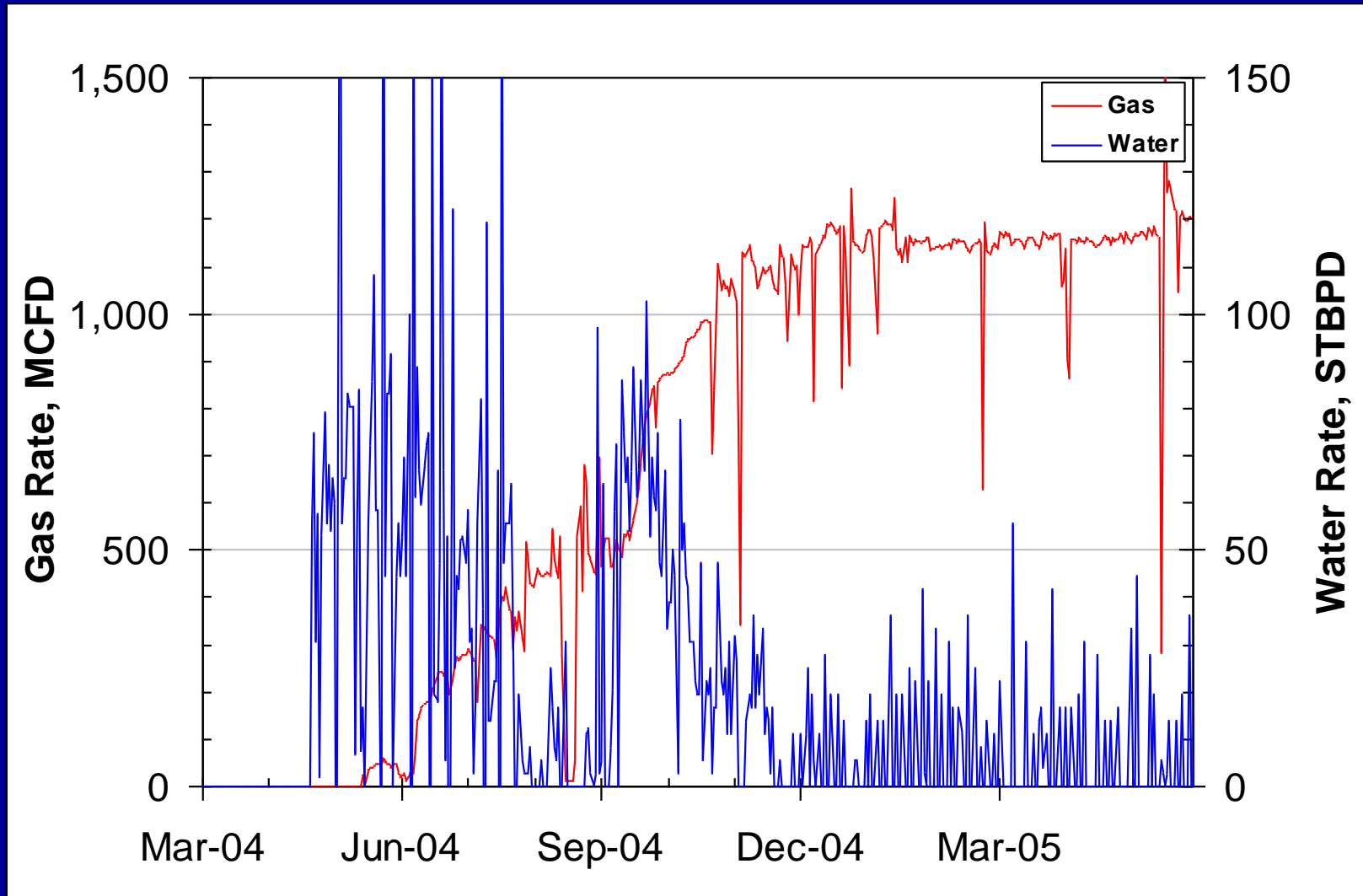
Factors Affecting Rate-Time Decline



Example of Successful Deliquification Program



Example of Successful Deliquification Program



Possible Solutions

- Velocity management
- Compression
- Foamers
- Artificial lift

Observations

- Complex Geometries require High Critical Velocity
- Proper Liquids Management offers significant benefit
- Liquids Management restores / maintains well productivity
- Liquids Management requires constant attention
- Determine Critical Velocity / Rate thru-out well
- Nodal Analysis offers insight to Long Term Performance

Questions?

Distinguished Lecturer Program

Your Feedback is Important

Enter your section in the DL Evaluation Contest by completing the evaluation form for this presentation :

Click on: [Section Evaluation](#)



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