Distinguished Lecturer Program

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Distinguished Lecturer Program
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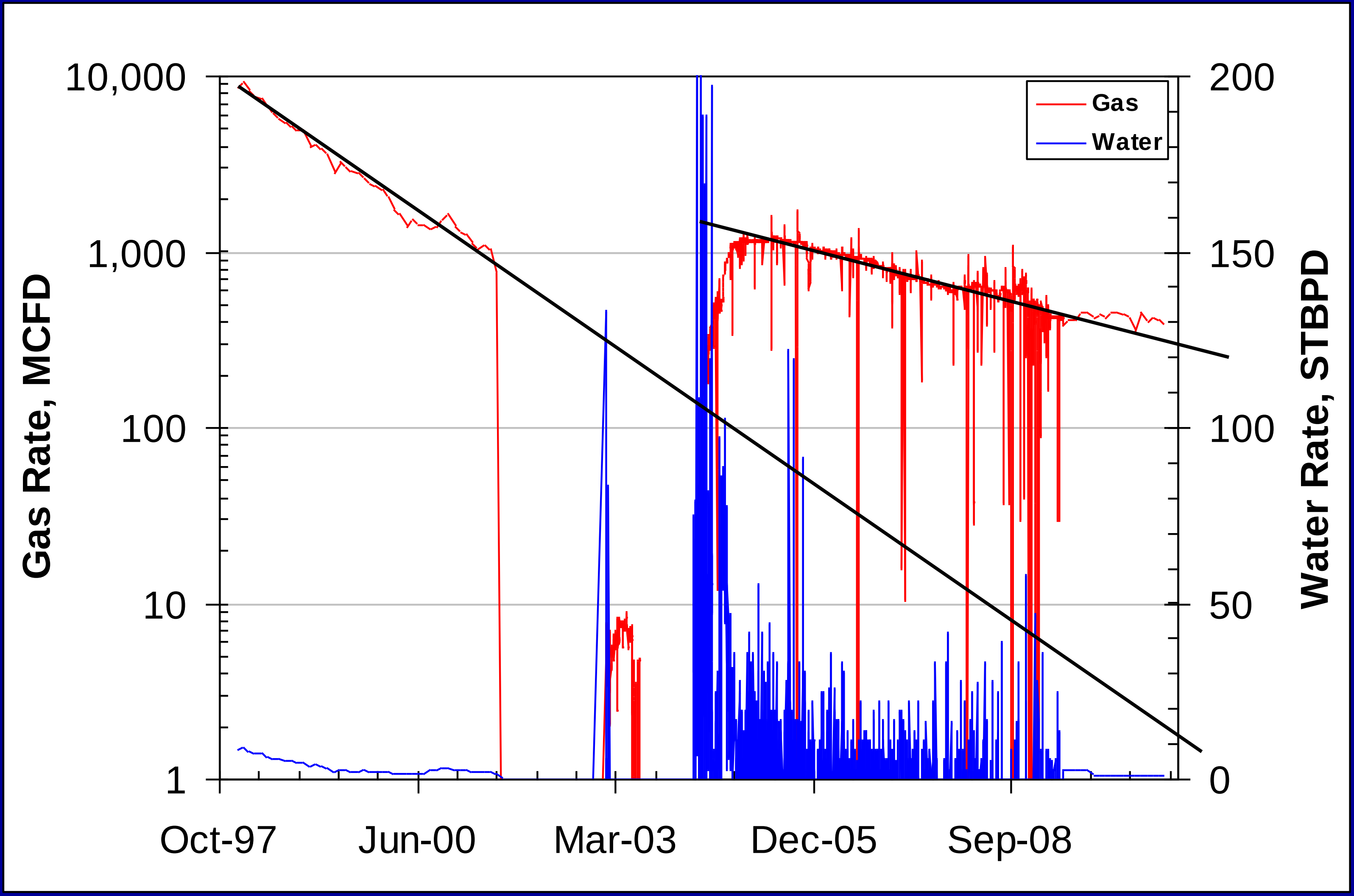
Understanding Liquid Loading Will Improve Well Performance

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

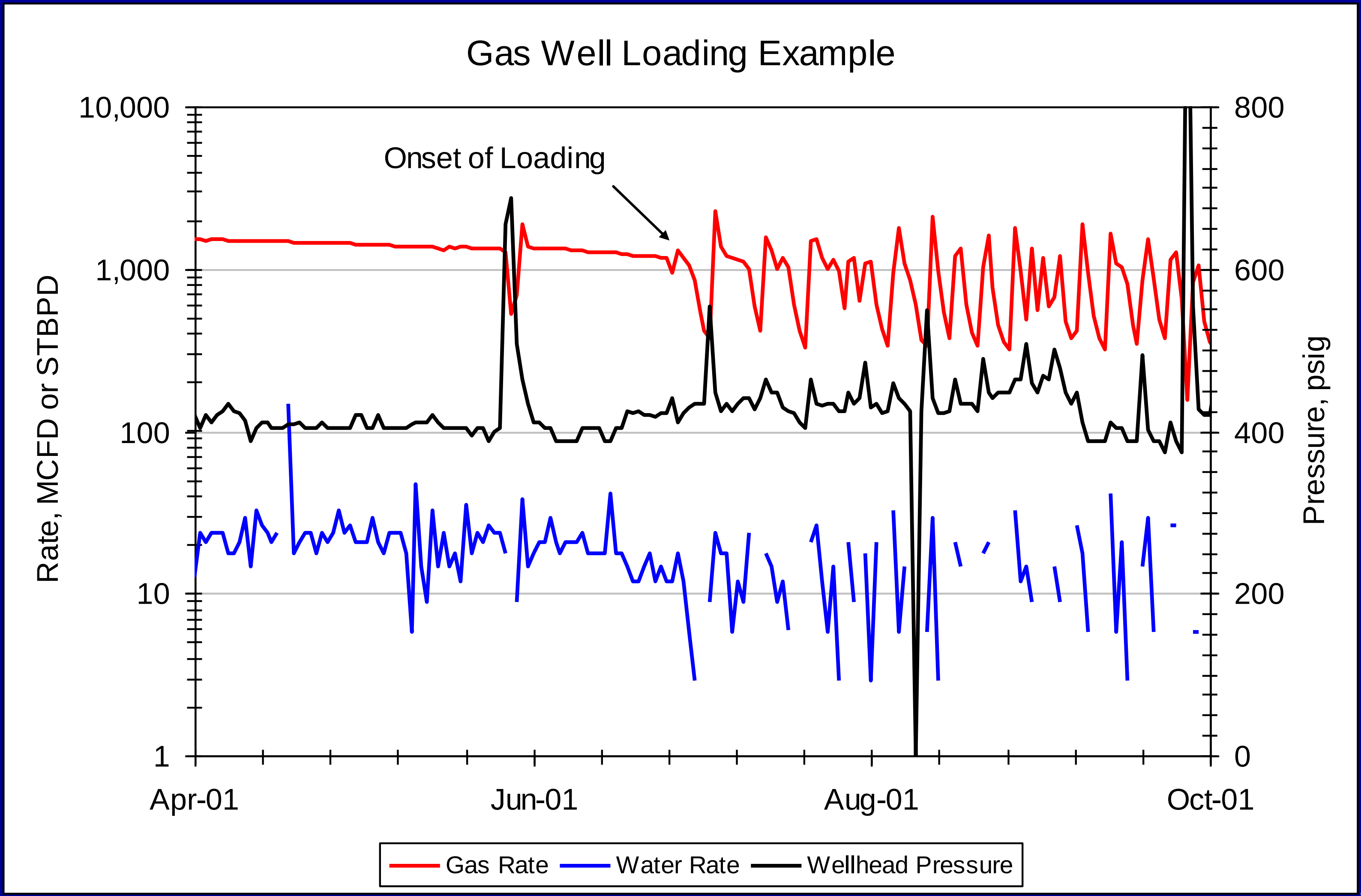
Analysis Techniques

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

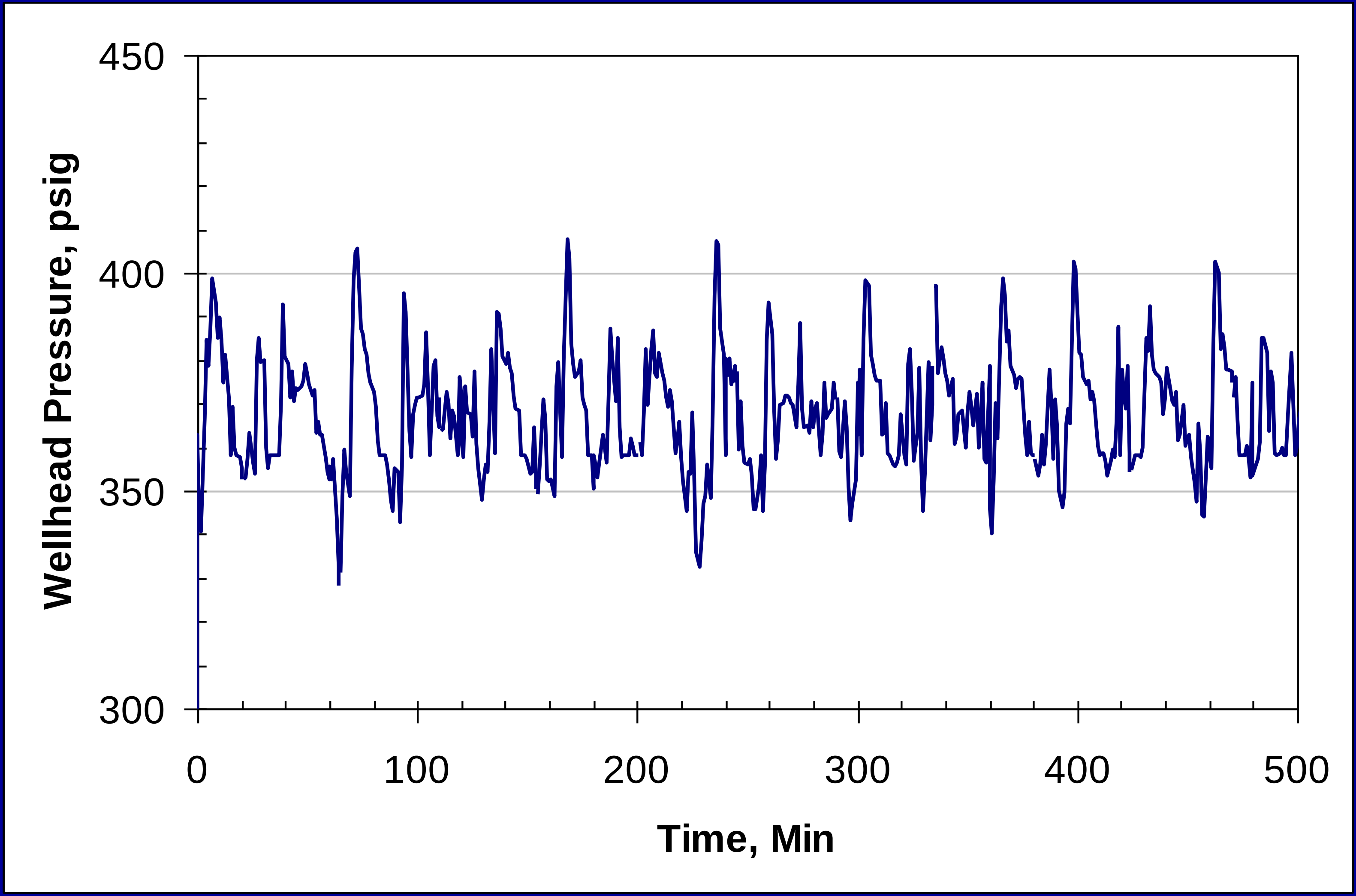
Complications

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

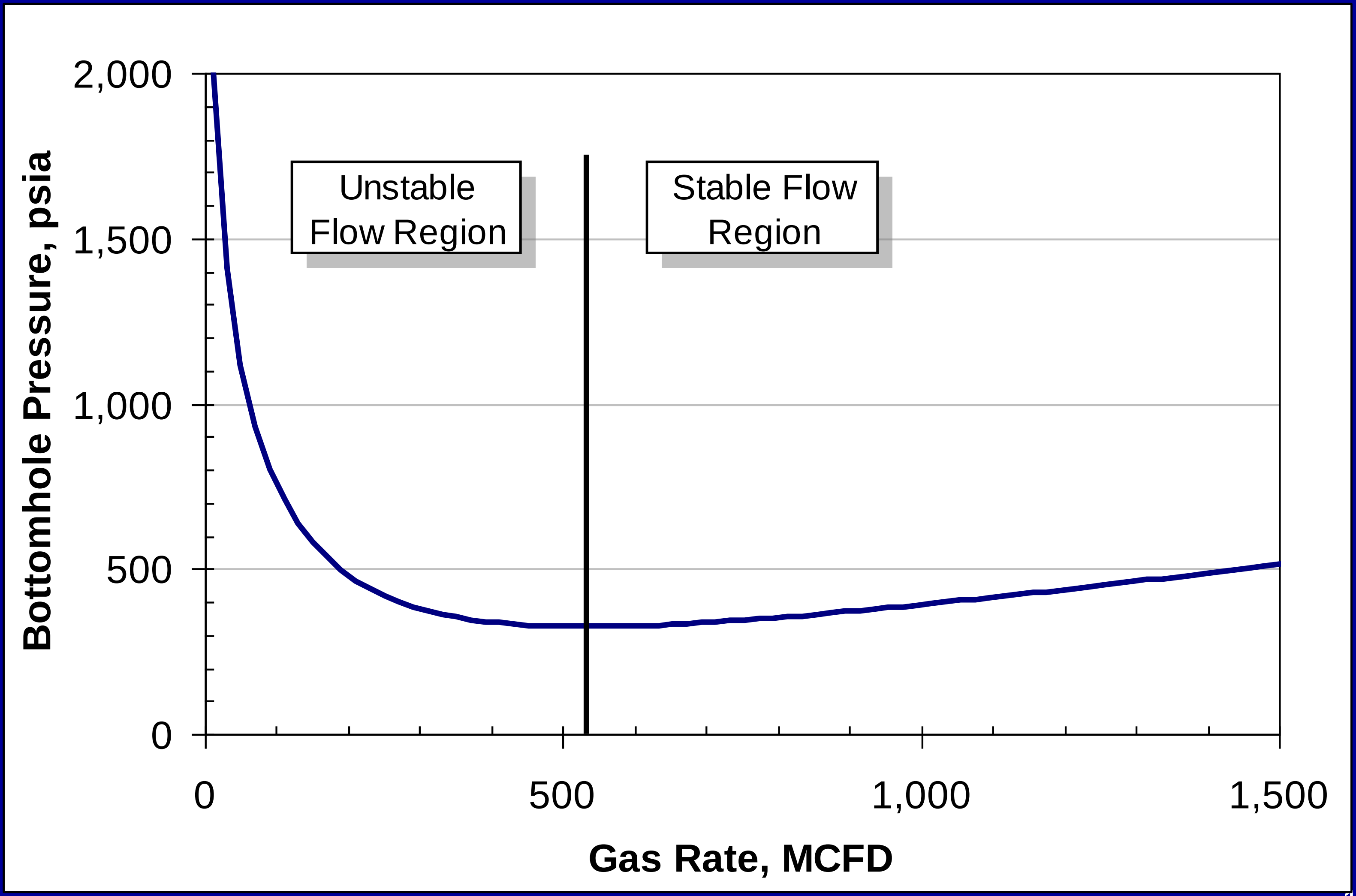
Production Data



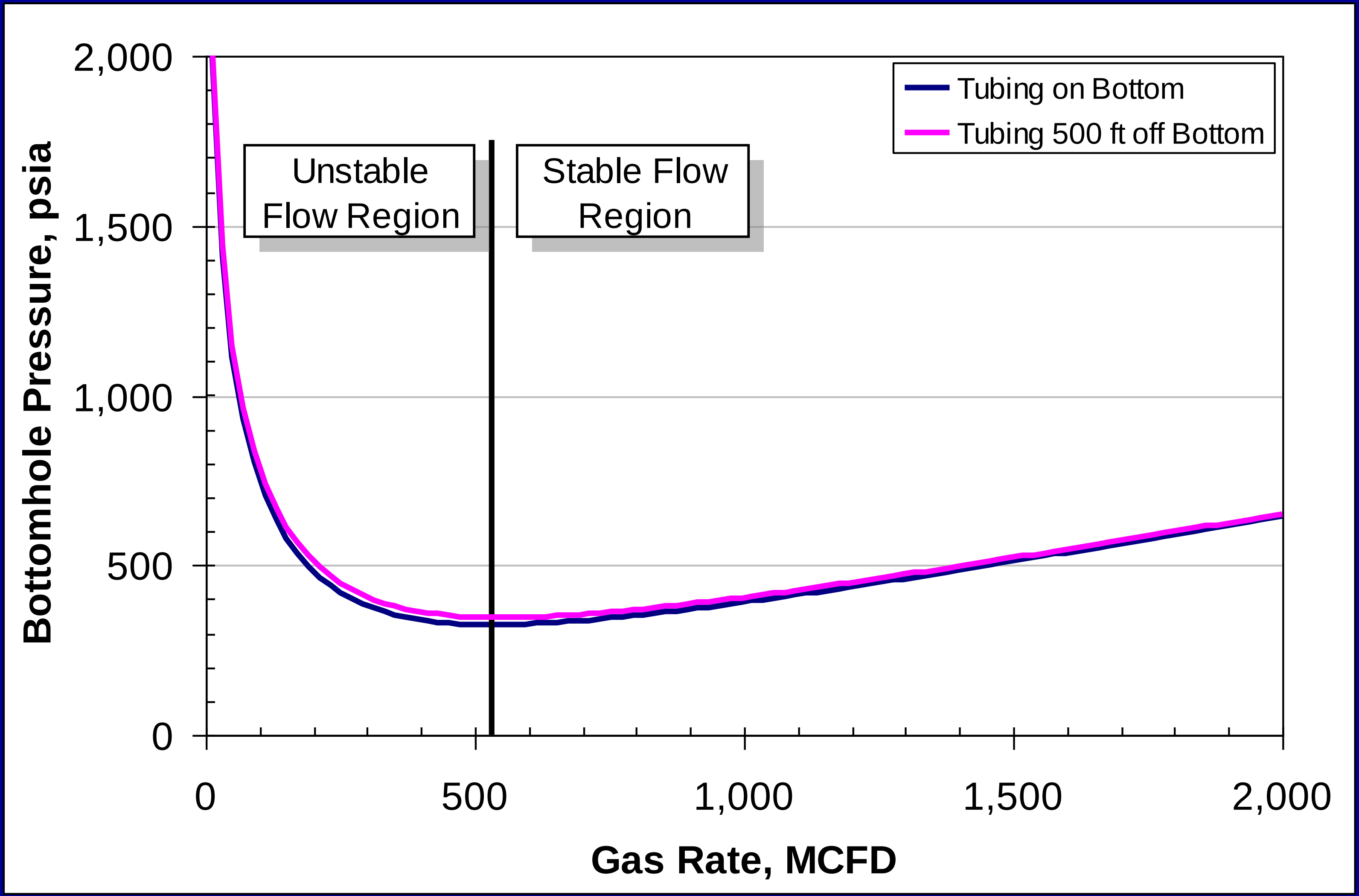
Pressure Data



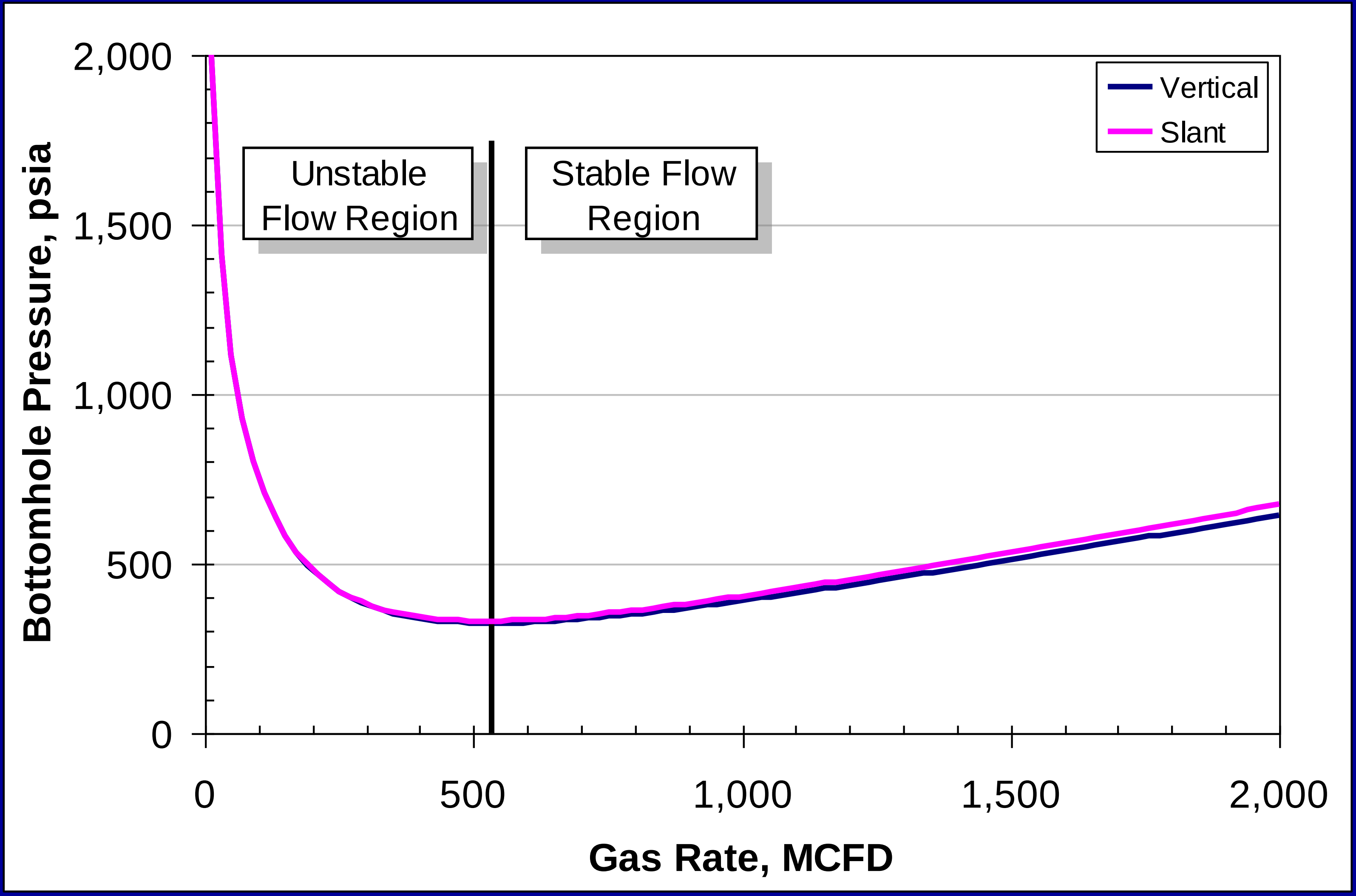
Critical Rate
Vertical Flow Performance



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

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

Without ±20% adjustment
Coleman Equation

where

ρ_g = gas phase density, lbm/ft^3

ρ_L = liquid phase density, lbm/ft^3

σ = surface tension, dynes/cm

$\boldsymbol{v_c}$ = critical velocity of liquid droplet, ft/sec

Turner Unloading Velocity

$$v_c = 1.5934\left[\frac{N_{we}}{30}\right]^{0.25}\left[\frac{\sigma\left(\rho_l - \rho_g\right)}{\rho_g^2}\right]^{0.25}\frac{\left[\sin\left(1.7\left(90-\theta\right)\right)\right]^{0.38}}{0.740767}$$

Turner Adjustment

Belfroid et al SPE 115567 Angle Correction

where

ρ_g = gas phase density, lbm/ft^3

ρ_L = liquid phase density, lbm/ft^3

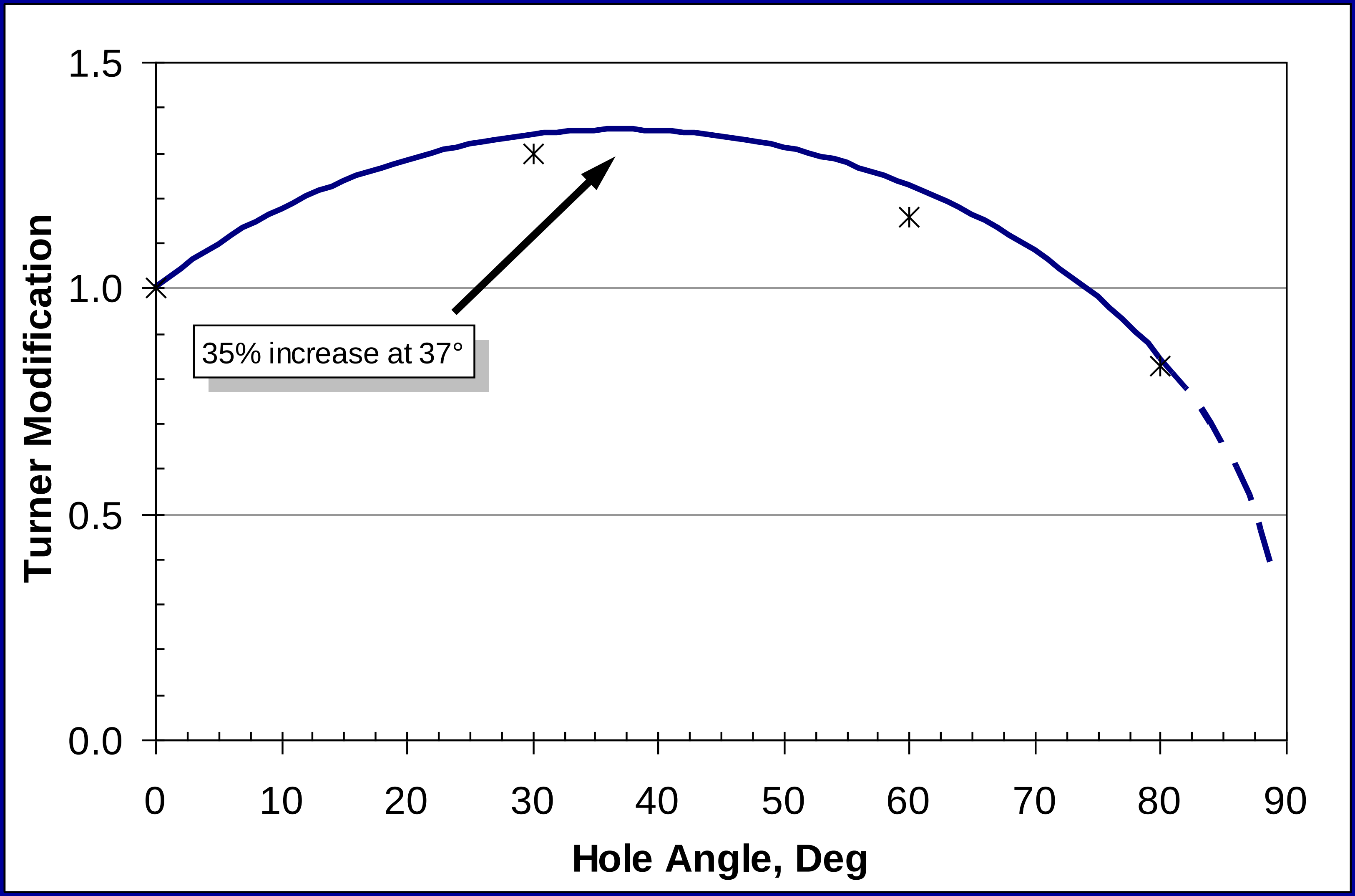
σ = surface tension, dynes/cm

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

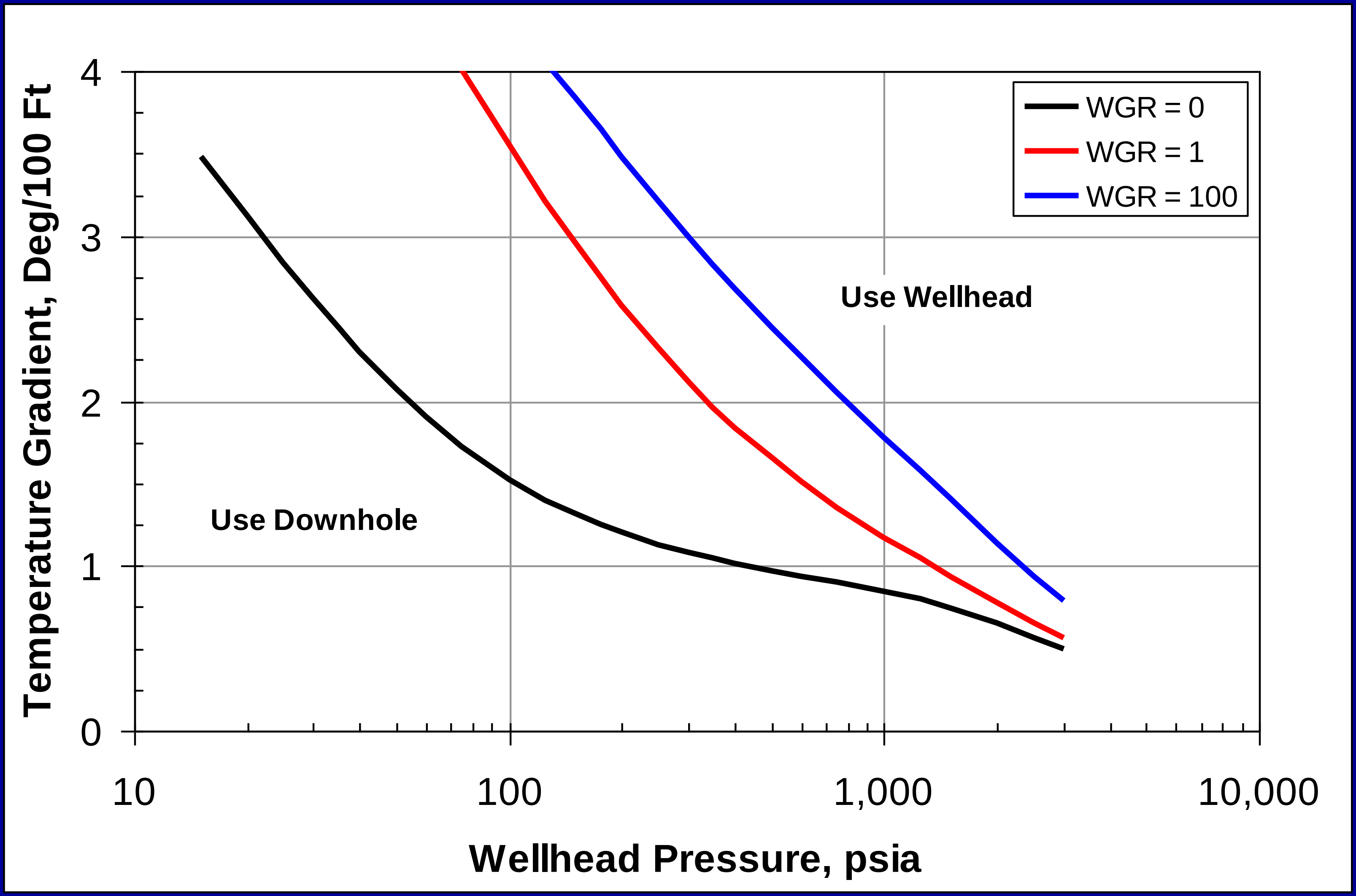
Θ = hole angle (Deg from vertical)

v_c = critical velocity of liquid droplet, ft/sec

Well Angle Modification to Turner



Evaluation Point

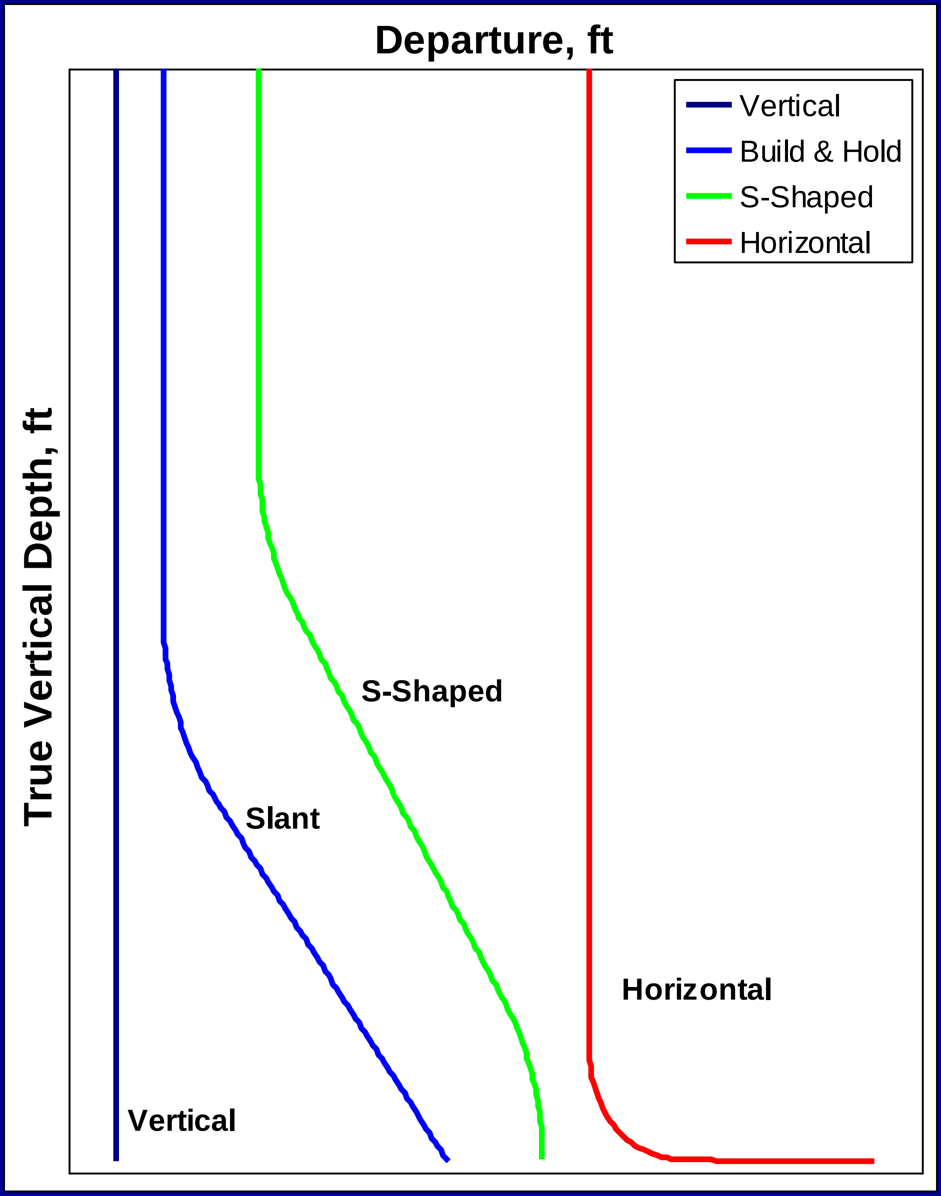


Dtbg = 2.441 in

γ_g = 0.65

SPE 120625

Assorted Well Profiles

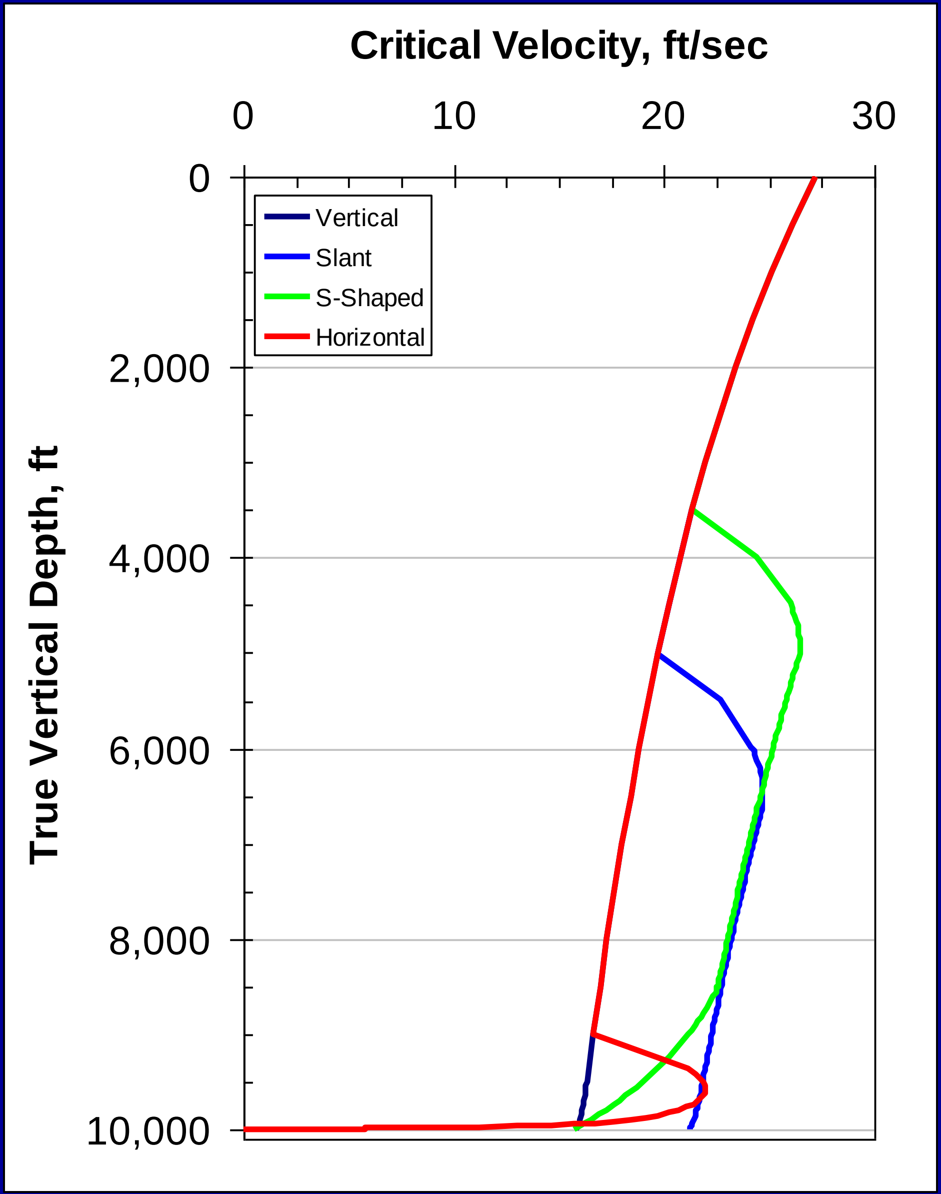


<u>Complex Profiles</u>

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

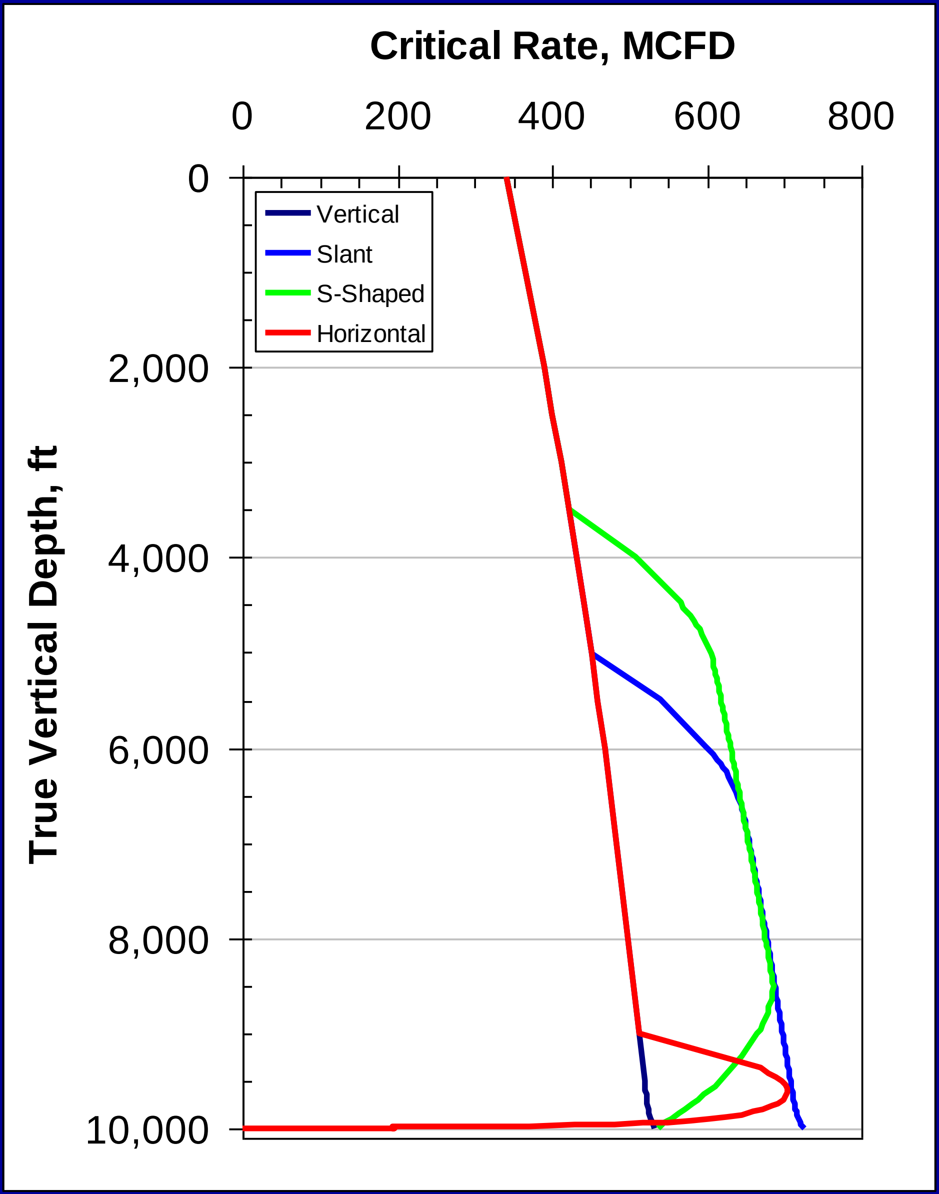
- Complexity increases velocity or rate to unload well

Example Critical Velocity Profiles



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

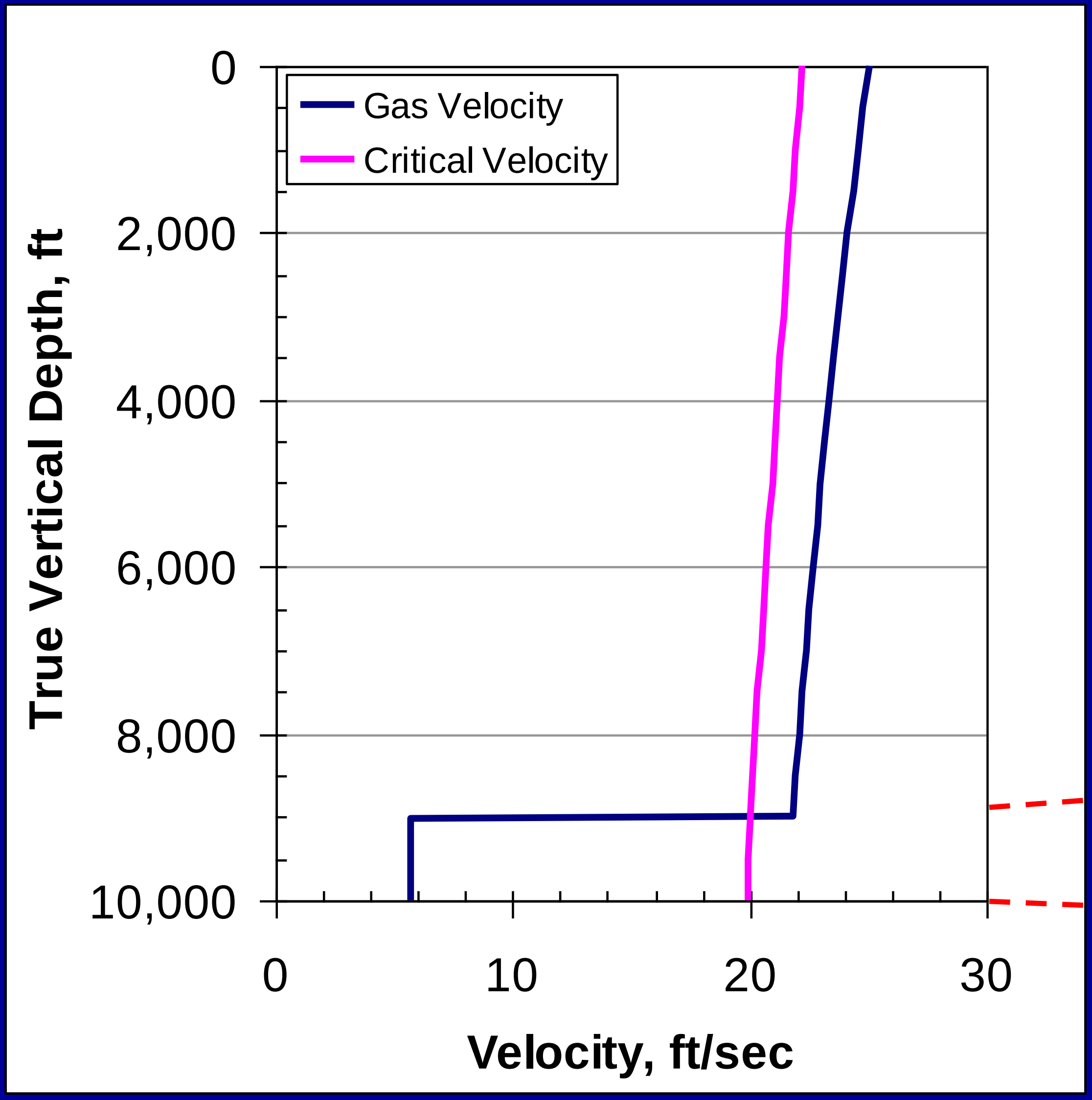
Example Critical Rate Profiles

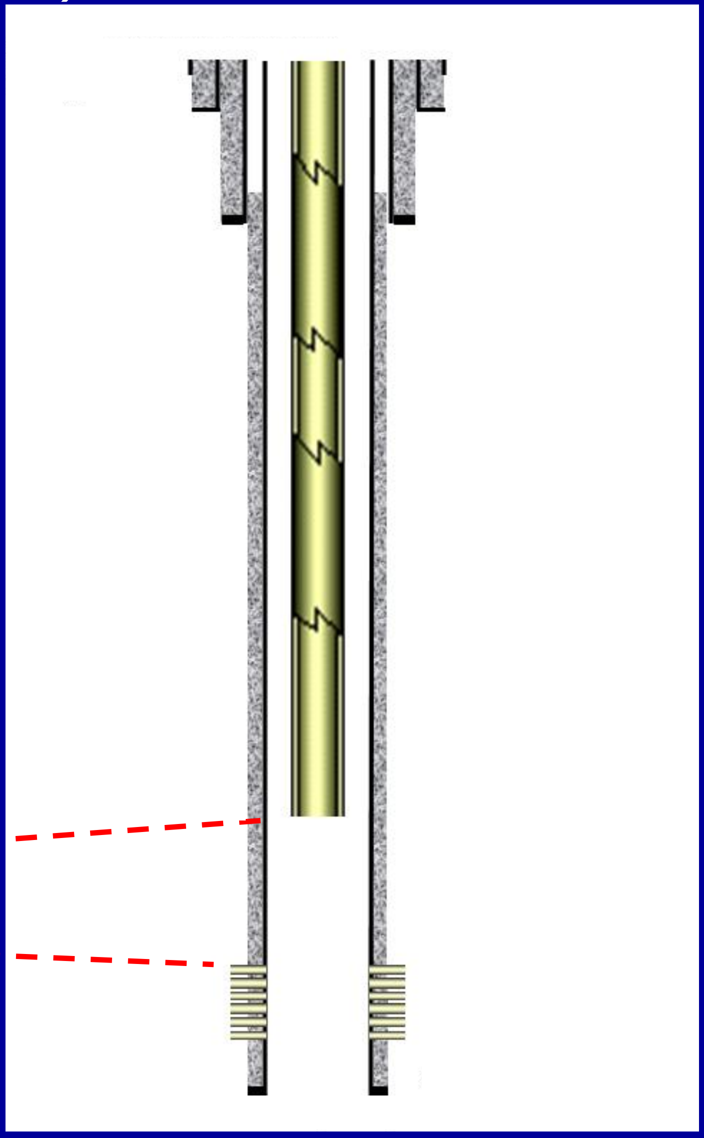


- Effects on critical rate
  - Pressure
  - Temperature
  - PVT
    - Gas gravity
    - Water salinity
  - Hole Angle
  - Pipe Diameter

Vertical Well Case

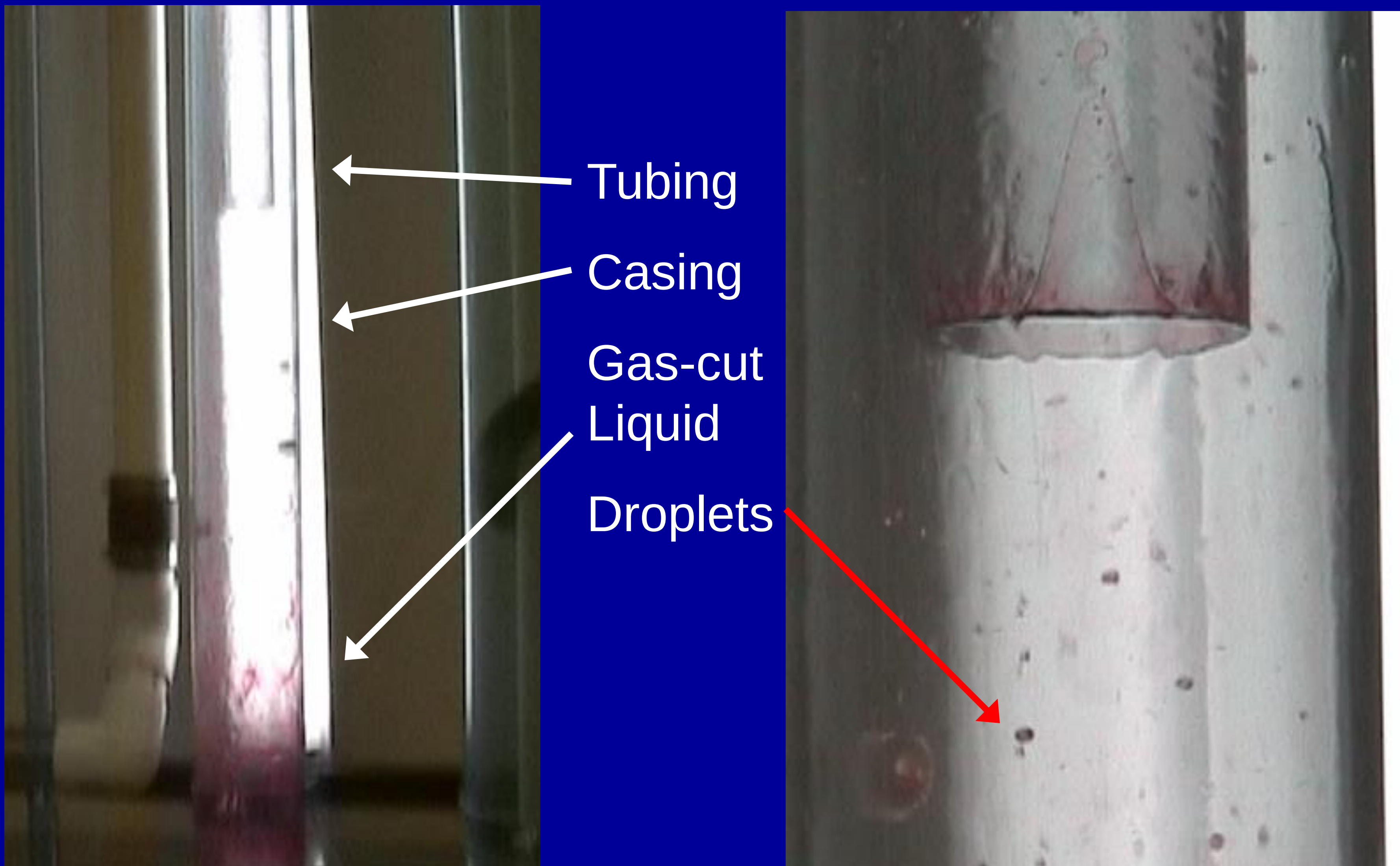
(Variable Tubing Size)





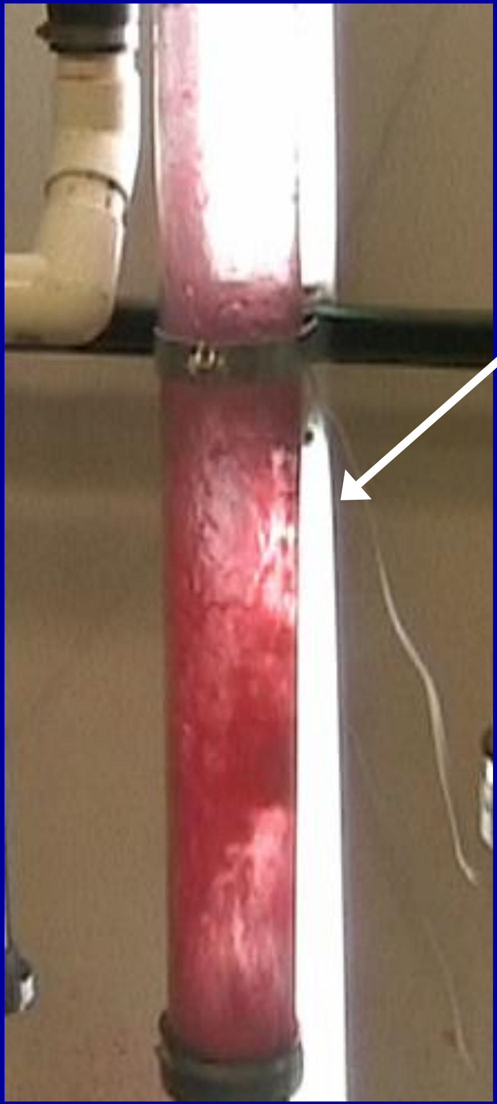
Liquid Loading

Bottom of Vertical Well



Liquid Loading

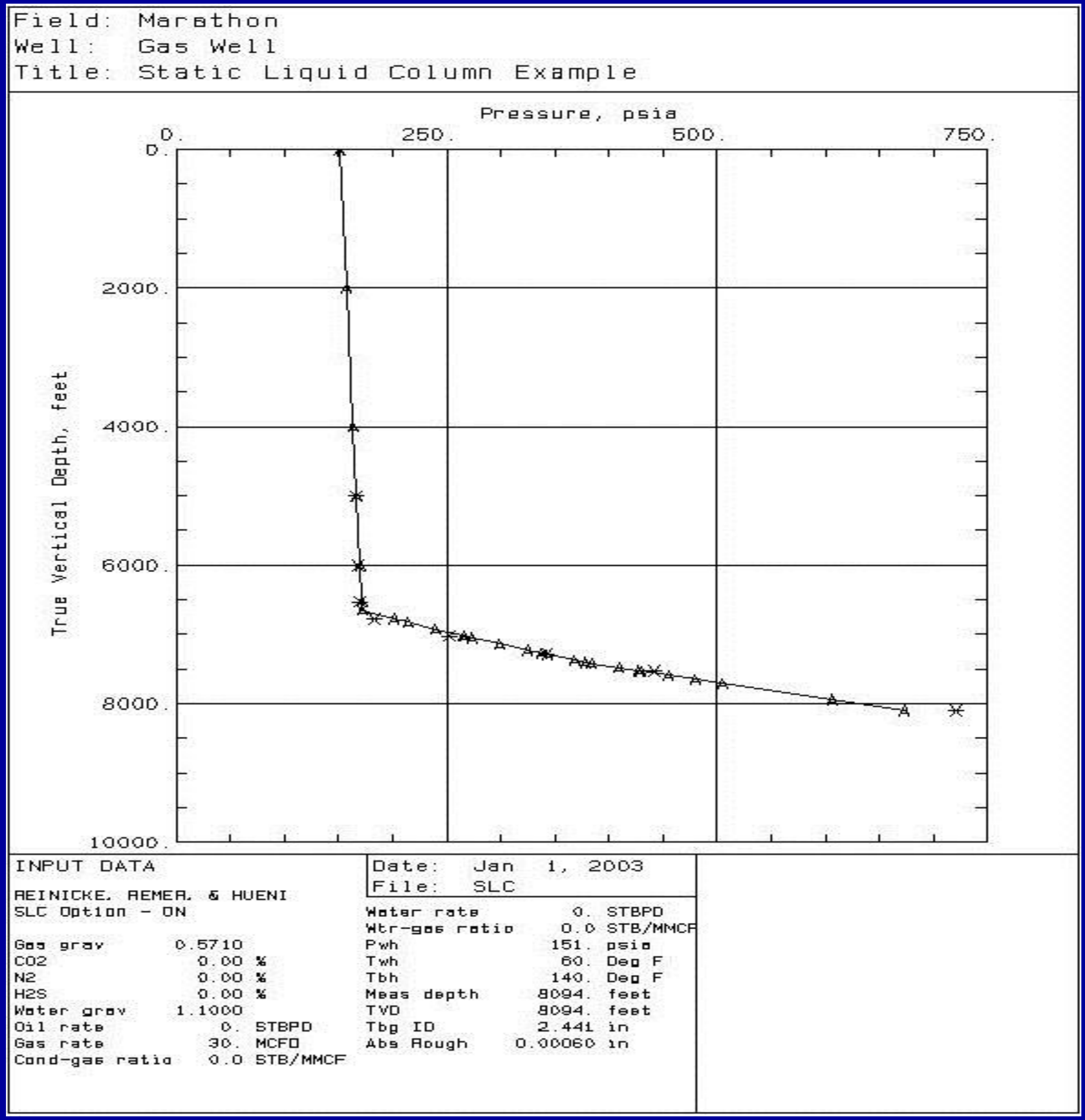
Bottom of Vertical Well



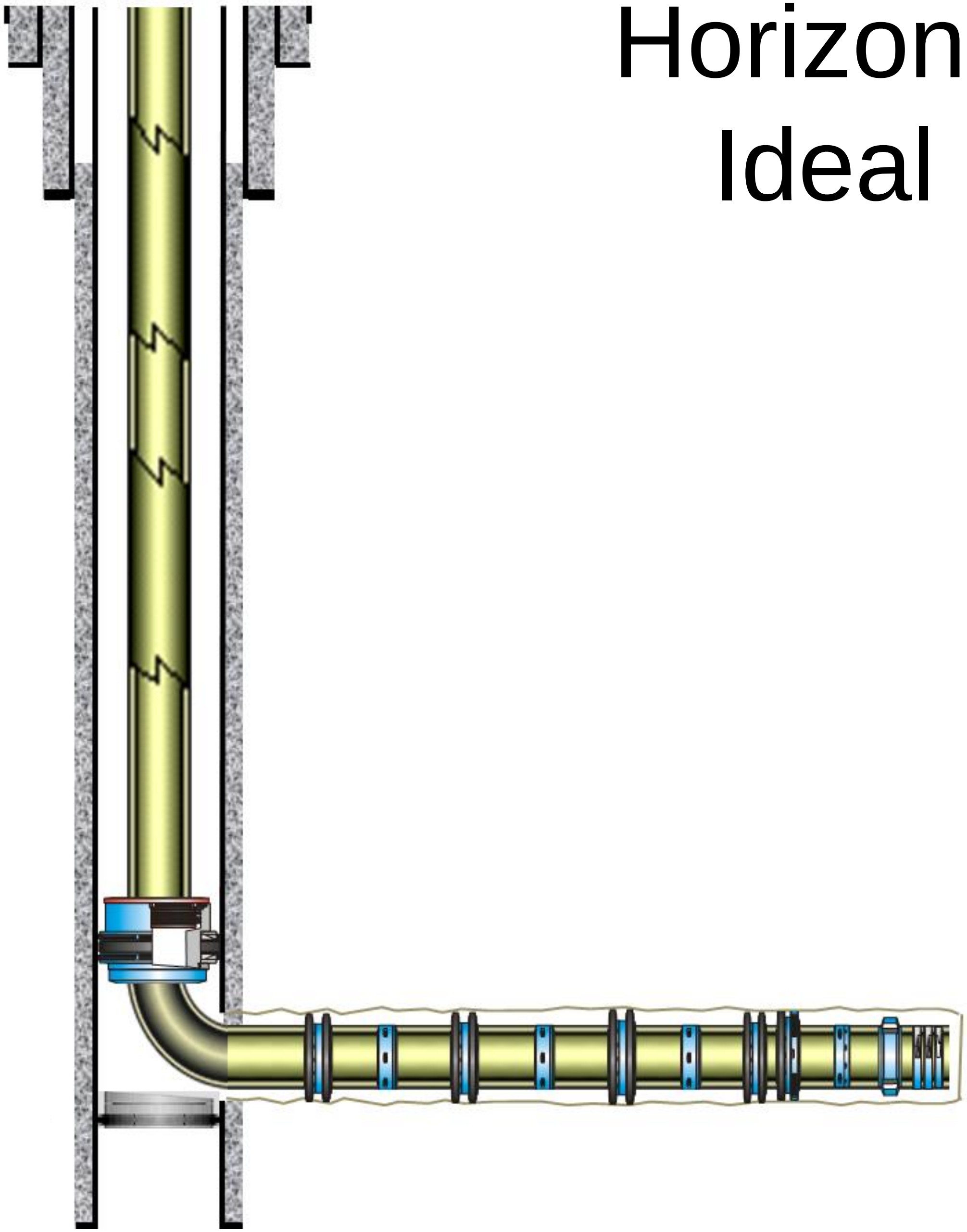
Gas-cut Liquid

Droplets variable size distribution

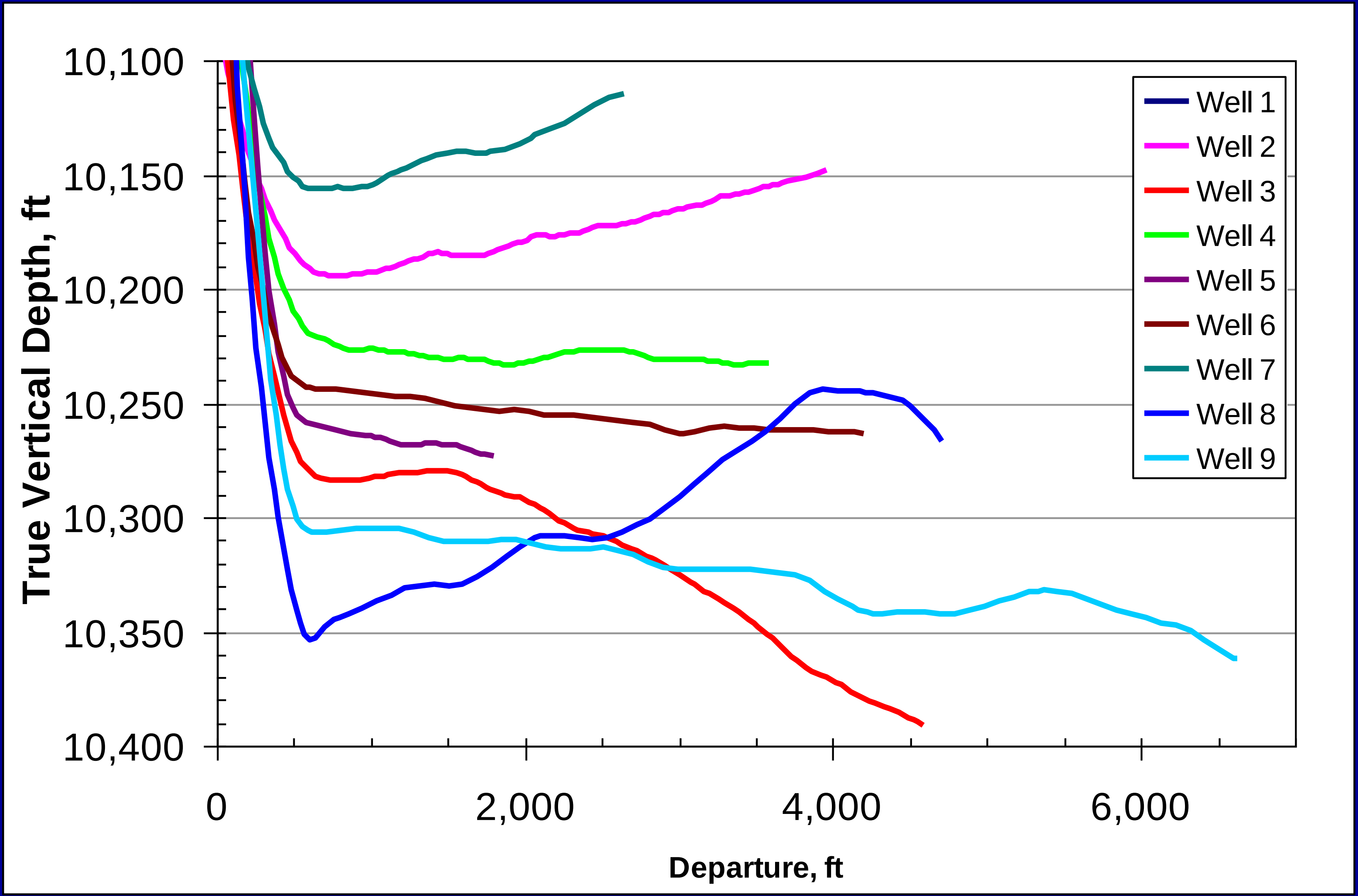
Static Liquid Column Pressure Profile



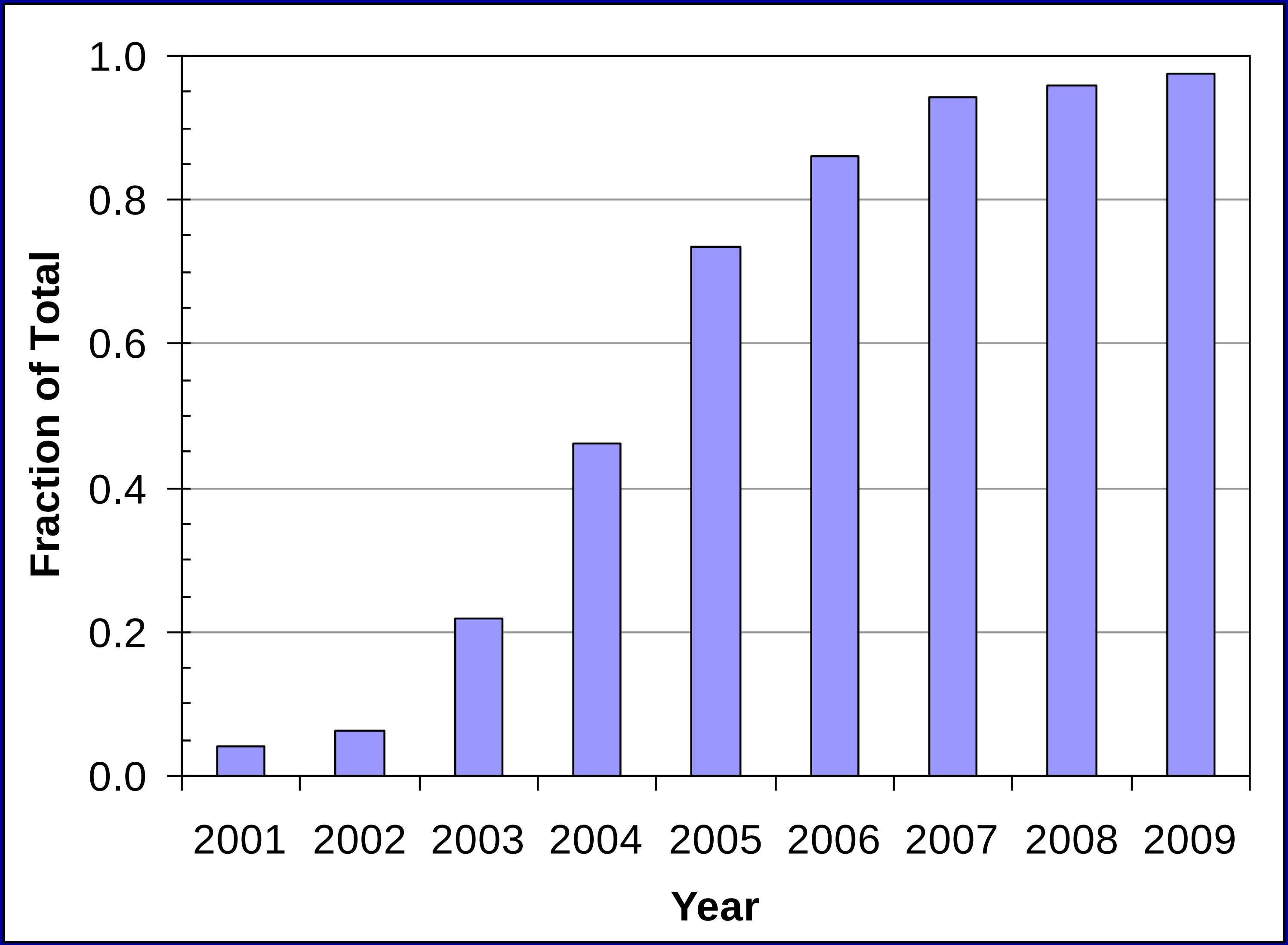
Horizontal Well Ideal Case



Complex Horizontal Well Profiles



Barnett Shale Horizontal & Vertical Wells



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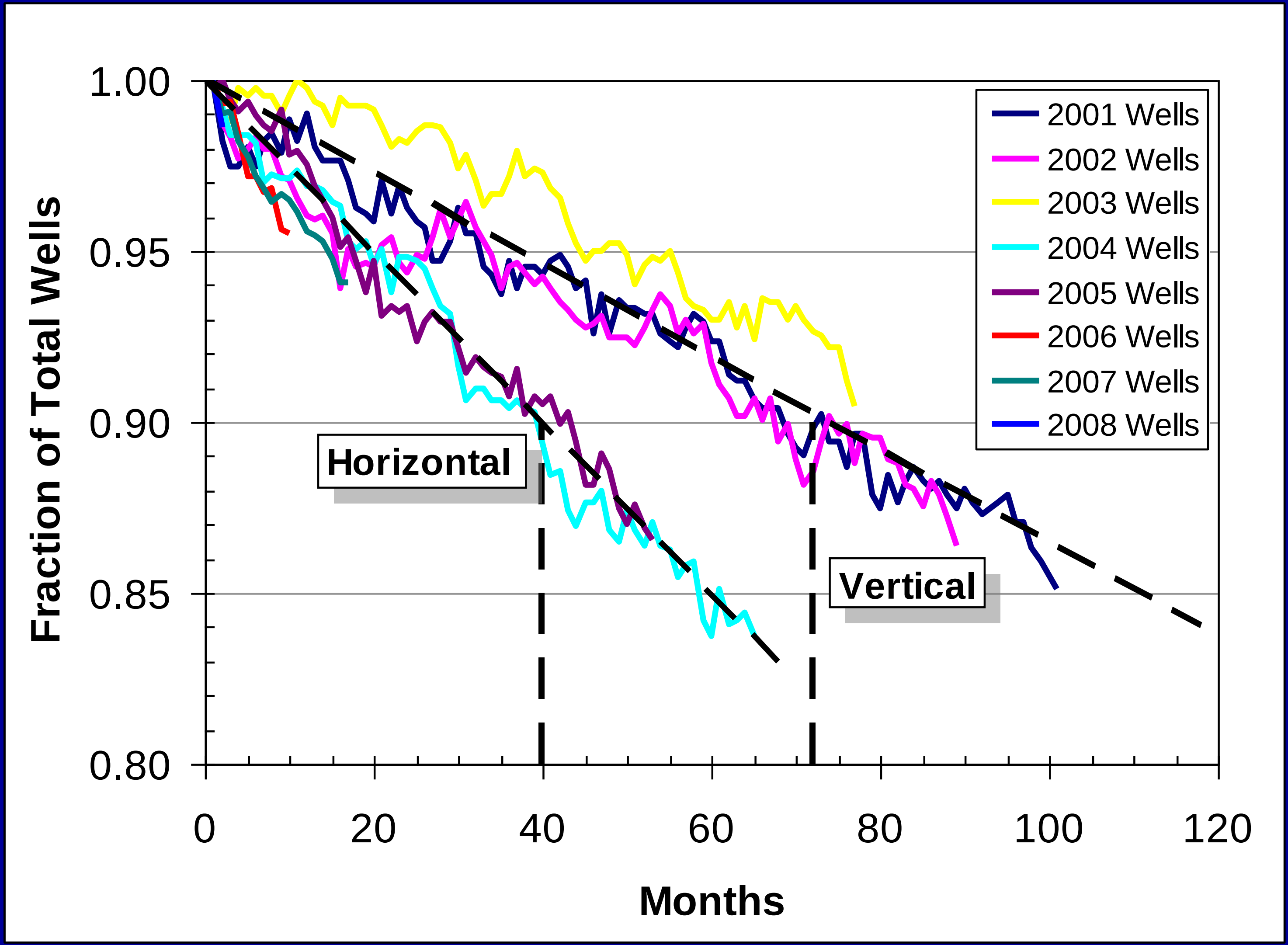
Vertical vs Horizontal Well Attrition



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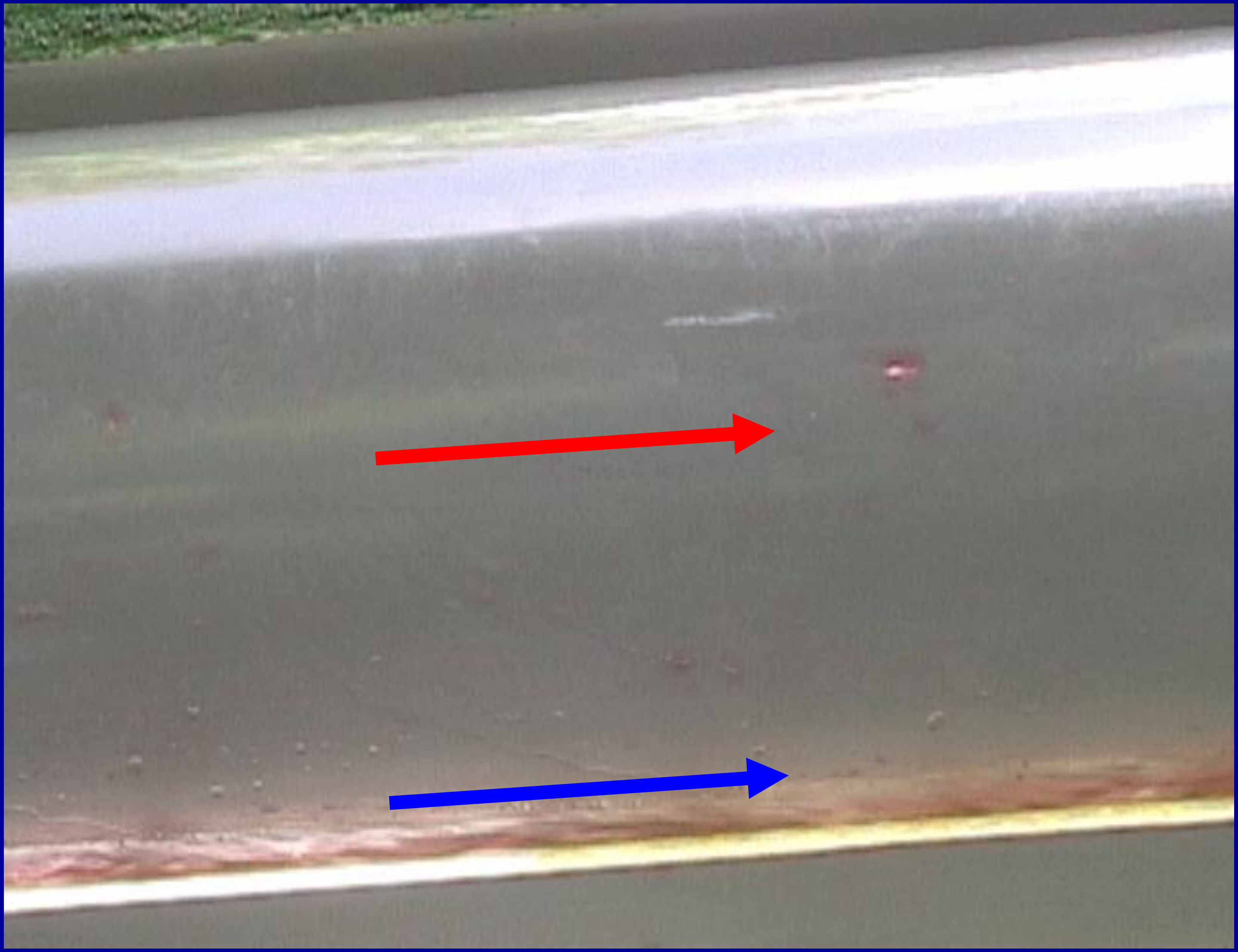
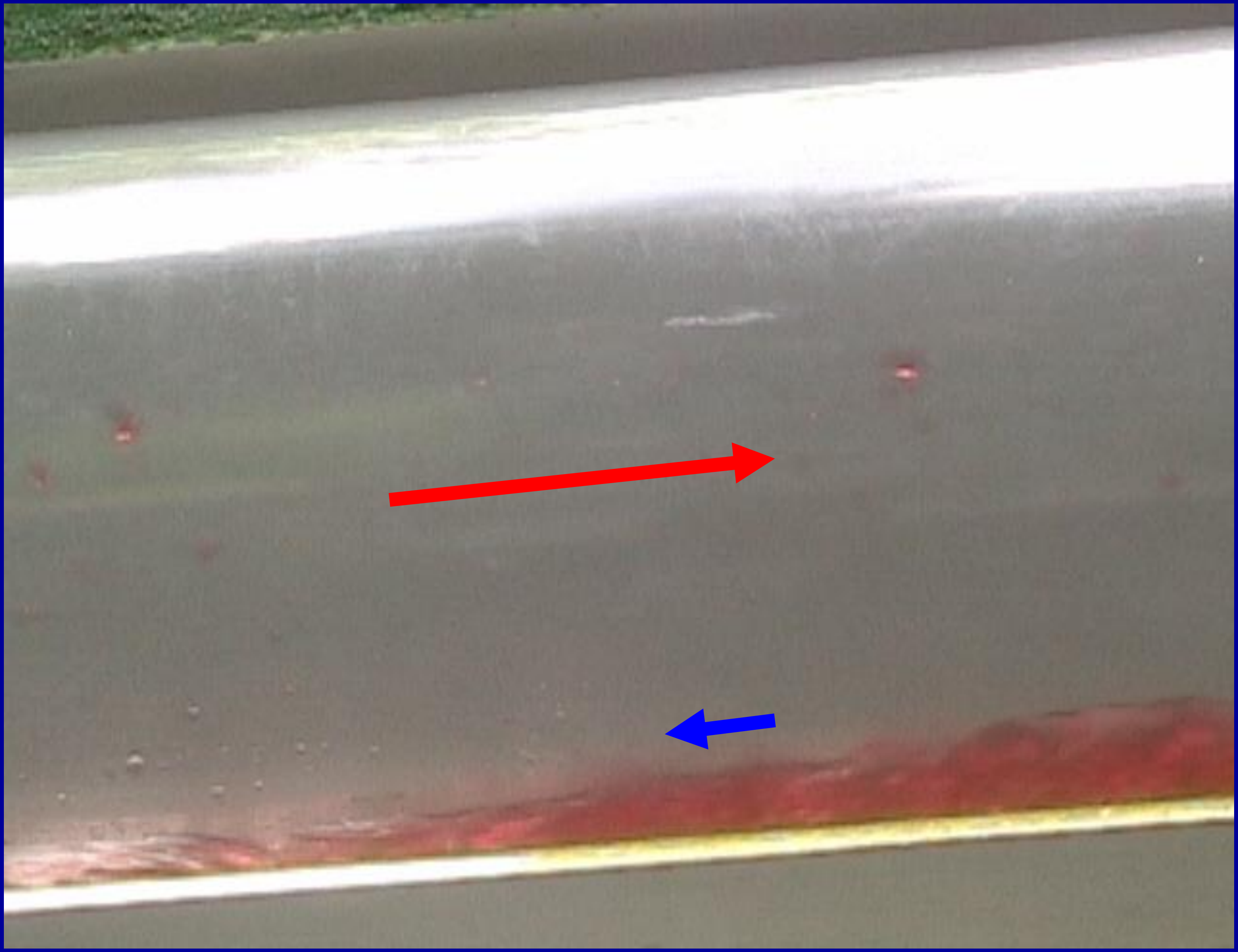
Liquid Loading at 86º from Vertical



4-in Pipe

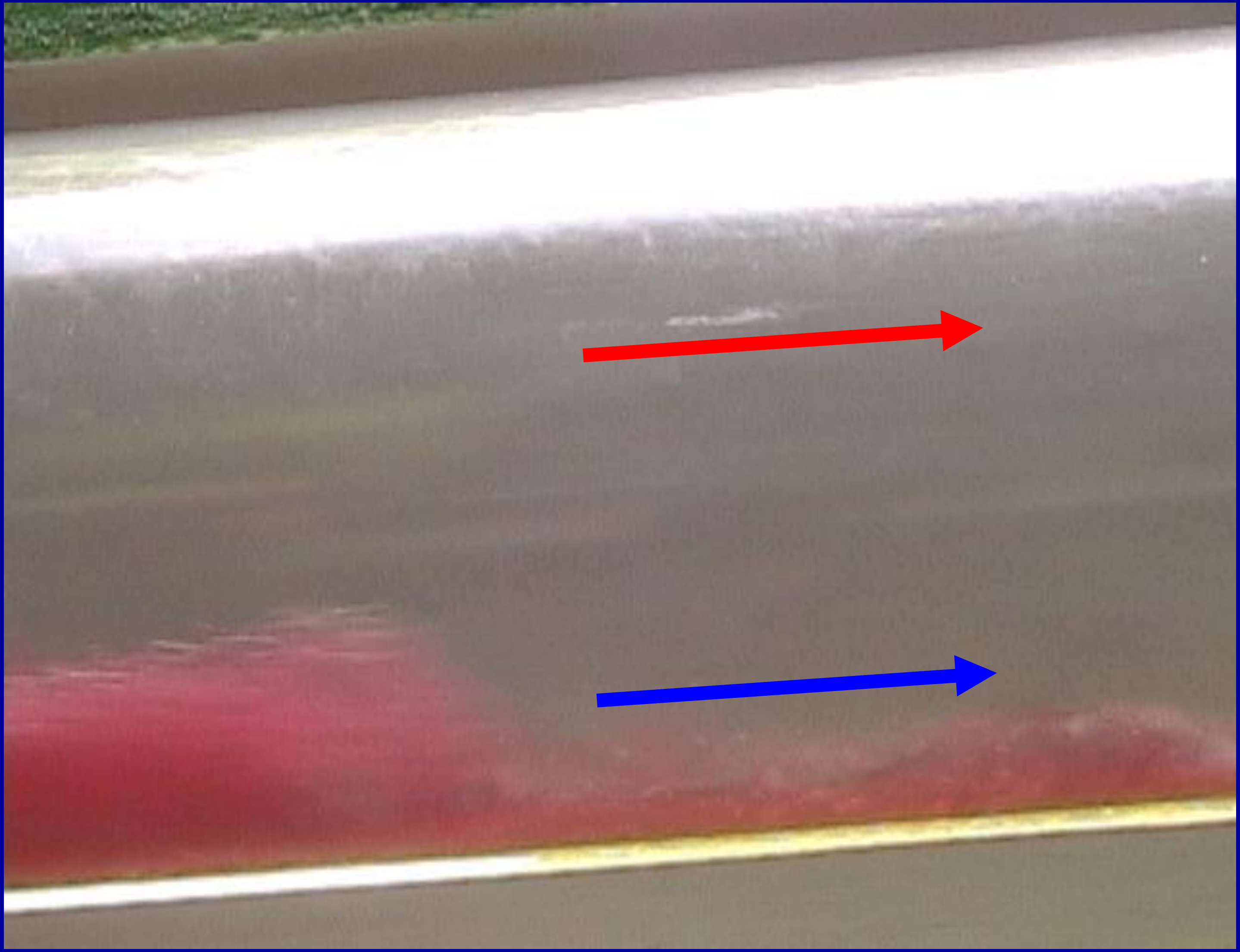
Stratified flow pattern

Liquid Loading at 86º from Vertical



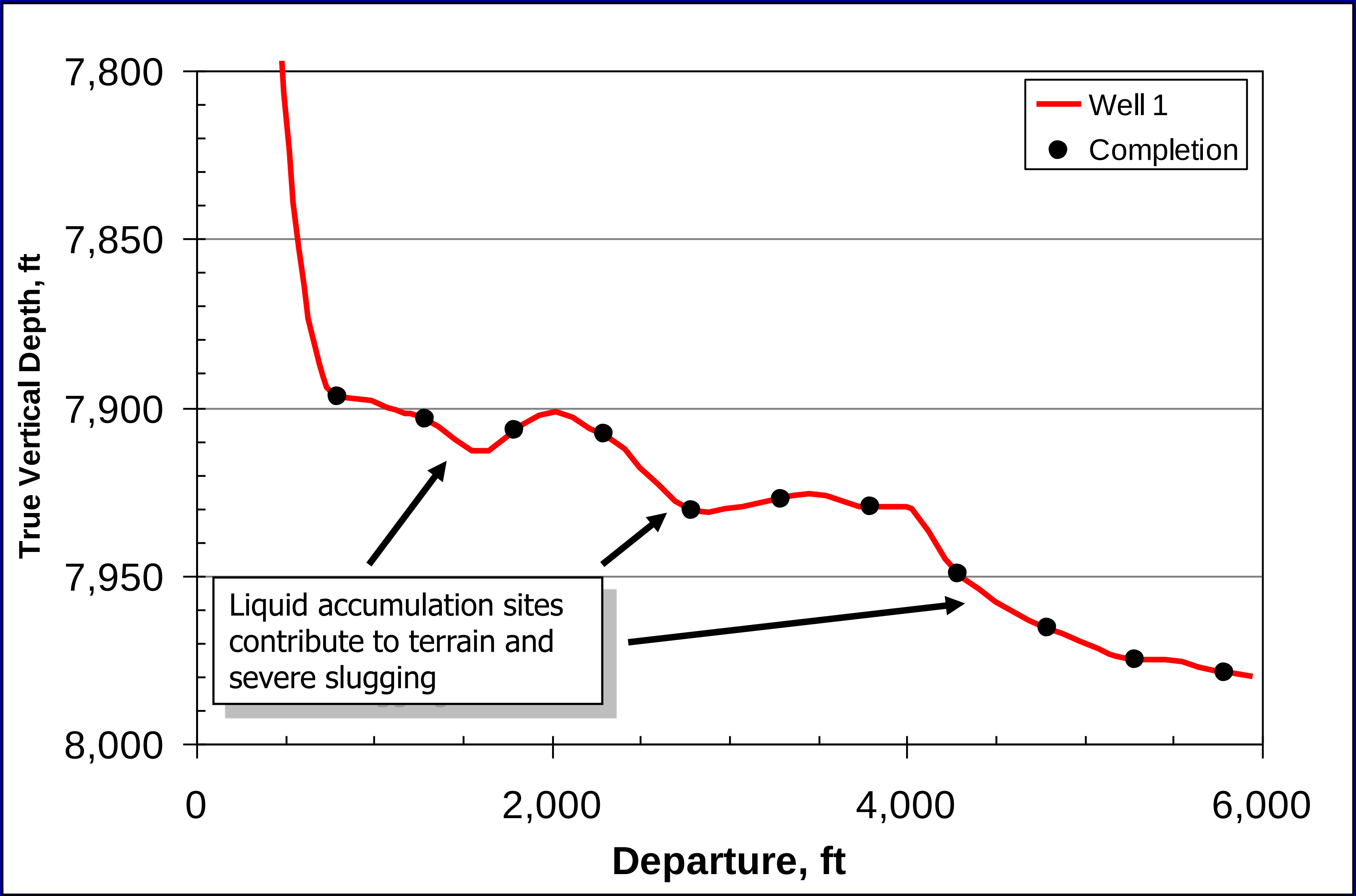
Liquid accumulation at gas velocity less than critical

Liquid Loading at 86º from Vertical

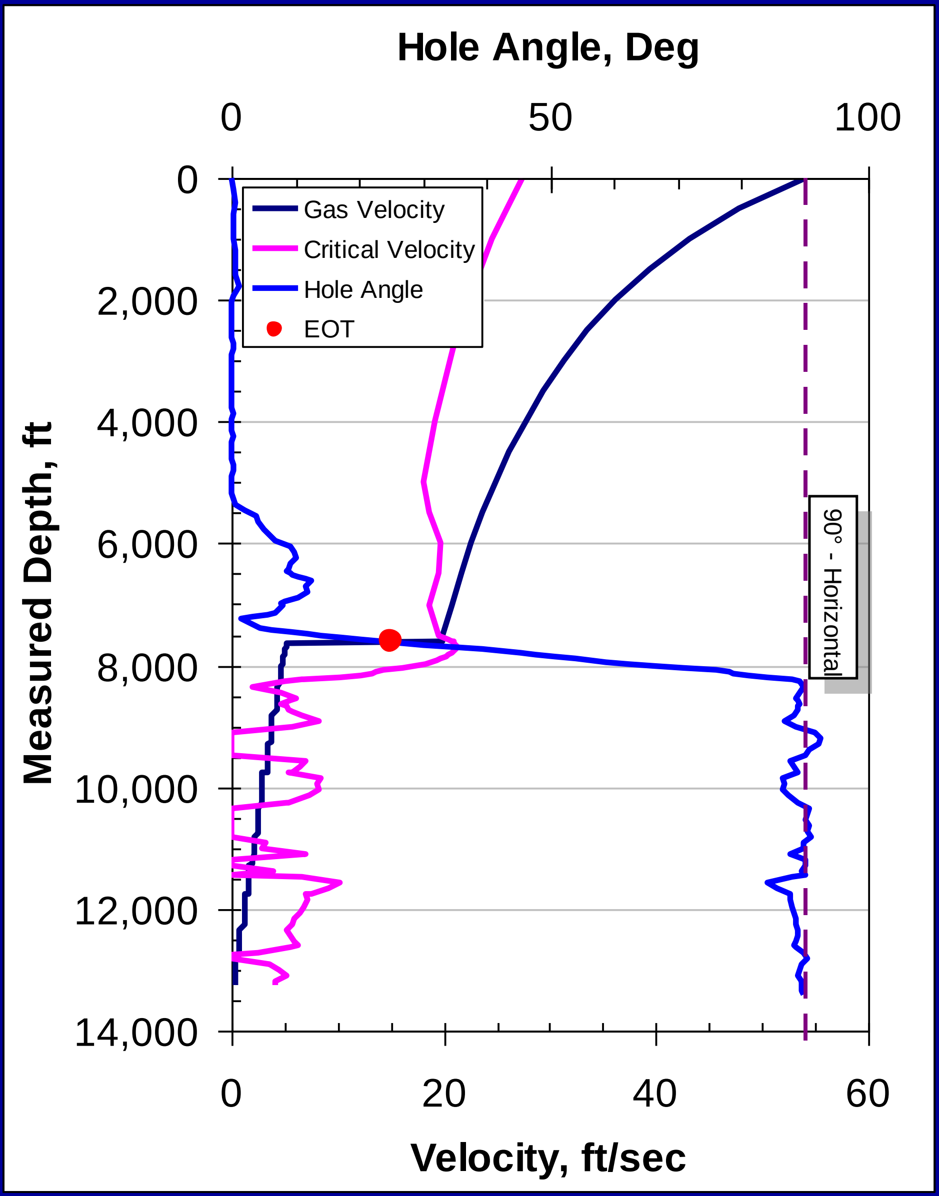


Onset of terrain slugging

Example Horizontal Well

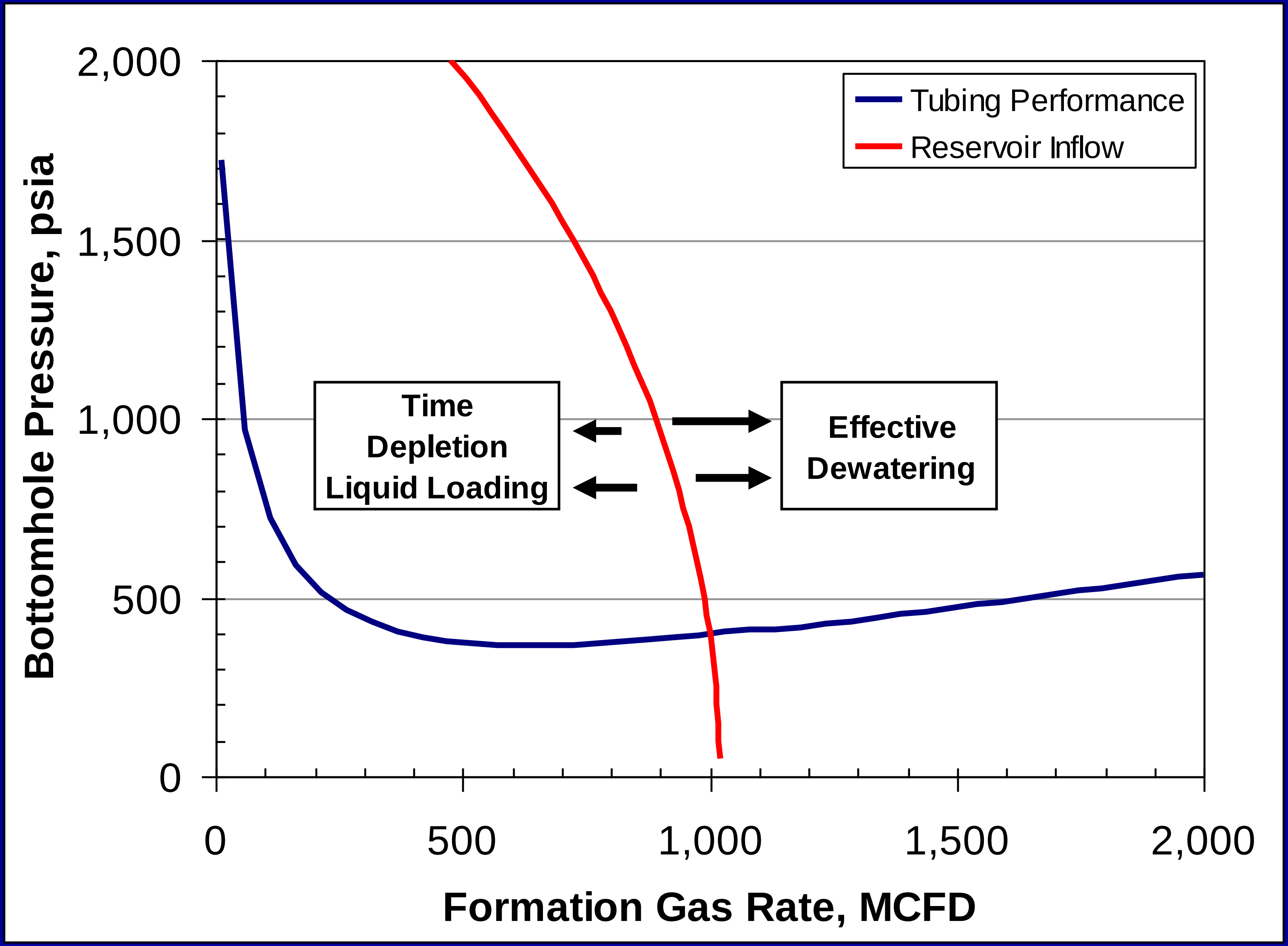


Example Horizontal Well

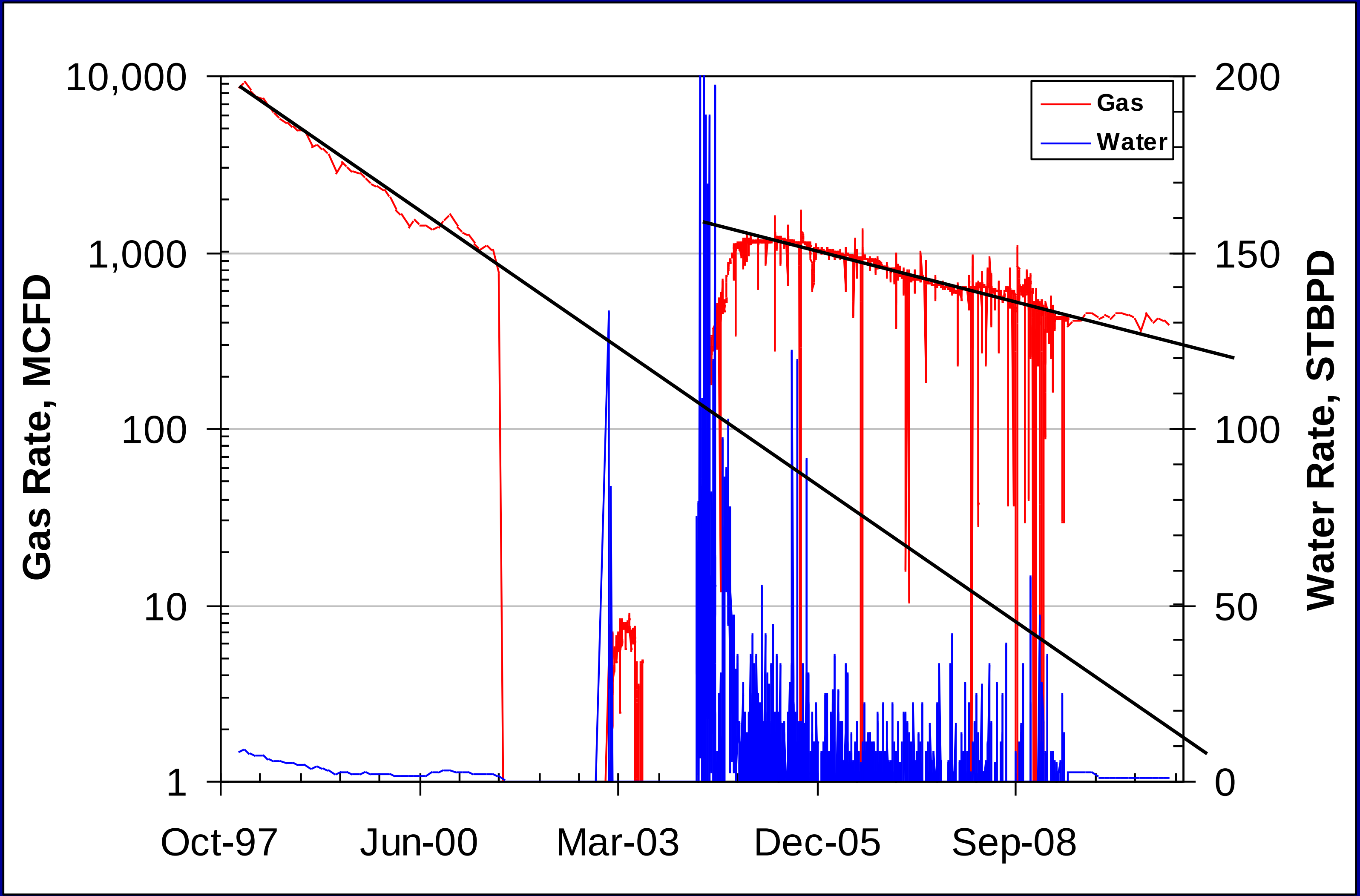


- Velocity profile
- Gas velocity
  - Comparison with critical velocity
- EOT at 25°
  - Shallow
  - Slugging in curve
  - Slugging in horizontal

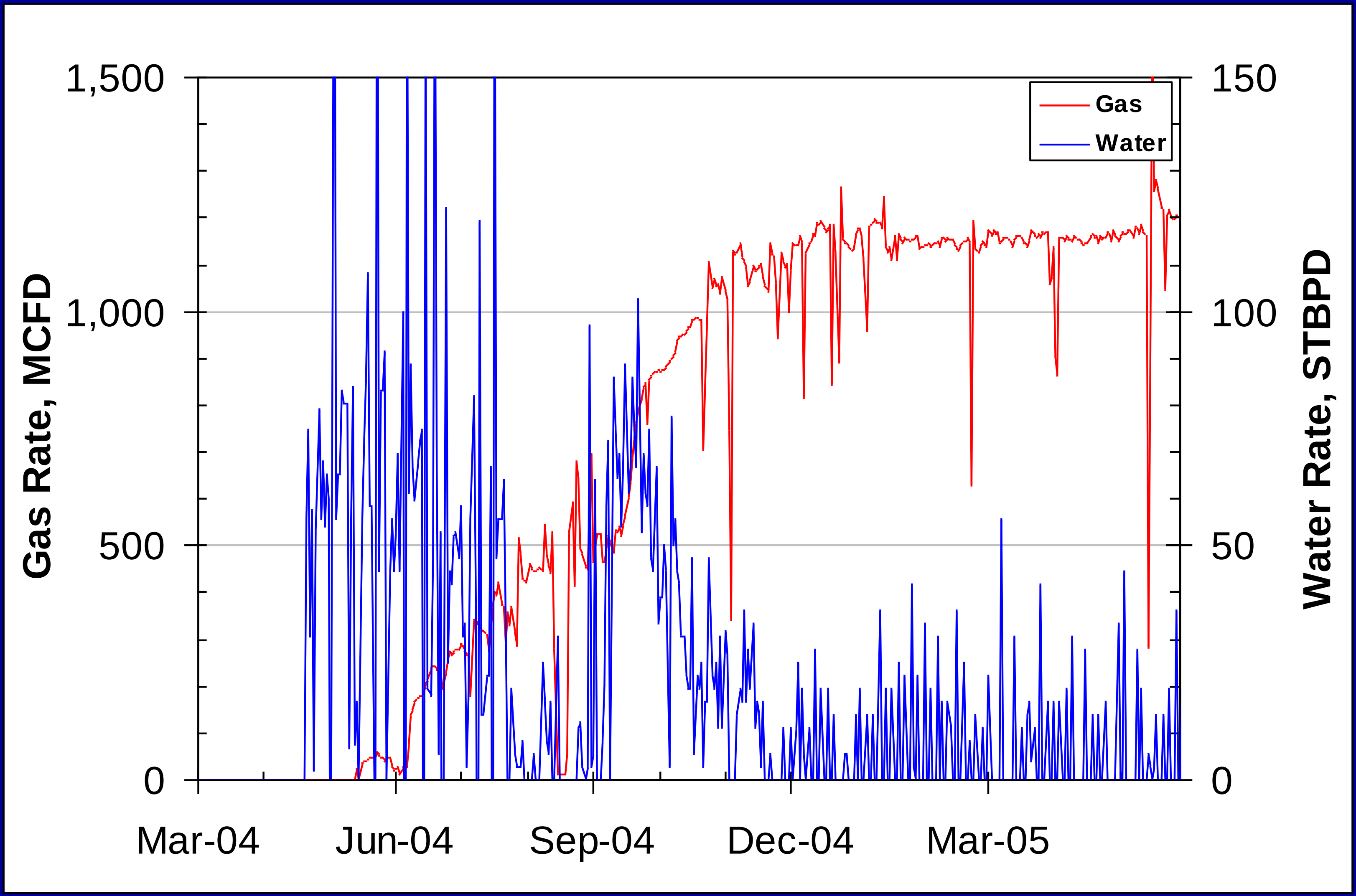
Factors Affecting Rate-Time Decline



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?

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