SPE 134165

Improving Stimulation Effectiveness – Field Results in the Haynesville Shale

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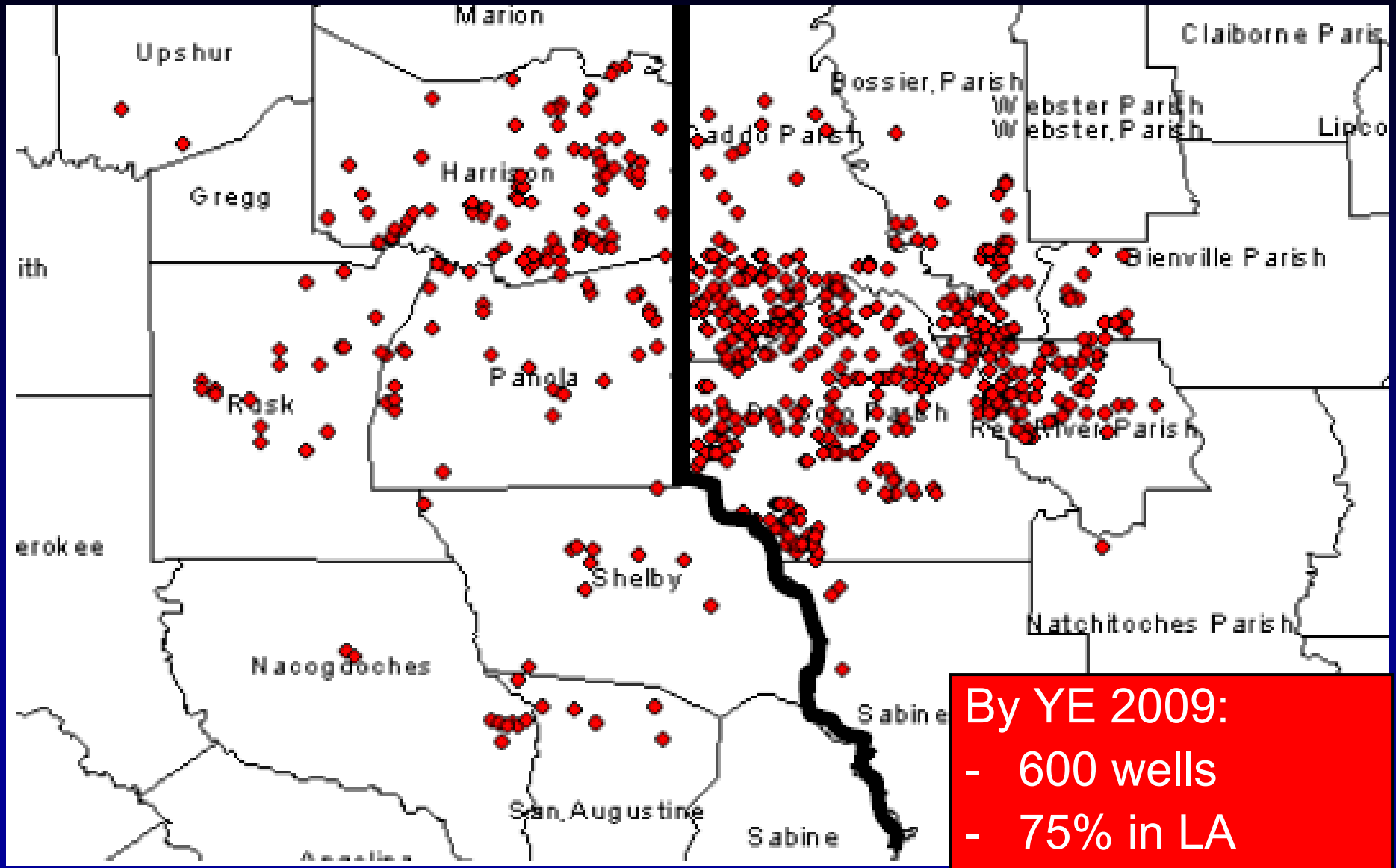
Outline

- Introduction
- Completion (Stimulation) Issues
- Production History Match
- Sensitivities
  - Field Validation
- Summary

Haynesville Shale Properties

- Black, organic rich shale ◄
- Clay content <40%
- Ro 1.3-2.4
- TOC – 3-5%
- Gas - 80% free, 20% adsorbed
- Pressure gradient – 0.84-0.88 psi/ft
- ~11,000-13,000’ TVD and 150-400’ thick ◄
- Perm 5-800 nanoDarcies ◄
- Porosity 6-12%
- S_w 25-35%
- Reservoir Temperature >300° F ◄

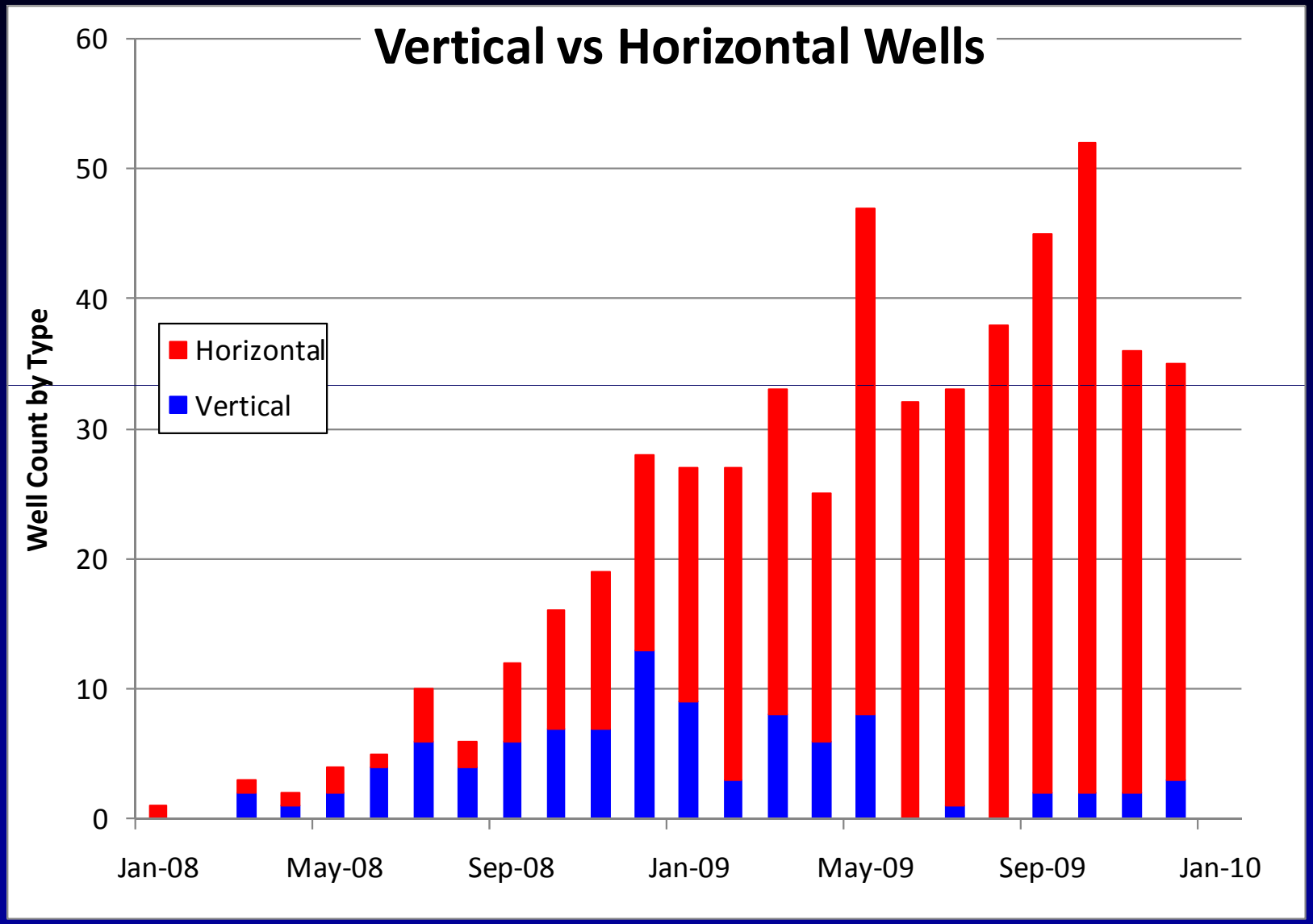
Haynesville Drilling Activity



By YE 2009:

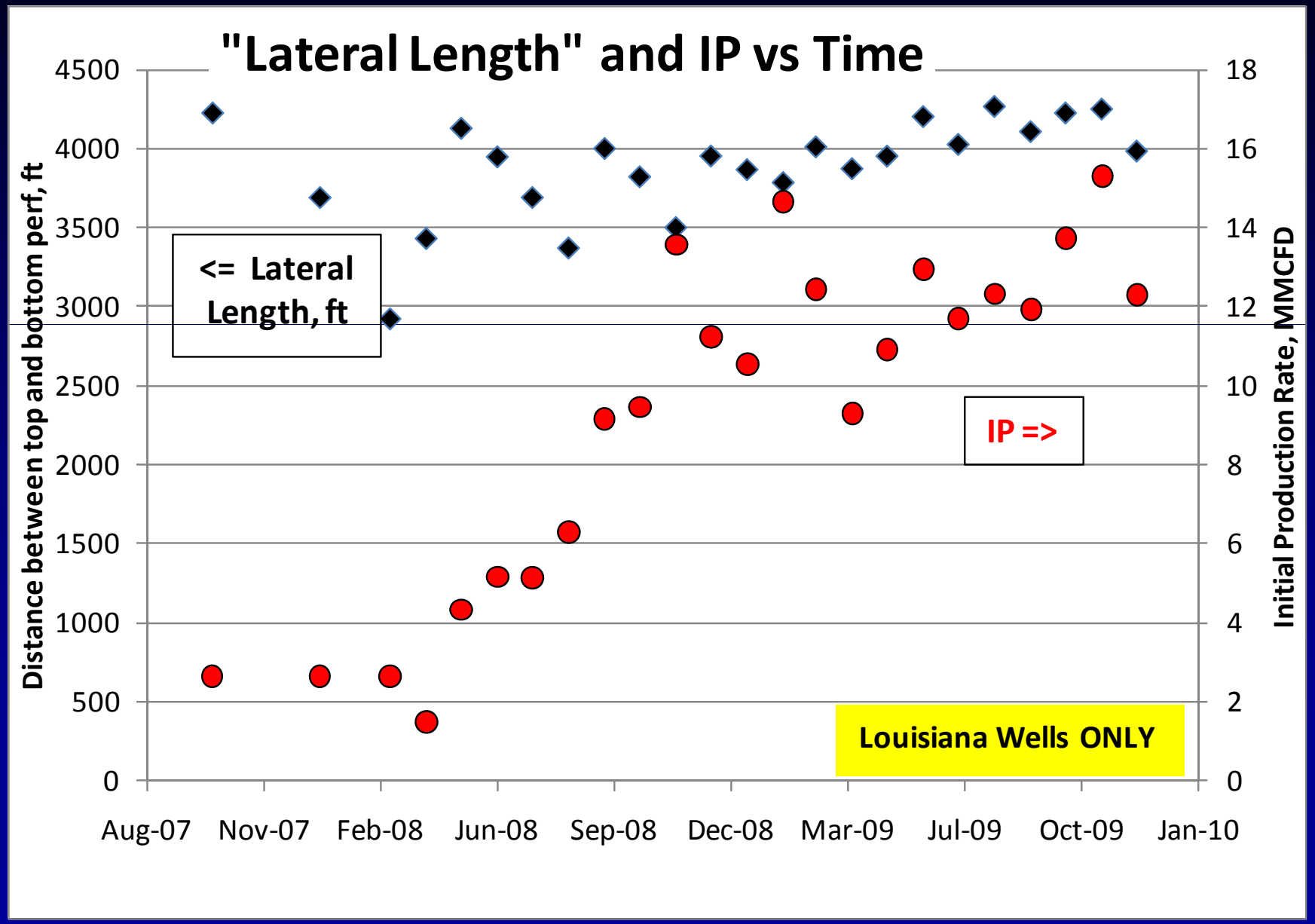
- 600 wells
- 75% in LA
- >80% Horizontal

Haynesville Drilling Activity

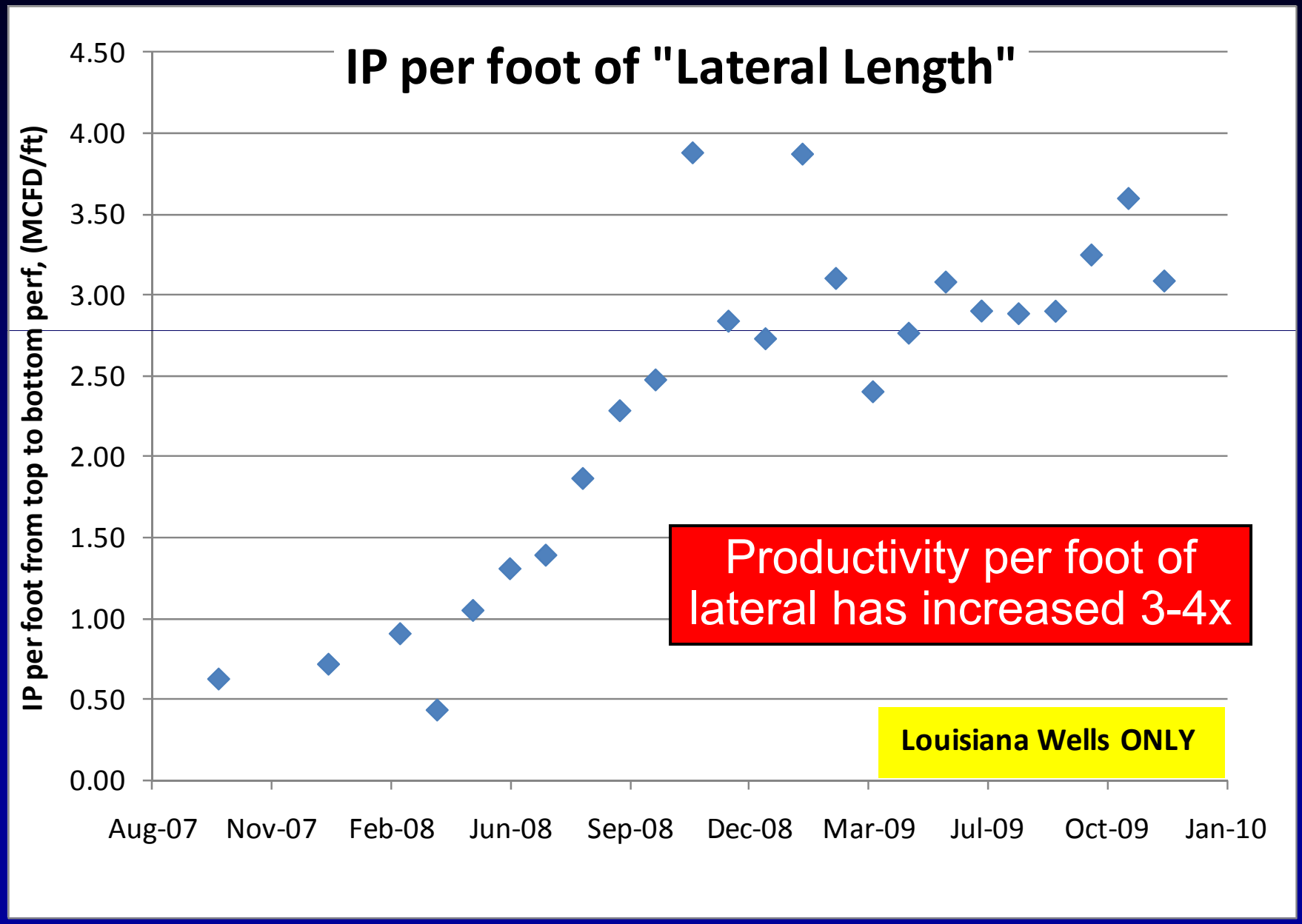


Majority now being drilled are Horizontal

Completion Improvements



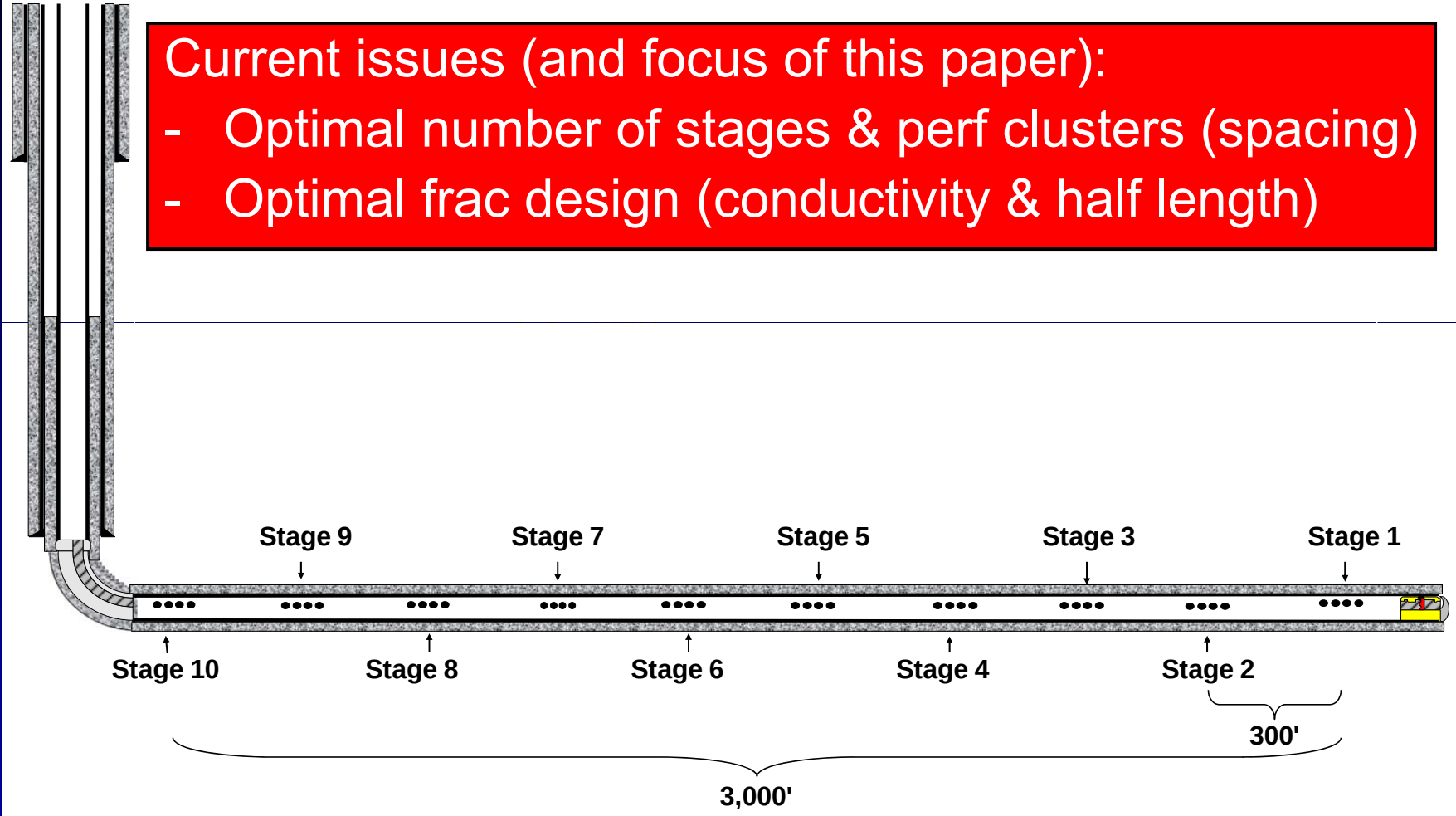
Completion Improvements



Completion (Stimulation) Issues

Current issues (and focus of this paper):

- Optimal number of stages & perf clusters (spacing)
- Optimal frac design (conductivity & half length)



Horizontal wells, 3000-6000’ laterals, multistage fracturing

History Match Methodology

- "History Match" actual production
  - Single HV well with 8 months production
  - 3D reservoir simulator
- Indentify match parameters
  - Half length, fracture conductivity, number of fracs
- Run Sensitivities
  - Optimal number of fracs, half length & conductivity
- Validate with Field Data

Model Parameters

Reservoir

- Reservoir pressure: 10,000 psi
  - Pressure gradient: 0.90 psi/ft
- Pay Thickness: 300’
- Porosity: 9%, Water Saturation: 30%
- Gas Gravity: 0.65, BH Temp: 325°F

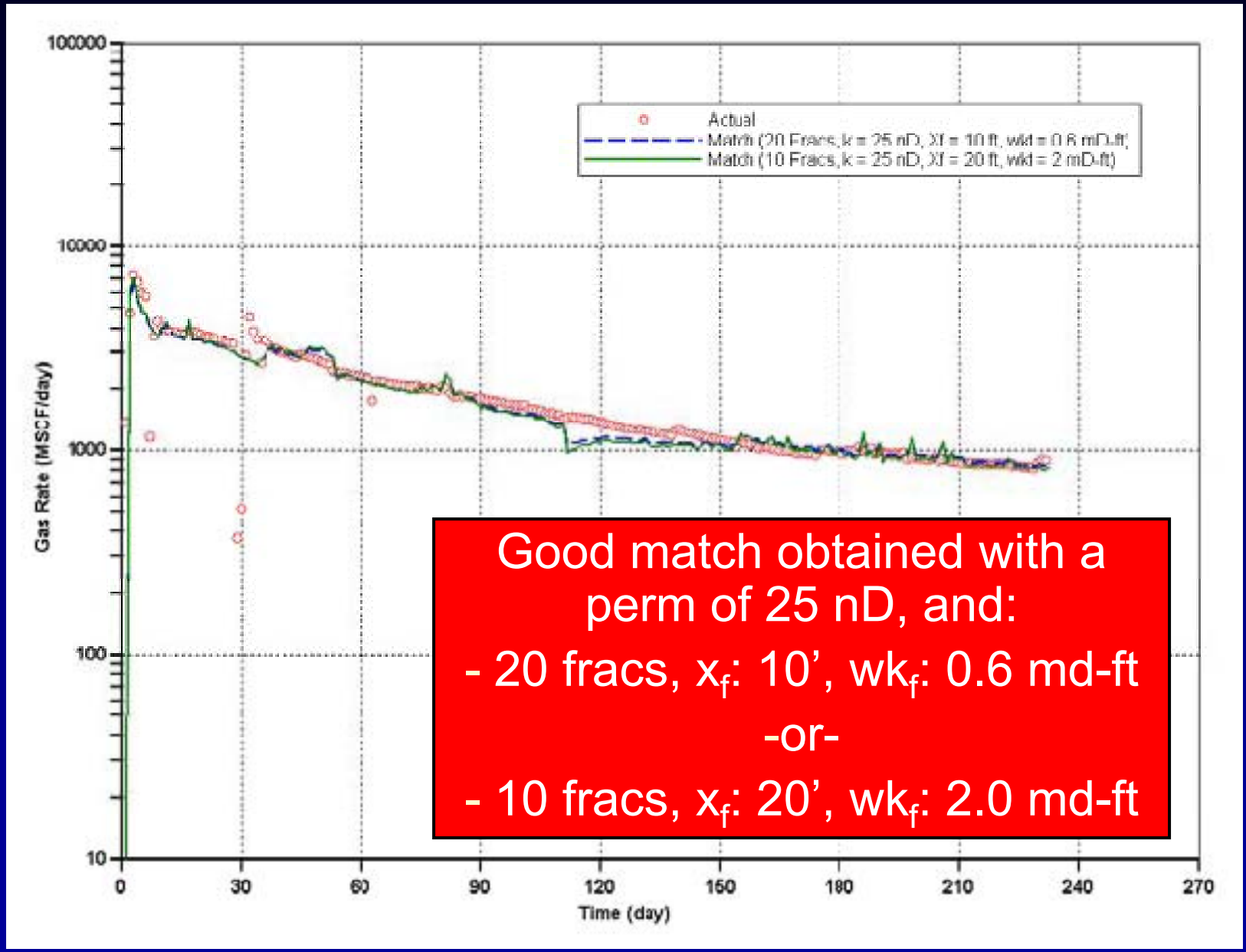
Completion

- 3,000’ lateral
- Multiple, transverse fracs equally spaced along lateral

Variables

- Reservoir permeability, drainage area, number of fracs, effective fracture conductivity and half length

Initial Match



Good match obtained with a perm of 25 nD, and:

- 20 fracs, x_f: 10', wk_f: 0.6 md-ft

-or-

- 10 fracs, x_f: 20', wk_f: 2.0 md-ft

Other Solutions

Other solutions explored

- Effective half lengths appeared very short
  - Designed and microseismic suggested >500’

Additional acceptable match obtained

- permeability: 25 nD
- 4 fracs
- x_f: 500’
- Tapered wk_f with 6 md-ft (0-5’) and 0.01 md-ft (5-500’)

Potential Solutions

Parameter	Reservoir Simulation History Matching		
Well model	Final Match	Alternate Match 1	Alternate Match 2
Reservoir permeability, nD	25	25	25
Number of fractures	20	10	4
Effective half-length, ft	10	20	500
Fracture conductivity, mD-ft	0.6	2	6 (< 5 ft) 0.01 (5-500 ft)
10 Year Cum Gas, BCF	1.0	1.0	1.1

Matches are non-unique

- However, results present unique optimization potential

Completion Sensitivities

PDA suggested short, low conductivity fracs
(see paper for more details)

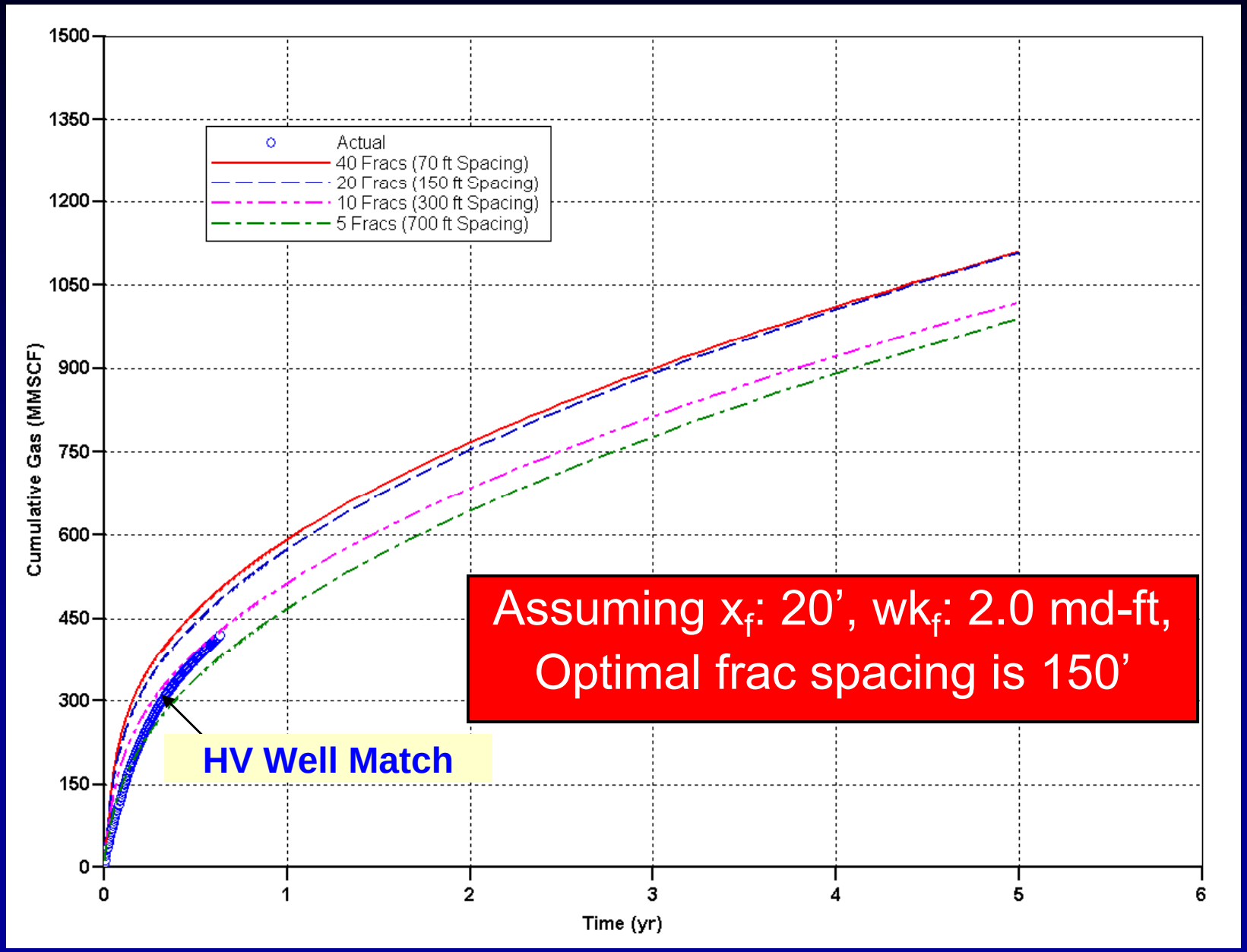
Base parameters in each case

- k: 25 nD
- 10 fracs (300’ spacing)
- x_f: 20’
- wk_f: 2 md-ft

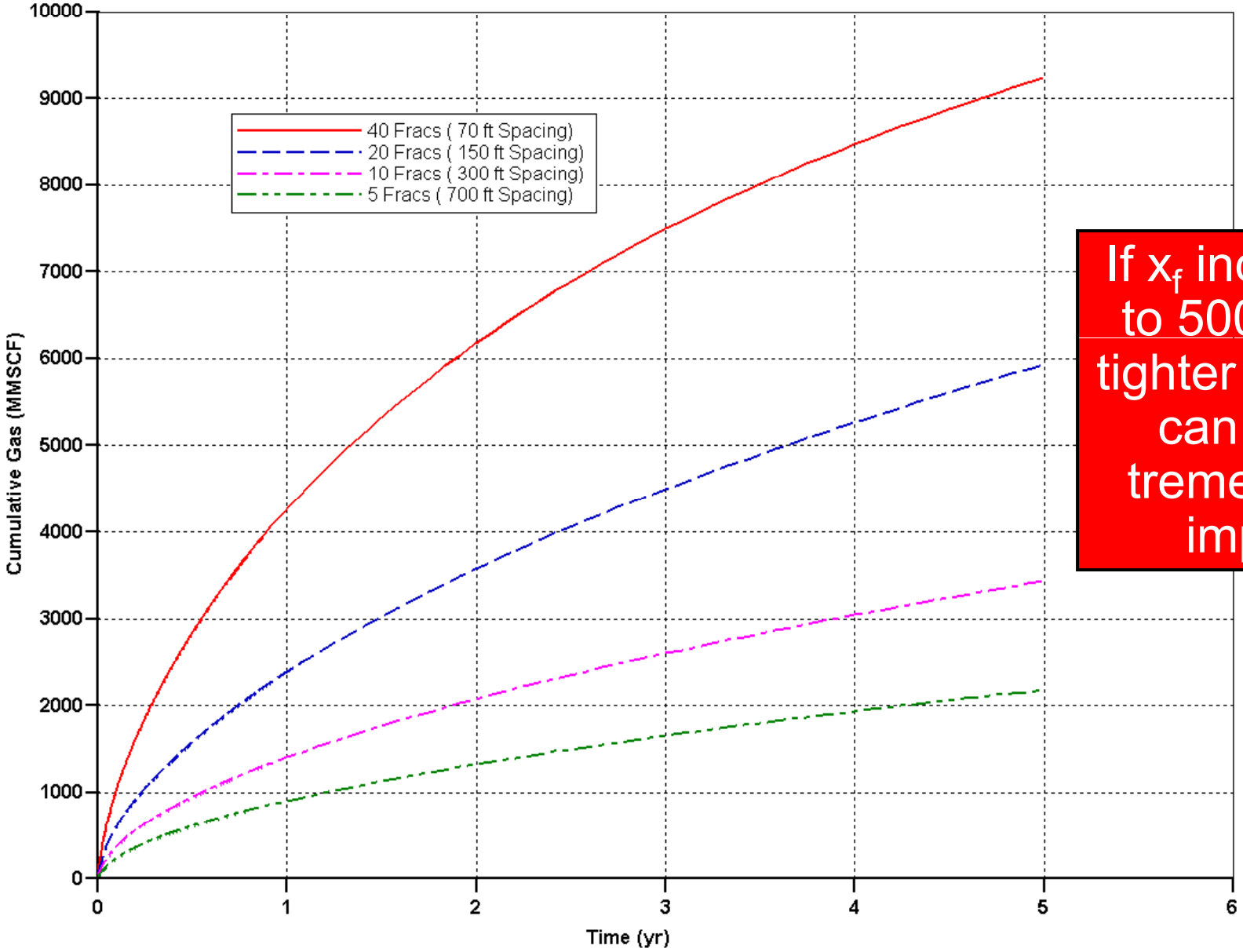
Three sensitivities

- Frac Spacing
- Effective Half Length
- Fracture Conductivity

Impact of Frac Spacing



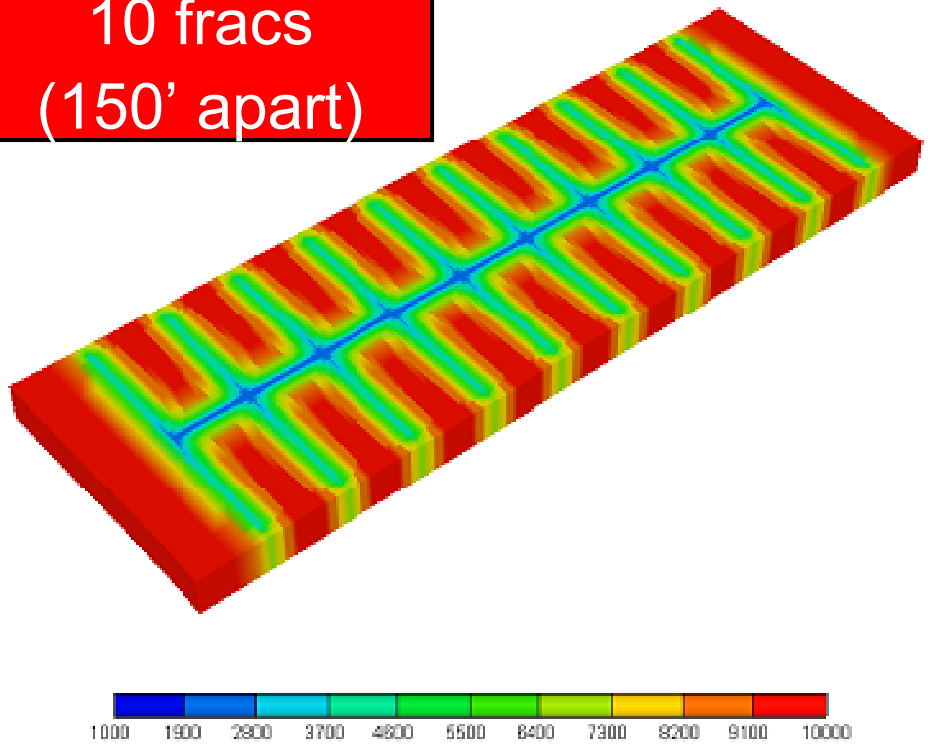
Impact of Frac Spacing



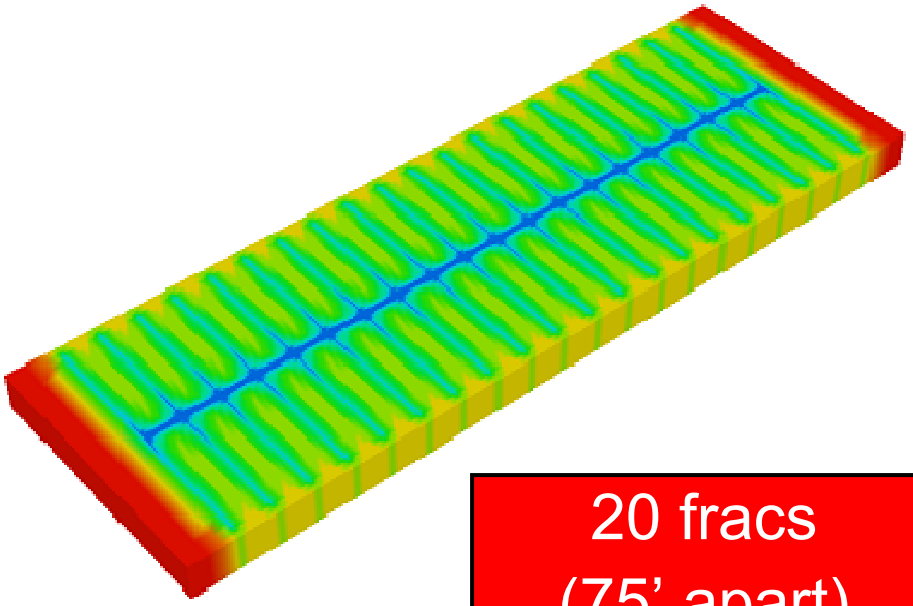
If x_f increased to 500', then tighter spacing can have tremendous impact

Impact on Recovery

10 fracs
(150’ apart)

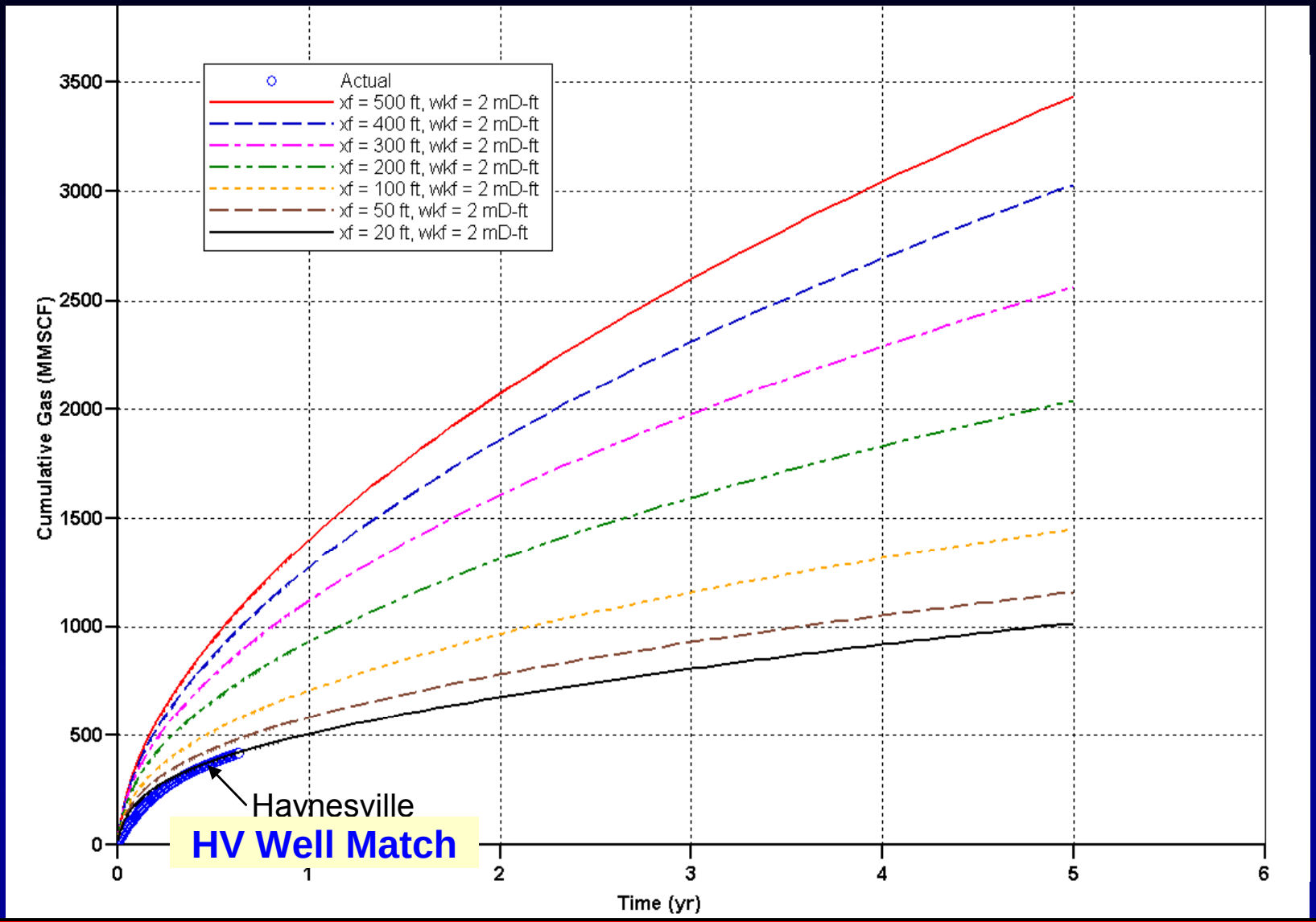


After 5 years
production



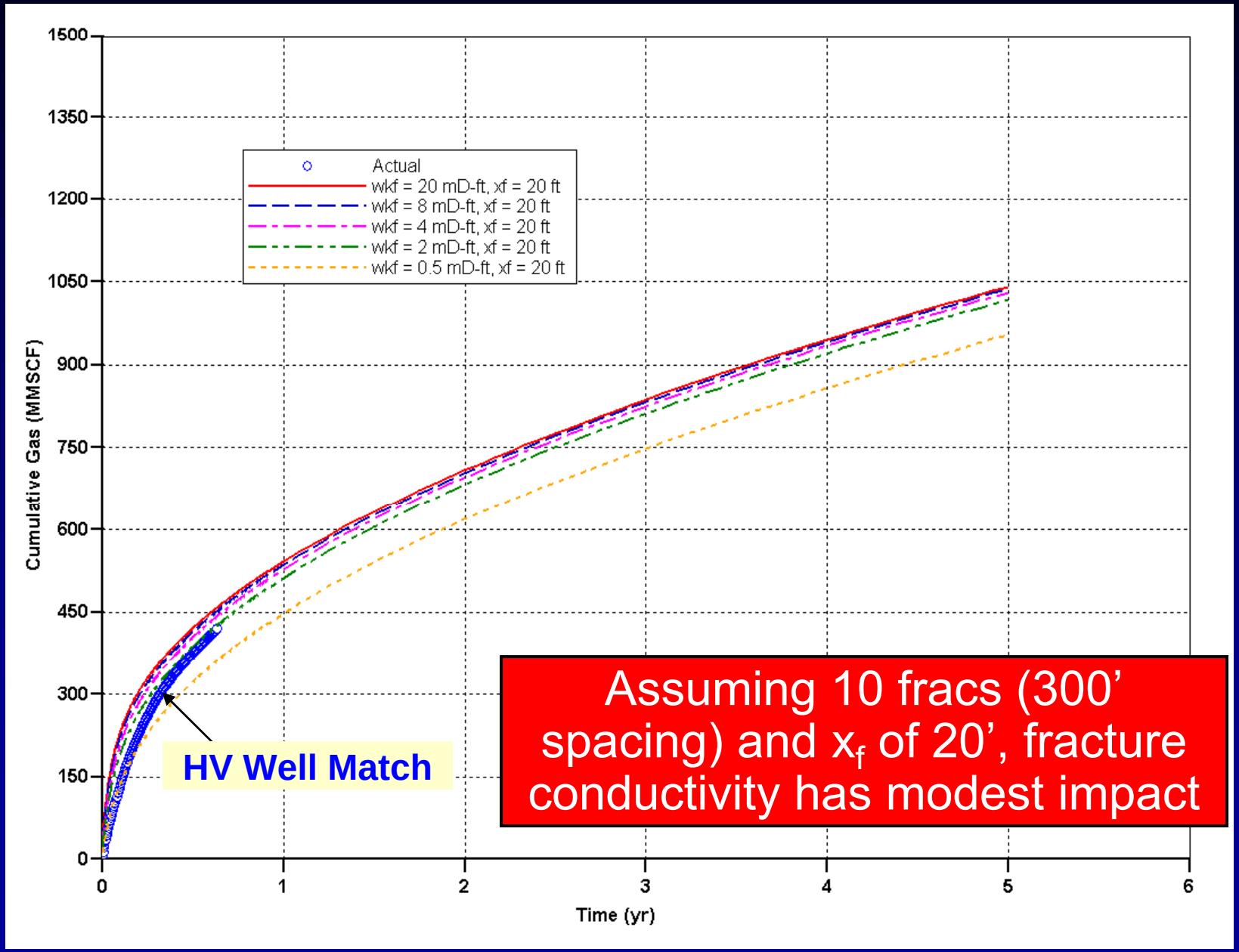
20 fracs
(75’ apart)

Impact of Effective Half Length



Assuming 10 fracs (300' spacing) and wk_f of 2.0 md-ft, increasing effective half length has dramatic impact on production

Impact of Fracture Conductivity



Conductivity Critical

Propped half lengths likely >>> 20’

- Microseismic data shows 600’+ fluid movement
- Simple material balance on proppant volumes pumped

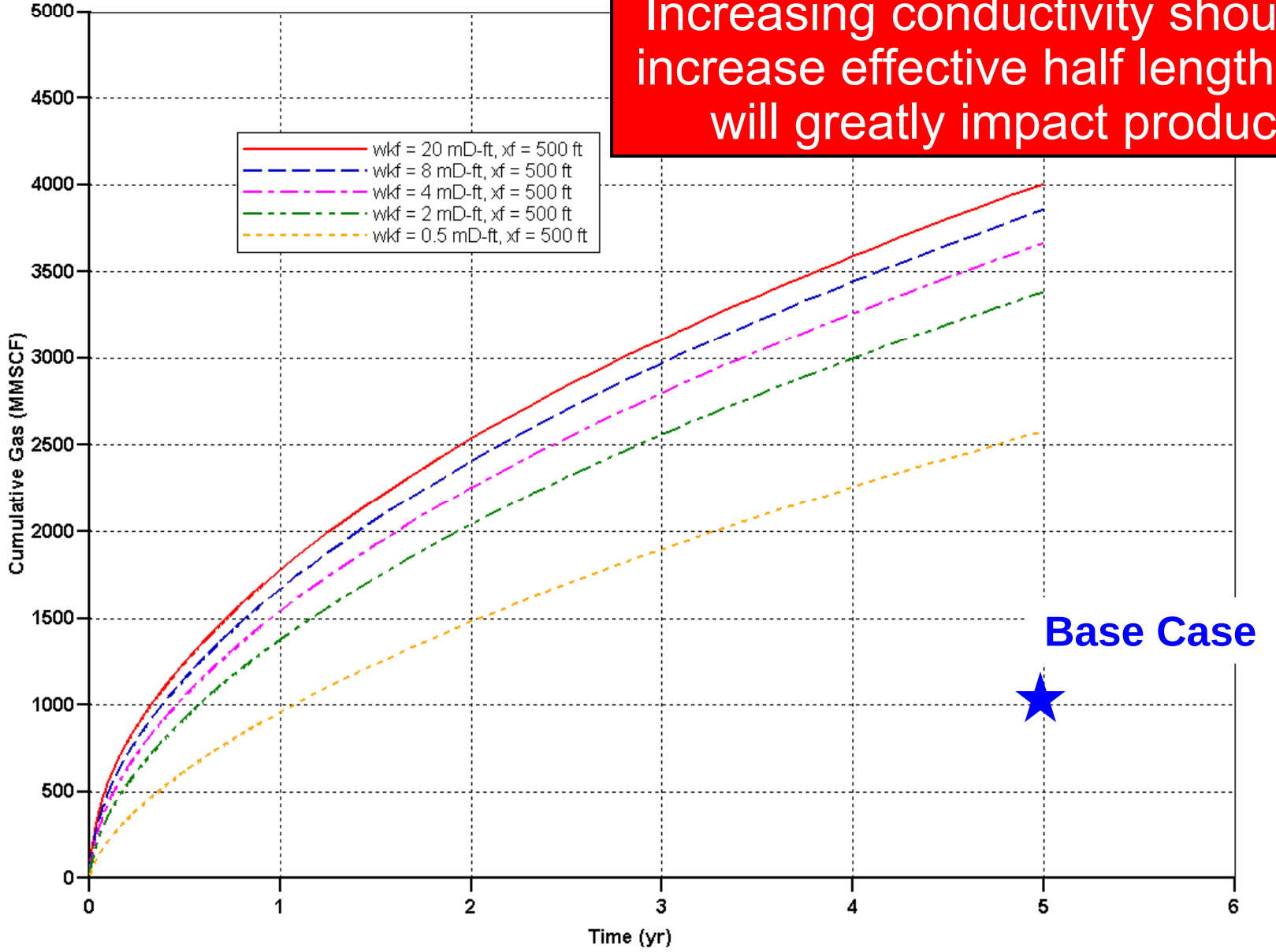
Effective Half Lengths being limited by conductivity

- Realistic Conductivity much lower than API/ISO conditions due to as embedment, low proppant concentrations, nonDarcy & multiphase flow, temperature (sand proppants), etc (SPE 106301)

- If conductivity is increased, then the effective half length should also increase.

Impact of Fracture Conductivity

Increasing conductivity should also increase effective half length, which will greatly impact production



Field Validation

PDA analysis performed on several HV wells from various areas

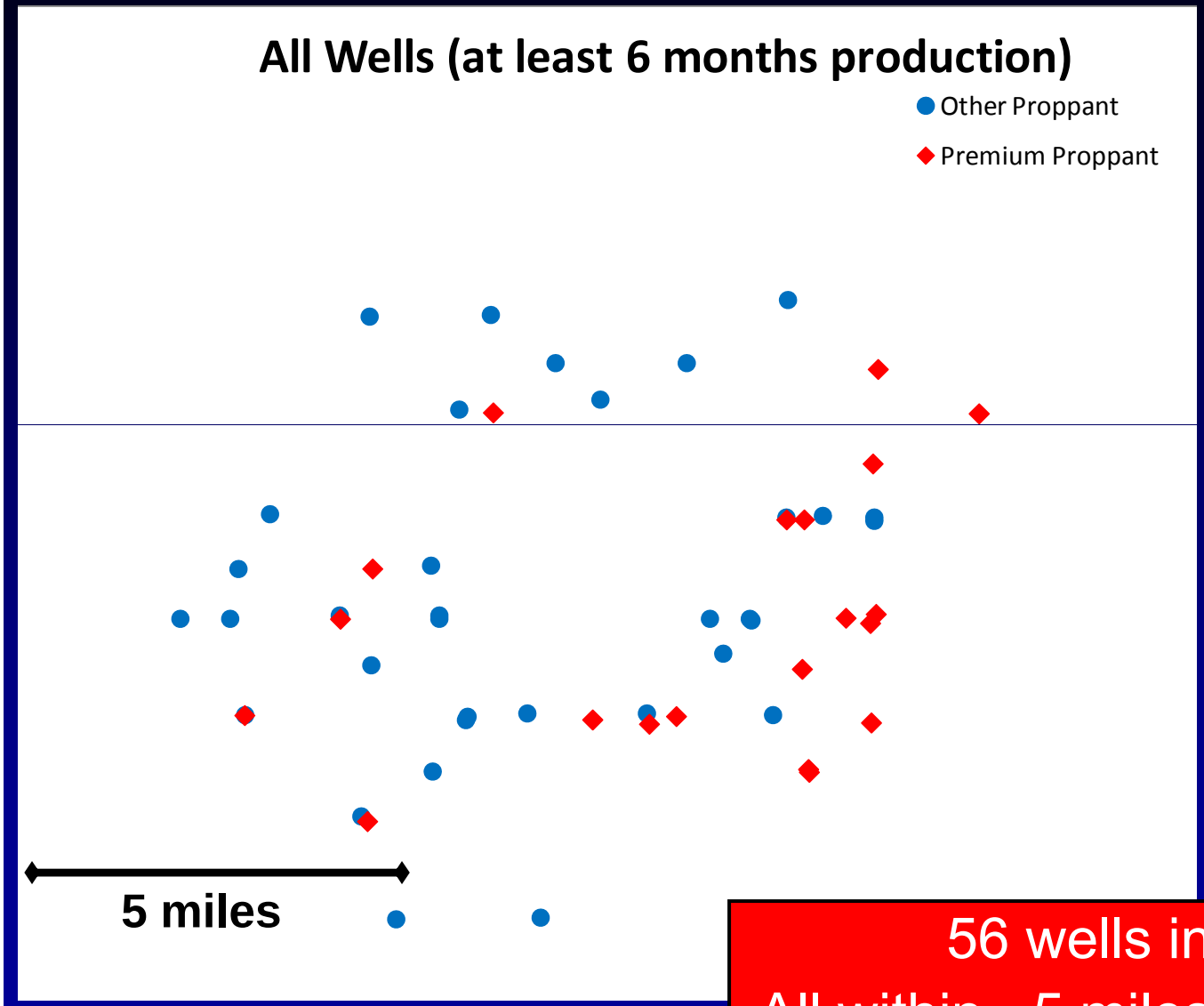
- All suggest short, low conductivity fractures

Production has improved over time in the HV:

- Lateral lengths have increased
- Number of frac stages has increased
- Other?

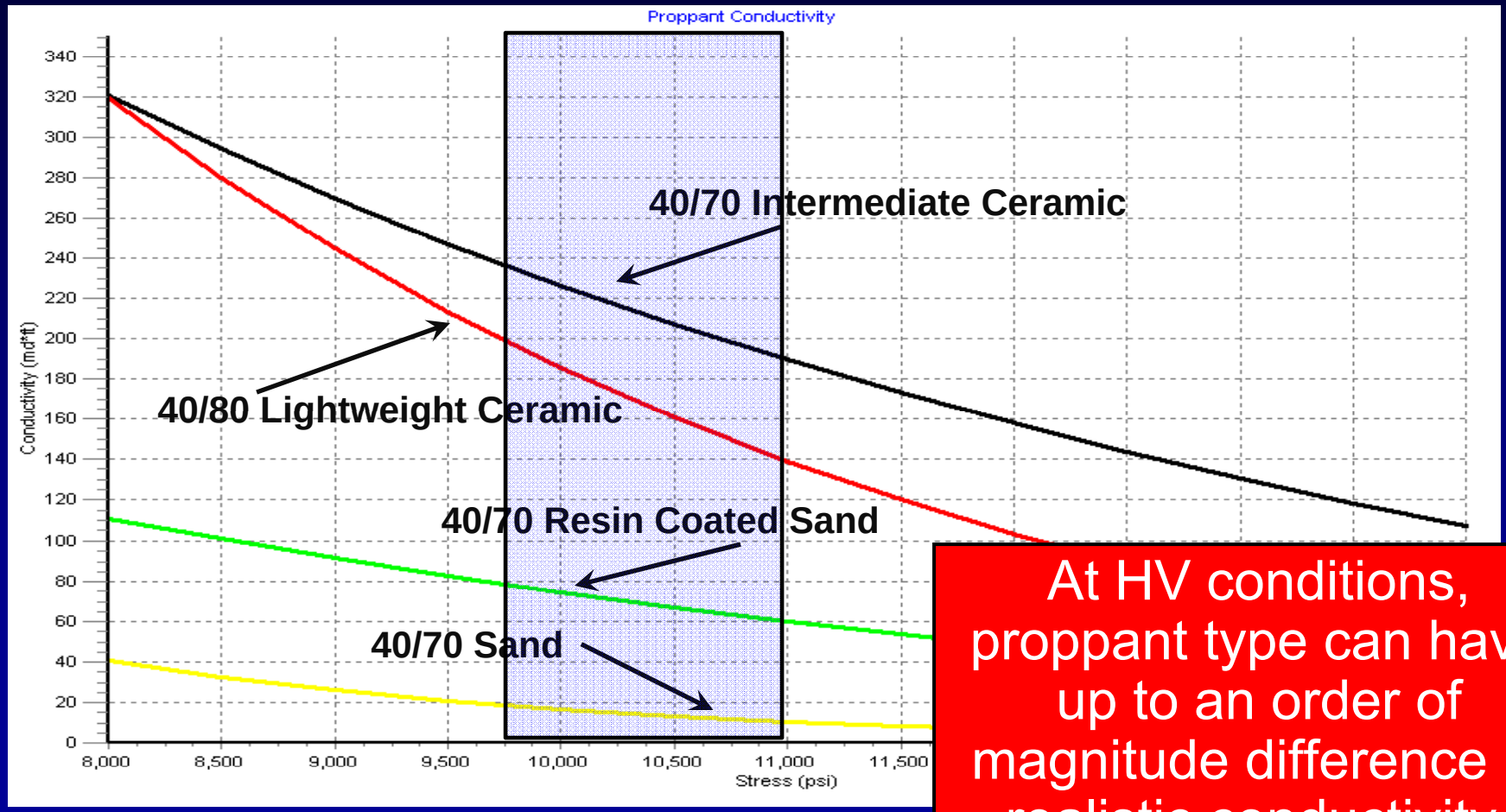
Conductivity impacts studied

Field Validation



56 wells in study area
All within ~5 miles radius (Louisiana)
At least 6 months production

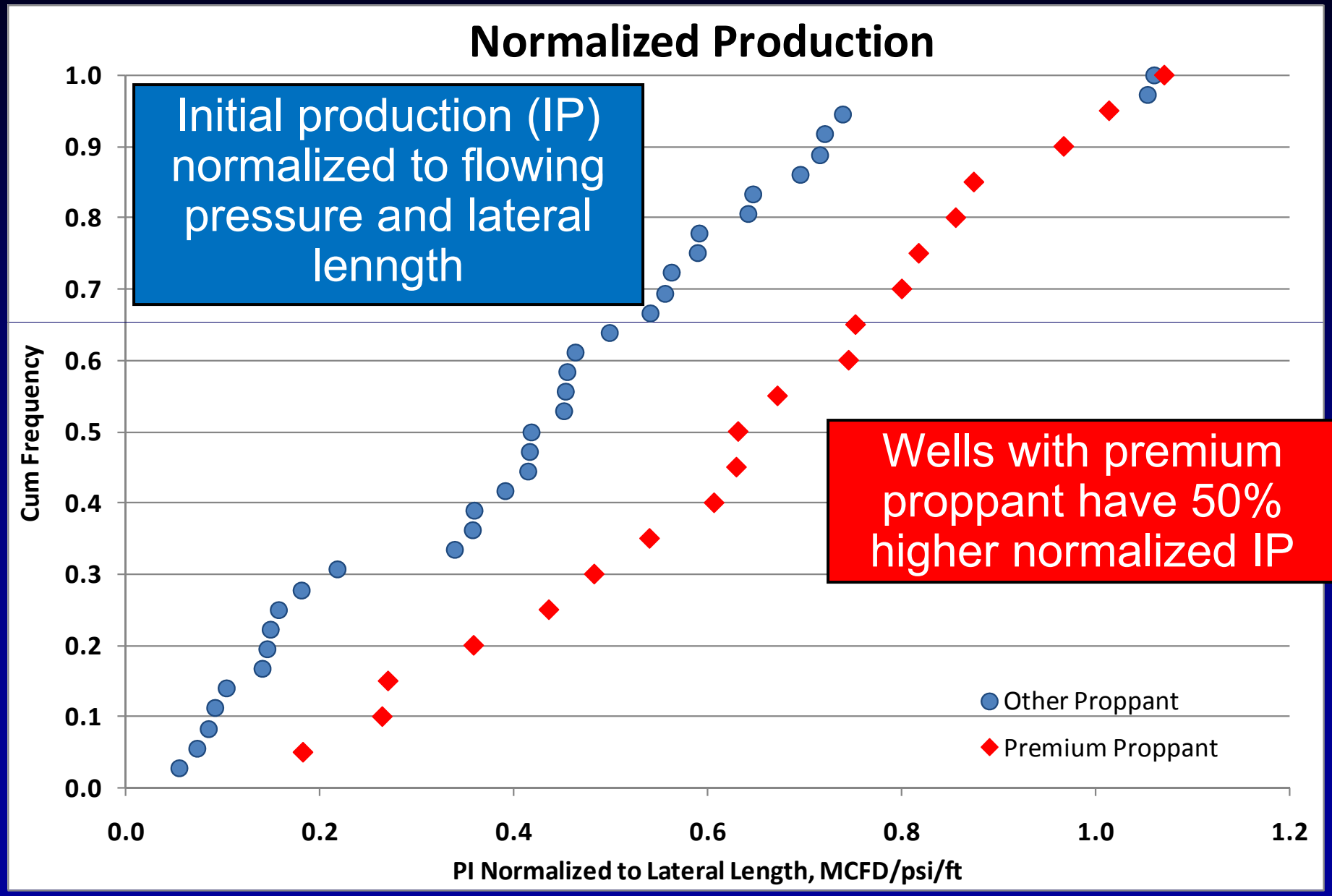
Realistic Conductivity Comparison of Most popular HV proppants



At HV conditions, proppant type can have up to an order of magnitude difference in realistic conductivity.

1 lb per sq ft and 325^{o} F

Field Validation



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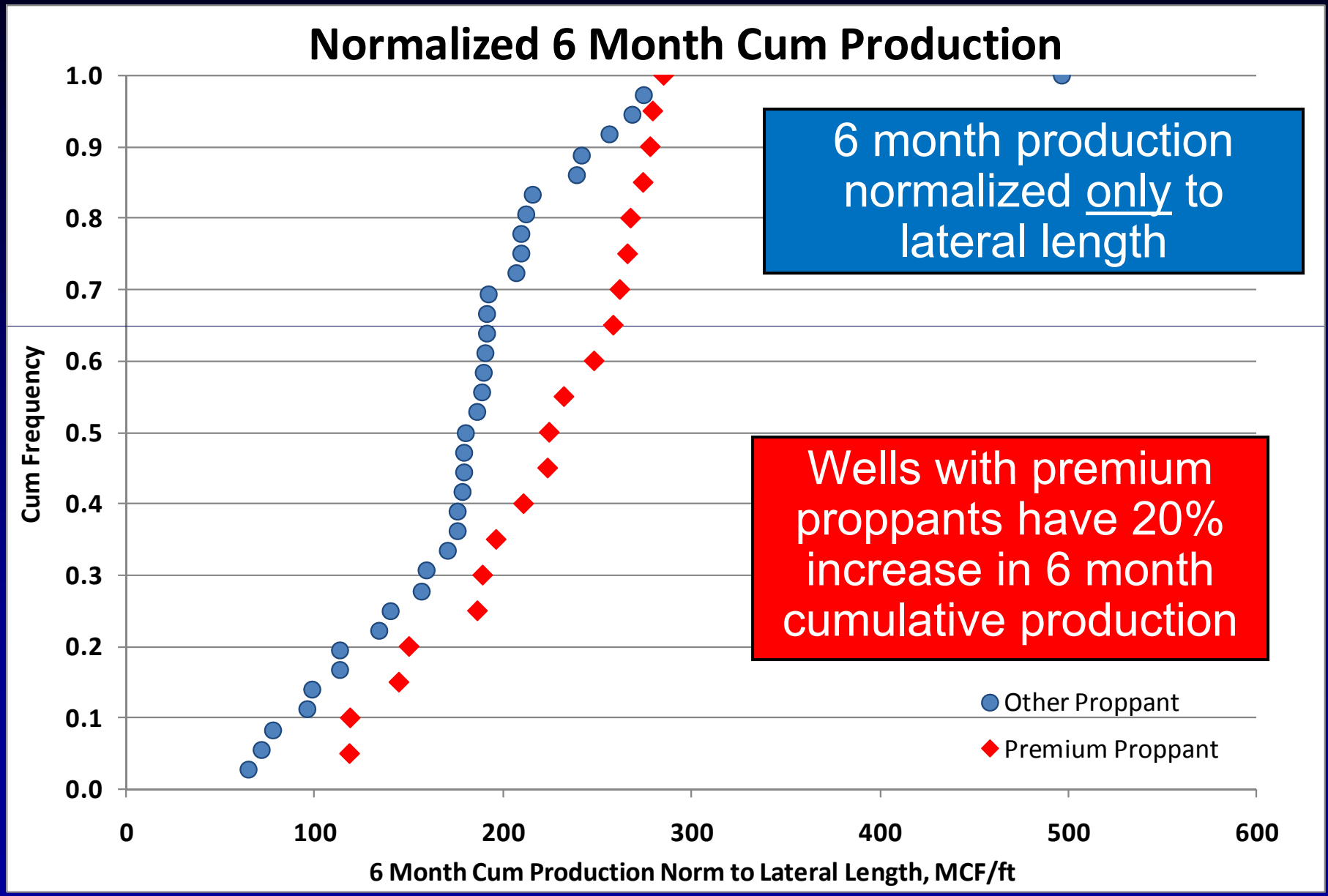

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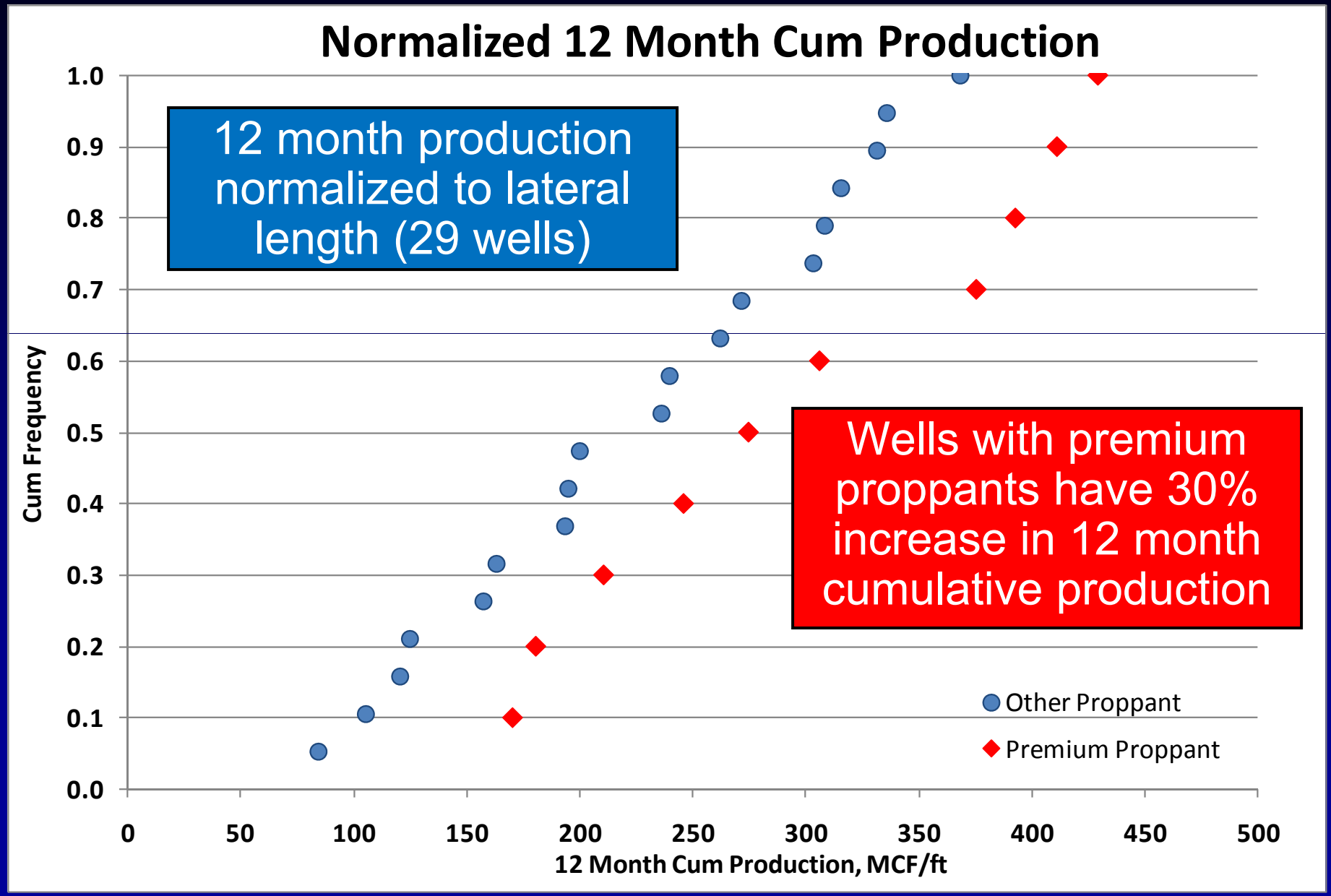

Summary

- HV Shale initial production (IP) per foot of lateral has increased 3-fold in 1st 2 years
  - Continuously improving completion designs
- Production History match successfully completed on actual HV Shale well
- Non-unique match, but PDA confirms:
  - Relatively short (10-20') effective half lengths and low conductivity

Summary cont.

- Sensitivities run in the study well to:
  - Frac Spacing, Effective Half length & Conductivity

- Half Length sensitivities suggest:
  - Increasing effective x_f significantly increases production
  - As effective x_f increases, optimal spacing decreases

Summary cont.

- Conductivity sensitivities suggest:
  - Increasing conductivity would be expected to increase effective half length, which will increase production
- Field data validates the modeling
  - 20-50% increase in production when using higher conductivity proppant
  - Indicates increasing effective half lengths, suggests higher recovery and drainage

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Questions?