2011 Middle East and North Africa Perforating Symposium - MENAPS

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Schlumberger

BUNDUQ

Acid Diversion Technique and Perforation Job Design Improves Injection Profile in Carbonate Reservoir

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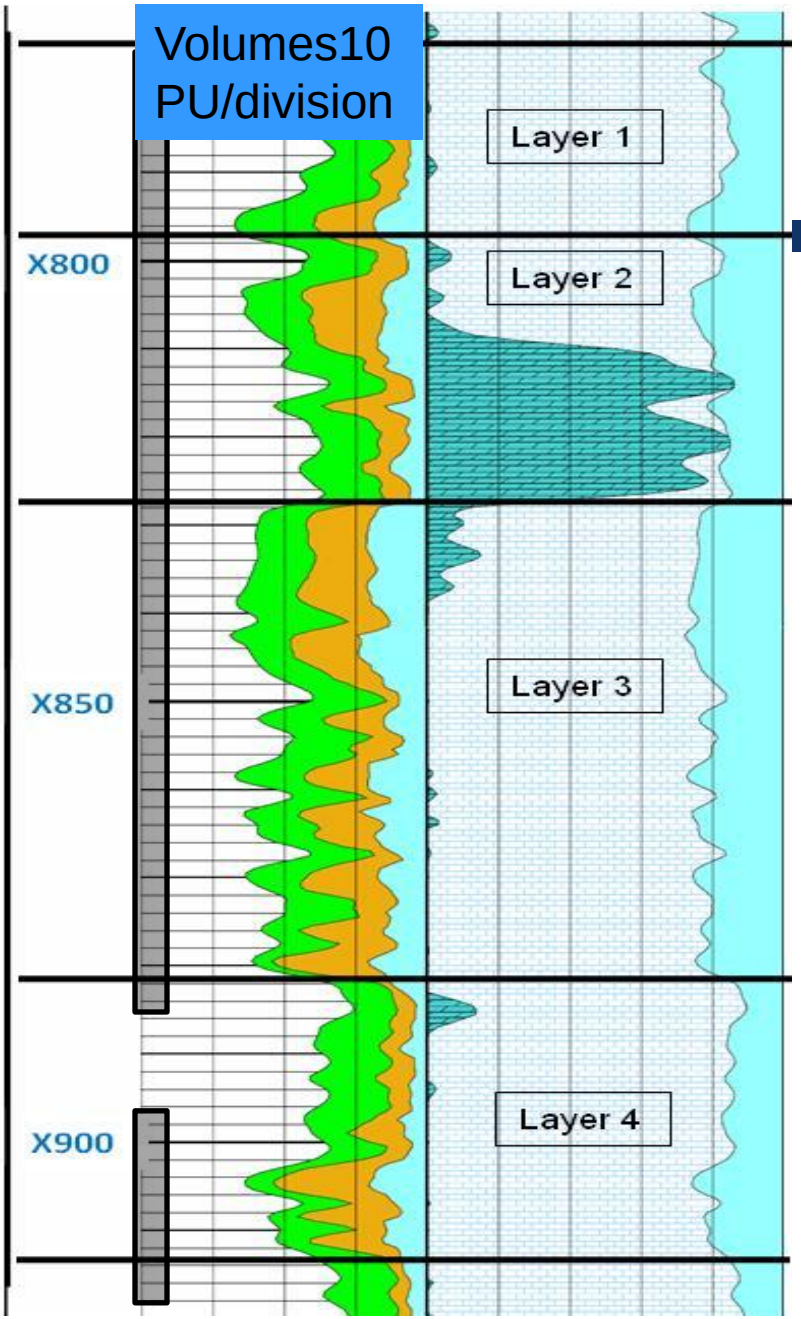
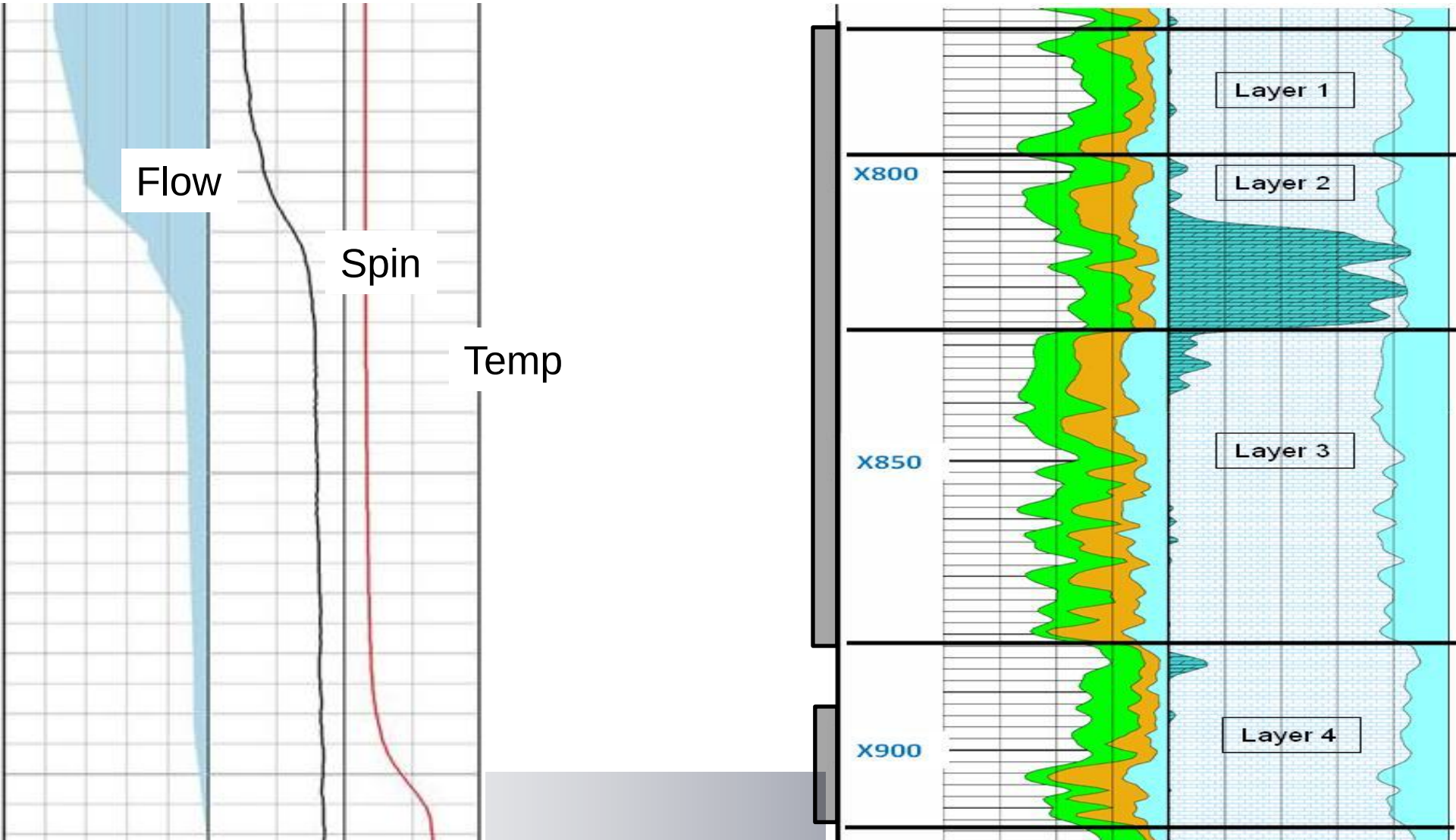
Carbonate Reservoir

- Continuous reservoir
  - Four layers
- Limestone – Dolomite mix
- Significant permeability variations

Perf Interval	Top	Bottom	Length (ft)	Perm (md)
1	x776	x798	22	9.5
2	x798	x828	30	44.7
3	x828	x882	54	16
4	x892	x912	20	3.6



Gas Injection Profile in 2005
9 5/8” casing shot with 2” Deep Penetration Guns

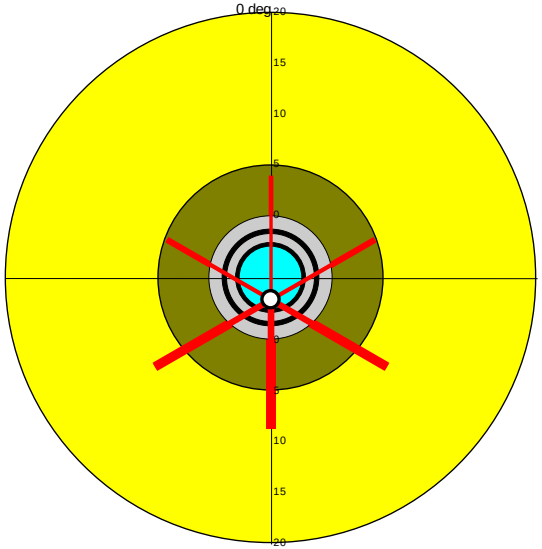


2009 Workover

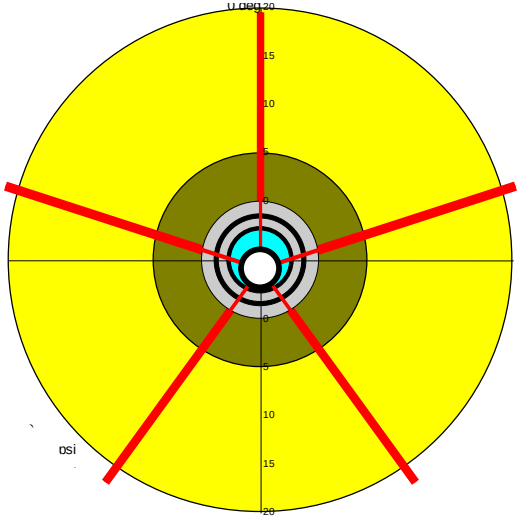
- Convert dual water string water injector into single string gas injector
- Cement 7” liner inside existing 9 5/8” casing
- Remove completion and squeeze perfs
- Re-perforate same intervals and stimulate
- Effort made to improve injection profile

Perforation Design
New 7” Casing Completion inside 9 5/8”

2” gun, 6 spf
Pen – 6.8”, avg EH – 0.17/0.13



4.5” gun, 5 spf
Pen – 21.3”, avg EH – 0.42/0.37



Inject Index (II) Modeled

- Predict II for each layer with each perforation option
- More consistent II with 2" gun in Layer 2
  - 4 ½" gun in layers 1, 3 and 4

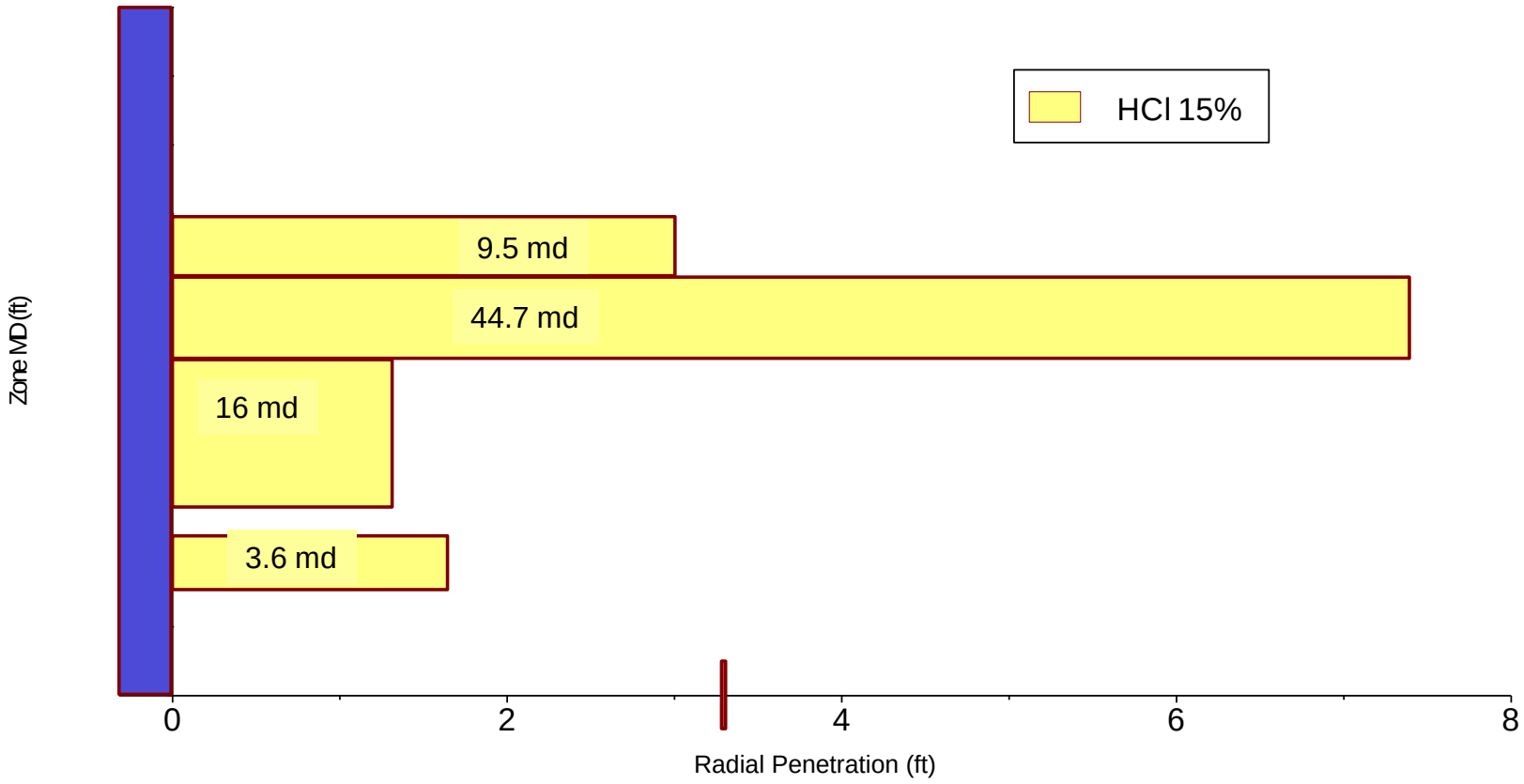
					Predicted Injection Index (mmscf/day/psi)			
Gun size (in)	Phasing (deg)	spf	Formation Penetration (in)	Average Entrance Hole inner/outer (in)	Layer 1 9.5 md	Layer 2 44.7 md	Layer 3 16 md	Layer 4 3.6 md
2	60	6	6.8	0.17/0.13	0.002	0.01	0.003	0.0009
4 ½	72	5	21.3	0.42/0.37	0.008	0.04	0.01	0.003

Matrix Acidizing Design

- Considered 3 different acid scenarios
  - 15% HCl
  - 15% HCl + 5% Self Diverting Acid
  - 28% Emulsified Acid + 5% Self Diverting Acid
    - +15% HCl post flush
- 15% HCl typical in this area
- Modeled using proprietary PC based modeling software
- Acid and diverter placed with coiled tubing
  - Assists with diversion requirement

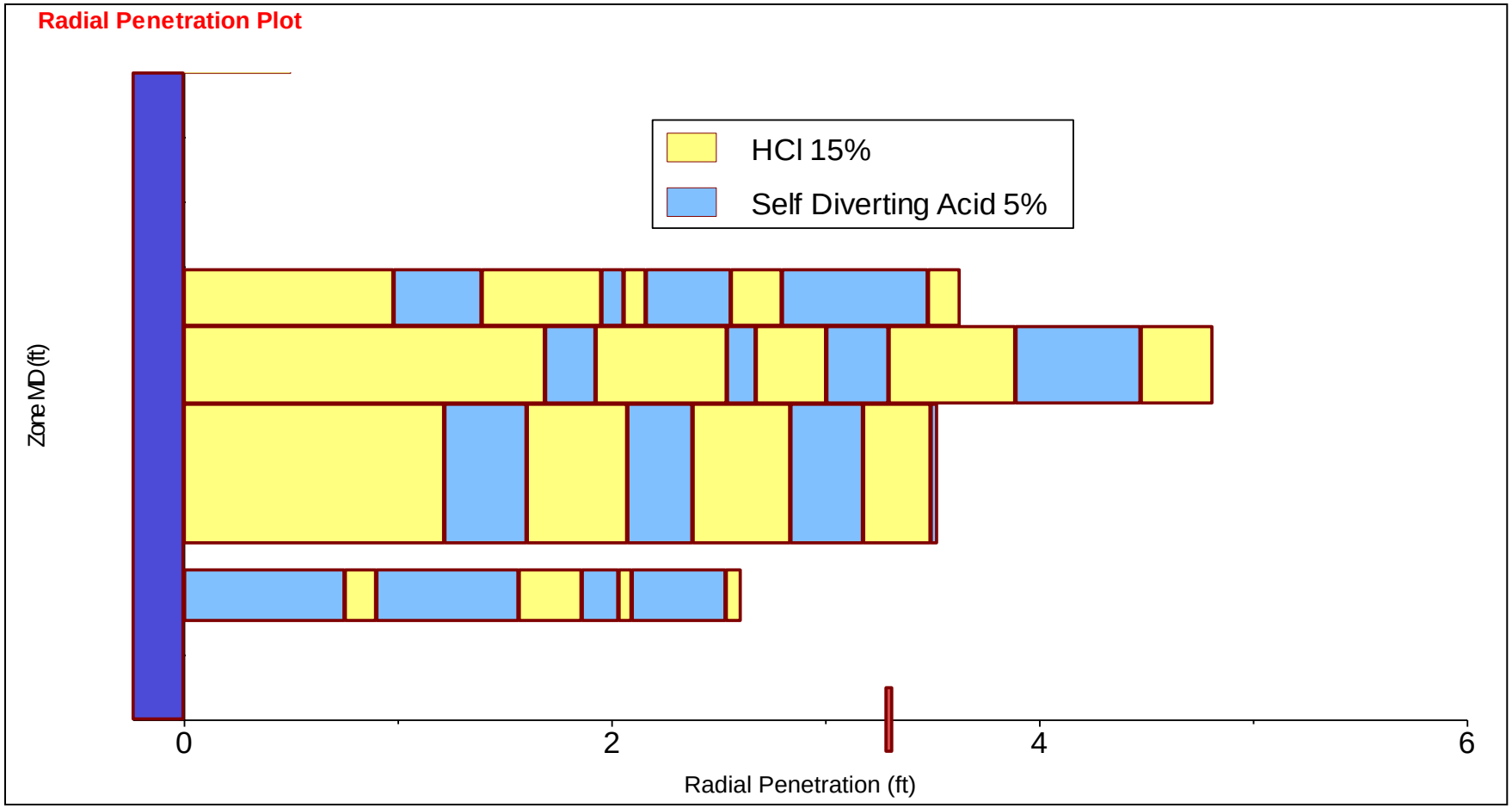
Radial Penetration Prediction

- 15% HCl



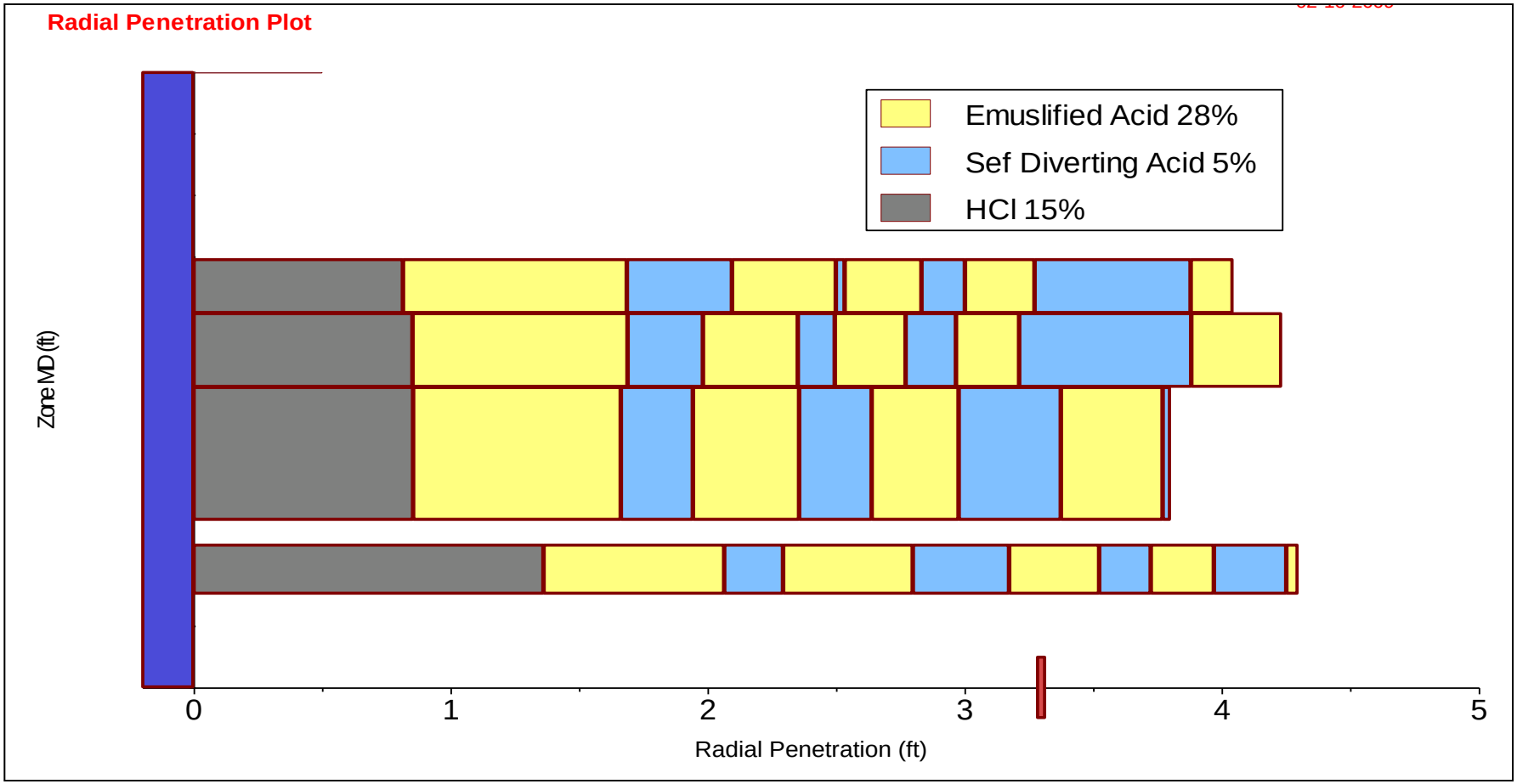
Radial Penetration Prediction

- 15% HCl + 5% self diverting acid



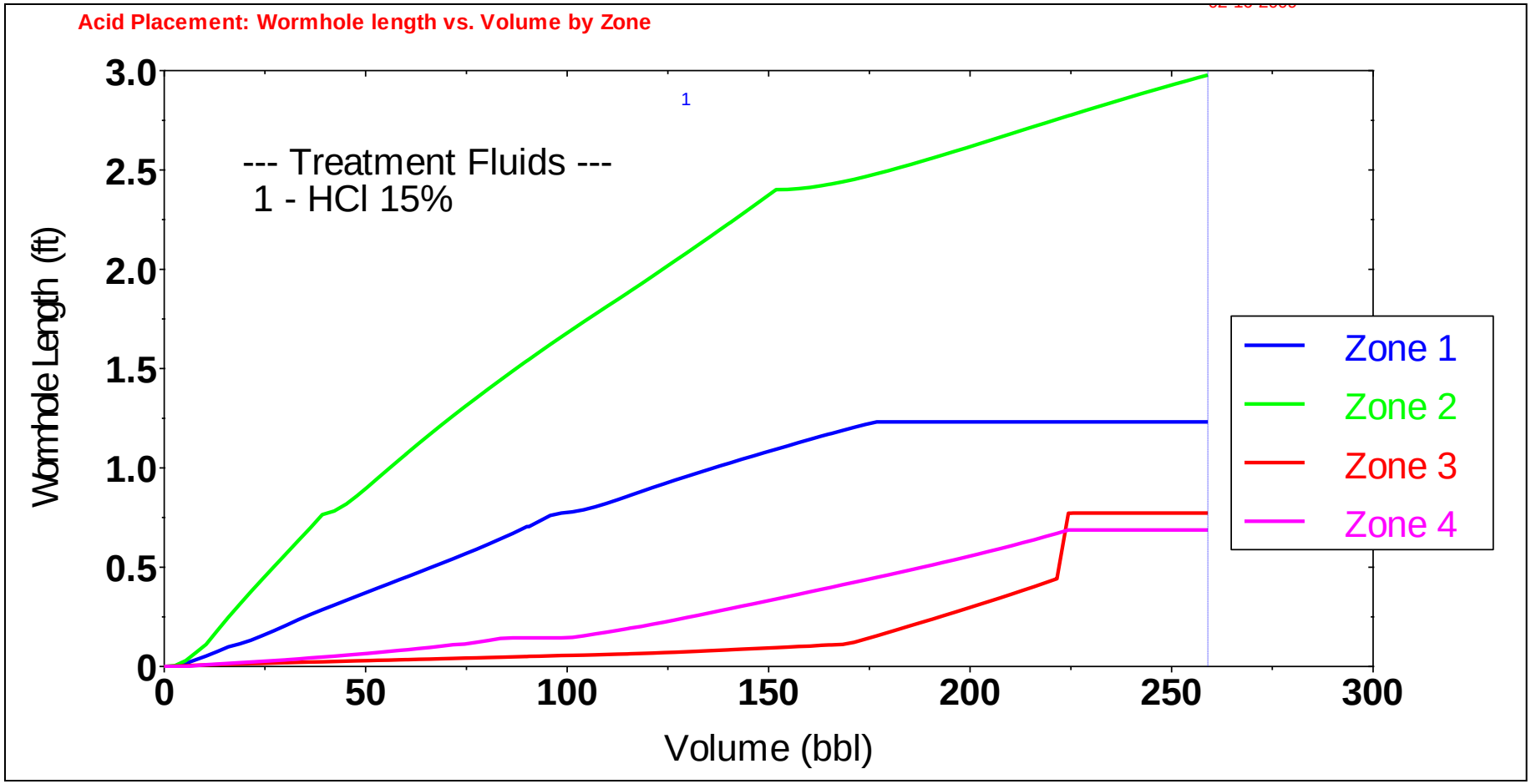
Radial Penetration Prediction

- **28% Emulsified Acid + 5% Self Diverting Acid +15% HCl**



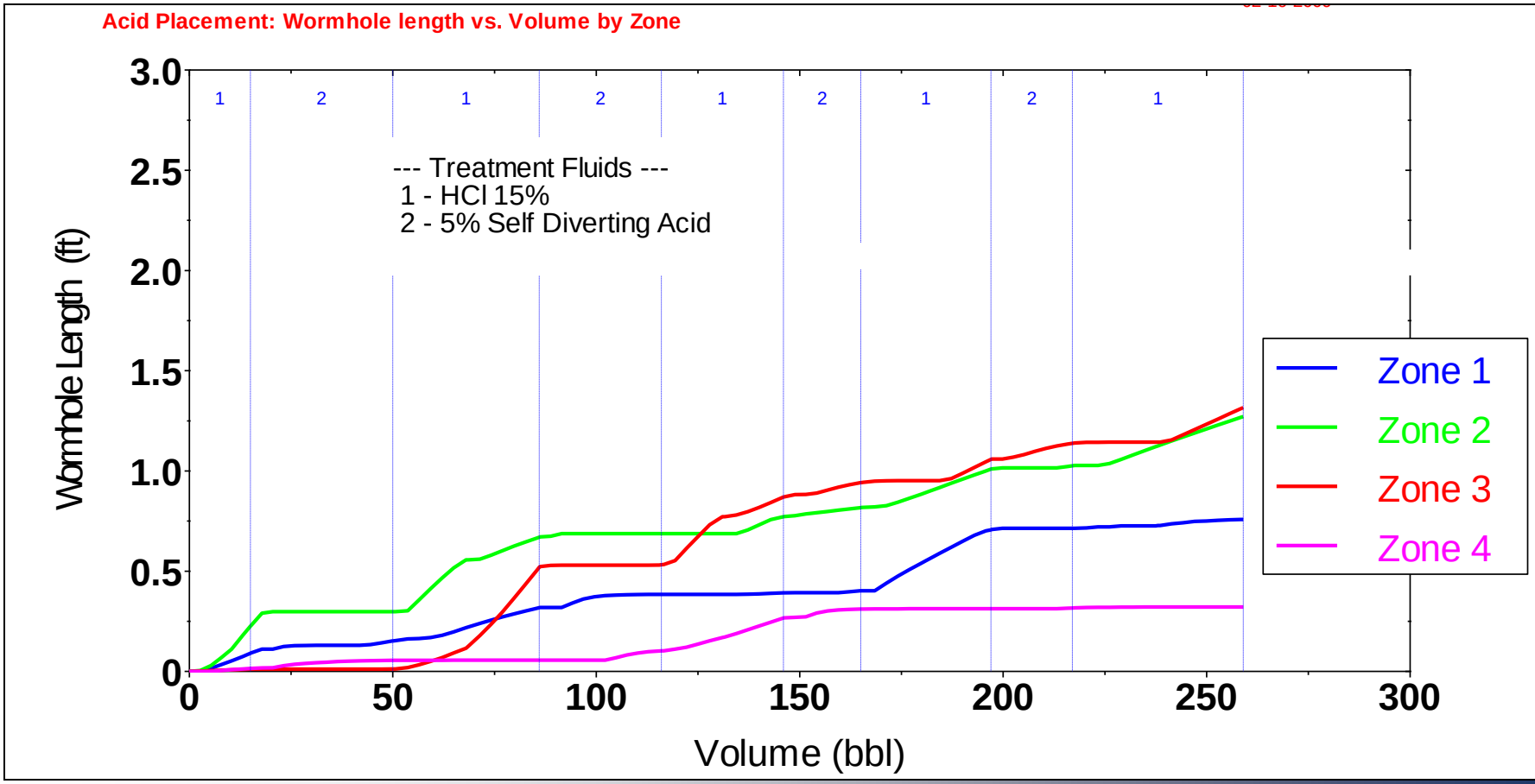
Wormhole Length Prediction

- 15% HCl



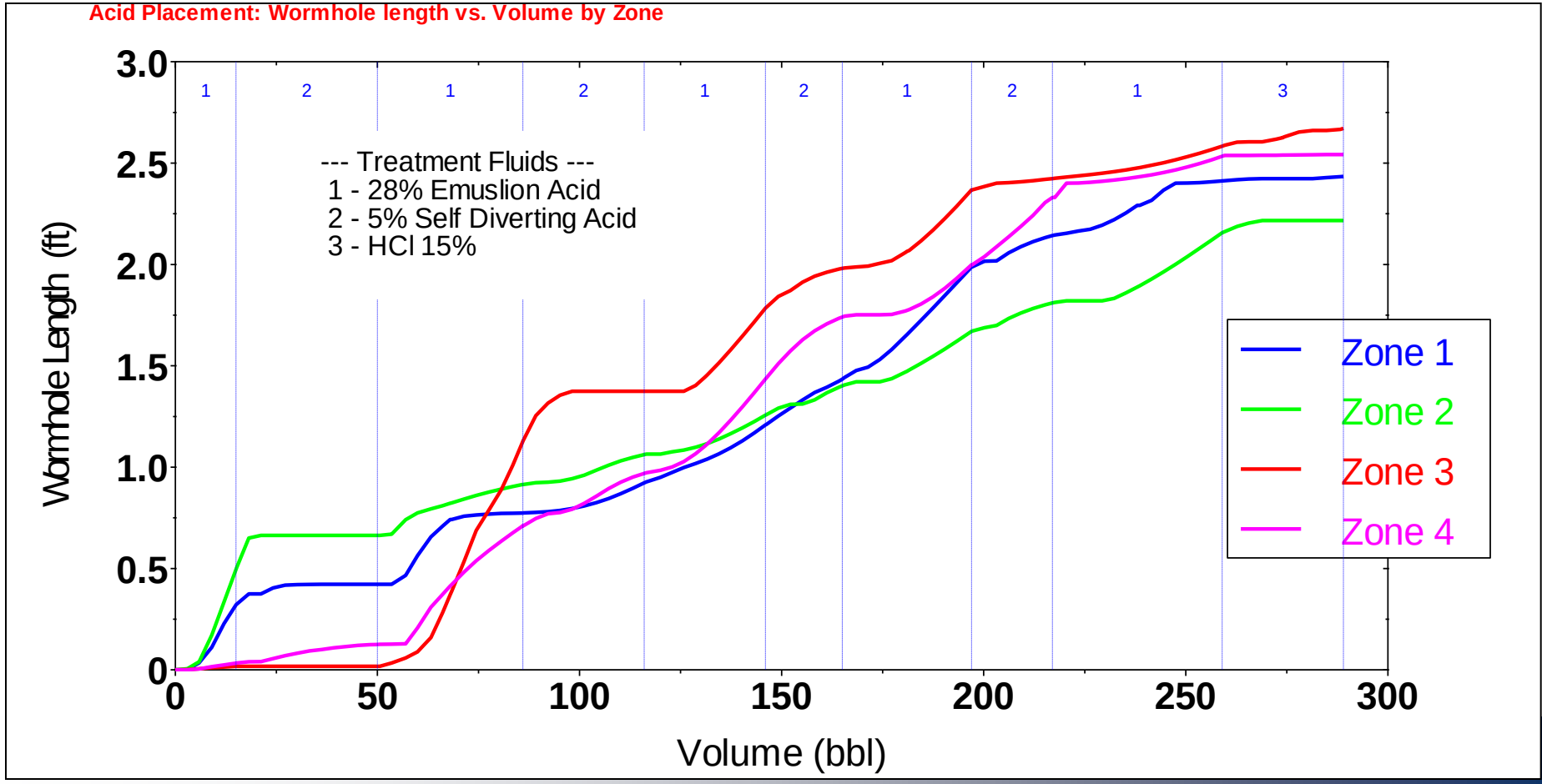
Wormhole Length Prediction

- 15% HCl, 5% Self Diverting Acid



Wormhole Length Prediction

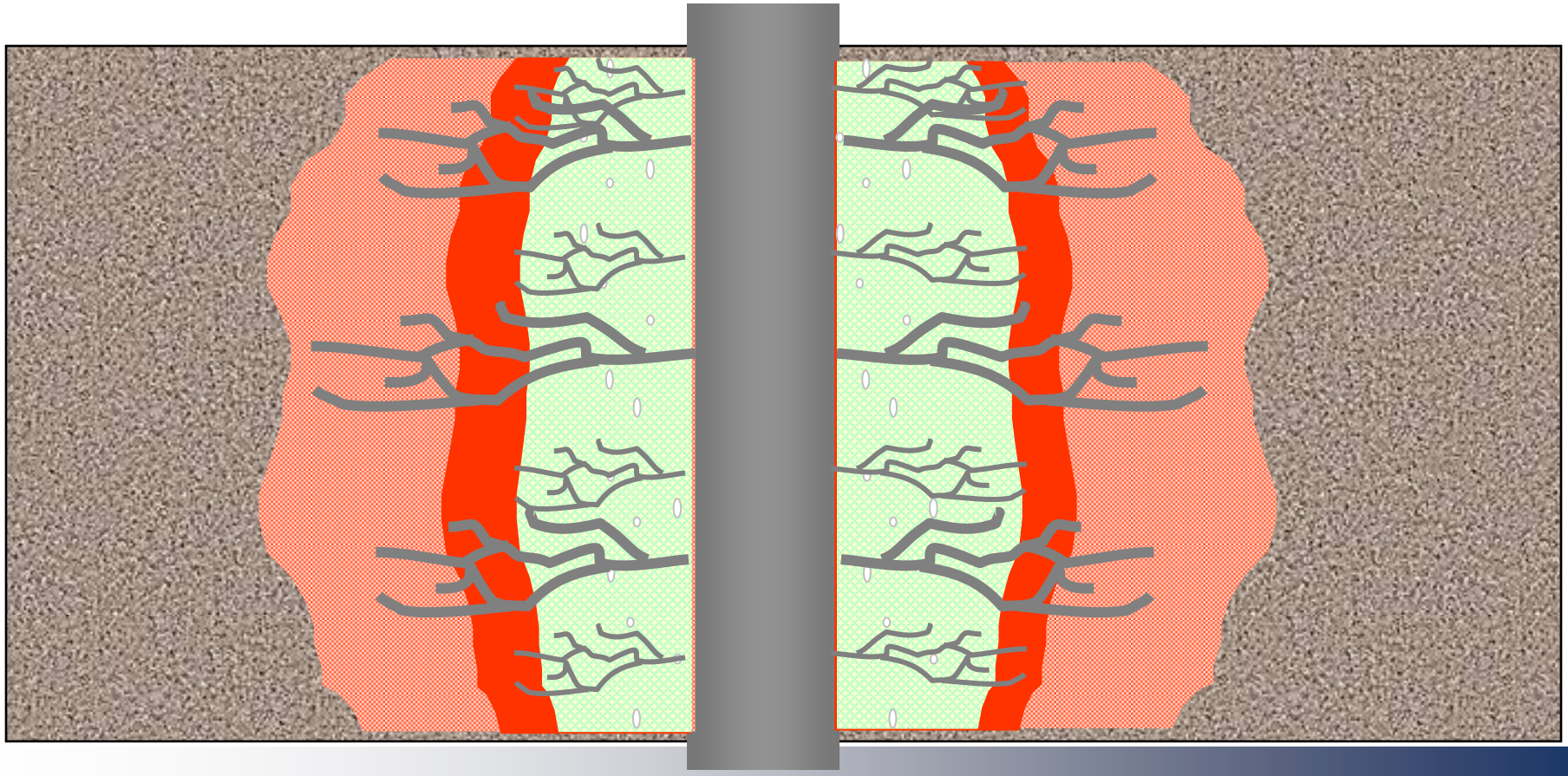
- 28% emulsified acid, 15% HCl, 5% self diverting acid



Final Stimulation Design

28% emulsified acid, 5% self diverting acid, 15% HCl

- What happens in each stage?



Execution- Pumping Record

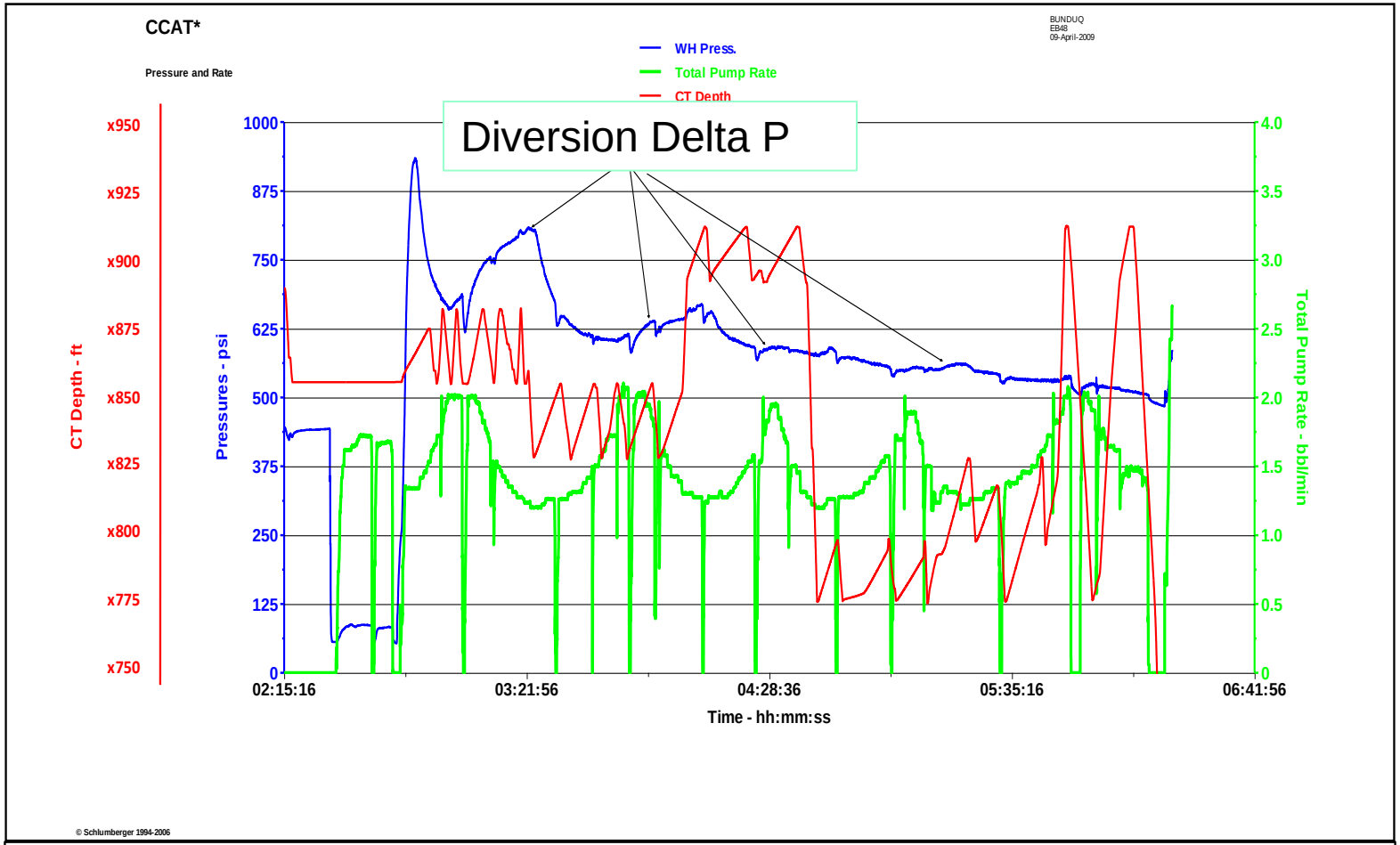
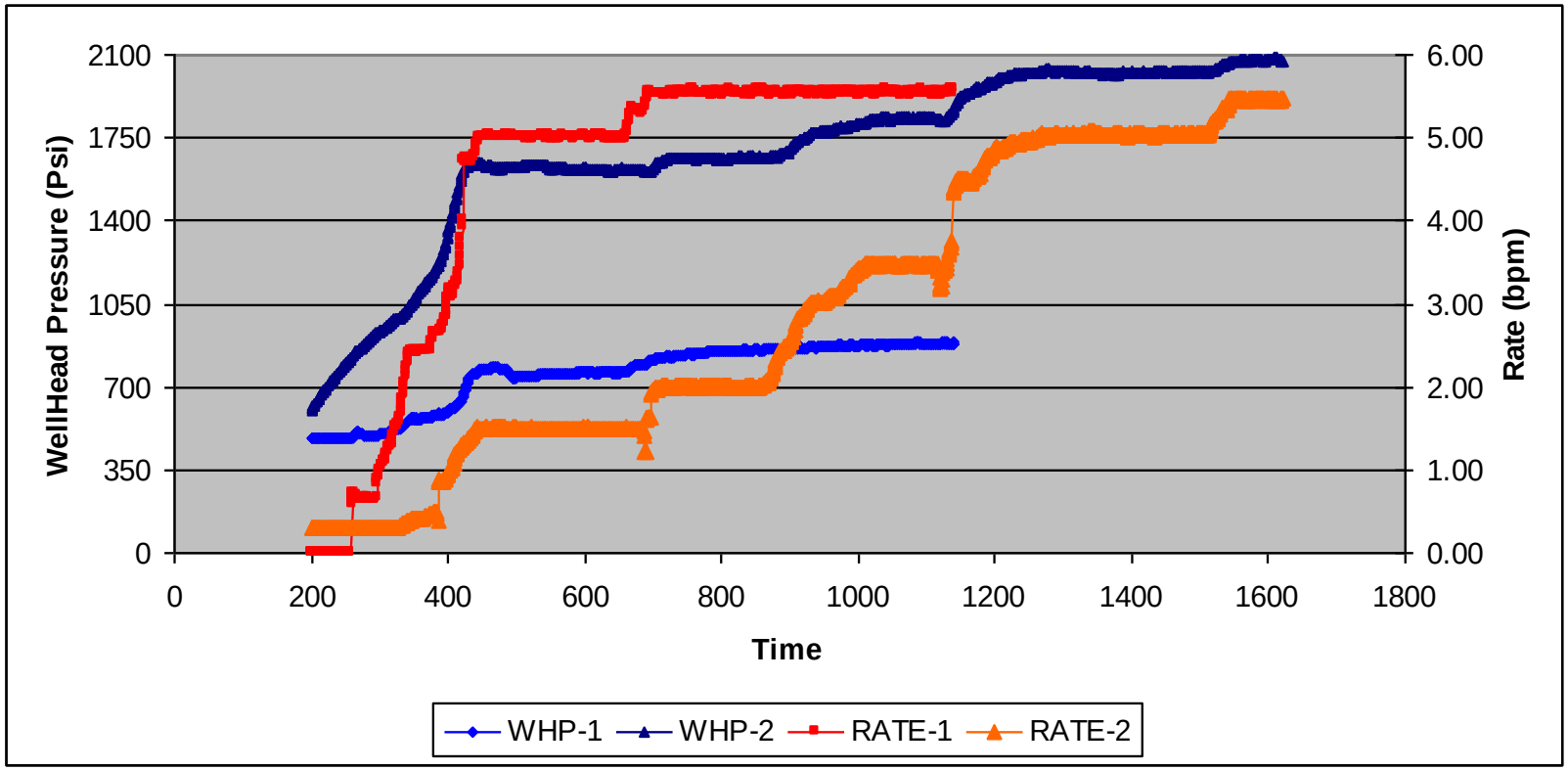
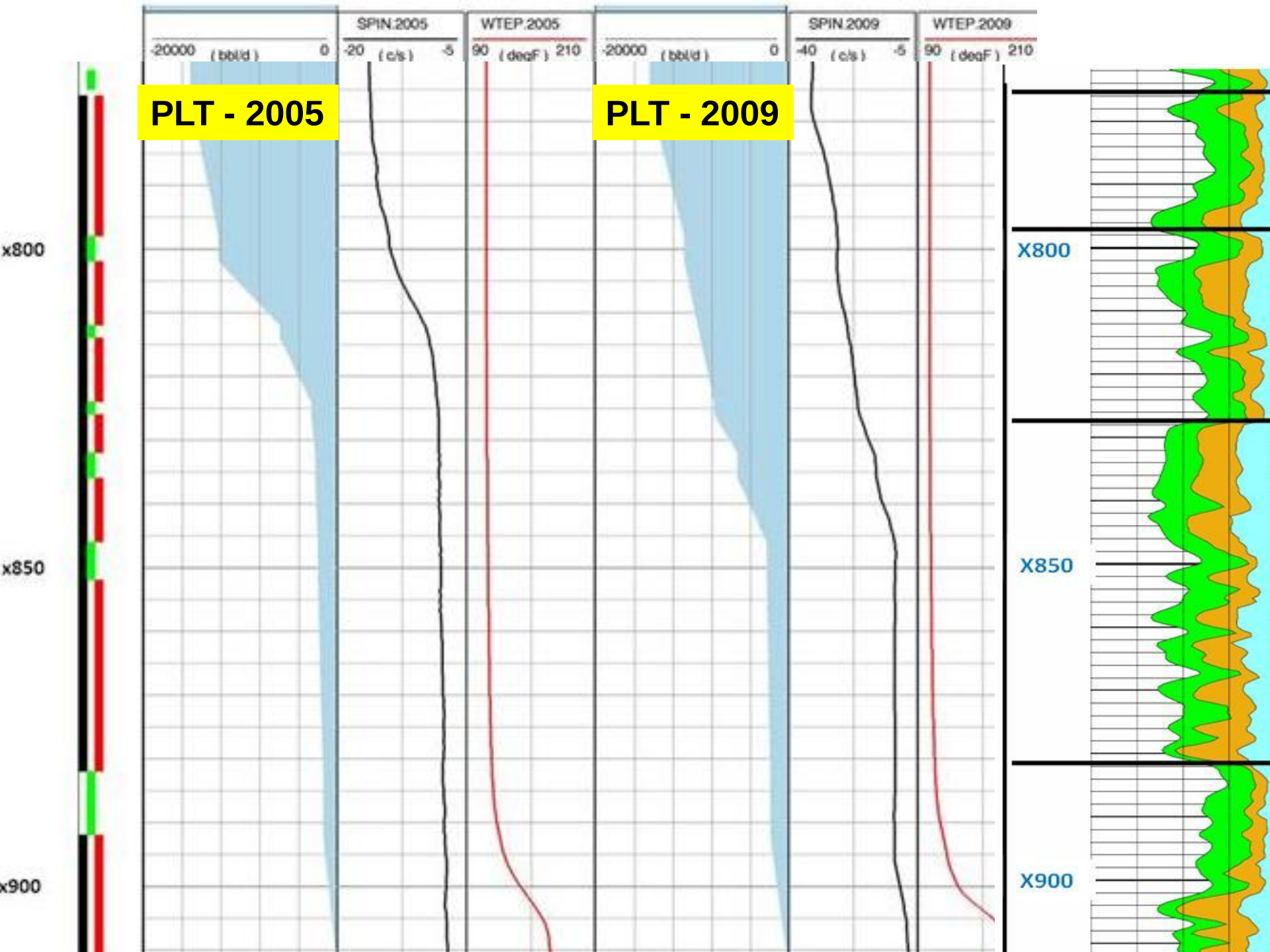


Figure-13: Execution chart; pumping rate, CT depth and wellhead pressure versus operational time

Immediate Results: Injectivity test



Injectivity test before and after the job, 1 being before and 2 being after the job


PLT - 2005
PLT - 2009
SPIN.2005
WTEP.2005
SPIN.2009
WTEP.2009
-20000 (bbl/d) 0
-20 (c/s) -5
90 (degF) 210
-40 (c/s) -5
x800
x850
x900
X800
X850
X900

Well Injection Results

- Injection profile improved
- Injection rate maintained
- Injection effect seen in nearby well
  - Initial increase in oil production

Conclusions

- Unique situation where 2 completion strategies could be evaluated on the same interval
- Combination of the tailored perforating program + the acid matrix stimulation improved the injection profile
- Improve bottom zone with additional perforating or Dynamic Underbalance clean-up

- Good set of well data + a team approach to planning and execution = successful job

Questions?