



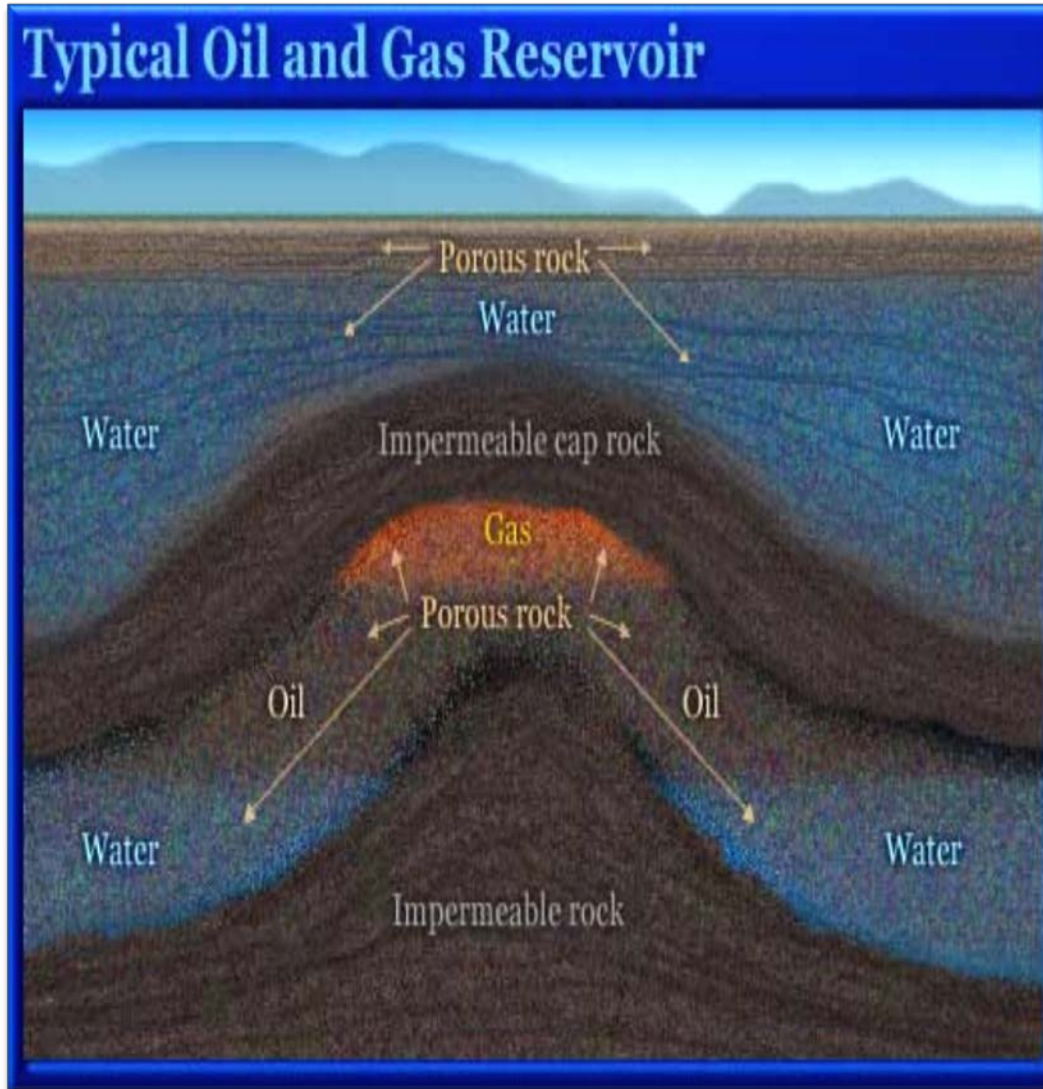
Injectivity – A Dose of Reality?

Wayne Rowe – Operations Manager
Schlumberger Carbon Services

16 June 2015

- Injection and Geologic Sequestration
 - *A New Application of Proven Technology*
 - *Confronting Subsurface Complexity*
 - *Darcy's Law Governs*
- Developing The SaskPower Injection Well
 - *Multiple Layers*
 - *Fracture Pressure – the key constraint*
 - *Fluid Sensitivity – A Loss of Permeability*
 - *Chronology of Development*

A New Application of Proven Technology

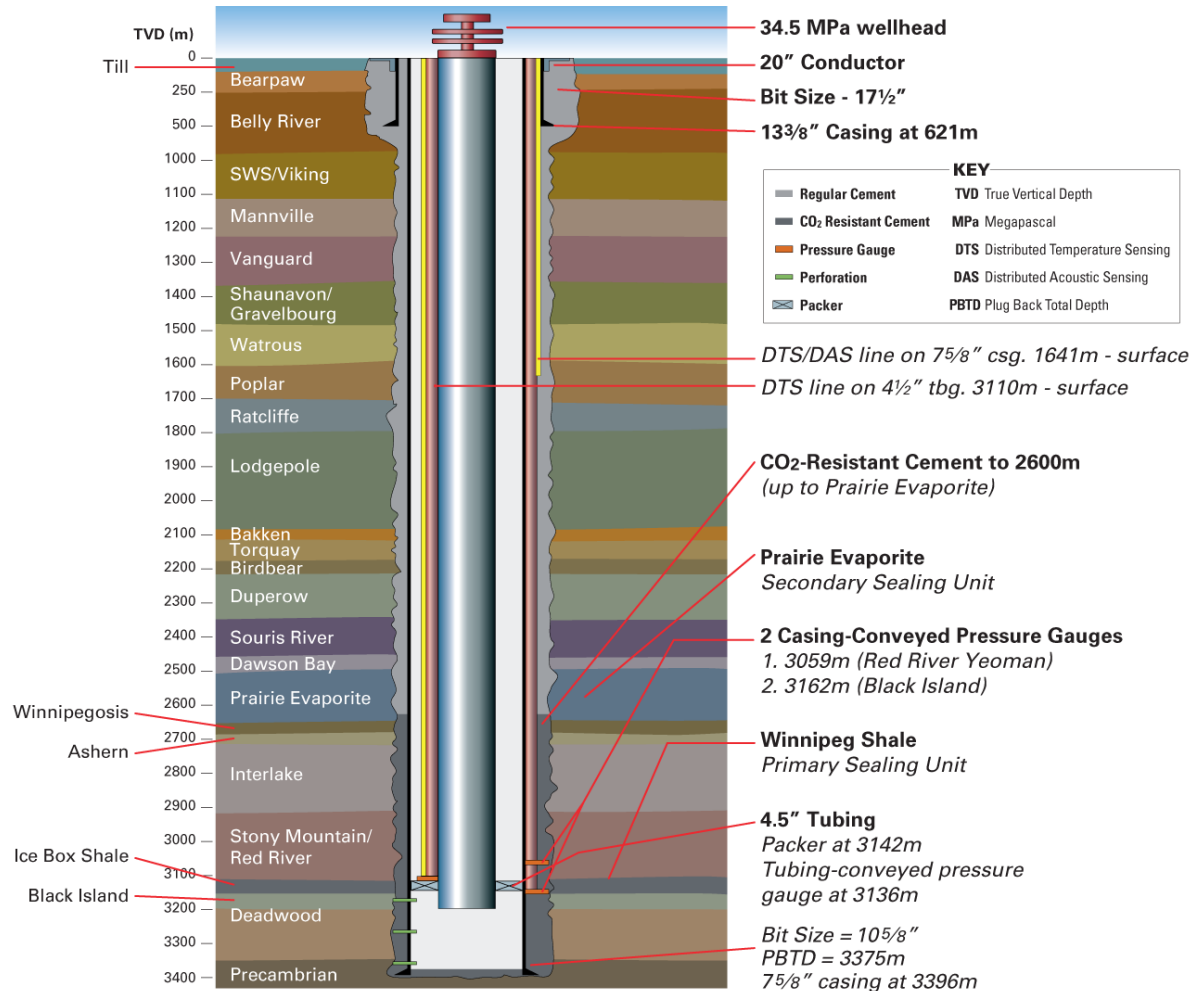


➤ Injectivity

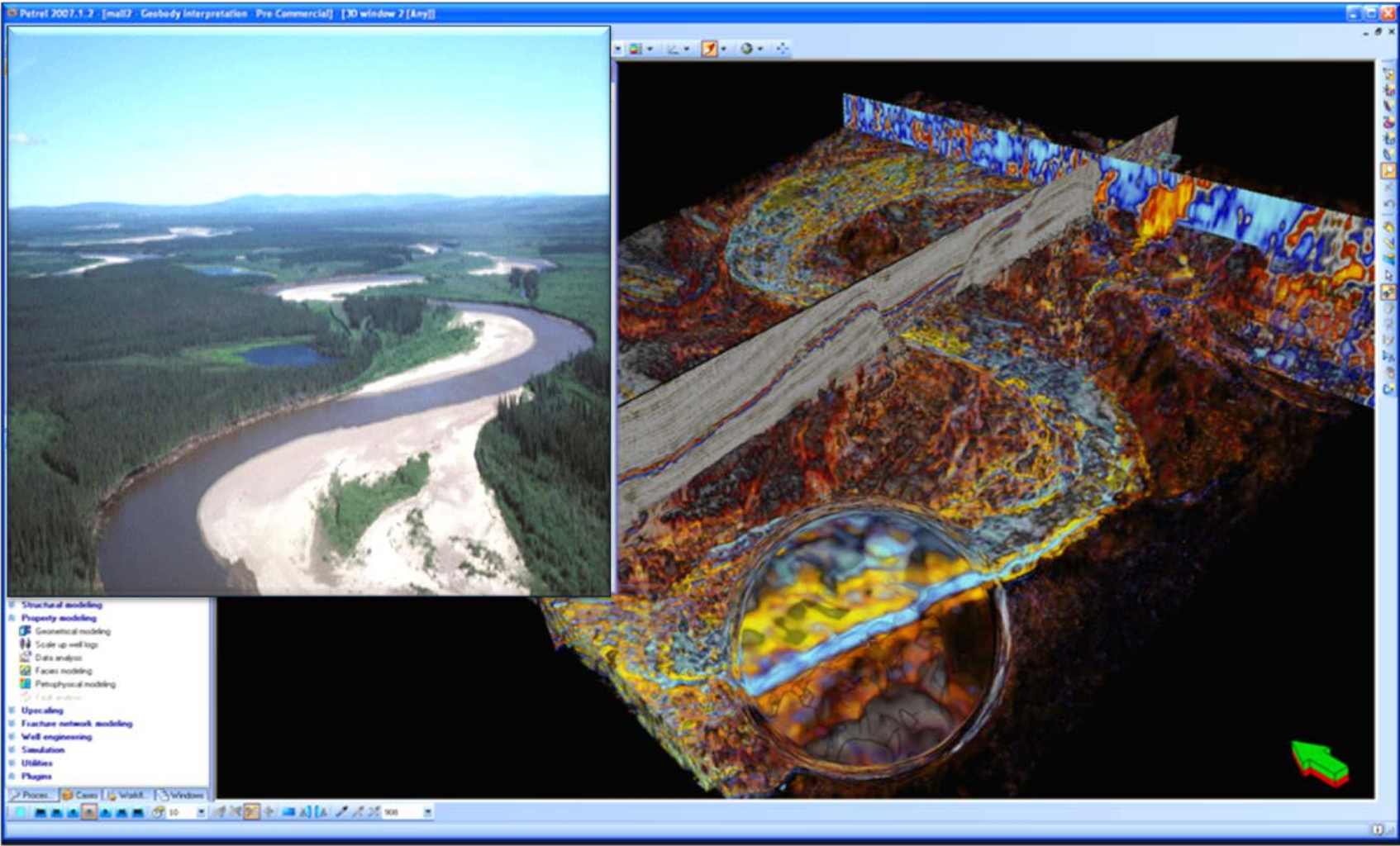
➤ Capacity

➤ Containment

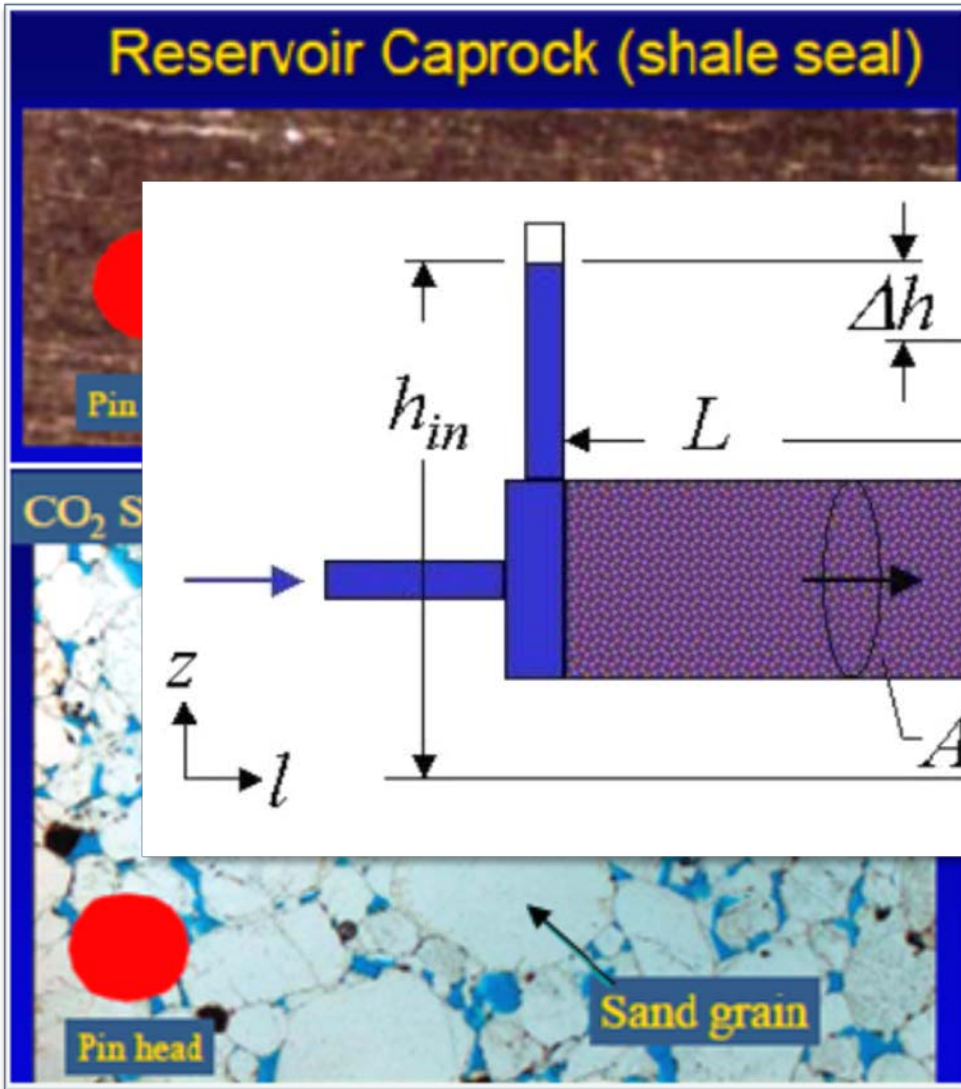
SaskPower Injection Well Schematic



Confronting Subsurface Complexity

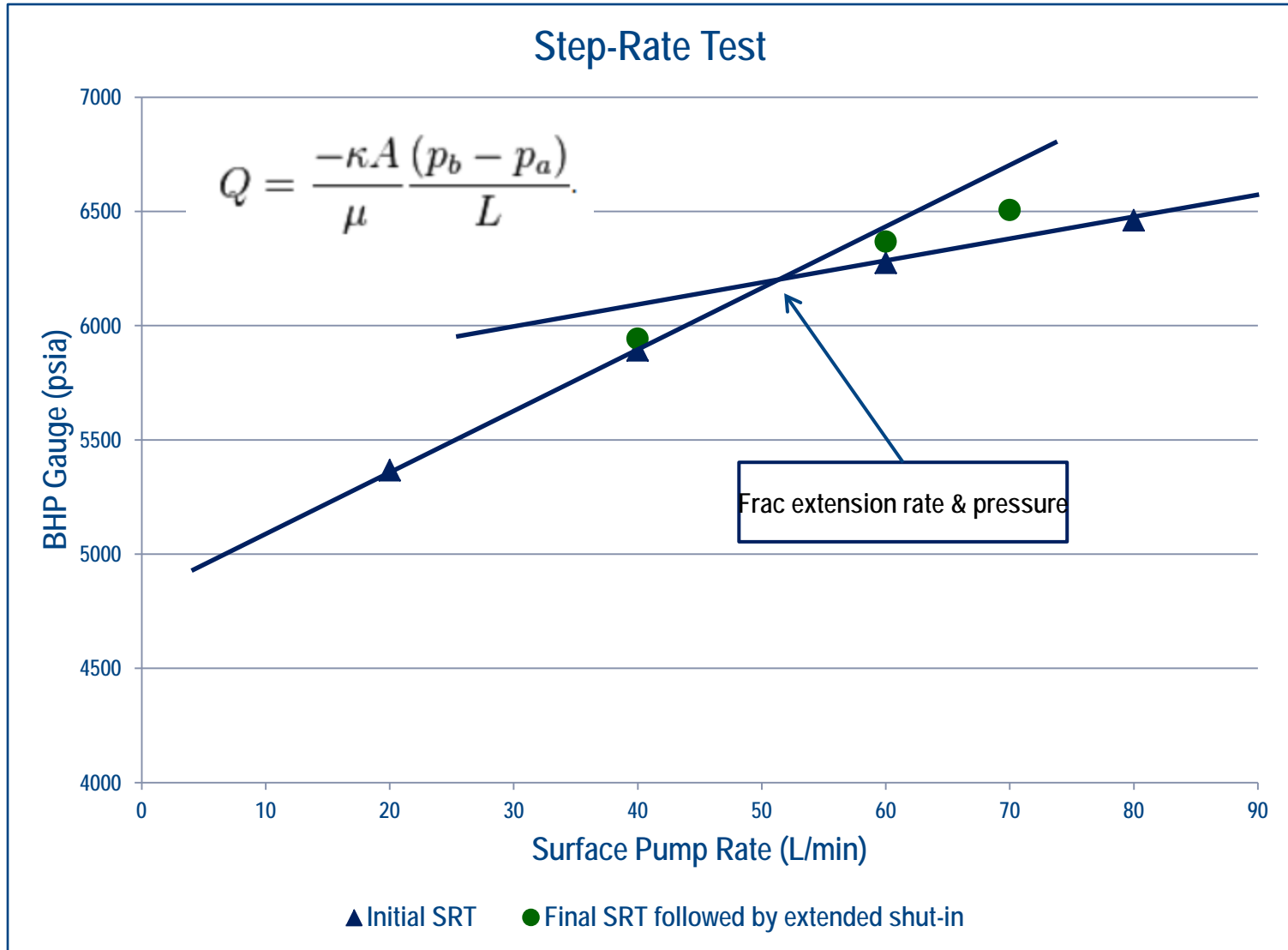


Darcy's Law Governs



ce

Injection Pressure limited to 90% of Fracture P



Define Whole System Injectivity – Injection/Falloff

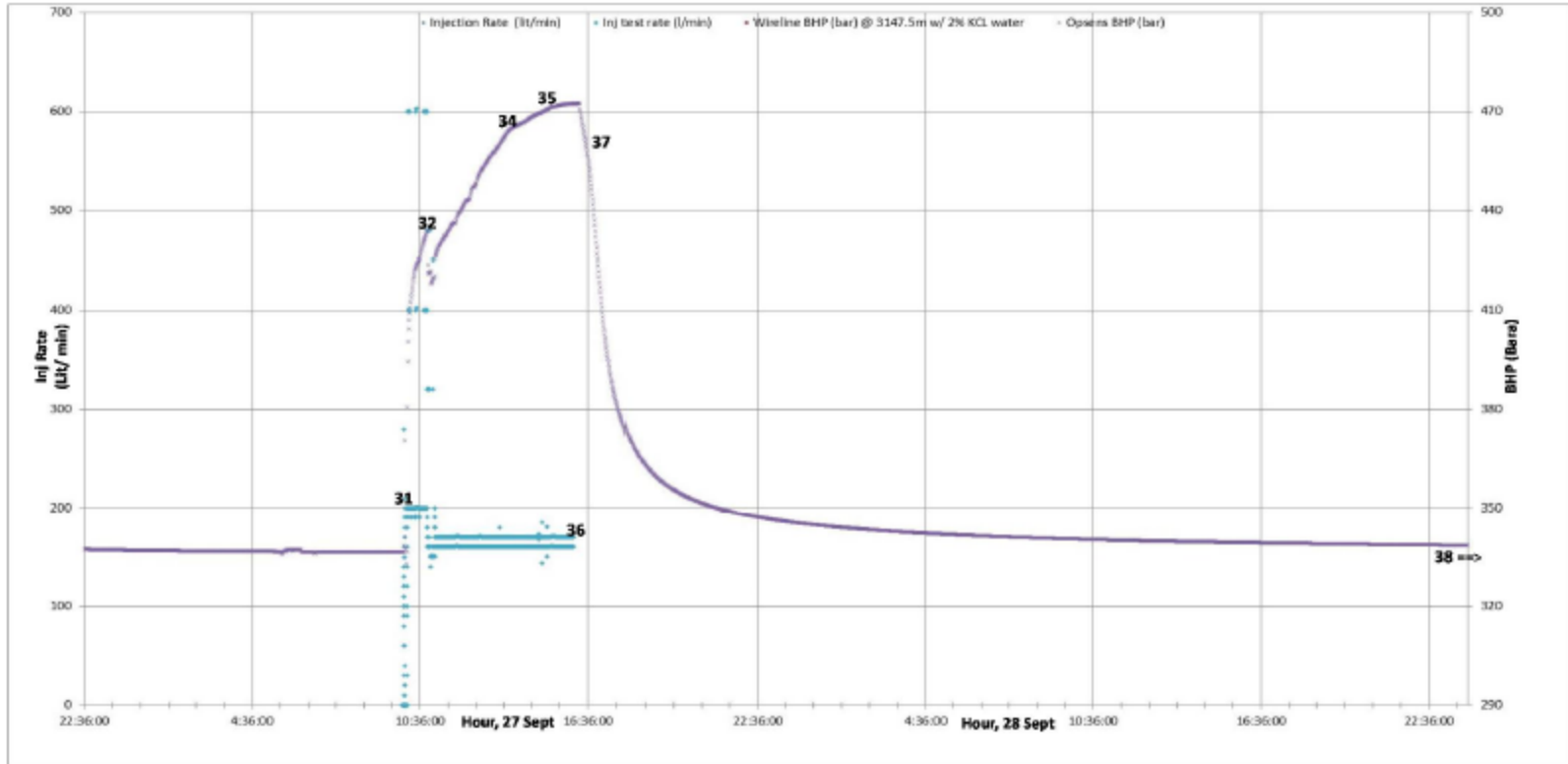
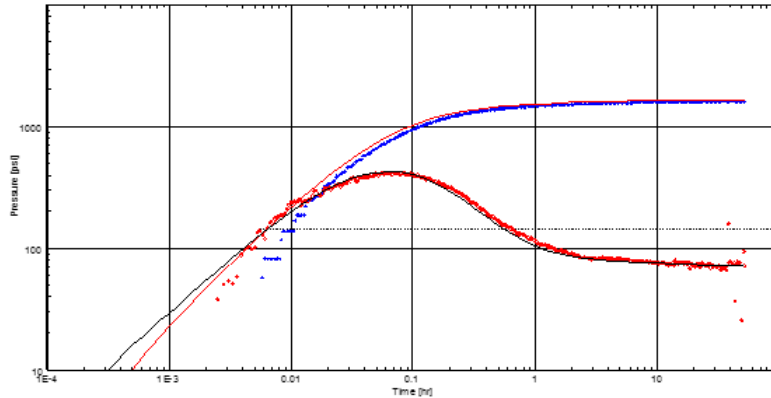
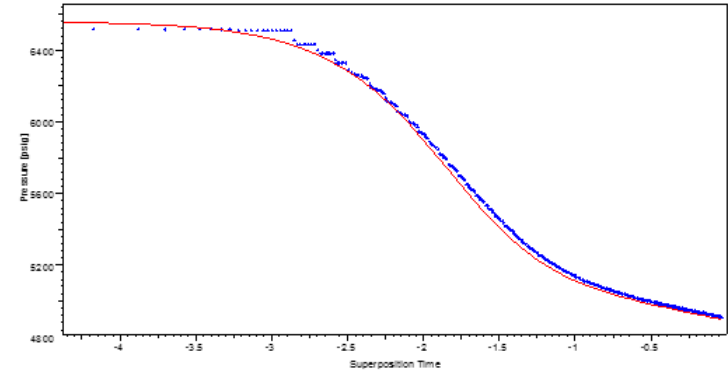


Figure 2-2. Injection test data from September 27, 28. Chronology of most events is indicated according to Event Number listed in Table 2-2. No wireline BHP data is visible on this figure.

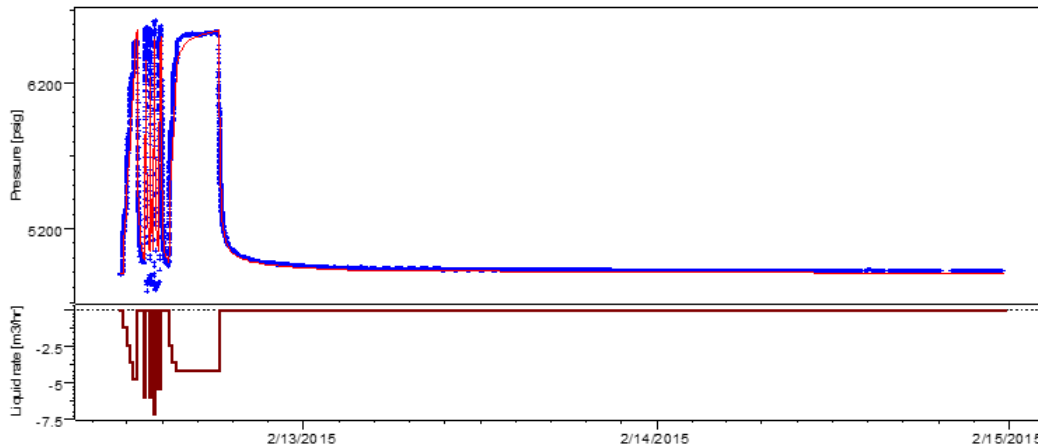
System Injectivity – Injection/Falloff Analysis



Log-log plot: $p-p@dt=0$ and derivative (psi) vs. dt (hr)



Semi-log plot: p (psi) vs. superposition time



History plot [pressure (psi), liquid rate (m3/hr) vs time (hr)]

Reservoir = Radial composite
Boundary = Infinite
 $P_i = 4,892$ psig
 $Kh, \text{ inner} = 54.4$ md*m
 $K, \text{ inner} = 1.43$ md
 $M, \text{ mobility ratio} = 0.5$
 $R, \text{ inner} = 12.7$ m
 $Skin = 0.295$
 $Kh, \text{ outer} = 108.8$ md*m
 $K, \text{ outer} = 2.86$ md

Injection Simulation

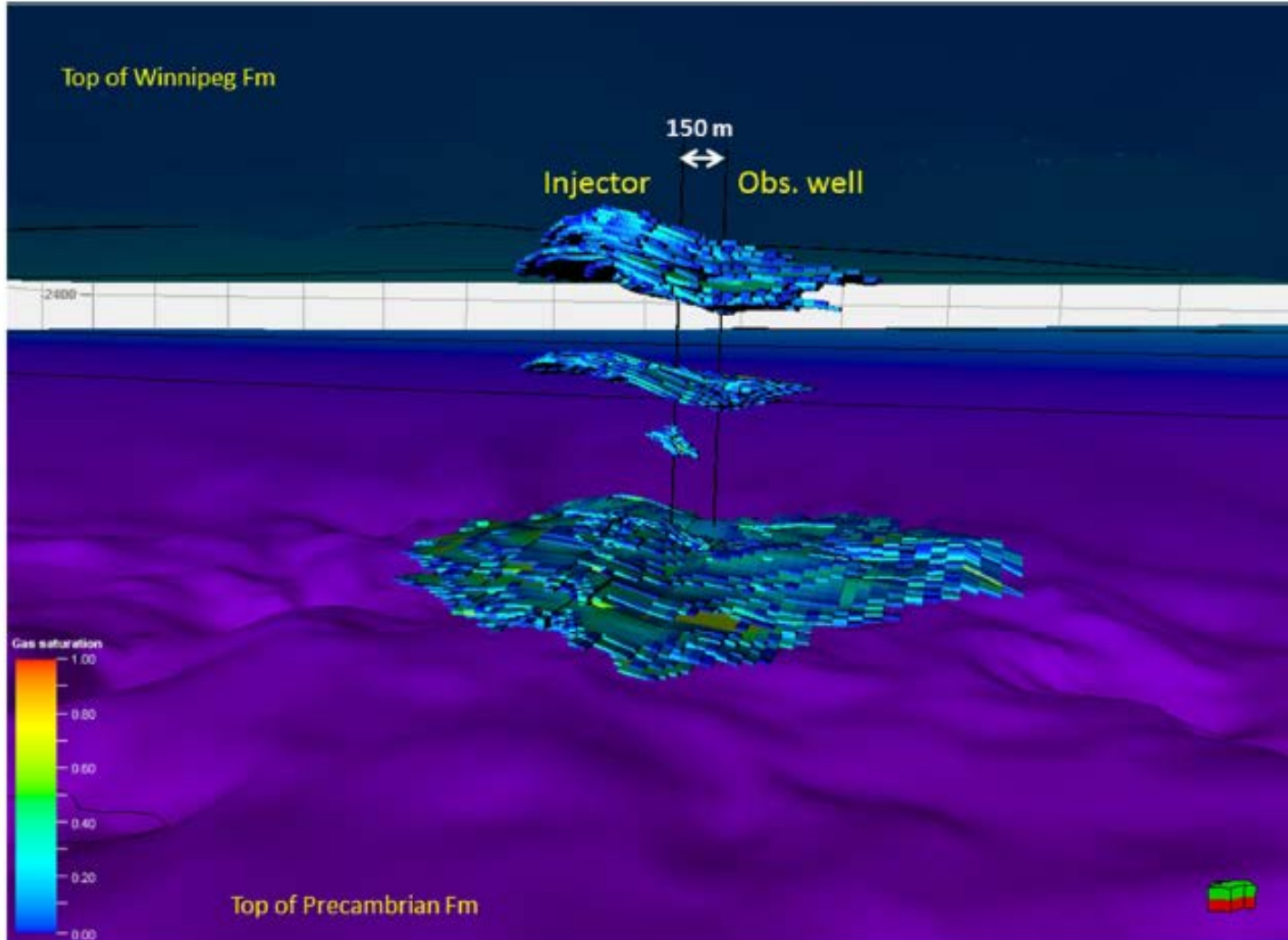
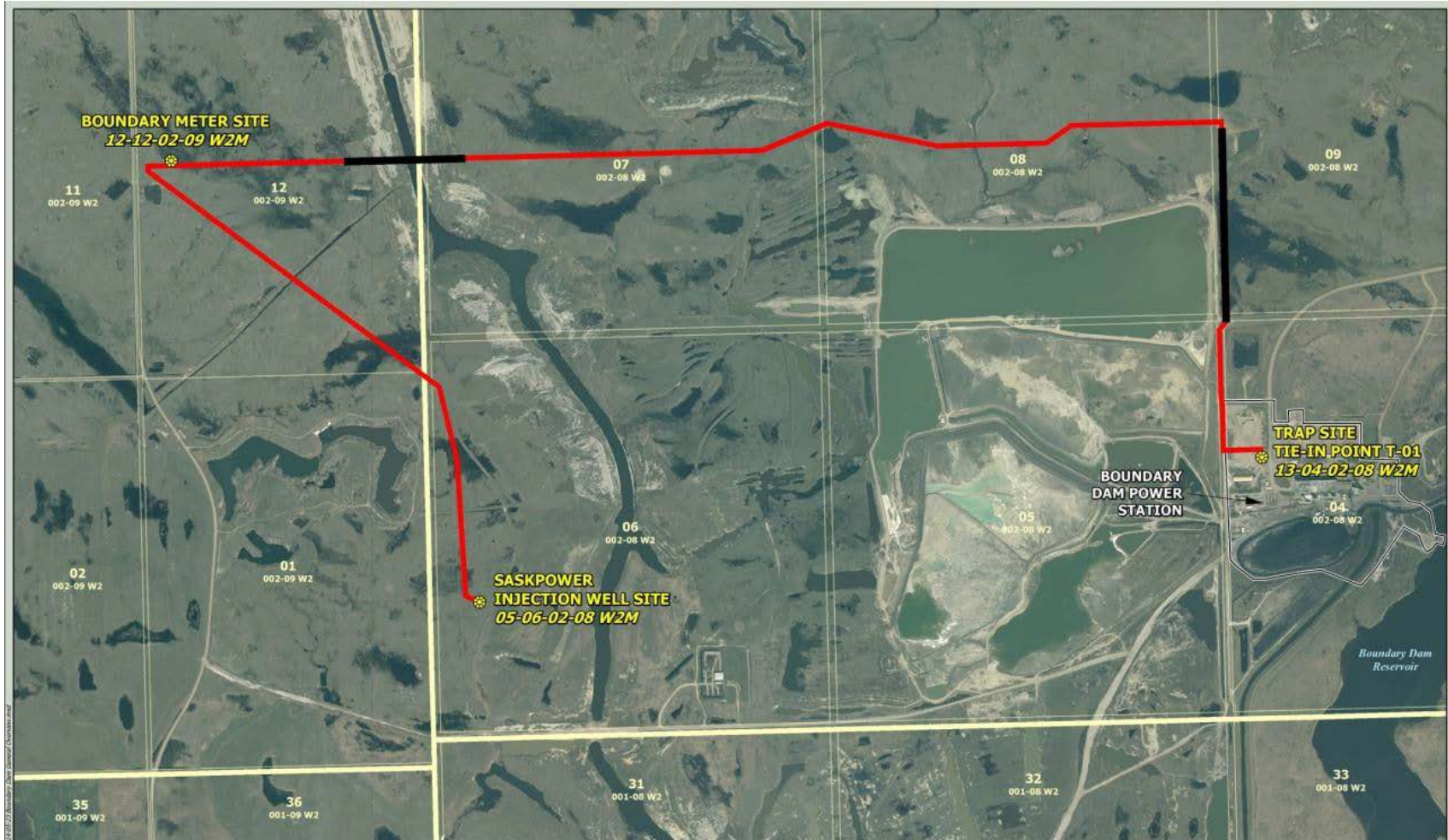


Figure 5-5. 3D simulated CO₂ plume distribution after 1 year since injection started. Vertical exaggeration is 5x.

Developing The SaskPower Injection Well

- Multiple Layers
- Fracture Pressure – the key constraint
- Fluid Sensitivity – A Loss of Permeability
- Chronology of Development
- Summary

SaskPower / PTRC Aquistore Injection Well Site



Multi-Layered System – Un-calibrated

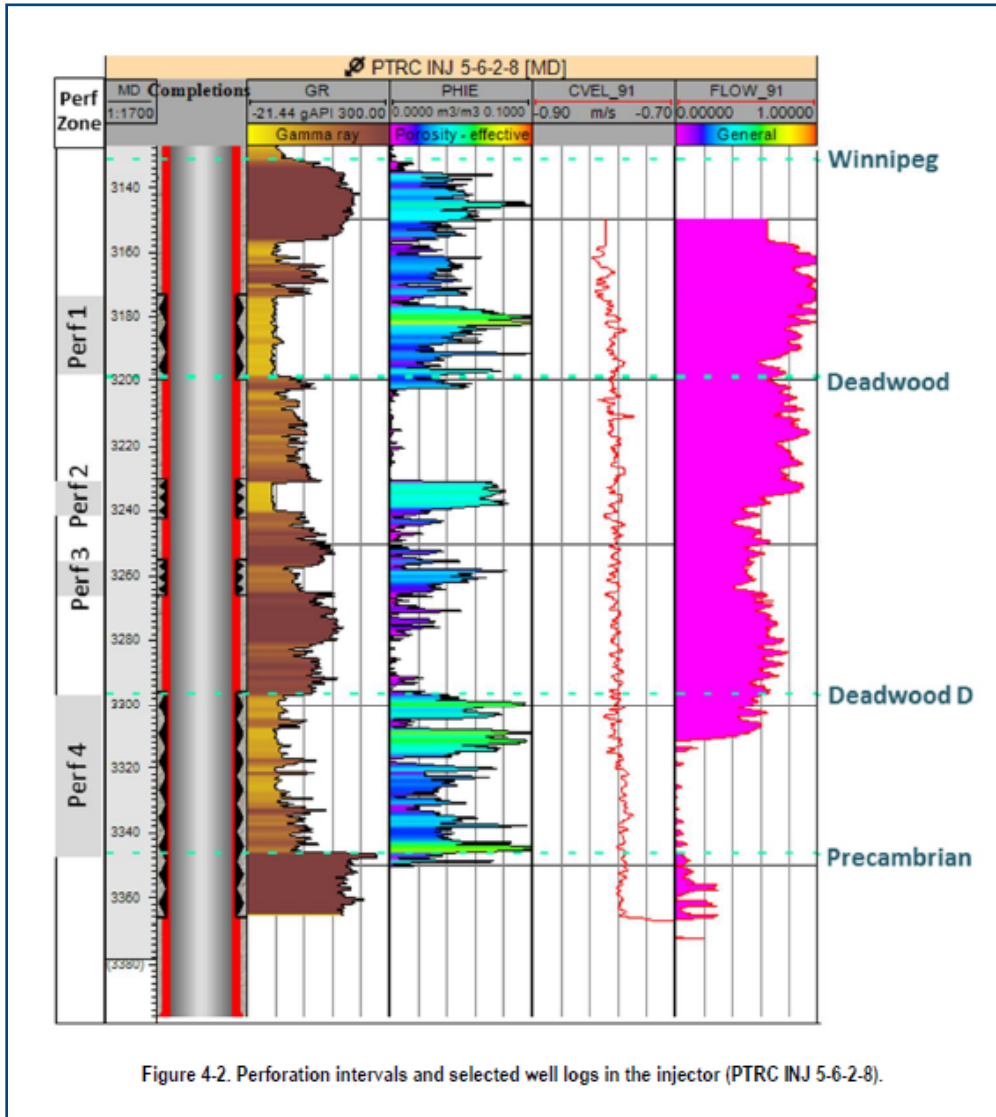


Figure 4.2. Perforation intervals and selected well logs in the injector (PTRC INJ 5-6-2-8).

- High Precision Data
- But...Near Wellbore
- Four Separate Injection Intervals
- System Not "Calibrated"

Initial Injection Test – September 2012

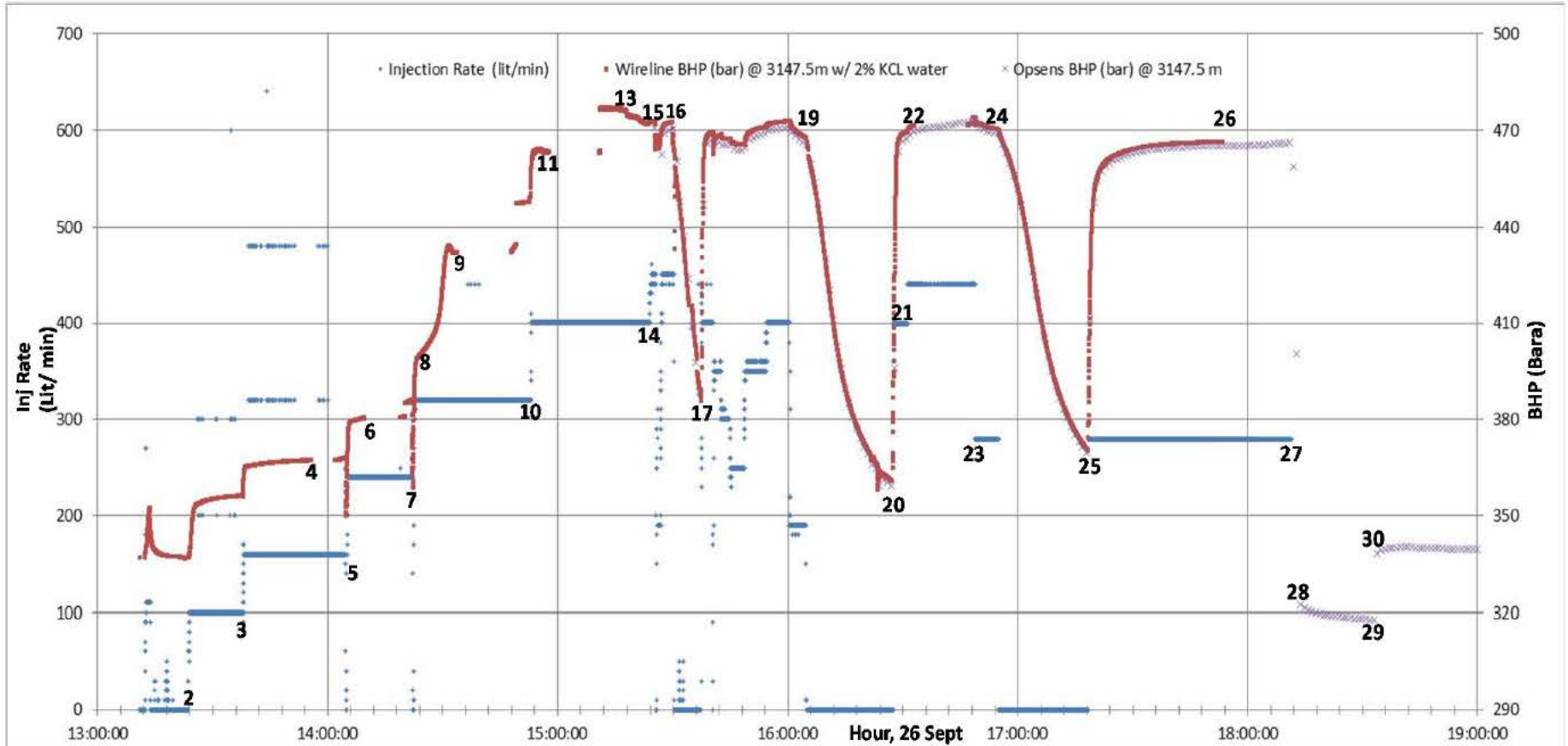


Figure 2-1. Injection test data from September 26. Chronology of most events is indicated according to Event Number listed in Table 2-2.

Spinner Logs - Injection Distribution

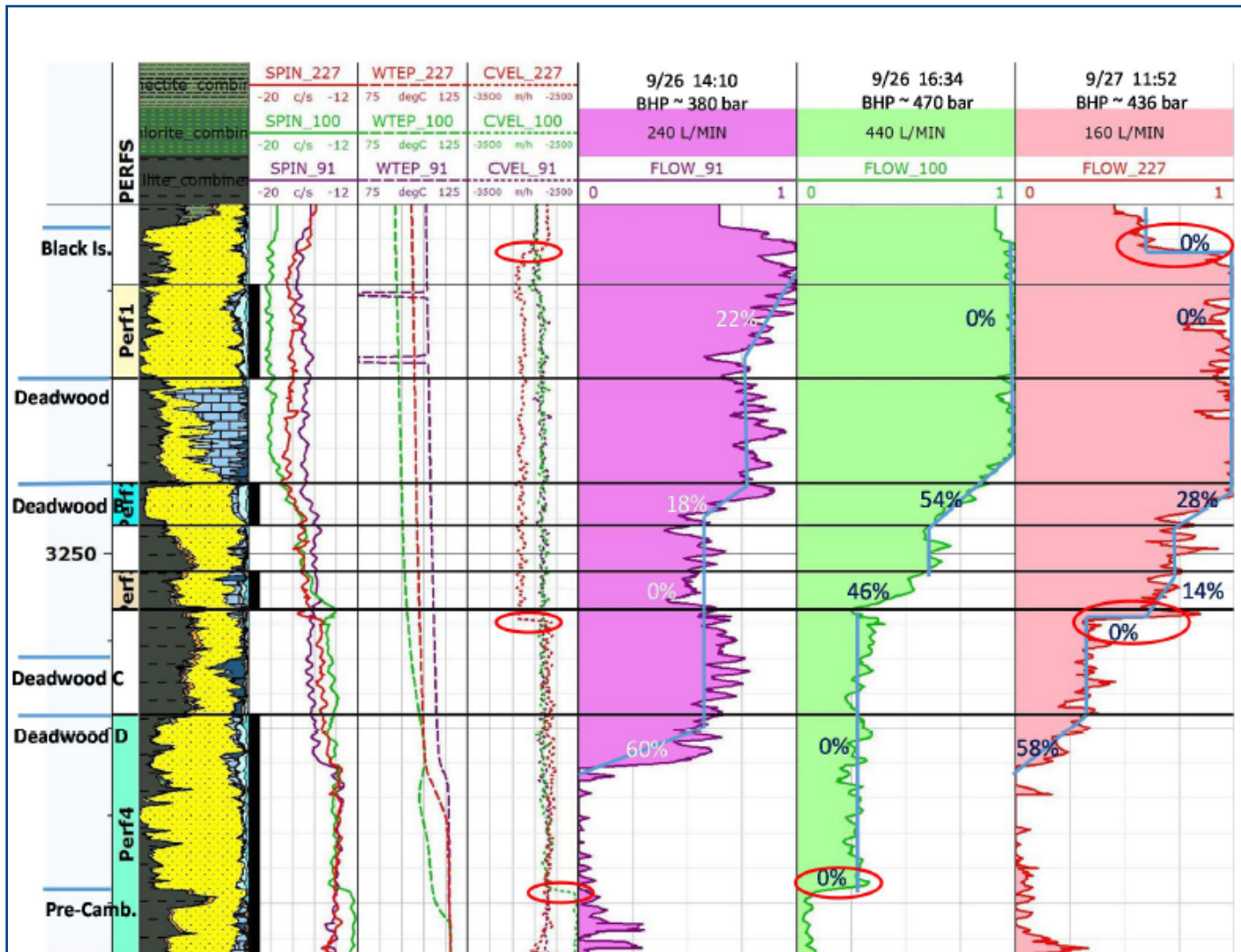
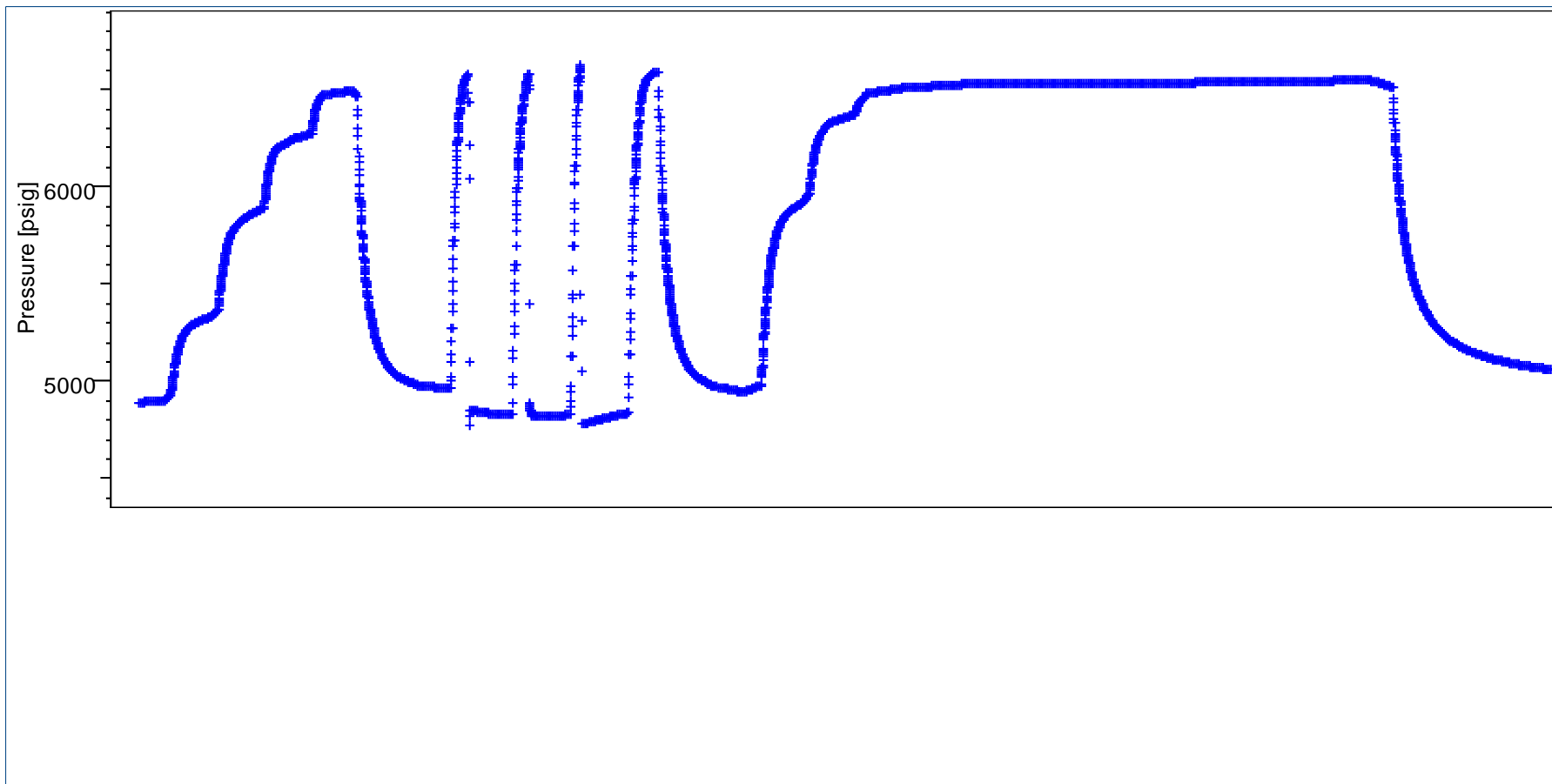
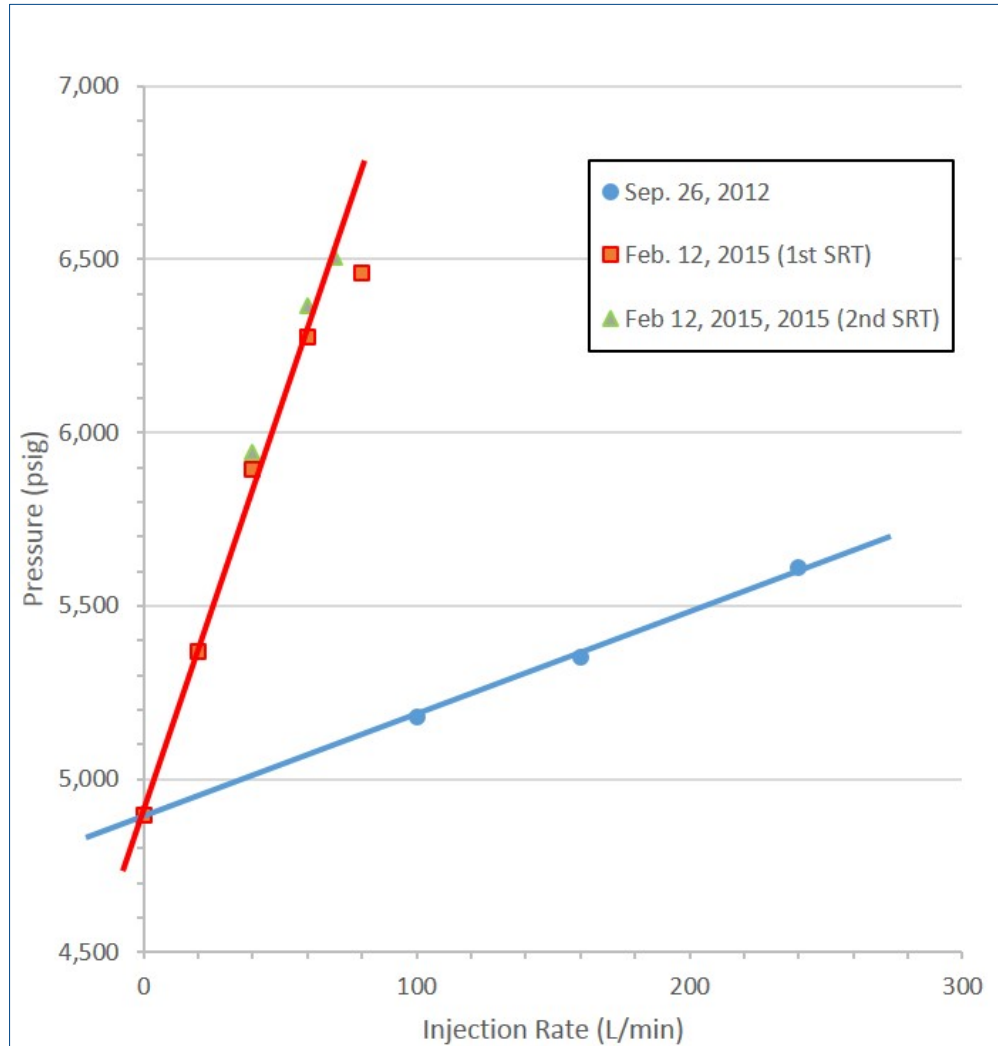


Figure 3-3. Production log analysis of perforation intervals during three injection periods during testing.

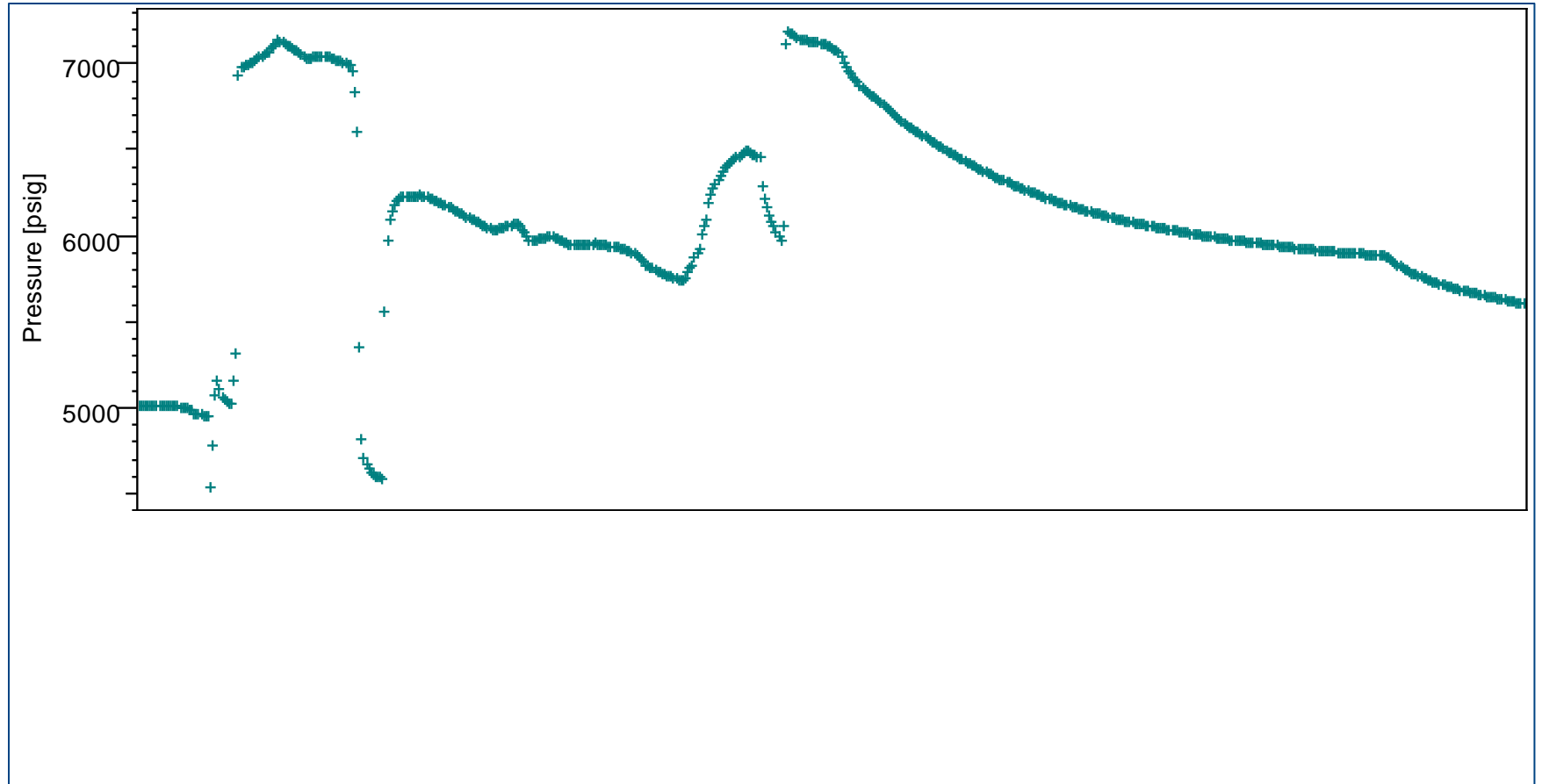
Repeat Injection Test – Feb 2015



2012 VS 2015 Injection Tests



Injection Test With Diversion – March 2015



Injection Profile After Diversion Treatment

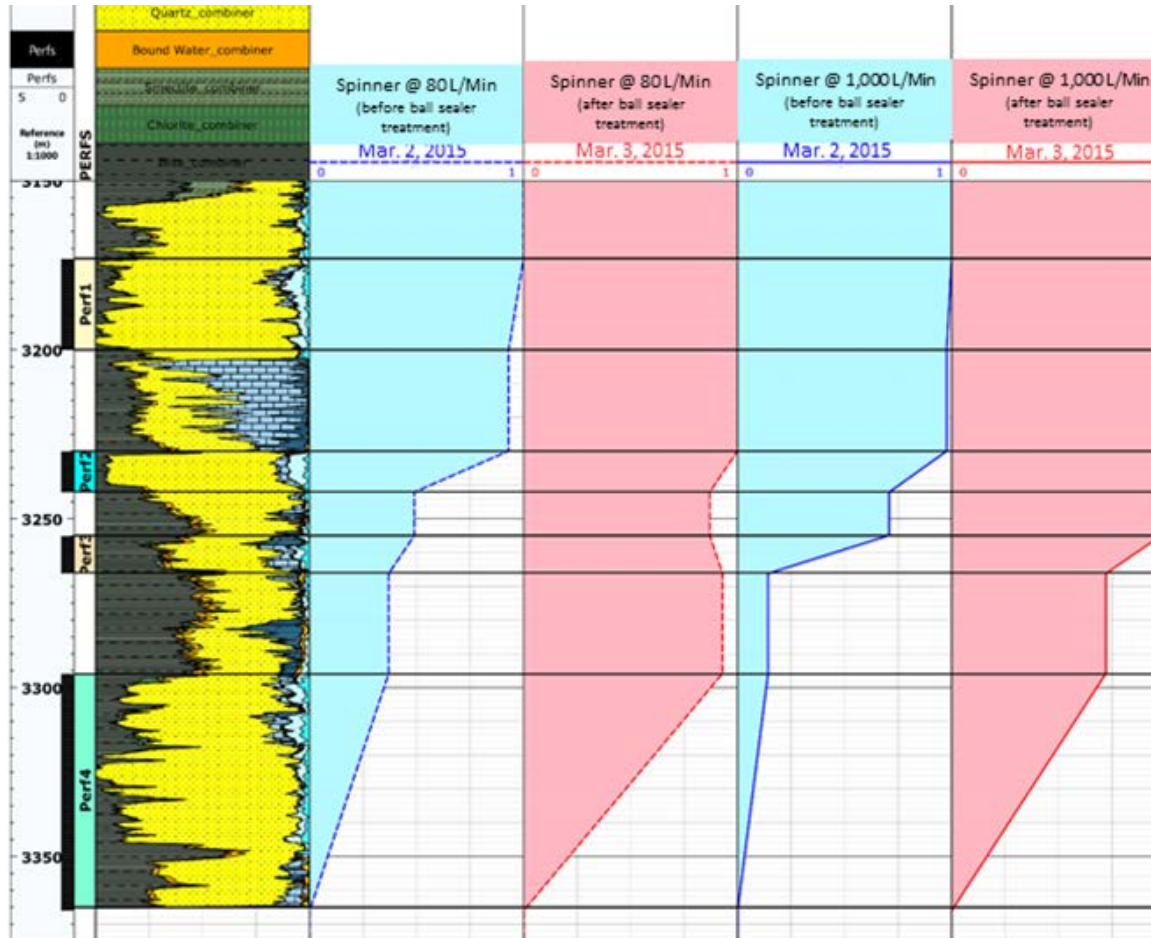
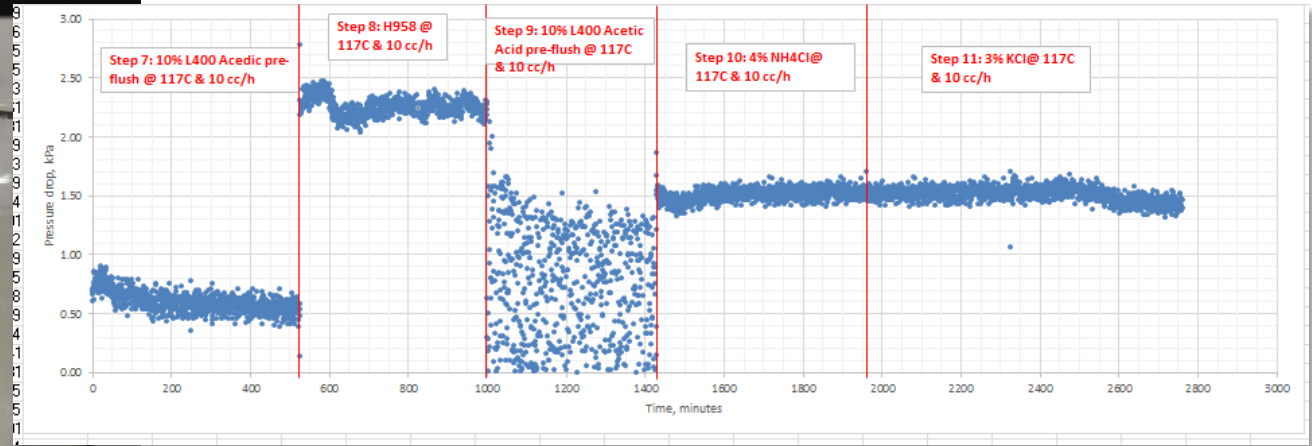
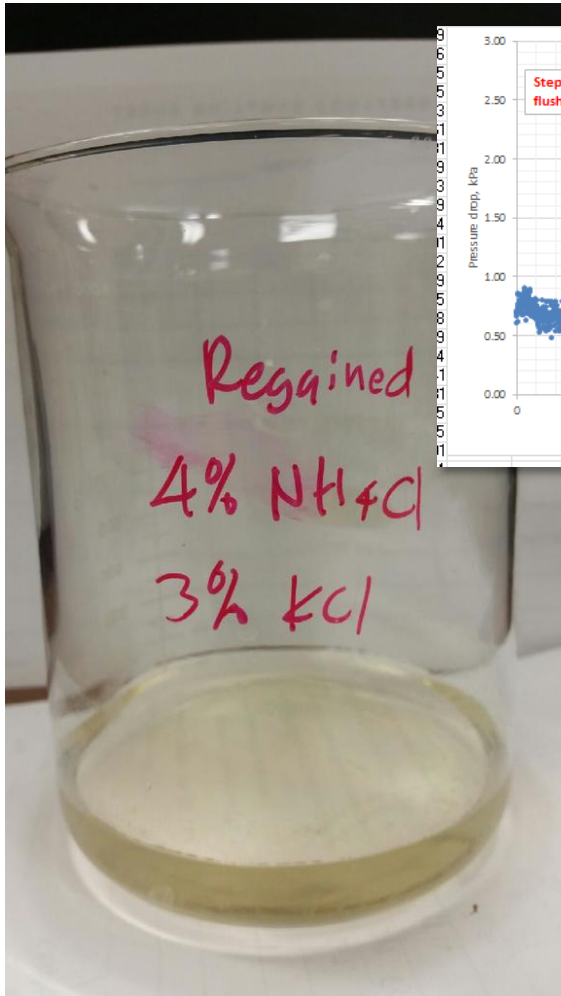
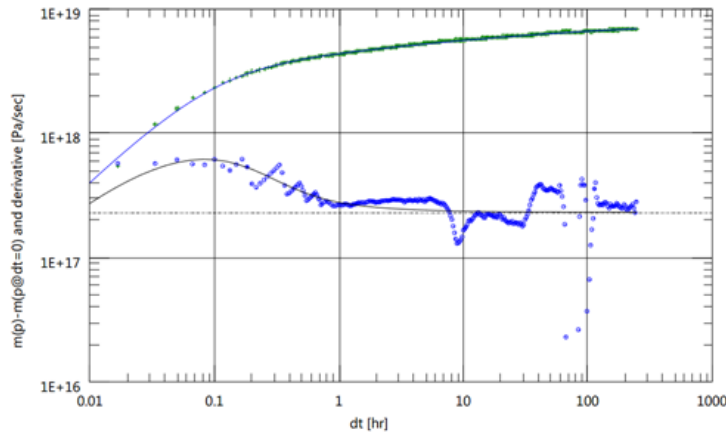


Figure 3. Spinner surveys showing the cumulative inflows into each perforation zone before and after the ball sealer treatment at two injection rates (80 and 1,000 L/min).

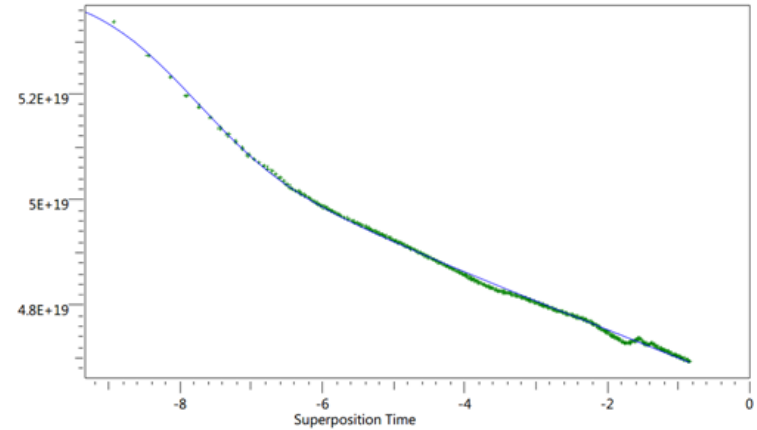
Core Flow and Fluid Sensitivity Testing



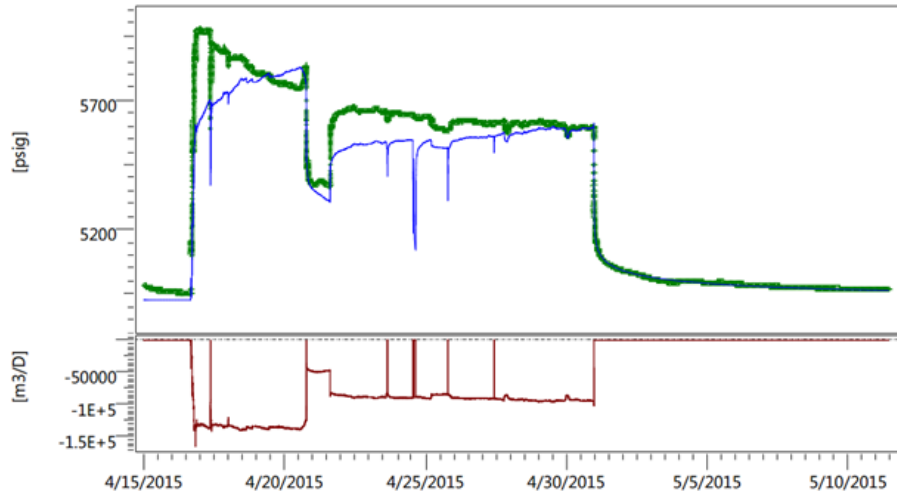
CO₂ Injection – April / May 2015



Log-log plot: p-p@dt=0 and derivative (psi) vs. dt (hr)



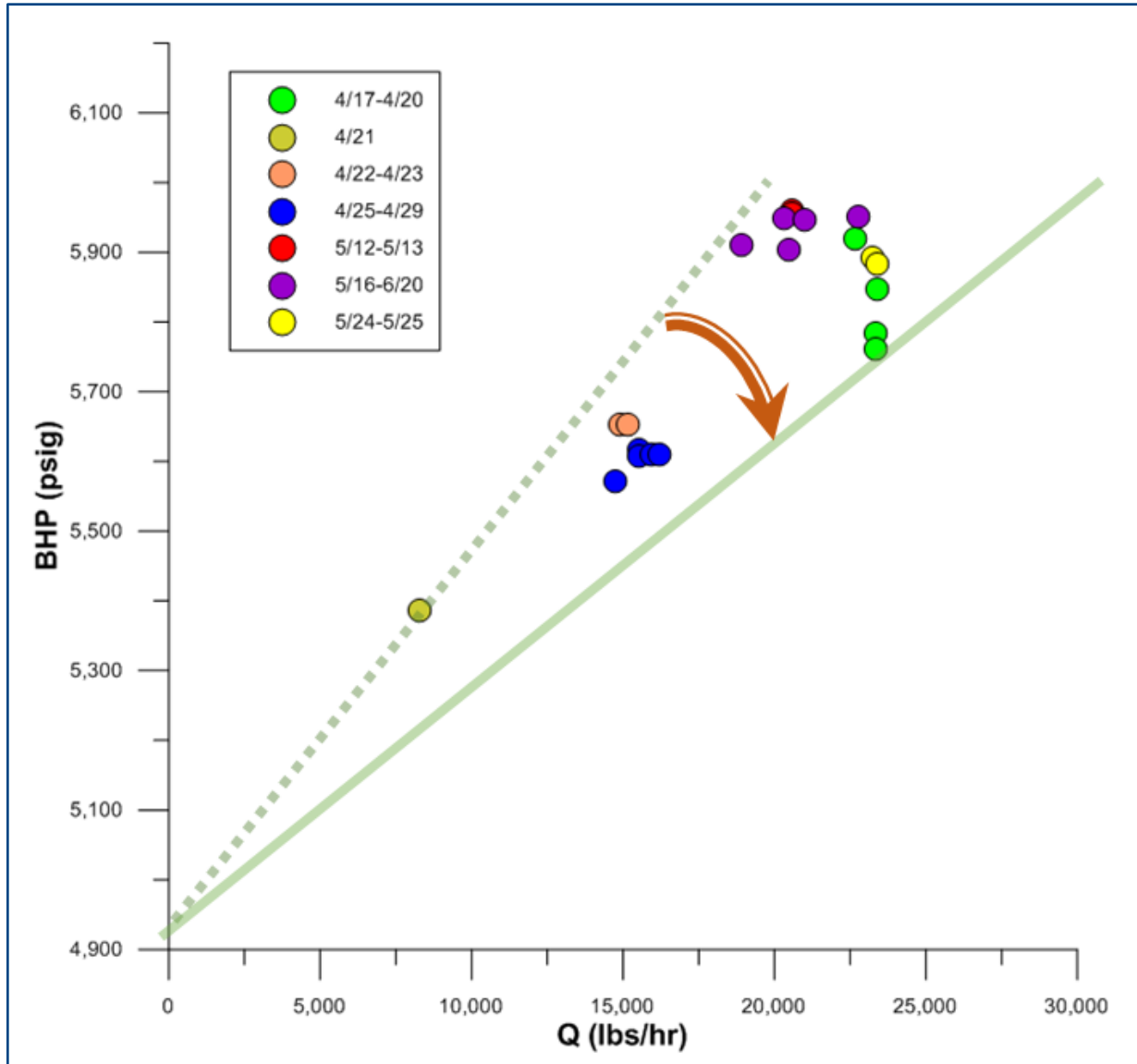
Semi-log plot: p (psi) vs. superposition time



History plot [pressure (psig), liquid rate (m3/D) vs time (date)]

Reservoir = Homogeneous
Boundary = Infinite
Pi = 4,927 psig
Kh = 46.9 md*m
Skin = -1.17

Improved Injectivity With Injection of CO₂



- Complex System, Proven Technology
- Darcy's Law Governs, Fracture Pressure – the key constraint
- Developing The SaskPower Injection Well
- Injecting Into Multiple Layers
- Fluid Sensitivity Damaged Upper and Lower Layers
- Diversion Technique Restored Lower Layer
- CO₂ Injection Improving Damaged Permeability

Acknowledgements

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Kevin England - Schlumberger

Questions?

