

Optimizing Unconventional Fracs with Distributed Fiber Optic Sensing

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Overview

- **What is Distributed Acoustic Sensing (DAS)**
- **Frac Data and Results**
- **Cross-Well Communication Data and Results**
- **Production Monitoring**
- **Monitoring Wells with No Fiber**

Frac Monitoring with Fiber Optics – DAS / DTS

What is it?

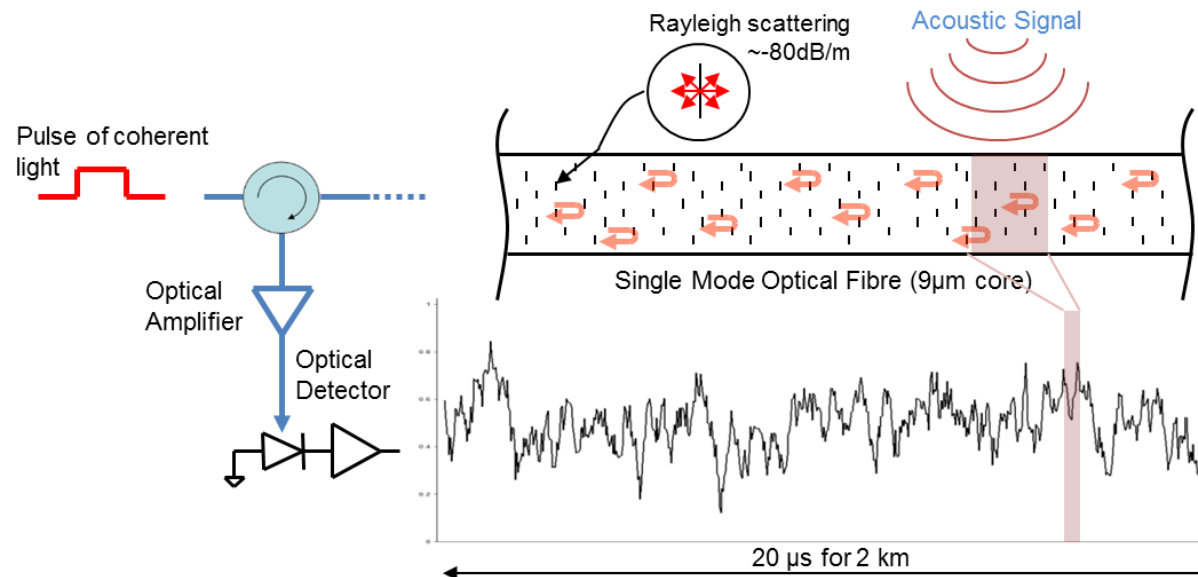
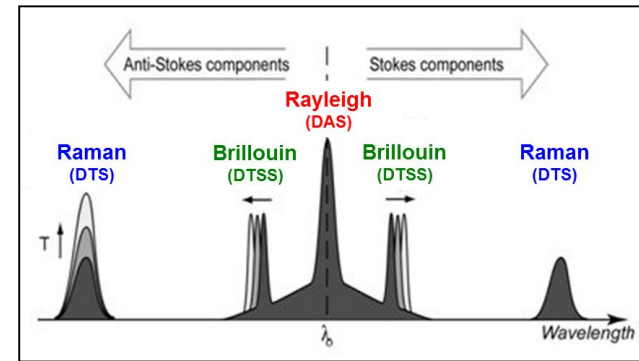
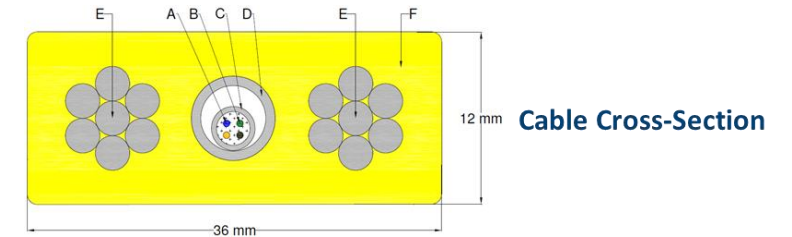
- Fiber Optics cable along the whole wellbore
- Laser pulse induced energy reflection (amplitude and phase)
- Local change in temperature / pressure / noise creates deformation (strain)
- Reflection amplitude / time quantifies strength of disturbance and location

What properties?

- Temperature (DTS)
- Acoustics/strain (DAS)

What information?

- Injection profile along completion
- Well integrity
- Inter-stage communication
- Cross-well communication



Hydraulic Fracture Profiling

The Data

Raw

- ODH3.1
- Sample Rate 10,000 Hz
- Single Pulse
- Spatial Resolution 1.3 m
- Spatial Sampling 1.0m

Fast Fourier Transform

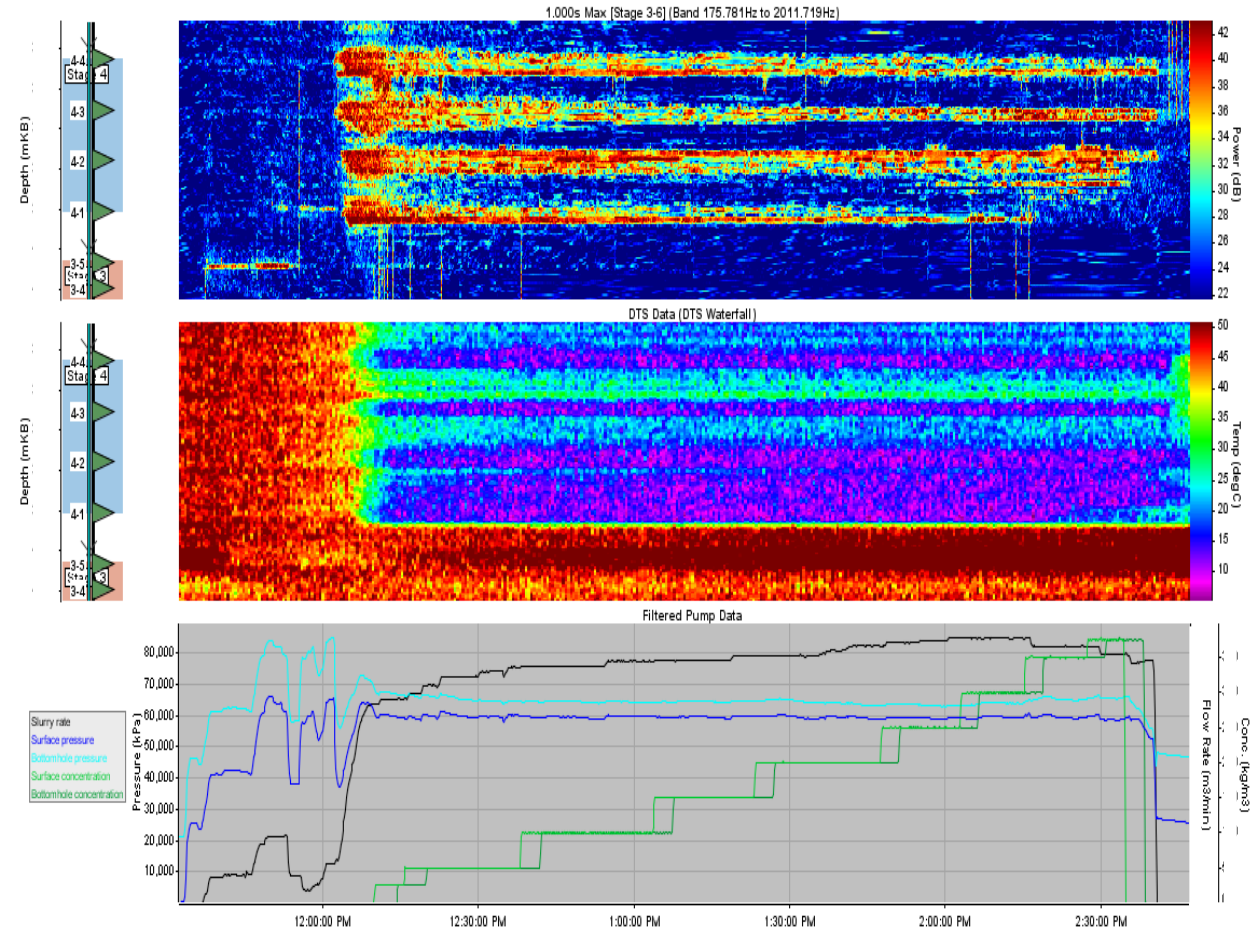
- Time domain to frequency domain

Frequency Band Extraction (FBE)

- 4 bands, 0 – 5000 Hz
- Large amplitude, broadband frequency signal
- Pump noise filtered to focus on injection profile

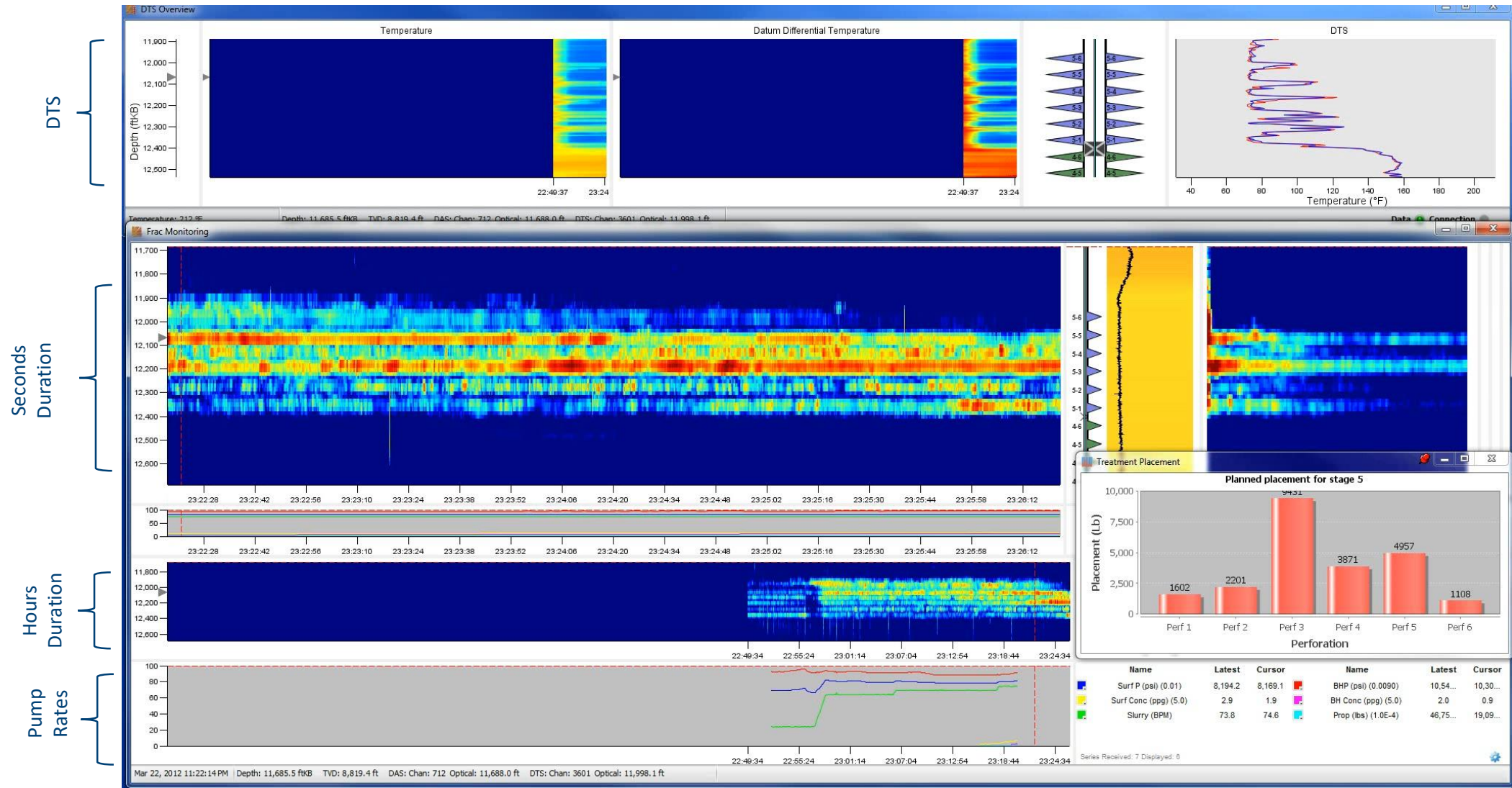
Surface Data (1-s update)

- Slurry rate
- Surface and bottom hole concentration
- Wellhead and bottom hole pressure



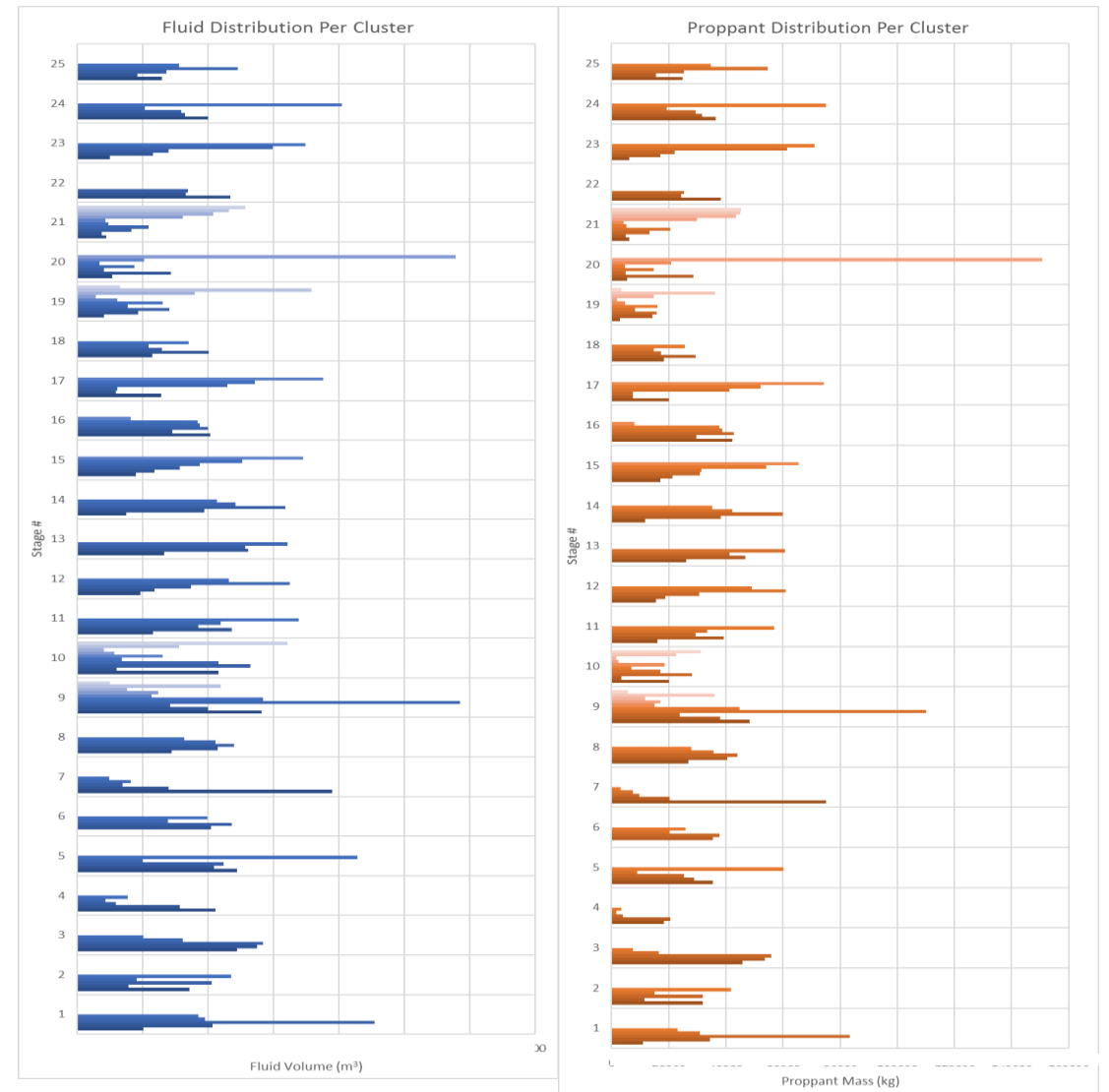
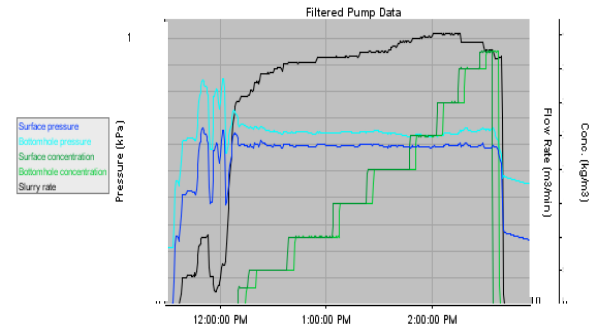
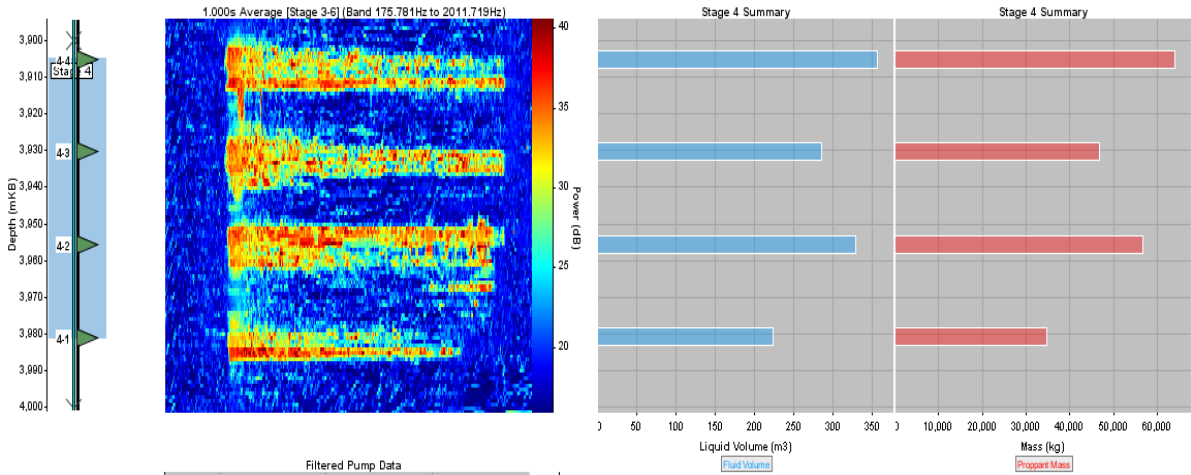
DAS, DTS, Pump Data from a Single Frac Stage

Live Monitoring

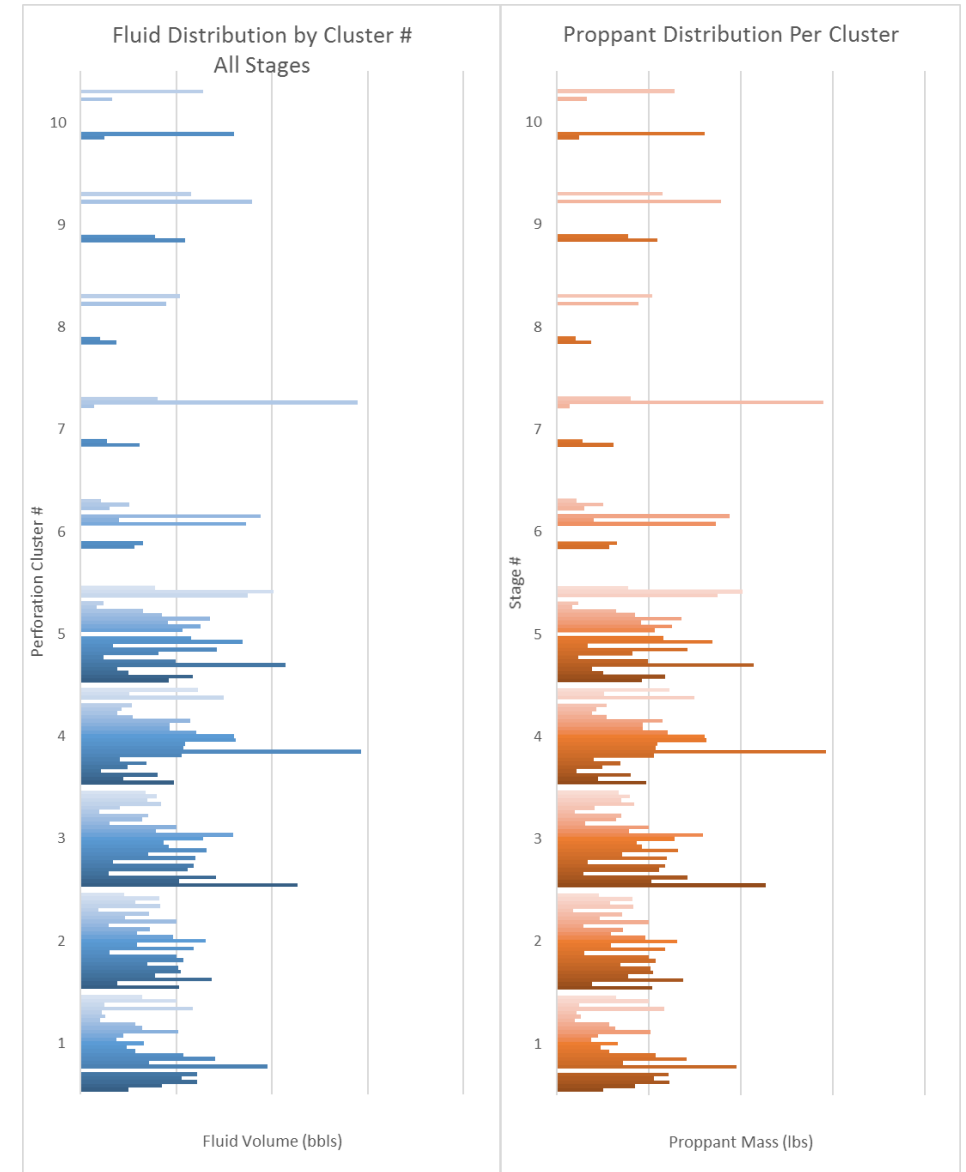
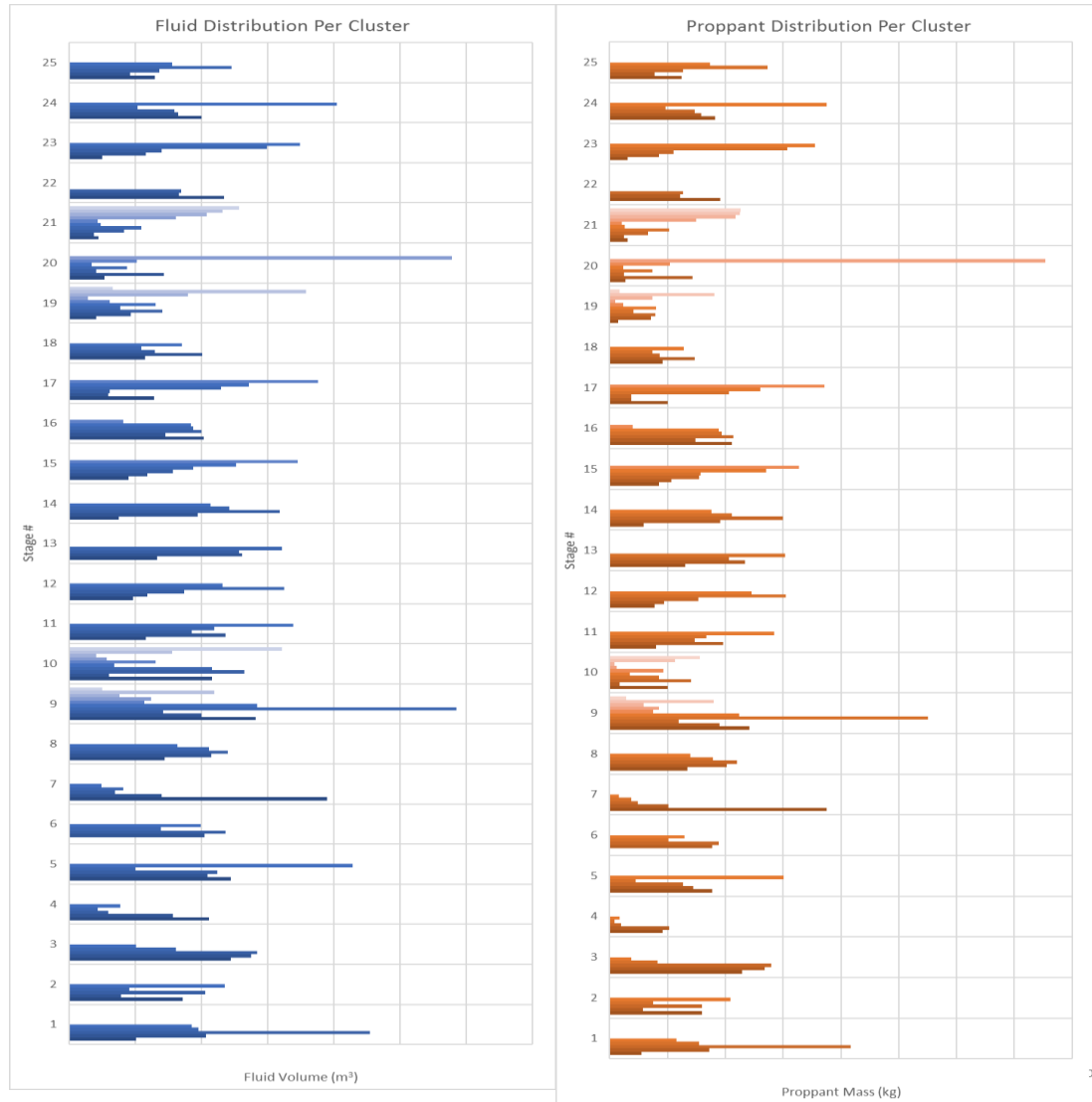


The Results

- Complete full-well quantitative injection profile

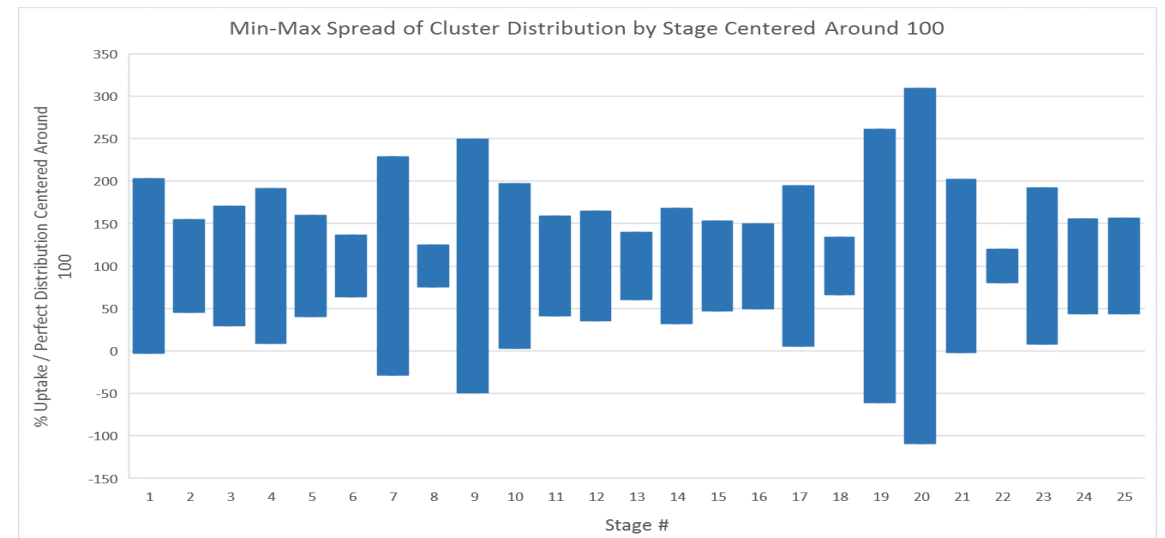
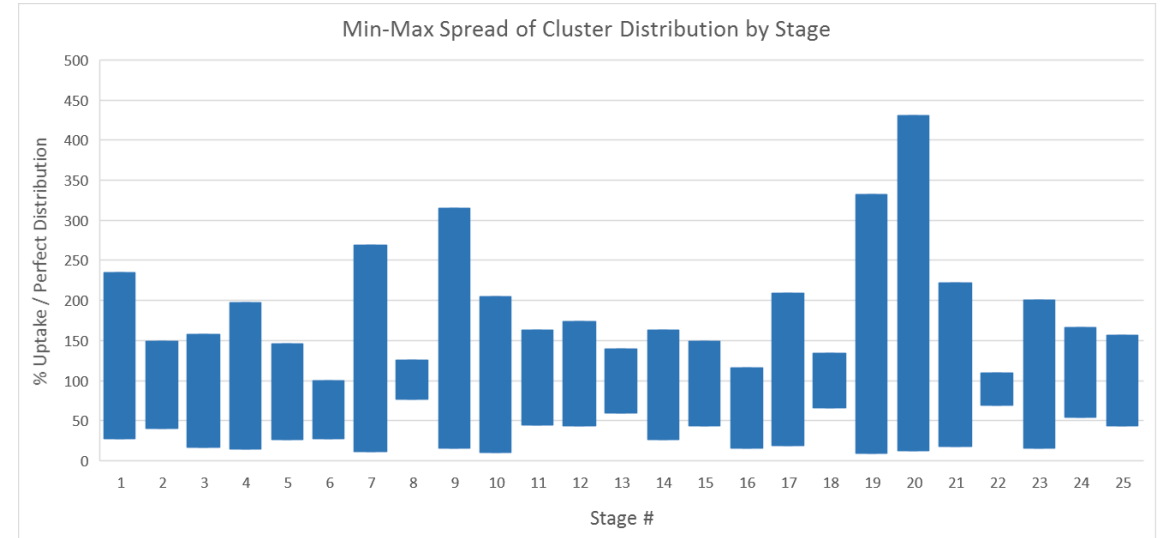
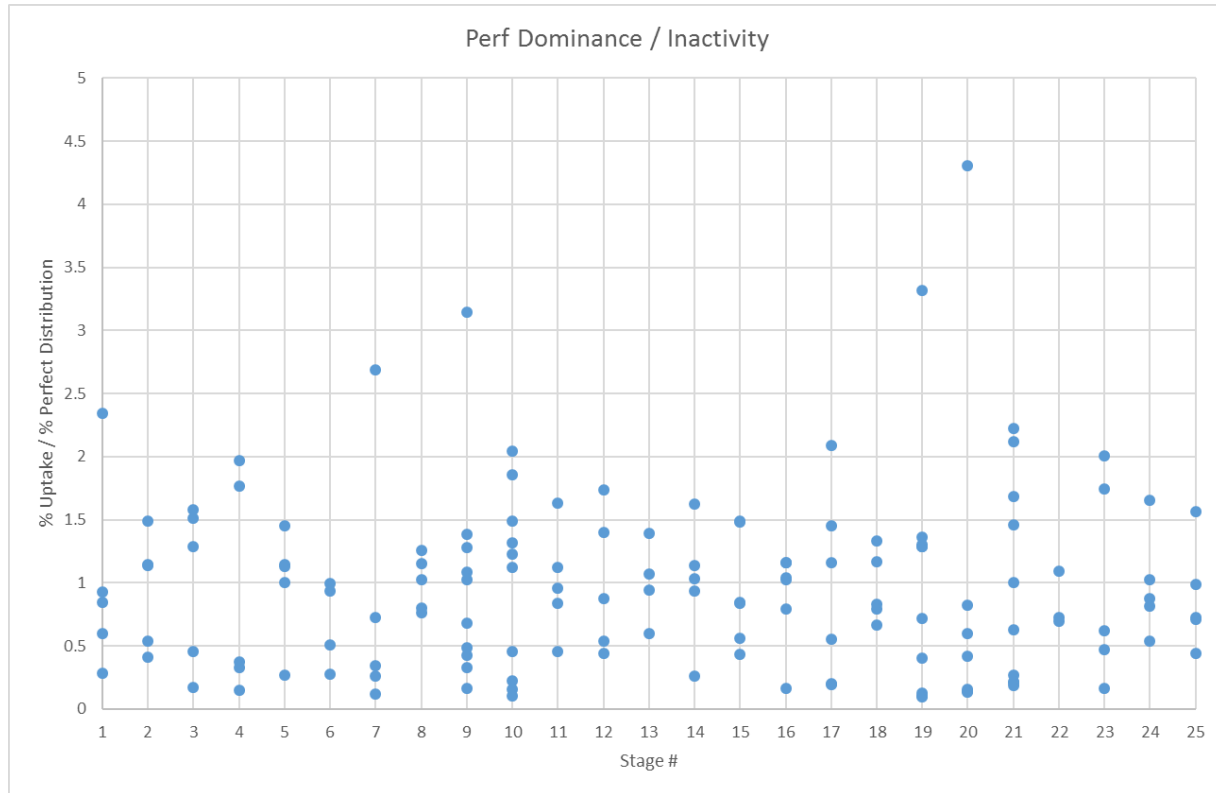


Injection Profiles



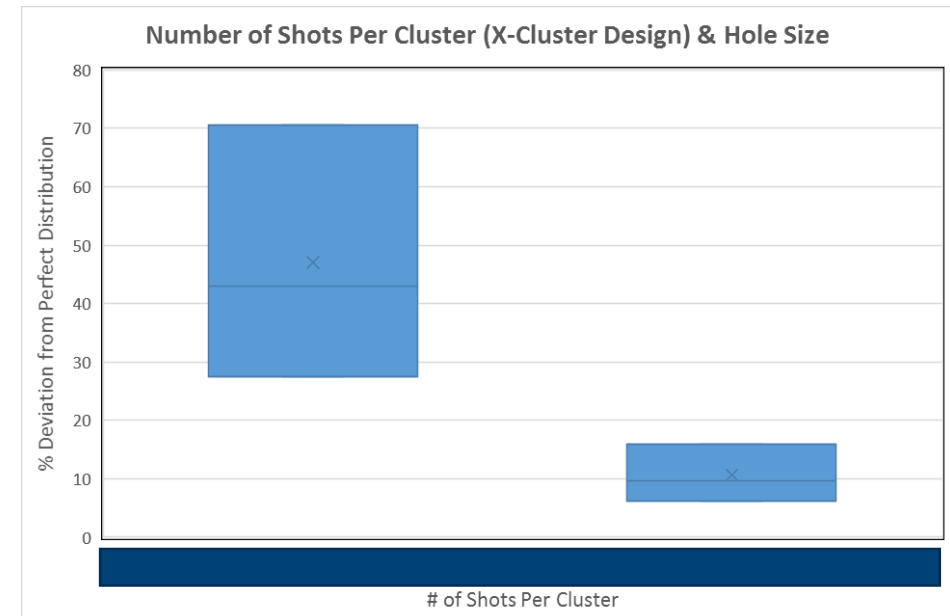
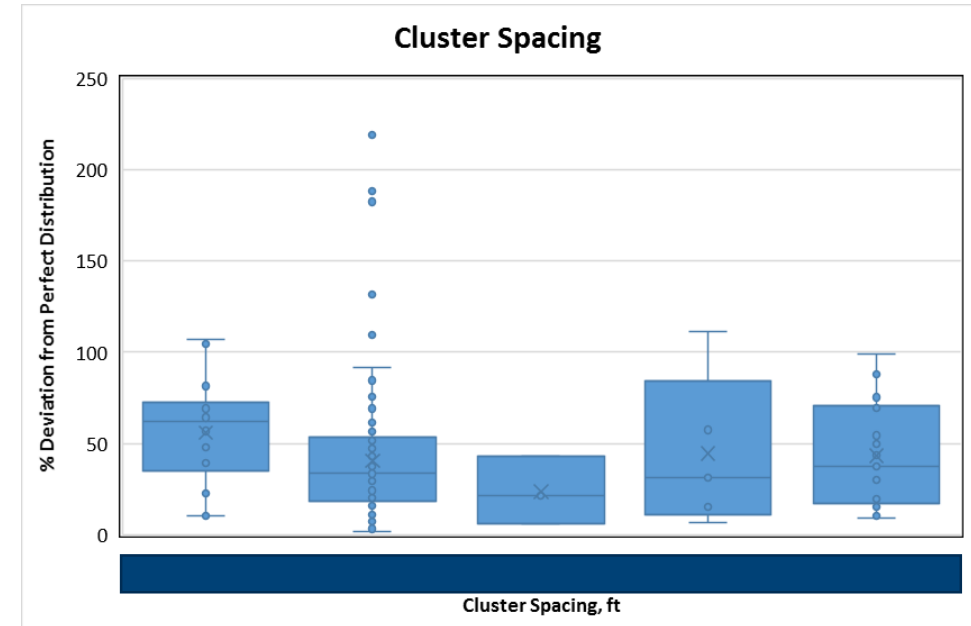
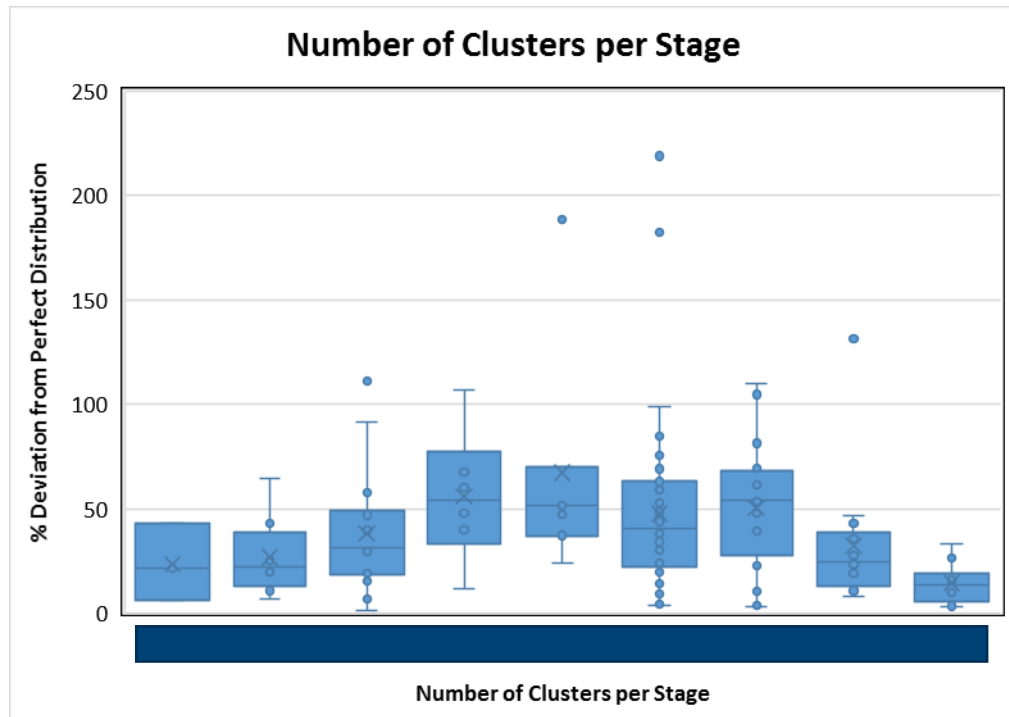
The Results

- Active and Inactive clusters



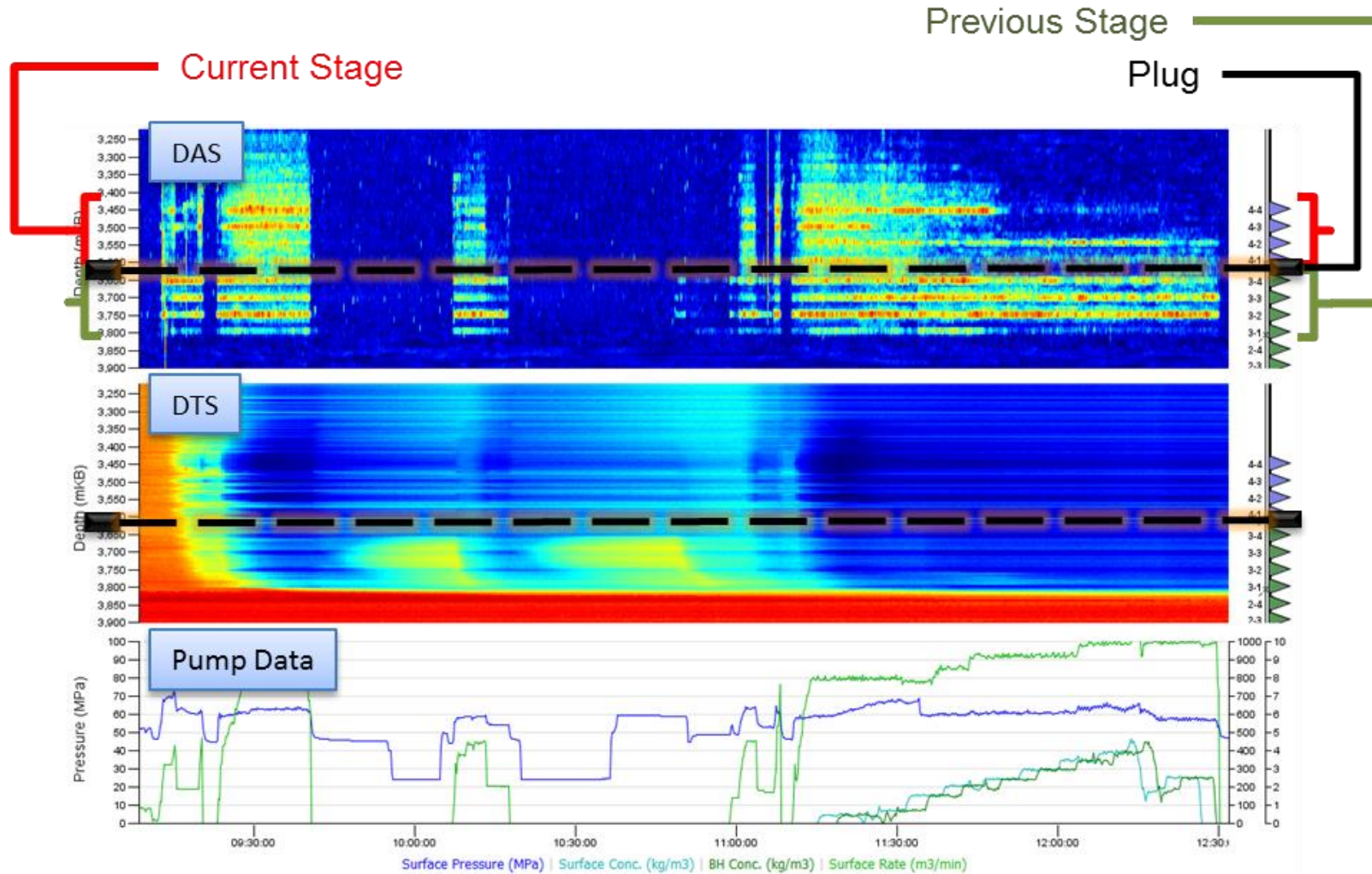
The Results

- Which completion designs provided most even distribution of proppant



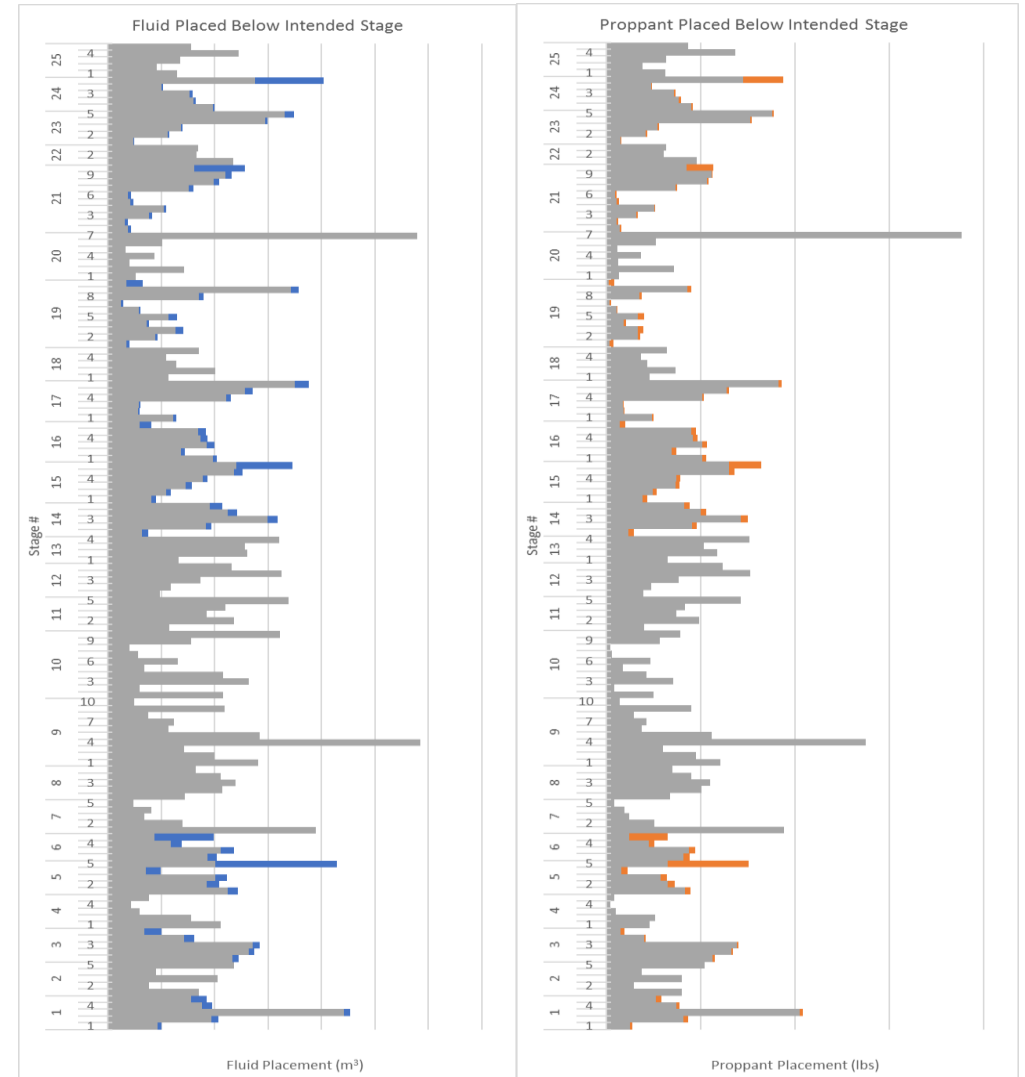
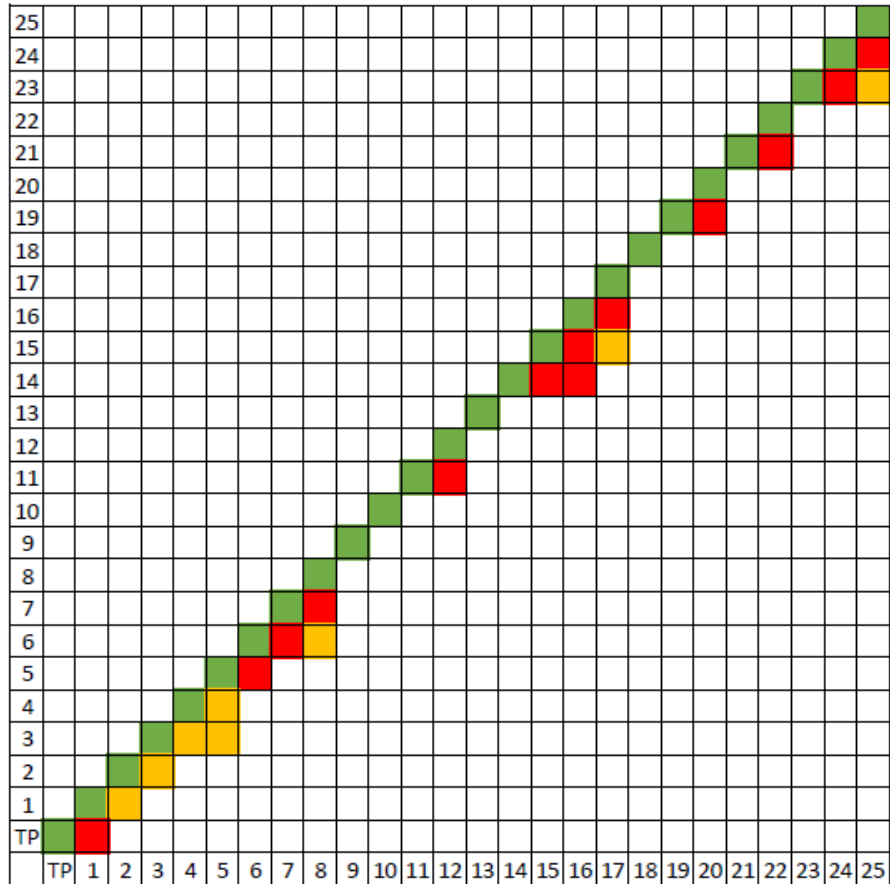
Identifying Inter-stage Communication

Critical failure of bridge plug

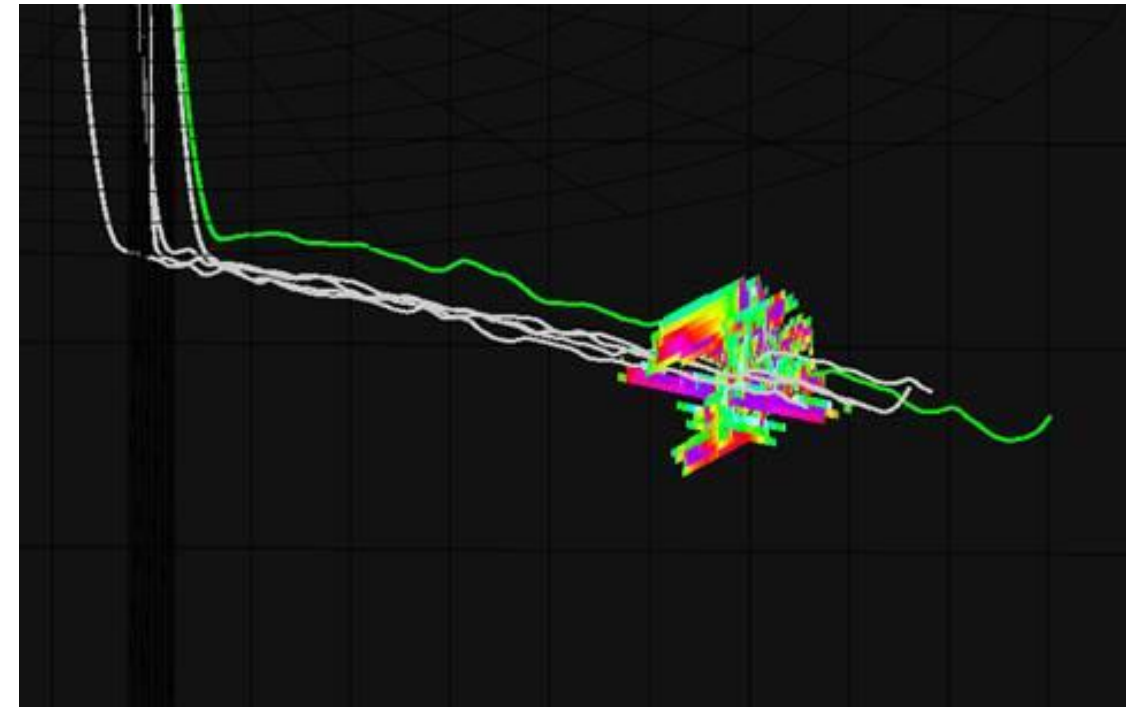
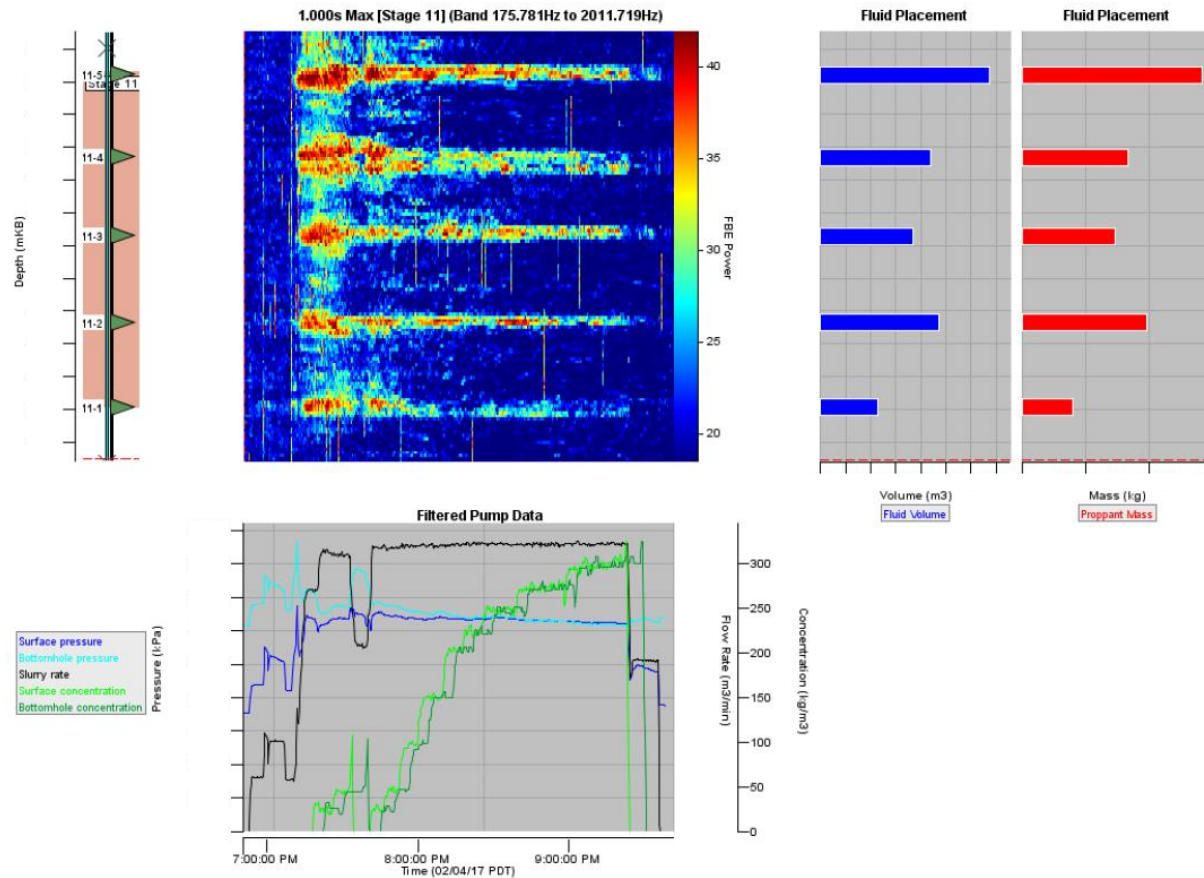


The Results

- Analysis and quantification of inter-stage communication



Hydraulic Fracture Modelling

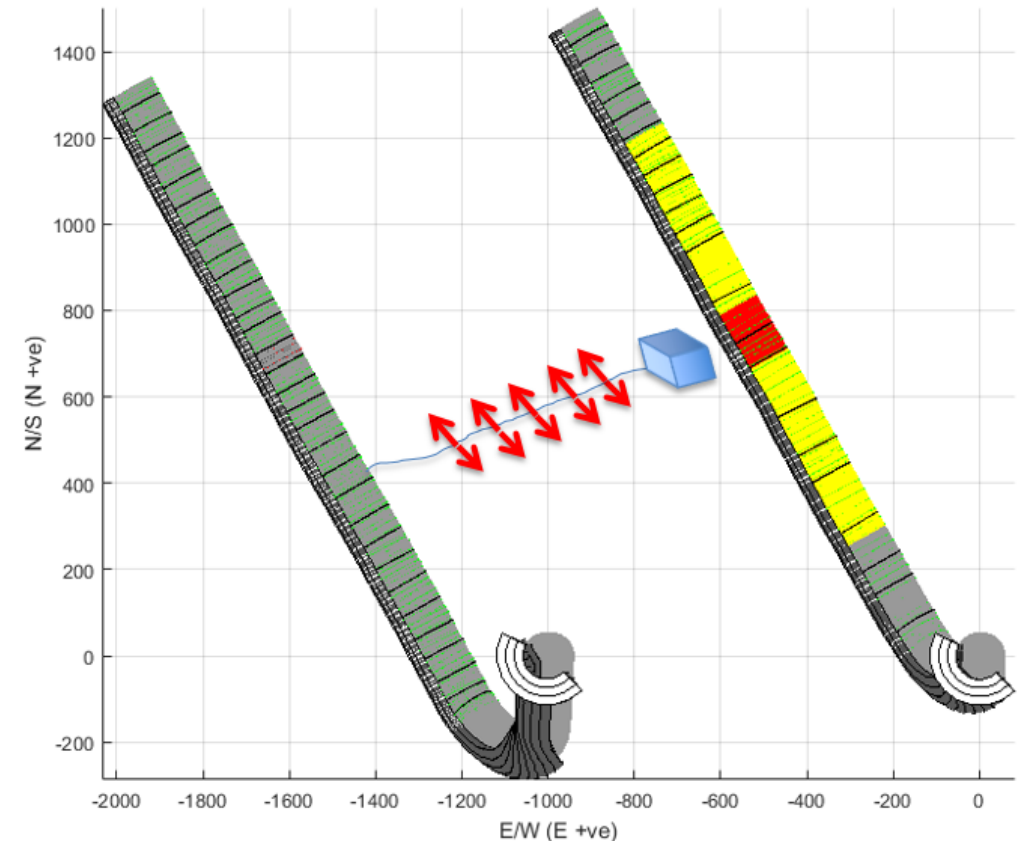


GOHFER 3D Fracture Simulation

Cross-Well Strain

Introduction

- During treatment, one or more fractures extend toward the neighboring well
- The pressure in the fracture changes the stresses on the rock face when the fracture opens
- The stress causes strain (deformation) of the rock
- The fiber, which is coupled to the cement, which is coupled to the rock, also experiences a change in strain due to deformation
- OptaSense can measure magnitude and polarity (a +ve or -ve change in strain), continuously and at all depths
- If the fracture reaches the neighboring well, even small amounts of fluid will cause large DTGS signals



The Data

Raw

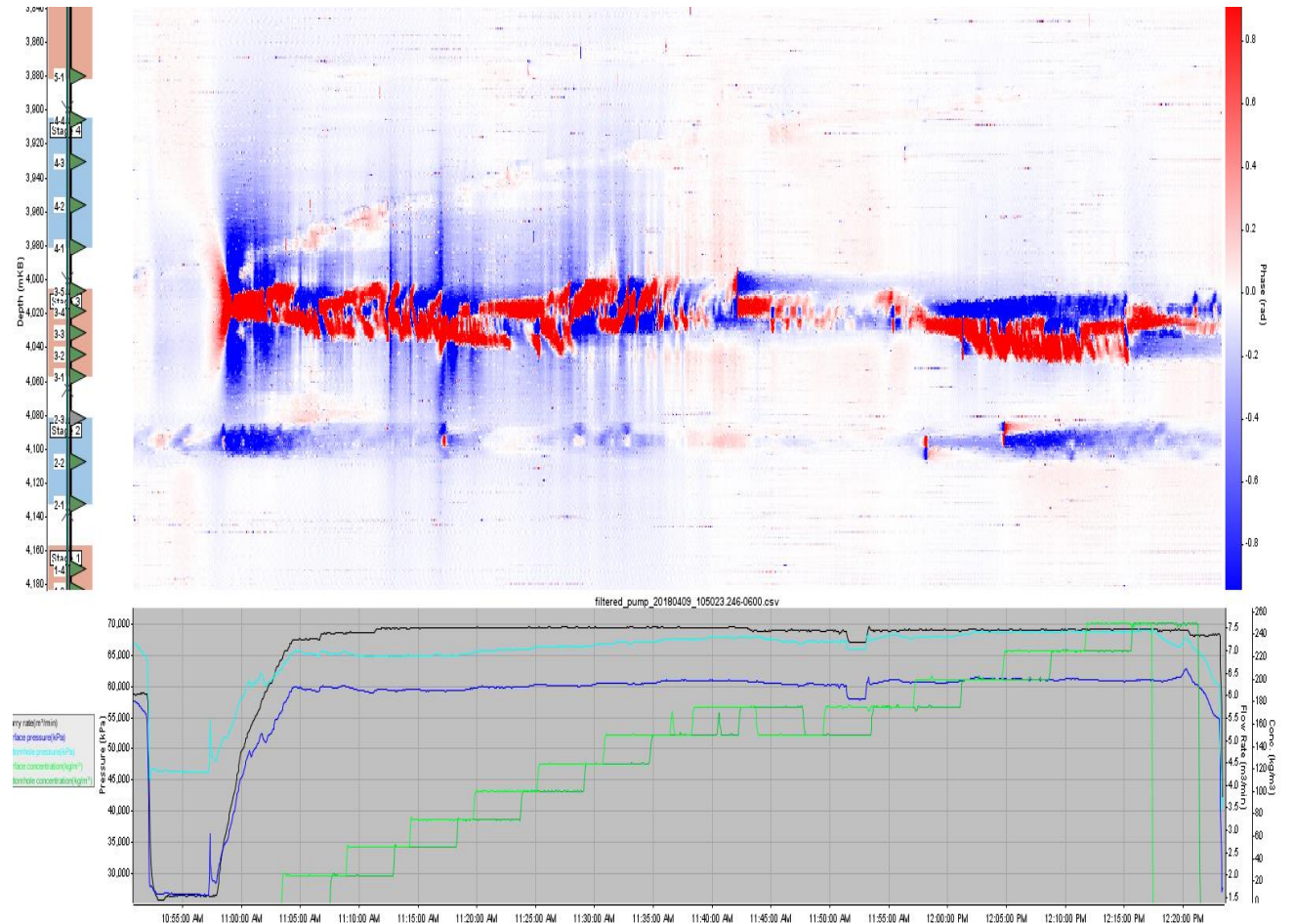
- ODH4
- Sample Rate 100 Hz
- Dual Pulse
- Spatial Sampling 1.0 m

Time Series

- +ve and -ve strain
- Distributed strain tracking ($\mu\text{m}/\text{m}$)
- Distributed strain rate ($\mu\text{m}/\text{m}/\text{s}$)

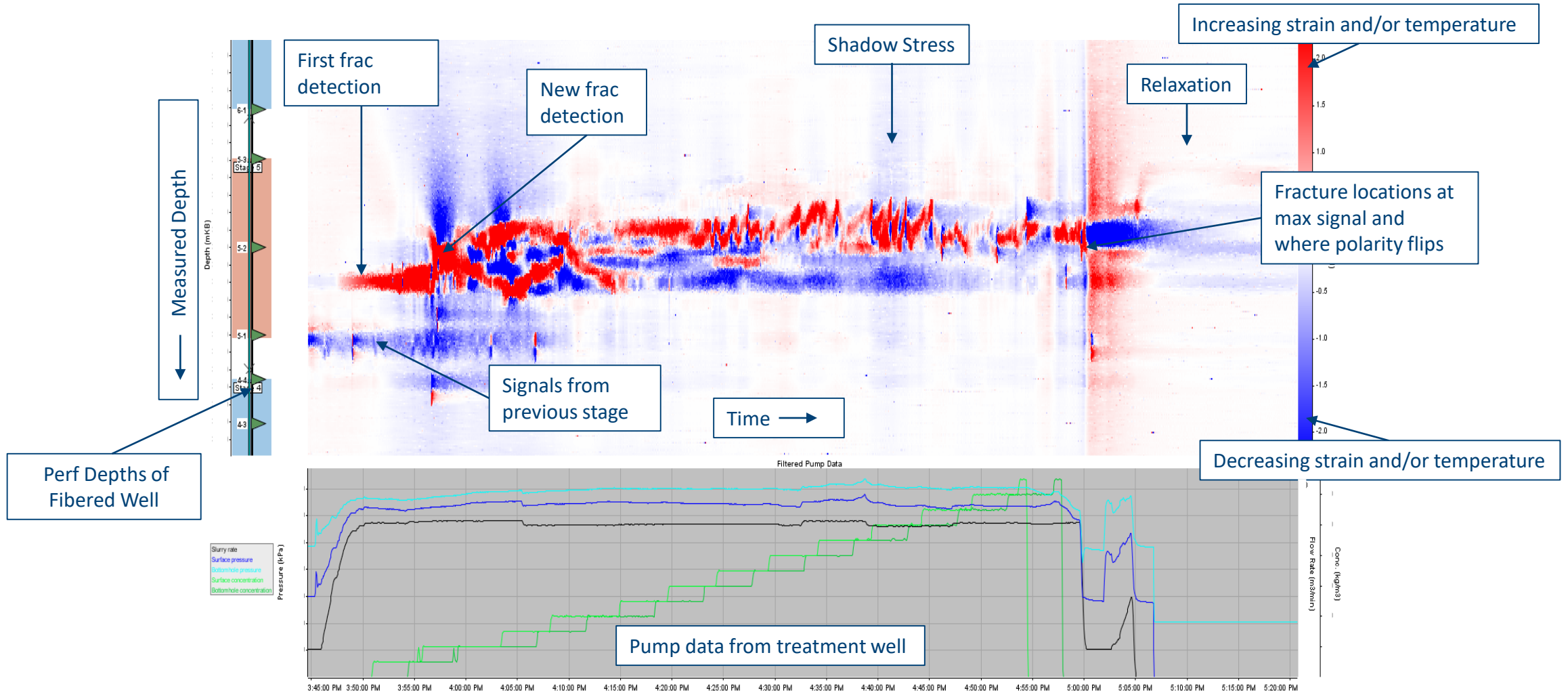
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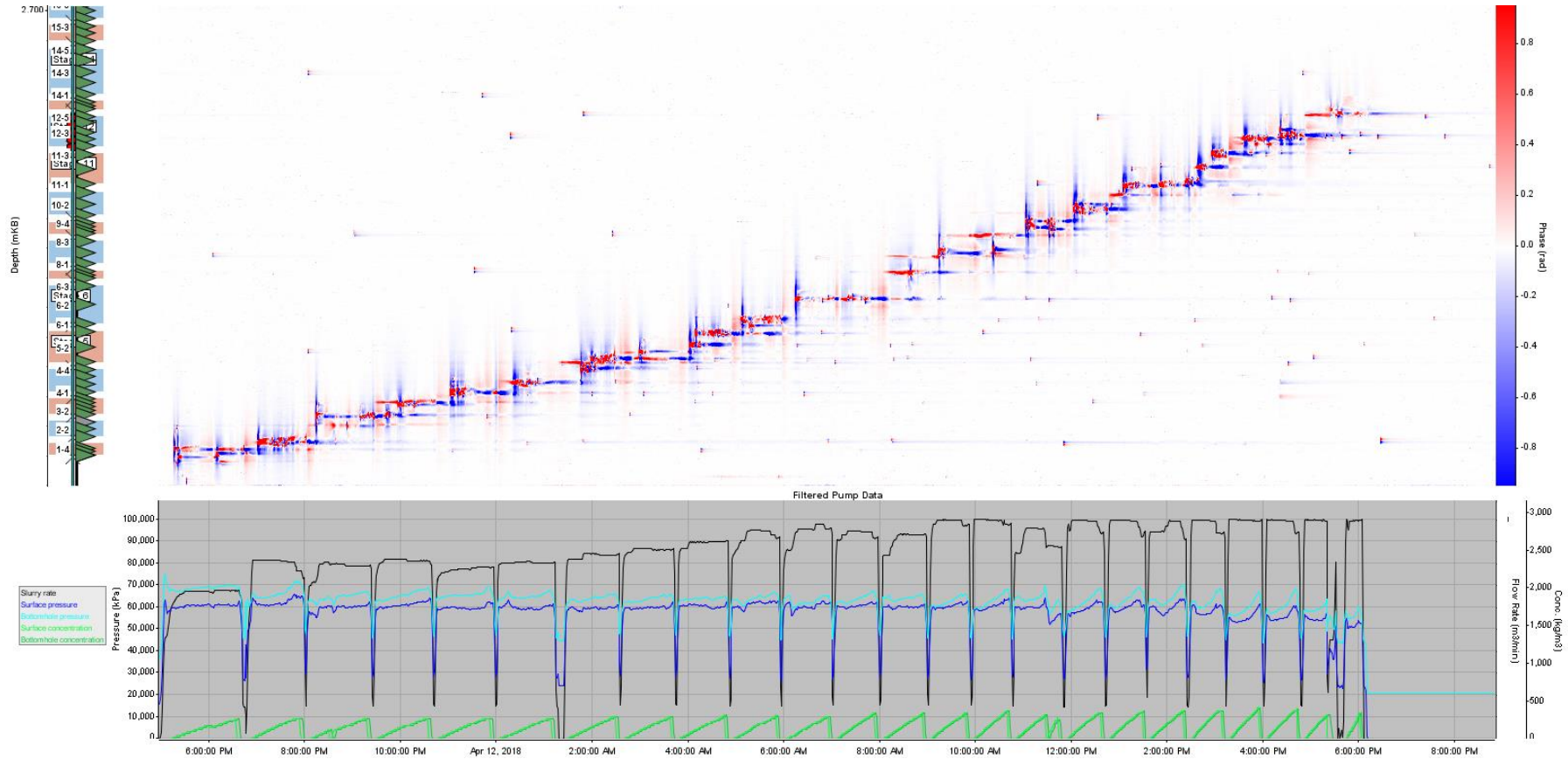


Strain of a Single Frac Stage

Description of Following Slides

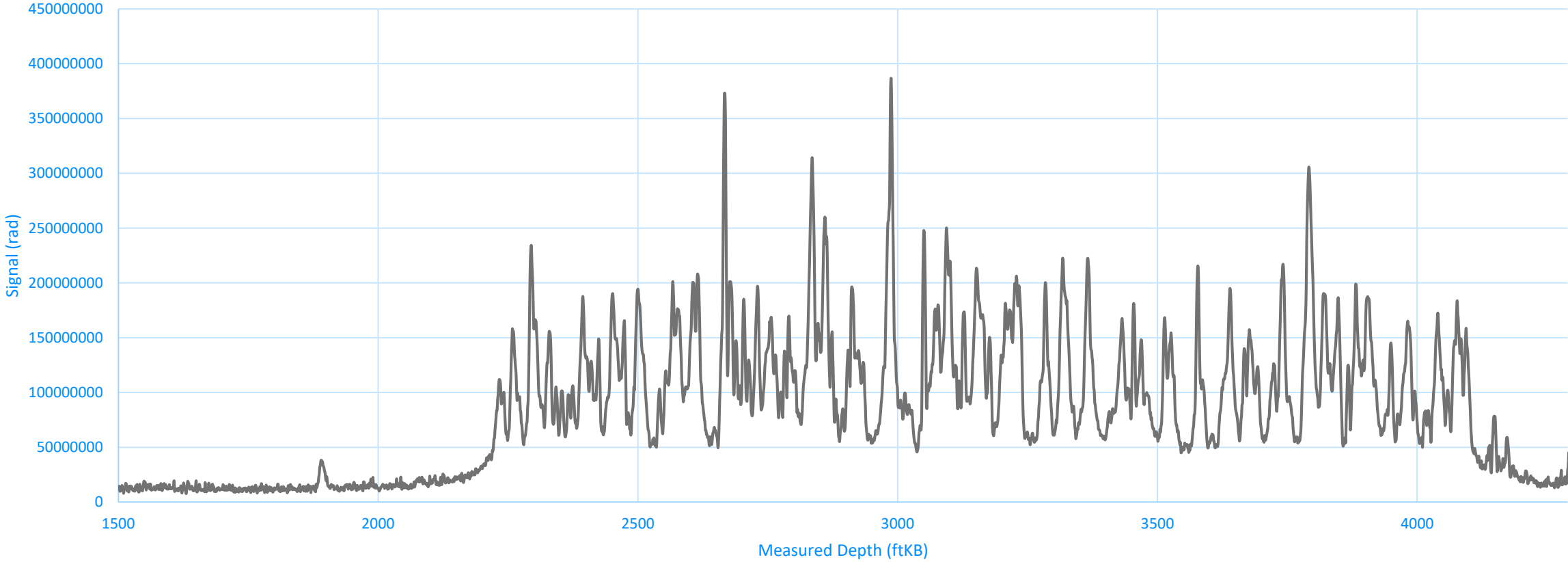


Well Overview



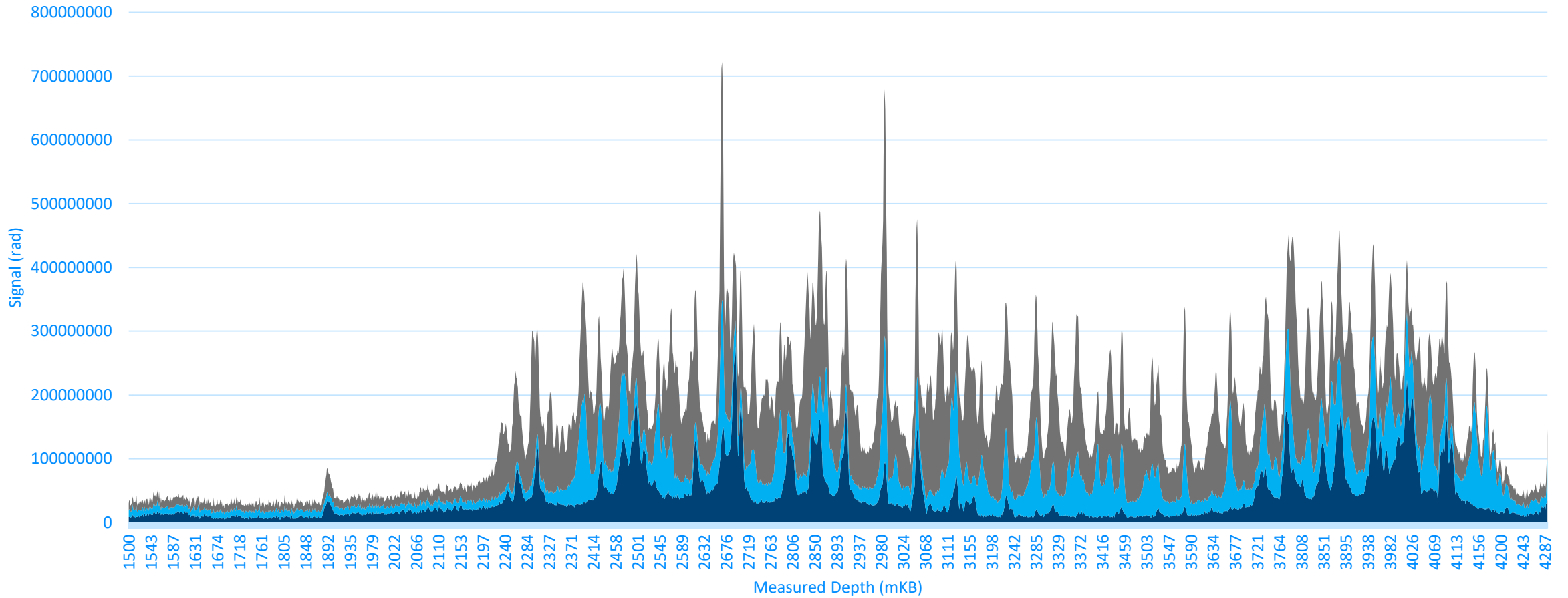
Strain Map – Single Well

Summed Strain by Depth



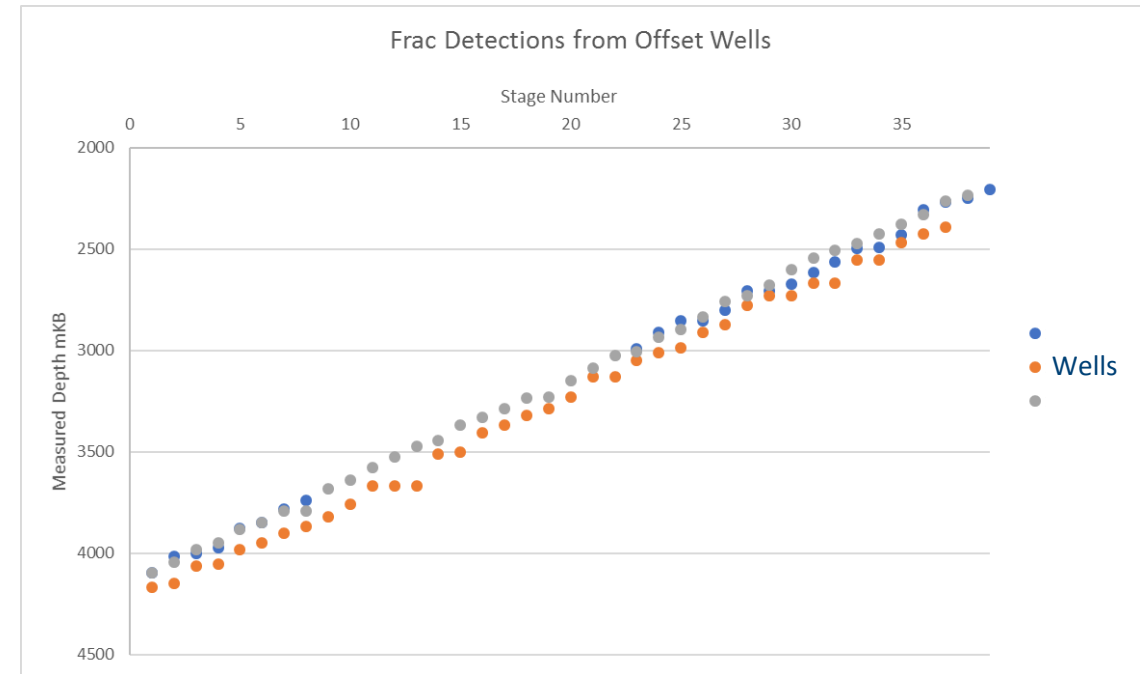
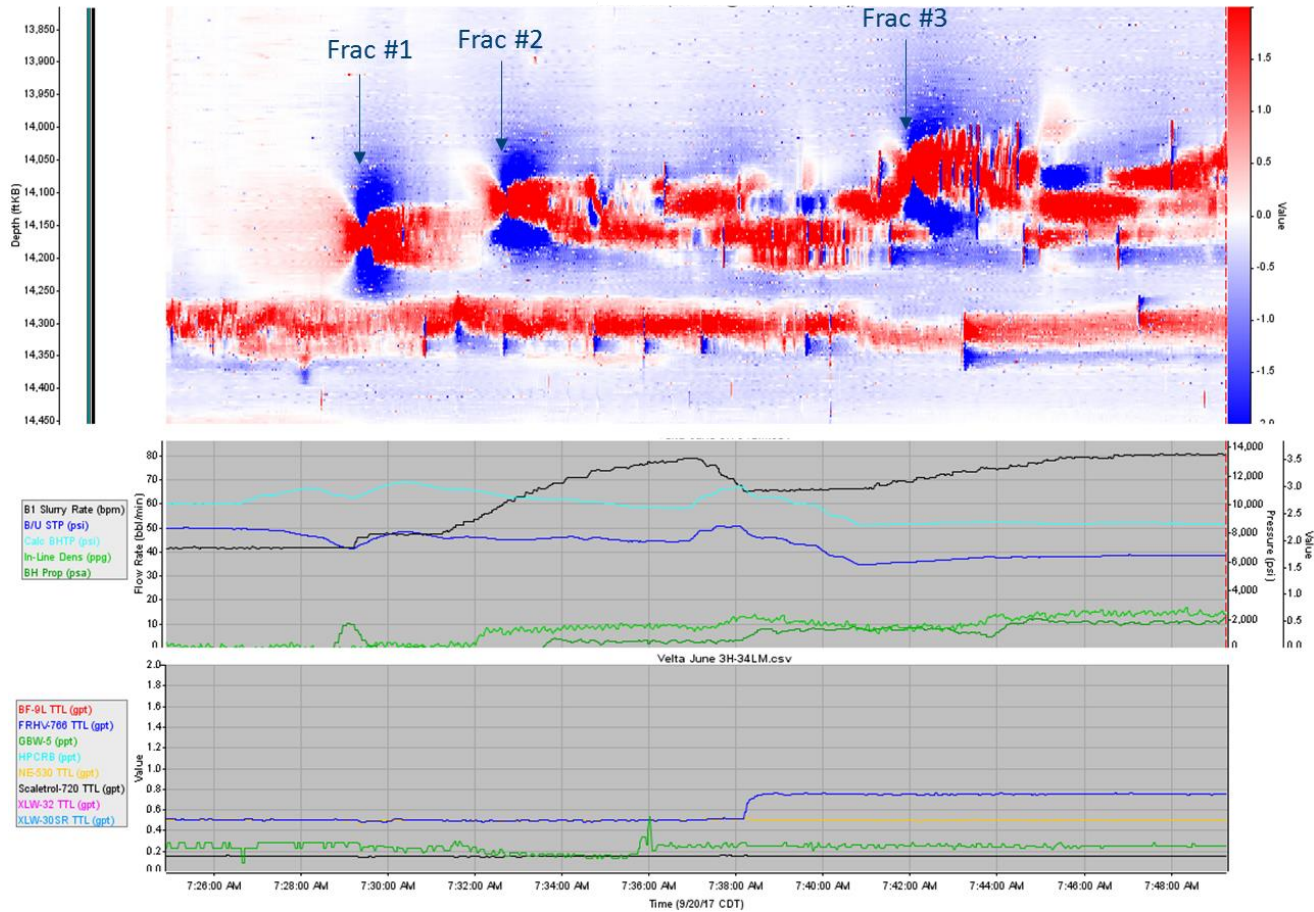
Strain Map – From All Wells (Stacked)

Summed Strain by Depth

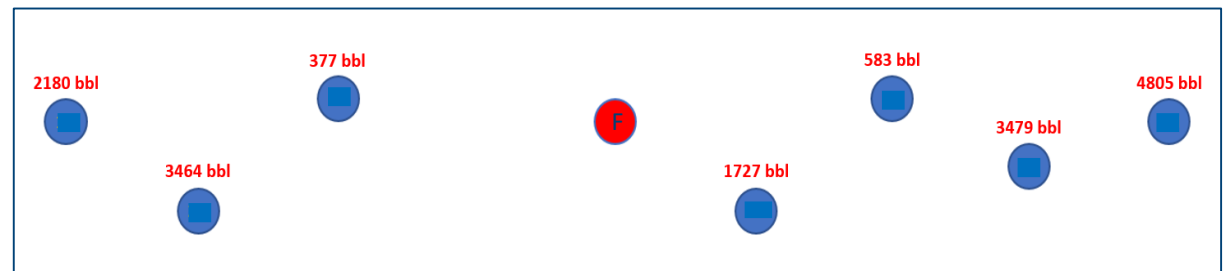
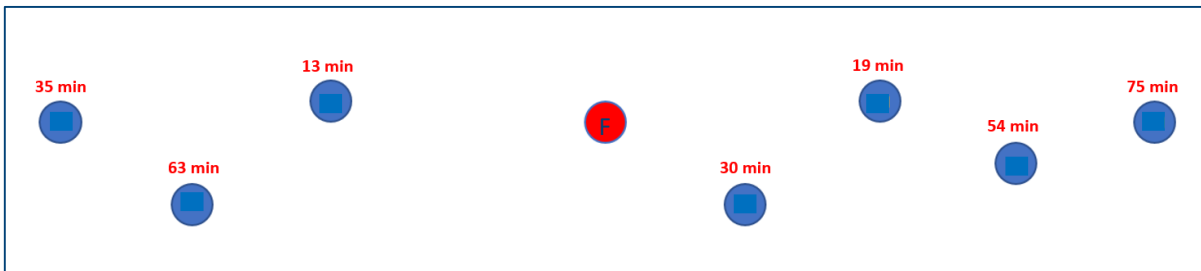
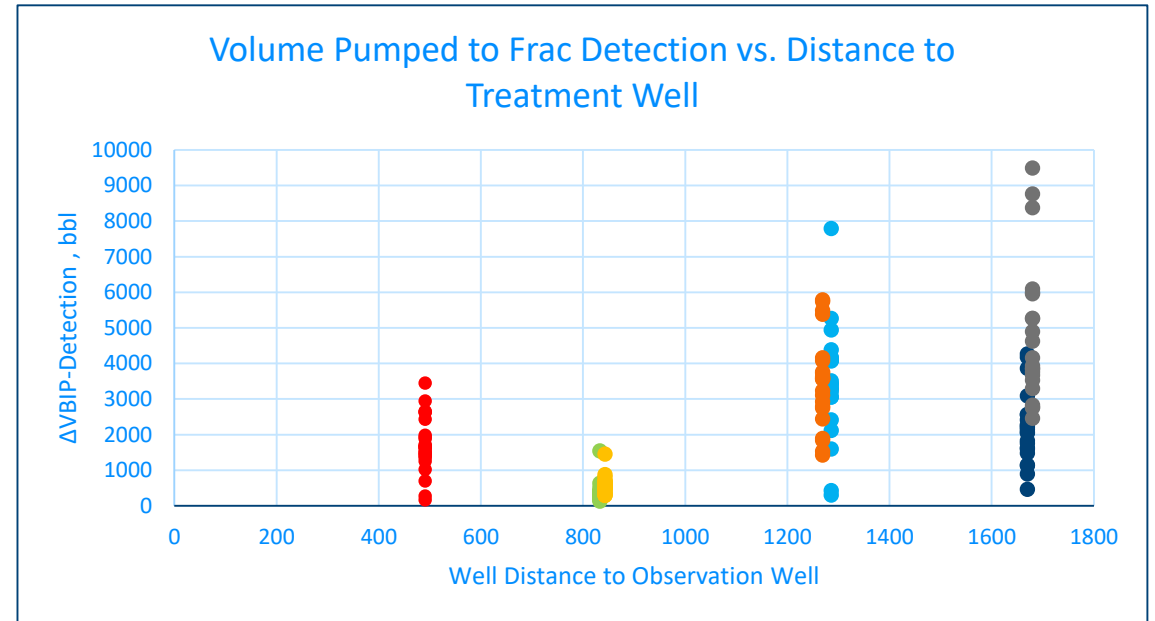
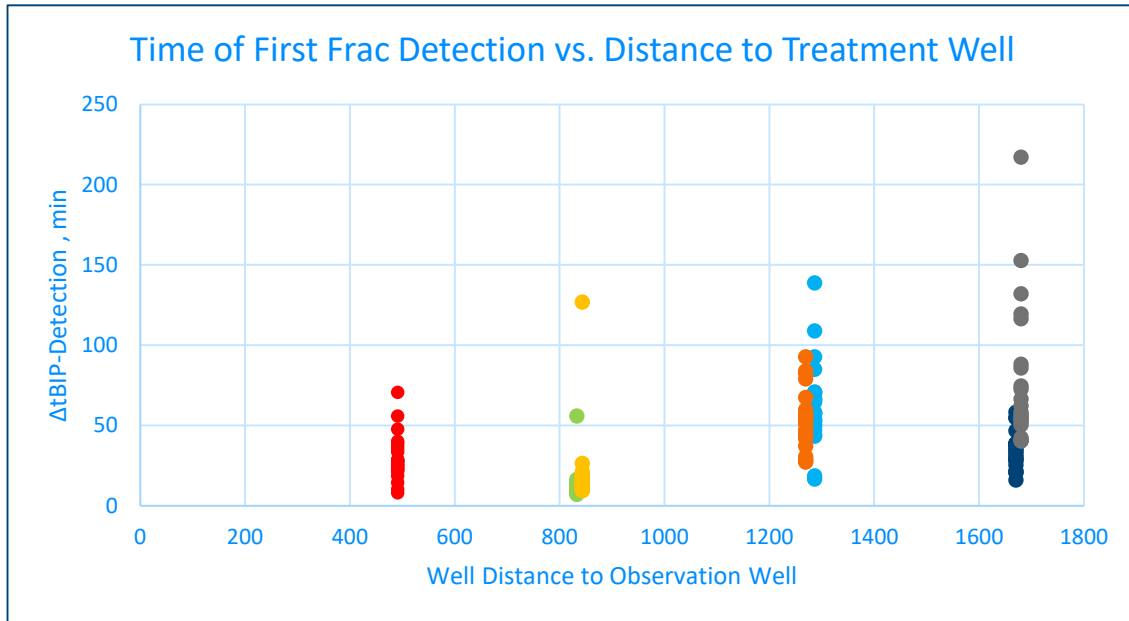


Observations

Counting Frac Hits

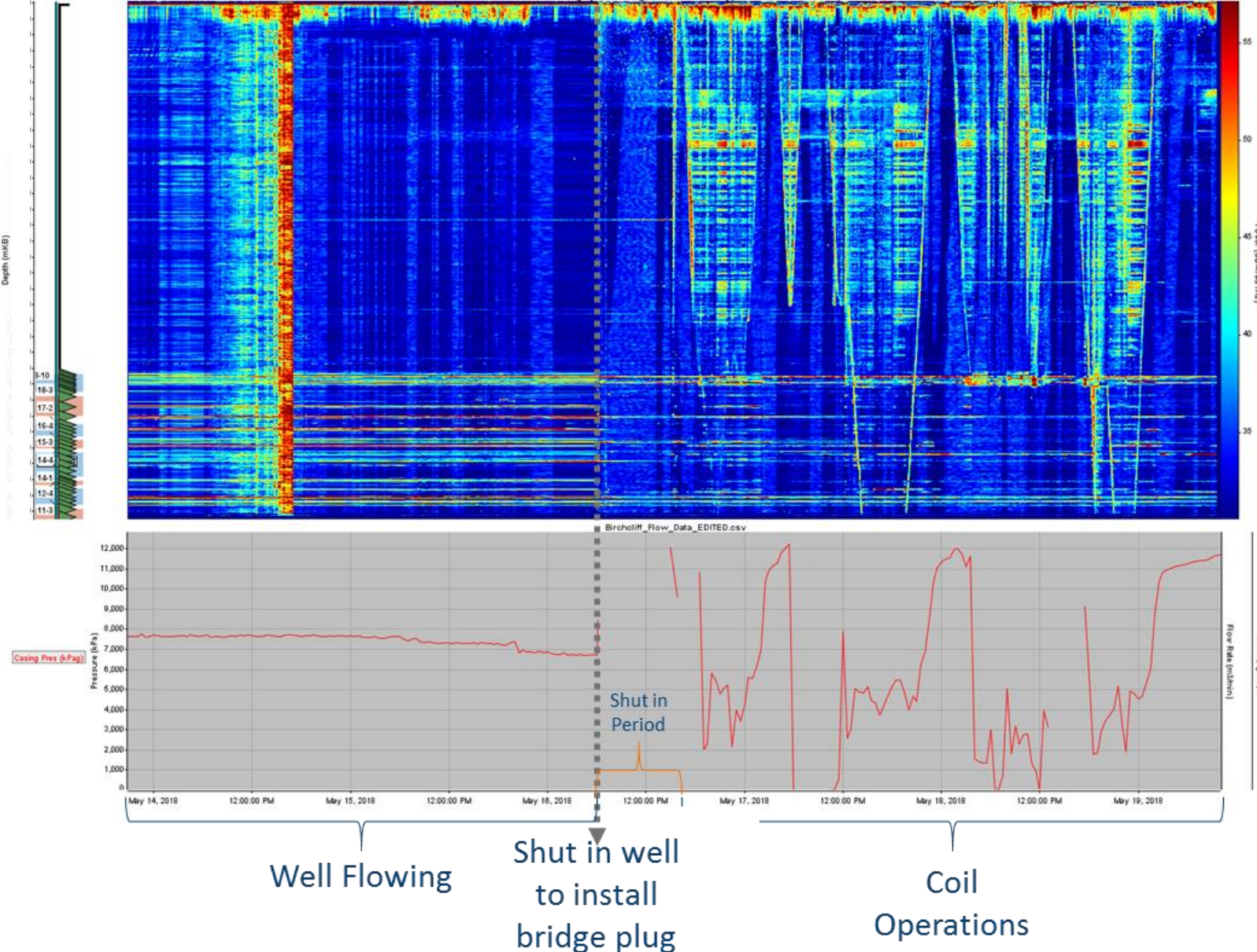


Time-Based Analyses

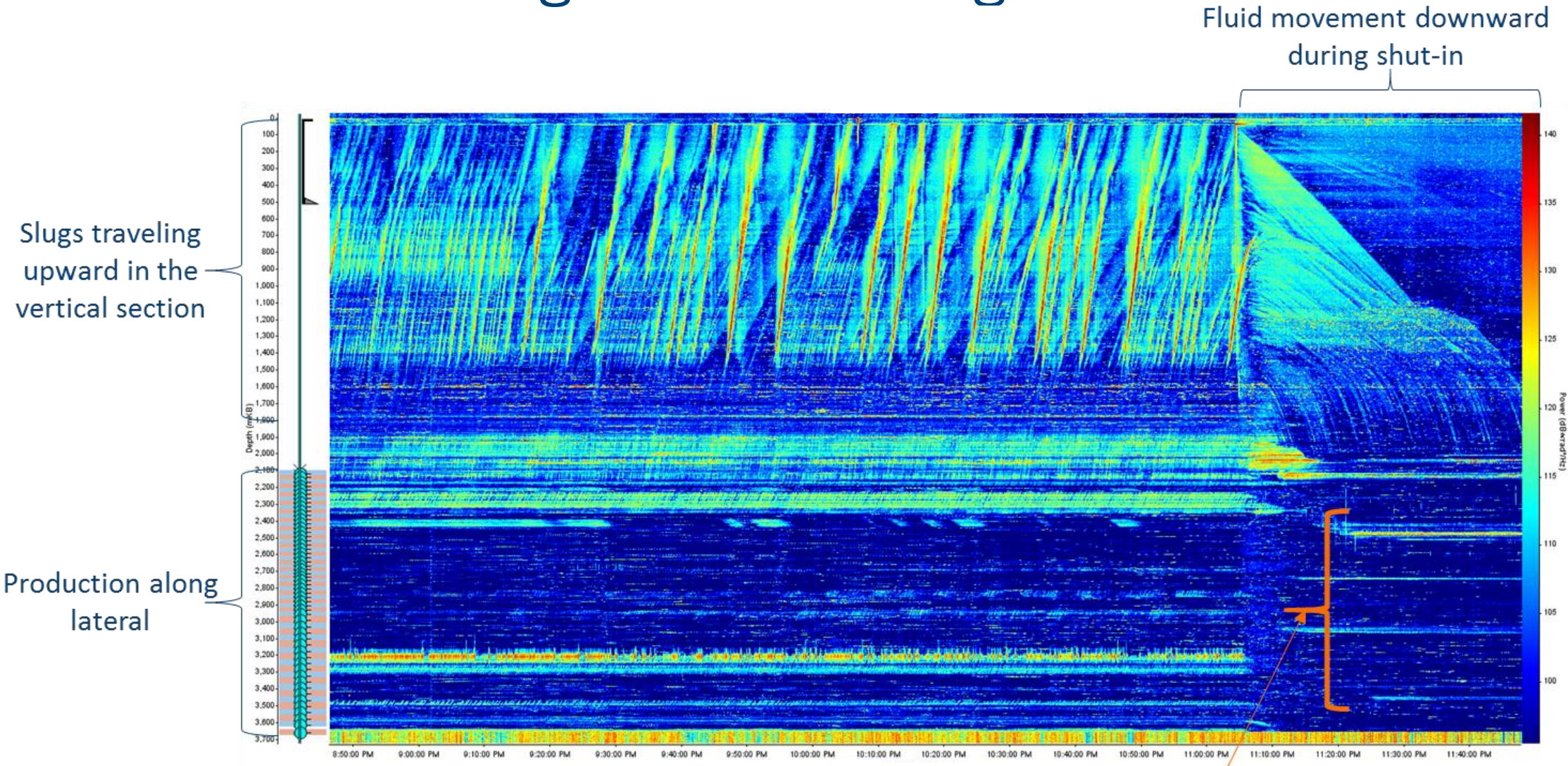


Production Monitoring

Full Wellbore Overview



Production Monitoring with Coil Tubing



Questions