

SPE-224019-MS

"Advanced Techniques for Addressing Critical Injection Well Challenges:
A Focus on Concentric and Hybrid Coiled Tubing, Innovative Inverted DTS
Algorithm and Coanda Effect Technology"

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A LUNA company

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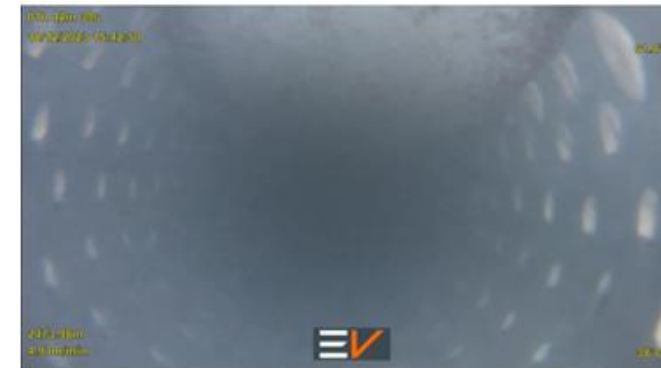
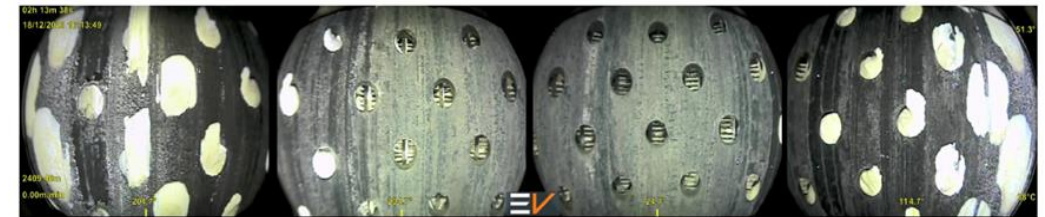
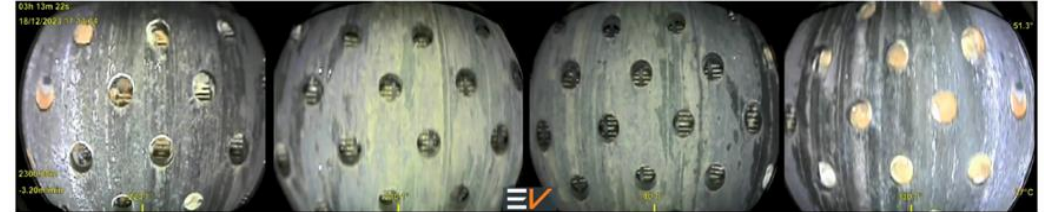


Presentation Outline

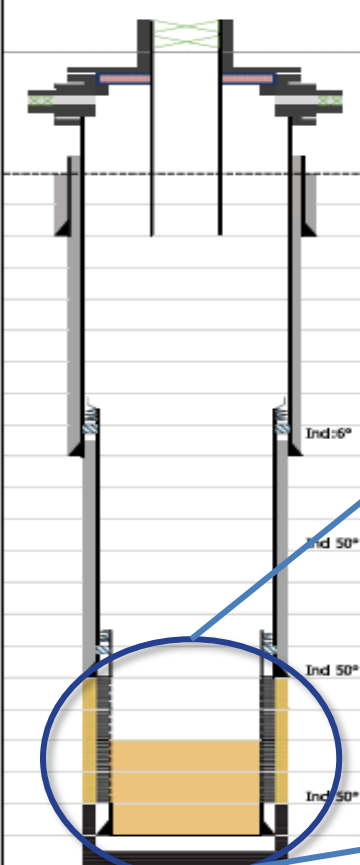
- Project Introduction & Background
- Challenges
- Solutions
- Technology Overview
- Well Intervention Design
- Execution
- DAS & DTS Results
- Results & Potential Improvements

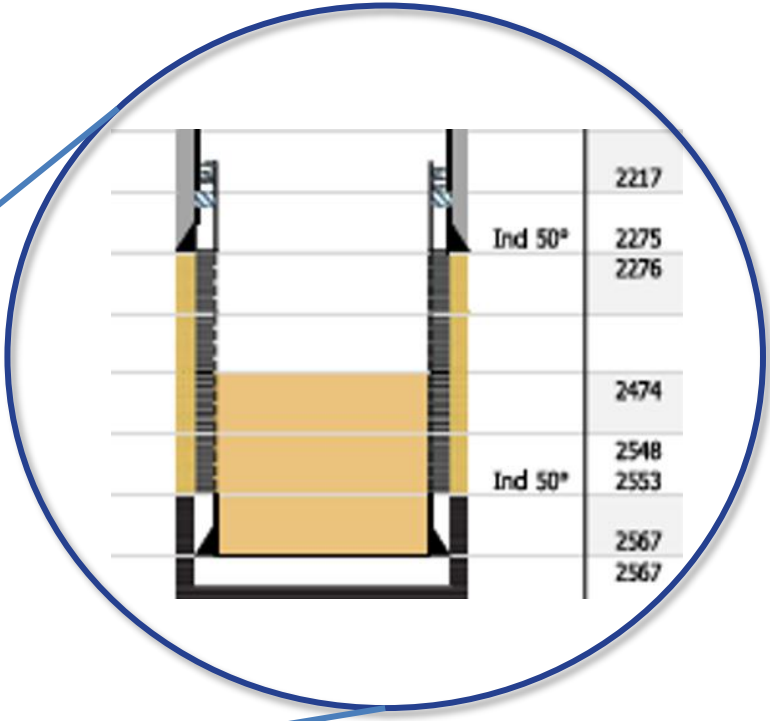
Project Background Overview

- Type of Well: Geothermal injection
- Injectivity Decline: Progressive reduction over time
- Significant drop in injectivity after each well shut-in, with no recovery
- Diagnostic Inspection (Dec 2023) Results:
 - I. HUD Shallower Than Expected: 2474m MD, 90.8m above TD of 2564.8m MD.
 - II. Only 15 out of 22 screens exposed to injection flow, restricting reservoir contact.
 - III. Scaling Buildup: Whiteish scaling material observed in screen holes, blocking fluid flow – most CaCO_3
 - IV. Scaling severity increased with depth, particularly on the low side



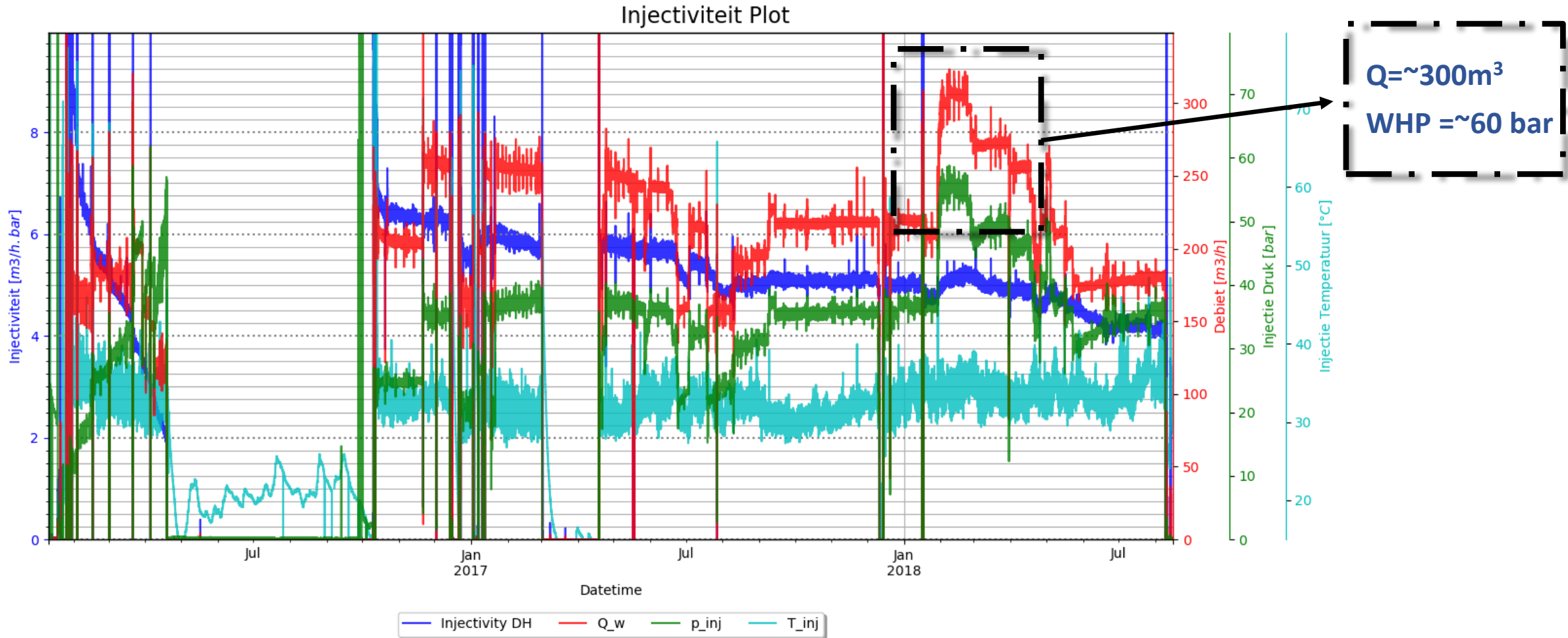
Project Background Overview

Well Code	BRI-GT-02		Revision Date:		
Well Schematic	Depth				
	mAHGL	m TVGL			
	7	7			
	0	0			
	70	70			
	16	16			
	127	127			
	217	217			
	1111	1111			
	Ind:6°	1136	1136		
		1234	1234		
		1233	1233		
	Ind 50°		1774		
		2217	1986		
	Ind 50°	2275	2023		
		2276	2024		
		2474			
		2548			
	Ind 50°	2553	2200		
		2567	2200		
		2567	2209		

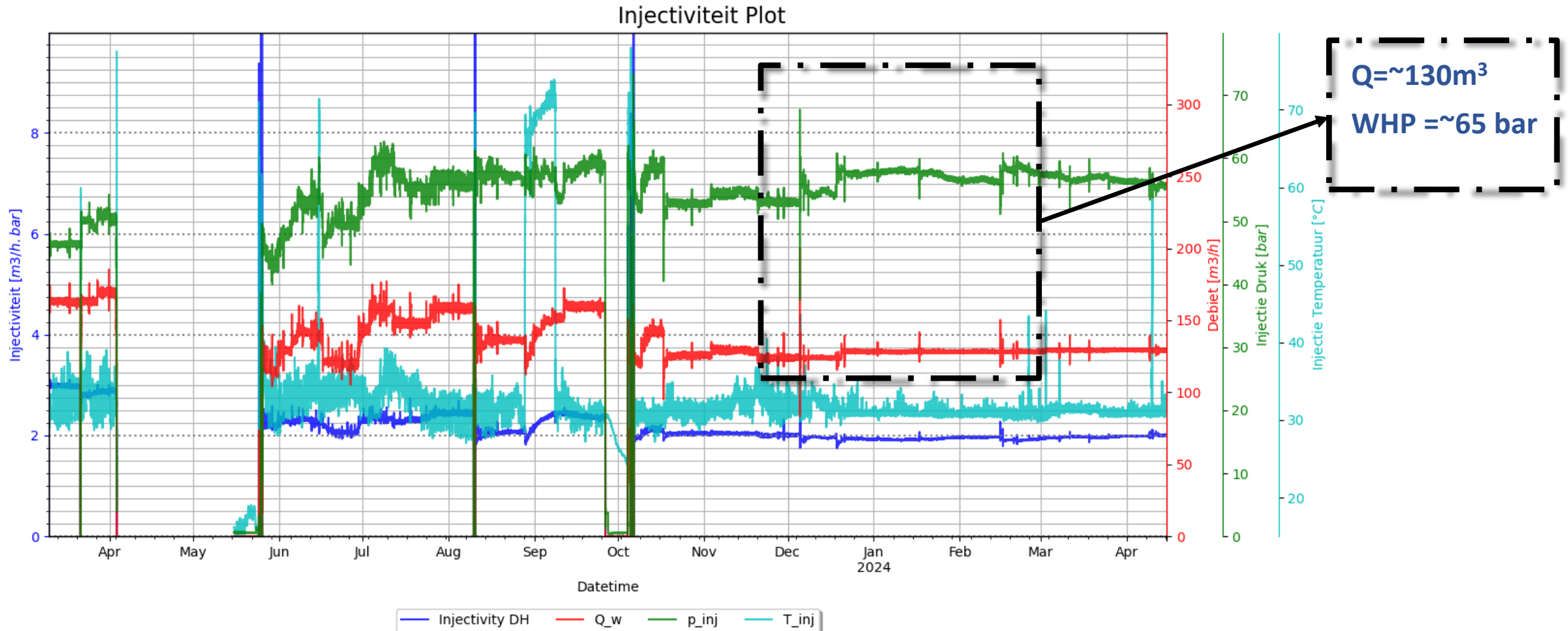


- **Large Completion:** 13 3/8" upper casing section.
- **Formation Limit:** Unable to support full water hydrostatic pressure.
- **Sand Compaction:** ~91m of compacted sand in 7" liner.
- **Inclination:** 50° deviation.
- **No Tapered Guide:** Step transition between 7" liner and 9 5/8" casing

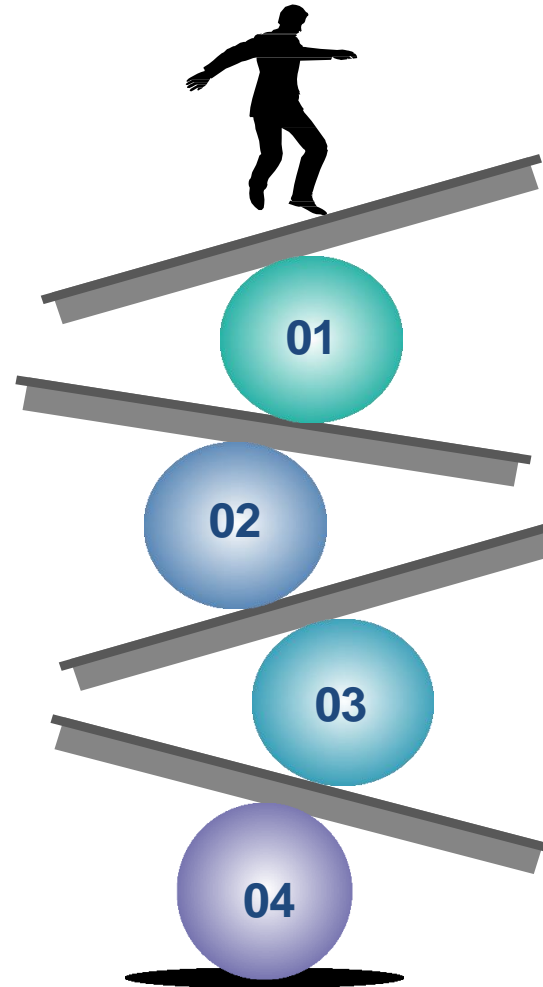
Initial Injectivity Plot



Recent Injectivity Plot



Key Challenges Ahead



2. Scale Removal from Screens:

- Targeted elimination of scale deposits obstructing screen flow paths
- Maximize reservoir contact exposing all 22 screen to the flow paths

4. Injection Profile & Treatment Assessment:

- Usually done after weeks to evaluate new injection parameters
- Water T > than reservoir

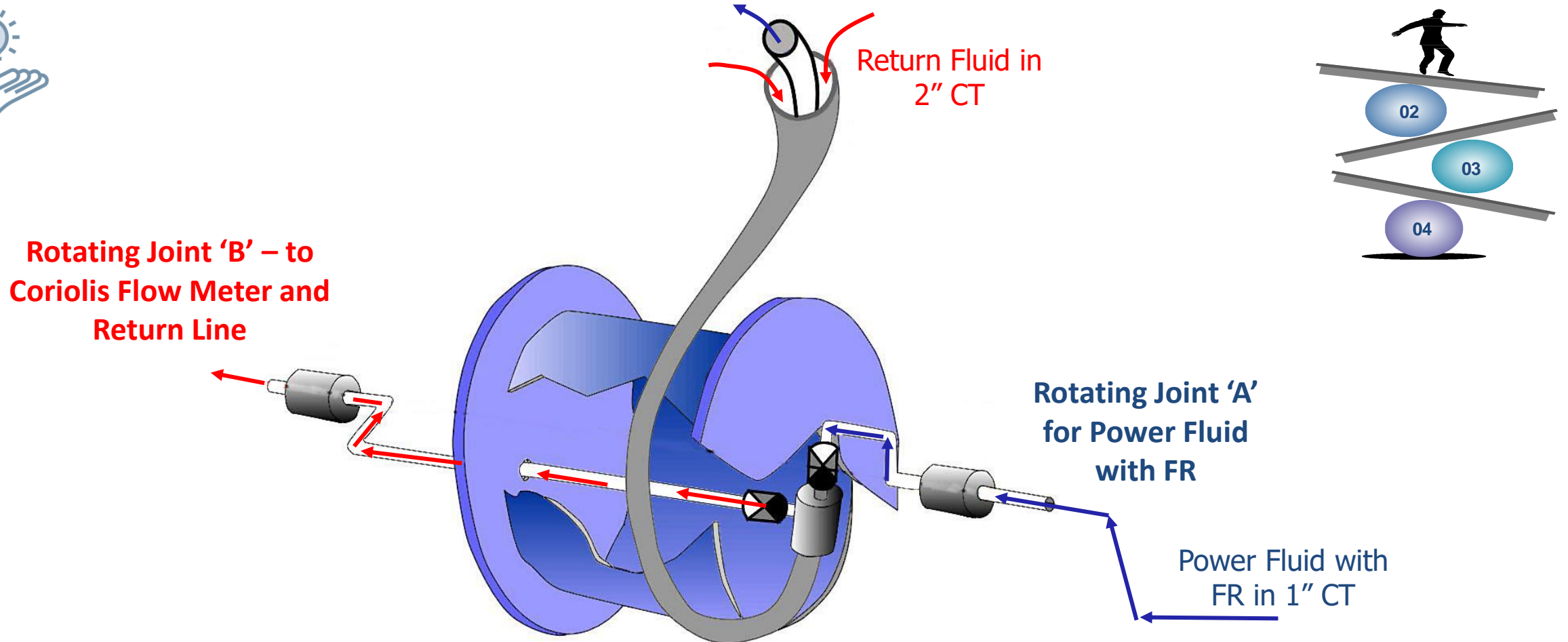
1. Effective Compacted Sand Clean out

- Low Annular Velocity, especially challenging in inclined sections.
- Foam Inefficiency based on previous operational experiences.
- Absence of Tapered in 9 5/8"

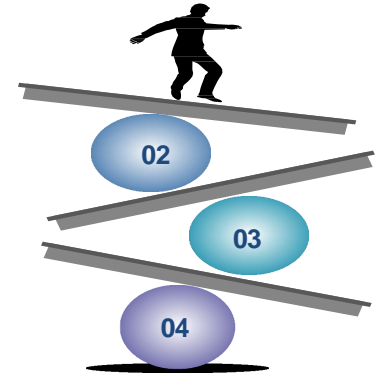
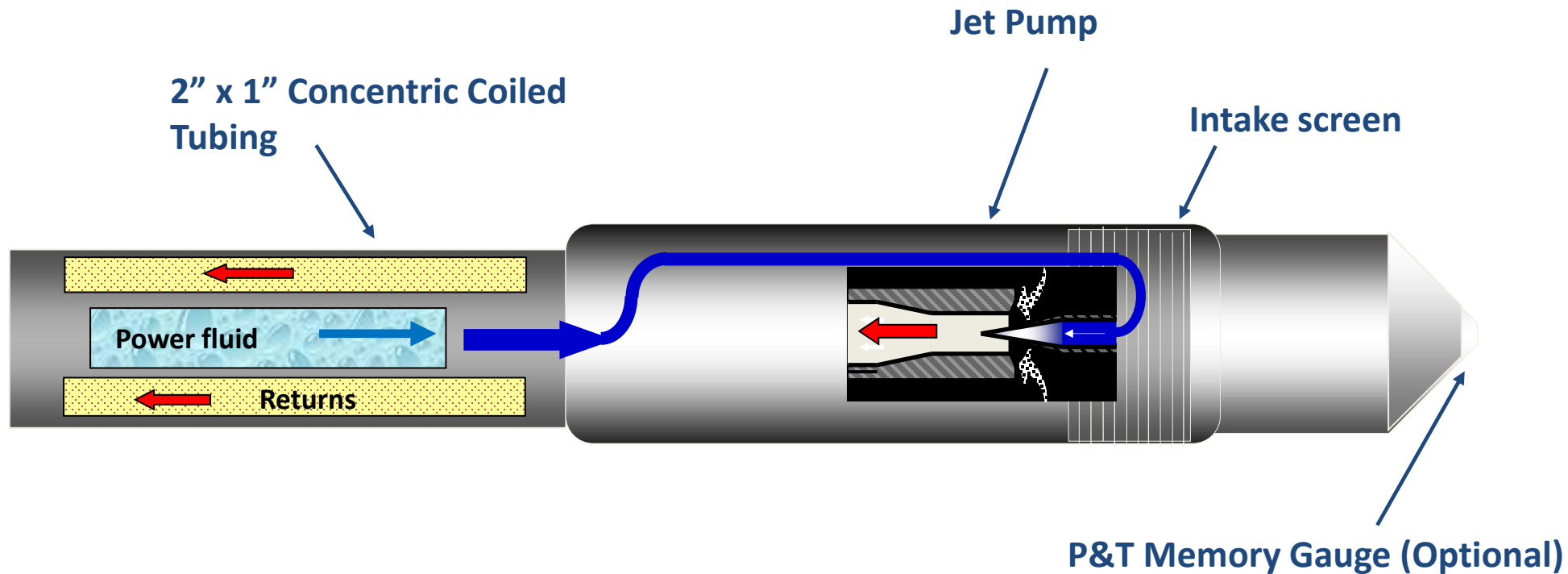
3. Matrix Stimulation:

- Optimize acid recipe due to limited success of previous treatment.
- Slow Acid Propagation: Initial effects observed ~ 10 days post-injection.

Concentric Coiled Tubing



Concentric Downhole Tool



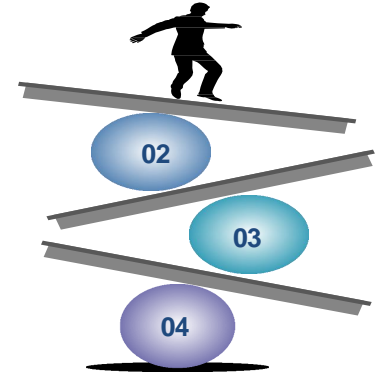
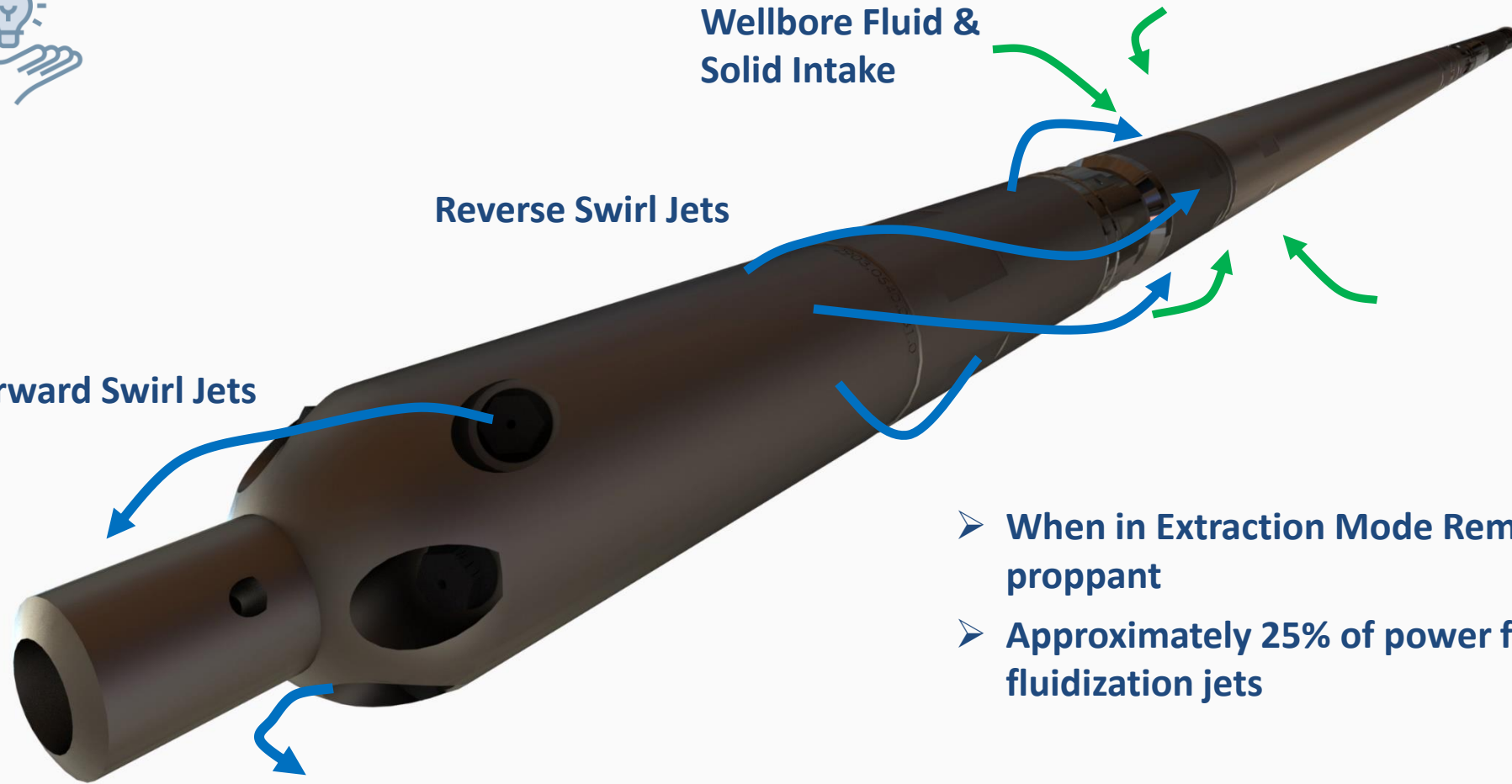
Concentric Downhole Tool – Extraction Mode



Wellbore Fluid & Solid Intake

Reverse Swirl Jets

Forward Swirl Jets



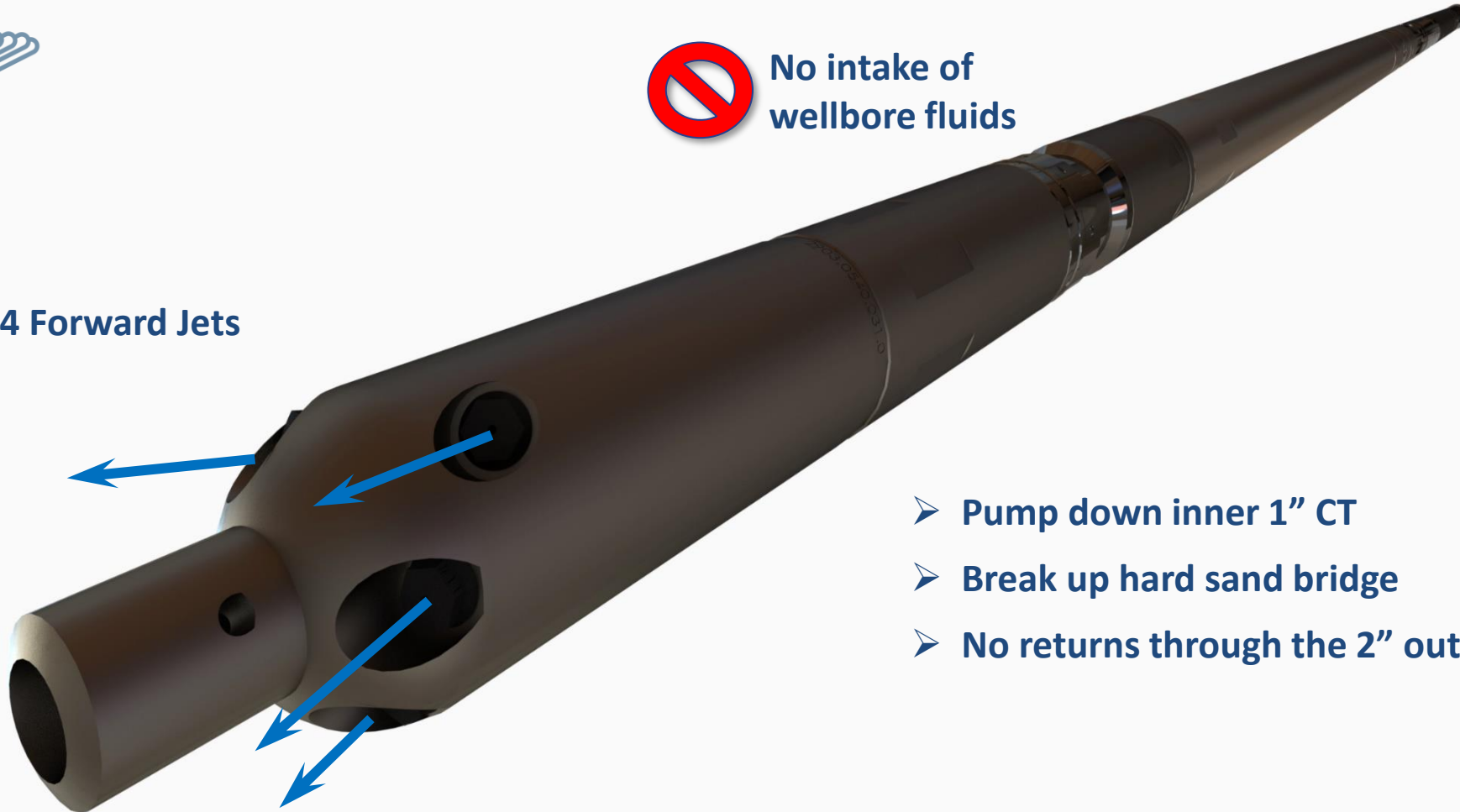
- When in Extraction Mode Remove sand or proppant
- Approximately 25% of power fluid goes to fluidization jets

Concentric Downhole Tool – Jetting Mode

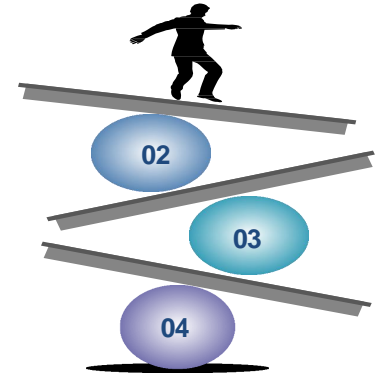


 No intake of wellbore fluids

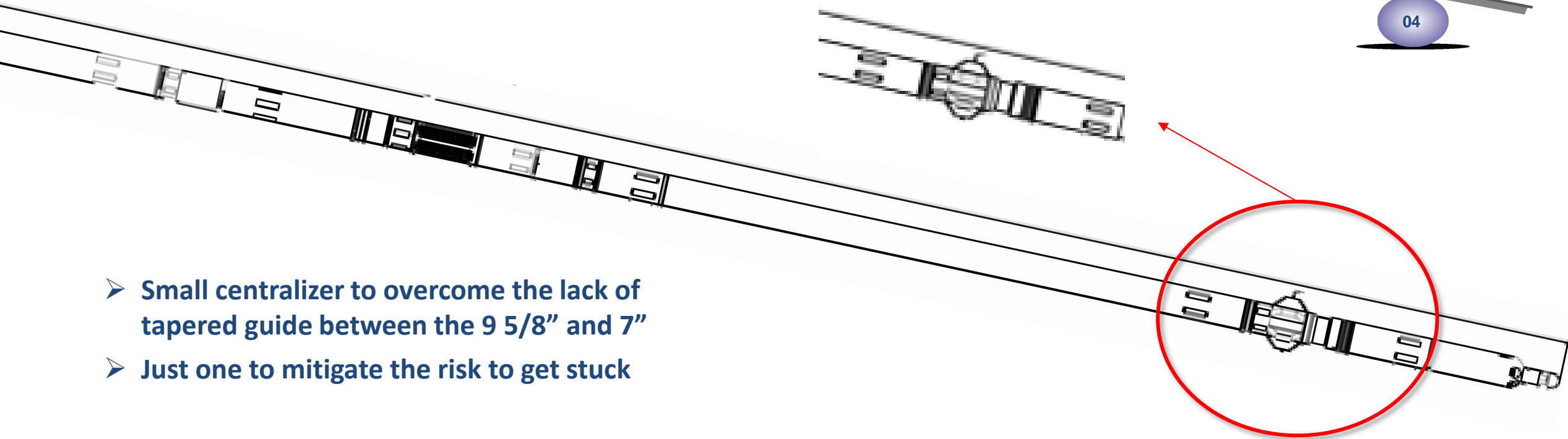
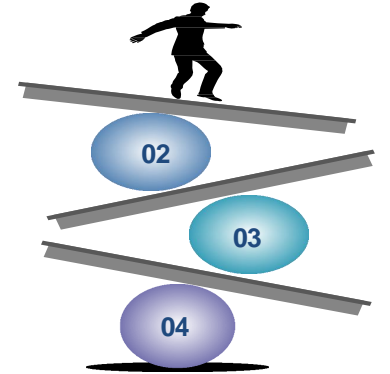
4 Forward Jets



- Pump down inner 1" CT
- Break up hard sand bridge
- No returns through the 2" outer CT



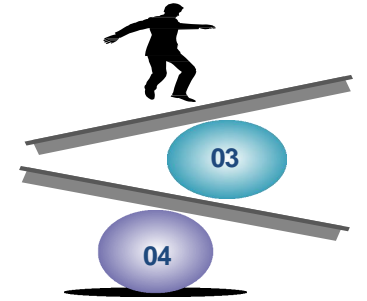
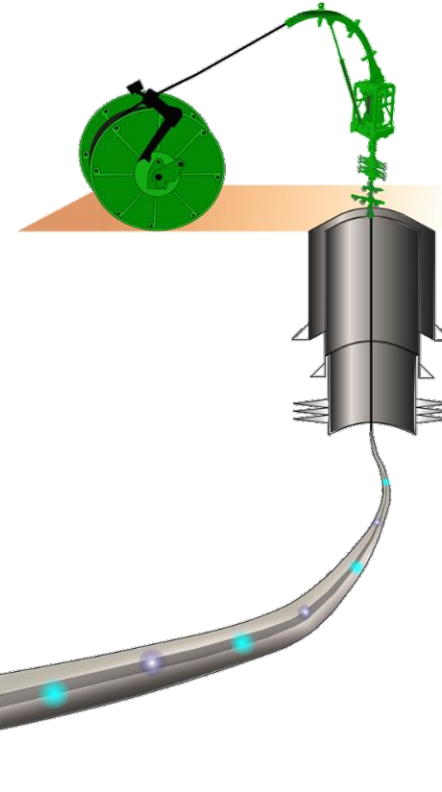
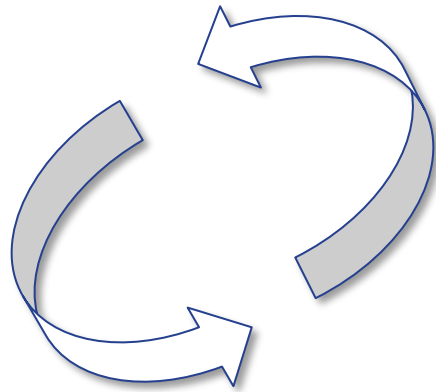
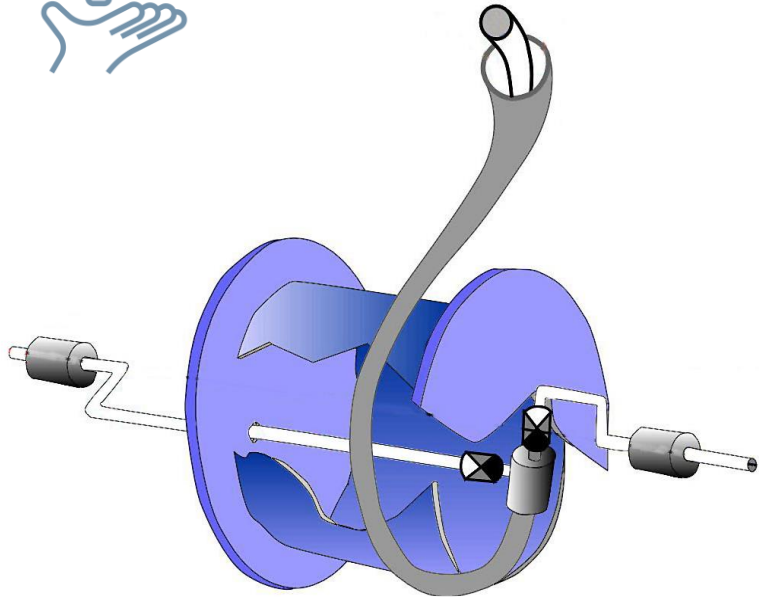
Concentric Downhole Tool – Customized Centralizer



- **Small centralizer to overcome the lack of tapered guide between the 9 5/8" and 7"**
- **Just one to mitigate the risk to get stuck**

Stimulation

Swapping Technologies – From CCT to HCTT

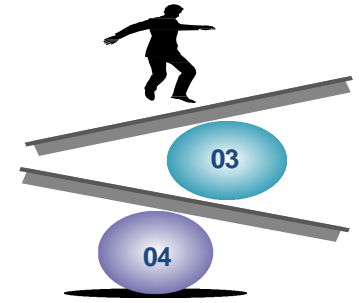
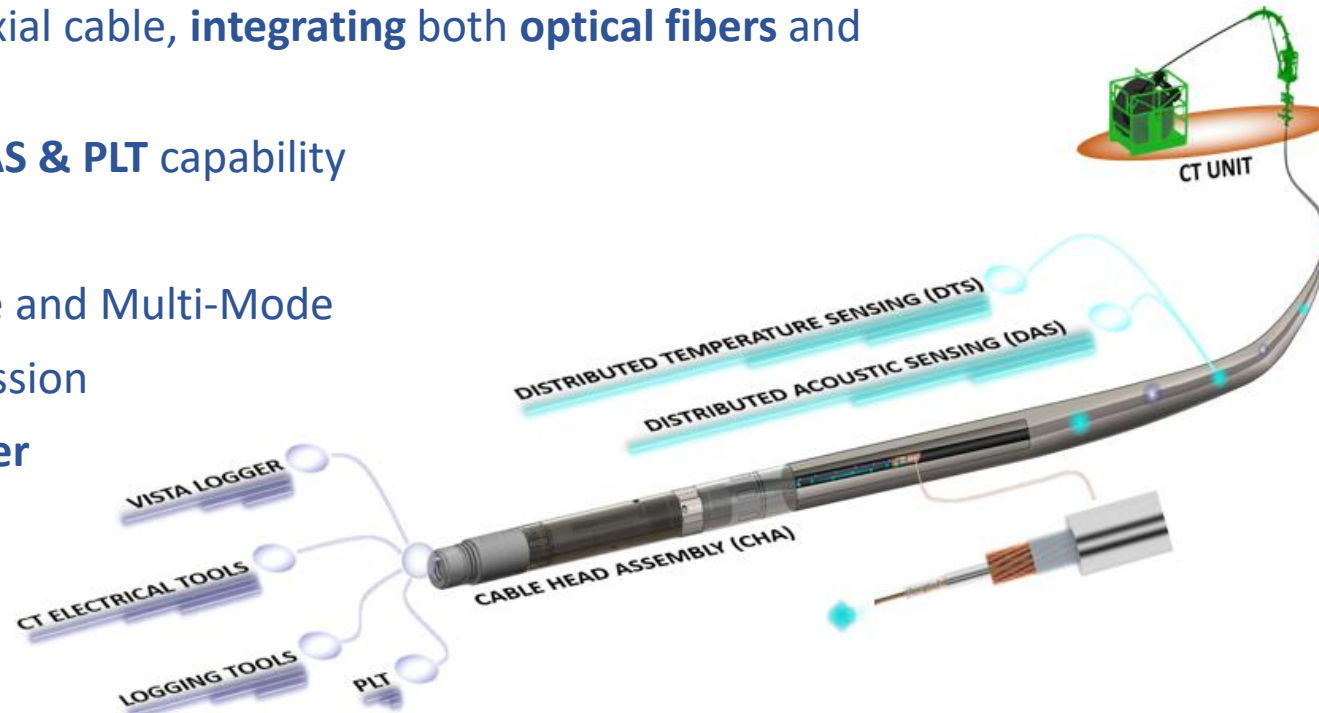


Hybrid CT Technology



Hybrid Coiled Tubing Technology:

- Combines CT with 4mm OD coaxial cable, **integrating** both **optical fibers** and **electrical conductor**
- Technology **Integration: DTS, DAS & PLT** capability
- Operational Mechanisms:
 - Optical Fibers: Single-Mode and Multi-Mode for **DFS**O and **Data** Transmission
 - Electrical Conductors: **Power** supply and **Data** transfer
- Real-Time **Sensing** BHA



Downhole Tool - COANDA Effect

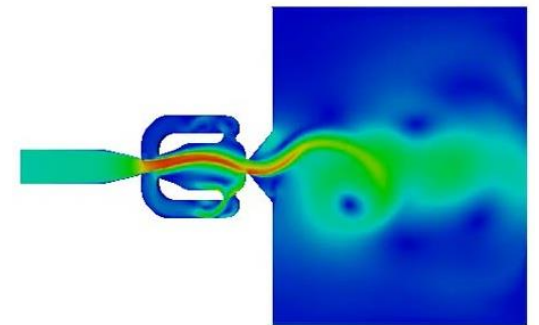
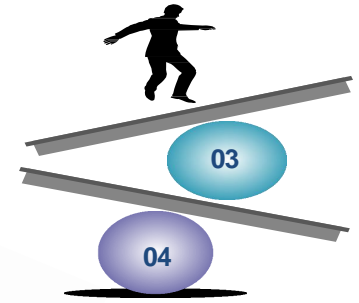
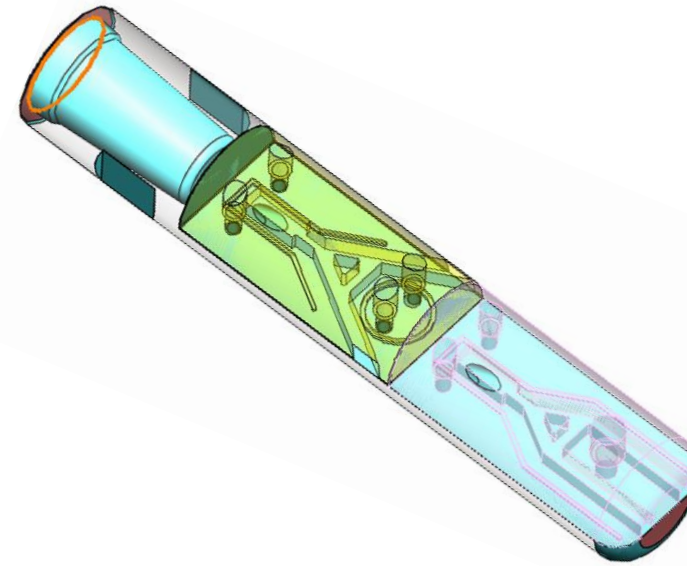


COANDA Technology

- Tool based on **COANDA*** effect, a proven fluidic **oscillator technology** which causes pressure waves, that create pulsating pressure waves within the wellbore and formation fluids.
- Pressure waves propagate radially from the tool and can breakup many obstacles
- Eliminates the standoff requirements of jetting nozzles
- Metal to Metal seals with no moving parts to fail

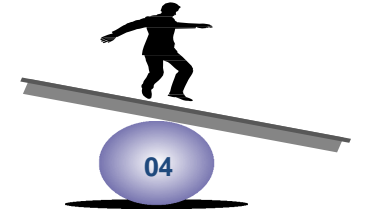


**Coanda Effect: A moving stream of fluid in contact with a curved surface will tend to follow the curvature of the surface rather than continue traveling in a straight line*



Stimulation

Equation for Matrix Stimulation



Restore or Improve Formation Injectivity

=

Chemical Action + Mechanical Action

⇒

Effective Matrix Stimulation

⇒

Increase Fluid Propagation Velocity Over Time = $\frac{\Delta v_{fluid}}{\Delta t} > 0$



Tailored Acid Recipe



Scale Removal Action:

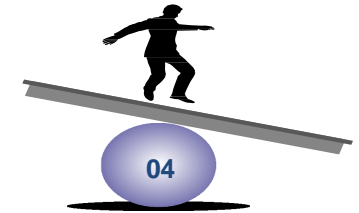
- HCl effectively removes scales by reacting with calcium carbonates ($CaCO_3$). Chemical Reaction:



- Fast reaction kinetics: 2 hours are enough for nearly complete carbonate conversion.

Preventive Action:

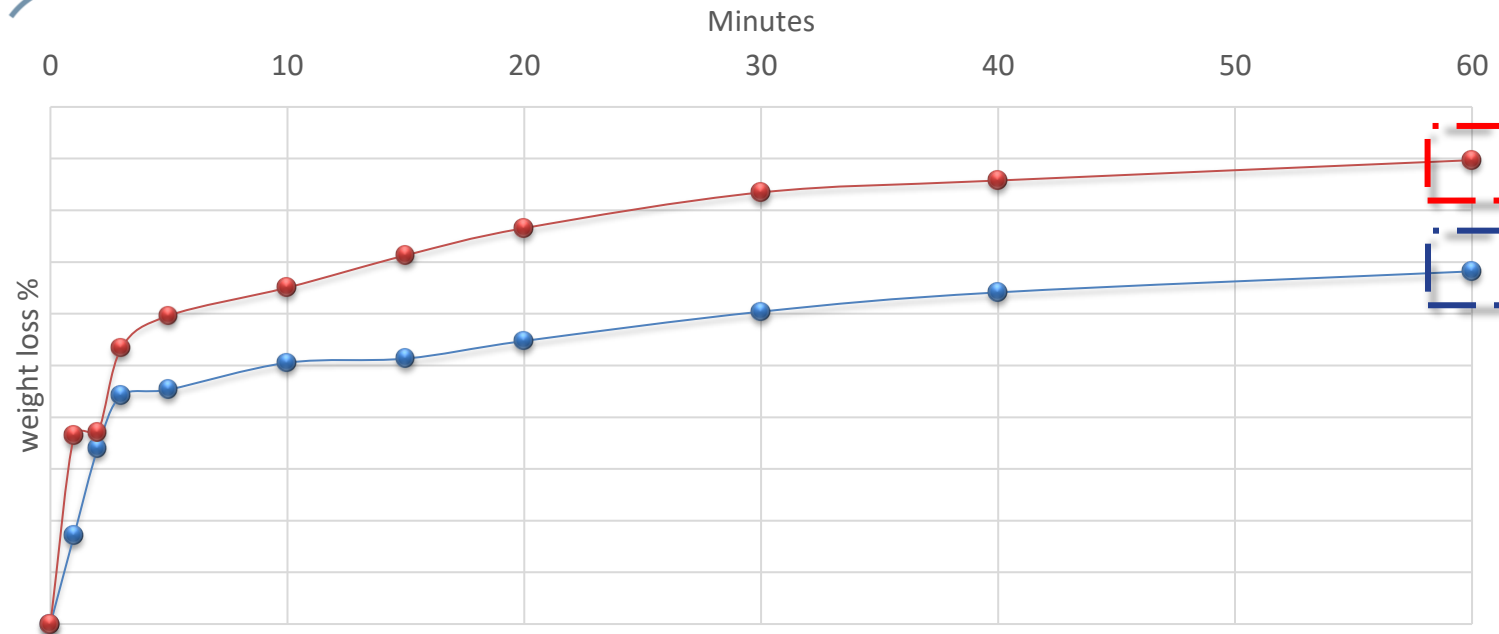
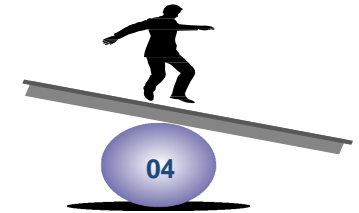
- Scale Preventer: XSCAL 2 Utilizes phosphonate acid (HPO_3^{2-}) to keep alkaline earth metal ions in soluble form by binding to their positive charges..



04



Tailored Acid Recipe



HCl 20% with a weight loss % of:

HCl 15% with a weight loss % of:



Inverted Algorithm – Cool Down Model



$$T_{\text{Water Injected}} > T_{\text{Reservoir}} \\ \Rightarrow$$

DTS warm-back model not applicable

\Rightarrow

A reverse version of the analytical warm-back

$=$

DTS cool-down model



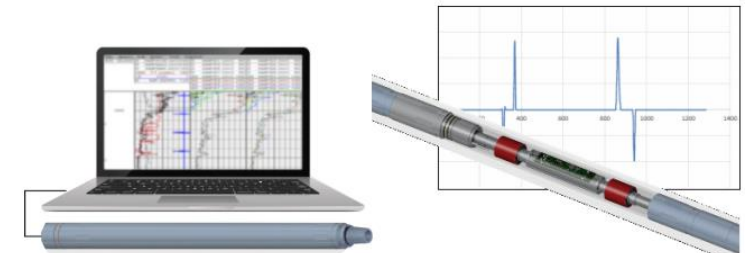
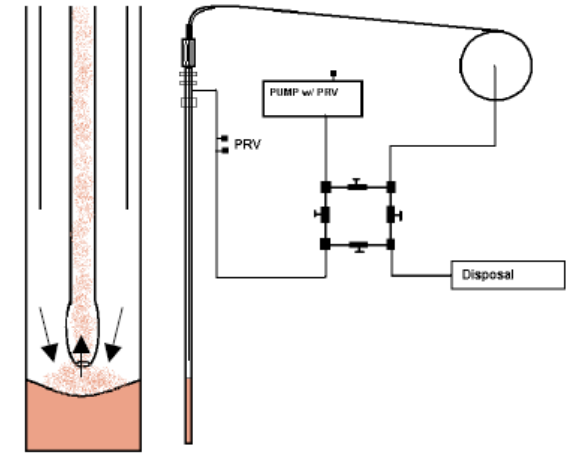
Final Job Desing

1. CCT Run:

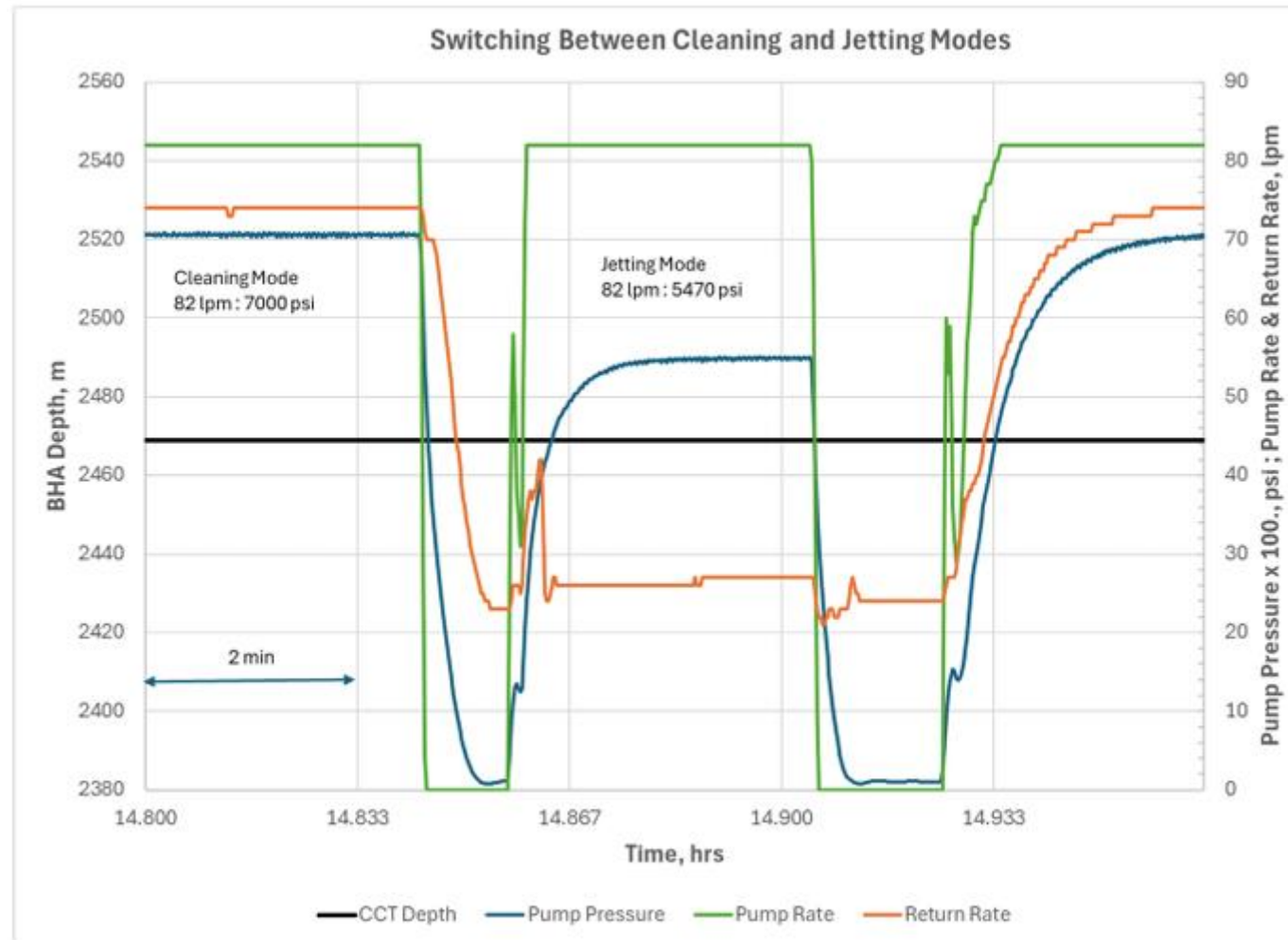
- Pump at target rate while descending, maximizing suction as much as possible.
- Upon approaching the Top of Sand proceed in bites of up to 10 ft.
- Switch to Jetting mode to break up the top of sand (when/if required).

2. HCTT Run

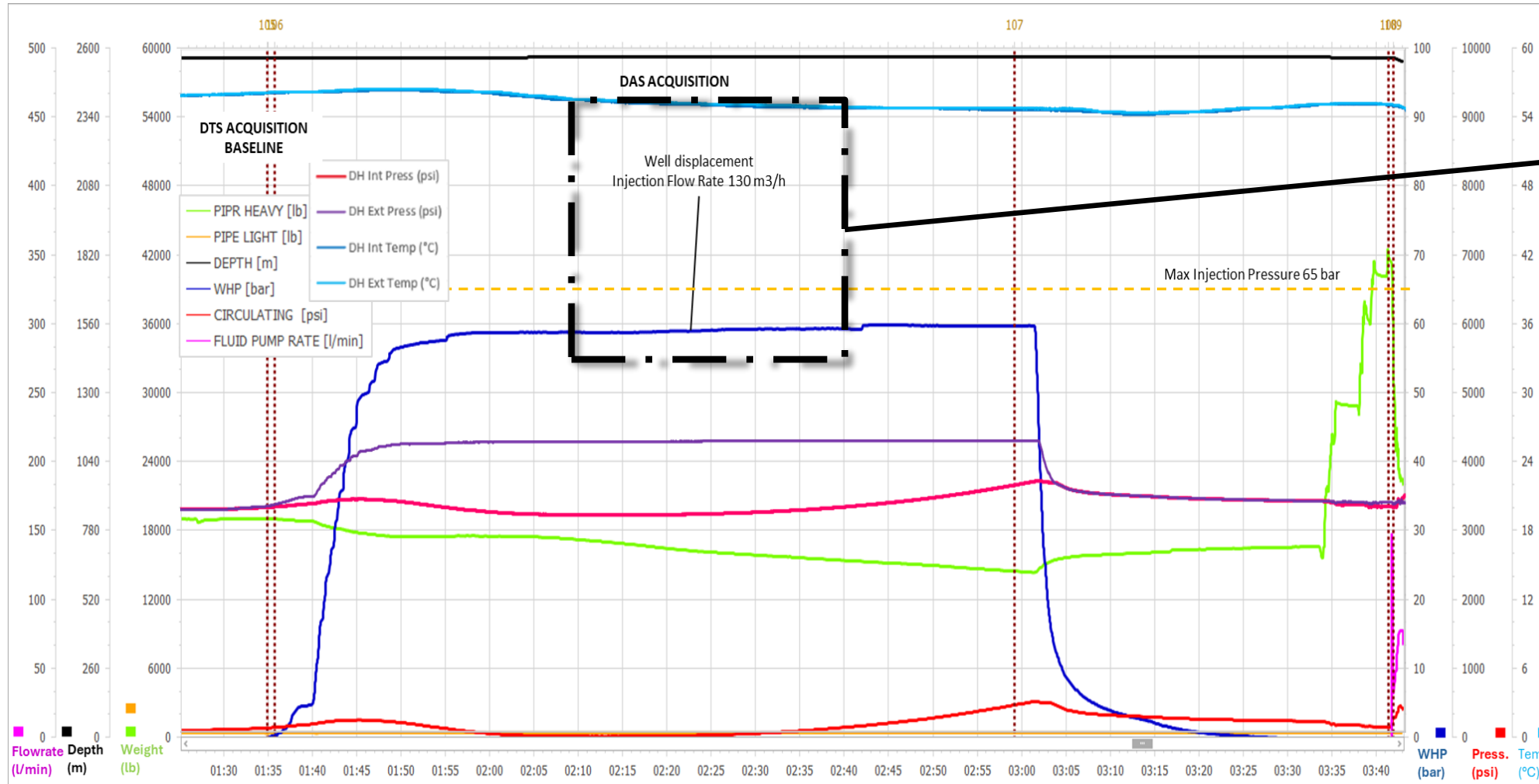
- Confirm TD and all 22-screen exposed to injection flow with RT BHA and Active CCL
- Acquire baseline DTS & DAS data and pre-stimulation injection profile.
- Conduct Acid Stimulation, leveraging the COANDA effect for pin-point stimulation.
- Perform Post-Acid DTS & DAS injection profile assessment



Well Intervention Execution



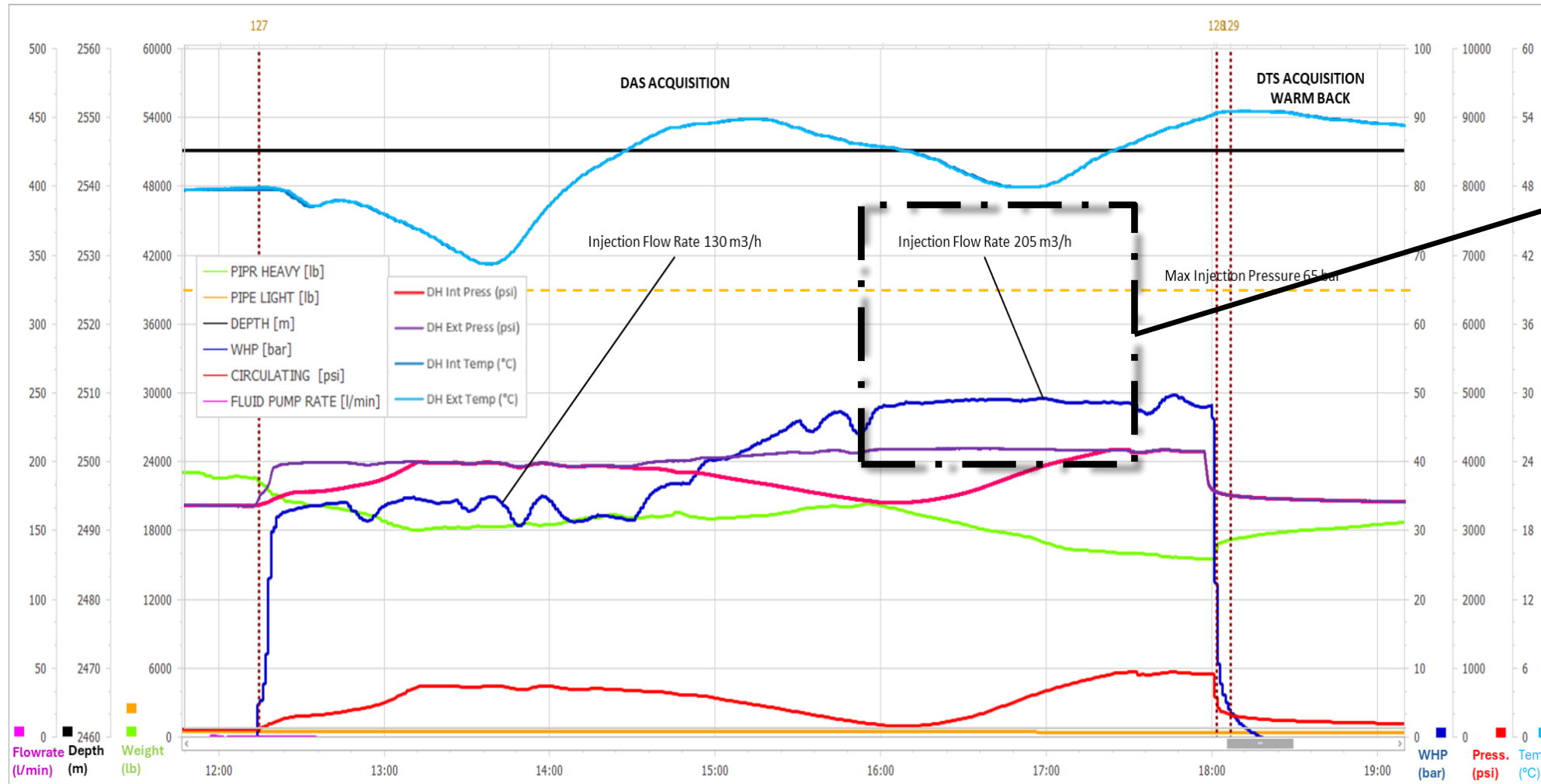
Well Intervention Execution



Q ≈ 130 m³
WHP ≈ 65 bar



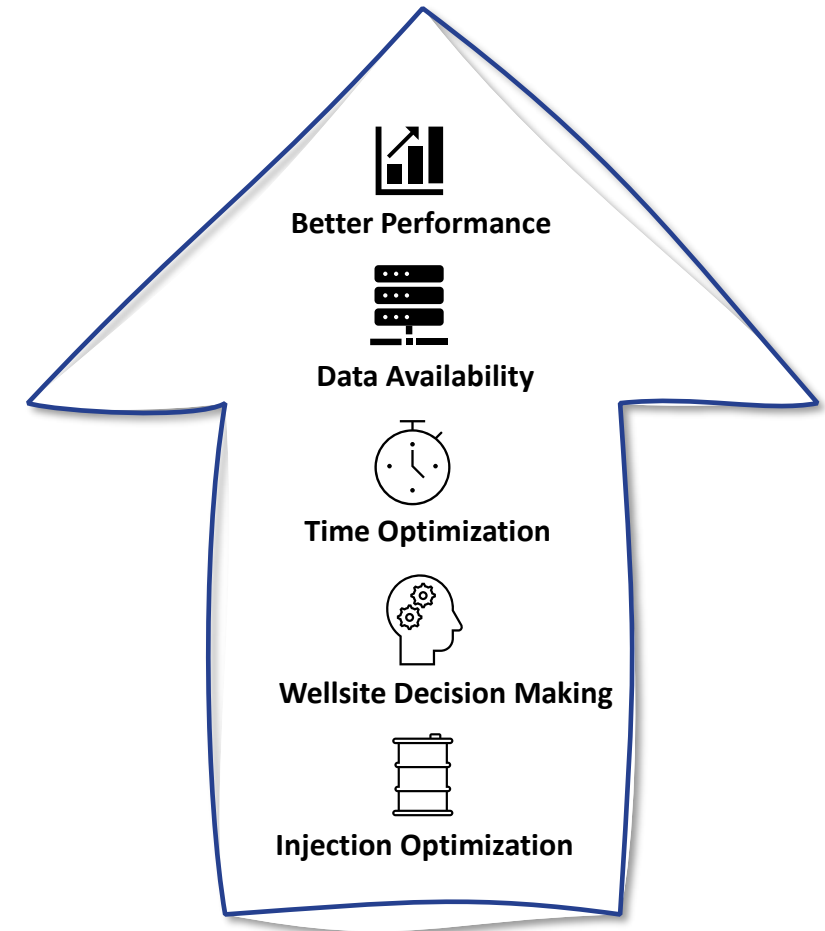
Well Intervention Execution



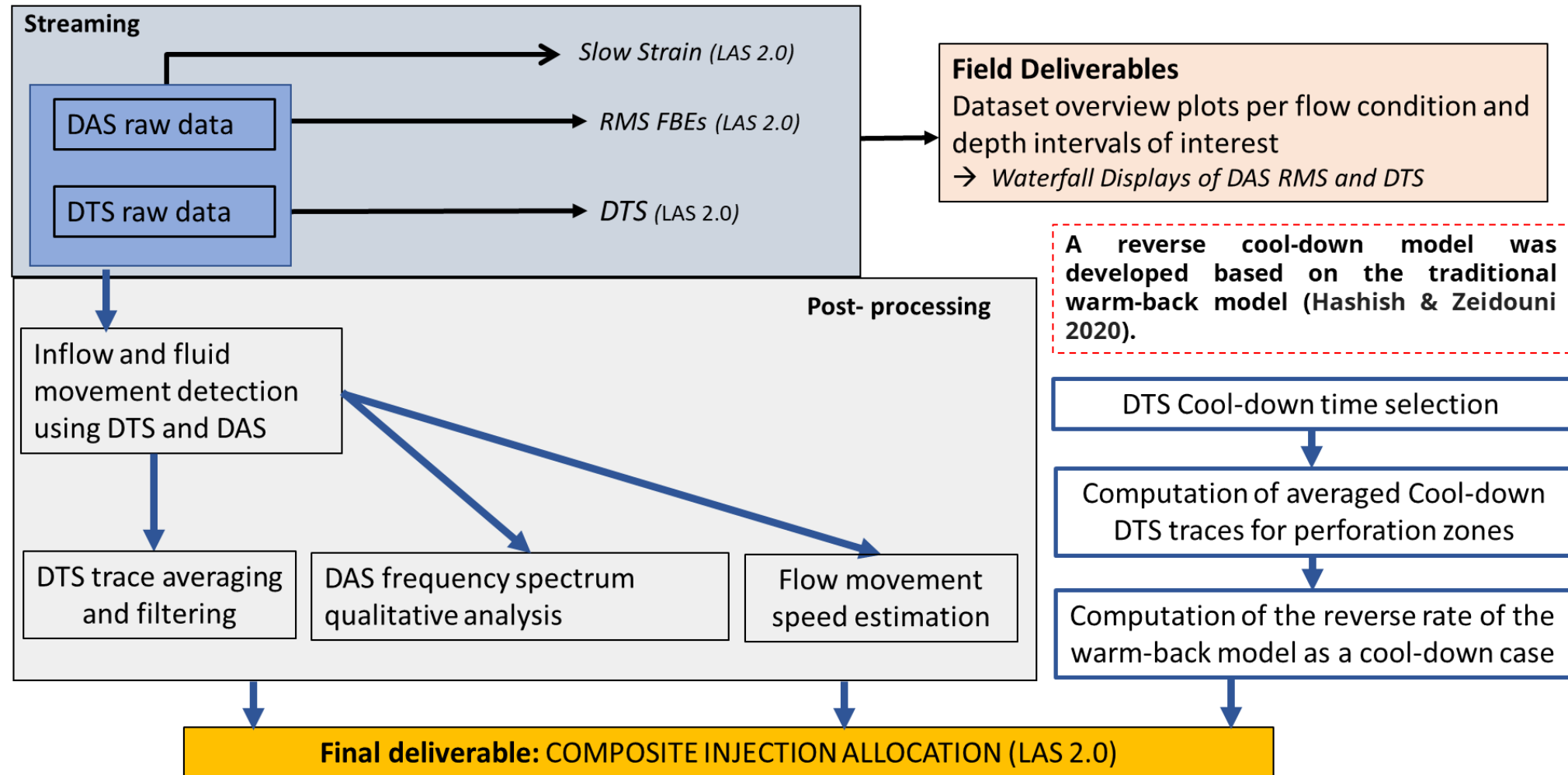
Q=~205m³
WHP =~40 bar

Results Overview and Possible Improvement

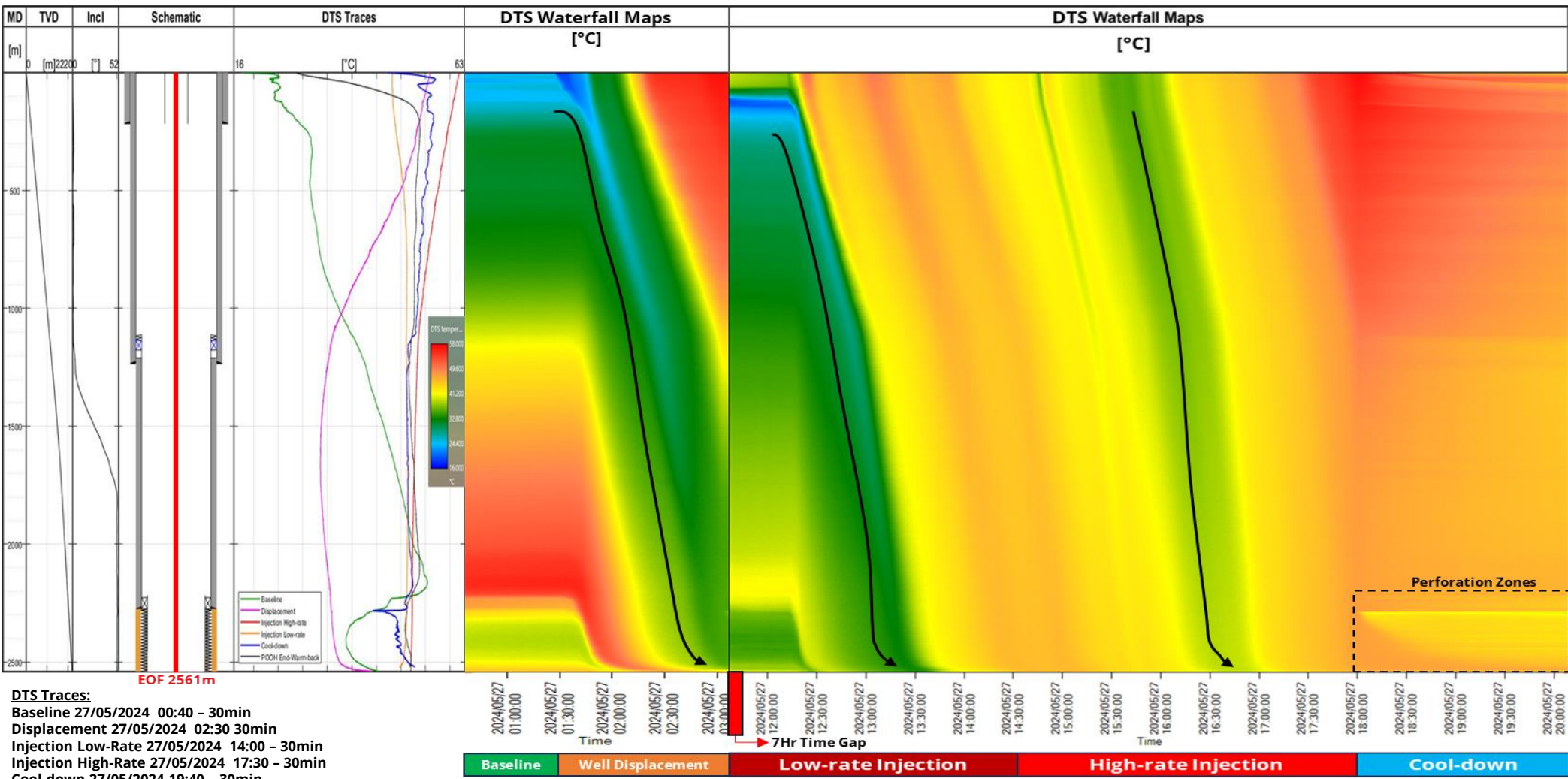
- **CCT Proven as Optimal Solution:** CCT confirmed to be the best option in similar conditions, achieving complete sand removal from the well.
- **Efficient CT Swap with Real-Time BHA:** Swapping Coiled Tubing took only a few hours, with significant contribution from the Real-Time BHA.
- **Enhanced Acid Propagation:** The COANDA effect combined with a tailored 20% HCL recipe significantly improved well performance and acid propagation.
- **DTS Analysis with Inverted Algorithm:** The inverted algorithm for DTS analysis demonstrated strong results.
- **DTS & DAS for Efficiency:** DTS & DAS analysis reduced time and costs by eliminating the need for additional well interventions for injection profiling.
- **Optimized Acid Treatment:** Leveraging DTS & DAS, along with the RT BHA and Coanda effect, a mud acid to treat the lower sandstone layer could be implemented.



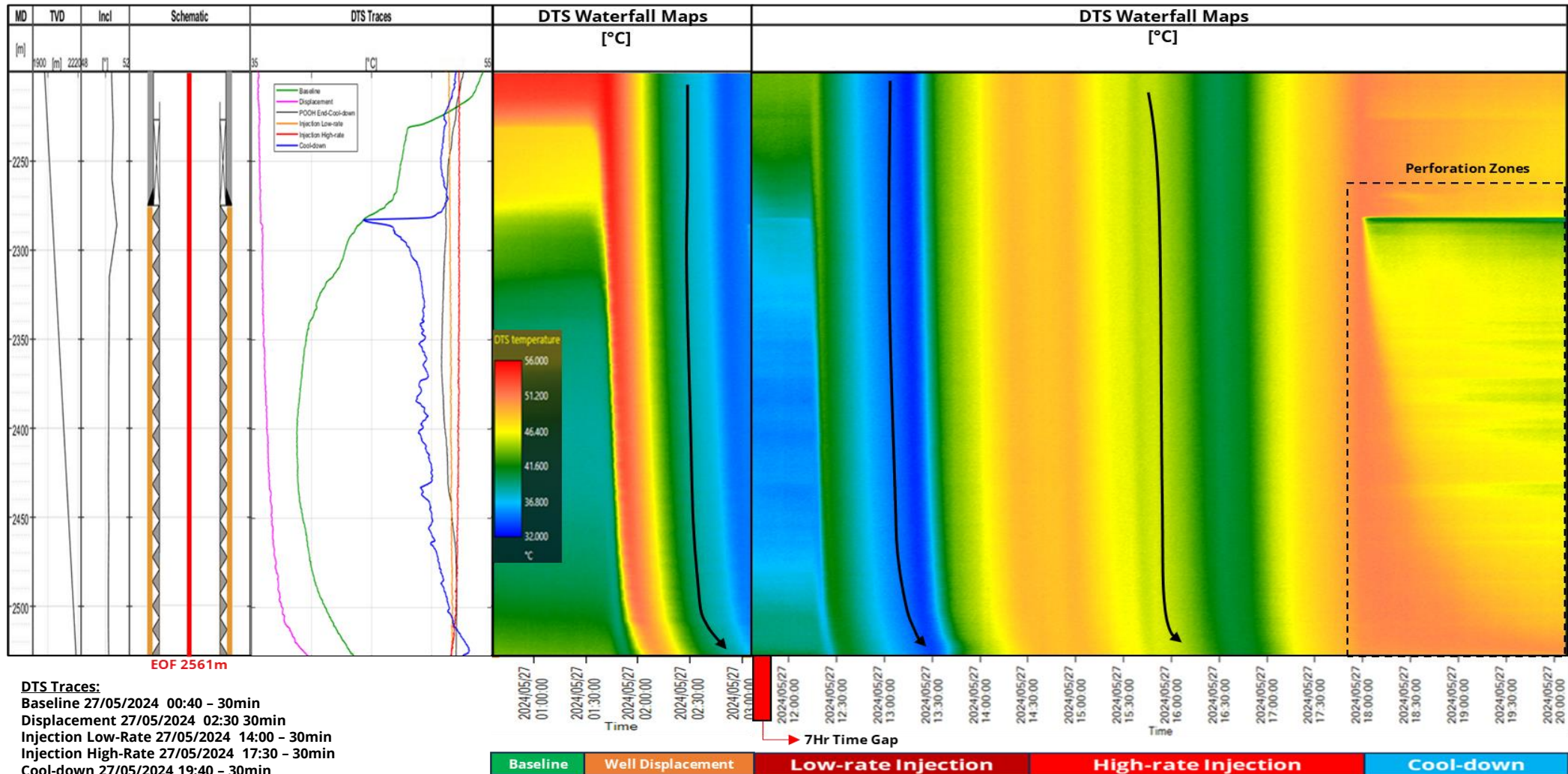
Enhancing Well Performance via Cool-Down Analysis of Post-Acid Hot Fluid



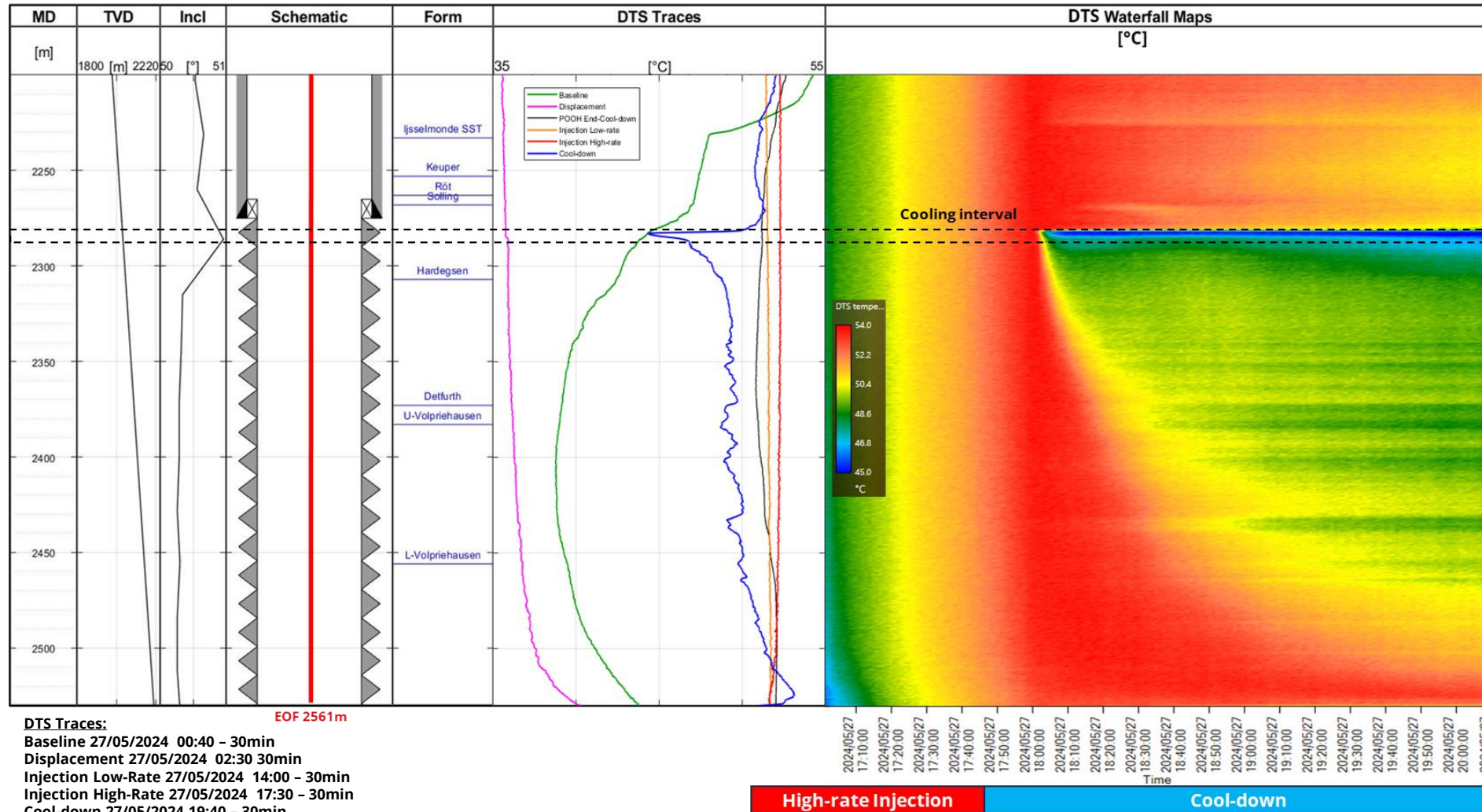
DTS Waterfall Plot: Full Wellbore Overview Across All Operational Phases



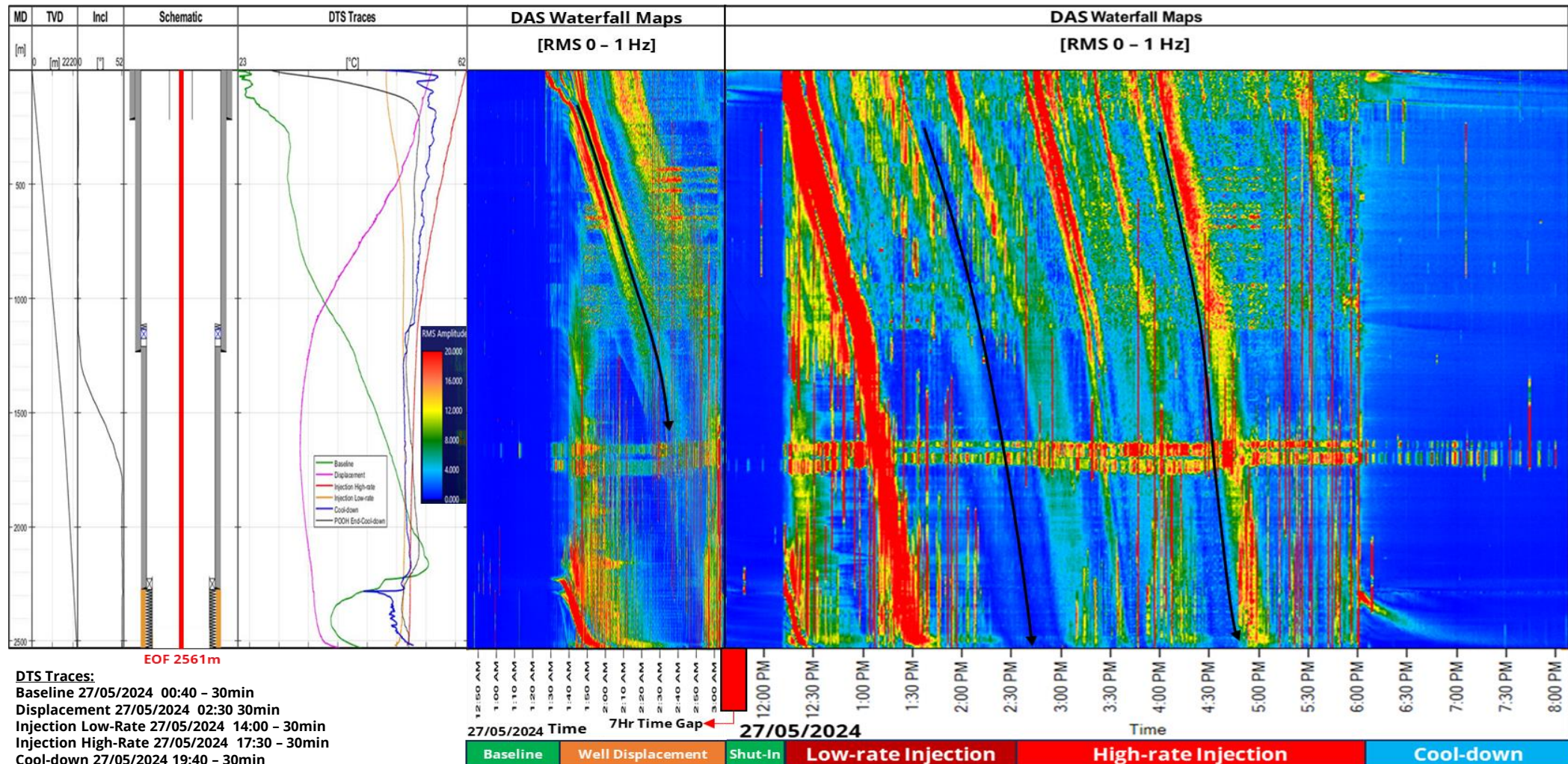
DTS Waterfall Plot: Lower Completion Overview Across All Operational Phases



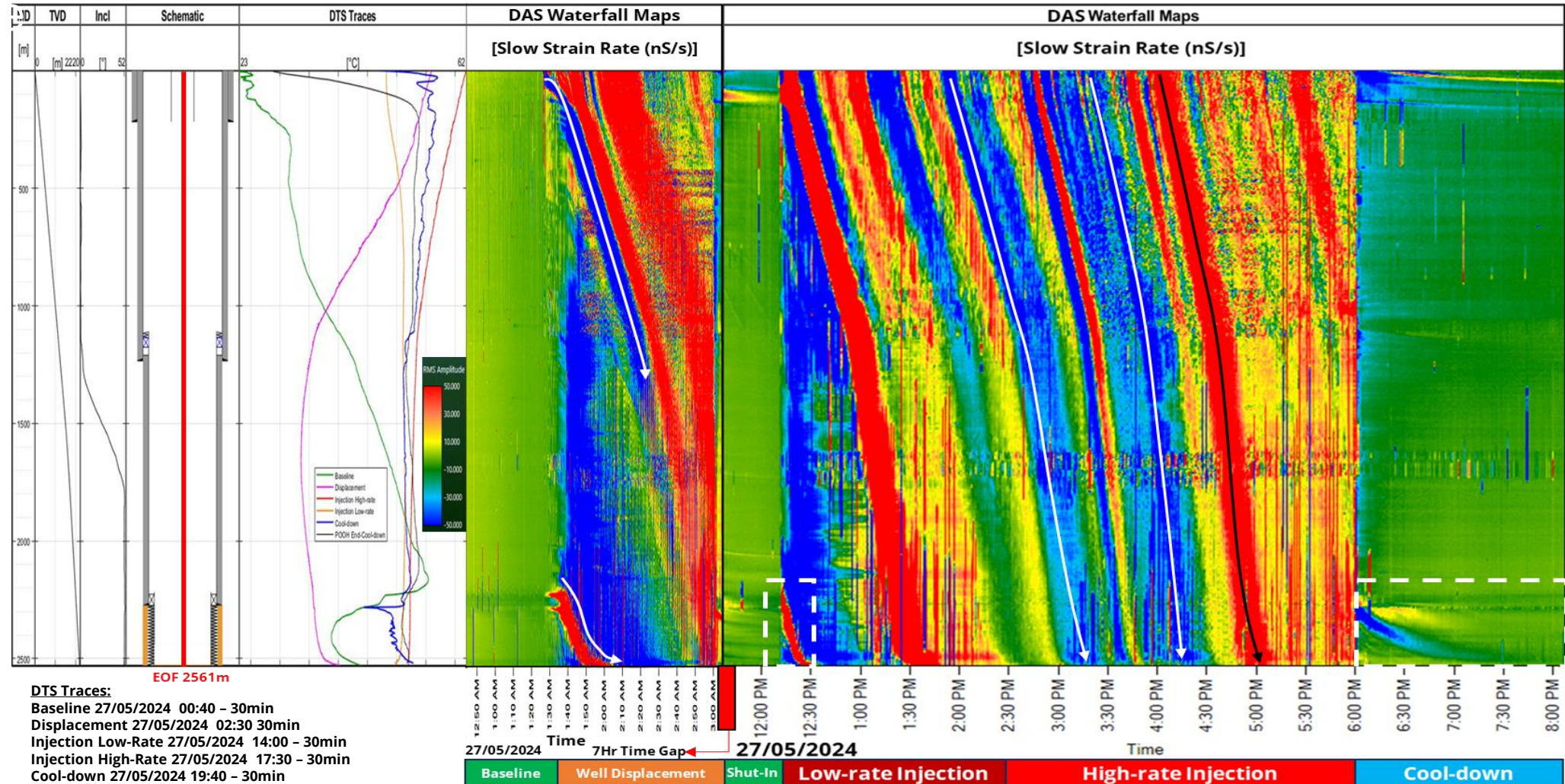
DTS Waterfall Plot: High Injection Rate and Cool-Down Phases in Lower Completion



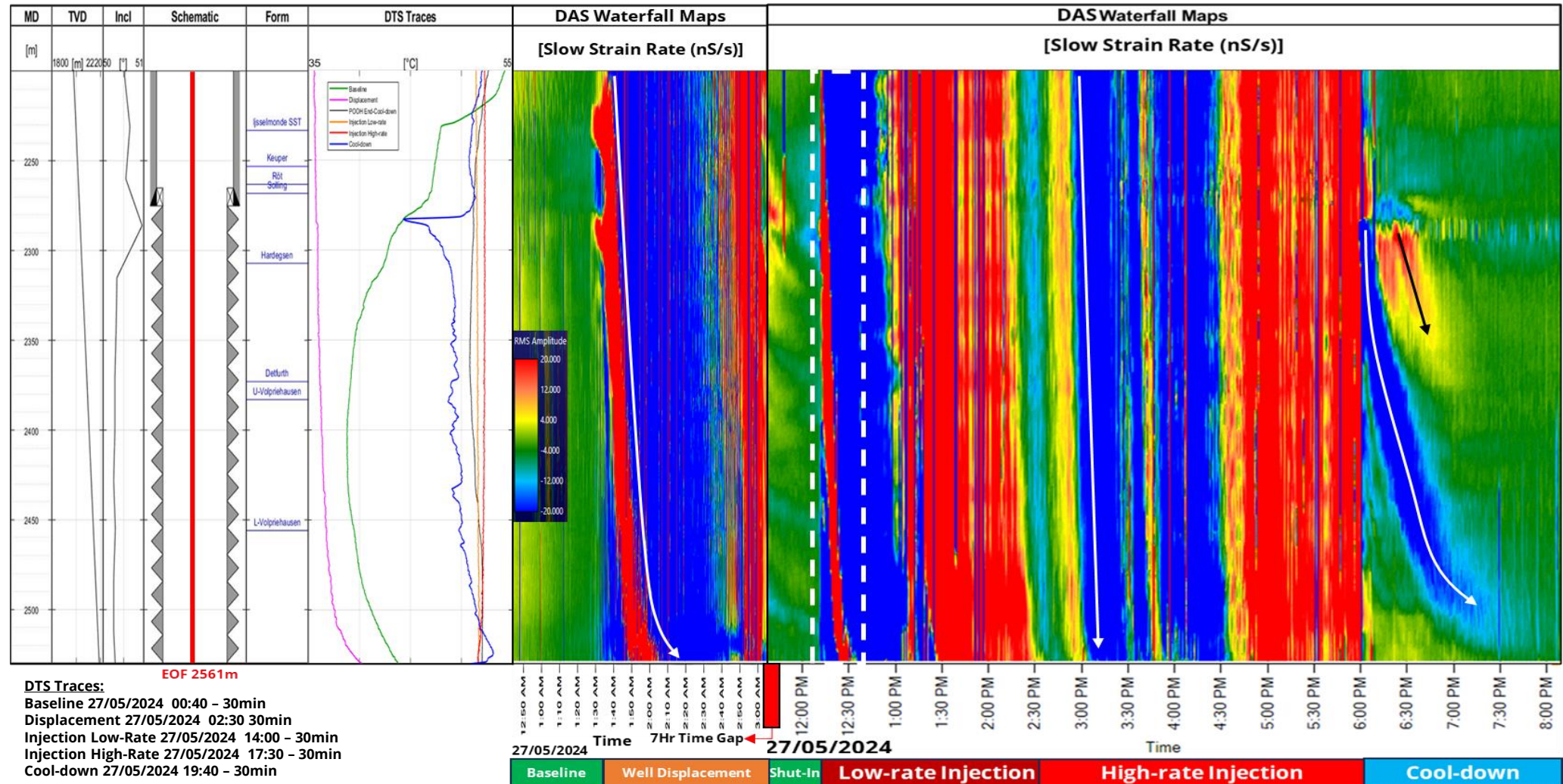
DAS FBEs 0-1Hz Waterfall Plot: Full Wellbore Overview Across All Operational Phases



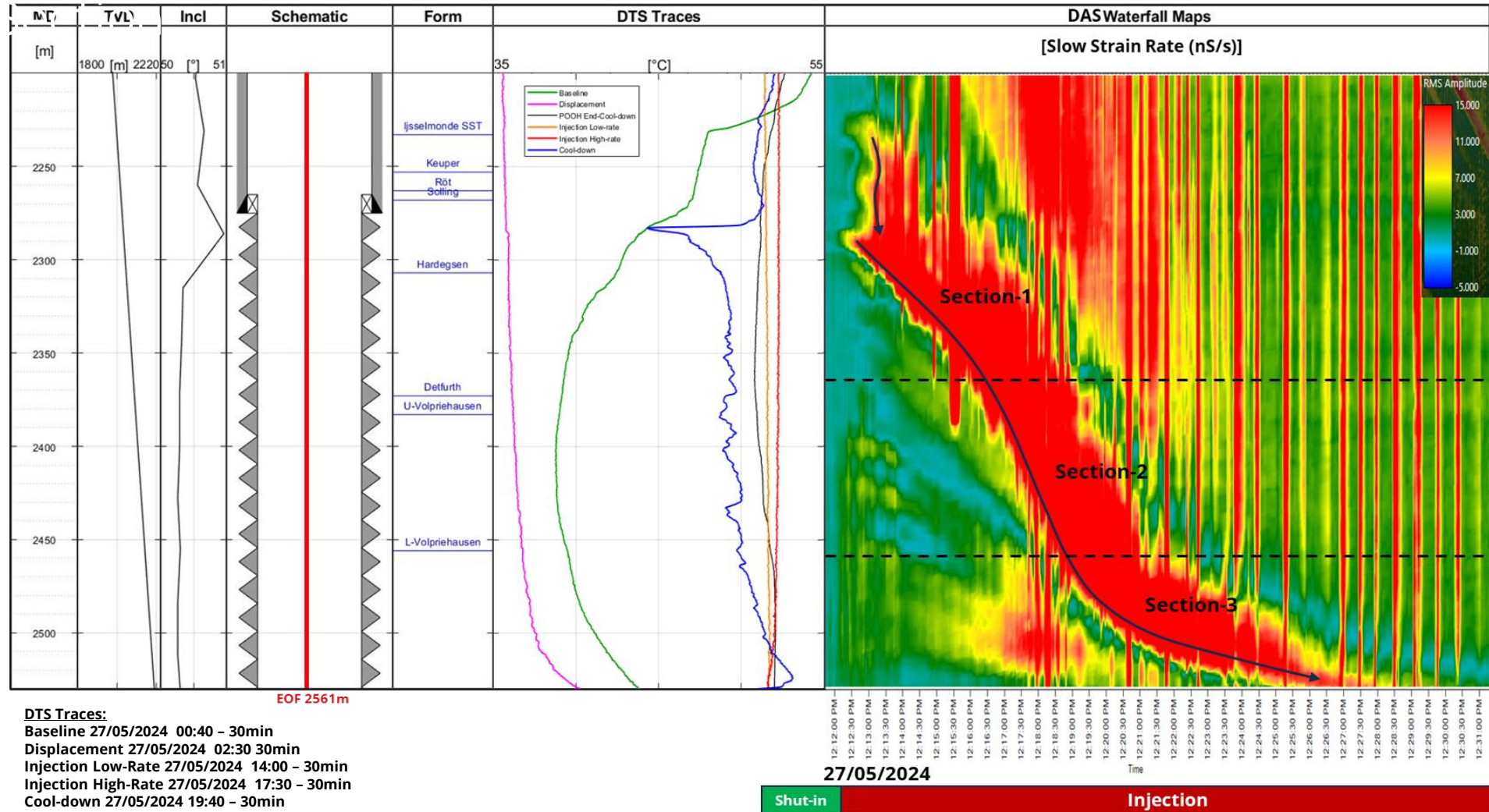
DAS Slow Strain Waterfall Plot: Overview Across All Operational Phases of the



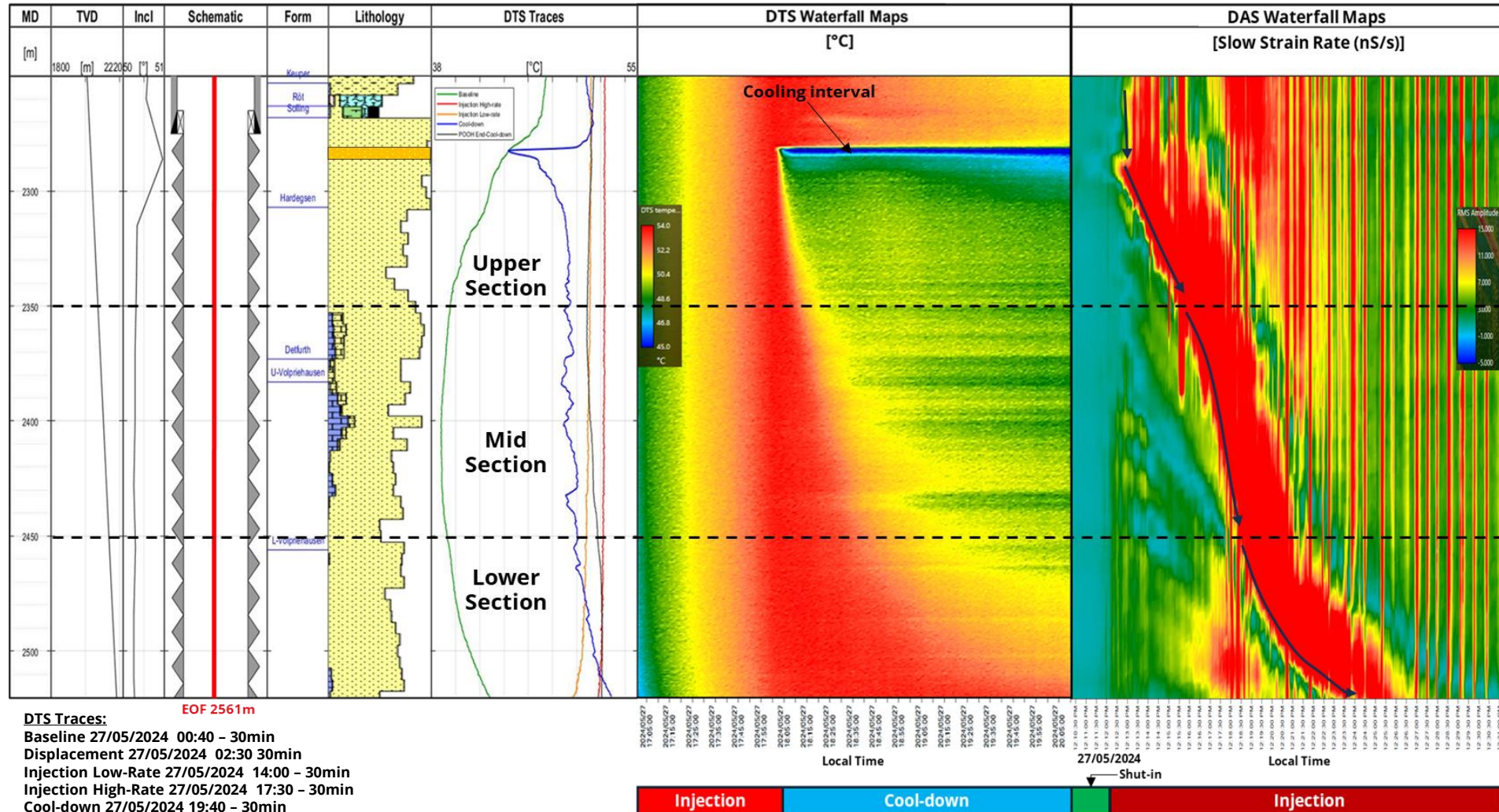
DAS Slow Strain Waterfall Plot: Overview Across All Operational Phases of the Lower



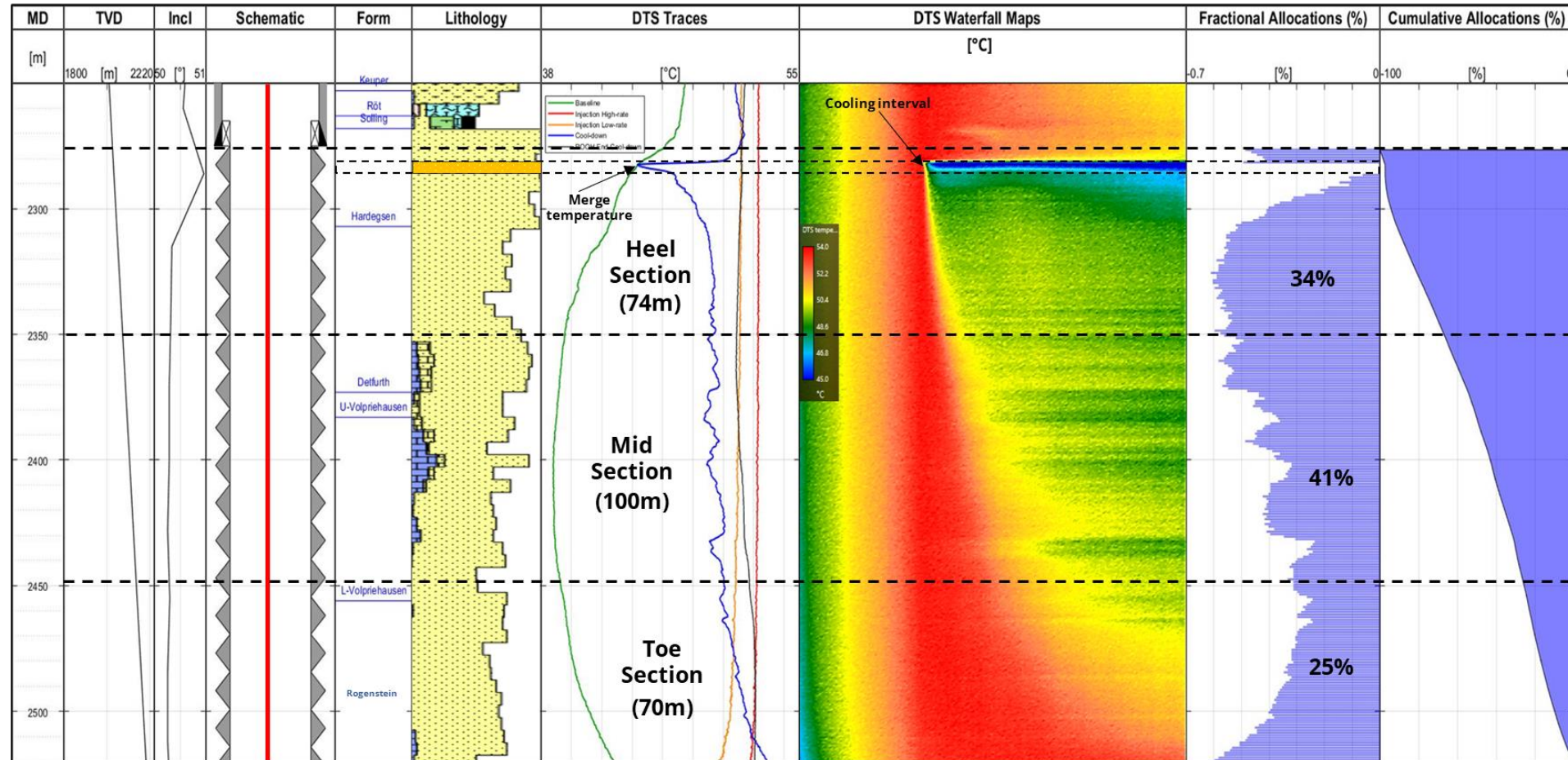
DAS Slow Strain Waterfall Map – Transition from the Shut-in to Injection Periods –



DTS and DAS Slow Strain Waterfall Maps – Over the Lower Completion Section



Quantitate Analysis using Analytical Cool-down Model Injection Allocation Results

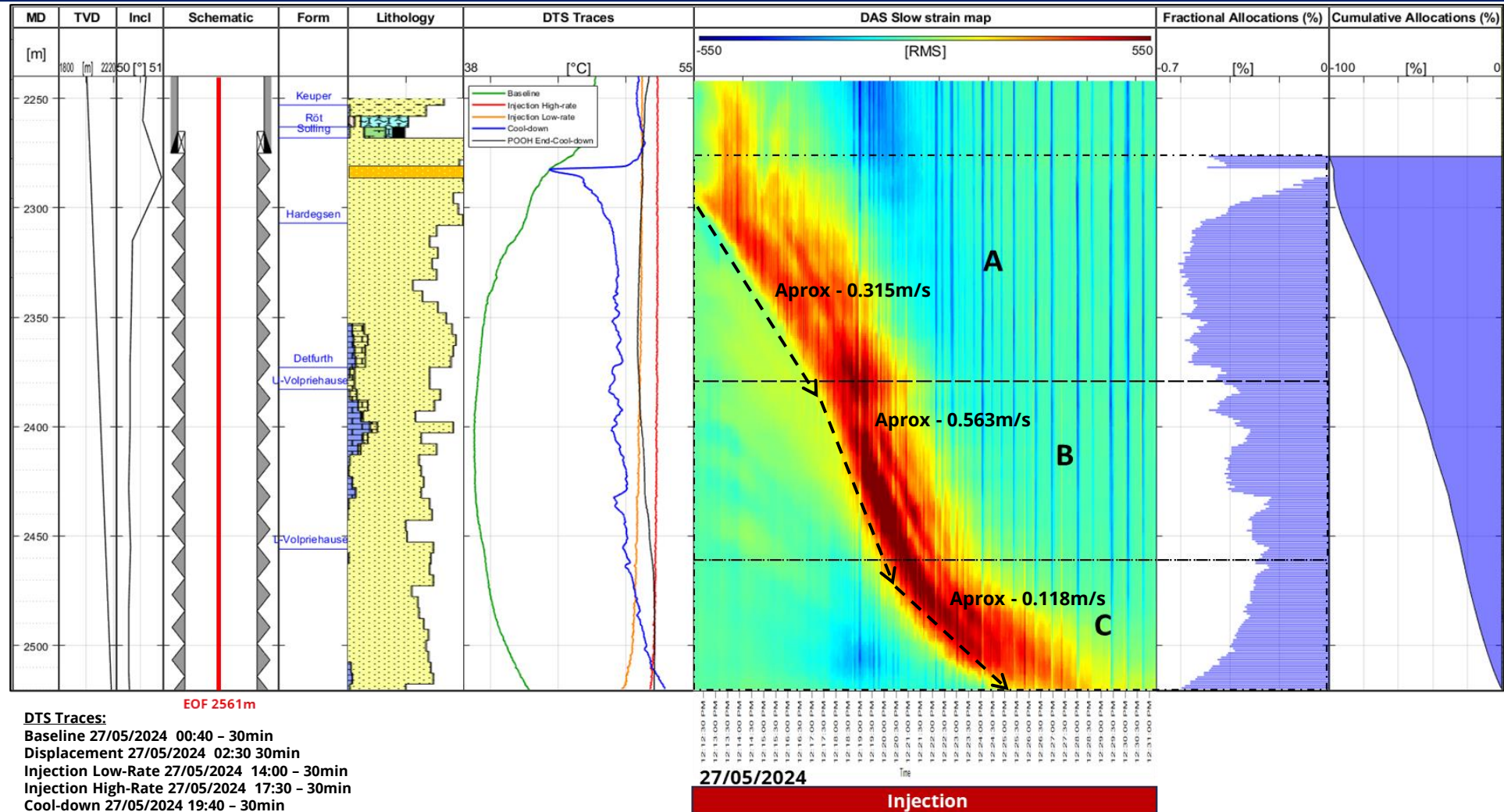


EOF 2561m

DTS Traces:
 Baseline 27/05/2024 00:40 - 30min
 Displacement 27/05/2024 02:30 - 30min
 Injection Low-Rate 27/05/2024 14:00 - 30min
 Injection High-Rate 27/05/2024 17:30 - 30min
 Cool-down 27/05/2024 19:40 - 30min



Qualitative Analysis of Transient DAS Slow Strain Plumes



Thank you

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Technical conference organised by

