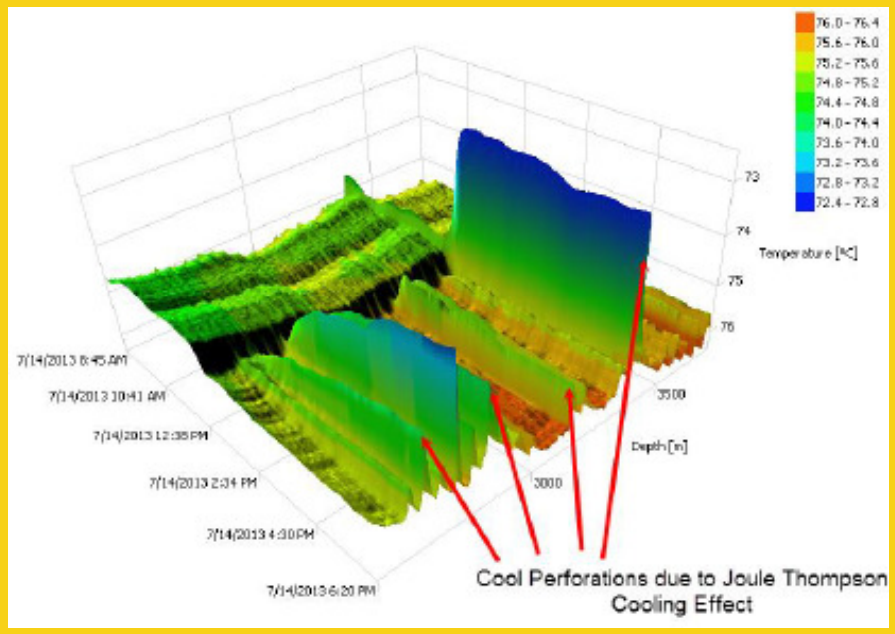
Shell iCoil & Memory Camera Logging



Laura Teterenko, Jordan Juschka, Robert Little (SLB), Hector MacQuarrie

What Were Our Goals?

- Log 4 wells total on two pads
- Wanted to:
  - Test PLT intervention capabilities of iCoil
    - Achievable depth
    - Comparison against original spinner logs
  - Lower costs via campaign execution
  - Look for scaling at perforation intervals
    - Evident on GR of previous iCoil log
  - Run camera
    - Confirm scaling
    - Quantify water production in lateral
    - QC perf production data

What Is iCoil?

- Fiber optic distributed temperature sensing (DTS).
- Sends 10 nanosecond bursts of light down the fiber optic cable.
- The back scattered light can be analyzed to measure the temperature along the entire fiber using time sampling.
- Joule-Thompson cooling effect at perforation intervals is used to determine flow distribution along the lateral.
- **iCoil provides a potential solution to mid-life PLT's in horizontal wells with tubing installed.**
  - Previously high risk operation
  - Expect higher quality data

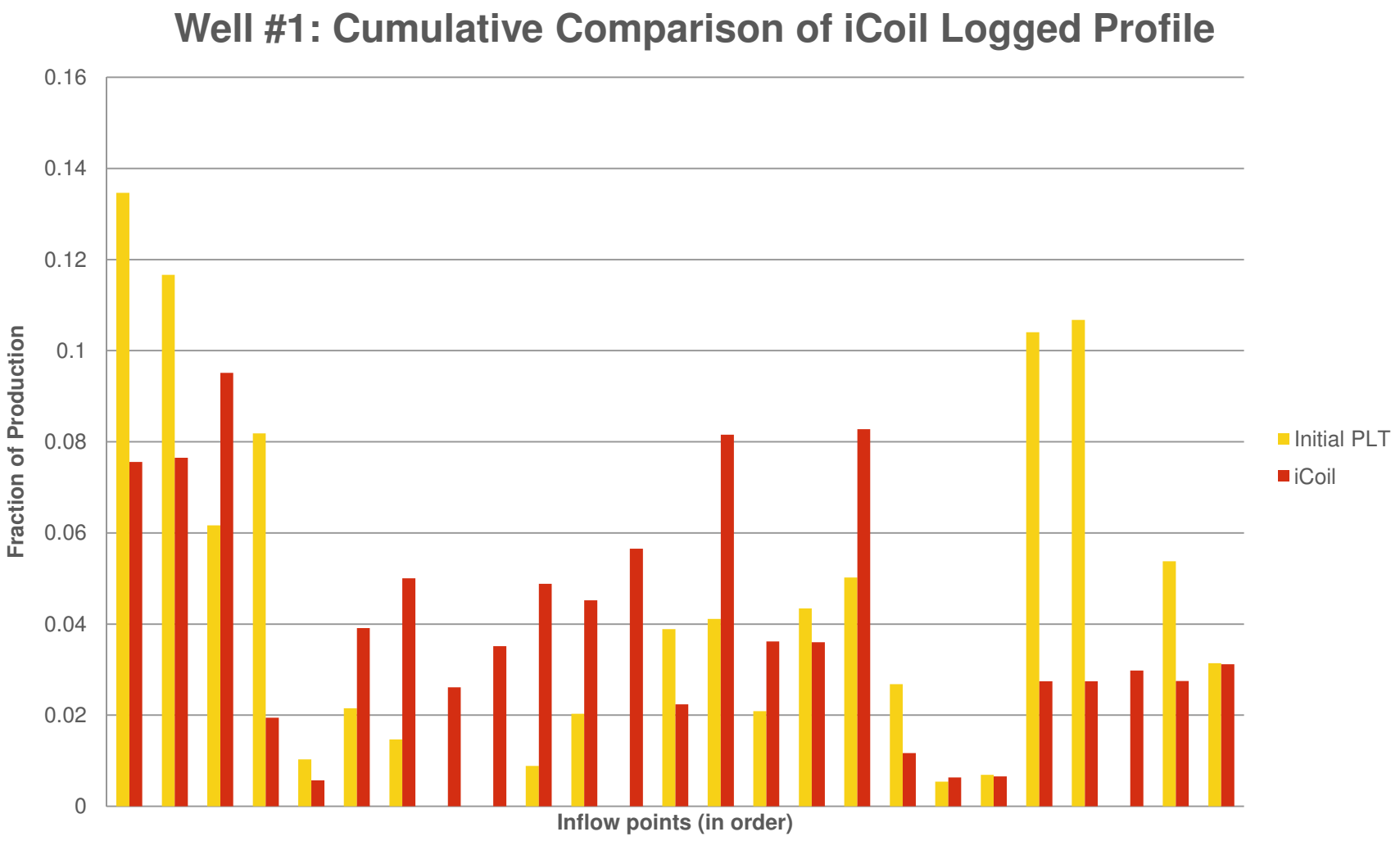
Background

- Montney Formation
- Lateral Lengths = 1500 - 2400m
- 3 Plug and Perf Completions, 1 Open Hole
- 3 Wells had initial PLT's (spinner)
- Wells completed b/w 2012 – 2013
- Completion Style:
  - 4-½"/5-½" Casing
  - 2-⅜" Tubing landed at heel
  - 10-12 Stages/well
  - 4-5 perf clusters per stage

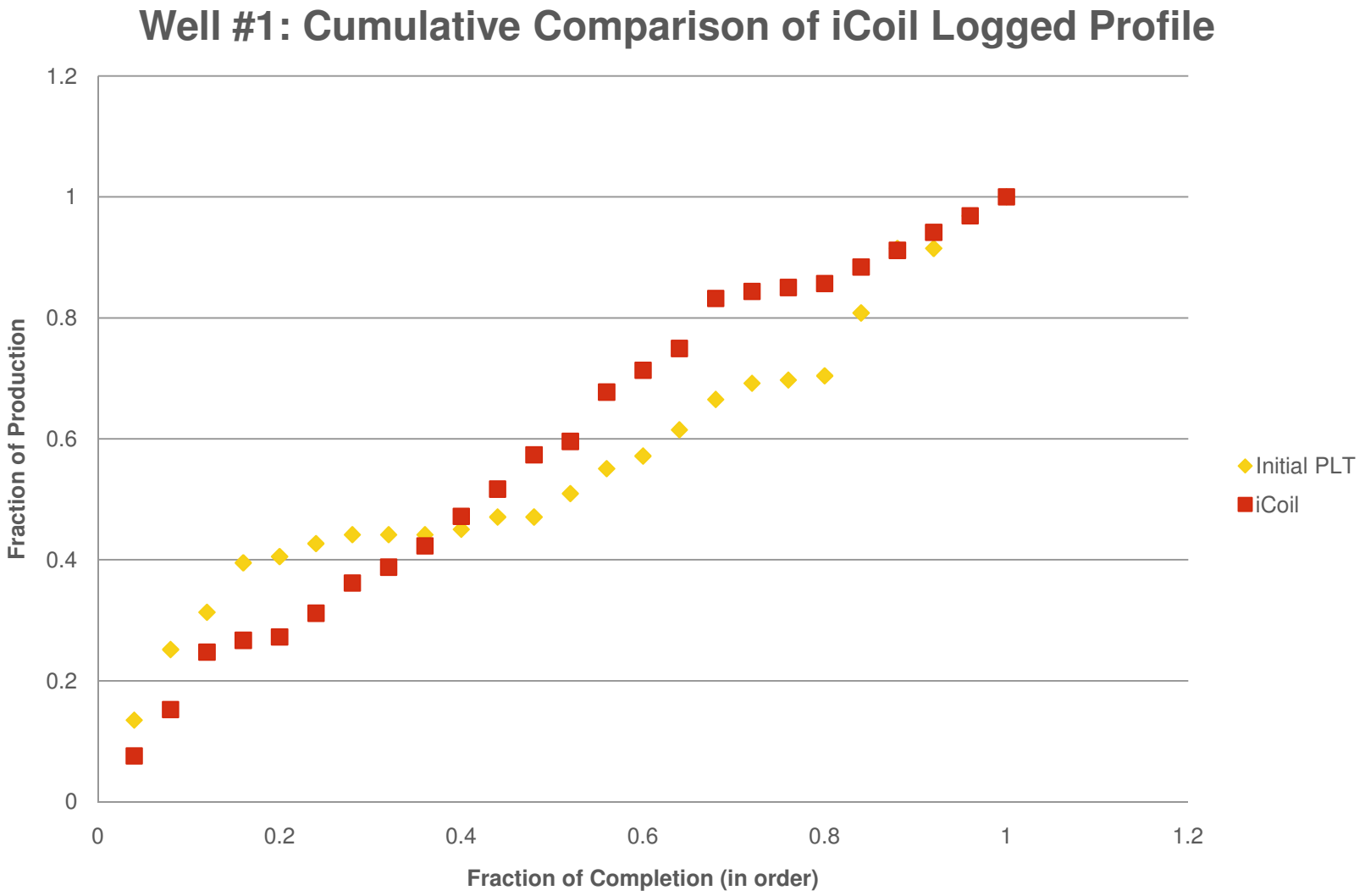
Well #1

- TD = 4680 mMD, TVD = 2346m, 5.5”
- 102 e3m3/d
- Coil to 3603 mMD (predicted lock-up at 4004 mMD)
- Logged 53% of lateral
- 83% of perfs producing
- Max Rate = 5.1 e3m3/d

Well #1


Well #1: Cumulative Comparison of iCoil Logged Profile
Fraction of Production
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Inflow points (in order)
Initial PLT
iCoil

Well #1


Well #1: Cumulative Comparison of iCoil Logged Profile
Fraction of Production
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
Fraction of Completion (in order)
Initial PLT
iCoil

Well #1

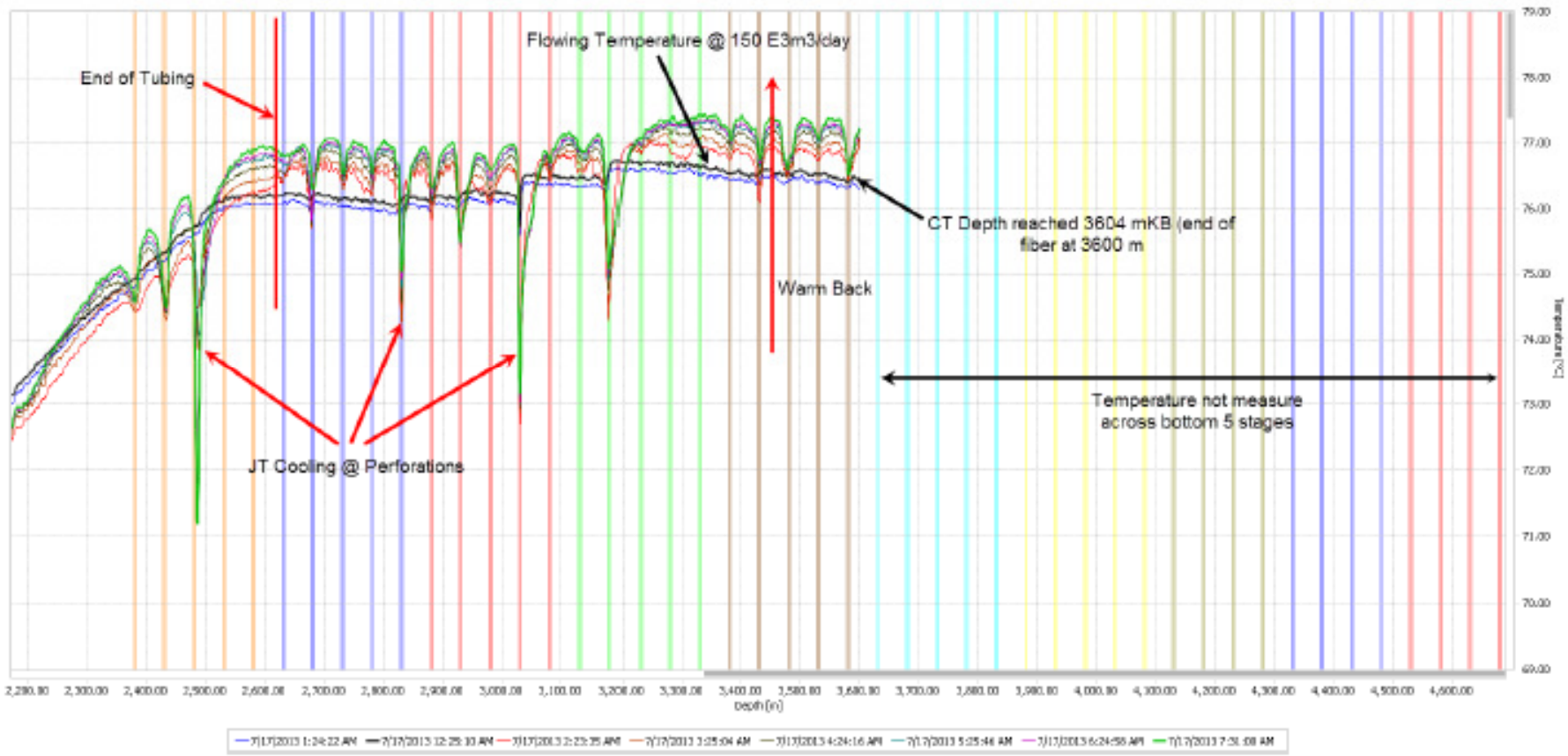
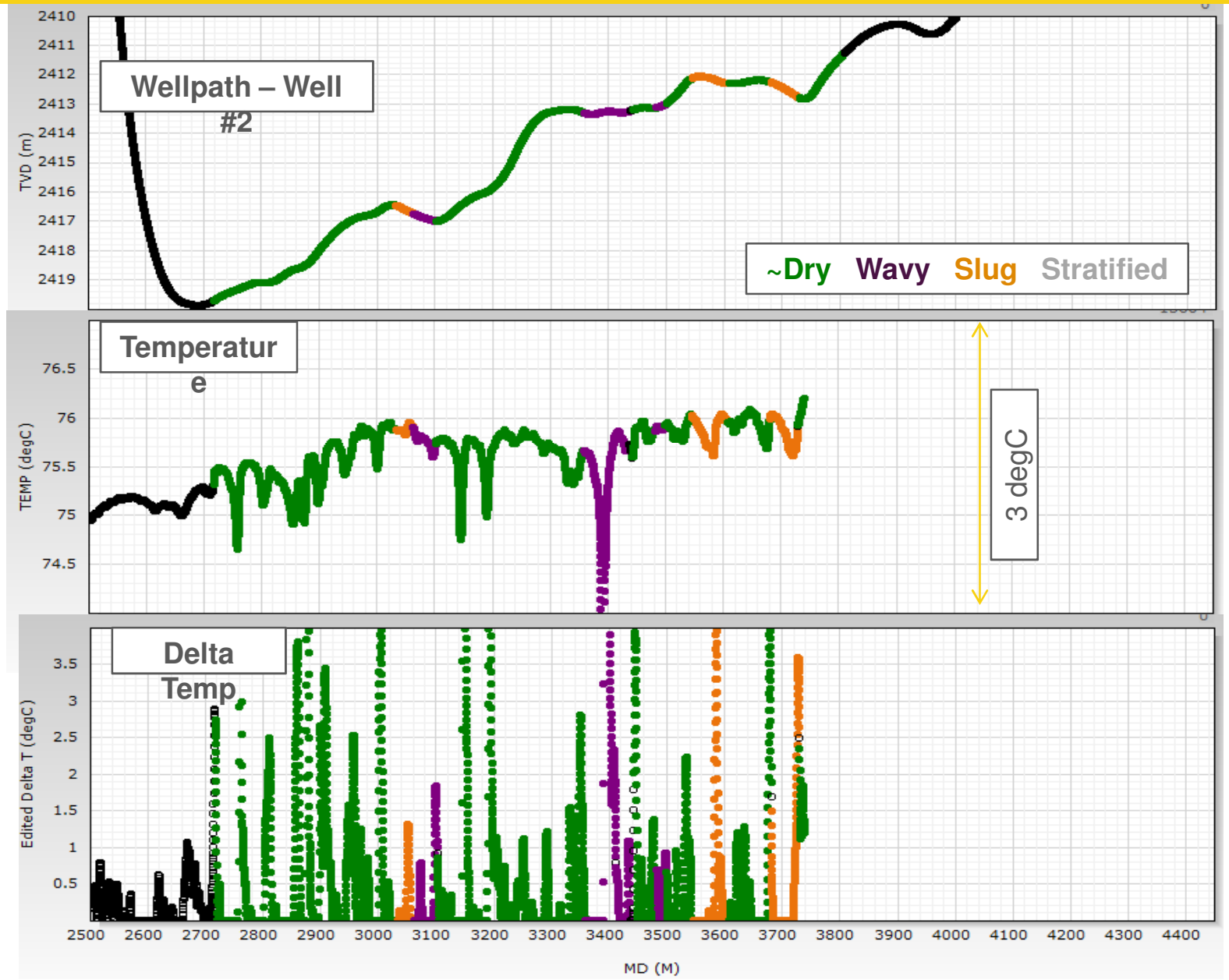


Figure 8 - Temperature vs. Depth for Selected Times

Well #2

- TD = 4376 mMD, TVD = 2404 mMD, 4.5”
- 100 e3m3/d
- Coil to 3742 mMD (predicted lock-up at 4161 mMD)
- Logged 64% of lateral
- 96% of perfs producing
- Max Rate = 6.3 e3m3/d

Well #2


Wellpath – Well #2
TVD (m)
2410
2411
2412
2413
2414
2415
2416
2417
2418
2419
~Dry
Wavy
Slug
Stratified
Temperatur e
TEMP (degC)
76.5
76
75.5
75
74.5
3 degC
Delta Temp
Edited Delta T (degC)
3.5
3
2.5
2
1.5
1
0.5
2500
2600
2700
2800
2900
3000
3100
3200
3300
3400
3500
3600
3700
3800
3900
4000
4100
4200
4300
4400
MD (M)

Well #2

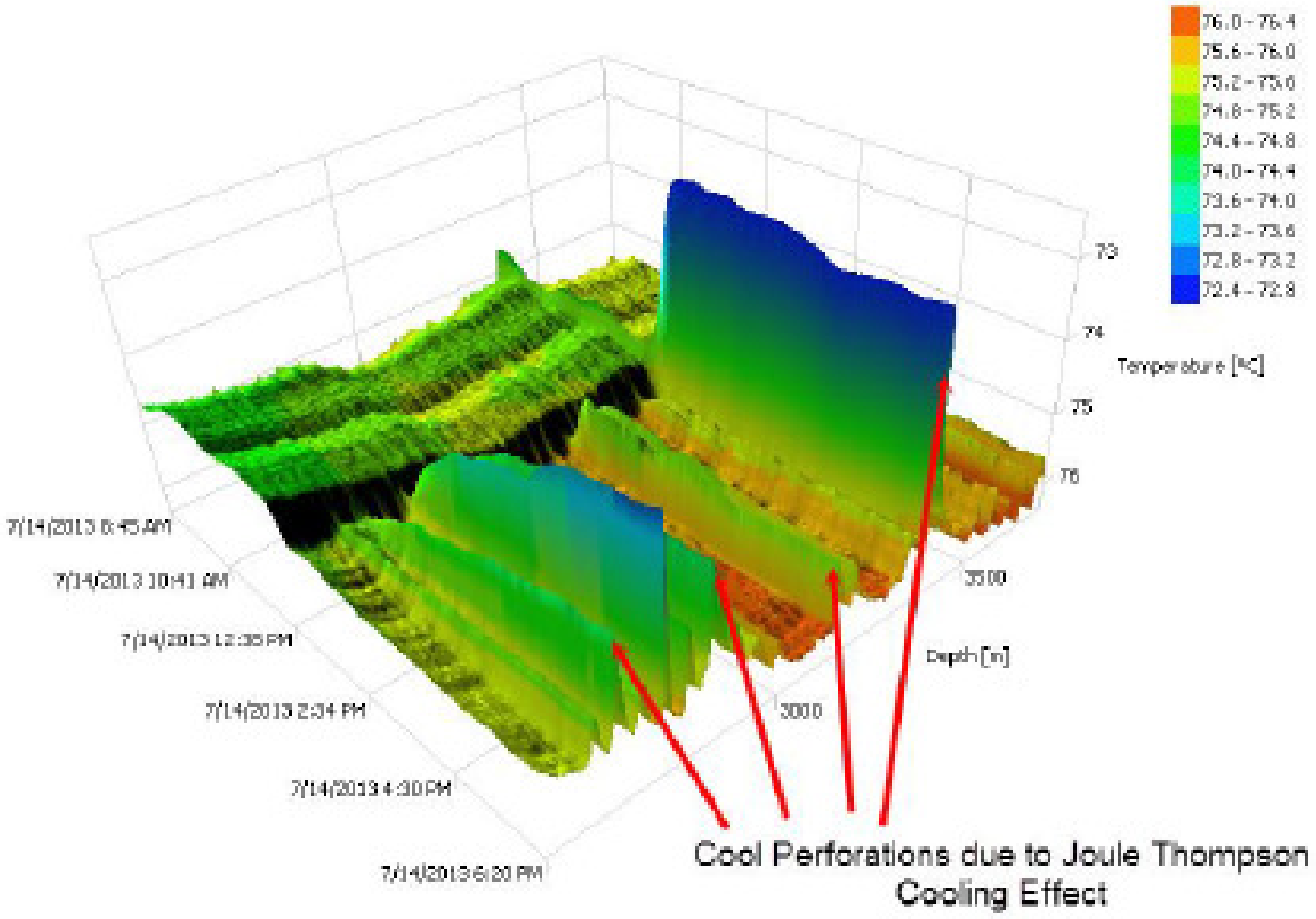


Figure 5 - 3D Plot of DTS data recorded along horizontal (Temperature Inverted)

Well #2

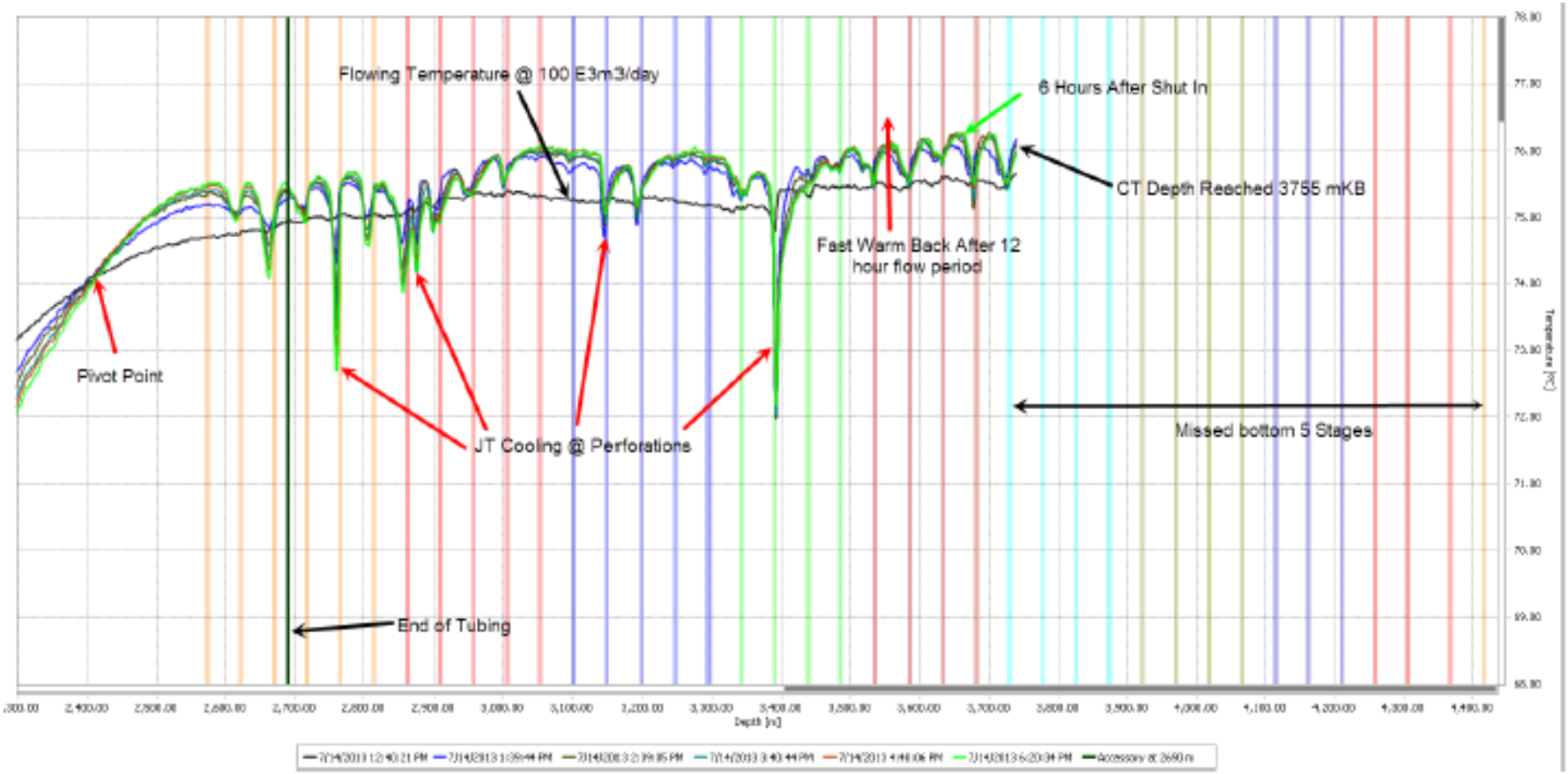
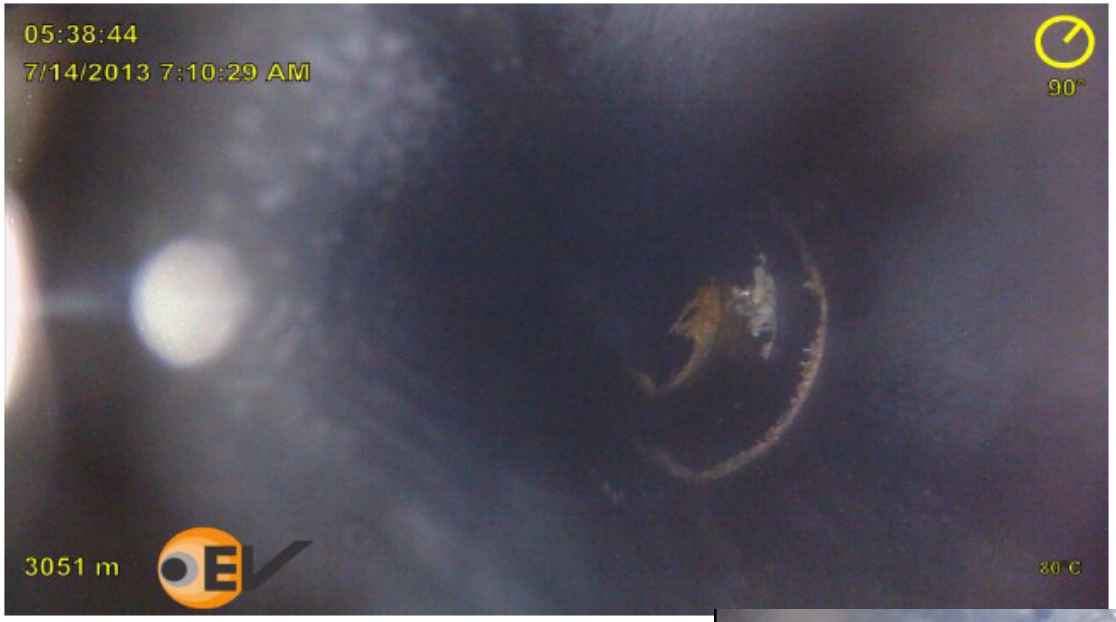


Figure 8 - Temperature vs. Depth for Selected Times

Well #2

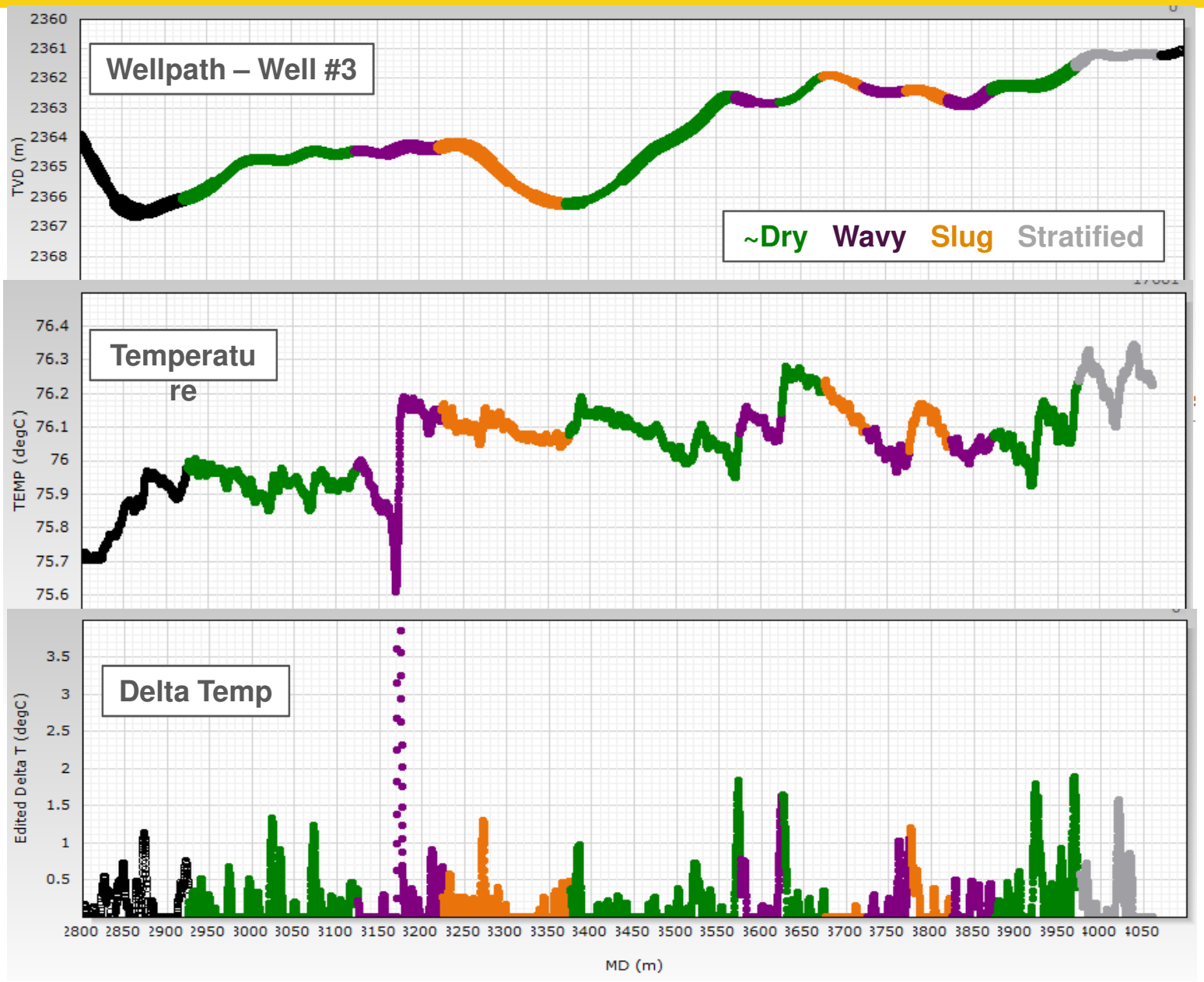

05:38:44
7/14/2013 7:10:29 AM
90°
3051 m
30 C


04:16:26
18/07/2013 9:37:02 PM
91°
2969 m
81°C

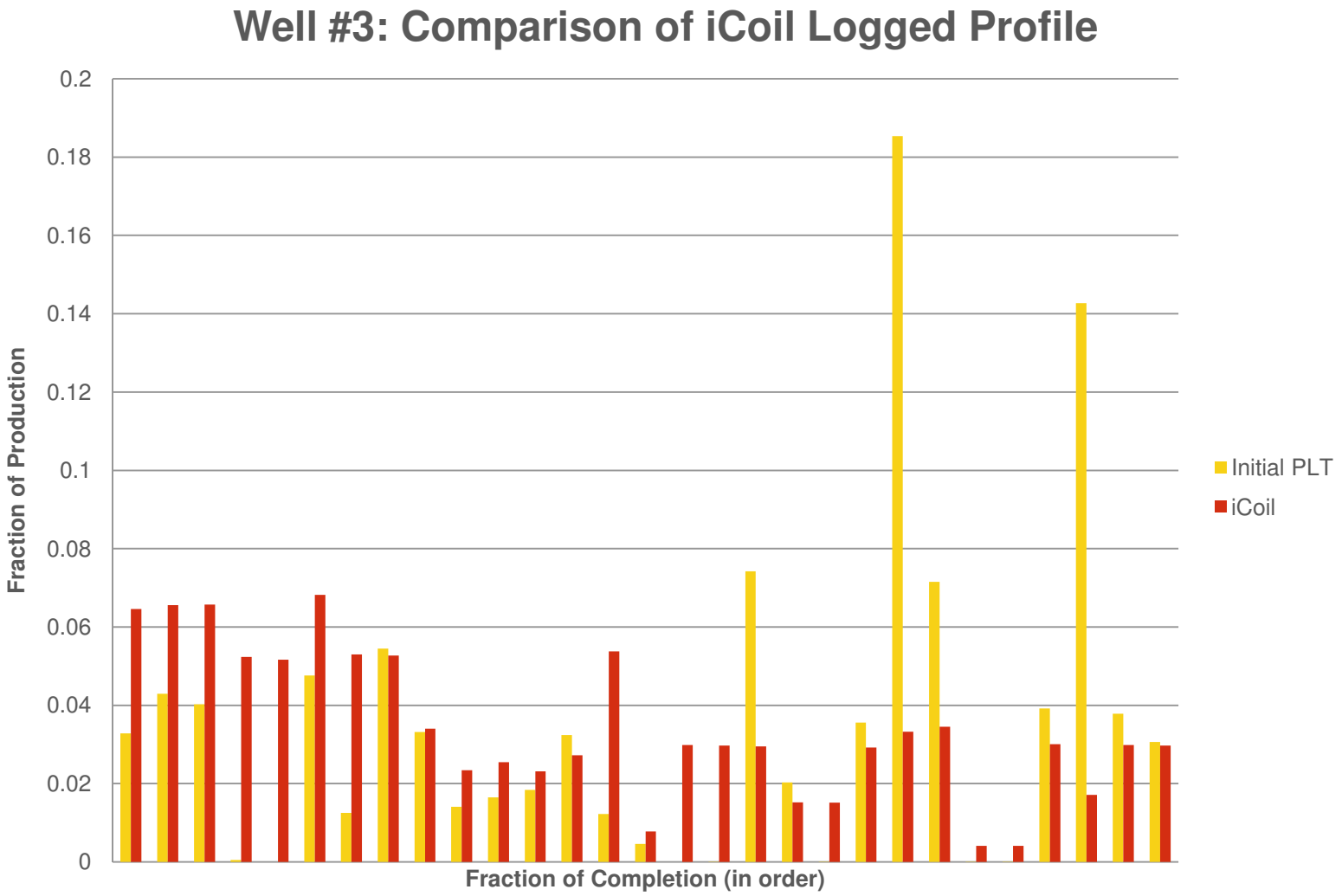
Well #3

- TD = 4925 mMD, TVD = 2351m, 5.5”
- 150 e3m3/d
- Coil to 4069 mMD (predicted lock-up at 4181 mMD)
- Logged 64% of lateral
- 90% of perfs producing
- Max Rate = 7.6 e3m3/d

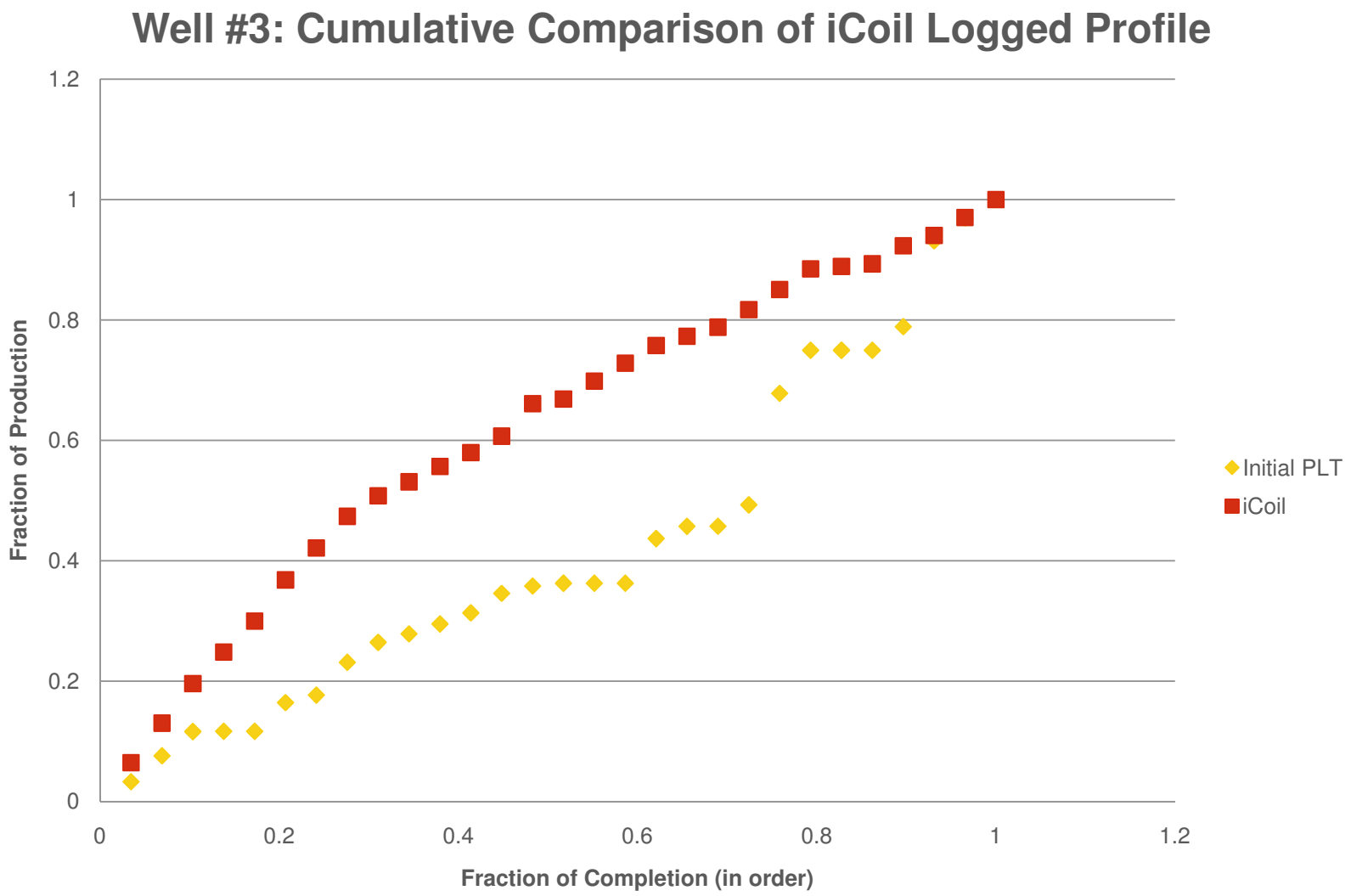
Well #3


Wellpath – Well #3
TVD (m)
2360
2361
2362
2363
2364
2365
2366
2367
2368
~Dry
Wavy
Slug
Stratified
Temperatu
re
TEMP (degC)
76.4
76.3
76.2
76.1
76
75.9
75.8
75.7
75.6
Delta Temp
Edited Delta T (degC)
3.5
3
2.5
2
1.5
1
0.5
2800 2850 2900 2950 3000 3050 3100 3150 3200 3250 3300 3350 3400 3450 3500 3550 3600 3650 3700 3750 3800 3850 3900 3950 4000 4050
MD (m)

Well #3


Well #3: Comparison of iCoil Logged Profile
Fraction of Production
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Fraction of Completion (in order)
Initial PLT
iCoil

Well #3

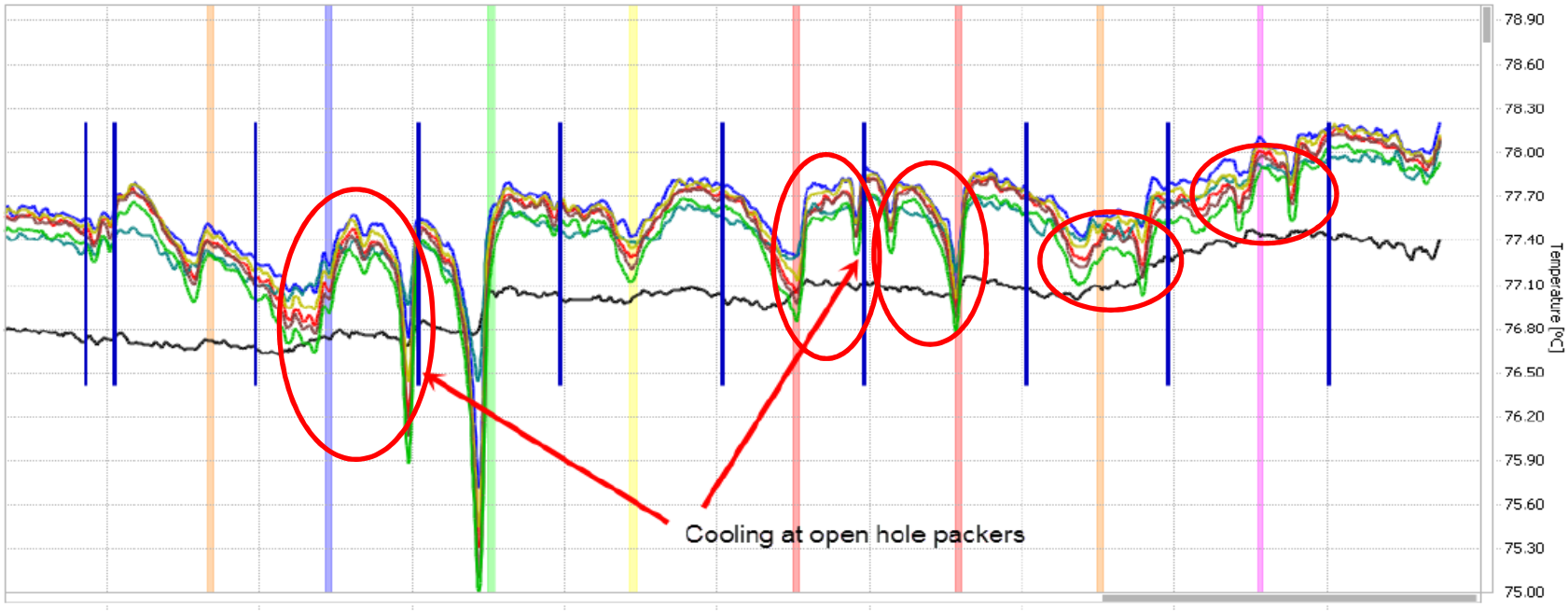

Well #3: Cumulative Comparison of iCoil Logged Profile
Fraction of Production
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
Fraction of Completion (in order)
Initial PLT
iCoil

Well #3

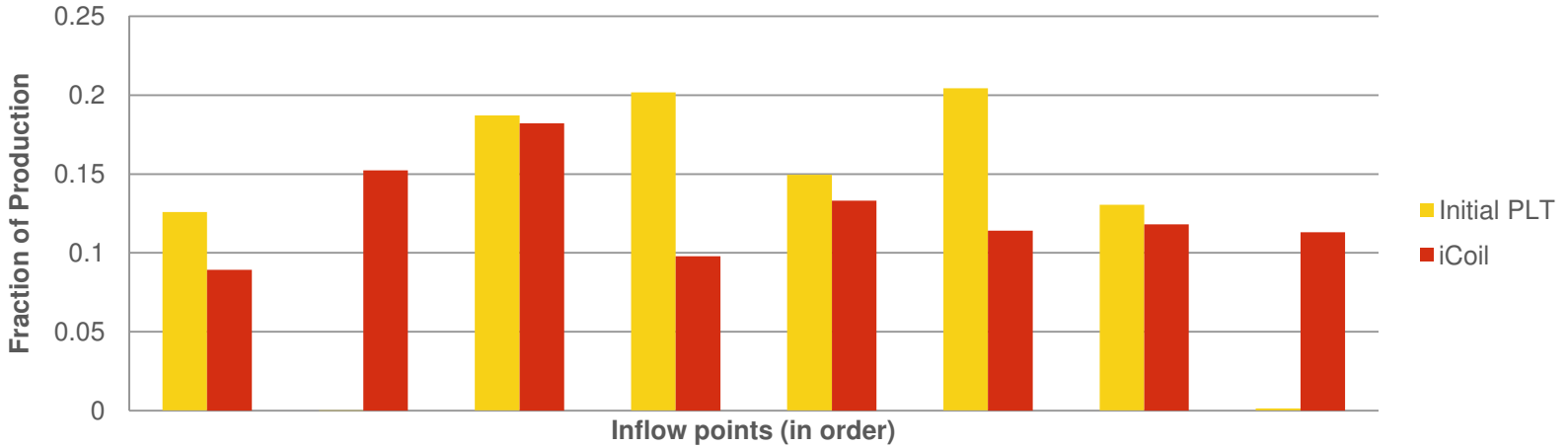
Well #4

- TD = 4292 mMD, TVD = 2470m, OH, 4.5”
- 67 e3m3/d
- Coil to 3784 mMD (no lock-up predicted)
- Logged 43% of lateral
- All ports producing
- Max rate = 6.8 e3m3/d

Well #4



Well #4: Comparison of iCoil Logged Profile (OH)



What Were Our Goals?

- Log 4 wells total on two pads
- Wanted to:
  - Test PLT intervention capabilities of iCoil
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    - Comparison against original spinner logs
  - Lower costs via campaign execution
  - Look for scaling at perforation intervals
    - Evident on GR of previous iCoil log
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    - Evident on GR of previous iCoil log
  - Run camera
    - Confirm scaling
    - Quantify water production in lateral
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What Were Our Goals?

- Log 4 wells total on two pads
- Wanted to:
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    - Achievable depth
    - Comparison against original spinner logs
  - Lower costs via campaign execution
  - Look for scaling at perforation intervals
    - Evident on GR of previous iCoil log
  - Run camera
    - Confirm scaling
    - Quantify water production in lateral
    - QC perf production data

What Were Our Goals?

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- Wanted to:
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    - Comparison against original spinner logs
  - Lower costs via campaign execution
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- Wanted to:
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  - Look for scaling at perforation intervals
    - Evident on GR of previous iCoil log
  - Run camera
    - Confirm scaling
    - Quantify water production in lateral
    - QC perf production data

Conclusions & Next Steps

- iCoil providing reliable data
  - More robust than initially expected wrt liquids
- Usefulness of initial PLT's
  - Stage: Yes
  - Perf Cluster: No
- Seeing improved lateral contribution with iCoil PLT's
  - Conflicts with DAS & DTS frac logs
- Memory camera a success
- Next Steps
  - Quantify effects of hold-up & scale production
  - Increase logged length
  - Ultimately, Engineered Stimulations

Acknowledgements

- Laura Teterenko – Shell
- Jordan Juschka – Shell
- Robert Little – Schlumberger
- Blaine Fusick – EV
- Curtis Jerrom – EV

What Were Our Goals?

- Planned to log 4 wells total on two pads (two wells on each pad).
- Wanted to:
  - Test PLT intervention capabilities of iCoil
    - Achievable depth
    - Comparison against original spinner logs
  - Lower execution costs with campaign style and pad execution
  - Look for scaling at perforation intervals
    - Evident on GR of previous iCoil log
  - Run camera
    - Confirm scaling
    - Look for water production in lateral and compare against iCoil data

Preliminary Results

- Lowered Costs, but still executed above AFE
  - AFE'd for 177k per well
  - Actuals at 202k
- Frictioned out shallow in 3 of 4 wells
  - Adjusted RIH procedure on last two wells and achieved good results
- DTS data successfully recovered on all 4 wells
  - Currently generating PLT of logged laterals in each well
- Excellent memory camera data
  - Saw fluid slugging and scale on perforations

Whats Next/Recommendation

- Camera Data
  - Will be used to review slugging/liquid hold-up in lateral and its effect on individual perf production
  - Coupled with GR log, will be used to quantify effects of scale/salt on perfs (if any)
- Asset will use iCoil data to make a decision on when and how frequently to run PLT's
- If decision is to run more, will explore 1.75" coil for further reach
- **Recommendation: iCoil is an excellent, low risk well intervention technique for PLT work in low LGR environments.**

Preliminary Results

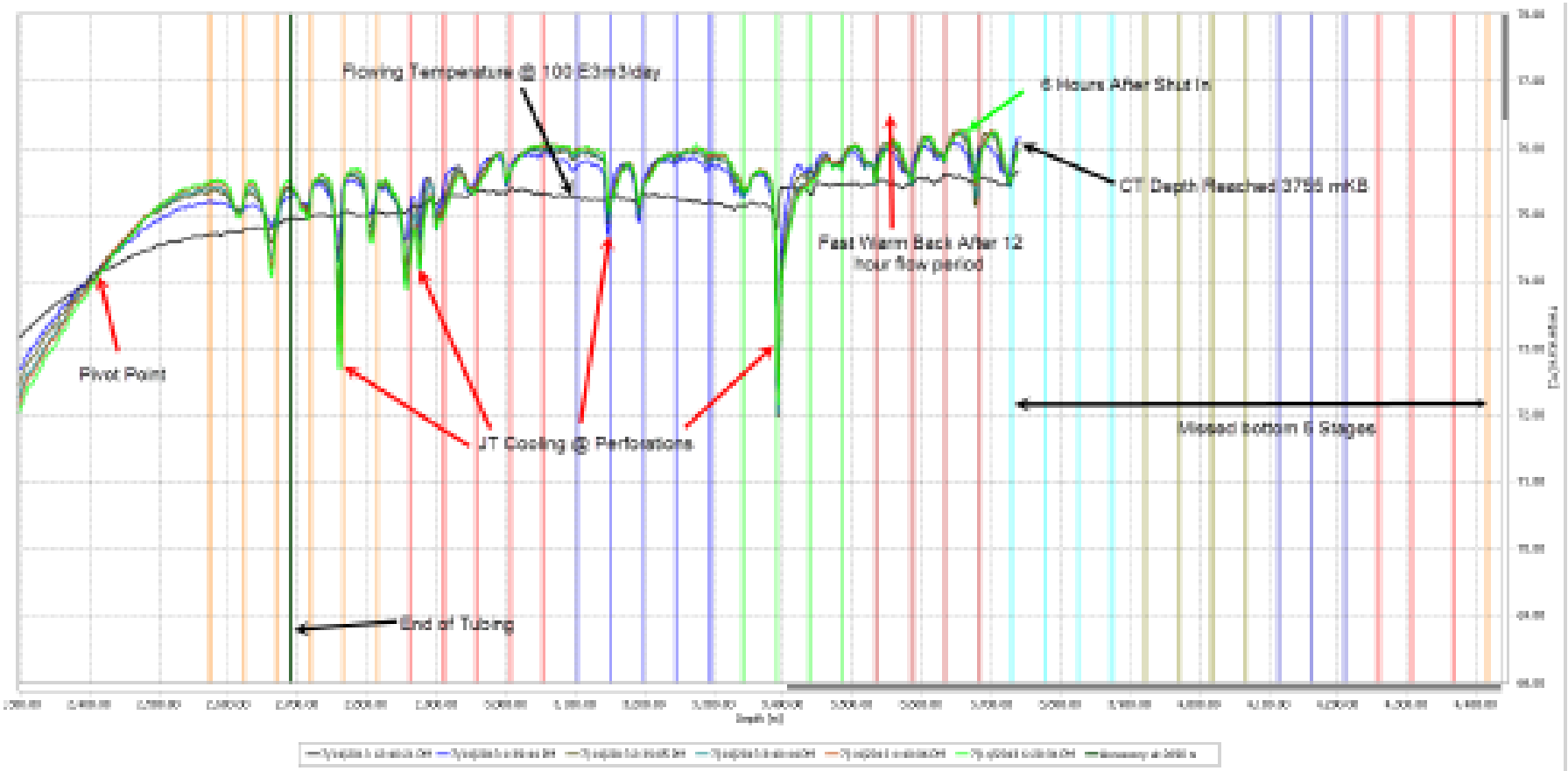

Figure 8 - Temperature vs. Depth for Selected Times

Preliminary Results

Figure 9 – Perforations with minimal cooling

Preliminary Results

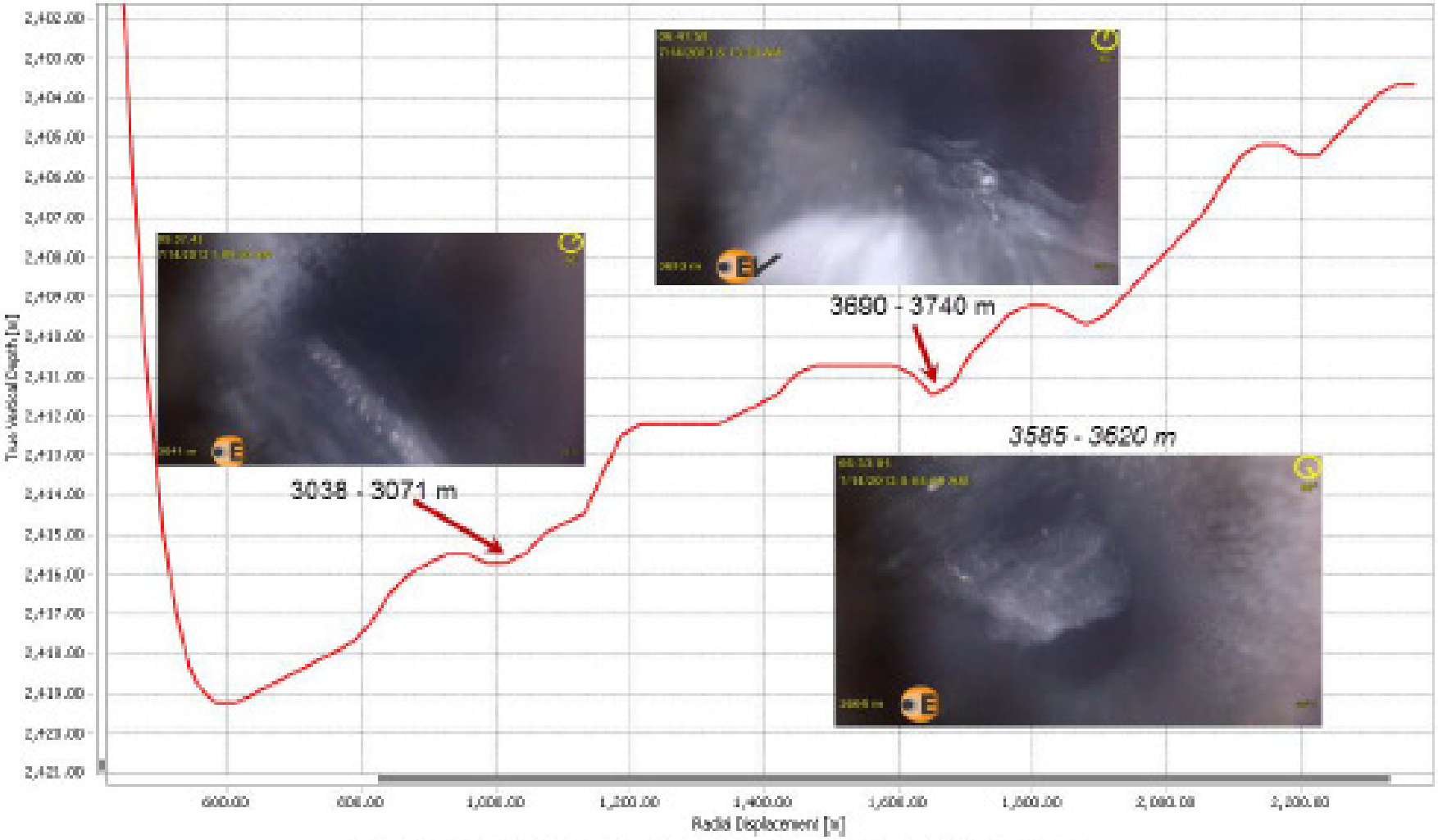

Figure 11 - Wellbore Trajectory and Water Hold Up

Execution

- Two pads, four wells total
- Ran in with 1-½” CT to lock-up depth
- Logged well
  - 4 hours flowing – Tbg x Csg annulus
  - 6 hours shut-in
- Adjusted for early lock-up

Questions/Goals

- Continue to prove up execution of technology
  - Lower execution costs
  - Begin to validate data
- Compare against initial PLT data
  - Are there significant differences?
- Gather data on lateral flow regimes
- Robustness of technology within liquids
- Gamma responses at perforations?