Stop Wasting Money! Drill Plugs Faster.

Prepared by; Jakob Kardash – Mountain Coil Tubing
Mike Zimmerman – Paramount Resources Ltd.

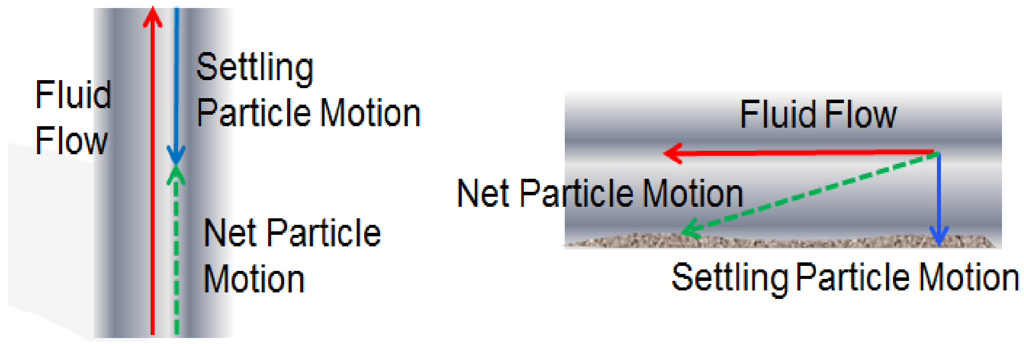
Stop Wasting Money! Drill Plugs Faster - Agenda

- *Review of "Current Industry Practices"*
- *Fluid Rheology and Solid Transport*
- *FRCS system unit overview*
- *Milling Efficiencies – Other Considerations*
- *Job Plot– Plug Milling*
- *Case Study – Horn River Plug Milling*
- *Case Study – Duvernay Plug Milling*
- *Questions*

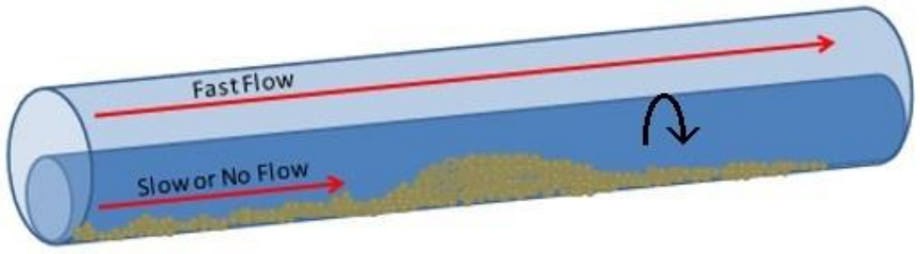
Paramount resources ltd.

MOUNTAIN COIL TUBING

“Current Industry Practices” – Drilling Influence

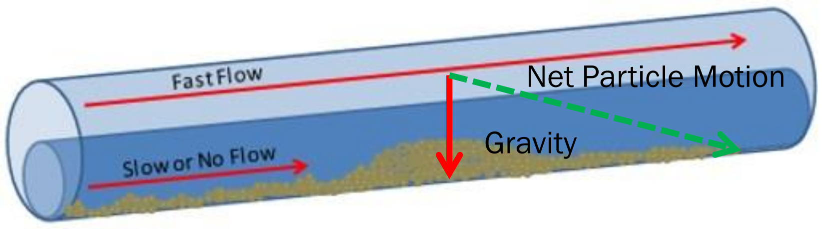


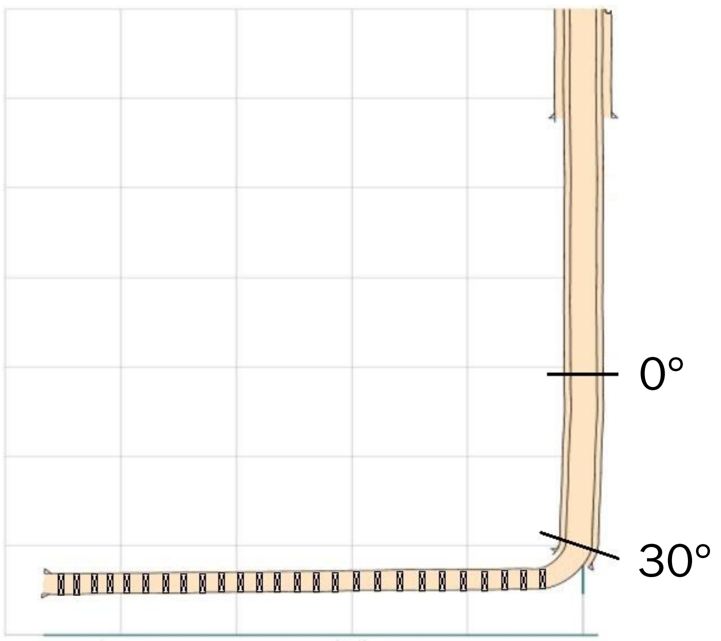
Mud pumped focuses on high carrying capacity through a high yield point or viscosity throughout operations. Fluid is also normally weighted to keep well overbalance.



Pipe rotation aids in debris removal in both the horizontal AND vertical by creating turbulence around drill pipe, transporting cuttings into the high velocity flow area of the annulus.

“Current Industry Practices” – Coiled Tubing Milling





Optimal pump rate balances BHA performance, annular velocity for hole cleaning and circulating pressure. Fluid friction reducer is dosed into fluid to allow for higher pump rates

Gel sweeps pumped normally in 1 – 2 m^3 volume, focusing on yield point or viscosity to increase carrying capacity. Sweeps are pumped sometimes after every plug removed.

Wiper Trips are often utilized at a prescribed interval to aid in debris removal. This interval can range from 2 – 10 plugs typically, depending on debris, geometry of the well, and the operators previous experience.

Paramount resources ltd.

MOUNTAIN COIL TUBING

Fluid Rheology and Solid Transport – Reynolds Number

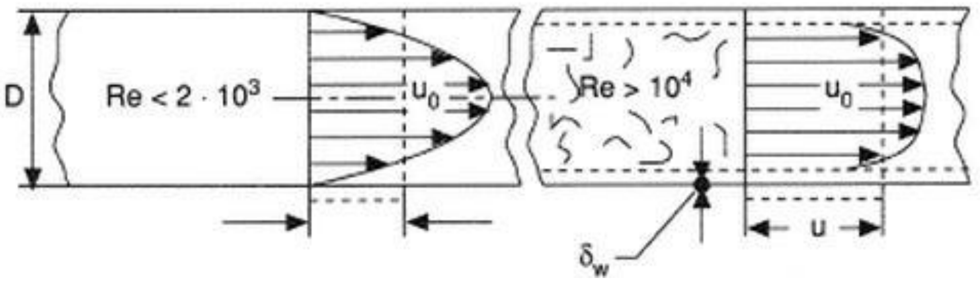
Reynolds Number = $\dfrac{Inertial\ Forces}{Viscous\ Forces} = \dfrac{\boldsymbol{\rho V} D_H}{\mu}$

$\rho = fluid\ density\ (kg/m^3)$

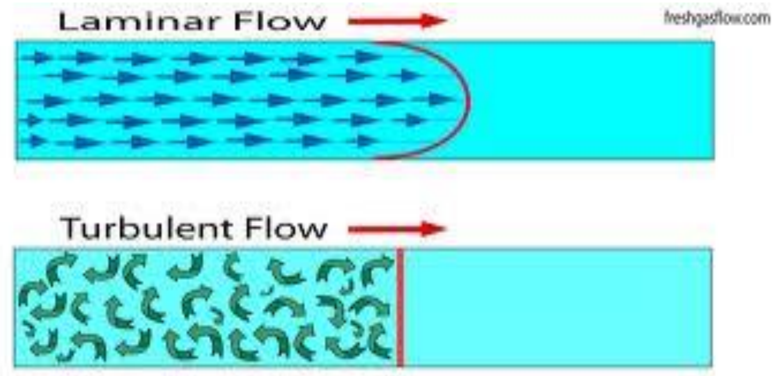
$\mathbf{V} = average\ fluid\ velocity\ (m/s)$

$D_H = Hydraulic\ Diameter$ (m)

$\mu = dynamic\ viscosity\ (poise)$



Khabakhpasheva, *Turbulent Flow*, 2011 February 2nd, http://www.thermopedia.com/content/1226/



Laminar Flow and Turbulence, https://astarmathsandphysics.com/a-level-physics-notes/fluid-dynamics/2752-laminar-flow-and-turbulence.html

Laminar<2300> Transition <11,500> Turbulent Flow in Annular Pipes

Paramount resources ltd.

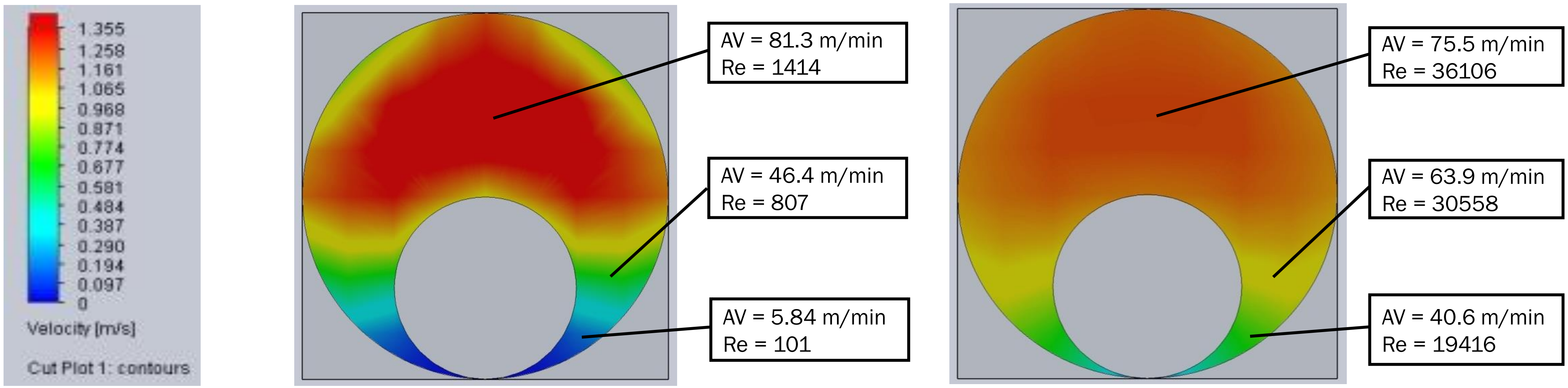
Mountain Coil Tubing

Fluid Rheology and Solid Transport – Effect of Viscosity

Simulation Parameters				
Casing ID (mm)	CT OD (mm)	Flow Rate (liters/min)	Average Velocity (m/min)	Average Velocity (m/sec)
118	60.3	600	74.3	1.238

Fluid Properties	
	Guar/Xantham Gel
Viscosity (100 sec-1)	55

Fluid Properties	
	Slickwater
Viscosity (100 sec-1)	2



Paramount resources ltd.

Mountain Coil Tubing

Fluid Rheology and Solid Transport – Horz. Wells

Bed Erosion Test Conditions:

Geometry: 139.7mm ID with 60.3mm OD CT

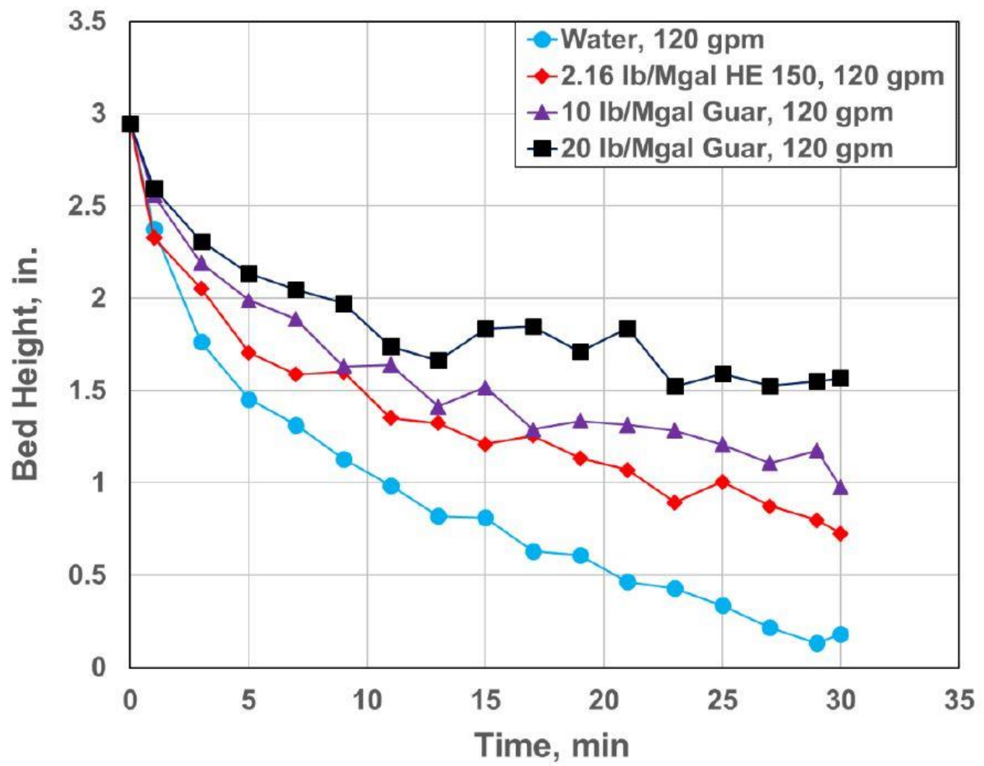
Proppant: 20/40 mesh sand

Inclination: 90°

Flow Rate: 454 l/min

Fluid Properties:

Fluid	Apparent Vis @ 511 sec -1 (CP)
Fresh Water	1
2.16 lb/Mgal HE - 150	2.77
10 lb/Mgal Guar	5.32
20 lb/Mgal Guar	14.39



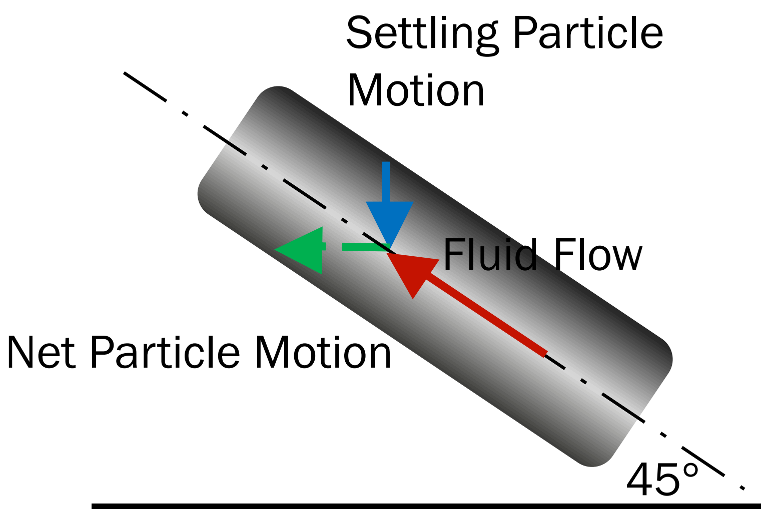
Naik, S. 2015, *Effect of fluid rheology and flow rate on wellbore cleanout operations in horizontal and deviated wells.* PHD Dissertation, University of Oklahoma, Norman Oklahoma, (Dec 2015)

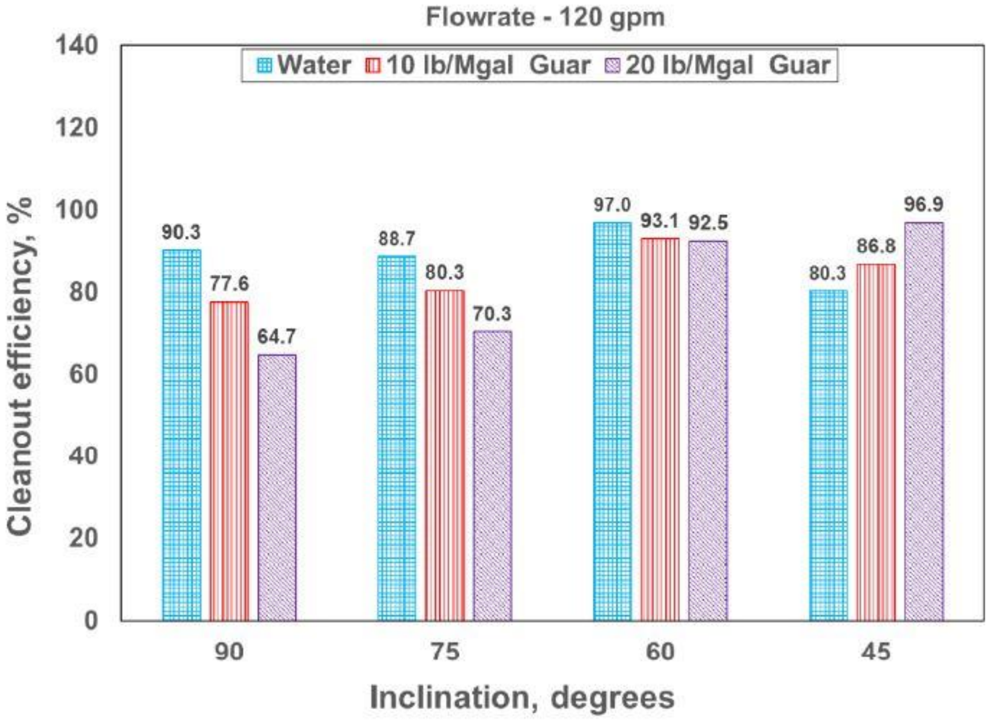
Paramount resources ltd.

MOUNTAIN COIL TUBING

Fluid Rheology and Solid Transport – Inclined Wells

$$Cleanout\ efficiency\ (\%) = \frac{Weight\ of\ Solids\ Removed}{Weight\ of\ Solids\ Loaded} \times 100$$





Naik, S. 2015, *Effect of fluid rheology and flow rate on wellbore cleanout operations in horizontal and deviated wells.* PHD Dissertation, University of Oklahoma, Norman Oklahoma, (Dec 2015)

Paramount resources ltd.

Mountain Coil Tubing

Fluid Rheology and Solid Transport – Flow Loop Videos

See video's of sand/plug slip debris in flow loop:

https://www.youtube.com/watch?v=jVbVkb1eRq8

https://www.youtube.com/watch?v=SIU0ZKQSTSo

FRCS System – Engineering a Better Fluid

Consistency

- *Consistent and precise chemical injection*
- *Base fluid is filtered and hardness, ph and chlorides are monitored throughout operation.*

Verification

- *Verification that fluids being supplied to the high pressure pumps are the proper rheological specifications.*

Optimization

- *Chemical loadings can be changed in seconds, all chemicals are pumped on the fly*
- *Ability to measure effectiveness of FR pre-/post-mix fluids in real time*

When ran with the correct principles, *provides a fluid with superior horizontal well-bore cleaning capabilities that allows for a NO wiper trip mill-out and more efficient clean-outs.*

Paramount resources ltd.

MOUNTAIN COIL TUBING

Milling Efficiencies – other considerations

BHA Optimization

- *Well design, plug design, extended reach tools and reservoir temperature all key factors.*
- *BHA Bit/Mill and plug design compatibly*

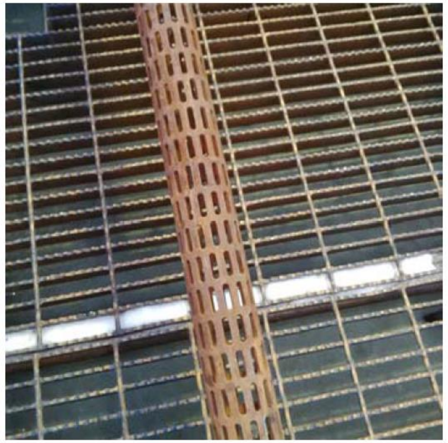
Milling Technique

- *Reducing/eliminate stalls*
- *Control plug drill times and pull out of hole speeds, controls debris size and debris fluid loading*

Milling Efficiencies – other considerations

Well Behavior Based Decisions:

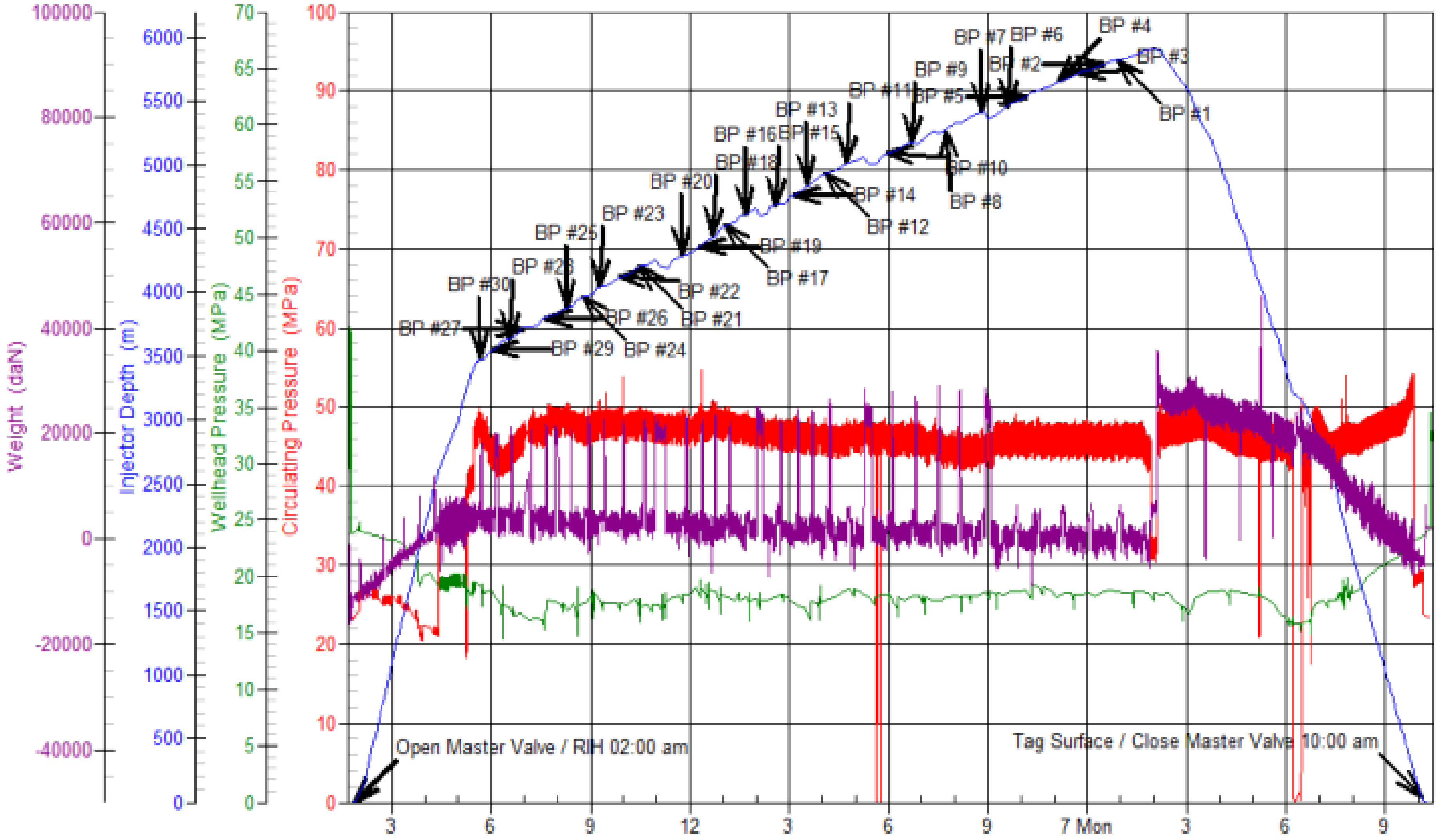
- Abnormal string weight
- Net fluid return rate (±50 litres of pump rate)
- Wellhead pressure fluctuations
- Fluid Tracking to watch for cross-flow
- Debris Benchmarking



Paramount resources ltd.

MOUNTAIN COIL TUBING

Job Plot– Plug Milling

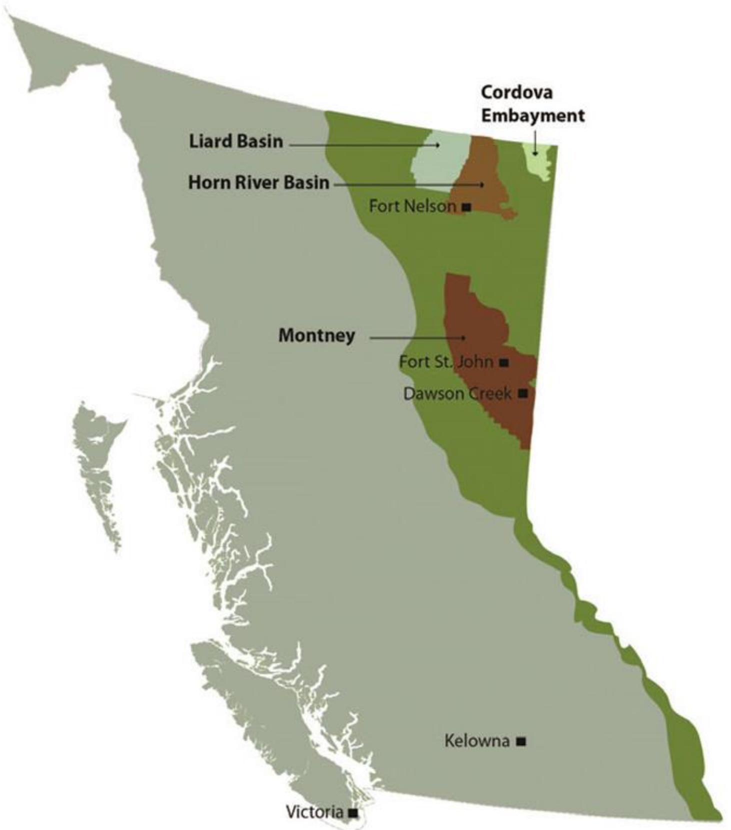


Paramount resources ltd.

MOUNTAIN COIL TUBING

Case Study – Horn River Millouts

- Horn River Basin
- Shale gas reservoir
- Average of 23 isolation plugs/well
- Average 2300m horizontal length
- 139.7mm Mono-bore completion
- Millouts performed by another coiled tubing provider.
- FRCS used in next 2 campaigns
- Data on 30 wells, +650 plugs
- Identical surface equipment (60.3mm CT) with exception of chemical injection system

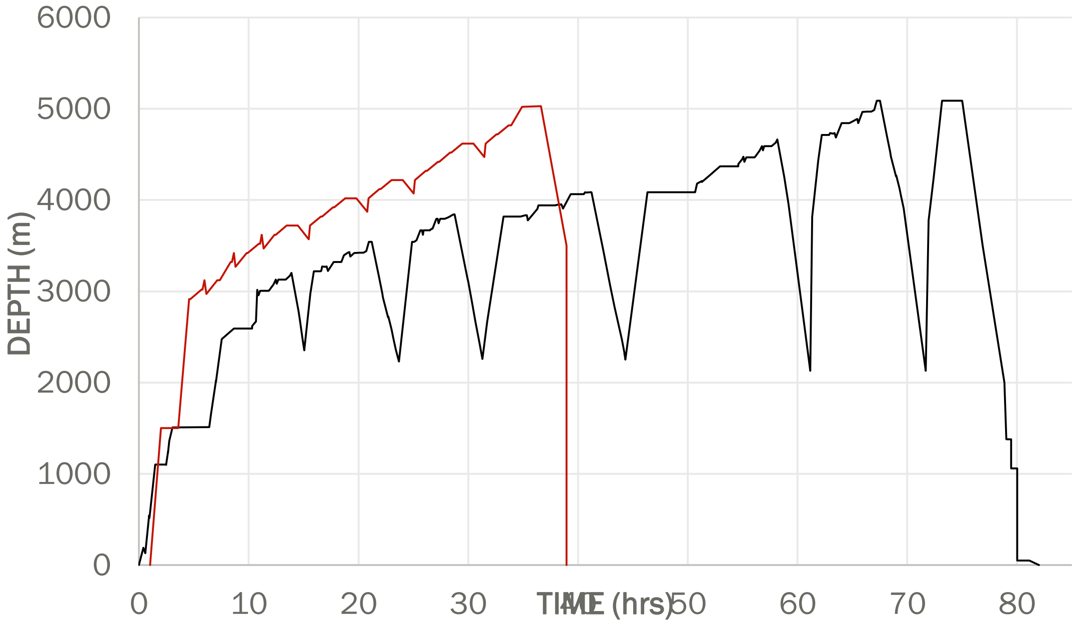


British Columbia's Shale and Tight Resources, 2017 July 25, http://www.nrcan.gc.ca/energy/sources/shale-tight-resources/17692

Paramount resources ltd.

MOUNTAIN COIL TUBING

Horn River Millouts – Performance Statistics



FRCS Milling

Traditional Milling

	Gel / Plug	FR / Plug	Stuck Time / Plug	Cycled Meters / Plug	Total Time / Plug	Total Cost / Plug
Percent Reduction	85%	83%	63%	56%	40%	32%

Paramount resources ltd.

MOUNTAIN COIL TUBING

Case Study – Optimized Duvernay Millouts

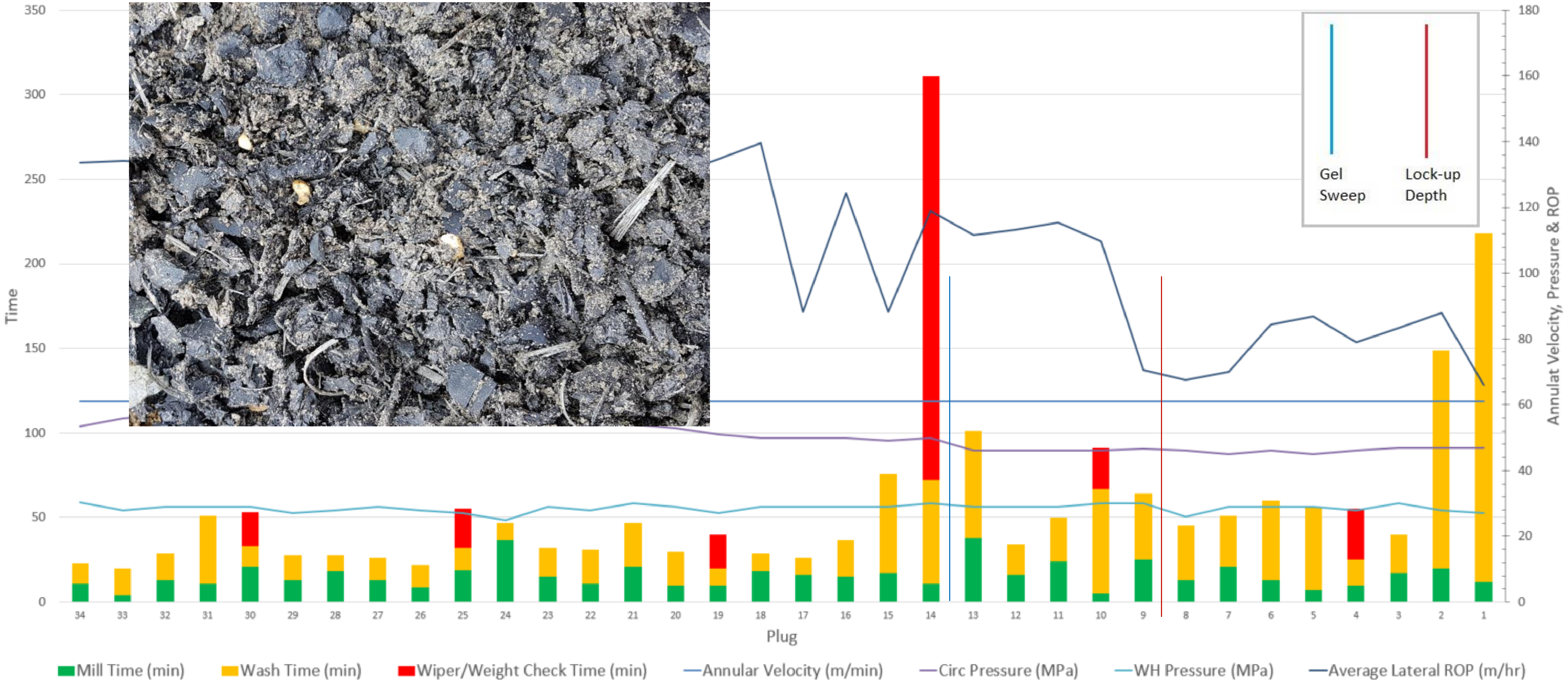
- Kaybob Basin, 6 well pad, total of 244 plugs
- 139.7mm Mono-bore completion
- Tapered 60.3mm CT used
- 2 different extended reach tools used
- FRCS used to supply quality control and treated fluid to both downhole CT pumps
- 600m^3 of fluid to be recirculated throughout operations

	# of plugs	Measured Depth (m)	Horz. Length (m)
Alpha	34	5479	2103
Bravo	34	5465	2124
Charlie	34	5465	2112
Delta	45	5515	2253
Echo	45	5463	2143
Foxtrot	52	5809	2496

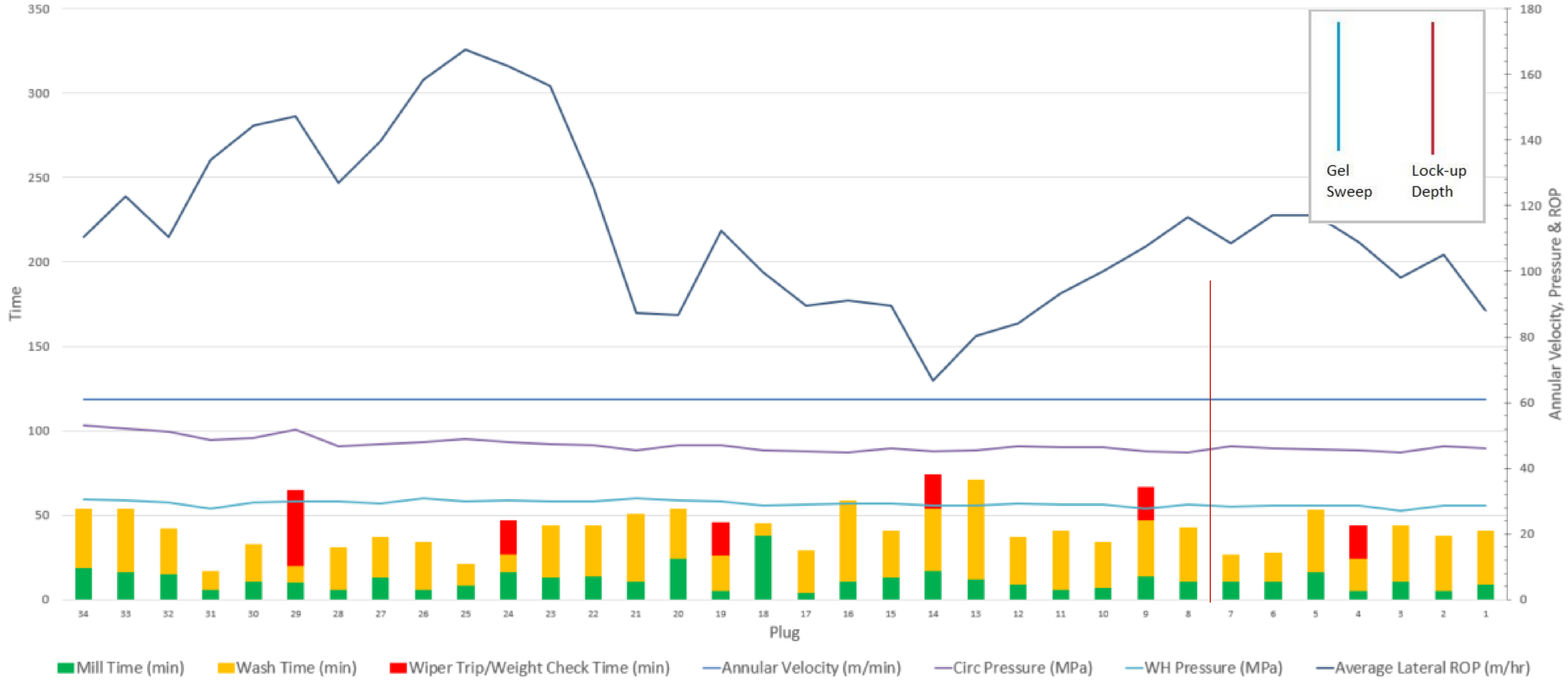
Paramount resources ltd.

Mountain Coil Tubing

Duvernay Millouts – Bravo Well



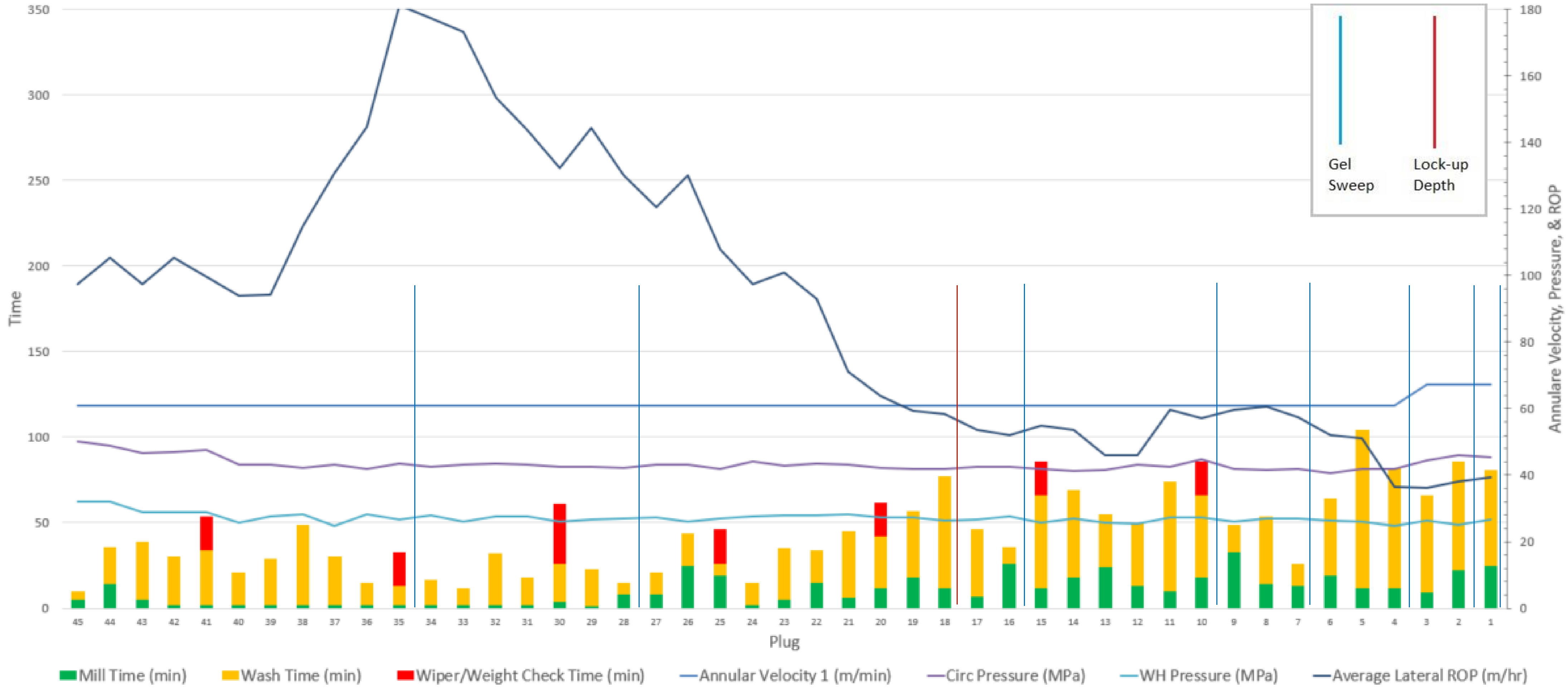
Duvernay Millouts – Charlie Well



Paramount resources ltd.

MOUNTAIN COIL TUBING

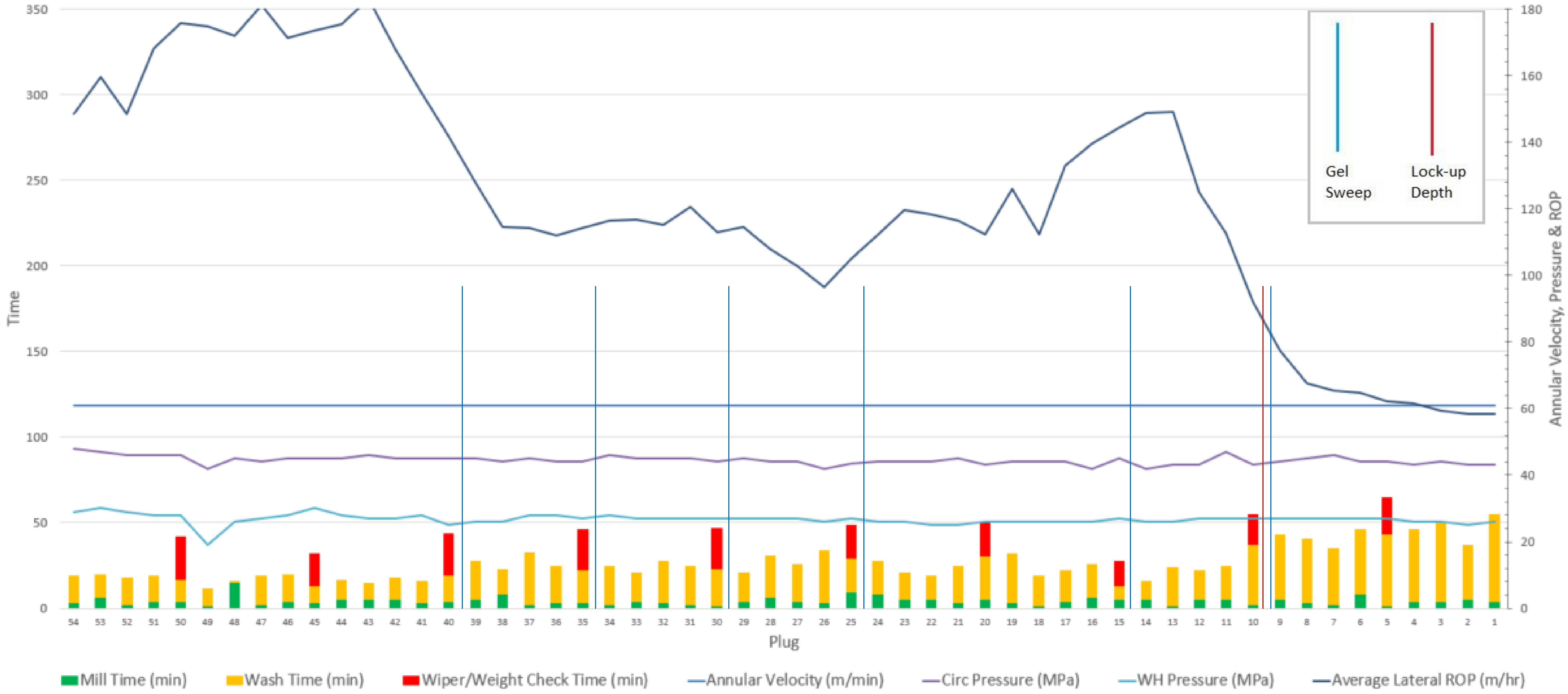
Duvernay Millouts – Echo Well



Paramount resources ltd.

Mountain Coil Tubing

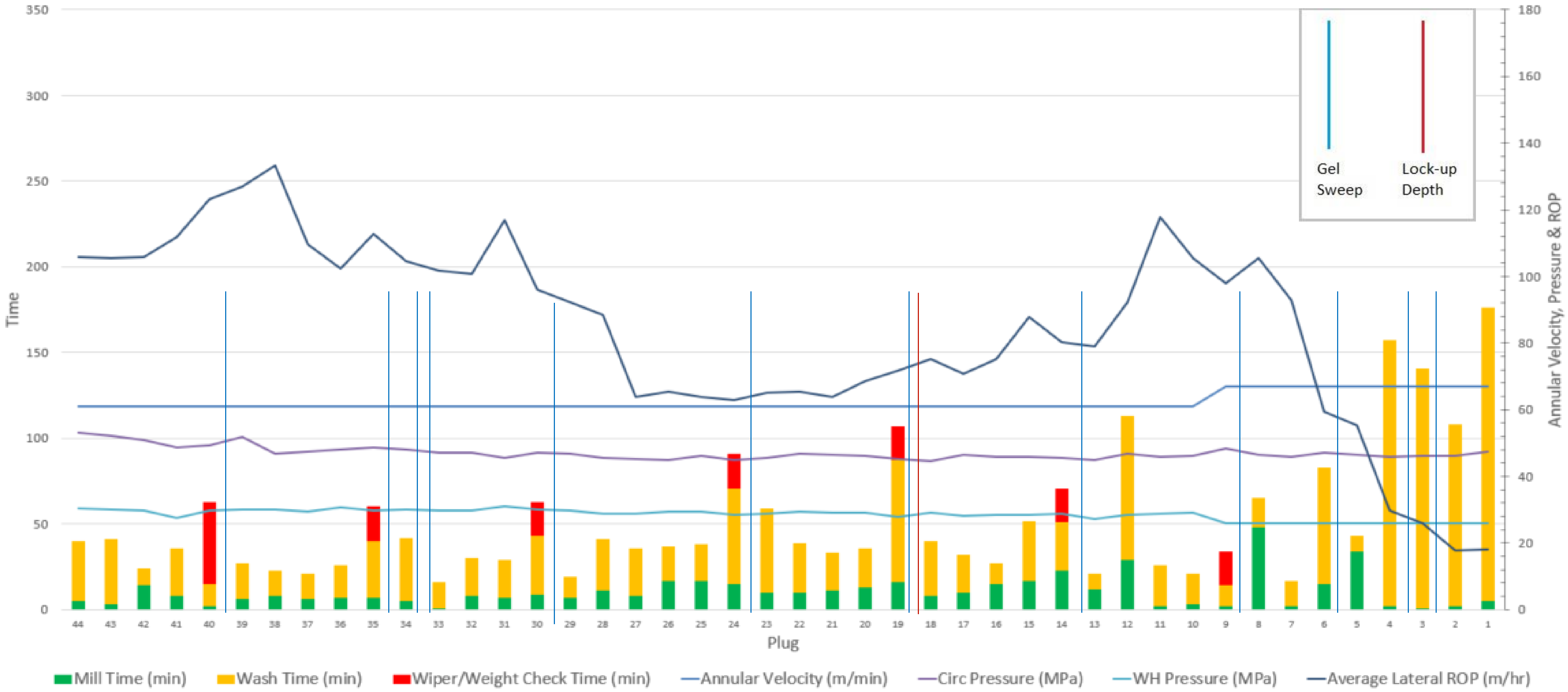
Duvernay Millouts – Foxtrot Well



Paramount resources ltd.

MOUNTAIN COIL TUBING

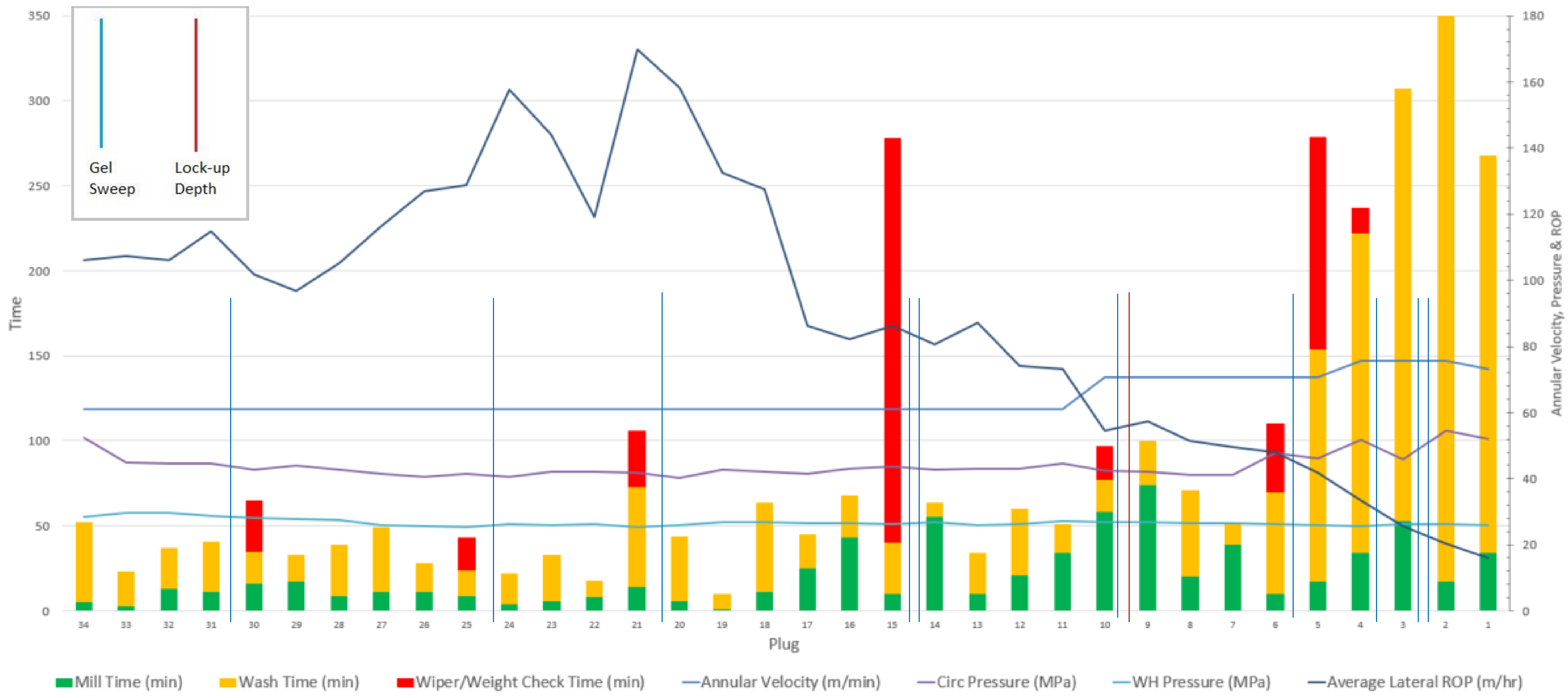
Duvernay Millouts – Delta Well



Paramount resources ltd.

Mountain Coil Tubing

Duvernay Millouts – Alpha Well



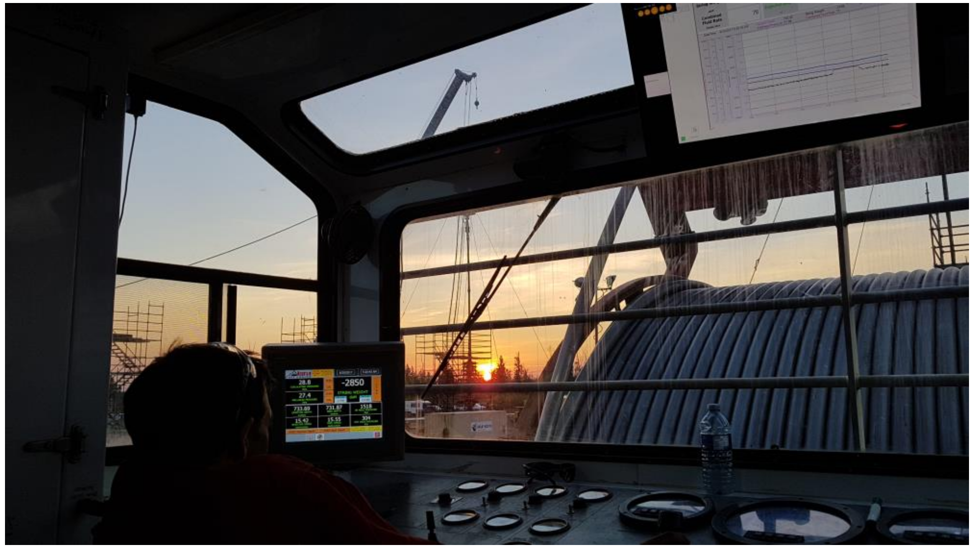
Paramount resources ltd.

Mountain Coil Tubing

Duvernay Millouts – Chemical Usage Stats

- Operations were designed with minimal chemical usage in mind
- Lubricant was the highest used chemical
- Gel pills did not bring up extra debris after bottoms up
- Friction reducer loadings were maintained at a low rate
- Charlie well was the fastest operating time with the least amount of gel pumped (38 hrs with 29 L of Gel)
- Alpha well used 31% of the lubricant, beads were also deemed effective on this well.

	Volume (Liters)
Gel (L)	1006
Friction Reducer (L)	3050
Lubricant (L)	7121
Biocide (L)	702
Beads (kg)	60



Paramount resources ltd.

Mountain Coil Tubing

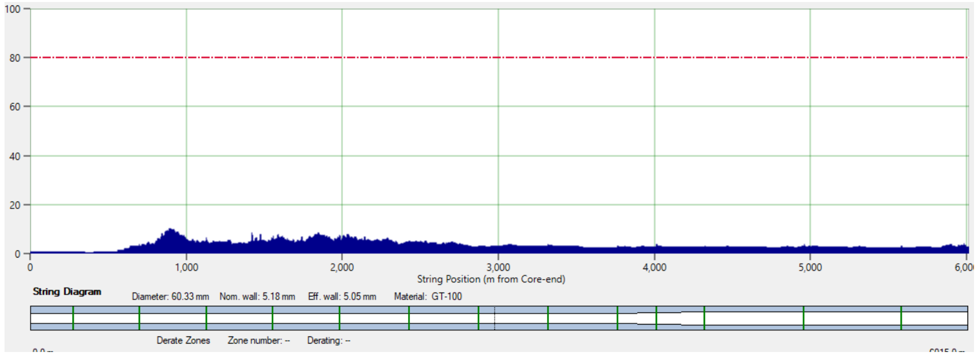
Duvernay Millouts – String Fatigue

String #1

- 90 KSI, 0.224” – 0.175” Taper Wall
- Completed prep, intervention, milling, and fishing operations
- Post project max fatigue 12.62%
- New string at the start of the project

String #2

- 100 KSI, 0.204” – 0.156” Taper Wall
- Completed milling operations on 3 wells
- Post project max fatigue 10.19%
- Pre project max fatigue was 5.31%



Minimal cycle meters, reduced stalls (only 1 documented), optimal FR loading for reduced circulation pressure all factor in minimizing string fatigue.

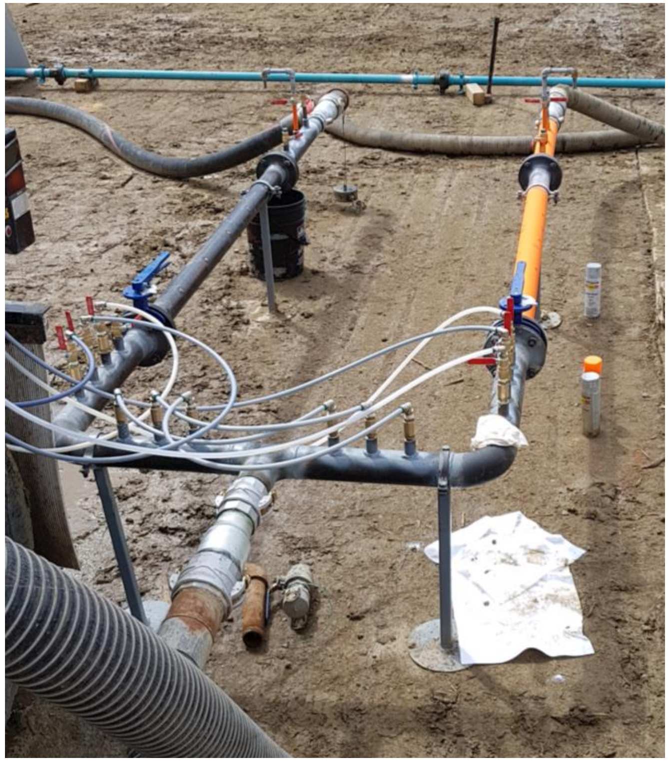
Note: Both strings were retired without failure at manufacture's recommended fatigue limit

Paramount resources ltd.

Mountain Coil Tubing

Duvernay Millouts – Conclusions

- Non viscous turbulent flow deemed adequate for debris removal in all sections of the well, gellant and wiper trips confirmed to be unnecessary in removing debris, or aiding in efficiencies
- Aggressive ERT deemed superior, however, plug milling times need to be managed in order to control debris size
- Supplying treating fluid to 2 CTU's from one FRCS a success
- Filter pots and minimal chemical dosage allowed for recirculated fluid to be utilized beyond expectation
- Wellbore conditions can have large effect on operating efficiencies
- Significant cost saving came from reduced total fluid needed, chemical consumption, cycled meters and overall operating time.



Paramount resources ltd.

Mountain Coil Tubing

Stop Wasting Money! Drill Plugs Faster.

Questions?

Paramount resources ltd.

MOUNTAIN COIL TUBING