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Stop, Drop And Circulate An Engineered Approach To Coiled Tubing Intervention in Horizontal Wells

Charles Pope
Complete Shale

Society of Petroleum Engineers
Distinguished Lecturer Program
www.spe.org/dl

Agenda

- Global coiled tubing usage
- Problems with historical practices
- Results from a few case histories
- Take away

Where and how coiled tubing is used

Coiled Tubing Intervention

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Initial Completion:

- Well Prep
- Perforating
- After Frac Drillouts
- Coiled Tubing Fracs

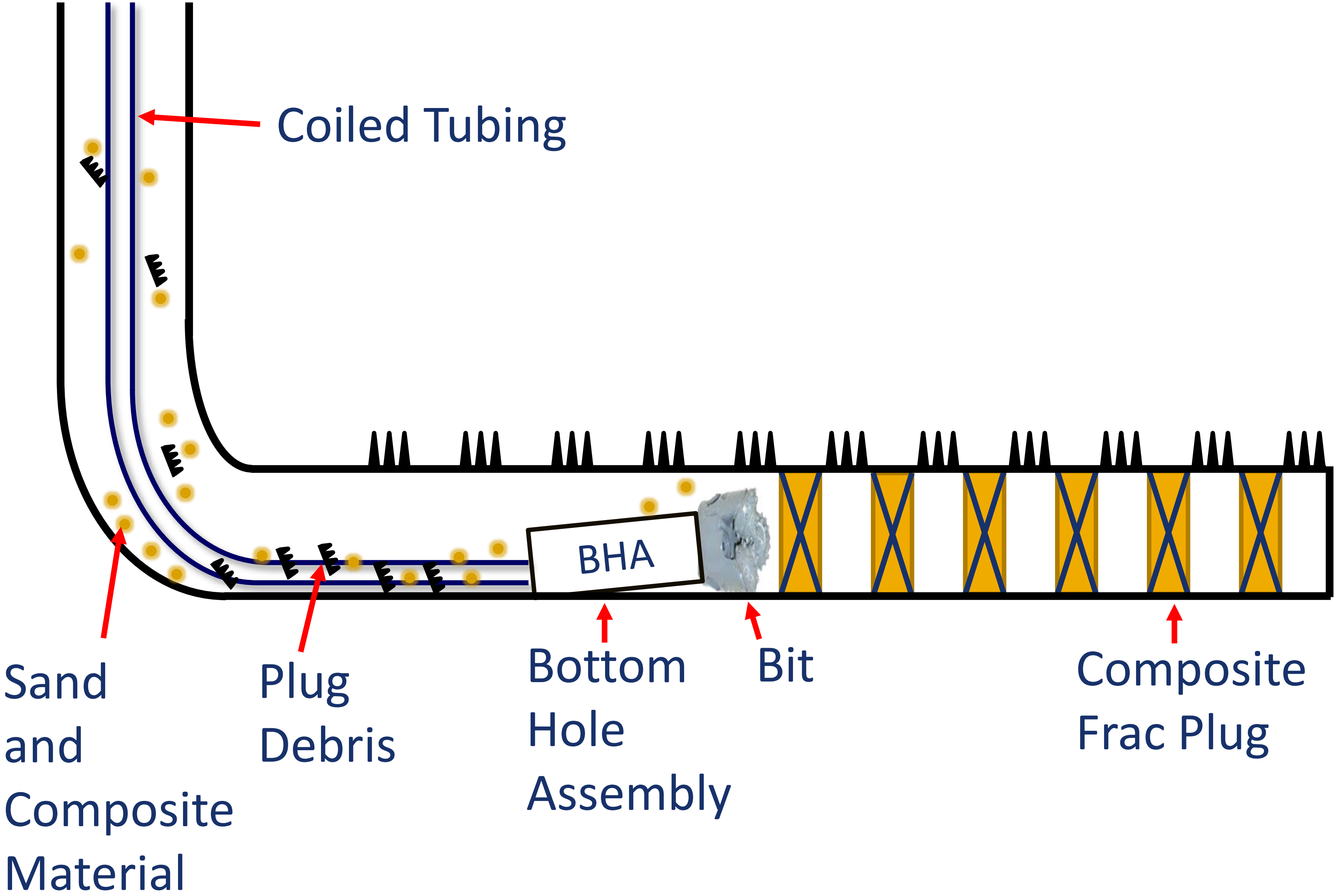
Cleanouts Prior to:

- Acid Stimulation
- Chemical Treatments

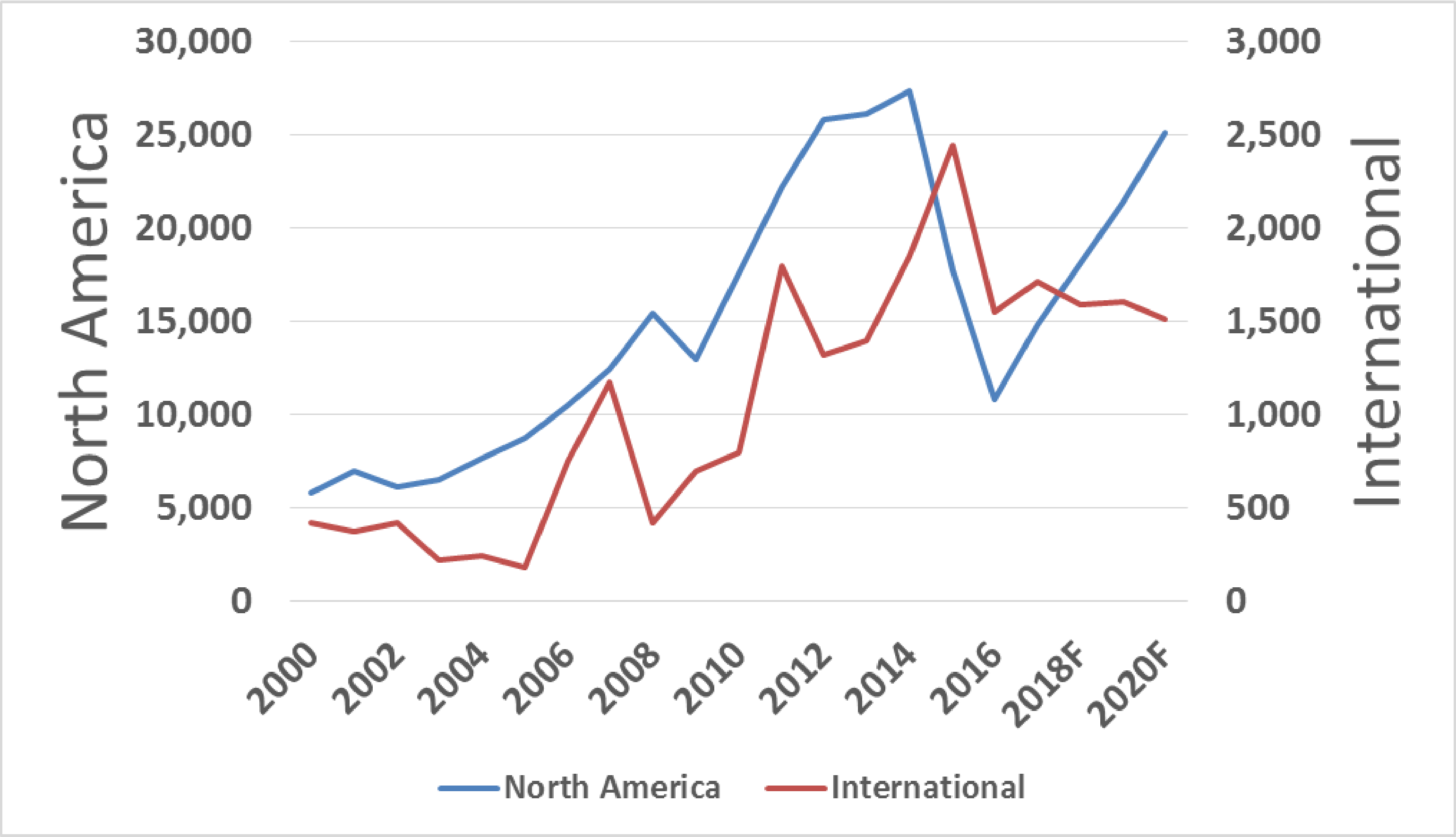
Also used for:

- Logging
- Fishing
- P&A

Typical Wellbore Configuration



Annual Horizontal Wells Drilled



- Sources: Rystad Energy, 2017; Baker Hughes

Active Coiled Tubing Units

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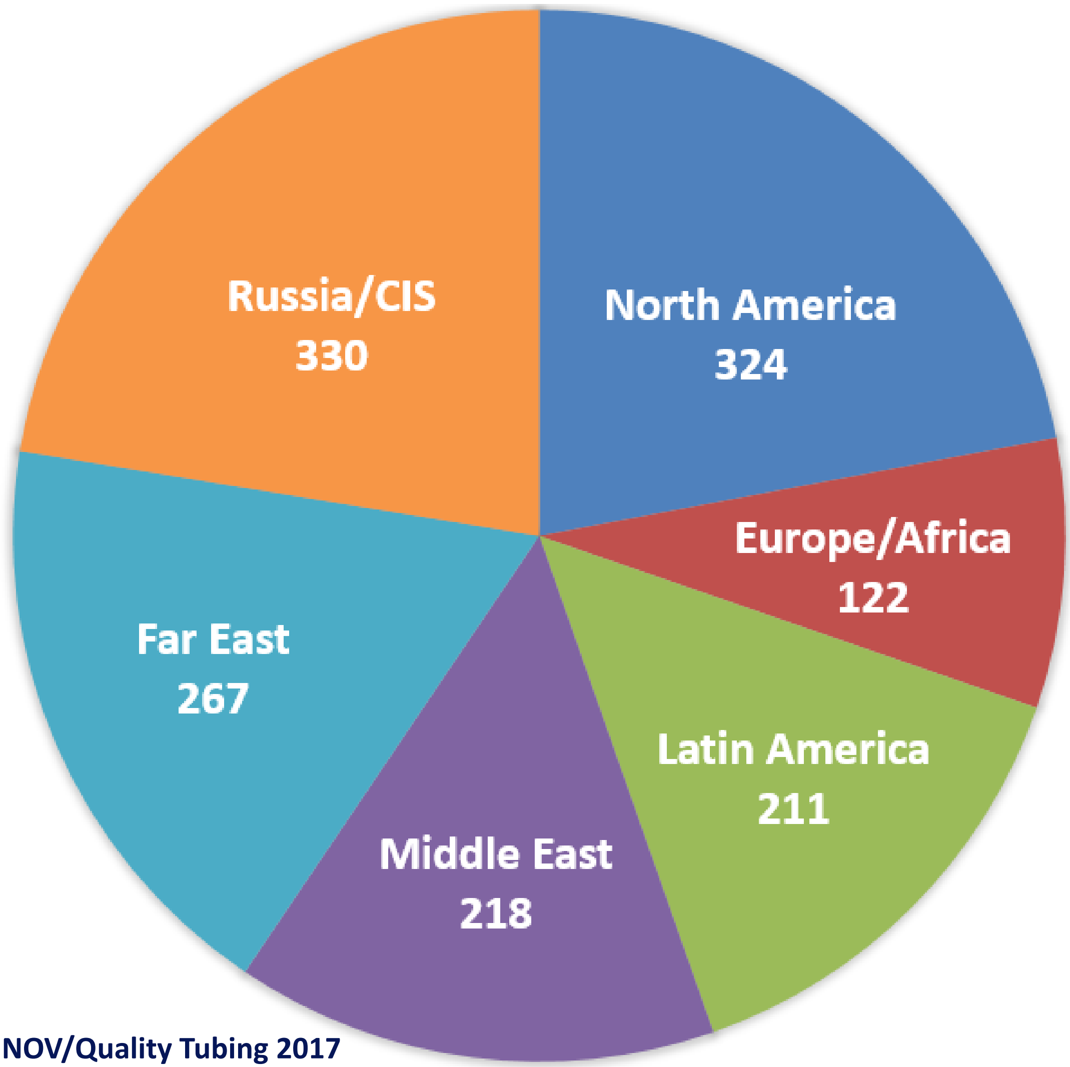
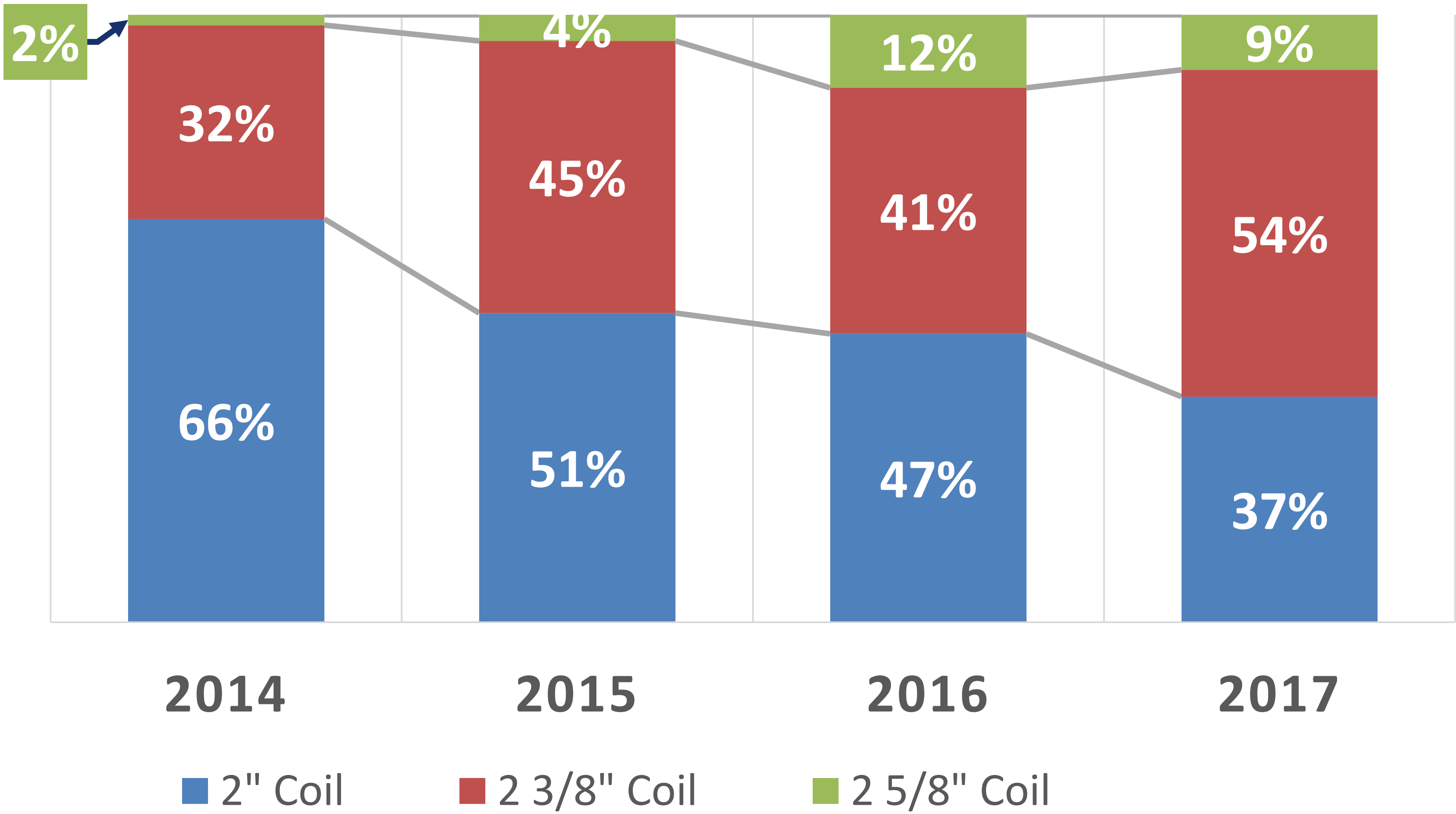


1472 Active Units

NOV/Quality Tubing 2017

Horizontal Wells Drive Larger Pipe



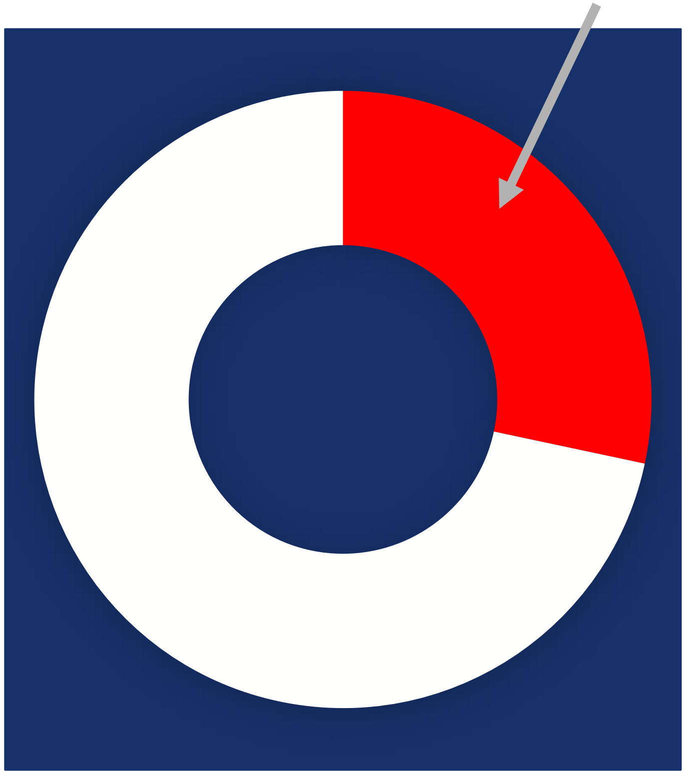
NOV/Quality Tubing 2017

Why is this Important?

28% of spend

Spent $60MM

Average costs $250k



2015

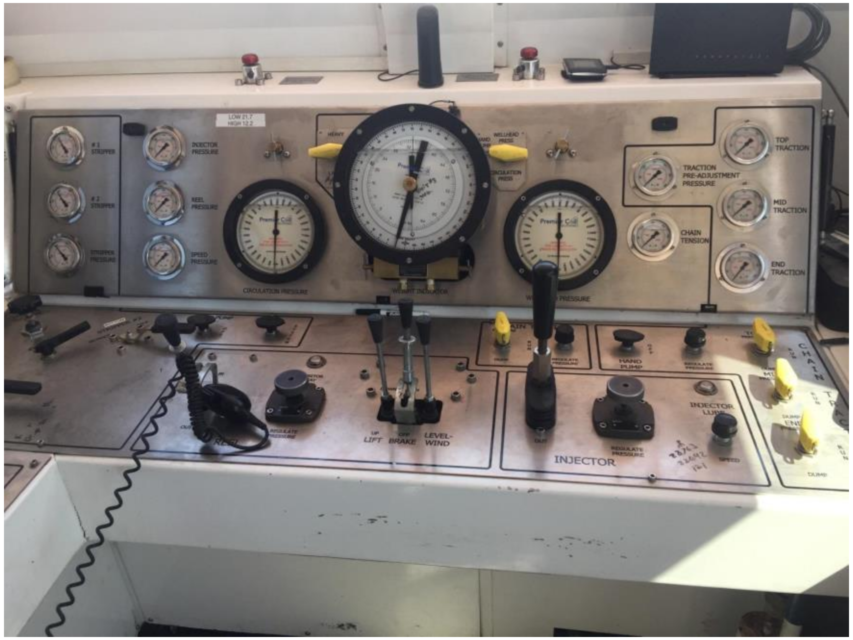
Top 10 drillouts cost $17MM

Cost overruns on 30% of wells

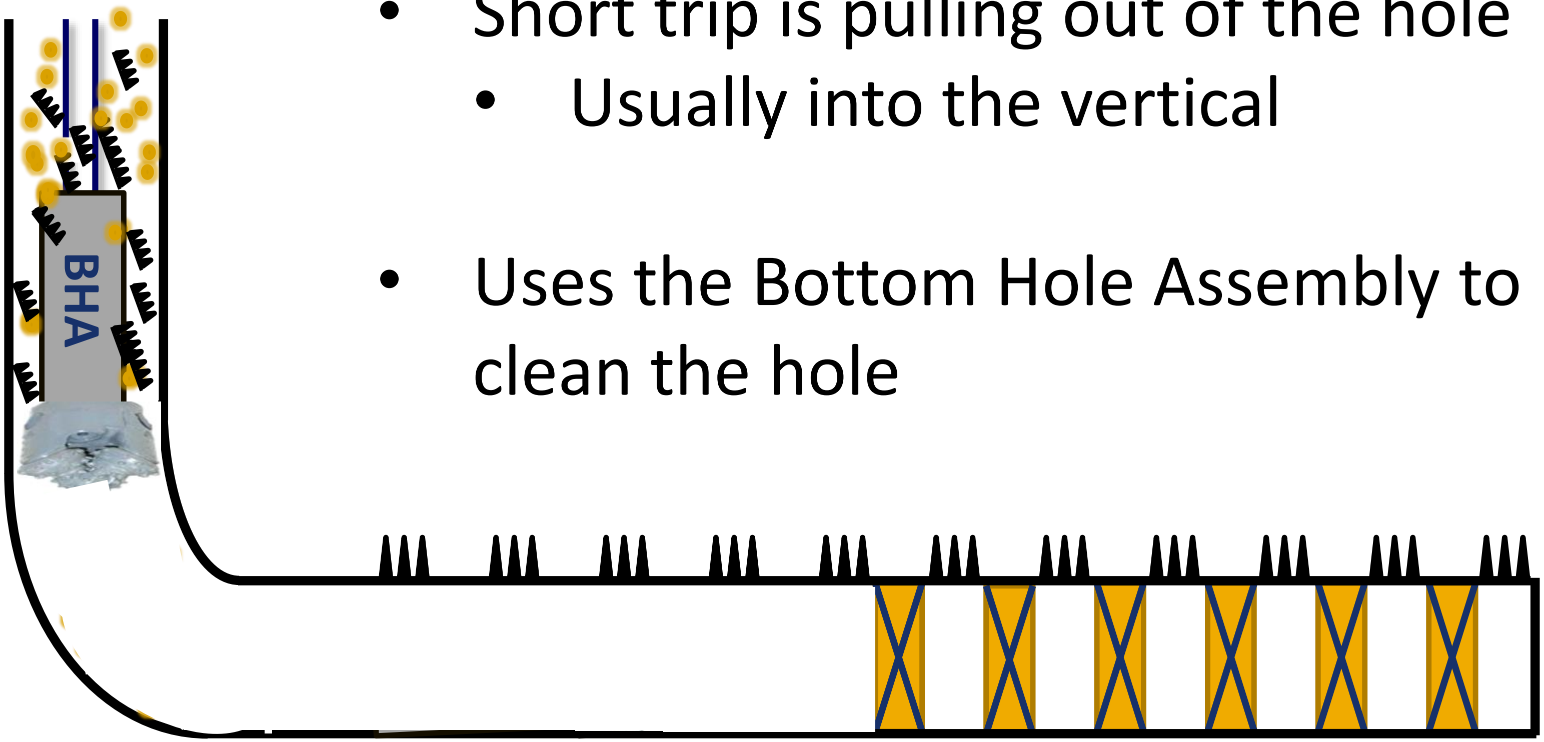
Stuck pipe: 1 well in 16

Historical Practices

- Very little engineering support
- Applied vertical well techniques
- Short trips
- Gel sweeps
- No digital data gathered



Short Trips



- Short trip is pulling out of the hole
  - Usually into the vertical
- Uses the Bottom Hole Assembly to clean the hole

How Common is Stuck Pipe?

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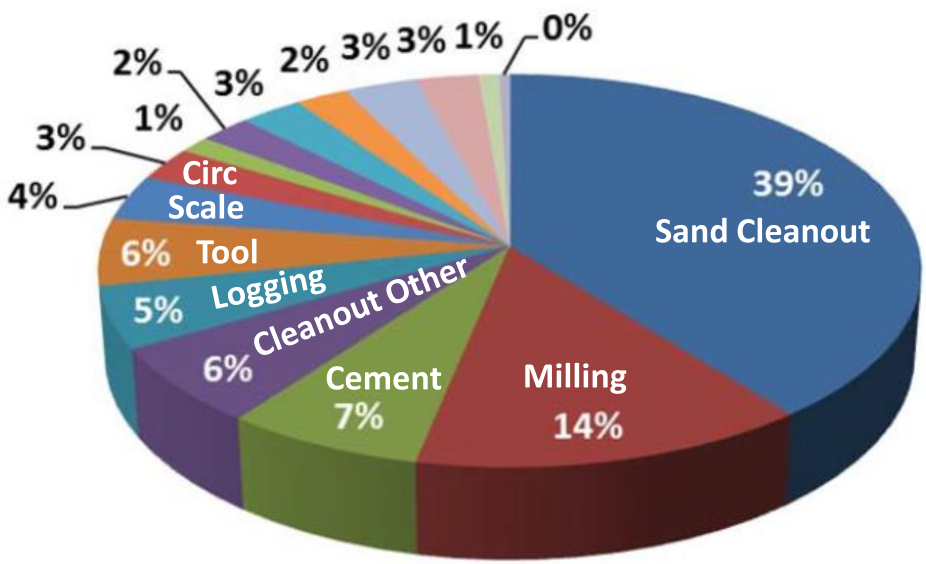
- From 2001 to 2010: stuck pipe incidents increased 43%. (Burgos, SPE 163914)
- 2012 in BC: stuck ~0.25 hrs per plug. (Lyndsey, SPE 178644-MS)
- From 2013 to 2015: 600 interventions, stuck 14 hrs per well. (Pope, SPE 187337-MS)

“An ounce of prevention is worth a pound of cure.” Benjamin Franklin

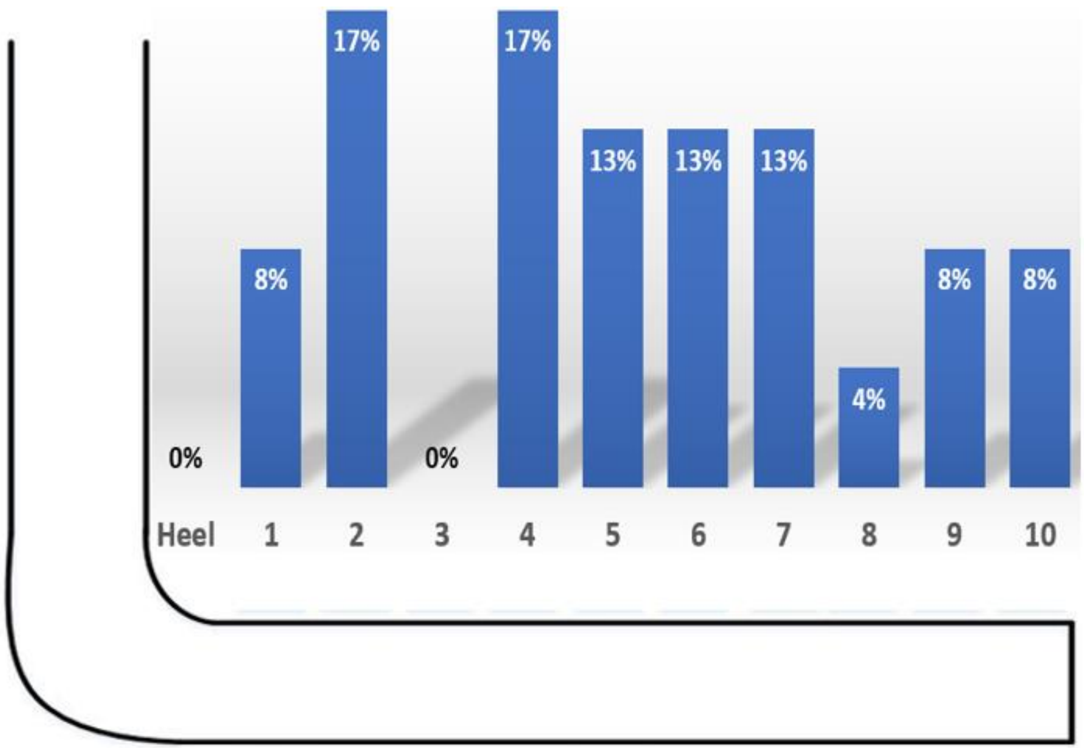
Causes of Stuck Pipe



- Sand cleanouts represent biggest hazard
- Routine interventions account for 63%

SPE 163914

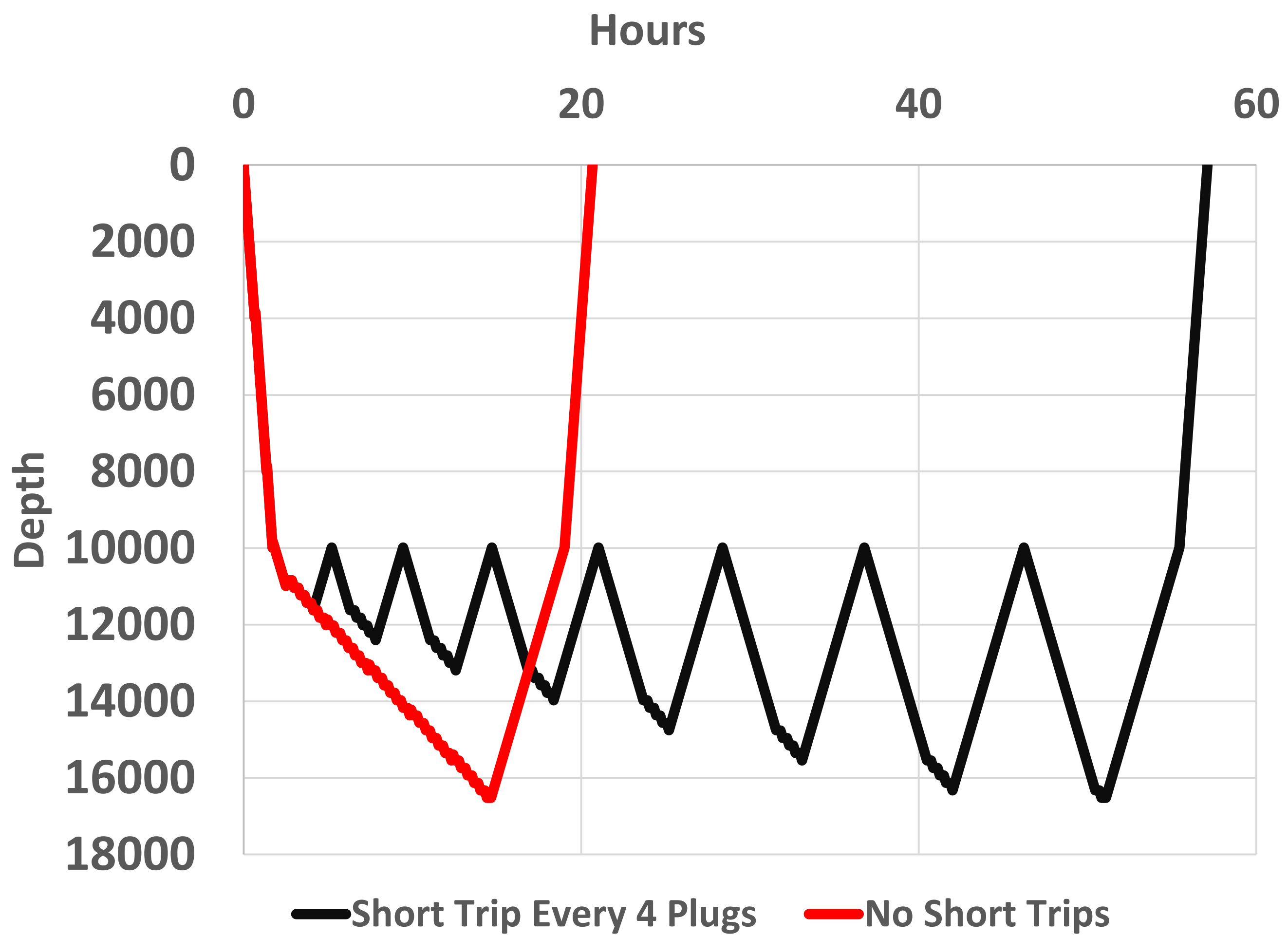
Where do we get Stuck?



Location of stuck pipe event normalized by lateral length

- 26 confirmed events
  - 22 short trips
  - 2 when picking up off bottom
- No stuck events in curve
- 85% of time stuck pipe is related to the short trip

Effect of Short Trips on Time



Example:

16,500 ft

30 Plugs

Sweeps

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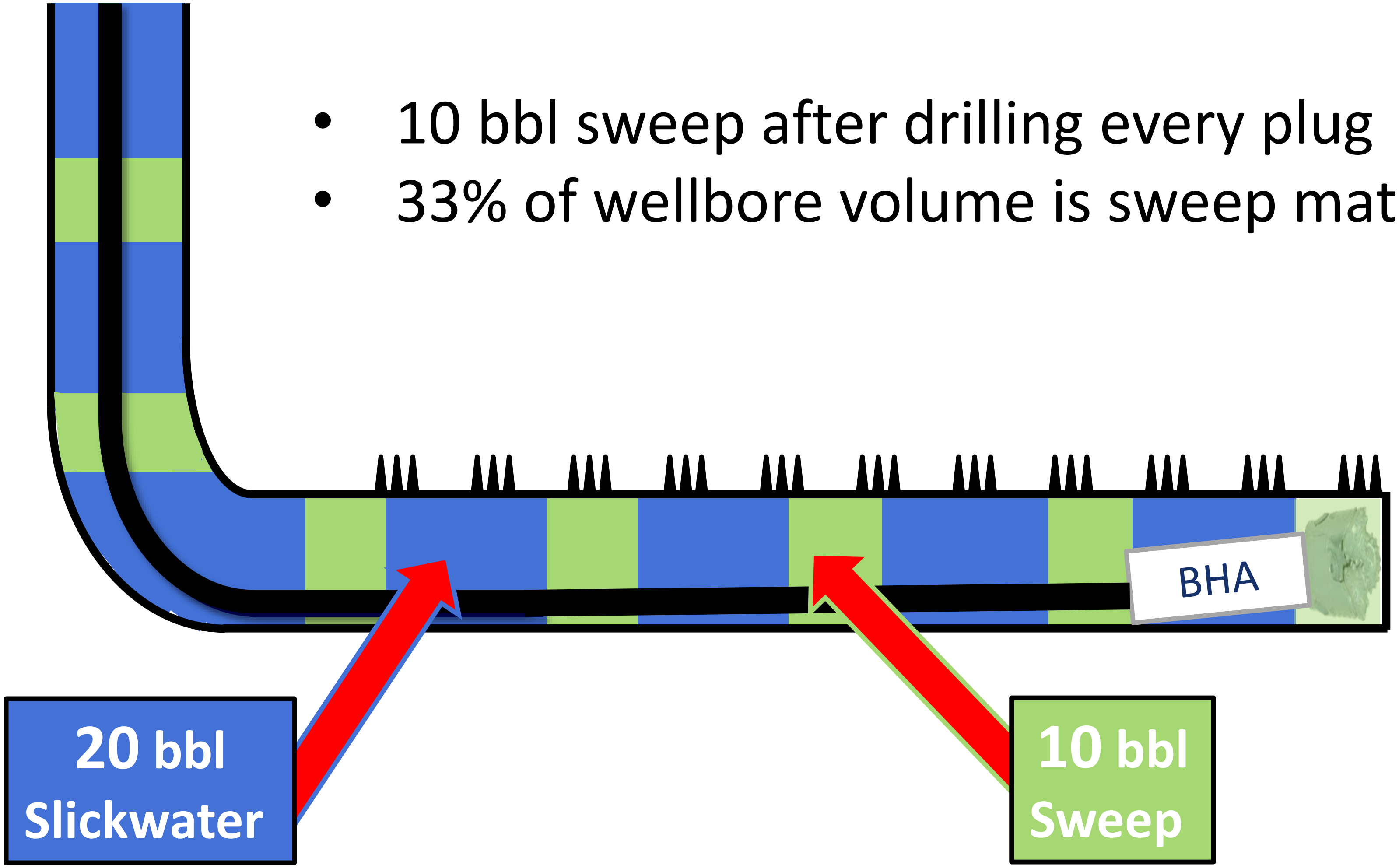
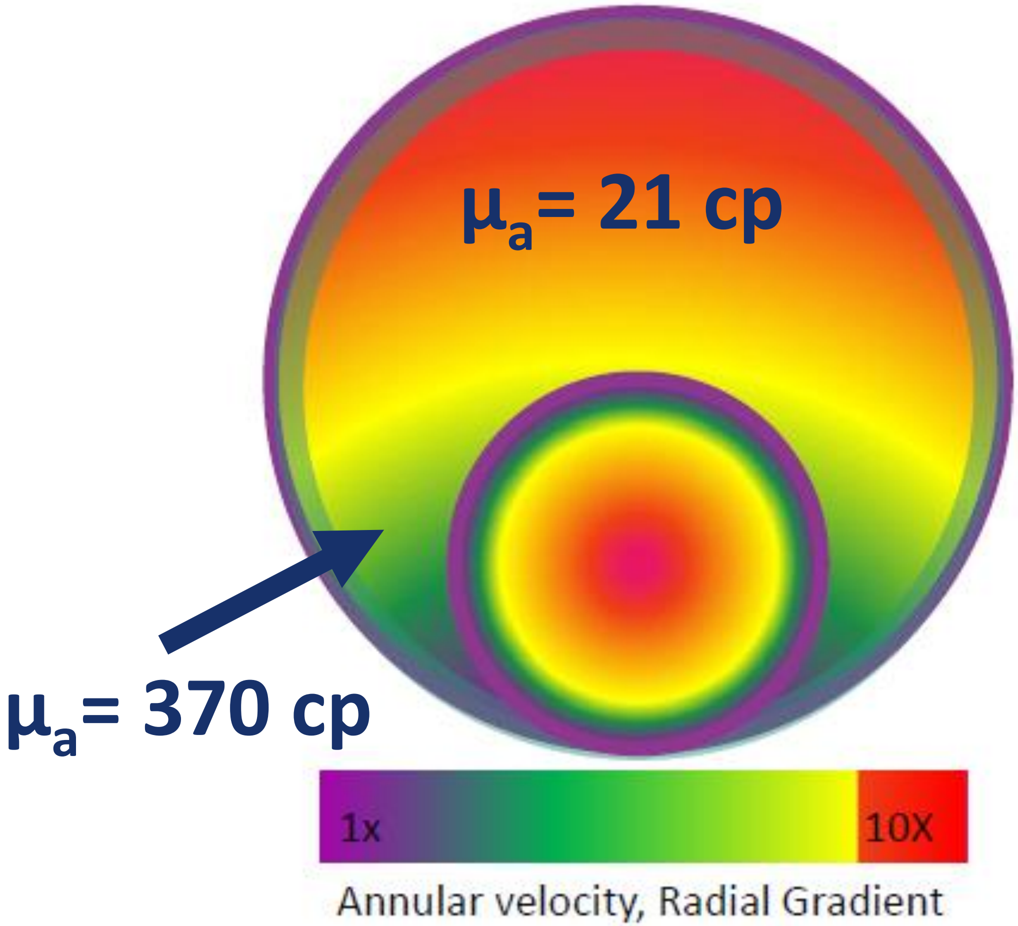
- 10 bbl sweep after drilling every plug
- 33% of wellbore volume is sweep material



Velocity and Viscosity



Modified from Hutchings (2013) and Chin (2001)

Model Parameters:

5 ½” Casing

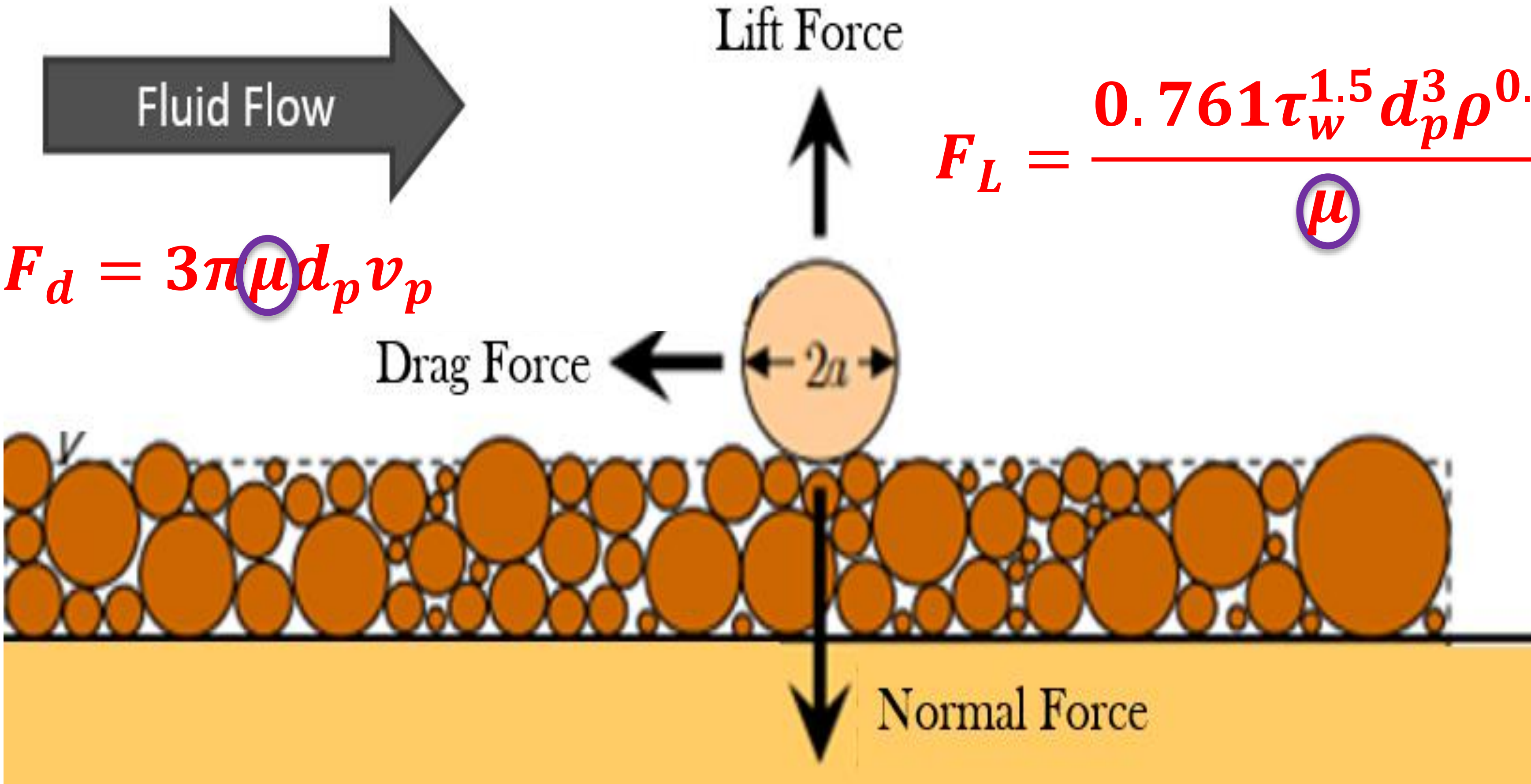
2” Coiled Tubing

3 BPM

175 fpm

108 cp

Lift and Drag Forces



$$F_L = \frac{0.761\tau_w^{1.5} d_p^3 \rho^{0.5}}{\mu}$$

$$F_d = 3\pi\mu d_p v_p$$

Modified from Farajzadeh, 2004

Investigate Laboratory Results

- Observe the fluid-debris interaction
- Are basic assumptions about hole cleaning valid?
- Many service companies have flow loops
- Several Universities have horizontal flow loop consortiums

Debris Movement
Viscous Fluid

200 Funnel vis, 3 BPM, 260 fpm

Debris Movement in Slickwater

27 Funnel vis, 3 BPM, 260 fpm

Annular Velocity and Reynolds Number

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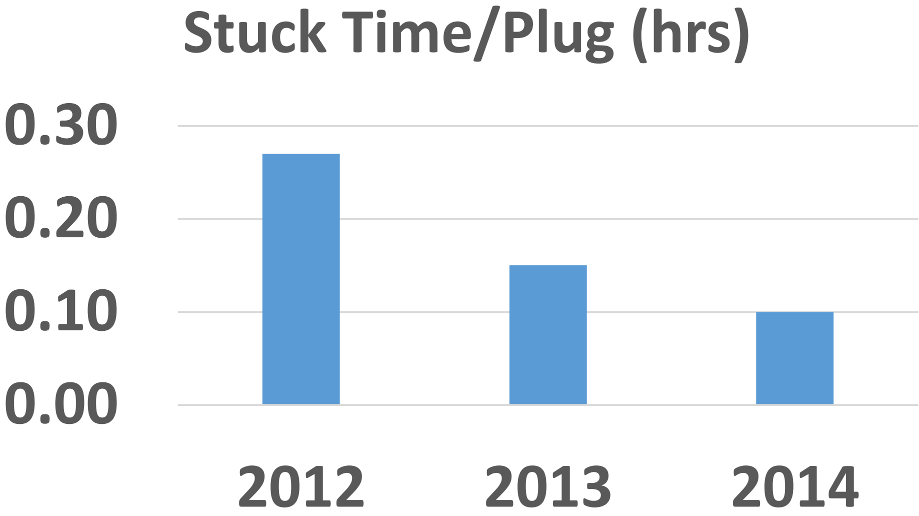
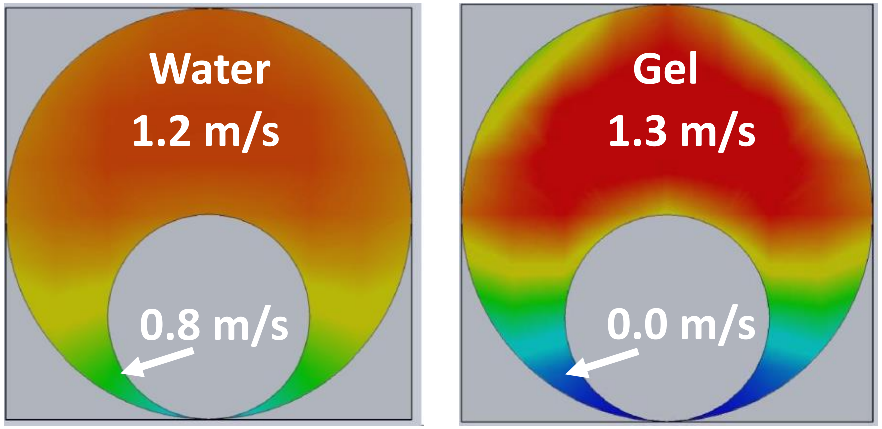
$$Re = \frac{928 * \rho * v * (d2 - d1)}{60 * \mu}$$

			Funnel Vis		
			27	36	200
BPM	AV, fpm				
3	260	Re	66,982	6,698	385

Sweep Displaced by Slickwater

British Columbia Case History

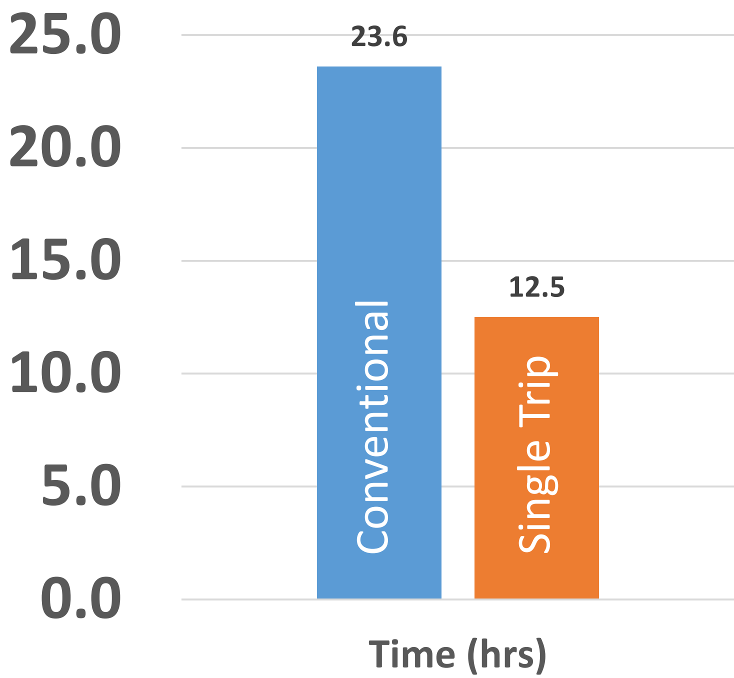




- Wiper Trip Matrix
- Stuck pipe: every well
- Fluid Costs > $40k
- Re-entrainment of solids a function of Reynolds number

SPE 178644-MS/URTeC:2155463 (2015)

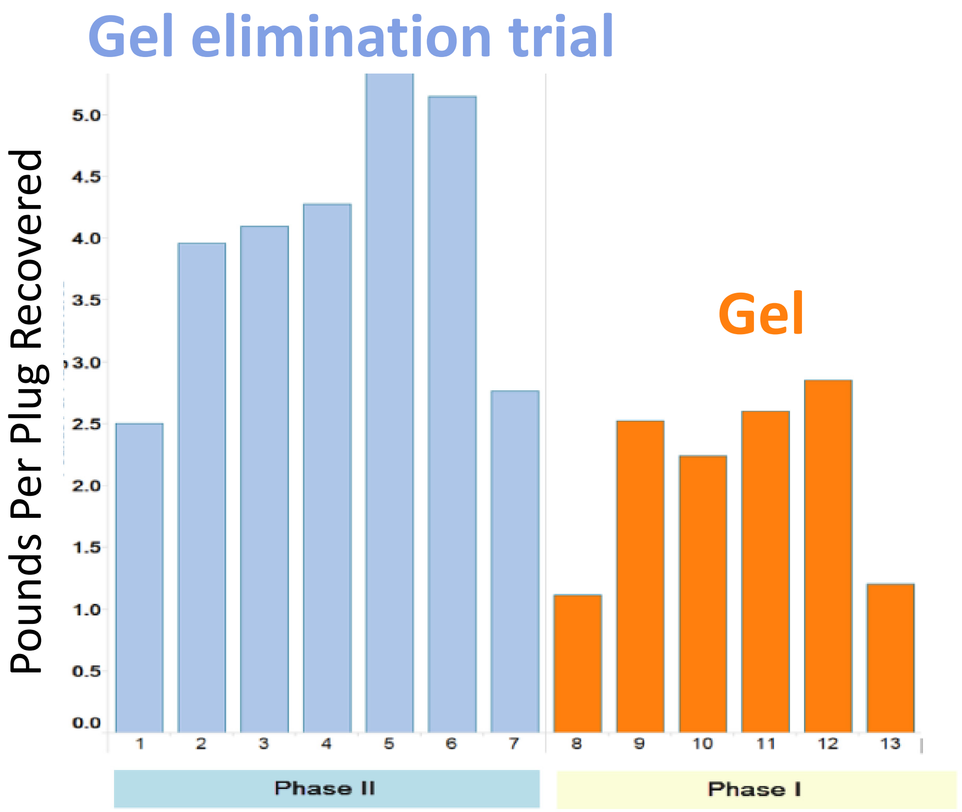
DJ & Williston Basin Case History



- Single Trip Cleanouts (some wiper trips)
- Gel Sweeps minimized
- Chemical usage down 95%
- Reynolds number >20,000

SPE179090–MS (2016)

Eagle Ford Shale Case History



- Single Trip Drillouts
- Non-Viscous Fluids
- ~2x plug recovery

SPE179070–MS (2016)

Woodford Case History

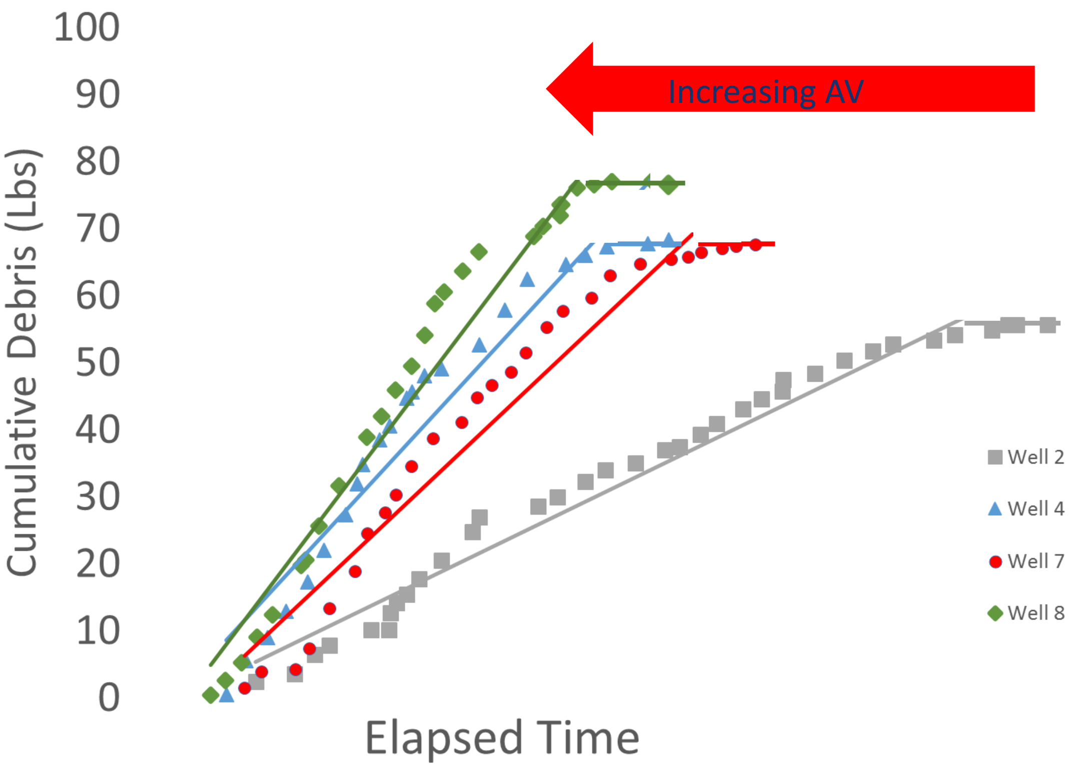
- 33 similar wells
- 2” Coiled Tubing, 5 ½” Casing
- 5000 ft laterals
- 30 or more composite frac plugs
- 1 coiled tubing vendor
- 1 chemical vendor
- No short trips
- No gel sweeps

SPE 187337–MS (2017)

Debris at Surface

- Weigh Debris
- Record Time
- Plot Data

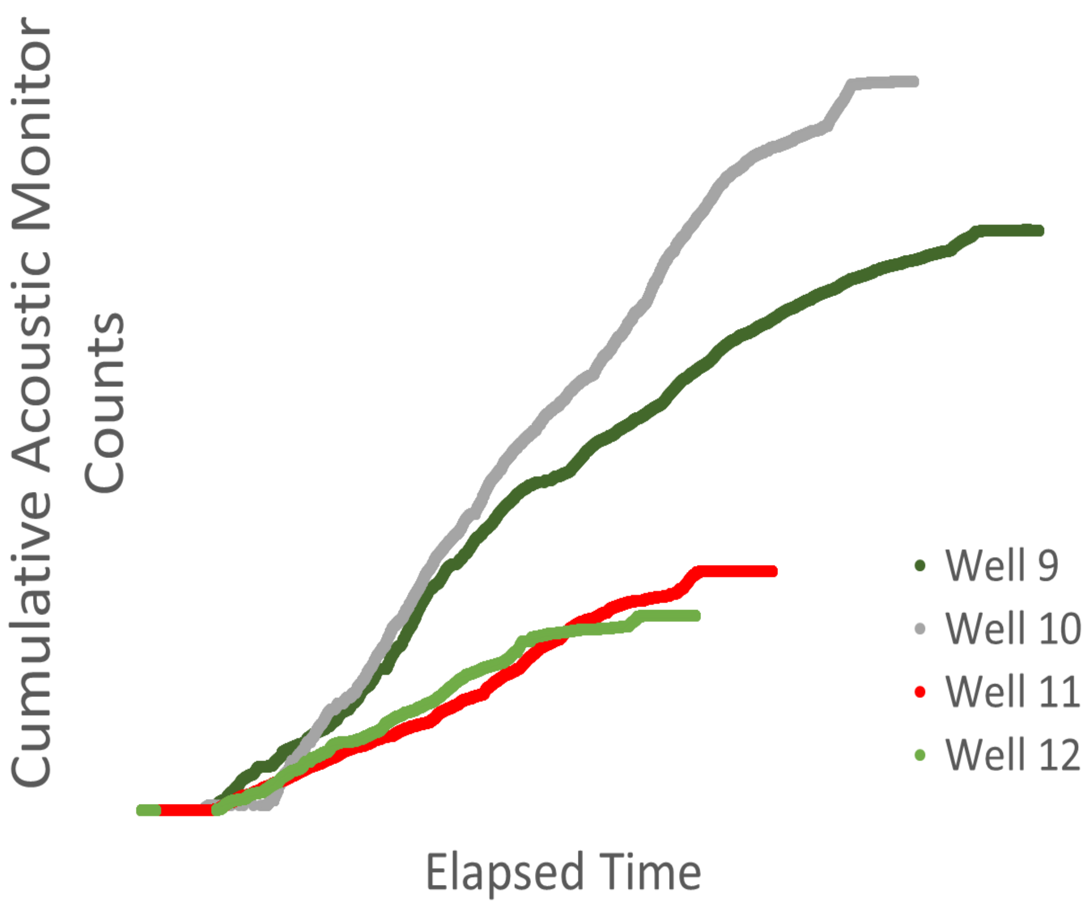
Debris Monitoring



- Better hole cleaning
  - Higher AV's up to 300 fpm
  - Higher Re up to 50,000
- BHA is not bringing up additional debris

SPE 187337–MS (2017)

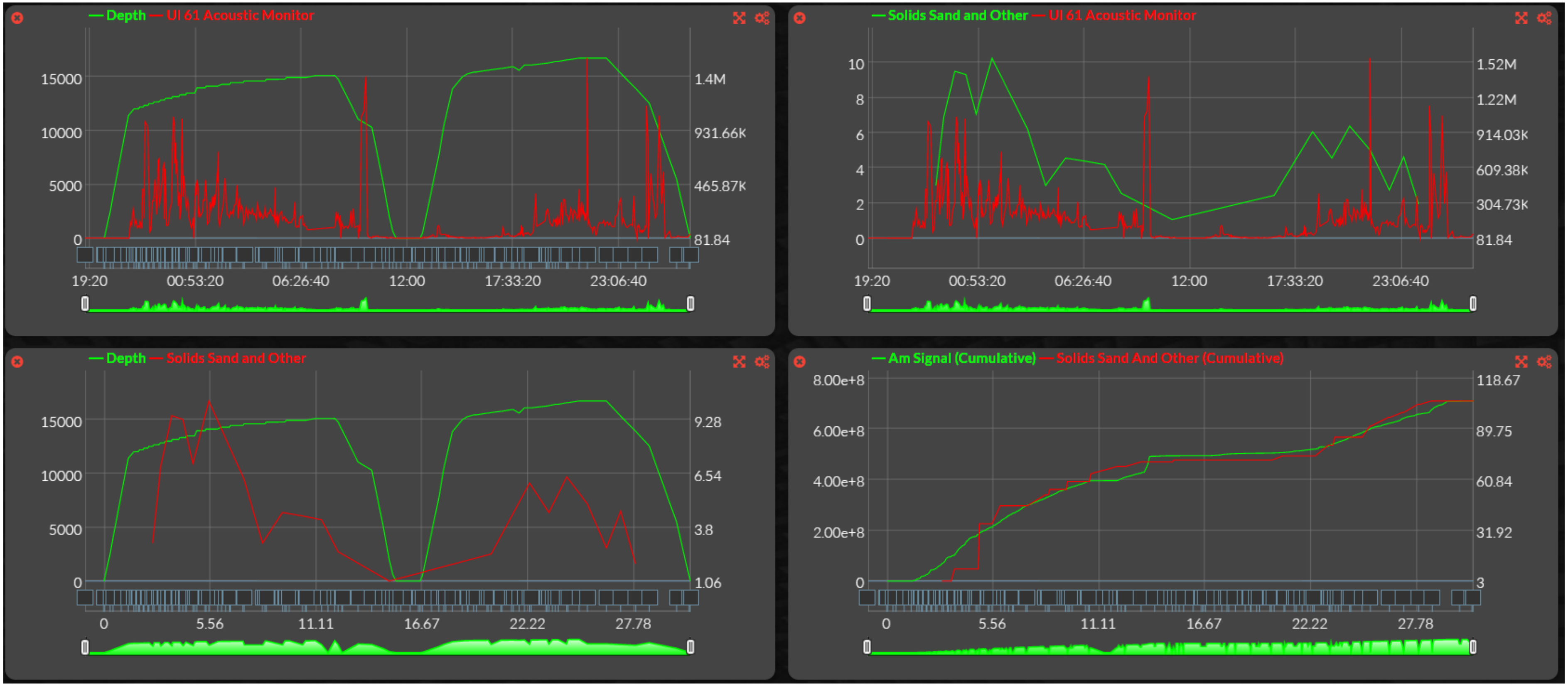
Sand Monitoring



- Acoustic meters provide continuous sand measurement
- Good hole cleaning
  - Linear response
  - Curve flattens as a BHA nears the surface

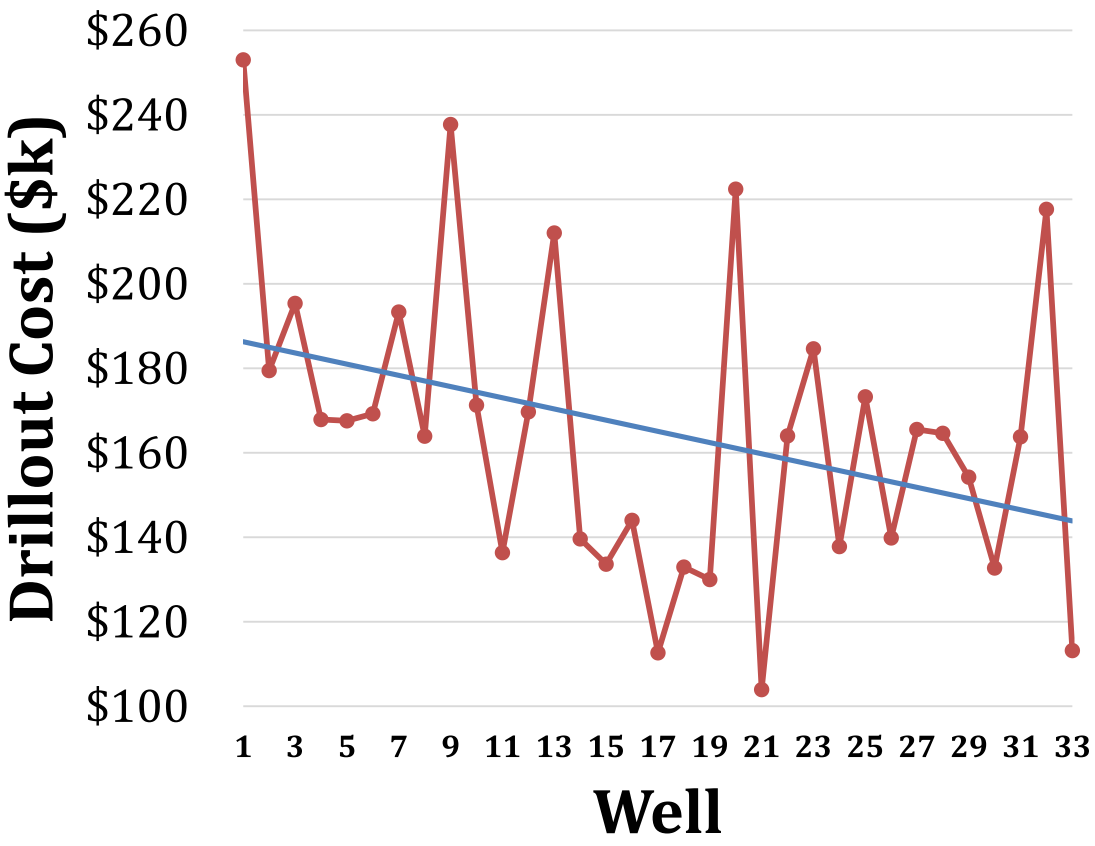
SPE 187337–MS (2017)

Example Well



AVG AV- **286 fpm** AVG RE# - **20,561** AVG SLW VIS – **30.9** Plugs – **28** HRS – **30.8** AM(tot) – **709MM** PP#(tot) - **106**

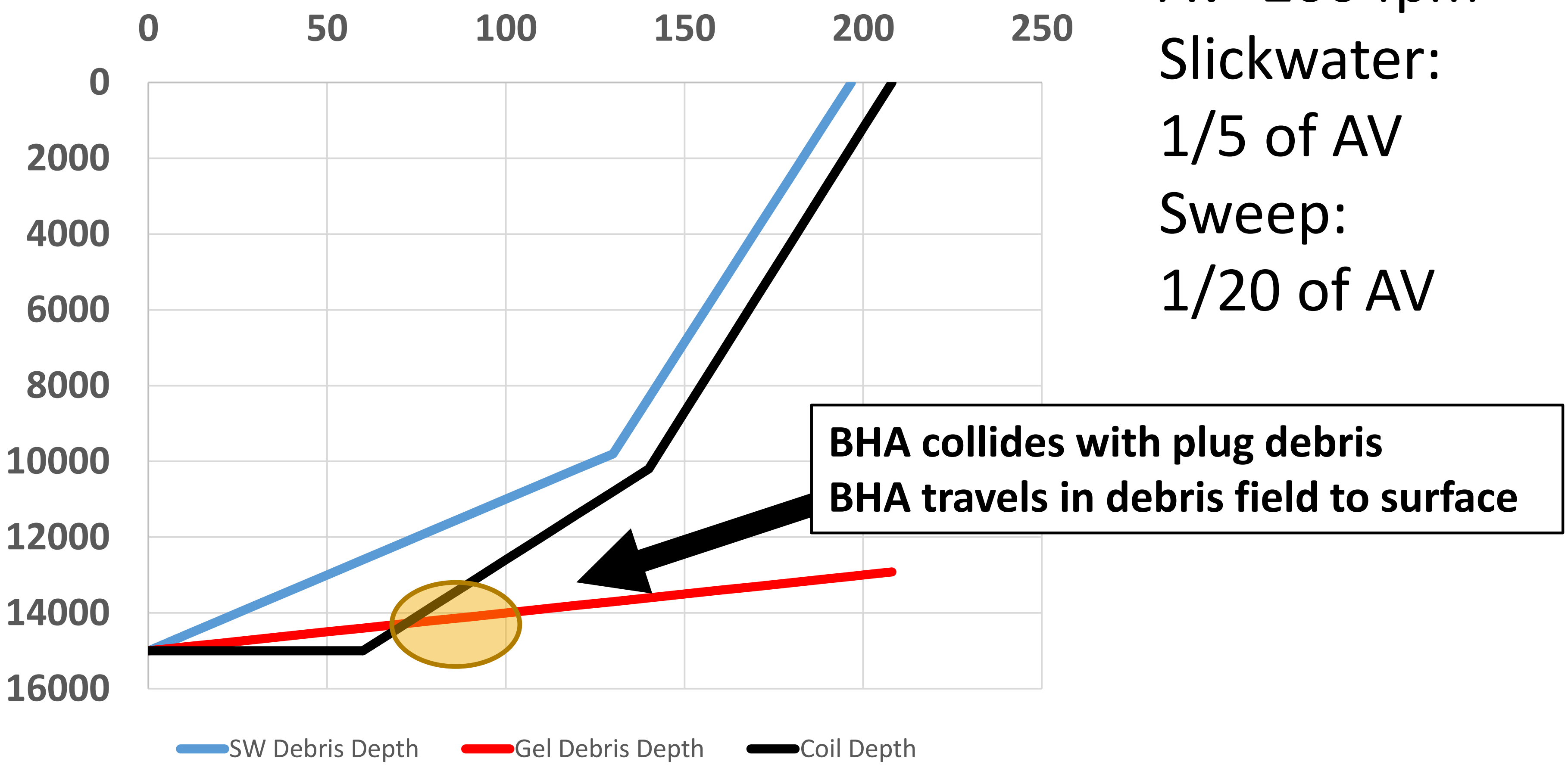
Woodford Results



- No stuck pipe
- Costs decreased 50%
- Time on location improved 50%

SPE 187337–MS (2017)

Location of Plug Debris



AV=200 fpm

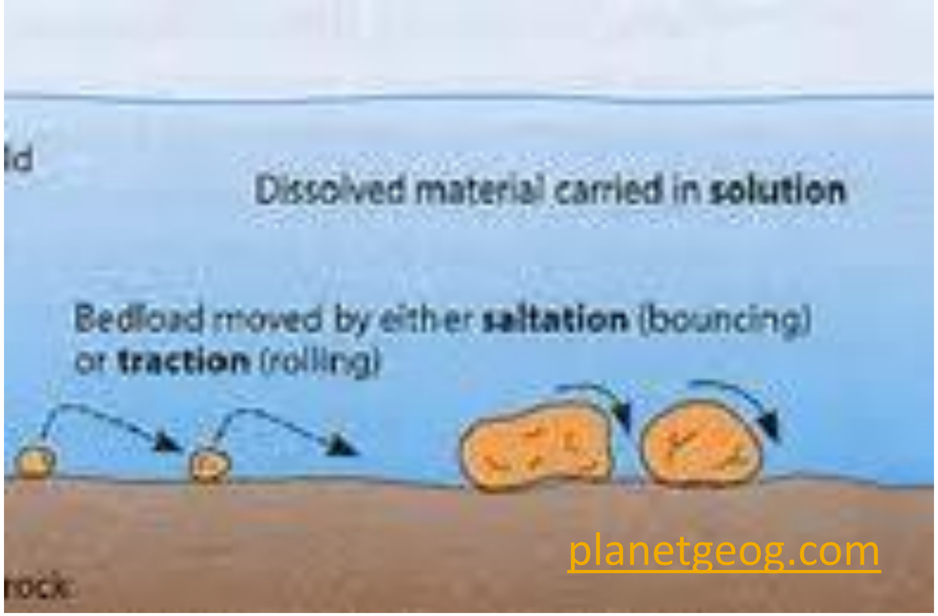
Slickwater:

1/5 of AV

Sweep:

1/20 of AV

Cleanouts



- Moved by saltation or traction
- 1 layer at a time
- Most likely to get stuck
- In viscous fluids sand is very difficult to pick up off bottom
- Need high Re for lift

(SPE 163914)

WHAT HAPPENS TO A GEL SWEEP WHEN IT IS PUMPED DOWNHOLE?

What’s Drilling Doing?

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- Drilling has been modeling horizontal wells for 30+ years
  - Mud schools
  - Torque and Drag Modeling
- Developed specialized commercial cementing simulators
- Understood effect of ECDs prior to drilling
  - Mud properties
  - Cement slurries

What happens to a gel sweep downhole?

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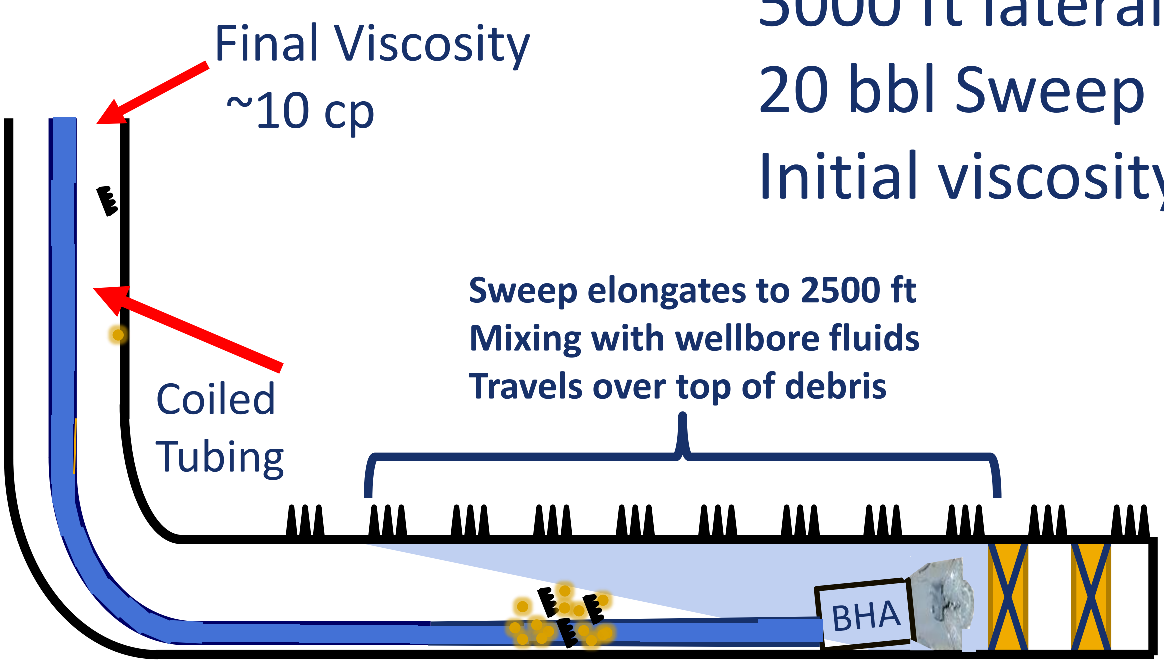
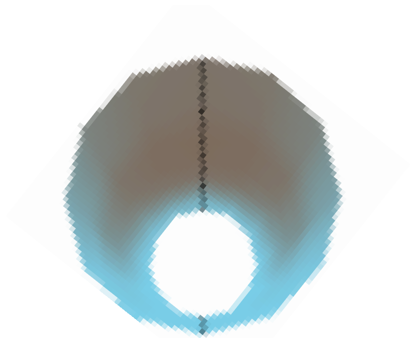
Commercial Cementing Simulator
2” Coil in 5 ½” casing
5000 ft lateral
20 bbl Sweep
Initial viscosity 150 cp





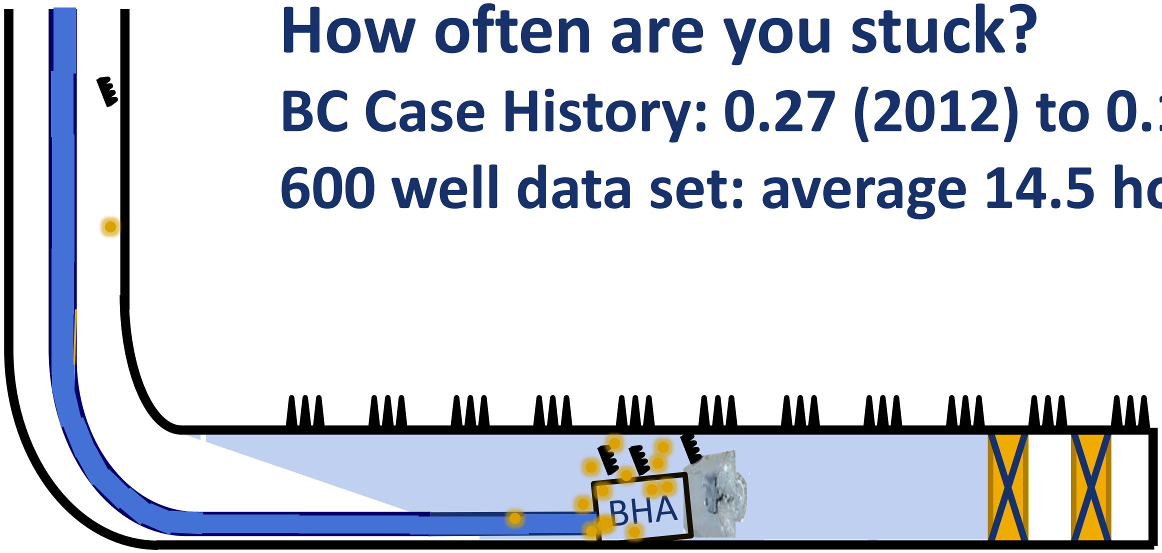
Flow Profile

Sweep-BHA-Debris Collide

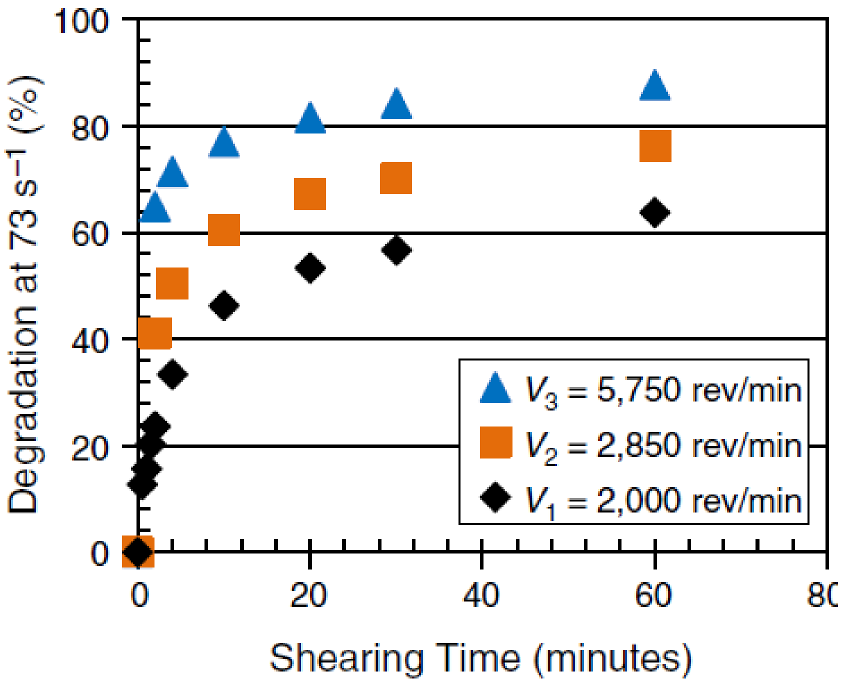
Debris doesn't move in sweep
BHA encounters the debris
Potential stuck or sticky pipe

How often are you stuck?

BC Case History: 0.27 (2012) to 0.1 (2014) hrs per plug
600 well data set: average 14.5 hours



Polymers Breakdown



- Mechanical forces
  - Pumps, motors, bit jets, etc.
- Chemical Reactions
  - O2
- Fluid loses 65-85% of original viscosity

SPE Journal Feb 2017 "Polymer Stability After Successive Mechanical-Degradation Events"

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OTHER CRITICAL ISSUES

Low Bottomhole Pressure

- Information Gap
  - Bottomhole pressure
  - Required N2 injection rate
  - Engineers do not recommend N2 injection rates
- Field is expected to just know the correct N2 rate
  - Results in over injection
  - Drives costs higher
- Wait too long to start N2
- Several commercial models are available
- Use gas lift curves to estimate circulation bottomhole pressure

Dissolvable plugs

- Reservoir is much slower to heat up after stimulation
- Don’t fully dissolve by the time ready to turn to production
- Diverters and debris left in well inhibit cleanup
- Drop in production
- Often a coiled tubing intervention is done as a precautionary
- Will improve with time and usage

Do Agitators Work?

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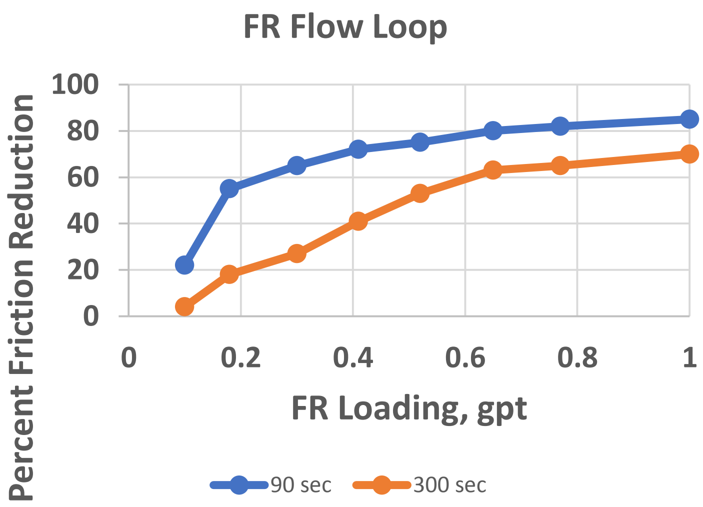
- Breaks static friction
- Effects are localized near the BHA
- Helps get weight to the bit
- Modeling suggests maximum reach can be extended
- Keeps particles on bottom of the hole moving

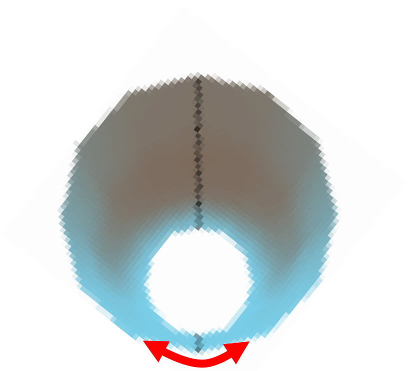
Friction Reducers

- Reduces the pumping pressure
- Polyacrylamide is most common
- Does not extend reach
- More is not better
  - Lab based loading
- Will not prevent stuck pipe
- Check effectiveness
  - Pump pressure before and after
  - Discontinue if not effective



Meal to Metal Friction Reducers

- Often called “Pipe on Pipe” (POP)
- Only works where there is:
  - **metal to POP to metal contact**
- Usually batch treated
- Usually applied too late
- Will not prevent stuck pipe
- Check effectiveness
  - Weight check before and after
  - Discontinue if not effective


Flow Profile

Warning Signs of Stuck Pipe

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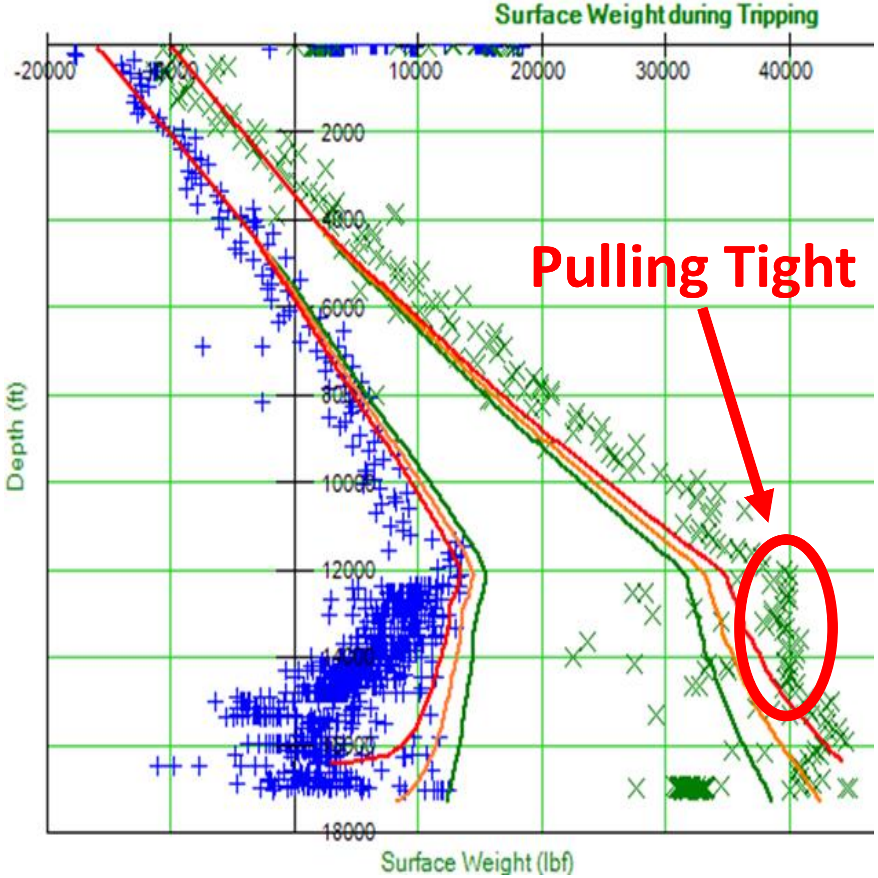
- Reduced or lost returns
- Abnormal weight check
- Erratic pump pressure/motor stalls
- Loss of plug debris being collected in plug catcher
- Reduction in produced sand at the surface

Preventing Stuck Pipe



Torque and Drag (TAD) Plot

What to do:

- **Stop, Drop and Circulate**
  - Do not continue to pull into tight spot
- Circulate 1 hole volume
- Perform a weight check
- Repeat until surface weight returns to trend

Increase Engineering Involvement

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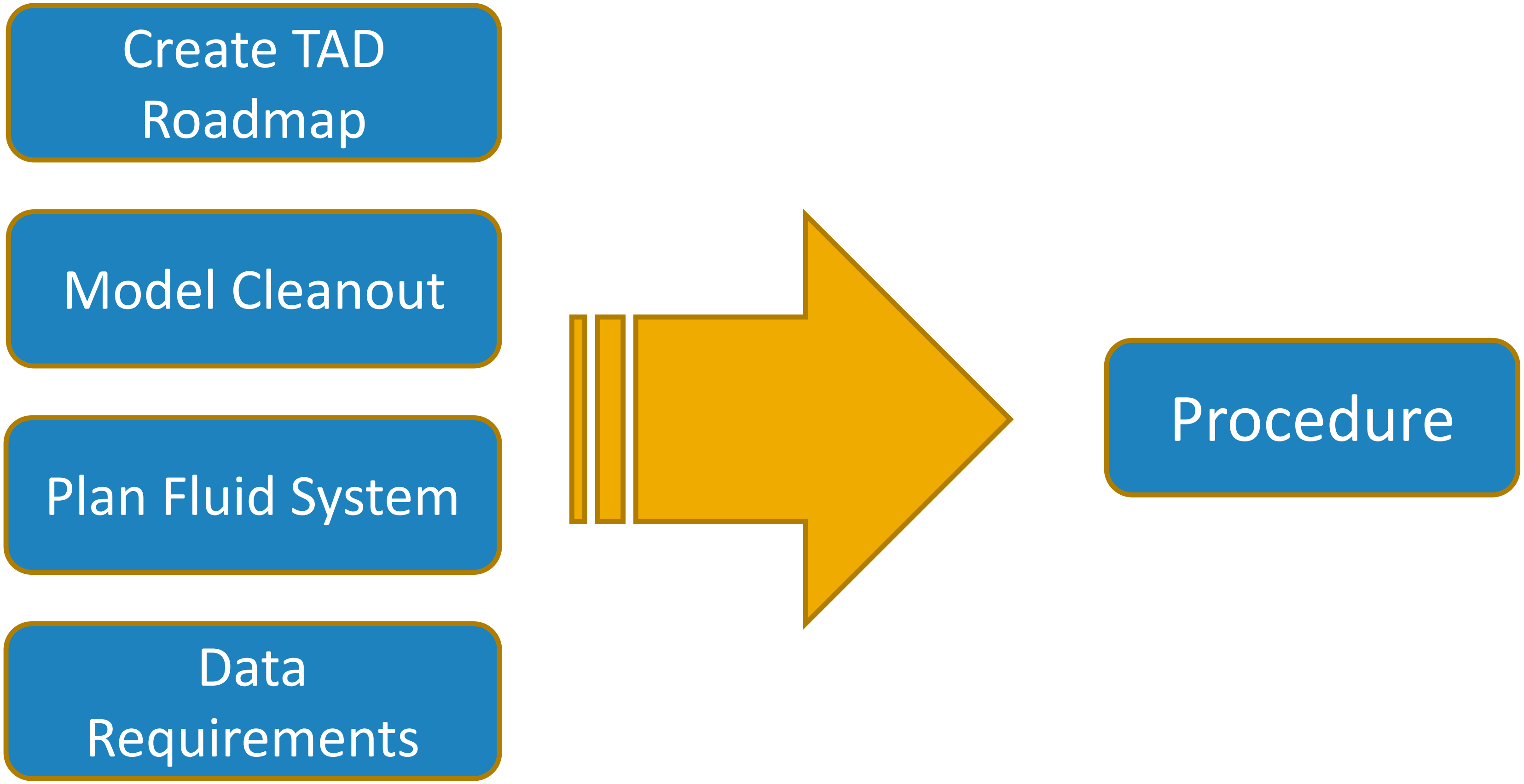

Capture Data

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- Record BHA accurately
- Weigh plug catcher debris at least hourly
- Use an acoustic meter to measure debris during drillout
- Collect fluid data (chemicals, volumes, rates)
- Coiled tubing data (depth, pipe weight, wellhead and circulating pressure, **injection rate, returns rate**)

“Without data we only have stories…..” Charles Pope

Realtime Monitoring

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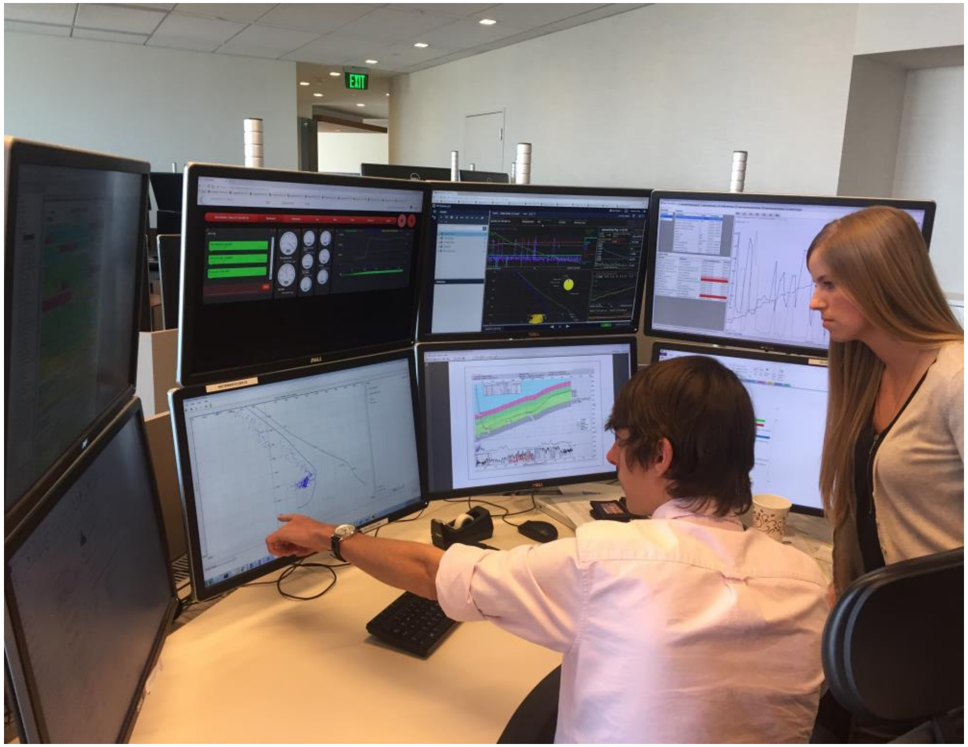

Monitoring

- Send key data live
- Improves rule following

Early Warnings

- Stuck pipe conditions
- Chemical issues
- BHA failures

Take Away

An Engineering Approach

- Use bit/BHA to drillout debris
- Use fluid to clean the hole
- Improved hole cleaning
  - High annular velocities
  - High Reynolds numbers
- Electronically record all the data
- Learn from the data
- Observe warning signs of getting stuck
  - **Stop, Drop and Circulate**

Thank You

- Complete Shale
- Drillout Group
- Industry Partners
- My Family
- SPE Foundation

Thank You!

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Questions?

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