SPE DISTINGUISHED LECTURER SERIES

is funded principally
through a grant of the

SPE FOUNDATION

The Society gratefully acknowledges
those companies that support the program
by allowing their professionals
to participate as Lecturers.

And special thanks to The American Institute of Mining, Metallurgical,
and Petroleum Engineers (AIME) for their contribution to the program.

BP EXPLORATION

Wellbore Quality Characterization for Drilling and Casing Running in Challenging Wells

Dr. Colin Mason
Senior Drilling Specialist
Sunbury-on-Thames
United Kingdom

Telephone: +44 1932 739518
Email: masoncj@bp.com

Lecture Overview

- Introduction
- Definition
- Measuring wellbore quality
- Managing wellbore quality
- Field case studies
- Conclusions

Introduction

- "Wellbore quality" common oilfield concept
- Often associated with directional drilling
- Often linked with performance improvements
- Diverse interpretations for each discipline
- No unique definition exists
- No proven method of measurement exist
- Context: Drilling and Completions

Wellbore Quality Parameters

Attribute	Influenced by
Tortuosity	Directional driller
Wellbore spiralling	Directional drilling BHA
Cuttings bed	Drilling practices
Ledging	Drilling practices / environment
Lost circulation	Drilling practices / environment
Wellbore breakout	Mud weight / exposure time
Formation damage	Mud type / mud properties
Target hole size	Planning / Learning
Measurable	Chosen methodology

Definition – Quality Wellbore

- Straight wellbore – minimal tortuosity and minimal hole spiralling (micro-tortuosity)
- Round gauge hole – minimal wellbore break-out, no wash-outs and hole not undergauge
- Smooth wellbore – minimal ledging
- Clean hole – minimal residual cuttings bed
- Integrity – no leakage, no formation damage
- Fit for purpose – casing or logs will run to depth

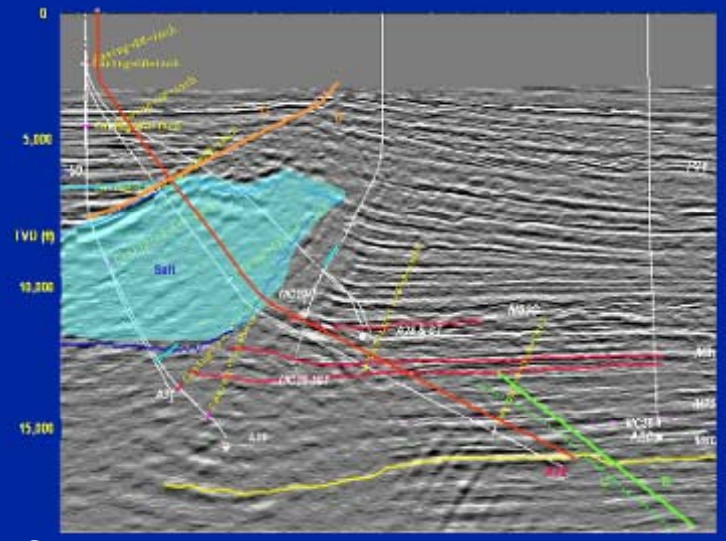
Benefits – Quality Wellbore

- Improved weight transfer – better ROP
- Good hole cleaning – gauge hole
- Lower vibration – constant drilling parameters
- Trouble-free trips & casing runs – gauge hole
- Better log quality – gauge, non-spiralled hole
- Competent cement bond – gauge hole
- Reduced torque and drag – low tortuosity

Influences: Subsurface Environment

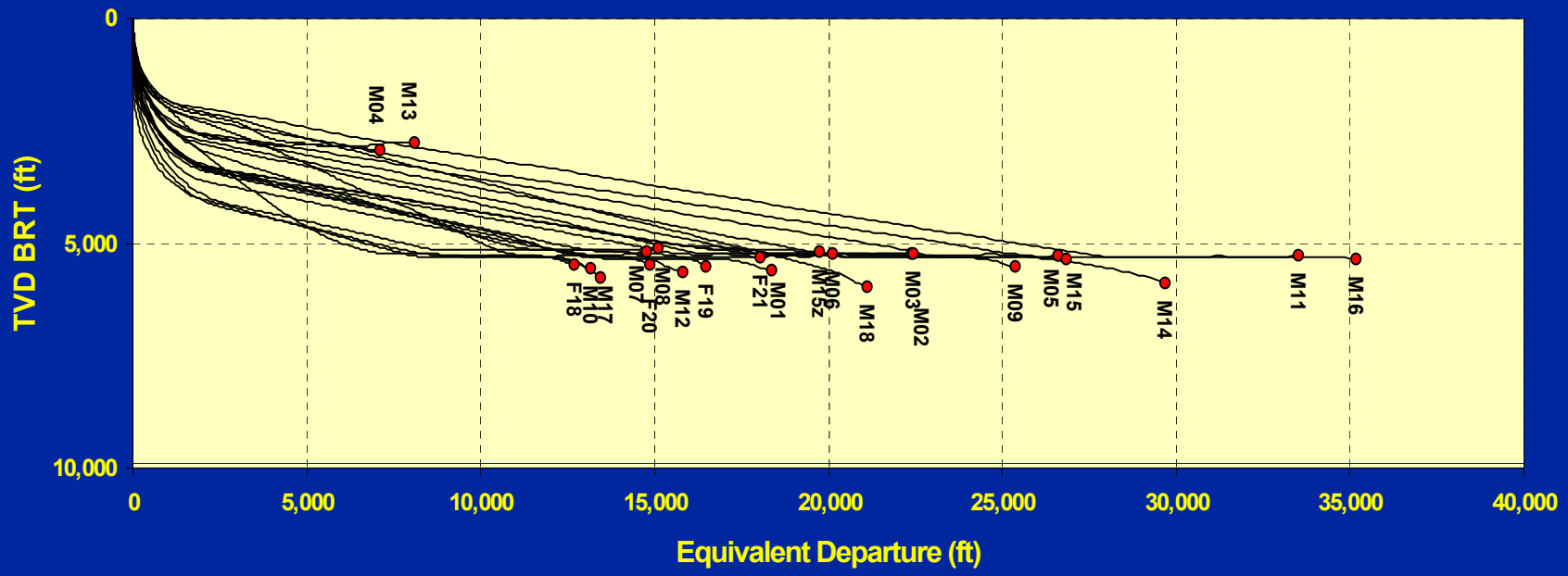
Geology influences wellbore quality

- Pore Pressure / Fracture Gradient
- Geothermal Gradient
- Formation Types
- Rock Strength
- Stress Orientation
- Fractures / Faulting
- Life of field issues – depletion

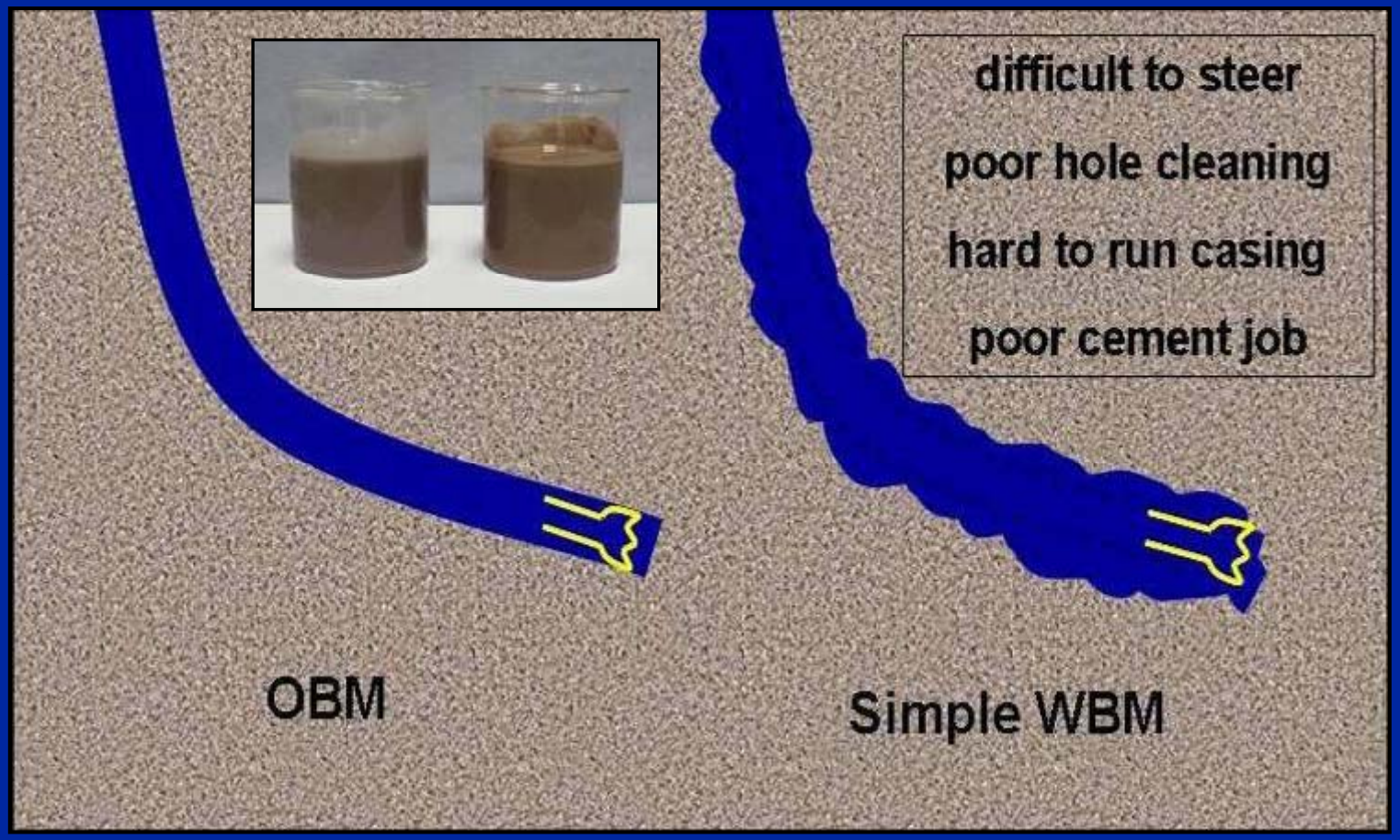


Influences: Wellbore Placement

- Wellpath selection
- Tortuosity (planned versus actual)



Influences: Mud System



In this application an OBM is needed to stabilise a shale

Influences: Directional Drilling Tools

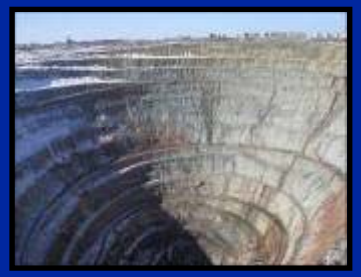
Rotary Steerable Tool

Long gauge PDC bit

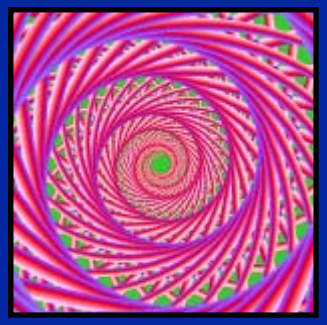
Steerable Motor

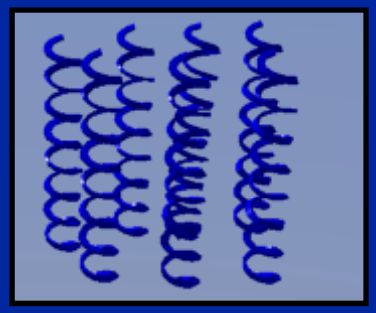
Tricone Bit

Hole Spiralling – Introduction

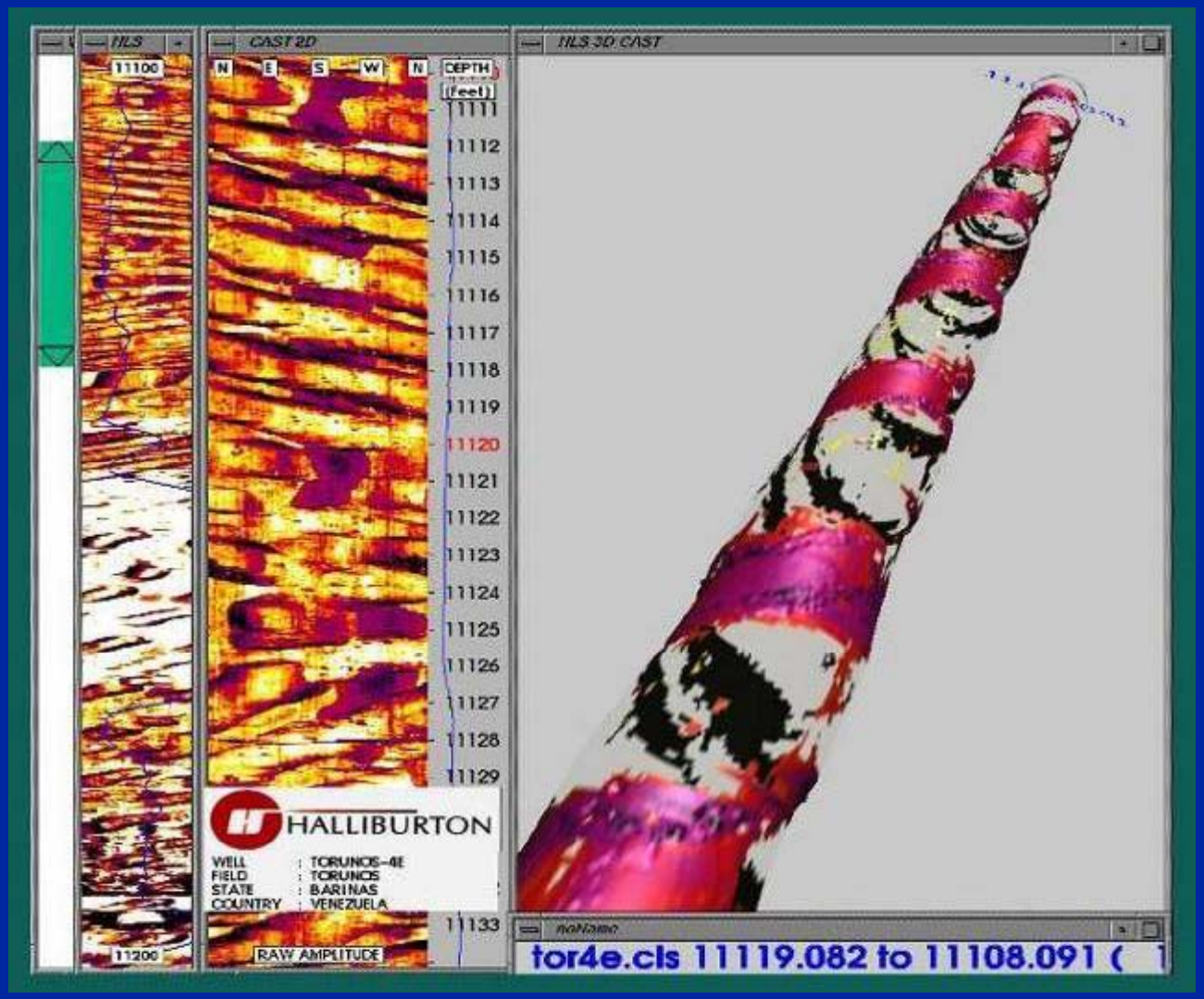


- Hole spiralling exists in most wells
- Pitch, amplitude, drift, gauge – key parameters
- Negatively impacts drilling and completion operations
- Usually can be detected from logs
- Effects more pronounced in horizontal / ERD wells
- Long gauge bits – tend to help reduce spiralling





Hole Spiralling – Imaging

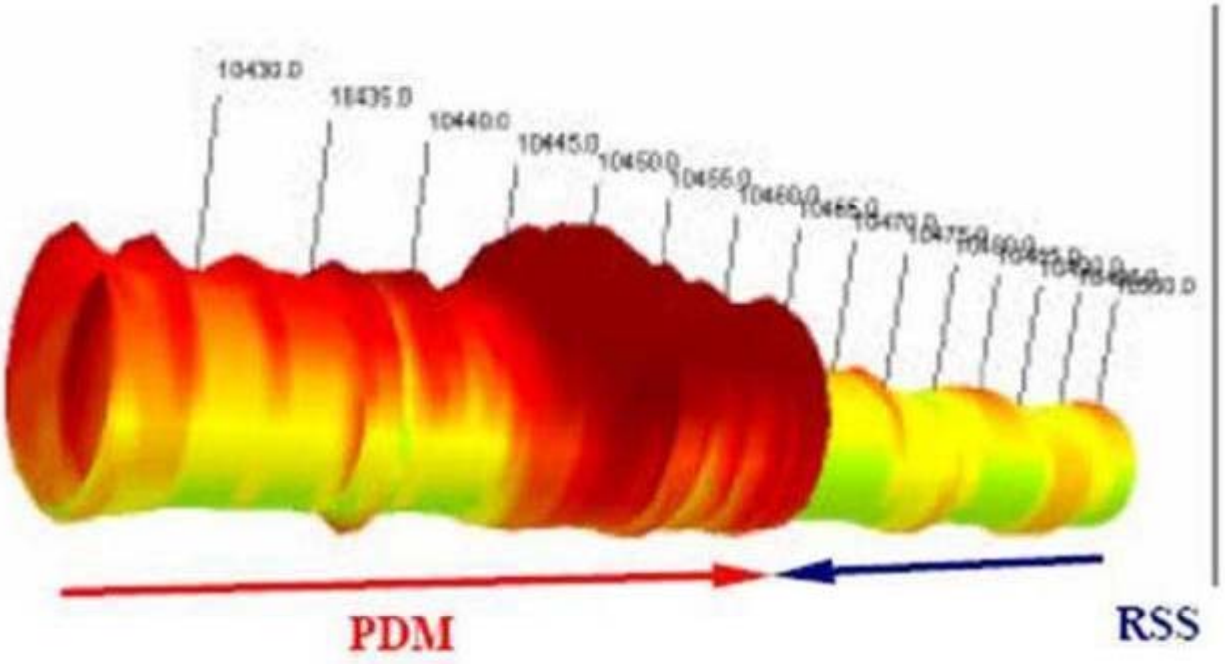


Hole Spiralling – Image Log

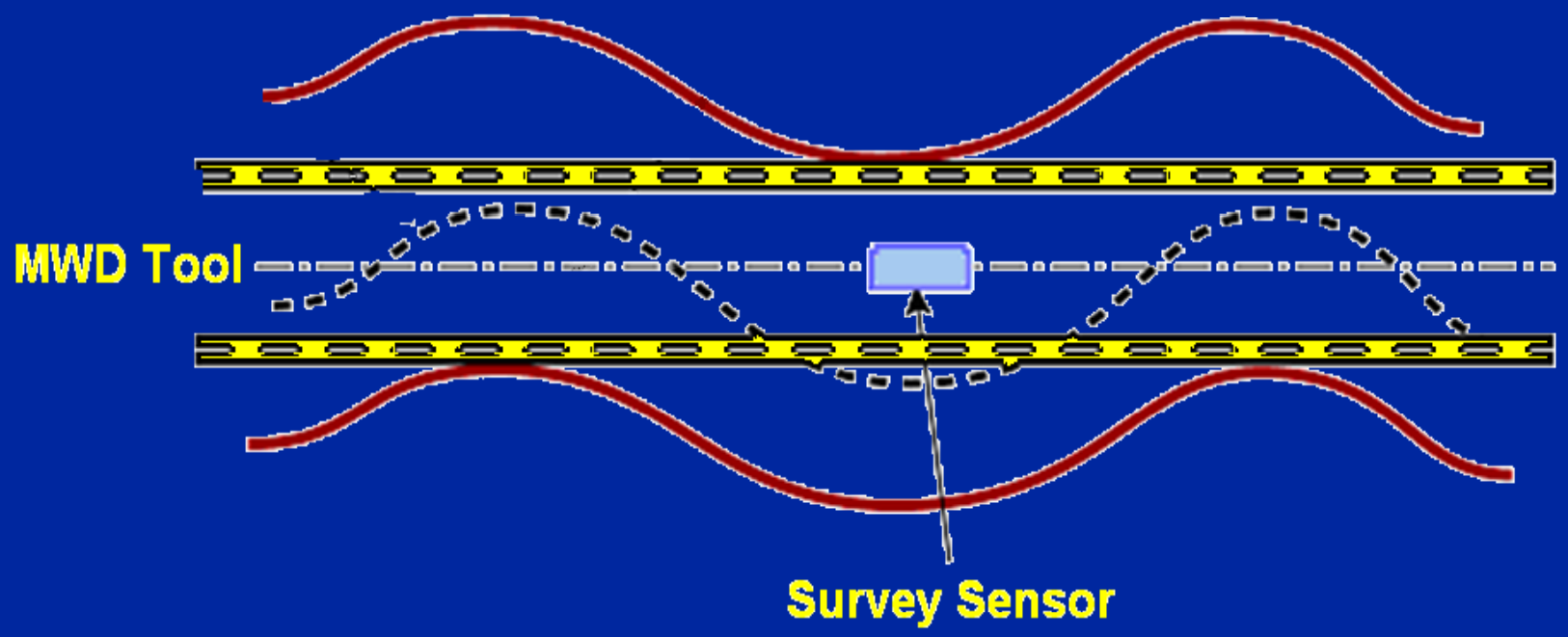
Example: Average hole size PDM, 9.5-10" with local washouts

Average hole size RSS - 8.7"

Image Log shows Spiral Hole from PDM and RSS (Cannot be seen in Survey)

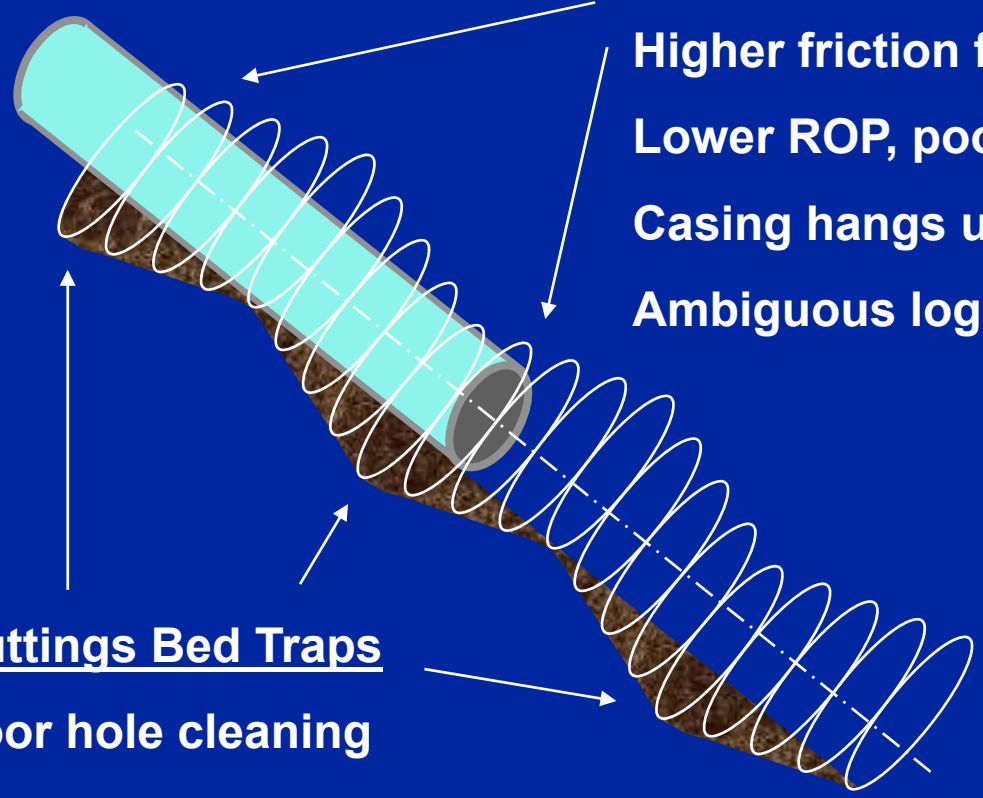


Limitation of MWD Survey Tools



MWD survey tool crosses the trough or valley of a spiral hole.
Inclination and direction of the *drift* is being measured.
This effect is called “micro-tortuosity”

Problems associated with a Spiralled Hole



Reduced Drift

Higher friction forces, higher T&D

Lower ROP, poor weight transfer

Casing hangs up

Ambiguous log response

Cuttings Bed Traps

Poor hole cleaning

Backreaming and short trips

Stuck pipe

Poor cement job

Unstable bit

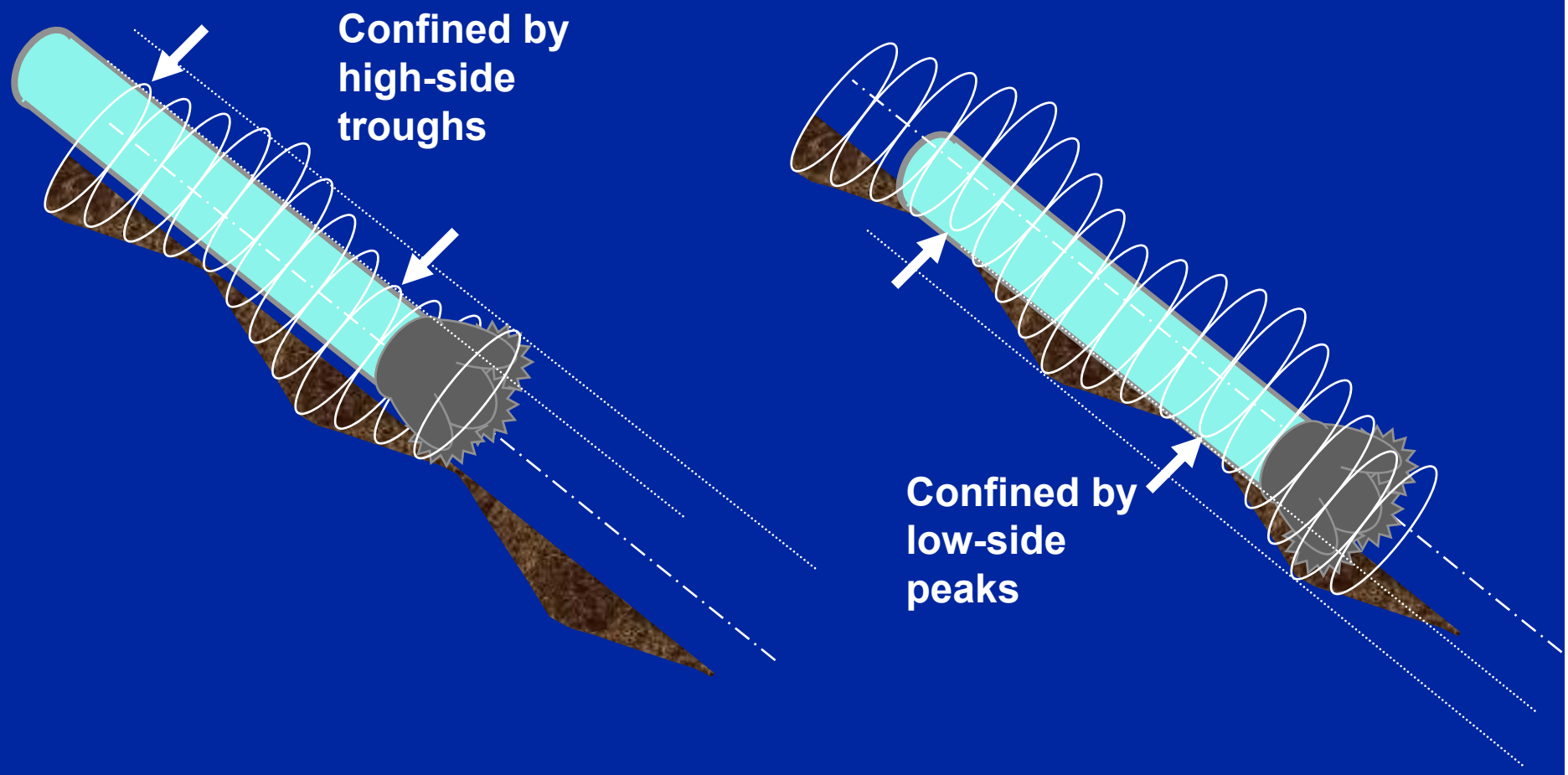
Higher vibration

More tool failures

Shortened bit life

More trips

Spiralling results from Unstable Bit



How Spiralling is Created

Measuring Wellbore Quality

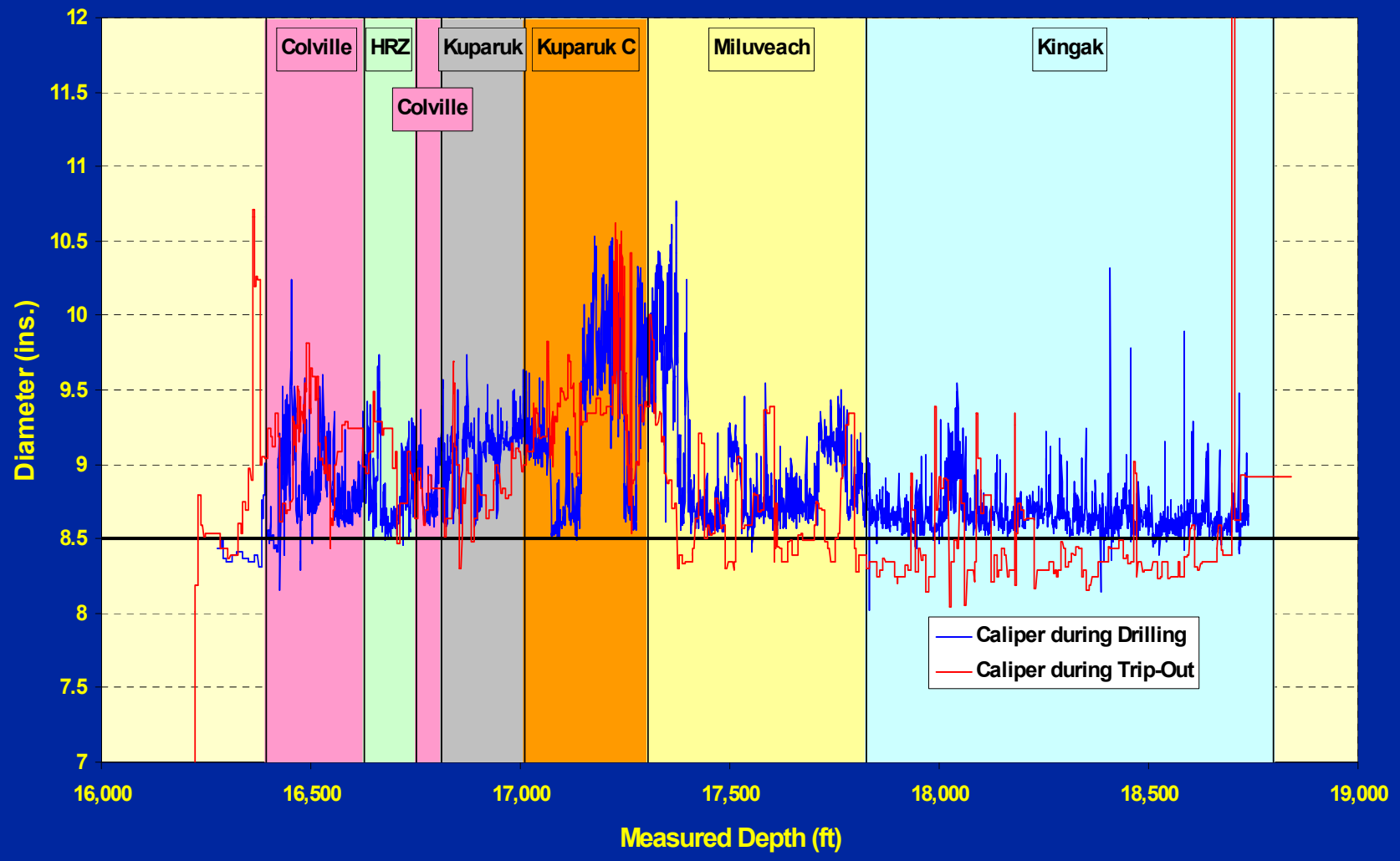
- Explicit methods – physical measurements
  - individual measures possible
  - difficult to interpret in terms of wellbore quality
  - specific examples illustrated
- Implicit methods – indirect measurements
  - measure responses to wellbore quality
  - Illustrated by analogy and applications

Measuring Wellbore Quality

Explicit Methods

- Drift – caliper logs
- Surface finish – inferred from image logs
- Micro-tortuosity / spiralling – pitch, amplitude
- Tortuosity / doglegs – statistical analysis
- Pseudo measure – directional difficulty index

Caliper Logs – Drilling vs. Trip-Out



Measuring Wellbore Quality

Implicit Methods

- Require a methodology / philosophy
- Identify appropriate response variable
- Information to characterize responses
- Analysis and interpretation
- Scoring / ranking process

Head Trauma Injury Assessment

Scenario

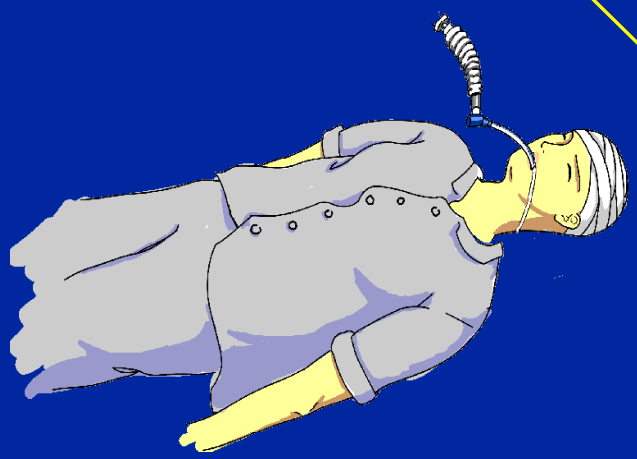
- Patient arrives at Emergency Room
- Apparent Head Injury
- Immediate assessment of brain function needed
- No immediate visual assessment possible
  – no useful explicit measure
- How does the physician carry out the evaluation?
- Responses to stimuli are carried out
  – implicit measures

Head Trauma Injury Assessment

Three responses determine overall severity of head trauma

Glasgow coma scale

		Score
Eye opening	spontaneously	4
	to speech	3
	to pain	2
	none	1
Verbal response	orientated	5
	confused	4
	inappropriate	3
	incomprehensible	2
	none	1
Motor response	obeys commands	6
	localises to pain	5
	withdraws from pain	4
	flexion to pain	3
	extension to pain	2
	none	1
Maximum score		15



GCS = Glasgow Coma Scale

GCS $\geq$ 13 Mild Brain Injury

9 $\leq$ GCS $\leq$ 12 Moderate Brain Injury

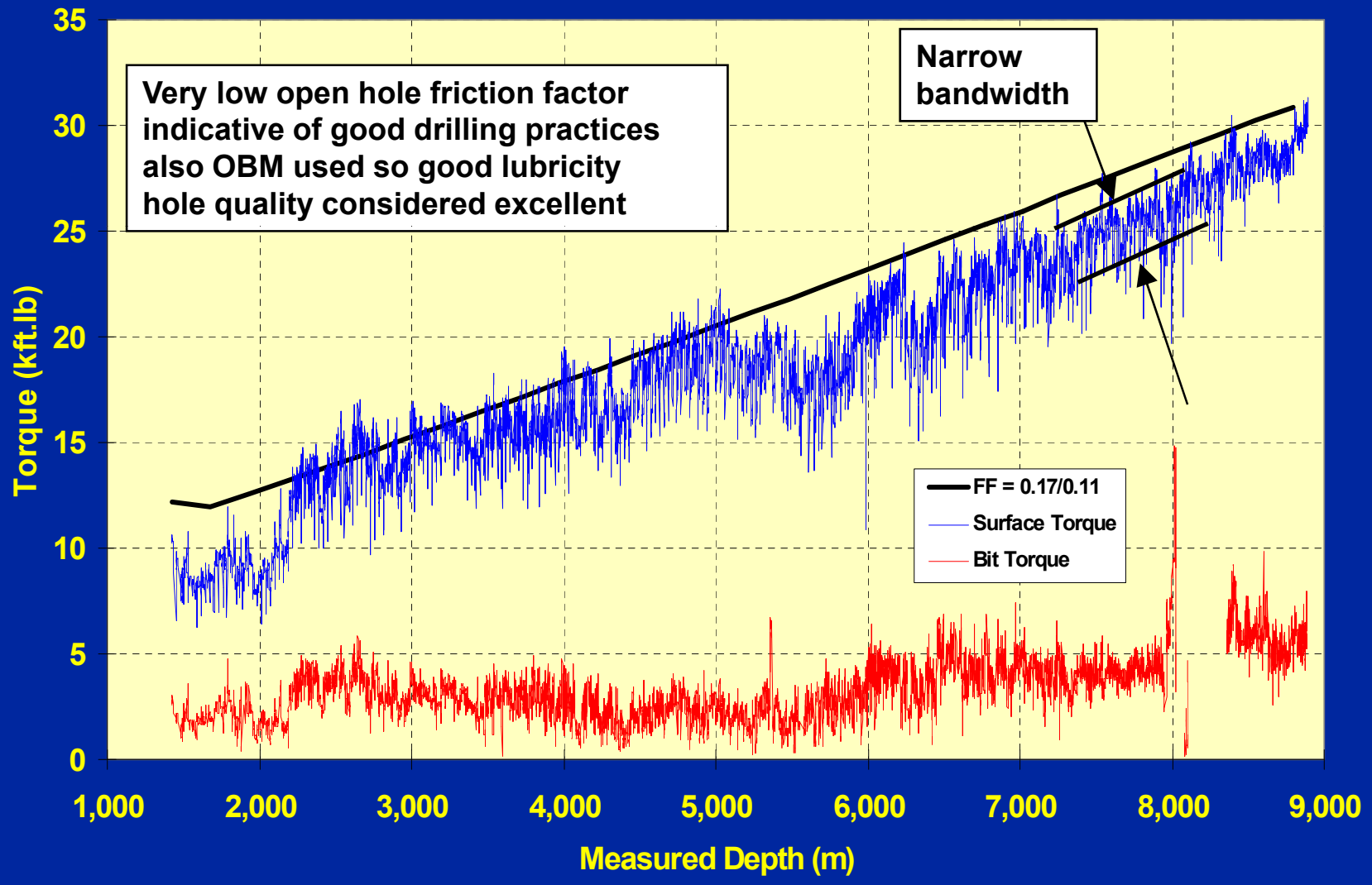
3 $\leq$ GCS $\leq$ 8 Severe Brain Injury

The Wellbore Quality Scorecard (WQS)

Methodology

- Technique based on head trauma assessment
- Wellbore quality inferred from response variables
  - drilling, tripping-out and casing running
- Primary response variables are T&D parameters
- Surface logging data used to characterize responses
- Trend analysis principal evaluation tool
- Extent and intensity of data variations evaluated

Example – Torque Trend Data



Wellbore Quality Scorecard – Guidelines

Drilling Response (5 points)	Score
Severe drilling problems	
- stuck pipe	0
- near stuck pipe incident	1
Transient drilling problems	
- poor hole cleaning with high cuttings bed	2
- severe pack-off	2
- severe loss circulation	2
- erratic torque and drag response	3
Torque and drag response	
- all parameters follow smooth trend	4
- lower than expected torque and drag	5

Final Trip-out Response (7 points)	Score
Stuck pipe	0
Residual cuttings bed / differential sticking	
- section length with overpulls > 100 klbs	1
- section length with overpulls > 50 klbs	2
Ledges	
- isolated overpulls > 100 klbs	3
- isolated overpulls > 50 klbs	4

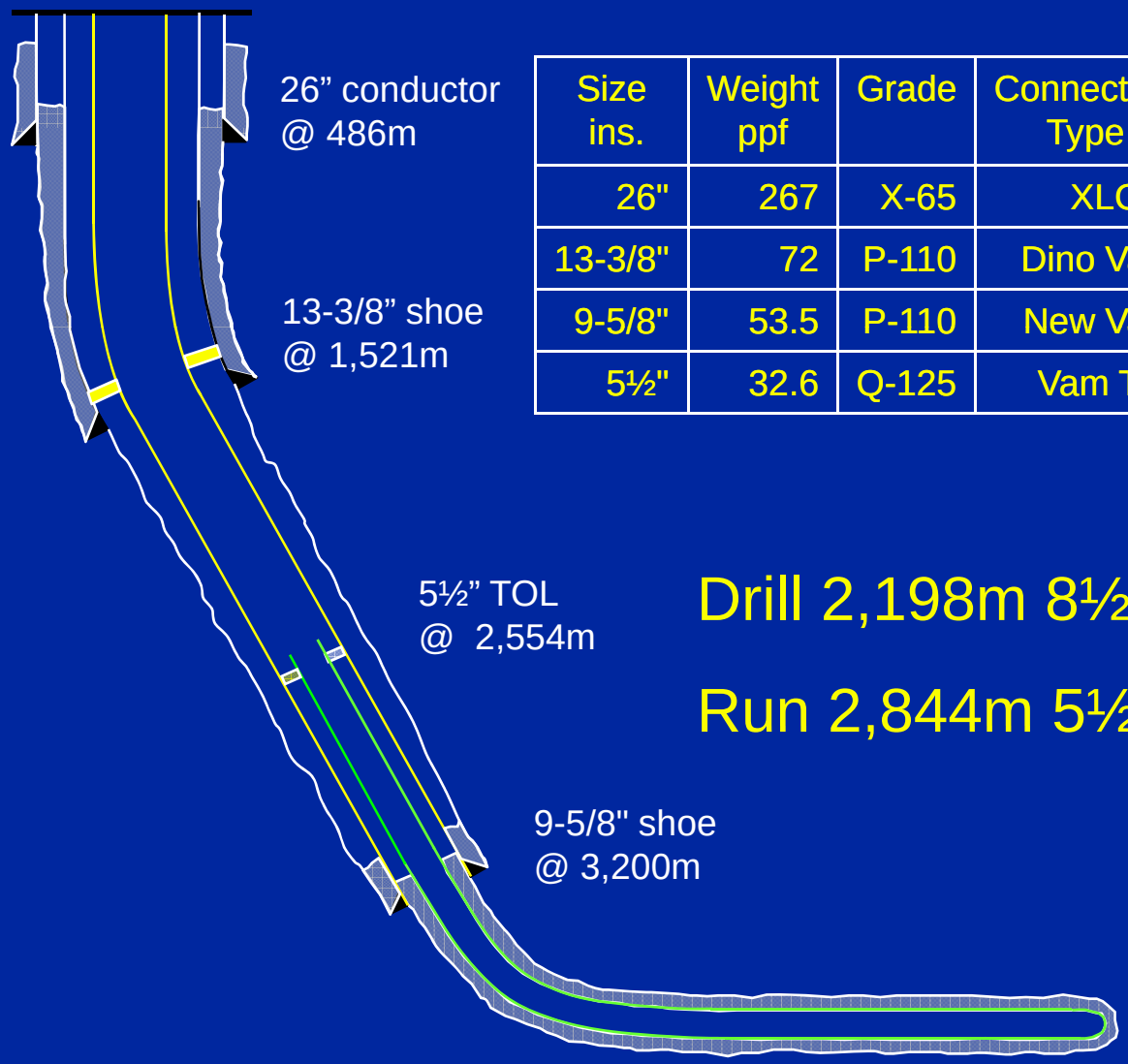
Casing Running Response (8 points)	Score
Severe casing running problems	
- stuck casing	0
- casing pulled due to downhole problems	0
Differential sticking environment	
- static friction > 100 klbs on connections	1
- static friction > 50 klbs on connections	2
Intervention needed during casing run	
- unplanned rotation needed	3
- unplanned circulation needed	4
- joints wiped to reduce drag	5
Casing run without significant problems	
- elevated but smooth drag levels	6
- achieved expected drag levels	7
- better than expected drag levels	8
Transient tripping-out problems	
- loss circulation	5
- unplanned circulation	5
- unplanned reaming and back-reaming	5
Drag response	
- smooth drag levels measured throughout	6
- better than expected drag levels recorded	7

Wellbore Quality Scores – Interpretation

- WQS is recorded as a response mnemonic
  - D4T5C5 (Drilling 4; Tripping-out 5; Casing Running 5)
- WQS = sum of each response score

0 < WQS ≤ 2	stuck pipe or stuck casing
2 < WQS ≤ 6	low quality wellbore
6 < WQS ≤ 10	medium wellbore quality
10 < WQS ≤ 14	high wellbore quality
14 < WQS < 20	excellent wellbore quality
WQS = 20	“The Perfect Wellbore!”

Case Study – Horizontal Well Norway

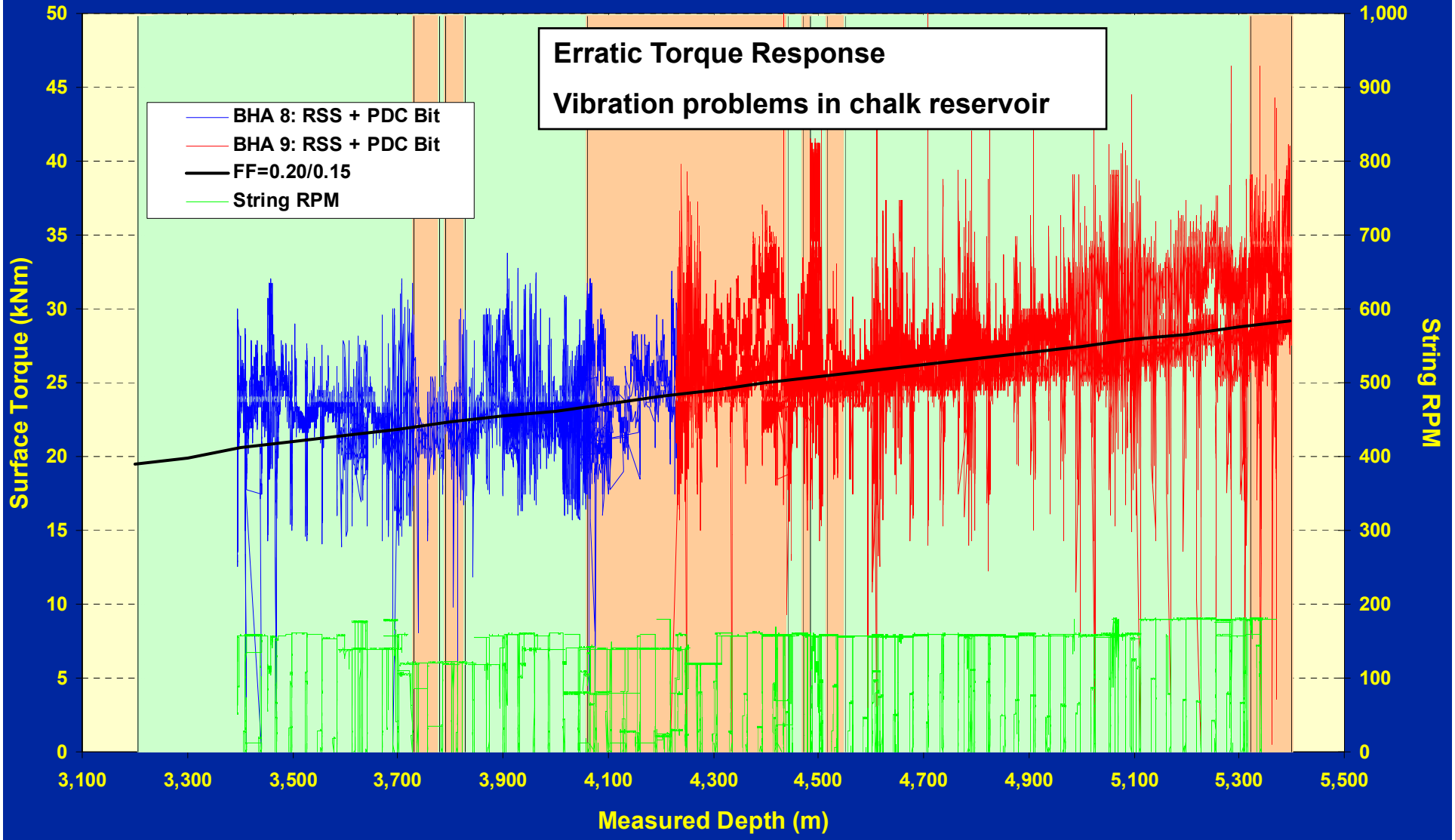


Size ins.	Weight ppf	Grade	Connection Type	Top TVD RKB	Bottom TVD RKB	Bottom MD RKB
26"	267	X-65	XLC-S	Surface	478 m	478 m
13-3/8"	72	P-110	Dino Vam	Surface	1443 m	1521 m
9-5/8"	53.5	P-110	New Vam	Surface	2654 m	3200 m
5½"	32.6	Q-125	Vam Top	2554 m MD	2516 m	5398 m

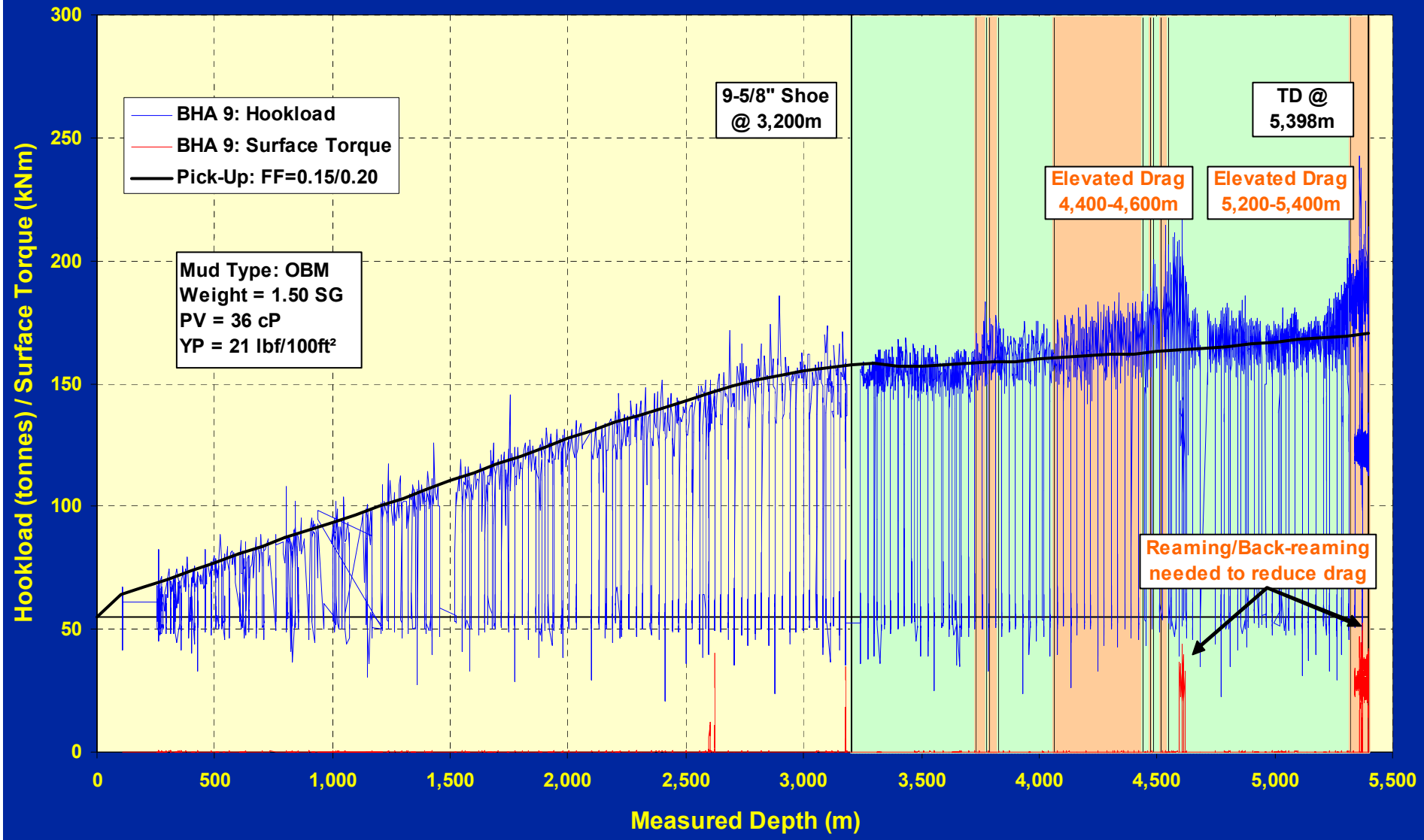
Drill 2,198m 8½” horizontal section

Run 2,844m 5½” thick wall liner

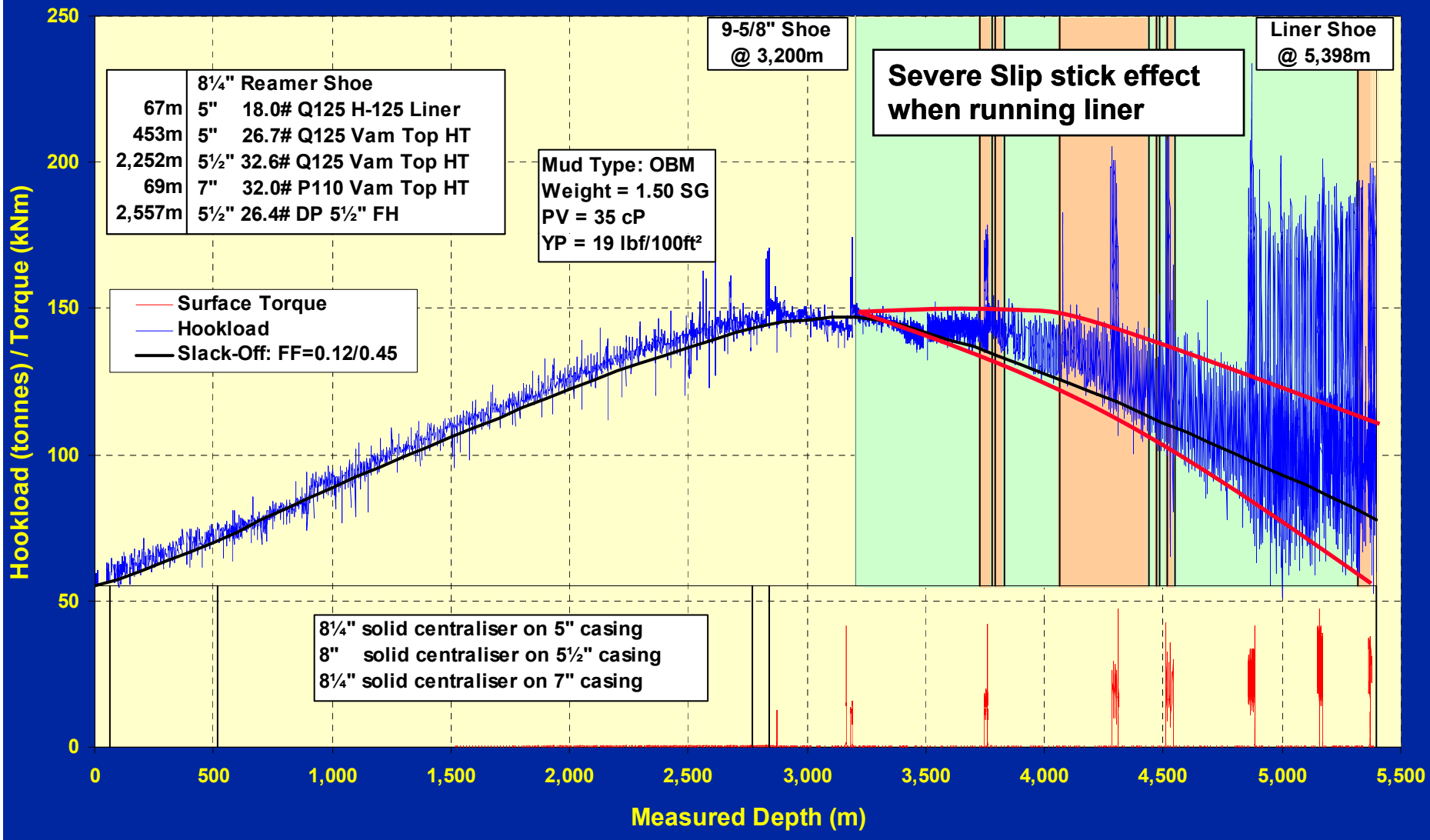
Case Study – Drilling Response (D3)



Case Study – Tripping-out Response (T2)



Case Study – Liner Running Response (C3)



Completed Wellbore Quality Scorecard

Horizontal Well Offshore Norway	WQS
Drilling Response (max 5 points) Persistent erratic torque response observed. Observation is indicative of vibration problems typically seen in the chalk reservoir. Vibrations are considered a transient problem and should not significantly impact overall wellbore quality. Average rotary friction factors of 0.20/0.15 are typical of field-wide torque behaviour.	3
Final Trip-out Of Hole Response (max 7 points) Elevated drag levels in excess of 50klbs are observed from 4,300 to 4,600m and from 5,200 to 5,400m indicating a possible hole cleaning problem. Overpulls also occur at chalk / shale transition zones. A form of slip-stick axial drag is also present when tripping-out through the open hole section. Average pick-up friction factors of 0.15/0.20 are typical of field-wide experience.	2
Liner Running Response (max 8 points) Liner running in open hole is far from smooth; significant axial slip-stick events observed which increase in intensity with depth. String has to be worked significantly over last 600m. String also had to be torqued to overcome tight spots / ledges. Slack-off friction factors of 0.12/0.45 are in line with field-wide experience.	3
WQS (D3T2C3) A score of 8 corresponds to a medium quality wellbore.	8

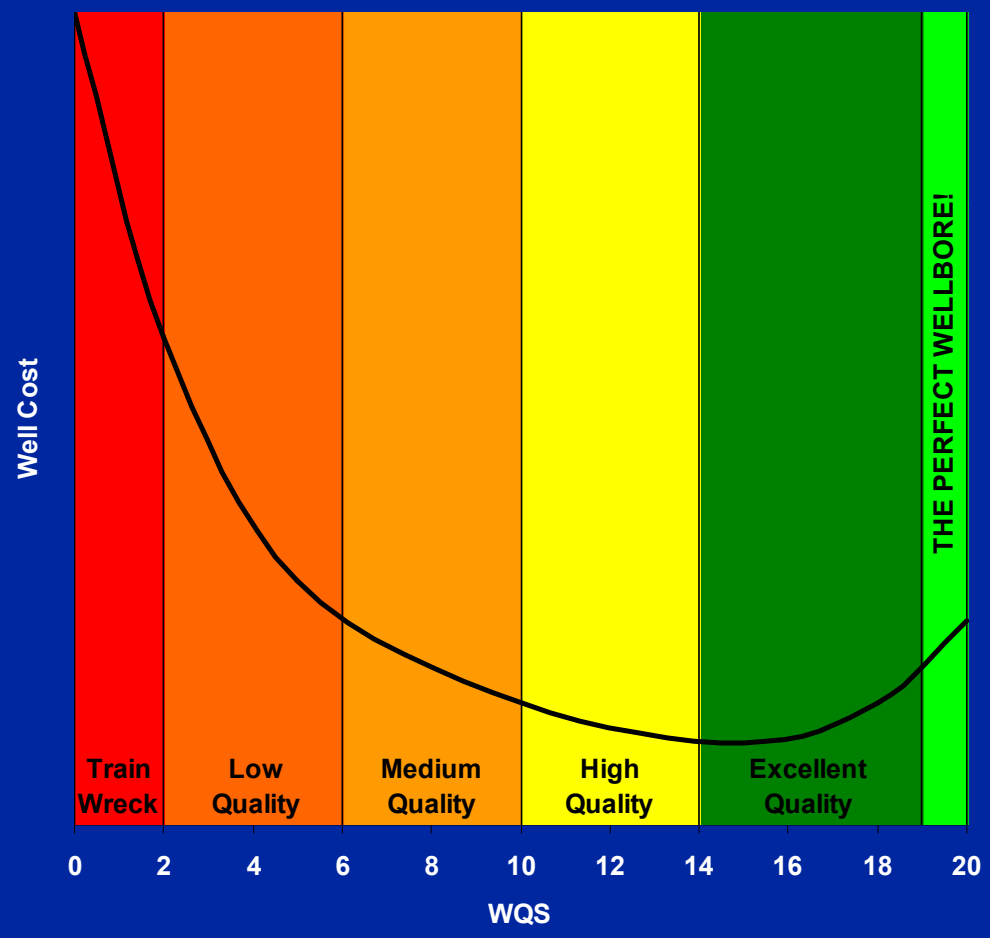
Cost vs. Wellbore Quality Relationship

Field data suggests

Low WQS ⇒
very high D&C costs

Too high WQS ⇒
higher D&C costs

Optimum WQS ⇒
lowest D&C costs



Wellbore Quality Scorecard

Learnings

- A low WQS does not always equate to poor performance
- A low WQS can be due to degree of difficulty of drilling and casing running in that field
- Poorly designed casing run can result in failure
- Implications of scoring wellbore quality need to be understood by operators / service companies
- Wellbore Quality has to be managed at field level
- Need to understand Cost vs. Wellbore Quality relationship

Managing Wellbore Quality

Drilling Practices

- Operating Parameters (WOB, RPM, Flow Rate)
- Connection practices
- Hole cleaning practices
- Mud weight management
- Managing pack-offs
- Vibration management
- ECD management

Managing Wellbore Quality

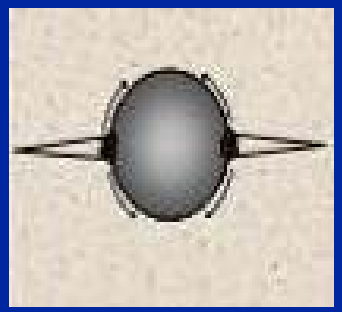
Tripping / Casing Running Practices

- Surge and Swab Pressure Cycles
  - can result in rock fatigue
- Managing Downhole Problems
  - cuttings bed, ledging, pack-offs, overpulls
- Circulation Losses
  - especially during casing running

Enhancing Wellbore Quality

Emerging Technologies

- Continuous Circulation System
  - reduces swab and surge cycles in well
- ECD Reduction
  - reduces downhole annular pressures
- Fracture Gradient Enhancement
  - strengthens wellbore by forming stress cage



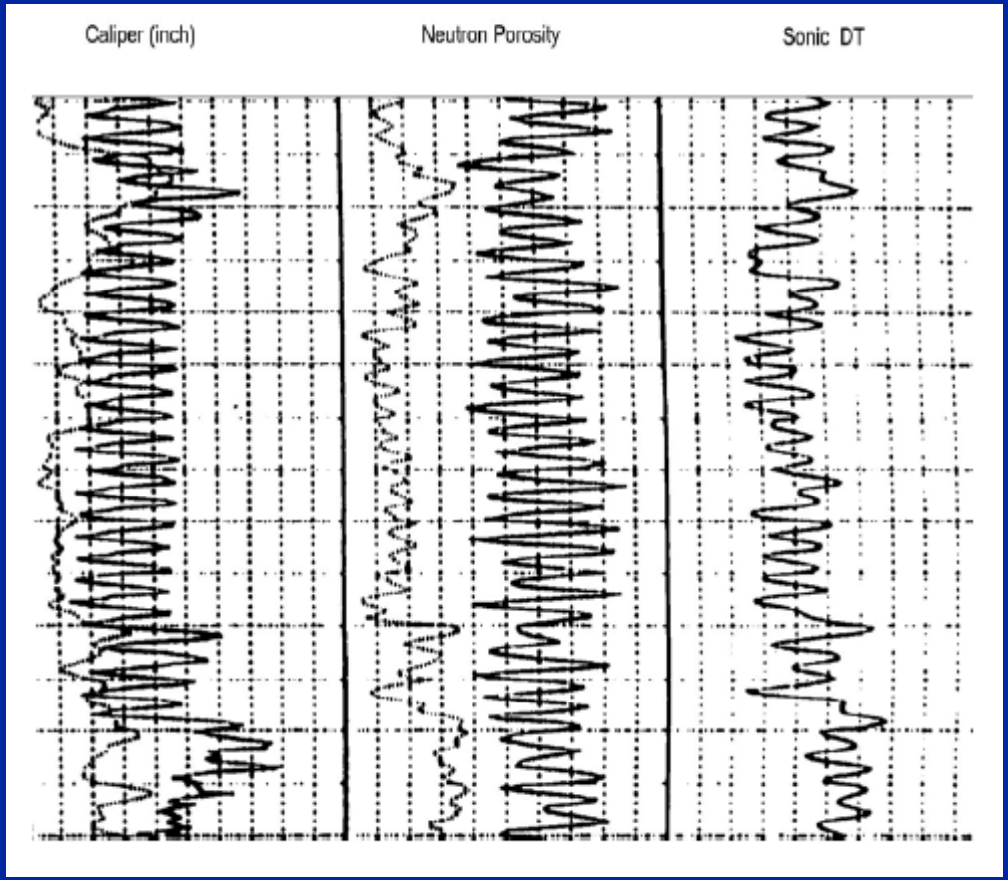
Wellbore Quality Characterization

Conclusions

- Characterization important concept
- Can reflect degree of difficulty
- Most value for horizontal and ERD wells
- Industry standard definition needed
- Measurement protocol biggest challenge
- Wellbore quality scorecard promising technique
- Software needed: efficiency, clarity & consistency
- Wellbore quality enhancing technology exists

Additional Slides

Hole Spiralling – Inferred from Logs



Log Evidence: Caliper vs. Neutron Porosity vs. Sonic DT

Image Log – 8½" Section

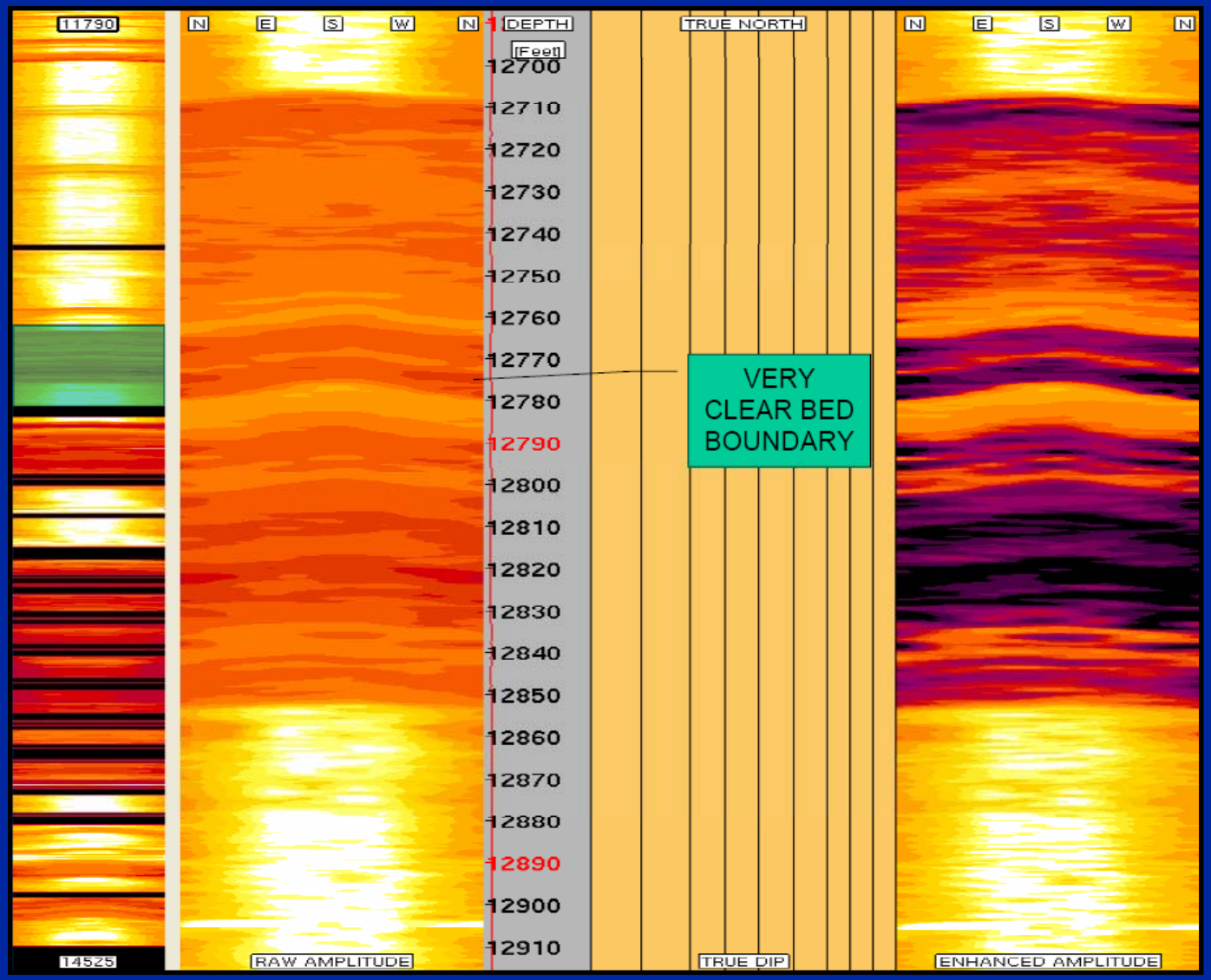


Image Logs – 6-1/8” Hole Spiralling

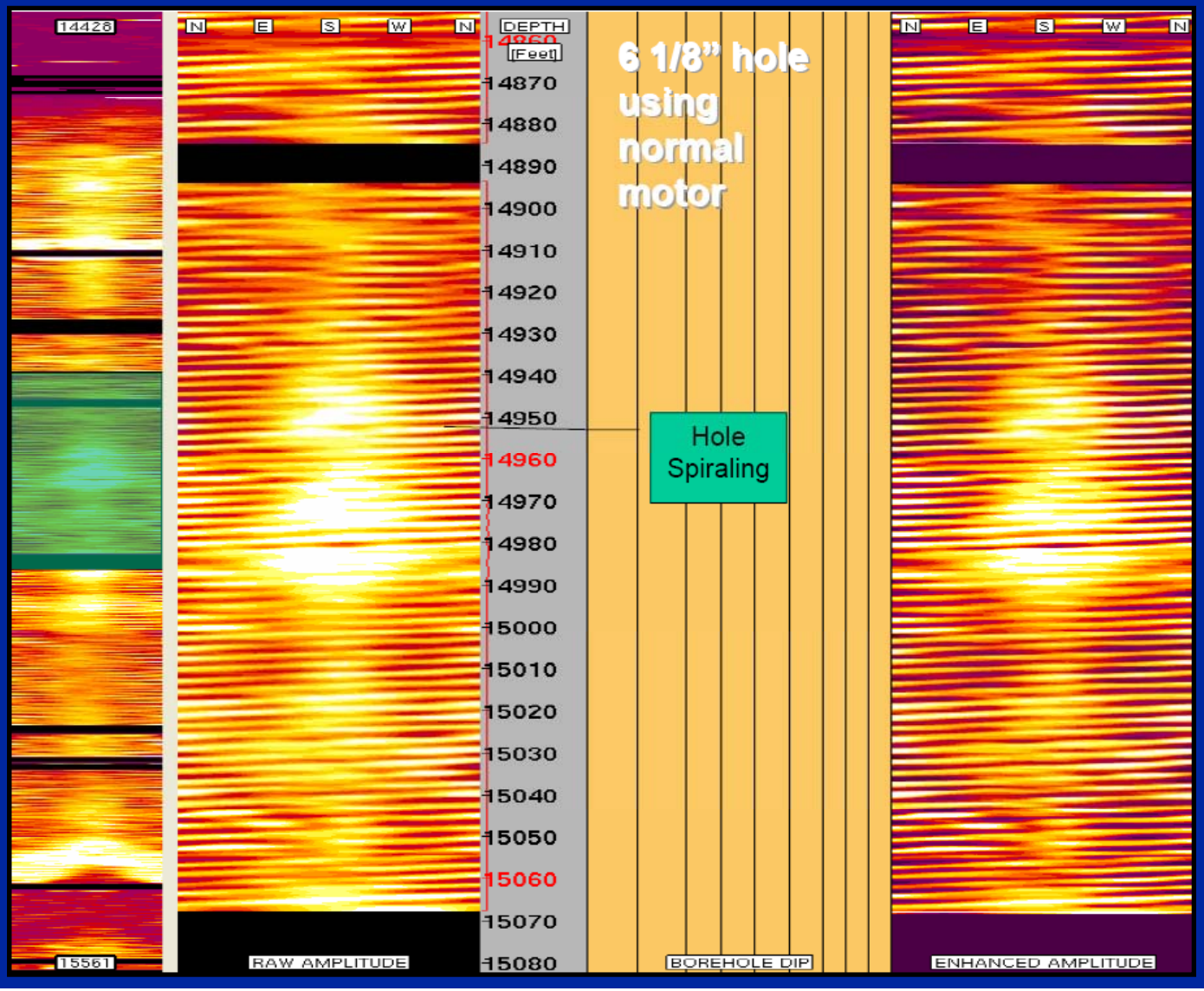
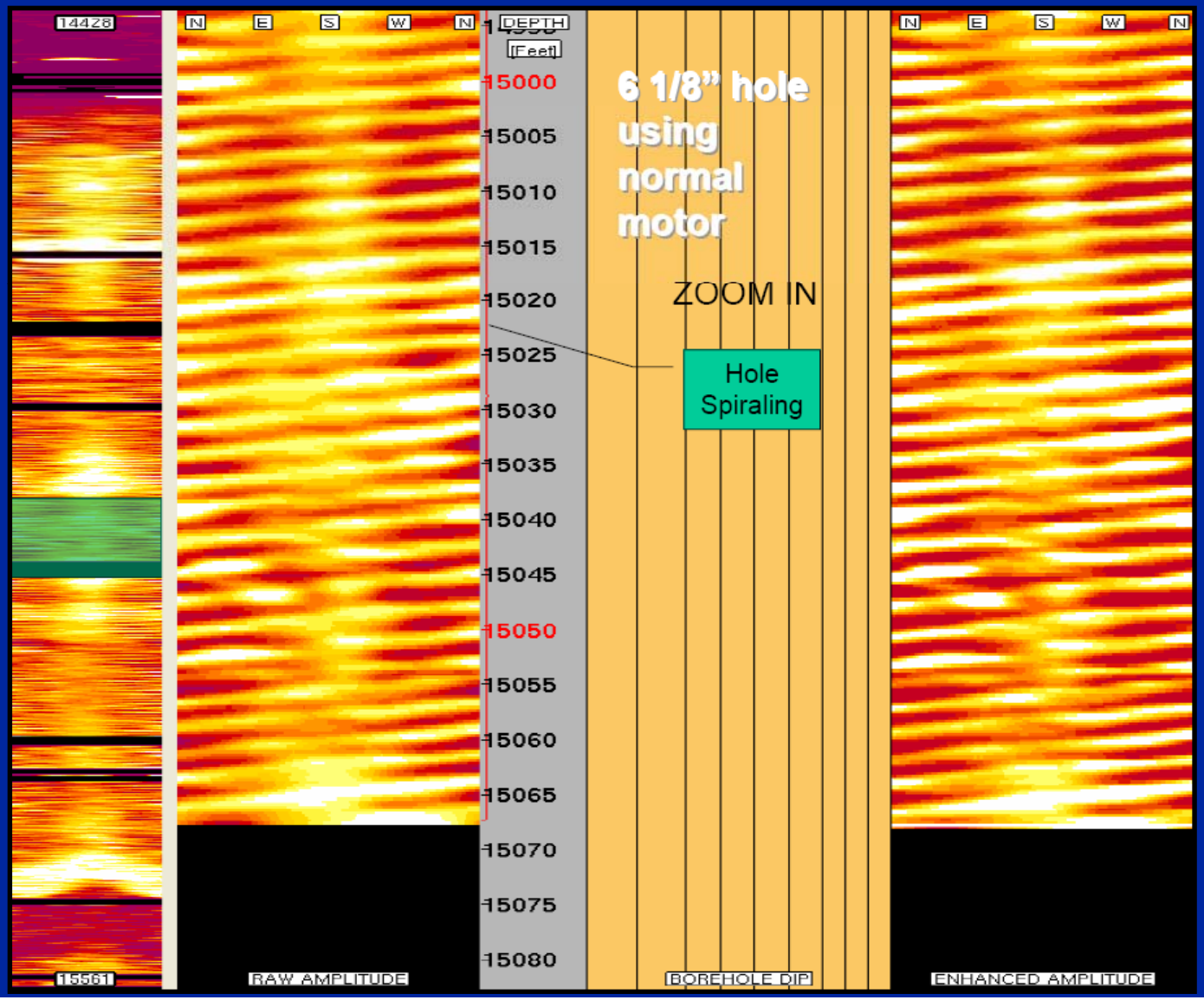
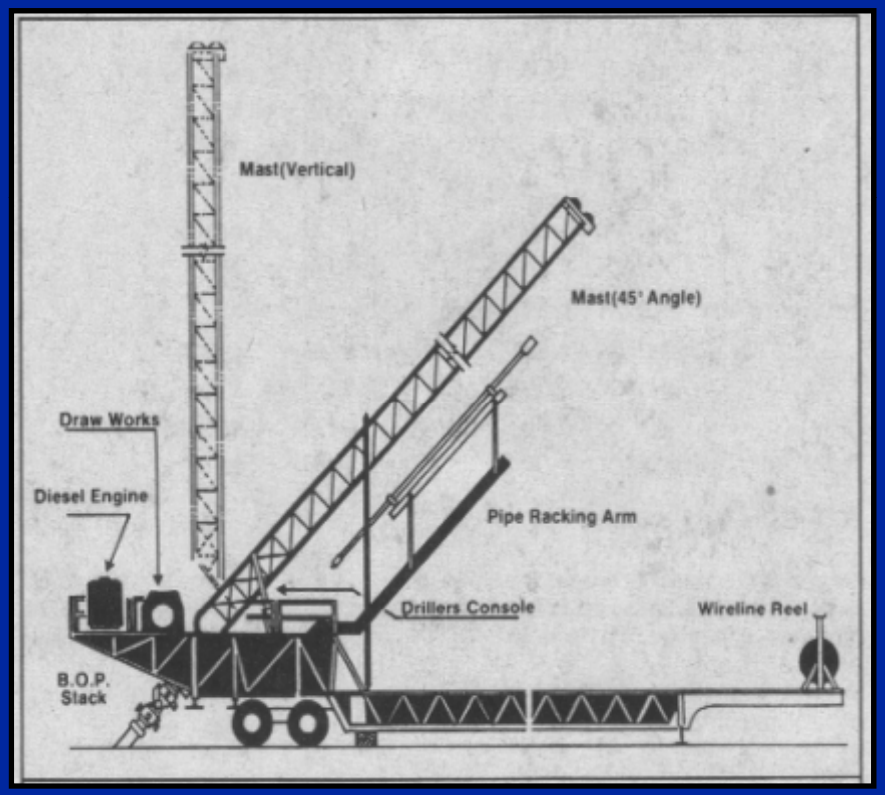


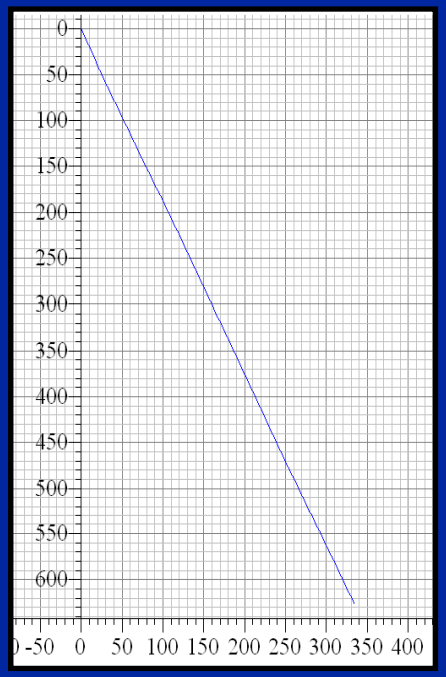
Image Logs – 6-1/8” Hole Spiralling



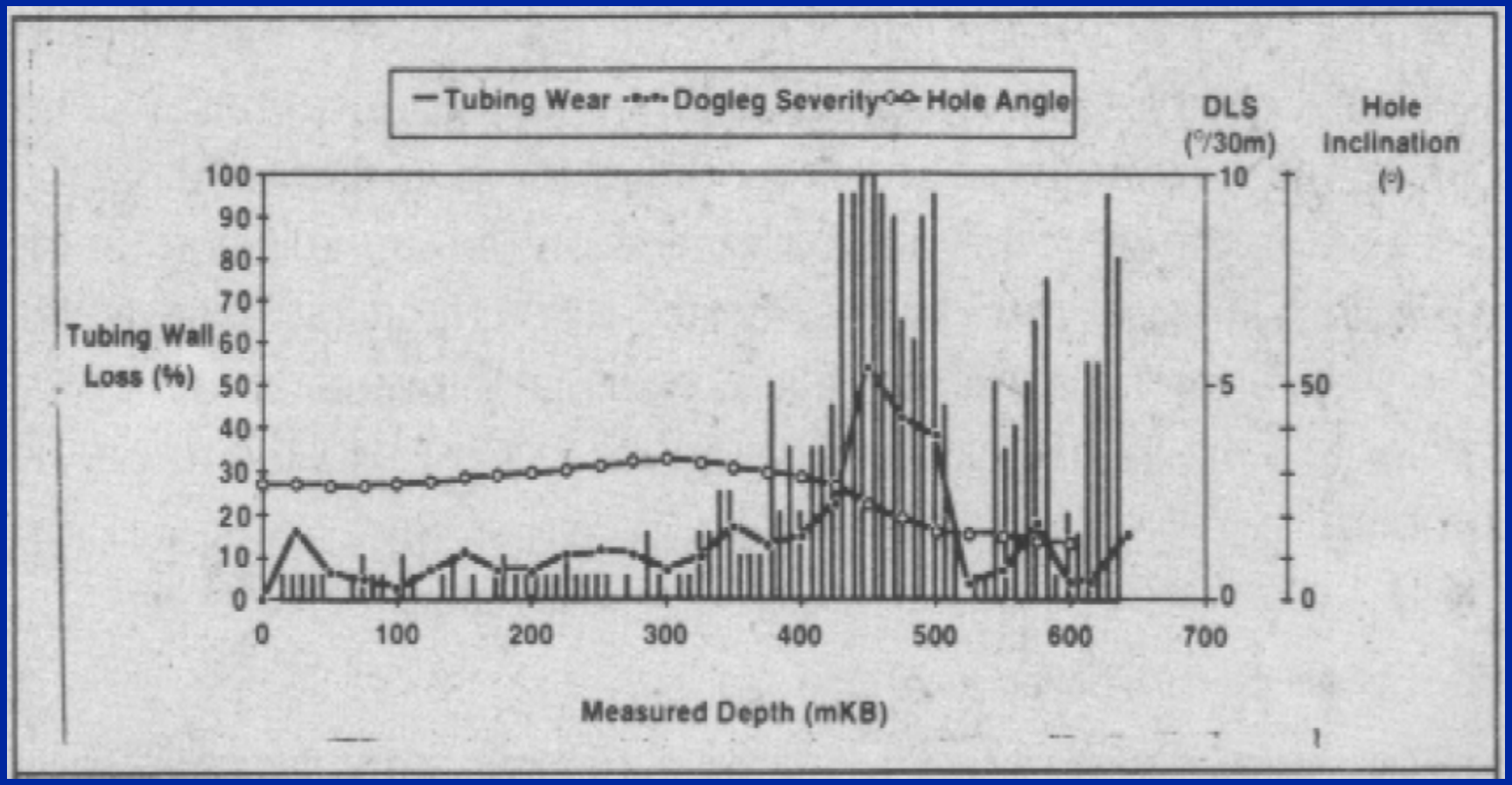
Wellbore Quality vs. Tubing Life



- Slant drilling Canada
- Heavy Oil Reservoir
- Pad Drilling
- 600m TVD

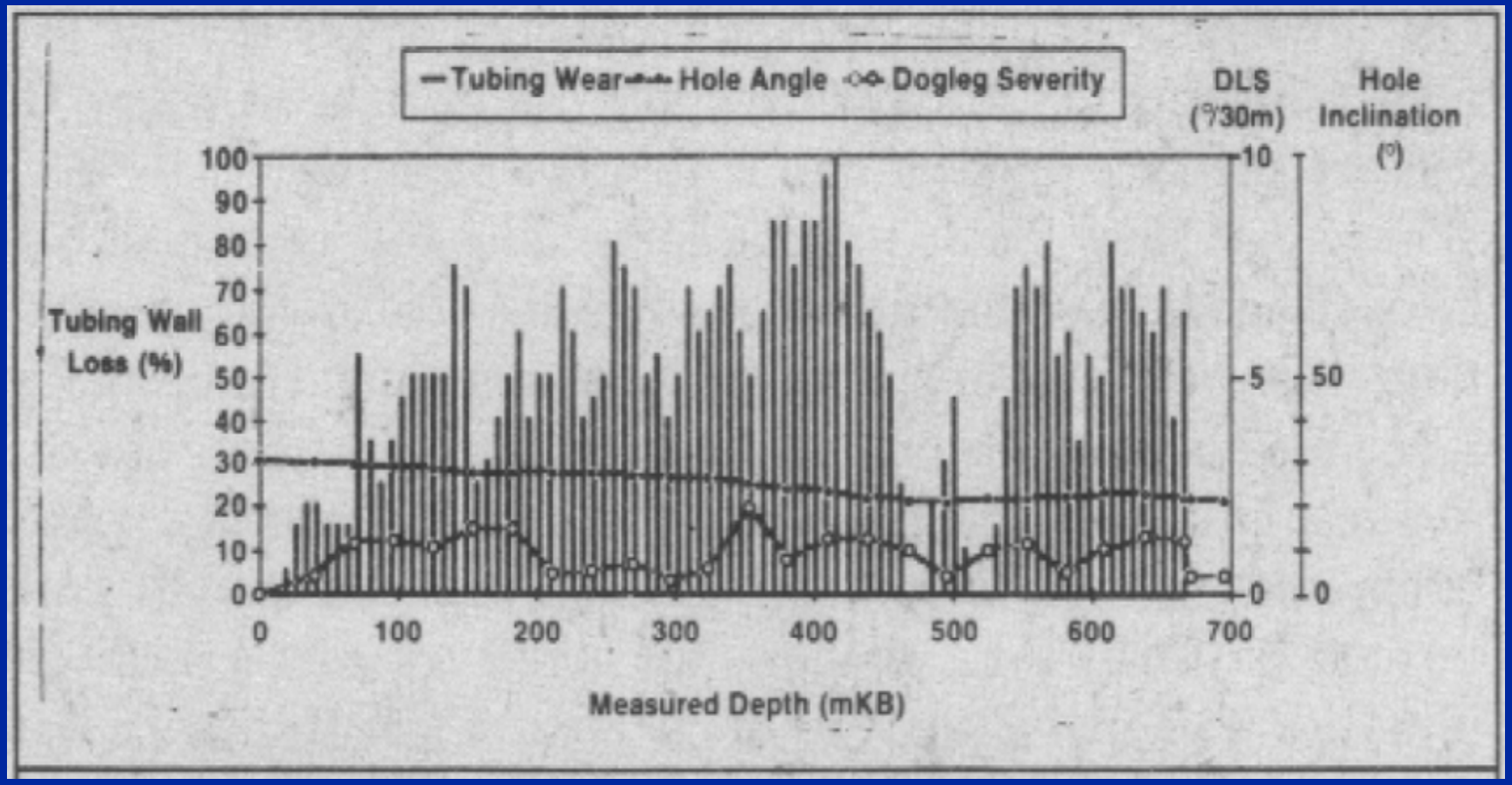


Canada – High DLS Slant Well



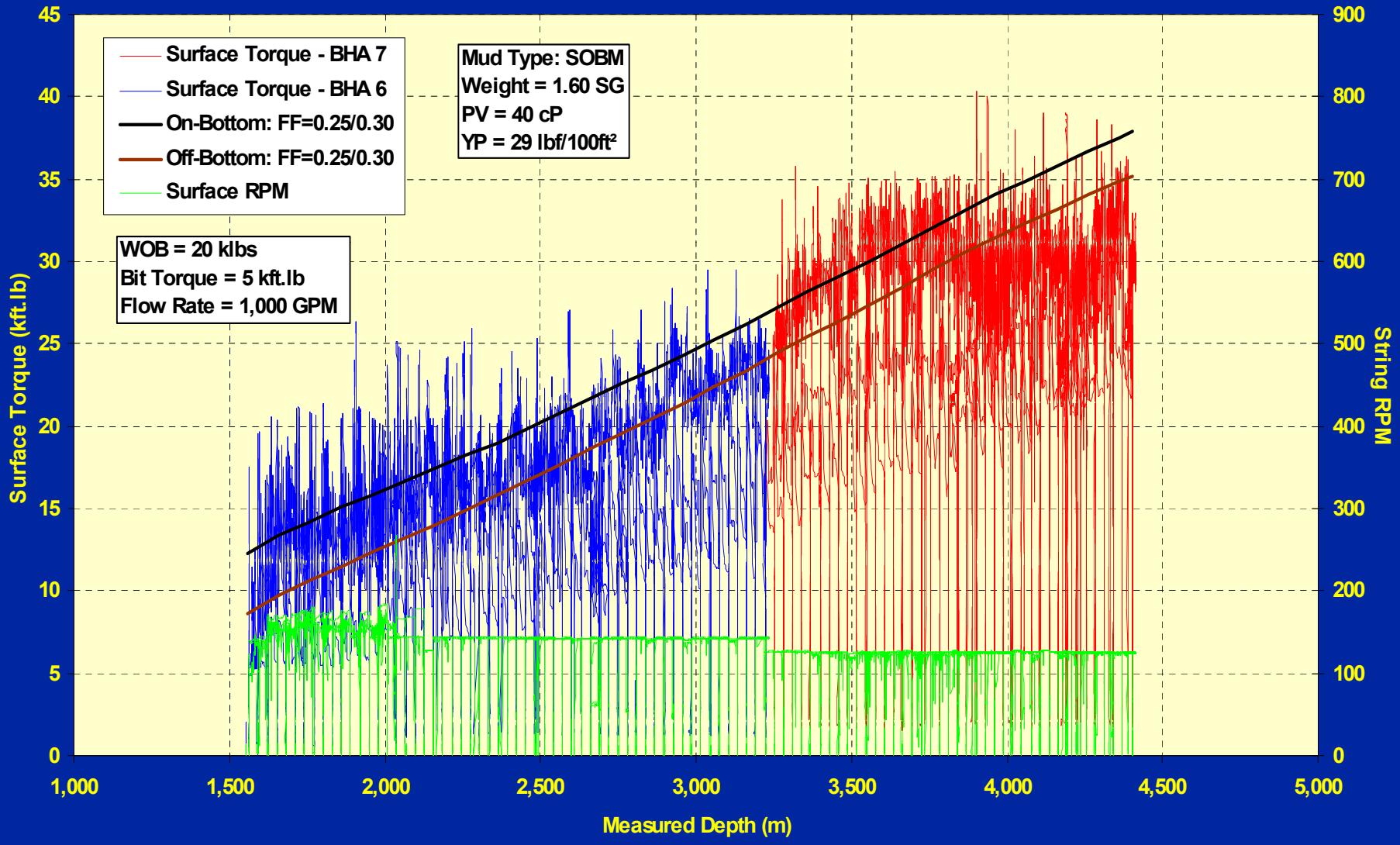
Tubing Wear vs. DLS/hole angle for high-DLS well
Well on production for 2½ months before failure

Canada – Low DLS Slant Well

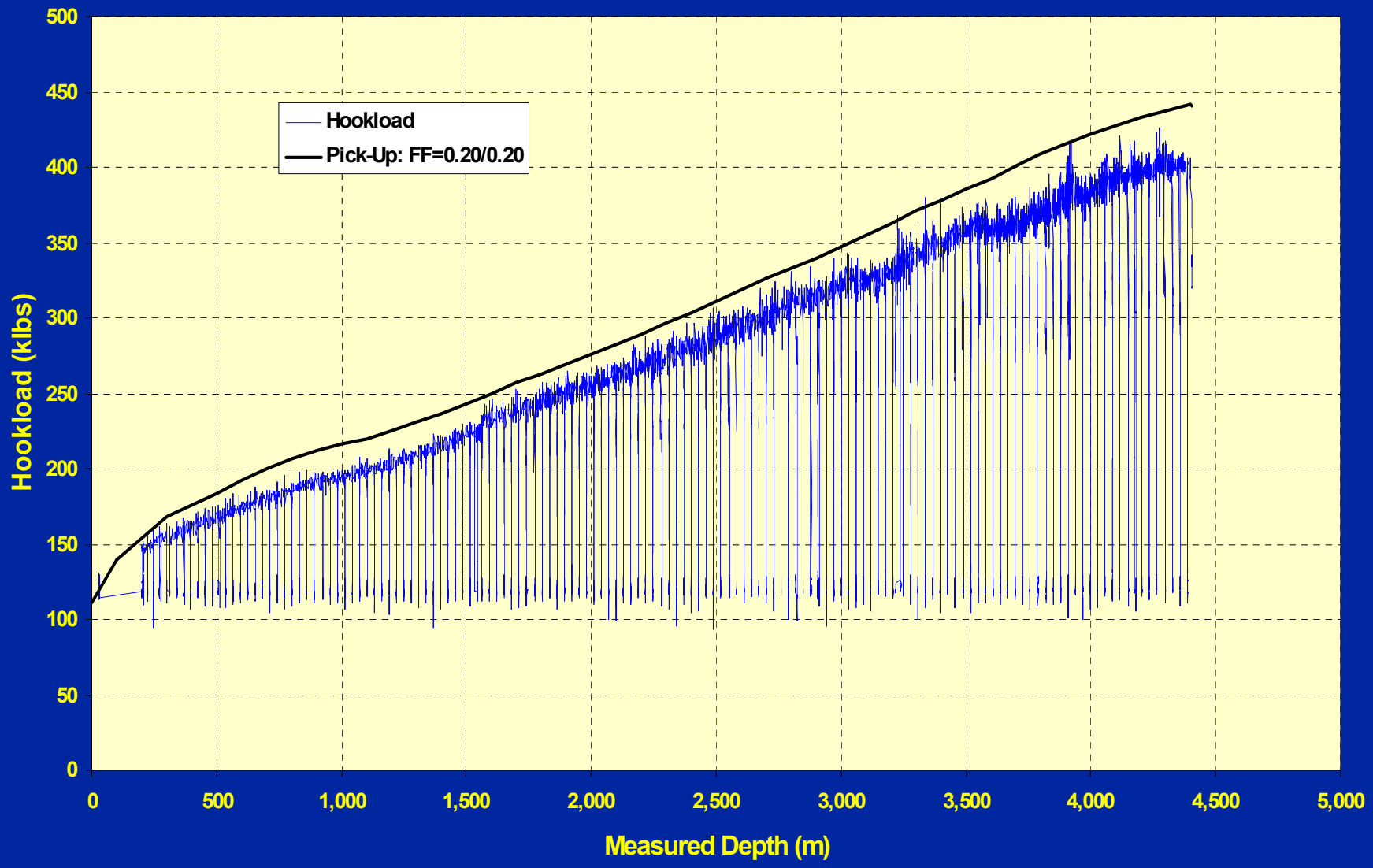


Tubing Wear vs. DLS/hole angle for low-DLS well
Well on production for 21 months before failure

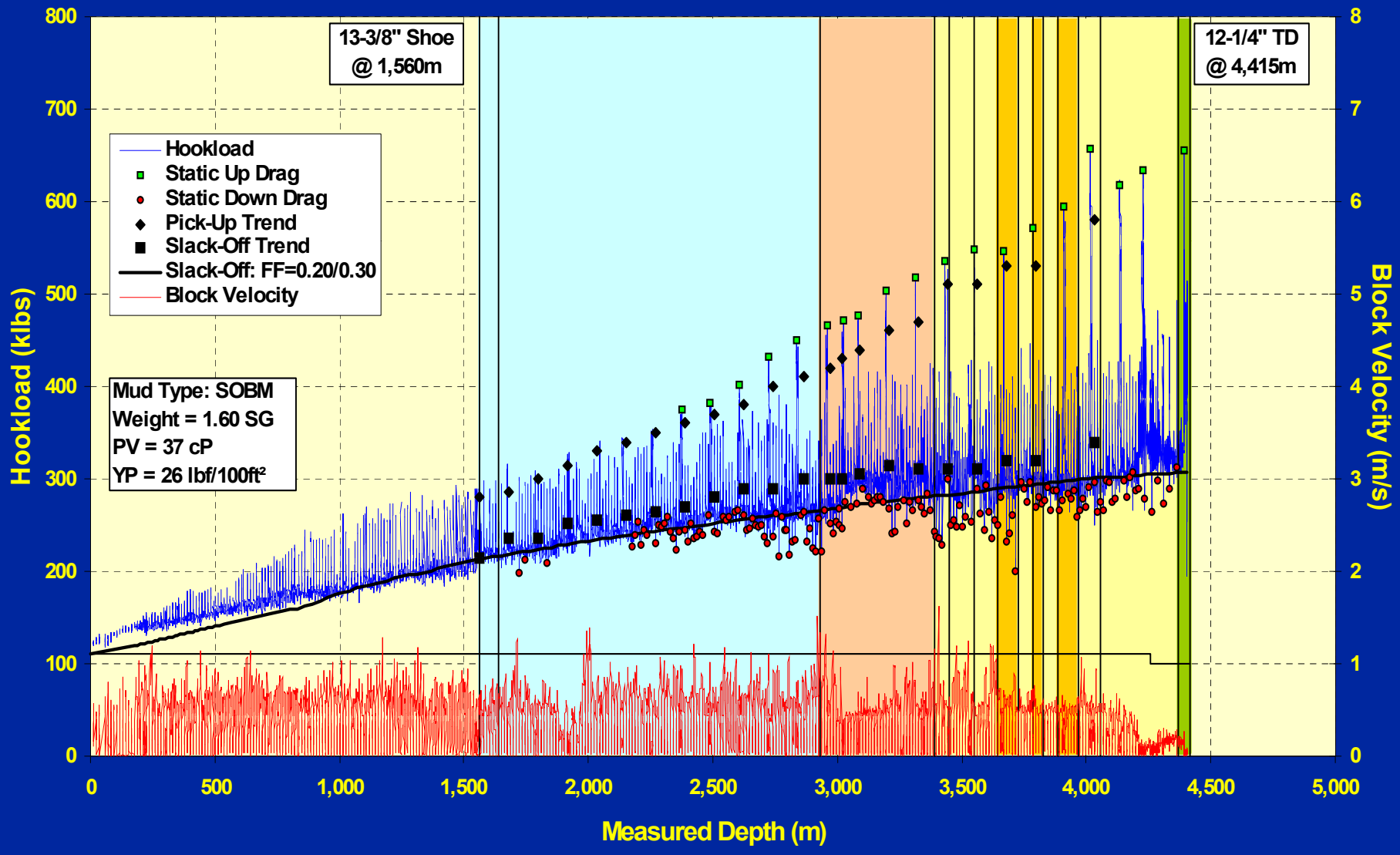
Drilling 12¼" Section – Azerbaijan Well



Tripping-out 12¼" Hole – Azerbaijan Well



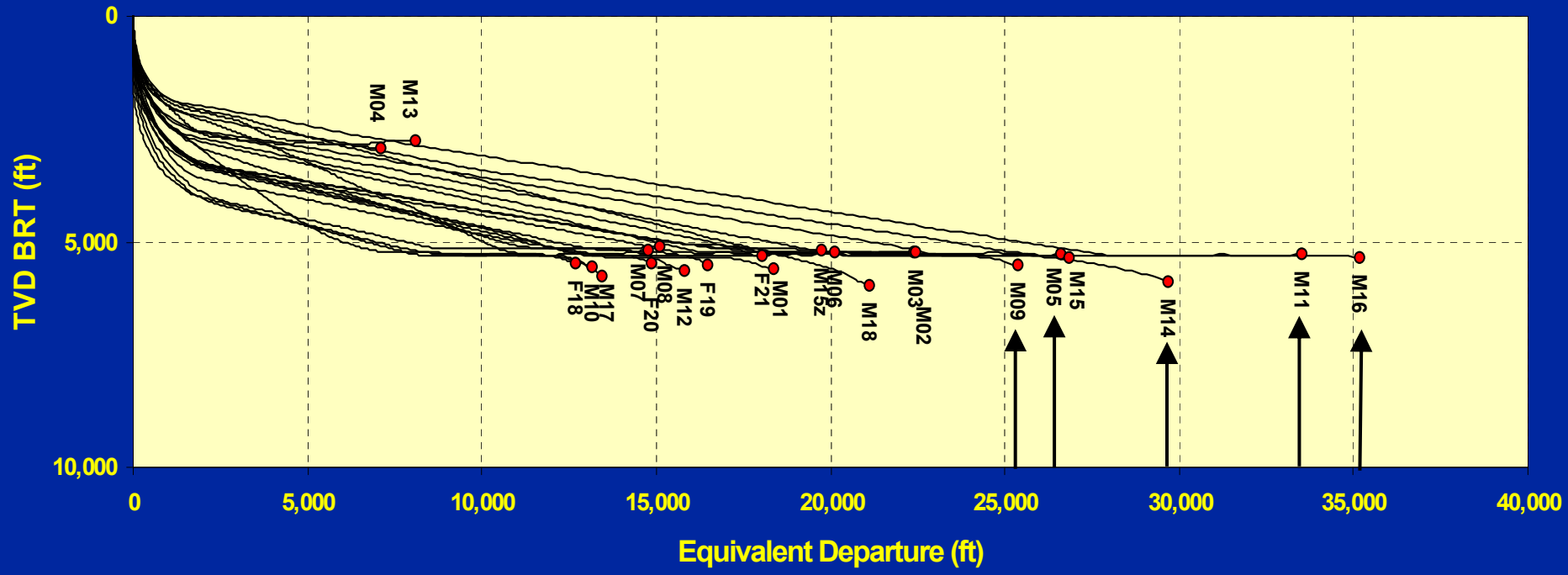
Running 9-5/8" Casing – Azerbaijan Well



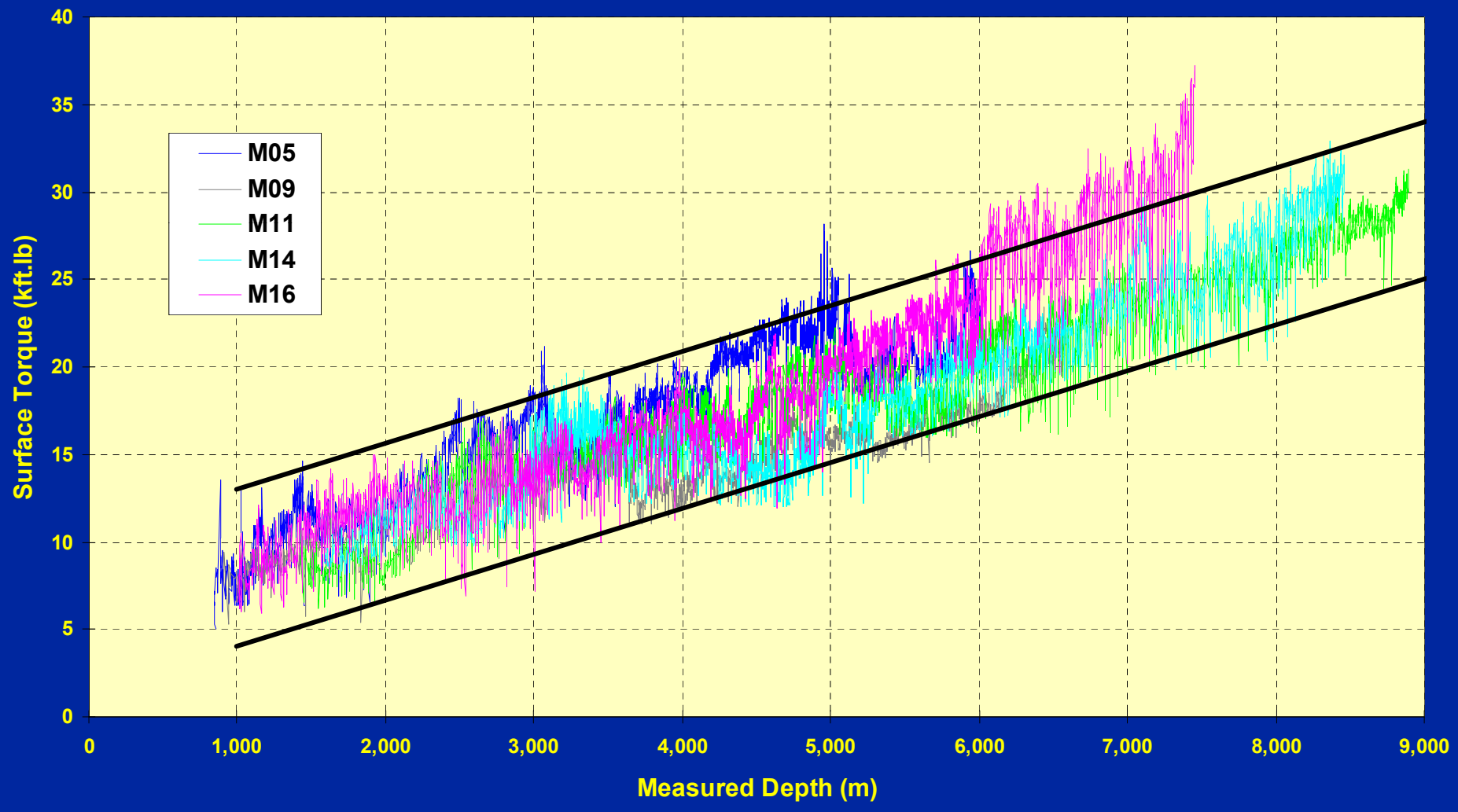
WQS – Azerbaijan Well

Build and Hold Profile, Azerbaijan	Score
Drilling Response (max 5 points) Persistent erratic torque response observed. This observation is indicative of vibration observed during drilling of the interbedded sand / shale sequence in overburden. Average cased/open hole rotary friction factors of 0.25/0.30 are typical of those in the region.	3
Final Trip-out Of Hole Response (max 7 points) The final trip-out of hole response is smooth and clean. Minor isolated overpulls are observed but are less than 30 klbs. The bandwidth of drag data is fairly narrow which is another indicator of very good hole quality. Average cased/open hole axial friction factors of 0.20/0.20 are similar to those from offset wells in the field. The high response score should provide confidence that casing should run easily to depth.	6
Casing Running Response (max 8 points) Casing running in this region is acknowledged as particularly challenging. Dynamic drag levels in open hole are in line with offset well performance correlating with cased/open friction factors of 0.20/0.30. Static friction forces are in evidence throughout most of the casing run. The highest clusters of static friction occur at the bottom of the Surakhany formation and in the upper Balakhany sands. Excess drag due to static friction exceeds 50 klbs but is less than 100 klbs.	2
WQS (D3T6C2) A score of 11 corresponds to a medium/high quality wellbore. (Maximum possible score 20)	11

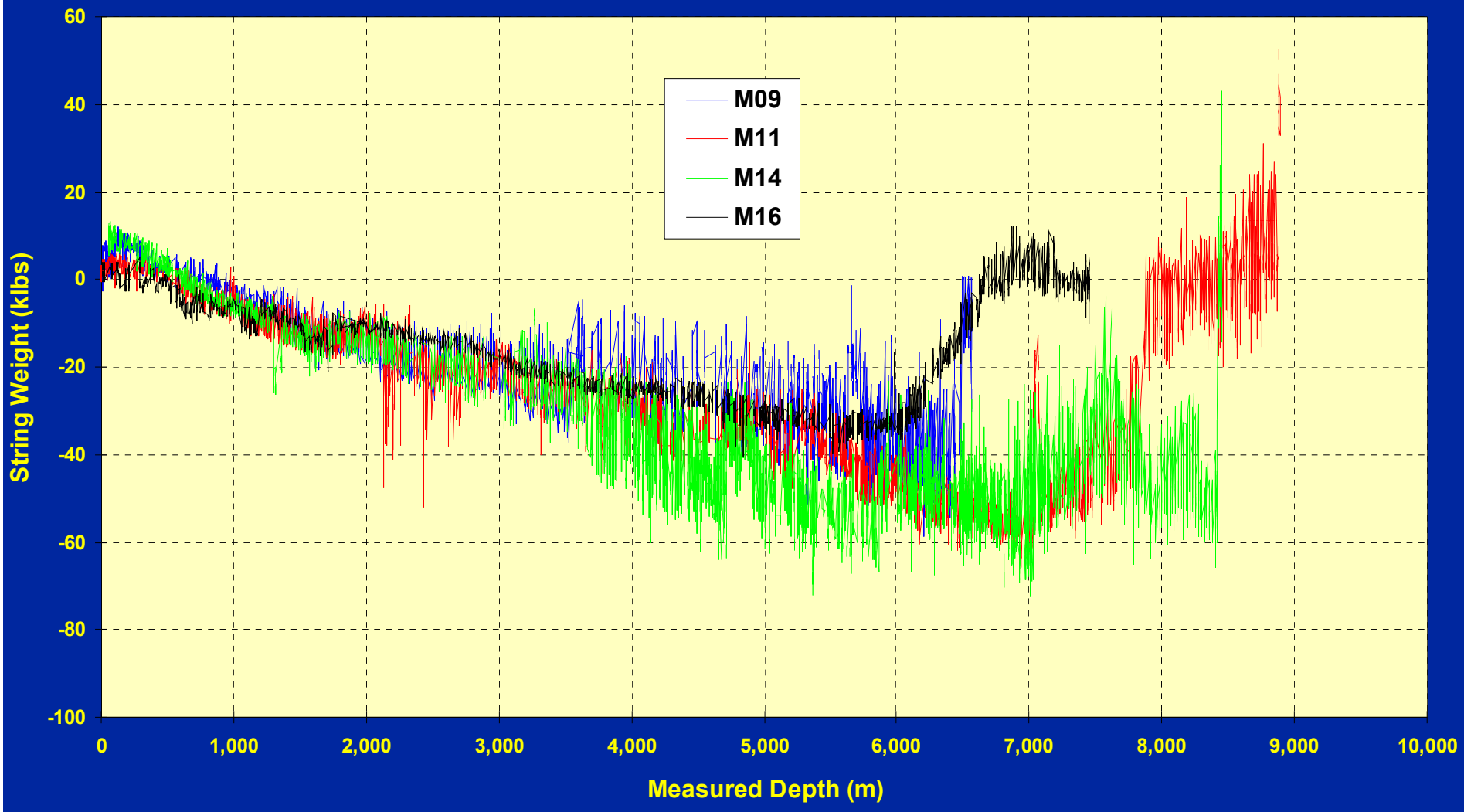
WQS: Wytch Farm ERD Wells



Wytch Farm – Torques 12¼" Section



Wytch Farm – 9-5/8” Casing Runs



Wytch Farm ERD Wells – WQS Summary

Well Name	Drilling Response (Max 5)	Tripping-out Response* (Max 7)	Casing Running Response (Max 8)	WQS (Max 20)
M05	4	3	4	11
M09	4	5	6	15
M11	5	4	5	14
M14	5	6	7	18
M16	4	6	7	17

* Estimated values based on casing running response

Comments on high WQS

- Good learning curve
- Continuous ERD drilling program