SPE GCS ANNUAL DRILLING SYMPOSIUM

Real-Time Rig Activity-Based Models and Drilling Analytics to Provide Early Indications of Hole Problems

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OUTLINE

- Well Challenges & Hazard Avoidance
- Big Picture
- How & Why?
- Evolution of Real-Time Modeling
- Drilling Efficiency
- How To Avoid Drilling Ourselves Into Trouble
- Conclusion

Well Challenges & Hazard Avoidance

		Real Time Hazard Avoidance				
		Early Prediction & Enhanced Management of Wellbore Behavior				
		Continuous Measurement of Downhole Pressures	Dynamic T&D and Hydraulics Surveillance	Precise Downhole Pressure Management	Real-Time Particle Size Distribution	Real-Time Wellbore Stability Analysis
Horizontal/Deviated Well Challenges	High Solids Build-up (excessive cuttings)	x	x		x	
	Differential Sticking	x		x	x	x
	Wellbore Instability (excessive cavings)	x	x		x	x
	Uncertainty of True Drilling Window	x		x		x

Big Picture

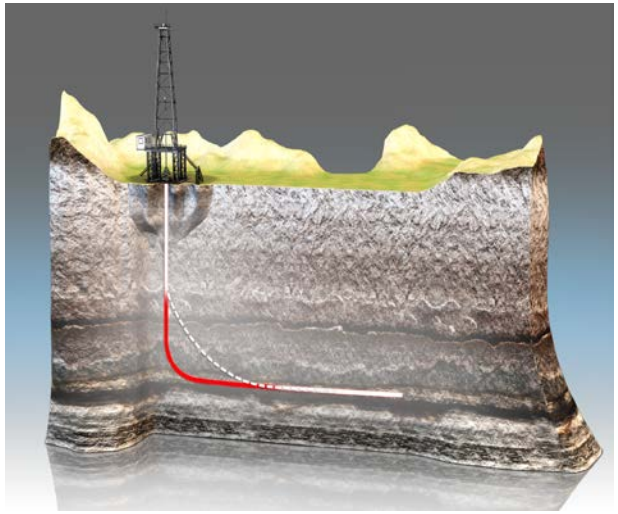
MITIGATE **LOST CIRCULATION** AND KICKS

AVOID **STUCK** PIPE

MAINTAIN **DRILLSTRING** INTEGRITY

DRILL WITHIN **TIGHT** MARGINS

MAXIMIZE **RATE OF** PENETRATION



Drilling Hazards Management

Wellbore Stability

Drilling Optimization

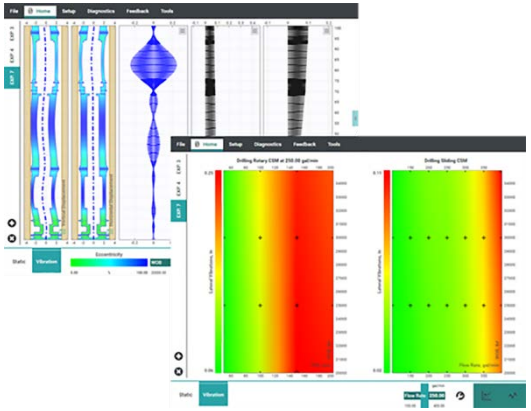
How & Why

PRE-DRILL

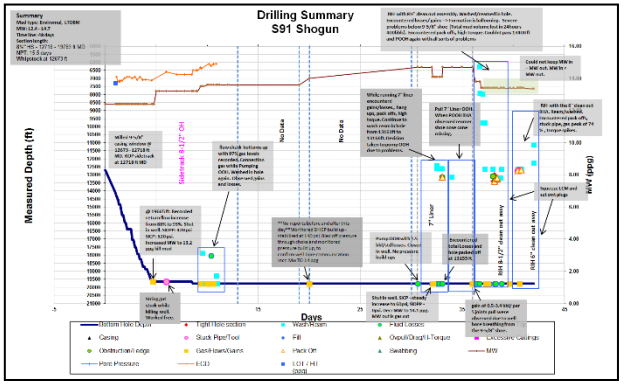
Drilling Optimization Plan
- Optimized trajectory
- Calibrated T&D, Hydraulics Models
- Optimized BHA design
- Driller's roadmap (DRM)
- Mechanical Specific Energy (MSE) analysis

DHM FEED Study
- Offset well data analysis
- Risk assessment
- Rig activity analysis (NPT, ILT)

Wellbore Stability
- Pore Pressure and Geomechanics Models data analysis



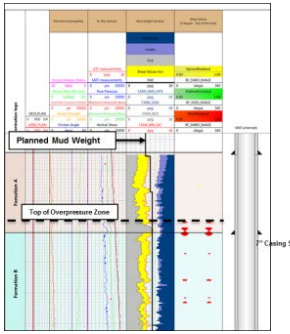
Optimized BHA



Offset Well Analysis

Depth Range (TVD)	Formation Name	BHA Details	Bit Details	Bit TFA	Surface WOB	Flow Rate	Surface RPM	Bit RPM	Differential Pressure
a094 - a650 ft	Yellow	8" OD 6/7 lobe 5.0 stage 0.18 rev/gal 1.5 deg. Bend	12.25" CutRox	0.90 in²	20 - 25 klb	800 gpm	30 rpm	175 rpm	400 - 500 psi
a650 - b043 ft	Pale Blue	8" OD 6/7 lobe 5.0 stage 0.18 rev/gal 1.5 deg. Bend	12.25" CutRox	0.90 in²	20 - 25 klb	800 gpm	30 rpm	175 rpm	400 - 500 psi
b043 - c131 ft	Finnish	8" OD 6/7 lobe 5.0 stage 0.18 rev/gal 1.5 deg. Bend	12.25" CutRox	0.90 in²	20 - 25 klb	800 gpm	45 rpm	190 rpm	500 - 600 psi
c131 - c680 ft	Purple	8" OD 6/7 lobe 5.0 stage 0.18 rev/gal 1.5 deg. Bend	12.25" CutRox	0.90 in²	15 - 20 klb	800 gpm	45 rpm	190 rpm	500 - 600 psi
c680 - e838 ft	Pea Green	8" OD 6/7 lobe 5.0 stage 0.18 rev/gal 1.5 deg. Bend	12.25" CutRox	0.90 in²	14 - 18 klb	800 gpm	45 rpm	190 rpm	300 - 400 psi
e838 - g219 ft	Salmony	6.75" 7/8 lobe 5.0 stage 0.29 rev/gal 1.5 deg. Bend	8.5" BitDrill	0.90 in²	16 - 20 klb	525 gpm	100 rpm	290 rpm	400 - 600 psi
g219 - g721 ft	Turquoise	6.75" 7/8 lobe 5.0 stage 0.29 rev/gal 1.5 deg. Bend	8.5" BitDrill	0.90 in²	14 - 18 klb	525 gpm	75 rpm	225 rpm	250 - 400 psi
g721 - h442 ft	Bluey	6.75" 7/8 lobe 5.0 stage 0.29 rev/gal 1.5 deg. Bend	8.5" BitDrill	0.90 in²	20 - 25 klb	525 gpm	75 rpm	225 rpm	400 - 500 psi
h442 - h648 ft	Greeny	6.75" 7/8 lobe 5.0 stage 0.29 rev/gal 2.12 deg. Bend	8.5" BitDrill	0.90 in²	15 - 20 klb	525 gpm	75 rpm	225 rpm	300 - 400 psi
h648 - h830 ft	Grey A	4.75" 7/8 lobe 3.8 stage 0.51 rev/gal 1.5 deg. Bend	6.75" ChopUp	0.54 in²	15 - 20 klb	315 gpm	75 rpm	225 rpm	550 - 700 psi
h830 - i144 ft	Grey B	4.75" 7/8 lobe 3.8 stage 0.51 rev/gal 1.5 deg. Bend	6.75" ChopUp	0.54 in²	12 - 18 klb	315 gpm	75 rpm	225 rpm	600 - 750 psi
i144 - i552 ft	Grey C	No data available	n/a	n/a	n/a	n/a	n/a	n/a	n/a
i552 - i947 ft	Grey D	No data available	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Driller's Roadmap



Pre-Drill WBS Model

How & Why

REAL-TIME

Hole Condition Monitoring:

- **Real-Time T&D, Hydraulics MvA**
- Improve hole cleaning efficiency & stability
- Avoid stuck pipe

- **Real-Time MSE analysis**
- ROP Enhancement
- Vibration mitigation

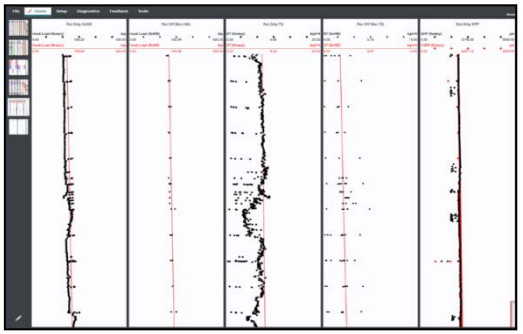
Real-time DHM:

- Engineering support
- Management of Change

Real-time Wellbore Stability:

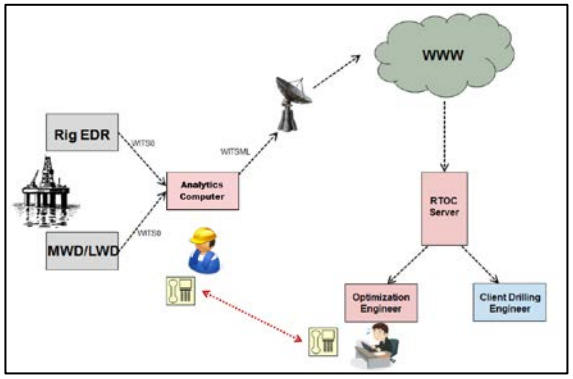
- Managing safe drilling window

Hole Condition Monitoring

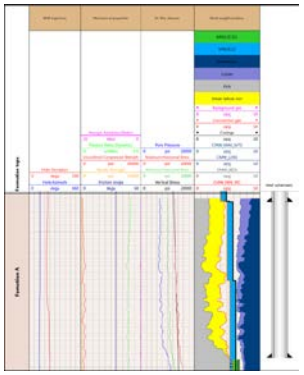


Model vs Actual (MvA) Analysis

- Torque & Drag
- Hydraulics



Engineering Support



Real-Time WBS Model

How & Why

POST-DRILL

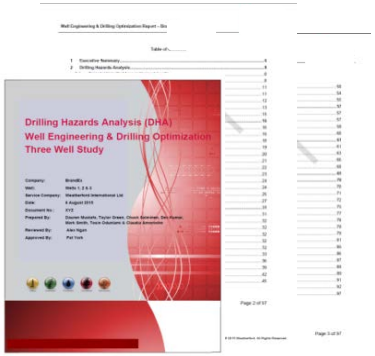
Drilling Performance Report:

- Review all engineering model vs actual parameter correlations
- Review & update Drillers' Road Map
- Analyze NPT & ILT to propose opportunities for improvement
- End-of-well report

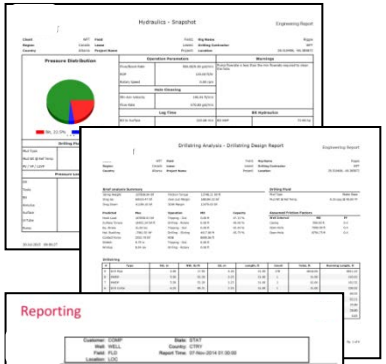
Lessons Learned and Improved Best Practices

- Drilling practices
- BHA adjustments

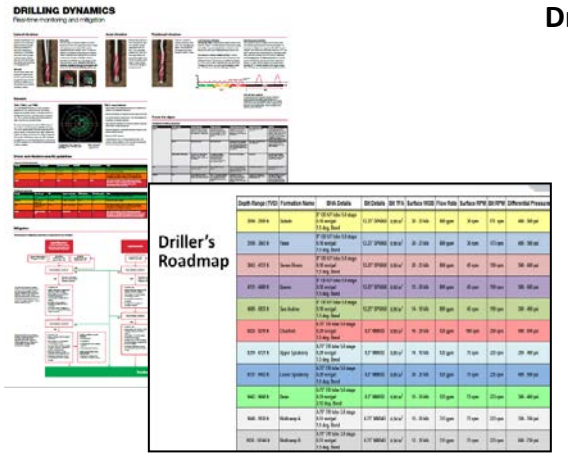
DHM EOW Analysis



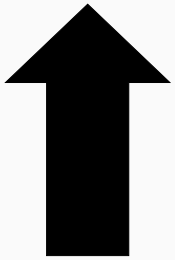
Drilling Optimization EOW Analysis



Lessons Learned & Best Practices



How & Why



IMPROVE
DRILLING
PERFORMANCE

REDUCE
NPT &
WELL COST

DELIVER
CONTINUOUS
IMPROVEMENT

Evolution of Real-Time Modeling

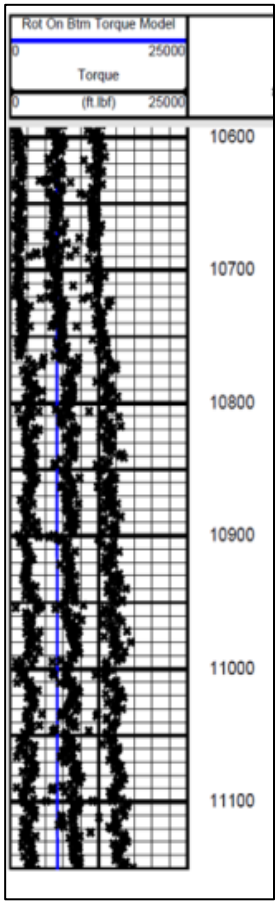
LEVEL 1

Torque & Drag/Hydraulics Model
- Static Model

Torque/SPP Data
- **Actual Sensor Data**

Rig Activity:
- No Rig Activity

Model Type:
- Depth Based



Evolution of Real-Time Modeling

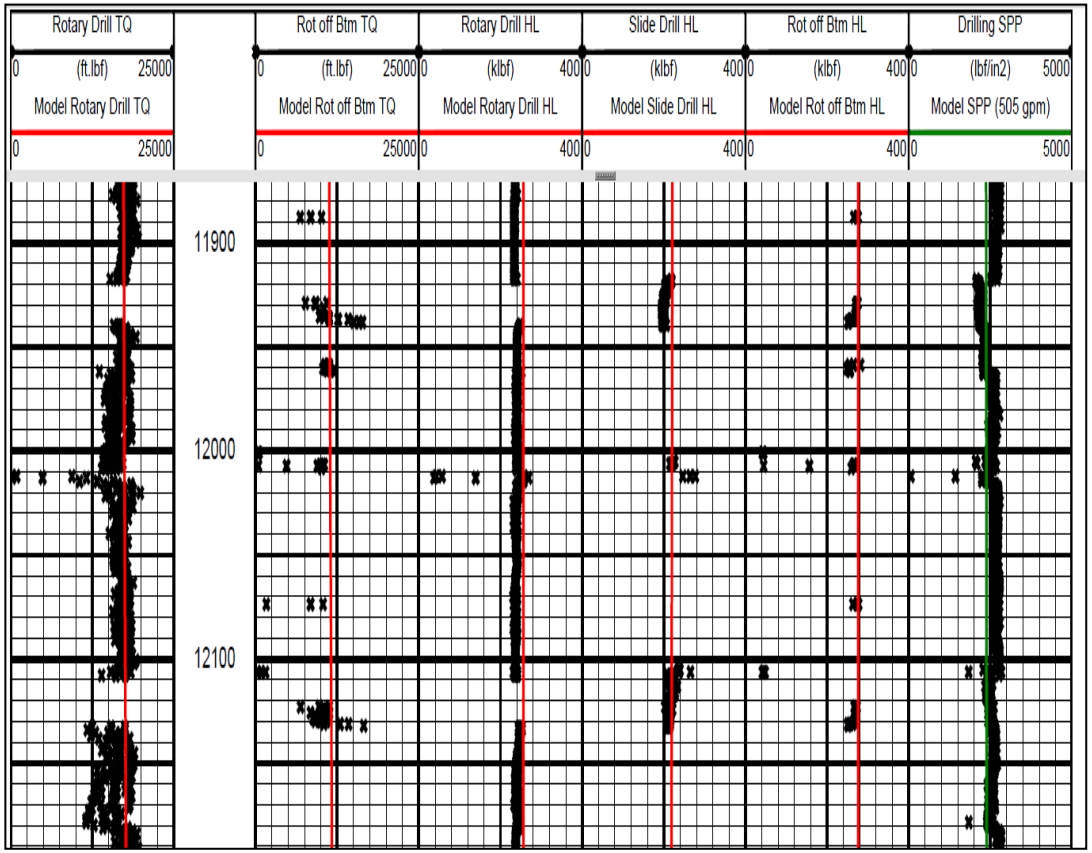
LEVEL 2

Torque & Drag/Hydraulics Model
- Static Model

Torque/SPP Data
- **Actual Sensor Data**

Rig Activity:
- **Rig Activity**

Model Type:
- Depth Based



Evolution of Real-Time Modeling

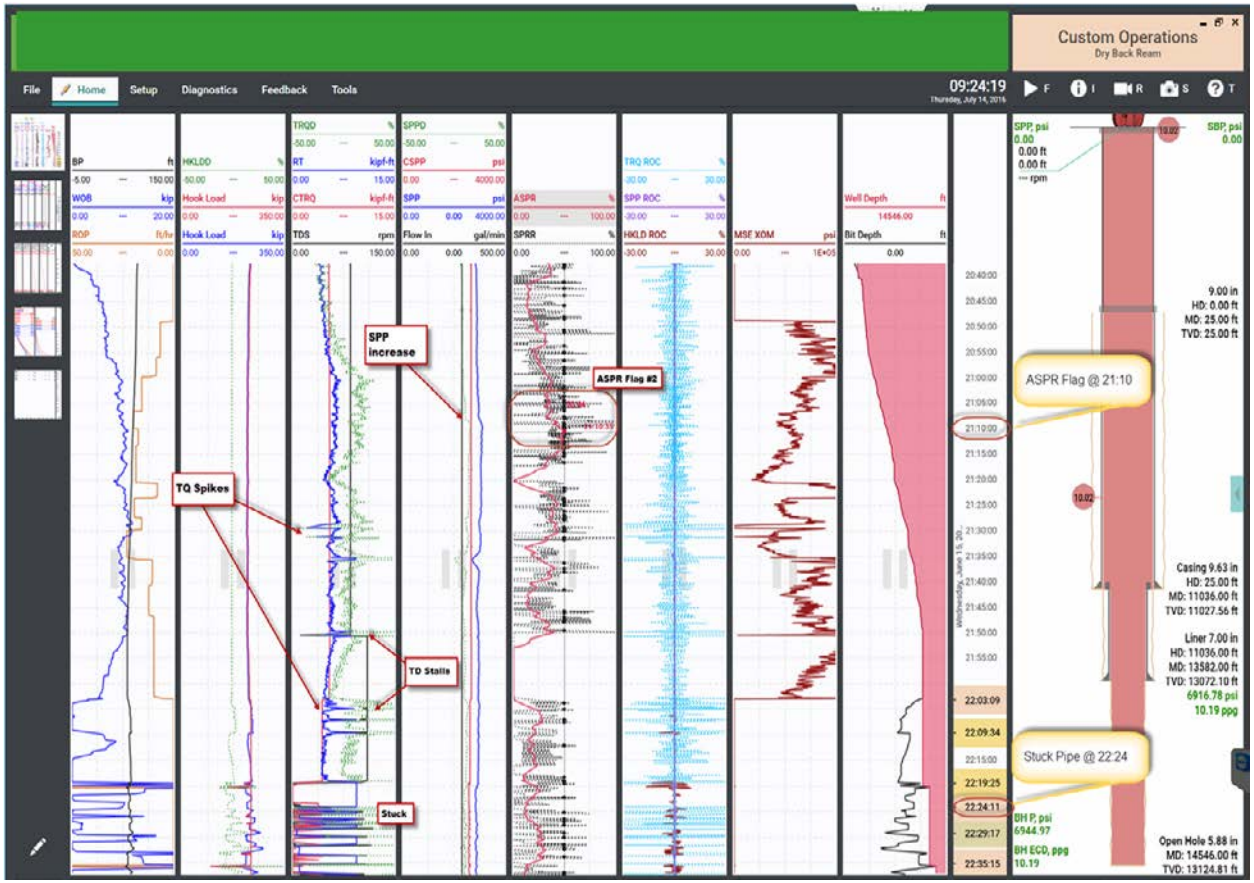
LEVEL 3

Torque & Drag/Hydraulics Model
- **Dynamic Model**

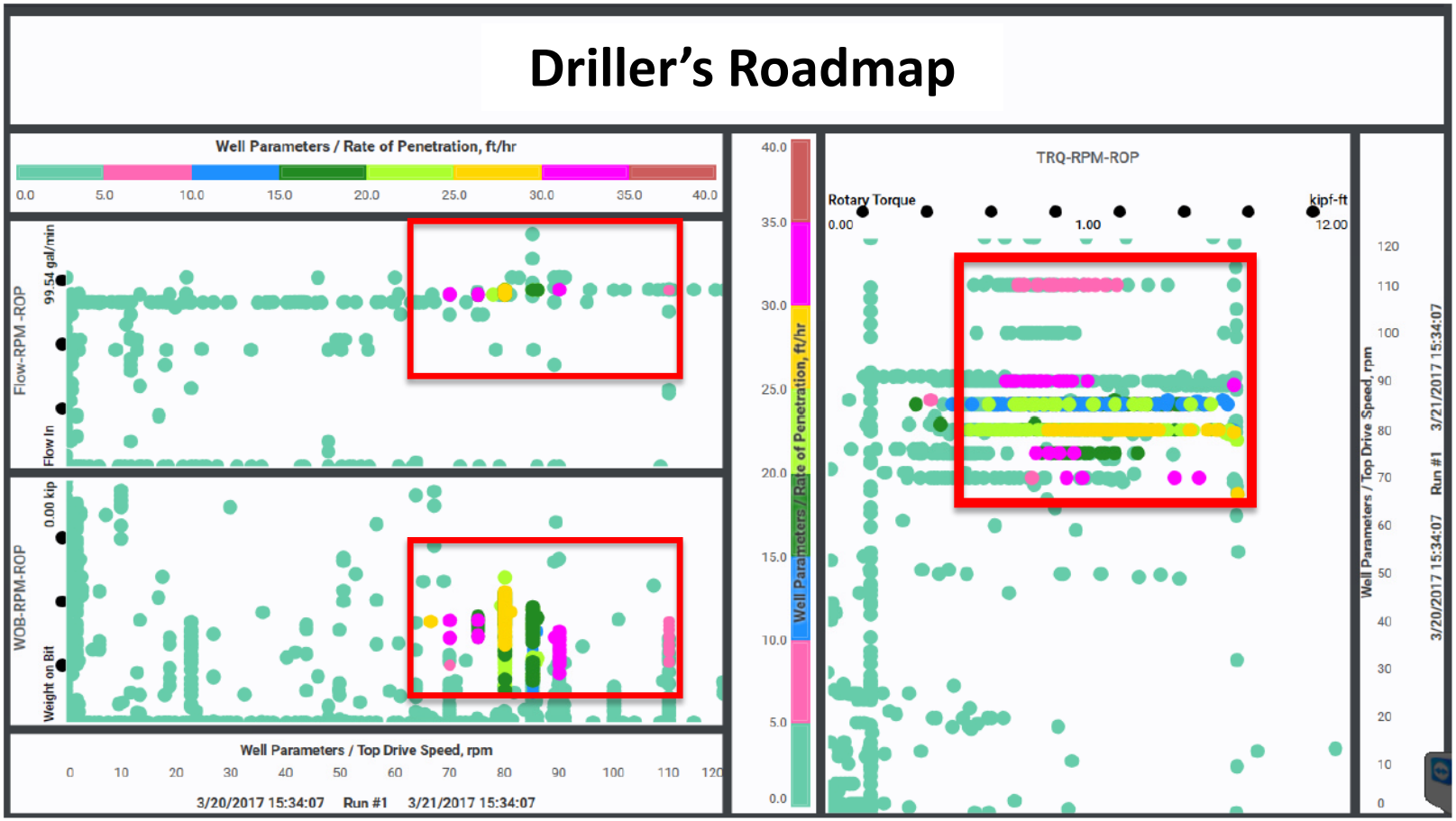
Torque/SPP Data
- **Actual Sensor Data**

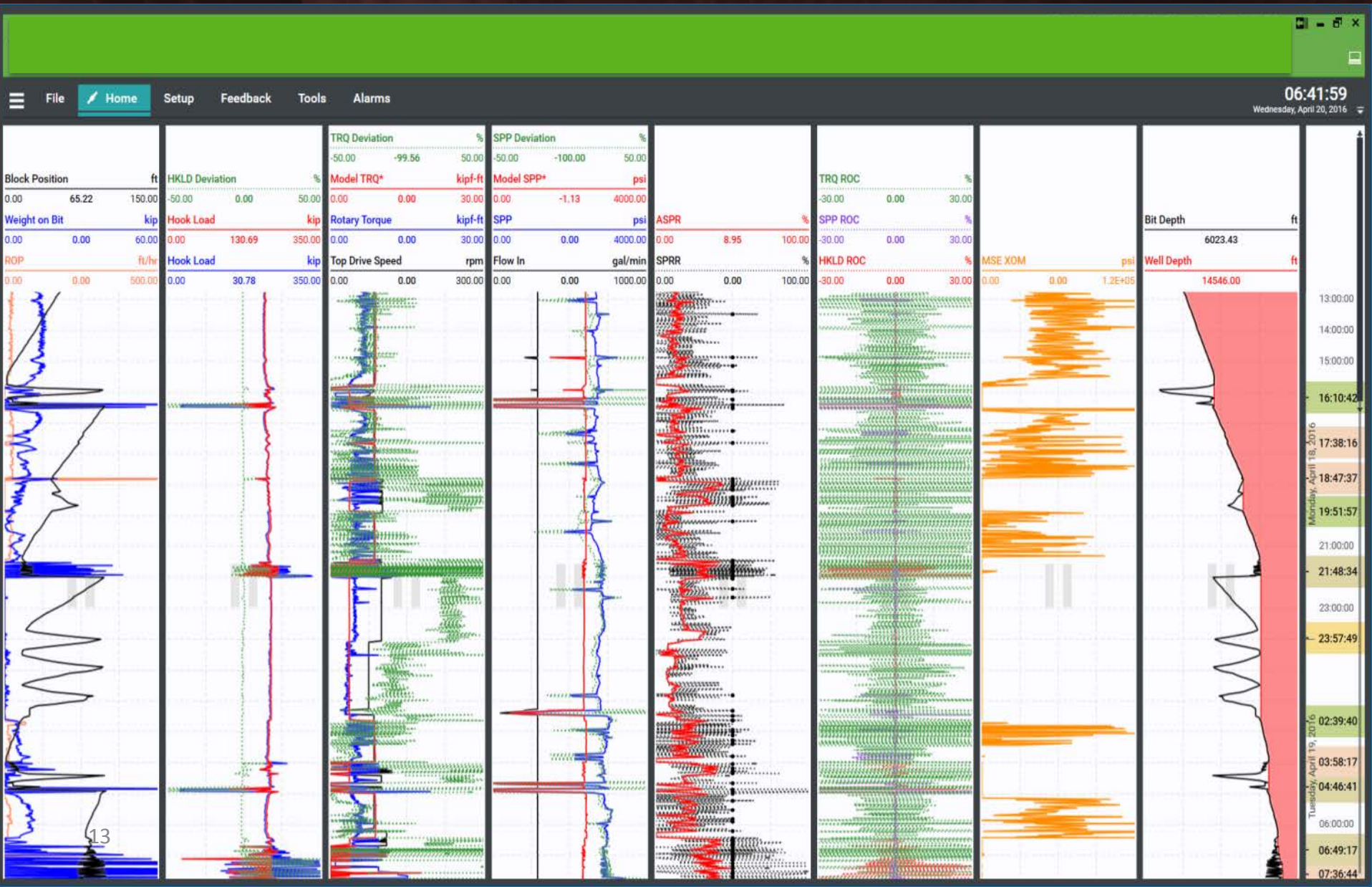
Rig Activity:
- **Rig Activity**

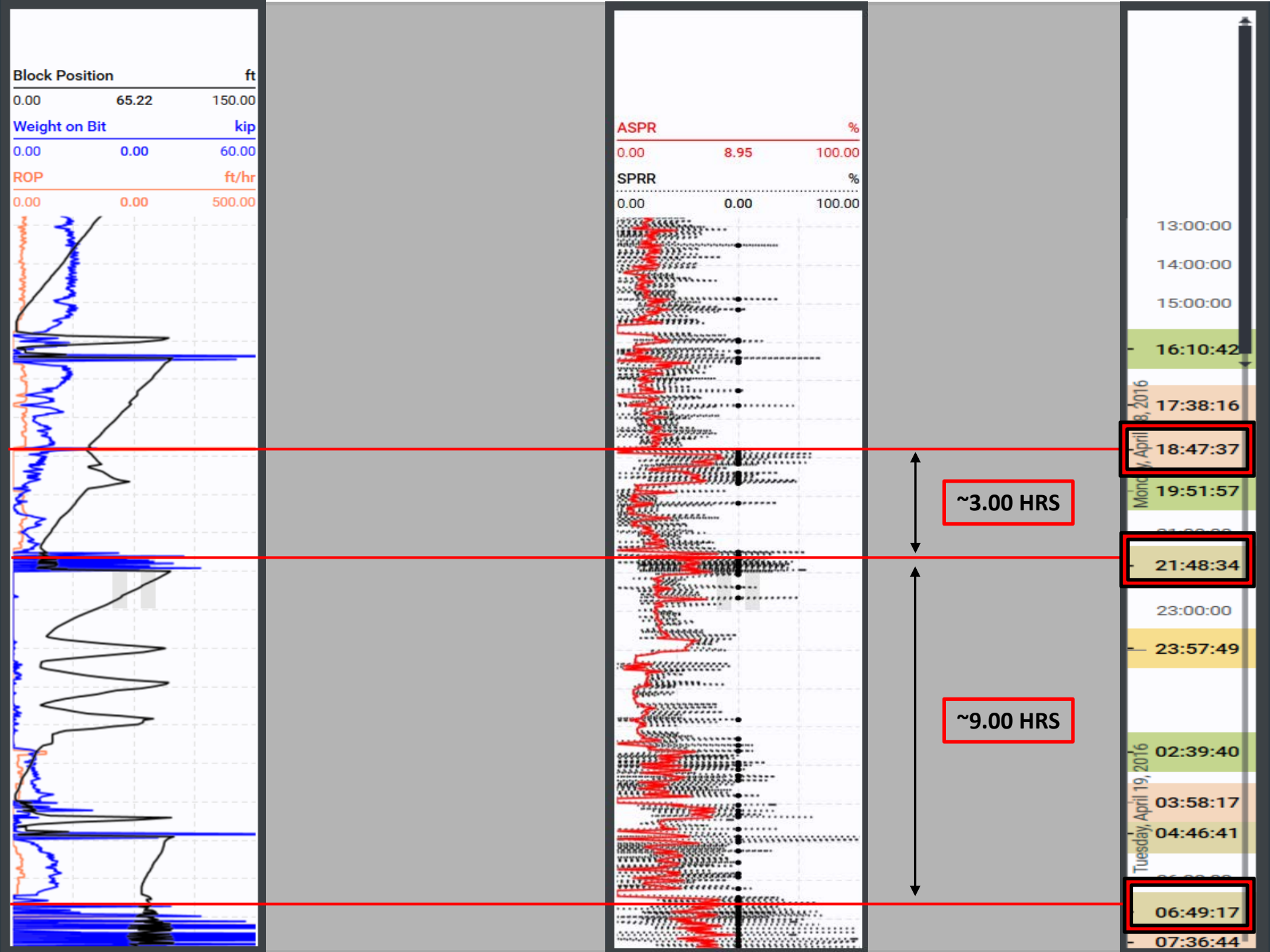
Model Type:
- **Time Based**



Drilling Efficiency






Block Position
ft
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65.22
150.00
Weight on Bit
kip
0.00
0.00
60.00
ROP
ft/hr
0.00
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500.00
ASPR
%
0.00
8.95
100.00
SPRR
%
0.00
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23:00:00
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03:58:17
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06:49:17
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~3.00 HRS
~9.00 HRS

Conclusion

- The ability to address the effects of deteriorating hole conditions requires their timely identification
- **Real-time**, **Dynamic**, **Time Based**, **Rig Activity** dependent models allows for that to happen
- In the example shown, there was 12 hours between the initial trigger and the tool getting stuck – more than enough time to do something…

Thank you

Questions?