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SPE Knowledge Forum

10 Rules for Cost Effective Reservoir Management

- RiskGuard™

- FullStream

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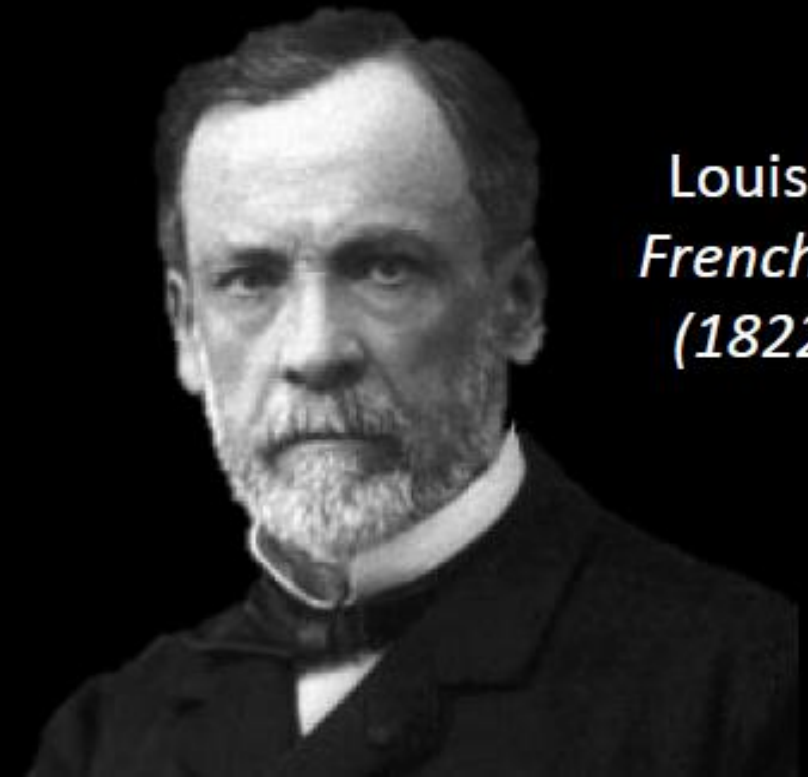
Business Development Manager
Geoscience and Petroleum Engineering

14 March 2019

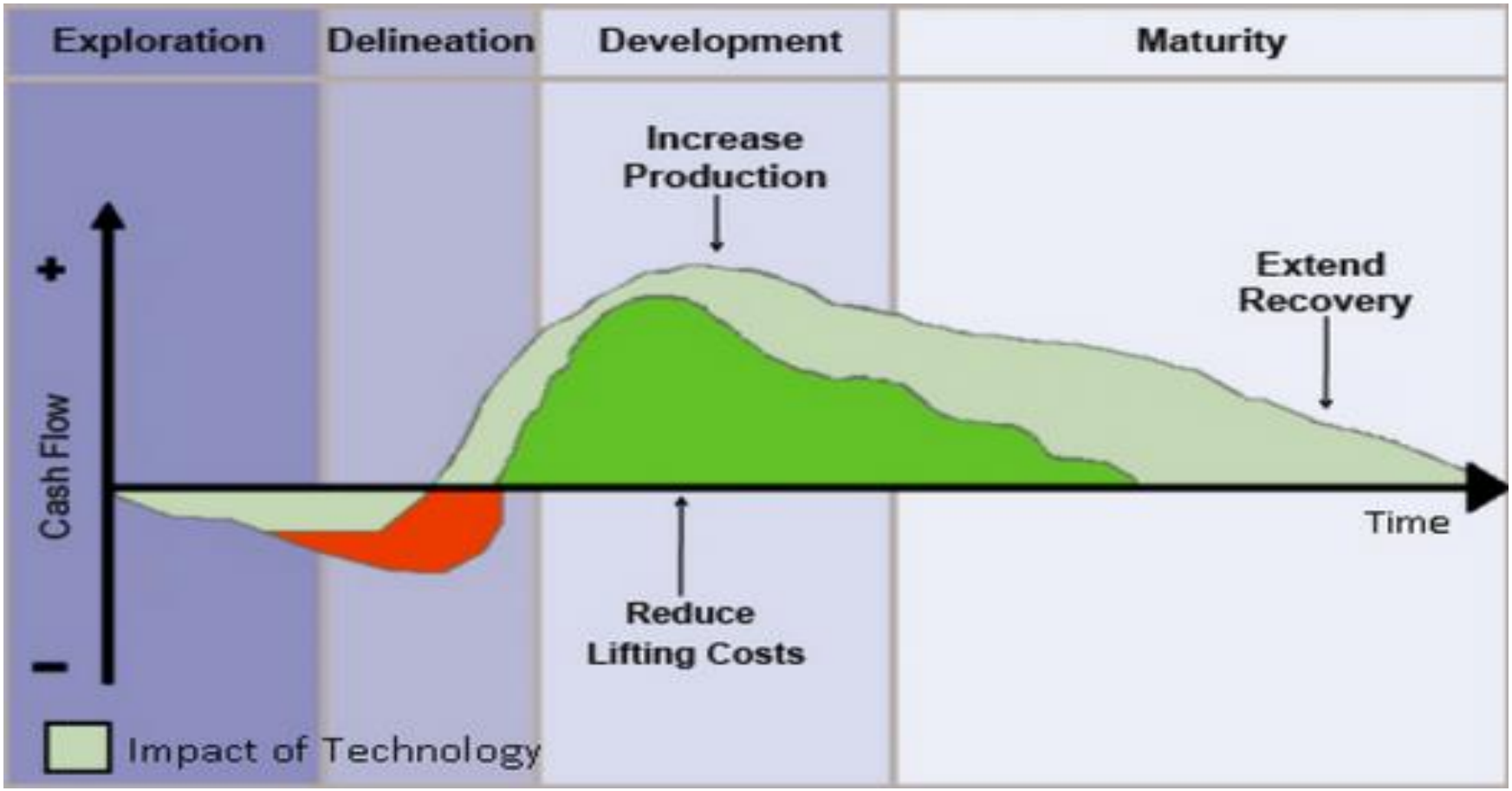
Plan for the unexpected

In the field of observation, chance favours only the prepared mind.



Louis Pasteur,
French biologist
(1822 - 1895)

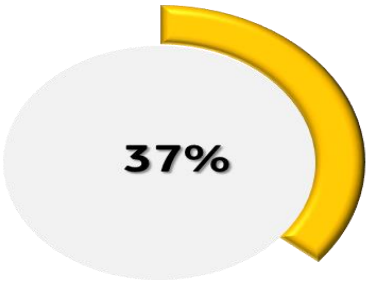
Impact of Information on E&P cash flow



Source: The Digital Oil Field – Oil and Gas Investor April 2004

Our Industry Performance – The Hard Facts

NPT



Geomechanics Related Incidents

COST OF NPT

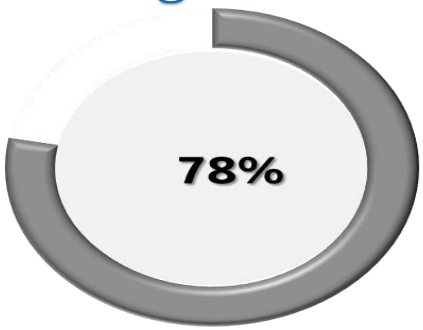
USD 26B

AN ESTIMATED

25%

OF TOTAL DRILLING COSTS

Org. Risks



Source of increasing Risk (2011)

KEY FACTORS

POOR

- ANALYSIS
- PLANNING
- COMMUNICATION
- BARRIER MONITORING
- CHANGE MANAGEMENT

ID. & Mitigation

Incident Identification

SOLUTIONS

PRE-DRILLING

GEOMECHANICS ANALYSIS

REAL-TIME

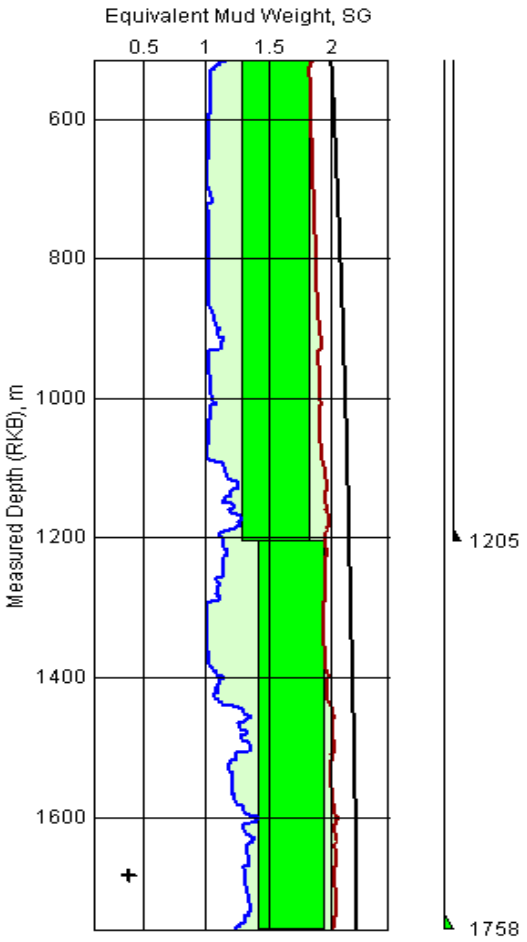
COMMUNICATION

LOGGING

WHILE DRILLING

Casing and Mud Design – More Realistic

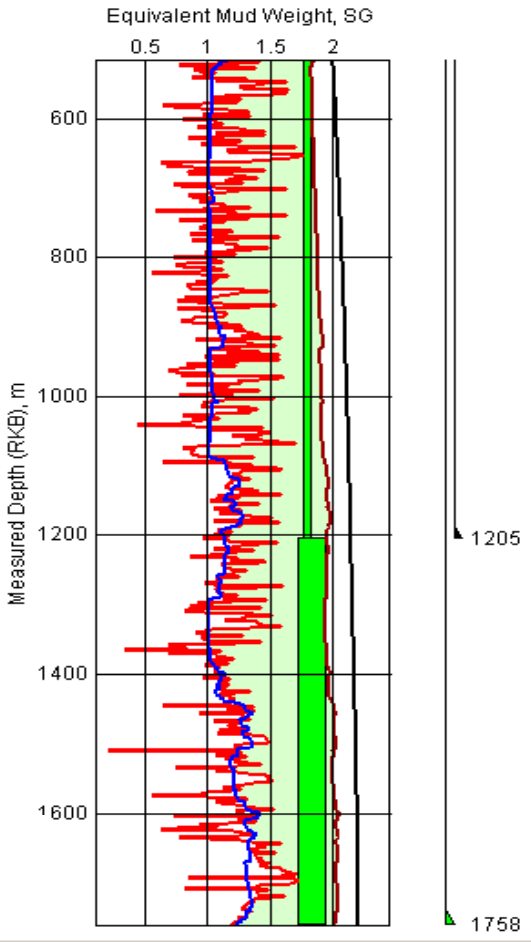
Without Geomechanics (PP/FG Study)



Include Geomechanics in wellbore stability mud weight design

Both pore pressure AND collapse pressure needed

With Geomechanics



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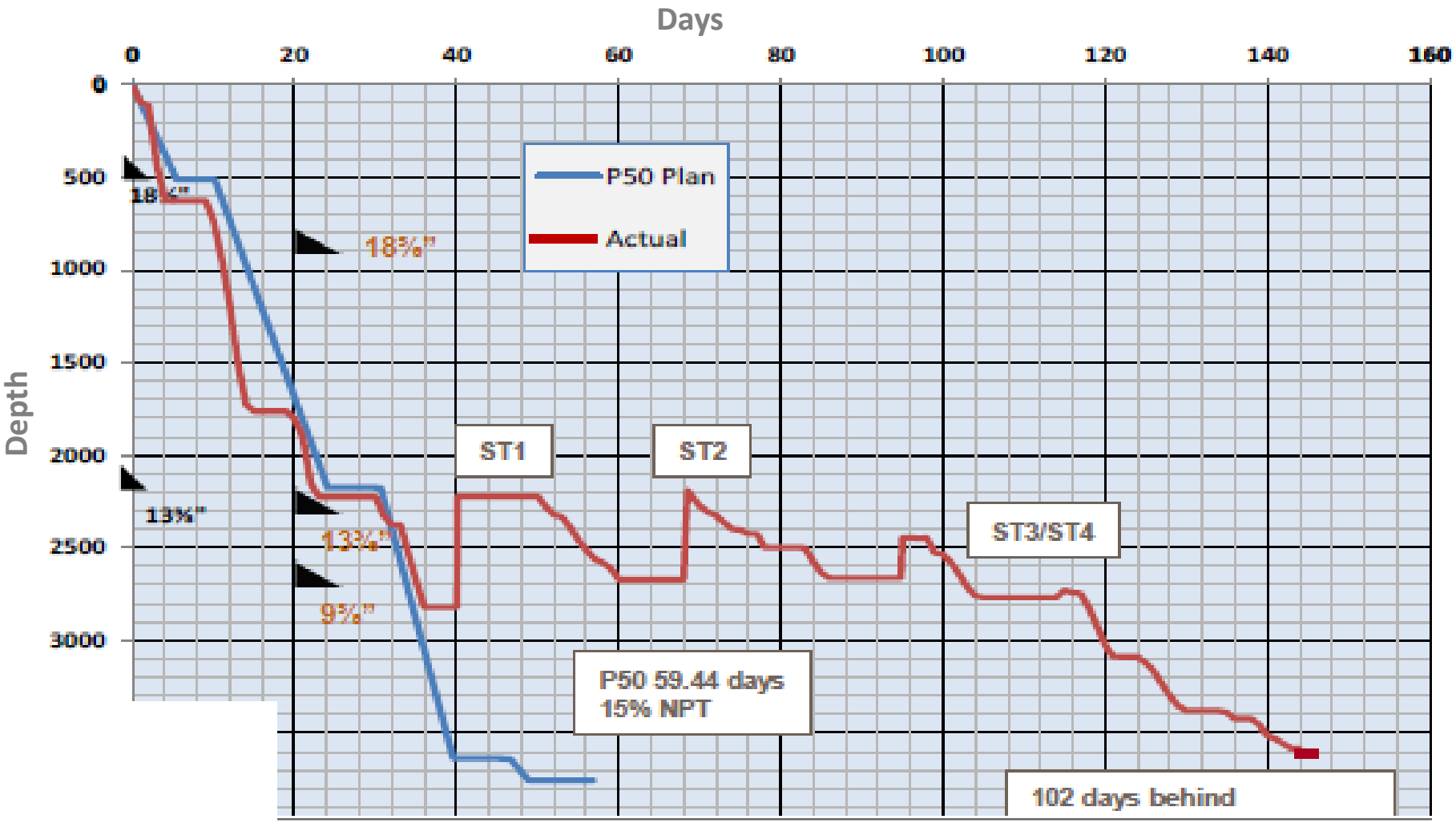
Exploration Drilling – loss of investment



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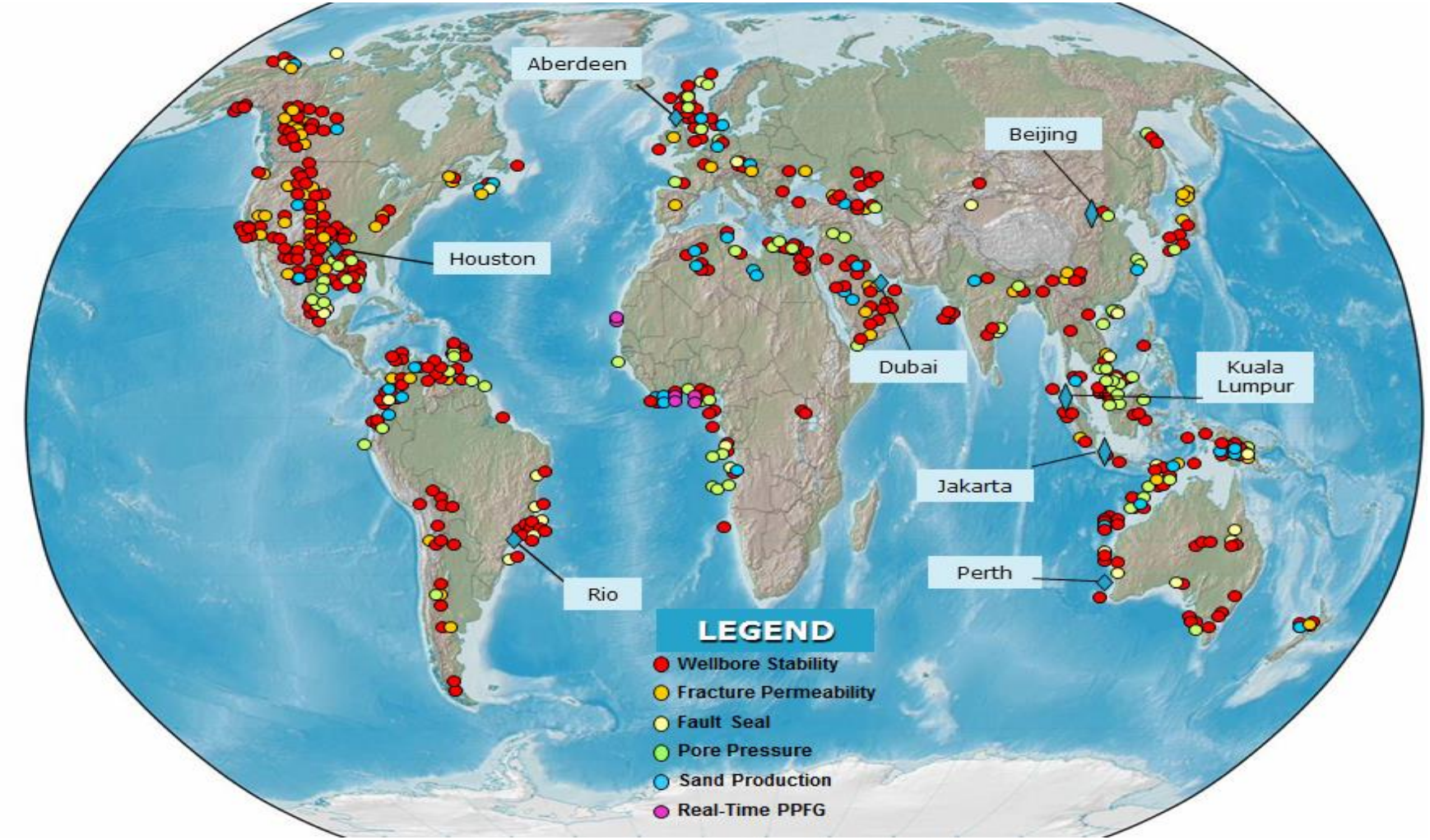
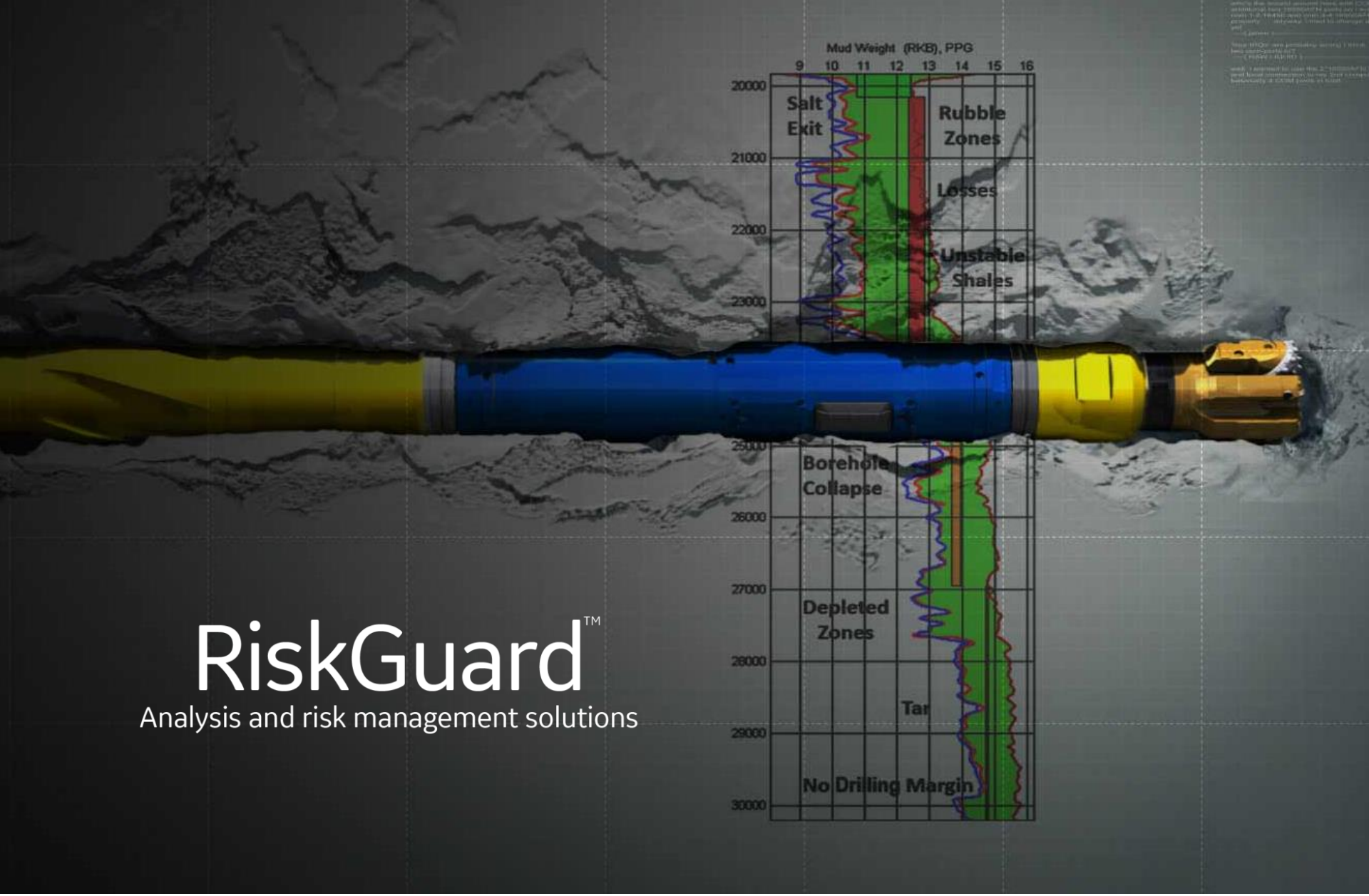
Bias

- **Availability Bias – prior experience influences concepts**
- Confirmation Bias – only use facts that support our decision
- **Blinkered mindset – don't know what you don't know**
- Hindsight Bias – the "I knew it all along" effect
- **Overconfidence – believing too much in our own decision competencies and estimates**
- The "Not-Invented-Here" bias
- **Sunk Cost Fallacy – to continue with a project after money, time and effort already invested**

Experience



Integrate and align goals



RiskGuard™

Analysis and risk management solutions

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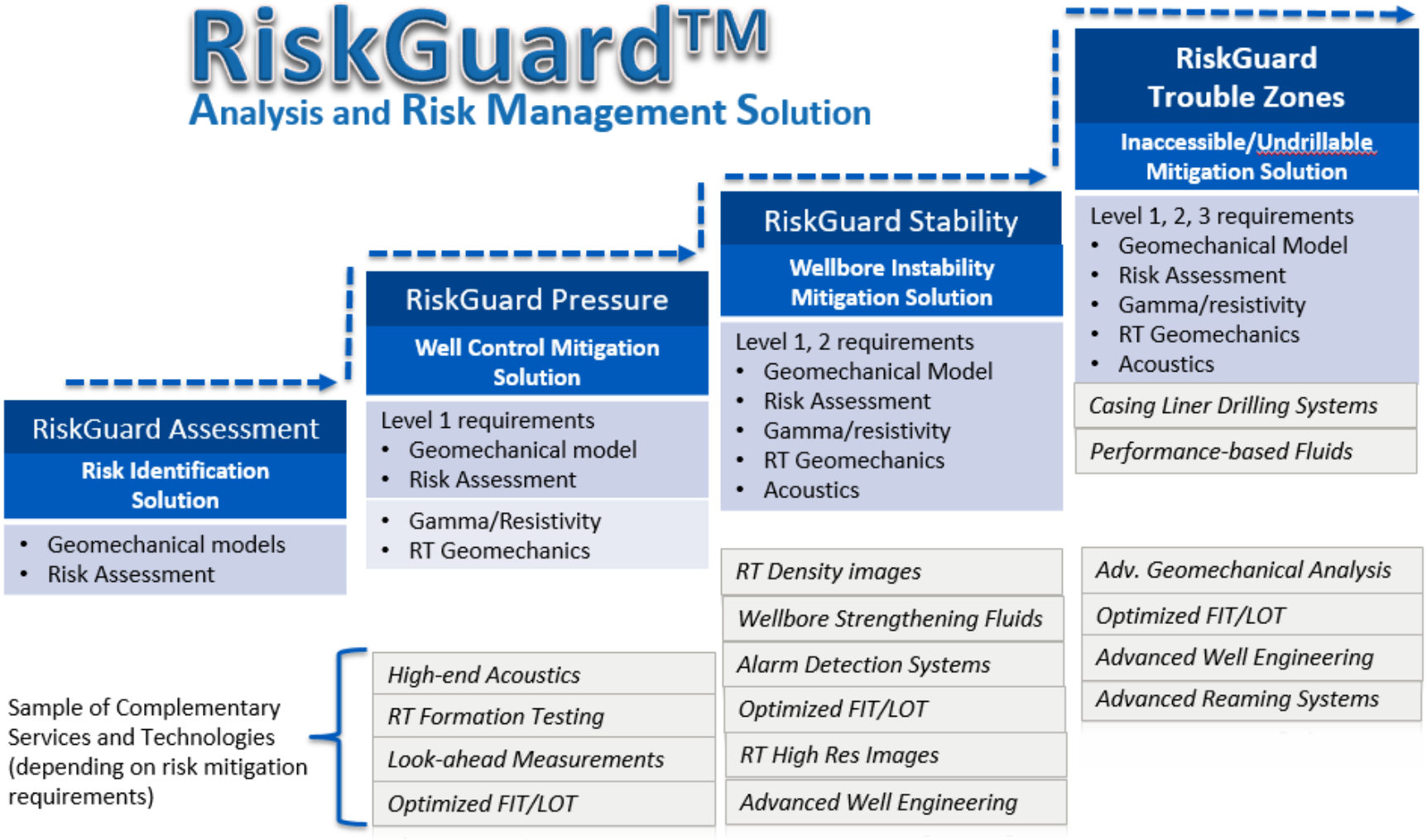
RiskGuard™ Drilling Solution Map

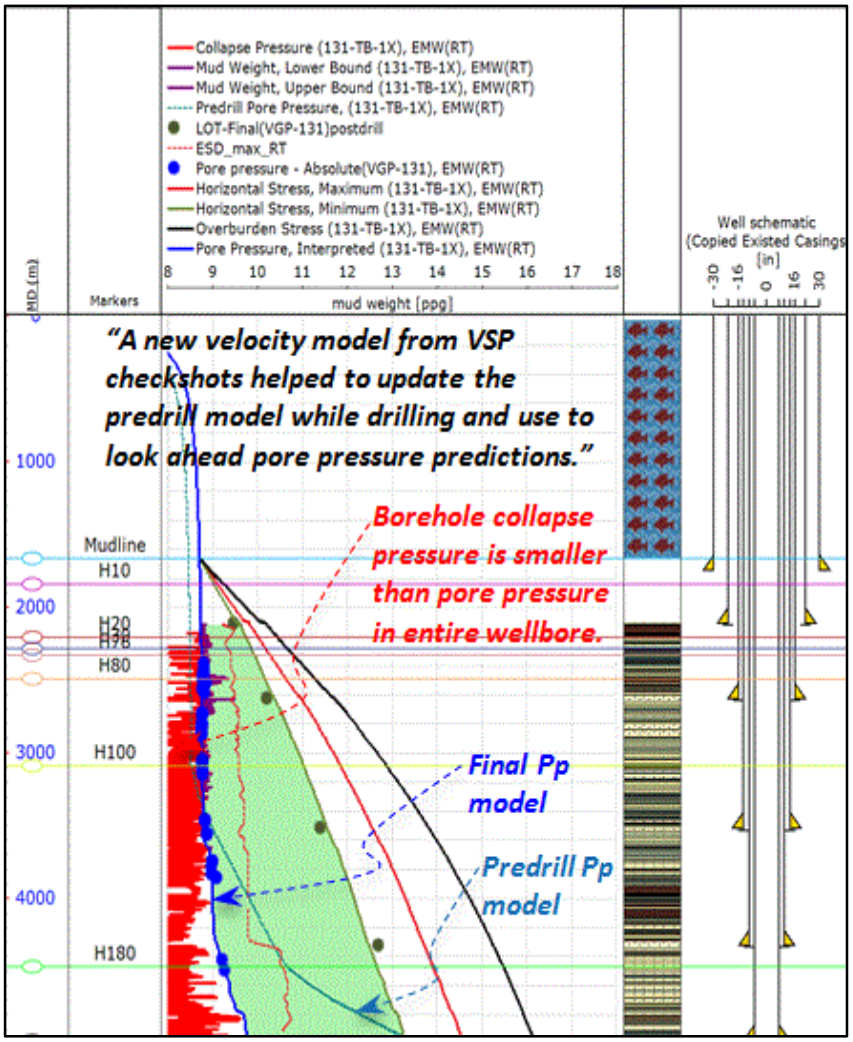


RiskGuard™ Assessment

Risk No.	Risk/Hazard Category	Risk/Hazard Details	Initial Risk Grade (H,M,L)	Actual or Potential NPT (hrs.)	Actual Cost of Event or NPT ($k)	Residual Risk Grade (H,M,L)	Proposed Baker Hughes Solution
1	Drilling Success	Uncertainty in the azimuth of SHmax effects knowledge of optimal drilling direction	M	24	96 (may have to side-track)	M	RiskGuard Assessment, RiskGuard Stability
2	LOT Uncertainty	Uncertainty in the magnitude of Shmin influences upper bound of MW window	H	24	96 (fighting losses)	M	RiskGuard Assessment, RiskGuard Stability
3	Fractured Formations	Losses due to critically stressed fracture network or more major faults	H	24	96 (fighting losses)	M	RiskGuard Trouble Zones
4	Pp Uncertainty	Occurrence of overpressure variation (spatial location and magnitude) across the field.	H	12	48 (circulating out gas, raising MW)	M	RiskGuard Assessment, RiskGuard Pressure
5	Pp Uncertainty	Drilling through and into depleted sandstones or reservoirs.	M	12	48 (time for wellbore strengthening)	M	RiskGuard Assessment, RiskGuard Pressure
6	Dipping Beds	Bedding plane failure due to angle of attack of the well.	H	24	96 (time for wellbore strengthening and fighting wellbore failure)	M	RiskGuard Trouble Zones
7	FG Uncertainty	Uncertainty in the fracture gradient in depleted sandstones	H	24	96 (fighting losses, wellbore strengthening)	M	RiskGuard Pressure
8	Drilling Success	Tight hole in the formations below the Paaratte Fm.	H	12	48 (reaming operations)	L	RiskGuard Stability
9	Drilling Success	Blocky and elongated cavings in the Belfast and Paaratte Fms.	H	6	24 (optimising MW, wellbore strengthening)	L	RiskGuard Stability
10	Drilling Success	Stuck pipe and stuck logging tools in the Waare Fm.	H	12	48 (fishing)	L	RiskGuard Stability
11	Inflows and Gas Events	Gas inflow in the reservoir section requires appropriate mud weight and design (to prevent formation damage)	M	12	48 (circulate out gas, raise MW)	M	RiskGuard Pressure, Other Services
12	Weak, Shallow Formation	Near mud line formation experienced tight hole and stuck pipe, possible due to reactive clays.	M	12	48 (optimise MW, low reactivity mud)	M	RiskGuard Assessment, RiskGuard Stability

- 70% reduction in NPT
- Optimize drilling, faster reaction time. Proactive not reactive
- Optimise completion, larger hole size = more production
- Explore deeper, further

Integrated RT Geomechanics - saved $30M



Background and Challenges

- Wildcat deepwater exploration
- Offset well is 100km away
- Poor 2D seismic, complex geology
- Uncertain pressure mechanisms **AND** stress distribution
- Narrow margin drilling

Approach and Solution

- Real Time Geomechanics
- Transition zone deeper, less dramatic
- Deepened hole section, lower mud weight
- Drilled faster

Results and Benefits

- Safely drilled to planned TD
- Omit un-necessary 6" hole section
- Reduce well costs by $30M

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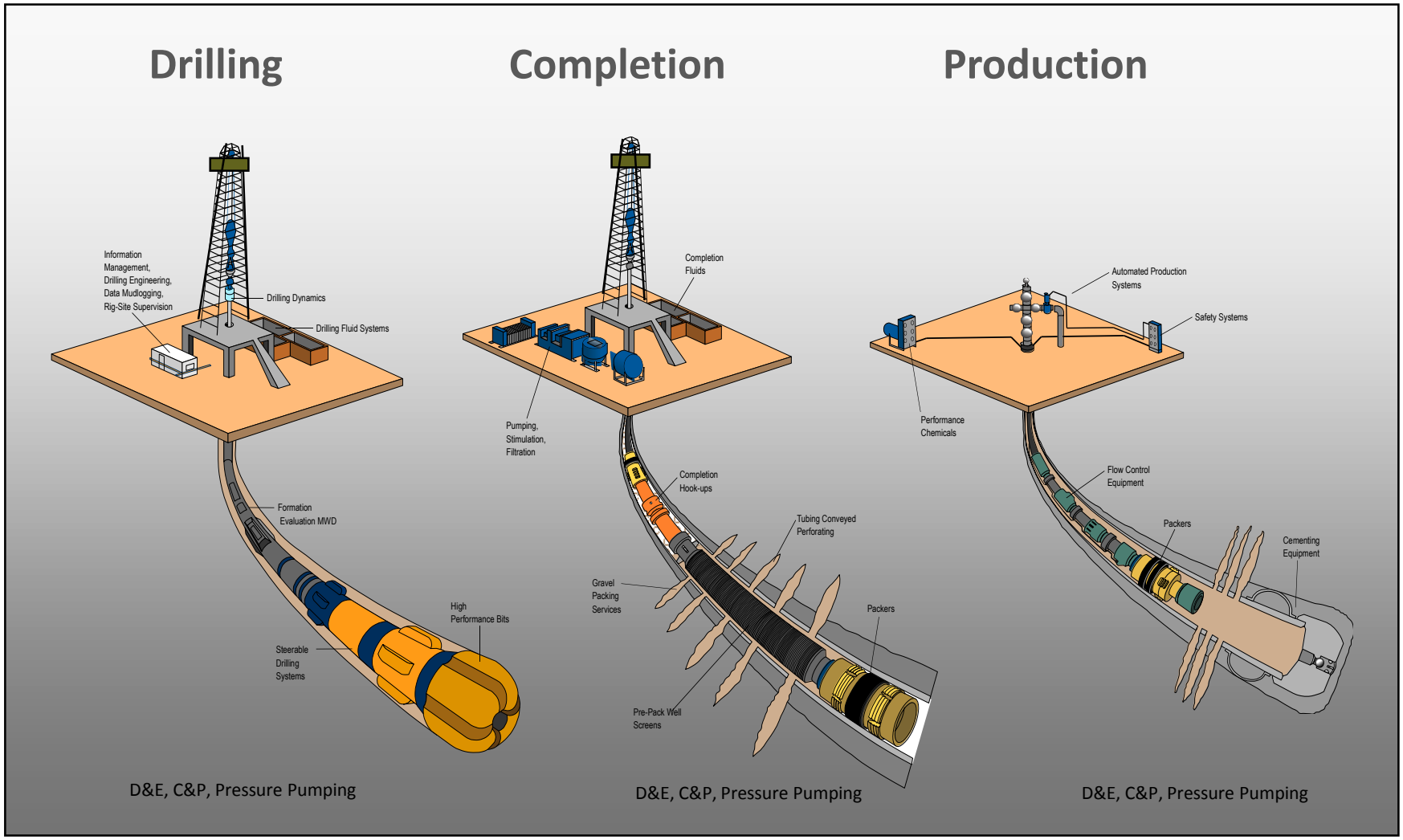
Well Life Cycle



Horizontal well tested validated

Background and Challenges

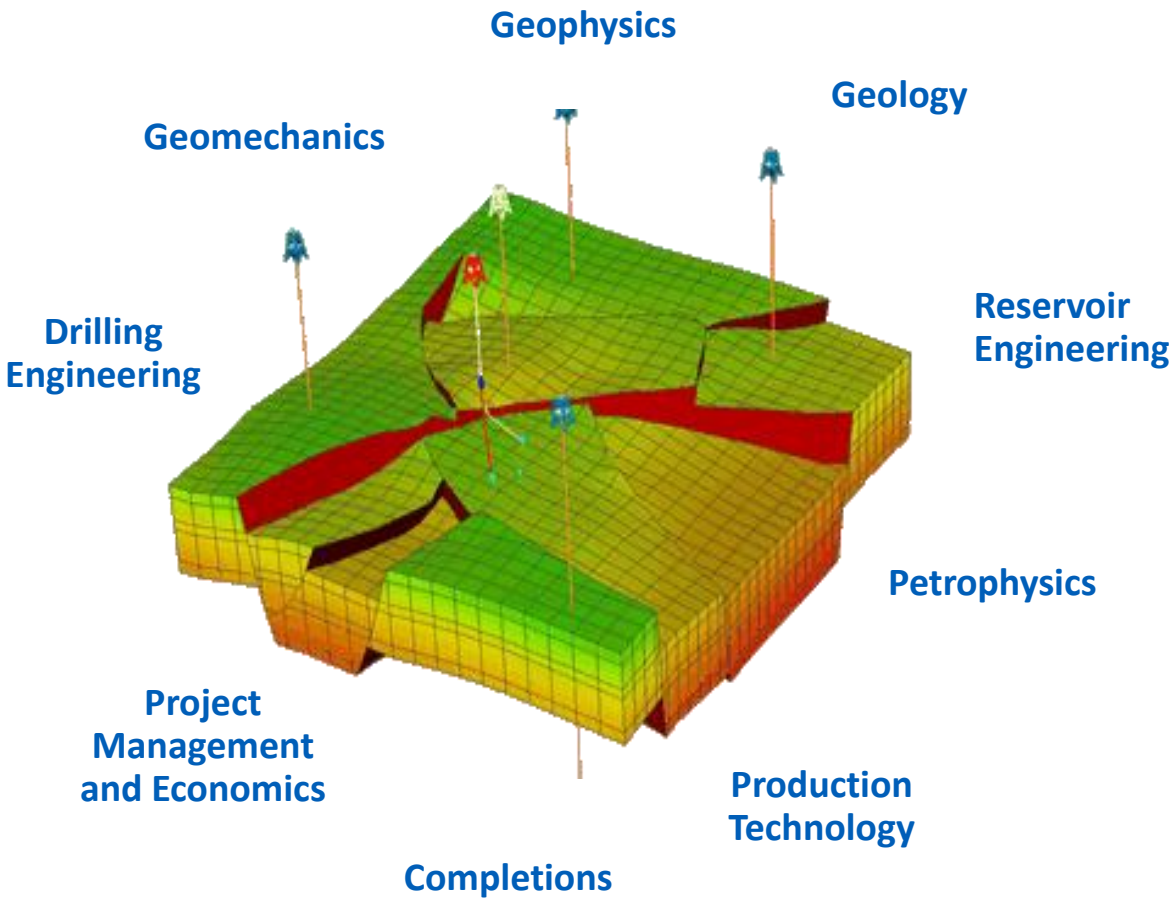
- 1037m horizontal
- Low-permeability sand
- Thin reservoir

Solution

- Pre-drill modelling
- Real Time Geomechanics
- Real Time Petrophysics
- Reservoir Navigation Services
- Well efficiency close to 100%.
- Gas inflow exceeded 1 mm3/d
- Potential to exceed 3 mm3/d

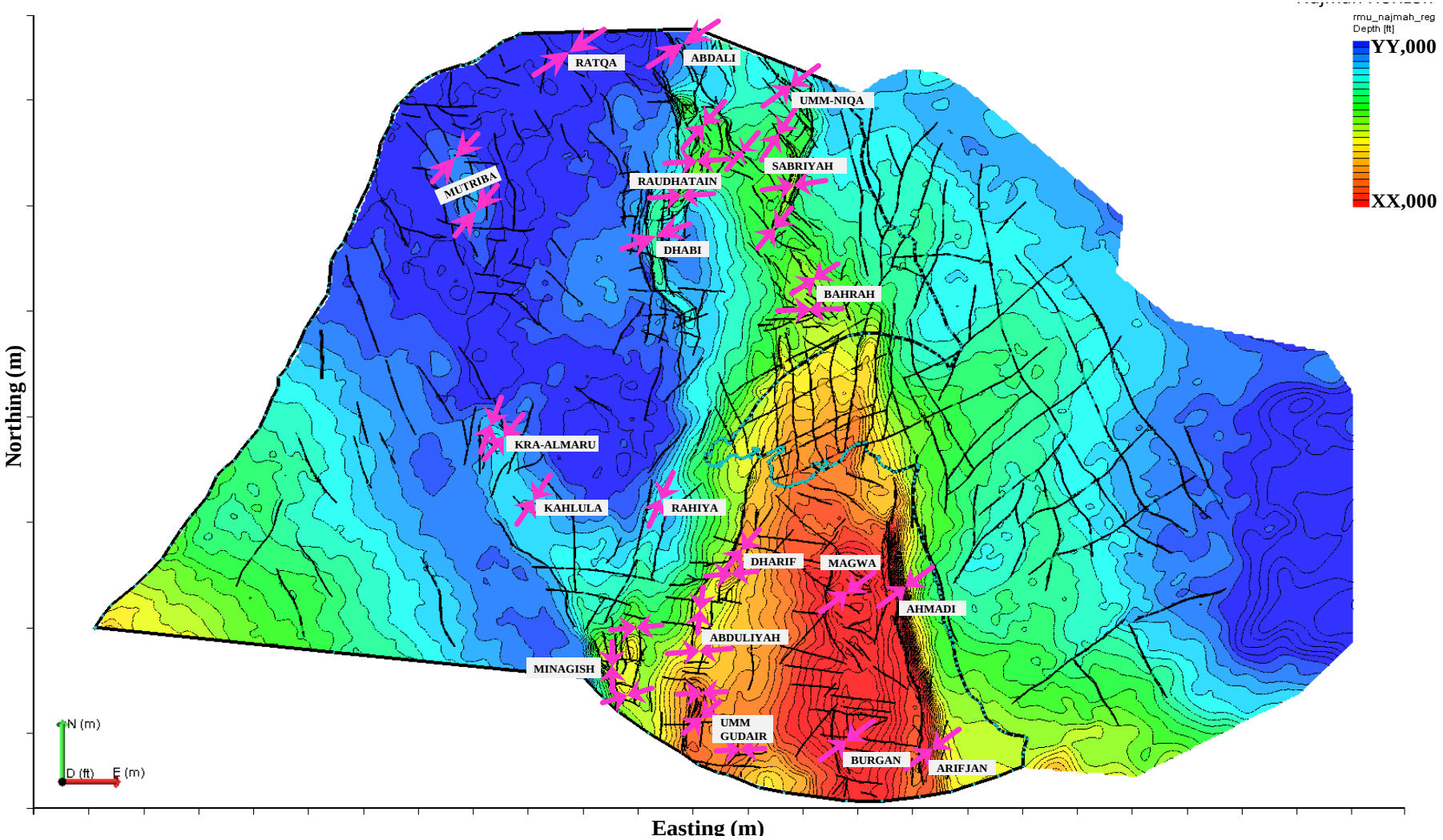
- Geological uncertainties eliminated: structural plans clarified, gas-water contact location established, resource base defined
- Horizontal well achievable with high flow rates
- **Commercial Discovery**

Benchmark Asset Performance

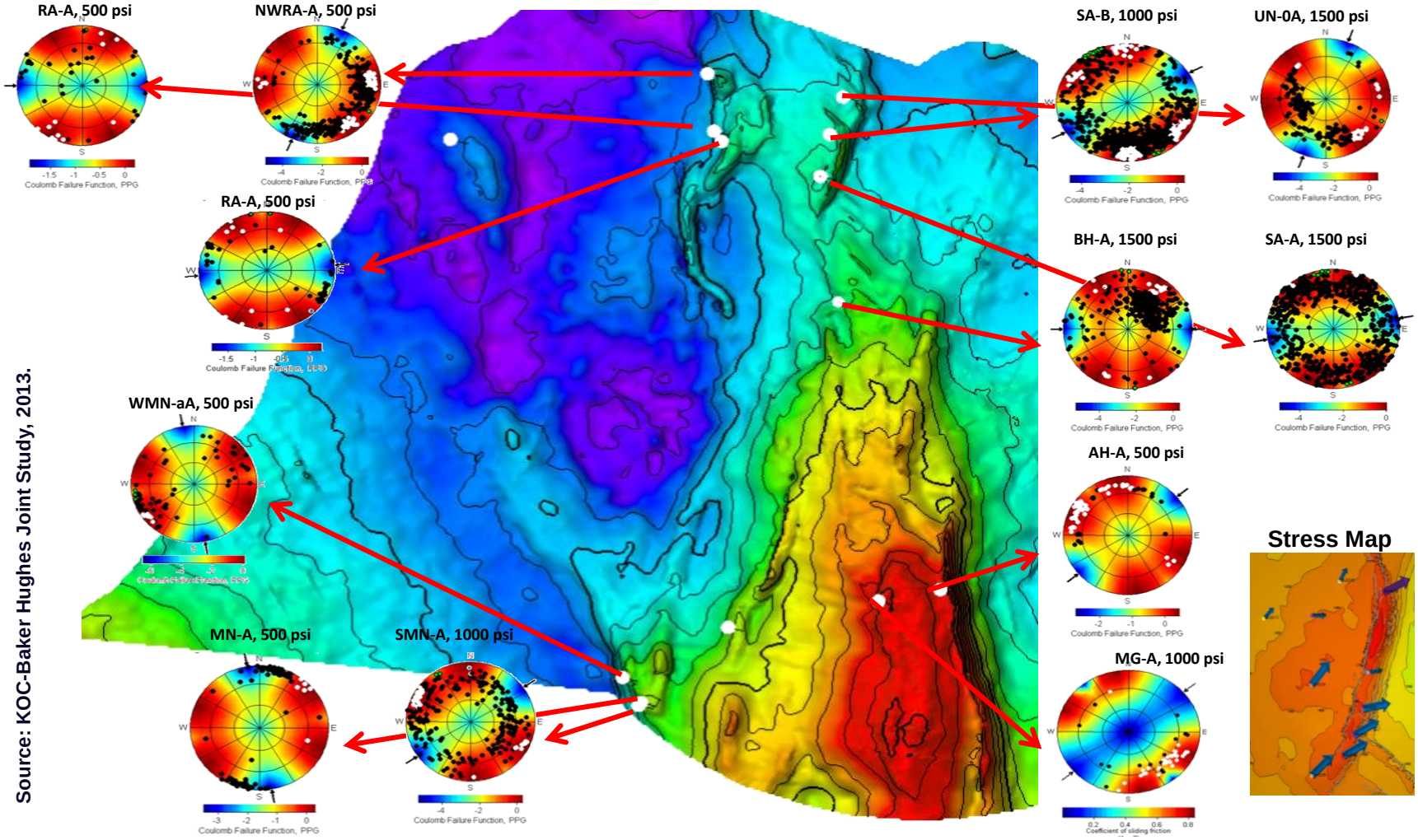


- Possible (3P) into Proven (1P)
- Sub commercial (3C) into commercial (1C)
- Explore deeper, further
- Enhanced Recovery and Company Wealth

Country Stress map (Kuwait)



Country Development Plan



BHGE solutions through project life cycle

World's only fullstream Oil & Gas company … ~70,000 employees in 120+ countries

Differentiated portfolio … leading franchises

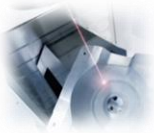
Oilfield Services (OFS)
- Drilling Services, Logging & Evaluation, Completions & Production, Artificial lift + Industrial Services

Turbomachinery & Process Solutions
- Centrifugal & Reciprocating Compressors + Drivers, (Gas & Steam turbines, Aero derivatives), Aftermarket Services

Oilfield Equipment (OFE)
- Subsea Production Systems, BOPs, Flexible Risers, Wellheads, Subsea Services, Surface Pressure Control

Digital Solutions
- Measuring & sensing technology, software + pipeline inspection

Driving technology synergies



Production Optimization
✓ Optimize reservoir performance, ↓cost

Drilling Wells Faster
✓ Faster development through enhanced technology

Digital & Sensor technology
✓ ↑Accuracy, Monitoring and predictivity

Fullstream commercial models; Lower cost of production / increasing industrial yield

Outcome based contracts; transfer global knowledge & experience -Well Delivery

Reduce costs. Increase productivity. Share risk and reward.

Norway: Johan Sverdrup

Project Details

- Integrated well construction project
- **Contract: 6 years (with option to extend to life of field)**
- 50 years estimated field life
- A trilateral partnership between BHGE, the operator, and the rig contractor

BHGE Scope

- BHGE's Oilfield Services (OFS) product and services portfolio, including Drilling, Cement, Fluids, Completions, and Wireline
- A dedicated BHGE project management team adding value over pure bundled services

Challenges

- Multiservice contract well construction and project management
- Flawless HSE
- **Deliver "The Perfect Well"**
- 50% reduction in well costs by 2018
- Reliability
- Standardization

Results

- No serious injuries or incidents to date
- **Initial drilling campaign delivered 8 months ahead of plan**
- All wells to date have been delivered according to requirements
- **A 50% cost reduction**
- 'Moving Perfect' improved by 25%
- **World record 17 ½' sections**

INTEGRATED WELL CONSTRUCTION

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Middle East Region: Shaybah

Project Details

- Onshore project in a remote geographical location
- **Five-year contract**
- **BHGE was contracted to deliver 90 multilateral wells**

Challenges

- Extremely tight mobilization schedule
- **Lump-sum turnkey project**
- 3D, multilateral wells
- Remote location
- Integrate multinational companies into a cohesive, safe and efficient team

BHGE Scope

- BHGE deployed a full project management team to work alongside the customer
- Responsible for management and contracting of multiple drilling rigs
- Leveraged the full breath of the Oilfield Services portfolio including: tubing running services, wellhead installation, drilling jars, rig and camp moving, waste management, H2S safety systems

Results

- Achieved all contractual obligations
- **The fastest and deepest drilling in the history of the field**
- **Substantial increase in feet drilled per day (34% to 167% improvement)**
- **Zero well control incidents**
- Successfully delivered 86 wells to date
- Contract extended due to good performance results

INTEGRATED WELL CONSTRUCTION

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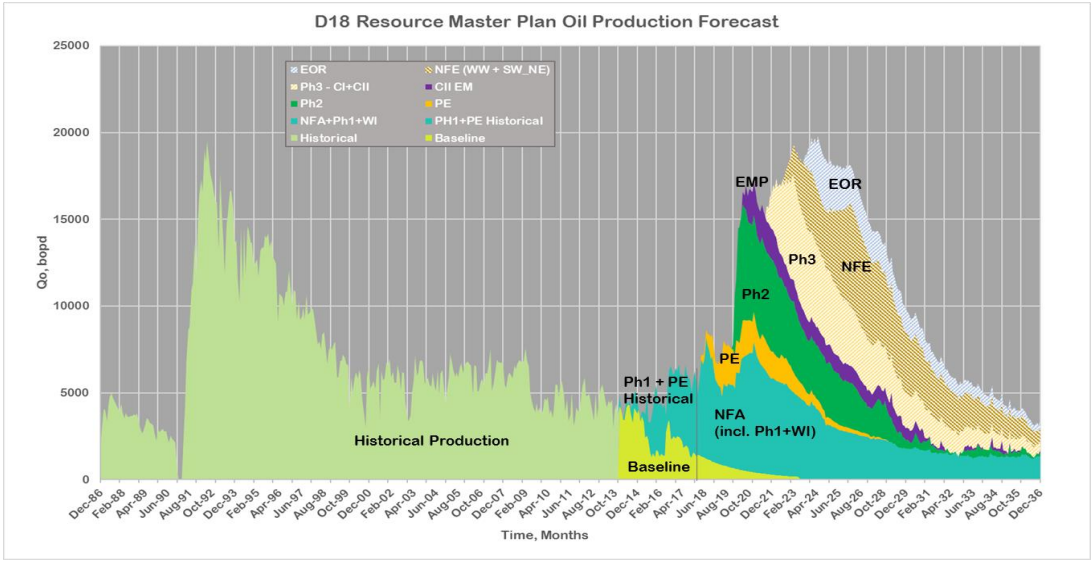
Malaysia, Petronas: D18 Redevelopment

Project Details

- Offshore SEA
- Mature field

BHGE Scope

- FDP, Project Management, Well Engineering, Logistics and 3rd Party Management, Perforation, Coiled Tubing, Acid Stimulation, Operations Vessel, Slick Line, Noise Mapping, Core Analysis



Challenges

- Multiple stacked oil and gas reservoirs with lateral and vertical faults. Highly compartmentalized.
- Decline 21,000 BOPD to 4000 BOPD
- Determine Oil In Place and establish connectivity
- Enhance Recoverable Reserves

Results

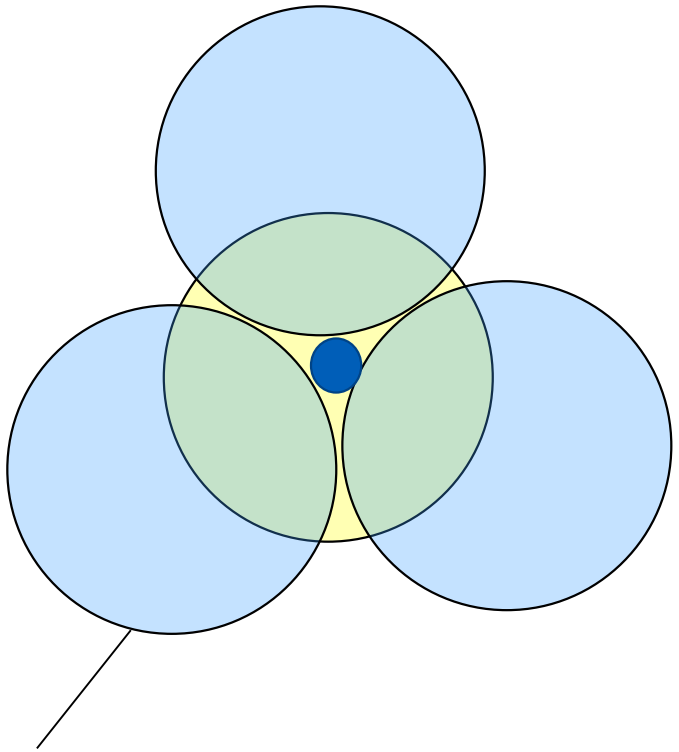
- **2007 safe man days; 4.1 million man hours w/o LTI**
- Deployed 30+ Petroleum Engineering and Geoscience disciplines for FDP
- **19 new technologies in 2018**
- Doubled production from 4000 BOPD to 8000 BOPD, reaching 15000 BOPD in 2019
- BHGE successfully completed 9 well program (NO LTI, low NPT)
- **Extended field life by 20 years**

Risk-Reward Basis - Field Redevelopment

What does upside look like for you?

Q: Increase Step Out on Subsea Development Wells?

- Can deviated wells be drilled in all directions?
- How will the reservoir produce?
- Is the reservoir a single connected unit or compartmentalized by the faults or fractures?
- Could increasing the step out eliminate a drilling centre



Potential reservoir reached by a Subsea Drilling Centre

10 rules for project success

- Every Project is Different
- Align project goals
- Start at exploration
- Strategic data acquisition
- Share knowledge between everyone
- Collaborate
- Use analogues (Local, Regional, Global)
- Introduce new technology and update
- Learn from experiences
- Remove Bias

Yes, ma'am, the more I practice, the luckier I get!

in response to a lady who said –
"that was a lucky shot!"

Gary Player,
Golfer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