Estimation of Risk Level Embedded in Drilling Operation Plans

SPE -Drilling Uncertainty Prediction Technical Section, Eric Cayeux, IRIS

Outline

1. Well construction life cycle
2. Risk based drilling operation plan
3. Type of risks
4. Factors Influencing a Drilling operations
5. Uncertainty Specification
6. Uncertainty Propagation
7. Examples
8. Conclusion

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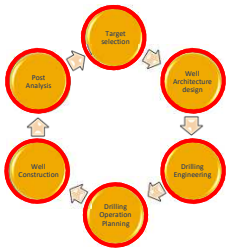
Well Construction Life Cycle



Well Construction Life Cycle

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Poll Question

Where are you located?

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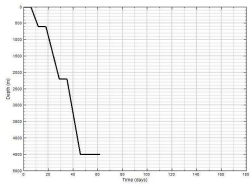
Risk based drilling operation planning

A drilling operation plan:

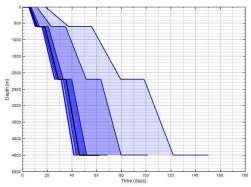
- Is often a best case scenario with one or two contingency plans



Risk based drilling operation planning

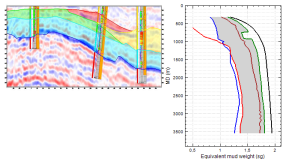
A drilling operation plan:

- Is often a best case scenario with one or two contingency plans
- But in reality there is a lot of uncertainty



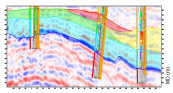
Risk based drilling operation planning

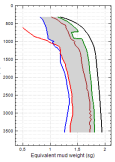
A drilling operation plan:
- Is often a best case scenario with one or two contingency plans
- But in reality there is a lot of uncertainty
  - Because of an uncertain geological environment
    - Structure and stratigraphy
    - Geo-mechanics



Risk based drilling operation planning

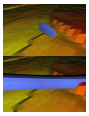
A drilling operation plan:
- Is often a best case scenario with one or two contingency plans
- But in reality there is a lot of uncertainty
  - Because of an uncertain geological environment
    - Structure and stratigraphy
    - Geo-mechanics
  - That can lead to drilling incidents like
    - Influx
    - Wellbore instabilities
    - Loss circulation
  - And affect drilling performance (ROP)

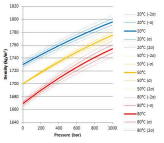




Risk based drilling operation planning

A drilling operation plan:
- Is often a best case scenario with one or two contingency plans
- But in reality there is a lot of uncertainty
  - Because of an uncertain geological environment
  - Because of variations around the initial well design:
    - Trajectory
    - Drilling fluid
    - Drill-string
    - Sections' TD





Risk based drilling operation planning

A drilling operation plan:
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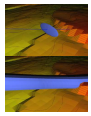
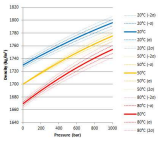
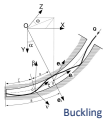
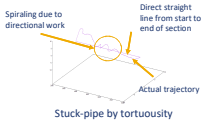
    - Trajectory
    - Drilling fluid
    - Drill-string
    - Sections' TD
  - That can impact:
    - Performance
    - Risk of drilling incidents







Buckling



Stuck-pipe by tortuousity

Risk based drilling operation planning

A drilling operation plan:
- Is often a best case scenario with one or two contingency plans
- But in reality there is a lot of uncertainty
  - Because of an uncertain geological environment
  - Because of variations around the initial well design
  - Because of likely variations of operational procedures
    - Drilling parameters
    - Connection procedures

Risk based drilling operation planning

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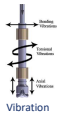
- Is often a best case scenario with one or two contingency plans
- But in reality there is a lot of uncertainty
  - Because of an uncertain geological environment
  - Because of variations around the initial well design
  - Because of likely variations of operational procedures
    - Drilling parameters
    - Connection procedures
- That impact
  - Drilling performance
  - Risk of drilling incidents

Pack-offs

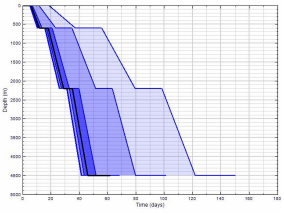


Vibration

Risk based drilling operation planning

A drilling operation plan:

- Is often a best case scenario with one or two contingency plans
- But in reality there is a lot of uncertainty with a skewed distribution
- Ideally, we would like a drilling operation plan that minimize risk and maximize performance under foreseeable uncertain conditions:
  - This is an optimization problem
  - The objective function is:
    - Overall operation duration
    - Drilling risk level



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Poll Question

What kind of challenges do you have with your wells?

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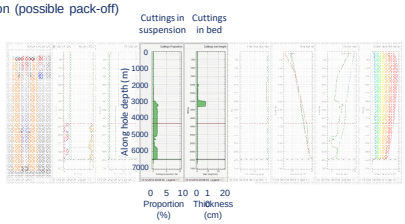
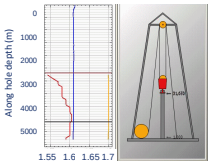
Type of risks

•Cuttings accumulation in beds
•High concentration of cuttings in suspension (possible pack-off)



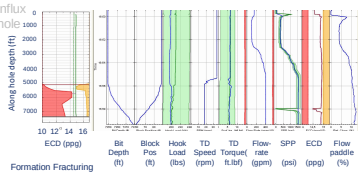
Type of risks

•Cuttings accumulation in beds
•High concentration of cuttings in suspension (possible pack-off)
•Too low annulus pressure causing influx
•Too low annulus pressure causing hole collapse



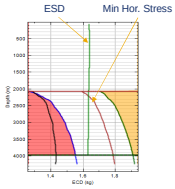
Type of risks

•Cuttings accumulation in beds
•High concentration of cuttings in suspension (possible pack-off)
•Too low annulus pressure causing influx
•Too low annulus pressure causing hole collapse
•Too high annulus pressure causing formation fracturing



Type of risks

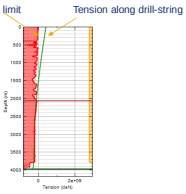
- Cuttings accumulation in beds
- High concentration of cuttings in suspension (possible pack-off)
- Too low annulus pressure causing influx
- Too low annulus pressure causing hole collapse
- Too high annulus pressure causing formation fracturing
- Too high hydrostatic pressure causing permanent mud losses in case of fracturing



Risk of permanent mud losses

Type of risks

- Cuttings accumulation in beds
- High concentration of cuttings in suspension (possible pack-off)
- Too low annulus pressure causing influx
- Too low annulus pressure causing hole collapse
- Too high annulus pressure causing formation fracturing
- Too high hydrostatic pressure causing permanent mud losses in case of fracturing
- Drill-string buckling



Buckling

Type of risks

- Cuttings accumulation in beds
- High concentration of cuttings in suspension (possible pack-off)
- Too low annulus pressure causing influx
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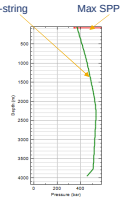
- Too high hydrostatic pressure causing permanent mud losses in case of fracturing
- Drill-string buckling
- Excessive pump pressure



Excessive pump pressure

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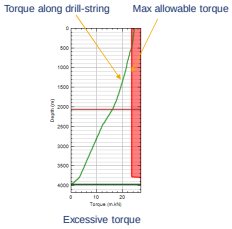
- Cuttings accumulation in beds
- High concentration of cuttings in suspension (possible pack-off)
- Too low annulus pressure causing influx
- Too low annulus pressure causing hole collapse
- Too high annulus pressure causing formation fracturing
- Too high hydrostatic pressure causing permanent mud losses in case of fracturing
- Drill-string buckling
- Excessive pump pressure
- Excessive top-drive torque



Excessive torque

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Poll Question

In your drilling operations, what is the most limiting factor that impact drilling performance?

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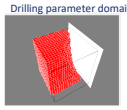
Factors Influencing a Drilling operations

- Drilling parameters
  - WOB/ROP
  - Drill-string rotational speed
  - Flow-rate

Influences:
- Cuttings production and transport
- Downhole pressures
- Temperature
- Torque

Drilling parameter domain that do not cause incidents



At start of section

At end of section

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Poll Question

In your drilling operations, what is your most recurrent drilling problem?

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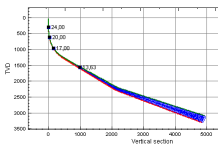
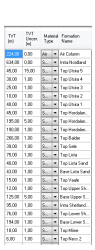
Uncertainty Specification

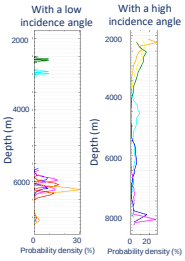
- Trajectory
  - Depends on surveying program
  - Depends on directional control capability
  - Most important is the potential variation of TVD



Uncertainty Specification

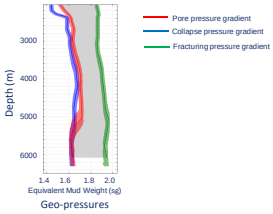
- Trajectory
- Geological framework





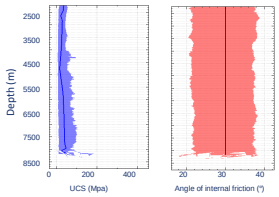
Uncertainty Specification

- Trajectory
- Geological framework
- Geo-pressure prognosis
  - Uncertainty on pore, collapse, fracturing pressure gradients
  - Probability of occurence of over-pressured zones
  - Probability of occurence of depleted zones



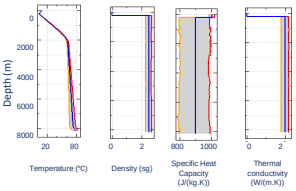
Uncertainty Specification

- Trajectory
- Geological framework
- Geo-pressure prognosis
- Formation Strength
  - Inverted from ROP performance in adjacent wells
  - Account for the probability of occurence of hard stringers



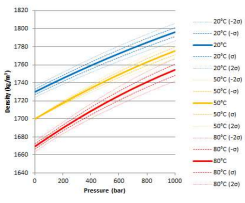
Uncertainty Specification

- Trajectory
- Geological framework
- Geo-pressure prognosis
- Formation Strength
- Geo-thermal description
  - Uncertainty on the geothermal gradient
  - Specific heat capacity and thermal conductivity of formation rocks depend on:
    - Formation type
    - Mineralogy
    - Type and quantity of pore fluids



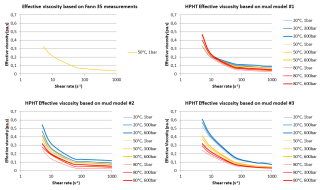
Uncertainty Specification

- Trajectory
- Geological framework
- Geo-pressure prognosis
- Formation strength
- Geo-thermal description
- Drilling fluid composition and density
  - Composed of a mix of brine, oil, various solids and additives
    - A desired density at a given temperature and pressure can be obtained by various compositions
  - Compressibility and thermal expansion are different for each component
    - PVT behaviour of each component may be uncertain or unknown



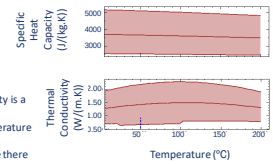
Uncertainty Specification

- Trajectory
- Geological framework
- Geo-pressure prognosis
- Formation strength
- Geo-thermal description
- Drilling fluid composition and density
- Drilling fluid rheological behavior
  - Usually charaterized by Fann 35 rheometry at atmospheric pressure and a given temperature
  - But fluid is used over a wide range of pressures and temperatures
  - Need to extrapolate as a function of p, T
  - Extrapolation depends very much on type of fluid



Uncertainty Specification

- Trajectory
- Geological framework
- Geo-pressure prognosis
- Formation strength
- Geo-thermal description
- Drilling fluid composition and density
- Drilling fluid rheological behavior
- Drilling fluid thermal behavior
  - Specific heat capacity and thermal conductivity is a function of the mix composition
  - Thermo-physical properties depend on temperature (and pressure)
  - Usually not measured at the rig site therefore there is no way to calibrate and the uncertainty is large



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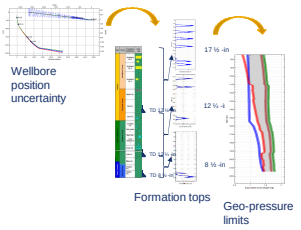
Poll Question

In your opinion, what is the largest contribution to uncertainty in your drilling program?

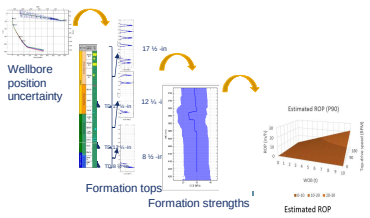
Uncertainty Propagation

- Limits
  - Pore pressure gradient
  - Collapse pressure gradient
  - Min hor. Stress
  - Fracturing pressure gradient



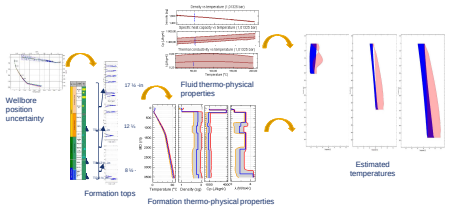
Uncertainty Propagation

- Limits
- Performance



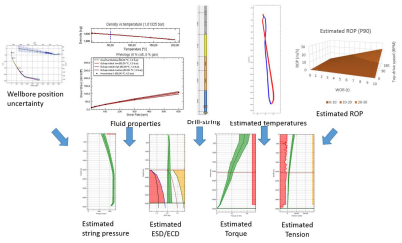
Uncertainty Propagation

- Limits
- Performance
- Temperature



Uncertainty Propagation

- Limits
- Performance
- Temperature
- Estimated downhole conditions



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Poll Question

In average, how much time do you use to drill a well to TD (excluding the time to plug and abandon a parent well for geological sidetrack and setting the completion string)?

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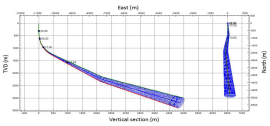
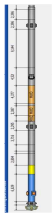
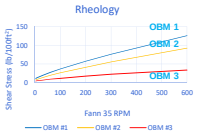
Example 1

- 12 ¼ section. 13 ½ enlargement.
- 4000mMD



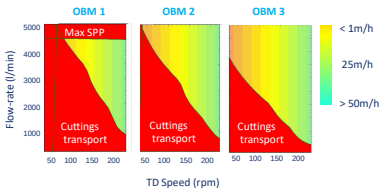




Example 1: Detailed analysis 1/3

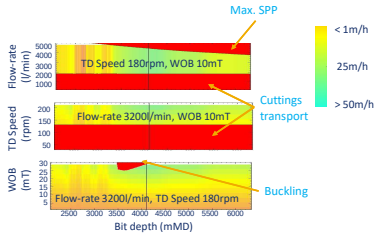
Flow-rate vs RPM cross section:
- Fixed WOB
- Start of section

Limiting risks:
- Cuttings transport
- Max. SPP



Example 1: Detailed analysis 2/3

Along depth projection:
- Flow-rate
- RPM
- WOB
- Two other parameters fixed

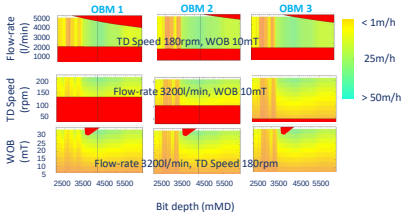


Example 1: Detailed analysis 3/3

Along depth projections

Quick comparison of the three mud systems

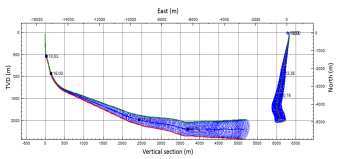
Mud 3 provides clearly more operational margins



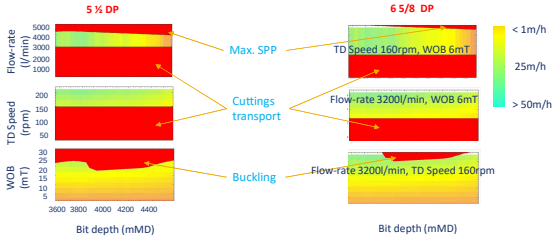
Example 2

Section:
- 12 ¼ x 13 ½

Two DP alternatives
- 5 ½ inches
- 6 5/8 inches



Example 2: along depth projections



1. Well construction life cycle
2. Risk based drilling operation plan
3. Type of risks
4. Factors Influencing a Drilling operations
5. Uncertainty Specification
6. Uncertainty Propagation
7. Examples
8. Conclusion

13 June 2017

Conclusion

A method has been presented that:

- Estimate the risk level in drilling operational plan
  - The presence of risks does not mean that the well cannot be drilled
  - But an action plan should be ready to deal with the risk
- Accounts for problem description uncertainty
  - Allow to evaluate which information matters to improve the control the risk evaluation
  - Either by acquiring more information or implementing better instrumentation
- Gives estimate of expected performance

Thank you
Any questions?