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Factors Influencing Wellbore Stability during Underbalanced Drilling

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Outlines

- Introduction.
- Problem statement.
- Objective.
- Methodology.
- Previous Study.
- Case Study.
- Results and discussion.
- Conclusions .
- References.

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Introduction

- Drilling of oil well under the circumstances of fluid seepage induced by the flow of formation fluid into well bore exert additional stresses on wellbore.
- The impact of fluid seepage has usually been ignored by conventional analysis of wellbore stability during underbalanced (UBD) drilling.
- This project considers the effects of fluid seepage, through use of collapse pressure model during underbalanced drilling for of horizontal well.

Introduction

Underbalanced drilling (UBD)

Pmud < **P**formation

Reasons to consider underbalanced drilling

- Maximizing hydrocarbon recovery.
- Minimizing pressure-related drilling problems.

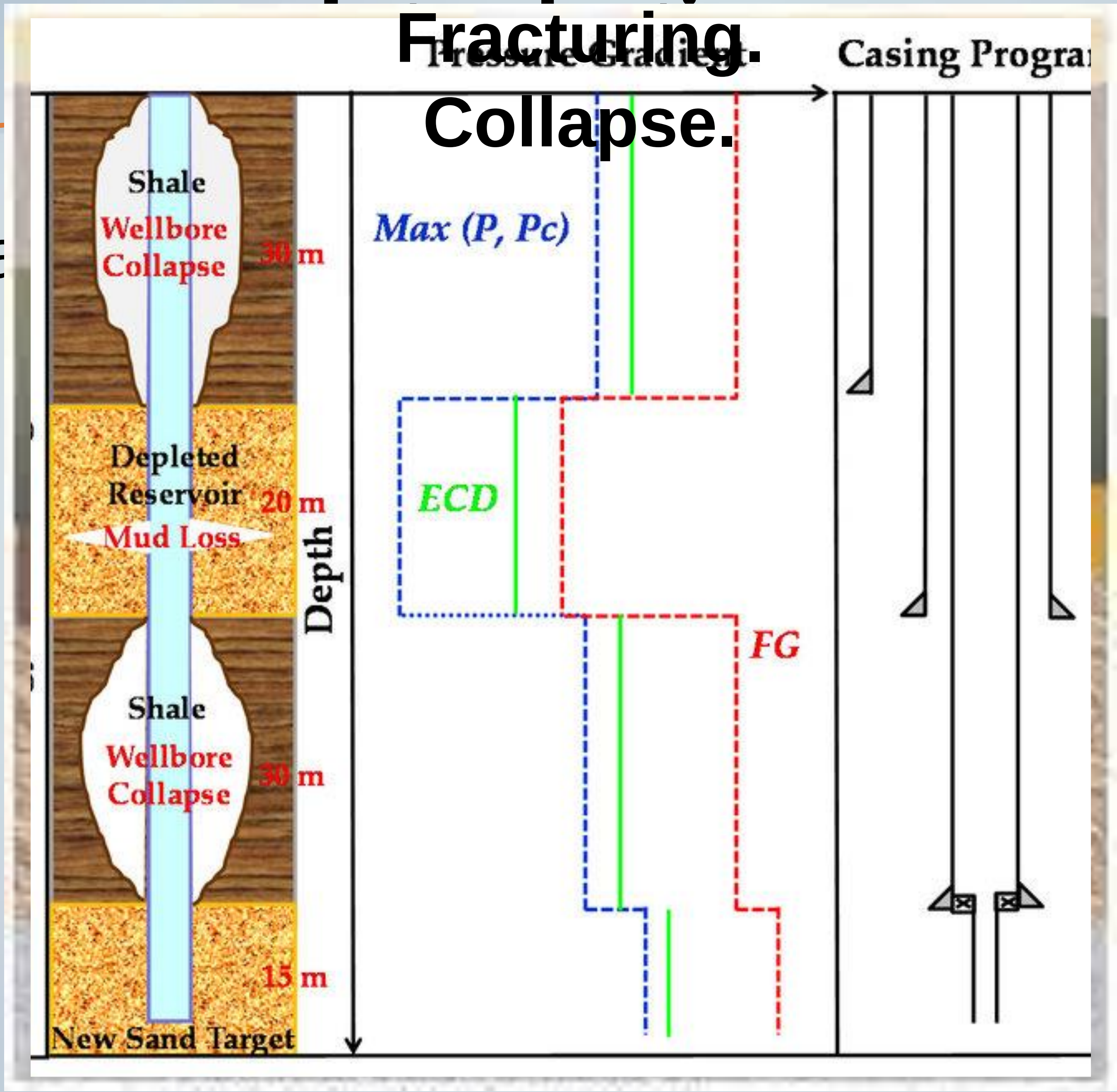
Introduction

Causes of wellbore instability

- Chemical
- Erosion
- Mechanical failure
  - Mechanical borehole failure
  - Compressive failure
  - Tensile failure

Fracturing.
Collapse.

- There a … bilities :



Introduction

Borehole-instability prevention

- Proper mud-weight selection and maintenance.
- Use of proper hydraulics to control the equivalent circulating density.
- Proper hole-trajectory selection.
- Use of borehole fluid compatible with the formation being drilled.
- Minimizing time spent in open hole.
- Using offset-well data (use of the learning curve).
- Monitoring trend changes (torque, circulating pressure, drag, fill-in during tripping) .

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Problem statement

- Flow of formation fluid into wellbore during UBD on horizontal drilling ,wellbore trajectory and wellbore radius have a main effect on Equivalent collapse density ECD value which is the indicator for well stability . appropriate analysis of this factors will reduce the chance of drilling problems .

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Objective

- To accurately study the effect of fluid seepage well trajectory (Inclination, Azimuthal angle) and well radius on borehole stability.

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Methodology

Data import MATLAB

Calculation of Tangential stress ,ECD,MECD

Plotting and Modeling

Tangential stress vs D, ECD vs Ɵ and ECD vs I

Results analysis

Methodology

Collapse pressure model

- Tangential stress
- Equivalent collapse density(ECD)
- Maximum (ECD)

$$
\begin{cases}
\sigma_r^f = P_{mud} - \alpha_e P_{mud} \\
\sigma_{\theta\max}^f = 0.5(\sigma_\theta + \sigma_z) + 0.5\sqrt{(\sigma_\theta - \sigma_z)^2 + 4\tau_{\theta z}^2} + \dfrac{r_e^2\left[2(1-\nu)(P_{op} - P_{mud}) + P_{op} - P_{mud}\right]}{(r_e^2 - R^2)(1-\nu)} - \dfrac{(P_{op} - P_{mud})\left[2\nu - 1\right]}{2(1-\nu)\ln(r_e/R)} - \alpha_e P_{mud} \\
\sigma_{\theta\min}^f = 0.5(\sigma_\theta + \sigma_z) - 0.5\sqrt{(\sigma_\theta - \sigma_z)^2 + 4\tau_{\theta z}^2} + \dfrac{r_e^2\nu\left[2(1-\nu)(P_{op} - P_{mud}) + P_{op} - P_{mud}\right]}{(1-\nu)(r_e^2 - R^2)} - \dfrac{\nu(P_{op} - P_{mud})\left[2\nu - 1\right]}{2(1-\nu)\ln(r_e/R)} - \alpha_e P_{mud}
\end{cases}
$$

llbore axis

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- $y - z$).

$\sigma_{\theta max}^f$, $\sigma_{\theta min}^f$,σ_r^f : maximum principal stress, intermediate principal stress and minimum principal stress.

r_e: is the radius of external boundary, m.

Methodology

MATLAB Program

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```
...............1...................
ah =input('enter ah = ');
aH =input('enter aH = ');
x =input('enter x = ');
i =input('enter i = ');
av =input('enter av = ');
axx=(aH*(cos(i^2)*(cos(x^2))))+(ah*(cos(i^2))*(sin(x^2)))+(av*(sin(i^2)));
ayy=(aH*(sin(x^2)))+(ah*(cos(x^2)));
azz=(aH*(sin(i^2))*(cos(x^2)))+(ah*(sin(i^2))*(sin(x^2)))+(av*(cos(i^2)));
txy=(-aH*(cos(i))*(cos(x))*(sin(x)))+(ah*(cos(i))*(cos(x))*(sin(x)));
tyz=(-aH*(sin(i))*(cos(x))*(sin(x)))+(ah*(sin(i))*(cos(x))*(sin(x)));
tzx=(aH*(cos(i))*(sin(i))*(cos(x^2)))+((ah*(cos(i))*(sin(i))*(sin(x^2)))+(av*(cos(i))*(sin(i))));
disp(' axx');
disp( axx);
disp(' ayy');
disp( ayy);
disp(' azz');
disp( azz);
disp(' txy');
disp( txy);
disp(' tyz');
disp( tyz);
disp(' tzx');
disp( tzx);
...............2.................
    pm =input('pm =');
st =input('st =');
ar=pm;
ast=-pm+(axx+ayy)-(2*(axx-ayy)*(cos(2*st)))+(4*txy*(sin(2*st)));
az=(2*tyz*(cos(st)))-(2*txy*(sin(st)));
tsz=(2*tyz*(cos(st)))-(2*tzx*(sin(st)));
tzr=0;
disp(' az');
disp( az);
```

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Previous Study

- P.BORIVOJE et al. (2007) analyzed indicators and diagnosing of wellbore instability as well as the wellbore stresses model.
- P.Shiming He et al.(2014) analyzed the factor influencing the radius and well trajectory in case of UBD.
- P.Kaiwan et al.(2018) analyzed of factors influencing the stability of multi branch radial wellbore, by using the two parameters of maximum shear stress and equivalent plastic strain, Based on finite element software ABAQUS.

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Case Study

The numerical analysis of influencing factors are carried out based on a certain well in Formation He1 of **Daniudi** gas field in China, which is in a normal stress regime (sv > sH > sh); and the core drilled from the sandstone formation (TVD = 2485.12-2520.18 m) having undergone rock mechanics experiment reveals basic data of rock mechanics and in-situ stresses of the formation as are shown in Table 1.

Case Study

Data :

Item	Value	Unit
Original pore pressure coefficient	0.93	/
Radius of external boundary (re)	100	M
Borehole radius (R)	0.108	M
TVD of horizontal section	2514	M
Maximum horizontal stress (σ H)	1.8	Mpa/100 m
Minimum horizontal stress (σ h)	1.6	Mpa/100 m
Vertical stress (σ v)	2	Mpa/100 m
Poison's ratio (n)	0.23	/
Cohesion strength of the rock (C)	20.71	Mpa
Internal friction angle (φ)	34.5	Deg
Effective stress coefficient (àe)	0.9	/
equivalent densities of drilling mud (pm)	0.768	g/cm3

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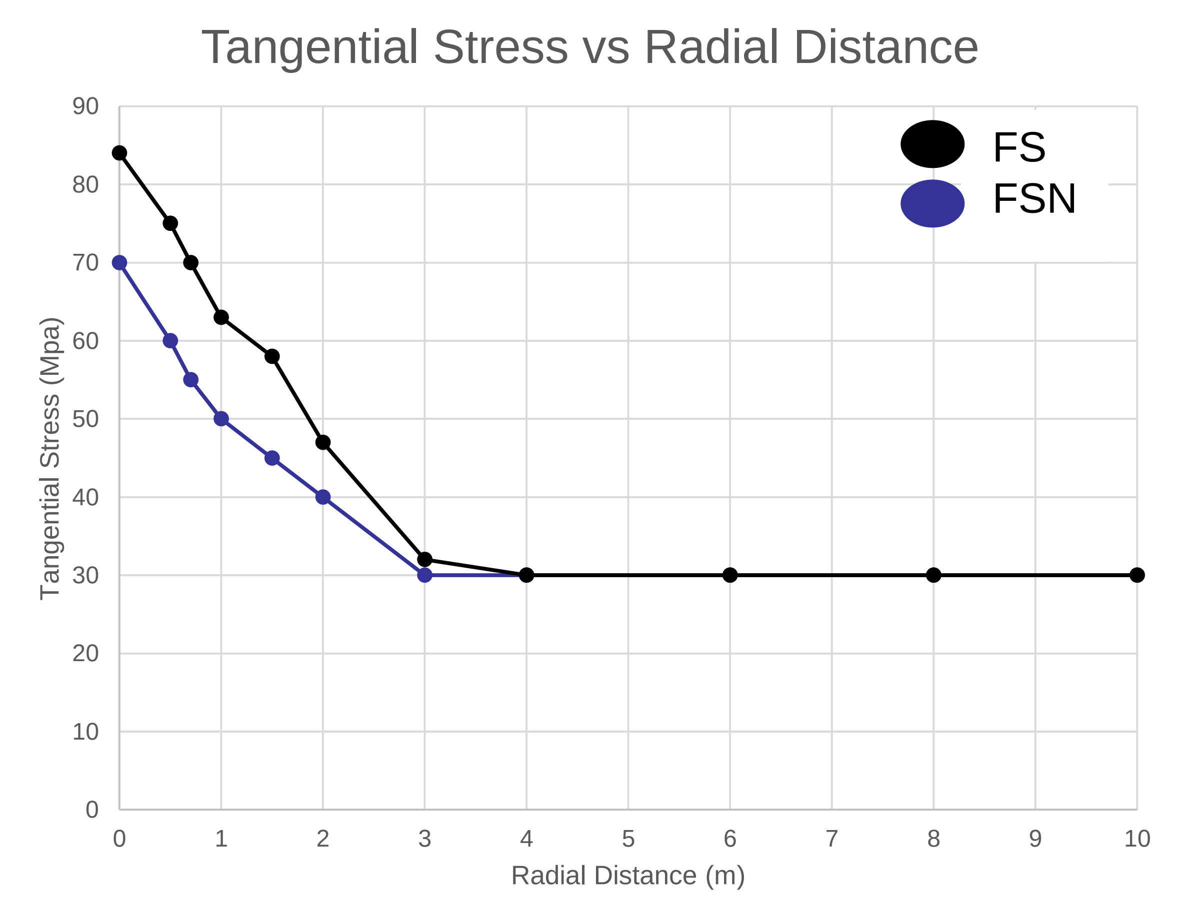
Results and discussion

Change of tangential stress with radial distance in both conditions

when I=90 α=90 θ=90 @ Eq (2),(7)

Tangential Stress (Mpa) FS	Tangential Stress (Mpa) FSN	Radial Distance (m)
84	70	0
75	60	0.5
70	55	0.7
63	50	1
58	45	1.5
47	40	2
32	30	3
30	30	4
30	30	6
30	30	8
30	30	10



Results and discussion

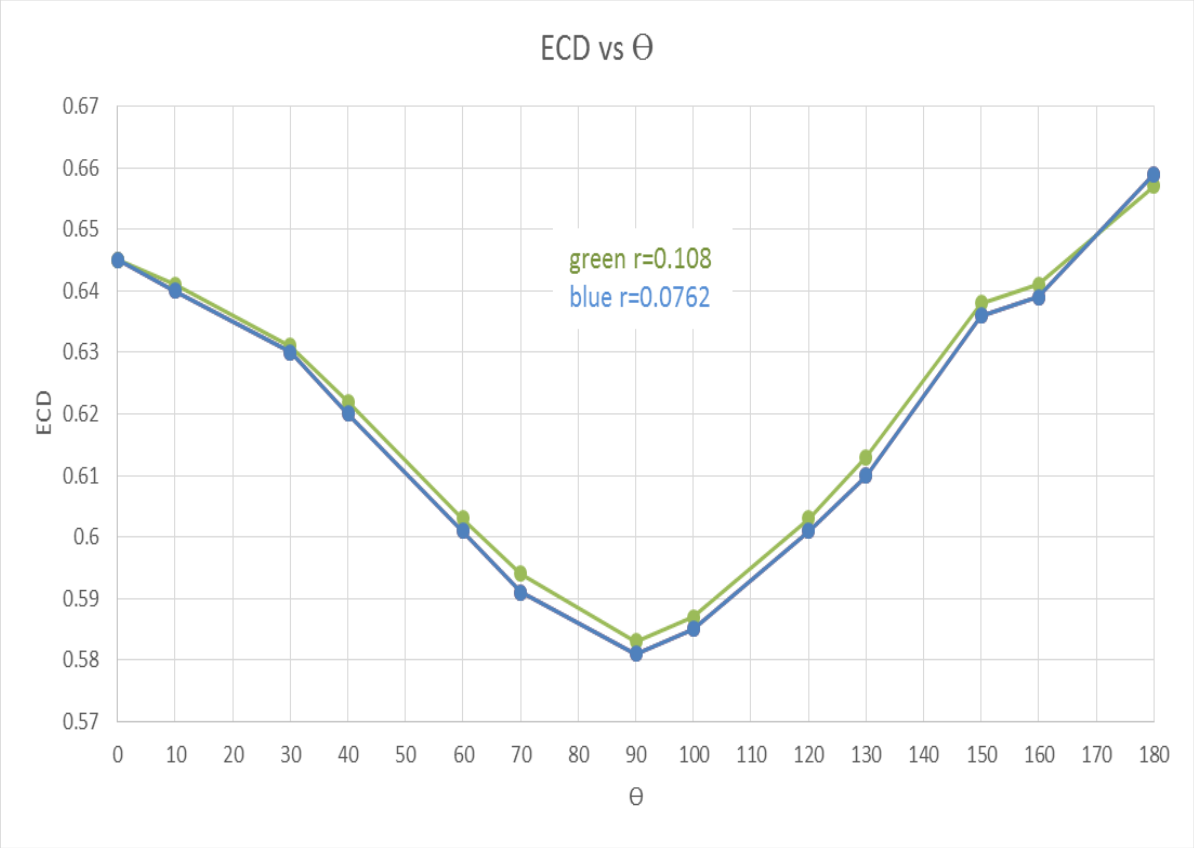
The change of ECD with θ when borehole radius varies

when I=30 α=0

Θ=(0,10,30,40,60,70,90,100,120,130,150,160,180) @ eq(7)

R=0.108 / 0.0762

ECD (r=0.108)	ECD (r=0.0762)	ϴ
0.645	0.645	0
0.64	0.641	10
0.63	0.631	30
0.62	0.622	40
0.601	0.603	60
0.591	0.594	70
0.581	0.583	90
0.585	0.587	100
0.601	0.603	120
0.61	0.613	130
0.636	0.638	150
0.639	0.641	160
0.659	0.657	180

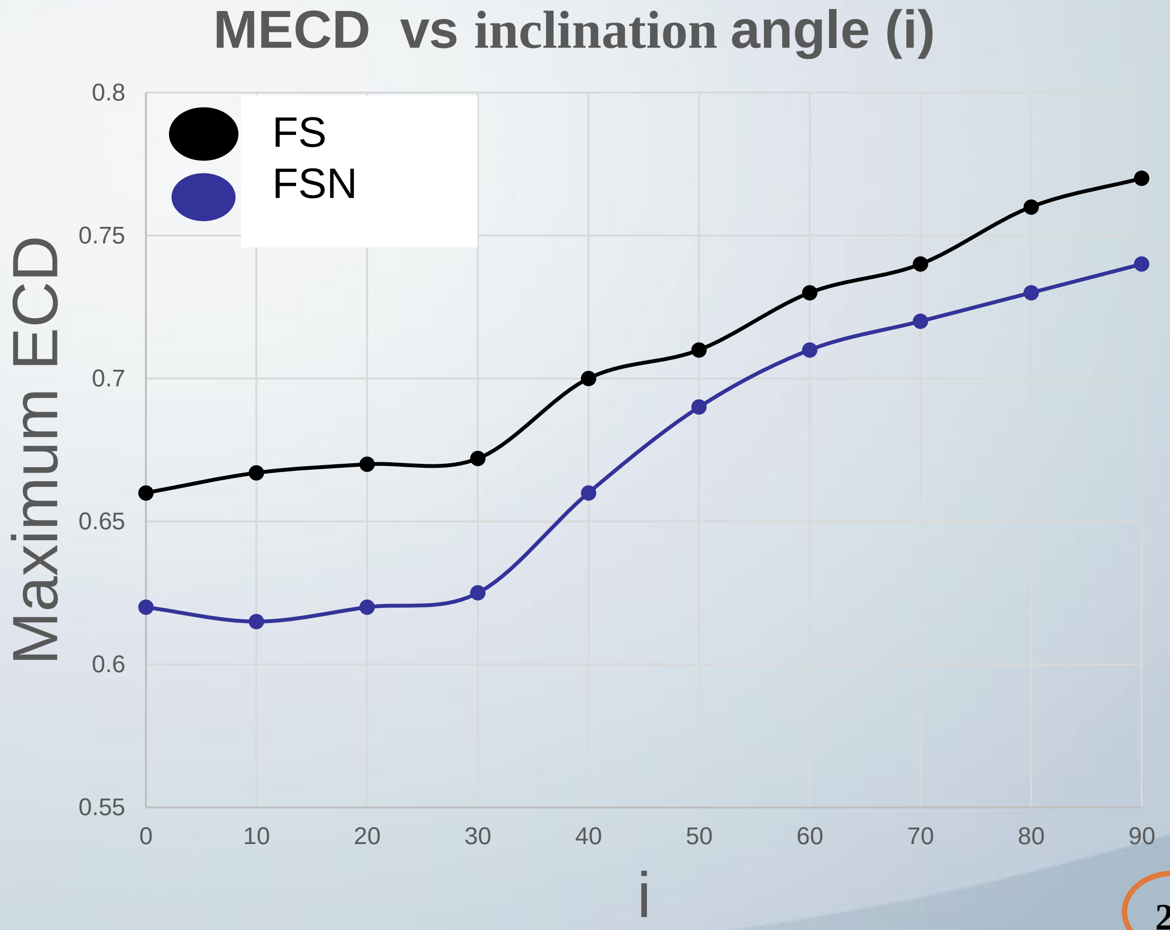


Results and discussion

The changing trend of MECD with the inclination angle

$\alpha = 90 \qquad \theta = 90$ @ eq(9)

Maximum ECD FS	Maximum ECD FSN	i
0.66	0.62	0
0.667	0.615	10
0.67	0.62	20
0.672	0.625	30
0.7	0.66	40
0.71	0.69	50
0.73	0.71	60
0.74	0.72	70
0.76	0.73	80
0.77	0.74	90



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Conclusions and recommendations

Conclusion:

- A comparison of the new model with the conventional one reveals that maximum equivalent collapse density (MECD) reduces with the decrease of borehole radius and that the wellbore is more stable.

- And with the change of the inclination angle, MECD is higher when fluid seepage is considered under a certain relative azimuthal angle, indicating a narrower mud weight window and a more unstable wellbore.

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"Thank You"