

MECHANICAL FEASIBILITY AND TORQUE-DRAG OPTIMIZATION FOR CONVERTING HIGHLY DEVIATED J-SHAPE WELLBORES INTO EXTENDED REACH DRILLING (ERD) PROFILES

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ABSTRACT

The economic sustainability of mature assets depends on maximizing reservoir drainage by repurposing existing infrastructure. This study evaluates the mechanical feasibility of converting a highly deviated J-shape well into an Extended Reach Drilling (ERD) profile to access stranded hydrocarbon volumes. Using Torque and Drag (T&D) simulations as the primary technical metric, the research benchmarks the mechanical loads of a conventional Positive Displacement Motor (PDM) against a modern Rotary Steerable System (RSS).

Operational constraints, including surface torque, hoisting capacity, and helical buckling limits, were modeled across various friction factors. Results demonstrate that while the conversion is technically viable, the RSS BHA is essential to mitigate torque and drag compared to PDM configurations. By establishing a decision-making framework based on precise modeling, this research underscores advanced simulation as a requirement for safe well conversions in mature fields.

Keywords: torque and drag, positive displacement motor, rotary steerable system, bottom hole assembly, extended-reach drilling, oil and gas drilling

INTRODUCTION

Extended-Reach Drilling (ERD) allows operators to access hydrocarbon reserves at significant lateral distances from surface locations, often exceeding 10–15 km. By consolidating infrastructure, ERD minimizes environmental footprints and capital expenditure while maximizing drainage, [1].

In mature field redevelopment, a strategic shift has emerged toward repurposing existing J-shaped wellbores to reach new targets, leveraging existing assets to unlock stranded reserves. However, transitioning to an ERD trajectory introduces profound technical risks, including wellbore instability and excessive torque and drag. Success depends on integrating advanced technologies such as Rotary Steerable Systems (RSS) and optimized fluid rheology, [2].

This study focuses on the IQ-KRI-78 well, identifying the critical thresholds for a 3,500 m lateral extension.

To transition from a conventional to an ERD profile, the following technical thresholds must be evaluated, [3]:

1. **Wellbore Stability:** Mitigating the increased exposure of unstable formations during extended lateral drilling.
2. **Torque and Drag:** Ensuring frictional forces do not exceed the mechanical limits of the drillstring.
3. **Hole Cleaning:** Managing the high risk of cuttings accumulation in long lateral sections.
4. **Casing Wear:** Addressing the impact of prolonged drilling operations on the integrity of existing casing strings.

These advantages make well conversion an attractive option for mature field development.

MATERIALS AND METHOD

This study presents a comprehensive feasibility assessment through, [4]:

1. Advanced well path optimization using software modeling,
2. Torque and drag simulations with sensitivity analysis.

Agbaji [5] has concluded several elements of success in ERD wells, these elements are: well trajectory design, bottom hole assembly, bit hydraulics, drill string design, torque and drag, hole cleaning and ECD management.

All of these elements are interrelated, means one element will directly influence the other. Such as BHA design has a big impact of drilling hydraulics and both have effect on hole cleaning and ECD management, [6],[7].

While planning to convert IQ-KRI-78 well to ERD all the above mentioned factors will be considered and implemented while drilling operations. J-shape wells are good candidate for converting to ERD wells, especially if the well has deep kick off point.

The IQ-KRI-78 well is located in the structurally complex Zagros Fold-and-Thrust Belt. The presence of tectonic stresses and the mobile sequences of the Gachsaran formation necessitate the use of an RSS BHA to maintain a smooth wellbore profile, which facilitates effective cuttings transport across the 3,500 m lateral.

This is because this kind of well trajectory gives minimum torque and drag issues if compared to other types of well trajectory. For instance, it will be technically unfeasible to convert an S-Shape well to ERD. Mainly due to high torque and drag issues.

Background information of the Well IQ-KRI-78 is drilled in Iraq in 2010 to a total depth of 2200 mMD /1630m TVD. 9 5/8" production casing was landed as last casing section at 2200 mMD /1630 mTVD. The 20 inch casing shoe is been set at 500 m MD/ 500m TVD.

The 17 1/2" hole started and the well was Kicked-off below 20 in casing shoe at 632 m with dogleg severity of 2.17°/30 m build-up rate and build to 61° incl and keeping same Azimuth of 90.00° till 17 1/2" hole section TD at 1600mMD /1424 mTVD.

Drilling is continued with a 12 1/4" PDC Bit and drilled the 12-1/4" hole from 1600 mMD /1424 mTVD to 2200 mMD /1630 mTVD with 1.1°/30m build-up rate and built the hole angle to 72.0° incl keeping the same 90.00° azimuth and set 9 5/8" production casing at well TD.

All the required information has been collected before and after the well has been drilled. Detailed data has been gathered about well design, wellbore trajectories, surveys, and casing seats, are presented in Figure 1.

This study does not investigate pulling out old completions string, plugging back 9 5/8" casing perforations, and drilling out 9 5/8" casing shoe and float equipment. As these activities are considered to be part of the well preparations to be converted to ERD.

Figure 1 is the current well schematic and Figure 2, is the current actual well trajectory profile. Well inclination at TD at 2200 mMD /1600 mTVD with 72° incl and 90° azimuth.

The plan is to continue drilling the well and build angle to 90 deg without making sharp doglegs and make the hole as smooth as possible to avoid excess torque and drag issues. Thus, the well will be deepened from 2200 mMD to 2500 mMD increasing well inclination from 72° to 90° incl with a maximum dogleg severity of 1.83 (°/100ft). At 2500 mMD, 1677.08 mTVD the well reaches to 90° incl, then continue drilling horizontally with tangent section and hold 90° incl to well TD at 6000 m MD 1677.08 mTVD keeping the same Azimuth of 90°.

Figure 3 is the planned well schematic and Figure 4 is the planned well trajectory profile.

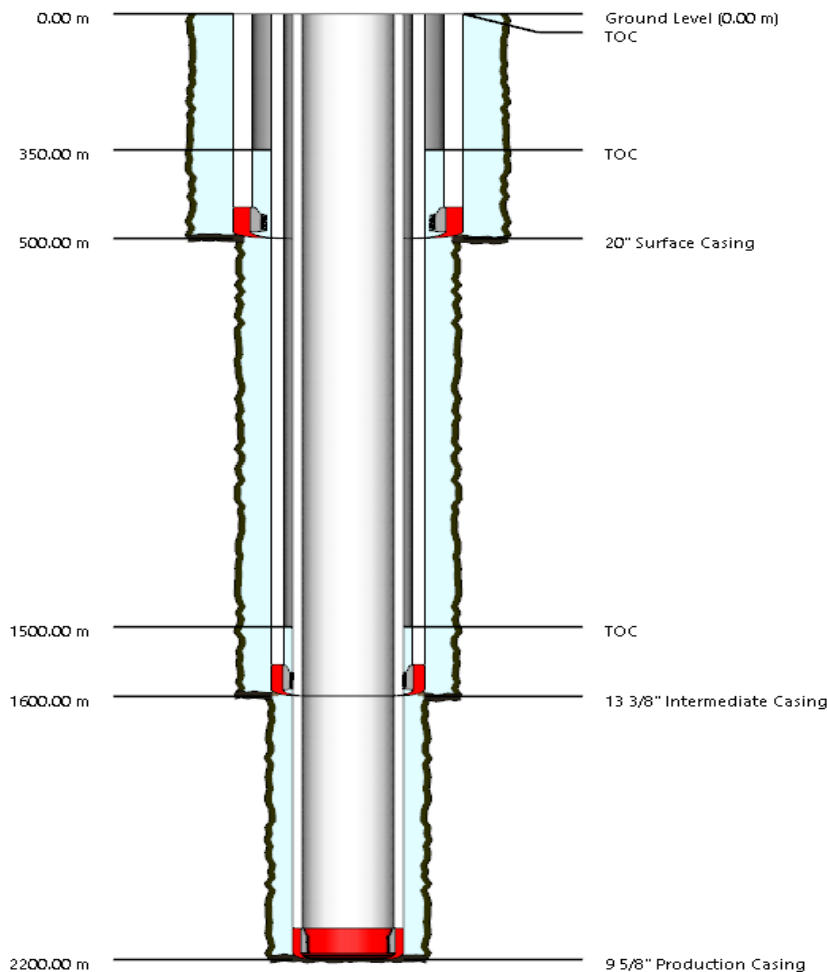


Figure 1. Current well schematic.

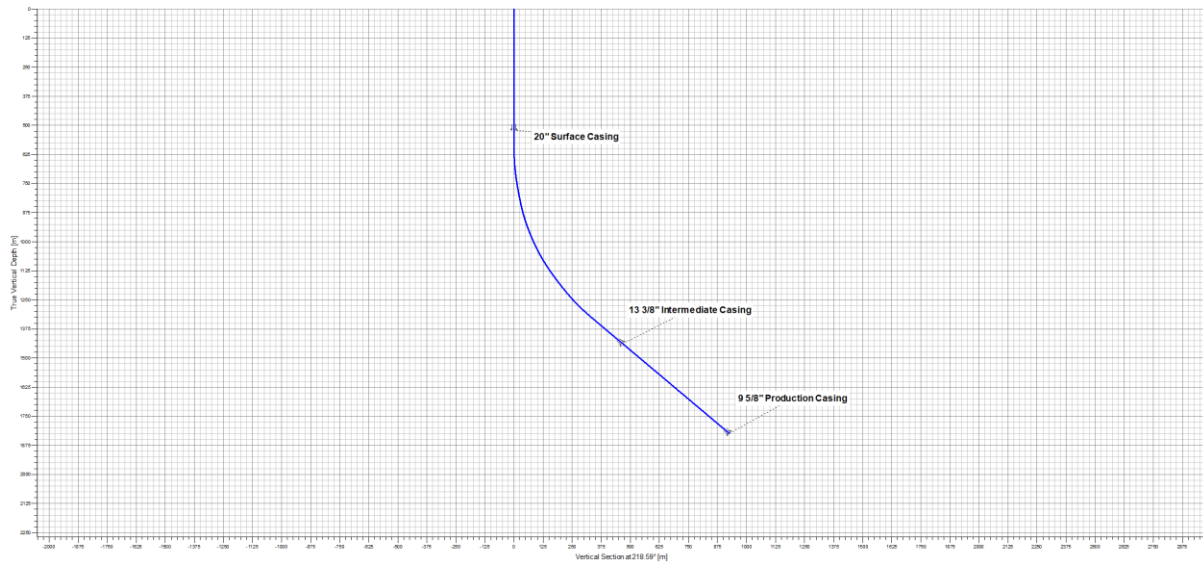


Figure 2. Actual well trajectory to 2200 m MD.

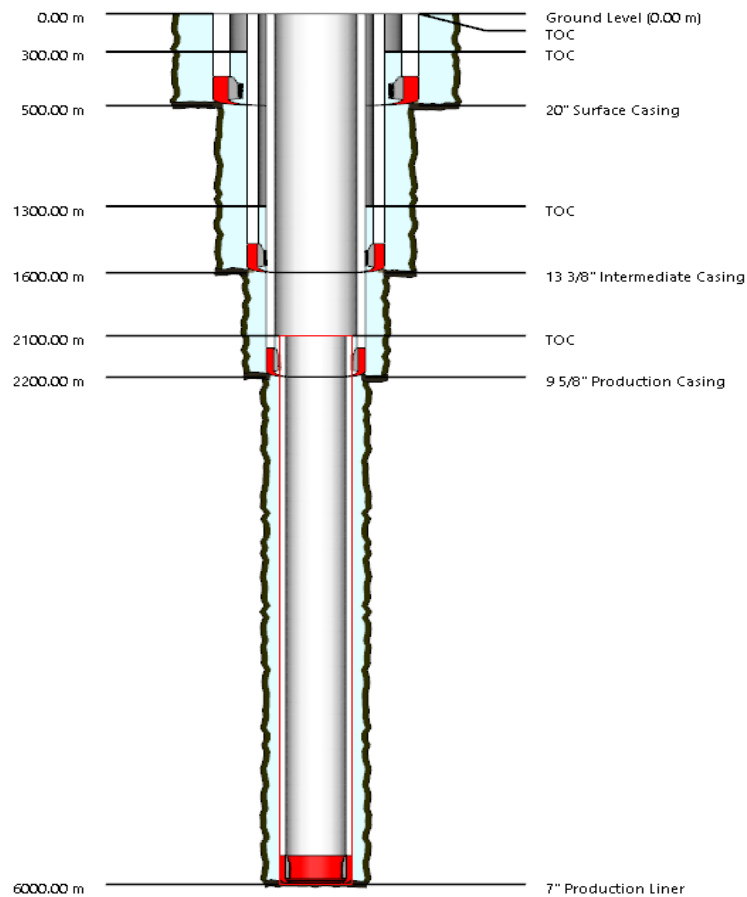


Figure 3. Planned well schematic.

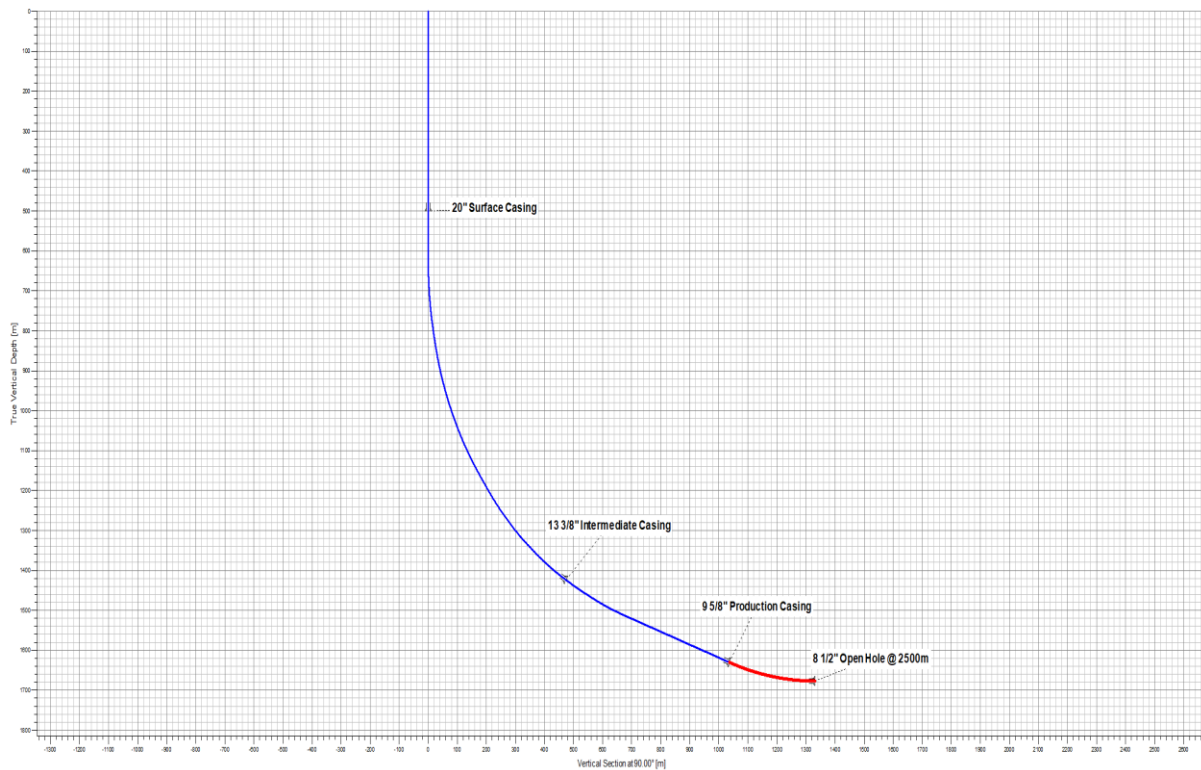


Figure 4. Planned well trajectory, 72 deg build to 90 Deg at 2,500 m MD.

ERD Well Planning is planning to IQ-KRI-78 Well is a J-Shape well drilled in North of Iraq in 2010. The well is highly deviated well drilled to a total depth of 2200 m MD with Maximum 72 Deg inclination at well TD. The well is cased with a 9 5/8" production casing at 2200 m MD. This paper will try to investigate the possibility of converting the well to ERD well by drilling another 8 1/2" section to a total depth of 6000mMD holding the 90 deg inclination.

It is planned to deepen the well with two different BHA's. The first BHA will be PDM, it will be run in hole to drill from 2200 mMD to 2500 mMD and its purpose is to build well inclination from 72 deg to 90 deg (Figure 4). Then the BHA #1 will be pulled out and BHA #2 RSS will be run to perform Geosteering and hold 90 deg inclination to the well TD at 6000 mMD (Figure 5).

The torque, drag, and hydraulic simulations were performed using *Landmark WellPlan™ (Halliburton)* to evaluate mechanical loads against the drillstring's design limits for each BHA run, complete T&D, tension, Hydraulics sensitivity, Hydraulics surge and swab and BHA design (Table 1, Table 2, Table 3), [8].

After careful selection of input data for all the software simulations it became apparent that the well can be drilled safely to planned TD without any design concerns and technical issues, [9], [10].

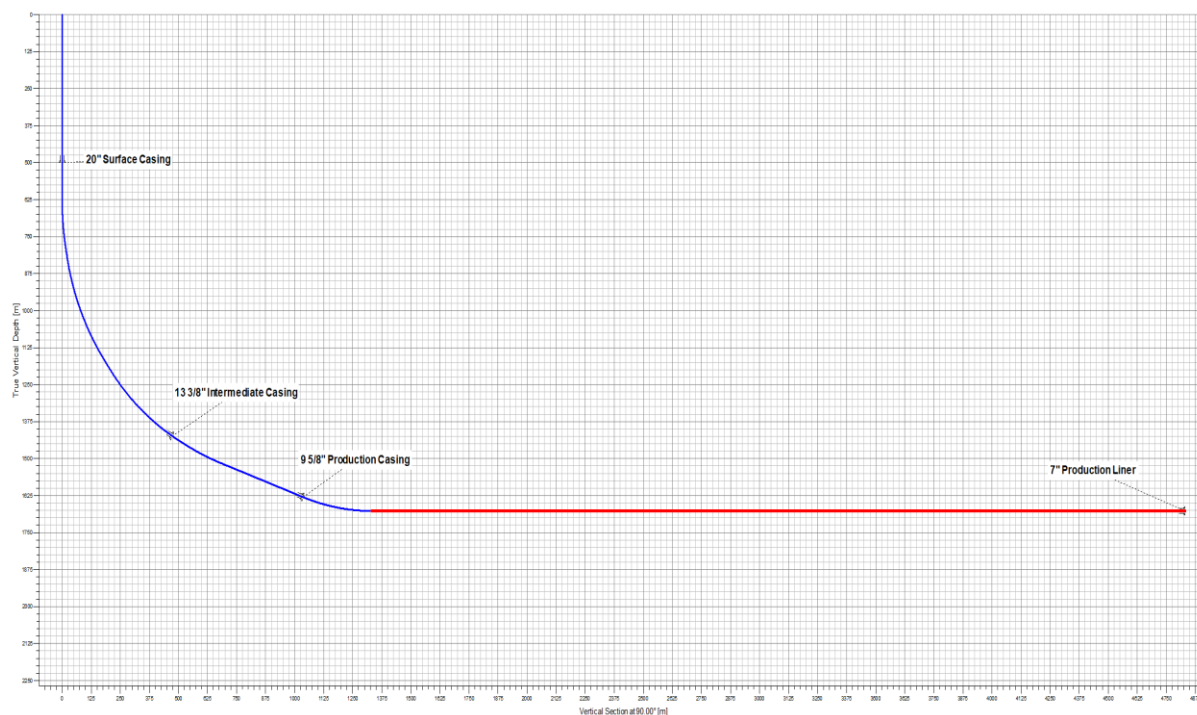


Figure 5. Planned well trajectory, Hold 90 Deg to Well TD at 6000 mMD.

Table 1. Current Actual Well State.

Hole Size (in)	Casing Sections	MD (m)	Inc (°)	Azi (°)	TVD (m)
N/A	30" CSG Shoe	20	0	0	20
20"	20" CSG Shoe (KOP 632 m)	500	0	9	500
17 ½"	13 3/8" CSG Shoe	1600	61	90	1424
12 ¼"	9 5/8" CSG Shoe	2200	72	90	1630
8 ½"	Open Hole	6000	90	90	1677

Table 2. BHA run summaries and purposes.

BHA #	BHA Run Purpose	Depth in	Depth Out	Inclination In	Inclination Out
BHA #1 PDM	To Build Angle	2200m	2500m	72 Deg	90 Deg
BHA #2 RSS	To Hold Angle	2500m	6000m	90 Deg	90 Deg

Table 3. Planned ERD trajectory.

Hole Size (in)	Casing Sections	MD (m)	Inc (°)	Azi (°)	TVD (m)
N/A	30" Conductor Shoe	20	0	0	20
26"	20" CSG Shoe	500	0	0	500
17 ½"	13 3/8" CSG Shoe	1600	61	90	1424
12 ¼"	9 5/8" CSG Shoe	2200	72	90	1630
8 ½"	Open Hole	6000	90	90	1677

RESULTS

A detailed torque and drag analysis were run to make sure the well can be drilled safely within used 5-1/2" drill pipe torque limit. The selected BHA were carefully designed to give optimum performance meanwhile provide minimum torque while drilling, [9]. Both planned BHA's were subjected to extensive T&D analysis using different friction factors for both open and cased hole sections and the results were showing satisfied outcomes. In extended reach drilling, managing Torque and Drag (T&D) is critical for well path feasibility, equipment selection, and avoiding costly downhole problems such as stuck pipe and premature tool failure, [10].

The choice of the directional drilling system, primarily between a conventional Positive Displacement Motor (PDM) with bent housing and a modern Rotary Steerable System (RSS), has a profound impact on T&D trends, [11].

While RSS technology is often marketed for its superior performance in this area, a nuanced understanding of the underlying mechanisms is essential. The high drag encountered during slide drilling with a PDM is a well-documented limitation, primarily due to the static friction of the non-rotating string, [12],[13]. Furthermore, the wellbore micro-tortuosity generated by the alternating slide-and-rotate sequences of a PDM BHA is a significant, often hidden, contributor to increased torque and drag, [14],[15].

Meanwhile, the RSS technology significantly reduces friction by maintaining continuous rotation, converting problematic static friction into lower dynamic friction, which is a key enabler for Extended-Reach Drilling (ERD), [16],[17].

Figure 6 graph integrates surface measurements of pick up, slack off, and free rotary weight versus depth, and inclination in the Motor BHA. It characterizes real-time mechanical loading on the BHA, identifying drilling inefficiencies, bit dysfunction, Over pull, stuck indicator or motor stall signatures through dynamic load response analysis.

The graph depicts the **hook load** measured while drilling with a Positive Displacement Motor (PDM) Bottom Hole Assembly (BHA). The graph is a classic **drag plot** used by drilling team, well planners to understand the frictional characteristics of the wellbore and to ensure that the drilling operation remains within safe mechanical limits.

The graph shows the hook load and friction (drag) for a drilling assembly. The two lines ("Trip In" and "Trip Out") demonstrate how the force needed to move the drill string increases as the well's inclination builds. While drilling operations, drillers record pick up, slack off, and rotary weights, and it will be plotted in the same graph, the line that matches with the actual drilling torque it will be considered as actual friction factors and it will be used in future wells.

The key observations about the graph plots are:

- **Two Distinct Curves:** There are two clear lines, representing "Trip In" (running the drill string into the well) and "Trip Out" (pulling the drill string out of the well).
- **Hook Load vs. Inclination:** It can be noted that the hook load changes as the well's inclination increases. The "Trip Out" load is consistently higher than the "Trip In" load.
- **Indication of Drag:** The difference between the "Trip Out" and "Trip In" curves represents the **drag force** or friction in the wellbore. This drag increases as the well becomes more inclined.
- **Friction factors:** the friction factors used for open hole. Later while drilling correct friction factors can be found and plotted in the graph.

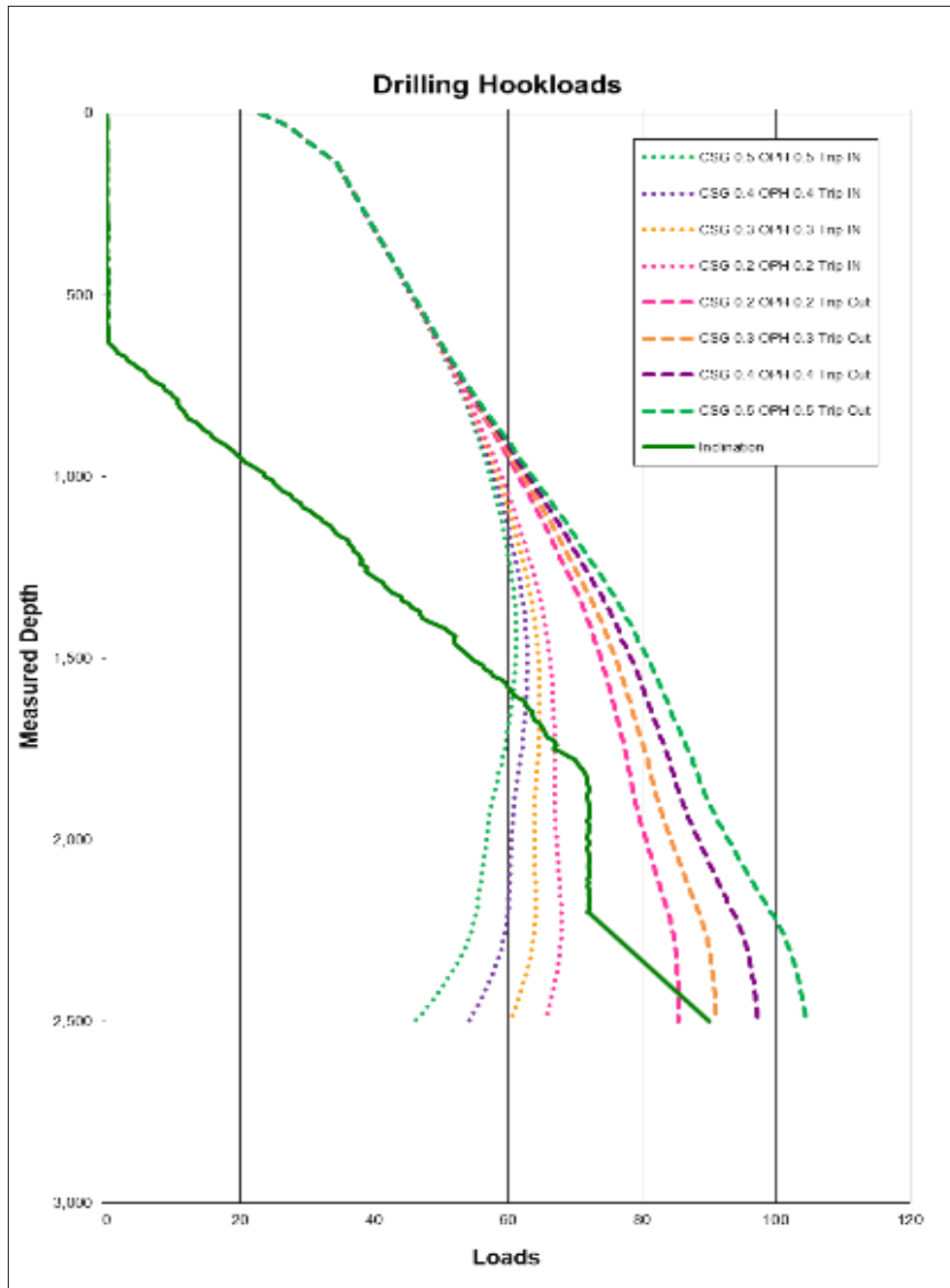


Figure 6. Simulated Hook Load profile vs. Measured Depth with different FF for PDM BHA

Figure 7 simulates the torque plot in Motor BHA delineates the interaction between surface torque and modeled downhole frictional resistance. Variations highlight differential sticking potential, torsional oscillations, and formation-dependent drag behaviors, allowing precise calibration of torque-and-drag models and verification of mechanical transfer efficiency. The graph represents the *surface torque* measured while drilling with a Positive Displacement Motor (PDM) Bottom Hole Assembly (BHA).

The key points are:

- **Torque vs. Inclination:** The graph shows how the torque load changes as the well's *inclination* increases.
- **Increasing Trend:** A clear pattern is that the torque required generally *increases with higher well inclination*, which is a typical result of increased friction between the drill string and the wellbore.

In short, this is a *torque plot* used to monitor drilling efficiency and ensure the surface equipment and drill string are not being overloaded due to wellbore friction.

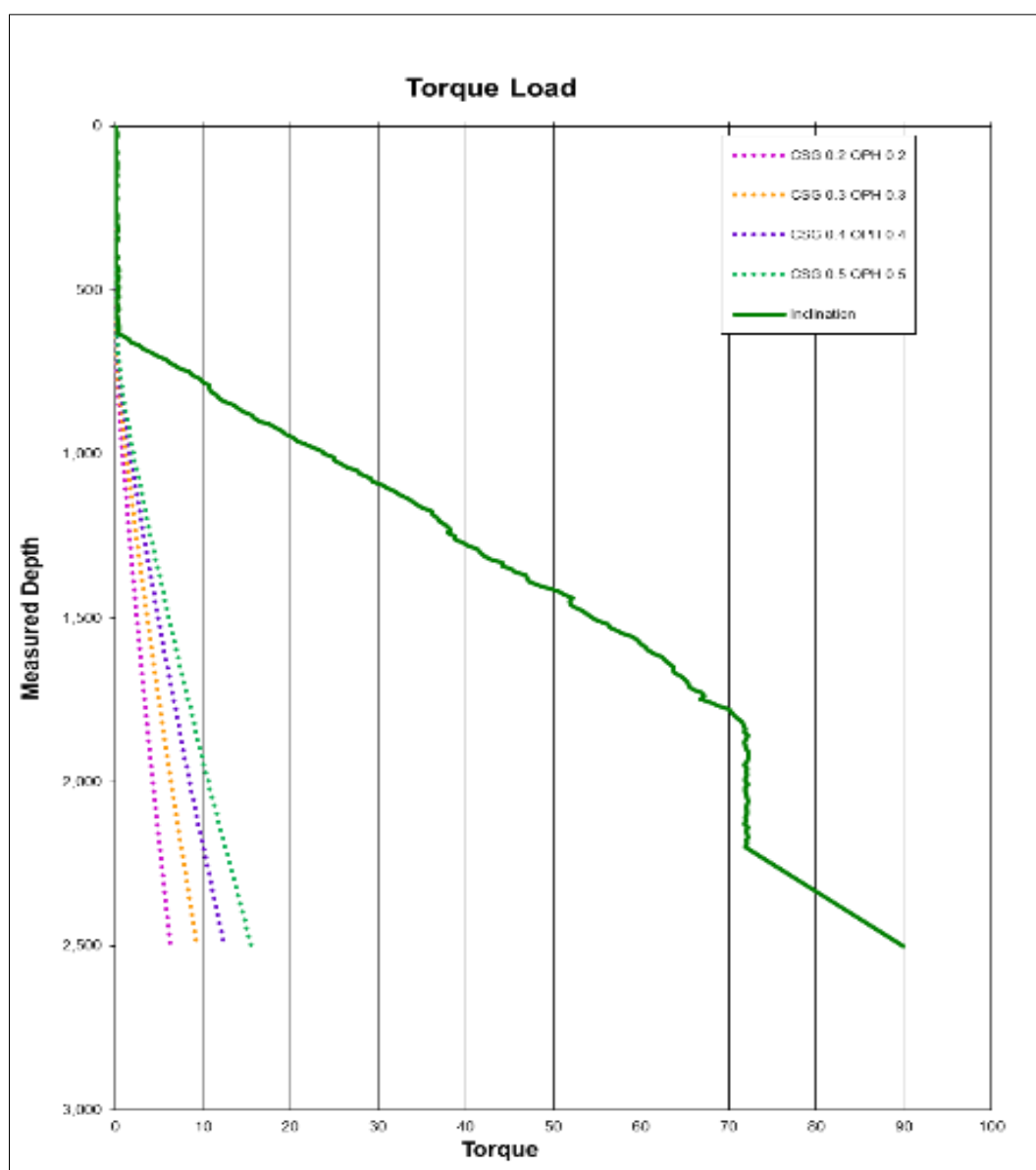


Figure 7. Simulated Torque Load profile vs. Measured Depth with different FF for PDM BHA.

Figure 8 shows the plot that correlates hook load, drag, and overpull trends throughout tripping sequences (In/Out). Deviations from modeled free-movement envelopes signify wellbore frictional irregularities, differential sticking, or cuttings accumulation, facilitating early detection of potential wellbore instability or hole cleaning deficiencies. It is the same of what loads we measure in drilling but this one special on Tripping in or out. The graph shows the **hook load** while tripping a Positive Displacement Motor (PDM) Bottom Hole Assembly (BHA) in and out of the well.

The key details are:

- **Two Main Curves:** It plots "Trip In" (running the drill string into the hole) and "Trip Out" (pulling it out) against the well's inclination.
- **Drag Force:** The consistent separation between the "Trip Out" (higher load) and "Trip In" (lower load) lines represent the **frictional drag** of the drill string against the wellbore.
- **Standard Analysis:** This is a standard drag plot used to ensure tripping operations are within safe load limits and to understand the frictional forces in the wellbore.

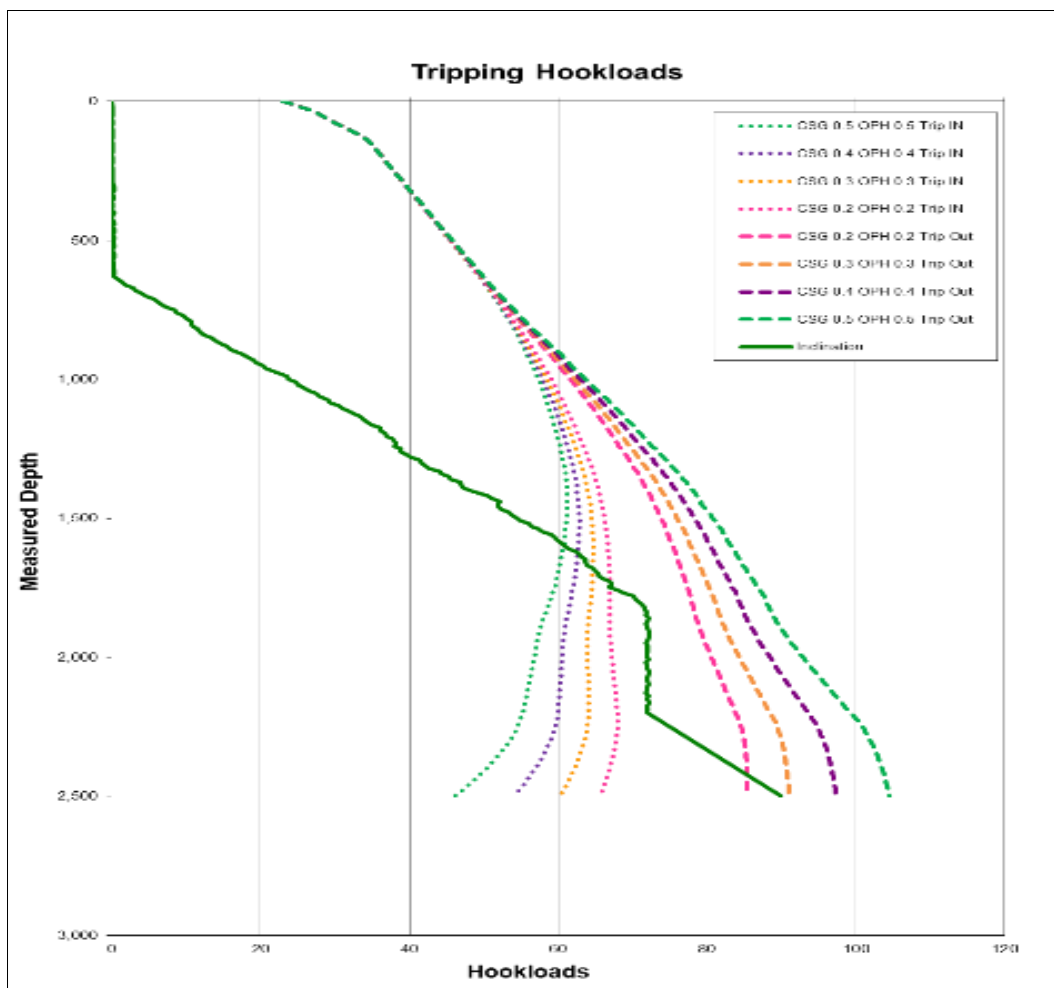


Figure 8. Simulated Tripping Hook Load profile vs. Measured Depth with different FF for PDM BHA.

Figure 9 simulates the Single Depth Analysis @ 2500 m evaluates the axial load distribution along the wellbore for a PDM bottom-hole assembly (Motor + MWD) configuration. The graph compares axial loads during different operational modes—rotating, sliding, tripping, and back-reaming—against the sinusoidal and helical buckling limits.

The inclination profile (blue curve) increases steadily to approximately 60°, indicating a build section typical of directional drilling. The axial load traces (red, yellow, and green curves) show minor fluctuations corresponding to frictional drag and contact forces along the wellbore.

Across all operational modes, axial load values remain below both buckling limits, confirming that the drill string is operating within safe mechanical margins. The applied DWOB of 12,000 kgf and stable load response indicates efficient weight transfer to the bit, minimal compressive instability, and no evidence of mechanical buckling. Overall, the analysis verifies effective BHA design and wellbore conditions suitable for controlled PDM drilling operations.

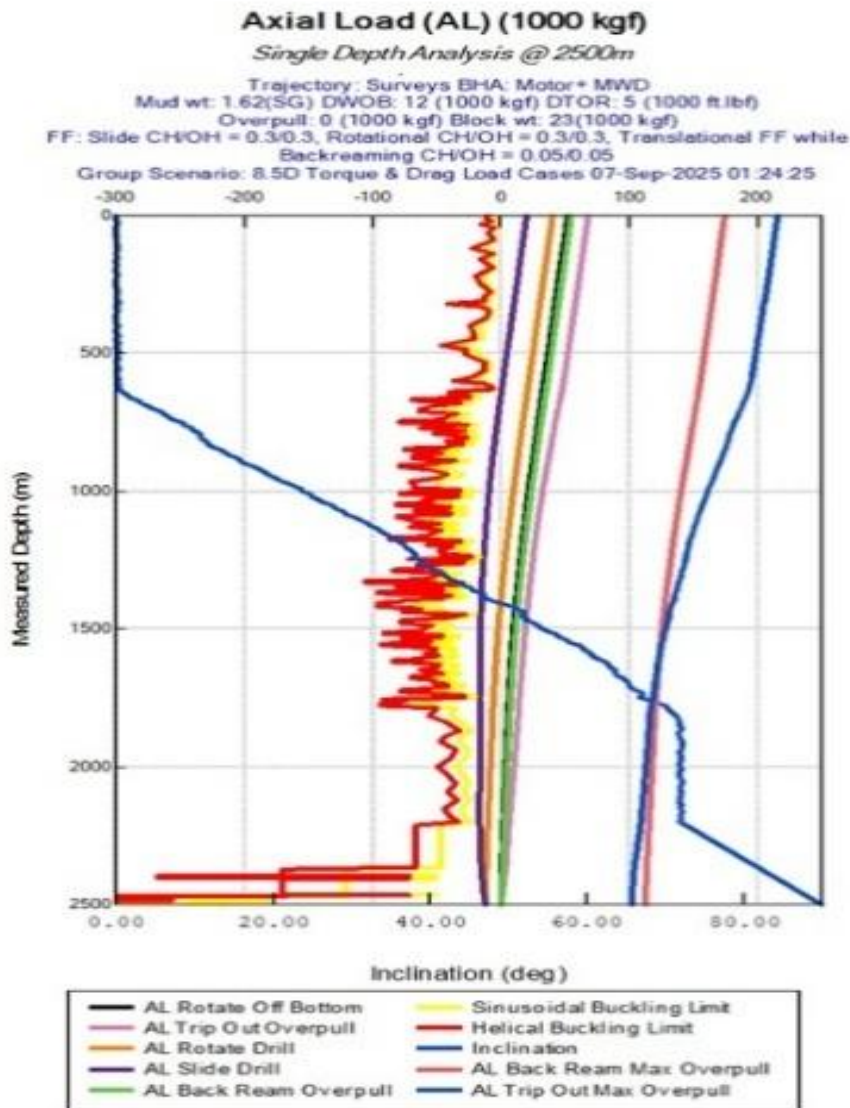


Figure 9. Simulated Axial Load profile vs. Measured Depth for PDM BHA.

Figure 10 simulates the Multi-Depth Analysis @ DWOB = 12,000 kgf evaluates the buckling stability of the PDM (Motor + MWD) bottom-hole assembly under drilling conditions. The graph compares sinusoidal and helical buckling margins for both rotary and slide drilling modes across bit depths from 2200 m to 2500 m. Results indicate that both sinusoidal (orange and purple) and helical (red and blue) buckling margins remain positive throughout the analyzed interval, confirming that the axial compressive loads are well below critical buckling thresholds. Slight fluctuations in margin values correspond to variations in inclination and localized contact forces but do not approach instability limits. The applied DWOB of 12,000 kgf and stable margin trends confirm that the PDM BHA operates within safe mechanical limits, maintaining structural integrity and effective weight transfer. Overall, the analysis verifies that no buckling or excessive compression is expected under the current drilling parameters, indicating robust mechanical stability and appropriate BHA design.

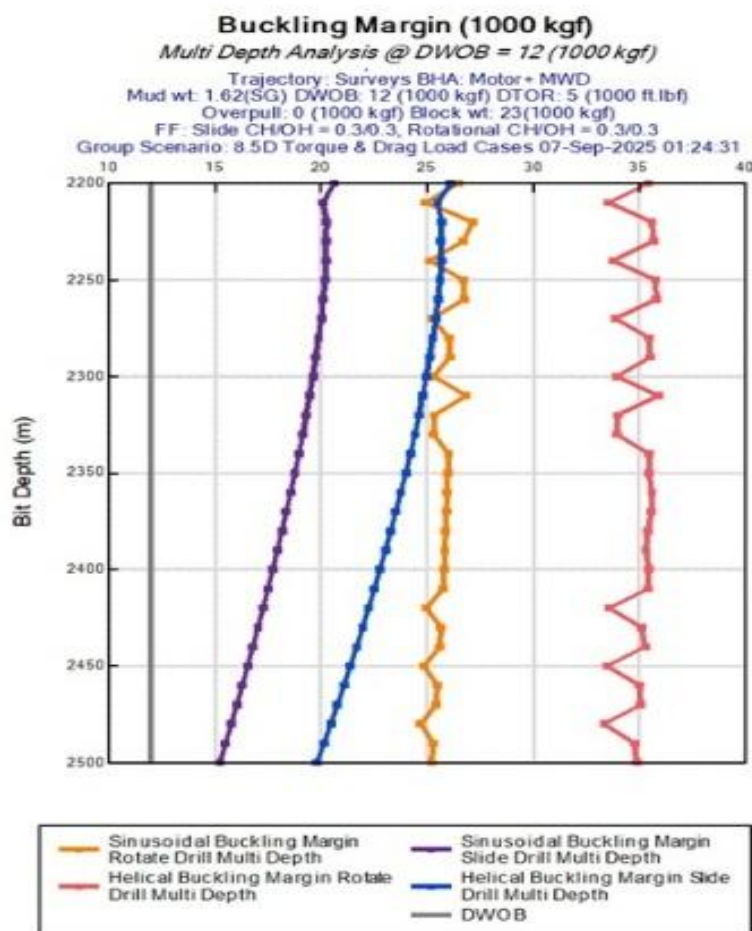


Figure 10. Simulated buckling margin profile vs. Measured Depth for PDM BHA.

Figure 11 shows the Single Depth Torque Analysis @ 2500 m evaluates the rotational torque behavior of the PDM (Motor + MWD) bottom-hole assembly under a DWOB of 12,000 kgf. The plot compares torque during rotary drilling (black line) and backreaming with overpull (pink line) against the well inclination profile (blue line). Results indicate a gradual increase in

torque with depth and inclination, reaching approximately 5,000 ft·lbf near the total depth. The similarity between the drilling and backreaming torque trends suggests minimal frictional or mechanical interference along the wellbore, confirming smooth torque transmission and adequate hole cleaning conditions.

No excessive torque spikes or instability were observed, implying no risk of torsional stick-slip or over-torque conditions for the modeled parameters. Overall, the PDM BHA demonstrates stable torsional performance and efficient rotary energy transfer, consistent with proper borehole geometry and lubrication under the given mud and friction factors.

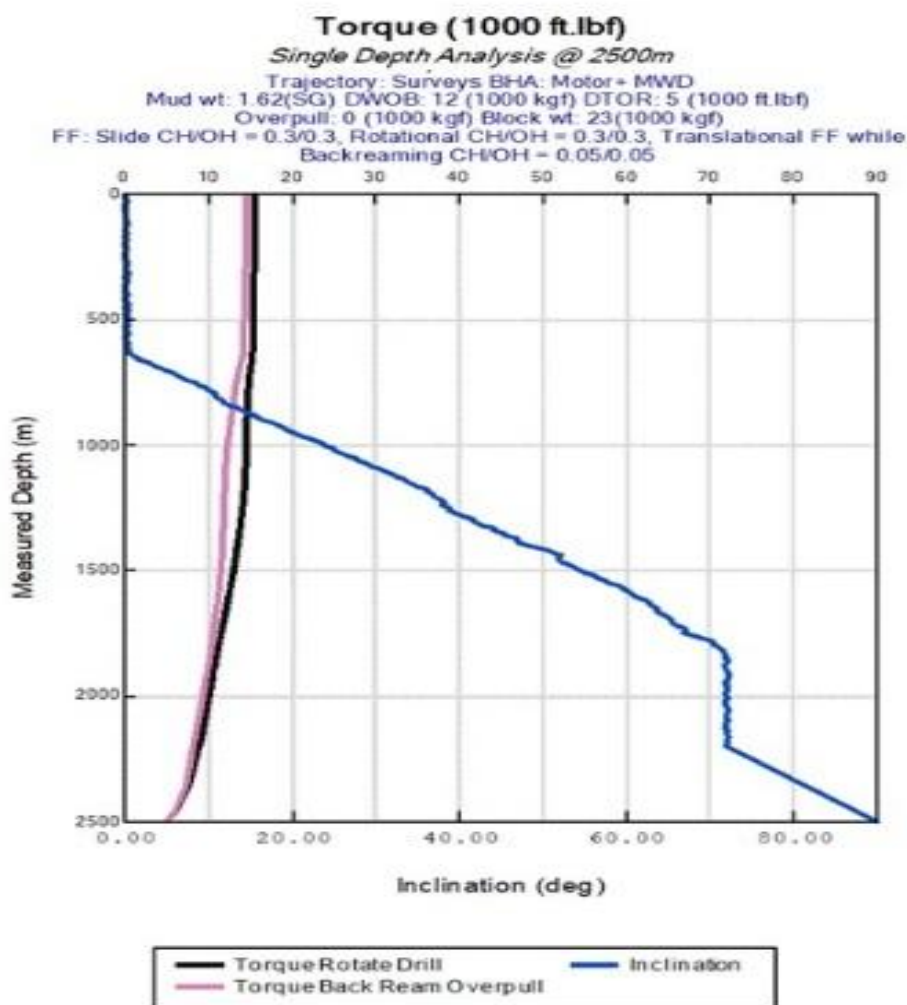


Figure 11. Torque Load profile vs. Measured Depth for PDM BHA.

Figure 12 displays the correlation of WOB, during rotary steerable operations (RSS BHA). The graph characterizes the mechanical–loads interaction of the RSS assembly, enabling evaluation of tool steering efficiency, bit-formation response, and real-time optimization of drilling parameters. This graph is a **drilling hook load simulation** for a Rotary Steerable System (RSS) BHA. It models the hook load required during drilling operations by using different friction factors to represent various wellbore conditions.

The key elements are:

- **Friction Factors:** The labels (CH1 0.2, 0.3, 0.4, 0.5) represent different friction factors used in the model.
 - A lower value (e.g., 0.2) typically models the smooth, low-friction environment of a *cased hole*.
 - Higher values (e.g., 0.3 to 0.5) model the increasingly rough and sticky conditions of an open hole.
- **Drilling Modes:** The "Trip In" and "Trip Out" lines do not represent physical tripping. Instead:
 - **"Trip In"** simulates the hook load during *sliding mode* (steering).
 - **"Trip Out"** simulates the hook load during *rotating mode*.

The main insight: The graph shows how hook load and drag *increase significantly* as the friction factor rises from cased-hole to open-hole conditions. This helps engineers predict forces, ensure the drill string can be pushed and rotated effectively, and plan for a safe drilling operation.

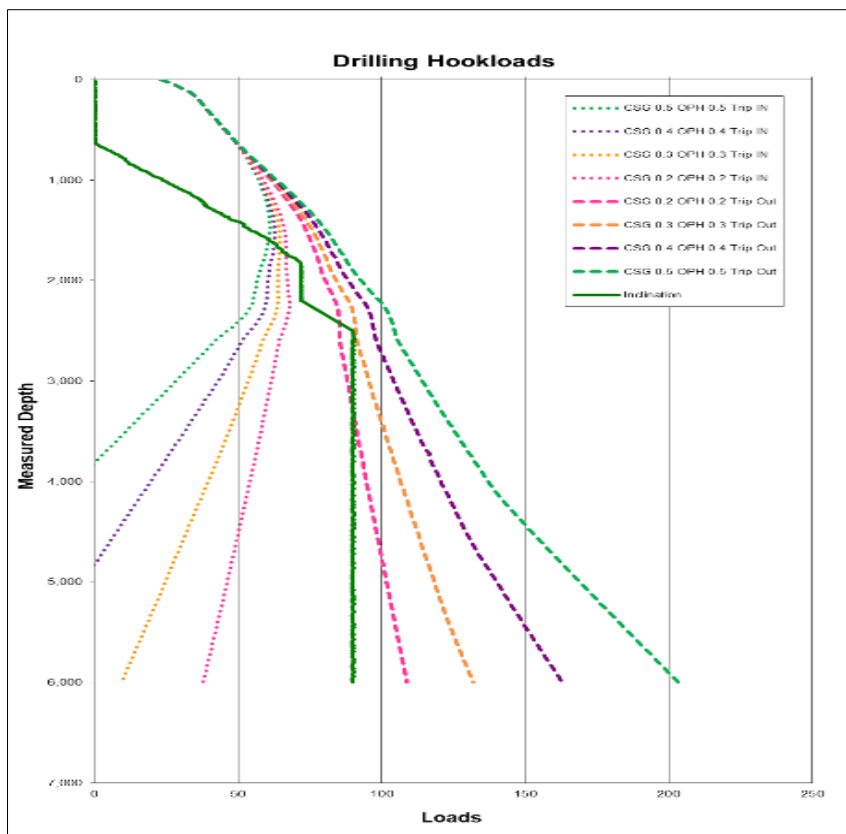


Figure 12. Simulated Hook Load profile vs. Measured Depth with different FF for RSS BHA

Figure 13 illustrates the evolution of surface and downhole torque along the drilled interval in RSS BHA. It captures torsional dynamics, tool-face control stability, and frictional interactions, providing a diagnostic framework for assessing RSS performance, formation contact forces, and torque-transfer efficiency. This graph is a *torque simulation* for a Rotary Steerable System

(RSS) BHA while drilling. It models how much torque is required to rotate the drill string under different wellbore conditions.

The key elements are:

- **Friction Factors:** The labels (OPH 0.2, 0.3, 0.4, 0.5) represent different friction factors.
 - A lower value (e.g., 0.2) typically models the smooth, low-friction environment of a *cased hole*.
 - Higher values (e.g., 0.3 to 0.5) model the increasingly challenging and sticky conditions of an *open hole*.
- **Trend:** The graph shows that as the well's *inclination* increases and as the *friction factor* rises, the torque required to drill also *increases significantly*.

In short, this is a *torque analysis plot*. It is used to predict the torque loads the drilling system will experience, helping to ensure that the surface equipment and drill string have sufficient capacity, especially when transitioning from the low-friction cased hole to the higher-friction open hole section.

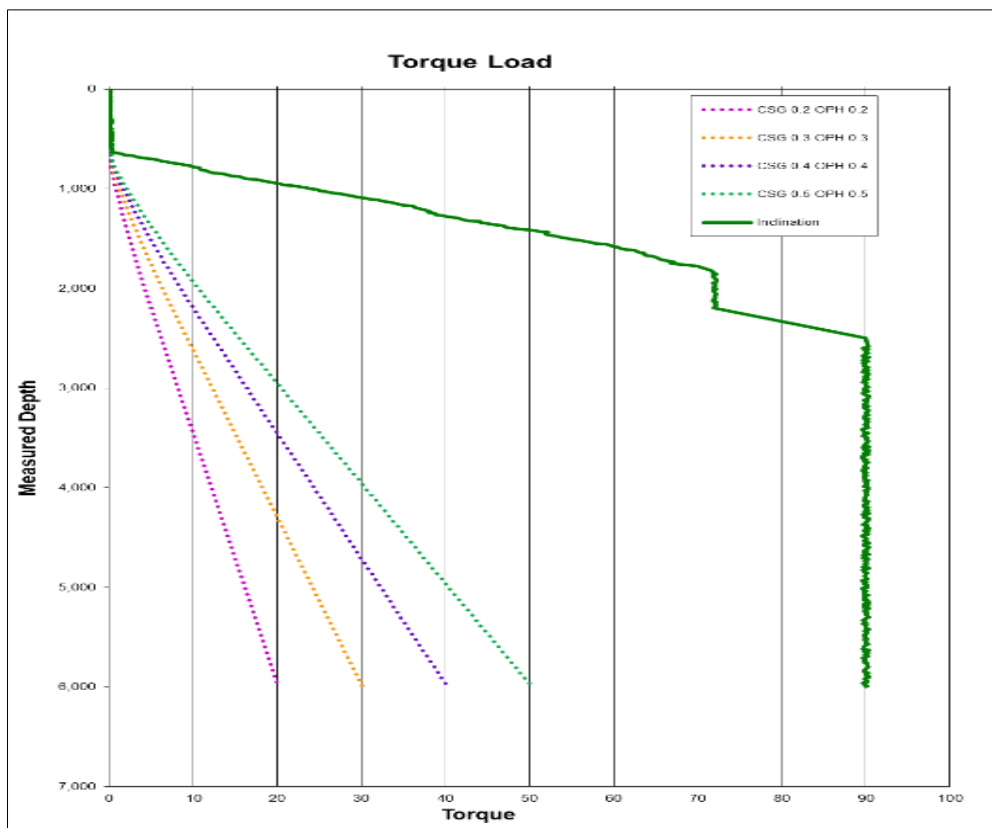


Figure 13. Simulated Torque Load profile vs. Measured Depth with different FF for RSS BHA

Figure 14 presents measured hookload versus depth during tripping with RSS BHA. Comparative analysis with modeled envelopes identifies friction anomalies, tight spots, or micro-doglegs, supporting validation of borehole integrity and optimization of tripping strategies under varying downhole frictional regimes. The graph is a *tripping hook load simulation* for a Rotary Steerable System (RSS) Bottom Hole Assembly (BHA). It models the

forces encountered when physically running the drill string into the well ("Trip In") and pulling it out ("Trip Out").

The key elements are:

- **Friction Factors:** The labels (e.g., OPH 0.2, 0.3, etc.) represent different friction factors.
 - Lower values (e.g., 0.2) model the low-friction conditions of a *cased hole*.
 - Higher values (e.g., 0.5) model the high-friction conditions of an *open hole*.
- **Tripping Operation:** The plot clearly shows the "Trip Out" load is consistently higher than the "Trip In" load for any given friction factor. This difference is the *drag force*.

The main insight: The graph demonstrates that both wellbore inclination and friction factor have a major impact on tripping loads. As either increases, the drag force grows significantly. This analysis is vital for planning safe tripping operations and ensuring the hoisting system can handle the maximum expected loads, especially in the open hole section.

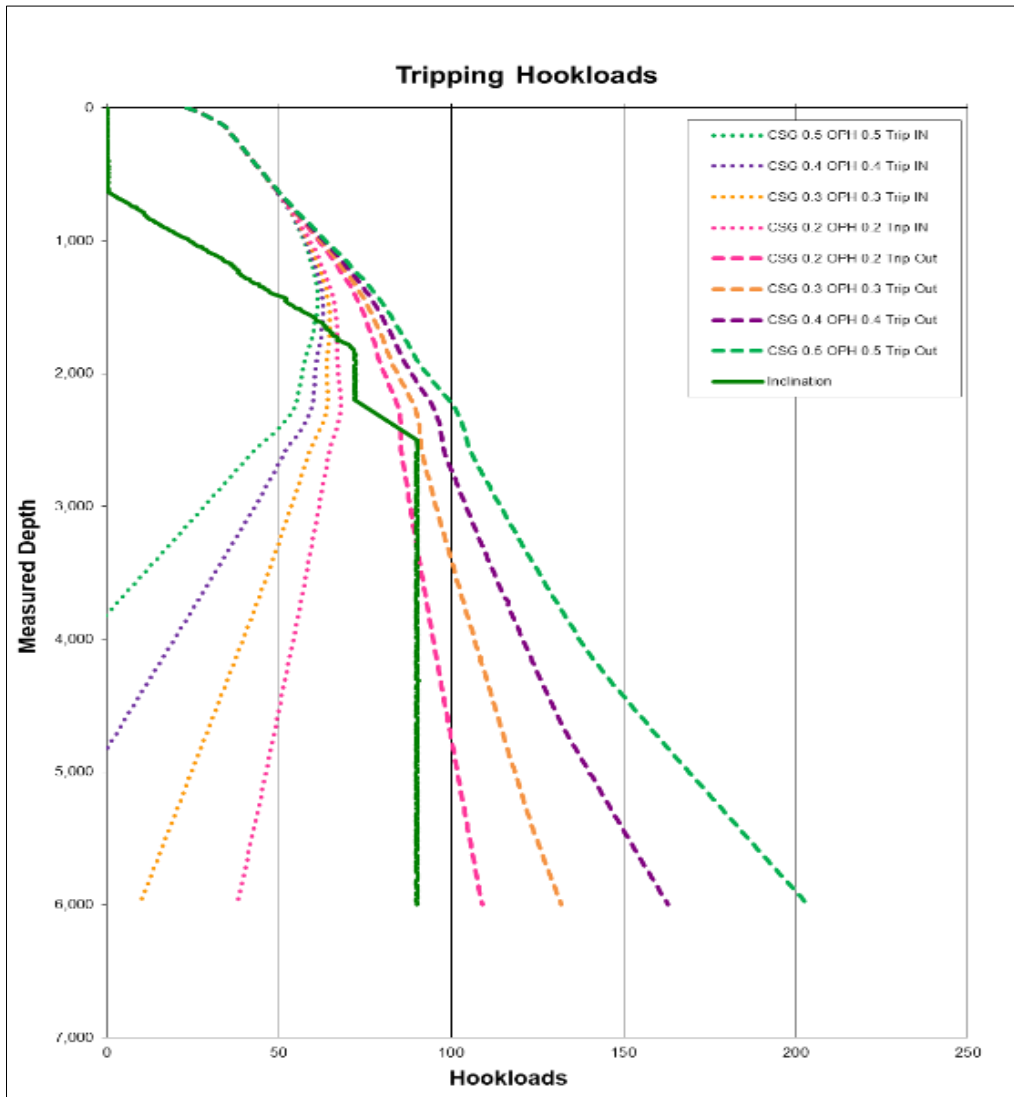


Figure 14. Simulated Tripping hook Load profile vs. Measured Depth with different FF for RSS BHA.

Figure 15 simulates the axial load analysis at 6000 m shows that the RSS bottom-hole assembly operates within safe mechanical limits throughout the wellbore. Axial loads increase with depth and inclination, reflecting higher drag and contact forces in the deviated and horizontal sections. Trip-out and back-ream operations exhibit the highest loads, but all values remain below the sinusoidal and helical buckling thresholds, indicating stable string behavior. Overall, the analysis confirms that the RSS assembly maintains structural integrity and efficient weight transfer along the entire wellbore.

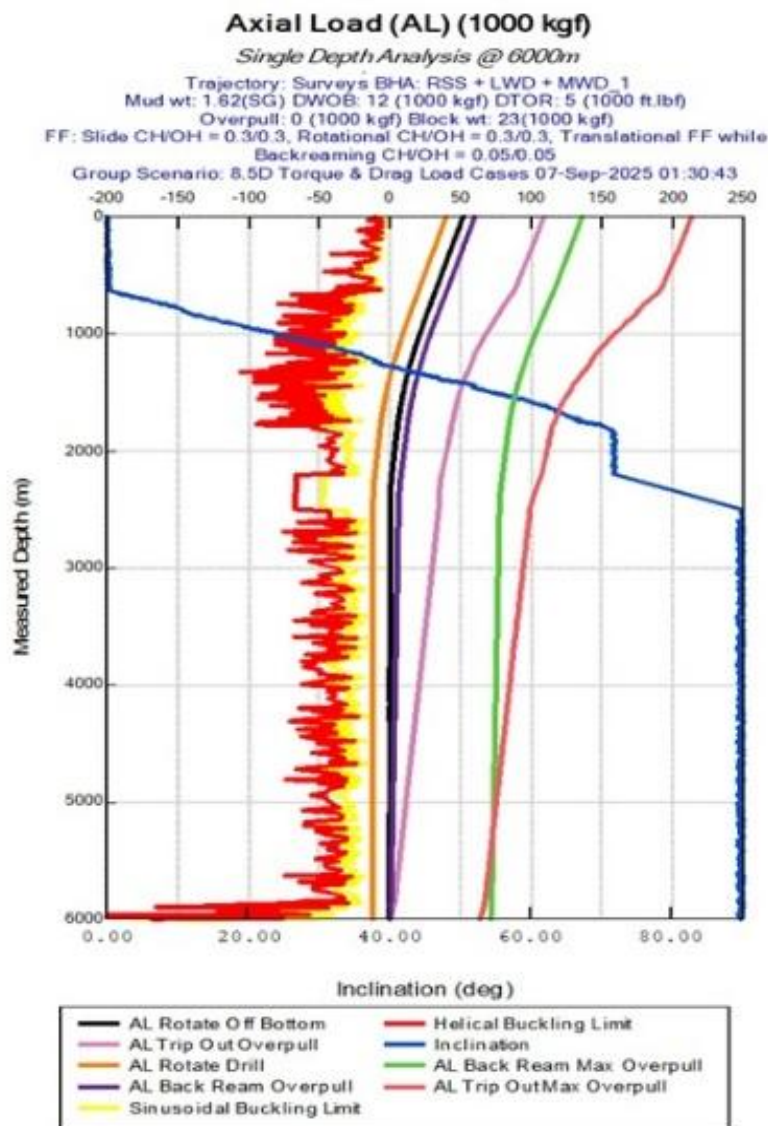


Figure 15. Simulated Axial Load profile vs. Measured Depth for RSS BHA

The absence of buckling or excessive load peaks demonstrates effective hole cleaning, optimized weight-on-bit (WOB) management, and controlled frictional behavior under the given mud and trajectory conditions. In Figure 16 results shows that both sinusoidal (orange) and helical (red) buckling margins remain positive throughout the well depth, indicating that

axial compression loads are within safe limits and the drill string is not at risk of mechanical buckling. Minor margin reductions at deeper intervals correspond to increased compression near the bit and higher frictional contact forces in deviated sections. The applied DWOB of 12,000 kgf and consistent margins across the analyzed depth confirm effective weight transfer and good borehole geometry. Overall, the analysis verifies that the RSS BHA maintains structural stability and operates well below the critical buckling thresholds under the given downhole loading and friction conditions.

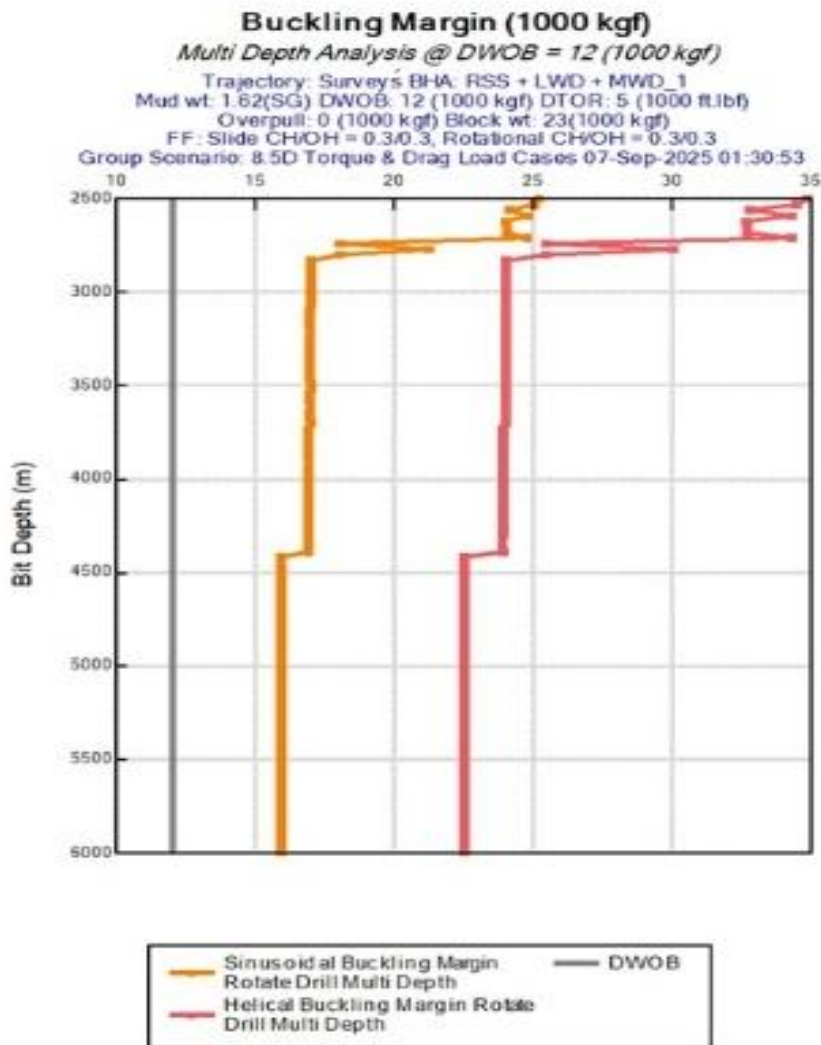


Figure 16. Simulated buckling margin profile vs. Measured Depth for RSS BHA

Figure 17 shows the torque analysis at 6000 m indicates a progressive increase in torque with measured depth and inclination, reflecting greater frictional resistance as the well transitions from vertical to high-angle and near-horizontal sections. The rotational torque remains consistently lower than the back-reaming torque, highlighting additional drag forces during upward string movement. Friction factor values (0.3–0.5) suggest moderate contact conditions and effective mud lubrication.

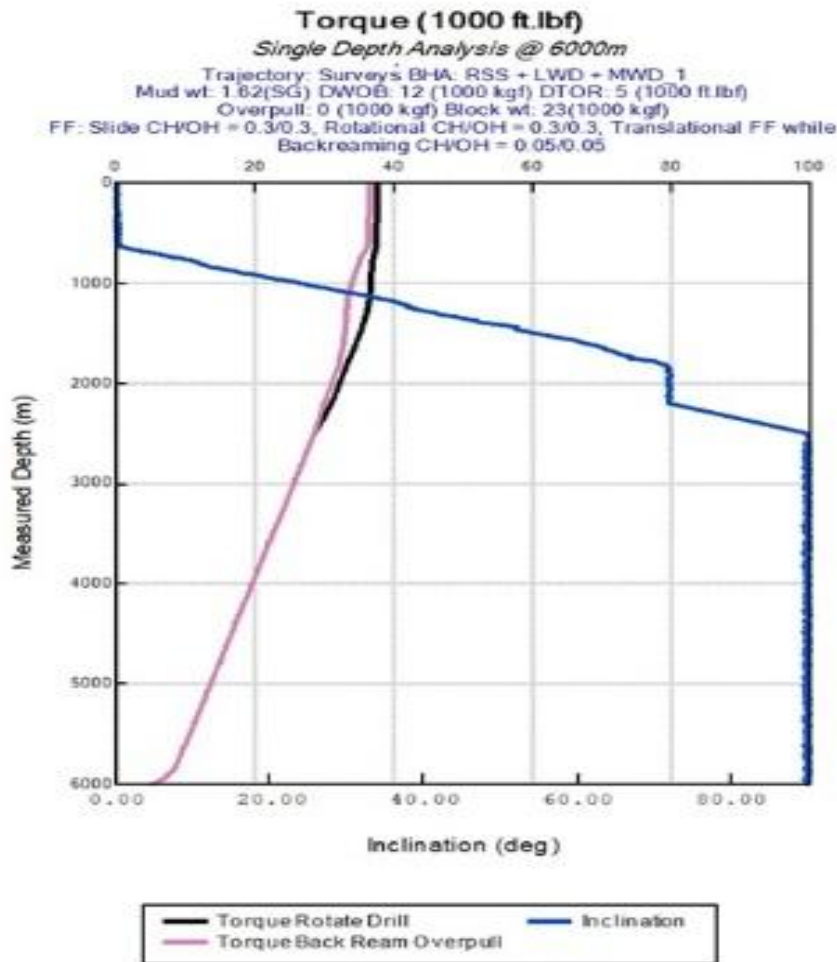


Figure 17. Torque Load profile vs. Measured Depth for RSS BHA

The absence of torque spikes or irregularities implies good hole cleaning efficiency, stable drilling dynamics, and minimal risk of mechanical sticking throughout the analyzed depth interval. Torque and Drag (T&D) analysis evaluates the mechanical loads acting on the drillstring during drilling and tripping operations. It helps determine whether surface torque, drag, and tension are within safe mechanical limits, and how efficiently torque is transmitted to the bit. This comparison examines the performance of a Rotary Steerable System (RSS) BHA versus a Positive Displacement Motor (PDM) BHA under equivalent conditions.

RSS BHA Rotary Steerable System are configuration: Fully rotating assembly with bit, stabilizers, MWD/LWD tools, RSS unit, and HWDP. Continuous surface rotation eliminates slide drilling.

Key Results:

- **Max Hookload (Trip Out):** $\approx 104.6 \times 10^3$ kgf, (PDM suffers from higher frictional drag),
- **Min Hookload (Trip In):** $\approx 23 \times 10^3$ kgf,

- **Drilling WOB:** 12×10^3 kgf,
- **Surface Torque:** $\approx 15.5 \times 10^3$ ft·lbf (PDM loses approximately 65 % of torque to friction)
- **Downhole Torque (at Bit):** $\approx 5 \times 10^3$ ft·lbf,
- **Von Mises Stress:** $\approx 35.8 \times 10^3$ psi,
- **Torque Efficiency:** Moderate (≈ 35 %) (PDM dissipates energy in sliding),
- **Side Force:** $\approx 5.5-7.0 \times 10^3$ kgf / 10 m (Sliding contact in PDM creates higher side forces).

RSS BHA run interpretation

- Continuous rotation produces and Significant/Wide PU–SO drag spread (Static friction during sliding increases the load gap).
- Smooth torque profile with minimal stick-slip.
- High torque transfer efficiency ($\approx 70\%$).
- No buckling observed; all stresses within safe design limits.
- Ideal for long lateral and extended-reach wells due to predictable mechanical performance and good hole cleaning.

PDM BHA Motor Assembly

Configuration: Includes bent motor, stabilizers, bit, and MWD. Operates in alternating slide (no rotation) and rotate modes, with higher friction during sliding.

Key Results are as follows:

A higher value reflecting the increased drag of a non-rotating string (e.g., $\approx 118.5 \times 10^3$ kgf),

Min Hookload (Trip In): $\approx 23 \times 10^3$ kgf,

Max Hookload (Trip Out): $\approx 118,5 \times 10^3$ kgf (PDM suffers from higher drag),

Drilling WOB: 12×10^3 kgf,

- **Surface Torque:** A significantly higher value reflecting the 65 % loss in efficiency (e.g., $\approx 31.2 \times 10^3$ ft·lbf),
- **Downhole Torque (at Bit):** $\approx 5 \times 10^3$ ft·lbf (limited by motor stall torque),
- A value that reflects the higher mechanical strain of sliding (e.g., $\approx 42.1 \times 10^3$ psi),
- **Side Force:** $\approx 3.8 \times 10^3$ kgf / 10 m.

PDM BHA run interpretation:

- Higher drag during slide mode due to lack of surface rotation.
- Larger PU–SO gap, indicating higher friction losses.
- Significant torque losses ($\sim 65\%$) observed in PDM, with more stick-slip.
- Slightly higher side forces, increasing wear and stuck-pipe risk.
- Suitable for short directional intervals, less efficient for long laterals.

The comparative T&D results confirm that continuous rotation of an RSS BHA minimizes static to dynamic friction transitions, resulting in smoother torque transmission and lower drag forces. The Motor BHA, though mechanically simpler, exhibits higher frictional energy dissipation during sliding, reflected by increased side-forces and torque losses.

These findings underscore the mechanical efficiency of RSS tools in extended-reach wells, where managing drag and torque directly dictates achievable lateral length, ROP, and risk of stuck pipe. Tabel 4 shows a comparative insights of RSS vs Motor BHA.

Table 4. Comparative Insights of RSS BHA compared to Motor BHA

<i>Aspect</i>	<i>RSS BHA</i>	<i>Motor BHA</i>	<i>Engineering Meaning</i>
Operational Mode	Fully rotating	Alternating slide/rotate	RSS yields continuous torque distribution
Torque Transfer Efficiency	High ($\approx 70\%$ losses)	Moderate ($\approx 35\%$ losses)	PDM dissipates energy in sliding
Side Forces	Moderate	Higher	Sliding contact leads to more wear
Frictional Drag	Lower	Higher	Explains larger PU-SO spread
Stress Utilization	Balanced	Slightly lower	RSS distributes loads over longer interval
Buckling Risk	Very low	Slight during slide	RSS maintains steady tension
Operational Implication	Smooth, efficient, less drag \rightarrow ideal for long laterals	Acceptable for short directional intervals	

While T&D simulations confirm mechanical viability, success in the 3,500 m lateral section is contingent on maintaining an **ECD** within the 1.62 SG mud weight window.

Analysis using the HCI model indicates that a minimum flow rate and a pipe rotation of **120+ RPM** are required to prevent cuttings bed accumulation, which otherwise would increase simulated torque by an additional **15-20%**.

While T&D simulations confirm mechanical viability, success is contingent on maintaining an Equivalent Circulating Density (ECD) within the 1.62 SG mud weight window. Analysis using the HCI model indicates that a pipe rotation of 120+ RPM is required to prevent cuttings bed accumulation, which would otherwise increase simulated torque by an additional 15–20%

CONCLUSIONS

This comprehensive feasibility study demonstrates that the conversion of the J-shape well IQ-KRI-78 into an Extended Reach Drilling (ERD) well is technically feasible and represents a strategically viable method for unlocking additional reserves.

The core of this assessment, a rigorous Torque and Drag (T&D) analysis, confirms that the planned 8 ½" section can be successfully drilled to a total depth of 6000 m MD, provided that specific engineering solutions and operational protocols are strictly followed.

The success of this conversion hinges on the critical finding that a two-part BHA strategy is essential to manage the distinct technical challenges of the well path.

The initial build section (2200 mMD to 2500 mMD), utilizing a Positive Displacement Motor (PDM), was shown to operate within safe mechanical limits for buckling and torque.

However, the subsequent long lateral section (2500 mMD to 6000 mMD) unequivocally requires a Rotary Steerable System (RSS).

The T&D simulations conclusively show that the RSS, by enabling continuous rotation, effectively mitigates the prohibitive drag forces that would otherwise be encountered with a PDM in sliding mode, thereby keeping surface torque and hook loads within the operational envelope of the drill string.

Key to this feasibility is the carefully engineered smooth well trajectory, which builds angle to 90 degrees with a minimal dogleg severity, effectively managing frictional forces.

The analysis further verifies that under the planned parameters and with appropriate friction factors, the drill string maintains positive margins against sinusoidal and helical buckling, ensuring efficient weight transfer to the bit and overall mechanical integrity.

However, to translate this on-paper feasibility into a successful field operation, several critical recommendations must be implemented:

Upgraded Casing Weight: The existing 9 5/8", 47# L-80 casing is adequate but not optimal. It is strongly recommended to use a heavier weight, such as 9 5/8", 53.5 or 68# L-80, in future analogous projects to better sustain long-term wear and well integrity during drilling and subsequent servicing.

Enhanced Rig Capacity: The original 1500 HP rig is insufficient. The project requires a rig with a minimum of 2000-3000 HP to provide the necessary hoisting power, torque, and hydraulic energy for the extended reach.

Optimized Drill Pipe Size: Replacing the 5" drill pipe with 5 1/2" or 5 7/8" drill pipe is essential to provide greater torsional strength and hydraulic efficiency, reducing the risk of torque limitations and improving hole cleaning in the long horizontal section.

In summary, this study provides a validated engineering roadmap for the conversion. By integrating an optimized trajectory, the strategic application of RSS technology, and the implementation of the specified equipment upgrades, the extended reach objectives for Well IQ-KRI-78 can be achieved safely and efficiently.

This project underscores that a disciplined, T&D centric approach is not merely a planning exercise but a fundamental prerequisite for successfully transforming existing wellbores into valuable, extended reach assets.

Final results are as follows:

- **Feasibility:** The conversion of IQ-KRI-78 is technically viable provided a two-part BHA strategy is utilized.
- **BHA Strategy:** The 3,500 m lateral unequivocally requires an **RSS BHA** to keep surface torque and hook loads within the operational envelope.
- **Infrastructure:** A rig upgrade to **2,000–3,000 HP** and a drill pipe upgrade to **5 1/2"** are essential for the required torsional strength and hydraulic energy

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