# Torque Reduction and Buckling Mitigation for Drilling Highly-Deviated Geothermal Wells

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*Torque, buckling, lateral, casing protection, NRP, non-rotating protector, AGS, EGS, hydrothermal, RSS*

## ABSTRACT

As directional drilling becomes more prevalent in geothermal wells with hydrothermal, Enhanced Geothermal System (EGS), and Advanced Geothermal System (AGS) wells, a host of issues may arise. With higher side forces on the wellbore and harder formations, factors including casing wear, drill pipe wear, parasitic torque and drag along the drill string, and buckling can become major challenges. If torque exceeds the limit of the drill string or rig, it could prevent completion of the well. Further developing the high-grade geothermal western United States, an operator in Nevada experienced high torque and excessive buckling while drilling the lateral section of an EGS injector well. Mechanical non-rotating friction reduction tools were investigated as a solution. High temperature, non-rotating friction reduction tools are often used in geothermal wells in the Salton Sea area for casing protection. A high strength version of these tools to withstand the high side forces was tested to provide drill pipe standoff for torque reduction and buckling mitigation. In a 11,500 ft (3,500 m) MD geothermal well with a 3,500 ft (1,067 m) lateral section, torque was reduced by 14% allowing for smooth drilling operations to TD. The friction reducers showed minimal wear and no signs of significant damage. Use of these tools on subsequent wells provided similar results indicating non-rotating friction reducers as an effective solution to casing wear, drill pipe wear, parasitic torque and drag, and buckling.

## 1. Introduction

Directional drilling is the practice of drilling wells with intentional deviation. This practice allows for efficient thermal extraction and reaching otherwise inaccessible formations. Directional drilling is fundamental for Enhanced Geothermal System (EGS) and Advanced Geothermal System (AGS) wells where efficient placement and accuracy is crucial for success. Challenges that come from added deviation in a wellbore include casing wear, drill pipe wear, and parasitic torque and drag along the drill string due to the drill string being pressed against the formation. Buckling can become an issue when horizontal directional drilling is implemented as the drill string will be in compression in the lateral section. When buckling becomes severe, it can prevent weight transfer to the bit, effectively halting drilling operation. If torque exceeds the limit of the drill string or rig, it also could prevent completion of the well. An operator drilling an EGS well in Nevada experienced high torque and buckling while drilling the lateral section of an injector well. Torque reached levels causing the planned TD to be shortened, and the operator investigated methods of reducing the parasitic torque. Non-rotating protectors (NRPs) were determined as a potential solution. High-temperature NRPs are often used in geothermal wells in the Salton Sea, USA area for casing protection. Although these NRPs were strengthened to a rating of 2,000 lb per 31 ft (range 2 drill pipe joint length), side forces in directional wells can reach more than this rating. Accounting for the planned well path, actual surveys, drill string, drilling fluids, and drilling parameters, a conventional torque and drag analysis was conducted to evaluate the estimated torque and drag along with methods to manage these parasitic factors. In a 11,500 ft (3,500 m) geothermal well with a 3,500 ft (1,100 m) lateral section, estimated side force reached up to 3,700 lbs per joint length at TD resulting in torque over 25 kft-lbs.

## 2. Evaluation of Current Methods

The high temperatures and occasionally hard formations of geothermal wells present a challenge for torque reduction and buckling mitigation. A few methods currently used are to optimize well geometry, add lubricants to the drilling fluid, and using a rotary steerable system (RSS) in place of a mud motor with a bent housing.

### *2.1 Optimizing Well Geometry*

Cost, infrastructure, and permitting may dictate the well shape, however the adoption of horizontal drilling for oil and gas carries over nicely into extending wellbore exposure into a geothermal reservoir. However, wellbore can only be adjusted to an extent based on surface and reservoir location.

### *2.2 Drilling Fluid Additives*

Adding lubricants or other additives to the drilling fluid can be an effective method of decreasing torque and drag across the entire wellbore. However, cost, environmental impact, and high temperatures may prevent use of drilling fluid additives or lubricants. Since geothermal wells often have faults and lost circulation zones, effectiveness of lubricants is reduced. Additionally, additives may complicate or foul mud coolers at the surface.

### *2.3 Using a Rotary Steerable System (RSS) Drilling Assembly*

While the use of an RSS allows for a less tortuous wellbore, it is currently cost prohibitive for geothermal wells with relatively simple well paths and 5,000 ft lateral lengths compared to complex oil and gas wells. Further, the gyro steering instruments of the RSS require 120 RPM speed to function, accelerating casing and drill pipe wear.

## 3. Non-Rotating Protector Evaluation for Drilling

Mechanical friction reducers or non-rotating protectors (NRPs) are attached on the drill pipe near the tool joint with axial stop collars allowing a sleeve to freely rotate on the drill pipe, providing standoff and reducing torque. These tools can be strategically placed along the drill string to target only the areas containing high side force that cause the most parasitic friction and wear. Based on experience using NRPs for casing protection in the Salton Sea, USA geothermal field, a contractor sought assistance in drilling a horizontal well in a new geothermal field in Nevada.

### *3.1 NRP Adaptation*

The Salton Sea geothermal field is approximately 500°F and pH of 2, highly corrosive for the casing. Further, the steel pipe drilling across casing causes galvanic corrosion of the dissimilar materials. Rubber rotating casing protectors are commonly run in cased hole but can detach to cause non-productive time (NPT). A high-temperature NRP for use in open-hole shown in Figure 1 was developed for improved protection of titanium and super-duplex stainless steel casing. Years of use of NRPs in this field established the tool as a common practice and development to a more robust design made NRPs attractive to operators in other fields, such as the developing field in Nevada. The robust design in Figure 2 included a dual hinge allowing for a stronger structure and rubber to be used.

**Figure 1: High-temperature non-rotating protector sleeve**

**Figure 2: Improved high-temperature non-rotating protector sleeve with dual-hinge design**

**Figure 3: Improved high-temperature non-rotating protectors installed on drill pipe**

### *3.2 Trial Well #1*

A total of 117 x 5" NRPs were installed to drill the remaining 800 ft of a 9-7/8" hole section of an injector well in a new field in Nevada. Figure 4 shows NRPs installed in the areas of deviation that cause side force, torque, and drag.

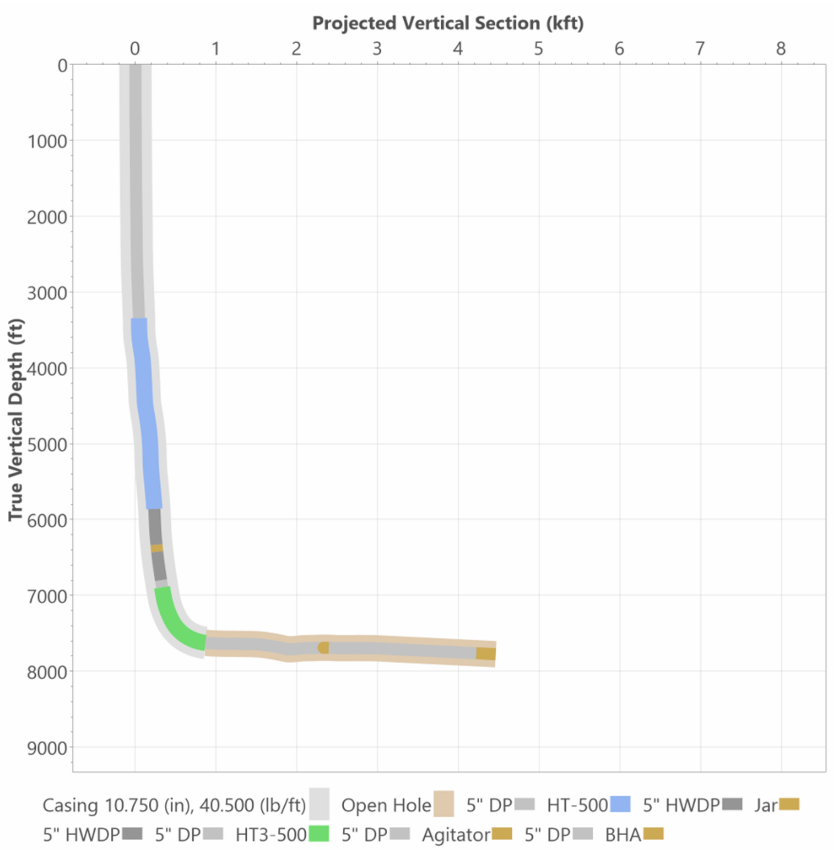


**Figure 4: Well #1 shape and NRP placement in colored zones**

The well deviations or doglegs cause side force seen in Figure 5, but also casing wear that can shorten the usable life of casing, particularly steel casing susceptible to corrosion at high geothermal temperatures. Further, wellbore pressure integrity is needed when using the casing to hydraulicly fracture less-permeable formations for enhanced stimulation or production from the reservoir.

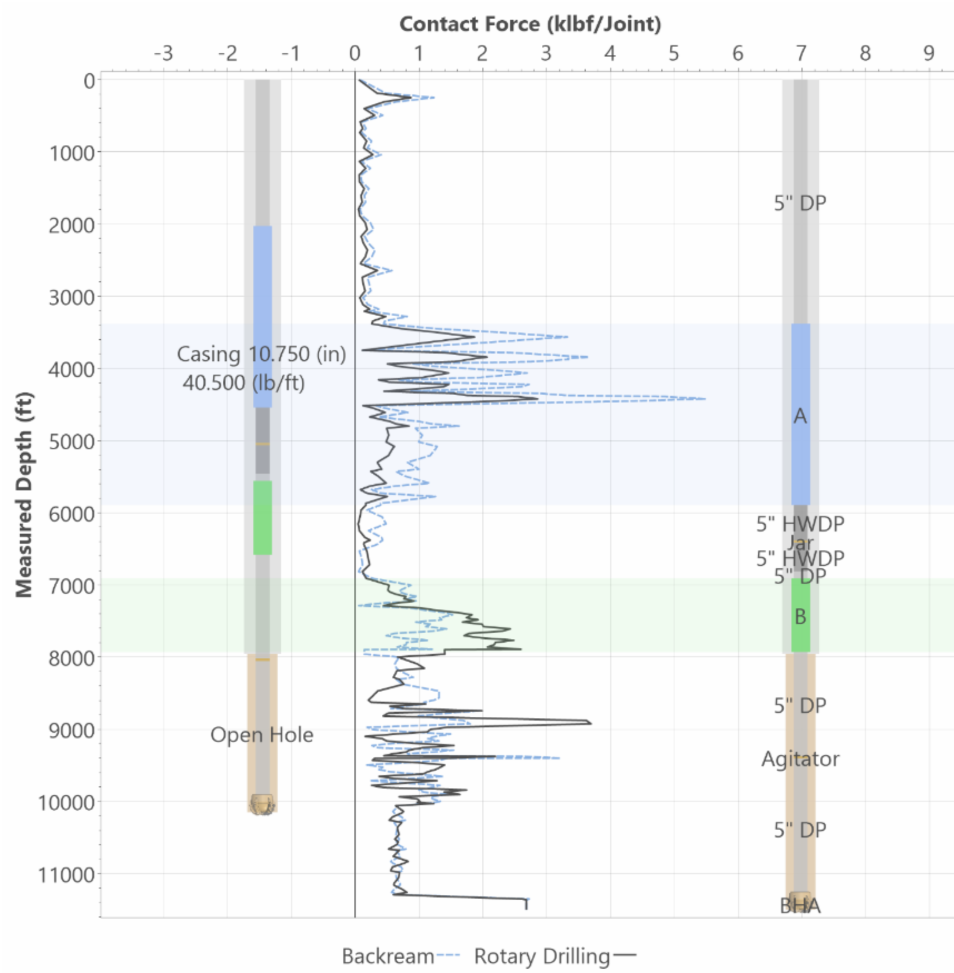


**Figure 5: Well #1 estimated side forces while drilling and backreaming.**

Rate of penetration (ROP) while drilling the hard granite formation was 10 to 30 ft/hr, an opportunity for improvement with more weight on bit (WOB) or bit selection with future wells.

The open hole was reamed and logged before a successful trial/dummy casing run with fiber optic cable attached before NRPs were removed. Running sensitive fiber optic cable on the casing may be used for temperature monitoring for energy production at the surface. Had the trial casing run been unsuccessful, further reaming of the hole would have occurred to ensure the casing reached well bottom.

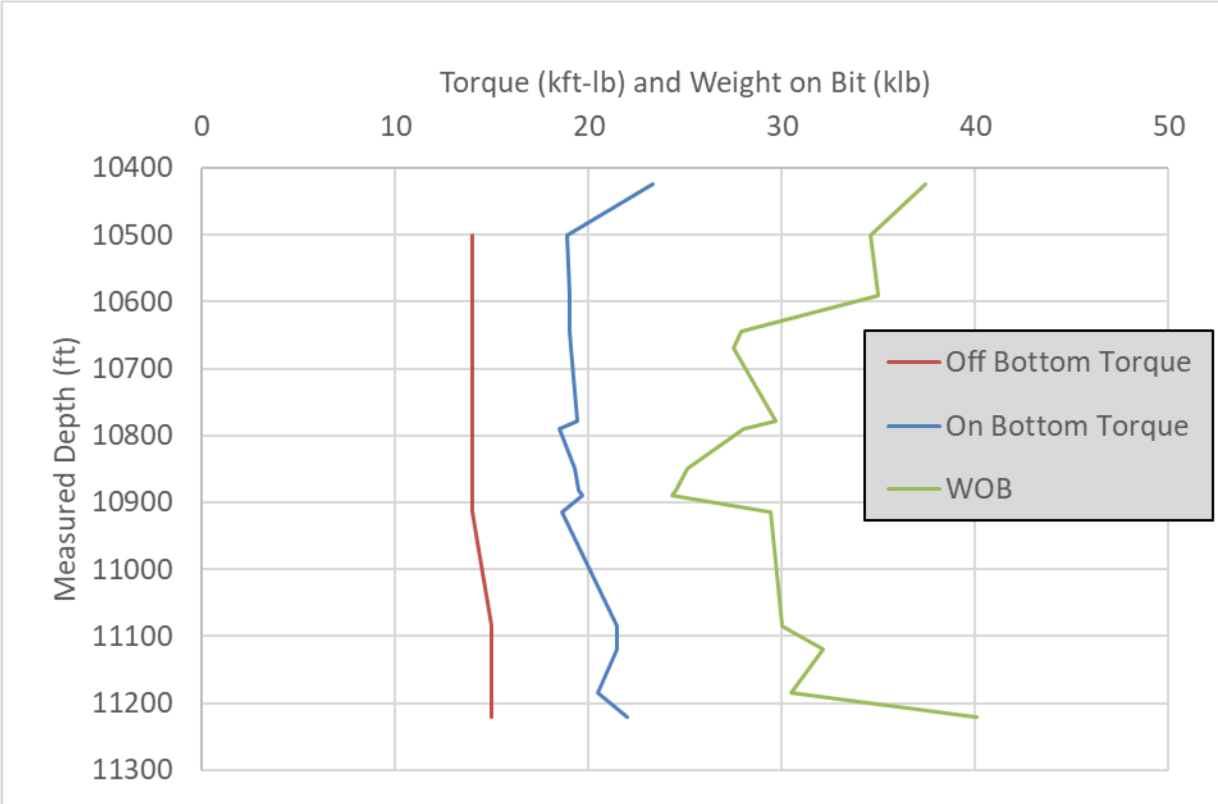


**Figure 6: Well #1 drilling parameters showing steadily increasing torque and decreasing WOB with NRPs installed.**

Knowing the local friction reduction of NRPs from other wells, the data indicates NRPs provided a 14% torque reduction in surface torque. In horizontal wells much of the surface torque is generated by the parasitic friction along the drill pipe, inhibiting delivering torque to the bit as intended. The off-bottom torque in Figure 6 was consistent both while drilling ahead at 10,500 ft and tripping out. This indicates good hole cleaning, due to the relatively low ROP. The protectors showed minimal wear and no signs of significant damage indicating that standoff was maintained for the entirety of the run, reducing drill pipe and casing wear. The operator was impressed with the performance and permitted use of NRPs on subsequent wells.

### *3.3 Trial Well #2*

A total of 87 x 5-1/2” NRPs were installed to drill the last 2,500 ft of the 9-7/8” hole section of a production well. The two wells were similar with exception of switching to 5-1/2” drill pipe for Well #2 and the lateral extending 5,000 ft (1,520 m) into the formation. Figure 7 shows the horizontal well shape for the production well.

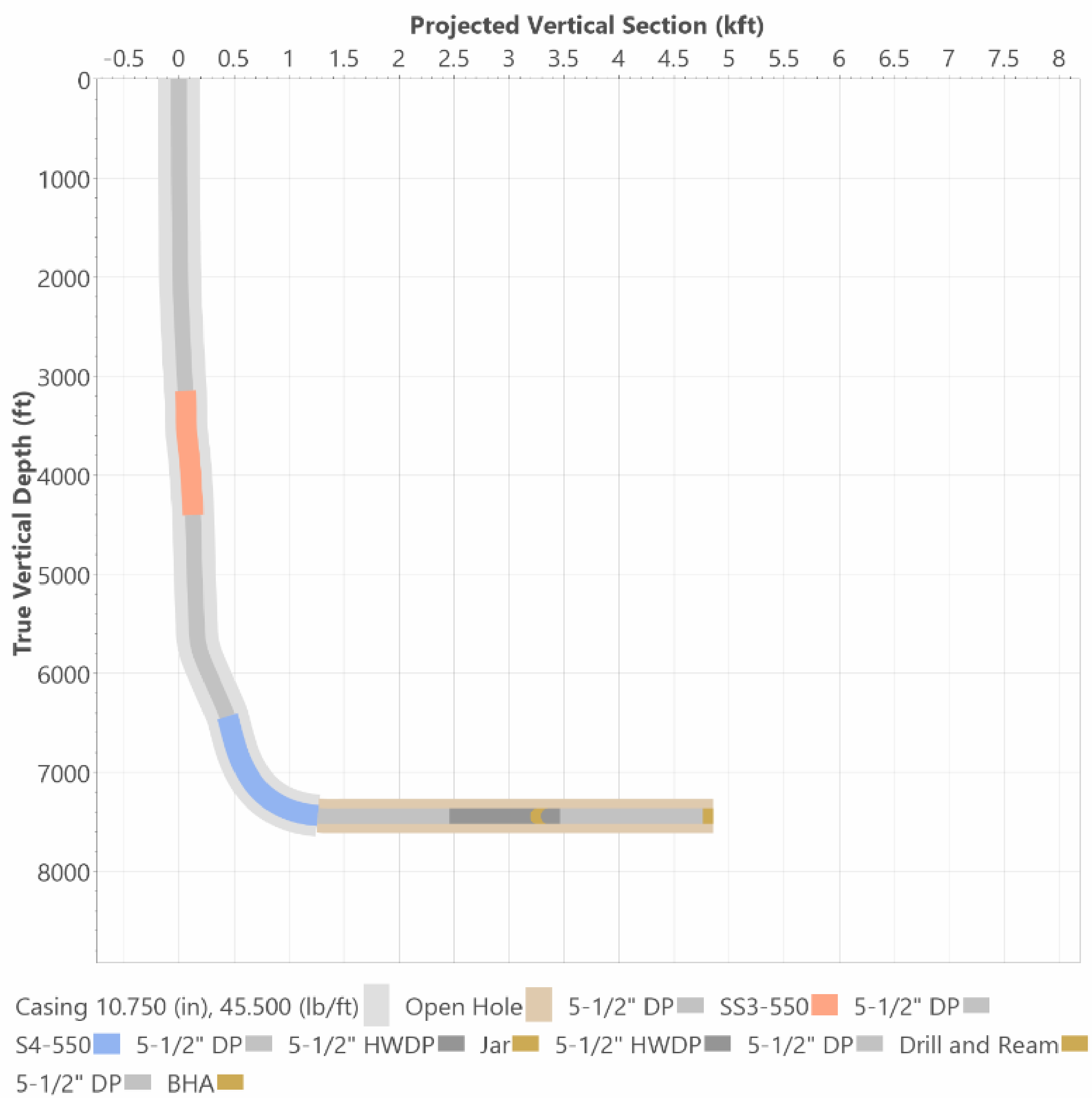


**Figure 7: Well #2 shape and NRP placement in colored zones**

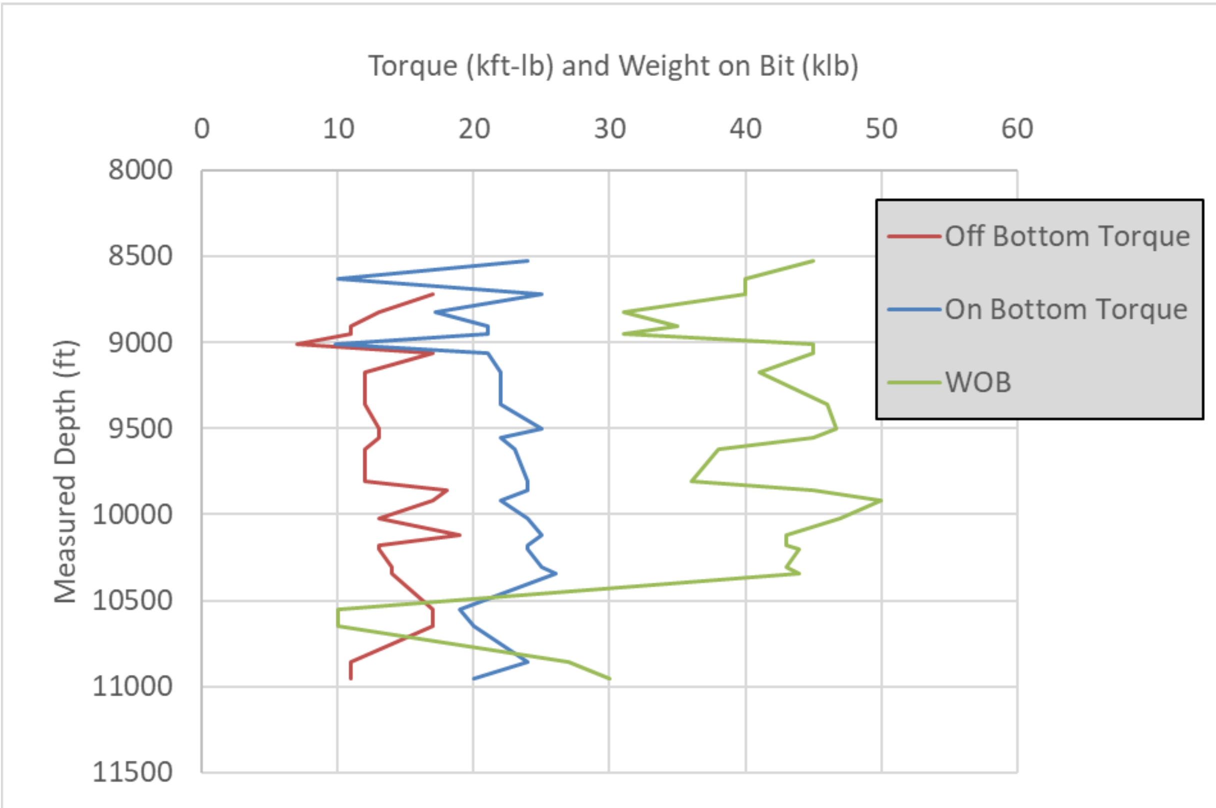


**Figure 8: Well #2 drilling parameters showing steadily increasing torque and decreasing WOB with NRPs installed.**

The data indicates NRPs provided an 8% torque reduction on Well #2 as fewer NRPs were used. The open hole was logged and NRPs were removed while laying down drill pipe.

The torque of the two wells was similar, though Well #2 had greater WOB as seen in Figure 8. Considering the rig and drill pipe could deliver 30 kft-lb, future wells could have extended laterals for greater exposure to the heat of the geothermal formation. With the use of NRPs, a rig with lower torque capacity could be used to reduce drilling cost. Or a larger open hole could be drilled to increase fluid volume flow to the reservoir, should casing pressure requirements allow.

## 4. Conclusion

Two long lateral wells with high deviations were successfully drilled with 5” and 5-1/2” drill pipe and the use of non-rotating protectors for casing protection and torque reduction.

Mechanical friction and wear reduction devices such non-rotating protectors are effective at reducing torque, protecting casing, and mitigating buckling to adopt directional and horizontal wells in geothermal drilling. Looking forward, highly-deviated geothermal wells, such as AGS and EGS, could benefit from a low-friction NRP for use in the open hole lateral to reduce drag and improve tripping operational efficiency.

While side forces that cause casing wear are usually towards the surface, horizontal wells with buckling of drill pipe across a hot geothermal lateral create a new challenge for friction devices. Further work to develop low-friction, high-temperature friction reducing NRP is ongoing.

**Acknowledgement**

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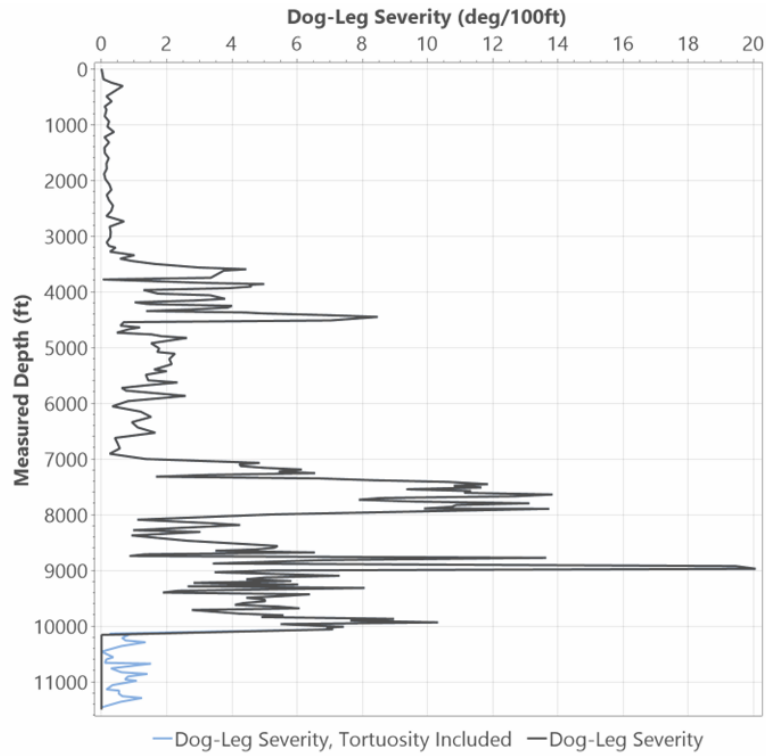
## REFERENCES

Tester, et al. "The Future of Geothermal Energy, Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century." Idaho National Laboratory, Idaho Falls, Idaho (2006)

**Appendix: Dogleg Severity Graphs**

Well #1




Well #2