

**Brownline**

# HDD Industry and Gyroscopic Navigation Intersects

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# HDD Intersect Crossings

- The intersect was invented to double the length of the HDD crossings.
- Since then, intersect projects have become common practice in the HDD industry.
- Today we see intersects being planned for other beneficial reasons even for relatively short crossings.
- To reduce the risks for blow outs, or with a casing on either side of the crossing in case of granular formations
- Several guidance systems are available for these intersects; however, it's not only the “intersect” which is important, more so, the integrity of the entire drill path.



# Introduction

- All steering systems will have tolerances, and often some corrections will be required to complete an intersect.
- Accurate steering will reduce the required intersect S-Curve where the bores meet.
- In this paper a typical (S-Curve) calculation will be made to show the implication of steering system tolerances.
- With a simplified mud pressure graph, I will explain why an intersect will reduce or mitigate blow out risks.



# Challenges of Long HDD Bores

- The HDD technology companies are always looking for innovations to push the limits of the trenchless industry.
- After several years of extending drill lengths to over 3000m from one side, the industry was looking for options to make even longer crossings and reduce the risks.
- This push in the industry had several challenges and required advancements in guidance technology.





# Challenges of Long HDD Bores

- The drill pipe dimensions over the years have increased substantially from 2-7/8" at the start of the HDD industry about 40 years ago, to 6-5/8", where even 7-5/8" drill pipe and bigger is not uncommon anymore.
- Even with these larger drill strings complications still exist to steer accurately over long distances.
- With very long HDD crossings it is not uncommon to have a large amount of torque within the drill string when steering and rotating the drill head.



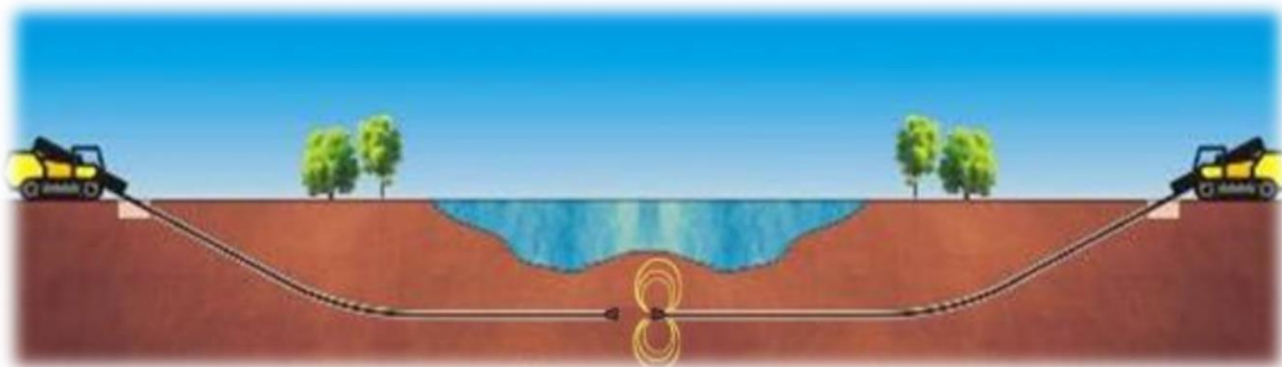
# Challenges of Long HDD Bores

- On long crossing projects, drill pipe torque can become quite high during drilling operations.
- Applying the use of a Gyro Steering Tool can reduce the related downhole torque over the length of a bore path over distance.
- Often, drill pipe can experience a couple of rotations on surface before any rotational movement at the BHA. This can make steering extremely challenging.
- For example: If you would like to steer directionally (Right / 3 O'Clock) it may be difficult to achieve this accurately with stored energy in the drill string.



# Tools for Intersects

- Vector Magnetics was the first company who developed a system where the distance between the two drill lines could be measured.
- This made intersect operation increasingly more successful.





# Tools for Intersects

- In the past, the intersect point was planned in a section where surface tracking could be done on both holes. This was difficult due to the limited accuracy of surface tracking specifically at greater depths.
- Often, although intersects were completed, the point of intersection was not within radial specifications. Once an intersect had been made, corrections to fix the radii could be time consuming and at times not achievable.
- Often, solutions would then be pushed into the reaming stages. For instance, by increasing the final ream sizes.





# Tools for Intersects

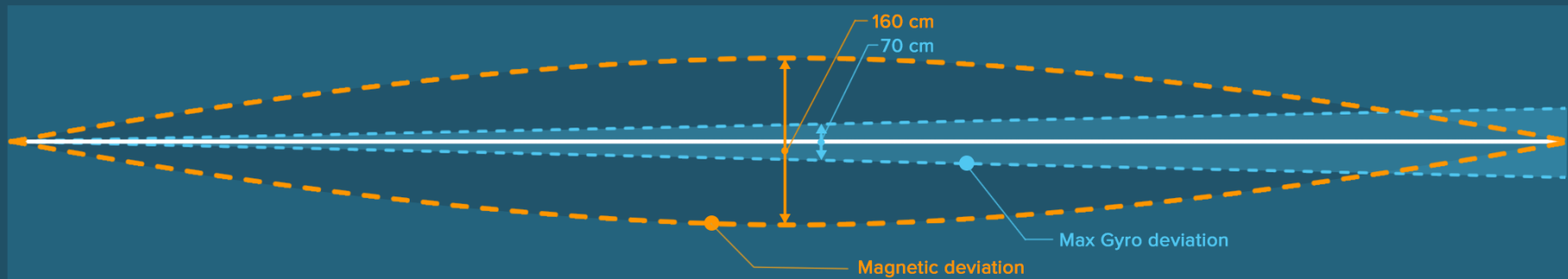
- The ultimate solution is to have a steering system that is not reliant on surface tracking.
- Greater accuracy allows for a smoother drill path and reduces the error at the intersect zone.
- With a Gyro Steering System this accuracy can be achieved, even with deep drillings or magnetic interferences.
- A smoother drill path translates to lower friction on the product line during installation.



# Theory

- Theoretical deviation for 40 m deep drillings without any interference

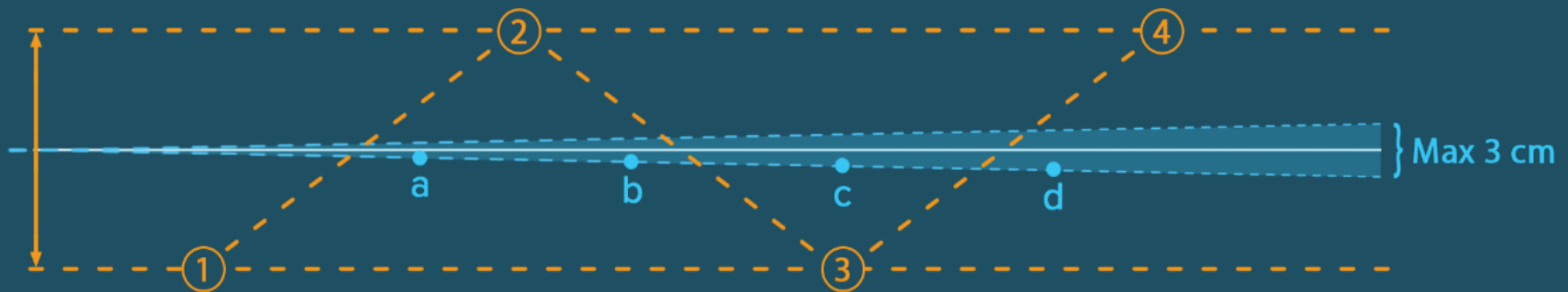
## Deviations comparison



# Tortuosity

- When comparing a magnetic tool to the Gyro Steering Tool, the tortuosity will be substantially lower with the GST, translating directly to lower pull forces.
- Many installed HDD lines are checked after installation, which proves the substantially lower tortuosity when using the Drillguide Gyro Steering Tool.

## Deviation 160 cm

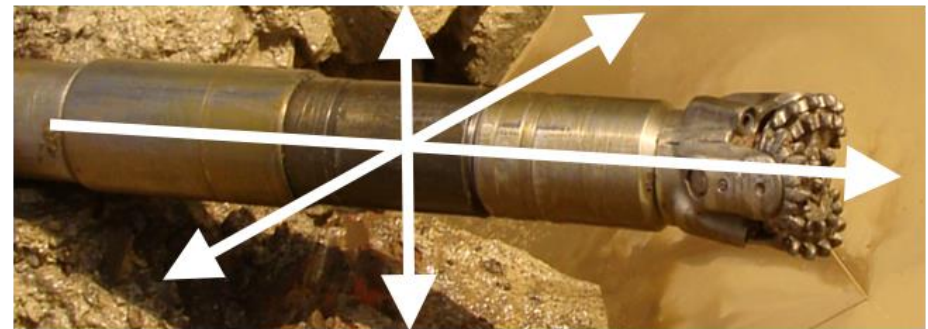
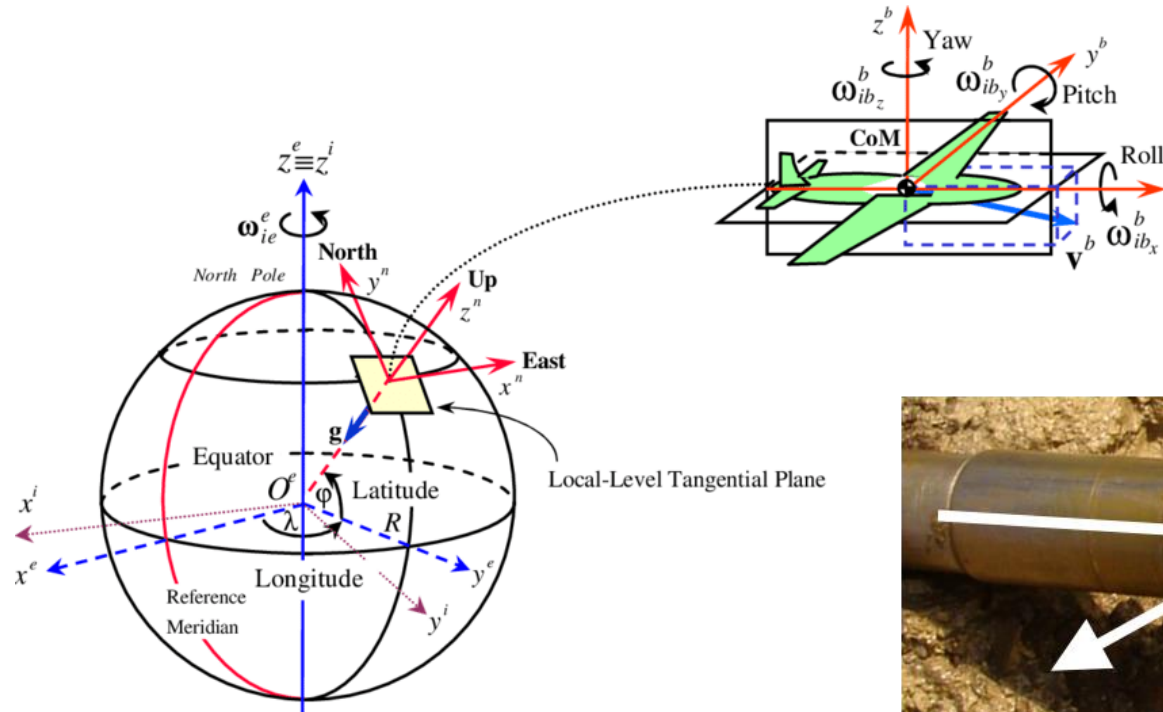


# Advantages of the Drillguide Gyro Steering Tool

- Not influenced by magnetic disturbances
- No setting up of conduit survey cables at the surface
- No surface access needed
- No restrictions for drilling in urbanized areas
- Unlimited drilling depth
- Continuous measuring while drilling
- Highest possible accuracy
- Smooth drill line, lower friction during sliding and pull back
- Fast setup time
- Real-time annular pressure measurements
- Measuring unit close to drill bit (no non-mags required)



# How it works



Z, Azimuth Axis

X, Roll Axis

# How it works

Setting of trajectory



Comparison planned and actual trajectory

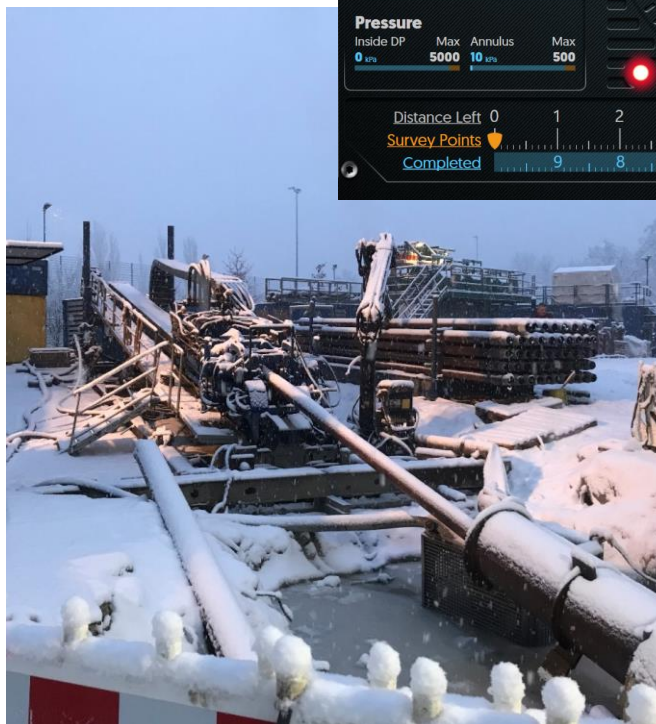


Calculation of the actual drill head trajectory in WGS-84 coordinates using:

- Measured length
- Azimuth
- Pitch



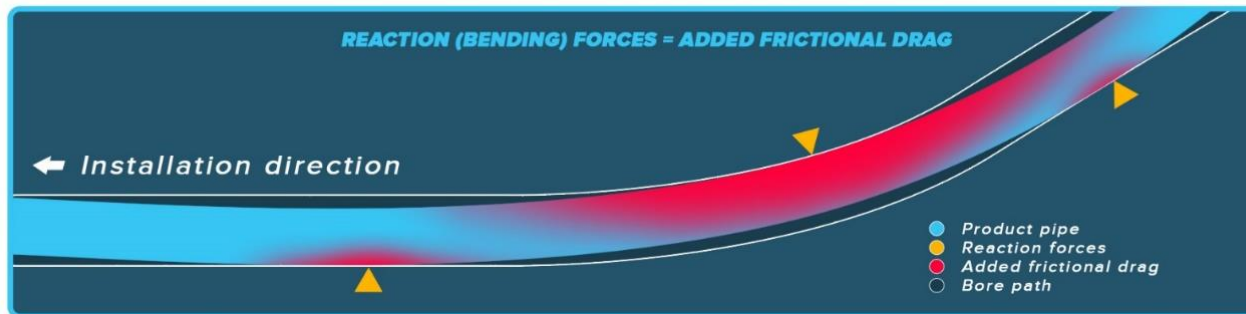
Wireline transmission  
10 times per second



User-friendly interface  
Hitting the target

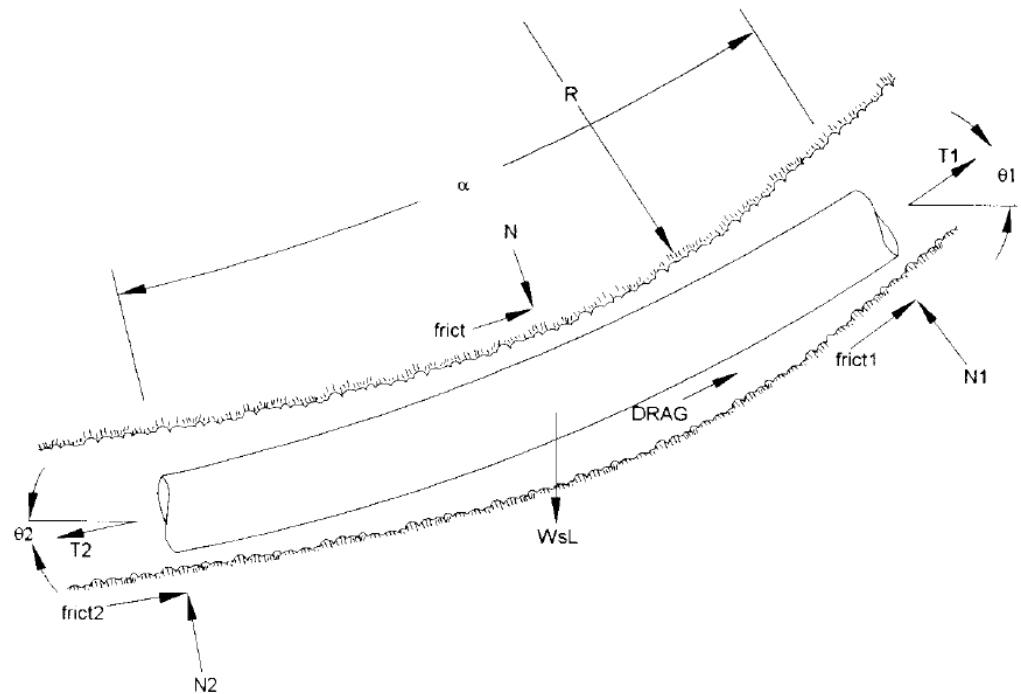
# PULL BACK IN TIGHT RADIUS BORE HOLE

INCREASED RISK OF STUCK PRODUCT PIPE / COATING DAMAGE



# Pull force and pipe stress

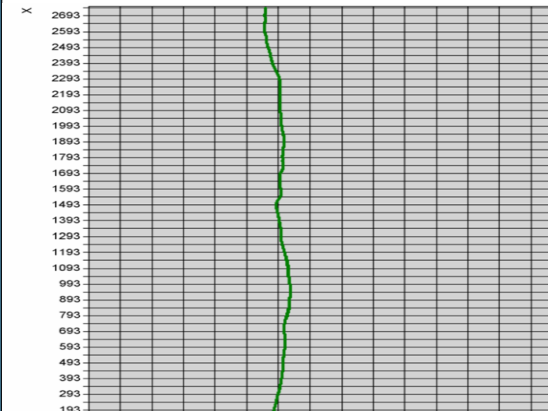
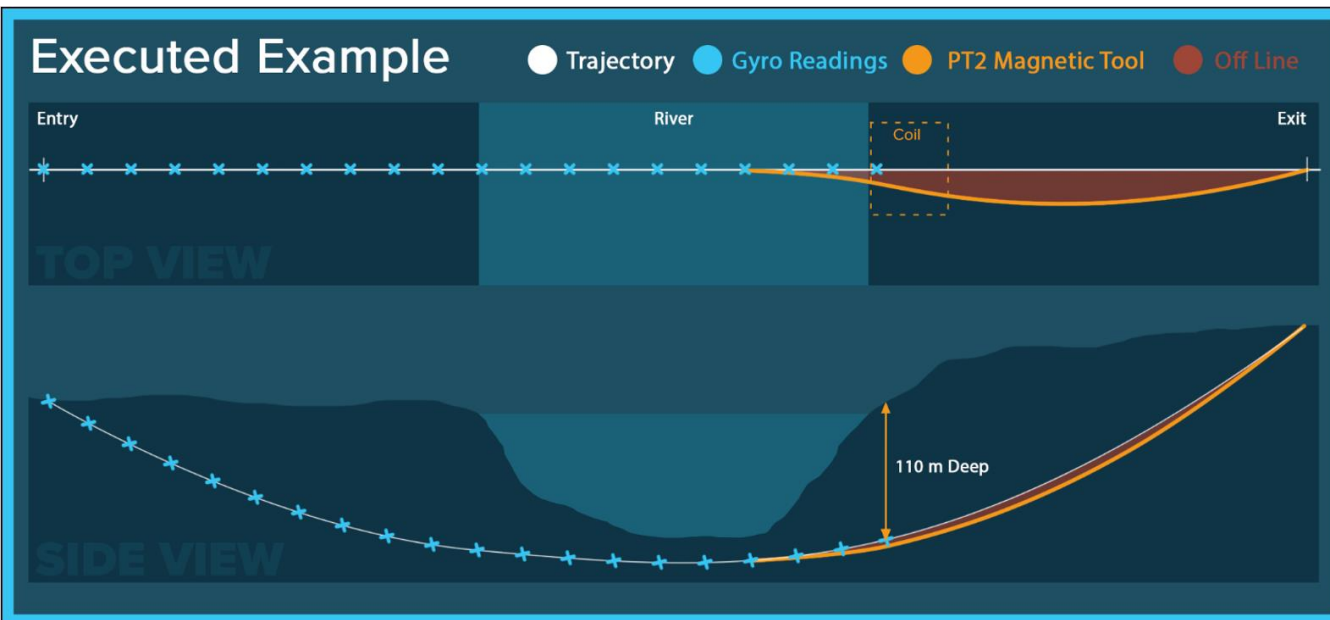
- If you drill with a radius 70% of the design radius, you will have in the bends a pro rata higher pipe stress caused by the bending radius
  - $\sigma = M/W$ , where  $M = E \cdot I / R$
  - If the radius is 70%, the pipe stress will be 140%





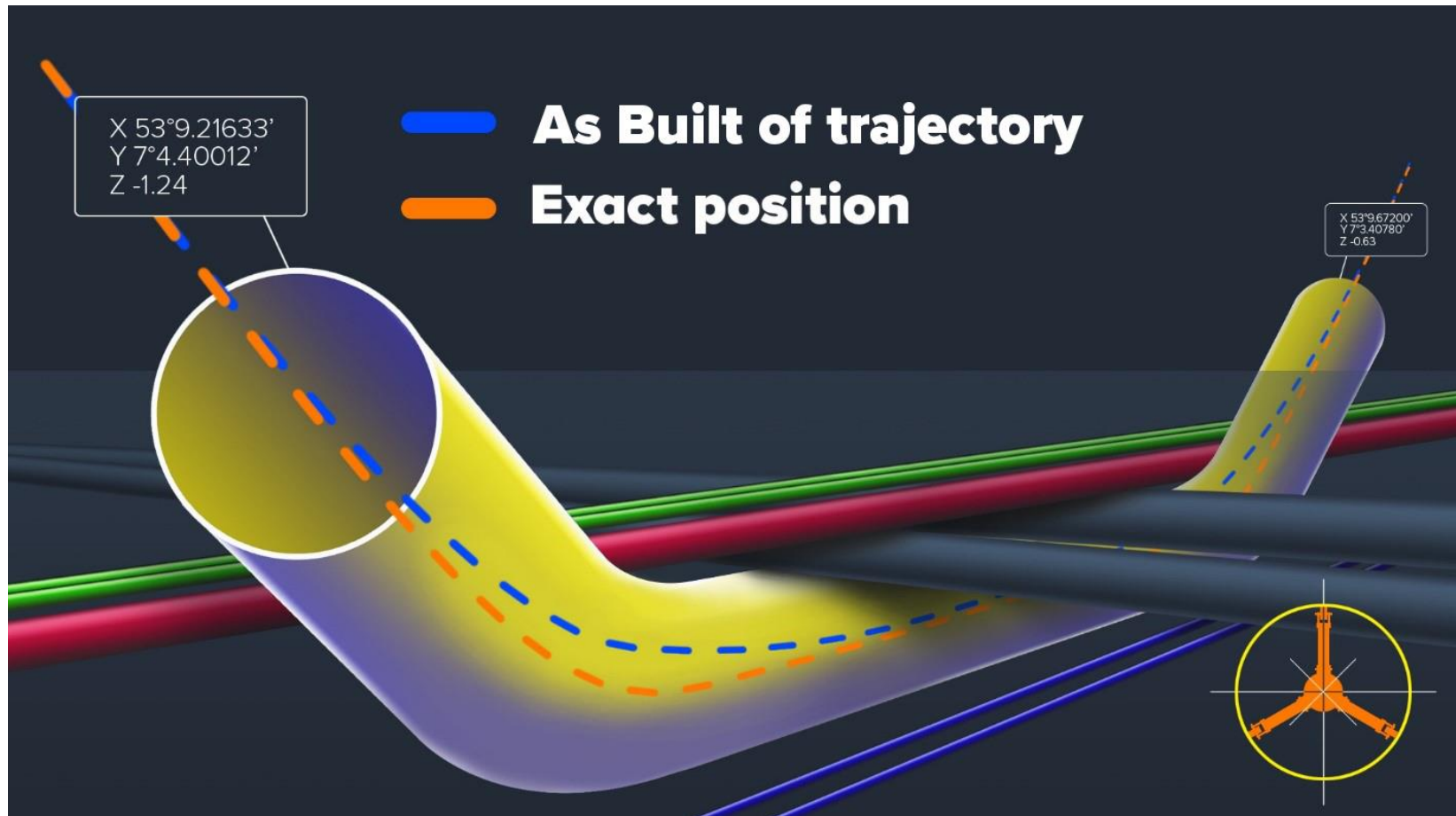
# Track check post installation

- True cases where a track check proved its purpose



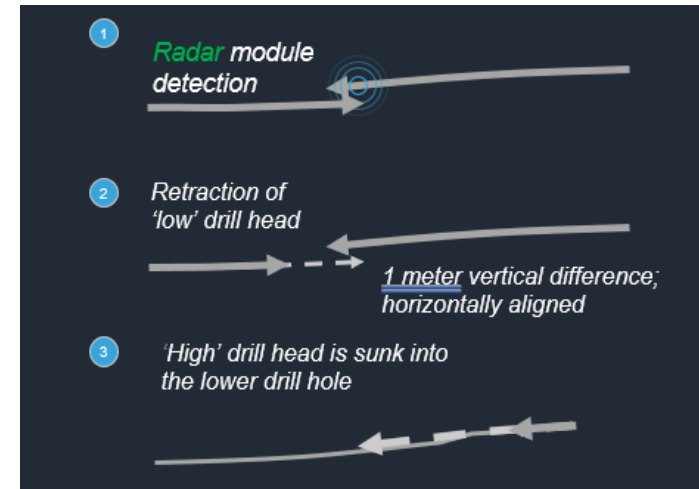


# Track check post installation



# Intersect procedure

- Contractors developed procedures to reduce the risk for damaging down hole tooling.
- The standard procedure is to retract one string and continue with the opposite drilling when reaching the intersect zone.
- During continuation of the drilling, pressure fluctuations can be good indicators for an upcoming intersect, and sometimes the drill string gradually floats in the opposite hole.
- If the intersect is completed at this first attempt, the BHA is pushed forward into the opposing hole and the intersect is measured for radii.
- Measurements are continued into the other hole to create an As Built over the entire drilling.



# Intersect procedure

- If no direct intersect is made, drilling is continued from one side until both steering systems are aligned.
- At this time the Radar system is activated and an exact deviation between the holes will be measured.
- This information is used to calculate the intersect curve based on separation and radii specifications.



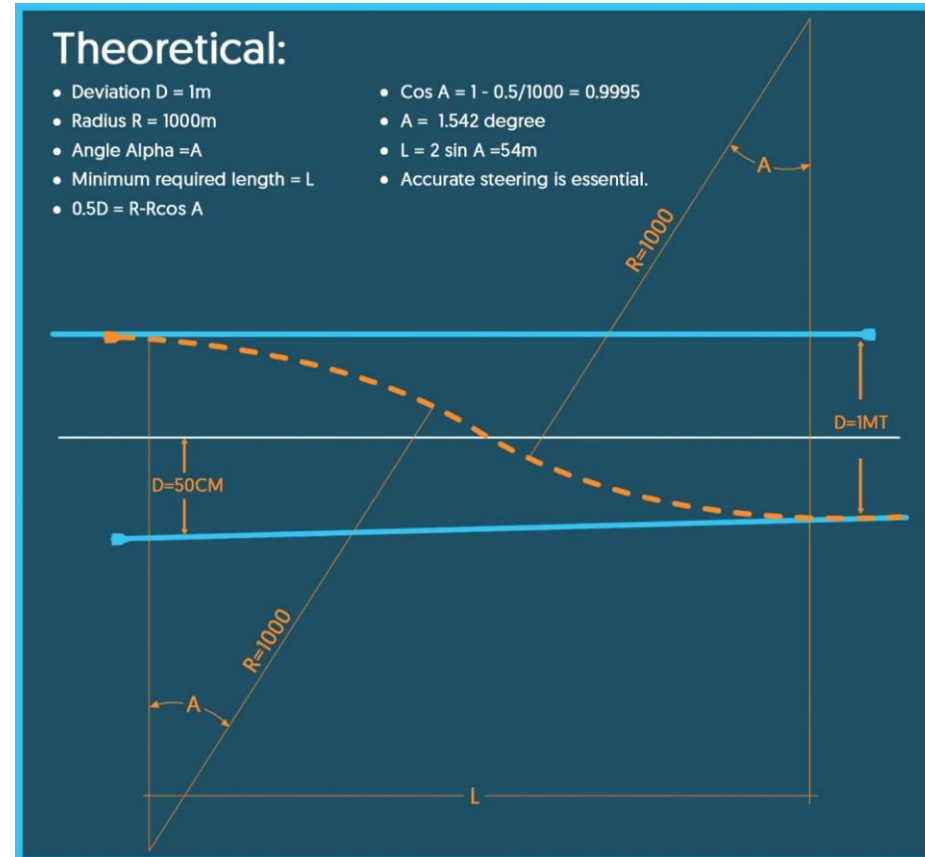
# S-Curve

- Today, downhole ranging systems are all magnetic in nature and measure the distance between a transmitter and a receiver based on electric power.
- The initial steering accuracy is essential to making a good intersect.
- The greater the distance between tools, the greater the chances of external influences.



# S-Curve

- Example: two approaching intersect bores are measured with a separation of 1 m. A plan is calculated to accomplish a smooth radially compliant intersect.
- In the example, the calculated drill distance required (L) to complete the intersect is already 54 m if the allowable radii for the pipeline is followed. (1000 m Radius)



# Case Study: Gyro Steering Intersects

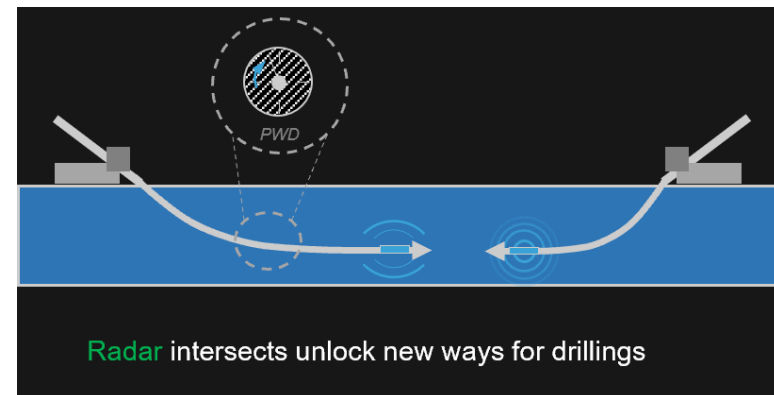
- Intersect project with a length of over 4500 m where the depth was 90 m.
- For a project of this length, there are many challenges to overcome for successful completion.
- For such projects, extreme accuracy and minimal deviation is a must. Guidance uncertainties are unacceptable.
- The maximum deviation using the Drillguide Gyro Steering Tool on this project was only 80 cm at the intersect point.
- This successful intersect was achieved within a few hours.



The longest HDD crossing in the world in 2017

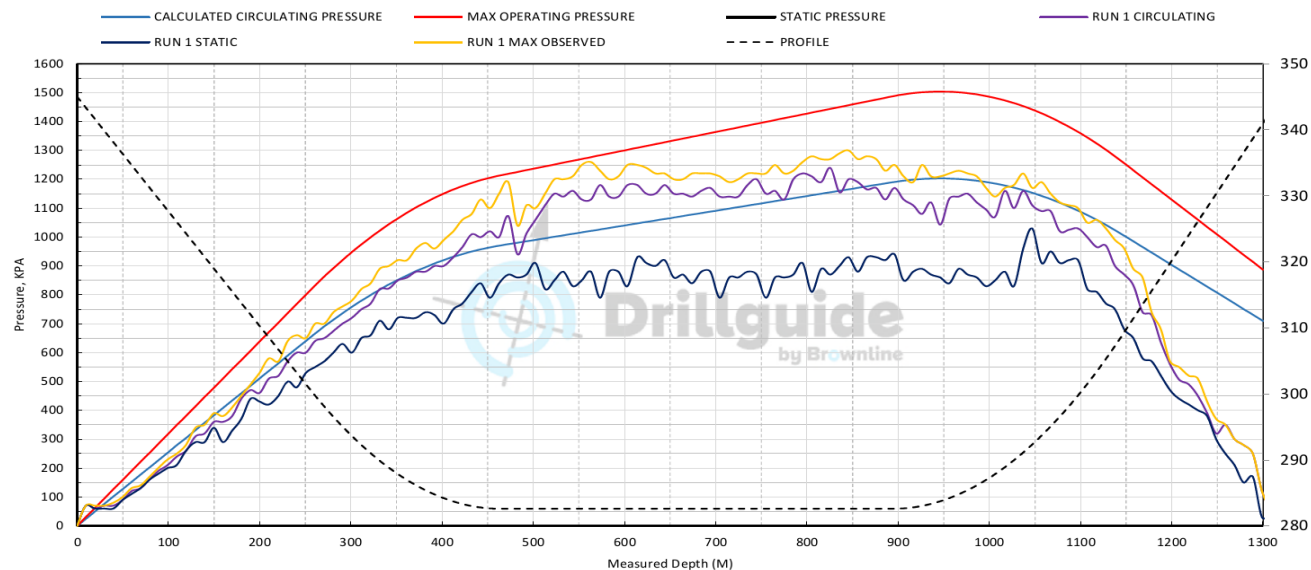
# Managing Drilling Fluid Pressure with Intersects

- An additional challenge with longer crossings, is higher annular mud pressure.
- The higher pressures often resulted in a loss of circulation back to the drill rig or “Frac-Outs” or “Blow Outs”.
- The required mud pressure to transport the cuttings from BHA to entry point is related to many variables but will increase with length.



# Managing Drilling Fluid Pressure with Intersects

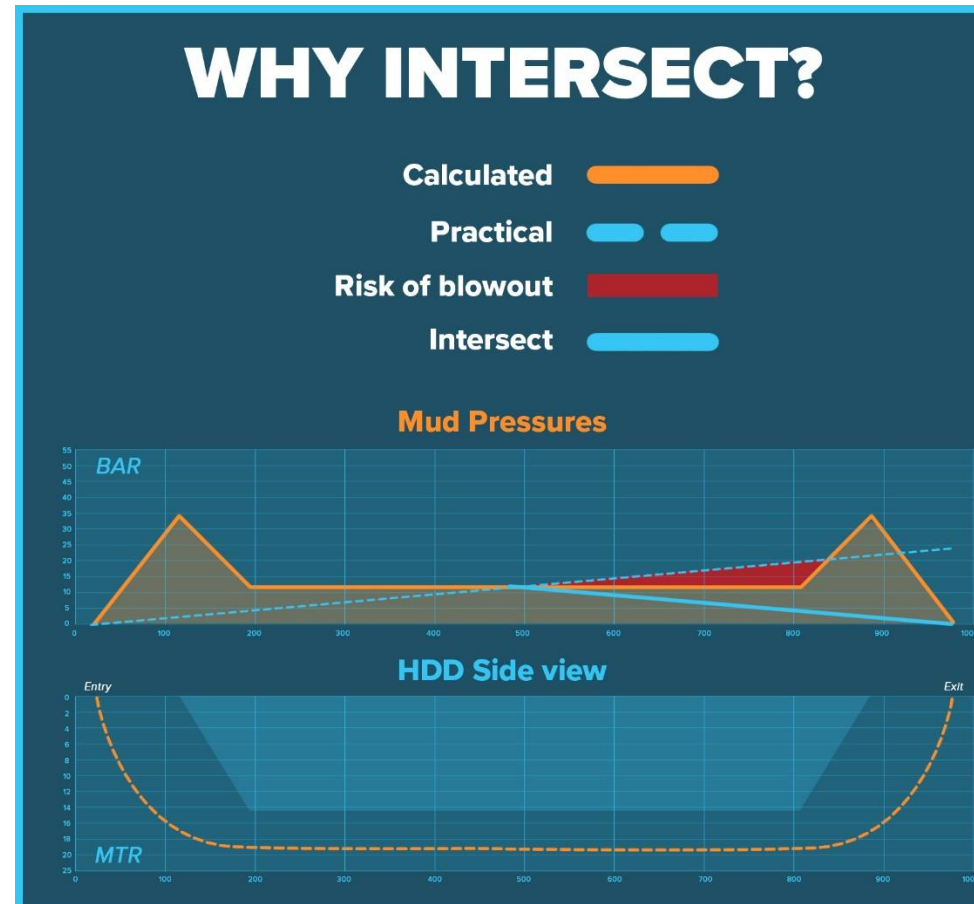
- Example of monitored Annular Pressures vs Calculated Pressures.
- Pressures are monitored in real time at the BHA.
- Annular pressure monitoring has become standard and has reduced the frequency of Blow Outs.





# Managing Drilling Fluid Pressure with Intersects

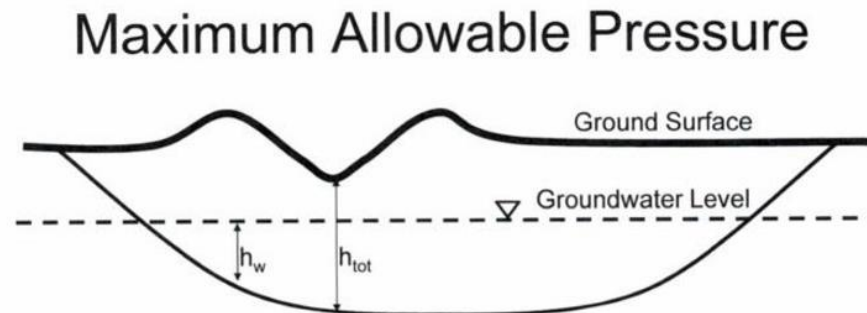
- In this Figure you see a simplified theoretical mud pressure diagram.
- The Red area indicates the drilling pressures exceeding the calculated overburden pressure.
- An intersect will mitigate the risk for hydrofracture.





# Managing Drilling Fluid Pressure with Intersects

- A planned intersect becomes a clear advantage for any crossing when needing to reduce annular pressures.
- As such, we see more projects planned as intersects even when length is not the main problem.



- Bore Geometry
  - Bore radius ( $R_0$ ) in feet
  - Total depth ( $h_{tot}$ ) in feet
  - Depth below groundwater ( $h_w$ ) in feet
- Soil Characteristics
  - Friction angle ( $\phi$ )
  - Cohesion ( $c$ ) in psf
  - Shear Modulus ( $G$ ) in psf
  - Unit weight of soil ( $\gamma$ ) in pcf

# Recent Intersect Projects

- Missouri River-USA
  - Den Helder-NL
  - Missouri River-USA
  - Scott Bay-USA
  - Port Lavaca-USA
  - Hidden Lake-Canada
  - Cartagena-Columbia
- 4700 m
  - 4600 m
  - 4037 m
  - 3750 m
  - 3585 m
  - 3540 m
  - 3395 m

# Missouri River, USA 2021



- 4700 m crossing
- DN610mm

The longest HDD in North America (2<sup>nd</sup> longest in the world). Won The Project of the Year – New Installation 2022.



# Den Helder - Texel, Netherlands 2017

- 4600 m crossing
- DN305mm



The longest HDD  
in Europe (3rd  
longest in the  
world).





# Missouri River, USA 2020



- 4037 m crossing
- DN508mm

The project won  
The Project of the  
Year – New  
Installation 2020.



# Scott Bay, Houston, USA 2015

- 3797 m crossing
- DN457mm



The project won  
The Project of the  
Year – New  
Installation 2015.



# Port Lavaca, Texas, USA 2015

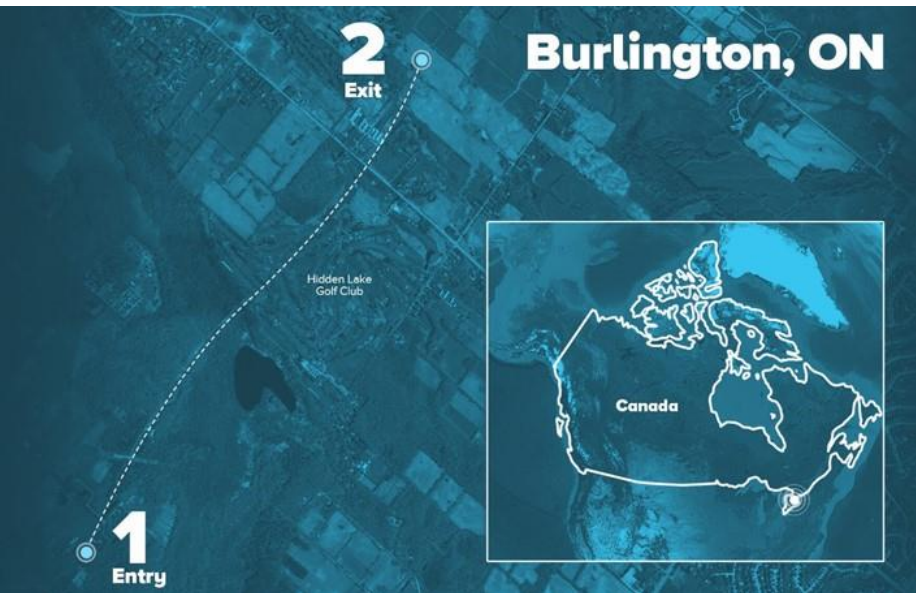


- 3585 m crossing
- Total  $3585 + 2840 + 2289 = 8714$  m crossing





# Hidden Lake, Ontario, Canada 2021



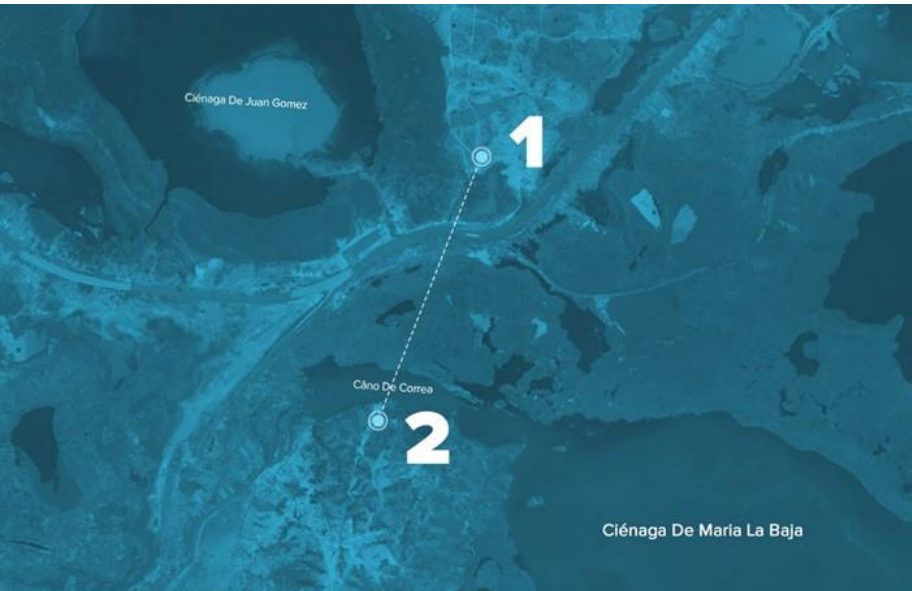
- 3540 m crossing
- DN305mm

The longest HDD crossing in Canada.





# Columbia, South America 2019



- 3395 m crossing
- DN406mm

The longest HDD crossing in South America.



# Summary

- Intersects can reduce risks for drilling substantially.
- Proper design and engineering of intersect drillings is essential.
- Without knowledge and proper equipment intersects will only raise the risks.
- If we all work together we might be able to drill 10km?

**Brownline**

Thank you!

Any questions please contact:

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