One could be forgiven for thinking that the current industry downturn would have made the application of extended reach drilling (ERD) technologies in drilling highly deviated wells unfeasible. However, the situation is actually the opposite. Applying ERD technologies is all about economics and the demanding market conditions over the last two years have driven operators to adopt these technologies to make projects economic. This can be seen with the implementation of high-angle drilling best practices and some lower cost ERD technologies to keep the unconventional plays going. At the other end of the spectrum, record step-out multi-laterals have been drilled from platforms to extend the life of mature fields without having to invest in expensive infrastructure.

This article discusses definitions and common misconceptions about ERD wells, the reasons behind deciding to drill an ERD well and finally, the core topic of what makes these types of wells different from conventional wells.
**Definitions**

An extended reach well is traditionally defined as a well with a step-out to true vertical depth (TVD) ratio of 2:1 or higher.

This inadequate definition often leads operators to a misconception that ERD technologies apply only to long and complex wells. It often makes them complacent about the less complex wells and this leads to problems. A better definition would include factors such as rig capabilities, key drilling challenges and water depth.

Figure 2 shows the spread of ERD wells drilled globally, plotted based on their true vertical depth (TVD) and step-out (departure).

**Why drill ERD wells?**

As wells are drilled closer to the edge of the drilling envelope, the challenges increase and when problems are encountered the resulting non-productive time (NPT) events can be significant. Despite the challenges and financial risks, there are many factors that make high step-out wells very attractive. Most of these factors come down to economics or minimising environmental footprint:

- **Drill-site location limitations:** A target located in an offshore reservoir would typically be drilled from an offshore installation and substantial infrastructure, such as platforms and pipelines, must be built. Instead, ERD wells can be drilled from the shore, which drastically reduces risk and cost (for example, the Chayvo field, Sakhalin island, Russia) while solving substantial logistical challenges (onshore versus offshore).

- **Early production:** Rather than constructing subsea tie-backs, which are expensive and take a few years to put together, targets drilled using ERD wells can be brought online earlier, which generate cash flow earlier; the benefits are further improved due to the time value of money concept.

- ** Increased recovery:** In most thin reservoirs long horizontals increase reservoir exposure several fold; driving higher production (profitability) compared to any other well. Good examples are developments in the Vincent project, Western Australia, and the numerous unconventional projects in the US that drove the ‘Shale Revolution.’

- **Access to resources:** Access to a more favourable surface location can be restricted for environmental or practical considerations for example the location directly above the target maybe a built-up area. Examples of locations where this has driven ERD development projects include offshore California (Santa Barbara Channel) and land-to-offshore on the south coast of the UK (BP Wytch Farm in Poole Harbour).

- **Defer abandonment:** Tapping into additional reserves can extend field life, deferring decommissioning costs. Again, the time value of money (TVM) concept further enhances the economic benefit.
What is different in ERD wells?

Having established the understanding that ERD wells can be cheaper and drive up the profitability of a project, it is imperative to discuss what makes ERD wells different from conventional wells:

Gravity: whilst gravity always acts vertically downwards, it is important to consider what happens if a vertical well is put on its side. Gravity affects the hydraulics and mechanical loads in ERD wells in a different way. Below are different inclinations versus the percentage of string weight acting against the low side (Figure 3). This directly affects mechanical loads.

- \( 30^\circ = 50\% \)
- \( 45^\circ = 71\% \)
- \( 60^\circ = 87\% \)
- \( 75^\circ = 97\% \)

Physics of motion and fluid dynamics: the fluid flows in a different mode due to additional annular friction from the extended length of the open hole and different annular clearances (high-side versus low-side).

Geology: reservoir geology is unchangeable. However, the inclination at which the well penetrates the reservoir leads to different geomechanical stress regimes, hence wellbore stability requires different forces to maintain it (often requiring higher mud weights).

Movement of cuttings: this is not straight up the wellbore, leading to different hole cleaning regimes. Failure to recognise and properly address this with adequate practices is one of the major reasons for problems in ERD wells (Figure 4).

The ‘more of everything’ factor:

- Drilling loads: often the more complex the well, the more fit-for-purpose equipment is required to stay within the load limits. Detailed engineering is required to mitigate them in the planning stage because substantial compromises will be necessary if loads are handled during the execution stage.
- Lead times: industry experience shows that a minimum of 9 - 12 months is required for adequate planning of an ERD well. This is due to the lead times for procuring fit-for-purpose equipment, performing detailed engineering, risk assessments and personnel training required to execute ERD wells.
- Risk, time, and cost: ERD wells have a much smaller margin for error because the operations are often at the limits and therefore consequences of an error are much greater than in conventional wells. Therefore, the frequency and severity of problems increase with inclination and length (Figure 5).
- Equipment: fit-for-purpose equipment is necessary. However, often operators opt for off-the-shelf equipment in an attempt to save time and cost but end up with escalated costs due to a major NPT or a lost well.
- Logistics: simply put, longer wells need more equipment, which increases the logistic challenge, especially when drilling from small footprint offshore platforms.
- QA/QC: the margin for error is minimal and therefore quality control of all equipment and processes is of utmost importance to the success of the entire well.

Operational practices: a low-angle drilling mindset can lead to complications since such practices are not applicable to ERD wells. The factors discussed above require special operational practices. High-angle drilling success requires engineering finesse rather than brute force.

Higher corporate visibility: unsurprisingly, ERD wells tend to get more attention from internal management, partners and regulatory agencies. This can be a distraction and increase the burden on the engineering team.
Teamwork: this is even more critical in complex operations – each position is a link in the chain. For instance, recognising cavings or a change in cuttings volume at the shakers is key in identifying wellbore instability or a potential hole cleaning problem; monitoring and maintaining fluid rheology is critical for hole cleaning; recording and evaluating torque and drag trends are key in ensuring trouble free trips and ultimate success of the well; directional control is important for well positioning and reaching the target; logistics is what keeps the entire operations going. The point is that executing ERD operations requires a strong team without weak links.

Figure 6 shows the industry drilling envelope with the typical challenges encountered in wells with different departures and TVD. This illustrates how some of the challenges described above differ with high-angle well types.

In shallow wells, drag and buckling loads are often high, torque will also tend to be high and sliding will become a problem by making tripping in and out of the well a major issue. Hole cleaning and cuttings bed development can also be problematic because more of the well bore is at a higher angle compared to deeper wells, which will have more low angle hole. Additionally, hookload is significantly lower than on deeper wells due to the pipe being supported by the borehole.

Deep wells, on the other hand, have higher tensions. This can lead to high side forces and casing wear can cause difficulties. ECD is less of an issue due to deeper TVD and higher formation integrity.

Industry achievements
The discussions above lead to a conclusion that there are a lot of differences between drilling conventional and ERD wells; the latter typically has a greater number of challenges and the consequences of getting it wrong can be severe. This raises questions regarding how these issues can be addressed and ensure the project is profitable. Nevertheless, industry experience shows that drilling ERD wells is economically feasible: the key is managing the risks. The following achievements are testaments that if the above challenges are properly addressed and managed, it is realistic to drill world record wells and expand the industry drilling envelope.

O-14 well
The O-14 well was drilled by ExxonMobil in the Chayvo Field, Orlan platform, Sakhalin Island, Russia (13 500 m MD, 12 033 m departure). Sakhalin wells lead the pack for global ERD wells, defining the outer limit of the industry drilling envelope boundaries. However, due to a very competent formation in the Chayvo field, drilling ERD wells on this project is relatively less complex compared to narrow margin subsea wells in the North Sea.²

BD04A well
The BD04A well was drilled by Maersk in the Al Shaheen Field, Qatar (12 293 m MD, 11 389 m departure). Maersk is one of the global leaders in ERD. They have put substantial efforts into continuously pushing the limits since 1992 and have set multiple world records along the way. Along with the measured depth record, this well had several other records, such as longest 8.5 in. hole section and longest length drilled with a rotary steerable bottom hole assembly.³

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M16Z well
The M16Z well was drilled by BP, Wytch Farm Field, UK (11,281 m MD, 10,731 m departure). This well was one of the first ERD wells drilled globally. It set a new world record, which was remarkable, considering the limited technology available in the 1990s. Moreover, it was drilled without rotary steerable tools or a casing drive system.4

Keys to success
C A proactive approach (at both the planning and engineering stage) can address almost all of the ERD challenges if competent personnel are engaged.
C Industry experience demonstrates that a reactive approach (at the execution stage) in solving ERD challenges is significantly less effective and offers limited success. Often compromises have to be made to reach the well objectives.
C Continuous improvement processes, including considering lessons learned from previous wells and the industry, is the foundation of successful execution.
C Competency in ERD alongside effective training of engineering and operations personnel on key aspects of drilling ERD and highly deviated wells is a crucial investment.

Conclusion
This article has discussed definitions and common misconceptions about ERD wells, the reasons behind deciding to drill an ERD well, and finally, the core topic of what makes these types of wells different from conventional wells. Based on the industry experience and discussions in the article, it was concluded that ERD wells are mainly driven by economics and environmental reasons; the key is managing the risks. Some key takeaways are:

C There is a significant prize in ‘getting it right the first time’ on directional and ERD wells.
C Different types of ERD wells have different challenges; detailed engineering must be performed and fit-for-purpose equipment used.
C ERD industry has been successful worldwide and has driven major technological and operational advancements in the drilling discipline.
C The majority of problems are avoidable if operators:
  ▪ Mitigate them in the planning stage.
  ▪ Understand what is going on downhole.
  ▪ Know the fundamentals.
  ▪ Listen to what the well is ‘telling’ them.
  ▪ Measure and interpret data available.
  ▪ Have procedures which address the risk.
  ▪ Use fit-for-purpose equipment and practices.

References
3. Sonowal, K., Bennetzen, B., ‘Continuous improvement lead to Maersk Oil Qatar’s longest horizontal well in the world’, Drilling Contractor (July/August, 2009).