AADE-25-NTCE-064

Efficiently Employing Open Hole Whipstock Systems for Preserving Extended Lateral Sections and Reducing Operational Expense

Manuel Solis, and Joseph Hopper, Wellbore Integrity Solutions

Abstract

Extending lateral sections in North America (NAM) basins is vital for accessing new production zones, yet poses several drilling risks and tool limitations, occasionally leading to interruptions such as leaving an unretrievable fish in the hole. To overcome these challenges and optimize well productivity, efficient open hole sidetracking operations are necessary. This study focuses on enhancing sidetracking techniques with Whipstocks to maximize the utilization of previous sections and ensure drilling continuity.

Traditional low sidetrack methods in lateral sections often involve identifying multiple high DLS areas to kick off, compromising salvageable lateral length and are prone to inefficiencies and inconsistencies. Employing modular open hole whipstocks with robust expandable anchoring systems, capable of adapting and navigating through high DLS, with pushing and flexible capabilities, presents an optimal solution for achieving OH sidetracking at desired setting depths. This approach ensures precise depth control and facilitates a first attempt reliable kickoff from the previous wellbore.

In the coming years, there will be a notable rise in lateral sidetracking applications, driven by the trend toward extended depths. Analyzing data from 197 documented successful cases, this study highlights the impact of meticulous planning, rigorous analysis, and the implementation of specific criteria in helping operators achieve total depth (TD) objectives across NAM and other regions.

This study highlights the efficacy of sidetracking with Open Hole Whipstocks (OHW) in addressing challenging drilling applications within lateral sections. The demonstrated success of this approach translates into significant cost savings, amounting to millions of dollars within the industry

Introduction

In many drilling operations, the risks and costs of open hole fishing often require alternative methods to resume drilling. Common options include setting a cement plug or using a whipstock to sidetrack around the fish. Conventional cement plugs have traditionally been preferred due to accessibility, low cost, and ease of installation. However, advancements in open hole sidetracking and equipment, along with more complex wellbore geometries, have made whipstocks a more cost-effective, faster, and lower-risk solution in many cases (Eubanks, A – August 1999). The efficiency advancements provided by the whipstock expandable anchor system have resulted in major time and cost savings in drilling programs for NAM operators.

Traditional Sidetracking Methods

Traditional sidetracking methods generally involve deploying a low-side directional motor or setting a cement plug as a base to serve a kickoff point with a directional assembly. This is followed by time-based drilling operations conducted at a controlled ROP to initiate the sidetrack. However, at greater depths, cement plugs often lack compressive strength exceeding that of the surrounding formation, thereby diminishing the likelihood of a successful sidetrack. In highly deviated wellbores, cement plugs are prone to inefficiencies due to the geometry and general physics of the wellbore. In addition cement contamination is a risk, which impacts proper curing and increases the likelihood of plug failure. In many cases, multiple cement plug placements are required to achieve the desired outcome, leading to increased non-productive time and cost expenditures.

Open Hole Whipstocks

The use of an open hole whipstock, as an alternative to a cement plug or low-siding a motor for a sidetrack, has proven to be both an effective and cost-efficient solution. Multiple whipstock configurations are available to accommodate a broad range of open hole sizes. The open hole whipstock can be configured as a one-trip system, which is deployed in the open hole, oriented to the desired tool face, set with an anchor, sheared off, and used to initiate the sidetrack wellbore, achieving both the window and rat hole objectives in the same trip. In lateral sections of the wellbore, the whipstock is typically deployed with a shear sub (running tool) rather than a milling assembly, providing additional push capacity to enable deployment to greater setting depths. An overview of the open hole whipstock system is shown in Fig. 1. The system includes several components, and the key features and functions of these components are described below, starting from the bottom up.

(1) Expandable anchor: Tri-axial anchor slip blocks spaced 120 degrees apart are hydraulically activated, providing a positive grip against the formation wall to counteract any axial movement or rotational tendency that may occur due to BHA rotation.

(2) Whipstock ramp: The sloped face of the ramp provides a known kickoff point, eliminating uncertainty as with traditional sidetracking methods.

(3a) Milling assembly: In a one-trip system setup, the milling assembly delivers the sidetracking window plus desired rat hole objectives for directional BHA pass through.

(3b) Shear Sub: In wellbores where the whipstock assembly is required to be run across sections with high DLS and/or into the lateral section, a shear sub replaces the milling assembly.
Top of the whipstock shoulders inside of the shear sub, allowing for greater push capacity when deploying the whipstock to extended depths.

Both the milling assembly and shear sub are mechanically attached to the top of the ramp with a shear mechanism to facilitate separation from the whipstock ramp after orienting the whipstock to the desired tool face orientation and setting the anchor.

(4) Running Tool: The running tool contains an oil reservoir to supply clean hydraulic oil to the anchor, proving a reliable means for the anchor setting operation.

(5) Flex Joint: A joint of HWDP or high grade DP to distribute bending stress as the milling assembly advances across the whipstock face.

(6) Multi cycle by-pass valve: The valve allows MWD tools to obtain pulses for whipstock tool face orientation within five cycles by allowing flow by-pass without setting the anchor. On the 6th cycle, the valve fully closes to allow hydraulic setting of the anchor.

(7) MWD or UBHO: A MWD or Gyro UBHO sub is orientation of the ramp face to the desired tool face.

Fig 1: Whipstock BHA layout

Whipstocks in Lateral Sections

When deploying a whipstock though the curve and into a lateral section where high DLS is present, exceeding 8 to 10 deg/100ft in open hole, the system is typically deployed on a shear sub instead of a 1-trip milling assembly. The shear sub has a smaller OD than the full gauge milling assembly, which facilities the ability to pass through potential tight spots downhole with ease. Additionally, the top of the whipstock slide shoulders inside of the shear sub with three points of contact (top, left, and right) of whipstock. This design feature prevents prematurely fatiguing the shear screw when working the whipstock assembly through tortuous sections of the wellbore. The shear screw is only subjected to loads in tension (overpull). A comparison showing the whipstock conveyed on a milling assembly versus shear sub is shown in Fig. 2.

Fig 2: Whipstock to mill system (left) vs whipstock to shear sub system (right).

Expandable Anchor Technology

The open-hole whipstock system is equipped with an expandable anchor, incorporating hydraulically actuated slip blocks. Designed for a high expansion rate, these slip blocks enable secure engagement with open-hole formations within a defined size range, effectively mitigating deployment challenges caused by wellbore irregularities. The variable expansion capability ensures more stable and reliable anchoring of the whipstock within the formation.

In the anchor's collapsed position during the run-in-hole, the outer diameter is intentionally designed to be smaller than the hole size. This allows for smoother passage through the wellbore and enables the anchor to reach the intended setting depth without obstruction. The max expansion is typically up to 60% larger than the collapsed OD, ensuring a firm grip on the surrounding formation. For example, in the case of an anchor deployed in an 8-1/2” or 8-3/4” open hole section, the collapsed OD of the anchor measures 8.19”. Upon expansion, the anchor can reach a maximum diameter of 13.17”.

Internal components of the anchor include a unidirectional locking nut that engages with the mandrel's wickers, eliminating the anchor from collapsing downhole once hydraulic pressure is released. If desired, the expandable anchor is fully retrievable and will collapse after applying the required overpull to shear the release mechanism. Detailed technical specifications, including typical open-hole size ranges as well as torsional and axial load capacities, are provided in Table 1.

Well Prep Cleanout Run

Before deploying the open hole whipstock system, it is recommended to run a full-gauge cleanup assembly to the setting depth. The cleanup assembly should closely mimic the whipstock assembly in terms of stiffness, effectively serving as a dummy run for the whipstock BHA. Any tight spots encountered should be reamed until the drag during tripping through the area is ideally reduced to less than 25% of the whipstock break bolt value. It is also advised to ream the entire curve section to facilitate with traversing the whipstock across the build into the lateral. Two typical cleanout run BHAs are provided in Table 2 below.

Table 2: Typical cleanout run BHA options

C/O BHA Option 1	C/O BHA Option 2
Drill bit	Drill bit
Bit Sub	Bit sub
Watermelon mill	1 Jt – DP or HWDP
Pony collar or pup joint	Eccentric Reamer
Watermelon mill	Pony collar
	Eccentric Reamer

Whipstock Operations

The whipstock BHA is tripped to the planned setting depth, typically between 5 to 100 ft above the top of fish. For sidetrack applications in the lateral, the whipstock face is recommended to be oriented between 30 to 60 degrees left or right of high side as a range to provide separation from the parent wellbore to sidetrack around the fish. However, alternative exit orientations, including low-side exits or those outside the recommended range, can be achieved with careful planning and appropriate configuration of the whipstock tool. In the case of a low-side exit, the whipstock can be customized to prevent top of the whipstock slide from shifting downward due to gravitational forces once the hydraulic anchor is activated. For high-side exits, the hinge connector design allows the back of the whipstock to sit flush with the open hole, preventing any obstruction of the window’s top.

After orienting the whipstock to the desired tool face reading, the multi-cycle bypass valve is indexed to the 6th position to energize the anchor with 3,000 psi and expand the hydraulic slip blocks. Hydraulic calculations are completed during pre-job planning to establish the required flow rate range necessary for indexing the MCBPV, based on the mud rheology. An example of the hydraulic calculations are presented in Fig 3 & 4.

Setting Mud Weight (ppg)	12.7
Valve Body Size (in)	5.00
Nozzle Size (in)	0.750
Break Circulation Rate (gpm)	50
Max Rate Before Piston Moves (gpm)	79
Min Required to Close Valve (gpm)	190
Max Flow Rate To Prevent Damage (gpm)	297
Time to ramp up pumps to required flow rate (min)	1

Fig 3: Results from hydraulic calculations for the operational flow rate required to successfully index the MCBPV.

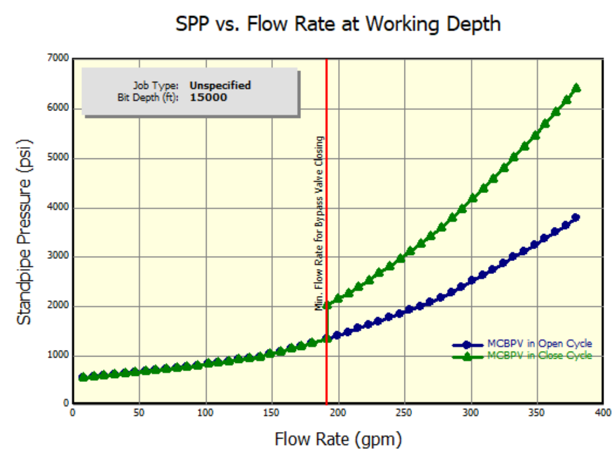

Fig 4: Hydraulic calcs showing flow behavior and flow rate vs stand pipe pressure for the MCBPV.

After energizing the hydraulic anchor, an axial push and pull test is completed at half of the rated shear release value while holding hydraulic pressure to confirm that the anchor has engaged into the open hole formation. After verifying the anchor is set, the shear sub is mechanically released by shearing upward with overpull. Next, trip out of hole to lay down the shear sub running tool and pickup the sidetracking BHA. A Torque and Drag (T&D) model is utilized to assess the required overpull at the surface to achieve the designated shear force downhole. In this analysis, a whipstock system designed for a 6-3/4” open hole has a nominal shear value of 40,000 lbs. T&D simulation results for a whipstock set at a depth of 18,025’ MD are presented in Fig. 5. The model indicates that an overpull of 64,000 lbs at the surface is necessary to transmit 40,000 lbs downhole to the shear sub, enabling the bolt to be sheared and whipstock released. A T&D analysis is also further reviewed for drag while tripping in the hole with the whipstock system at various depths through the curve and lateral to determine surface slack off weight vs weight at the whipstock downhole to determine push capacity on a shear sub vs traditional mill to whip hookup with the objective to mitigate fatigue on the break bolt.

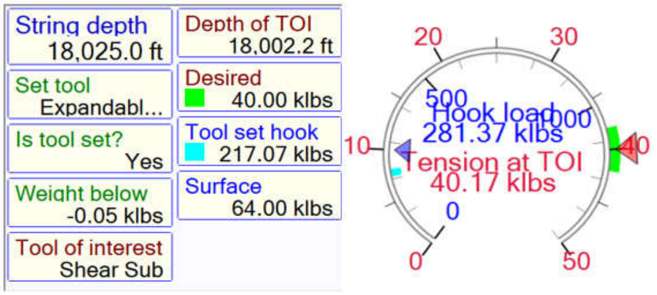

Fig 5: T&D model results show 64 klbs of surface overpull is needed to apply 40 klbs to the break bolt downhole.

Sidetracking BHA

After setting the whipstock, the sidetrack can be initiated by using either a milling assembly to deliver both the window and rat hole objectives. Or alternatively, the directional BHA is often used to sidetrack off the whipstock face in open hole.

Milling Assembly for Sidetracking

A dedicated BiMill run offers the option to open the window and achieve rat hole objectives, providing a clear path for the directional BHA to pass through. In this process, the BiMill drills across the whipstock face and creates a 5 to 10-foot rat hole, facilitating the burial of the next directional BHA in open-hole formation. The milling technology employed on sidetracks, initiated with a dedicated milling assembly, utilizes cylindrical cutters with a combination of TCI and PDC buttons, strategically placed on the lead mill as an optimized cutting structure for open hole sidetracks where medium to hard formations are present. See Fig. 6 showing a 6-1/8" OD BiMill assembly after delivering a sidetrack with lead mill measuring 1/16" undergauge and follow mill in gauge.

Fig 6: 6-1/8" OD Bimill Assembly.

Directional BHA for Sidetracking

At greater setting depths, initiating the sidetrack from a whipstock with a bent motor directional BHA is often preferred to optimize time efficiency. The sidetrack should begin by orienting the tool face to slide/trough minimum of 10 ft above the top of the whipstock slide. Once a locked-in tool face is established, proceed with slow slide drilling off the whipstock face. It is recommended to continue slide drilling until the top stabilizer is positioned below the bottom of the whipstock slide. After the directional BHA is successfully buried into the new formation, drilling operations can continue as normal to progress along the lateral.

Open Hole Whipstock Runs

To date, 197 recorded OH whipstock runs, conveyed on a shear sub, have been successfully executed across North America. A summary of OH whipstock runs per year from 2007 through 2024 is presented in Fig 7. These runs represent a significant volume of operations in a variety of challenging wellbore conditions, demonstrating the system's reliability and versatility. A comprehensive review of key lateral sidetracks completed throughout the 2024 calendar year is included in Table 3, which provides detailed data for each run. The table includes key parameters such as the total setting depth, distance in the lateral, whipstock face orientation, the maximum dogleg severity (DLS), and the DLS at the setting depth. This data offers valuable insights into the performance of the whipstock system in different well configurations.

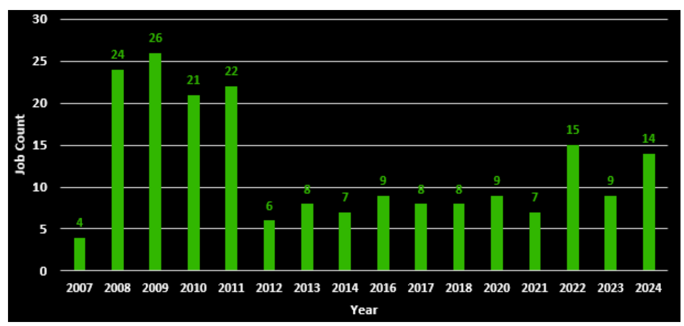

Fig 7: Open hole whipstocks set in lateral from 2007 to 2024

The highest DLS encountered by the whipstock system to date is 20.41°/100ft, which highlights the tool's capability to effectively navigate through wells with challenging geometries. Achieving such a high DLS is a notable accomplishment, as it demonstrates the system's ability to traverse tight and tortuous sections of the wellbore while maintaining the integrity of the sidetrack operations. The whipstock's design allows for precise orientation and reliable performance in conditions where high dogleg severity might otherwise present challenges for alternative sidetracking methods.

The record setting depth for a whipstock was deployed to 9,750 feet in a 6-3/4" lateral at a setting depth of 18,675' MD in the Permian Basin. On a subsequent trip, a dedicated BiMill kickoff assembly was utilized, creating an 11-foot window along with 10 feet of rat hole. The unique design features of the open-hole whipstock system, equipped with a shear sub, played a key role in enabling the client to resume drilling and successfully sidetrack the well around a fish, even in challenging wellbore conditions. This reliable sidetracking method, with a known kickoff point, significantly reduced the risks and uncertainties often associated with alternative sidetracking approaches. A detailed depiction of the wellbore and setting depth is provided in Fig. 8.

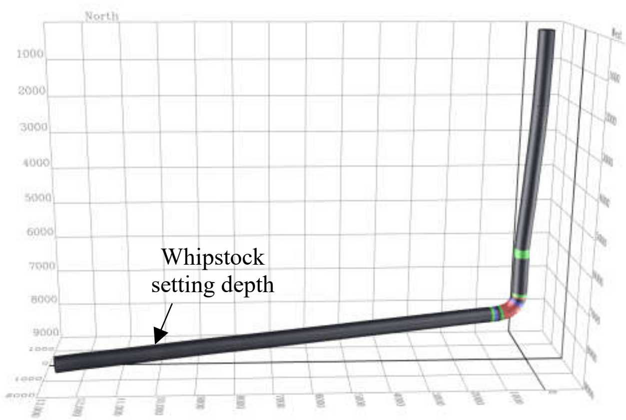

Fig 8: Record OH whipstock setting depth ~9,750' into lateral.

By consistently delivering successful sidetrack operations in a wide range of wellbore environments, this open-hole whipstock system has proven to be a valuable tool for operators, reducing risks and improving efficiency during sidetracking operations.

Dual Open Hole Whipstock Run

An innovative open hole sidetracking strategy with dual whipstock deployment was completed for a Delaware Basin operator during the 2024 calendar year. Following drilling 4,100 ft of lateral footage, the BHA became stuck and was unable to be retrieved out of the wellbore, necessitating a strategic response to safeguard the existing lateral progress. After reviewing the application, a sidetracking strategy plan was developed. Both parties meticulously planned and executed a 6-1/8" OH lateral sidetrack located at 14,500 ft MD. Once operations resumed with the drill-ahead BHA, the operator encountered another obstruction requiring a secondary sidetrack deeper than the initial whipstock placement, due to a 2nd unretrievable fish. Despite extensive track record in successfully executing open hole sidetracks using whipstocks in lateral sections, scenarios of this nature introduce heightened challenges and risks. These circumstances necessitate the deployment of a second whipstock beyond the initial sidetrack. Fig. 9 provided in the appendix represents the dual whipstock run.

The 6-1/8" open hole whipstock system with hydraulic anchor was tripped into the hole and passed through the 1st whipstock window as per the planned procedure. Subsequently, it was oriented to the desired direction using MWD and set at 15,850' MD, approximately 1,350' beyond the initial sidetrack depth. Following the activation of the hydraulic anchor, the shear sub was disengaged from the whipstock as per design, through the application of overpull. Results from the T&D model are presented in Fig 10 showing 72 klbs of overpull at surface was required to deliver 40 klbs to the break bolt donwhole (TOI). Running tools were POOH and laid down, the directional BHA was used to initiate the kickoff of the whipstock, facilitating the continuation of drilling operations. The open hole sidetracking system delivered a high-quality sidetrack successfully on the first attempt, resulting in over 5 estimated days of saved rig time by eliminating the necessity for plug back and re-drilling of lateral footage.

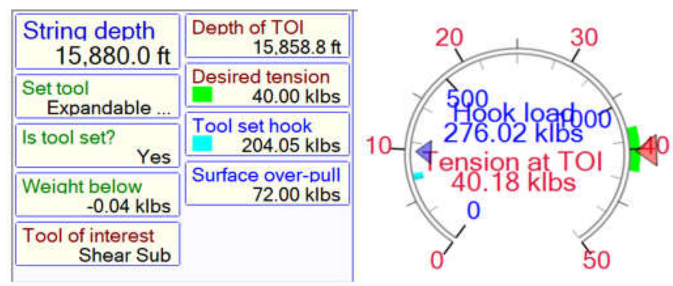

Fig 10: T&D model results show 72 klbs of surface overpull is needed to apply 40 klbs to the break bolt downhole.

Reducing Operational Expense

Open-hole whipstocks offer a significant advantage in operational efficiency by minimizing both time and cost associated with sidetracking operations. Permian Basin operators report that utilizing a bent housing motor for a conventional low-side sidetrack in a lateral section typically results in time-drilling rates of 5–7 inches per hour, making it a slow and methodical process. This approach necessitates thorough evaluation of wellbore tortuosity to identify a suitable dogleg that enables an efficient kickoff. However, achieving the desired deviation can be challenging, often leading to incomplete section recovery and requiring redrilling of previously drilled footage, adding to operational inefficiencies. The difficulty escalates when sidetracking from a wellbore drilled with a Rotary Steerable System (RSS). The uniform hole geometry created by RSS reduces natural doglegs and potential sidetrack initiation points, limiting the ability of a downhole motor to engage the OH formation effectively. Without a natural discontinuity to exploit, the motor may struggle to initiate a controlled deviation, leading to increased time, costs, and a higher likelihood of unsuccessful sidetrack attempts. Additionally, excessive sidetracking attempts can result in wellbore instability, poor hole conditions, and increased wear on downhole tools. Consequently, planning for sidetracking in lateral sections should incorporate geological assessments, and appropriate tool selection to maximize efficiency and mitigate operational risks.

Figures 11 and 12 present a comparative analysis between OH whipstocks and conventional sidetracking methods, which often require multiple attempts due to failed cement plugs, time-drilling challenges, or both. The analysis, based on a sidetrack depth of 15,000' MD in the Permian Basin, incorporates a high rig spread rate along with tangible costs such as cement plug expenditures, cleanout runs, and whipstock system implementation. In all scenarios, OH whipstocks demonstrate superior time savings over conventional sidetracking techniques.

When comparing the total cost of successfully delivering a sidetrack on the first attempt, the expenditure is nearly equivalent to that of an open-hole whipstock. However, if multiple plug or time-drill sidetrack attempts are required, open-hole whipstocks offer substantial cost savings over traditional approaches.

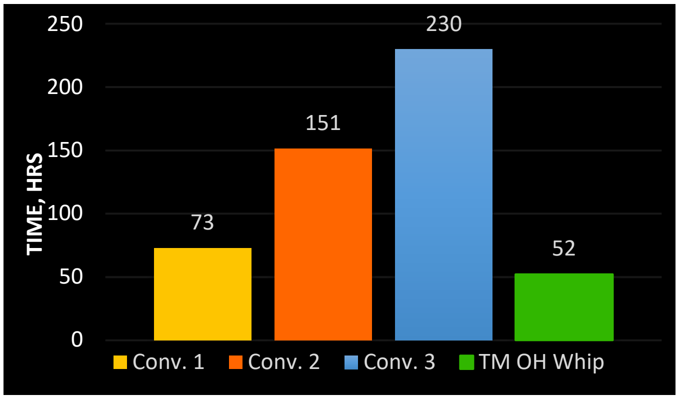

Fig 11: Plot comparing cumulative time for conventional sidetrack methods vs an open hole whipstock.

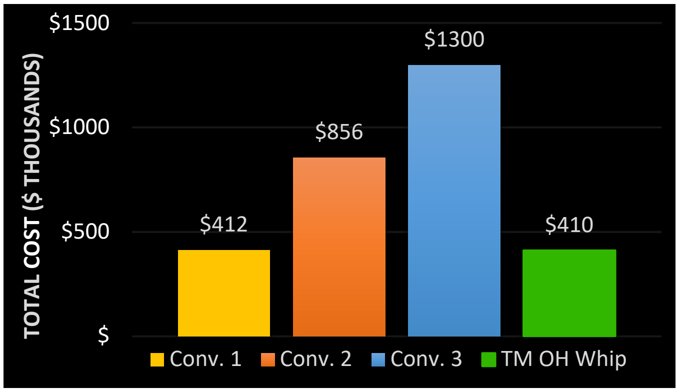

Fig 12: Plot comparing cumulative cost ($ thousands) for conventional sidetrack methods vs an open hole whipstock.

Beyond efficiency gains, OH whipstocks provide a critical advantage in optimizing drilling program timelines, particularly in planned or unplanned sidetrack scenarios within lateral sections. Unsuccessful conventional sidetracks not only disrupt drilling schedules but also delay production handover. As illustrated in Fig 13, and utilizing data on a Delaware Basin well for a 10,000 ft lateral length, initial production exceeds 1,000 bbl/day (Novilabs – Nov 2024 Weekly Insights). In cases where a second sidetrack attempt fails, the resulting delay could lead to an estimated production deferment of more than 5,000 bbls, emphasizing the economic impact of selecting a reliable sidetracking method.

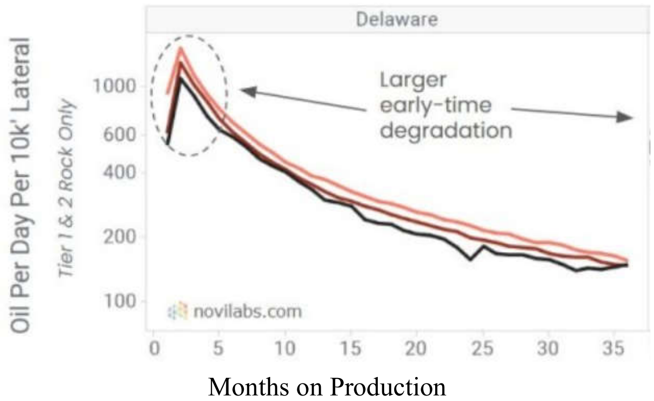

Fig 13: Production rate for a 10,000' lateral in Delaware basin.

Conclusions

In conclusion, open hole whipstocks provide many advantages during sidetracking operations compared to conventional open hole sidetracking methods. The open hole whipstock, with its expandable anchoring system and robust design, has proven to be a reliable tool, ensuring a higher success rate and reducing the risks of non-productive time.

The data presented in this paper demonstrates that open hole whipstocks deliver a time savings of over 20 hours compared to conventional sidetrack methods on the first attempt based on a sidetrack depth at 15,000' MD. When multiple conventional sidetrack attempts are required, the time savings can exceed 175 hours. From a cost perspective, the expenditure associated with whipstock operations is nearly equivalent to that of a successful first-attempt sidetrack using conventional methods. However, when multiple cement plug or time drill sidetrack attempts are necessary, the cost savings with open hole whipstocks increase significantly.

Through 197 recorded open hole lateral sidetrack cases, this paper highlights the effectiveness of whipstock technology in sidetracking operations, demonstrating substantial cost savings and enhanced wellbore management. The ability to sidetrack with precision by providing a known kick off point, even at deeper depths or through highly deviated sections, ensures optimal wellbore utilization and minimizes downtime. As sidetracking applications in lateral sections are expected to rise with the ongoing trend toward deeper drilling, the open hole whipstock system stands out as a transformative tool that enables operators to achieve their drilling objectives with greater efficiency and reliability.

Ultimately, the proven success of whipstock technology in lateral sidetracking paves the way for more cost-effective and reliable drilling operations in challenging environments, positioning it as a key tool for the future of wellbore optimization and risk mitigation in basins worldwide.

Acknowledgments

The authors sincerely appreciate the invaluable insights and collaboration of our colleagues and industry professionals, which were instrumental in the successful completion of this work. We also extend our gratitude to our customers for their trust in Wellbore Integrity Solutions for their sidetracking operations.

Nomenclature

NAM = North America
DLS = Dog-leg severity
OH = Open Hole
OHW = Open Hole Whipstocks
ROP = Rate of Penetration
BHA = Bottom Hole Assembly
HWDP = Heavy Weight Drill Pipe
MCBPV = Multi-Cycle Bypass Valve
MWD = Measurement While Drilling
UBHO = Universal Bottom Hole Orientation Sub
OD = Outer Diameter
C/O = Cleanout
T&D = Torque and Drag
TOI = Tool of Interest
TCI = Tungsten Carbide Insert
PDC = Polycrystalline Diamond Compact
MD = Measured Depth
POOH = Pull Out of Hole
RSS = Rotary Steerable System
HS = High Side

References

(Eubanks, A., - August 1999) “Whipstocks: An alternative to openhole fishing”, World Oil, August 1999

(Novilabs – Nov 2024 Weekly Insights) “ Long Laterals: How Do They Compare in the Permian?”

Table 1: Whipstock expandable anchor technical specifications.

Size (in.)	OD (in.)	Max. Expanded Diameter (in.)	Torque (lb-ft)	Push Capacity (lb)	Max Overpull (Release) (lb)	Recommended OH Size (in.)
7 x 9 ⅝	5.76	9.13	30,000	100,000	65,000	6.00 – 7.75
9 ⅝ x 13 ⅜	8.19	13.17	50,000	150,000	95,000	8.50 – 11.75
13 ⅜ x 20	11.94	19.09	80,000	150,000	114,000	12.38 – 17.50

Fig 9: Image representing dual whipstocks in lateral application to sidetrack around multiple fish.

Table 3: Open hole Permian whipstock runs filtered for lateral applications during 2024 calendar year.

Region	Hole Size	Whip Top Measured Depth (ft)	Hole Angle (deg)	Orientation (LHS/RHS)	Orientation from HS (deg)	Distance in Lateral (ft)	Max DLS (deg/100 ft)	DLS @ Setting Depth (deg/100ft)
Permian Basin	6.750	14380.00	90.00	LHS	45.00	5330.00	16.77	0.25
Permian Basin	6.125	14189.00	89.00	RHS	45.00	4789.00	13.40	2.29
MidCon	6.125	11980.00	92.00	LHS	56.00	2905.00	12.90	1.20
Permian Basin	6.125	16981.00	92.00	LHS	56.00	6181.00	13.57	2.28
Permian Basin	6.125	15600.00	91.00	LHS	45.00	5200.00	18.15	3.69
Permian Basin	6.125	10200.00	89.00	LHS	34.00	650.00	19.28	2.76
MidCon	8.500	12975.00	90.00	RHS	51.00	575.00	16.82	0.44
MidCon	8.500	16700.00	90.00	LHS	45.00	6400.00	15.10	2.00
Permian Basin	6.125	16610.00	91.00	LHS	45.00	6960.00	**20.41**	2.40
Permian Basin	6.125	15847.00	89.00	LHS	50.00	5147.00	13.85	2.21
Permian Basin	6.125	14480.00	93.00	LHS	45.00	3780.00	13.85	5.83
Permian Basin	6.125	16985.00	89.00	LHS	56.30	7485.00	17.10	4.50
Permian Basin	6.750	**18675.00**	90.00	LHS	65.00	**9750.00**	12.87	0.25
Permian Basin	6.750	11966.00	90.00	LHS	60.00	2466.00	12.76	1.28