LOW COST MULTILATERAL ON GULLFAKS

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Abstract

Gullfaks is a typical mature field where cost efficient solutions need to be in focus. There is also the challenge that old wells produce at low rates, but nevertheless at rates not drastically lower than those that an alternative use of the slot can deliver. One solution to this challenge is to maintain production from the old well while simultaneously gaining inexpensive access to new a drainage point(s).

B-1A on the Gullfaks field was drilled and completed in January 2003 using hollow whipstock technology. The operation was a technical success which proved that Multilateral (MLT) solutions can be delivered at costs only marginally above those of a conventional sidetrack. To further enhance the value of the slot, a second through tubing MLT lateral was added in January 2005.

The key considerations during the planning phase were proven solutions, cheap technology and low risk. This paper illustrates the decision process prior to choosing this particular technology, the installation process itself, the lessons learned and the strategy which may be applied in the future.

Introduction

The Gullfaks field is located offshore Norway and is one of the largest producing fields in the North Sea (see Fig 1.). The field is operated by Statoil and has produced since 1986. It has been developed with three concrete integrated production and drilling platforms; namely the Gullfaks A, B and C. The total production rate from the Gullfaks field is currently some 26 000 Sm3/d with estimated total recoverable reserves of 360 million Sm3.

B-1 was the first well to be completed on the Bravo platform and since the well came on line in 1989 it has produced almost 10 million Sm3. The well is a typical mature Gullfaks well with a decline curve that is characterized by a long and drawn out tail as the water cut gradually increases.

In January 2003 the well was producing some 250Sm3/d with 84% water cut. A new prospect had been identified in the same segment and it was desirable to use the B-1 slot for its exploitation. However the new prospect was not anticipated to produce at a rate of more than 500 Sm3/d and it was therefore clear that plugging back the old B-1 was not an economically viable option.

The operator decided to investigate the possibility of maintaining the old B-1 production while simultaneously producing from the new branch B-1A. It was very important that the multilateral solution should be technically robust and not jeopardize the contribution already available in B-1. It was also desirable that the cost of the solution be compatible with the modest additional volumes available in the new lateral.

Selection Process – Criteria

The option of maintaining production from B-1 seemed very tempting to the reservoir engineers. They did however present a challenge that would have to be met during the planning phase in that the perforations in the motherbore could not be exposed to drilling fluids. Some type of isolation would therefore have to be in place while drilling the lateral.

On the technical side it was considered most important that the installation process differ as little as possible from a conventional sidetrack procedure and that only equipment with a proven track record be used. It was known, from experience when sidetracking in old wells, that equipment tolerances would have to be liberal in order to accommodate corrosion, wear and tear on existing tubulars and the debris created in the sidetracking process itself. A robust system was therefore considered to be of great importance.

A further reservoir prospect, not yet matured, was also identified in the region and it was important that it would be possible to reach this target from this same well at some later stage. It was considered preferable that this additional sidetrack be conducted with another MLT solution and, if at all possible, using Thru Tubing Rotary Drilling (TTRD) techniques.

One important criterion that was identified early in the process was that access to the motherbore was not a prerequisite to the system. No more intervention work was planned for this wellbore and only hydraulic communication to the mainbore would be required. It was also decided that considerations for sand control, zonal isolation and pressure integrity between the wellbores were not critical issues.

As remaining reserves, both in the motherbore and in the new prospects, were limited, the well construction cost was an important issue. A multilateral solution would have to compare favourably with conventional plug, abandon and sidetrack methods.

Technical Solution

The old B-1 was completed in 1989 with a 9 5/8” x 7” production liner and the original 5 x 5 ½” bottleneck completion was still in place. (See Fig 2).

A 900m lateral would have to be drilled in order to gain access to the new reserves (See Fig. 3). As the well had a bottleneck completion, TTRD solutions were ruled out early in the process and in any case the tubing was so old that it was overdue for recompletion due to corrosion.

It was decided that a mechanical isolation would be required to isolate the motherbore perforations while operations were performed. Fluid solutions such as kill pills were considered but primarily ruled out due to the complications that could result when bringing the motherbore back into production again at a later stage.

As a consequence of these limitations it was decided that a wireline run isolation plug would be utilized. As mechanical access to the motherbore would not be available after drilling of the lateral, opening of this plug would have to be operated by a timer system.

For the MLT system itself several systems were considered. During the selection process it was of course important to keep in mind what criteria would have to be met, but equally important were features that were not required. The most important of these being that no subsequent mechanical access to the motherbore would be required.

Early in the process it became obvious that some variation of hollow whipstock technology would be suitable for this application. The final selection was a system that could be run almost like a conventional whipstock sidetrack system. Only after all drilling and completion operations were completed would the whipstock be perforated to obtain hydraulic access to the motherbore. It was decided that the following features would characterize the selected system:

- Allow production from both main bore and lateral with negligible pressure losses in either branch
- Same whipstock in place during the entire operation
- Full access to lateral, hydraulic access to mainbore
- Hydraulic isolation at junction (cement only)

In terms of TAML level, this well is categorized as level 4 which is defined as: "In a level 4 multilateral, the mainbore is cased and cemented and the cemented junction provides mechanical junction integrity."

Description of Components

The system chosen is intended for existing well applications and provides full bore access to the lateral wellbore. The installation also provides mechanical integrity at the junction with the liner being cemented for optimum support and to provide an element of hydraulic integrity.

A single whipstock run is sufficient due to the hollow whipstock anchor system being utilized in both the drilling and completion phases. After milling the window and drilling the lateral a conventional liner assembly is run and cemented. There is actually no requirement, other than well design, to cement the liner in place; so a Level 3 junction can be constructed. Since there is no necessity to reach bottom with the liner in order to successfully complete the junction, the liner can be hung off in the main bore above the window, thereby dramatically reducing the risks inherent in the installation. The new reservoir can then be produced separately or commingled with the original wellbore at anytime. Production from the original wellbore is regained by perforating across the pressure plate of the hollow whipstock. This system is designed to be a low cost enabling technology that would allow marginal reserves to be drilled with an inherently low installation risk. Varying sizes of the system allow smaller completions to remain in place while TTRD ML operations are conducted.

Equipment Specifications

The Timer Plug

The sole purpose of this device is to provide hydraulic isolation of the motherbore until the whipstock could be put in place. Subsequently it should open up for hydraulic communication and ideally not cause a pressure restriction in the wellbore.
Several tests were performed on this plug, the final test being performed in B-1 where a plug was installed some weeks before the sidetrack operations and set to open in 48 hours. This opening was observed as planned and a pressure drop of approximately 5 bars measured across the device.

The Hollow Whipstock

The hollow whipstock used in this junction was designed to meet a number of practical requirements which were identified and are listed below:

- Allow the milling system to exit the casing above the top of the whipstock to create a long window
- Ensure the milling system does not damage the pressure integrity of the barrier and perforation plate
- Hold sufficient differential pressure to maintain junction integrity during drilling operations
- Be a usable tool during drilling and completion operations without being pulled
- Contain an area which can be reliably perforated in a controlled manner.
- Allow flow of hydrocarbons or injection of fluids to support economical development.

Some MLT systems are based on first running a tool to perform the milling function and then running a second deflector, containing the perforating zone, to divert the drilling assembly and liner into the lateral. The junction created for this system is unique in that it allows for the use of the same tool to perform both functions, thus eliminating a sometimes difficult whipstock fishing operation.

In order to perform a dual function, the whipstock has features that shield the perforation and pressure holding capabilities from damage. As the milling assemblies are adapted to pass over the face of the whipstock without damaging it, a single whipstock can perform both functions safely. The whipstock assembly itself consists of a hollow whipstock, with a perforation plate which has a 3-degree angle on the ramp (See Fig 4). However the milling tool that operates with it is designed so as to cut a window longer than the concave itself. This assembly is pressure tested to 5,000 psi in burst and collapse.

The whipstock also includes a small kick over device to ensure that the tip of the whipstock lies on the low side of the casing. Without such a device, it is probable that the whipstock would remain centered in the well, with the tip of the whipstock slightly off the low side. Standard wireline perforation techniques require a low side orientation but recent developments allow perforation with Tubing Conveyed Perforating (TCP) at up to a 45 degree toolface offset. The whipstock is fitted with Radioactive (RA) tags to provide for depth correlation for the subsequent perforation job.

The Whipstock Anchor

Several options were looked at when choosing an anchor able to operate in both drilling and completion environments. The packer has to be able to take 10,000 ft-lbs in torque while allowing hydrocarbons to be produced through the inner bore. A new packer was developed that would reliably meet this requirement for both a drilling and production anchor. All of the weight range variants of the packer were tested to ISO 14310 Grade V3 standards. The packer features a 3-inch inner diameter to allow for flow through the tool after perforation of the hollow concave.

Retrievability

A fully retrievable packer module was designed and built for the multilateral system in order to reduce the overall risk of the system installation. Since the system was designed as an integral unit, the junction hardware can be run and retrieved if necessary. It was designed for a single trip “straight pull” release with the die-collar retrieving tool screwing onto the top of the whipstock. An over pull of 120,000 lbs releases the whipstock and packer unit and the system can then be safely tripped out of the hole.

The Milling System

The milling system that creates the window through the parent bore casing is specifically designed to minimize risk during the formation of the junction. Two milling trips ensure that the pressure barrier created by the installation of the packer/hollow whipstock barrier remains in place during the milling and drilling phases. The preliminary mill is a tri-bladed starter mill that cuts out above the top of the whipstock and elongates the window to provide a long exit (See Fig 5). This is useful because the longer window when complete facilitates better transition of stiff drilling and completion Bottomhole Assemblies (BHA). It also controls the start of the junction while implementing the cut out portion of the window. A subsequent run with a multilateral window mill completes the window and drills the rat hole. It only has forward cutting action to achieve and contains special features that allow the mill to pass over the perforation plate while maintaining its integrity. The multilateral window mill has an extended gauge section and a tapered face design to ensure that the whipstock is not damaged during milling operations.

Hollow Whipstock Perforation System

The multilateral system operates as a milling/drilling and production barrier until production is re-established from the mainbore below. Perforation techniques allow the specially designed gun system to be run into the lateral liner where the junction consisting of the hollow whipstock, liner and cement needs to be perforated. The design of the charge required considerable work and testing before the correct mix of penetration and hole size were found. The perforation charges are designed to limit penetration into the junction while supplying sufficient flow area through the whipstock so as to minimize pressure drop. The perforation charges are intended to penetrate the liner and a thickness of cement to a maximum deflection possible within the junction environment and the hollow whipstock face plate. Depth of penetration was calculated so as not to affect the production casing behind the junction which could produce debris from the junction area.

During testing a charge was developed that created a Total Flow Area (TFA) equal to 2.75 sq.in.. After testing the charge in a full-scale fixture, testing confirmed the predicted results (See Fig 6). This flow area can be increased with multiple perforation runs towards 7.0 sq.in., equivalent to the flow area through the packer**.**

The perforation gun string can be run on wireline or TCP and can be readily positioned in the required location using the RA tags placed in the whipstock at both the top and the bottom.

Installation process

Planned Sequence of Operations (See Fig 7)

Preparing the Well for Sidetrack Operations

Prior to performing the sidetracking operations the existing perforations would need to be isolated and the old completion string pulled. Isolation of the old perforations was achieved using a timer controlled device designed to safely isolate the perforations until the whipstock was run in place and tested. A plug with the timer operated opening device, set to open after 30 days, was run on wireline some days before rig access could be gained to the well. The plug was successfully inflow tested before the tubing was punched and circulated to brine. Finally the old completion string was pulled off the extension joint and POOH.

Running the Whipstock

With the installation of any multilateral or permanent packer system, it is important to ensure that the casing is clean and a gauge run is performed before attempting to run the multilateral system in the well. This ensures the packer setting depths are clean, that the packer slips have a good grip on the casing wall and that the stiff whipstock assembly can reach setting depth with no problems.

Prior to picking up the whipstock assembly, the RA pipe tags were installed into the premachined holes, top and bottom of the whipstock. A cycling control valve, with 4 positions 3 open and one closed, was used for hydraulic setting of the whipstock system. The control valve was indexed through all these positions before it was attached to the running tool. The whipstock was made up to the running tool using a quick hydraulic connection to ensure that a clean reservoir of fluid was available throughout the packer setting system. A scribe line was taken from the machined face on the running tool and aligned with the Measurement While Drilling (MWD) tool for orientation.

The hollow whipstock was RIH at a steady rate, similar to procedures for a conventional whipstock. Once on depth, the whipstock system was positioned so that the exit was between two couplings. The control valve controls the flow of fluid to the packer system and the MWD tool, thus allowing for circulation through the MWD tool in order to align the system in the hole. Once orientation had been achieved, the control valve was indexed to stop the flow to the annulus and pressure thereby directed to the hydraulic setting chamber in the packer. 2,500 psi was held on the packer and the drill string slacked off 30,000lbs to confirm the packer was set. The MWD tool was used to check orientation after setting and, following successful readings, the running tool assembly was sheared upwards from the whipstock and tripped out of hole. At this stage the well was also displaced to mud in preparation for the drilling phase.

Creating the window

A tri-bladed, cone tipped starter mill is used to create the initial portion of the junction window. The cone of the mill tags the sacrificial brass lug which forces the mill into the top of the casing, while simultaneously protecting the hollow whipstock. The tri-bladed design places a beginning cut on the inside of the casing at approximately 57 inches above the top of the whipstock, thereby providing for a longer window These are theoretical numbers using a nominal diameter for 9 5/8 inch 47 ppf casing).

8-1/2 Inch MLS (Multilateral System) Mill

The third BHA of the junction installation sequence uses a unique mill known as the MLS mill. The side cutting action of the starter mill ensures that a pocket is created for the MLS mill to sit into so that it only has to cut in a forward action. The aggressive geometry on the face of the mill cuts down the window without damaging the integrity of the hollow whipstock barrier. The MLS mill has a tapered section on the front which ensures that no damage is done to the whipstock face. The blades on the mill are wrapped in order to maintain stabilization, increase balance and protect the perforation plate. Once the window had been milled and 3.35m of rat hole drilled, the assembly was pulled to the top of the window where a pill was circulated. A Formation Integrity Test (FIT) was then conducted and the milling assembly pulled out of hole.

Drilling the lateral

With this window established the remaining sidetrack procedure could be performed exactly as in a conventional sidetrack. To avoid unnecessary wear and strain on the whipstock face plate, procedures were put in place during the drilling phase to ensure that the string was always oriented to the high side while tripping past the whipstock. In addition rotation was not allowed when BHA components where located across the whipstock.

The well was successfully drilled approximately 900m to oil bearing formations in two runs. A 7” liner was run, cemented and cleaned out without incident and with progress equal to a conventional well.

Finally the 7” upper completion was run, leaving the well in the situation as illustrated in Fig. 7 sub drawing #7.

Further history on the well

The lateral was perforated on wireline tractor. After a 6 month period of production from the lateral only, the whipstock was perforated. To confirm that the motherbore was indeed contributing, an isolation plug was run in the lateral before perforation of the whipstock.

The perforation was performed according to plan and the contributions from the motherbore confirmed by a well test. The perforation was followed by a substantial although short-lived increase in the production rate, as both wellbores were taken in simultaneously.

As the lateral had encountered formations with substantially higher productivity index (PI) than the motherbore the lateral naturally dominated production. Due to this an addition of the rates from the two wells could not be achieved without further flow control being installed although some added production was achieved from the commingled flow and installation costs were easily recovered (SeeFig 8).

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Results

All the technical objectives for the installation were fulfilled:

- The lateral was constructed without incident
- Time and money spent on the lateral were only marginally higher than for a conventional sidetrack
- Communication with the motherbore was proven after perforation of the whipstock

The completion of this multilateral has proved the technology to the satisfaction of the operator and we are confident that MLT solutions of this kind can be run with no greater technical risks and at a very small cost premium when compared to conventional P&A sidetracks.

Second Lateral

When planning B-1A it was already known that another reservoir prospect was available in the opposite direction to B-1A and, as production rates in B-1 / B-1A declined, the desire for yet another lateral materialized in 2004. The new prospect required a wellbore some 1100m away from the original wellbore to a separate geological segment that was assumed to be able to produce commingled after an initial period of pressure depletion (See Fig. 9). The target was considered to be within reach of a 6” TTRD sidetrack which could typically save 20-30% when compared to a conventional 6” sidetrack because pulling and re-running the tubing could be avoided.

The concept was the same in that no physical access was required to the old wellbore (now the combined B-1 / B-1A) as long as hydraulic communication could be established when needed (See Fig.10).

System design and testing

The MLT system for such an application had not yet been run anywhere and there was the added complexity of exiting through two strings of tubulars (7” tubing and 12 ¼” liner).

Therefore the operator decided that before committing to the system a full scale test of the casing exit would have to be performed in a test fixture. For this challenge a test was designed that would enable a full casing window to be created using all the worst case parameters available: No cement between the 7” and 9 5/8” strings, no centralization of the inner string and no gravity assistance.

Over a period of two days the window was created. The test rig (See Fig. 11) provided the advantage of being able to pull out and photograph the progress of the window at various stages of the process. It was of great importance to investigate when the mills would start wearing into the whipstock faceplate while generating the new window. By repeatedly measuring whipstock face wear and recording the drilling parameters, an understanding of the relationship between these factors was developed. The window was successfully milled with some minor changes suggested to the milling process and mill construction.

Constructing the second lateral

Much of the same procedure used for B-1A was repeated for this well (See Fig. 7 for details). The proven timer plug was run on wireline prior to the start of rig operations. Once the well was bullheaded to seawater and the plug was confirmed in place, the rig operations could commence and the following steps were performed:

- Displaced to mud
- Set whipstock
- Created window in two runs
- Drilled new lateral – had severe hole problems and struggled with this for a long time
- Ran liner and cemented same
- Perforated lateral

Although the formation troubles encountered made it a rather expensive well, the MLT technology functioned as planned. In fact it performed well under even more severe conditions than were originally planned as the well in the end required four openhole sidetracks to reach the target. Even with all this tripping and drilling, the whipstock faceplate did not suffer any critical damage.

Results

Well B-1B was completed in January 2005 and is now one of the better producers on Gullfaks delivering some 900 sm3/d. As the pressure in this lateral is still somewhat higher and the water cut substantially lower than in the old branches B-1 / B-1A the plan is to let B-1B produce alone for a period before again introducing the old wells into the wellbore by perforating the whipstock. When this is performed the well will be produced from three separate wellbores simultaneously.

Lessons learned and further development

Technically both MLT installations were performed more or less flawlessly. On the production side not all expectations were fulfilled although this was caused by productivity issues and not the technology.

The well has not yet been through its full MLT lifetime cycle and the limited costs of the MLT system will doubtlessly be recovered several times over the years to come.

To further enhance the MLT concept the operator can envisage some of the following options:

- Flow control of lateral and/or motherbore
- Less pressure drop across isolation plug and perforated whipstock
- Intelligent control in whipstocks
- Multistack of more than three branches

Developments in hollow whipstock applications

With a good number of this junction type having been deployed in the North Sea, the attributes of the hollow whipstock system has been shown to provide a rugged solution to develop marginal reserves economically. In order to advance the system to its next logical stage and help recover smaller pockets or indeed control the drainage system more efficiently, a number of engineering developments are on-going.

One obvious step towards cost reduction is to cut the number of trips involved in deploying the system to a minimum. The service provider is working towards a one trip system that will essentially cut two trips from the junction installation and provide a far more economical intervention solution overall. Being able to install the junction hardware and mill the window in one trip while providing a shallow angle ramp will leverage this niche technology by providing increased value.

TTRD technology and experience is growing in the North Sea, both due to necessity and because of obvious economic gains and the hollow whipstock system has its part to play here too. By deploying the smaller sizes of the hollow whipstock in a thru tubing application, it is possible to create multilateral windows without using a main rig. Testing has been conducted to allow deployment of the junction hardware on wireline away from main rig activity. Windows have been successfully milled using coil tubing and TTRD procedures to promote more cost effective offshore operations. To date, there have been eight TTRD hollow whipstocks run through completions to create level 3 & 4 junctions.

The interaction of completion components, including intelligent multiposition sleeves as well as expandable junction and formation isolation tubulars further opens this low level junction to new and exciting application. Being able to remotely shut off or stimulate legs in a multilateral brings added value to reservoir management.

Conclusions

- The hollow whipstock solution is now ‘proven technology’ for the operator
- It has proven to be a cost effective way of obtaining multiple drainage points
- It can, in principle, provide for unlimited multiple stacks (but only with access to the last lateral)
- The installation process is very transparent to the rig crew almost like conventional sidetracks
- The equipment is proven to be low risk technology

- It can be combined with other technology such as TTRD/CT drilling.

For this operator this solution is one of many to keep in the toolbox to enhance the value of the many mature wells on the field. For some wells the technology may not be applicable due to pressure differences, productivity issues and so on, however many wells can benefit from the technology and this operator has already completed other similar installations successfully.

We are confident that by combining all the tools in the box this technology will see more use in the future.

Acknowledgements
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References
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2. Redlinger, T., Constantine, J., Makin, G., Glaser, M., Brown, C., Cooke, D., McLaughlin, J.: Multilateral Technology coupled with an Intelligent Completion System Provides Increased Recovery in a Mature Field at BP Wytch Farm, UK, SPE/IADC 79887, Amsterdam 2003

Figure 1 – Location of the Gullfaks field

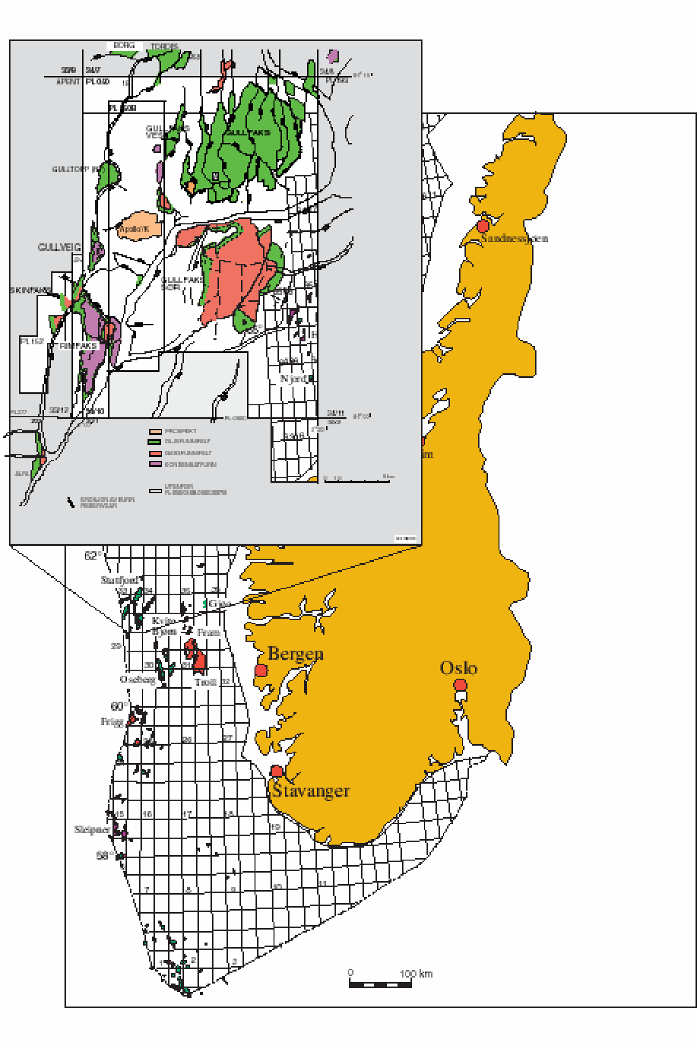


Figure 2 well schematic prior to start of operations

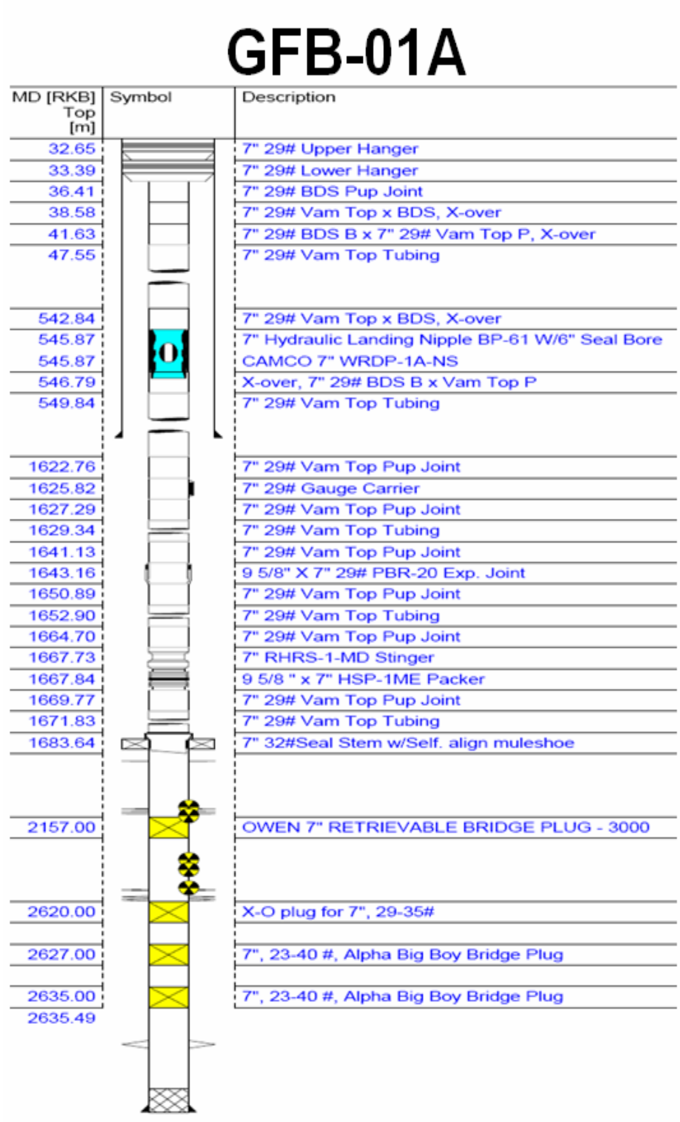


Figure 3 Geological setting

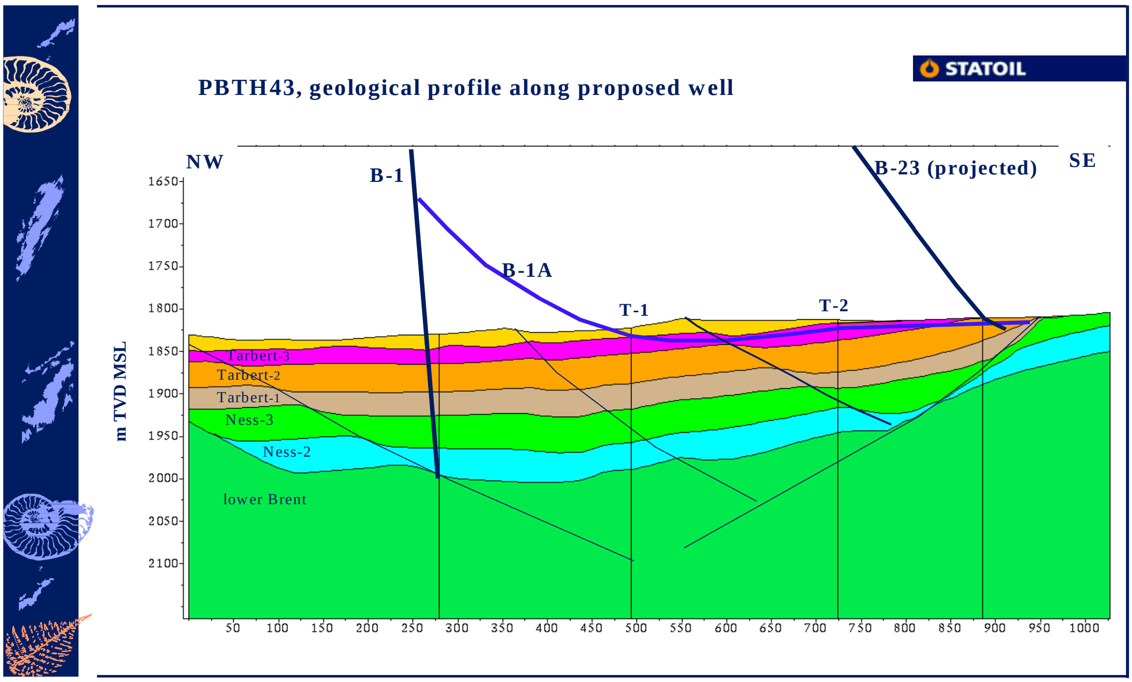


Figure 4 Hollow whipstock sssembly picture

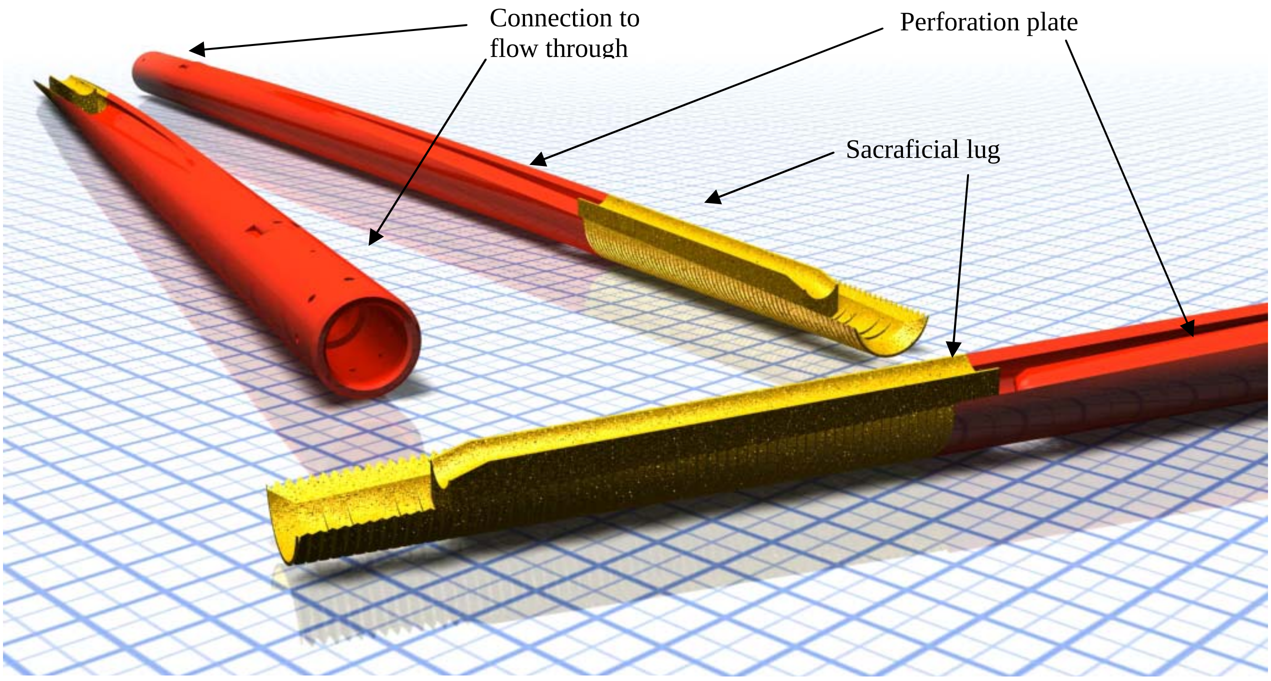


Figure 5 Hollow whipstock main mills

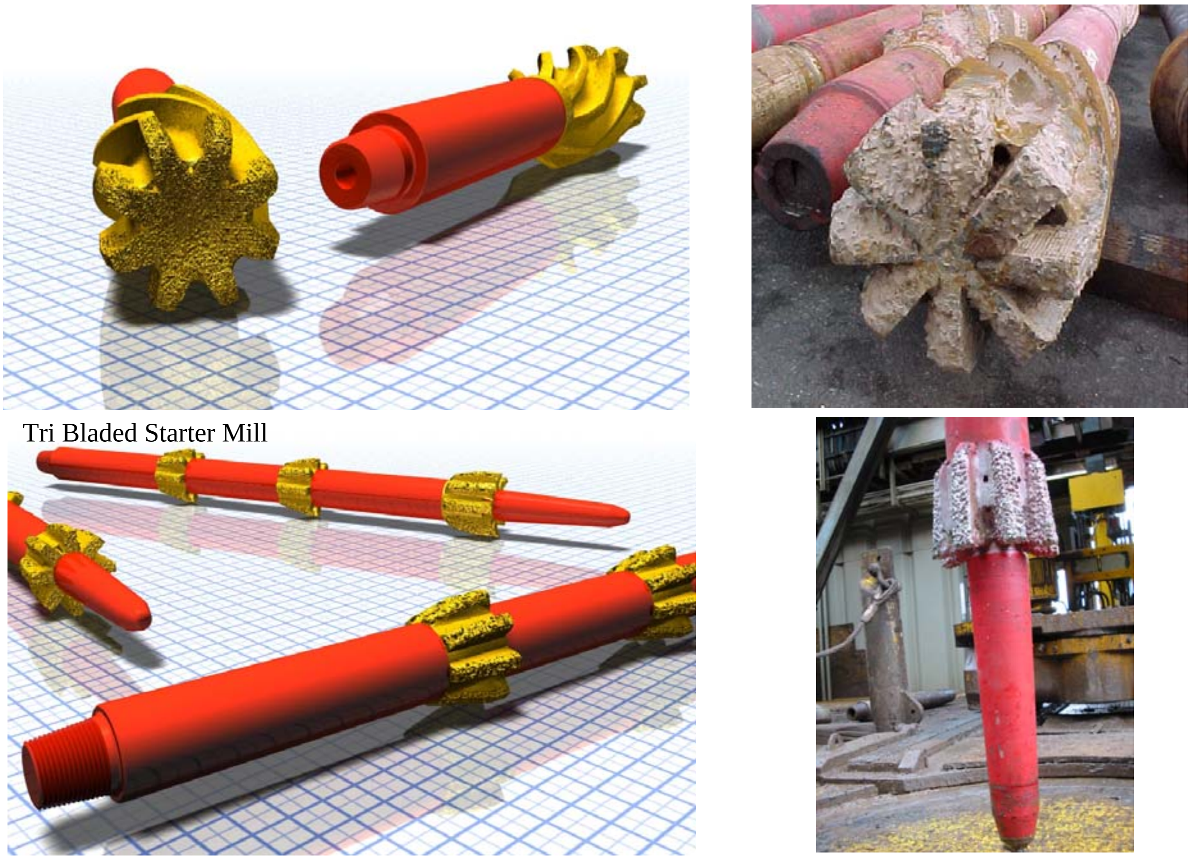


Figure 6 Perforated junction with associated pressure loss

StarBurst™ perforation – The result:

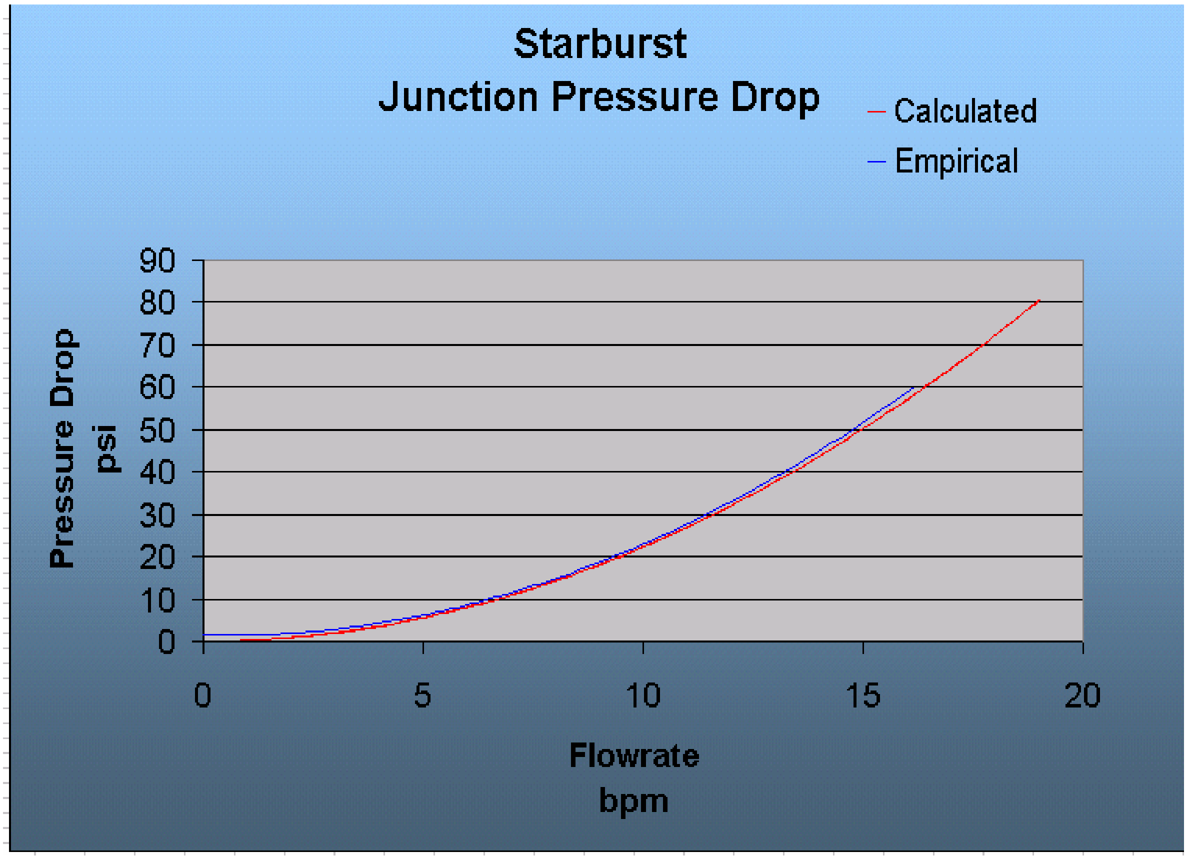
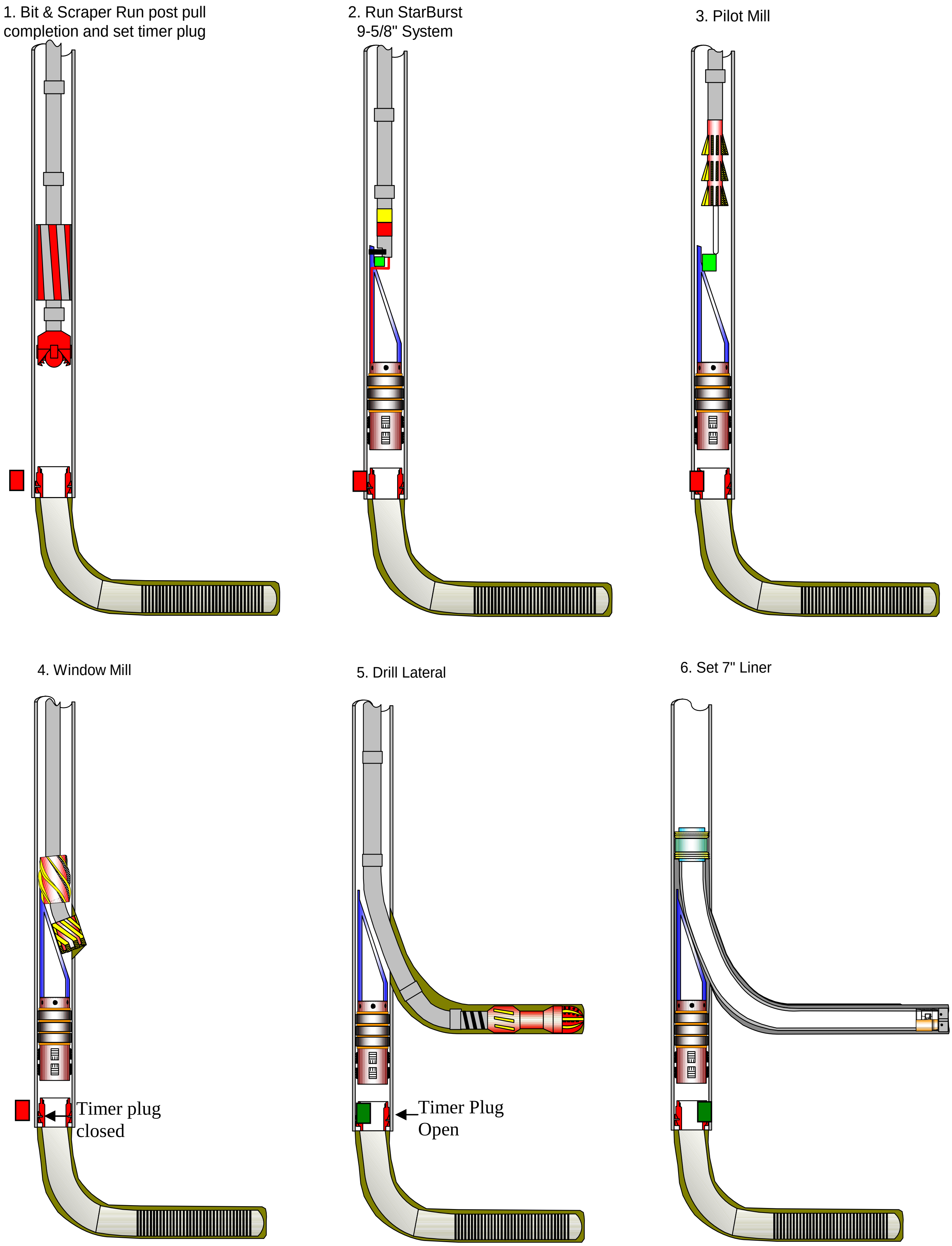
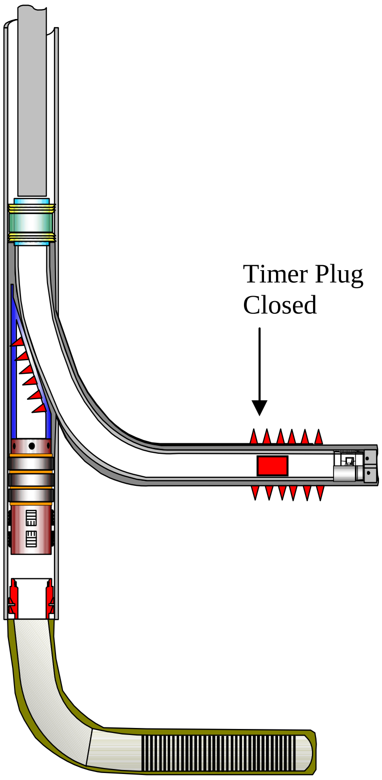


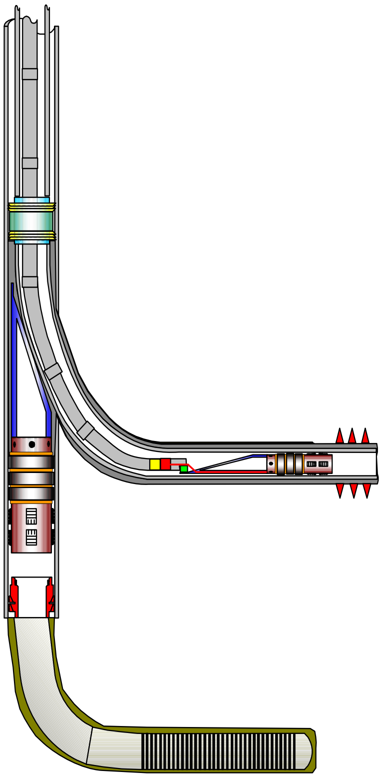
Figure 7 Installation sequence - Gullfaks dual MLT installation



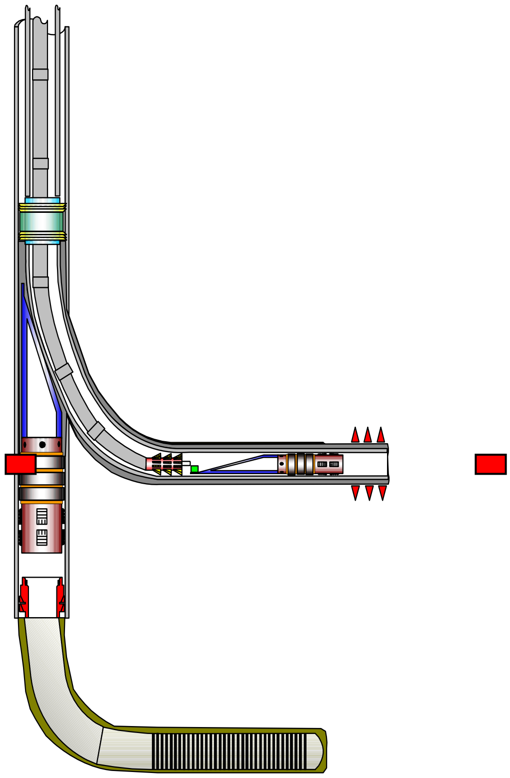
7. Run completion and perforate



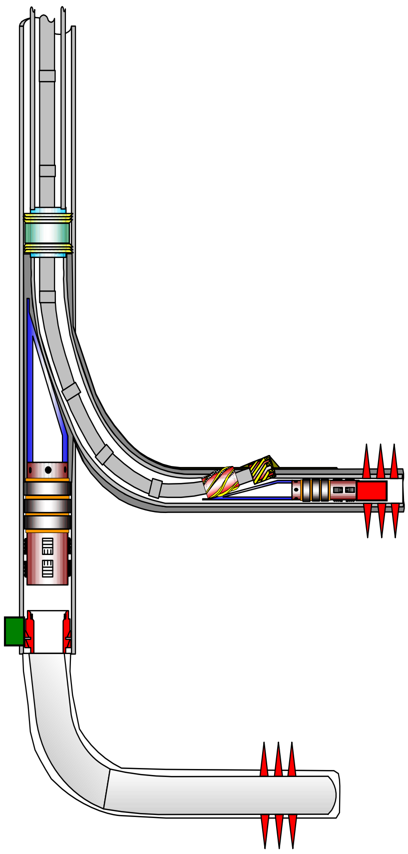
8. RIH with 7" StarBurst System thru completion



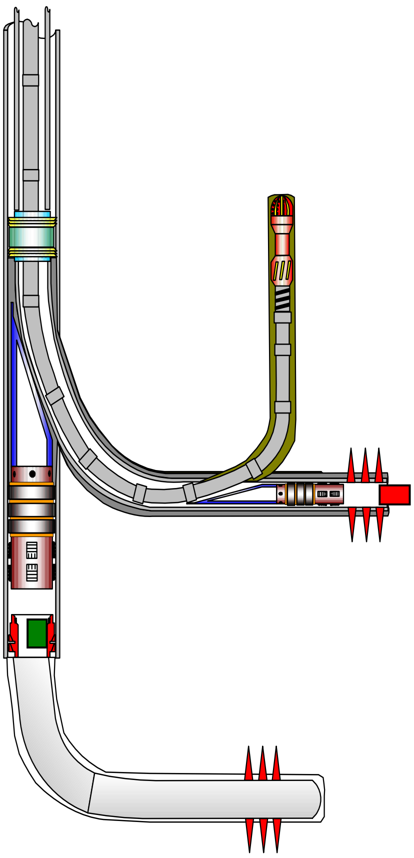
9. Pilot Mill



10. Window Mill



11. Drill 6" OH Lateral



12. RIH with liner hanger & Perforate zone

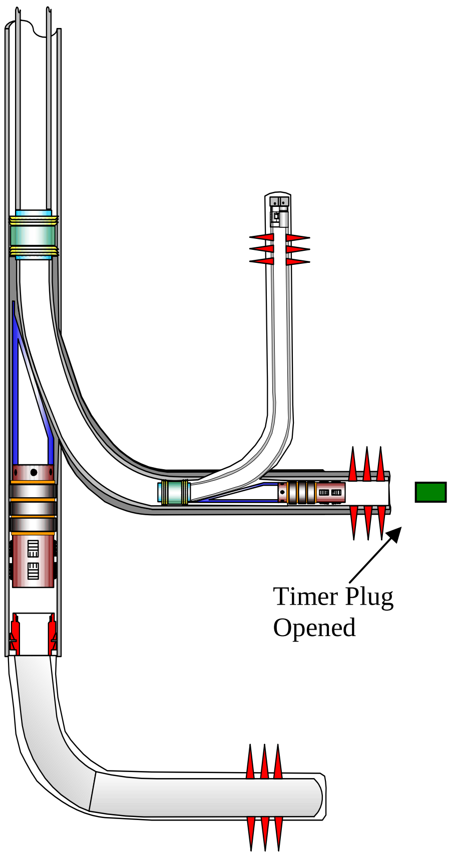


Figure 8 Production History B1A

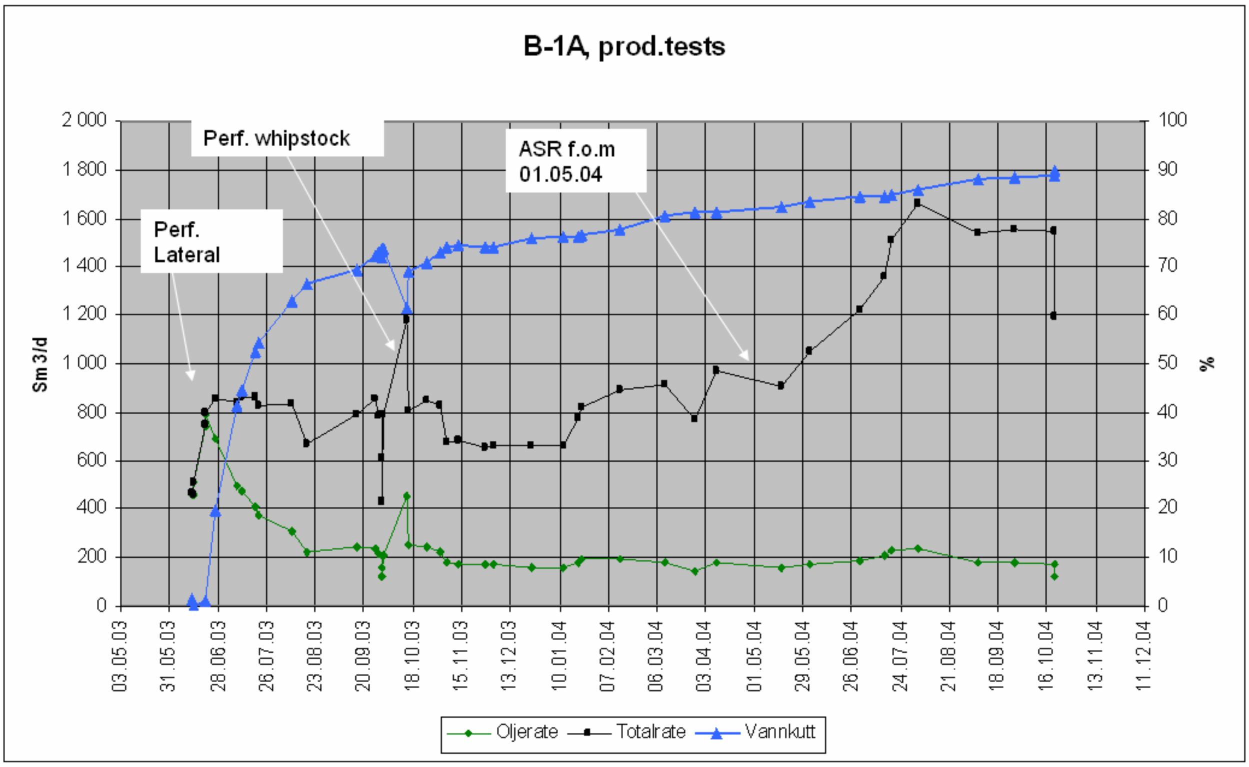


Figure 9 shows the geological setting for the two wells.

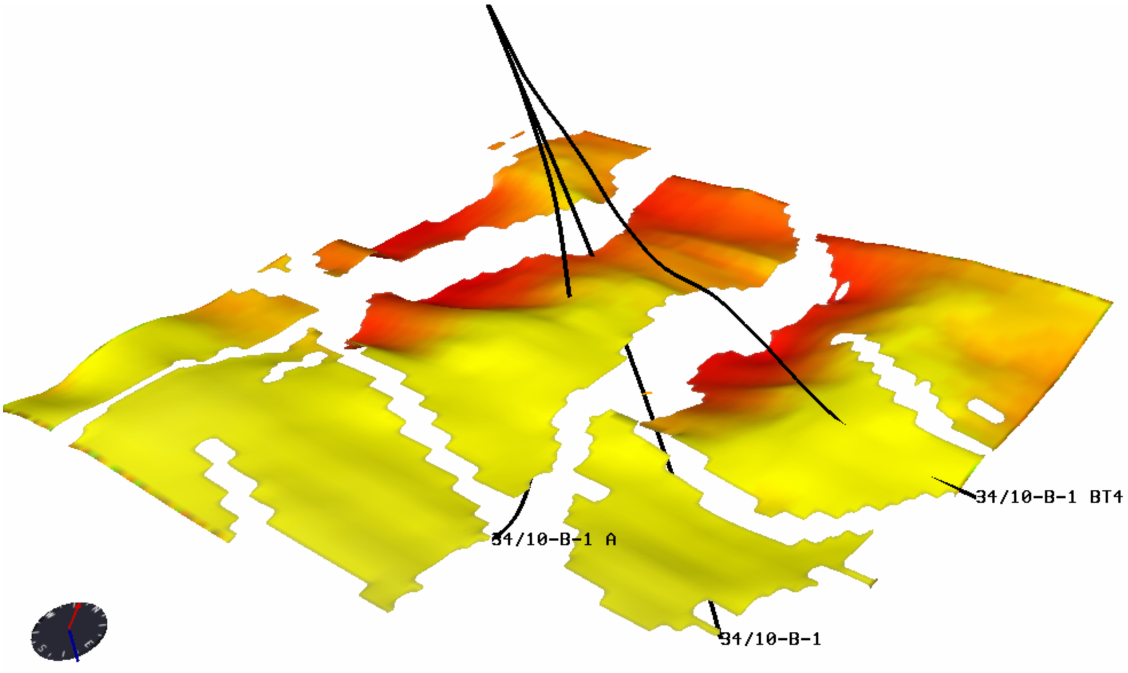


Figure 10 illustrates the concept design for the complete tri-lateral well.

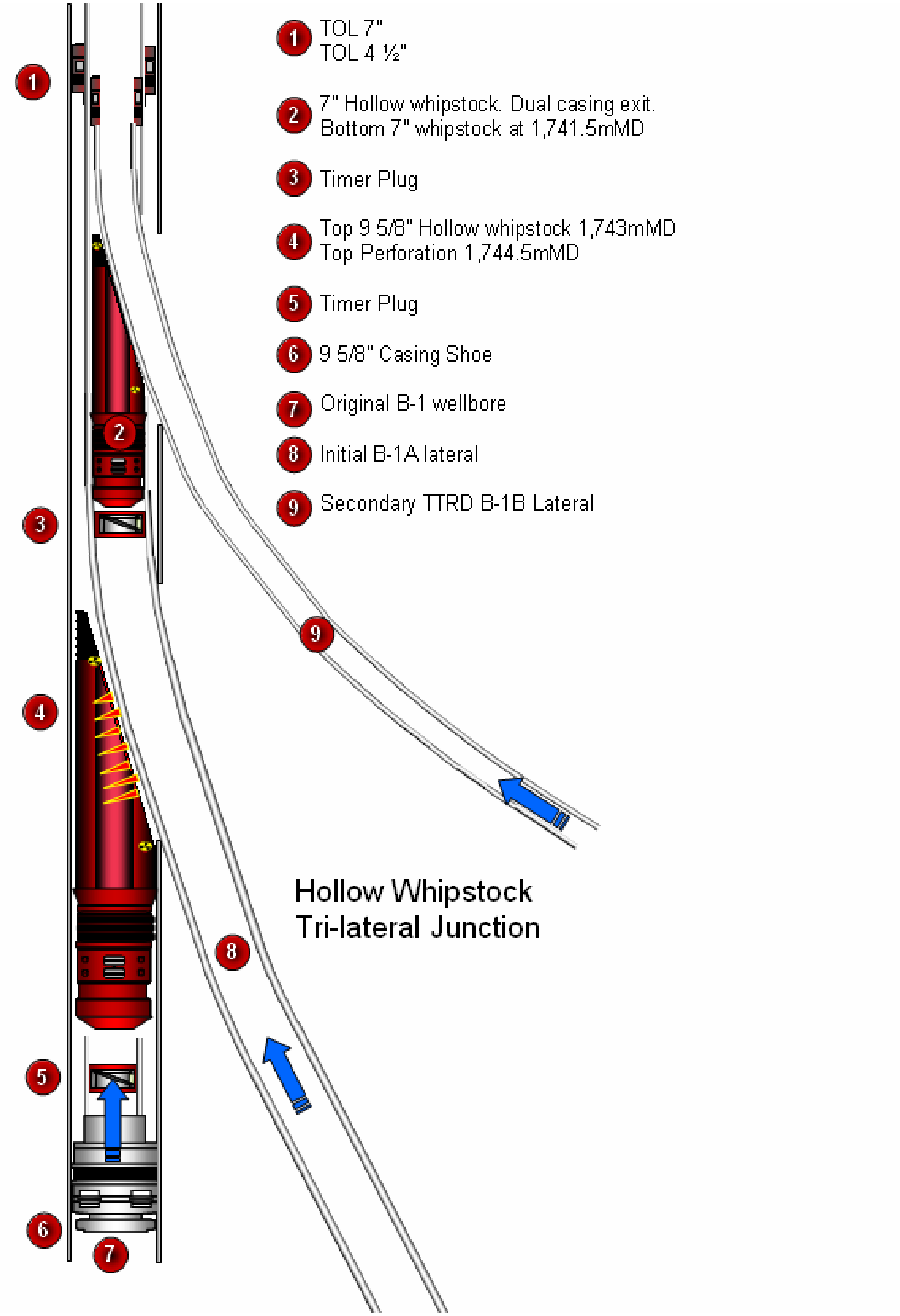


Figure 11 illustrates the test setup