vol. 20, n.° 2, julio-diciembre de 2022
ISSN impreso: 1657-6527 • ISSN en línea: 2145-8502

FUENTES
EL REVENTÓN ENERGÉTICO

Design of Multilateral Wells for the Conditions of Guajira Offshore Basin in the Colombian Caribbean Sea

Diseño de pozos multilaterales para las condiciones de la Cuenca costa afuera de la Guajira en el Caribe Colombiano

Emiliano Ariza León*[1], Daniel Sebastián Ortiz Riaño[1], Geovanni Rodríguez Turizo[1], Jairo Humberto Cabrera Tovar[2]

[1]Universidad Industrial de Santander, Bucaramanga- Colombia.

[2]Universidad Tecnológica de Bolivar, Cartagena-Colombia

e-mail: earizal@uis.edu.co

Recibido: 26 de junio, 2022. Aprobado: 06 de septiembre, 2022. Versión final: 28 de noviembre, 2022

ABSTRACT

This article proposes the design of a multilateral well on the Tayrona area conditions located in the Guajira Offshore basin that belongs to the Colombian Caribbean. This zone has a strategic importance for Colombia, because is where the Orca-1 well was drilled, integrating a substantial gas reservoir detection in 2014, which is a project with great development potential, that can help meet the energy needs of the country, where Ecopetrol, Petrobras, and Repsol are contributing.

Reviewed to know about the technique of drilling multilateral wells, perform an analysis of the conventional and modern existing alternatives and both the environmental and operational variables influencing the drilling of this kind of offshore wells. In addition, a research study of environmental and geological conditions of the interest area, the Colombian Guajira offshore, was carried out to determine the feasibility of the application of this technology.

The design of the multilateral well UIS-OFF-MO1 was proposed, with two opposite branches to increase production in the reservoir in which Orca-1 well is situated, to increase the drainage area and contact an area of the reservoir, which is separated by a normal no-flow fault.

Key words: Multilaterals wells, Guajira offshore Basin, metoceanic conditions, wells planning and design, Drilling and completion multilateral wells.

RESUMEN

En este artículo propone el diseño de un pozo multilateral para las condiciones del área Tayrona ubicado en la cuenca Offshore de la Guajira que pertenece al Caribe colombiano. Esta zona tiene una importancia estratégica para Colombia, ya que es donde se perforó el pozo Orca-1, integrando un importante yacimiento de detección de gas en 2014, que es un proyecto con gran potencial de desarrollo, que puede ayudar a satisfacer las necesidades energéticas del país, donde han explorado Ecopetrol, Petrobras y Repsol.

Como citar: Ariza León, E., Ortiz Riaño, D. S., Rodríguez Turizo, G. & Cabrera Tovar, J. H. (2022). Design of Multilateral Wells for the Conditions of Guajira Offshore Basin in the Colombian Caribbean Sea. *Fuentes, el reventón energético, 20*(2), 103-118. https://doi.org/10.18273/revfue.v20n2-2022009

Se ha revisado la técnica de perforación de pozos multilaterales, realizando un análisis de las alternativas convencionales y modernas existentes y las variables tanto ambientales como operativas que influyen en la perforación de este tipo de pozos marinos. Además, se realizó un estudio de investigación de las condiciones ambientales y geológicas del área de interés, costa afuera de la Guajira colombiana, para determinar la factibilidad de la aplicación de esta tecnología.

Se planteó el diseño del pozo multilateral UIS-OFF-MO1, con dos ramales opuestos para aumentar la producción en el yacimiento en el que se encuentra el pozo Orca-1, aumentar el área de drenaje y contactar con un área del yacimiento, que se encuentra separada por una falla normal sin flujo.

Palabras claves: Pozos multilaterales, cuenca Guajira costa fuera, condiciones metaoceánicas, diseño y planeación de pozos, perforación y completamiento de pozos multilaterales.

Introduction

Increasing energy demand and declining reserves of conventional reservoirs have led several oil companies to focus their efforts on exploring and exploiting more complex areas such as offshore reservoirs. However, investments associated with drilling in these environments are significantly higher than onshore activities. Therefore, it is necessary to use techniques such as multilateral drilling, which allows optimizing costs in these projects.

Multilateral technology consists of drilling two or more directional or horizontal branches, constructed from the main well which can be vertical, directional, and horizontal. This alternative offers excellent in comparison with conventional wells. Some of these are the increase of the drainage area of reservoirs, the possibility of contacting more than one formation, the optimization of production and the ability to exploit areas with high heterogeneity or mature fields.

In this study, the design of a multilateral well in the Colombian Caribbean is proposed, more specifically at the Tayrona Block, located in the Guajira Offshore basin. For this purpose, a bibliographic review of the generalities and tools used in this type of wells, aside from other techniques used in offshore drilling, was initially carried out. Subsequently, the operational variables involved in constructing this type of well were analyzed. Finally, the design of the UIS-OFF-MO1 well is proposed, considering the specific characteristics of the study area.

Design methodology

The design of the well proposed to be conducted through several stages (Figure 1), initially, a literature review of the factors methoceanics and operational factors impacting the drilling of both offshore well, and directional and multilateral wells; subsequently, the findings in the Colombian Caribbean were reviewed, consolidating important information to select the application location; and finally the planning of the proposed well was developed, considering the operational factors influencing the selected application case. We briefly present the review carried out on each of the items established in the methodology.

Multilateral well drilling engineering

In this section, the process of construction of multilateral wells was reviewed and classified (Figure 2.) according to Multilateral TAML Levels revision (Westgard, D. 2002) and depending on the application cases.

In the drilling of this class of wells, directional tools are required, as well as tools that boost a deviation through the completion of the central well. These types of wells are classified according to the level of completion (Jardon. 2003) or depending on the configuration of the perforated arrangement.

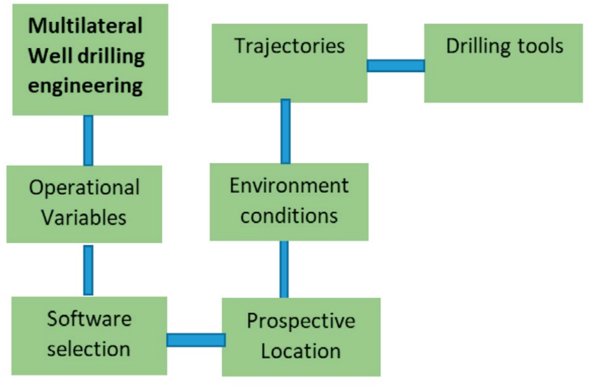

Figure 1 Proposed well design methodology.

Note: Well design methodology proposed by authors for research purpose. Authors.

Level 1: Both the main and the lateral wells are open hole, this type of completion can be used in formations with a highly consolidated rock.

Level 2: Main is well covered and cemented and lateral wells are open hole. In the same way as in the previous case, this type of completion is carried out when the formations are consolidated. However, in this one, casing and cement are used in the central well, reducing the chances of loss of integrity in the main section.

Level 3: Main well cased and cemented and the side is cased, but not cemented, so it has additional support to that provided by the rock matrix and partial isolation of the formation, which can be useful to prevent the entry of fluid from other formations into the well.

Level 4: Main well and sides lined and cemented. This type of completion provides mechanical integrity to both the central and lateral wells, without separating the fluids coming from each branch of the well.

Level 5: Main well cased and cemented, and side section cased, where integrity and hydraulic insulation are provided by additional termination components located within the central well, being useful for drilling sides on areas with different reservoir pressures.

Level 6: cased and cemented main well, and cased, cemented or non-cemented side section, where integrity and hydraulic insulation are provided by the primary casing pipe at the intersection of the side section casing pipe without additional termination components inside the main well.

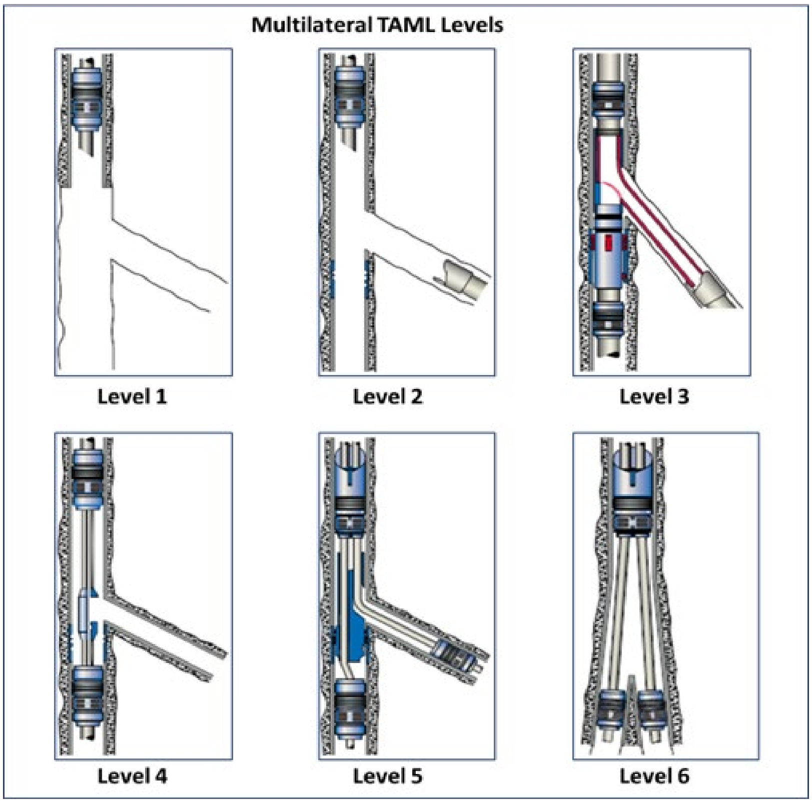

Figure 2. Classification of Multilateral wells by TAML level (Rick von Flatern 2016)
Note: Categories of well construction based on TAML Classification

The multilateral drilling technique has been studied to optimize the production of hydrocarbons in multiple difficult-to-access scenarios through conventional drilling techniques such as: in heavy crude oil reservoir, stratified and thin reservoir, reservoir with isolated compartments, and naturally fractured reservoir.

Through experience, it has been determined that the positioning of branches in this kind of projects is fundamental to optimizing production of the desired reservoir. This positioning, and the number of branches, will depend on the type of reservoir geological structure. A detailed study of the target reservoir is fundamental to success of a multilateral drilling project, the development of more detailed geological studies and accurate positioning tools with real-time monitoring capabilities (well placement) might allow the design and construction of wells with a high probability of success.

Operational Variables: the variables involved in the drilling process of a multilateral offshore well, as well as the external factors impacting the operation which were considered of high importance for the research objectives, and therefore included in the design, are the following:

External Phenomenon:

Environmental conditions: pressure and temperature conditions that can lead to methane generation.

Hydrodynamic forces: factors such as waves, winds, and sea currents.

Geological factor: based on stratigraphy of the area and formations pressure conditions.

Operational characteristics: These are addressed to the specific issues on the operation, as the election of central and lateral well path, Drilling fluids, Pipes for drilling, Tools, Completion

Software: For the design of the well trajectories, a software commonly used named Compass from Halliburton was used. That software provides the necessary tools to design the proposed multilateral well and is available for academic use at the Universidad Industrial de Santander. This tool allows to design or planning with different types of trajectories, the design of wells with multiple branches, and the inclusion of coordinates, geological formations properties and anti-collision analysis for the design of multi-lateral or directional boreholes infill on a mature field.

Location of the prospectus: Once the operational variables have been identified, a location is sought for the application case, which depends on the potential hydrocarbon content, as well as the quantity and quality of information available in the area.

Geological conditions: It is intended to identify geological conditions that justify the drilling of multilateral wells in the selected area, according to the available information.

Arrangement and trajectories: These depend on the shape of the reservoir, as well as the characteristics of the different types of rock to be drilled until reaching the target. The number of laterals is related to the area of the interest formation or geological units. The trajectories are selected to reduce the risks associated with directional drilling (collision with nearby wellbores) and achieve the objectives required within the area of interest.

Drilling tools: Once the wells paths to be designed have been defined, we proceed to determine the different types of pipes, surface tools, fluids and Bottom Hole Assembly (BHA) arrangements necessary to carry out the proposed drilling project. The specifications of these tools are determined by calculations and engineering considerations, made from the literature review.

Methodology and development

Following the methodology presented above, a design proposal for a multilateral well application case was made for the conditions in the Guajira offshore basin. A step-by-step is showed below for the well design, which is called UIS-OFF-MO1 in the remainder of this document.

Location: It is known that the area corresponding to the block Tayrona, where the discovery of an accumulation of gas by the well Orca-1 was made, has a representative amount of potential hydrocarbon resources, which are expected to be developed during the next few years and represents a strategic importance for the supply of this valuable energy resource within the country.

The design of the UIS-OFF-MO1 well, in the vicinity of the Orca-1 well (Figure 3), was proposed as a developing alternative on the field once that phase is reached. The well Orca-1 is located at coordinates of latitude 12° 46’ 57.4’N and a longitude of 71° 35’ 49,2’W, was drilled to a depth of 13,910 ft in an area with water depths of 2,211 ft (674 m), finding hydrocarbons at a depth of approximately 12,000 ft1.

Figure 3. Location well UIS-OFF-MO1
Note: Orca 1 Well and UIS-OFF-MO-1 Design location positioned by Authors, using Google earth web tool.

For the location of the prospect, Orca-1 well was taken as an offset well, because most of the information available from this offshore area is associated with the study carried out for the drilling of this well, the position in respect of the existing well was determined based on the knowledge about the geological structure of reservoir with potential hydrocarbon content.

Geological conditions of the area: using existing seismic sections, as well as correlation with wells drilled in the area, it is possible to estimate the structure and stratigraphy of the formation of interest. In the case study, 2D seismic is available, from which it is possible to consider that the formations of interest have the presence of faults, as shown in Figure 4.

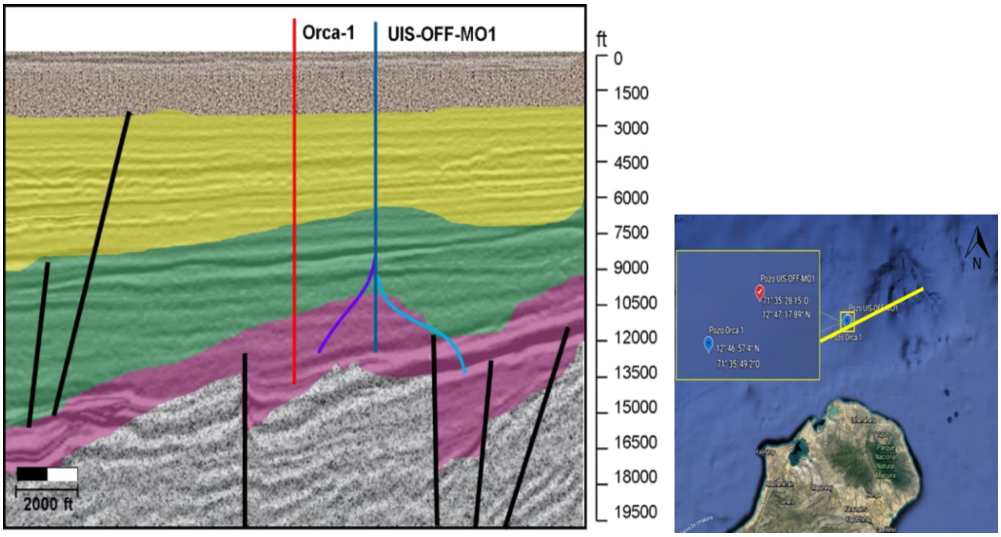

Figure 4. Cross section of interest formation
Note: Modified from OLAYA, Iván. Futuros descubrimientos de hidrocarburos en Colombia Offshore. Universidad de los Andes [Presentation]. Mansarovar Energy. 2020.

The geological structure of the area allows to consider the approach of a multilateral well to achieve an isolated formation, if the evidenced fault in the vicinity of the proposed UIS-OFF.MO1 well, presents non-flow conditions.

On the other hand, from the stratigraphic column of the area Siamaná and Guaralamai formations correspond to Oligocene and upper Cretaceous units, which have potential hydrocarbon content. There is a possibility of hydrocarbon accumulation in these sandstones. The seal rock are claystones from formation Uitpa and Jimol Units .

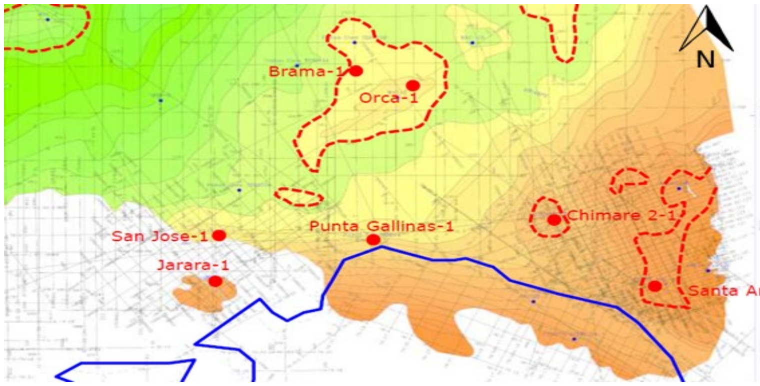

Figure 5. Top View Oligocene producer formations in the Colombian Caribbean
Note: Colombian offshore producer and potencial reservoirs, geographic and stratigraphic reference. Taken from OLAYA, Iván. Futuros descubrimientos de hidrocarburos en Colombia Offshore. Universidad de los Andes [Presentation]. Mansarovar Energy. 2020.

Additionally, from the Oligocene formations around Orca-1 well on the Figure 5, if the formations with potential hydrocarbon content have an elongated shape in a Northeast direction, which influences the selection of the lateral arrangement for the well proposal.

Metoceanic conditions: In the design of an offshore drilling plan, it is necessary to know the environmental conditions (Figure 6), which the equipment required to drill the well will face. In the review, metoceanic conditions were identified for the Colombian Caribbean, obtained from the National Oceanic and Atmospheric Administration - WaveWatch III structural model. These conditions are very important for selecting the type of platform and positioning devices planned for well drilling to ensure safe and efficient operation.

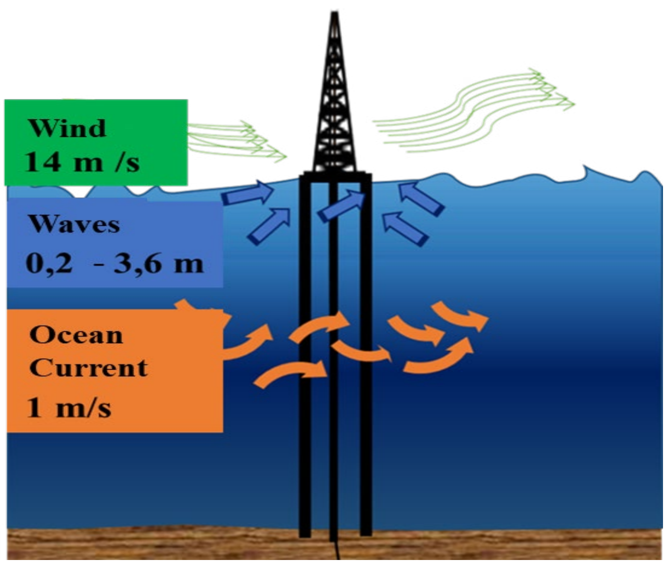

Figure 6 Metoceanic boundary conditions in Colombian Caribbean**.**
Note: Figure adapted by authors, based on the information about Colombian Caribbean conditions from the research: MORALES, D; MONTOYA, S. & BERNAL, O. Assessment of extreme wind and waves in the Colombian Caribbean Sea for Offshore applications. Universidad Nacional de Colombia, 2017.

Selection And Arrangement of Trajectories

Once the geographical and geological conditions of the area are determined for the design, an arrangement of branches of the UIS-OFF-MO1 well (mother bore) is proposed. The forward plan to drill a vertical well to a depth of 14,750 ft TVDSS (True Vertical Depht SubSea), according with the geological available information, in an area with a water depth of 2,211 ft (670 m). This design is extended by two branches in opposite directions, which derives from the assumption that the target zone has an elongated shape in the direction N45°E. In the Figure 7, we present the trajectory of the main well, including rock formations.

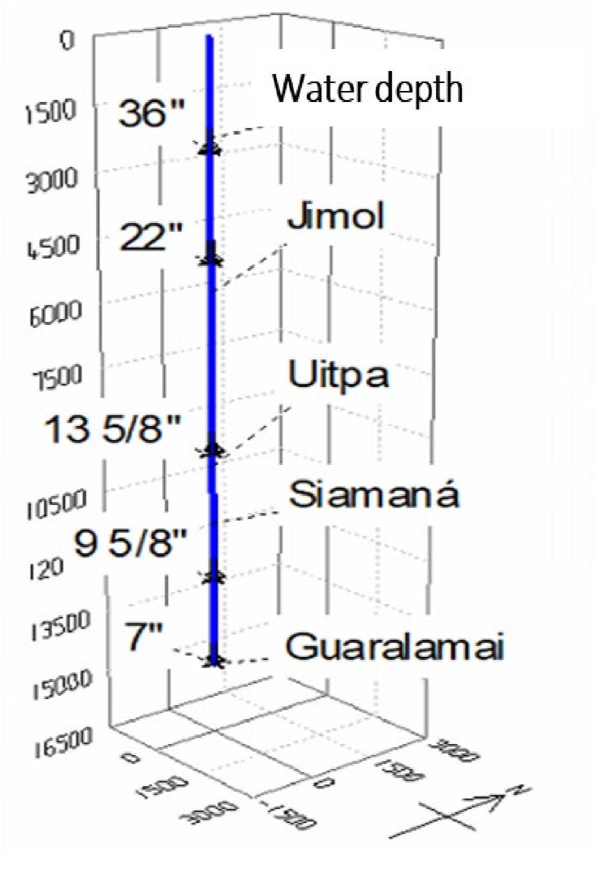

Figure 7 Principal Well UIS-OFF-MO1.
Note: Figure generated by authors using Compass Landmark suite application. Target planned according known to geological condition from GIRALDO, Camilo y RODRIGUEZ, Daniela. Evaluación de formaciones para un descubrimiento de gas seco en el Caribe Colombiano, incorporando soluciones inversas, a partir de respuestas a modelos numéricos y analíticos. Fundación Universidad de América. 2017.

The first branch of the multilateral well corresponds to the design of a lateral type J, called UIS-OFF-MO1-L1, which objective is to reach the same reservoir where the vertical section target is planned, reaching a target with a horizontal separation of 2000 ft in the direction S46°W. The direction was selected considering the orientation of the producing formation from Orca-1 Well, which is elongated on the N45°E direction, so this lateral is designed on the opposite direction, trying to cover the largest possible area of the formation. This well section consists of two stages, the first consists on angle construction, with a Build Up Rate (BUR) of 2.2°/100 ft, and a section of angle maintenance, whose maximum dip angle is 36.6° (Figure 8). To realize the emplacement starting the drilling of the lateral sections it should be installed a guide shoe allowing lead the bit to the preferential direction. An oriented casing also can be used to ease the emplacing of the lateral window in the desired direction. These considerations would be also helpful when a reentry is required to one of the branches, either using the guide shoe, or installing oriented casings. Also, it must be used a bit with the required features to mill the casing, as a junk mill. And the entry slope should be greater than 5°.

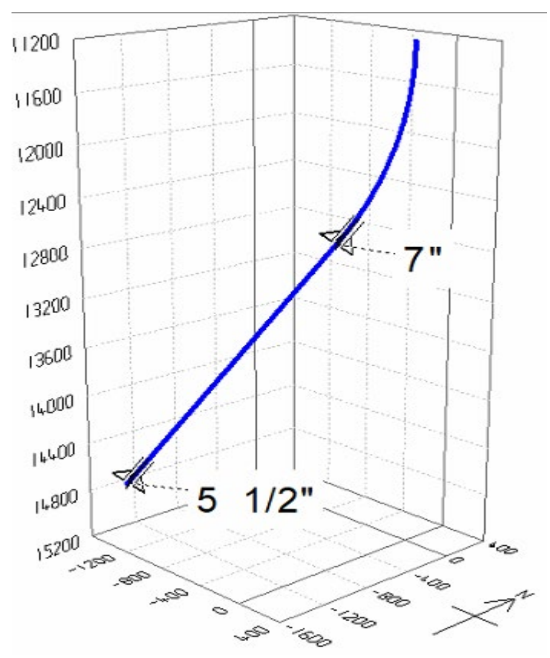

Figure 8. Lateral UIS-OFF-MO1-L1.
Note: Figures of lateral well sections were generated by authors using Compass Landmark suite application.

On the other hand, the second lateral corresponds to an S type, which seeks to contact a section of the formation that is separated by a non-flow fault 850 ft below the main one, with a lateral displacement of 2100 ft in direction N45°E, which is the direction where the interest formation is elongated (figure 3) also contacting the main formation before the fault. With this objective, the lateral consists of 3 sections, the first of angle construction, with a BUR of 3.65°/100ft, followed by a sustained angle of 42.1°, and an angle drop of 2.1°/100ft (Figure 9). Further from the considerations on the first lateral well. This one is designed as a S type well, with the objective of comprise a bigger area of the formation, and surpass a non-flow fault we identified from the 2D seismic studies on the zone, reaching another formation isolated by the fault.

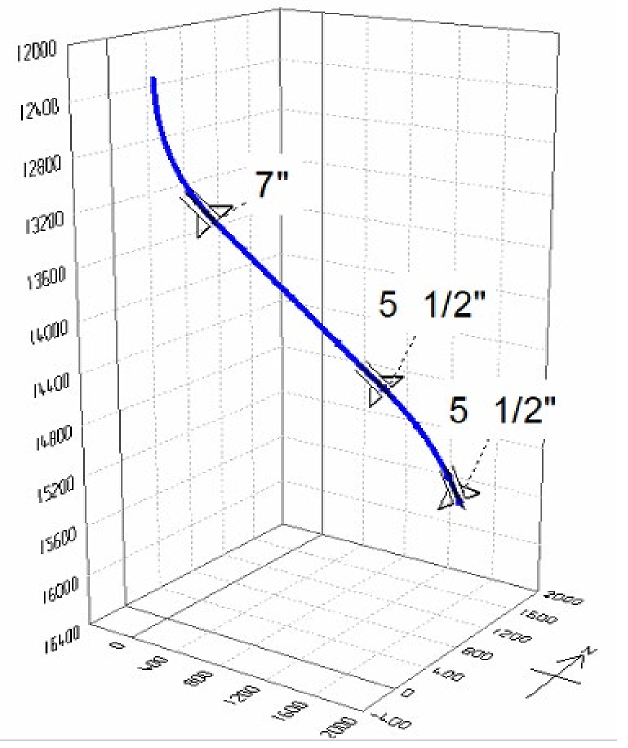

Figure 9 Lateral UIS-OFF-MO1-L2.
Note: Figures of lateral well sections were generated by authors using Compass Landmark suite application.

Drilling mud

This operating range was determined from information from the mud density drilling plan used for Orca-1 well, following the methodology presented in Figure 8. Given that a well design is proposed for a location in the vicinity of Orca-1 well, it is estimated that the drilling fluids required to drill the well should have rheological properties like those of the fluid used in the existing well.

From the obtained mud-weight window (Figure. 9), the mechanical state design for the main well is carried out (Figure 10). Since no pore pressure data are known, the minimum mud density was taken the mud density used in drilling Orca-1 well. The equivalent fracture density was estimated using the Hubert & Willys method (Boniface, 2012) and the maximum sludge density was determined by subtracting a value of 0.5 ppg from the equivalent fracture density.

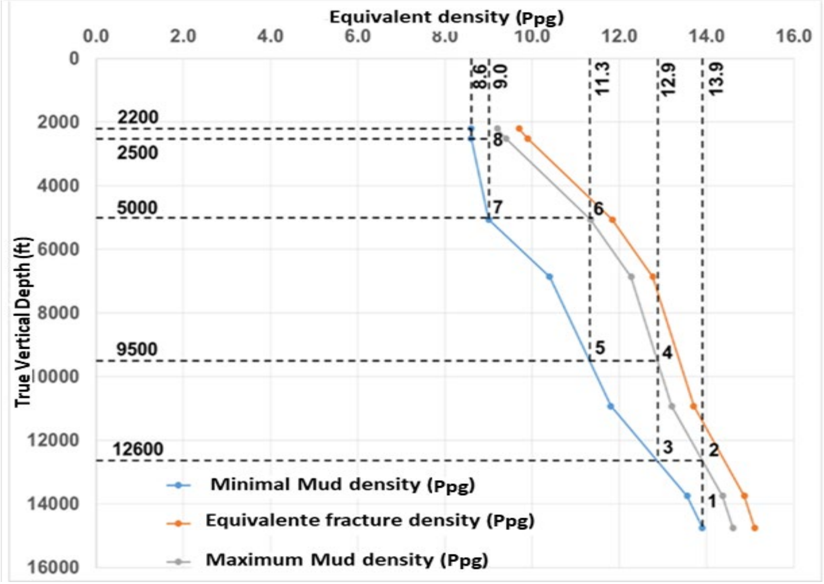

Figure 10. Mud Window UIS-OFF-MO1
Note: Mud Window estimated using Hubert and Willys method, from the article: A. Boniface,O. and Ogbonna J. (2012) “A New Fracture Gradient Prediction Technique That Shows Good Results in Gulf of Guinea.” Paper presented at the Abu Dhabi International Petroleum Conference and Exhibition, Abu Dhabi, UAE, November 2012.

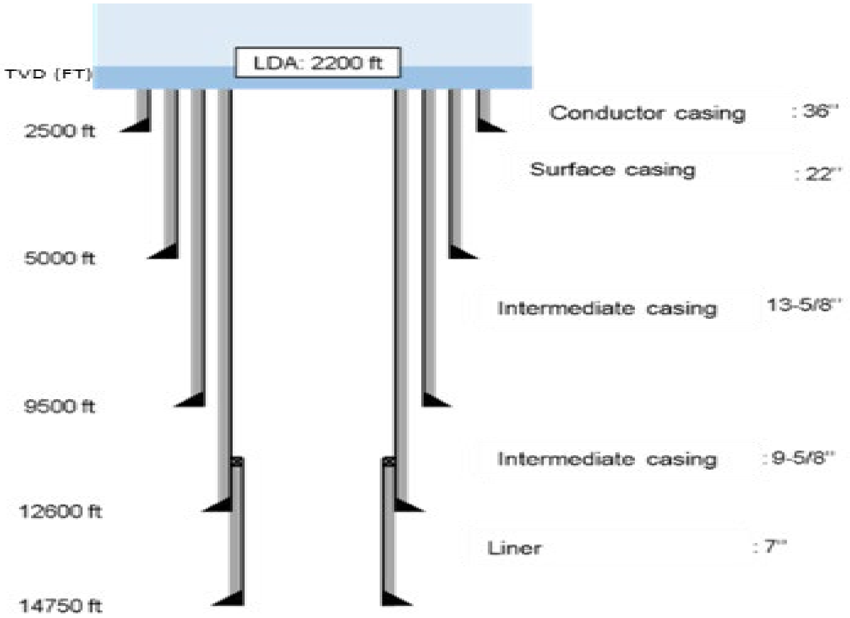

Figure 11. Mechanical condition UIS-OFF-MO1.
Note: Mechanical condition proposed by authors, considering Mud Window on Figure 10.

Based on the mechanical state determined from the mud window, it is possible to design a well drilling fluid program (Table 1), the densities raised are within limits established in the mud window previously shown (Figure. 10). The use of seawater in areas where reservoir pressure allows it, and oil-based mud in the underlying sections, considering less difficulty for the treatment and disposal of drilling waste.

Table 1. Well fluid program UIS-OFF-MO1.

Section	**Depth TVDSS (ft)**	**Mud Type**	**Mud density (ppg)**
Water	2,200	-	-
1	2,500	Sea Water	8.6
2	5,000	Sea Water	9.0
3	9,500	Water based mud	11.3
4	12,600	Water based mud	12.9
5	14,750	Water based mud	13.9

Note: Mud densities proposed by authors, considering Mud Window on Figure 10.

Mud weight were also calculated for the two proposed well branches, as they are shown on the next tables (2 & 3). Mud Weight is similar to the one proposed for the mother bore, this assumption was made considering that the first Branch UIS-OFF-MO1-L1 is going to drilling the same formations with similar True vertical depth. On the other side, the second lateral will reach a deepest formation, but according to the geologic data, it may be the same formation separated by a fault, therefore, the pressure gradient should be similar to that on the same formation.

Table 2. Well fluid program UIS-OFF-MO1-L1

Section	**Depth Interval MD (ft)**	**Mud Type**	**Mud density (ppg)**
1	12,100-13,650	Water based mud	13.0
2	**13,650-15,650**	Water based mud	**14.0**

Note: Mud densities proposed by authors, considering Mud Window on Figure 10.

Table 3. Well fluid program UIS-OFF-MO1-L2

Section	**Depth Interval MD (ft)**	**Mud Type**	**Mud density (ppg)**
1	12,600-13,650	Water based mud	13.0
2	13,650-15,015	Water based mud	14.0
3	15,015-15,950	Water based mud	14.0

Note: Mud densities proposed by authors, considering Mud Window on Figure 10.

Bit planning

Tables 4, 5 and 6 present the proposed drill program for the UIS-OFF-MO1 well and its respective side wells. This proposal is based on the expected hardness of formations at different depths, taking as a reference the information available on the properties of the rock in similar projects, such as the drilling of Orca-1 offset well.

Table 4. Well bit program UIS-OFF-MO1.

Section	Depth TVDSS (ft)	Bit	**Diameter (in)**
Water Layer	2,200	-	-
1	2,500	Tricone	26
2	5,000	PDC	26
3	9,500	PDC	16-1/2
4	12,600	Diamond Inserts	12-1/4
5	14,750	Diamond Inserts	8-1/2

Note: Bit selection proposed by authors, according to hole diameter, depth, and stratigraphic and geological knowledge of the area.

Table 5. UIS-OFF-MO1 - L1 drill program

Section	**Depth TVDSS (ft)**	**Bit**	**Diameter (in)**
1	11,200-12,750	Diamond Inserts	8-1/2
2	12,750-14,750	Diamond Inserts	6-1/4

Note: Bit selection proposed by authors, according to hole diameter, depth, and stratigraphic and geological knowledge of the area.

Table 6. UIS-OFF-MO1-L2 drill program.

Section	Depth TVDSS (ft)	Bit	**Diameter (in)**
1	12,250-13,300	Diamond Inserts	8-1/2
2	13,300-14,665	Diamond Inserts	6-1/4
3	14.665-15.600	Diamond Inserts	6-1/4

Note: Bit selection proposed by authors, according to hole diameter, depth, and stratigraphic and geological knowledge of the area.

Bottom Hole Assembly

A BHA was designed for drilling the proposed vertical central well, in which it is proposed to vary the lengths of Drill Collar and Heavy Weight Drill Pipe (HWDP) according to the weights determined in the drill program for each section.

Table 7 presents the proposed BHA for the well (Figure 12), with the Drill collar and HWDP lengths in each central well section, representing 35% and 65% by weight over the bit, respectively.

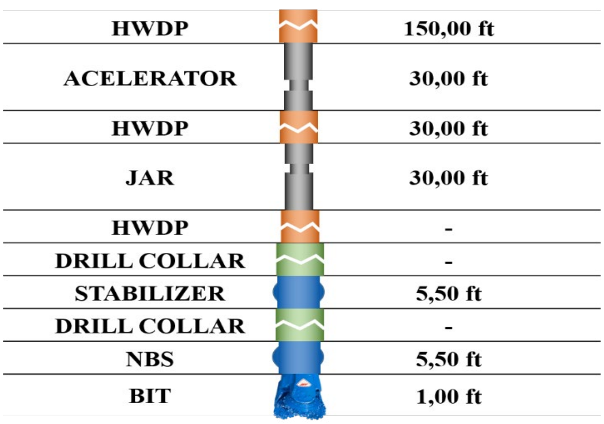

Figure 12. Proposed BHA-Vertical main well
Note: BHA proposed by author. Adapted from SANTOS, Oscar. Estudio de los problemas operacionales durante la perforación de los pozos direccionales en la plataforma drago norte 2. Facultad de ingeniería en geología y petróleos. Instituto politécnico nacional. 2015.

Table 7. DC and HWDP lengths in each section of the main well.

Section	**Depth(ft)**	**DC Length (ft)**	**HWDP Length (ft)**
Water layer	2,200	-	-
1	2,500	94.50	360.00
2	5,000	126.00	420.00
3	9,500	189.00	750.00
4	12,600	220.50	870.00
5	14,750	220.50	780.00

Note: BHA proposed by authors, according to hole diameter, depth estimated pressures, and required WOB.

The proposed lengths are designed to provide the weight on the drill bit required to drill each of the sections identified by the mud window. The pipe proposed in the design is drill collar of 6½", with ID of 2" and nominal weight of 102 pound/ft, while the HWDP has a nominal diameter of 5½", ID of 4 " and weight of 46.66 pound/ft.

In addition, a slightly modified BHA is proposed for the branches of the well, in which special tools are used for the drilling of a directional well, such as the Measure While Drilling (MWD) tool and a Rotary Steerable System (RSS), whose provides greater reliability on directional perforation In addition, as part of the design it is proposed to include the Well Commander tool (valve allows operators to boost circulation to remove cuttings at strategic points in the drillstring) for avoid problems in the MWD tool (Figure 13).

A guide shoe must be installed on the depth the lateral will be placed. To realize this emplacement, it must be selected a bit with the features required to mill the casing and drill out of cement with a junk mill tool. Also, should be considered an inclination grade of at least 5° on the placement point. Then the trajectory could be corrected as the proposed on the figures 6 and 7, where the Build up rate is less than 4°/100 ft, and the maximum dip until 45°. These trajectories reduce the probabilities of collapse on the open hole branches and improve the integrity performance of branches during the completion.

In addition, it is noted that the BHA has stabilizers, whose position must vary depending on the directional effect that is to be generated in each section.

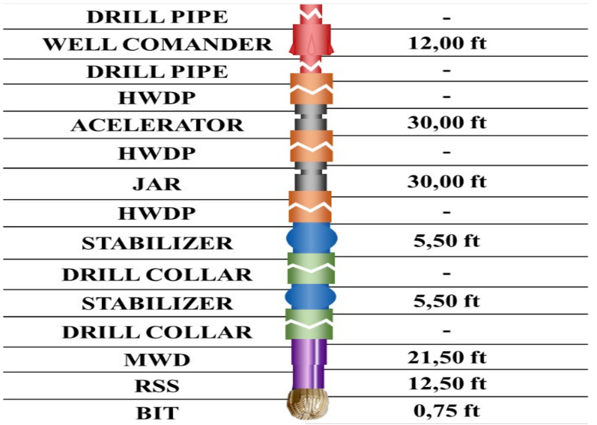

Figure 13. Proposed BHA- lateral wellbores.
Note: BHA proposed by authors, Adapted from: ROQUE, Alexander y VARGAS, Arquímedes. Experiencia de Geonavegación en el Pozo "CRÑ-1" utilizando el software especializado StarSteer, en el Bloque Ayacucho de la Faja Petrolífera del Orinoco, Anzoátegui – Venezuela, Venezuela Geosteering School.

The weight over the bit is distributed with 80% HWDP and 20% DC, this is because a flexible weight pipe is required to drill the directional sides (Table 8 and 9).

Table 8. DC and HWDP lengths in each section of the UIS-OFF-MO1-L1 well.

Section	Depth MD(ft)	DC Length (ft)	HWDP Length (ft)
1	12,750	157.50	1,350.00
2	14,750	157.50	1,200.00

Note: BHA proposed by authors, according to hole diameter, depth estimated pressures, and required WOB on the first proposed branch

Table 9. DC and HWDP lengths in each section of the UIS-OFF-MO1-L2 well.

Section	Depth MD(ft)	DC Length (ft)	HWDP Length (ft)
1	13,300	189.00	1,440.00
2	14,665	157.50	1,290.00
3	15,600	157.50	1,320.00

Note: BHA proposed by authors, according to hole diameter, depth estimated pressures, and required WOB on the second proposed branch.

Drill pipe

Once the length of the BHA was designed, the length of the drill pipe to be used in each of the sections was determined. Tables 10, 11 and 12 present the collapse and stress values that the drill pipe must withstand according to the design, from which the X-95 pipe of 5'' diameter, and 19.5 lb/ft was selected. The drill pipe grade selected on the next assemblies, for drilling e principal well and the branches, depends principally on the critical strengths these tubulars would support during the drilling conditions; as tensile strength and collapse, and others like burst pressure and torsion. On the tables 10 to 12 are specified the tension and collapse strengths the drill pipe would support in each of the sections to be drilled. With those considerations, we selected a drill pipe grade that supports the maximum strengths calculated on the well on each stage. These strengths were calculated, the collapse pressure based on the estimated maximum hydrostatic pressure the casings will support during perforation and operation stages, which corresponds to an extreme condition, where the well is full of fluid inside de casing, and without fluid on the annular; and the second is calculated using the string weight, corrected by buoyancy factor. It should be noted that for both criteria a safety factor is used, in the case of collapse pressure it is 1.125; while for stress on the pipe, 1.2 is used in addition to the over pull margin, which in this case was selected with a value of 100,000 lb.

Table 10. Collapse pressures and stresses on the pipe in each section of the main well

Section	Length of drill pipe (ft)	Collapse pressure (psi)	Tensile strength (pound)
1	1,980.00	996.14	199,467.29
2	4,410.00	2,321.87	259,061.01
3	8,490.00	5,612.31	361,931.52
4	11,460.00	8,648.29	424,644.68
5	13,680.00	11,123.89	459,878.41

Note: Strength calculated by authors.

Table 11. Collapse pressures and stresses on the pipe in each section of the UIS-OFF-MO1-L1 well.

Section	Length of drill pipe (ft)	Collapse pressure (psi)	Tensile strength (pound)
1	11,250.00	8,522.72	421,453.07
2	13,890.00	11,294.65	453,638.95

Note: Strength calculated by authors.

Table 12. Collapse pressures and stresses on the pipe in each section of the UIS-OFF-MO1-L2 well.

Section	Length of drill pipe (ft)	Collapse pressure (psi)	Tensile strength (pound)
1	11,670.00	8,806.77	433,771.94
2	13,710.00	11,148.29	451,326.00
3	14,760.00	12,002.09	468,100.91

Note: Strength calculated by authors.

Completion of the lateral wells

Since the two drill targets have the same forming pressure, it was determined that the laterals do not require hydraulic separation with the UIS-OFF-MO1 main well. However, given the length and complexity of the operation of this type of offshore wells, it is proposed to use a complete that has mechanical integrity, that is, Type IV according to the TAML classification, that is, both the main hole and the branches have cemented and cased, whose supplies a better integrity performance and more durability of the laterals because of the isolation from the well to formation provided by the casing and cement. On the proposed design, an interlateral interference is not considered because we are assuming similar pressures on each zone of the formation the wells will produce. In case of evidence from different pressures on the target formations, Completion of the well as Type V or Type VI, with hydraulic isolation should be considered, to reach an optimized production form each zone without interference. It is proposed to complete only with slotted liner in the area of interest. Tables 13 and 14 present the types of completion on the sides UIS-OFF-MO1-L1 and UIS-OFF-MO1-L2, respectively. The Casing grade is selected with similar considerations as the used on the drill pipe selection. However, the most critical strengths in this design could be the collapse and burst pressure. Choice criteria is mainly focused on the operational issues, production is not considered because lack of information about production volume, there is no additional considerations associated to the geometry because the low angle build up rates and inclination angles proposed where a conventional casing can be installed

Table 13. Completion selected for each section of the UIS-OFF-MO1-L1 well.

Section	Interval (ft)	Completion	Diameter (in)
1	11,200-12,750	Casing	7
2	12,750-14,750	Liner	5-1/2

Note: Casing diameters and depth proposed by authors, according to Mud Window.

Table 14. Completion selected for each section of the UIS-OFF-MO1-L2 well.

Section	Interval (ft)	Completion	Diameter (in)
1	12,250-13,300	Casing	7
2	13,300-14,665	Liner	5-1/2
3	14,665-15,600	Liner	5-1/2

Note: Casing diameters and depth proposed by authors, according to Mud Window.

Results and analysis

In Figure 14 shows it is presented the top view showing that there is no risk of collision for the multilateral well UIS-OFF-MO1 because the nearest well is Orca-1, located approximately 1000 ft from the lateral UIS-OFF-MO1-L1, sufficient distance so that the anti-collision module of the COMPASS application does not report any collision risk alarm, considering the typical errors of the MWD tool.

To carry out the anti-collision analysis, the International Geomagnetic Reference Field (IGRF) model was used, it is possible to determine the measurement error associated with the MWD tool. Additionally, as a safety factor, 1.5 times the value determined by the model was taken, recalculated for each depth as the lateral is drilled. Likewise, Figure 15 presents a frontal view showing the trajectory of the multilateral well UIS-OFF-MO1 showing that it does not interfere with that of Orca-1 well.

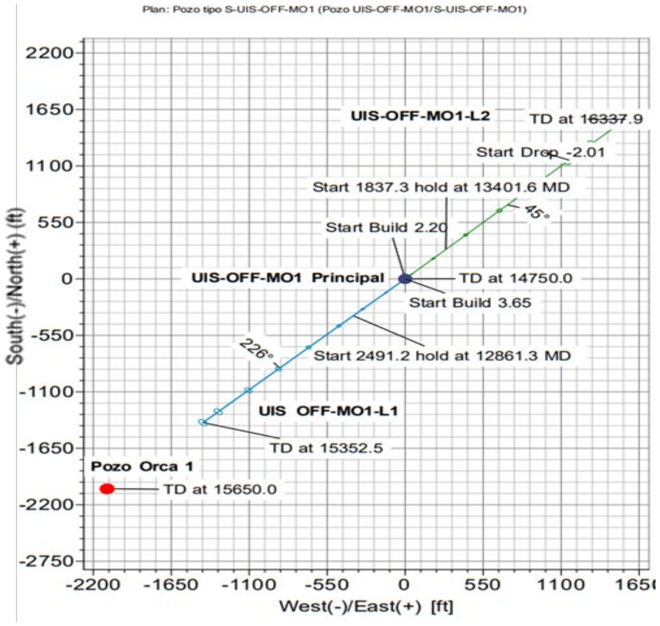

Figure 14 Map view of Orca-1 well and UIS-OFF-MO1 multilateral well.
Note: Figures of multilateral well were generated by authors using Compass Landmark suite application.

In figure 15 it is presented the parameters of the different sections of sides; these parameters were selected for each side, under the premise of increasing the contact area between the well and the areas of interest with potential hydrocarbon content. It is also evident that construction and angle drop rates are moderate, to reduce the risks of well collapse during drilling. However, it is proposed to use the Well Commander tool (drilling circulating valve) or a similar one, which optimizes the construction of directional sections of the well, reducing the risk of integrity.

In figure 14 shows the formations through which the drilling of the multilateral well is proposed. The Siamaná, Macarao and Guaralamai formations are those that have potential hydrocarbon content according to studies and wells drilled in the area.

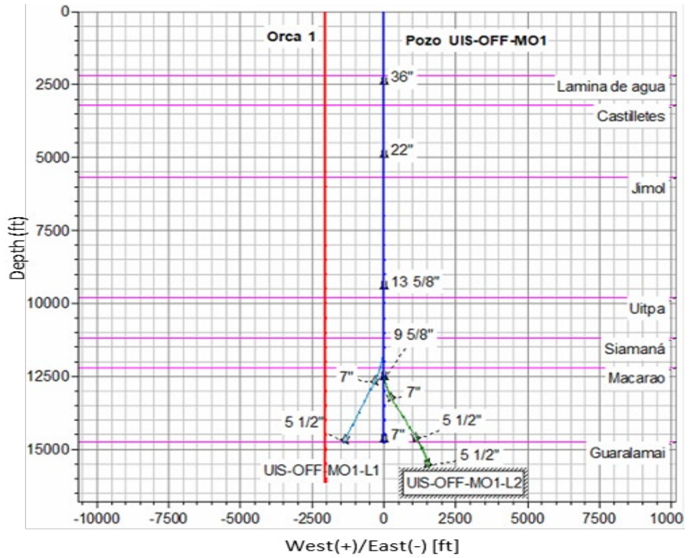

Figure 14. Front view of Orca-1 well and the UIS-OFF-MO1 multilateral well.
Note: Figures of multilateral well were generated by authors using Compass Landmark suite application

In Figure 15 shows the final design of the UIS OFF-MO1 well in 3D. Geological, environmental, directional, and technical parameters were considered to design the trajectories and tools necessary for the construction of a well that adapts to the conditions of the study area in the Colombian Caribbean. This conceptual engineering design can serve as a basis for the design of wells to develop the Colombian Caribbean gas zone, which has great potential to maintain the country's self-sufficiency in natural gas production in future years. A detailed understanding of the geology of the area is important to improve the trajectories of multilateral wells, if they are to be implemented in the area, which would optimize the development of the oil field, and the costs associated with drilling wells.

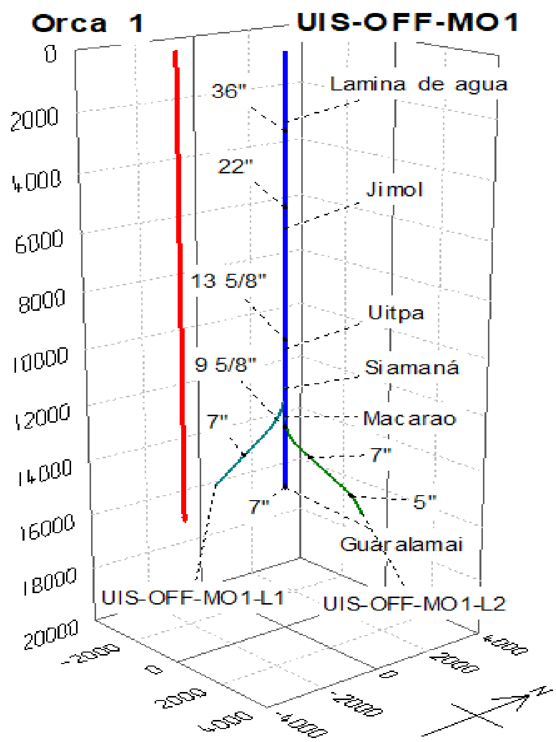

Figure 15. 3D view from l UIS-OFF-MO1 well design.
Note: Figures of multilateral well were generated by authors using Compass Landmark suite application

Conclusions

- It proposed to drill a multilateral well with opposite branches in the basin Guajira Offshore Block, Tayrona, contacting the formation Guaralamai near the already drilled Orca-1 well, offshore project on which country has the short-term expectation to produce the gas that allows to meet energy needs in all economic sectors, especially in the residential and industrial.
- The implementation of multilateral drilling can be an appropriate alternative for the study area once it is in the development stage with knowledge geological conditions of the formation indicate the possibility of increasing production and drainage area, contacting new compartments and optimizing operating costs.
- Compared to other offshore drilling alternatives, Multilateral technology offers the best cost-benefit ratio. There are successful application cases worldwide in both new wells and mature fields, so its use is recommended.
- The Colombian Caribbean offshore basin has a complex geology with many faults and formations with considerable gas potential, which makes possible the use of multilateral wells in areas of interest that are difficult to achieve with the drilling of conventional wells.

Acknowledgement

The authors thank the Universidad Industrial de Santander and School of Petroleum Engineering, as well as to the company Halliburton who facilitated an agreement that allows to have the Landmark suite for academic use, which was very useful for the development of this work.

References

[1] 1219. Rangel, P. & Amaya, J. (2012). Evaluation of Multilateral Well Drilling Technology Applied to the Colorado Field [Graduate Thesis]. Bucaramanga: Industrial University of Santander. Faculty of Physicochemical Engineering; 150p

[2] A. Boniface,O. and Ogbonna J. (2012) "A New Fracture Gradient Prediction Technique That Shows Good Results in Gulf of Guinea." Paper presented at the Abu Dhabi International Petroleum Conference and Exhibition, Abu Dhabi, UAE, November 2012.

[3] Abouzar, M. & Moghadasi, J. (2009). An Overview To Applicability Of Multilateral Drilling In The Middle East Fields. Society Of Petroleum Engineers.

[4] Adams, N. & Kuhlman L. (1991). Shallow Gas Blowout Kill Operations. Society Of Petroleum Engineers. Doi:10.2118/21455-Ms.

[5] Agencia Nacional De Hidrocarburos. (2004). Contrato De Exploración Y Explotación Bloque Tayrona.

[6] Ayokunle, A. & Hashem, M. (2016). Design Optimization Of Multilateral Wells In Heterogeneous Reservoirs. P. 25–28. Https://Doi.Org/10.2118/182764-Ms.

[7] Bosworth, S., El-Sayed, H., Ismail, G., Ohmer, H., Stracke, M., West, C. & Retnanto, A. (1998). Key Issues In Multilateral Technology Drilling, Completing And Later Reentering Wells With Multiple Branches To Improve. Oilfield Review, 10(4), 14–28.

[8] Colombia. Ministry of Mines and Energy. Resolution 40295 of October 7, 2020. By which the Technical Criteria for the Exploration and Exploitation of Offshore Hydrocarbons in Colombia are Established. Title 1, Article 4.Daniel, I., Higgings, A. & Ayala, C. (2015). Caracterización Del Régimen Del Viento Y El Oleaje En El Litoral Del Departamento Del Atlántico, Colombia. Boletín Científico Cioh, 33: 231–244.

[9] Eaton, B. A. (1974, January). Fracture gradient prediction and application. In Northern Ohio Geol. Soc. Symp. Salt;(United States) (Vol. 2, No. CONF-7304100-). Universal Drilling and Eng Consult Inc.

[10] Gallivan, J.; Newitt, D.; & Olsen, M. (1995). Quantifying The Benefits Of Multilateral Producing Wells. Spe 30441.

[11] Giraldo, A. (2014). Ecopetrol Announces First Discovery of Hydrocarbons in Deep Waters of the Colombian Caribbean.

[12] Hill A. D., Zhu D. & Economides M. J., Multilateral Wells Book. Society Of Petroleum Engineers. 2008.

[13] Jardon, M., Paez, R., Sotomayor, G. & Umudjoro, K. (2003). Nuevos Aspectos De La Construcción De Pozos Multilaterales. Oilfield Review, 56–75.

[14] Lopez, A. (2019). Orca, The Well With Which Offshore Extraction Will Begin [News]. Briefcase. [Consulted: June 20, 2020]. Available From: Shorturl.At/Mtydz.

[15] Lyu, Z., Song, X. & Geng, L. (2018). A Semi-Analytical Method For The Multilateral Well Design In Different Reservoirs Based On The Drainage Area. Journal Of Petroleum Science And Engineering. Https://Doi.Org/10.1016/J.Petrol.2018.09.024.

[16] Mao, L., Zeng, S., Liu, Q., Wang, G. & He, Y. (2020). Dynamical Mechanics Behavior And Safety Analysis Of Deep Water Riser Considering The Normal Drilling Condition And Hang-Off Condition. Ocean Engineering, 199, 106996.

[17] Medley, G. (1998). Shallow Water Flow Technology Update. Offshore Technology Conference. Doi:10.4043/8731-Ms.

[18] Mitchell, R. & Miska, S. (2011). Fundamentals Of Drilling Engineering, Vol 12. Society Of Petroleum Engineering.

[19] Morales, D. Montoya, S. & Bernal, O. (2017). Assessment Of Extreme Wind And Waves In The Colombian Caribbean Sea For Offshore Applications. Universidad Nacional De Colombia.

[20] Oceanographic and Hydrographic Research Center. (2019). Caribbean Climatology, Climatic Seasons in the Colombian Caribbean Coast [Online]. [Accessed October 25, 2020]. Available At: Shorturl.At/Hpgk5.

[21] Perez, A. (2018). Compass, Setting The Course [Presentatión]. Landmark, Halliburton.

[22] Rendon, U. (2013). Casing Layout and Design Guide. National Polytechnic Institute.

[23] Westgard, D. (2002). Multilateral TAML Levels Reviewed, Slightly Modified