Well Design Profile Directional Drilling Cluster System in Offshore Platform

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I. Abstract

HK Field Drilling is an offshore drilling that is planned in the form of a cluster where there are 4 target wells with well distances that are close to each other and the target points spread with different azimuth directions. In this study, there are 4 directional drilling wells that will be planned, namely "A1, A2, A3 & A4" on a production platform with a fixed platform rig type. Drilling was carried out in shallow water with a depth of 80 ft, Conductor Casing depth of 100 ft with a KOP (Kick Off Point) depth of 250 ft TVD/MD, and the distance between the platform to the target point as far as 2500 ft TVD with an estimated drain radius of 250 ft.

This research was conducted to calculate the depth of End of Build, Measured Depth Target, Horizontal Departure and Casing Setting Depth in each well. In this case study, the radius of curvature method is used to determine the length of the vertical section, build up section and tangential section. After calculating, it is known that well A1 has an inclination angle of 31^o with an azimuth direction of N53^{o}E. well A2 has an inclination angle of 31o with an azimuth direction of N162^{o}E. well A3 has an inclination angle of 31^o with an azimuth direction of N219^{o}E. well A4 has an inclination angle of 31^o with an azimuth direction of N323^{o}E.

Keywords: Directional drilling, well profile, cluster system offshore, shallow sea

II. Introduction

Directional drilling is a drilling technique in which the drilling trajectory is deflected following a planned trajectory towards a certain direction to reach a predetermined target below the earth's surface. Initially, directional drilling was used to correct the deflection that occurred in vertical wells. However, along with its development, directional drilling is increasingly being applied such as sidetrack drilling, relief wells, horizontal wells, offshore drilling from one drilling platform, and drilling where vertical drilling cannot be carried out due to the influence of natural conditions. The factors that cause directional drilling are due to surface conditions, geological reasons, economics, and other reasons. So directional drilling is only carried out for special reasons and circumstances.

As the cost of developing reserves increases, the need for directional drilling will also increase. Drilling with a cluster system is needed to drill a formation that is located on a surface that is limited in area. The implementation of multilateral drilling is carried out and can be economically justified, considering that the implementation of this drilling technique requires expensive costs.

In determining the drill hole trajectory, it is very important to design directional and horizontal drilling. Especially in the case of multi-well platforms where a number of aspects must be carefully examined before designing the final well path to the target. In well track design, targets are usually determined by a geologist with acceptable tolerances. To reach the target, the target zone should be selected as large as possible. If more than one zone is reached, the designed drilling trajectory must be reasonable and achievable without causing drilling problems.

In this drilling operation, directional drilling will be carried out in the offshore field. The drilling is planned to be in the form of a cluster with 4 wells on a fixed platform type. The purpose of this drilling by planning 4 wells in 1 cluster is to save the use of small land and also to facilitate control if 1 cluster is made on 1 platform. Another objective is to drain hydrocarbons believed to be within a radius of 250 ft. Then the drainage plan will be made to have 4 different directions from each well. The determination of the KOP in the planning of this drilling operation will be carried out with a shallow deviation type because to avoid potential interference problems between wells if it is carried out at deep deviation.

III. Literature Review

Well trajectory design in directional drilling can be done by calculating the directional coordinates of directional drilling wells. After that, calculate the true vertical depth (TVD) vertical section, true vertical depth in the EOB section total depth (TD), and horizontal departure. Methods that can be used in designing well trajectory, such as methods: tangential, balanced tangential, average angle, radius of curvature and minimum of curvature (Farah Omar Farah, 2014). This paper discusses well trajectory design planning using the radius of curvature method and well trajectory design calculations using the Bourgoyne equation. In planning the well trajectory of directional drilling wells, it is necessary to take into account the azimuth angle, build up rate angle, TVD length, horizontal displacement length, KOP, total length MD. Well trajectory calculation method using the radius of curvature method. Calculations are done manually and by using the Microsoft Excel and Compass programs and then compared. The results obtained are the results of calculations using the Compass program are closer to manual calculations compared to excel (Krishnan, 2016). However, in the writing of this paper, the calculations are only done manually and using Microsoft Excel. In determining the drill hole trajectory, it is very important to design directional and horizontal drilling. Especially in the case of multi-well platforms where a number of aspects must be carefully examined before designing the final well path to the target. In well track design, targets are usually determined by a geologist with acceptable tolerances. To reach the target, the target zone should be selected as large as possible. If more than one zone is reached, the designed drilling trajectory must be reasonable and achievable without causing drilling problems (Halafawi, 2019). In cluster drilling clusters offshore directional drilling, the depth or depth of the well affects the economy, especially in reducing the cost of building and constructing the platform line (Pfau, 1969). Well design planning with shallow kick off points can also reduce the maximum inclination angle (Chewaroungroaj, 2021).

In shallow sediments, unlike deep sediments with elastic behavior, the failure mechanism of the casing shoe is strongly affected by the plasticity of the rock. Hence, the common practice in casing design which is based on using the pore pressure and fracture pressure gradients plots is not applicable in shallow sediments. In general, casing design, like any other design process, should be justified and planned in advance. An optimal design solution is sought, by finding the best compromise to satisfy the design requirements. The factors considered for a casing design based on the well control issues include: Casing shoe depth, Hole size, Kick volume, Mud weight For a constant well geometry, as the depth increases, there would be a linear increase in the casing shoe failure pressure (Paknejad et al, 2009).

IV. Research Methodology

In this plan, the radius of curvature method is used to determine the length of the trajectory in the build up section and the tangential method is used to determine the length of the trajectory in the tangential section.

Build and Hold (J-Shaped) Well Profile:

In the vertical section, calculations are carried out to find the azimuth angle and determine the KOP point. The KOP point is determined from the data, while to find the azimuth angle, the equation from Bourgoyne is used as in equation (1):

$$\alpha = \tan^{-1}\left(\frac{x}{y}\right) \tag{1}$$

In the Build up section, calculations are carried out to find the length of the radius of curvature in equation (2), the maximum inclination angle in equations (3) & (4), the length of the measured depth (MD) using equation (5), the length of the TVD using equation (6), and horizontal displacement in the build up section using equation (7):

$$r1 = \frac{180}{\pi x BUR} \tag{2}$$

if $r1 > X_3$

$$\theta = \arctan\left(\frac{TVD_3 - TVD_1}{r1 - X_3}\right) - \arccos\left(\left(\frac{r1}{TVD_3 - TVD_1}\right) x \sin\left(\arctan\left(\frac{TVD_3 - TVD_1}{r1 - X_3}\right)\right)\right) \tag{3}$$

Or

if r1 < X_3

$$\theta = 180 - \arctan(\frac{TVD_3 - TVD_1}{r1 - X_3}) - \arccos((\frac{r1}{TVD_3 - TVD_1}) x \sin(\arctan(\frac{TVD_3 - TVD_1}{r1 - X_3}))) \quad (4)$$

$$MD_2 = \frac{\theta}{BUR} \quad (5)$$

$$TVD_2 = r1 \times \sin\theta + TVD_1 \quad (6)$$

$$X_2 = r1 \times (1 - \cos\theta) \quad (7)$$

In the Tangential section, calculations are carried out to find the length of the measured depth tangent section in equation (8), TVD in the tangent section in equation (9), horizontal length in the tangential section in equation (10) and the total measured depth in equation (13):

$$MD_3 = \frac{TVD_3 - TVD_2}{\cos\theta} \quad (8)$$

$$TVD_3 - TVD_2 = MD_3 \times \cos\theta \quad (9)$$

$$X_3 - X_2 = (MD_3 \times \sin\theta) \quad (10)$$

$$TMD = MD_1 + MD_2 + MD_3 \quad (11)$$

Table 1.
Directional Drilling Well Profile Parameters

Vertical Section	**Build Up Section**	**Tangential Section**
Surface Location Point	*Kick off Point* (KOP)	*Tangential Inclination*
Kick off Point (KOP)	*Build Up Rate* (BUR)	TVD Tangential
TVD *Vertical Section*	*Radius of Curvature* (r1)	*Measured Depth* Target
Measured Depth Vertical Section	Maximum Inclination	*Horizontal Displacement* Target
	TVD *Build Up Section*	
	Measured Depth Build Up Section	
	Horizontal Displacement Build Up Section	

V. Results & Discussion

In this study, data obtained from one directional drilling platform is used to plan the well profile and hole geometry of each well in this 1 cluster. And also will determine the azimuth direction of each well profile will be planned.

1. Well Profile A1

   Well A1 is a J-Shaped directional drilling well with a target depth of 2500 ftTVD/2557 ftMD with a KOP of 300 ftTVD/MD. In planning the profile of the A1 well, it will consist of 3 sections, namely, a vertical section at a depth of 0-300 ft, a build up section at a depth of 300-560 ftMD, and a Tangential section at a depth of 560-2557 ftMD. The vertical section consists of 2 drilling routes, namely the conductor casing route using a 20" OD casing at a depth of 0-100 ft and a surface casing route using a 13⅜" OD casing at a depth of 100-300 ft. Furthermore, the build up section consists of 1 route, namely the intermediate casing route using a 9⅝" OD casing at a depth of 300-560 ftMD. And the tangential section has 1 route, namely the production casing route using a 7" OD casing at a depth of 560-2557 ftMD. In the A1 well, the azimuth direction is N53°E with a maximum inclination angle of 31°.

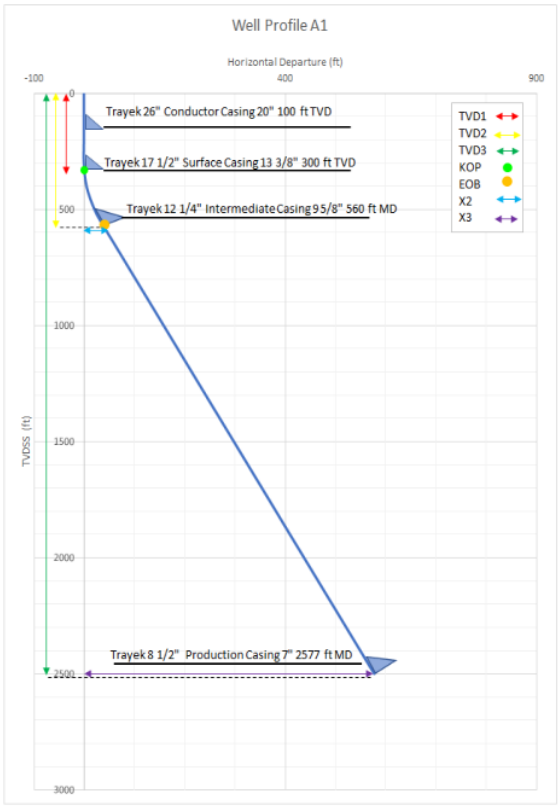

Figure 1. Well Profile A1

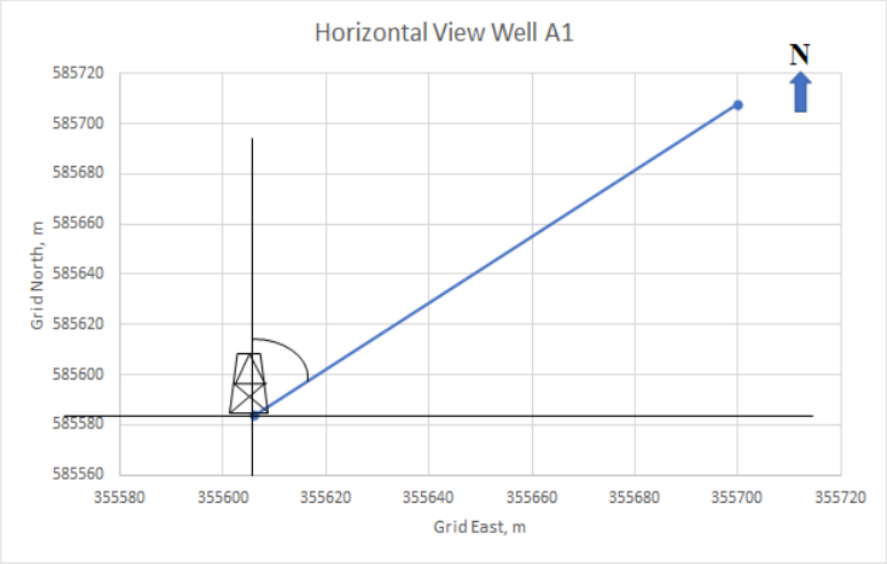

Figure 2. Horizontal View Well A1

Table 2.
Parameter of Well Profile A1

Section	Drilling Trajectory	Bit Size	OD Casing	Length Casing	BUR	MD (ft)	TVD (ft)	H (ft)	θ
Vertical Section (0-300 ft)	Conductor Casing (0-100 ft)	26”	20”	100 ft	0º	100	100	0	0º
	Surface Casing (100-300ft)	17½”	13⅜”	300 ft	0º	200	300	0	0º
Build Up Section (300 – 560 ftMD)	Intermediate Casing 300 –560 ftMD	12¼”	9⅝”	560 ft	6º/100 ft	260	556	35	N53ºE
Tangential (560 –2557 ftMD)	Production Casing 560–2557 ftMD	8½”	7”	2557 ft	0º	2003	2500	518	N53ºE

2. Well Profile A2

Well A2 is a J-Shaped directional drilling well with a target depth of 2500 ftTVD/2575 ftMD with a KOP of 300 ftTVD/MD. In planning the profile of the A2 well, it will consist of 3 sections, namely, a vertical section at a depth of 0-300 ft, a build up section at a depth of 300-557 ftMD, and a Tangential section at a depth of 557-2575 ftMD. The vertical section consists of 2 drilling routes, namely the conductor casing route using a 20” OD casing at a depth of 0-100 ft and a surface casing route using a 13⅜” OD casing at a depth of 100-300 ft. Furthermore, the build up section consists of 1 route, namely the intermediate casing route using a 9⅝" OD casing at a depth of 300-557 ftMD. And the tangential section has 1 route, namely the production casing route using a 7” OD casing at a depth of 557-2575 ftMD. In well A2, the azimuth direction is N162ºE with a maximum inclination angle of 31º.

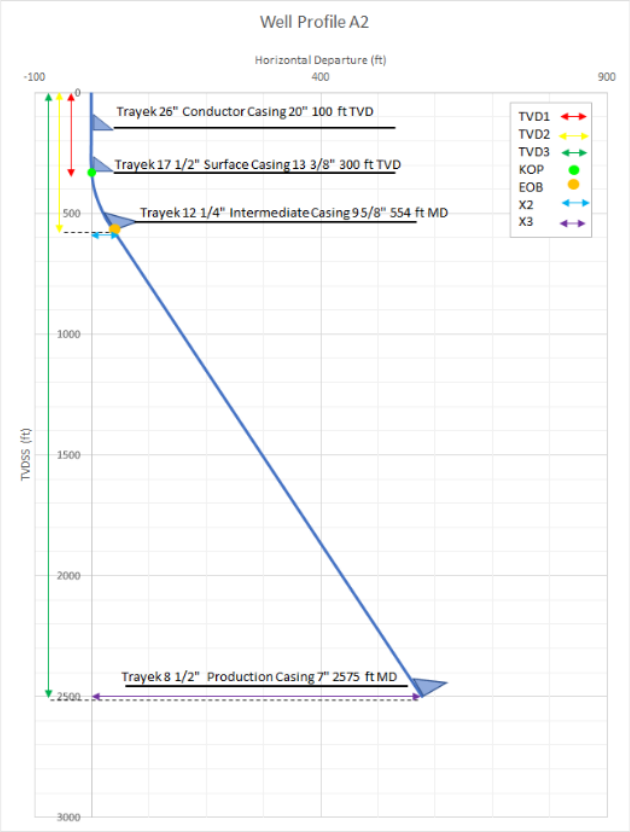

Figure 3. Well Profile A2

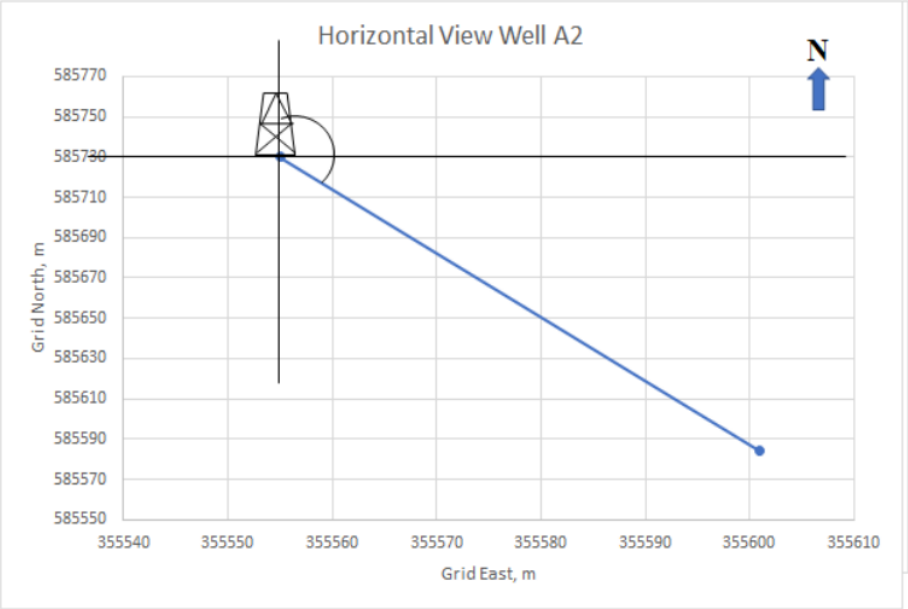

Figure 4. Horizontal View Well A2

Table 3
Parameter of Well Profile A2

Section	Drilling Trajectory	Bit Size	OD Casing	Length Casing	BUR	MD (ft)	TVD (ft)	H (ft)	θ
Vertical Section (0-300 ft)	Conductor Casing (0-100 ft)	26”	20”	100 ft	0º	100	100	0	0º
	Surface Casing (100-300ft)	17½”	13⅜”	300 ft	0º	200	300	0	0º
Build Up Section (300 – 557 ftMD)	Intermediate Casing 300 –557 ftMD	12¼”	9⅝”	557 ft	6º/100 ft	257	554	34	N162ºE
Tangential (557 –2575 ftMD)	Production Casing 557–2575 ftMD	8½”	7”	2575 ft	0º	2018	2500	502	N162ºE

3. Well Profile A3

Well A3 is a J-Shaped directional drilling well with a target depth of 2500 ftTVD/2577 ftMD with a KOP of 300 ftTVD/MD. The A3 well profile will consist of 3 sections, namely, a vertical section at a depth of 0-300 ft, a build up section at a depth of 300-560 ftMD, and a Tangential section at a depth of 560-2577 ftMD. The vertical section consists of 2 drilling routes, namely the conductor casing route using a 20” OD casing at a depth of 0-100 ft and a surface casing route using a 13⅜” OD casing at a depth of 100-300 ft. Furthermore, the build up section consists of 1 route, namely the intermediate casing route using a 9⅝" OD casing at a depth of 300-560 ftMD. And the tangential section has 1 route, namely the production casing route using a 7" OD casing at a depth of 560-2577 ftMD. In the A3 well, the azimuth direction is N219oE with a maximum inclination angle of 31o.

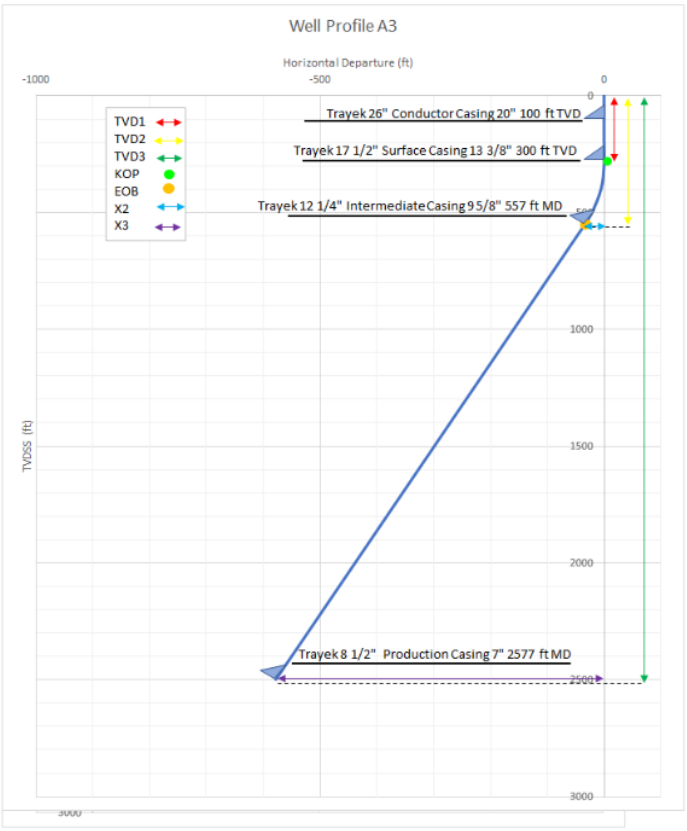

Figure 5. Well Profile A3

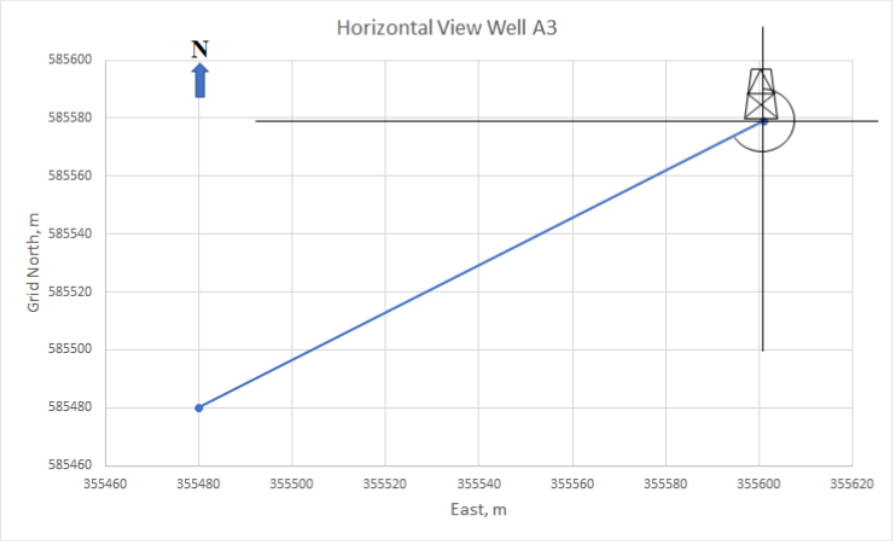

Figure 6. Horizontal View Well A3

Table 4
Parameter of Well Profile A3

Section	Drilling Trajectory	Bit Size	OD Casing	Length Casing	BUR	MD (ft)	TVD (ft)	H (ft)	θ
Vertical Section (0-300 ft)	Conductor Casing (0-100 ft)	26”	20”	100 ft	0º	100	100	0	0º
	Surface Casing (100-300ft)	17½”	13⅜”	300 ft	0º	200	300	0	0º
Build Up Section (300 – 560 ftMD)	Intermediate Casing 300 –560 ftMD	12¼”	9⅝”	560 ft	6º/100 ft	260	557	35	N219ºE
Tangential (557 –2577 ftMD)	Production Casing 560–2577 ftMD	8½”	7”	2577 ft	0º	2017	2500	512	N219ºE

4. Well Profile A4

The A4 well is a J-Shaped directional drilling well with a target depth of 2500 ftTVD/2577 ftMD with a KOP of 300 ftTVD/MD. The A4 well profile will consist of 3 sections, namely, a vertical section at a depth of 0-300 ft, a build up section at a depth of 300-560 ftMD, and a Tangential section at a depth of 560-2577 ftMD. The vertical section consists of 2 drilling routes, namely the conductor casing route using a 20” OD casing at a depth of 0-100 ft and a surface casing route using a 13⅜” OD casing at a depth of 100-300 ft. Furthermore, the build up section consists of 1 route, namely the intermediate casing route using a 9⅝" OD casing at a depth of 300-560 ftMD. And the tangential section has 1 route, namely the production casing route using a 7" OD casing at a depth of 560-2577 ftMD. In the A4 well, the azimuth direction is N323ºE with a maximum inclination angle of 31º.

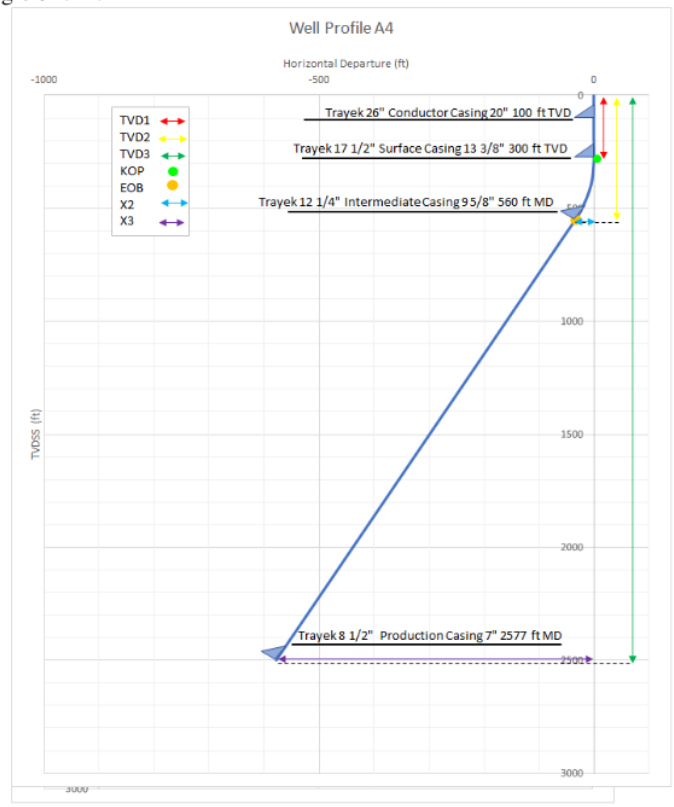

Figure 7. Well Profile A4

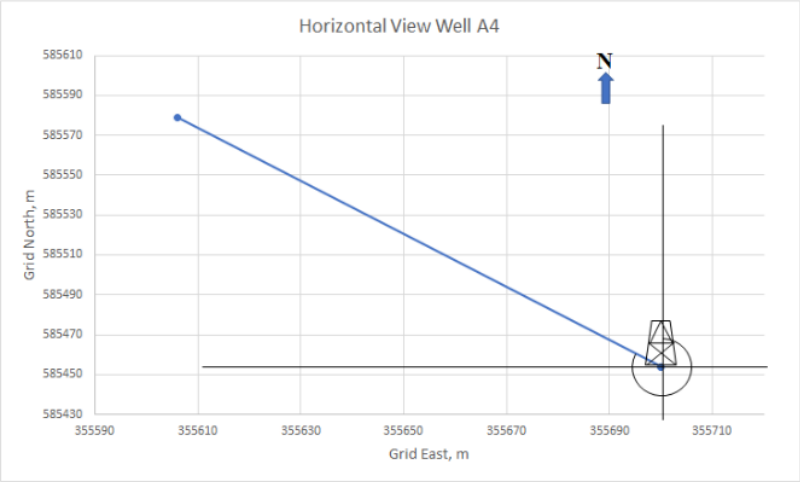

Figure 8. Horizontal View Well A4

Table 5
Parameter of Well Profile A4

Section	Drilling Trajectory	Bit Size	OD Casing	Length Casing	BUR	MD (ft)	TVD (ft)	H (ft)	θ
Vertical Section (0-300 ft)	Conductor Casing (0-100 ft)	26”	20”	100 ft	0º	100	100	0	0º
	Surface Casing (100-300ft)	17½”	13⅜”	300 ft	0º	200	300	0	0º
Build Up Section (300 – 560 ftMD)	Intermediate Casing 300 –557 ftMD	12¼”	9⅝”	557 ft	6º/100 ft	260	557	35	N323ºE
Tangential (557 –2577 ftMD)	Production Casing 557–2577 ftMD	8½”	7”	2577 ft	0º	2017	2500	512	N323ºE

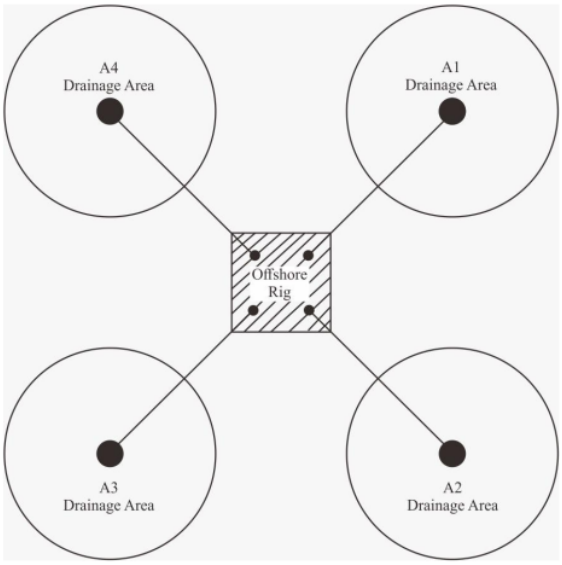

Fig. 9. Direction and Position Well in Platform

This drilling plan is carried out using a cluster system with 4 directions which functions to be able to obtain the maximum drain area as shown in Figure 9, where each drilling target is carried out.

VI. Conclusion

Based on the results of the research and discussion that have been presented, the following conclusions can be drawn:

1. Drilling planning is carried out with different cardinal directions to maximize the drain area in the reservoir.
2. Well A1 in the vertical section consists of 2 drilling routes, namely the conductor casing route using a 20" OD casing at a depth of 0-100 ft & a surface casing route using a 13⅜" OD casing at a depth of 100-300 ft. Furthermore, the build up section consists of 1 route, namely the intermediate casing route using a 9⅝" OD casing at a depth of 300-560 ftMD. And the tangential section has 1 route, namely the production casing route using a 7" OD casing at a depth of 560-2557 ftMD. In the A1 well, the azimuth direction is N53^{o}E with a maximum inclination angle of 31^{o}.
3. Well A2 in the vertical section consists of 2 drilling routes, namely the conductor casing route using a 20" OD casing at a depth of 0-100 ft & a surface casing route using a 13⅜" OD casing at a depth of 100-300 ft. Furthermore, the build up section consists of 1 route, namely the intermediate casing route using a 9⅝" OD casing at a depth of 300-557 ftMD. And the tangential section has 1 route, namely the production casing route using a 7" OD casing at a depth of 557-2575 ftMD. In well A2, the azimuth direction is N162^{o}E with a maximum inclination angle of 31^{o}.
4. The A3 well in the vertical section consists of 2 drilling routes, namely the conductor casing route using a 20" OD casing at a depth of 0-100 ft & a surface casing route using a 13⅜" OD casing at a depth of 100-300 ft. Furthermore, the build up section consists of 1 route, namely the intermediate casing route using a 9⅝" OD casing at a depth of 300-560 ftMD. And the tangential section has 1 route, namely the production casing route using a 7" OD casing at a depth of 560-2577 ftMD. In the A3 well, the azimuth direction is N219^{o}E with a maximum inclination angle of 31^{o}.
5. The A4 well in the vertical section consists of 2 drilling routes, namely the conductor casing route using a 20" OD casing at a depth of 0-100 ft & a surface casing route using a 13⅜" OD casing at a depth of 100-300 ft. Furthermore, the build up section consists of 1 route, namely the intermediate casing route using a 9⅝" OD casing at a depth of 300-557 ftMD. And the tangential section has 1 route, namely the production casing route using a 7" OD casing at a depth of 557-2577 ftMD. In the A4 well, the azimuth direction is N323^{o}E with a maximum inclination angle of 31^{o}.

VII. Acknowledgement

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