ANTI-COLLISION SYSTEM MANAGEMENT IMPROVES THE DEVELOPMENT WELL PLACEMENT

MANAGEMENTUL SISTEMULUI ANTI-COLIZIUNE ÎMBUNĂTĂȚEȘTE PLASAREA PUȚULUI DE DEZVOLTARE

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Abstract: *Future development plans are often being continued during production. These plans includes wells repair, reservoir enhancements, or new development wells in order to increase and optimize the field production. Therefore, the main objective of this article is to develop an anti-collision system for Zubair field based on offset data and manage this system for drilling new 3 development wells in order to improve wellbore stability and select the best hole cleaning drilling practices for new wells of this field. Well placement is selected so as to avoid and reduce the risk of wells colliding. Moreover, ant-collision methods are presented. Overview of this field is discussed including geological column, wells locations, contour maps, wells and their production. A spider plot is constructed for all wells based on anti-collision methods and directional survey calculations.*

Keywords: Anti-collision system, spider plot, separation factor, wellbore trajectory

Rezumat: *Planurile de dezvoltare viitoare sunt deseori continuate în timpul producției. Aceste planuri includ reparații de puțuri, îmbunătățiri ale zăcămintelor sau noi godeuri de dezvoltare pentru a crește și optimiza producția pe teren. Prin urmare, obiectivul principal al acestui articol este acela de a dezvolta un sistem anti-coliziune pentru câmpul Zubair bazat pe date offset și de a gestiona acest sistem pentru forajul a 3 noi puțuri de dezvoltare, pentru a îmbunătăți stabilitatea puțurilor și a selecta cele mai bune practici de foraj pentru curățarea noilor puțuri. din acest domeniu. Amplasarea puțurilor este selectată astfel încât să se evite și să se reducă riscul de coliziune a puțurilor. Mai mult, sunt prezentate metode anticoliziune. Prezentarea generală a acestui câmp este inclusă coloana geologică, locațiile puțurilor, hărțile conturului, puțurile și producția acestora. Un complot de păianjen este construit pentru toate puțurile bazate pe metode anticoliziune și calcule direcționale ale sondajului.*

Cuvinte cheie: Sistem anti-coliziune, complot de păianjen, factor de separare, traiectoria puțurilor

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1. Introduction

The Anti-Collision System is a job of continuously managing the drilling wells position during developing a certain petroleum field. This means the driller can focus on information and controls, instead of being potentially overwhelmed with actual drilling tasks in order to avoid wells interference. In offshore drilling environment where the slot accessibility is restricted, anti-collision management has become an essential factor while planning and drilling the wells. This means a highly significant concentration on avoiding collisions with offset wellbores in developed crowded offshore drilling fields for optimizing production. Collision with a producing well may lead to a loss of well control, resulting in a significant influence on productive time and income from shut-in wells.

An understanding of anti-collision problems, their causes, their anticipation and planning for field development is a key factor to estimate the possible hazards and risks in order to control and succeed in reaching the target safely. The stability of new development wells is therefore achieved in order to drill them safely. Therefore, this paper puts emphasis on anti-collision techniques and methods to reduce NPT and risk while drilling new three wells in crowded drilling environment of Zubair field. Increased emphasis was directed towards wells' placement and orientation to minimize the risk of collisions while reducing NPT, reducing directional uncertainty, and collision avoidance using the traveling cylinder plot and spider plot. Additionally, overview of this field is described. In order to fill full future development plans, anti-collision of wells are also determined for new wells.

2. Anti-collision of drilling wells

Collision of drilling wells should be avoided. Various companies utilize diverse methods and strategies in order to determine a safety factor that expresses a distance between the reference and the offset well. There are several methods to determine the true distance between two wells or to estimate the risk of two wells colliding. These methods include [1-13]:

1. Separation factor (SF). Two ways are used to calculate separation factor: The simplest one is to use well coordinates (X,Y) without considering ellipses of uncertainty and the second one is to determine the SF using equations 1 & 2 to evaluate uncertainties related to survey errors considering the ellipses of uncertainty.

$$SF = \frac{\text{CENTER TO CENTER DISTANCE}}{\text{CENTER TO CENTER DISTANCE} - \text{DISTANCE BETWEEN ELLIPSOIDS}} \quad (1)$$

$$SF = \frac{\text{CENTER TO CENTER DISTANCE}}{\text{SUM OF THE MAJOR HALF} - \text{AXIS}} \quad (2)$$

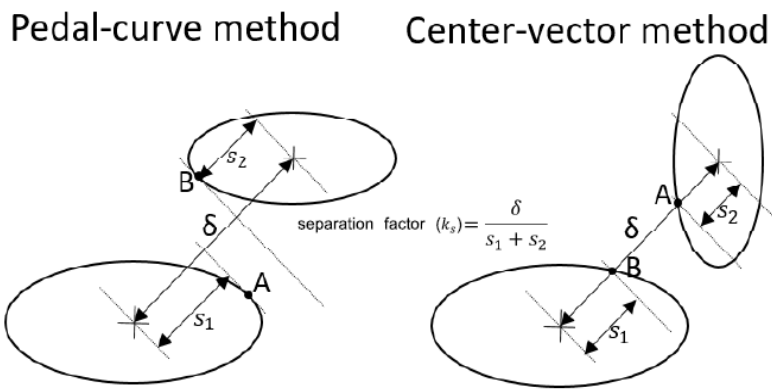


Figure 1. Principles of pedal curve method, and center vector method [1]

2. Collision Probability. In this method, a normal distribution is the base to estimate the ellipsoid of uncertainty. It means that it is linked to probability. Probability-based equations are used to predict the collision likelihood.

$$P = \frac{d^2}{2\,(\sigma_A^2 - \sigma_B^2)}\, EXP^{-\frac{D^2}{2\,(\sigma_A^2 - \sigma_B^2)}} \quad (3)$$

$$P = \frac{\frac{d_S + d_O}{\sigma\sqrt{2\pi}}\, EXP^{\frac{\left[s - \frac{d_S + d_O}{2}\right]^2}{2\,\sigma^2}}}{\sigma\sqrt{2\pi}} \quad (4)$$

where and do are the diameters of the subject and object well, and σ is the combined standard deviation $\sigma = \sqrt{\sigma \quad \sigma}$

3. Scanning method. It measures how close a well location of interest is towards a reference well. This method visualizes the specific condition during drilling to create a horizontal plane in order to check for adjacent wells intersecting.

4. Closest distance. Three methods are used to determine the separation distance between wells. These methods are pedal curve method, center vector method and expanded ellipses method.

Bang and Nyrnes [8], and ISCWSA [9-13] presented distances' calculation between the reference well and the offset wells for four different companies based on the principles of center to center and ellipsoid to ellipsoid. These calculations are expressed in the following four equations:

$$SF = \frac{D-(r_r+r_o)}{3\,(R_r+R_O)} \tag{5}$$

$$SF = \frac{D}{2\,(R_r+R_O)} \tag{6}$$

$$SF = \frac{D-(r_r+r_o)}{2.79\,\sqrt{2}\,(R_r+R_O)} \tag{7}$$

$$SF = \frac{D-(r_r+r_o)}{2.878\,\sqrt{2}\,(R_r+R_O)} \tag{9}$$

where D is center to center distance, r_r & r_o are casing radius of reference and offset well, respectively) and Rr & Ro are ellipsoid radius of reference and offset well, respectively).

3. Well profile survey for a wellbore trajectory

In order to perform anti-collision calculations, it is required to determine well profile survey parameters. The five methods [10], which are used to implement survey calculations, are average angle method (AAM), radius of curvature (RCM), constant build and turn rate (CBTM), constant curvature and build rate (CCBM) (constant tool face), and minimum curvature method (MCM).. However, MCM is the most used by the petroleum industry for both well-trajectory planning and directional-survey evaluation [14-15]. Recently, Sawaryn and Thorogood [16] presented algorithms for directional-well planning and deflection-tool orientation. MCM equations are simply deduced from these algorithms:

$$RF = \frac{\Delta MD}{\beta}\tan\frac{\beta}{2} \tag{10}$$

$$\Delta X = (sin\varphi_1 cos\vartheta_1 + sin\varphi_2 cos\vartheta_2)RF \tag{11}$$

$$\Delta Y = (sin\varphi_1 sin\vartheta_1 + sin\varphi_2 sin\vartheta_2)RF \quad (12)$$

$$\Delta Z = (cos\varphi_1 + cos\varphi_2)RF \quad (13)$$

where RF= Ratio Factor, β= Dog-leg angle, deg, φ=inclination angle, deg. ϑ=Azimuth angle, deg.

4. Anti-collision management

In onshore and offshore drilling environment, many development wells are drilled in vicinity to each other, making a rigorous anti-collision procedure highly essential. Due to poor 2D visualizations of the offset wells, the visualization of a 3D borehole profile is utilized on traditional vertical section and plan view plots although it is very difficult. There are two plots to perform anti-collision management: Traveling cylinder plot, and spider plot [2,17].

Traveling cylinder plot. In order to visualize the 3D wellbore profile, the traveling cylinder plot is a very useful tool. A better understanding of the well's position with respect to offset wells can be achieved using this method. Moreover, the vicinity of the offset wells can be demonstrated in relation to the planned borehole. These plots are considered as part of the planning process and the drilling phase itself. In this method, a normal plane is utilized to show the intersection of wells with a plane made in space at 90o angle to the planned borehole. In this plot, the 12 o'clock position with true north or grid north is used as a standard. Additionally, depths used in the plots are measured depths (MD). The comparative separation between the planned well and adjacent wells is shown by the point's location at consecutive depths. The SF does not take into consideration the orientation of the ellipse of uncertainty which can sometimes be pointless restrictive. In order to avoid this problem, pedal curve calculations are utilized to determine the SF which consider the perpendicular distance from center to center of two wells' ellipses [2,17].

Spider plot. It is a conventional tool has utilized in the petroleum industry for a long time. It is defined as a plan view of the planned borehole along with offset wells. The real well trajectory is constructed based on true vertical depth (TVD) and north/east coordinates to determine aberration from the planned wellbore and vicinity with the offset wells. A spider map is considered an optimum and effective tool along with the traveling cylinder plot in order to do the steering decision, plan a well and avoid wells collision [2,17].

Table 1. **Geological column for Zubair field**

Formation	MD RTE (m)	TVD RTE (m)	TVDSS (m)	Uncertainty (m)	Lithology
Dibdibba	Surface	Surface	Surface		Sandstone, Clay, Sand and Gravel
Lower Fars	376.62	376.62	364	20	Marl - Anhydrite – Limestone – Gypsum
Abu Ghar	583.62	583.62	571	20	Sand and Gravel, Sandstone, Claystone and Limestone
Dammam	707.62	707.62	695	20	Dolomite
Rus	928.62	928.62	916	20	Anhydrite and Dolomite
Umm-Er-Radhuma	998.62	998.62	986	20	Dolomite and Anhydrite
Tayarat	1,476.62	1,476.62	1,464.00	20	Bituminous Shale and Dolomite
Shiranish	1,666.62	1,666.62	1,654.00	20	Marl and Argillaceous Limestone
Hartha	1,764.62	1,764.62	1,752.00	20	Dolomite and Argillaceous Limestone
Sadi	1,918.62	1,918.62	1,906.00	20	Chalky Limestone and Argillaceous Limestone
Tanuma	2,145.95	2,137.62	2,125.00	20	Shale
Khasib	2,175.00	2,163.62	2,151.00	20	Limestone and Argillaceous Limestone
Mishrif	2249	2230.62	2218,00	10	Chalky Limestone
Rumaila	2,414.12	2,377.62	2,365.00	10	Argillaceous Limestone
Ahmadi	2,500.16	2,454.62	2,442.00	20	Shale dark grey fissile w/Limestone, gray shaly compact
Mauddud	2,662.19	2,599.62	2,587.00	20	Limestone beige brown detrital porous
Nahr Umr	2,817.51	2,738.62	2,726.00	20	Shale black fissile w/Limestone grey shaly compact inter. w/Sandstone fine med. grain
Shuaiba	3,161.67	3,046.62	3,034.00	20	Chalky Limestone
Upper Shale Mbr	3,214.19	3,093.62	3,081.00	10	Shale, black, gray, fissile
Upper Sandstone (3rd Pay)	3,333.75	3,200.62	3,188.00	**10**	**Sandstone fine m. grained friable**
Middle Shale Mbr	3,456.66	3,310.62	3,298.00	10	Shale, black, fissile
Lower Sandstone (4th Pay)	3,509.18	3,357.62	3,345.00	**10**	**Sandstone fine m. grained friable**
Lower Shale Mbr	3,601.00	3,440.00	3,428.00	10	Shale, black, fissile
TD	**3662**	**3494**	**3482**		

1. Zubair field description

Zubair field is an oil reservoir field with various domes located in southern Iraq. Geological column for the Zubair field is shown in Table 1. Structural map for reservoir pay zones and reference wells location is shown in Fig.1. Reservoir domes map, the offset well production performance from the 3rd and 4th pay zones, and their completions from are appeared in Figs.1 through 3.

2. Future development plans

Each company has its own plans for future performance in order to keep its position in the competitive market of the petroleum industry. These future plans are divided into plans of increasing the production and plans of exploring new fields. The present plans for our company is a development strategy. In order to increase the oil production from the 3rd pay zone of Zubair field reservoir, three development wells are, therefore, required to be drilled. There are 14 wells producing from the 3rd pay zone. The three wells, which will be drilled, are called ZB-390, ZB-391, and ZB-398.

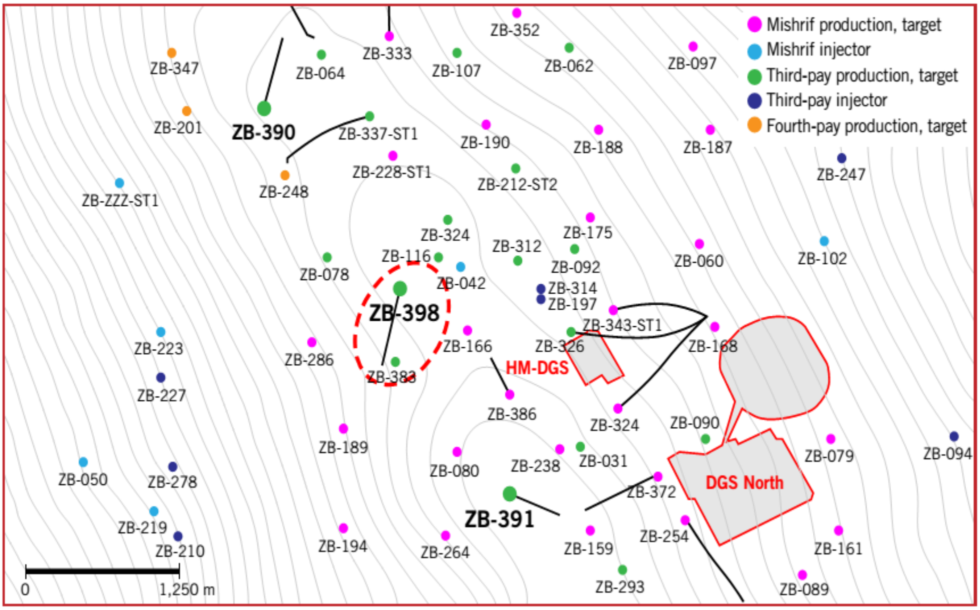


Figure 2. Structural map for reservoir pay zones and reference wells location [18]

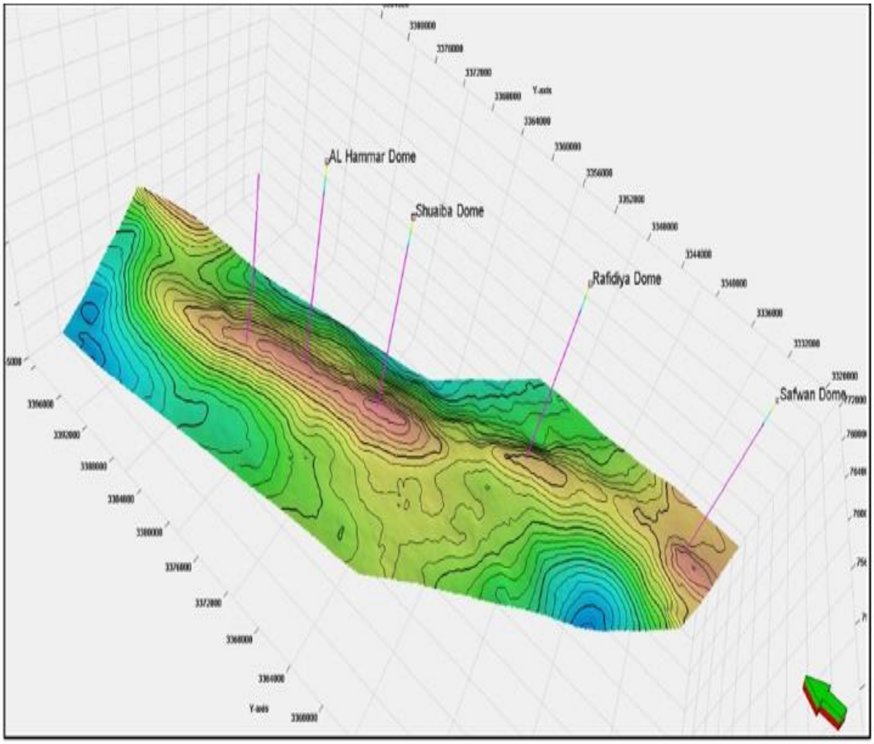


Figure 3. Reservoir domes map

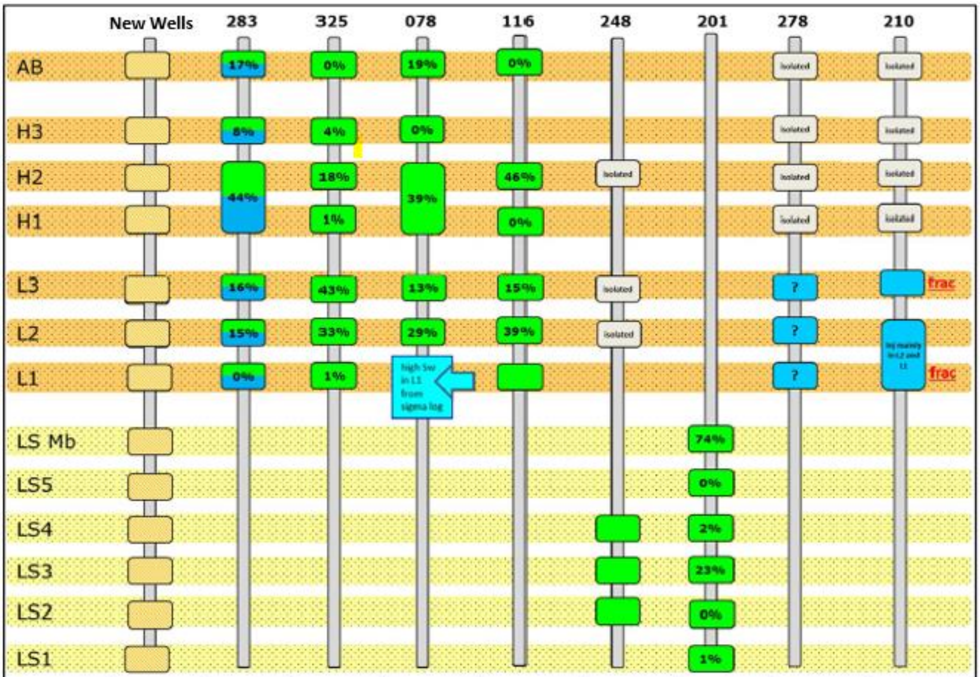
3. Results and discussions

In order to perform a development strategy for Zubair field, three development wells are, therefore, required to be drilled. There are 14 wells producing from the 3rd pay zone while the three wells, which are called ZB-390, ZB-391, and ZB-398, will be drilled to enhance productivity of the 3rd and 4th pay zones. However, anti-collision management system should be implemented due to the presence of many wells in this field as shown in wells location map (Fig. 1). In order to keep wellbore stability and avoid wells colliding, anti-collision system are performed utilizing SF methods which are previously discussed. Directional survey calculations are illustrated in Table 2. Anti-collision calculations for 3 wells are given in Table 3. Due to long anti-collision calculations, results of 3 wells are only given but other calculations are the same. Based on the anti-collision and the directional survey calculations, a spider plot map is constructed for zubair field (Fig. 4).

It was found that the dogleg severity appeared only in the building section with value $3.6^{o}/100ft$, the maximum inclination angle to hit targets is 26.5^{o}, and well azimuth is 12.82^{o} (Table 2). Additionally, the resulted separation factors are (Table 3):

- 260.750 (CC,ES), and 227.776 SF for well ZB-372
- 70.776 (CC, ES, SF) for well ZB-390
- 108.363 CC, and 107.386 ES for well ZB-391

The places and locations of ZB-390, ZB-391, and ZB-398 wells relative to other offset wells after anti-collisions management are shown in the spider map (Fig. 4)



WC	-	14%	0%	20%	0%	0%	0%	/	/
Oil (WI)rate	-	2,600	5,600	950	4,000	1,400	2,900	15,750	4,950
Last available PLT	-	Dec-2017	Feb-2018	Feb-2012	Feb-2017(during PLT L1 was not perforated)	/	Oct-2012 (PLT before perfs in Middle shale)	/ (asphaltene issues in H levels)	/

Figure 4. Nearby wells completions and production performances

Table 2. **Directional Survey Calculations**

Measured Depth (m)	Inclination (°)	Azimuth (°)	TVD below System (m)	Vertical Depth (m)	Local Coordinates		Map Coordinates		Dogleg Rate (°/30m)	Vertical Section (m)
					Northing (m)	Easting (m)	Northing (m)	Easting (m)		
0.00	0.00	0.00	-12.62	0.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
30.00	0.00	0.00	17.38	30.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
60.00	0.00	0.00	47.38	60.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
90.00	0.00	0.00	77.38	90.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
120.00	0.00	0.00	107.38	120.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
150.00	0.00	0.00	137.38	150.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
180.00	0.00	0.00	167.38	180.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
210.00	0.00	0.00	197.38	210.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
240.00	0.00	0.00	227.38	240.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
270.00	0.00	0.00	257.38	270.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
300.00	0.00	0.00	287.38	300.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
330.00	0.00	0.00	317.38	330.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
360.00	0.00	0.00	347.38	360.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
376.62	0.00	0.00	364.00	376.62	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
Lower_Fars										
390.00	0.00	0.00	377.38	390.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
420.00	0.00	0.00	407.38	420.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
450.00	0.00	0.00	437.38	450.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
480.00	0.00	0.00	467.38	480.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
510.00	0.00	0.00	497.38	510.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
540.00	0.00	0.00	527.38	540.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
570.00	0.00	0.00	557.38	570.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
583.62	0.00	0.00	571.00	583.62	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
Ghar										
600.00	0.00	0.00	587.38	600.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
630.00	0.00	0.00	617.38	630.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
660.00	0.00	0.00	647.38	660.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
690.00	0.00	0.00	677.38	690.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
707.62	0.00	0.00	695.00	707.62	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
Dammam										
717.62	0.00	0.00	705.00	717.62	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
18 5/8"										
720.00	0.00	0.00	707.38	720.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
750.00	0.00	0.00	737.38	750.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
780.00	0.00	0.00	767.38	780.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
810.00	0.00	0.00	797.38	810.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
840.00	0.00	0.00	827.38	840.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
870.00	0.00	0.00	857.38	870.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
900.00	0.00	0.00	887.38	900.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
928.62	0.00	0.00	916.00	928.62	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
Rus										
930.00	0.00	0.00	917.38	930.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
960.00	0.00	0.00	947.38	960.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
990.00	0.00	0.00	977.38	990.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
998.62	0.00	0.00	986.00	998.62	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
Umm_Er_Radhuma										
1,020.00	0.00	0.00	1,007.38	1,020.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,050.00	0.00	0.00	1,037.38	1,050.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,080.00	0.00	0.00	1,067.38	1,080.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,110.00	0.00	0.00	1,097.38	1,110.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,140.00	0.00	0.00	1,127.38	1,140.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,170.00	0.00	0.00	1,157.38	1,170.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,200.00	0.00	0.00	1,187.38	1,200.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,230.00	0.00	0.00	1,217.38	1,230.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,260.00	0.00	0.00	1,247.38	1,260.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,290.00	0.00	0.00	1,277.38	1,290.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,320.00	0.00	0.00	1,307.38	1,320.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,350.00	0.00	0.00	1,337.38	1,350.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,380.00	0.00	0.00	1,367.38	1,380.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,410.00	0.00	0.00	1,397.38	1,410.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,440.00	0.00	0.00	1,427.38	1,440.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,470.00	0.00	0.00	1,457.38	1,470.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,476.62	0.00	0.00	1,464.00	1,476.62	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
Tayarat										
1,500.00	0.00	0.00	1,487.38	1,500.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,530.00	0.00	0.00	1,517.38	1,530.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,560.00	0.00	0.00	1,547.38	1,560.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,590.00	0.00	0.00	1,577.38	1,590.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,620.00	0.00	0.00	1,607.38	1,620.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,650.00	0.00	0.00	1,637.38	1,650.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,666.62	0.00	0.00	1,654.00	1,666.62	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
Shiranish										
1,680.00	0.00	0.00	1,667.38	1,680.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,710.00	0.00	0.00	1,697.38	1,710.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,740.00	0.00	0.00	1,727.38	1,740.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,764.62	0.00	0.00	1,752.00	1,764.62	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
Hartha										
1,770.00	0.00	0.00	1,757.38	1,770.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,800.00	0.00	0.00	1,787.38	1,800.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,830.00	0.00	0.00	1,817.38	1,830.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,860.00	0.00	0.00	1,847.38	1,860.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,888.62	0.00	0.00	1,876.00	1,888.62	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
13 3/8"										
1,890.00	0.00	0.00	1,877.38	1,890.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
1,918.62	0.00	0.00	1,906.00	1,918.62	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
Sadi										

Measured Depth (m)	Inclination (°)	Azimuth (°)	TVD below System (m)	Vertical Depth (m)	Local Coordinates Northing (m)	Local Coordinates Easting (m)	Map Coordinates Northing (m)	Map Coordinates Easting (m)	Dogleg Rate (°/30m)	Vertical Section (m)
1,920.00	0.00	0.00	1,907.38	1,920.00	0.00 N	0.00 E	3,379,852.06	747,370.78	0.000	0.00
Start DLS 3.600 TFO 12.82										
1,950.00	3.60	12.82	1,937.36	1,949.98	0.92 N	0.21 E	3,379,852.98	747,370.99	3.600	0.94
1,980.00	7.20	12.82	1,967.22	1,979.84	3.67 N	0.84 E	3,379,855.73	747,371.62	3.600	3.76
2,010.00	10.80	12.82	1,996.85	2,009.47	8.25 N	1.88 E	3,379,860.31	747,372.66	3.600	8.46
2,040.00	14.40	12.82	2,026.12	2,038.74	14.63 N	3.33 E	3,379,866.69	747,374.11	3.600	15.00
2,070.00	18.00	12.82	2,054.92	2,067.54	22.79 N	5.19 E	3,379,874.85	747,375.97	3.600	23.37
2,100.00	21.60	12.82	2,083.15	2,095.77	32.69 N	7.44 E	3,379,884.75	747,378.22	3.600	33.53
2,130.00	25.20	12.82	2,110.67	2,123.29	44.31 N	10.08 E	3,379,896.37	747,380.86	3.600	45.44
2,140.84	26.50	12.82	2,120.43	2,133.05	48.92 N	11.13 E	3,379,900.98	747,381.91	3.600	50.17
Start 1192.91 hold at 2140.84 MD										
2,145.95	26.50	12.82	2,125.00	2,137.62	51.14 N	11.64 E	3,379,903.20	747,382.42	0.000	52.45
Tanuma										
2,160.00	26.50	12.82	2,137.58	2,150.20	57.26 N	13.03 E	3,379,909.32	747,383.81	0.000	58.72
2,175.00	26.50	12.82	2,151.00	2,163.62	63.78 N	14.51 E	3,379,915.84	747,385.29	0.000	65.41
Khasib										
2,190.00	26.50	12.82	2,164.42	2,177.04	70.31 N	16.00 E	3,379,922.37	747,386.78	0.000	72.10
2,220.00	26.50	12.82	2,191.27	2,203.89	83.36 N	18.97 E	3,379,935.42	747,389.75	0.000	85.49
2,249.87	26.50	12.82	2,218.00	2,230.62	96.35 N	21.92 E	3,379,948.41	747,392.70	0.000	98.82
Upper Mishrif										
2,250.00	26.50	12.82	2,218.12	2,230.74	96.41 N	21.94 E	3,379,948.47	747,392.72	0.000	98.88
2,280.00	26.50	12.82	2,244.97	2,257.59	109.47 N	24.91 E	3,379,961.53	747,395.69	0.000	112.26
2,307.97	26.50	12.82	2,270.00	2,282.62	121.64 N	27.68 E	3,379,973.70	747,398.46	0.000	124.74
Middle Mishrif										
2,310.00	26.50	12.82	2,271.82	2,284.44	122.52 N	27.88 E	3,379,974.58	747,398.66	0.000	125.65
2,340.00	26.50	12.82	2,298.66	2,311.28	135.57 N	30.85 E	3,379,987.63	747,401.63	0.000	139.03
2,360.49	26.50	12.82	2,317.00	2,329.62	144.49 N	32.88 E	3,379,996.55	747,403.66	0.000	148.18
Lower Mishrif										
2,370.00	26.50	12.82	2,325.51	2,338.13	148.62 N	33.82 E	3,380,000.68	747,404.60	0.000	152.42
2,400.00	26.50	12.82	2,352.36	2,364.98	161.68 N	36.79 E	3,380,013.74	747,407.57	0.000	165.81
2,414.12	26.50	12.82	2,365.00	2,377.62	167.82 N	38.18 E	3,380,019.88	747,408.96	0.000	172.11
Rumaila										
2,430.00	26.50	12.82	2,379.21	2,391.83	174.73 N	39.76 E	3,380,026.79	747,410.54	0.000	179.19
2,460.00	26.50	12.82	2,406.06	2,418.68	187.78 N	42.73 E	3,380,039.84	747,413.51	0.000	192.58
2,490.00	26.50	12.82	2,432.90	2,445.52	200.83 N	45.70 E	3,380,052.89	747,416.48	0.000	205.97
2,500.16	26.50	12.82	2,442.00	2,454.62	205.26 N	46.70 E	3,380,057.32	747,417.48	0.000	210.50
Ahmadi										
2,520.00	26.50	12.82	2,459.75	2,472.37	213.89 N	48.67 E	3,380,065.95	747,419.45	0.000	219.35
2,550.00	26.50	12.82	2,486.60	2,499.22	226.94 N	51.64 E	3,380,079.00	747,422.42	0.000	232.74
2,580.00	26.50	12.82	2,513.45	2,526.07	239.99 N	54.61 E	3,380,092.05	747,425.39	0.000	246.12
2,610.00	26.50	12.82	2,540.29	2,552.91	253.04 N	57.57 E	3,380,105.10	747,428.35	0.000	259.51
2,640.00	26.50	12.82	2,567.14	2,579.76	266.10 N	60.54 E	3,380,118.16	747,431.32	0.000	272.90
2,662.19	26.50	12.82	2,587.00	2,599.62	275.75 N	62.74 E	3,380,127.81	747,433.52	0.000	282.80
Mauddud										
2,670.00	26.50	12.82	2,593.99	2,606.61	279.15 N	63.51 E	3,380,131.21	747,434.29	0.000	286.28
2,700.00	26.50	12.82	2,620.84	2,633.46	292.20 N	66.48 E	3,380,144.26	747,437.26	0.000	299.67
2,730.00	26.50	12.82	2,647.69	2,660.31	305.26 N	69.45 E	3,380,157.32	747,440.23	0.000	313.06
2,760.00	26.50	12.82	2,674.53	2,687.15	318.31 N	72.42 E	3,380,170.37	747,443.20	0.000	326.44
2,790.00	26.50	12.82	2,701.38	2,714.00	331.36 N	75.39 E	3,380,183.42	747,446.17	0.000	339.83
2,817.51	26.50	12.82	2,726.00	2,738.62	343.33 N	78.12 E	3,380,195.39	747,448.90	0.000	352.10
Nahr_Umr										
2,820.00	26.50	12.82	2,728.23	2,740.85	344.41 N	78.36 E	3,380,196.47	747,449.14	0.000	353.21
2,850.00	26.50	12.82	2,755.08	2,767.70	357.47 N	81.33 E	3,380,209.53	747,452.11	0.000	366.60
2,880.00	26.50	12.82	2,781.93	2,794.55	370.52 N	84.30 E	3,380,222.58	747,455.08	0.000	379.99
2,910.00	26.50	12.82	2,808.77	2,821.39	383.57 N	87.27 E	3,380,235.63	747,458.05	0.000	393.37
2,940.00	26.50	12.82	2,835.62	2,848.24	396.62 N	90.24 E	3,380,248.68	747,461.02	0.000	406.76
2,970.00	26.50	12.82	2,862.47	2,875.09	409.68 N	93.21 E	3,380,261.74	747,463.99	0.000	420.15
3,000.00	26.50	12.82	2,889.32	2,901.94	422.73 N	96.18 E	3,380,274.79	747,466.96	0.000	433.53
3,030.00	26.50	12.82	2,916.17	2,928.79	435.78 N	99.15 E	3,380,287.84	747,469.93	0.000	446.92
3,060.00	26.50	12.82	2,943.01	2,955.63	448.83 N	102.12 E	3,380,300.89	747,472.90	0.000	460.30
3,090.00	26.50	12.82	2,969.86	2,982.48	461.89 N	105.09 E	3,380,313.95	747,475.87	0.000	473.69
3,120.00	26.50	12.82	2,996.71	3,009.33	474.94 N	108.06 E	3,380,327.00	747,478.84	0.000	487.08
3,150.00	26.50	12.82	3,023.56	3,036.18	487.99 N	111.03 E	3,380,340.05	747,481.81	0.000	500.46
3,161.67	26.50	12.82	3,034.00	3,046.62	493.07 N	112.19 E	3,380,345.13	747,482.97	0.000	505.67
Shuaiba										
3,165.67	26.50	12.82	3,037.58	3,050.20	494.81 N	112.58 E	3,380,346.87	747,483.36	0.000	507.45
9 5/8"										
3,180.00	26.50	12.82	3,050.40	3,063.02	501.05 N	114.00 E	3,380,353.11	747,484.78	0.000	513.85
3,210.00	26.50	12.82	3,077.25	3,089.87	514.10 N	116.97 E	3,380,366.16	747,487.75	0.000	527.24
3,214.19	26.50	12.82	3,081.00	3,093.62	515.92 N	117.38 E	3,380,367.98	747,488.16	0.000	529.10
Top Zubair Fm										
3,240.00	26.50	12.82	3,104.10	3,116.72	527.15 N	119.94 E	3,380,379.21	747,490.72	0.000	540.62
3,270.00	26.50	12.82	3,130.95	3,143.57	540.20 N	122.91 E	3,380,392.26	747,493.69	0.000	554.01
3,300.00	26.50	12.82	3,157.80	3,170.42	553.26 N	125.88 E	3,380,405.32	747,496.66	0.000	567.39
3,330.00	26.50	12.82	3,184.64	3,197.26	566.31 N	128.85 E	3,380,418.37	747,499.63	0.000	580.78
3,333.75	26.50	12.82	3,188.00	3,200.62	567.94 N	129.22 E	3,380,420.00	747,500.00	0.000	582.45
Start 328.18 hold at 3333.75 MD - Top Upper Sst										
3,360.00	26.50	12.82	3,211.49	3,224.11	579.36 N	131.82 E	3,380,431.42	747,502.60	0.000	594.17
3,390.00	26.50	12.82	3,238.34	3,250.96	592.41 N	134.79 E	3,380,444.47	747,505.57	0.000	607.55
3,420.00	26.50	12.82	3,265.19	3,277.81	605.47 N	137.76 E	3,380,457.53	747,508.54	0.000	620.94
3,450.00	26.50	12.82	3,292.04	3,304.66	618.52 N	140.73 E	3,380,470.58	747,511.51	0.000	634.33
3,456.66	26.50	12.82	3,298.00	3,310.62	621.42 N	141.39 E	3,380,473.48	747,512.17	0.000	637.30
Top Middle Shale										
3,480.00	26.50	12.82	3,318.88	3,331.50	631.57 N	143.70 E	3,380,483.63	747,514.48	0.000	647.71
3,509.18	26.50	12.82	3,345.00	3,357.62	644.27 N	146.59 E	3,380,496.33	747,517.37	0.000	660.73
Top Lower Sandstone										
3,510.00	26.50	12.82	3,345.73	3,358.35	644.62 N	146.67 E	3,380,496.68	747,517.45	0.000	661.10
3,540.00	26.50	12.82	3,372.58	3,385.20	657.68 N	149.64 E	3,380,509.74	747,520.42	0.000	674.48
3,570.00	26.50	12.82	3,399.43	3,412.05	670.73 N	152.61 E	3,380,522.79	747,523.39	0.000	687.87
3,600.00	26.50	12.82	3,426.28	3,438.90	683.78 N	155.58 E	3,380,535.84	747,526.36	0.000	701.26
3,601.93	26.50	12.82	3,428.00	3,440.62	684.62 N	155.77 E	3,380,536.68	747,526.55	0.000	702.12
Top Lower Shale										
3,630.00	26.50	12.82	3,453.12	3,465.74	696.83 N	158.55 E	3,380,548.89	747,529.33	0.000	714.64
3,660.00	26.50	12.82	3,479.97	3,492.59	709.89 N	161.52 E	3,380,561.95	747,532.30	0.000	728.03
3,661.93	26.50	12.82	3,481.70	3,494.32	710.73 N	161.71 E	3,380,562.79	747,532.49	0.000	728.89
TD at 3661.93 - 7"										

Table 3. **Anti-collision calculations for 3 wells (1 offset and 2 planned)**

Project	**Zubair Field**	**Local Coordinate reference**	**Site ZB-398**
Reference site	ZB-398	TVD reference	DFE @ 12.62 m
Site error	3 m	MD Reference	DFE @ 12.62 m
Reference well	ZB-398	North reference	Grid
Well error	3 m	Survey calculation method	MCM
Reference wellbore	H1	Output errors	2 σ
Reference design	ZB-398 H1	Offset TVD reference	Offset datum

Table 4. **Anti-collision calculations for 3 wells (1 offset and 2 planned), cont.**

Site Name/Offset Well/ Wellbore/Design	**Reference Measured Depth, m**	**Offset Measured Depth, m**	**Distance between centers, m**	**Distance between ellipses**	**Separation Factor (SF)**
ZB-372					
ZB-372-H1- ZB-372 actual survey	773.44	773.14	2118.69	2110.56	260.750 CC,ES
ZB-372-H1- ZB-372 actual survey	1860.00	1200.00	2242.17	2232.31	227.776 SF
ZB-390					
ZB-390-H1- ZB-390 Final	3661.93	3631.70	1923.10	1895.93	70.776 CC, ES, SF
ZB-391					
ZB-391-H1- ZB-390 actual survey	2671.64	3246.32	1833.07	1816.15	108.363 CC
ZB-391-H1- ZB-390 actual survey	2700.00	3266.40	1833.22	1816.15	107.386 ES
ZB-391-H1- ZB-390 actual survey	2661.93	3550.00	1981.64	1969.59	88.663

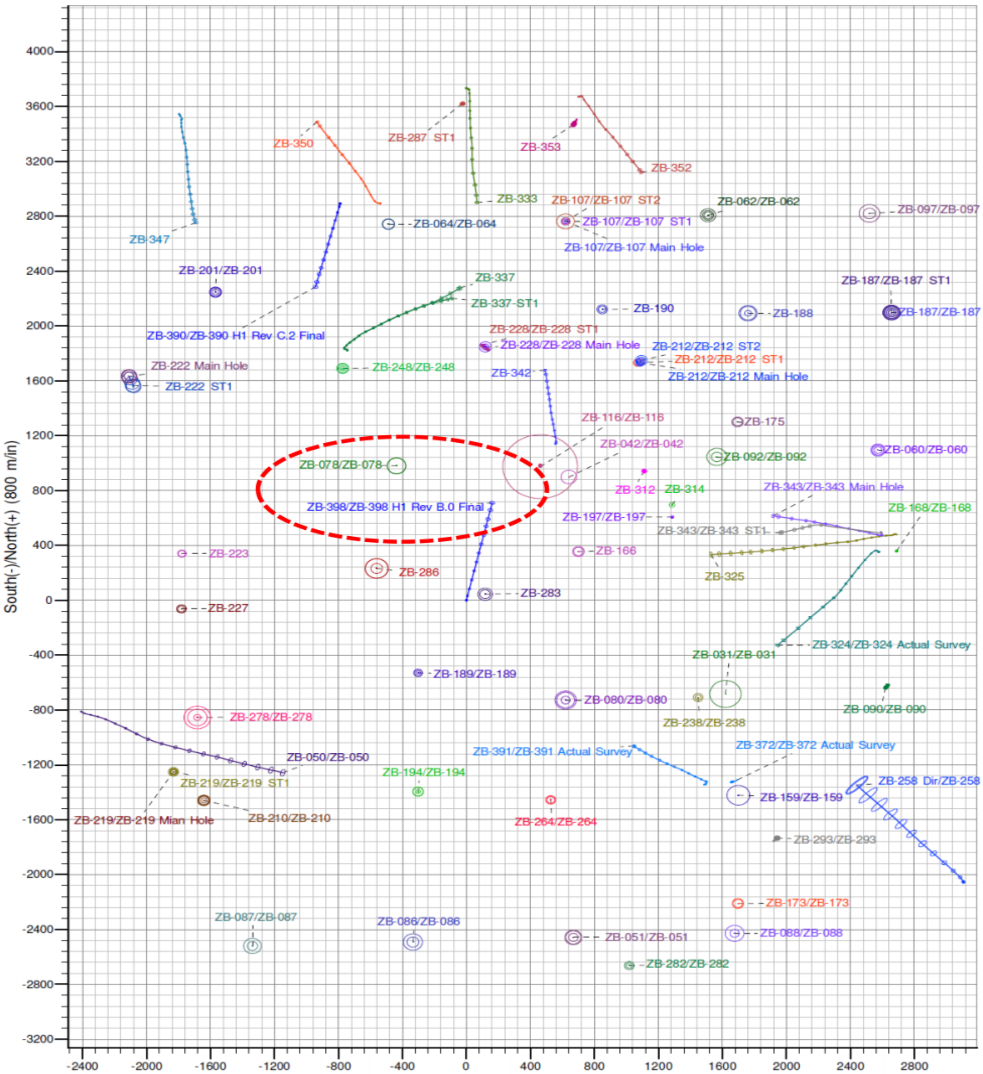


Figure 5. Spider plot for wells of Zubair field

4. Conclusions and recommendations

Based on the results and analysis, the following conclusions are extracted:

1. Zubair offset well analysis enhance the preformation of new development wells
2. Offset well analysis can identify major problems of Zubair stratigraphic column and reduce non-productive time for future operations
3. Anti-collision management system is an effective method in well planning to prevent wells intersection
4. The use of spider plot in wellbore planning helps to make the directional path, keep borehole stability and avoid wells collision
5. Future development plans of Zubair field are improved by enhancing drilling well stability and identifing the best hole cleaning practices

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