Optimization of Hole Cleaning In Iraqi Directional Oil Wells

Ayad A. Al-Haleem, Abd Al-Razzaq
Assistant Professor
Email:ayadah62@yahoo.com
College of Engineering –University of Baghdad

Abdul-Aali Dabbaj
Instructor
Ministry Of Oil
Email: resaldabaj@yahoo.com

Firas Mohammed Hadi
Master Student
College of engineering-University of Baghdad
Email: firasmoh_70@yahoo.com

ABSTRACT

Efficient cuttings transport and hole cleaning are very important factors for obtaining an effective drilling operation. In an inclined and horizontal drilling, hole cleaning issue is a common and complex problem.

The scope of this research is to study the drilling parameters which affect hole cleaning in Iraqi directional wells through studying and analyzing some drilled wells (vertical , directional (30 degree) , directional (60 degree) and horizontal).An excel sheet is prepared to calculate carrying capacity index which represents an indicator for good hole cleaning in different sections. The study indicated through the field investigations, practical experiences and theoretical calculations that the most effective drilling parameters for optimum hole cleaning were flow rate, yield point, mud weight, plastic viscosity, rotation of the drill string, and pH.

Key words: hole cleaning, rate of penetration, equivalent circulating density, directional well, cuttings bed

التنظيف الامثل للتجاويف المحفورة في الابار الاتجاهية النفطية العراقية

أياد عبد الحليم عبد الرزاق
استاذ مساعد
كلية الهندسة – جامعة بغداد

عبد العالي الدباج
خبير
وزارة النفط

فراس محمد هادي
الباحث

الخلاصه

ان كفاءة نقل القطع الصخرية وتنظيف تجويف البئر تعتبر من العوامل المهمة في زيادة فعالية عمليات حفر الابار النفطية . يعتبر تنظيف تجويف البئر من المشاكل المألوفة والمعقدة وخاصة في الابار المحفورة اتجاهيا" او افقيا" .

هذا البحث يركز على دراسة القيم التي تؤثر على عملية التنظيف ورفع القطع الصخرية للآبار النفطية العراقية المحفـورة بصورة مائلة او افقية من خلال دراسة وتحليل بعض الابار المحفورة (عموديا" ، مائلة بزاوية 30 درجة ، مائلة بزاوية 60 درجة والافقية).

اعدت حسابات مؤشر رفع القطع الصخرية باستخدام ملف Excel بعد ادخال القيم والحصول على النتائج التي تبين كفاءة التنظيف ورفع القطع الصخرية في مختلف المقاطع المحفورة .

أظهرت الدراسة من خلال المشاهدات الحقلية والخبرة العملية والحسابات النظرية ان اهم العوامل التي تؤثر على التنظيف الامثل هي : معدل التدفق (Q)، نقطة الخضوع (Yp)، كثافة سائل الحفر ، اللزوجة البلاستيكية ، دوران خيط الحفر وقاعدية او حامضية سائل الحفر .

الكلمات الرئيسيه: تنضيف البئر، معدل التثقيب، كثافه التدوير المكافئه، البئر الاتجاهي.

1. INTRODUCTION

Poor hole cleaning can cause severe drilling problems including : excessive over pull on trips, high rotary torque , stuck pipe , hole pack – off , excessive equivalent circulating density(ECD), formation break down , slow rates of penetration and difficulty running casing and logs. The sticking of the drill string is very expensive to remedy, **Fig. 1, Adari, et al., 2000.**

Insufficient hole cleaning is responsible for a large portion of all stuck pipe. Some would argue that it is the number one cause of stuck pipe around the world, especially in high - angle holes. Previous study in the North Sea attributed 33% of the stuck pipe incidents to poor hole cleaning alone**, Sifferman, et al.,1990.**

A study showed that drill string rotation has a moderate to significant effect on hole cleaning, and that this effect also depends on the hole angle and other cuttings properties. Also the drill string rotation enhances hole cleaning more when the used mud has a higher viscosity with smaller cuttings sizes. It was found that for hole angle at 65 degrees, and at horizontal, the effect drill string rotation caused an improvement in cuttings transport**, Bassal, 1995.** A new mathematical method for estimating the minimum fluid transport velocity for system with the inclination between 55° to 90° was developed. It was found that the model worked fairly well within inclination angle 55° to 90° and there were no correction factors yet for inclination less than 55°. From Larsen method it was known that there are three parameters which affect determination of minimum fluid annular velocity for inclined hole: inclination, ROP, and mud density**, Larsen et al., 1997.**

A new simulations show drill pipe rotation can improve the cuttings transport but the effect is more renounced for smaller particle size. Cutting transport efficiency has a decreasing trend with increase in annular velocity. In addition, inclination and ROP also have major impacts on cuttings concentration**, Bilgesu,et al., 2002.**

Another study was investigated the effect of fluid rheology and cuttings sizes on the circulation rate required to ensure that the drilling cuttings in horizontal wells are efficiently transported to the surface. The results of this study observed that much higher annular velocities are required for effective hole cleaning in horizontal wells. It was also observed that higher viscosity drilling fluid yield better transport than lower viscosity drilling fluid within the same flow regime**, Al-Zubaidi, 2007.**

1.1 Area of Study

Iraqi West Qurna oil field has been selected to simulate a study for the possibility of using hole cleaning in directional and horizontal well to minimize the problems which happen because that. Also, a horizontal well in Halfaya oil field have been selected.

West Qurna oil field is one of the largest oil fields in Iraq with a reserve of about 43 billion barrel of crude oil. This field located on the south-eastern part of Iraq, about 45 km north-westwards from Basra and 30 km from Zubair oil field**, BP Company, 2010.**

RESULTS AND DISCUSSION*:*

1- Field Investigations

Below a list of results based upon field observations and practical experiences:

A) During connection process of additional drill pipe to the string, an increasing in pressure can be noticed because of shut off the mud pump until the pipe connection is finished .An obstruction may be happened due to settling of cuttings on the bit .

B) When there is remarkable changes on the hole inclination and azimuth during drilling, drilling parameters such as (weight on bit, rate of penetration, flow rate) and BHA should be adjusted immediately to correct the hole trajectory.

C) Wiper trip should be make to break building up of any cutting bed at high angle hole regularly with high viscosity pill pump down for better hole cleaning.
D) When the flapper valve is used, fill in mud every 10 – 15 stands to avoid the flapper valve from damage.
E) At the end of drilling the 8.5" hole, circulate to clean the hole and make wiper trip with reamers to control the hole condition before logging and casing.
F) In case of lost circulation, stop drilling and pull out of hole as fast as possible meanwhile fill in mud. Pull the string inside the $9^{5/8}$" casing and check the flow and loss rate, If necessary.
G) Monitoring the shale shakers before trip out or pull out of the hole (POOH) in order to ensure that cuttings return rate has reduced.
H) During drilling operation, it is common to circulate wellbore several times (the process is called circulate bottom-up) before starting tripping out of hole. The purpose is to avoid stuck of drill pipe during pull out and be able to reach the bottom hole with drill bit or casing, when running into the hole again(RIH). The common practice is to have at least three bottoms-up with slow pipe rotation before tripping out of the hole. If ECD measurement tool is available on the BHA, it has to be controlled that the ECD has dropped to normal level.

2- Concentration of the Cuttings

An increase in rate of penetration will increase the concentration of cuttings in the hole and a longer time will be needed for cleaning the hole, **Fig. 2**.
The figure indicates that an increasing in the ROP lead to an increase in the cuttings concentration, therefore, more than one cycle to clean the hole is needed besides additional time.
If a comparison has been made between the wells to show the total time of drilling, for the state of wells, we can notice:
In WQ-404, the total time to complete the drilling operation is (30) days, **Fig. 3.**
While the total time for drilling operation of directional well less than 30 degree well (WQ-416) is about thirty-two (32) days, **Fig. 4.**
The similarity in needed time can be attributed to use the same drilling factors which affect on hole cleaning in vertical wells and directional wells less than 30 degree.
Accordingly, for the directional well with high deviated angle (WQ-271) (62degree) the total time of drilling operation is about fifty- five(55) days, **Fig. 5,** whereas for horizontal well (HF-69) the total time is ninety (90)days, **Fig. 6.** From the previous cases, it is evident that time values increases rapidly as hole inclination increases.

3- Sample of Calculations

Following a sample of Carrying Capacity Index (CCI), and flow rate for selected sections of some wells, which prepared to show the optimality of the field data in achieving the best hole cleaning. **Tables 1, 2, and 3** show the CCI and calculations using field data for the 1st hole, 2nd hole, and 3rd hole respectively. Such as CCI for the second hole for the well WQ-416:

$$n=3.32 \log [(2\mu p+Yp)/(\mu p+Yp)] \quad (1)$$
$$n=3.32 \log [(2*60+15)/(60+15)]$$
$$=0.848$$

$$\mu_e = 511^{(1-n)} (\mu p + Yp) \quad (2)$$
$$\mu_e = 194\ cp$$

$$V = \frac{24.5\,Q}{Dh^2 - Dp^2} \quad (3)$$

=155.4 ft/min.

$CCI = (\rho\ \mu_e\ V)/400000$ (4)

=0.703

Where:

n = Power Law Index

µp: Plastic Viscosity cp

Yp: Yield Point lb/100ft

µe: Effective Viscosity cp

Q: Flow Rate gpm

Dh: Hole Diameter in , Dp: pipe diameter in

V : Annular Velocity ft/min

CCI: Carrying Capacity Index

It can be noticed in the second hole (WQ-416) that the CCI value which equal to 0.7 represent poor hole cleaning and this case may be cause many problems especially the stuck pipe so increasing yield point value is necessary to obtain proper hole cleaning. Absolutely, the CCI results for the selected section show that the drilling parameters used in different well types are the same. Simply, the need to change the parameters begins with high deviated wells.

Finally, a horizontal drilling program for West Qurna oil field was prepared and a plan to drill a horizontal well in this oil field due to absence of such well type. The present proposal consist of four holes shown in **Fig. 7**

CONCLUSIONS:

Based on the theoretical and experimental observations and analysis, the following conclusions can be drawn regarding optimization of hole cleaning in horizontal oil well:

1- The rheological properties play a crucial role to ensure adequate hole cleaning, i.e. proper rheology is the key for efficient solids removal. So the yield point was maintained to 15-20 lb/100 ft^2, which were enough to clean the hole while drilling vertical & directional wells.

2- In case of highly inclined or tight well, it is important to ream the wellbore with help of a back reamer. It helps creating a bigger hole that can eliminate risk of stuck drill-pipe.

3-The flow rate should be high enough (during drilling operation) or increased to its upper level, especially in the range of higher angles between 55° to 90° degrees to obtain optimum hole cleaning.

4-The hole cleaning in deviated holes can be assisted by the following topics:

-Turbulent flow

-Low viscosity and high flow rates

-Maximize flow rates at all times unless ECD problems require lower rates

-Low Viscosity Sweeps (10-20 bbl)

-Followed by High Viscosity Weighted sweep to remove cuttings

-Pipe rotation at high rpm

-Reaming and wiper trips can stir up cuttings beds

RECOMMENDATIONS:

Some of the issues which should be investigated in future studies are listed below:

1- OBM or Polymer drilling fluid system has the outstanding abilities on cuttings lifting, lubrication, hole cleaning etc., so it is very important to be used for the successful drilling in the build- up and horizontal sections.

2- In cases, where drill pipe does not rotate, it is difficult to remove cuttings bed. In these situations, wiper trips are necessary to improve hole cleaning. Usually, a normal range of drill pipe rotation is around 90 to 180 rpm. The pipe can rotate up to 120-rpm when drill bit is on-bottom, and 180-rpm drill bit is off-bottom.
3- One has to be aware that inclinations between 40° to 45° degrees are critical since cuttings can slide down during connections when pumps are off.

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NOMENCLATURES AND ABBREVIATIONS:

BHA = bottom hole assembly.
CCI = carrying capacity index.
Dp = pipe diameter in
Dh = hole diameter in
ECD = equivalent circulating density, ppg .
FWB = fresh water bentonite .
HF = halfaya oil field .
OBM = oil base mud
POOH = pull out of the hole .
Q = flow rate gpm
RIH = running in the hole .
ROP = rate of penetration ft/hr .
Rpm = rotation per minute .
V = annular velocity ft/min .
WQ = west qurna oil field .
Yp = yield point lb/100 ft^2
ρf = fluid density ppg

μp = plastic viscosity cp
μe = effective viscosity cp

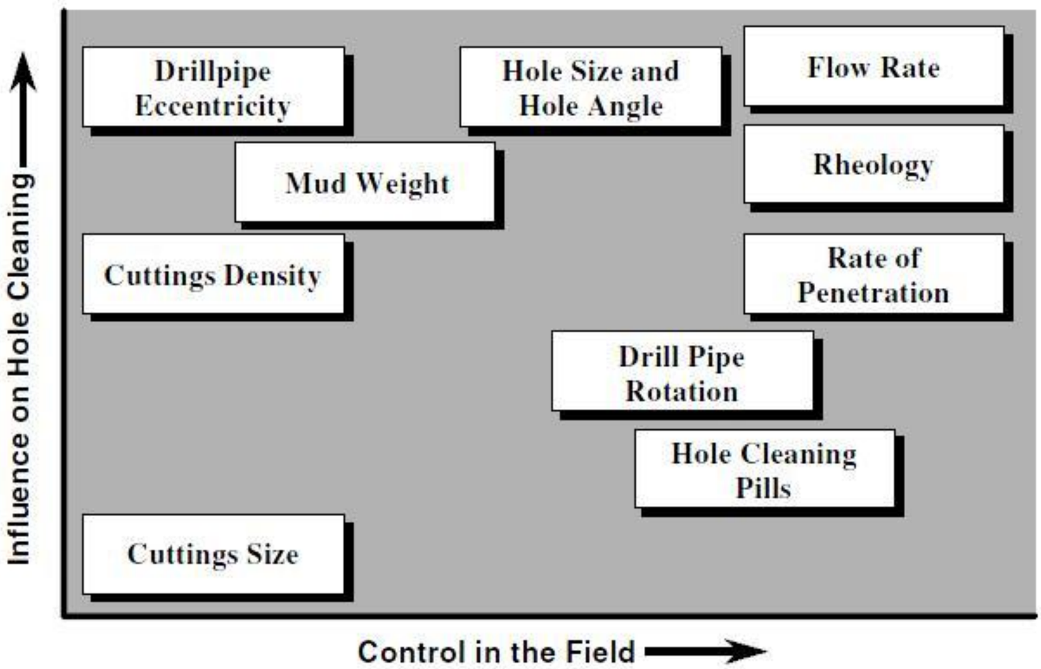

Figure 1. Key variables controlling cuttings transport**, Adari, et al., 2000.**

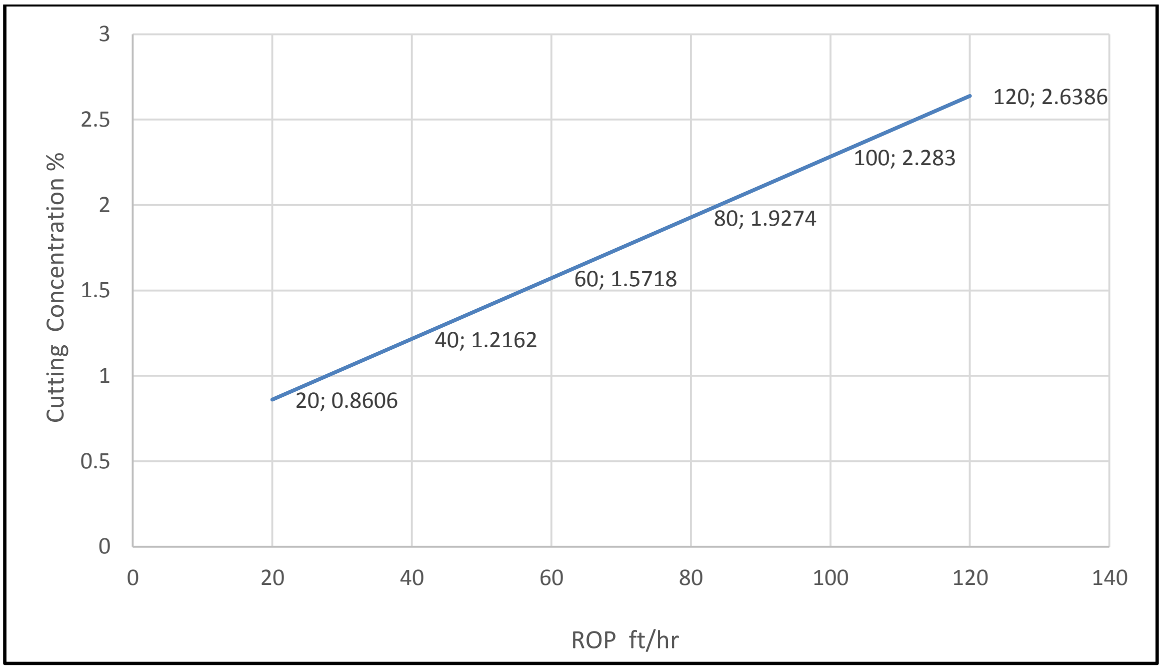

Figure 2. Relationship between ROP and cuttings concentration.

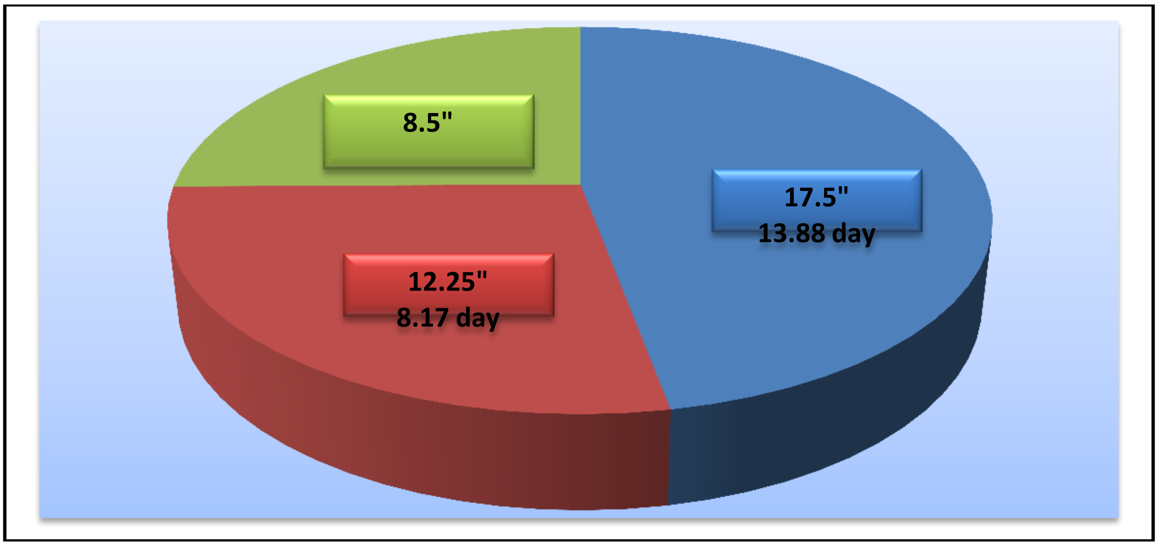

Figure 3. Pie chart show time vs hole size for vertical well (WQ-404).

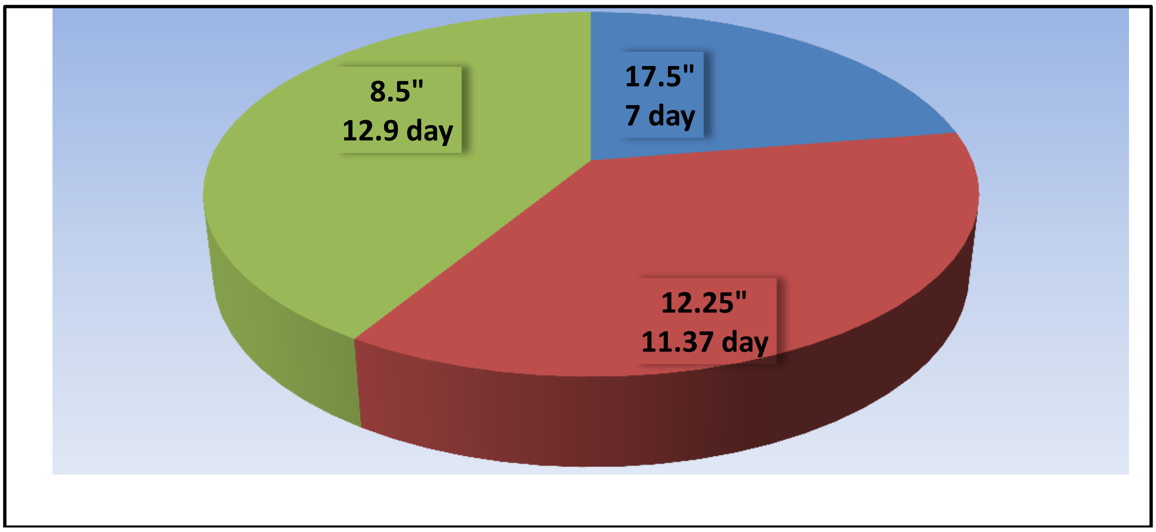

Figure 4. Pie chart show time vs hole size for directional well (WQ-416).

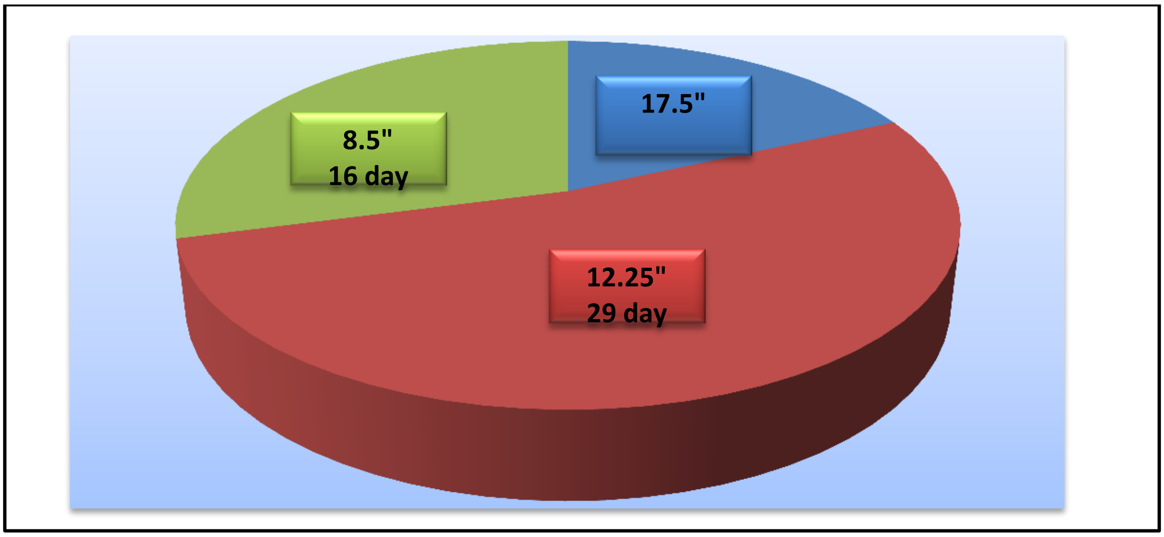

Figure 5. Pie chart show time vs hole size for directional well.

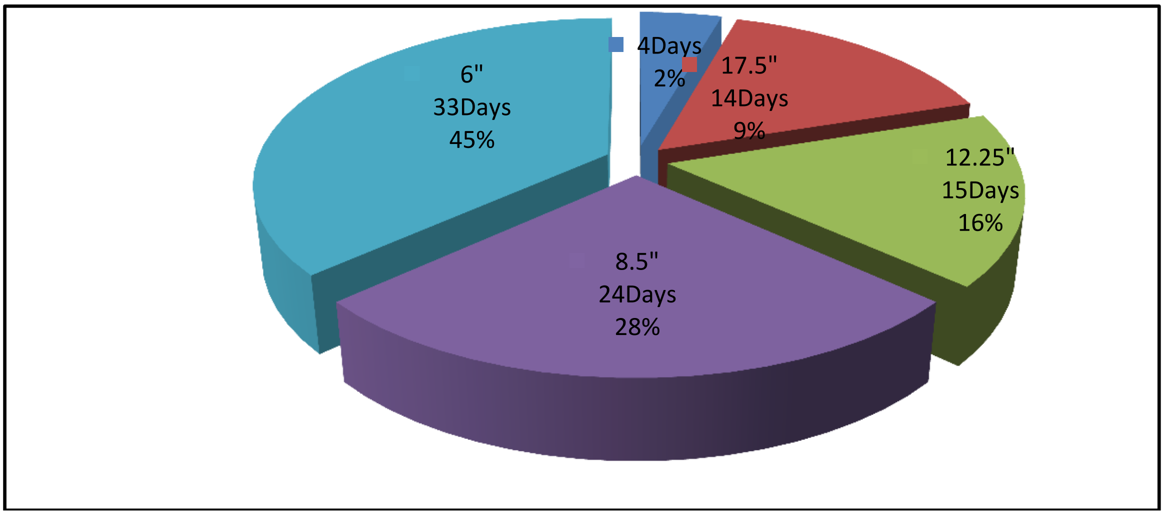

Figure 6. Pie chart show time vs hole size for well (HF-69).

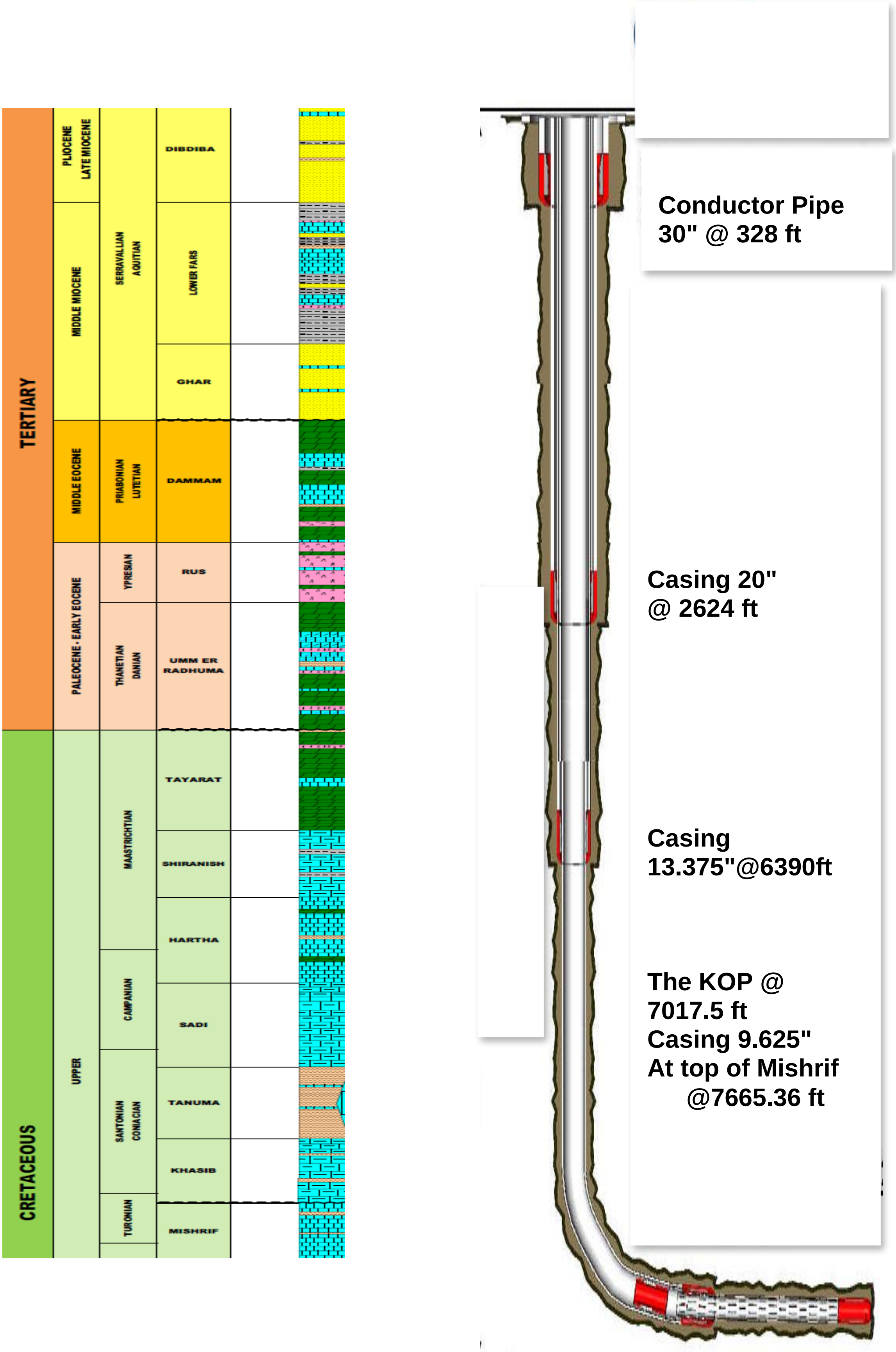

Figure 7. Casing program for the proposal horizontal well in west Quran oil field

Table 1. Excel sheet of CCI calculation for 17.5" hole.

Variable	Calculated value	Units
ρf	8.75	ppg
Yp	20	$lb/100ft^2$
μp	14	cp
N	0.497	
μe	782.1	cp
Dp	5	in
Dh	17.5	in
Q	700	gpm
V	60.98	ft/min
CCI	1.043	

Table 2. Excel sheet calculation CCI for 12.25" hole

Variable	Calculated value	Units
ρf	10.4	Ppg
Yp	17	$lb/100ft^2$
μp	12	Cp
N	0.499	
μe	659	Cp
Dp	5	In
Dh	8.5	In
Q	425	Gpm
V	220.3	ft/min
CCI	3.7	

Table 3. Excel sheet calculation CCI for 8.5" hole

Variable	Calculated value	Units
ρf	10.4	Ppg
Yp	17	$lb/100ft^2$
μp	12	Cp
N	0.499	
μe	659	Cp
Dp	5	In
Dh	8.5	In
Q	425	Gpm
V	220.3	ft/min
CCI	3.7	