بسم الله الرحمن الرحيم

Sudan University of Science &Technology

College of Petroleum Engineering &Technology

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Solving The Problem of wellbore instability by using simulation software

Sudanese Oilfield Al-Rawat (Alrateena Well, Case Study)

حل مشكلة استقرار البئرباستخدام برامج المحاكاة في الحقول السودانيه , حقل الراوات

(بئر الرتينه, دراسه حاله)

Submitted in partial Fulfillment of the Requirement of the Degree of B.Sc technology in petroleum Engineering

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الاستهلال

قال تعالي:

(فتعالي الله الملك الحق ولا تعجل بالقران من قبل ان يقضي اليك وحيه وقل رب زدني علما)

صدق الله العظيم

الايه 114 من سورة طه

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Abstract

Wellbore instability is one of challenge is facing engineers during drilling the wells, the causes of wellbore are grouped under three interrelated headings ,Mechanical Wellbore Instability ,Rock- Chemical Interaction (shale) Instability and Man-Made Wellbore Instability.

In this study we dealt with the problem that faced engineers in the field of ALRAWATT during the drilling of the ALRATTENA well by analyzing the case using commercial software. Through the analysis of the problem (caving), we conduct a Bottom Hole Assembly (BHA) design using the software and Microsoft Excel for solving the problem.

Through this study the best mud drilling fluid was chosen as well as the best design for Bottom Hole Assembly and preventing the caving.

Finally, good understanding of the main causes of rock failure were established and reduction of drilling cost was obtained.

التجريد

ان عدم استقرارية جدار البئر واحده من المشاكل التى تمثل تحديات للمهندسين والفنيين العاملين في حقول النفط . حيث يمكننا ان نصف اسباب عدم استقرار جدار البئر الي عدة عوامل :

عوامل ميكانيكيه ،عوامل كيميائيه وعوامل صناعيه.

سنتاول في هذه الدراسه مشكلة تكهف caving حدثت في احدي الابار(الرتينه) التي تقع في احد الحقول السودانيه (الراوات) فى ولاية النيل الابيض.

حيث تم عمل تحليل لهذه المشكله باستخدام برنامج land mark ومن ثم اجرينا عدة سيناريوهات لوضع افضل تصور لحل هذه المشكله.

ومن خلال هذه الدراسه توصلنا الي انسب سائل حفر يمكن استخدامه لحل هذه المشكله .

يساعدنا في حماية الابار من التكهف وفهم الاسباب التي ادت الي التكهف ليتم تجنبها مستقبلا وبالتالي تقل تكلفة الحفر.

Nomenclature:-

API	American Petroleum Institute
TVD	Total Vertical Depth
MD	Measure Depth
WOB	Weight on Bit
MW	Mud Weight
DC	Drill Collar
DP	Drill Pipe
LOT	Leak-Off test
HWDP	Heavy Weight Drill Pipe
PV	Plastic Viscosity
FP	Formation Pressure
YP	Yield Point
MWD	Measure while Drilling
BHA	Bottom Hole Assemble
ECD	Equivalent Circulation Density
τma	Maximum shear stress
PP	Pore Pressure
PPN	Normal pore pressure
ν	Poisson's ratio
E	young module
τ	Shear Stress
$\sigma; S$	Formation Stress
σ'	Effective Stress
ρ	Density of the Rock
d	Diameter of the hole

D	Vertical depth
H	Thickness of the formation
μ	Viscosity
η	Poro-elastic stress coefficient
$\boldsymbol{PH}$	Hydrostatic Pressure
$\boldsymbol{mtot}$	Total mass equals
$\boldsymbol{PPG}$	Pore pressure Gradient
Ø	Porosity
$\boldsymbol{V}$	Bulk Volume
$\boldsymbol{Vv}$	Pore Volume
$\boldsymbol{\rho m}$	Matrix Density
$\boldsymbol{\rho b}$	Bulk Density
$\boldsymbol{\rho f}$	Pore Fluid Density
$\boldsymbol{\sigma}$	Overburden Pressure
$\boldsymbol{\sigma og}$	Overburden gradient
$\boldsymbol{\sigma 1}$	Maximum principal Stress
$\boldsymbol{\sigma 2}$	intermediate principal Stress
$\boldsymbol{\sigma 3}$	Minimum Principal Stress

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Chapter One

Introduction

Chapter One

Introduction

1.1 Introduction:

Maintaining a stable wellbore is one of the major challenges when drilling a well. Studies indicate that unscheduled events relating to wellbore instability account for more than 10% of well costs, with estimate over $1 billion in annual cost to the industry.

Wellbore instability is caused by a radical change in both the mechanical stress and the chemical and physical environments when a hole is drilled, exposing the formation to drilling mud. Hole instability is seen most often as sloughing and caving shale, resulting in hole enlargement, bridges and fill. The most common consequences are stuck pipe, sidetracks, logging and interpretation difficulties, sidewall core recovery difficulties, difficulty running casing, poor cement jobs, and lost circulation. All contribute to increased costs, the possibility of losing part of the hole or the entire well, or reduced production.

1.1.1 Wellbore instability is caused by:

- Formations imbalanced stress.
- Pipe Sticking.
- Formation Caving.
- Shale in stability, Swelling or Sloughing.
- Formation Fluid kicks.
- Well Fluids Loss of Circulation.
- Bad Drilling Practices.

1.1.2 Borehole Collapse:

Hole collapse means that the formation near the borehole fails mechanically, most often by shear failure, but occasionally also by tensile failure. The results of such failures can be divided into:

1.1.2.1 Increased borehole size.

Increased borehole size due to brittle failure and caving of the wellbore wall. If the cavings are not transported away, this represents a potential source of a stuck pipe situation.

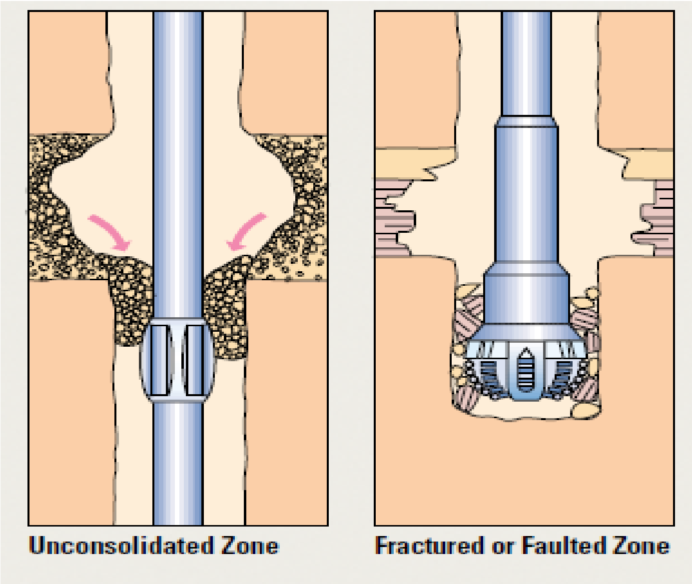

Figure (1-1) Unconsolidated Zone & Fractured Zone

1.1.2.2 Reduced borehole size:

Reduced borehole diameter may occur in weak (plastic) shales, sandstone sand salt. Some chalk formation scans also show such behavior. It has traditionally been thought that large hole diameter reductions might be caused by swelling clays. The potential chemical swelling of a shale in down hole stress conditions is however every limited. Large hole deformation is thus a result of primarily plastic shale deformation.

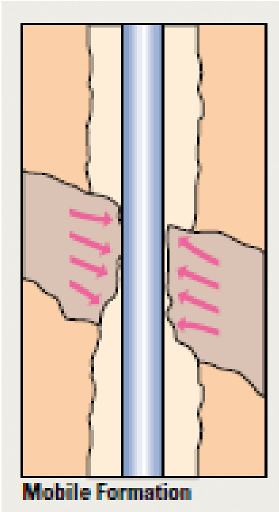

Figure (1-2) Mobile Formation

1.2 Statement of the Problem:

At ALRAWAT field BLOCK A (ALRATEENA-1 WELL) drilled to 3839m, suddenly top drive system stopped (TDS), wiper trip to casing shoe (intermediate casing) to replaced top drive system by Kelly, that replacement took long time and the hole was at static condition due to that the equivalent circulation density (ECD) became lost, then the hydrostatic pressure became less than the formation pressure.

After run in hole (RIH) ,touchdown 2957m (max drag 70 ton) and it became very difficult to be reamed from 2957m to 3839m with observed frequency and severity of caving signs on the shale shakers encountered (see Figure(1-3)). From above mentioned conditions, one can conclude that there may be an instability problem has took place.

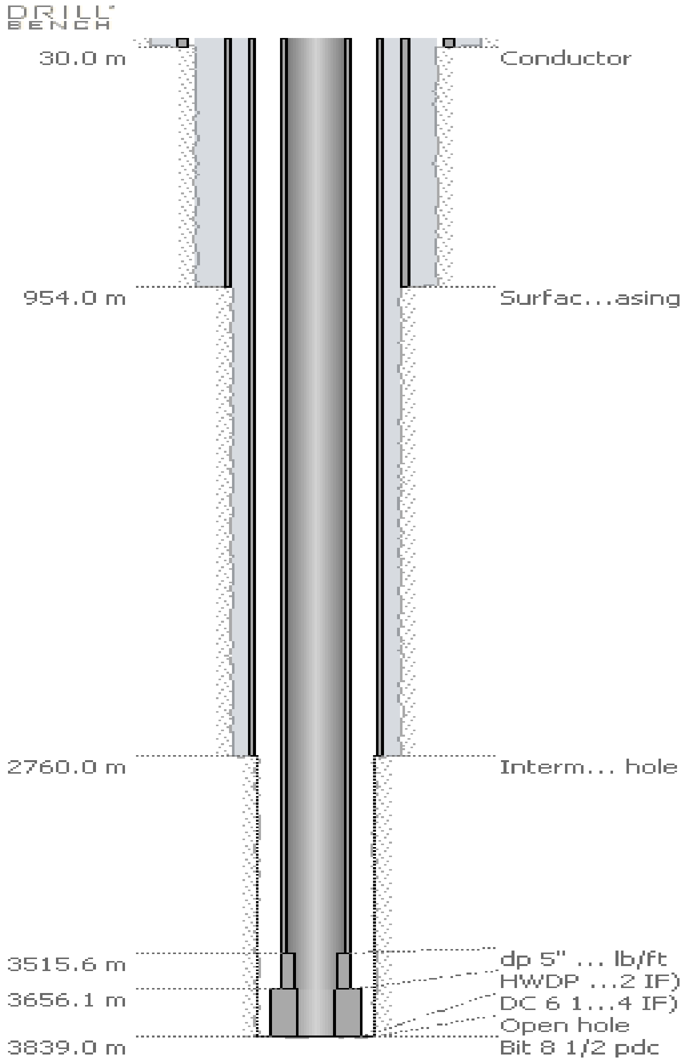

Figure (1-3) Alrateena-1 Well

1.3 Objectives of the Project:

In this research for **ALRATEENA-1** well at ALRAWAT we are tried

- To perform technical design analysis of mechanical pressure collapse.
- To design suitable mud weight to support wellbore pressure.
- To analyze wellbore stability using finite element software.
- To provide a good contribution to petroleum industry by solving ALRATEENA wellbore instability problem.

Chapter 2

Theoretical Background and Literature Review

Chapter 2

Theoretical Background and Literature Review

2.1 Theoretical Background

Wellbore instability is one of the main problems that engineers meet during drilling is recognized when the hole diameter is markedly different from the bit size and the hole does not maintain its structural integrity. A good working knowledge of all areas of the operation, as well as a basic background in mechanics and geophysics, and water and clay chemistry, are necessary. A number of possible causes must be evaluated in resolving wellbore instability. By evaluating these interrelated conditions, the most likely failure mode can be determined and an appropriate response can be applied to resolve or tolerate the instability These include mechanical conditions such as:

- **Naturally Fractured Faulted Formations:**

  Hole collapse problems may became quite severe if weak bedding planes intersect a wellbore at unfavorable angles. Such fractures in shale.

- **Tectonically stressed formations:**

wellbore instability is caused when highly stressed formation are drilled and if exists a significant difference between the near wellbore stress and the restraining pressure provided by drilling fluid density, when a hole is drilled in an area of high tectonic stresses the rock around the wellbore will collapse into wellbore and produce splintery cavings .

- **Unconsolidated formations:**

An unconsolidated formations falls into the wellbore because it is loosely packed with little or no bonding between particles, the collapse of formation is caused by removing the supporting rock as the well is drilled ,it happens in wellbore when little or no filter cake is present.

The un bonded formation cannot be supported by hydrostatic over balance as the fluid simply flows into the formations .sand or gravel then falls into the hole and packs off the drilling string.

Wellbore instability can result in lost circulation where tensile stresses have occurred due to high drilling mud pressure. breakouts and hole closure in case of compressive and shear failures. During drilling phase an open hole is supported by drilling mud pressure to keep wellbore from collapse. If the mud weight is lower than the shear failure stress or collapse stress, the shear failure and compressive failure occur in the wellbore in the minimum far-field stress direction, causing hole collapse or breakout. If the mud weight exceeds the rock tensile strength, the tensile fracture is induced in the maximum far-field stress direction.

2.1.1 Overburden pressure:

Is the volume and weight of all formations and fluids above a given formation the total stress imposed by the overburden that a subsurface formation is subjected to be called the geostatic, lithostatic or total overburden pressure (PO).

Overburden pressure (PO) is equal to the total pressure from the weight of the sediments (PS) plus the pressure from the weight of the fluids (PF) that exist above a particular formation and which must be mechanically supported by the formation or PO = PS + PF.

2-1-2 Pore pressure gradient:

Is the Pore pressure increase per unit of vertical depth

Table (2-1) Solid & Fluid Density

Lithology	Matrix Density (g/cc)
Sandstone	2.65
Limestone	2.71
Dolomite	2.87
Anhydrite	2.98
Halite	2.03
Gypsum	2.35
Clay	~2.7-2.8
Fresh Water	1.0
Salt Water	1.15
Oil	0.80

2.1.3 Stress shale:

Mud weights are usually increased to control the flow of gas and liquids into the well. If the formation is stressed due to tectonic forces, then mud weight may be needed to prevent wellbore instability. Shale of this type may be described as shale that does not hydrate appreciably but sloughs into the hole when penetrated. These shales are found in areas where diastrophic or tectonic movements (the process by which the earth's crust is deformed, producing continents, oceans, mountains, etc.) have occurred. The shales may be inclined considerably from the horizontal, in steeply dipping bedding planes. Forces may be acting upon the formations which, when relieved, cause the shale to fall into the hole.

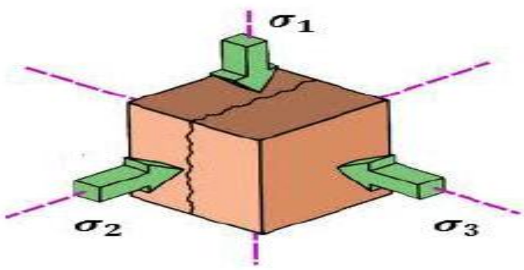

Figure (2-1) Stress shale

2-1-4 Pressure:

Pressure is defined as force per unit area.

2-1-5 Density (MW):

The density of a substance is its mass per unit volume.

2-1-6 Hydrostatic Pressure in drilling wells:

Hydrostatic pressure is the pressure caused by the density or Mud Weight and True Vertical Depth of a column of fluid. The hole size and shape of the fluid column have no effect on hydrostatic pressure.

2-1-7 Formation Fracture Pressure:

Fracture pressure is the pressure required to rupture a formation physically, allowing entry of drilling fluids into the formation.

2-1-8 Equivalent Circulation Density (ECD):

The pressure on a formation while circulating is equal to the total annular circulating pressure losses from the point of interest to the bell nipple, plus the hydrostatic pressure of the mud. This force is expressed as the density of mud that would exert a hydrostatic pressure equivalent to this pressure. This equivalent mud weight is called the Equivalent Circulating Density (ECD).

2-1-9 Pressure Loss (PL):

Pressure Losses sums the total pressure loss and hydraulic power across each work string section inside the string and in the annulus. For example, inside the work string, it calculates the total pressure loss across the entire drill pipe section, the HWDP section, and then the drill collar section. Similarly, in the annulus, it calculates the pressure drop across the entire drill pipe section, the HWDP section, etc.

The pressure losses through the surface equipment are shown along with the total system pressure loss at the specified flow rate.

Finally, the report splits the annulus into separate sections based on a change in either the wellbore effective diameter and/or a change in the outside diameter of the workstring. For each annular section, the report displays the following information:

a. Hole OD
b. Pipe OD
c. Pressure loss
d. Average velocity
e. Reynolds number
f. Critical flow rate
g. Flow regime (laminar, transitional, or turbulent)

2.2 Literature Review:

See Hong Ong and J-e. Roegiers (1993). He discussed wellbore collapse by an anisotropic model for calculating the stress around wellbore, analysis wellbore stability by computer program, collapse is a manifestation of shear failure, is significantly affected by high degrees of rock anisotropy, Horizontal borehole position can influence the stability, and borehole trajectory must be optimally selected in order to avoid the potential of borehole collapse.

Ramiro J. Liz-Losada(2000). This paper study wellbore instability through rock mechanical parameters that can be used to predict rock failure. However, apart from drilling practices, there is only one key factor that can be changed in order to avoid well instability. This is the mud weight. Accurate monitoring of the mud weight used. By using different rock mechanical failure criteria, the range of mud weight values that guarantee well stability can be estimated.

H.Abass , A. M. Khar (May 2006).They were study problem of caving through shale formation that was usually cause over 90% of wellbore instability problem . those problem can be simple washout to complete collapse of the hole .the problem of shale stability are related to the mechanical properties (strength and deformation under stress) . rock mechanical testing was performed to evaluate the effect of drilling fluid on shale strength and used PBORE-3D module to determine mud weight window.

Moamen Abutaleb, Jim Lantz, Salah Abdel Kareem,(2010). The solving problem of well instability by following procedure first we analyze drilling reports in offset wells to gather the evidence for borehole failure. Then we develop a geomechanical model . This analysis assures that we choose the optimum drilling mud weight.
SAMUEL O.OSISANYA (2011-2012). He was study wellbore instability while drilling causes by wall weak and poor hole cleaning we must optimize hole cleaning , minimize open hole time and raise mud weight.

LIU Zhiyuan1,*, CHEN Mian1, JIN Yan1, YANG Xiangtong2, LU Yunhu1, XIONG Qiquan1(2014). The collapse volume decreases with the increase of borehole fluid density, and collapse volume is more sensitive to the change of fluid density when it is near the equivalent density of pore pressure.

B. Benny, R. Usmar, F. Irawan, and A. Setiawan, Weatherford (25 March 2016). They discussed collapse problem through software (MPD) Manage Pressure Drilling , offers a relatively more dynamic wellbore pressure control by adjusting the surface back pressure (SBP) applied to the annulus for a given (HP). Instead of shifting the MW or changing drilling parameters, MPD provide adjustment to the required equivalent circulating density (ECD) or equivalent static density (ESD) based on formation collapse gradient. Additionally, in the event of mud losses due to high ECD/ESD.

Husam R. Abbood, E. Flori, and Andreas Eckert(2017). In this study, used a 1D MEM model to determine the optimum mud weight to prevent stability problems based on the principal stresses of an arbitrary oriented wellbore. And determine the mud weight window as a function of the wellbore inclination and azimuth. This model is applied to analyze the mechanical stability.

CHAPTER THREE

Methodology

Chapter three

Methodology

This chapter presents the steps and procedures that have been followed for the analysis collapse by commercial software (land mark).

3.1 Land Mark Software:

This software is used to simulate drilling operation. It can either be used to plan or analysis the process of building a new site or to evaluate possible alternatives in actual problem. The user required to input the data and the software has a range of modules to assess the data, this software developed by Halliburton. Land mark software mainly contains the following:

- Compass, it involves varies input data like survey to ensure well path in 3D plot.
- Well plan. It involved varies input data about the well to analysis effective parameter like bottom hole assembly analysis.

3-2 Well plan:

WELLPLAN is based on a database and data structure common to many of Landmark's drilling applications. This database is called the Engineer's Drilling Data Model (EDM) and supports the different levels of data that are required to use the drilling software. This is a significant advantage while using the software because of improved integration between drilling software products. Currently WELLPLAN, COMPASS, **Stress Check** and **Casing Seat** use the common database and data structure. Although the common database improves integration between drilling products, those products that don't use the common database continue to share data using DEX.

3-3Data Requirement:

3-3-1BottomHole Assembly (BHA):

A combination of drill collars, reamers, stabilizers, and specialized tools that provide weight on the bit. BHA is also used to control hole deviation and direction.

Table (3-1) Drilling String

DRILLSTRING												
Type	Length (m)	Depth (m)	OD (in)	ID (in)	AveraJoint Length	Length (m)	OD (in)	ID (in)	Weight (ppf)	MTL	Grade	Class
Drill Pipe	3,513.44	3,513.44	5	4.276	9.14	0.433	5.813	3	22.32	CS_API 5D/7	G	2
HWDP	140.5	3,653.94	5	3	9.14	1.219	6.5	3.063	49.7	CS_1340 MOD	1340 MOD	
Drill Collar	109.68	3,763.62	6.5	2.813					91.76	CS_API 5D/7	4145H MOD	
Jar	11.067	3,774.69	6.75	2.5					68.85	CS_API 5D/7	4145H MOD	
Drill Collar	57.384	3,832.08	6.25	2.813					83.25	CS_API 5D/7	4145H MOD	
Stabilizer	1.524	3,833.60	4.25	1.5		0.305	6.219		42.27	CS_API 5D/7	4145H MOD	
MWD Tool	5.2	3,838.80	6.75	2.875					100.8	SS_15-15LC	15-15LC MOD (1)	
PDC Bit	0.201	3,839.00	8.5						85			

3-3-2 Hole Section:

Since a wellbore can have multiple cases, you need to enter data in this spreadsheet to define the well profile and well depth of a particular case for analysis. From this data, you can define the components of the hole section and the material properties of the components. The hole section configuration is common for all analysis modes and is available in all WELLPLAN modules.

You must enter the hole section information from the surface down to the bottom of the well. When you make a selection from a Section Type cell (other then Open Hole), a dialog specific to that section type appears. You must fill in the data in the dialog in order for that section type to be recorded in that cell. You also must fill in all editable cells in the spreadsheet row.

The results from this data are listed in the report's Hole Section block.

Fields, Controls, and Columns

a. Hole Name

   Specify a name for the hole section.

b. Hole Section Depth

   Specify the hole section depth. This depth is used to automatically calculate the length for the bottom section of the wellbore.

c. Copy String

   Click to copy a string from another design.

d. Section Type

Specify the section type. Enter all section types from the surface down. Only one type can be specified for each row. You must also enter data into all remaining editable cells associated with the row.

Each type, except Open Hole, accesses a dialog specific to that section type. You must enter data in the dialog's fields in order for the type to be accepted. All choices are provided below.

a. Bit - Displays the Bit Specification Dialog
b. Casing, - Displays the Casing Specification dialog.
c. Casing Shoe - Displays the Casing Shoe Specification Dialog
d. Float Collar - Displays the Float Collar Specification Dialog
e. Hangers - Displays the Completion Tool Specification Dialog
f. Open Hole - Contains data entered manually or derived automatically by Importing a Caliper Log. Upon import of a caliper log, the list of open hole diameters is added automatically to the Hole Section Editor spreadsheet at each appropriate depth.

Table (3-2) Hole Section

HOLE SECTION										
Type	Section Depth (m)	Section Length (m)	Shoe Depth (m)	Tapered	Hole ID (in)	Drift (in)	Effective Hole Diameter (in)	Coefficient of Friction	Linear Capacity (bbl/ft)	Volume Excess (%)
Casing	30	30	30		18.395	20	24	0.25	0.3287	
Casing	954	924	954		12.515	13.375	17.25	0.25	0.1523	
Casing	2,760.00	1,806.00	2,760.00		8.835	9.625	12.25	0.25	0.0759	
Open Hole	3,839.00	1,079.00			7.646		8.503	0.3	0.0702	45.16

3-4 Hydrostatic pressure:

a. More than one fluid is present in the annulus.
b. Surface pressure is being applied to the annulus.
c. Different fluid densities exist in the annulus and string.

HP (psi) = 0.052 x MW (ppg) x TVD (ft)··· ··· ··· ··· ··· ···(3-1)

3-5 Hydraulic:

You can analyze these pressure losses in the Pressure: Pump Rate Range report. You can also analyze the ECD (Equivalent Circulating Density) at any depth.

Table (3-3) Hydraulic drag chart summary

HYDRAULICS DRAG CHART SUMMARY TABLE									
MD (m)	TVD (m)	Pore Pressure (psi)	HydoPressu (psi)	Fracture Pressu (psi)	Pore EMW (ppg)	String ECD (ppg)	Annulus ECD (ppg)	Fracture EMW (ppg)	Stand Pipe Press (psi)
2,759.80	2,759.57	5,050.70	5,229.10	7,332.80	10.74	15.34	11.12	15.59	3,792.40
2,912.20	2,911.89	5,370.90	5,530.50	7,770.70	10.82	15.15	11.14	15.66	3,867.90
3,064.60	3,064.22	5,691.10	5,825.20	8,208.60	10.9	14.97	11.15	15.72	3,936.30
3,217.00	3,216.56	6,011.30	6,117.80	8,646.50	10.97	14.8	11.16	15.77	4,002.20
3,369.40	3,368.88	6,315.90	6,410.40	9,071.90	11	14.65	11.16	15.8	4,069.10
3,521.80	3,521.20	6,601.40	6,703.00	9,482.00	11	14.51	11.17	15.8	4,135.70
3,674.20	3,673.52	6,887.00	6,995.60	9,892.20	11.1	14.38	11.17	15.8	4,202.20
3,826.60	3,825.84	6,888.00	7,288.20	9,893.20	11.16	14.26	11.18		4,268.60
3,938.80	3,938.04	6,889.00	7,503.60		11.2	14.18	11.18		4,317.40

3-6 Total flow area (TFA):

To calculate the TFA produced for a specified number of nozzles and sizes, Total flow area of the nozzles are calculated using the following:

$$TFA = \sum_{i=1}^{n} n_i \frac{\pi}{4} \left(\frac{d_i}{32}\right) 2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3\text{-}2)$$

Table (3-4) Bit Nozzles

DRILLSTRING NOZZLES				
T Type	Component	Nozzles (1/32nd")	Percent Diverted Flow (%)	TFA (in²)
BIT	Polycrystalline Diamond Bit	13/13/13/13/13/13		0.778

3-7 Bit Hydraulic Power Calculation:

Bit hydraulic power is calculated using the flow rate entered in the input section of the Rate dialog.

Bit Hydraulic Power (hp) $= \frac{Q * Pb}{1714} \cdots\cdots\cdots\cdots\cdots (3\text{-}3)$

Q = Circulation rate, gpm

Pb= Pressure loss across bit nozzles, psi

Table (3-5) Bit parameters

BIT PARAMETERS			
Pump Rate: 521.2 gpm		Stand Pipe Pressure :	2,558.9 psi
Bit Pressure Loss: 7.0psi		Percent Power at Bit :	0.27 %
Bit Hydraulic Power / Area(HSI): 0.0 hp/in² Bit Hydraulic Power: 2.1 hp		Bit Nozzle Velocity : Bit Impact Force :	26.9 ft/s 78.5 lbf
Total Bit Flow Area : 0.778			

3-8 Annulus Information:

This table has pressure loss and Minimum (critical) flow rates for a range of specified flow rates. You can use this table to determine the flow regime, critical pump rate, annular velocity, and pressure loss for all annular cross-sectional areas.

Table (3-6) Annulus information

Annulus Information							
Depth (m)	Hole OD (in)	Pipe OD (in)	Pressure Loss (psi)	Annulus Velocity (m/min)	Reynolds Number	Critical Pump Rate (gpm)	Flow Regime
30.00	18.395	5.000	1.1	12.42	22	4,691.9	LAMINAR
954.00	12.515	5.000	17.0	29.58	120	2,047.1	LAMINAR
2,760.00	8.835	5.000	18.9	29.58	120	2,035.8	LAMINAR
3,513.70	8.192	5.000	18.9	29.58	121	2,026.7	LAMINAR
3,654.20	8.192	5.000	4.9	29.58	121	2,024.4	LAMINAR
3,839.00	8.192	6.500	31.0	73.39	657	876.9	LAMINAR

3-9 Equivalent Circulation Density:

$$ECD\ (PPG) = MW\ (PPG) + \frac{Pa\ (psi)}{0.052 * TVD(ft)} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(3-4)}$$

Chapter four

Results and Discussion

Chapter four

Results and Discussion

After confirming all the data are correctly inputted into the software, the basic model is then finalized and ready for WELLPLAN simulation.

4-1 Well data showed in table below

Table (4-1) Fluid Rheology (Density 10.40 ppg)

FLUID RHEOLOGY							
FLUID: 8.5in Fluid #2							
RheologyModel:	Bingham Plastic						
Cement:	No			Spacer:	No	Foamed:	No
Base Type:	Water			Base Fluid:	Water		
Rheology Data							
Temperature:	160.0°F	Pressure:	14.7psi	Base Density:	10.40ppg	Ref. Fluid Properties :	Yes
Plastic Viscosity:	25.00cp			Yield Point:	32.000 lbf/100ft²		

Table (4-2) Hydraulic drag summary

HYDRAULICS DRAG CHART SUMMARY TABLE									
MD (m)	TVD (m)	Pore Pressure (psi)	Annulus Pressu (psi)	Fracture Pressu (psi)	Pore EMW (ppg)	String ECD (ppg)	Annulus ECD (ppg)	Fracture EMW (ppg)	Stand Pipe Press (psi)
2,760.00	2,759.77	5,051.1	5,090.2	7,333.4	10.74	10.95	10.82	15.59	1,833.5
2,912.40	2,912.09	5,371.3	5,480.6	7,771.3	10.82	11.17	11.04	15.66	2,006.3
3,064.80	3,064.42	5,691.5	5,792.9	8,209.2	10.90	11.22	11.09	15.72	2,100.0
3,217.20	3,216.76	6,011.8	6,084.2	8,647.1	10.97	11.23	11.10	15.77	2,171.9
3,369.60	3,369.08	6,316.2	6,375.6	9,072.4	11.00	11.23	11.10	15.80	2,245.6
3,522.00	3,521.40	6,601.8	6,666.5	9,482.6	11.00	11.24	11.11	15.80	2,317.6

Table (4-2) showing the pressures in the circulating system will be calculated at the flow rate specified on the Rate dialog using the rheological model selected on the Fluid Editor dialog. You can analyze the pressure (dynamic (ECD) and static pressures (HP) combined) at any depth from surface to TD in the work string, annulus, or the bit pressure.

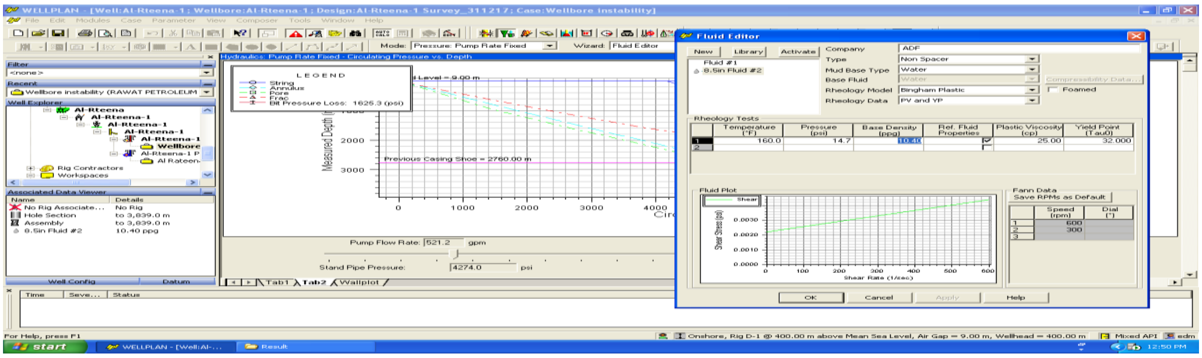

Figure (4-1) fluid editor in software at 10.4ppg

Figure (4-1) above is used in multiple Cases within the same Wellbore, any changes to the fluid will be applied in all Cases where the fluid is used.

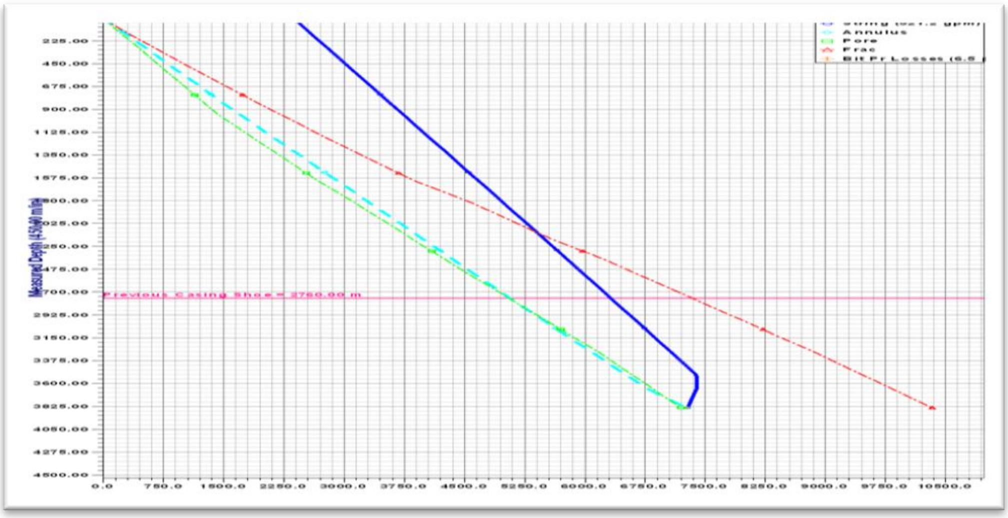

Figure (4-2) Hydrostatic pressure (HP) vs measured depth (MD)

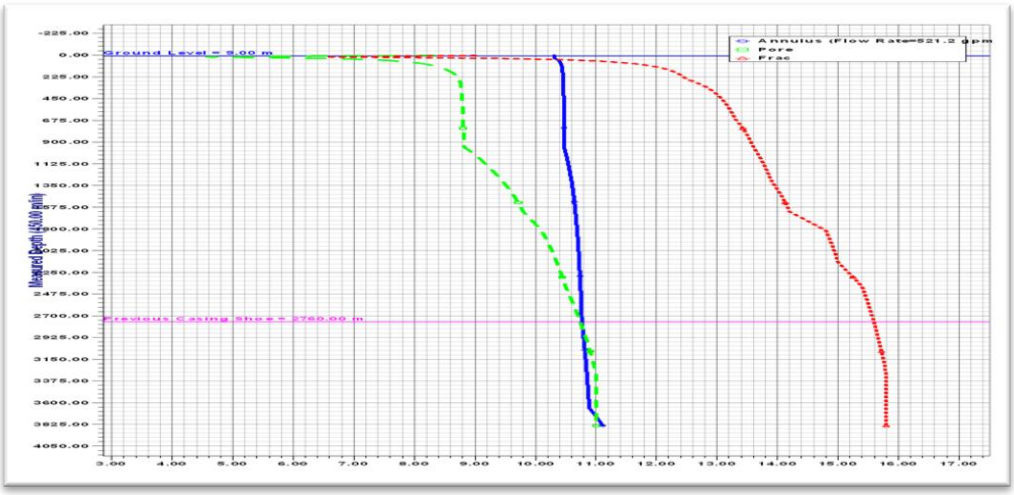

Figure (4-3) ECD vs depth

Figure (4-2) &(4-3) showing the Pressure vs Depth Plot to analyze pressure or ECD at any point in the string assuming the bottom of the string is at the total depth. While analyzing the pressure or ECD at a certain running depth, use the Circulating Pressure/ECD vs. Run Depth Chart.

- **Analyses of result:**

Simulate the instability using existing data figure above we observed that the hydrostatic pressure exceeded the pore pressure @ 2925m, which cause the caving /collapse of wellbore.

4-2 To we will take some try solving this problem scenarios by changing the mud weight we are notice that

4-2-1 Scenario one:

By increase mud weight to 10.60 ppg in the software (Fluid editor figure (4-4))

Table (4-3) Fluid Rehology (Density 10.6ppg)

FLUID RHEOLOGY							
FLUID: 8.5in Fluid #2							
Rheology Model:	Bingham Plastic						
Cement:	No	Spacer:	No	Foamed:	No		
Base Type:	Water	Base Fluid:	Water				
Rheology Data							
Temperature:	160.0°F	Pressure:	14.7psi	Base Density:	10.60ppg	Ref. Fluid Properties :	Yes
Plastic Viscosity:	25.00cp	Yield Point:	32.000 lbf/100ft²				

Table (4-4) Hydraulic summary

HYDRAULICS CHART SUMMARY TABLE									
MD (m)	TVD (m)	Pore Pressure (psi)	Annulus Pressu (psi)	Fracture Pressu (psi)	Pore EMW (ppg)	String ECD (ppg)	Annulus ECD (ppg)	Fracture EMW (ppg)	Stand Pipe Press (psi)
2,759.80	2,759.57	5,050.7	5,229.1	7,332.8	10.74	15.34	11.12	15.59	3,792.4
2,912.20	2,911.89	5,370.9	5,530.5	7,770.7	10.82	15.15	11.14	15.66	3,867.9
3,064.60	3,064.22	5,691.1	5,825.2	8,208.6	10.90	14.97	11.15	15.72	3,936.3
3,217.00	3,216.56	6,011.3	6,117.8	8,646.5	10.97	14.80	11.16	15.77	4,002.2
3,369.40	3,368.88	6,315.9	6,410.4	9,071.9	11.00	14.65	11.16	15.80	4,069.1
3,521.80	3,521.20	6,601.4	6,703.0	9,482.0	11.00	14.51	11.17	15.80	4,135.7
3,674.20	3,673.52	6,887.0	6,995.6	9,892.2	11.00	14.38	11.17	15.80	4,202.2
3,826.60	3,825.84		7,288.2			14.26	11.18		4,268.6
3,938.80	3,938.04		7,503.6			14.18	11.18		4,317.4

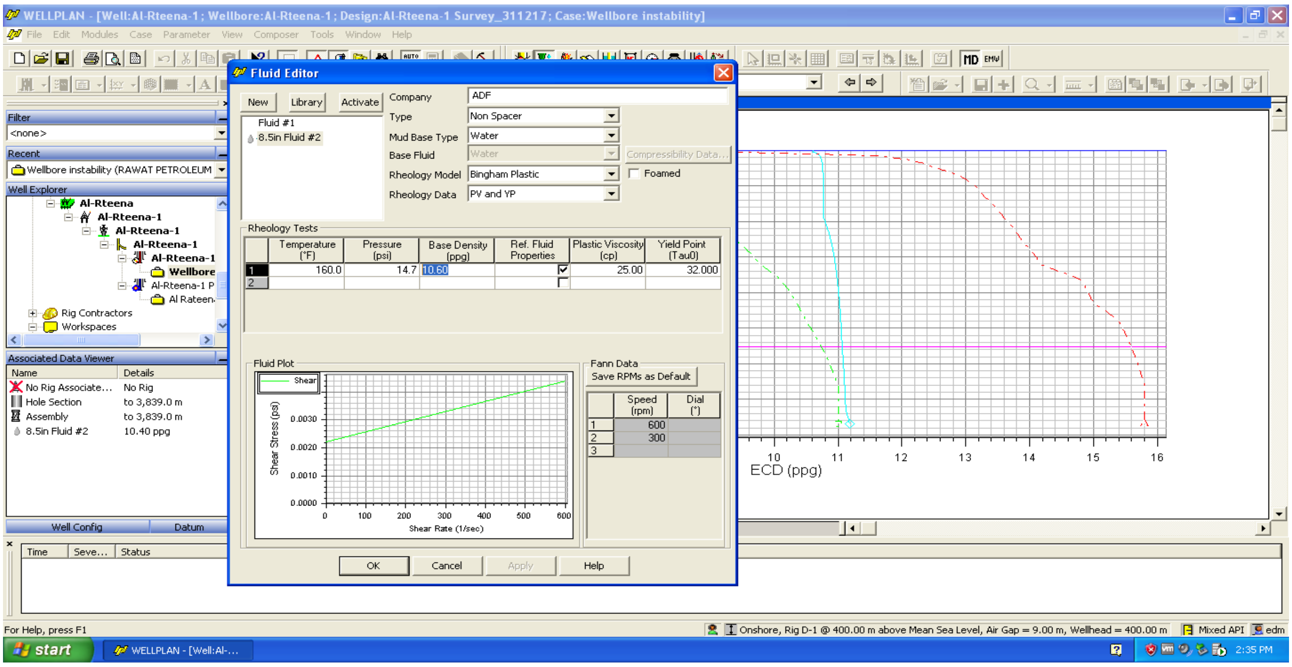

Figure (4-4) Showing fluid editor parameter in software at 10.6ppg

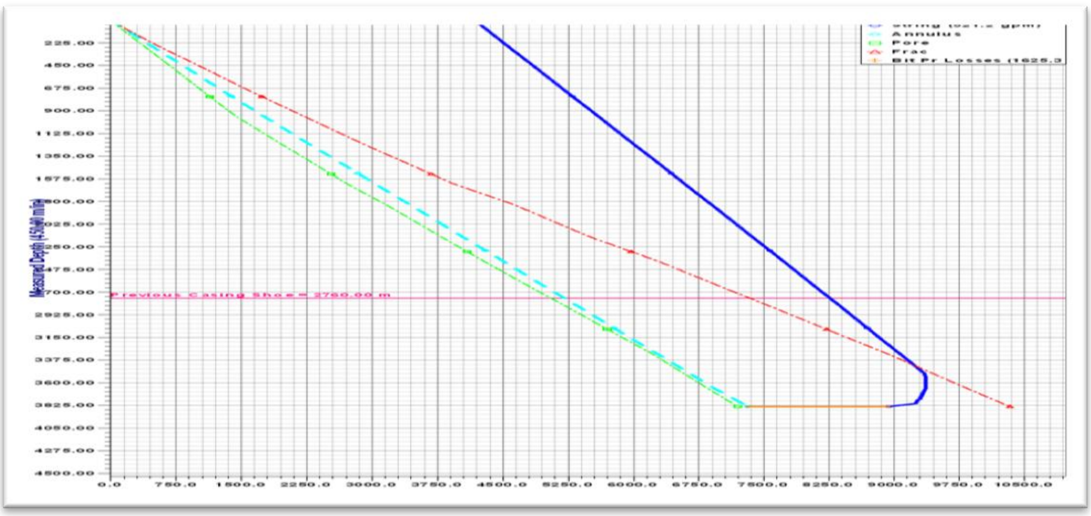

Figure (4-5) Hydrostatic pressure (HP) vs measured depth (MD)

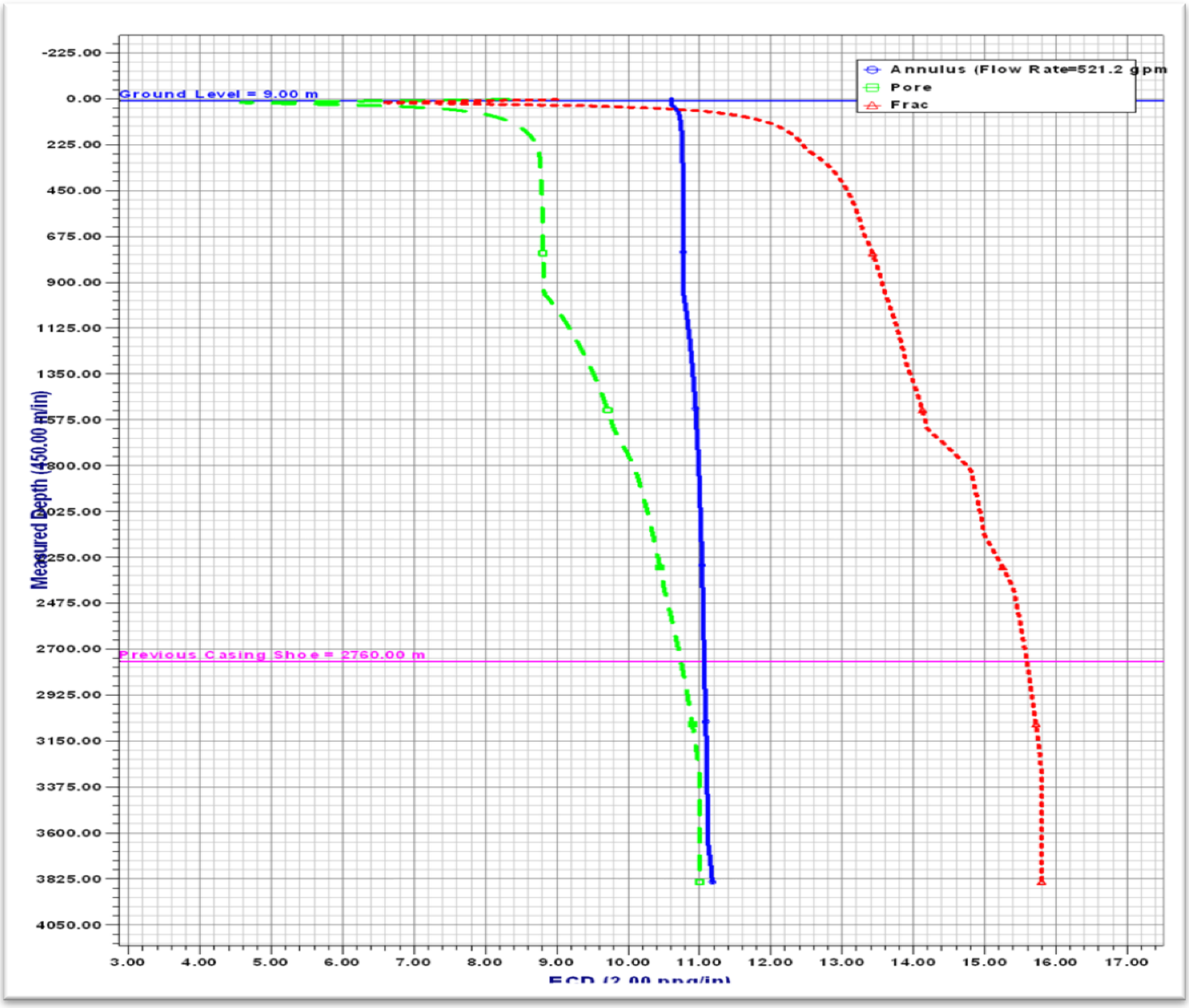

Figure (4-6) ECD vs depth

- **Analysis of result:**

After we are increasing MW to 10.6ppg notice the hydrostatic pressure curve become greater than pore pressure curve (Figure (4-5) & (4-6) but it still at critical point (so close from pore pressure @ 3150m-3839m)

4-2-2 Scenario two:

By increase MW to 10.80ppg in the software (fluid editor figure (4-4))

Table(4-5) Fluid Rheology (Density 10.80ppg)

FLUID RHEOLOGY							
FLUID: 8.5in Fluid #2							
RheologyModel:	Bingham Plastic						
Cement:	No		Spacer:	No	Foamed:	No	
Base Type:	Water		Base Fluid:	Water			
Rheology Data							
Temperature:	160.0°F	Pressure:	14.7psi	Base Density: 10.80ppg		Ref. Fluid Properties :	Yes
Plastic Viscosity:	25.00cp		Yield Point:	32.000 lbf/100ft²			

Table (4-6) Hydraulic –pressure ECD

HYDRAULICS - PRESSURE ECD									
HYDRAULICS CHART SUMMARY TABLE									
MD (m)	TVD (m)	Pore Pressure (psi)	Annulus Pressu (psi)	Fracture Pressu (psi)	Pore EMW (ppg)	String ECD (ppg)	Annulus ECD (ppg)	Fracture EMW (ppg)	Stand Pipe Press (psi)
2,760.00	2,759.77	5,051.1	5,418.5	7,333.4	10.74	11.65	11.52	15.59	1,902.1
2,912.40	2,912.09	5,371.3	5,833.8	7,771.3	10.82	11.89	11.75	15.66	2,084.1
3,064.80	3,064.42	5,691.5	6,165.6	8,209.2	10.90	11.94	11.81	15.72	2,181.3
3,217.20	3,216.76	6,011.8	6,474.9	8,647.1	10.97	11.95	11.81	15.77	2,255.4
3,369.60	3,369.08	6,316.2	6,784.3	9,072.4	11.00	11.95	11.82	15.80	2,331.3
3,522.00	3,521.40	6,601.8	7,093.3	9,482.6	11.00	11.95	11.82	15.80	2,405.6

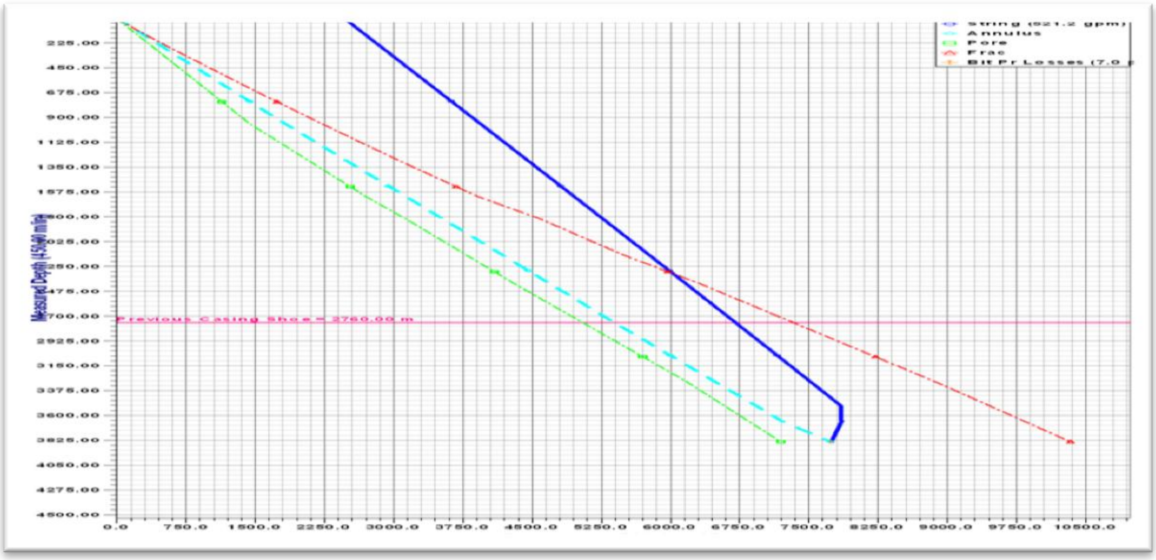

Figure (4-7) Pressure vs depth

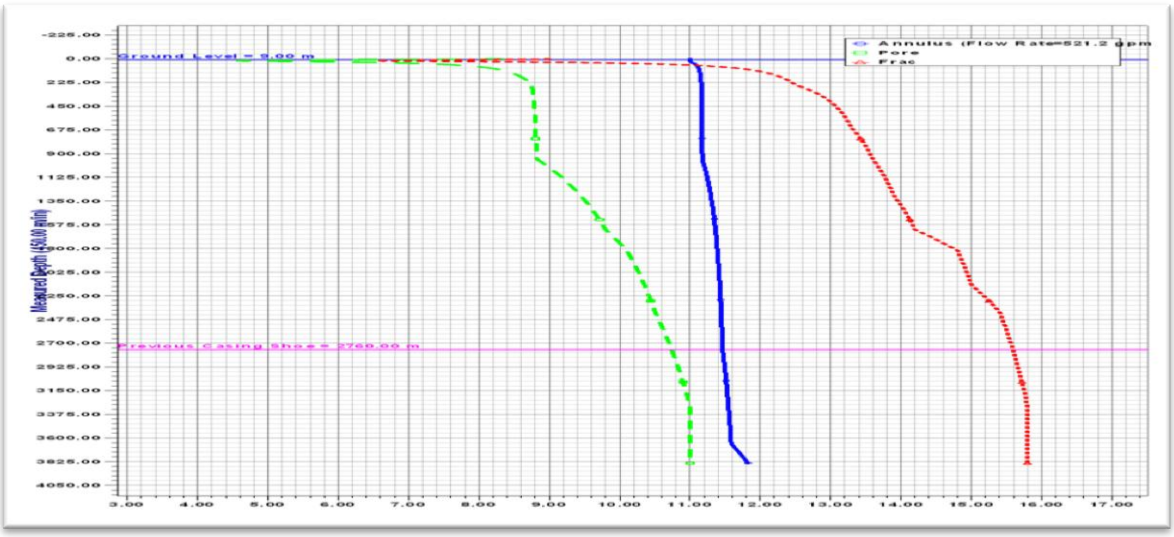

Figure (4-8) ECD vs depth

- **Analysis of result**

At mud weight 10.8ppg we can see from figure (4-7) & (4-8) that the mud window is adequate using this value .

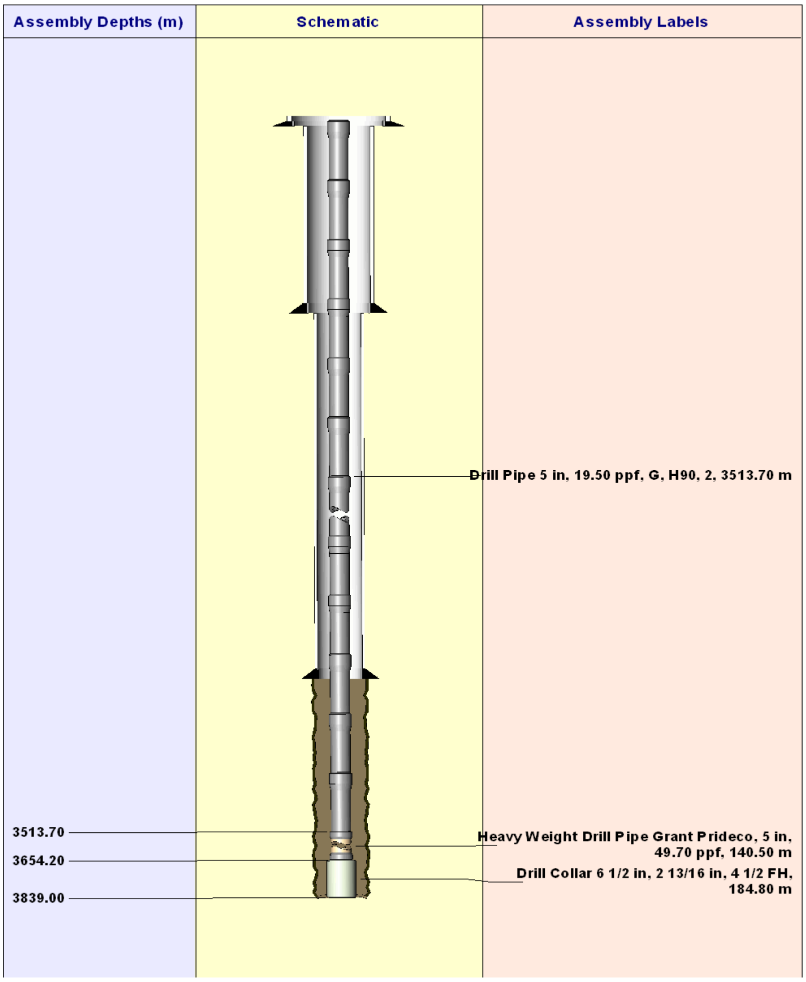

Figure (4-9) well schematic - full string

Chapter five

Conclusion and Recommendations

Chapter five

Conclusion and Recommendations

5-1 **conclusion**:

From simulation of wellbore instability using commercial software for ALRATTENA-1 filed data, we come to the following conclusion:

a. The wellbore was collapse due to insufficient mud weight.
b. When changing the mud weight to a value 10.60ppg observed that the situation is changed.
c. At mud weight 10.80ppg, the wellbore was stable, thus we strongly recommend that for such cause the mud weight should be 10.80ppg.

5-2 Recommendations:

a. The recommended minimum static mud weight was 10.80ppg with maximum ECD 11.82ppg.
b. The wellbore fluid pressure (HP) must not exceed the fracturing pressure and must be greater than the pore pressure (Po).
c. We recommended ensuring sufficient hole cleaning to effectively removing the caving that could result from pack off.
d. Should be design drilling parameters (MW, flow rate ,RPM,……etc) by using software programs.

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Appendix

HP & ECD VS DEPTH:

PRESSURE - ECD VS. DEPTH								
MD (m)	TVD (m)	Pore Pressure (psi)	String Pressure (psi)	Annulus Pressure (psi)	Fracture Pressure (psi)	Pore EMW (ppg)	Annulus ECD (ppg)	Fracture EMW (ppg)
0.00	0.00		2,458.9	0.0			11.01	
15.36	15.36	11.6	2,482.6	28.8	16.6	5.26	11.01	6.98
30.71	30.71	33.6	2,506.4	57.6	48.0	6.26	11.01	8.94
46.07	46.07	57.3	2,530.1	86.9	81.9	7.26	11.07	10.38
61.42	61.42	81.1	2,553.9	116.2	115.9	7.73	11.10	11.04
76.78	76.78	104.9	2,577.6	145.4	149.8	8.01	11.11	11.44
92.14	92.14	128.6	2,601.3	174.7	183.7	8.19	11.12	11.69
107.49	107.49	152.4	2,625.1	203.9	217.7	8.31	11.13	11.88
122.85	122.85	176.1	2,648.8	233.2	251.6	8.41	11.14	12.01
138.20	138.20	199.9	2,672.5	262.4	285.5	8.48	11.14	12.12
153.56	153.56	223.6	2,696.3	291.7	319.5	8.54	11.15	12.21
168.92	168.92	247.4	2,720.0	321.0	353.4	8.59	11.15	12.27
184.27	184.27	271.1	2,743.7	350.2	387.3	8.63	11.15	12.33
199.63	199.63	294.9	2,767.5	379.5	421.3	8.67	11.15	12.38
214.98	214.98	318.7	2,791.2	408.7	455.2	8.70	11.16	12.42
230.34	230.34	342.4	2,815.0	438.0	489.2	8.72	11.16	12.46
245.70	245.70	366.2	2,838.7	467.3	523.1	8.74	11.16	12.49
261.05	261.05	389.4	2,862.4	496.5	558.6	8.75	11.16	12.55
276.41	276.41	412.6	2,886.2	525.8	594.7	8.76	11.16	12.62
291.76	291.76	435.7	2,909.9	555.0	630.7	8.76	11.16	12.68
307.12	307.12	458.8	2,933.6	584.3	666.8	8.76	11.16	12.74
322.48	322.48	481.9	2,957.4	613.5	702.9	8.77	11.16	12.79
337.83	337.83	505.0	2,981.1	642.8	739.0	8.77	11.16	12.83
353.19	353.19	528.1	3,004.8	672.1	775.1	8.77	11.16	12.88
368.54	368.54	551.2	3,028.6	701.3	811.2	8.78	11.17	12.91
383.90	383.90	574.3	3,052.3	730.6	847.3	8.78	11.17	12.95
399.26	399.25	597.5	3,076.0	759.8	883.3	8.78	11.17	12.98
414.61	414.61	620.6	3,099.8	789.1	919.4	8.78	11.17	13.01
429.97	429.97	643.7	3,123.5	818.3	955.5	8.78	11.17	13.04
445.32	445.32	666.8	3,147.3	847.6	991.6	8.79	11.17	13.06
460.68	460.68	689.9	3,171.0	876.8	1,027.7	8.79	11.17	13.09
476.04	476.03	713.0	3,194.7	906.1	1,063.8	8.79	11.17	13.11
491.39	491.39	736.1	3,218.5	935.4	1,099.8	8.79	11.17	13.13
506.75	506.75	759.2	3,242.2	964.6	1,135.9	8.79	11.17	13.15
522.10	522.10	782.3	3,265.9	993.9	1,172.0	8.79	11.17	13.17
537.46	537.46	805.4	3,289.7	1,023.1	1,208.1	8.79	11.17	13.19
552.82	552.81	828.6	3,313.4	1,052.4	1,244.2	8.79	11.17	13.21
568.17	568.17	851.7	3,337.1	1,081.6	1,280.3	8.80	11.17	13.22
583.53	583.52	874.8	3,360.9	1,110.9	1,316.4	8.80	11.17	13.24
598.88	598.88	897.9	3,384.6	1,140.2	1,352.4	8.80	11.17	13.25
614.24	614.24	921.0	3,408.3	1,169.4	1,388.5	8.80	11.17	13.26
629.60	629.59	944.1	3,432.1	1,198.7	1,424.6	8.80	11.17	13.28
644.95	644.95	967.2	3,455.8	1,227.9	1,460.7	8.80	11.17	13.29
660.31	660.30	990.4	3,479.6	1,257.2	1,497.1	8.80	11.17	13.30
675.66	675.66	1,013.5	3,503.3	1,286.4	1,534.2	8.80	11.17	13.32

MD (m)	TVD (m)	Pore Pressure (psi)	String Pressure (psi)	Annulus Pressure (psi)	Fracture Pressure (psi)	Pore EMW (ppg)	Annulus ECD (ppg)	Fracture EMW (ppg)
691.02	691.01	1,036.7	3,527.0	1,315.7	1,571.5	8.80	11.17	13.34
706.38	706.37	1,059.9	3,550.8	1,344.9	1,608.9	8.80	11.17	13.36
721.73	721.73	1,083.1	3,574.5	1,374.2	1,646.2	8.81	11.17	13.38
737.09	737.08	1,106.3	3,598.2	1,403.4	1,683.6	8.81	11.17	13.40
752.44	752.44	1,129.5	3,622.0	1,432.7	1,720.9	8.81	11.17	13.42
767.80	767.79	1,152.7	3,645.7	1,461.9	1,758.3	8.81	11.17	13.44
783.16	783.15	1,175.9	3,669.5	1,491.2	1,795.6	8.81	11.17	13.45
798.51	798.50	1,199.1	3,693.2	1,520.5	1,833.0	8.81	11.17	13.47
813.87	813.86	1,222.3	3,716.9	1,549.7	1,870.3	8.81	11.17	13.48
829.22	829.21	1,245.5	3,740.7	1,579.0	1,907.7	8.81	11.17	13.50
844.58	844.57	1,268.7	3,764.4	1,608.2	1,945.1	8.81	11.17	13.51
859.94	859.92	1,291.9	3,788.1	1,637.5	1,982.4	8.82	11.17	13.53
875.29	875.28	1,315.1	3,811.9	1,666.7	2,019.8	8.82	11.17	13.54
890.65	890.64	1,338.3	3,835.6	1,696.0	2,057.1	8.82	11.17	13.55
906.00	905.99	1,361.5	3,859.3	1,725.2	2,094.5	8.82	11.17	13.56
921.36	921.35	1,384.7	3,883.0	1,754.5	2,131.8	8.82	11.17	13.58
936.72	936.70	1,407.9	3,906.7	1,783.7	2,169.2	8.82	11.17	13.59
952.07	952.06	1,432.1	3,930.5	1,813.0	2,206.7	8.83	11.17	13.60
967.43	967.41	1,459.6	3,954.2	1,843.3	2,244.9	8.85	11.18	13.62
982.78	982.77	1,488.8	3,977.9	1,873.7	2,283.5	8.89	11.19	13.63
998.14	998.12	1,518.0	4,001.6	1,904.2	2,322.0	8.92	11.19	13.65
1,013.50	1,013.48	1,547.2	4,025.3	1,934.6	2,360.6	8.96	11.20	13.67
1,028.85	1,028.83	1,576.4	4,049.0	1,965.1	2,399.1	8.99	11.21	13.68
1,044.21	1,044.19	1,605.6	4,072.8	1,995.6	2,437.6	9.02	11.21	13.70
1,059.56	1,059.54	1,634.8	4,096.5	2,026.0	2,476.2	9.05	11.22	13.71
1,074.92	1,074.90	1,664.1	4,120.2	2,056.5	2,514.7	9.08	11.23	13.73
1,090.28	1,090.25	1,693.3	4,143.9	2,086.9	2,553.3	9.11	11.23	13.74
1,105.63	1,105.61	1,722.5	4,167.6	2,117.4	2,591.8	9.14	11.24	13.75
1,120.99	1,120.96	1,751.7	4,191.3	2,147.8	2,630.3	9.17	11.24	13.77
1,136.34	1,136.32	1,780.9	4,215.0	2,178.3	2,668.9	9.20	11.25	13.78
1,151.70	1,151.67	1,810.1	4,238.8	2,208.7	2,707.4	9.22	11.25	13.79
1,167.06	1,167.03	1,839.3	4,262.5	2,239.2	2,746.0	9.25	11.26	13.81
1,182.41	1,182.38	1,868.5	4,286.2	2,269.6	2,784.5	9.27	11.26	13.82
1,197.77	1,197.74	1,897.8	4,309.9	2,300.1	2,823.0	9.30	11.27	13.83
1,213.12	1,213.09	1,927.1	4,333.5	2,330.5	2,861.6	9.32	11.27	13.84
1,228.48	1,228.45	1,956.4	4,357.2	2,360.9	2,900.1	9.34	11.28	13.85
1,243.84	1,243.80	1,985.8	4,380.9	2,391.3	2,938.7	9.37	11.28	13.86
1,259.19	1,259.16	2,015.2	4,404.6	2,421.8	2,977.2	9.39	11.28	13.87
1,274.55	1,274.51	2,044.5	4,428.3	2,452.2	3,015.7	9.41	11.29	13.88
1,289.90	1,289.86	2,073.9	4,451.9	2,482.6	3,054.3	9.43	11.29	13.89
1,305.26	1,305.22	2,103.3	4,475.6	2,513.1	3,093.6	9.45	11.30	13.91
1,320.62	1,320.57	2,132.6	4,499.3	2,543.5	3,133.8	9.48	11.30	13.92
1,335.97	1,335.93	2,162.0	4,523.0	2,573.9	3,174.1	9.50	11.30	13.94
1,351.33	1,351.28	2,191.4	4,546.7	2,604.4	3,214.4	9.52	11.31	13.96
1,366.68	1,366.64	2,220.7	4,570.3	2,634.8	3,254.8	9.53	11.31	13.97
1,382.04	1,381.99	2,250.1	4,594.0	2,665.2	3,295.1	9.55	11.32	13.99
1,397.40	1,397.35	2,279.5	4,617.7	2,695.6	3,335.4	9.57	11.32	14.01
1,412.75	1,412.70	2,308.8	4,641.4	2,726.1	3,375.7	9.59	11.32	14.02
1,428.11	1,428.05	2,338.2	4,665.1	2,756.5	3,416.1	9.61	11.33	14.04
1,443.46	1,443.41	2,367.6	4,688.7	2,786.9	3,456.4	9.62	11.33	14.05
1,458.82	1,458.76	2,396.9	4,712.4	2,817.4	3,496.7	9.64	11.33	14.06
1,474.18	1,474.12	2,426.3	4,736.1	2,847.8	3,537.1	9.66	11.33	14.08
1,489.53	1,489.47	2,455.7	4,759.7	2,878.2	3,577.4	9.67	11.34	14.09
1,504.89	1,504.82	2,485.0	4,783.3	2,908.6	3,617.7	9.69	11.34	14.11

1,520.24	1,520.18	2,514.4	4,807.0	2,939.0	3,658.0	9.70	11.34	14.12
1,535.60	1,535.53	2,543.8	4,830.6	2,969.4	3,698.4	9.72	11.35	14.13
1,550.96	1,550.89	2,573.1	4,854.3	2,999.8	3,738.7	9.73	11.35	14.14
1,566.31	1,566.24	2,602.5	4,877.9	3,030.3	3,779.0	9.75	11.35	14.16
1,581.67	1,581.59	2,631.9	4,901.5	3,060.7	3,819.4	9.76	11.35	14.17
1,597.02	1,596.95	2,661.2	4,925.2	3,091.1	3,859.7	9.78	11.36	14.18
1,612.38	1,612.30	2,690.6	4,948.8	3,121.5	3,900.0	9.79	11.36	14.19
1,627.74	1,627.66	2,721.5	4,972.4	3,151.9	3,945.2	9.81	11.36	14.22
1,643.09	1,643.01	2,754.2	4,996.1	3,182.3	3,996.2	9.84	11.36	14.27
1,658.45	1,658.37	2,787.0	5,019.7	3,212.7	4,047.8	9.86	11.37	14.32
1,673.80	1,673.72	2,819.9	5,043.4	3,243.1	4,099.5	9.89	11.37	14.37
1,689.16	1,689.07	2,852.8	5,067.0	3,273.5	4,151.1	9.91	11.37	14.42
1,704.51	1,704.43	2,885.7	5,090.6	3,304.0	4,202.8	9.93	11.37	14.47
1,719.87	1,719.78	2,918.6	5,114.3	3,334.4	4,254.5	9.96	11.38	14.51
1,735.23	1,735.14	2,951.5	5,137.9	3,364.8	4,306.1	9.98	11.38	14.56
1,750.58	1,750.49	2,984.4	5,161.6	3,395.2	4,357.8	10.00	11.38	14.61
1,765.94	1,765.85	3,017.3	5,185.2	3,425.6	4,409.4	10.03	11.38	14.65
1,781.29	1,781.20	3,050.2	5,208.7	3,456.0	4,461.1	10.05	11.38	14.70
1,796.65	1,796.55	3,083.1	5,232.3	3,486.4	4,512.7	10.07	11.39	14.74
1,812.01	1,811.91	3,115.9	5,255.9	3,516.8	4,564.0	10.09	11.39	14.78
1,827.36	1,827.26	3,147.7	5,279.5	3,547.2	4,611.0	10.11	11.39	14.81
1,842.72	1,842.62	3,178.5	5,303.1	3,577.6	4,653.1	10.12	11.39	14.82
1,858.07	1,857.97	3,209.2	5,326.6	3,608.0	4,695.3	10.13	11.39	14.83
1,873.43	1,873.33	3,240.0	5,350.2	3,638.4	4,737.5	10.15	11.40	14.84
1,888.79	1,888.68	3,270.7	5,373.8	3,668.8	4,779.7	10.16	11.40	14.85
1,904.14	1,904.04	3,301.5	5,397.4	3,699.2	4,821.9	10.17	11.40	14.86
1,919.50	1,919.39	3,332.3	5,421.0	3,729.6	4,864.1	10.19	11.40	14.87
1,934.85	1,934.74	3,363.0	5,444.6	3,760.0	4,906.2	10.20	11.40	14.88
1,950.21	1,950.10	3,393.8	5,468.1	3,790.3	4,948.4	10.21	11.40	14.89
1,965.57	1,965.45	3,424.5	5,491.7	3,820.7	4,990.6	10.22	11.41	14.90
1,980.92	1,980.81	3,455.3	5,515.3	3,851.1	5,032.8	10.23	11.41	14.91
1,996.28	1,996.16	3,486.0	5,538.9	3,881.5	5,075.0	10.25	11.41	14.92
2,011.63	2,011.52	3,516.8	5,562.5	3,911.9	5,117.2	10.26	11.41	14.93
2,026.99	2,026.87	3,547.5	5,586.0	3,942.3	5,159.3	10.27	11.41	14.94
2,042.35	2,042.23	3,578.3	5,609.6	3,972.7	5,201.5	10.28	11.41	14.94
2,057.70	2,057.58	3,609.1	5,633.2	4,003.1	5,243.7	10.29	11.42	14.95
2,073.06	2,072.93	3,639.8	5,656.7	4,033.5	5,285.9	10.30	11.42	14.96
2,088.41	2,088.29	3,670.6	5,680.2	4,063.9	5,328.1	10.31	11.42	14.97
2,103.77	2,103.64	3,701.3	5,703.7	4,094.3	5,370.3	10.32	11.42	14.98
2,119.13	2,119.00	3,732.1	5,727.2	4,124.7	5,412.4	10.33	11.42	14.99
2,134.48	2,134.35	3,762.8	5,750.7	4,155.0	5,454.6	10.34	11.42	14.99
2,149.84	2,149.71	3,793.6	5,774.3	4,185.4	5,499.4	10.35	11.42	15.01
2,165.19	2,165.06	3,824.3	5,797.8	4,215.8	5,548.4	10.36	11.43	15.04
2,180.55	2,180.41	3,855.1	5,821.3	4,246.2	5,597.5	10.37	11.43	15.06
2,195.90	2,195.77	3,885.8	5,844.8	4,276.6	5,646.6	10.38	11.43	15.09
2,211.26	2,211.12	3,916.6	5,868.3	4,307.0	5,695.6	10.39	11.43	15.11
2,226.62	2,226.48	3,947.3	5,891.8	4,337.4	5,744.7	10.40	11.43	15.14
2,241.97	2,241.83	3,978.1	5,915.3	4,367.7	5,793.8	10.41	11.43	15.16
2,257.33	2,257.19	4,008.9	5,938.8	4,398.1	5,842.8	10.42	11.43	15.19
2,272.68	2,272.54	4,039.6	5,962.4	4,428.5	5,891.9	10.43	11.43	15.21
2,288.04	2,287.89	4,070.4	5,985.9	4,458.9	5,941.0	10.44	11.44	15.24
2,303.40	2,303.25	4,101.1	6,009.4	4,489.3	5,990.0	10.45	11.44	15.26
2,318.75	2,318.60	4,131.9	6,032.9	4,519.7	6,039.1	10.46	11.44	15.28
2,334.11	2,333.96	4,162.6	6,056.4	4,550.1	6,088.2	10.46	11.44	15.31

MD (m)	TVD (m)	Pore Pressure (psi)	String Pressure (psi)	Annulus Pressure (psi)	Fracture Pressure (psi)	Pore EMW (ppg)	Annulus ECD (ppg)	Fracture EMW (ppg)
2,349.46	2,349.31	4,193.4	6,079.9	4,580.4	6,137.2	10.47	11.44	15.33
2,364.82	2,364.66	4,224.1	6,103.3	4,610.8	6,186.3	10.48	11.44	15.35
2,380.18	2,380.02	4,254.9	6,126.8	4,641.2	6,235.3	10.49	11.44	15.37
2,395.53	2,395.37	4,285.8	6,150.2	4,671.6	6,283.8	10.50	11.44	15.39
2,410.89	2,410.72	4,317.5	6,173.7	4,701.9	6,330.0	10.51	11.44	15.41
2,426.24	2,426.08	4,349.7	6,197.1	4,732.3	6,374.2	10.52	11.44	15.42
2,441.60	2,441.43	4,382.0	6,220.6	4,762.7	6,418.3	10.53	11.45	15.42
2,456.96	2,456.79	4,414.3	6,244.0	4,793.1	6,462.4	10.54	11.45	15.43
2,472.31	2,472.14	4,446.6	6,267.5	4,823.4	6,506.6	10.55	11.45	15.44
2,487.67	2,487.49	4,478.8	6,290.9	4,853.8	6,550.7	10.56	11.45	15.45
2,503.02	2,502.85	4,511.1	6,314.4	4,884.2	6,594.9	10.58	11.45	15.46
2,518.38	2,518.20	4,543.4	6,337.8	4,914.6	6,639.0	10.59	11.45	15.47
2,533.74	2,533.56	4,575.7	6,361.3	4,944.9	6,683.1	10.60	11.45	15.48
2,549.09	2,548.91	4,607.9	6,384.7	4,975.3	6,727.3	10.61	11.45	15.49
2,564.45	2,564.27	4,640.2	6,408.1	5,005.7	6,771.4	10.62	11.45	15.49
2,579.80	2,579.62	4,672.5	6,431.6	5,036.1	6,815.5	10.63	11.45	15.50
2,595.16	2,594.97	4,704.7	6,455.0	5,066.4	6,859.7	10.64	11.46	15.51
2,610.52	2,610.32	4,737.0	6,478.5	5,096.8	6,903.8	10.65	11.46	15.52
2,625.87	2,625.68	4,769.3	6,501.9	5,127.2	6,947.9	10.66	11.46	15.53
2,641.23	2,641.03	4,801.6	6,525.3	5,157.6	6,992.1	10.67	11.46	15.53
2,656.58	2,656.38	4,833.8	6,548.7	5,187.9	7,036.2	10.68	11.46	15.54
2,671.94	2,671.73	4,866.1	6,572.1	5,218.3	7,080.3	10.69	11.46	15.55
2,687.30	2,687.09	4,898.4	6,595.4	5,248.7	7,124.5	10.70	11.46	15.56
2,702.65	2,702.44	4,930.6	6,618.8	5,279.0	7,168.6	10.71	11.46	15.56
2,718.01	2,717.79	4,962.9	6,642.1	5,309.4	7,212.7	10.71	11.46	15.57
2,733.36	2,733.14	4,995.2	6,665.5	5,339.8	7,256.9	10.72	11.46	15.58
2,748.72	2,748.49	5,027.4	6,688.8	5,370.1	7,301.0	10.73	11.46	15.59
2,764.08	2,763.84	5,059.7	6,712.2	5,400.8	7,345.1	10.74	11.47	15.59
2,779.43	2,779.19	5,092.0	6,735.6	5,432.1	7,389.3	10.75	11.47	15.60
2,794.79	2,794.54	5,124.2	6,758.9	5,463.4	7,433.4	10.76	11.47	15.61
2,810.15	2,809.89	5,156.5	6,782.3	5,494.7	7,477.5	10.77	11.47	15.61
2,825.50	2,825.24	5,188.8	6,805.6	5,526.0	7,521.6	10.78	11.48	15.62
2,840.86	2,840.59	5,221.0	6,829.0	5,557.2	7,565.7	10.78	11.48	15.63
2,856.21	2,855.94	5,253.3	6,852.3	5,588.5	7,609.9	10.79	11.48	15.63
2,871.57	2,871.28	5,285.6	6,875.7	5,619.8	7,654.0	10.80	11.48	15.64
2,886.93	2,886.63	5,317.8	6,899.0	5,651.1	7,698.1	10.81	11.49	15.65
2,902.28	2,901.98	5,350.1	6,922.4	5,682.4	7,742.2	10.82	11.49	15.65
2,917.64	2,917.33	5,382.3	6,945.7	5,713.7	7,786.3	10.83	11.49	15.66
2,932.99	2,932.68	5,414.6	6,969.0	5,745.0	7,830.5	10.83	11.49	15.67
2,948.35	2,948.02	5,446.9	6,992.3	5,776.3	7,874.6	10.84	11.50	15.67
2,963.71	2,963.37	5,479.1	7,015.6	5,807.6	7,918.7	10.85	11.50	15.68
2,979.06	2,978.72	5,511.4	7,038.9	5,838.9	7,962.8	10.86	11.50	15.68
2,994.42	2,994.06	5,543.6	7,062.1	5,870.2	8,006.9	10.86	11.50	15.69
3,009.77	3,009.41	5,575.9	7,085.4	5,901.4	8,051.0	10.87	11.51	15.70
3,025.13	3,024.76	5,608.2	7,108.7	5,932.7	8,095.2	10.88	11.51	15.70
3,040.49	3,040.11	5,640.4	7,132.0	5,964.0	8,139.3	10.89	11.51	15.71
3,055.84	3,055.46	5,672.7	7,155.2	5,995.3	8,183.4	10.89	11.51	15.71
3,071.20	3,070.82	5,705.0	7,178.5	6,026.6	8,227.6	10.90	11.52	15.72
3,086.55	3,086.17	5,737.2	7,201.8	6,057.9	8,271.7	10.91	11.52	15.73
3,101.91	3,101.52	5,769.5	7,225.1	6,089.2	8,315.8	10.91	11.52	15.73
3,117.27	3,116.87	5,801.8	7,248.4	6,120.5	8,359.9	10.92	11.52	15.74
3,132.62	3,132.22	5,834.0	7,271.7	6,151.8	8,404.1	10.93	11.52	15.74
3,147.98	3,147.57	5,866.3	7,294.9	6,183.1	8,448.2	10.94	11.53	15.75
3,163.34	3,162.92	5,898.6	7,318.2	6,214.3	8,492.3	10.94	11.53	15.75

PRESSURE - ECD VS. DEPTH								
MD (m)	TVD (m)	Pore Pressure (psi)	String Pressure (psi)	Annulus Pressure (psi)	Fracture Pressure (psi)	Pore EMW (ppg)	Annulus ECD (ppg)	Fracture EMW (ppg)
3,178.69	3,178.27	5,930.8	7,341.5	6,245.6	8,536.4	10.95	11.53	15.76
3,194.05	3,193.62	5,963.1	7,364.8	6,276.9	8,580.6	10.96	11.53	15.76
3,209.40	3,208.97	5,995.4	7,388.0	6,308.2	8,624.7	10.96	11.53	15.77
3,224.76	3,224.32	6,027.6	7,411.3	6,339.5	8,668.8	10.97	11.54	15.77
3,240.12	3,239.67	6,059.9	7,434.5	6,370.8	8,712.9	10.98	11.54	15.78
3,255.47	3,255.02	6,092.2	7,457.7	6,402.1	8,757.1	10.98	11.54	15.79
3,270.83	3,270.36	6,124.4	7,481.0	6,433.4	8,801.2	10.99	11.54	15.79
3,286.18	3,285.71	6,156.7	7,504.2	6,464.6	8,845.3	10.99	11.54	15.80
3,301.54	3,301.06	6,188.6	7,527.4	6,495.9	8,889.1	11.00	11.55	15.80
3,316.90	3,316.41	6,217.5	7,550.6	6,527.2	8,930.6	11.00	11.55	15.80
3,332.25	3,331.75	6,246.3	7,573.8	6,558.5	8,971.9	11.00	11.55	15.80
3,347.61	3,347.10	6,275.0	7,597.1	6,589.8	9,013.2	11.00	11.55	15.80
3,362.96	3,362.45	6,303.8	7,620.3	6,621.1	9,054.5	11.00	11.55	15.80
3,378.32	3,377.80	6,332.6	7,643.5	6,652.3	9,095.9	11.00	11.56	15.80
3,393.68	3,393.15	6,361.4	7,666.7	6,683.6	9,137.2	11.00	11.56	15.80
3,409.03	3,408.50	6,390.1	7,689.9	6,714.9	9,178.6	11.00	11.56	15.80
3,424.39	3,423.85	6,418.9	7,713.2	6,746.2	9,219.9	11.00	11.56	15.80
3,439.74	3,439.20	6,447.7	7,736.4	6,777.5	9,261.2	11.00	11.56	15.80
3,455.10	3,454.55	6,476.5	7,759.6	6,808.8	9,302.6	11.00	11.56	15.80
3,470.46	3,469.89	6,505.2	7,782.8	6,840.1	9,343.9	11.00	11.57	15.80
3,485.81	3,485.24	6,534.0	7,806.0	6,871.3	9,385.2	11.00	11.57	15.80
3,501.17	3,500.58	6,562.8	7,829.2	6,902.6	9,426.5	11.00	11.57	15.80
3,516.53	3,515.93	6,591.5	7,848.3	6,933.9	9,467.8	11.00	11.57	15.80
3,531.88	3,531.27	6,620.3	7,849.1	6,965.2	9,509.2	11.00	11.57	15.80
3,547.24	3,546.62	6,649.1	7,849.8	6,996.4	9,550.5	11.00	11.57	15.80
3,562.59	3,561.97	6,677.8	7,850.6	7,027.7	9,591.8	11.00	11.58	15.80
3,577.95	3,577.32	6,706.6	7,851.3	7,059.0	9,633.1	11.00	11.58	15.80
3,593.31	3,592.67	6,735.4	7,852.0	7,090.3	9,674.5	11.00	11.58	15.80
3,608.66	3,608.02	6,764.2	7,852.6	7,121.6	9,715.8	11.00	11.58	15.80
3,624.02	3,623.37	6,793.0	7,853.3	7,152.9	9,757.2	11.00	11.58	15.80
3,639.37	3,638.71	6,821.7	7,853.9	7,184.2	9,798.5	11.00	11.58	15.80
3,654.73	3,654.06	6,850.5	7,854.2	7,215.9	9,839.8	11.00	11.59	15.80
3,670.09	3,669.41	6,879.3	7,844.9	7,259.2	9,881.1	11.00	11.61	15.80
3,685.44	3,684.75	6,908.0	7,835.6	7,302.5	9,922.5	11.00	11.63	15.80
3,700.80	3,700.10	6,936.8	7,826.3	7,345.8	9,963.8	11.00	11.65	15.80
3,716.15	3,715.44	6,965.6	7,817.0	7,389.1	10,005.1	11.00	11.67	15.80
3,731.51	3,730.78	6,994.3	7,807.7	7,432.4	10,046.4	11.00	11.69	15.80
3,746.87	3,746.12	7,023.1	7,798.4	7,475.7	10,087.7	11.00	11.71	15.80
3,762.22	3,761.47	7,051.9	7,789.1	7,519.0	10,129.1	11.00	11.73	15.80
3,777.58	3,776.83	7,080.7	7,779.8	7,562.4	10,170.4	11.00	11.75	15.80
3,792.93	3,792.18	7,109.4	7,770.5	7,605.7	10,211.7	11.00	11.77	15.80
3,808.29	3,807.54	7,138.2	7,761.2	7,649.0	10,253.1	11.00	11.79	15.80
3,839.00	3,838.24		7,742.7	7,735.7			11.83	

ALRATTENA -1 Survey:

WELLPATH - Calculation Method: Minimum Curvature						
MD (m)	Inclination (°)	Azimuth (°)	TVD (m)	Build (°/100ft)	Walk (°/100ft)	DLS (°/100ft)
0.00	0.00	0.00	0.00	0.00	0.00	0.00
1,487.00	0.90	277.52	1,486.94	0.02	0.00	0.02
2,005.00	0.80	302.82	2,004.88	-0.01	1.49	0.02
2,462.00	1.00	332.42	2,461.83	0.01	1.97	0.03
2,489.00	0.90	319.12	2,488.83	-0.11	-15.01	0.27
2,517.00	0.90	223.92	2,516.82	0.00	-103.63	1.45
2,546.00	1.10	319.52	2,545.82	0.21	100.48	1.56
2,785.00	1.50	323.62	2,784.76	0.05	0.52	0.05
2,812.00	1.80	325.82	2,811.75	0.34	2.48	0.35
2,841.00	2.00	330.72	2,840.73	0.21	5.15	0.27
2,869.00	2.10	333.52	2,868.71	0.11	3.05	0.15
2,898.00	1.70	341.62	2,897.70	-0.42	8.51	0.51
2,926.00	1.70	342.62	2,925.69	0.00	1.09	0.03
2,955.00	2.00	334.62	2,954.67	0.32	-8.41	0.42
2,984.00	2.20	332.22	2,983.65	0.21	-2.52	0.23
3,014.00	1.60	340.12	3,013.63	-0.61	8.03	0.66
3,042.00	1.40	343.12	3,041.62	-0.22	3.27	0.23
3,072.00	1.30	347.82	3,071.62	-0.10	4.78	0.15
3,099.00	1.40	351.52	3,098.61	0.11	4.18	0.15
3,129.00	1.50	345.22	3,128.60	0.10	-6.40	0.19
3,158.00	1.80	347.02	3,157.59	0.32	1.89	0.32
3,186.00	1.70	0.82	3,185.57	-0.11	15.02	0.47
3,213.00	1.70	2.52	3,212.56	0.00	1.92	0.06
3,243.00	1.70	3.72	3,242.55	0.00	1.22	0.04
3,273.00	1.80	5.92	3,272.54	0.10	2.24	0.12
3,302.00	1.90	7.82	3,301.52	0.11	2.00	0.12
3,329.00	2.00	2.32	3,328.50	0.11	-6.21	0.24
3,359.00	1.80	353.72	3,358.49	-0.20	-8.74	0.35
3,386.00	1.70	342.62	3,385.48	-0.11	-12.53	0.40
3,416.00	1.50	316.42	3,415.46	-0.20	-26.62	0.76
3,445.00	1.80	312.22	3,444.45	0.32	-4.41	0.34
3,465.00	2.00	311.82	3,464.44	0.30	-0.61	0.31
3,474.00	2.10	315.72	3,473.44	0.34	13.21	0.58
3,503.00	2.40	320.72	3,502.41	0.32	5.26	0.38
3,531.00	2.10	320.02	3,530.39	-0.33	-0.76	0.33
3,560.00	1.80	325.52	3,559.37	-0.32	5.78	0.37
3,587.00	1.50	325.72	3,586.36	-0.34	0.23	0.34
3,616.00	1.70	319.12	3,615.35	0.21	-6.94	0.29
3,644.00	1.80	313.90	3,643.34	0.11	-5.68	0.20
3,674.00	2.20	316.12	3,673.32	0.41	2.26	0.41
3,704.00	2.60	321.92	3,703.29	0.41	5.89	0.47
3,732.00	2.40	322.62	3,731.27	-0.22	0.76	0.22
3,760.00	1.40	318.52	3,759.25	-1.09	-4.46	1.10
3,790.00	0.80	302.52	3,789.25	-0.61	-16.26	0.68
3,819.00	0.40	293.42	3,818.24	-0.42	-9.56	0.43

	ADF	MUD REPORT Water-based	Report No.	120
			Date	17/03/2018
			Time	23:00
	Address	Khartoum-Sudan	MD (m)	3839
	E-mail	Phone	TVD (m)	3839
	Engineer	Cell	Inc (deg)	0.40
	E-mail	Office	Azi (deg)	293.42

Spud date	18/11/2017	API well No.		Rig	NUS D-1	Activity	POOH
Operator	RPOC	Contractor	NUS	Stock point	Rawat		
Report for		Report for		Phone			

Well name/No.	Field/Block	Section-Township-Range	County/Parish/Offshore area	State/Province	Country
Alteena	Rawat			White Nile	Sudan

DRILLSTRING / CASED/OPEN HOLE / BIT

Description	OD (in)	ID (in)	Length (m)	Description	OD (in)	Top (m)	Shoe (m)	BIT	
								Mfr.	AZICO
DP	5.000	4.250	3513.6	Conductor casing	20.000	0.0	30.0	Bit type	PDC BIT
HWDP	5.000	3.000	140.5	Surface Casing	13.375	0.0	954.0	Bit No.	11
DC	6.500	2.800	9.3	Intermediate Casing	9.625	0.0	2760.0	Size (in)	8.500
JAR	6.500	2.800	5.5					Depth (m)	3839.0
DC	6.500	2.800	130.8	Description	ID (in)	MD (m)	Washout	TFA (in2)	0.778
STB	8.375	2.800	1.7	Main Hole	8.500	3839.0	10.00	Nozzle (1/32in)	
BDM	6.750	2.800	18.7					13/13/13/13/13/13	
DC	6.500	2.800	18.8						

DRILLING INFO / VOLUME (bbl) / SOLIDS CONTROL EQUIPMENT

DRILLING INFO		VOLUME (bbl)			Screen size	Time (hr)		U/F (ppg)	O/F (ppg)	Time (hr)
WOB (ton)	8.000	Hole	987							
Rot. wt. (ton)		Annulus	671	Shaker 1	120*120*120	8.25	De-sander			0.00
S/O wt. (ton)		String	211	Shaker 2	120*120*120	8.25	De-silter			8.25
P/U wt. (ton)		Pits	909	Shaker 3	120*120*120	8.25	Centrifuge	10.20	9.90	3
RPM (rpm)	195.0	Storage	30	Shaker 4	120*120*120		Barite rec.			
ROP (m/hr)	7.0	Total	1821	Mud cleaner	120/230/140	8.25	Centrifuge	10.20	10.00	
		Below bit	0							

PUMP / CIRCULATION / FANN

Pump #	1	2	3	4		Path	Minutes	Strokes	FANN	
Liner ID (in)	6.693	6.693				Surf. - bit	17.00	1700	600	82
Rod OD (in)					Total (gpm)	Btm up	54.06	5406	300	57
Stk length (in)	12.000	12.000			521.2	Surf. - surf.	71.05	7105	200	45
Eff. (%)	95.00	95.00			Pump P. (psi)	Pits	73.25	7325	100	33
(stk/min)	50.00	50.00			2729	Total circ.	144.30	14430	60	
(bbl/stk)	0.1241	0.1241							30	
(gpm)	260.6	260.6							6	10
									3	8

MUD PROPERTY

Property	Sample 1	Sample 2*	Sample 3	Sample 4
Sample from	Suction	Suction		
Time sample taken	10:00	23:00		
Flowline temp. (F)	160	160		
Depth (m)	3839.0	3839.0		
MW (ppg)	10.40	10.40		
Funnel viscosity (sec/qt)	61	61		
Temp. for PV (F)	120	120		
PV (cP)	25	25		
YP (lbf/100ft2)	32	32		
Gel strength (10 sec) (lbf/100ft2)	8	8		
Gel strength (10 min) (lbf/100ft2)	10	10		
Gel strength (30 min) (lbf/100ft2)				
API filtrate (ml/30 min)	3.6	3.6		
Temp. for HTHP (F)				
HTHP filtrate (ml/30 min)				
Cake thickness API (1/32in)	1	1		
Cake thickness HTHP (1/32in)				
Solids content (%)	10.6	10.6		
Oil content (%)	0.00	0.00		
Water content (%)	89.4	89.4		
Sand content (%)	0.30	0.30		
MBT capacity (lb/bbl)	7.00	7.00		
pH	9.50	9.50		
Mud alkalinity(Pm) (ml/N50 H2SO4)	2.10	2.10		
Filtrate alkalinity(Pf) (ml/N50 H2SO4)	1.60	1.60		
Filtrate alkalinity(Mf) (ml/N50 H2SO4)	2.30	2.30		
Calcium (mg/L)	40.00	40.00		
Chlorides (mg/L)	66700.00	67100		
Total hardness (mg/L)				
Excess lime (lb/bbl)	0.13	0.13		
K+ (mg/L)	4500	46500.00		
Make up water: Chlorides (mg/L)	500.00	500.00		
Solids adjusted for salt (%)	7.25	7.25		

SPECIFICATION

Mud type	KCL Polymer	MW	10.0 - 10.20 ppg
Viscosity	50 - 60 sec/qt	pH	8 - 10.5
YP	26 - 34 ib/100ft2	API filtrate	< 4 cc/30min

RECOMMENDED TOUR TREATMENTS

Transferred 40 bbls of KCl polymer (lower weight to refresh active, since SCE working with low efficiency) to maintain volume as well as the desire mud properties as per RPOC instructions.

Treat active system with Drispac, caustic soda and PAC LV and KCl (depletion rate raised to 1 lb/bbl) .

Run all available SCE's to prevent solids build up. Cuttings shape looks well inhibited and free well at shakers.

Note: -- Screens (shaker 140&170 & mud cleaner 200&230) not arrived yet.

-- They repaired mud cleaner feed pump but still poor efficiency, also not fix the leakage on broken cone joint on de-sander.

Formation: Galhak Oil
Last sample @ 3838m
SS: 90% ClyS= 10 % SILT:0%

REMARKS

Continued drilling 8 1/2" from 3806m to 3839m. Circulate hole clean. POOH from 3839m to csg shoe . W/O TDS. Continued POOH from 2760m to 907m.@ RT.

LCM (lb/bbl)				
KCL (ppb)	30	31		

BIT HYDRAULICS

No. of nozzles	6	HHP bit (HP)	130.8
TFA (in2)	0.778	HSI	2.30
Nozzle vel. (ft/s)	215	Sys HHP (HP)	829.8
Impact force (ton)	0.302	Sys HHP (%)	15.76
DP bit (psi)	430	BH ECD (ppg)	11.51

ANNULAR HYDRAULICS

Section (in)	8.835 x 5.000	9.350 x 5.000	9.350 x 6.500	9.350 x 8.375	9.350 x 6.750	9.350 x 6.500
Sect. length (m)	2760.0	894.1	145.7	1.7	18.7	18.8
Ann. vel. (ft/min)	241.4	205.2	283.5	740.9	305.9	283.5
Crit. vel. (ft/min)	413.1	400.0	448.9	689.0	461.7	448.9
Crit. rate (gpm)	894.2	1018.6	827.2	485.8	788.4	827.2
Re ann	4870.13	4695.67	4250.79	3800.05	4184.67	4250.79
Re lam	2751.63	2751.63	2751.63	2751.63	2751.63	2751.63
Re turb	8338.72	9158.23	6732.97	3535.08	6317.30	6732.97
Eff. vis. (cP)	88	101	71	27	66	71
Flow	Lam	Lam	Lam	Tur	Lam	Lam
ECD (ppg)	11.55	11.52	11.51	11.54	11.55	11.55
CCI	Good	Good	Good	Good	Good	Good
P. drop (psi)	531	147	41	4	6	5
Slip vel. (ft/s)	30.8	29.4	32.9	39.1	33.6	32.9
CTR (%)	87.24	85.69	88.40	94.73	89.02	88.40

SOLIDS ANALYSIS

	Sample 1	Sample 2	Sample 3	Sample 4
Low gravity (%Vol)	3.50	3.48		
Low gravity (lb/bbl)	31.86	31.67		
High gravity (%Vol)	3.87	3.86		
High gravity(lb/bbl)	56.82	56.79		
Bentonite (%Vol)	0.70	0.70		
Bentonite(lb/bbl)	6.34	6.41		
Drill solids (%Vol)	2.80	2.78		
Drill solids(lb/bbl)	25.51	25.25		
DS/Bent ratio	4.02	3.94		
Avg. SG of solids	3.34	3.34		