Sudan University of Science and Technology

College of Petroleum Engineering and Technology

Petroleum Engineering Department

Project Title:

Bottom Hole Assembly Analysis Using Finite Element Analysis Software

(Case Study: Well X in Field Y, Block 2B)

نمذجةمعدات أسفل البئر بإستخدام برنامج Landmark

(دراسة حالة لبئر X في حقل Y، مربع 2B)

Submitted in Partial Fulfillment of the Requirements of the Degree of B.Tech. in Petroleum Engineering

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Opening

قال تعالى:

﴿ إِلاَّ أَنْ يَشَاءَ اللَّهُ نَرْفَعُ دَرَجَاتٍ مَنْ نَشَاءُ وَفَوْقَ كُلِّ ذِي عِلْمٍ عَلِيمٌ ﴾

صدق الله العظيم

سورة يوسف الأية (76)

قال صلي الله عليه وسلم :

(لا يزال المرء عالماً ما دام يطلب العلم فإن ظن أنه علم فقد جهل)

Dedication

To the spirit of our fathers, brothers, teachers, and academic supervisor Dr. Yousif Bagadi for his kindness, gentleness, and generous. We won't stop asking Allah for him to forgive him and give him the highest levels of the paradise.

To our fathers and mothers who taught us great lessons about life, guiding, motivation,

innovation and support us along life's level.

Without them we would not become the people who we are today.

To our brothers and sisters who stand with us, encourage us and taught us the real meaning of

helping other people with all we have.

For future generations that hold future of the oil industry in Sudan.

We are honor to offer you this modest work.

Thanks all for giving us a chance to prove and improve our self through all

levels of university life.

Acknowledgment

Several sources of information have been used to make this project. We would like to express our sincere gratitude and appreciation to our academic supervisor**Dr. Yousif Bagadi** for his consistent advice and receptiveness to opinions and ideas while we worked on this project. We would like to give a special thanks to for his support and guidance. Also a special thanks goes Mr. Khazk korak GNPOC drilling superintendent.

Abstract

Bottom hole assembly (BHA) is a component of a drill string that used to drill oil and gas wells. A BHA resides in the drill string above the drill bit and below the drill pipe. The primary component of the BHA is the drill collar. Figure (1.1), shows the possible component of a BHA and their typical location within a BHA.

In this project, the BHA Analysis model was used to analyze and simulate a well X by using Landmark-Wellplan software. BHA model has been modified into two different design configurations in order to determine the appropriate BHA model in terms of the resultant wellbore angle, direction change, and contact points or forces.

The results showed that the original BHA configuration has the best inclination tendency when the drilling parameters i.e. WOB, RPM remain constant and the modified BHA – second scenario gives less contact between the drill string and the wellbore, which shows the effect of the number of stabilizers in BHA configuration.

التجريد

تعتبر معدات أسفل البئر من أهم مكونات عمود الحفر والتي تحدد مسار عملية حفر البئر حيث أنها تعطي الوزن علي الحافرة المطلوب لإختراق التكوينات التحت سطحية كما أنها تحدد معدل الحفر. ويمكن تقليل مشاكل الحفر المختلفة عن طريق الإختيار الأمثل لمعدات أسفل البئر.

في هذا البحث، تم إجراء عملية نمذجة أو محاكاة لمعدات أسفل البئر والتي أستخدمت لحفر الجزء الأساسي للبئر X بقطر 8.5 بوصة بإستخدام برنامج Landmark-Wellplan. تم إجراء تعديل علي المعدات المستخدمة علي مرحلتين وتمت عملية النمذجة بإستخدام نفس البرنامج للحصول علي أفضل المعدات والتي تعطي نتائج جيدة من حيث زاوية ميلان البئر، إتجاهه، وقوي أو نقاط التلامس بين عمود الحفر والبئر.

أظهرت النتائج أن معدات أسفل البئر التي أستخدمت لحفر الجزء الأساسي من البئر تعطي نتائج جيدة من ناحية الحفاظ علي زاوية ميلان البئر وذلك عندما تكون العوامل الأخري مثل الوزن علي الحافرة ومعدل الدوران ثابتة. معدات أسفل البئر المعدلة – المرحلة الثانية ينتج عنها أقل عدد من نقاط التلامس بين عمود الحفر وجدار البئر ويرجع ذلك لإستخدام المستقرات والتي ظهر أنه كلما زاد عددها كلما قل عدد نقاط التلامس بين عمود الحفر و جدار البئر وبالتالي تقل قوي التلامس.

List of Contents

Chapter 1: Introduction

Chapter 2: Literature Review and Theoretical Background

Chapter 3: Methodology

Chapter 4: BHA Analysis, Results and Discussion

Chapter 5: Conclusions and Recommendations

List of Figures

List of tables:

Nomenclature:

ERD Extended Reach Drilling

MD Measured Depth

TVD True Vertical Depth

HD Horizontal displacement

TD Total Depth

T&D Torque and Drag

BHA Bottom Hole Assembly

ERW Extended Reach Well

DLSDog Leg Severity

WOB Weight on Bit

BWOB Downhole Weight on Bit

DTOB Downhole Torque on Bit

RIH Running In Hole

POOH Pulling Out Of Hole

WBM Water Based Mud

OBM Oil Based Mud

MWD Measurements While Drilling

HWDP Heavy Weight Drill Pipe

ROP Rate of Penetration

RPM Revolution per Minute

RSS Rotary Steerable System

2D Two Dimensional

3D Three Dimensional

EDM Engineer's Data Model

TDA Torque Drag analysis

PRS Pickup/Rotate/slack off

Chapter One

Introduction

1.1 Definition:

The bottom hole assembly is one of the most critical down hole drilling string components that determines the course of the drilling operation and it is efficiency. It provides the required weight on bit to penetrate the formations and enables directional drilling. BHA also affects the hole shape, direction, and it also plays an important role in determining the rate of penetration. Drilling problems are also minimized through BHA optimization.

1.1.1 Purpose of Bottom Hole Assembly:

The purpose of BHA is as follows:

- Protect the drill pipe from excessive bending and torsional loads.
- Control Direction and inclination in directional holes.
- Drill more vertical holes.
- Drill straighter holes.
- Reduce severities of doglegs and keyseats.
- Assure that casing can be run into a hole.
- Increase drill bit performance.
- Reduce rough drilling and vibrations.

1.1.2 Types of Bottom Hole Assembly:

- **The Slick BHA:** is composed only of drill collars. It is least expensive and perhaps carries the least risk in regard to fishing and recovery.
- **The Pendulum BHA:** is designed **to** drill holes more vertically and to drop inclination in inclined holes.The application of a Pendulum assembly is that when the inclination has been increased beyond the intending trajectory and must be reduced to bring the well back on course
- **The Packed BHA:** is designed to drill straight holes and to reduce the severities of doglegs and keyseats. It provides the highest assurance that casing can be run into a

hole. Packed assemblies do not maintain inclination angle; rather, they minimize angle build or drop. A packed BHA can be expensive and perhaps carries the highest risk in regard to fishing and recovery (Advanced Oil Well Drilling Engineering, Mitchell).

- **The Fulcrum BHA:** This type of assembly is usually run in a directional well after the initial kick-off has been achieved using a deflection tool. A single stabilizer placed above the bit will cause building. The addition of further stabilizer(s) will modify the rate of build to match the required well trajectory (Drilling Engineering, Curtin University).

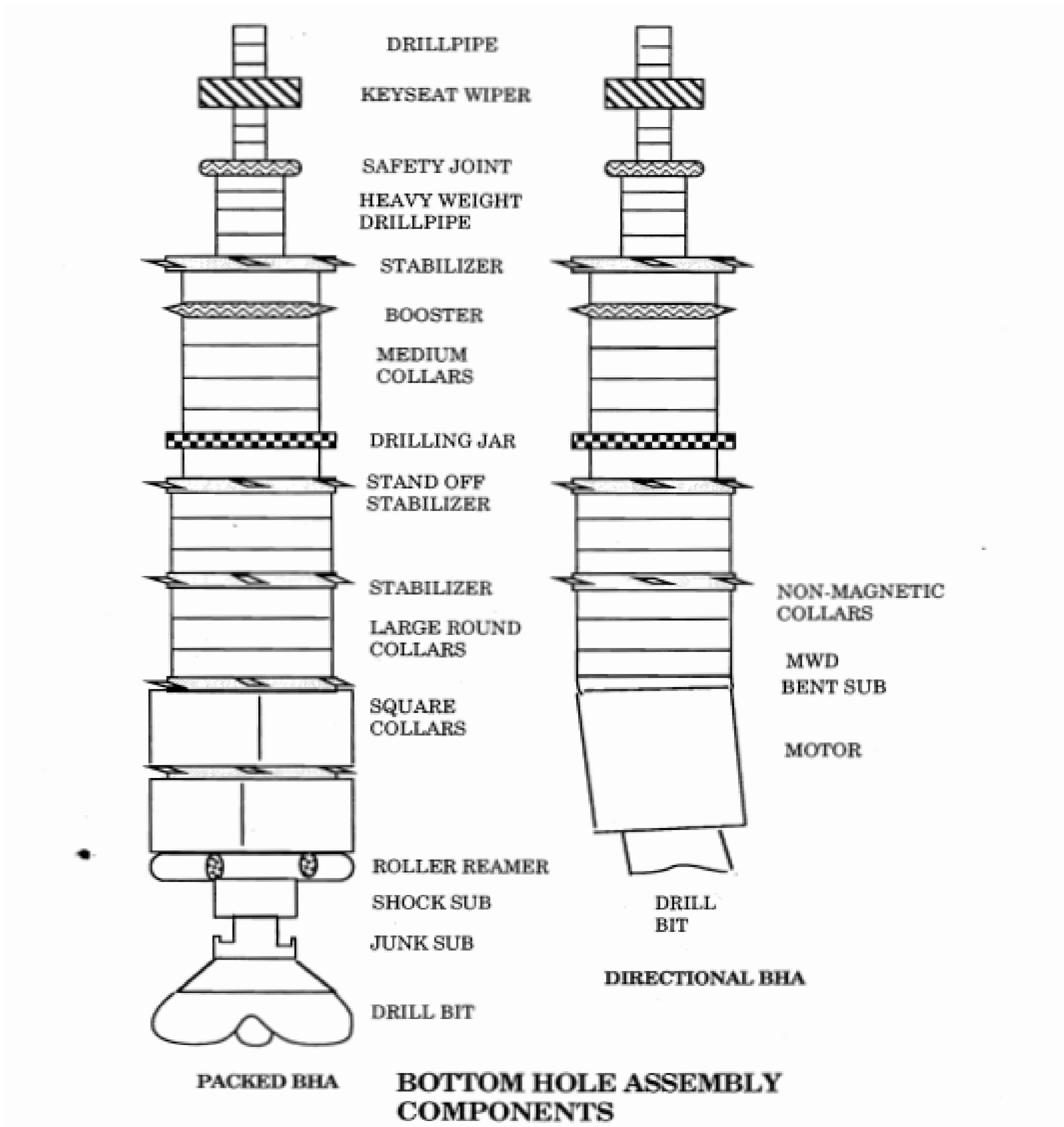

Fig1.1: BHA Components (Advanced Oil Well Drilling Engineering, Mitchell).

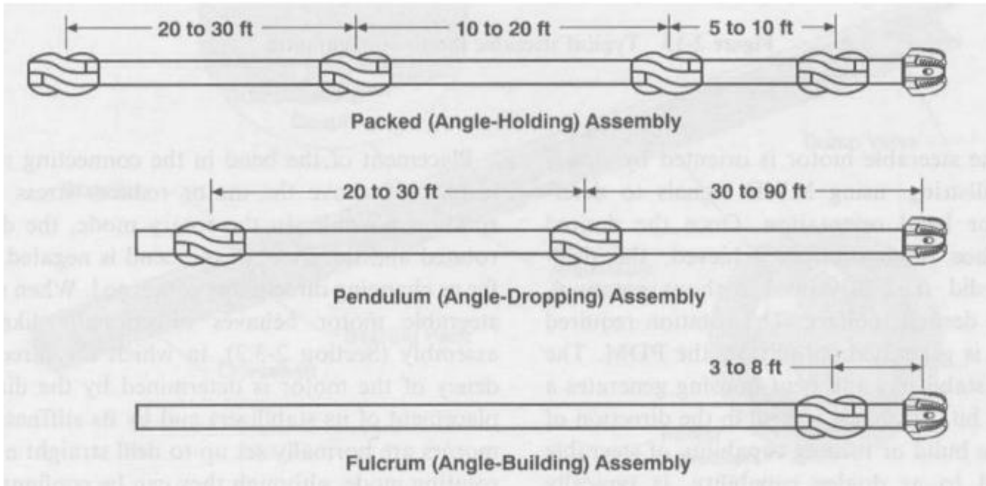

Fig.1.2: Types of BHA (Drilling Engineering, Curtin University).

1.2 Bottom Hole Assembly Components:

The BHA is the portion of the drillstring that affects the trajectory of the bit and, consequently, of the wellbore. It is construction could be simple, having only a drill bit, collars, and drillpipe, or it may be complicated, having a drill bit, stabilizers, magnetic collar, telemetry unit, shock subs, collars, reamers, jars, crossover subs, heavy weight drillpipe (Applied Drilling Engineering, 1991). The physical properties of the various downhole components of the BHA have a significant effect on how the bit will drill. In most drilling situations, the bottom 100 to 300 [ft] of the bottom hole assembly has the greatest influence on its behavior. The construction of the bottom hole assembly can be as simple as consisting of a drill bit, collars, and drill pipe, or may be as complicated as including a drill bit, stabilizers, collars of different sizes and materials, heavy-weight drill pipe, drill pipe etc. (Drilling Engineering, Curtin University).

1.2.1 Drill Collars:

Drill collars are the predominant components of the bottom hole assembly. The primary function of the drill collars is to be able to apply weight to the bit without buckling the drill pipe. Since the collars are under compression, they will tend to bend under the applied load. The amount of bending will depend on the material and the dimensions of the collar. The shape of the drill collar may have a circular or square cross section. A string of square collars provides good rigidity and wear resistance, but it is expensive, has high maintenance costs for certain conditions and may become stuck in key-seated dog-leg. Typically, standard and spiral drill collars with external grooves cut into their profile may be used to reduce the contact area between the BHA and the formation. In deviated holes the total weight of the drill collars is not applied to the bit. Part of that weight is applied to the wall of the hole depending on the amount of deviation. The actual weight on bit is a function of cos α where α is the angle of inclination (Drilling Engineering, Curtin University).

1.2.2 Drill Collars Profiles:

1.2.2.1 Slick Drill Collar:

As the name implies, slick drill collars have the same nominal outside diameter over the total length of the joint. These drill collars have the following profiles:

- a slip recess for safety, and
- an elevator recess for lifting.

1.2.2.2 Spiral Drill Collars:

Spiral drill collars are used primarily to reduce the risk of differential sticking. The spirals reduce the weight of drill collar and also reduce the contact area, which is proportional to sticking force, by about 50%.

1.2.2.3 Square Drill Collars:

These are used in special drilling situations to reduce deviations in crooked hole formations. They are used primarily due to their rigidity (Well Engineering and Construction, Rabia).

Fig.1.3: Drill Collars Profiles (Well Engineering and Construction, Rabia).

1.2.3 Stabilizers:

Stabilizers are fairly short subs with blades attached to the external surface. By providing support to the bottom hole assembly at certain points they can be used to control the trajectory of the well. Drilling straight or directional holes requires proper positioning of the stabilizers in the bottom hole assembly.

It is important to note that the position of the first stabilizer and the clearance between the wall of the hole and the stabilizers has a considerable effect in controlling the hole trajectory. Stabilizers can be grouped into:

- **Rotating Blade Stabilizers, and**
- **Non-rotation Blade Stabilizers.**

A rotating blade stabilizer can have a straight blade or spiral blade configuration. In either case the blades may be short or long. The spiral blades can give 360◦ contact with the bore hole. All rotating blades stabilizers have good reaming ability and good wear life. Non rotating rubber sleeve stabilizers are used to centralize the drill collars, where the rubber sleeve allows the string to rotate while the sleeve remains stationary. Since the sleeve is stationary, it acts like a drill bushing and does not dig or damage the wall of the hole. It is most effective in hard formation (Drilling Engineering, Curtin University).

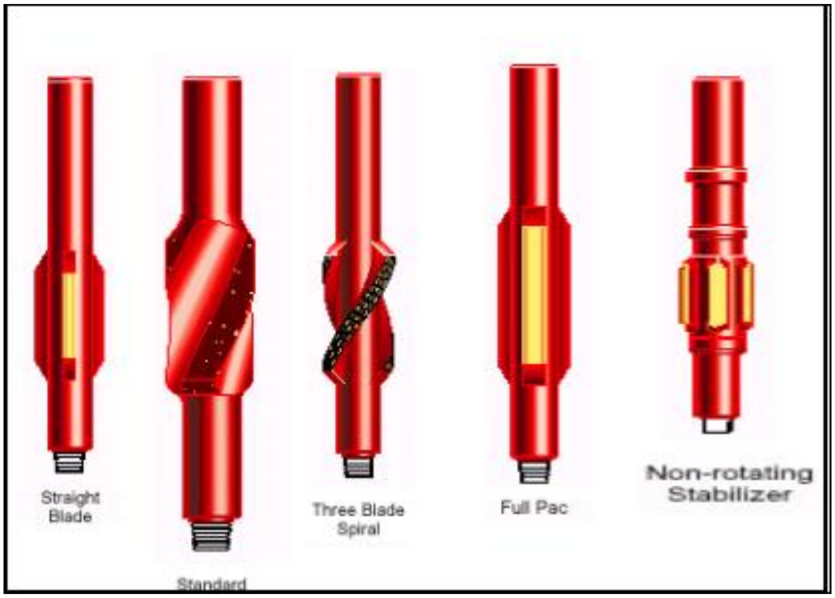

Fig.1.4: Types of Stabilizers (Well Engineering and Construction, Rabia).

1.2.4 Reamers:

Roller reamers are used to replace near bit and string stabilizers in bottom hole assemblies where high torque and swelling or abrasive formations are encountered.

Roller reamers can have either 3 or 6 cutter sets. Both near bit and string reamers are available. Consideration should be given to replacing the near bit and first string stabilizer with a roller reamer if high torque or severe gauge wear of stabilizers has been encountered. The standard configuration is to replace the near bit and first string stabilizer with a three point roller reamer. For severely abrasive formations or wear significant high torque is encountered a six point roller reamer may be used in place of the near bit stabilizer.

Fig.1.5: Types Roller Reamers (Well Engineering and Construction, Rabia).

1.2.5 Drilling Jars:

Jars provide a means of supplying powerful upward or downward blows to the stuck drillstring. A jar is a mandrel which slides within a sleeve. The free end of the mandrel is shaped in the form of a hammer to provide a striking action against the face of the anvil.

Depending on the type of tripping mechanism, there are two basic types of jar: mechanical and hydraulic.

1.2.5.1 Mechanical jars:

Ithave a preset load that causes the jar to trip; hammer striking the anvil. They are thus sensitive to load being used and not to time. Mechanical jars are pre-set at surface.

1.2.5.2 Hydraulic jars:

It uses a hydraulic fluid to control the firing of the jar until the driller can apply the appropriate load to the string to give a high impact. This controlled action (delay) is provided by hydraulic fluid which is forced through a small port or series of jets. Hydraulic jar firing delay is dependent upon the combination of load and time. Hence hydraulic jars are adjustable according to down hole overpull.

1.2.5.3 **Oil jars**:

It provides means for applying upward blows to release a stuck pipe.

1.2.5.4 **Accelerators**:

It stores energy above the drill collars in order to increase the impact efficiency of oil jars.

1.2.5.5 **Bumper jars**:

It provides free travel to assist in engaging the fish and to allow downward blows to be transmitted to the fish and for releasing overshots downhole and at surface.

Two phenomena have to be considered when jarring. These are the impact force and the impulse of the jarring action. The impact force must be high enough to break the binding force causing the pipe to stick. The impact force must also act long enough to move the pipe this is what is termed the impulse. Both forces are influenced by the number of drill collars located above the jar. The smaller the quantity of drill collars, the higher the impact force. Conversely the larger the number of drill collars the greater the impulse force. A compromise has to be reached where both impact and impulse are working together to free the pipe.

The jars should be run in tension wherever possible. This is mandatory for mechanical jars. For hydraulic manufacturer’s state that they can be run in compression however this is not advisable as inadvertent cocking of the jar is possible with applied WOB. For vertical wells the amount of drill collars to be run below the jar should be the sufficient to allow the required bit weight and place the neutral point at least 30 feet away from the jar.

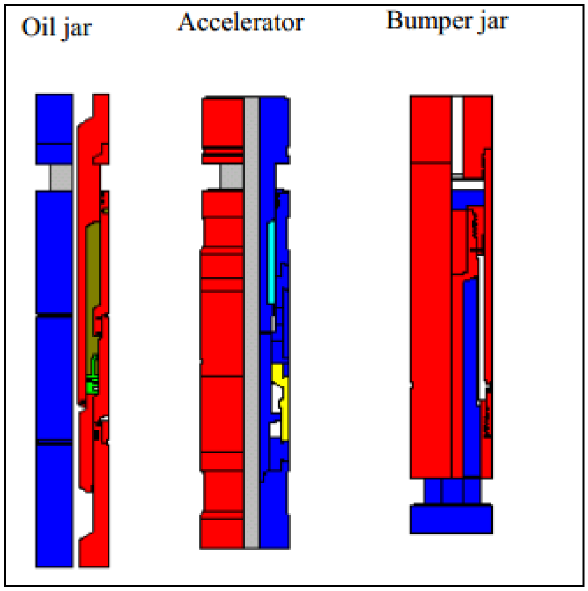

Fig.1.6: Types of Drilling Jars (Well Engineering and Construction, Rabia).

1.3 Types of Bottom Hole Assembly:

1.3.1 Building Assembly:

This type of assembly is usually run in a directional well after the initial kick-off has been achieved using a deflection tool. A single stabilizer placed above the bit will cause building. The addition of further stabilizer(s) will modify the r ate of build to match the required well trajectory. If the near bit stabilizer becomes under-gauge, the side force r educes. The amount of weight on bit applied to these assemblies will also affect their building tendencies. Normally the higher the bit weight the higher the building tendency (Drilling Engineering, Curtin University).

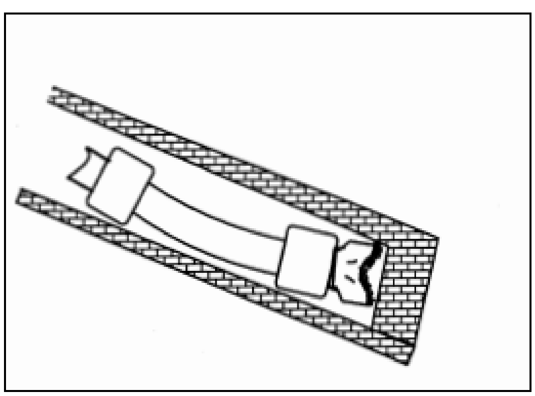

Fig.1.7: Building Assembly (Advanced Oil Well Drilling Engineering, Mitchell).

1.3.2 Holding Assembly:

Once the inclination has been built to the required angle, the tangential section of the well is drilled using a holding assembly. Holding assemblies do not maintain inclination angle; rather, they minimize angle build or drop. Minimal tilt angle at the bit, as well as stiffness of the bottom hole assembly near the bit helps maintain inclination angle. Change in weight on bit does not affect the directional behavior of this type of assembly and so optimum weight on bit can be applied to achieve maximum penetration rates (Drilling Engineering, Curtin University).

1.3.3 Dropping Assembly:

The application of a dropping assembly is that when the inclination has been increased beyond the intending trajectory and must be reduced to bring the well back on course. Normally these BHA configurations are more effective in high angled holes. If the hole angle does not decrease, the weight on bit can be reduced with use of these assemblies, although this will also reduce the penetration rate (Drilling Engineering, Curtin University).

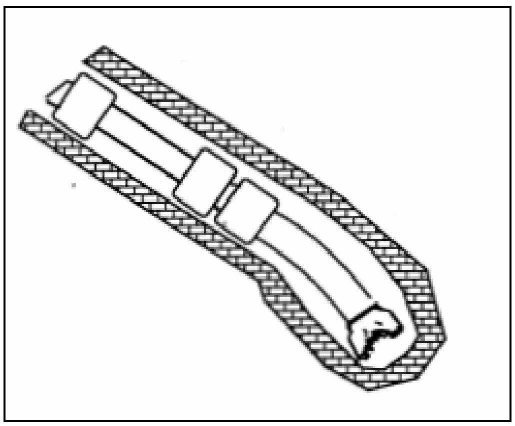

Fig.1.8: Dropping Assembly (Advanced Oil Well Drilling Engineering, Mitchell).

1.4 Statement of the Problem:

The main issue in directional drilling is to control the direction of the borehole to conform to a predetermined trajectory. Undesirable deviations from the planned well-path increase the drilling cost through the need for course corrections, and the added troubles associated with key seating, pipe sticking, and even side tracking due to lost tool.

The cause of undesirable hole deviation is still not well understood. Proper BHA design and optimization can be considered as the main factor affect the hole deviation.

1.5 Objectives:

The main objective of this project is to study, analyze and simulate the performance or behavior of BHA intended to be used to drill the main hole of the directional well X located in field Y. Then, in order to optimize BHA behavior, this BHA is modified, analyzed as well, and it is performance is predicted in order to find the most appropriate BHA to drill the main hole of this well.

1.6 Methodology:

This project work is broken down into the following:

1- The performance of BHA intended to be used to drill the main hole of well X will be predicted using finite element technique (Landmark-Wellplan software).

2- This BHA will be modified and it is behavior will be predicted again. This is done mainly in order to optimize BHA behavior.

The modeling or simulation process of BHA intended to be used to drill the main hole of well X will be done using Landmark-Wellplan software.

Chapter two

Literature Review&Theoretical Background

2.1 Literature Review:

Apparently, the earliest attempts at explaining·'the structural behavior of drill strings and Bottom Hole Assemblies, BHA's, in terms of beam mechanics and elastic bending theory dates back to the early work of Capelushnikov and Clark in the 1930's.

Drilling mechanics did not, however, really come into its own as a discipline until the

LubinskiandWoods:

1950's whenLubinski and Wood**s** in their pioneering work carried out buckling studies on rotary drill strings and addressed such questions as the factors affecting inclination and dog-legging in rotary boreholes and the use of stabilizers in controlling hole deviation.

Huang, **Dareing and Fischer:**

Initial efforts, such as the work of Huang and Dareingand Fischer to develop computer models of BHA's and drill strings were largely based on procedures such as the finite difference method which operates directly on the differential equations of bending of a structural model. Paralleling developments in advanced structural analysis occurring in other industries finite difference BHA models began, in the early 1970's, to evolve to more powerful potential energy or virtual work-based finite element models.

Nicholson and Wolfson:

The first applications of the finite element method in drilling mechanics can probably be attributed to- work undertaken initially by Nicholson and later by Wolfson at the University of Tulsa. Nicholson's study dealt with the finite element analysis of constrained BHA's in straight inclined wellbores using the penalty function method to define the wellbore boundary. Wolfson generalized these ideas to include curved wellbores in three dimensions. Following Nicholson and Wolfson's studies, Millheim, Jordan and Ritter went on to demonstrate the practicality of implementing a large, general purpose, nonlinear finite element code for routine BHA analysis.

Millheimand Apostal:

were the first to implement complex three-dimensional dynamic models of a rotating BHA to study the effect BHA dynamics has on the trajectory of a bit. This work was instrumental in demonstrating that the intermittent contact and dynamic torque and friction effects associated with a rotating BHA were important factors in directional (especially azimuth) responses of a drilling BHA. Previously, these responses had been attributed to formation effects. More recent efforts in this area are represented by the studies of Mitchell and Allen and Birades.

Dunayevsky, **JudzisandMills:**

implemented analytical models of the entire drill string (notjust the BHA) to investigate the onset of drill string precession in directional boreholes and the dynamic stability of drill strings under fluctuating weight on bit (Williams, 1989).

2.2 Theoretical Background:

2.2.1 The Principals:

Forces acting on a Bit in an inclined hole (for a string rotating off bottom) .

Available weight:

$$W = w \times L \times BF \times \cos(\theta)$$

Where:

θ is the hole inclination in degrees

W is the available weight of the DCs

w is weight per unit length

L is the length of DCs available

BF is the buoyancy factor

BF = 1-(mwt/65.5) (for ppg

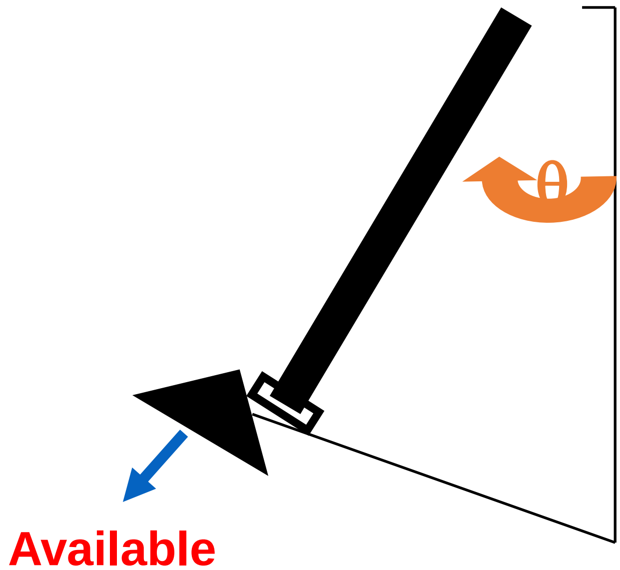

Fig 2.1: available weight of the DCs

2.2.2 BHA Side Force:

BHA’s cause a side force at the bit that makes the bit build, drop or hold angle.

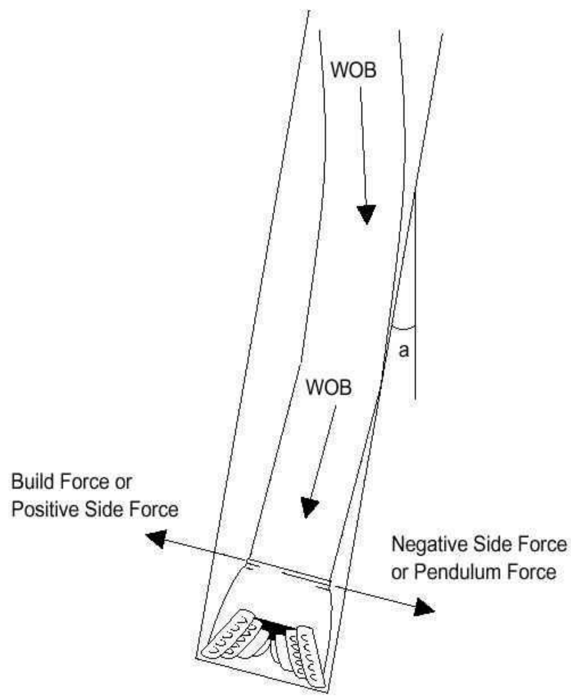

Fig 2.2: BHA Side Force

2.2.3 Negative Side Force:

Increased WOB results in a shorter tangent to bit distance this reduces the pendulum effect and increases bit tilt,

Pendulum force with zero WOB:

H = w x L x BF x sin(inc)/2

Where: H is side force

W is the weight of the DCs

w is weight per unit length

L is the length of unsupported DCs below the Tangent

BF is the buoyancy factor

Pendulum force (negative side force)

2.2.4 Positive Side Force:

With WOB we can induce Bit Tilt by moving the tangent closer to the bit and thus generate a Build Force (positive side force).

If the Build Force is great enough it will become greater than the pendulum force and an increase in hole angle will result.

Increased WOB results in a shorter tangent to bit distance This reduces the pendulum effect and increases bit tilt, resulting in greater positive side force

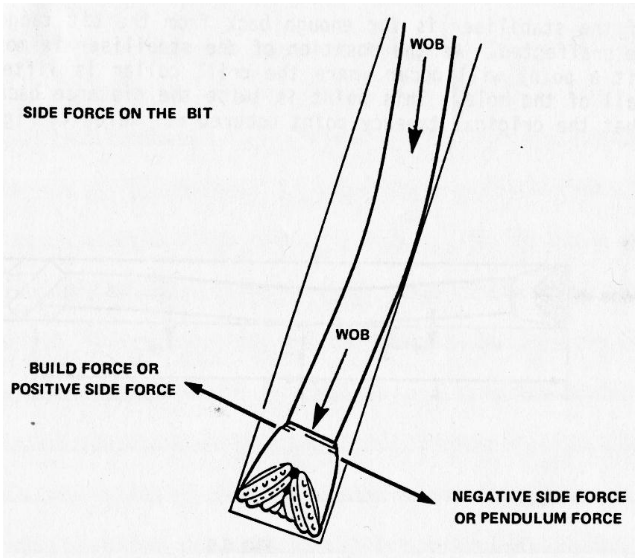

Fig 2.3: Positive Side Force

2.2.5 Single stabilizer effect:

The effect of a single stabilizer changes with it's proximity to the bit. As the distance reduces it's effect goes from none, when the tangent is the same distance as if no stabilizer was run, to maximum build when it becomes a Near Bit Stabilizer.

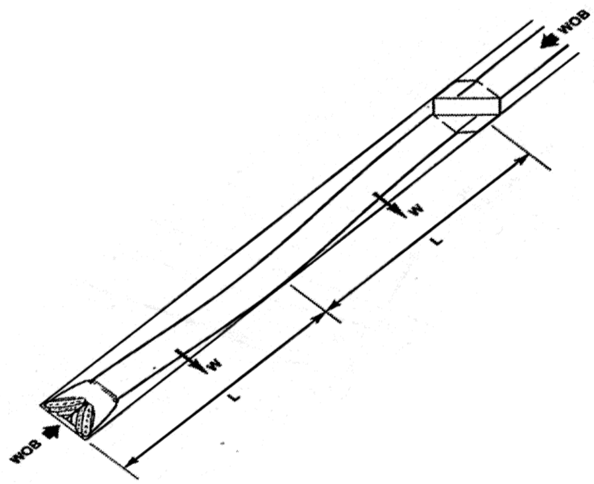

Fig 2.4: Single stabilizer effect

2.2.6 Two stabilizers effect:

With Two stabilizers, by controlling their relative position to the bit create almost any behavioral tendency that we require. The spacing in this example is twice that of the Tangent point from the first stabilizer, so there is no effect from the second stabilizer.

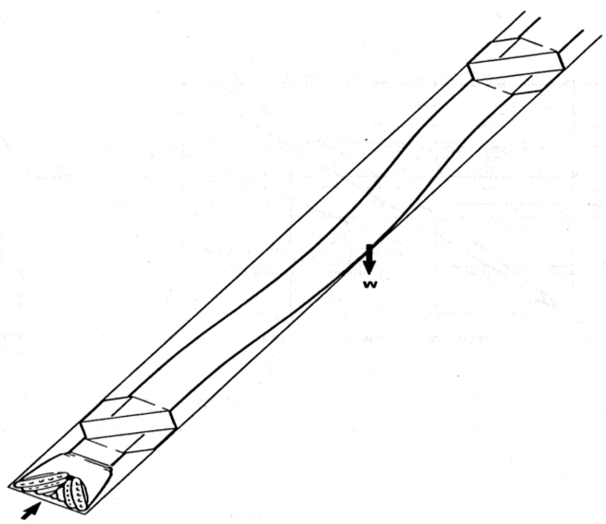

Fig 2.5: Two stabilizers effect

Chapter Three

Methodology

3.1 Finite Element Analysis using Landmark-Wellplan:

Wellplan is a component of Landmark software developed by Halliburton. Wellplan software is able to solve number of technical challenges such as ERD, slim hole drilling, deep water drilling, and environmentally sensitive drilling areas. Wellplan software can be used at the rig site and in the office to provide integration between engineering functions. It is used during the design and operational phases for drilling and well completion. This software allows the user to identify potential problems during the drilling and completion process in terms of wellbore design. Integrated technologies enables the user to study and evaluate BHA, torque and drag, stuck pipe, cementing, hydraulics and well kick scenarios. For this particular project the main focus will be on the T&D module.

The BHA module was designed to predict the directional drilling performance of a bottom hole assembly. The module can provide an accurate representation of the forces acting on the assembly as it exists in the wellbore. This type of analysis can be useful for explaining unexpected performance or for determining the causes of tool failures. In addition, the module can solve a "drillahead" scenario to represent the expected behavior of the bottom hole assembly as it drills new hole. The Bottom Hole Assembly module analyzes a bottom hole assembly, BHA, in a static "in-place" condition or in a "drillahead" mode.

Many different factors influence the behavior of a BHA including weight on bit, WOB, drillstring component size and placement, formation type and other factors. Because a BHA is composed of many different elements of varying dimensions, it lends itself quite well to the Finite Element Analysis, FEA, method. The FEA Method solves complex problems by breaking it into smaller problems. Each of the smaller problems can then solved much easier. The individual solutions to the smaller problems can be combined to solve the complex problem **(Landmark Wellplan user manual, 2000).**

3.1.1 Advantages of Bottom Hole Assembly Modeling:

There are many times where the Bottom Hole Assembly module can be useful. Among these are:

- Analyze the contact forces and displaced shape of a bottom hole assembly including the bit tilt, side forces, and wellbore contact points.
- Study previous directional failures through analysis of contact forces on tools.
- Predict the directional behavior (including build, walk, and drop) of a bottom hole assembly as it drills ahead through a specified interval.
- Predict the transient effect when new assembly is run in hole. l Adjust operating parameters to affect bottom hole assembly performance.
- Study effects of bent assemblies, collar size, stabilizer placement, eccentric stabilizers, stabilizer wear, hole enlargement, operating parameters for optimal performance.
- Select proper bent sub to achieve desired build or drop rate.
- Estimate the additional torque drawn from a motor due to lateral forces at bit.
- Determine the downhole mechanism controlling the bottom hole assembly.
- Determine the orientation of a bottomhole assembly (0 - 180 degrees left or right of high side) for achieving optimum performance in a well deflection scenario.
- Compare a rotary versus steerable assembly performance for a given well trajectory analysis.
- Optimize the design of a steerable system through modeling of number of bends and eccentric contact points in the bottom hole assembly. **(Landmark Wellplan user manual, 2000).**

3.2Analysis Methodology:

Three Fundamental Requirements of Structural Analysis The Finite Element Analysis (FEA) method used in the Bottom Hole Assembly module adheres to **three basic conditions of structural analysis:**

• First, the internal forces must balance the external forces.

• Second, the solutions for each separate element must be compatible with the next element. This is necessary so that the deformed structure fits together.

• Third, the laws of material behavior must be followed. Defining the Finite Element Mesh The first step completed during the analysis is to divide the drillstring into a 40 element mesh. This 40 element mesh is divided into three sections, or "zones." The total length of the mesh, the length of each zone, and the maximum length of each element in a zone can all be set by the user to create a coarser or finer mesh. The Bottom Hole Assembly module has preset defaults for the total length of the mesh, the lengths of the individual zones, and for the elements within the zones. It is recommended that the defaults be used unless the user is very familiar with Finite Element Analysis methods. The defaults for lengths of zones 1 and 2 are 500 and 2500 feet, respectively. The length of zone 3 varies depending on the remaining length of drillstring and the remaining number of available nodes.

The Aspect Ratios for zones 1, 2 and 3 default to 20, 100, and 500 respectively. The following example explains how Aspect Ratios Landmark WELLPLAN Bottom Hole Assembly determine element lengths. Assume there is an 8" collar in zone 1. The maximum element length in zone 1 for an 8" collar would be: 8" X 20 (default for Aspect Ratio 1) = 160" or 13.3 ft. An exception to this is in the bottom 12 feet of zone 1 where there is a 3-foot limit for element length. The 3-foot limit is included because the drillstring closest to the bit has a significant impact on the bottom hole assembly behavior. **(Landmark Wellplan user manual, 2000).**

3.3Compute the Local Stiffness Matrix and the Global Stiffness Matrix:

After the drillstring has been divided into elements, each element is closely examined in terms of geometrical and physical properties. The correct representation of geometrical and physical properties including component weight, dimensions, moment of inertia and modulus of elasticity is very important in order to accurately represent the component for the remaining analysis.

The Bottom Hole Assembly module has a catalog containing much of the information, but it is important that the user carefully selects each component to model the drillstring as closely as possible. The user should verify that all selected component properties accurately reflect the component. The local stiffness matrix K is an important piece of the analysis as it represents how rigid or bendable a component is.

The individual element stiffness matrices are computed and combined to form the global stiffness matrix. This is a necessary step towards ensuring a complete solution for the entire bottom hole assembly, rather than a number of individual solutions for several elements. The global matrix is a necessary step towards satisfying the fundamental requirements of structural analysis mentioned earlier.

The Bottom Hole Assembly module provides six default boundary conditions that can be selected for the top and bottom nodes. The Bottom Hole Assembly module's system defaults do not apply boundary conditions to nodes between the top and bottom nodes. An experienced user familiar with FEA (and with assistance from Landmark) can define additional boundary conditions and can enforce boundary conditions at additional nodes. It is recommended that the defaults be used unless the user is familiar with finite element analysis methods. The following list defines the seven default boundary conditions selections available for the top and bottom nodes.

- Full pin: All three translations are specified and rotations are free.
- Full Fix: All three translations and rotations are specified.
- Pin with Axial Slider: Two lateral translations (X, Y) are specified. Z translation is free, and all three rotations are specified.
- Fix with Axial Slider: Two lateral translation (X, Y) are specified. Z translation is free, and all three rotations are specified.
- Fix Axial: Two lateral translations (X, Y) are free. Z is specified, and X,Y, and Z rotations are free.
- Fix Torsion: All three translations (X, Y, Z) are free, two rotations (X, Y) are free, and Z rotation is specified.
- Fix Rotations: All three translations are free (X, Y, Z) and two lateral rotations (X, Y) are specified, and Z rotation is specified. (Landmark Wellplan user manual, 2000).

3.4 Constructing the Wellbore and Bottom Hole Assembly Reference Axis:

Survey data and wellbore diameters are important pieces of information supplied by the user. The Bottom Hole Assembly module uses this information to construct the wellbore. Each survey data point supplied by the user is used to calculate location reference coordinates for each survey point of the wellbore using the survey calculation method supplied by the user. Next, the coordinates of the bottom hole assembly nodes are determined as if the bottom hole assembly is lying along the centerline of the wellbore, with the bit at the depth specified by the user.

A bottom hole assembly reference axis (Z) is established by using the inclination and direction as interpolated at the bit location. The Z reference axis is tangent to the wellbore and points toward the surface. The X and Y reference axes are also established. The X axis points toward the surface (vertical) and theY-axis is parallel to the surface (lateral). Hole diameters are assumed to be constant over the interval specified by the user in the WELLPLAN Wellbore Editor. (Landmark Wellplan user manual, 2000)..

3.5 Calculating the Solution:

Using the information from the previous steps of the analysis, the force/contact solution can be calculated. This is a complex, iterative procedure. First, the drillstring finite element model is laid out along the z-axis described above. Unless the wellbore is straight, the drillstring finite element model penetrates the wellbore described by the surveys.

At this point, the program begins to determine the force acting between the wellbore and the drillstring. The boundary conditions are enforced on the nodes specified. All other nodes have no boundary conditions applied. The program determines where the drillstring has (theoretically) penetrated the wellbore and calculates the restoring force necessary to move the node back into the wellbore. If the node is already inside the wellbore, no force or displacements are applied to the node. These steps are repeated until the changes in displacements at all nodes fall below a set tolerance.

The objective is to determine the forces necessary to move the nodes along the reference axis to the corresponding nodal position lying along the wellbore centerline. When this is accomplished, the solution is considered complete. At this point, the axial forces, torque, stresses and coordinates (X, Y, and Z) of each node are known. (Landmark Wellplan user manual, 2000).

3.6 Drillahead Solutions:

The Bottom Hole Assembly module is capable of two analysis modes:

- The static or "in-place" solution has been explained in the previous discussion. A static solution assumes the bit is stationary at the user specified depth.
- The "drillahead" solution advances the bit depth, into a certain intervals, through the interval specified by the user. At each of these intervals, a static solution is performed. The drillahead solution assumes:

• The bit will drill in the direction it is pointed.

• The bit will cut sideways due to the presence of side forces generated in the inclination and direction axes.

• The formation has isotropic rock properties. Although side cutting is affected by penetration rate, it is not entirely a function of the same parameters that affect penetration rate. Lateral penetration rates do not always vary with penetration rate. One reason for this can be attributed to the variety of bits available. Different bits have different side cutting abilities. (Landmark Wellplan user manual, 2000).

3.7 Bit Coefficient:

Bit coefficients indicate how efficient a bit will cut sideways. Values for bit coefficient range from 1 - 100. Note that a value of 0 indicates the bit does not cut sideways, and the wellbore trajectory will be based solely on bit tilt. The following table includes suggested bit coefficients for roller cone bits. Typically range for this type of bit is 20 - 80, with 20 used for soft formations, and 80 used for hard formations.

IADC Series	Bit Coefficient
8	20-30
3,7	30-40
2.6	40-60
1,4,5	60-80

The values for fixed cutter bit coefficients are more difficult to determine from the IADC classification system. Cutter size, density, and placement impact the determination of bit coefficient. (Landmark Wellplan user manual, 2000).

Fixed Cutter Bits	Bit Coefficient
Flat Faced Diamond	0-5
Step profile / Small Cutters	10-20
Bladed/Small Cutters	20-40
Step Profile/Large Cutters	40-60
Bladed/ Large Cutters	60-80

3.8 Formation Hardness:

Formation hardness is used to model the formations resistance to the bit side cutting capability. Formation hardness is a number between 0 and 60, with the larger numbers indicating the relative hardness of the formation. The table below correlates formation hardness to rate of penetration and formation description.

(Landmark Wellplan user manual, 2000).

3.9 Bottom Hole Assembly Modeling:

To model the bottom hole assembly, the following steps were taken into account:

3.9.1 Analysis of the Existing Data:

The analysis process involves reviewing of the available well and field data to understand and collect the data needed for the modeling process such as:

- Field and wells surface and subsurface data. In addition to the target location data.
- BHA and drillstring data for the well.
- Well trajectory
- Mud properties

Then, the above data is loaded into the Landmark-Wellplan software in order to get the geometry of the wells and simulate or model the bottom hole assembly. (Landmark Wellplan user manual, 2000)

3.9.2 Data Analysis into Landmark-Wellplan:

The data entered into Landmark-Wellplan can be divided into two groups:

1- General data that can be used by all other modules.

2- Specific data that can be used by the BHA module alone.

Each of these groups is reviewed in details in the following paragraphs.

- **Wellbore Editor:**

Wellbore editor enables the user to input the wellbore information for casing and open hole such as Length, internal diameter, ID. The classification of each section type on the table sheet above has been followed up by Catalogue format divided by Nominal Diameter, Weight and Grade by API Casing/Tubing Catalogue database.

The purpose of using this spread sheet is to define the wellbore profile and inner configuration of the well. Entering the hole section information from surface down to the bottom of the well.

- **String Editor:**

String and BHA data can be inputted in the string editor. It includes the outer diameter, yield strength, torsional strength and weight. As we observe from the table above. We can distinguish that each item description belongs to the Drill pipe catalogue from API Drill Pipe database. On this example, each section type has been set mainly by Nominal diameter, Nominal Weight, Grade, Connection and Class.

As mentioned previously, the main hole BHA configuration is modified in two different ways, as can be seen in figures below, in order to model, analyze and optimize the directional behavior of the BHA intended to drill the main hole section.

- **Survey Editor:**

In Survey editor, MD, Inclination and Azimuth are inserted. The TVD, dogleg, Vertical section is calculated automatically as the MD, Inclination and Azimuth data inserted. This table sheet attached above describe fully the well path data being input values (MD, Inclination and Azimuth), and the rest ones are the output results. It must be noticed that the values of the well path data, are for the planned well path not for the actual well path. Using the WellPath editor commands, allows the user to identify the main critical issues:

- Vertical Section vs. Target Vertical Depth (TVD).
- Plan View
- Dogleg Severity(DLS) vs. Measured Depth(MD)
- Inclination vs. Measured Depth
- Azimuth vs. Measured Depth
- Absolute Tortuosity vs. Measured Depth
- Relative Tortuosity vs. Measured Depth
- **Fluid Editor:**

Fluid editor options enable the user to input the fluid used in the drilling such as: rheology properties, mud base and other mud properties.

3.10 Bottom Hole Assembly Module Data:

As stated previously,The Bottom Hole Assembly module analyzes a bottom hole assembly, BHA, in a static "in-place" condition or in a "drillahead" mode. The following paragraphs include a detailed description of each of these two analysis modes and the data associated with each type.

- **Analyzing a Static Bottom Hole Assembly:**

Static, in-place, analysis of the bottom hole assembly can be useful in determining the contact forces and displaced shape of a bottom hole assembly, including bit tilt, side forces, and wellbore contact points. This may be helpful in analyzing previous directional failures through analysis of contact forces on tools.

There are some parameters, Fig. 3.6, that need to be entered to perform the calculations. Drillahead check box is not marked at this time because we are analyzing the bottom hole assembly at the current depth. (Landmark Wellplan user manual, 2000).

- **Torque at Bit:**

Type the actual torque at the bit. Obtain typical bit torque values from the bit manufacturer.

- **Weight at Bit:**

Type the actual weight applied at the bit. Weight on bit is the compressive axial load that is applied to the formation by the bit face. It is the difference between the net weight of the entire drillstring and the resulting reduced weight when the bit is resting on bottom.

- **Rotary Speed:**

Type the rotating speed of the drillstring and bit once steady state conditions are reached. For rotary assemblies, type the rotating speed of the drillstring. For hydraulic motor assemblies where the drillpipe does not turn, type the rotating speed of the bit.

Analyzing a Drillahead Bottom Hole Assembly:

The drillahead box is checked to solve a "drillahead" scenario to represent the expected behavior of the bottom hole assembly as it drills new hole. The "drillahead" solution advances the bit depth, in 5-foot intervals, through the drill interval specified below. At each of the 5-foot intervals, a static solution is performed. The drillahead solution assumes the following:

- The bit will drill in the direction it is pointed.
- The bit will cut sideways due to the presence of side forces generated in the inclination and direction axes.
- The formation has isotropic rock properties.

The additional parameters, Fig. 3.7, that need to be entered to solve for drillahead scenario are:

- **Steering Tool Orient:**

Steering tool orientation is the orientation of the steering tool (scribe line) relative to the high side of the hole, measured clockwise from the high side. The tool orientation is used in conjunction with the Tool Reference to determine the orientation of the bend, relative to the high side of the hole. To use this parameter,a steering tool must be present in the drillstring in order to enter a tool orientation.

- **Drill Interval:**

Drill interval is the total measured depth distance that the current bottom hole assembly will drill ahead. Usually, 100 to 200 feet is sufficient to determine the directional behavior of the bottom hole assembly. A minimum value of 100 feet is recommended.

- **Overgauge:**

Overgauge is the amount of washout expected as the bottom hole assembly is drilling. This effect can be modeled without having to change the hole size on the Wellbore Editor.

- **Record Interval:**

Record interval is the distance at which the survey points will be generated for the final output.

- **Bit Coefficient:**

The bit coefficient is a number between 0 and 100 that indicates the efficiency at which a drill bit will cut sideways. The typical range for roller bits is 20-80, 80 being used for soft formation bits and 20 for hard formation bits. A bit coefficient of 0 means the bit does not cut sideways.

- **Formation Hardness:**

The formation hardness is a number between 0 and 60 which is used in the lateral ROP model to resist the bit side cutting capability.

- **Rate of Penetration:**

The rate of penetration is the speed at which the drillstring is drilling the hole.

3.11 Bottom Hole Assembly Analysis Explanation:

3.11.1 Static Bottom Hole Assembly:

First the current position of the bottom hole assembly will be analyzed. We will investigate the position of the bottom hole assembly in the wellbore and we will determine the side forces acting on the bottom hole assembly where it is in contact with the wellbore. The results of the modelling process can be displayed in the following two forms**: (Landmark Wellplan user manual, 2000).**

3.11.1.1 Plots:

Two plots are available for analysis. The Displacement plot allows you to determine how the bottom hole assembly is lying in the wellbore. The Side Force plot tells you the side force acting on the bottom hole assembly as it lies in the wellbore.

- **Displacement Plot:**

It displays the displacement from the centerline versus distance from bit. Three measures of displacement are used:

- **Inclination:** the displacement of the analyzed portion of the drillstring from the wellbore centerline in the inclination plane.
- **Directional:** the displacement of the analyzed portion of the drillstring from the wellbore centerline in the direction plane.
- **Clearance:** the displacement of the analyzed portion of the drillstring from the wellbore centerline.
- **Side Force Plot:**

This plot displays the calculated side force (at each node analyzed) versus distance from bit. This information is also displayed in table form in the BHA Forces section of the report.

3.11.1.2 Reports:

The BHA report contains information regarding the forces acting the bottom hole assembly and the resulting displacements. The BHA report provides information concerning the forces acting on each element and node as well. BHA report answers questions like:

1- What is Happening at the Bit?

2- What are the Forces Acting on the Bottom Hole Assembly?

3- Where is the Bottom Hole Assembly Located in the Wellbore?

4- What are the Stresses at Each Node?

5- What is the Inclination and Azimuth of the Drillstring or Wellbore?

3.11.2 Drillahead Bottom Hole assembly:

The drillahead analysis is useful in the planning stages, as well as during the operational stages. Drillahead analysis can be used to predict the directional behavior of a bottom hole assembly during the planning stages. Drillahead analysis makes it possible to study the effects of various components, including bent assemblies, collar sizes, stabilizer placement, hole enlargement, and component wear. During well operations, drillahead analysis can be used to adjust operating parameters to optimize performance.

The drillahead analysis first performs the same analysis as in the static analysis. The program then drills ahead in 5-foot increments to predict the bottom hole assembly behavior over the user specified drillahead interval. Data is presented on the reports in increments specified by the user.

The report generated for the drillahead analysis is similar to the static analysis except that information for a user specified drillahead interval is included. The results of the modelling process of drillahead scenario are the same as those available for the static analysis discusses previously. (Landmark Wellplan user manual, 2000).

Chapter Four

BHA Analysis, Results and Discussion

Bottom hole assembly (BHA) is a component of a drill string that used to drill oil and gas wells. A BHA resides in the drill string above the drill bit and below the drill pipe.

4.1 Input Data into Landmark-Wellplan:

The data entered into Landmark-Wellplan can be divided into two groups:

1- General data that can be used by all other modules.

2- Specific data that can be used by the BHA module alone.

Each of these groups is reviewed in details in the following paragraphs.

4.1.1 Well X Data:

4.1.1.1 General:

In this section inputting the general well data such as origin N, E, azimuth, well depth MD and reference point is inputted.

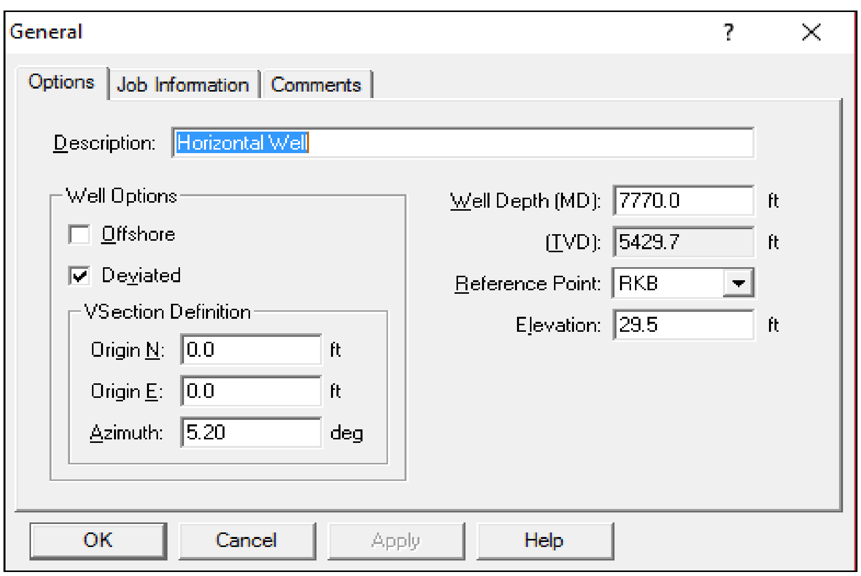

Fig.4.1: Well X General Data (Landmark-Wellplan).

4.1.1.2 String Editor:

String and BHA data can be inputted in the string editor. It includes the outer diameter, yield strength, torsional strength and weight.

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Wellbore Editor

Well Depth (MD): 7770.0 ft

	Section Type	Depth (ft)	Length (ft)	ID (in)	Drift (in)	Effective Hole Diameter (in)	Friction Factor	Volume Excess (%)	Catalog Summary
1	Casing	6760.0	6760.00	8.835	8.750	12.250	0.00		CAS 9 5/8 in, 40.00 ppf, K55, BTC
2	Open Hole	7770.0	1010.00	8.835		8.500	0.00	0.00	
3									

Fig.4.2: Well X Wellbore Editor (Landmark-Wellplan).

String Editor

String Initialization

String Type: Drill String String Depth: 7766.9 ft Specify: Top to Bottom

	Section Type	Length (ft)	Depth (ft)	OD (in)	ID (in)	Weight (ppf)	Catalog Description
1	Drill Pipe	4314.62	4314.6	5.000	4.276	22.60	DP 5 in, 19.50 ppf, S, NC50(XH), 1
2	Heavy Weight	542.00	4856.6	5.000	3.000	49.70	HW Grant Prideco, 5 in, 49.70 ppf
3	Drill Pipe	2797.00	7653.6	5.000	4.276	23.40	DP 5 in, 19.50 ppf, S, 5 1/2 FH, 1
4	Heavy Weight	30.00	7683.6	5.000	3.000	49.70	HW Grant Prideco, 5 in, 49.70 ppf
5	Jar	18.80	7702.4	6.500	2.750	91.79	JRH Dailey Hyd., 6 1/2 in
6	Heavy Weight	30.50	7732.9	5.000	3.000	49.14	HW SMFI, 5 in, 49.14 ppf
7	Drill Collar	30.00	7762.9	6.500	3.000	88.86	DC 6 1/2 in, 3 in,
8	Sub	3.00	7765.9	6.720	3.000	97.72	XO 6 3/4, 6 3/4 x3 in
9	Bit	1.00	7766.9	8.500			
10							

Fig.4.3: Well X String Editor (Landmark-Wellplan)

String Editor

String Initialization

String Type: Drill String | String Depth: 7766.9 ft | Specify: Top to Bottom

	Section Type	Length (ft)	Depth (ft)	OD (in)	ID (in)	Weight (ppf)	Catalog Description
1	Drill Pipe	4312.62	4312.6	5.000	4.276	22.60	DP 5 in, 19.50 ppf, S, NC50(XH), 1
2	Heavy Weight	542.00	4854.6	5.000	3.000	49.70	HW Grant Prideco, 5 in, 49.70 ppf
3	Drill Pipe	2797.00	7651.6	5.000	4.276	23.40	DP 5 in, 19.50 ppf, S, 5 1/2 FH, 1
4	Heavy Weight	30.00	7681.6	5.000	3.000	49.70	HW Grant Prideco, 5 in, 49.70 ppf
5	Jar	18.80	7700.4	6.500	2.750	91.79	JRH Dailey Hyd., 6 1/2 in
6	Heavy Weight	30.50	7730.9	5.000	3.000	49.14	HW SMFI, 5 in, 49.14 ppf
7	Drill Collar	30.00	7760.9	6.500	3.000	88.86	DC 6 1/2 in, 3 in,
8	Stabilizer	5.00	7765.9	4.250	2.000	37.59	NBS 6 1/2" FG, 4 1/4 x2 in
9	Bit	1.00	7766.9	8.500			
10							

Fig.4.4 Well X String Editor First scenario (Landmark-Wellplan).

String Editor

String Initialization

String Type: Drill String | String Depth: 7766.9 ft | Specify: Top to Bottom

	Section Type	Length (ft)	Depth (ft)	OD (in)	ID (in)	Weight (ppf)	Catalog Description
1	Drill Pipe	4307.62	4307.6	5.000	4.276	22.60	DP 5 in, 19.50 ppf, S, NC50(XH), 1
2	Heavy Weight	542.00	4849.6	5.000	3.000	49.70	HW Grant Prideco, 5 in, 49.70 ppf
3	Drill Pipe	2797.00	7646.6	5.000	4.276	23.40	DP 5 in, 19.50 ppf, S, 5 1/2 FH, 1
4	Heavy Weight	30.00	7676.6	5.000	3.000	49.70	HW Grant Prideco, 5 in, 49.70 ppf
5	Jar	18.80	7695.4	6.500	2.750	91.79	JRH Dailey Hyd., 6 1/2 in
6	Heavy Weight	30.50	7725.9	5.000	3.000	49.14	HW SMFI, 5 in, 49.14 ppf
7	Stabilizer	5.00	7730.9	4.250	2.000	37.59	IBS 6 1/4" FG, 4 1/4 x2 in
8	Drill Collar	30.00	7760.9	6.500	3.000	88.86	DC 6 1/2 in, 3 in,
9	Stabilizer	5.00	7765.9	4.250	2.000	37.59	NBS 6 1/4" FG, 4 1/4 x2 in
10	Bit	1.00	7766.9	8.500			
11							

Fig.4.5: Well X String Editor Second Scenario (Landmark-Wellplan).

4.1.1.3 Well X Survey Editor:

Survey Editor

Identification

Name: ABMO-1 Description: Horizontal Well

	MD (ft)	INC (deg)	AZ (deg)	TVD (ft)	DLS (deg/100ft)	AbsTort (deg/100ft)	RelTort (deg/100ft)	VSect (ft)	North (ft)	East (ft)	Build (deg/100ft)	Walk (deg/100ft)
11	984.3	0.00	5.20	984.3	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
12	1082.7	0.00	5.20	1082.7	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
13	1181.1	0.00	5.20	1181.1	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
14	1279.5	0.00	5.20	1279.5	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
15	1378.0	0.00	5.20	1378.0	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
16	1476.4	0.00	5.20	1476.4	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
17	1574.8	0.00	5.20	1574.8	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
18	1673.2	0.00	5.20	1673.2	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
19	1771.7	0.00	5.20	1771.7	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
20	1870.1	0.00	5.20	1870.1	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
21	1968.5	0.00	5.20	1968.5	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
22	2066.9	0.00	5.20	2066.9	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
23	2165.4	0.00	5.20	2165.4	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
24	2263.8	0.00	5.20	2263.8	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
25	2362.2	0.00	5.20	2362.2	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
26	2460.6	0.00	5.20	2460.6	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
27	2559.1	0.00	5.20	2559.1	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
28	2657.5	0.00	5.20	2657.5	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
29	2755.9	0.00	5.20	2755.9	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
30	2854.3	0.00	5.20	2854.3	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
31	2952.8	0.00	5.20	2952.8	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
32	3051.2	0.00	5.20	3051.2	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
33	3149.6	2.40	5.20	3149.6	2.44	0.08	0.00	2.1	2.1	0.2	2.44	0.00
34	3248.0	4.80	5.20	3247.8	2.44	0.15	0.00	8.2	8.2	0.7	2.44	0.00
35	3346.5	7.20	5.20	3345.7	2.44	0.22	0.00	18.5	18.5	1.7	2.44	0.00
36	3387.4	8.20	5.20	3386.2	2.44	0.24	0.00	24.0	23.9	2.2	2.44	0.00
37	3416.5	8.20	5.20	3415.1	0.00	0.24	0.00	28.2	28.1	2.6	0.00	0.00
38	3444.9	8.89	5.21	3443.1	2.43	0.26	0.00	32.4	32.2	2.9	2.43	0.04
39	3543.3	11.29	5.22	3540.0	2.44	0.32	0.00	49.6	49.4	4.5	2.44	0.01
40	3641.7	13.69	5.22	3636.1	2.44	0.38	0.00	70.9	70.6	6.4	2.44	0.00
41	3740.2	16.09	5.23	3731.2	2.44	0.43	0.00	96.2	95.8	8.7	2.44	0.01

Fig.4.6: Well X Survey Editor (Landmark-Wellplan).

4.1.1.4 Wellbore Editor:

Wellbore editor enables the user to input the wellbore information for casing and open hole such as Length, internal diameter, ID. The classification of each section type on the table sheet above has been followed up by Catalogue format divided by Nominal Diameter, Weight and Grade by API Casing/Tubing Catalogue database.

The purpose of using this spread sheet is to define the wellbore profile and inner configuration of the well. Entering the hole section information from surface down to the bottom of the well.

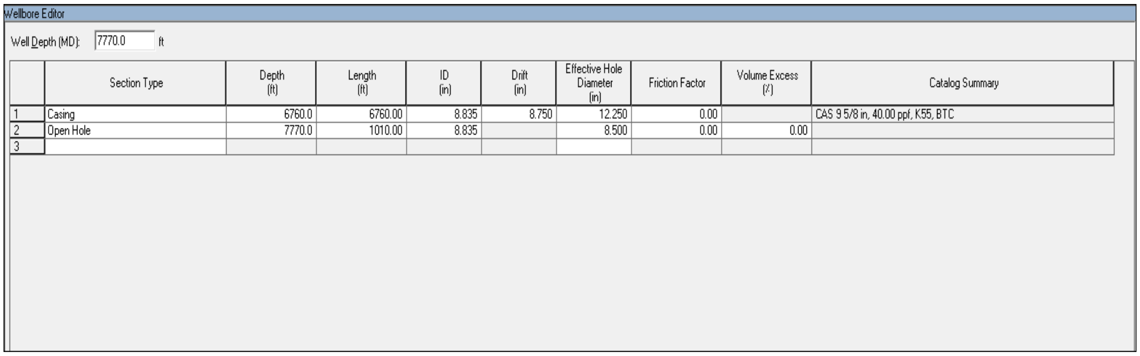

Fig.4.7: Well X Wellbore Editor (Landmark-Wellplan).

4.1.1.5 Fluid Editor:

Fluid editor options enable the user to input the fluid used in the drilling such as: rheology properties, mud base and other mud properties.

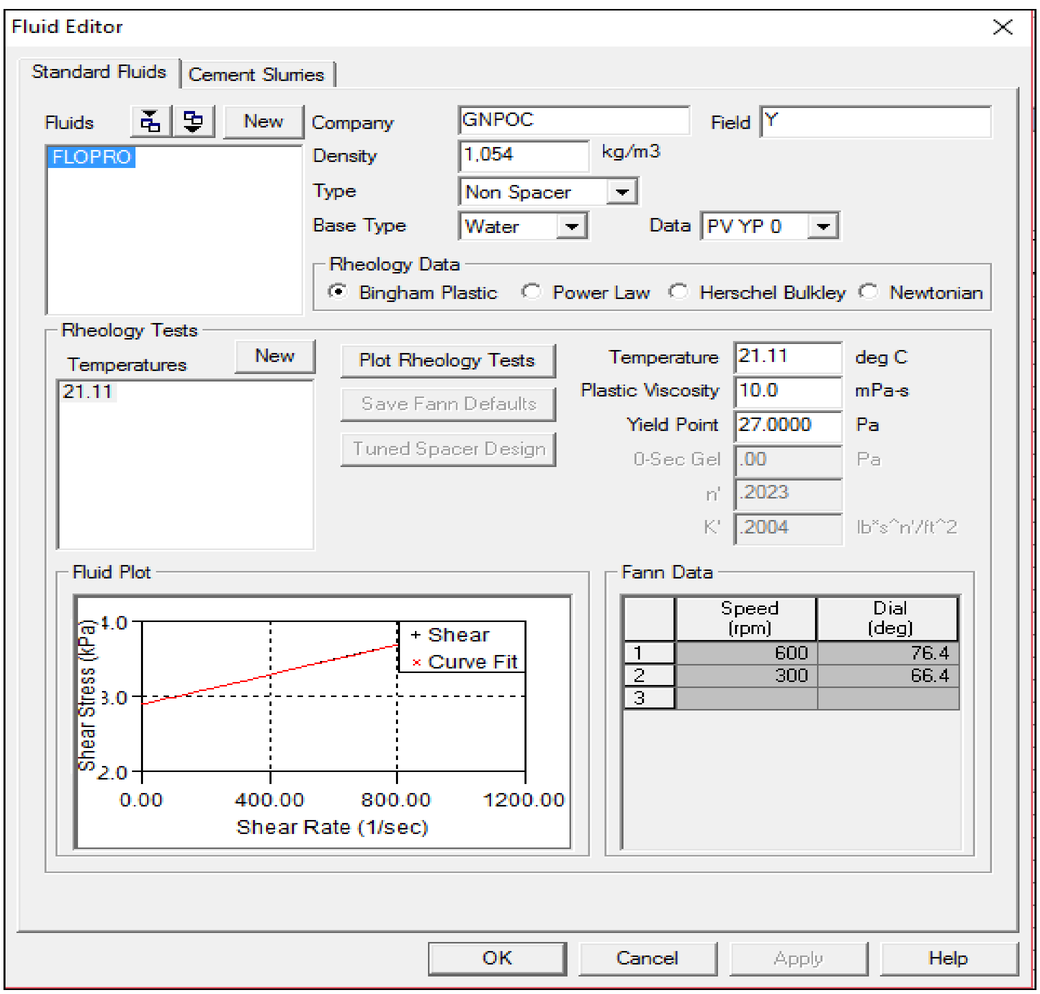

Fig.4.8: Well X Fluid Editor (Landmark-Wellplan).

4.1.1.6 Rotary Speed:

Type the rotating speed of the drillstring and bit once steady state conditions are reached. For rotary assemblies, type the rotating speed of the drillstring. For hydraulic motor assemblies where the drillpipe does not turn, type the rotating speed of the bit.

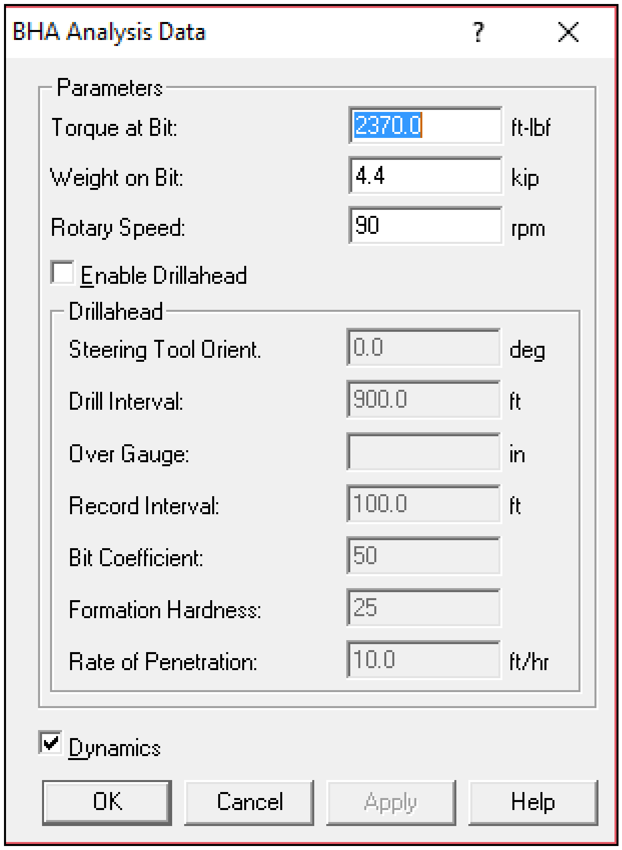

Fig. 4.9: Static BHA Condition Analysis (Landmark-Wellplan).

4.2 8 ½ Main Hole Section BottomHole Assembly Analysis Results:

4.2.1 Well X Description:

As mentioned previously, the well X is a horizontal well located in field Y. The well start vertically with a kick off point of approximately 3048ft MD and a first build section from kick off point to 3386ft MD. From this depth the second build section starts to build the angle from 8.2° to 90° at 6780ft MD. Then a horizontal section starts from 6780ft MD to TD i.e. 7767ft MD. The following plots show the vertical section, inclination, azimuth and dog leg severity (DLS).

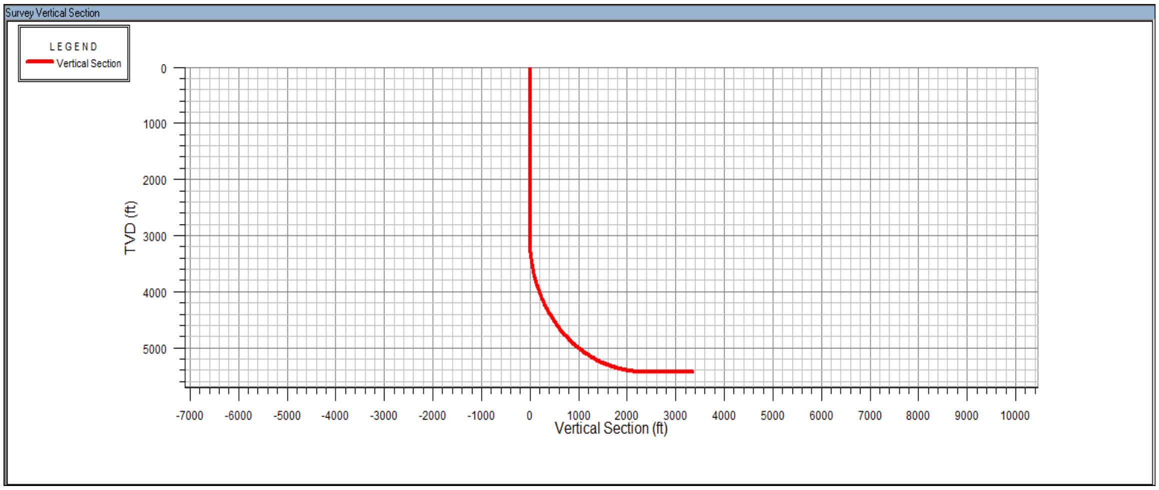

Fig.4.10: Well X Vertical Section (Landmark-Wellplan).

As can be seen in Fig. 4.1, well X vertical section starts from approximately 3100 ft MD where the well start the first kick off and continue to increase.

figure Bellow shows the Well X inclination. Start to increase from 3100 ft MD till reach the value of 90 degrees at 6200 ft MD.

The figure 4.11 shows the Well X Azimuth. The figure indicates the change in well direction. It starts to increase from a value of 5.2 degrees at depth 3400 ft MD and continues to increase till reach 8.8 degrees at TD

Well X inclination:

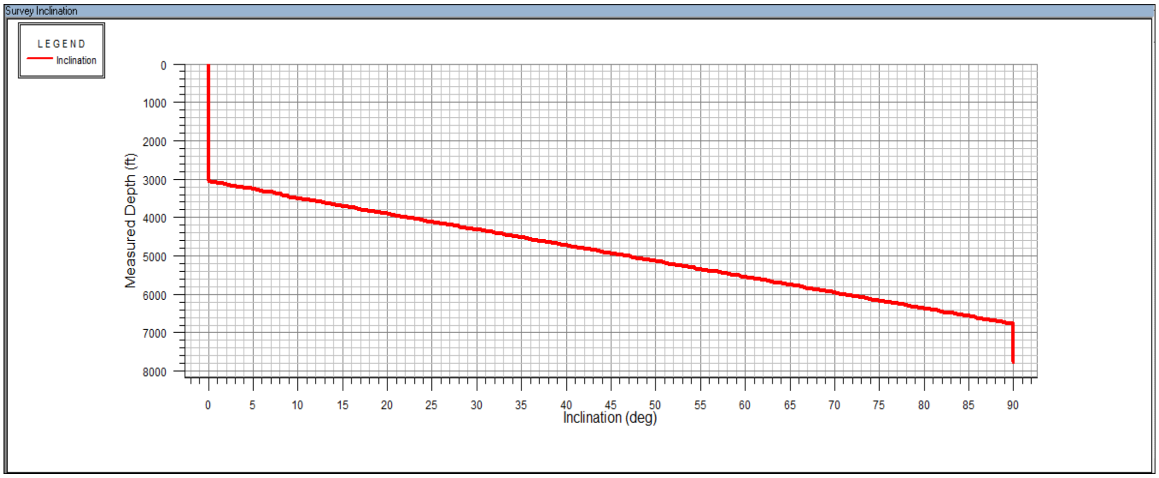

Fig.4.11: Well X Inclination (Landmark-Wellplan).

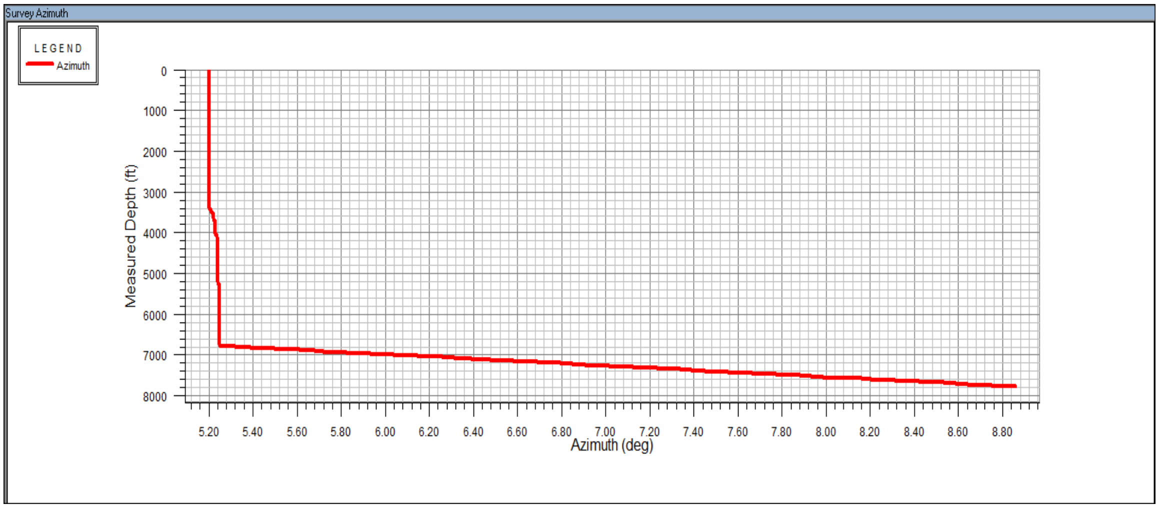

Fig.4.12: Well X Azimuth (Landmark-Wellplan).

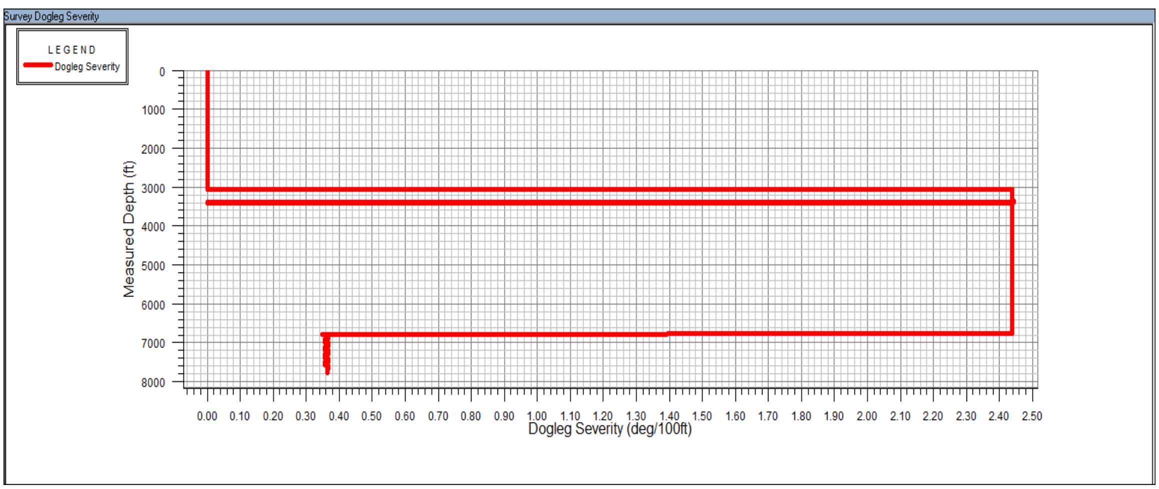

Fig.4.13: Well X DLS (Landmark-Wellplan).

The figures4.12 and 4.13 show the Well X DLS. The maximum value is approximately 2.4 deg/100ft which is within the safe limit.

4.2.2 Slick Bottom Hole Assembly Analysis: (No stabilizer in this BHA)

4.2.2.1 Analyzing Static Bottom Hole Assembly:

4.2.2.1.1 Displacement Plot:

The Displacement Plot shows the displacement from the centerline versus distance from bit. Three measures of displacement are used:

Figure 4.14 shows the displacement plot during static mode analysis. Inclination curve lies in the negative portion of the plot which indicates that the inclination is toward the low side of the well. Direction curve can be considered constant with small changes between negative and positive portions of the plot which indicates small changes in direction from right side to the left side.

Clearance curve shows the distance between the string and the well. It can be seen that near the bit the distance between string and well is small due to presence of large diameter components. The largest value for clearance is more than one inch at a distance of approximately 500 ft from the bit which is the distance between the well and the drill pipe.

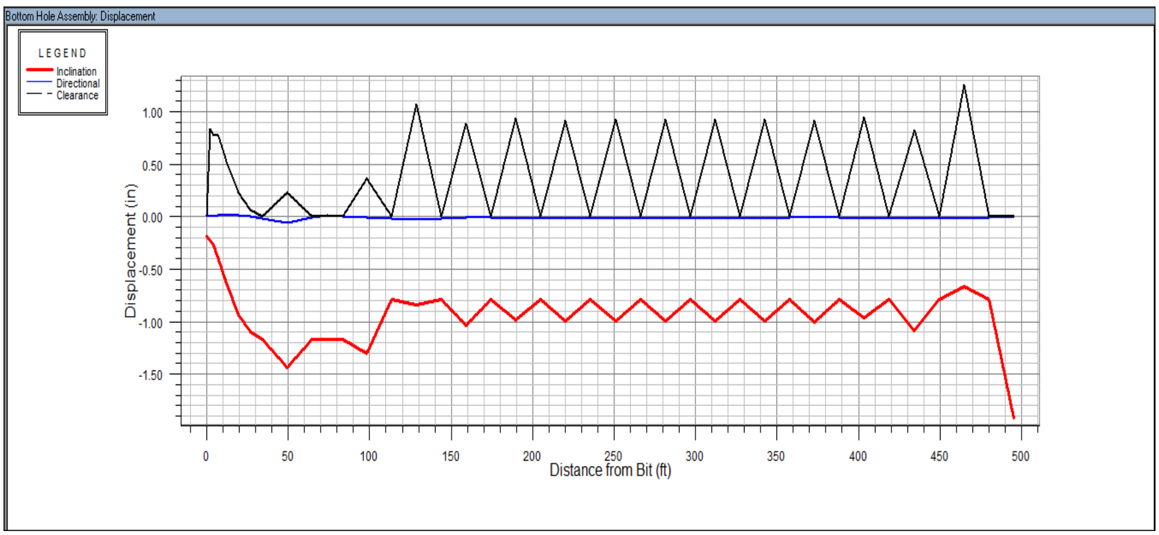

Fig.4.14: Well X 8 ½ Section Static Mode Displacement Plot (Landmark-Wellplan).

4.2.2.1.2 Side Force:

Fig.4.15 displays the calculated side force (at each node analyzed) versus distance from bit. Normally, the maximum side force is at the bit.

Figure below shows side force during static condition. At distance 40ft from the bit the side force is approximately 1650 Lbf due to presence of large diameter components near the bit i.e. drill collars. Side force decrease between 100 and 450 ft from the bit due to presence of drill pipe and then start to increase again at 500 ft from the bit.

It should be noted that positive side force indicates building angle while negative side force indicates dropping angle.

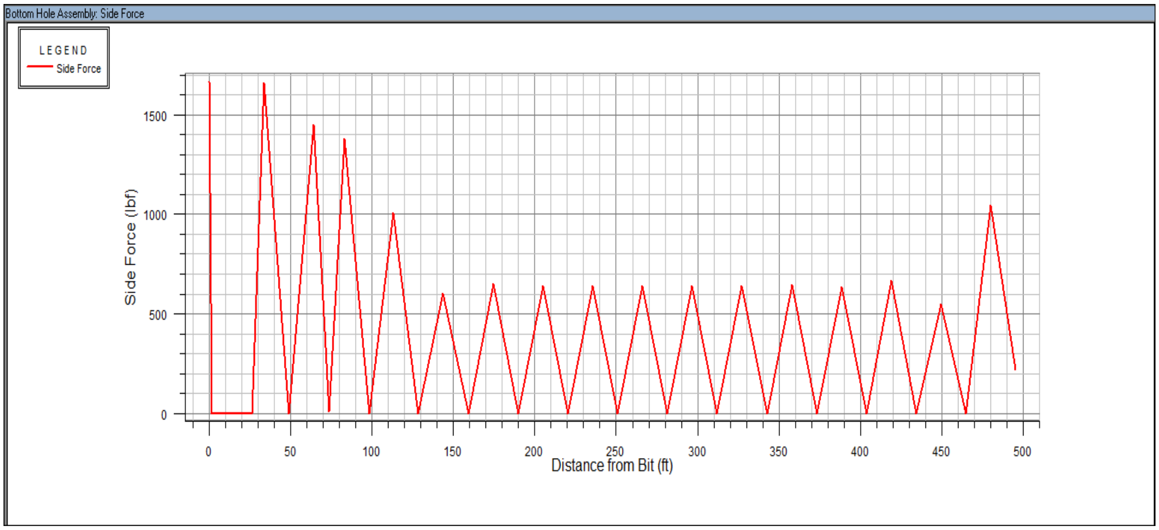

Fig.4.15: Well X 8 ½ Section Static Mode Side Force Plot (Landmark-Wellplan).

4.2.2.1.3 Report:

The BHA report contains information regarding the forces acting on the bottom hole assembly and the resulting displacements. The BHA report provides information concerning the forces acting on each element and node as well.

BHA report consists of several parts or sections as following:

- Survey points indicate the depth, inclination, direction, build, walk and DLS for various points along the wellbore.
- BHA report includes a section that indicates the bit condition in both the inclination and direction planes. The positive and negative values have a certain meaning. Positive direction indicates the right direction while negative direction indicates the left direction. Positive inclination indicates the high side of the well while the negative inclination indicates the low side of the well. Positive side force indicates building angle while negative side force indicates dropping angle.

- BHA report also shows the forces acting on the bottom hole assembly. Force information is useful in determining where the bottom hole assembly is in contact with the wellbore along with the corresponding side force at the contact point, the contact points are normally at the large diameter parts of the string,. This can be helpful if an assembly is not building or dropping as expected. Perhaps there is no contact between stabilizers for a build assembly, or the contact point is not in the proper location. The BHA Forces information may also be useful in determining areas where casing wear may become a problem.
- BHA report also shows the location of BHA in the wellbore or how the bottom hole assembly is lying in the wellbore. This information can also be gained from the displacement plot.
- BHA report shows the resultant wellbore angle and direction change for the BHA.

With reference to the following 81/2 main hole section static BHA report, the following notes can be drown out:

In terms of contact points, there are 19 contact points within the lower 480 ft of the drill string between the drill string and the wellbore since there is no stabilizer in this BHA.

In terms of the resultant angle,

- The string inclination at the bit is 90.1 degrees.
- The string inclination at distance 12 ft from the bit is 90.2 degrees.
- The string inclination at distance 464 ft from the bit is 89.9 degrees.

In terms of the contact forces,

- The maximum contact force is at the bit and equals 1664 Ibf and this is due to the fact that there are no stabilizers in this BHA configuration that can reduce the contact forces at the bit.
- At distance 34 ft from the bit i.e. at the end of drill collars, the contact force is 1659 Ibf.
- At distance 64 ft from the bit i.e. at the end of heavy weight drill pipe, the contact force is 1448 Ibf.

- At distance 480 ft from the bit i.e. within the drill pipe region, the contact force is 1046 Ibf

4.2.2.2 Analyzing Drill ahead Bottom Hole Assembly:

Figure below shows displacement plot during drill ahead mode. Inclination Curve changes between negative and positive portions of the plot which indicate the inclination changes from low side to high side of the well during drilling using this BHA configuration. Change in direction curve between negative and positive portions of the plot indicate that the bit direction change from right direction to the left direction. Clearance curve is approximately constant except for the distance near the bit.

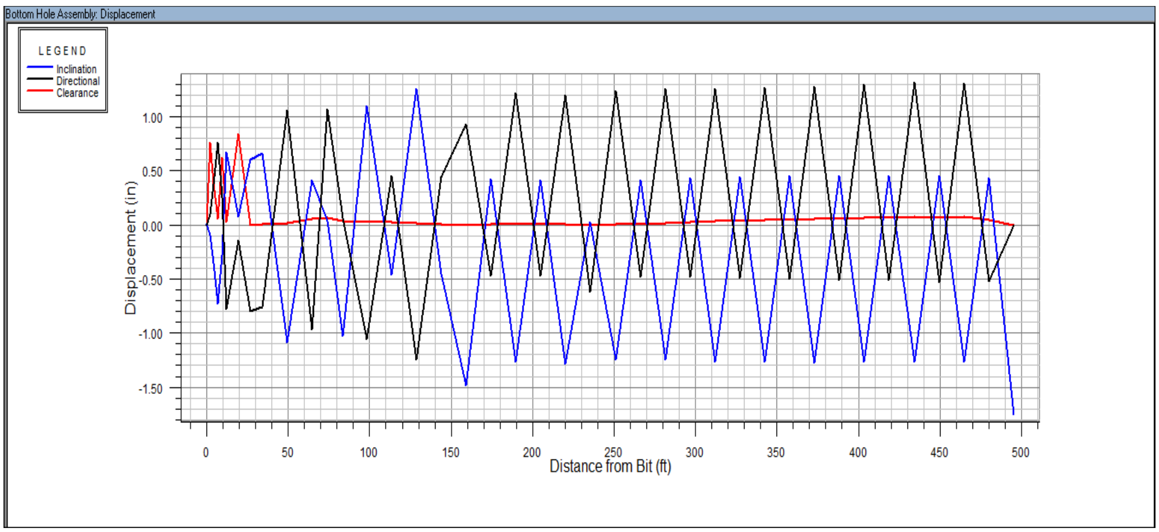

Fig.4.16: Well X 8 ½ Section Drillahead Mode Displacement Plot (Landmark-Wellplan).

4.2.2.2.1 Side Force Plot:

The side force plot below shows side forces during drilling using this BHA configuration, drillahead mode, It can be noticed that the side forces are high compared to those obtained during static mode and this is may be due to the fact the BHA is drilling in this case and not static.

At distance 70 ft from the bit the side force is high approximately 80000 Ibf. Side force decrease at distance 160 ft and 240 ft from the bit. The highest side force value is at distance 440 ft from the bit and equals more than 120000 Ibf. Side force is positive which indicates building angle.

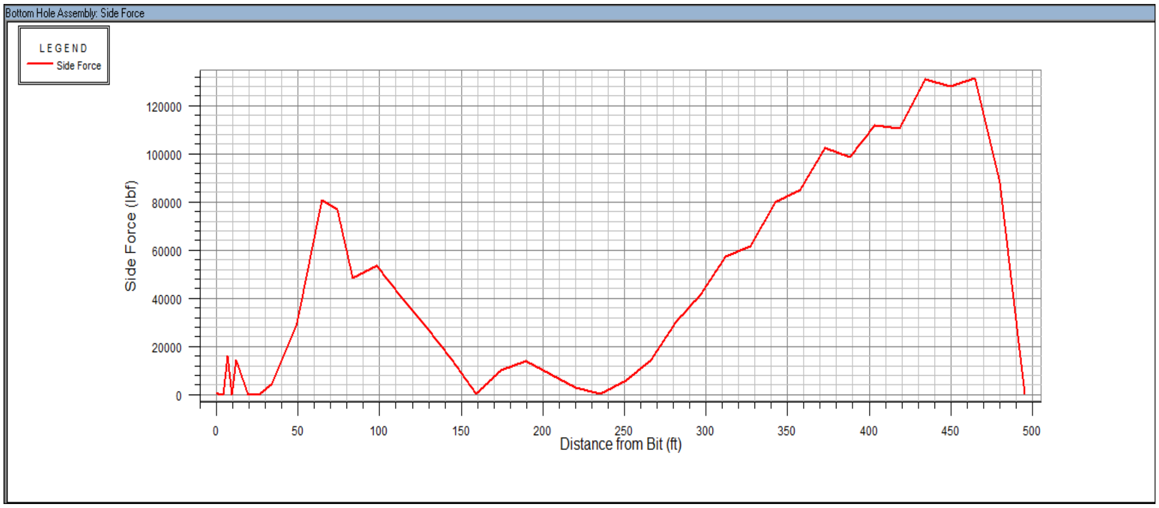

Fig.4.17: Well X 8 ½ Section Drillahead Mode Side Force Plot (Landmark-Wellplan).

4.2.3 Case Study I

First Scenario:8 ½ Main Hole Section Bottom Hole Assembly Analysis.(One stabilizer - added near the bit).

4.2.3.1 Analyzing Static Bottom Hole Assembly:

4.2.3.1.1Displacement Plot:

Figure below shows the displacement plot during static mode analysis for the modified BHA - first scenario. Inclination curve lies in the negative portion of the plot which indicates that the inclination is toward the low side of the well. Direction curve can be considered constant with small changes between negative and positive portions of the plot which indicates small changes in direction from right side to the left side.

Clearance curve shows the distance between the string and the well. It can be seen that near the bit the distance between string and well is less than one inch. The largest value for clearance is more than one inch at a distance of approximately 130 ft from the bit which is the distance between the well and the drill pipe

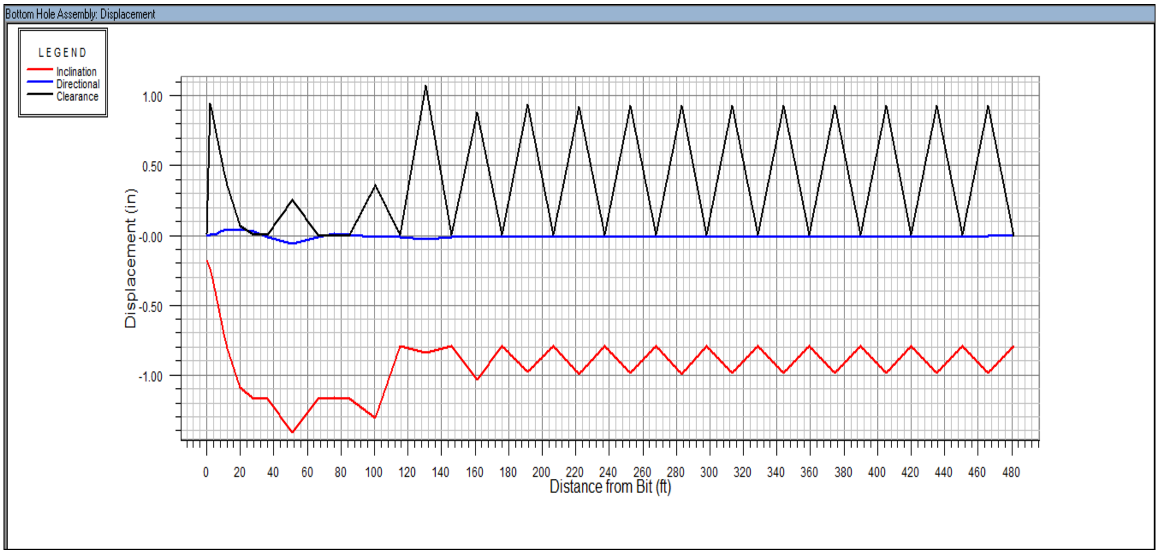

Fig.4.18: Well X 8 ½ Section Static Mode Displacement Plot – First Scenario (Landmark-Wellplan).

4.2.3.1.2Side Force Plot:

Figure below shows side force during static condition for the modified BHA - first scenario. It can be noticed that the side force at the bit is not the largest value in this case and the largest value is at distance of 40ft from the bit, the side force is approximately more than 1400 Ibf due to the fact that one stabilizer is added near the bit and due to presence of large diameter components near the bit i.e. drill collars. Side forces continue to increase and reach the highest value at the end of each drill string component within the first 120 ft of the string. Side force decrease between 130 and 480 ft from the bit due to presence of drill pipe.

Positive side force indicates building angle.

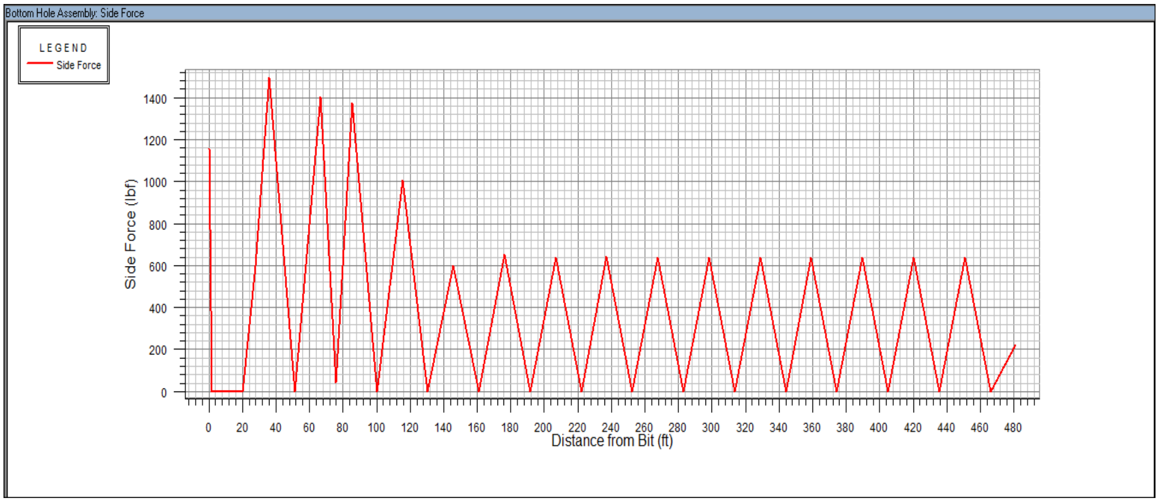

Fig.4.19: Well X 8 ½ Section Static Mode Side Force Plot – First Scenario (Landmark-Wellplan).

4.2.3.1.3Report:

With reference to the following 81/2 main hole section static BHA report, the following notes can be drown out:

In terms of contact points, there are 19 contact points within the lower 480 ft of the drill string between the drill string and the wellbore since there is near the bit stabilizer in this BHA. These contact points are different in location than those obtained from the previous BHA configuration.

In terms of the resultant angle,

- The string inclination at the bit is 90.1 degrees.
- The string inclination at distance 10 ft from the bit is 90.3 degrees.
- The string inclination at distance 481 ft from the bit is 90 degrees.

In terms of the contact forces,

- The contact force at the bit equals 1158 Ibf and it can be seen that it is not the maximum contact force in this case and this is due to the fact that there is near bit stabilizer in this BHA configuration that causes the contact forces at the bit to be reduced.
- At distance 36 ft from the bit i.e. at the end of drill collars, the contact force is 1495 Ibf.

- At distance 66 ft from the bit i.e. at the end of heavy weight drill pipe, the contact force is 1403 Ibf.
- At distance 480 ft from the bit i.e. within the drill pipe region, the contact force is 219 Ibf.

It can be seen that the presence of the near bit stabilizer reduces the contact forces at the bit, drill collar, heavy weight drill pipe, and drill pipe.

4.2.3.2 Analyzing Drill ahead Bottom Hole Assembly:

4.2.3.2.1Displacement Plot:

Figure below shows displacement plot during drill ahead mode for the modified BHA – first scenario. Inclination Curve changes between negative and positive portions of the plot which indicate the inclination changes from low side to high side of the well during drilling using this BHA configuration. Change in direction curve between negative and positive portions of the plot indicate that the bit direction change from right direction to the left direction. Clearance curve is approximately constant except for the distance near the bit and 250 ft from the bit.

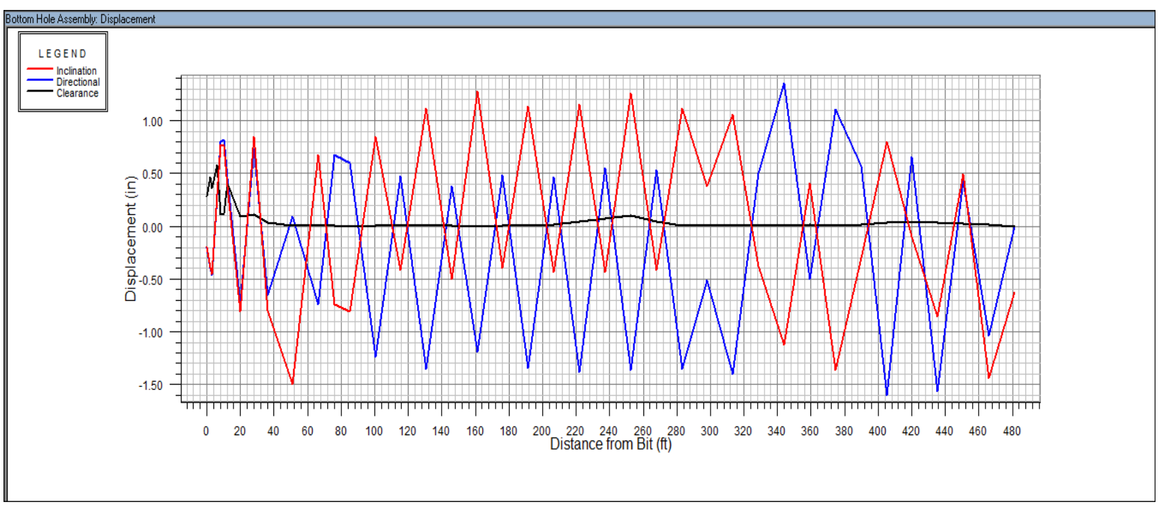

Fig.4.20: Well X 8 ½ Section Drillahead Mode Displacement Plot – First Scenario (Landmark-Wellplan).

4.2.3.2.2Side Force Plot:

The side force plot below shows side forces during drilling using this BHA configuration, drillahead mode. It can be noticed that the side forces curve for drillahead mode is different in shape from static mode side force curve.

At the bit, the side force is approximately 35000 Ibf and it is not the highest value due to presence of a near bit stabilizer. 30 ft from the bit i.e. at the drill collars the side force is more than 110000 Ibf. The highest side force value is at the drill pipe region 250 ft from the bit which is approximately equals to 195000 Ibf.

It should be noted that the highest side force values in drillahead mode compared to static mode are due to the fact that the BHA is drilling i.e. dynamic condition.

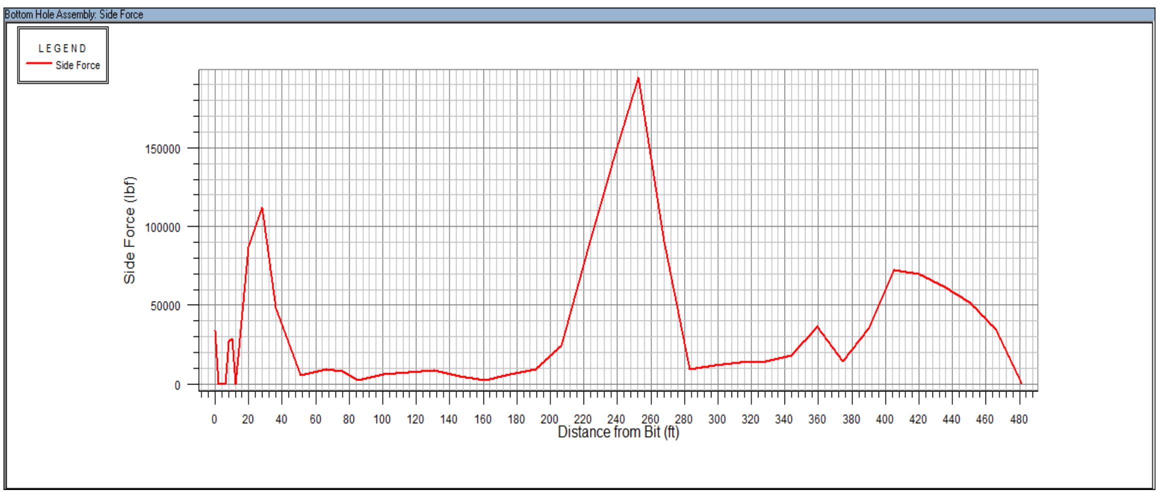

Fig.4.21: Well X 8 ½ Section Drillahead Mode Side Force Plot – First Scenario (Landmark-Wellplan).

4.2.4 Case Study II

Second Scenario:8 ½ Main Hole Section Bottom Hole Assembly Analysis. (Two stabilizers are added near the bit).

4.2.4.1 Analyzing Static Bottom Hole Assembly:

4.2.4.1.1Displacement Plot:

Figure below shows the displacement plot during static mode analysis for the modified BHA - second scenario. Inclination curve lies in the negative portion of the plot which indicates that the inclination is toward the low side of the well. Direction curve can be considered constant with small changes between negative and positive portions of the plot which indicates small changes in direction from right side to the left side.

Clearance curve shows the distance between the string and the well. It can be seen that near the bit the distance between string and well is approximately one inch. The largest value for clearance is approximately 1.3 inch at a distance of approximately 410 ft from the bit which is the distance between the well and the drill pipe.

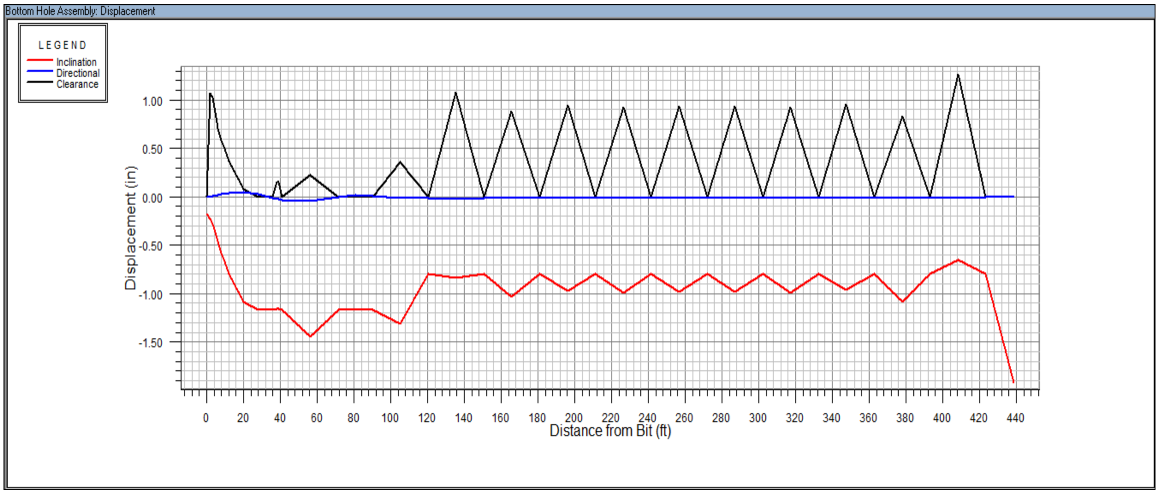

Fig.4.22: Well X 8 ½ Section Static Mode Displacement Plot – Second Scenario (Landmark-Wellplan).

4.2.4.1.2 Side Force Plot:

Figure below shows side force during static condition for the modified BHA - second scenario. It can be noticed that the side force at the bit is not the largest value in this case the side force at the bit is approximately more than 1150 Ibf due to the fact that one stabilizer is added near the bit and another stabilizer is added between the drill collar and heavy weight drill pipe.

The largest side force value is at distance of 75 ft from the bit heavy weight drill pipe region and equals to 1450 Ibf. Side forces are approximately constant between 140 and 410 ft from the bit at 600 Ibf and continue to increase again at 430 ft from the bit.

Positive side force indicates building angle.

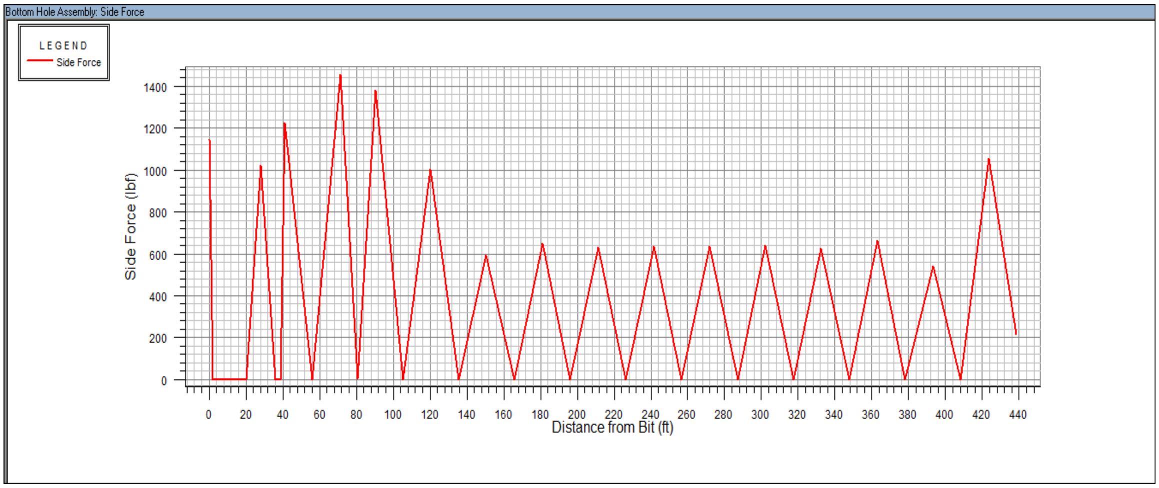

Fig.4.23: Well X 8 ½ Section Static Mode Side Force Plot – Second Scenario (Landmark-Wellplan).

4.2.4.1.2 Report:

With reference to the following 81/2 main hole section static BHA report, the following notes can be drown out:

In terms of contact points, there are 18 contact points within the lower 480 ft of the drill string between the drill string and the wellbore since there are two stabilizers in this BHA configuration. Presence of stabilizers causes the contact points number to decrease.

In terms of the resultant angle,

- The string inclination at the bit is 90.1 degrees.
- The string inclination at distance 10 ft from the bit is 90.3 degrees.
- The string inclination at distance 438 ft from the bit is 90 degrees.

In terms of the contact forces,

- The maximum contact force equals 1455 Ibf at distance 71 ft from the bit in the end of heavy weight drill pipe. It should be noted that the maximum contact force is not at the bit and this is due to the fact that there are two stabilizers in this BHA configuration that reduce the contact forces at the bit. The contact force at the bit equals 1145 Ibf.

  At distance 28 ft from the bit i.e. at the end of drill collars, the contact force is 1022 Ibf.

- At distance 71 ft from the bit i.e. at the end of heavy weight drill pipe, the contact force is 1455 Ibf.
- At distance 423 ft from the bit i.e. within the drill pipe region, the contact force is 1055 Ibf.

It can be clearly seen that the contact forces decrease due to presence of two stabilizers in this BHA configuration that cause the contact points between the drill string and BHA to decrease.

4.2.4 .2 Analyzing Drill ahead Bottom Hole Assembly:

4.2.4 .2.1 Displacement Plot:

Figure below shows displacement plot during drillahead mode for the modified BHA – second scenario. Inclination Curve changes between negative and positive portions of the plot which indicate the inclination changes from low side to high side of the well during drilling using this BHA configuration. Change in direction curve between negative and positive portions of the plot indicate that the bit direction change from right direction to the left direction. Clearance curve is approximately constant except for the distance near the bit from 0 to 40 ft from the bit and 350 ft from the bit.

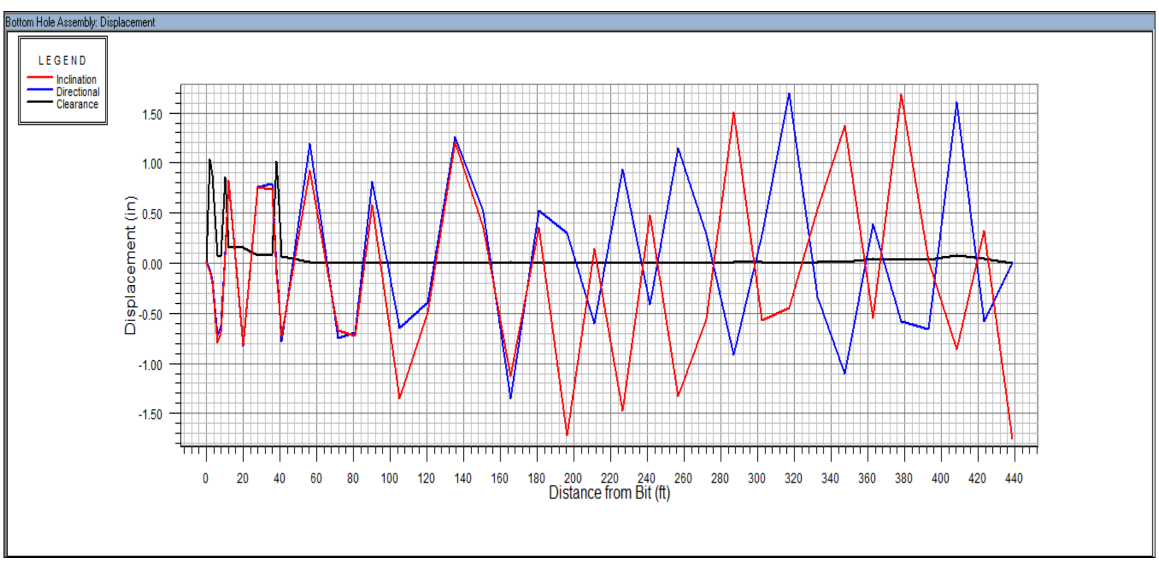

Fig.4.24: Well X 8 ½ Section Drill ahead Mode Displacement Plot – Second Scenario (Landmark-Well plan).

4.2.4 .2.2 Side Force Plot:

Figure below shows the side force plot during drilling using this BHA configuration, drillahead mode.

At the bit, the side force is low compared to above cases. At the center of drill collars, i.e at distance equals 20 ft from the bit, the side force is more than 140000 Ibf and it is the highest value in this case. The side force continue to decrease between 40 ft to 340 ft and starts to rise again and reach the value of 135000 Ibf at distance 410 ft from the bit, i.e. at the drill pipe region.

It should be noted that the highest side force values in drillahead mode compared to static mode are due to the fact that the BHA is drilling i.e. dynamic condition.

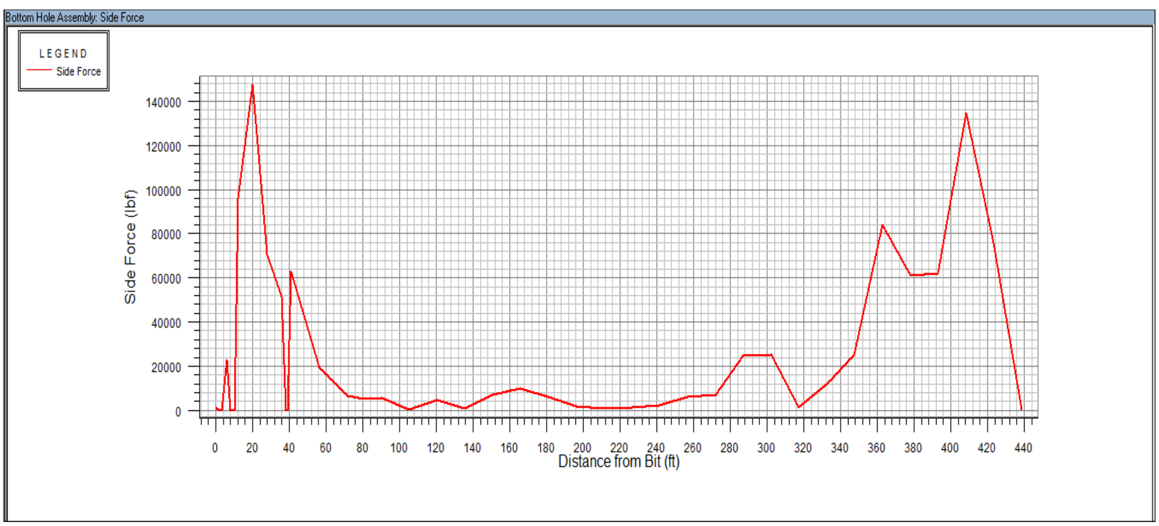

Fig.4.25: Well X 8 ½ Section Drillahead Mode Side Force Plot – Second Scenario (Landmark-Wellplan).

4.2.5 Analysis Results for Studied cases:-

4.2.5.1 Slick Bottom Hole Assembly Analysis:

(No stabilizer in this BHA):-

Table.4.1: Slick Bottom Hole Assembly Analysis Results

contact points	19point
The string inclination at distance 12 ft from the bit	90.2 degree
The **maximum** contact force is at the bit	1664 Ibf
the contact force (At distance 480 ft from the bit)	1659 Ibf.
the contact force (At distance 64 ft from the bit)	1448 Ibf.
the contact force (At distance 480 ft from the bit)	1046 Ibf.

4.2.5.2 First Design: (One stabilizer is added near the bit).

Table.4.2: First Design (Bottom Hole Assembly Analysis Results)

contact points	19point
The string inclination at distance 10 ft from the bit	90.3 degree
The contact force is at the bit	1158 Ibf
the contact force (At distance 480 ft from the bit)	219 Ibf.
the contact force (At distance 66 ft ft from the bit)	1403 Ibf.
the **maximum**contact force (At distance 36ft from the bit)	1495 Ibf.

4.2.5.3 Second Design (: (Two stabilizers in this BHA configuration).

Table.4.3: Second Design ((Bottom Hole Assembly Analysis Results)

contact points	18point
The string inclination at distance 10 ft from the bit	90.3 degree
The **maximum** contact force is at distance 71 ft from the bit in the end of heavy weight drill pip	1455 Ibf
The contact force at the bit equals	1145 Ibf.
the contact force (At distance 28 ft from the bit)	1022 Ibf.
the contact force (At distance 423 ft from the bit)	1055 Ibf.

Chapter Five

Conclusion and Recommendations

Through studies and analysis of BHA design with different cases using Finite Element Analysis (Landmark Tool) ,Trajectories that can hit the target have been obtained.

5.1 Conclusion:

- Using Finite Element Analysis Landmark to Simulate the behavior of Bottom Hole Assembly.
- Landmark-Wellplan three dimensional BHA model has been used to simulate the behavior of the BHA used to drill the 81/2 main hole section of well X.
- The same BHA has been modified and simulated using the same three dimensional BHA model.
- A three dimensional BHA analysis computer program is necessary for determining the deviation tendencies (i.e. build/drop and walk) of BHAs in curved boreholes.
- The deviation tendencies of BHAs are strongly affected by the existing curvature of the borehole. This is due to the natural tendency of the BHAs to return to a straight profile when they are placed in a curved borehole.
- Based on the analysis results the following points can be drown out:
    - In terms of resultant angle, the three analyzed BHA configurations provide the same resultant angle but the original BHA used to drill 81/2 main hole section can be considered the best when the other factors such as WOB, RPM, and Torque remain constant.
    - In terms of contact points, the modified BHA – second scenario has the least contact points between the drill string and the wellbore and this due to the fact that there are two stabilizers that cause the contact points to be reduced. The other BHA's has the same number of contact points i.e. 19 but with different locations.
    - In terms of contact forces, the contact force at the bit, drill collars, heavy weight drill pipe, and drill pipe decreases as the number of stabilizers in BHA configuration increases. For first BHA configuration, the maximum side force was at the bit but for the remaining BHA configurations the contact forces at the

bit and other parts of the string decrease in accordance with increasing number of stabilizers.

5.2 Recommendations:

Through the results and discussion obtained in this research, the following recommendations have been signed:

1- Study **other parameters** effect such as Weight on Bit **(WOB)** and Rotation Per Minute **(RPM).**

2- It is recommended to increase the **number of stabilizers** to reduce the contact points and therefore contact forces between drill string and wellbore.

3- More **data** is required.

References:

1- Halliburton, 2001. Wellplan (2000). [Computer Program] Landmark Graphics Corporation.

2- Alotaibi, B., Otalvora, C., William, B., Nefai, M., “Bottom-Hole Assembly Management System (BHAMS)”, SPE 172175, *SPE Saudi Arabia Section Annual Technical Symposium and Exhibition*. Al-Khobar, Saudi Arabia, 21-24 April 2014.

3- Rafie, S., Ho, H.S., Chandra, U., “Application of a BHA Analysis Program in Directional Drilling”, IADC/SPE 14765, *lADC/SPE Drilling Conference.* Dallas, TX, February 10-12, 1986.

4- Lubinski, A. and Woods, H. B., “Factors Affecting the Angle of Inclination and Dog Legging in Rotary Bore Hole”, Drill. & Prod. Prace, API (1953) 222-250.

5- Aadnoy, B., Huusgaard, P., “Analytical Models For Design of Wellpath and BHA”, IADC/SPE 77220, *lADC/SPE Asia Pacific Drilling Technology.* Jakarta, Indonesia, 9-11 September 2002.

6- Zhu, X., Jia, Y., Tong, H., “A New BHA’s Theoretical Analysis and It’s Successful Application”, SPE 130923, *CPS/SPE International Oil & Gas Conference and Exhibition.* Beijing, China, 8-10 June 2010.

7- Williams, J.B., Apostal, M.C., Haduch, G.A., “An Analysis of Predicted Wellbore Trajectory Using a Three Dimensional Model of a Bottom Hole Assembly With Bent Sub, Bent Housing, and Eccentric Contact Capabilities”, SPE *19545, 64th Annual Technical Conference and Exhibition of the Society of Petroleum Engineers.* San Antonio, TX, 8-11 October 1989.

8- Mitchell, B., 1995. *Advanced Oil Well Drilling Engineering*. West New Mexico: Lakewood Co.

9- Rabia, H., 2004. *Well Engineering and Construction*. Chester: P.L.C.

10- Prassl, W.F., *Drilling Engineering*. Australia: Curtin University of Technology.

11- Bourgoyne, A.T., Millheim, K.K., Chenevert, M.E., Young, F.S., 1991. *Applied Drilling Engineering*. Richardson, TX: Society of Petroleum Engineers.

Appendix

Appendix (A)

1- Slick Bottom Hole Assembly Analysis:

(No stabilizer in this BHA):-

CPET

Bottom Hole Assembly Report (Non-Drillahead)

Case Name:	ABMO-1 Well	**Date:**	7/19/2017	**Time:**	20:56:19	**Page:**	1
Description:	Horizontal Well						
Well Name:	Well X	**Project Name:**	BHA Analysis				
Well Description:	Horizontal Well	**Project Description:**					

DRILLING PARAMETERS OUTPUT

MUD WEIGHT	8.80 ppg
TORQUE AT BIT	2370.0 ft-lbf
MEASURED DEPTH	7770.0 ft
ROTARY SPEED	90 rpm
DRILLAHEAD INTERVAL	900.00 ft
BIT COEFFICIENT	50
WELLBORE OVERGAUGE	in
FORMATION HARDNESS FACTOR	25

WEIGHT ON BIT STUDY REPORT

WEIGHT ON BIT kip	RATE OF PENETRATION ft/hr	BUILD RATE deg/100ft	WALK RATE deg/100ft
4.4	10.0	0.00	0.00

DRILLSTRING

	<-------- LENGTH -------->		<--BODY-->		<---- STABILIZER / TOOL JOINT ---->							
TYPE	COMPONENT ft	TOTAL ft	OD in	ID in	LENGTH ft	OD in	ID in	FISHNECK ft	WEIGHT ppf	MTL	GRADE	CLASS*
DP	4314.62	4314.62	5.000	4.276		6.625	2.750		22.60	CS_API 5D/7	S	1
HW	542.00	4856.62	5.000	3.000		6.500	3.063		49.70	CS_1340 MOD	1340 MOD	
DP	2797.00	7653.62	5.000	4.276		7.250	3.500		23.40	CS_API 5D/7	S	1
HW	30.00	7683.62	5.000	3.000		6.500	3.063		49.70	CS_1340 MOD	1340 MOD	
JAR	18.80	7702.42	6.500	2.750					91.79	CS_API 5D/7	4145H MOD (1)	
HW	30.50	7732.92	5.000	3.000		6.500	3.000		49.14	CS_1340 MOD	1340 MOD	
DC	30.00	7762.92	6.500	3.000					88.86	CS_API 5D/7	4145H MOD (1)	
BS	3.00	7765.92	6.720	3.000					97.72	CS_API 5D/7	4145H MOD (1)	
BIT	1.00	7766.92	8.500						170.00			

WELLBORE

TYPE	SECTION DEPTH ft	SECTION LENGTH ft	EFFECTIVE INSIDE DIAMETER in	COEFFICIENT OF FRICTION	VOLUME EXCESS %
CAS	6760.0	6760.00	8.835	0.00	
OH	7770.0	1010.00	8.835	0.00	

Survey **Tortuosity: None** **Calculation Method: Minimum Curvature**

Md ft	Incl deg	Direc deg	Tvd ft	Build deg/100ft	Walk deg/100ft	Dls deg/100ft
0.0	0.00	5.20	0.0	0.00	0.00	0.00
98.4	0.00	5.20	98.4	0.00	0.00	0.00
196.9	0.00	5.20	196.9	0.00	0.00	0.00
295.3	0.00	5.20	295.3	0.00	0.00	0.00
393.7	0.00	5.20	393.7	0.00	0.00	0.00
492.1	0.00	5.20	492.1	0.00	0.00	0.00
590.6	0.00	5.20	590.6	0.00	0.00	0.00
689.0	0.00	5.20	689.0	0.00	0.00	0.00
787.4	0.00	5.20	787.4	0.00	0.00	0.00
885.8	0.00	5.20	885.8	0.00	0.00	0.00
984.3	0.00	5.20	984.3	0.00	0.00	0.00
1082.7	0.00	5.20	1082.7	0.00	0.00	0.00
1181.1	0.00	5.20	1181.1	0.00	0.00	0.00
1279.5	0.00	5.20	1279.5	0.00	0.00	0.00
1378.0	0.00	5.20	1378.0	0.00	0.00	0.00
1476.4	0.00	5.20	1476.4	0.00	0.00	0.00
1574.8	0.00	5.20	1574.8	0.00	0.00	0.00
1673.2	0.00	5.20	1673.2	0.00	0.00	0.00
1771.7	0.00	5.20	1771.7	0.00	0.00	0.00
1870.1	0.00	5.20	1870.1	0.00	0.00	0.00
1968.5	0.00	5.20	1968.5	0.00	0.00	0.00
2066.9	0.00	5.20	2066.9	0.00	0.00	0.00
2165.4	0.00	5.20	2165.4	0.00	0.00	0.00
2263.8	0.00	5.20	2263.8	0.00	0.00	0.00
2362.2	0.00	5.20	2362.2	0.00	0.00	0.00
2460.6	0.00	5.20	2460.6	0.00	0.00	0.00
2559.1	0.00	5.20	2559.1	0.00	0.00	0.00
2657.5	0.00	5.20	2657.5	0.00	0.00	0.00
2755.9	0.00	5.20	2755.9	0.00	0.00	0.00
2854.3	0.00	5.20	2854.3	0.00	0.00	0.00

CPET

Bottom Hole Assembly Report (Non-Drillahead)

Case Name:	ABMO-1 Well	**Date:**	7/19/2017	**Time:**	20:56:19	**Page:**	2
Description:	Horizontal Well						
Well Name:	Well X	**Project Name:**	BHA Analysis				
Well Description:	Horizontal Well	**Project Description:**					

Survey **Tortuosity: None** **Calculation Method: Minimum Curvature**

Md ft	Incl deg	Direc deg	Tvd ft	Build deg/100ft	Walk deg/100ft	Dls deg/100ft
2952.8	0.00	5.20	2952.8	0.00	0.00	0.00
3051.2	0.00	5.20	3051.2	0.00	0.00	0.00
3149.6	2.40	5.20	3149.6	2.44	0.00	2.44
3248.0	4.80	5.20	3247.8	2.44	0.00	2.44
3346.5	7.20	5.20	3345.7	2.44	0.00	2.44
3387.4	8.20	5.20	3386.2	2.44	0.00	2.44
3416.5	8.20	5.20	3415.1	0.00	0.00	0.00
3444.9	8.89	5.21	3443.1	2.43	0.04	2.43
3543.3	11.29	5.22	3540.0	2.44	0.01	2.44
3641.7	13.69	5.22	3636.1	2.44	0.00	2.44
3740.2	16.09	5.23	3731.2	2.44	0.01	2.44
3838.6	18.49	5.23	3825.2	2.44	0.00	2.44
3937.0	20.89	5.23	3917.9	2.44	0.00	2.44
4035.4	23.29	5.23	4009.0	2.44	0.00	2.44
4133.9	25.69	5.24	4098.6	2.44	0.01	2.44
4232.3	28.09	5.24	4186.4	2.44	0.00	2.44
4330.7	30.49	5.24	4272.2	2.44	0.00	2.44
4429.1	32.89	5.24	4356.0	2.44	0.00	2.44
4527.6	35.29	5.24	4437.5	2.44	0.00	2.44
4626.0	37.69	5.24	4516.6	2.44	0.00	2.44
4724.4	40.09	5.24	4593.2	2.44	0.00	2.44
4822.8	42.49	5.24	4667.2	2.44	0.00	2.44
4921.3	44.89	5.24	4738.3	2.44	0.00	2.44
5019.7	47.29	5.24	4806.6	2.44	0.00	2.44
5118.1	49.69	5.24	4871.8	2.44	0.00	2.44
5216.5	52.09	5.24	4933.9	2.44	0.00	2.44
5315.0	54.49	5.25	4992.7	2.44	0.01	2.44
5413.4	56.89	5.25	5048.2	2.44	0.00	2.44
5511.8	59.29	5.25	5100.2	2.44	0.00	2.44
5610.2	61.69	5.25	5148.7	2.44	0.00	2.44
5708.7	64.09	5.25	5193.5	2.44	0.00	2.44
5807.1	66.49	5.25	5234.7	2.44	0.00	2.44
5905.5	68.89	5.25	5272.0	2.44	0.00	2.44
6003.9	71.29	5.25	5305.6	2.44	0.00	2.44
6102.4	73.69	5.25	5335.2	2.44	0.00	2.44
6200.8	76.09	5.25	5360.8	2.44	0.00	2.44
6299.2	78.49	5.25	5382.5	2.44	0.00	2.44
6397.6	80.89	5.25	5400.1	2.44	0.00	2.44
6496.1	83.29	5.25	5413.6	2.44	0.00	2.44
6594.5	85.69	5.25	5423.1	2.44	0.00	2.44
6692.9	88.09	5.25	5428.4	2.44	0.00	2.44
6771.3	90.00	5.25	5429.7	2.44	0.00	2.44
6791.3	90.00	5.32	5429.7	0.00	0.35	0.35
6889.8	90.00	5.68	5429.7	0.00	0.37	0.37
6988.2	90.00	6.03	5429.7	0.00	0.36	0.36
7086.6	90.00	6.39	5429.7	0.00	0.37	0.37
7185.0	90.00	6.74	5429.7	0.00	0.36	0.36
7283.5	90.00	7.10	5429.7	0.00	0.37	0.37
7381.9	90.00	7.45	5429.7	0.00	0.36	0.36
7480.3	90.00	7.81	5429.7	0.00	0.37	0.37
7578.7	90.00	8.16	5429.7	0.00	0.36	0.36
7677.2	90.00	8.52	5429.7	0.00	0.37	0.37
7770.3	90.00	8.86	5429.7	0.00	0.36	0.36

RESULTS AT THE BIT (+ IS UP/RIGHT, - IS DOWN/LEFT)

	WELLBORE deg	STRING deg	TILT deg	FORCE lbf
INCLINATION	90.0	90.1	0.1	-1664
DIRECTION	8.8	8.8	0.0	16

BHA FORCES

MEASURED DEPTH ft	DISTANCE FROM BIT ft	TYPE	CONTACT	|<----CONTACT FORCES---->| INCLINATION lbf	DIRECTION lbf	RESULTANT lbf	AXIAL FORCE lbf	TORQUE ft-lbf
7766.9	0.0	PDC	YES	-1664	16	1664	-4400	2370.0
7764.9	2.0	XO	NO	-0	0	0	-4400	2370.0
7762.9	4.0	XO	NO	-0	0	0	-4400	2370.0
7760.3	6.7	DC	NO	-0	0	0	-4400	2370.0

CPET

Bottom Hole Assembly Report (Non-Drillahead)

Case Name:	ABMO-1 Well	**Date:**	7/19/2017	**Time:**	20:56:19	**Page:**	3
Description:	Horizontal Well						
Well Name:	Well X	**Project Name:**	BHA Analysis				
Well Description:	Horizontal Well	**Project Description:**					

BHA FORCES

MEASURED DEPTH ft	DISTANCE FROM BIT ft	TYPE	CONTACT	|<-----CONTACT FORCES----->| INCLINATION lbf	DIRECTION lbf	RESULTANT lbf	AXIAL FORCE lbf	TORQUE ft-lbf
7757.6	9.3	DC	NO	-0	0	0	-4400	2370.0
7754.9	12.0	DC	NO	-0	0	0	-4400	2370.0
7747.6	19.3	DC	NO	-0	0	0	-4400	2370.0
7740.3	26.7	DC	NO	-0	0	0	-4400	2370.0
7732.9	34.0	DC	YES	-1659	-29	1659	-4400	2370.0
7717.7	49.2	HW	NO	-0	0	0	-4400	2370.0
7702.4	64.5	HW	YES	-1448	-12	1448	-4400	2370.0
7693.0	73.9	JRH	YES	-10	0	10	-4400	2370.0
7683.6	83.3	JRH	YES	-1377	7	1377	-4400	2370.0
7668.6	98.3	HW	NO	-0	0	0	-4400	2370.0
7653.6	113.3	DP	YES	-1006	-18	1006	-4400	2370.0
7638.3	128.6	DP	NO	-0	0	0	-4400	2370.0
7623.1	143.9	DPj	YES	-600	-10	600	-4400	2370.0
7607.8	159.1	DP	NO	-0	0	0	-4400	2370.0
7592.5	174.4	DPj	YES	-653	-8	653	-4400	2370.0
7577.2	189.7	DP	NO	-0	0	0	-4400	2370.0
7561.9	205.0	DPj	YES	-638	-9	638	-4400	2370.0
7546.7	220.3	DP	NO	-0	0	0	-4400	2370.0
7531.4	235.5	DPj	YES	-642	-8	642	-4400	2370.0
7516.1	250.8	DP	NO	-0	0	0	-4400	2370.0
7500.8	266.1	DPj	YES	-641	-9	641	-4400	2370.0
7485.5	281.4	DP	NO	-0	0	0	-4400	2370.0
7470.3	296.7	DPj	YES	-642	-8	642	-4400	2370.0
7455.0	311.9	DP	NO	-0	0	0	-4400	2370.0
7439.7	327.2	DPj	YES	-641	-9	641	-4400	2370.0
7424.4	342.5	DP	NO	-0	0	0	-4400	2370.0
7409.1	357.8	DPj	YES	-644	-8	644	-4400	2370.0
7393.9	373.1	DP	NO	-0	0	0	-4400	2370.0
7378.6	388.3	DPj	YES	-634	-8	634	-4400	2370.0
7363.3	403.6	DP	NO	-0	0	0	-4400	2370.0
7348.0	418.9	DPj	YES	-668	-9	668	-4400	2370.0
7332.7	434.2	DP	NO	-0	0	0	-4400	2370.0
7317.5	449.5	DPj	YES	-549	-9	549	-4400	2370.0
7302.2	464.7	DP	NO	-0	0	0	-4400	2370.0
7286.9	480.0	DPj	YES	-1046	-6	1046	-4400	2370.0
7271.6	495.3	DP	YES	-220	0	220	-4400	2370.0

BHA DISPLACEMENTS

MEASURED DEPTH ft	DISTANCE FROM BIT ft	TYPE	DISPLACEMENT FROM WELL CENTERLINE INCLINATION in	DIRECTION in	RESULTANT in	CLEARANCE in
7766.9	0.0	PDC	-0.181	0.002	0.181	0.014
7764.9	2.0	XO	-0.219	0.004	0.219	0.838
7762.9	4.0	XO	-0.279	0.006	0.279	0.778
7760.3	6.7	DC	-0.385	0.008	0.385	0.782
7757.6	9.3	DC	-0.509	0.011	0.509	0.659
7754.9	12.0	DC	-0.636	0.013	0.636	0.532
7747.6	19.3	DC	-0.937	0.014	0.937	0.231
7740.3	26.7	DC	-1.100	0.005	1.100	0.068
7732.9	34.0	DC	-1.169	-0.020	1.169	0.001
7717.7	49.2	HW	-1.440	-0.055	1.441	0.226
7702.4	64.5	HW	-1.168	-0.010	1.168	0.001
7693.0	73.9	JRH	-1.167	0.017	1.168	0.000
7683.6	83.3	JRH	-1.168	0.006	1.168	0.001
7668.6	98.3	HW	-1.307	-0.012	1.307	0.360
7653.6	113.3	DP	-0.793	-0.014	0.793	0.001
7638.3	128.6	DP	-0.845	-0.024	0.846	1.072
7623.1	143.9	DPj	-0.793	-0.014	0.793	0.000
7607.8	159.1	DP	-1.035	-0.012	1.035	0.883
7592.5	174.4	DPj	-0.793	-0.010	0.793	0.000
7577.2	189.7	DP	-0.980	-0.013	0.980	0.938
7561.9	205.0	DPj	-0.793	-0.011	0.793	0.000
7546.7	220.3	DP	-0.996	-0.013	0.996	0.922
7531.4	235.5	DPj	-0.793	-0.010	0.793	0.000
7516.1	250.8	DP	-0.991	-0.013	0.991	0.926
7500.8	266.1	DPj	-0.793	-0.011	0.793	0.000
7485.5	281.4	DP	-0.992	-0.013	0.992	0.925
7470.3	296.7	DPj	-0.793	-0.010	0.793	0.000
7455.0	311.9	DP	-0.993	-0.013	0.993	0.925

CPET

Bottom Hole Assembly Report (Non-Drillahead)

Case Name:	ABMO-1 Well	**Date:**	7/19/2017	**Time:**	20:56:19	**Page:**	4
Description:	Horizontal Well						
Well Name:	Well X	**Project Name:**	BHA Analysis				
Well Description:	Horizontal Well	**Project Description:**					

BHA DISPLACEMENTS

MEASURED DEPTH ft	DISTANCE FROM BIT ft	TYPE	DISPLACEMENT FROM WELL CENTERLINE INCLINATION in	DIRECTION in	RESULTANT in	CLEARANCE in
7439.7	327.2	DPj	-0.793	-0.011	0.793	0.000
7424.4	342.5	DP	-0.990	-0.014	0.990	0.928
7409.1	357.8	DPj	-0.793	-0.010	0.793	0.000
7393.9	373.1	DP	-1.000	-0.012	1.000	0.917
7378.6	388.3	DPj	-0.793	-0.011	0.793	0.000
7363.3	403.6	DP	-0.964	-0.013	0.964	0.953
7348.0	418.9	DPj	-0.793	-0.010	0.793	0.000
7332.7	434.2	DP	-1.088	-0.014	1.088	0.829
7317.5	449.5	DPj	-0.793	-0.012	0.793	0.000
7302.2	464.7	DP	-0.662	-0.014	0.662	1.255
7286.9	480.0	DPj	-0.793	-0.005	0.793	0.001
7271.6	495.3	DP	-1.918	0.000	1.918	0.000

ELEMENT FORCES TABLE

ELEMENT	NODE	FX lbf	FY lbf	FZ lbf	MX ft-lbf	MY ft-lbf	MZ ft-lbf
1	1	1555	17	4400	-1205.2	12517.7	2370.0
1	2	-1555	-17	-4400	1171.2	-9407.5	-2370.0
2	2	1390	18	4400	-1171.2	9407.3	2370.0
2	3	-1390	-18	-4400	1136.2	-6627.7	-2370.0
3	3	1206	18	4400	-1136.2	6628.0	2370.0
3	4	-1206	-18	-4400	1087.8	-3411.9	-2370.0
4	4	1003	19	4400	-1087.8	3411.5	2370.0
4	5	-1003	-19	-4400	1037.5	-736.2	-2370.0
5	5	799	20	4400	-1037.5	736.0	2370.0
5	6	-799	-20	-4400	985.2	1393.9	-2370.0
6	6	412	21	4400	-986.1	-1396.7	2370.0
6	7	-412	-21	-4400	833.7	4415.7	-2370.0
7	7	-159	22	4400	-833.5	-4416.6	2370.0
7	8	159	-22	-4400	669.8	3247.4	-2370.0
8	8	-728	24	4400	-669.6	-3244.5	2370.0
8	9	728	-24	-4400	496.8	-2096.9	-2370.0
9	9	322	-2	4400	-504.0	2099.1	2370.0
9	10	-322	2	-4400	527.5	2805.1	-2370.0
10	10	-355	5	4400	-527.3	-2801.9	2370.0
10	11	355	-5	-4400	456.4	-2617.0	-2370.0
11	11	397	-4	4400	-449.8	2612.1	2370.0
11	12	-397	4	-4400	487.5	1117.5	-2370.0
12	12	-339	-3	4400	-487.6	-1117.9	2370.0
12	13	339	3	-4400	513.1	-2068.8	-2370.0
13	13	340	8	4400	-519.2	2067.8	2370.0
13	14	-340	-8	-4400	399.5	3038.0	-2370.0
14	14	-337	13	4400	-397.6	-3038.4	2370.0
14	15	337	-13	-4400	208.8	-2015.3	-2370.0
15	15	195	-1	4400	-210.8	2039.9	2370.0
15	16	-195	1	-4400	224.8	933.3	-2370.0
16	16	-131	4	4400	-224.2	-944.9	2370.0
16	17	131	-4	-4400	164.4	-1049.4	-2370.0
17	17	158	-2	4400	-164.1	1044.4	2370.0
17	18	-158	2	-4400	201.7	1366.7	-2370.0
18	18	-176	2	4400	-201.8	-1363.3	2370.0
18	19	176	-2	-4400	173.1	-1332.8	-2370.0
19	19	169	-2	4400	-173.2	1334.3	2370.0
19	20	-169	2	-4400	204.2	1240.5	-2370.0
20	20	-163	2	4400	-204.1	-1241.5	2370.0
20	21	163	-2	-4400	168.1	-1250.3	-2370.0
21	21	165	-2	4400	-168.1	1249.9	2370.0
21	22	-165	2	-4400	201.1	1277.2	-2370.0
22	22	-167	2	4400	-201.1	-1276.9	2370.0
22	23	167	-2	-4400	168.0	-1274.4	-2370.0
23	23	166	-2	4400	-168.0	1274.5	2370.0
23	24	-166	2	-4400	200.6	1266.6	-2370.0
24	24	-166	2	4400	-200.5	-1266.7	2370.0
24	25	166	-2	-4400	167.2	-1267.0	-2370.0
25	25	166	-2	4400	-167.2	1267.0	2370.0
25	26	-166	2	-4400	203.3	1269.2	-2370.0
26	26	-166	2	4400	-203.3	-1269.1	2370.0
26	27	166	-2	-4400	172.6	-1270.4	-2370.0
27	27	166	-2	4400	-172.6	1270.4	2370.0

CPET

Bottom Hole Assembly Report (Non-Drillahead)

Case Name:	ABMO-1 Well	**Date:** 7/25/2017	**Time:** 02:37:06	**Page:**	5
Description:	Horizontal Well				
Well Name:	Well X	**Project Name:**	BHA Analysis		
Well Description:	Horizontal Well	**Project Description:**			

ELEMENT FORCES TABLE

ELEMENT	NODE	FX lbf	FY lbf	FZ lbf	MX ft-lbf	MY ft-lbf	MZ ft-lbf
32	32	-165	2	4400	-205.7	-1287.5	2370.0
32	33	165	-2	-4400	170.2	-1226.1	-2370.0
33	33	159	-2	4400	-170.2	1227.0	2370.0
33	34	-159	2	-4400	201.3	1207.2	-2370.0
34	34	-172	2	4400	-201.2	-1205.0	2370.0
34	35	172	-2	-4400	166.2	-1415.9	-2370.0
35	35	189	-2	4400	-166.2	1412.7	2370.0
35	36	-189	2	-4400	201.1	1480.9	-2370.0
36	36	-147	2	4400	-201.2	-1488.5	2370.0
36	37	147	-2	-4400	170.1	-764.5	-2370.0
37	37	86	-2	4400	-170.2	775.6	2370.0
37	38	-86	2	-4400	207.3	541.1	-2370.0
38	38	-230	2	4400	-207.3	-515.0	2370.0
38	39	230	-2	-4400	176.4	-3000.6	-2370.0
39	39	524	0	4400	-176.1	2947.4	2370.0
39	40	-524	0	-4400	179.2	5053.7	-2370.0

ELEMENT FORCES TABLE SUMMARY

	FX lbf	FY lbf	FZ lbf	MX ft-lbf	MY ft-lbf	MZ ft-lbf
(NODE)	37	15	1	17	38	4
MINIMUM	-86	-0	-4400	-164.0	-515.0	-2369.0
(NODE)	1	8	1	1	1	1
MAXIMUM	1555	23	4400	1205.0	12517.0	2370.0

WELLBORE VS. DRILLSTRING ANGLE TABLE

NODE	MEASURED DEPTH ft	DISTANCE FROM BIT ft	INCLINATION: WB INC deg	DS INC deg	INC DIFF deg	AZIMUTH: WB AZM deg	DS AZM deg	AZM DIFF deg
1	7766.9	0.0	90.0	90.1	0.1	8.8	8.8	0.0
2	7764.9	2.0	90.0	90.1	0.1	8.8	8.8	0.0
3	7762.9	4.0	90.0	90.2	0.2	8.8	8.8	0.0
4	7760.3	6.7	90.0	90.2	0.2	8.8	8.8	0.0
5	7757.6	9.3	90.0	90.2	0.2	8.8	8.8	0.0
6	7754.9	12.0	90.0	90.2	0.2	8.8	8.8	0.0
7	7747.6	19.3	90.0	90.2	0.2	8.8	8.8	0.0
8	7740.3	26.7	90.0	90.1	0.1	8.7	8.8	0.0
9	7732.9	34.0	90.0	90.0	0.0	8.7	8.7	0.0
10	7717.7	49.2	90.0	90.0	0.0	8.7	8.7	0.0
11	7702.4	64.5	90.0	90.0	0.0	8.6	8.6	0.0
12	7693.0	73.9	90.0	90.0	0.0	8.6	8.6	0.0
13	7683.6	83.3	90.0	90.0	0.0	8.5	8.6	0.0
14	7668.6	98.3	90.0	89.9	-0.1	8.5	8.5	0.0
15	7653.6	113.3	90.0	89.9	-0.1	8.4	8.4	0.0
16	7638.3	128.6	90.0	90.0	0.0	8.4	8.4	0.0
17	7623.1	143.9	90.0	90.0	0.0	8.3	8.3	0.0
18	7607.8	159.1	90.0	90.0	0.0	8.3	8.3	0.0
19	7592.5	174.4	90.0	90.0	0.0	8.2	8.2	0.0
20	7577.2	189.7	90.0	90.0	0.0	8.2	8.2	0.0
21	7561.9	205.0	90.0	90.0	0.0	8.1	8.1	0.0
22	7546.7	220.3	90.0	90.0	0.0	8.0	8.0	0.0
23	7531.4	235.5	90.0	90.0	0.0	8.0	8.0	0.0
24	7516.1	250.8	90.0	90.0	0.0	7.9	7.9	0.0
25	7500.8	266.1	90.0	90.0	0.0	7.9	7.9	0.0
26	7485.5	281.4	90.0	90.0	0.0	7.8	7.8	0.0
27	7470.3	296.7	90.0	90.0	0.0	7.8	7.8	0.0
28	7455.0	311.9	90.0	90.0	0.0	7.7	7.7	0.0
29	7439.7	327.2	90.0	90.0	0.0	7.7	7.7	0.0
30	7424.4	342.5	90.0	90.0	0.0	7.6	7.6	0.0
31	7409.1	357.8	90.0	90.0	0.0	7.5	7.5	0.0
32	7393.9	373.1	90.0	90.0	0.0	7.5	7.5	0.0
33	7378.6	388.3	90.0	90.0	0.0	7.4	7.4	0.0
34	7363.3	403.6	90.0	90.0	0.0	7.4	7.4	0.0
35	7348.0	418.9	90.0	90.0	0.0	7.3	7.3	0.0
36	7332.7	434.2	90.0	90.0	0.0	7.3	7.3	0.0
37	7317.5	449.5	90.0	89.9	-0.1	7.2	7.2	0.0
38	7302.2	464.7	90.0	89.9	-0.1	7.2	7.2	0.0

CPET

Bottom Hole Assembly Report (Non-Drillahead)

Case Name:	ABMO-1 Well	**Date:**	7/25/2017	**Time:**	02:37:06	**Page:**	6
Description:	Horizontal Well						
Well Name:	Well X	**Project Name:**	BHA Analysis				
Well Description:	Horizontal Well	**Project Description:**					

WELLBORE VS. DRILLSTRING ANGLE TABLE

NODE	MEASURED DEPTH ft	DISTANCE FROM BIT ft	INCLINATION WB INC deg	INCLINATION DS INC deg	INCLINATION INC DIFF deg	AZIMUTH WB AZM deg	AZIMUTH DS AZM deg	AZIMUTH AZM DIFF deg
39	7286.9	480.0	90.0	90.3	0.3	7.1	7.1	0.0
40	7271.6	495.3	90.0	90.0	0.0	7.1	7.1	0.0

Appendix (B)

2-First Design: (One stabilizer is added near the bit).

CPET

Bottom Hole Assembly Report (Non-Drillahead)

Case Name:	ABMO-1 Well	**Date:**	7/19/2017	**Time:**	21:32:57	**Page:**	1
Description:	Horizontal Well						
Well Name:	Well X	**Project Name:**	BHA Analysis				
Well Description:	Horizontal Well	**Project Description:**					

DRILLING PARAMETERS OUTPUT

MUD WEIGHT	8.80 ppg
TORQUE AT BIT	2370.0 ft-lbf
MEASURED DEPTH	7770.0 ft
ROTARY SPEED	90 rpm
DRILLAHEAD INTERVAL	900.00 ft
BIT COEFFICIENT	50
WELLBORE OVERGAUGE	in
FORMATION HARDNESS FACTOR	25

WEIGHT ON BIT STUDY REPORT

WEIGHT ON BIT kip	RATE OF PENETRATION ft/hr	BUILD RATE deg/100ft	WALK RATE deg/100ft
4.4	10.0	0.00	0.00

DRILLSTRING

	<-------- LENGTH -------->		<--BODY-->		<---- STABILIZER / TOOL JOINT ---->							
TYPE	COMPONENT ft	TOTAL ft	OD in	ID in	LENGTH ft	OD in	ID in	FISHNECK ft	WEIGHT ppf	MTL	GRADE	CLASS*
DP	4312.62	4312.62	5.000	4.276		6.625	2.750		22.60	CS_API 5D/7	S	1
HW	542.00	4854.62	5.000	3.000		6.500	3.063		49.70	CS_1340 MOD	1340 MOD	
DP	2797.00	7651.62	5.000	4.276		7.250	3.500		23.40	CS_API 5D/7	S	1
HW	30.00	7681.62	5.000	3.000		6.500	3.063		49.70	CS_1340 MOD	1340 MOD	
JAR	18.80	7700.42	6.500	2.750					91.79	CS_API 5D/7	4145H MOD (1)	
HW	30.50	7730.92	5.000	3.000		6.500	3.000		49.14	CS_1340 MOD	1340 MOD	
DC	30.00	7760.92	6.500	3.000					88.86	CS_API 5D/7	4145H MOD (1)	
IBS	5.00	7765.92	4.250	2.000	1.00	6.469		3.00	37.59	CS_API 5D/7	4145H MOD (1)	
BIT	1.00	7766.92	8.500						170.00			

WELLBORE

TYPE	SECTION DEPTH ft	SECTION LENGTH ft	EFFECTIVE INSIDE DIAMETER in	COEFFICIENT OF FRICTION	VOLUME EXCESS %
CAS	6760.0	6760.00	8.835	0.00	
OH	7770.0	1010.00	8.835	0.00	

Survey **Tortuosity: None** **Calculation Method: Minimum Curvature**

Md ft	Incl deg	Direc deg	Tvd ft	Build deg/100ft	Walk deg/100ft	Dls deg/100ft
0.0	0.00	5.20	0.0	0.00	0.00	0.00
98.4	0.00	5.20	98.4	0.00	0.00	0.00
196.9	0.00	5.20	196.9	0.00	0.00	0.00
295.3	0.00	5.20	295.3	0.00	0.00	0.00
393.7	0.00	5.20	393.7	0.00	0.00	0.00
492.1	0.00	5.20	492.1	0.00	0.00	0.00
590.6	0.00	5.20	590.6	0.00	0.00	0.00
689.0	0.00	5.20	689.0	0.00	0.00	0.00
787.4	0.00	5.20	787.4	0.00	0.00	0.00
885.8	0.00	5.20	885.8	0.00	0.00	0.00
984.3	0.00	5.20	984.3	0.00	0.00	0.00
1082.7	0.00	5.20	1082.7	0.00	0.00	0.00
1181.1	0.00	5.20	1181.1	0.00	0.00	0.00
1279.5	0.00	5.20	1279.5	0.00	0.00	0.00
1378.0	0.00	5.20	1378.0	0.00	0.00	0.00
1476.4	0.00	5.20	1476.4	0.00	0.00	0.00
1574.8	0.00	5.20	1574.8	0.00	0.00	0.00
1673.2	0.00	5.20	1673.2	0.00	0.00	0.00
1771.7	0.00	5.20	1771.7	0.00	0.00	0.00
1870.1	0.00	5.20	1870.1	0.00	0.00	0.00
1968.5	0.00	5.20	1968.5	0.00	0.00	0.00
2066.9	0.00	5.20	2066.9	0.00	0.00	0.00
2165.4	0.00	5.20	2165.4	0.00	0.00	0.00
2263.8	0.00	5.20	2263.8	0.00	0.00	0.00
2362.2	0.00	5.20	2362.2	0.00	0.00	0.00
2460.6	0.00	5.20	2460.6	0.00	0.00	0.00
2559.1	0.00	5.20	2559.1	0.00	0.00	0.00
2657.5	0.00	5.20	2657.5	0.00	0.00	0.00
2755.9	0.00	5.20	2755.9	0.00	0.00	0.00
2854.3	0.00	5.20	2854.3	0.00	0.00	0.00

CPET

Bottom Hole Assembly Report (Non-Drillahead)

Case Name:	ABMO-1 Well	**Date:**	7/19/2017	**Time:**	21:32:57	**Page:**	2
Description:	Horizontal Well						
Well Name:	Well X	**Project Name:**	BHA Analysis				
Well Description:	Horizontal Well	**Project Description:**					

Survey **Tortuosity: None** **Calculation Method: Minimum Curvature**

Md ft	Incl deg	Direc deg	Tvd ft	Build deg/100ft	Walk deg/100ft	Dls deg/100ft
2952.8	0.00	5.20	2952.8	0.00	0.00	0.00
3051.2	0.00	5.20	3051.2	0.00	0.00	0.00
3149.6	2.40	5.20	3149.6	2.44	0.00	2.44
3248.0	4.80	5.20	3247.8	2.44	0.00	2.44
3346.5	7.20	5.20	3345.7	2.44	0.00	2.44
3387.4	8.20	5.20	3386.2	2.44	0.00	2.44
3416.5	8.20	5.20	3415.1	0.00	0.00	0.00
3444.9	8.89	5.21	3443.1	2.43	0.04	2.43
3543.3	11.29	5.22	3540.0	2.44	0.01	2.44
3641.7	13.69	5.22	3636.1	2.44	0.00	2.44
3740.2	16.09	5.23	3731.2	2.44	0.01	2.44
3838.6	18.49	5.23	3825.2	2.44	0.00	2.44
3937.0	20.89	5.23	3917.9	2.44	0.00	2.44
4035.4	23.29	5.23	4009.0	2.44	0.00	2.44
4133.9	25.69	5.24	4098.6	2.44	0.01	2.44
4232.3	28.09	5.24	4186.4	2.44	0.00	2.44
4330.7	30.49	5.24	4272.2	2.44	0.00	2.44
4429.1	32.89	5.24	4356.0	2.44	0.00	2.44
4527.6	35.29	5.24	4437.5	2.44	0.00	2.44
4626.0	37.69	5.24	4516.6	2.44	0.00	2.44
4724.4	40.09	5.24	4593.2	2.44	0.00	2.44
4822.8	42.49	5.24	4667.2	2.44	0.00	2.44
4921.3	44.89	5.24	4738.3	2.44	0.00	2.44
5019.7	47.29	5.24	4806.6	2.44	0.00	2.44
5118.1	49.69	5.24	4871.8	2.44	0.00	2.44
5216.5	52.09	5.24	4933.9	2.44	0.00	2.44
5315.0	54.49	5.25	4992.7	2.44	0.01	2.44
5413.4	56.89	5.25	5048.2	2.44	0.00	2.44
5511.8	59.29	5.25	5100.2	2.44	0.00	2.44
5610.2	61.69	5.25	5148.7	2.44	0.00	2.44
5708.7	64.09	5.25	5193.5	2.44	0.00	2.44
5807.1	66.49	5.25	5234.7	2.44	0.00	2.44
5905.5	68.89	5.25	5272.0	2.44	0.00	2.44
6003.9	71.29	5.25	5305.6	2.44	0.00	2.44
6102.4	73.69	5.25	5335.2	2.44	0.00	2.44
6200.8	76.09	5.25	5360.8	2.44	0.00	2.44
6299.2	78.49	5.25	5382.5	2.44	0.00	2.44
6397.6	80.89	5.25	5400.1	2.44	0.00	2.44
6496.1	83.29	5.25	5413.6	2.44	0.00	2.44
6594.5	85.69	5.25	5423.1	2.44	0.00	2.44
6692.9	88.09	5.25	5428.4	2.44	0.00	2.44
6771.3	90.00	5.25	5429.7	2.44	0.00	2.44
6791.3	90.00	5.32	5429.7	0.00	0.35	0.35
6889.8	90.00	5.68	5429.7	0.00	0.37	0.37
6988.2	90.00	6.03	5429.7	0.00	0.36	0.36
7086.6	90.00	6.39	5429.7	0.00	0.37	0.37
7185.0	90.00	6.74	5429.7	0.00	0.36	0.36
7283.5	90.00	7.10	5429.7	0.00	0.37	0.37
7381.9	90.00	7.45	5429.7	0.00	0.36	0.36
7480.3	90.00	7.81	5429.7	0.00	0.37	0.37
7578.7	90.00	8.16	5429.7	0.00	0.36	0.36
7677.2	90.00	8.52	5429.7	0.00	0.37	0.37
7770.3	90.00	8.86	5429.7	0.00	0.36	0.36

RESULTS AT THE BIT (+ IS UP/RIGHT, - IS DOWN/LEFT)

	WELLBORE deg	STRING deg	TILT deg	FORCE lbf
INCLINATION	90.0	90.1	0.1	-1158
DIRECTION	8.8	8.8	0.0	-13

BHA FORCES

MEASURED DEPTH ft	DISTANCE FROM BIT ft	TYPE	CONTACT	|<------CONTACT FORCES------>| INCLINATION lbf	DIRECTION lbf	RESULTANT lbf	AXIAL FORCE lbf	TORQUE ft-lbf
7766.9	0.0	PDC	YES	-1158	-13	1158	-4400	2370.0
7764.9	2.0	NBS	NO	-0	0	0	-4400	2370.0
7763.9	3.0	NBS	NO	-0	0	0	-4400	2370.0
7760.9	6.0	DC	NO	-0	0	0	-4400	2370.0

CPET

Bottom Hole Assembly Report (Non-Drillahead)

Case Name: ABMO-1 Well	**Date:** 7/19/2017	**Time:** 21:32:57	**Page:** 3
Description: Horizontal Well			
Well Name: Well X	**Project Name:** BHA Analysis		
Well Description: Horizontal Well	**Project Description:**		

BHA FORCES

MEASURED DEPTH ft	DISTANCE FROM BIT ft	TYPE	CONTACT	|<------CONTACT FORCES------>| INCLINATION lbf	DIRECTION lbf	RESULTANT lbf	AXIAL FORCE lbf	TORQUE ft-lbf
7758.9	8.0	DC	NO	-0	0	0	-4400	2370.0
7756.9	10.0	DC	NO	-0	0	0	-4400	2370.0
7754.9	12.0	DC	NO	-0	0	0	-4400	2370.0
7746.9	20.0	DC	NO	-0	0	0	-4400	2370.0
7738.9	28.0	DC	YES	-598	15	598	-4400	2370.0
7730.9	36.0	DC	YES	-1495	-13	1495	-4400	2370.0
7715.7	51.2	HW	NO	-0	0	0	-4400	2370.0
7700.4	66.5	HW	YES	-1403	-14	1403	-4400	2370.0
7691.0	75.9	JRH	YES	-40	1	40	-4400	2370.0
7681.6	85.3	JRH	YES	-1373	7	1373	-4400	2370.0
7666.6	100.3	HW	NO	-0	0	0	-4400	2370.0
7651.6	115.3	DP	YES	-1005	-17	1005	-4400	2370.0
7636.4	130.5	DP	NO	-0	0	0	-4400	2370.0
7621.1	145.8	DPj	YES	-599	-10	599	-4400	2370.0
7605.9	161.0	DP	NO	-0	0	0	-4400	2370.0
7590.6	176.3	DPj	YES	-652	-8	652	-4400	2370.0
7575.4	191.5	DP	NO	-0	0	0	-4400	2370.0
7560.2	206.8	DPj	YES	-636	-9	636	-4400	2370.0
7544.9	222.0	DP	NO	-0	0	0	-4400	2370.0
7529.7	237.3	DPj	YES	-641	-8	641	-4400	2370.0
7514.4	252.5	DP	NO	-0	0	0	-4400	2370.0
7499.2	267.7	DPj	YES	-640	-9	640	-4400	2370.0
7483.9	283.0	DP	NO	-0	0	0	-4400	2370.0
7468.7	298.2	DPj	YES	-640	-8	640	-4400	2370.0
7453.4	313.5	DP	NO	-0	0	0	-4400	2370.0
7438.2	328.7	DPj	YES	-640	-9	640	-4400	2370.0
7422.9	344.0	DP	NO	-0	0	0	-4400	2370.0
7407.7	359.2	DPj	YES	-640	-8	640	-4400	2370.0
7392.5	374.5	DP	NO	-0	0	0	-4400	2370.0
7377.2	389.7	DPj	YES	-640	-8	640	-4400	2370.0
7362.0	405.0	DP	NO	-0	0	0	-4400	2370.0
7346.7	420.2	DPj	YES	-640	-9	640	-4400	2370.0
7331.5	435.4	DP	NO	-0	0	0	-4400	2370.0
7316.2	450.7	DPj	YES	-640	-8	640	-4400	2370.0
7301.0	465.9	DP	NO	-0	0	0	-4400	2370.0
7285.7	481.2	DPj	YES	-219	0	219	-4400	2370.0

BHA DISPLACEMENTS

MEASURED DEPTH ft	DISTANCE FROM BIT ft	TYPE	DISPLACEMENT FROM WELL CENTERLINE INCLINATION in	DIRECTION in	RESULTANT in	CLEARANCE in
7766.9	0.0	PDC	-0.177	-0.002	0.177	0.010
7764.9	2.0	NBS	-0.234	0.001	0.234	0.949
7763.9	3.0	NBS	-0.283	0.003	0.283	0.900
7760.9	6.0	DC	-0.463	0.015	0.464	0.704
7758.9	8.0	DC	-0.585	0.025	0.586	0.582
7756.9	10.0	DC	-0.701	0.033	0.702	0.466
7754.9	12.0	DC	-0.807	0.039	0.807	0.360
7746.9	20.0	DC	-1.094	0.046	1.095	0.072
7738.9	28.0	DC	-1.168	0.029	1.168	0.001
7730.9	36.0	DC	-1.169	-0.010	1.169	0.001
7715.7	51.2	HW	-1.411	-0.057	1.413	0.255
7700.4	66.5	HW	-1.168	-0.012	1.168	0.001
7691.0	75.9	JRH	-1.167	0.016	1.168	0.000
7681.6	85.3	JRH	-1.168	0.006	1.168	0.001
7666.6	100.3	HW	-1.307	-0.011	1.307	0.360
7651.6	115.3	DP	-0.793	-0.014	0.793	0.001
7636.4	130.5	DP	-0.843	-0.024	0.844	1.074
7621.1	145.8	DPj	-0.793	-0.014	0.793	0.000
7605.9	161.0	DP	-1.033	-0.012	1.033	0.884
7590.6	176.3	DPj	-0.793	-0.010	0.793	0.000
7575.4	191.5	DP	-0.978	-0.013	0.978	0.940
7560.2	206.8	DPj	-0.793	-0.011	0.793	0.000
7544.9	222.0	DP	-0.994	-0.013	0.994	0.924
7529.7	237.3	DPj	-0.793	-0.010	0.793	0.000
7514.4	252.5	DP	-0.989	-0.013	0.989	0.928
7499.2	267.7	DPj	-0.793	-0.011	0.793	0.000
7483.9	283.0	DP	-0.991	-0.013	0.991	0.927
7468.7	298.2	DPj	-0.793	-0.010	0.793	0.000

CPET

Bottom Hole Assembly Report (Non-Drillahead)

Case Name:	ABMO-1 Well	**Date:**	7/19/2017	**Time:**	21:32:57	**Page:**	4
Description:	Horizontal Well						
Well Name:	Well X	**Project Name:**	BHA Analysis				
Well Description:	Horizontal Well	**Project Description:**					

BHA DISPLACEMENTS

MEASURED DEPTH ft	DISTANCE FROM BIT ft	TYPE	DISPLACEMENT FROM WELL CENTERLINE			CLEARANCE
			INCLINATION in	DIRECTION in	RESULTANT in	in
7453.4	313.5	DP	-0.990	-0.013	0.990	0.927
7438.2	328.7	DPj	-0.793	-0.011	0.793	0.000
7422.9	344.0	DP	-0.990	-0.013	0.990	0.927
7407.7	359.2	DPj	-0.793	-0.010	0.793	0.000
7392.5	374.5	DP	-0.990	-0.012	0.990	0.927
7377.2	389.7	DPj	-0.793	-0.010	0.793	0.000
7362.0	405.0	DP	-0.990	-0.013	0.990	0.927
7346.7	420.2	DPj	-0.793	-0.011	0.793	0.000
7331.5	435.4	DP	-0.990	-0.014	0.990	0.927
7316.2	450.7	DPj	-0.793	-0.009	0.793	0.000
7301.0	465.9	DP	-0.990	-0.006	0.990	0.927
7285.7	481.2	DPj	-0.793	0.000	0.793	0.000

ELEMENT FORCES TABLE

ELEMENT	NODE	FX lbf	FY lbf	FZ lbf	MX ft-lbf	MY ft-lbf	MZ ft-lbf
1	1	1053	-13	4400	-364.4	5293.7	2370.0
1	2	-1053	13	-4400	389.6	-3187.6	-2370.0
2	2	1012	-12	4400	-389.4	3186.1	2370.0
2	3	-1012	12	-4400	401.2	-2174.6	-2370.0
3	3	951	-11	4400	-401.6	2175.3	2370.0
3	4	-951	11	-4400	433.6	677.3	-2370.0
4	4	825	-10	4400	-433.2	-678.0	2370.0
4	5	-825	10	-4400	452.5	2328.3	-2370.0
5	5	670	-9	4400	-452.5	-2328.5	2370.0
5	6	-670	9	-4400	471.4	3668.9	-2370.0
6	6	515	-9	4400	-471.4	-3668.9	2370.0
6	7	-515	9	-4400	489.8	4698.3	-2370.0
7	7	124	-9	4400	-490.5	-4704.7	2370.0
7	8	-124	9	-4400	559.0	5695.0	-2370.0
8	8	-502	-7	4400	-559.1	-5693.4	2370.0
8	9	502	7	-4400	618.6	1680.8	-2370.0
9	9	-522	9	4400	-618.6	-1676.4	2370.0
9	10	522	-9	-4400	548.9	-2502.6	-2370.0
10	10	341	0	4400	-556.6	2508.1	2370.0
10	11	-341	0	-4400	554.8	2685.6	-2370.0
11	11	-335	7	4400	-554.2	-2686.1	2370.0
11	12	335	-7	-4400	453.1	-2422.2	-2370.0
12	12	371	-4	4400	-446.4	2418.2	2370.0
12	13	-371	4	-4400	485.5	1072.4	-2370.0
13	13	-334	-2	4400	-485.5	-1072.7	2370.0
13	14	334	2	-4400	508.8	-2068.2	-2370.0
14	14	340	8	4400	-514.8	2067.1	2370.0
14	15	-340	-8	-4400	397.5	3039.7	-2370.0
15	15	-337	12	4400	-395.6	-3040.0	2370.0
15	16	337	-12	-4400	209.5	-2012.9	-2370.0
16	16	194	-1	4400	-211.5	2037.4	2370.0
16	17	-194	1	-4400	224.9	925.9	-2370.0
17	17	-130	4	4400	-224.4	-937.5	2370.0
17	18	130	-4	-4400	164.3	-1042.4	-2370.0
18	18	157	-2	4400	-164.0	1037.4	2370.0
18	19	-157	2	-4400	201.6	1361.0	-2370.0
19	19	-176	2	4400	-201.7	-1357.6	2370.0
19	20	176	-2	-4400	173.4	-1327.0	-2370.0
20	20	168	-2	4400	-173.4	1328.5	2370.0
20	21	-168	2	-4400	203.9	1234.3	-2370.0
21	21	-163	2	4400	-203.8	-1235.3	2370.0
21	22	163	-2	-4400	167.7	-1244.3	-2370.0
22	22	165	-2	4400	-167.7	1243.8	2370.0
22	23	-165	2	-4400	200.8	1271.2	-2370.0
23	23	-167	2	4400	-200.8	-1270.9	2370.0
23	24	167	-2	-4400	168.3	-1268.3	-2370.0
24	24	166	-2	4400	-168.3	1268.4	2370.0
24	25	-166	2	-4400	200.7	1260.5	-2370.0
25	25	-165	2	4400	-200.7	-1260.6	2370.0
25	26	165	-2	-4400	167.4	-1261.3	-2370.0
26	26	166	-2	4400	-167.5	1261.3	2370.0
26	27	-166	2	-4400	203.3	1263.6	-2370.0
27	27	-166	2	4400	-203.4	-1263.6	2370.0

CPET

Bottom Hole Assembly Report (Non-Drillahead)

Case Name:	ABMO-1 Well	**Date:**	7/25/2017	**Time:**	02:32:21	**Page:**	5
Description:	Horizontal Well						
Well Name:	Well X	**Project Name:**	BHA Analysis				
Well Description:	Horizontal Well	**Project Description:**					

ELEMENT FORCES TABLE

ELEMENT	NODE	FX lbf	FY lbf	FZ lbf	MX ft-lbf	MY ft-lbf	MZ ft-lbf
32	32	166	-2	4400	-173.6	1262.9	2370.0
32	33	-166	2	-4400	205.1	1262.9	-2370.0
33	33	-166	2	4400	-205.1	-1262.9	2370.0
33	34	166	-2	-4400	169.6	-1262.9	-2370.0
34	34	166	-2	4400	-169.5	1262.9	2370.0
34	35	-166	2	-4400	201.2	1262.9	-2370.0
35	35	-166	2	4400	-201.2	-1262.9	2370.0
35	36	166	-2	-4400	167.1	-1262.9	-2370.0
36	36	166	-2	4400	-167.1	1262.9	2370.0
36	37	-166	2	-4400	204.1	1262.9	-2370.0
37	37	-166	2	4400	-204.2	-1262.9	2370.0
37	38	166	-2	-4400	174.4	-1262.8	-2370.0
38	38	166	-2	4400	-174.3	1262.8	2370.0
38	39	-166	2	-4400	198.3	1262.9	-2370.0
39	39	-166	3	4400	-198.1	-1262.9	2370.0
39	40	166	-3	-4400	157.3	-1263.0	-2370.0

ELEMENT FORCES TABLE SUMMARY

	FX lbf	FY lbf	FZ lbf	MX ft-lbf	MY ft-lbf	MZ ft-lbf
(NODE)	7	10	1	40	4	4
MINIMUM	-123	-0	-4400	-157.0	-677.0	-2369.0
(NODE)	1	1	1	9	8	1
MAXIMUM	1053	12	4400	618.0	5695.0	2370.0

WELLBORE VS. DRILLSTRING ANGLE TABLE

NODE	MEASURED DEPTH ft	DISTANCE FROM BIT ft	INCLINATION WB INC deg	INCLINATION DS INC deg	INCLINATION INC DIFF deg	AZIMUTH WB AZM deg	AZIMUTH DS AZM deg	AZIMUTH AZM DIFF deg
1	7766.9	0.0	90.0	90.1	0.1	8.8	8.8	0.0
2	7764.9	2.0	90.0	90.2	0.2	8.8	8.8	0.0
3	7763.9	3.0	90.0	90.3	0.3	8.8	8.8	0.0
4	7760.9	6.0	90.0	90.3	0.3	8.8	8.8	0.0
5	7758.9	8.0	90.0	90.3	0.3	8.8	8.8	0.0
6	7756.9	10.0	90.0	90.3	0.3	8.8	8.8	0.0
7	7754.9	12.0	90.0	90.2	0.2	8.8	8.8	0.0
8	7746.9	20.0	90.0	90.1	0.1	8.8	8.8	0.0
9	7738.9	28.0	90.0	90.0	0.0	8.7	8.8	0.0
10	7730.9	36.0	90.0	90.0	0.0	8.7	8.7	0.0
11	7715.7	51.2	90.0	90.0	0.0	8.7	8.7	0.0
12	7700.4	66.5	90.0	90.0	0.0	8.6	8.6	0.0
13	7691.0	75.9	90.0	90.0	0.0	8.6	8.6	0.0
14	7681.6	85.3	90.0	90.0	0.0	8.5	8.6	0.0
15	7666.6	100.3	90.0	89.9	-0.1	8.5	8.5	0.0
16	7651.6	115.3	90.0	89.9	-0.1	8.4	8.4	0.0
17	7636.4	130.5	90.0	90.0	0.0	8.4	8.4	0.0
18	7621.1	145.8	90.0	90.0	0.0	8.3	8.3	0.0
19	7605.9	161.0	90.0	90.0	0.0	8.3	8.3	0.0
20	7590.6	176.3	90.0	90.0	0.0	8.2	8.2	0.0
21	7575.4	191.5	90.0	90.0	0.0	8.1	8.1	0.0
22	7560.2	206.8	90.0	90.0	0.0	8.1	8.1	0.0
23	7544.9	222.0	90.0	90.0	0.0	8.0	8.0	0.0
24	7529.7	237.3	90.0	90.0	0.0	8.0	8.0	0.0
25	7514.4	252.5	90.0	90.0	0.0	7.9	7.9	0.0
26	7499.2	267.7	90.0	90.0	0.0	7.9	7.9	0.0
27	7483.9	283.0	90.0	90.0	0.0	7.8	7.8	0.0
28	7468.7	298.2	90.0	90.0	0.0	7.8	7.8	0.0
29	7453.4	313.5	90.0	90.0	0.0	7.7	7.7	0.0
30	7438.2	328.7	90.0	90.0	0.0	7.7	7.7	0.0
31	7422.9	344.0	90.0	90.0	0.0	7.6	7.6	0.0
32	7407.7	359.2	90.0	90.0	0.0	7.5	7.5	0.0
33	7392.5	374.5	90.0	90.0	0.0	7.5	7.5	0.0
34	7377.2	389.7	90.0	90.0	0.0	7.4	7.4	0.0
35	7362.0	405.0	90.0	90.0	0.0	7.4	7.4	0.0
36	7346.7	420.2	90.0	90.0	0.0	7.3	7.3	0.0
37	7331.5	435.4	90.0	90.0	0.0	7.3	7.3	0.0
38	7316.2	450.7	90.0	90.0	0.0	7.2	7.2	0.0

CPET

Bottom Hole Assembly Report (Non-Drillahead)

Case Name:	ABMO-1 Well	**Date:** 7/25/2017	**Time:** 02:32:21	**Page:**	6
Description:	Horizontal Well				
Well Name:	Well X	**Project Name:**	BHA Analysis		
Well Description:	Horizontal Well	**Project Description:**			

WELLBORE VS. DRILLSTRING ANGLE TABLE

NODE	MEASURED DEPTH ft	DISTANCE FROM BIT ft	<---INCLINATION--- WB INC deg	DS INC deg	INC DIFF deg--->	<---AZIMUTH--- WB AZM deg	DS AZM deg	AZM DIFF deg--->
39	7301.0	465.9	90.0	90.0	0.0	7.2	7.2	0.0
40	7285.7	481.2	90.0	90.0	0.0	7.1	7.1	0.0

Appendix (C)

3- Second Design:(Two stabilizers in this BHA configuration).

CPET
Bottom Hole Assembly Report (Non-Drillahead)

Case Name:	ABMO-1 Well	**Date:**	7/19/2017	**Time:**	21:50:00	**Page:**	1
Description:	Horizontal Well						
Well Name:	Well X	**Project Name:**	BHA Analysis				
Well Description:	Horizontal Well	**Project Description:**					

DRILLING PARAMETERS OUTPUT

MUD WEIGHT	8.80 ppg
TORQUE AT BIT	2370.0 ft-lbf
MEASURED DEPTH	7770.0 ft
ROTARY SPEED	90 rpm
DRILLAHEAD INTERVAL	900.00 ft
BIT COEFFICIENT	50
WELLBORE OVERGAUGE	in
FORMATION HARDNESS FACTOR	25

WEIGHT ON BIT STUDY REPORT

WEIGHT ON BIT kip	RATE OF PENETRATION ft/hr	BUILD RATE deg/100ft	WALK RATE deg/100ft
4.4	10.0	0.00	0.00

DRILLSTRING

	<-------- LENGTH -------->		<--BODY-->		<---- STABILIZER / TOOL JOINT ---->						
TYPE	COMPONENT ft	TOTAL ft	OD in	ID in	LENGTH ft	OD in	ID in	FISHNECK ft	WEIGHT ppf	MTL GRADE	CLASS*
DP	4307.62	4307.62	5.000	4.276		6.625	2.750		22.60	CS_API 5D/7 S	1
HW	542.00	4849.62	5.000	3.000		6.500	3.063		49.70	CS_1340 MOD 1340 MOD	
DP	2797.00	7646.62	5.000	4.276		7.250	3.500		23.40	CS_API 5D/7 S	1
HW	30.00	7676.62	5.000	3.000		6.500	3.063		49.70	CS_1340 MOD 1340 MOD	
JAR	18.80	7695.42	6.500	2.750					91.79	CS_API 5D/7 4145H MOD (1)	
HW	30.50	7725.92	5.000	3.000		6.500	3.000		49.14	CS_1340 MOD 1340 MOD	
IBS	5.00	7730.92	4.250	2.000	1.00	6.219		2.00	37.59	CS_API 5D/7 4145H MOD (1)	
DC	30.00	7760.92	6.500	3.000					88.86	CS_API 5D/7 4145H MOD (1)	
IBS	5.00	7765.92	4.250	2.000	1.00	6.219		3.00	37.59	CS_API 5D/7 4145H MOD (1)	
BIT	1.00	7766.92	8.500						170.00		

WELLBORE

TYPE	SECTION DEPTH ft	SECTION LENGTH ft	EFFECTIVE INSIDE DIAMETER in	COEFFICIENT OF FRICTION	VOLUME EXCESS %
CAS	6760.0	6760.00	8.835	0.00	
OH	7770.0	1010.00	8.835	0.00	

Survey **Tortuosity: None** **Calculation Method: Minimum Curvature**

Md ft	Incl deg	Direc deg	Tvd ft	Build deg/100ft	Walk deg/100ft	Dls deg/100ft
0.0	0.00	5.20	0.0	0.00	0.00	0.00
98.4	0.00	5.20	98.4	0.00	0.00	0.00
196.9	0.00	5.20	196.9	0.00	0.00	0.00
295.3	0.00	5.20	295.3	0.00	0.00	0.00
393.7	0.00	5.20	393.7	0.00	0.00	0.00
492.1	0.00	5.20	492.1	0.00	0.00	0.00
590.6	0.00	5.20	590.6	0.00	0.00	0.00
689.0	0.00	5.20	689.0	0.00	0.00	0.00
787.4	0.00	5.20	787.4	0.00	0.00	0.00
885.8	0.00	5.20	885.8	0.00	0.00	0.00
984.3	0.00	5.20	984.3	0.00	0.00	0.00
1082.7	0.00	5.20	1082.7	0.00	0.00	0.00
1181.1	0.00	5.20	1181.1	0.00	0.00	0.00
1279.5	0.00	5.20	1279.5	0.00	0.00	0.00
1378.0	0.00	5.20	1378.0	0.00	0.00	0.00
1476.4	0.00	5.20	1476.4	0.00	0.00	0.00
1574.8	0.00	5.20	1574.8	0.00	0.00	0.00
1673.2	0.00	5.20	1673.2	0.00	0.00	0.00
1771.7	0.00	5.20	1771.7	0.00	0.00	0.00
1870.1	0.00	5.20	1870.1	0.00	0.00	0.00
1968.5	0.00	5.20	1968.5	0.00	0.00	0.00
2066.9	0.00	5.20	2066.9	0.00	0.00	0.00
2165.4	0.00	5.20	2165.4	0.00	0.00	0.00
2263.8	0.00	5.20	2263.8	0.00	0.00	0.00
2362.2	0.00	5.20	2362.2	0.00	0.00	0.00
2460.6	0.00	5.20	2460.6	0.00	0.00	0.00
2559.1	0.00	5.20	2559.1	0.00	0.00	0.00
2657.5	0.00	5.20	2657.5	0.00	0.00	0.00
2755.9	0.00	5.20	2755.9	0.00	0.00	0.00

CPET

Bottom Hole Assembly Report (Non-Drillahead)

Case Name:	ABMO-1 Well	**Date:** 7/19/2017	**Time:** 21:50:00	**Page:**	2
Description:	Horizontal Well				
Well Name:	Well X	**Project Name:**	BHA Analysis		
Well Description:	Horizontal Well	**Project Description:**			

Survey **Tortuosity: None** **Calculation Method: Minimum Curvature**

Md ft	Incl deg	Direc deg	Tvd ft	Build deg/100ft	Walk deg/100ft	Dls deg/100ft
2854.3	0.00	5.20	2854.3	0.00	0.00	0.00
2952.8	0.00	5.20	2952.8	0.00	0.00	0.00
3051.2	0.00	5.20	3051.2	0.00	0.00	0.00
3149.6	2.40	5.20	3149.6	2.44	0.00	2.44
3248.0	4.80	5.20	3247.8	2.44	0.00	2.44
3346.5	7.20	5.20	3345.7	2.44	0.00	2.44
3387.4	8.20	5.20	3386.2	2.44	0.00	2.44
3416.5	8.20	5.20	3415.1	0.00	0.00	0.00
3444.9	8.89	5.21	3443.1	2.43	0.04	2.43
3543.3	11.29	5.22	3540.0	2.44	0.01	2.44
3641.7	13.69	5.22	3636.1	2.44	0.00	2.44
3740.2	16.09	5.23	3731.2	2.44	0.01	2.44
3838.6	18.49	5.23	3825.2	2.44	0.00	2.44
3937.0	20.89	5.23	3917.9	2.44	0.00	2.44
4035.4	23.29	5.23	4009.0	2.44	0.00	2.44
4133.9	25.69	5.24	4098.6	2.44	0.01	2.44
4232.3	28.09	5.24	4186.4	2.44	0.00	2.44
4330.7	30.49	5.24	4272.2	2.44	0.00	2.44
4429.1	32.89	5.24	4356.0	2.44	0.00	2.44
4527.6	35.29	5.24	4437.5	2.44	0.00	2.44
4626.0	37.69	5.24	4516.6	2.44	0.00	2.44
4724.4	40.09	5.24	4593.2	2.44	0.00	2.44
4822.8	42.49	5.24	4667.2	2.44	0.00	2.44
4921.3	44.89	5.24	4738.3	2.44	0.00	2.44
5019.7	47.29	5.24	4806.6	2.44	0.00	2.44
5118.1	49.69	5.24	4871.8	2.44	0.00	2.44
5216.5	52.09	5.24	4933.9	2.44	0.00	2.44
5315.0	54.49	5.25	4992.7	2.44	0.01	2.44
5413.4	56.89	5.25	5048.2	2.44	0.00	2.44
5511.8	59.29	5.25	5100.2	2.44	0.00	2.44
5610.2	61.69	5.25	5148.7	2.44	0.00	2.44
5708.7	64.09	5.25	5193.5	2.44	0.00	2.44
5807.1	66.49	5.25	5234.7	2.44	0.00	2.44
5905.5	68.89	5.25	5272.0	2.44	0.00	2.44
6003.9	71.29	5.25	5305.6	2.44	0.00	2.44
6102.4	73.69	5.25	5335.2	2.44	0.00	2.44
6200.8	76.09	5.25	5360.8	2.44	0.00	2.44
6299.2	78.49	5.25	5382.5	2.44	0.00	2.44
6397.6	80.89	5.25	5400.1	2.44	0.00	2.44
6496.1	83.29	5.25	5413.6	2.44	0.00	2.44
6594.5	85.69	5.25	5423.1	2.44	0.00	2.44
6692.9	88.09	5.25	5428.4	2.44	0.00	2.44
6771.3	90.00	5.25	5429.7	2.44	0.00	2.44
6791.3	90.00	5.32	5429.7	0.00	0.35	0.35
6889.8	90.00	5.68	5429.7	0.00	0.37	0.37
6988.2	90.00	6.03	5429.7	0.00	0.36	0.36
7086.6	90.00	6.39	5429.7	0.00	0.37	0.37
7185.0	90.00	6.74	5429.7	0.00	0.36	0.36
7283.5	90.00	7.10	5429.7	0.00	0.37	0.37
7381.9	90.00	7.45	5429.7	0.00	0.36	0.36
7480.3	90.00	7.81	5429.7	0.00	0.37	0.37
7578.7	90.00	8.16	5429.7	0.00	0.36	0.36
7677.2	90.00	8.52	5429.7	0.00	0.37	0.37
7770.3	90.00	8.86	5429.7	0.00	0.36	0.36

RESULTS AT THE BIT (+ IS UP/RIGHT, - IS DOWN/LEFT)

	WELLBORE deg	STRING deg	TILT deg	FORCE lbf
INCLINATION	90.0	90.1	0.1	-1144
DIRECTION	8.8	8.8	0.0	-14

BHA FORCES

MEASURED DEPTH ft	DISTANCE FROM BIT ft	TYPE	CONTACT	CONTACT FORCES INCLINATION lbf	CONTACT FORCES DIRECTION lbf	CONTACT FORCES RESULTANT lbf	AXIAL FORCE lbf	TORQUE ft-lbf
7766.9	0.0	PDC	YES	-1144	-14	1145	-4400	2370.0
7764.9	2.0	NBS	NO	-0	0	0	-4400	2370.0
7763.9	3.0	NBS	NO	-0	0	0	-4400	2370.0

CPET

Bottom Hole Assembly Report (Non-Drillahead)

Case Name:	ABMO-1 Well	**Date:** 7/19/2017	**Time:** 21:50:00	**Page:**	3
Description:	Horizontal Well				
Well Name:	Well X	**Project Name:**	BHA Analysis		
Well Description:	Horizontal Well	**Project Description:**			

BHA FORCES

MEASURED DEPTH ft	DISTANCE FROM BIT ft	TYPE	CONTACT	|<----CONTACT FORCES INCLINATION lbf	DIRECTION lbf	RESULTANT lbf ---->|	AXIAL FORCE lbf	TORQUE ft-lbf
7760.9	6.0	DC	NO	-0	0	0	-4400	2370.0
7758.9	8.0	DC	NO	-0	0	0	-4400	2370.0
7756.9	10.0	DC	NO	-0	0	0	-4400	2370.0
7754.9	12.0	DC	NO	-0	0	0	-4400	2370.0
7746.9	20.0	DC	NO	-0	0	0	-4400	2370.0
7738.9	28.0	DC	YES	-1022	26	1022	-4400	2370.0
7730.9	36.0	IBS	NO	-0	0	0	-4400	2370.0
7728.9	38.0	IBS	NO	-0	0	0	-4400	2370.0
7727.9	39.0	IBS	NO	-0	0	0	-4400	2370.0
7725.9	41.0	HW	YES	-1224	-31	1224	-4400	2370.0
7710.7	56.2	HW	NO	-0	0	0	-4400	2370.0
7695.4	71.5	HW	YES	-1455	-6	1455	-4400	2370.0
7686.0	80.9	JRH	YES	-5	0	5	-4400	2370.0
7676.6	90.3	JRH	YES	-1379	7	1379	-4400	2370.0
7661.6	105.3	HW	NO	-0	0	0	-4400	2370.0
7646.6	120.3	DP	YES	-1003	-18	1003	-4400	2370.0
7631.5	135.5	DP	NO	-0	0	0	-4400	2370.0
7616.3	150.6	DPj	YES	-594	-10	594	-4400	2370.0
7601.1	165.8	DP	NO	-0	0	0	-4400	2370.0
7586.0	180.9	DPj	YES	-648	-8	649	-4400	2370.0
7570.8	196.1	DP	NO	-0	0	0	-4400	2370.0
7555.7	211.2	DPj	YES	-633	-9	633	-4400	2370.0
7540.5	226.4	DP	NO	-0	0	0	-4400	2370.0
7525.4	241.6	DPj	YES	-637	-8	638	-4400	2370.0
7510.2	256.7	DP	NO	-0	0	0	-4400	2370.0
7495.0	271.9	DPj	YES	-635	-8	635	-4400	2370.0
7479.9	287.0	DP	NO	-0	0	0	-4400	2370.0
7464.7	302.2	DPj	YES	-639	-8	639	-4400	2370.0
7449.6	317.3	DP	NO	-0	0	0	-4400	2370.0
7434.4	332.5	DPj	YES	-628	-8	628	-4400	2370.0
7419.3	347.7	DP	NO	-0	0	0	-4400	2370.0
7404.1	362.8	DPj	YES	-664	-9	664	-4400	2370.0
7389.0	378.0	DP	NO	-0	0	0	-4400	2370.0
7373.8	393.1	DPj	YES	-541	-9	541	-4400	2370.0
7358.6	408.3	DP	NO	-0	0	0	-4400	2370.0
7343.5	423.4	DPj	YES	-1055	-6	1055	-4400	2370.0
7328.3	438.6	DP	YES	-218	0	218	-4400	2370.0

BHA DISPLACEMENTS

MEASURED DEPTH ft	DISTANCE FROM BIT ft	TYPE	DISPLACEMENT FROM WELL CENTERLINE INCLINATION in	DIRECTION in	RESULTANT in	CLEARANCE in
7766.9	0.0	PDC	-0.177	-0.002	0.177	0.010
7764.9	2.0	NBS	-0.233	0.001	0.233	1.075
7763.9	3.0	NBS	-0.281	0.003	0.281	1.027
7760.9	6.0	DC	-0.460	0.015	0.460	0.707
7758.9	8.0	DC	-0.581	0.025	0.581	0.586
7756.9	10.0	DC	-0.695	0.033	0.696	0.472
7754.9	12.0	DC	-0.800	0.038	0.801	0.367
7746.9	20.0	DC	-1.087	0.046	1.088	0.080
7738.9	28.0	DC	-1.168	0.029	1.169	0.001
7730.9	36.0	IBS	-1.166	-0.009	1.166	0.002
7728.9	38.0	IBS	-1.160	-0.019	1.160	0.148
7727.9	39.0	IBS	-1.158	-0.024	1.159	0.149
7725.9	41.0	HW	-1.168	-0.029	1.169	0.001
7710.7	56.2	HW	-1.445	-0.044	1.445	0.222
7695.4	71.5	HW	-1.168	-0.005	1.168	0.001
7686.0	80.9	JRH	-1.167	0.019	1.168	0.000
7676.6	90.3	JRH	-1.168	0.006	1.168	0.001
7661.6	105.3	HW	-1.308	-0.013	1.308	0.360
7646.6	120.3	DP	-0.793	-0.014	0.793	0.001
7631.5	135.5	DP	-0.839	-0.024	0.840	1.078
7616.3	150.6	DPj	-0.793	-0.014	0.793	0.000
7601.1	165.8	DP	-1.028	-0.012	1.028	0.889
7586.0	180.9	DPj	-0.793	-0.010	0.793	0.000
7570.8	196.1	DP	-0.973	-0.014	0.973	0.944
7555.7	211.2	DPj	-0.793	-0.011	0.793	0.000
7540.5	226.4	DP	-0.989	-0.012	0.989	0.928
7525.4	241.6	DPj	-0.793	-0.010	0.793	0.000

CPET

Bottom Hole Assembly Report (Non-Drillahead)

Case Name:	ABMO-1 Well	**Date:**	7/19/2017	**Time:**	21:50:00	**Page:**	4
Description:	Horizontal Well						
Well Name:	Well X	**Project Name:**	BHA Analysis				
Well Description:	Horizontal Well	**Project Description:**					

BHA DISPLACEMENTS

MEASURED DEPTH ft	DISTANCE FROM BIT ft	TYPE	DISPLACEMENT FROM WELL CENTERLINE INCLINATION in	DIRECTION in	RESULTANT in	CLEARANCE in
7510.2	256.7	DP	-0.985	-0.013	0.985	0.932
7495.0	271.9	DPj	-0.793	-0.011	0.793	0.000
7479.9	287.0	DP	-0.984	-0.013	0.984	0.934
7464.7	302.2	DPj	-0.793	-0.010	0.793	0.000
7449.6	317.3	DP	-0.994	-0.013	0.994	0.924
7434.4	332.5	DPj	-0.793	-0.011	0.793	0.000
7419.3	347.7	DP	-0.958	-0.013	0.958	0.960
7404.1	362.8	DPj	-0.793	-0.010	0.793	0.000
7389.0	378.0	DP	-1.082	-0.014	1.082	0.835
7373.8	393.1	DPj	-0.793	-0.013	0.793	0.000
7358.6	408.3	DP	-0.654	-0.014	0.654	1.263
7343.5	423.4	DPj	-0.793	-0.005	0.793	0.001
7328.3	438.6	DP	-1.918	0.000	1.918	0.000

ELEMENT FORCES TABLE

ELEMENT	NODE	FX lbf	FY lbf	FZ lbf	MX ft-lbf	MY ft-lbf	MZ ft-lbf
1	1	1039	-13	4400	-360.8	5222.2	2370.0
1	2	-1039	13	-4400	387.5	-3143.6	-2370.0
2	2	998	-13	4400	-387.4	3142.1	2370.0
2	3	-998	13	-4400	399.9	-2144.5	-2370.0
3	3	937	-11	4400	-400.3	2145.2	2370.0
3	4	-937	11	-4400	434.6	665.8	-2370.0
4	4	811	-10	4400	-434.2	-666.4	2370.0
4	5	-811	10	-4400	455.1	2289.0	-2370.0
5	5	656	-10	4400	-455.1	-2289.2	2370.0
5	6	-656	10	-4400	475.6	3601.8	-2370.0
6	6	501	-10	4400	-475.6	-3601.9	2370.0
6	7	-501	10	-4400	495.5	4603.3	-2370.0
7	7	110	-9	4400	-496.2	-4609.7	2370.0
7	8	-110	9	-4400	570.8	5490.5	-2370.0
8	8	-515	-8	4400	-570.9	-5488.8	2370.0
8	9	515	8	-4400	636.3	1370.0	-2370.0
9	9	-112	19	4400	-636.3	-1367.3	2370.0
9	10	112	-19	-4400	486.0	471.5	-2370.0
10	10	-453	20	4400	-485.5	-470.4	2370.0
10	11	453	-20	-4400	445.6	-436.0	-2370.0
11	11	-501	21	4400	-445.4	436.3	2370.0
11	12	501	-21	-4400	424.5	-937.3	-2370.0
12	12	-548	22	4400	-424.6	938.0	2370.0
12	13	548	-22	-4400	381.1	-2033.8	-2370.0
13	13	319	-6	4400	-387.3	2034.5	2370.0
13	14	-319	6	-4400	476.2	2824.2	-2370.0
14	14	-359	0	4400	-476.7	-2820.4	2370.0
14	15	359	0	-4400	480.2	-2647.2	-2370.0
15	15	401	-3	4400	-473.8	2642.2	2370.0
15	16	-401	3	-4400	503.6	1124.0	-2370.0
16	16	-340	-2	4400	-503.7	-1124.4	2370.0
16	17	340	2	-4400	521.7	-2073.5	-2370.0
17	17	341	8	4400	-527.9	2072.4	2370.0
17	18	-341	-8	-4400	403.9	3040.7	-2370.0
18	18	-336	13	4400	-402.0	-3041.1	2370.0
18	19	336	-13	-4400	208.2	-2005.7	-2370.0
19	19	194	-1	4400	-210.1	2030.1	2370.0
19	20	-194	1	-4400	223.7	908.3	-2370.0
20	20	-128	4	4400	-223.2	-919.9	2370.0
20	21	128	-4	-4400	164.4	-1025.3	-2370.0
21	21	156	-2	4400	-164.2	1020.4	2370.0
21	22	-156	2	-4400	201.3	1346.7	-2370.0
22	22	-175	2	4400	-201.4	-1343.3	2370.0
22	23	175	-2	-4400	173.3	-1312.6	-2370.0
23	23	167	-2	4400	-173.3	1314.1	2370.0
23	24	-167	2	-4400	203.3	1219.3	-2370.0
24	24	-162	2	4400	-203.2	-1220.3	2370.0
24	25	162	-2	-4400	167.5	-1228.8	-2370.0
25	25	164	-2	4400	-167.5	1228.4	2370.0
25	26	-164	2	-4400	200.2	1255.8	-2370.0
26	26	-166	2	4400	-200.3	-1255.5	2370.0
26	27	166	-2	-4400	168.3	-1254.4	-2370.0

CPET

Bottom Hole Assembly Report (Non-Drillahead)

Case Name:	ABMO-1 Well	**Date:** 7/25/2017	**Time:** 02:16:22	**Page:**	5
Description:	Horizontal Well				
Well Name:	Well X	**Project Name:**	BHA Analysis		
Well Description:	Horizontal Well	**Project Description:**			

ELEMENT FORCES TABLE

ELEMENT	NODE	FX lbf	FY lbf	FZ lbf	MX ft-lbf	MY ft-lbf	MZ ft-lbf
31	32	-167	2	-4400	206.9	1266.0	-2370.0
32	32	-163	2	4400	-206.9	-1266.6	2370.0
32	33	163	-2	-4400	173.6	-1204.1	-2370.0
33	33	158	-2	4400	-173.6	1205.1	2370.0
33	34	-158	2	-4400	206.2	1185.0	-2370.0
34	34	-170	2	4400	-206.2	-1182.8	2370.0
34	35	170	-2	-4400	172.1	-1398.0	-2370.0
35	35	189	-2	4400	-172.1	1394.7	2370.0
35	36	-189	2	-4400	205.1	1464.1	-2370.0
36	36	-145	2	4400	-205.1	-1471.8	2370.0
36	37	145	-2	-4400	171.7	-732.2	-2370.0
37	37	82	-2	4400	-171.8	743.3	2370.0
37	38	-82	2	-4400	206.8	504.5	-2370.0
38	38	-231	2	4400	-206.8	-478.2	2370.0
38	39	231	-2	-4400	174.9	-3020.8	-2370.0
39	39	534	0	4400	-174.5	2967.3	2370.0
39	40	-534	0	-4400	173.3	5121.9	-2370.0

ELEMENT FORCES TABLE SUMMARY

	FX lbf	FY lbf	FZ lbf	MX ft-lbf	MY ft-lbf	MZ ft-lbf
(NODE)	37	14	1	21	11	4
MINIMUM	-82	-0	-4400	-164.0	-436.0	-2369.0
(NODE)	1	12	1	9	8	1
MAXIMUM	1039	21	4400	636.0	5490.0	2370.0

WELLBORE VS. DRILLSTRING ANGLE TABLE

NODE	MEASURED DEPTH ft	DISTANCE FROM BIT ft	INCLINATION			AZIMUTH		
			WB INC deg	DS INC deg	INC DIFF deg	WB AZM deg	DS AZM deg	AZM DIFF deg
1	7766.9	0.0	90.0	90.1	0.1	8.8	8.8	0.0
2	7764.9	2.0	90.0	90.2	0.2	8.8	8.8	0.0
3	7763.9	3.0	90.0	90.3	0.3	8.8	8.8	0.0
4	7760.9	6.0	90.0	90.3	0.3	8.8	8.8	0.0
5	7758.9	8.0	90.0	90.3	0.3	8.8	8.8	0.0
6	7756.9	10.0	90.0	90.3	0.3	8.8	8.8	0.0
7	7754.9	12.0	90.0	90.2	0.2	8.8	8.8	0.0
8	7746.9	20.0	90.0	90.1	0.1	8.8	8.8	0.0
9	7738.9	28.0	90.0	90.0	0.0	8.7	8.8	0.0
10	7730.9	36.0	90.0	90.0	0.0	8.7	8.7	0.0
11	7728.9	38.0	90.0	90.0	0.0	8.7	8.7	0.0
12	7727.9	39.0	90.0	90.0	0.0	8.7	8.7	0.0
13	7725.9	41.0	90.0	90.1	0.1	8.7	8.7	0.0
14	7710.7	56.2	90.0	90.0	0.0	8.6	8.6	0.0
15	7695.4	71.5	90.0	90.0	0.0	8.6	8.6	0.0
16	7686.0	80.9	90.0	90.0	0.0	8.6	8.5	0.0
17	7676.6	90.3	90.0	90.0	0.0	8.5	8.5	0.0
18	7661.6	105.3	90.0	89.9	-0.1	8.5	8.5	0.0
19	7646.6	120.3	90.0	89.9	-0.1	8.4	8.4	0.0
20	7631.5	135.5	90.0	90.0	0.0	8.4	8.4	0.0
21	7616.3	150.6	90.0	90.0	0.0	8.3	8.3	0.0
22	7601.1	165.8	90.0	90.0	0.0	8.2	8.2	0.0
23	7586.0	180.9	90.0	90.0	0.0	8.2	8.2	0.0
24	7570.8	196.1	90.0	90.0	0.0	8.1	8.1	0.0
25	7555.7	211.2	90.0	90.0	0.0	8.1	8.1	0.0
26	7540.5	226.4	90.0	90.0	0.0	8.0	8.0	0.0
27	7525.4	241.6	90.0	90.0	0.0	8.0	8.0	0.0
28	7510.2	256.7	90.0	90.0	0.0	7.9	7.9	0.0
29	7495.0	271.9	90.0	90.0	0.0	7.9	7.9	0.0
30	7479.9	287.0	90.0	90.0	0.0	7.8	7.8	0.0
31	7464.7	302.2	90.0	90.0	0.0	7.8	7.8	0.0
32	7449.6	317.3	90.0	90.0	0.0	7.7	7.7	0.0
33	7434.4	332.5	90.0	90.0	0.0	7.6	7.6	0.0
34	7419.3	347.7	90.0	90.0	0.0	7.6	7.6	0.0
35	7404.1	362.8	90.0	90.0	0.0	7.5	7.5	0.0
36	7389.0	378.0	90.0	90.0	0.0	7.5	7.5	0.0
37	7373.8	393.1	90.0	89.9	-0.1	7.4	7.4	0.0

CPET

Bottom Hole Assembly Report (Non-Drillahead)

Case Name:	ABMO-1 Well	**Date:** 7/25/2017	**Time:** 02:16:22	**Page:**	**6**
Description:	Horizontal Well				
Well Name:	Well X	**Project Name:**	BHA Analysis		
Well Description:	Horizontal Well	**Project Description:**			

WELLBORE VS. DRILLSTRING ANGLE TABLE

NODE	MEASURED DEPTH ft	DISTANCE FROM BIT ft	|<---INCLINATION--- WB INC deg	DS INC deg	INC DIFF deg	--->|<---AZIMUTH--- WB AZM deg	DS AZM deg	AZM DIFF deg --->|
38	7358.6	408.3	90.0	89.9	-0.1	7.4	7.4	0.0
39	7343.5	423.4	90.0	90.3	0.3	7.3	7.3	0.0
40	7328.3	438.6	90.0	90.0	0.0	7.3	7.3	0.0