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Drilling Optimization on a New Vertical Exploration Well Designed for Niger Delta X-Field Reservoir

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Abstract: *There is no drilling optimization without proper well planning. This research looked at optimal exploratory well design possibilities for two reservoirs (A and B) located within a Niger Delta X-Field, south of Nigeria. After much data analysis from both reservoirs the researchers concluded that reservoir A is a gas reservoir and reservoir B is an oil reservoir. Well design work was discontinued for reservoir A (the gas reservoir) because there are no gas facilities in place to transport and distribute possible gas production. Our research team carried out further analysis and completed the well design for optimal oil production from reservoir B (the oil reservoir). This study is inclusive of graph(s), well design assumptions, relevant equations and applicable calculations used in generating our design results (as summarized in a table). Various schematics to illustrate our optimal well design are also provided.*

Keywords: *Well optimization design, optimal well design, Niger Delta, Oil reservoir, well design calculations*

1. Introduction

There is no drilling optimization without proper well planning. So, what is well planning? Well planning is probably the most tasking aspect of a drilling engineer's job when considering drilling optimization. It will take the integration of engineering principles, corporate or personal philosophies, experience and expertise as factors. Though, well planning methods/practices varies within the drilling industry. But, the end drilling design must be a safely drilled minimum cost well that should satisfy the reservoir engineer's design for optimal production of oil and gas from the well drilled into the newly licensed Niger Delta-X field. Experienced well planners are usually armed with these three common traits:

- Experienced drilling engineers that have knowledge of how all areas of the drilling operation can be coordinated with ease.
- She/he uses available engineering tools like computers and third-party recommendations as a guide for developing the well plan.
- Finally, he/she must have an investigative intuition that motivates him/her towards researching and reviewing every aspect of the well. This has the potential of eliminating, isolating and removing possible problem areas.

1.1. An Overview on Well Planning Process

Well planning is an established and organized orderly process. It is expedient that basic aspects of the plan be put in place before designing other areas. For instance, the mud density/weight plan must be designed before the casing plan since mud weight(s) has an impact on pipe demands. The aspect of bit programming can be carried out any time in the well planning phase provided the historical data(s) from the field has been properly analyzed. Such bit programs are commonly generated from drilling parameters gathered from offset wells. Although, selecting the right bit for the design can be affected too by the mud plan (like the performance of a polycrystalline-diamond (PCD) bit in oil-mud). However, the casing and tubing plan can be implemented as an integral part of the drilling design plan (a fact that is importantly valid for production casing plan). A criterion for consideration during tubing design is the drift diameter of the production casing. But, the packer to tubing stresses generated by possible tubing movement can potentially affect the production casing (Well Engineering and Construction textbook).

1.2. What Are The Objectives Of Planning This Well?

The objective(s) of planning the proposed new vertical exploration well in the newly licensed Niger Delta-X field reservoir is to put in place from numerous variables a design program/plan for drilling a well that has the following characteristics:

- A well that must be safe
- Designed at minimum cost to
- Produce oil and gas at optimal capacities

All the same, it is not usually possible to accomplish these objectives for every exploration well due to formation geology, drilling equipment, temperature, casing limitations, hole-sizing, and budget limitations. But our aim/objectives and end results was to safely drill a minimum cost hole that must satisfy the reservoir engineering team of the Nigeria Petroleum Development Corporation's (NPDC) requirements for oil and gas production in Niger Delta, South of Nigeria. It is important to emphasize here that achieving a minimum cost-hole that can produce optimally must not come at the expense of the safety of drilling personnel and the environment.

1.3. Well Type Classification

As a drilling engineer you are required to plan different well types such as:

- Wildcats: This are wells drilled with poor geological information
- Exploratory holes: This wells are also drilled relying on seismic data obtained
- Step-outs: Such wells are drilled after exploratory outcomes
- In-fills: Wells are drilled based on production zones
- Re-entries: Existing well(s) are re-entered for various reasons like deepening it, side-tracking etc. It requires tremendous planning and proper execution.

Wildcats need careful planning than the other types. Whereas, in-fill well and re-entries requires less planning most times (Martin et al., 2012).

1.4. Formation Pressure(S)

Drilling engineers know too well that formation pore pressures encountered greatly influences well plan. These formation pore pressures are:

- Normal: Normal pressured wells do not commonly create planning issues for drilling engineers. Usually, the mud densities are in the range of 8.5 to 9.5 lbm / gal. Kicks or blowout-prevention (BOPs) issues can be minimized but not eliminated completely as the case may be. Note that for wells with depth greater than 20,000ft casing demands can be an issue even for a normal pressured well due to tension / collapse design limitations.
- Abnormal: This type of pressures is known to adversely affect well planning in many areas like casing and tubing design, mud weight and type selection, casing setting-depth selection, and cement planning. Drilling engineers also take into serious consideration the following issues due to high formation pressures. Problems like kicks and blowouts, differential pressure pipe sticking, lost circulation resulting from high mud densities, and heaving shale.
- Subnormal: It requires setting more casing strings to take care of weaker or low pressured zones. Such unusually subnormal pressures commonly results from geological, tectonic factors or pressure depletion from producing intervals.

2. Well Design Characteristics

Who can design a well to produce optimally without taking into account well design characteristics? Therefore, the drilling engineer must first and foremost pursue the different types of data available to him/her to gain insight needed to develop the projected drilling conditions.

2.1. Offset Well Selection Criteria(S)

Drilling engineers are not saddled usually with the task of selecting well sites. But, they must work along with geologists for the following reasons to:

- Develop better knowledge and understanding of the expected drilling geology conditions.
- Define fault block structures to help select offset wells similar in nature to the prospect well.
- Identify possible geological anomalies that might be encountered during the drilling stage.

A close working relationship between drilling and geology groups can be the difference between a producer and an abandoned well (Drilling Engineering textbook).

2.2. Data Source Identification

Common data types used by drilling engineers are:

- Bit: It contains data relative to the actual on-bottom drilling operations
- Mud: Describes the physical and chemical characteristics of the mud system such as mud weight, mud pH, funnel viscosity, plastic viscosity, yield point, gel strength, mud chloride/calcium contents, solid content, cat-ion exchange capacity and fluid losses.
- Mud-logs: A mud log is a foot-by-foot record of drilling, mud, and formation parameters
- Operator's drilling records
- IADC reports (International Association of Drilling Contractors): It contains hourly reports for drilling operations, drill string properties, mud properties, bit performance, and time break-downs for all operations.
- Scout tickets: Current scout tickets contain a brief summary of the well data/parameters like well name, location and operator, spud/completion dates, casing geometries/cement volumes, production test data, completion information, and tops of various geological zones.
- Log headers: This contains logging depths, mud weight and viscosity at each logging depth, bit sizes, inferred casing sizes, and actual setting depths.
- Production history: It provides clues to issues that may be encountered in the prospect well.
- Seismic studies: A good agreement on the pore pressures can be attained with seismic and sonic-log data.
- Well surveys
- Geological contours
- Data bases of service company files.

3. WELL DESIGN CALCULATIONS FOR NIGER DELTA X-FIELD RESERVOIR

3.1. Pore and Fracture Pressure Consideration

Fracture pressure is that pressure needed to cause a formation to fail or split. What this means is that it is the pressure that causes the formation to fracture and the circulating fluid lost in the process. It is usually expressed as a gradient with units in psi/ft (kPa/m) or ppg (kg/m3). The reliability and success of a casing design is greatly depended on the formation pore pressure. Proper determination /utilization of the formation pore and fracture gradients at the design stage of the well can prevent or control outcomes like fluid kicks, lost circulation, surface blowouts and underground blowouts (Nguyen et al., 1999).

3.1.1. Pore Pressure Determination

Considering available data(s) from the Niger Delta X-field reservoir we have that:

For Pore Pressure Data

Surface to 4,000 ft at normal pressure = 8.9 ppg, Equivalent Mud Weight (EMW)

At 9,000 ft the pore pressure is expected to rise to 10.5 ppg (EMW)

From 9,000 ft to 11,750ft (TD) the pore pressure is constant at 10.5 ppg (EMW)

Figure 1.0 and Table 1.0 below illustrate the relationship of Depth and Equivalent Mud Weight.

Table1.0. *Pore Pressure data(s)*

DEPTH (ft)	EMW (ppg)
4,000	8.9
9,000	10.5
11,750	10.5

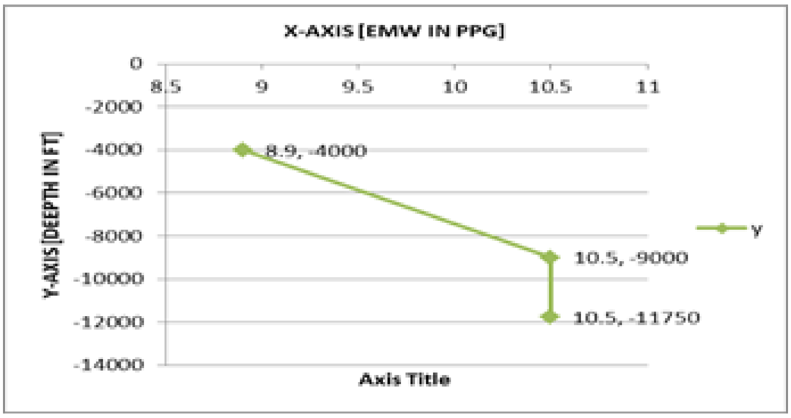

Fig1.0. *Graph of Depth (ft) against Equivalent Mud Weight, EMW (ppg)*

Pore Pressure (Pp) = 0.052 x EMW (ppg) x Depth (ft) 3.1

Therefore:

At 4,000ft and 8.9ppg (EMW), Pore Pressure, P_p = 0.052 x 8.9 x 4,000 = 1851psi

At 9,000ft and 10.5ppg (EMW), Pore Pressure, P_p = 0.052 x 10.5 x 9,000 = 4914psi

At 11,750ft and 10.5ppg (EMW), Pore Pressure, P_p = 0.052 x 10.5 x 11,750 = 6416psi

3.2. Determination of the Mud Pit Capacity

From available data we also have that:

For Casing Data

20" surface casing was set at 550ft below GL with a casing weight of 133 lb/ft, 13 3/8" intermediate casing was also set at 4,000ft below GL with casing weight of 72 lb/ft, 9 5/8" production casing set at 10,000ft below GL with casing weight of 54.5 lb/ft, 7" production liner set at 12,000ft below GL.

Where:

GL = Ground Level

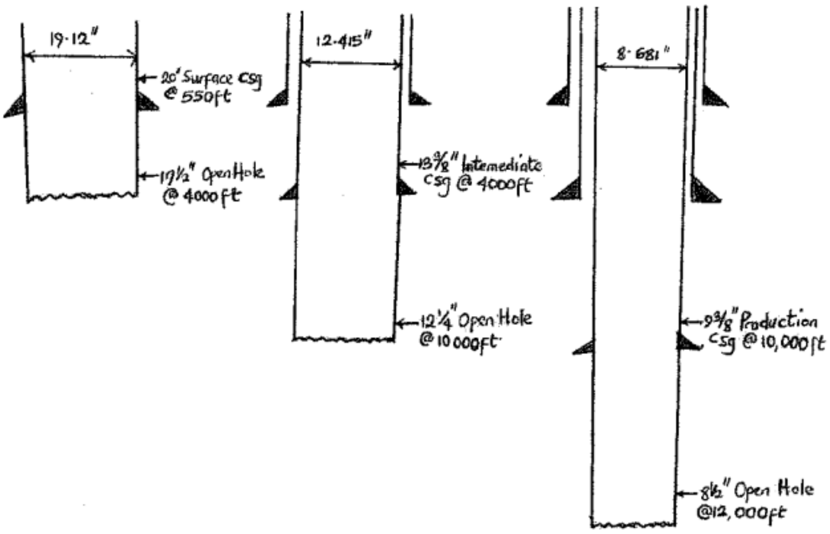

Fig2. *Open hole well design schematics*

Casing or Open Hole Capacity = $\frac{(I.D)^2}{1029.4\text{bbl/ft}}$ 3.2

Casing or Open Hole Volume = $\frac{\text{Casing}}{\text{Open Hole Capacity x TVD}}$ 3.3

Mud Pit Capacity = Casing Volume + Open Hole Volume + Open hole excess 3.4

Considering 17.5" Open Hole:

Casing Capacity = $(19.12)^2$ / 1029.4 = 0.355bbl/ft

Casing Volume = 0.355 (bbl/ft) x 550 (ft) = 195.3bbls

Open Hole Capacity = $(17.5)^2$ / 1,029.4 = 0.298bbl/ft

Open Hole Volume = 0.298 (bbl/ft) x 3,450 (ft) = 1,028bbls

50% Open Hole Excess = 0.5 x 1,028 bbl = 514bbls

Total Open Hole Volume = (514 + 1028) bbls = 1,542bbls

Mud Pit Capacity at 4,000ft = (195.3 + 1,542) bbls = 1,737bbls

Considering 12.25" Open Hole:

Casing Capacity = $(12.415)^2$ / 1,029.4 =0.150bbl/ft

Casing Volume = 0.150 x 4,000 = 598.9bbls

Open Hole Capacity = $(12.25)^2$ / 1,029.4 = 0.146bbl/ft

Open Hole Volume = 0.146 x 6,000 = 876bbls

25% Open Hole Excess = 0.25 x 876 = 219bbls

Total Open Hole Volume = (219 + 876) bbls = 1,095bbls

Mud Pit Capacity = (598.9 + 1,095) bbls = 1,693.9bbls

Considering 8.5" Open Hole:

Casing Capacity = $(8.681)^2$ / 1,029.4 = 0.073bbl/ft

Casing Volume = 0.073 x 10,000 = 730bbls

Open Hole Capacity = $(8.5)^2$ / 1,029.4 = 0.070bb/ft

Open Hole Volume = 0.070 x 2,000 = 140bbls

10% Open Hole Excess = 0.1 x 140 = 14bbls

Total Open Hole Volume = (14 + 140) bbls = 154bbls

Mud Pit Capacity = (154 + 730) bbls = 884bbls

Therefore, Total Mud Pit Capacity = (1,737 + 884 + 1,693) bbls = 4,316bbls

3.3. Down-hole Equipment Design for The Well

We considered two reservoirs (reservoir A and B respectively) located within the Niger Delta X-Field. Details of both reservoirs are given below:

Reservoir A: Is at 10,500ft to 10,600ft. It was identified as a gas reservoir (containing basically methane with a gas gradient of 0.12 psi/ft). Since there are no means of evacuating or exporting any gas produced from this gas reservoir for possible utilization (as in power plant gas turbines) as gas fuel. No further exploratory well design was carried out. Hence, we moved on to consider reservoir B.

Reservoir B: Is at 11,000ft to 11,750ft. This is the primary oil reservoir, and will provide the initial production from the Niger Delta X-Field.

Figure 2.0 below illustrates the exploratory well design schematic for the well to be drilled in the Niger Delta X-Field resrvoir.

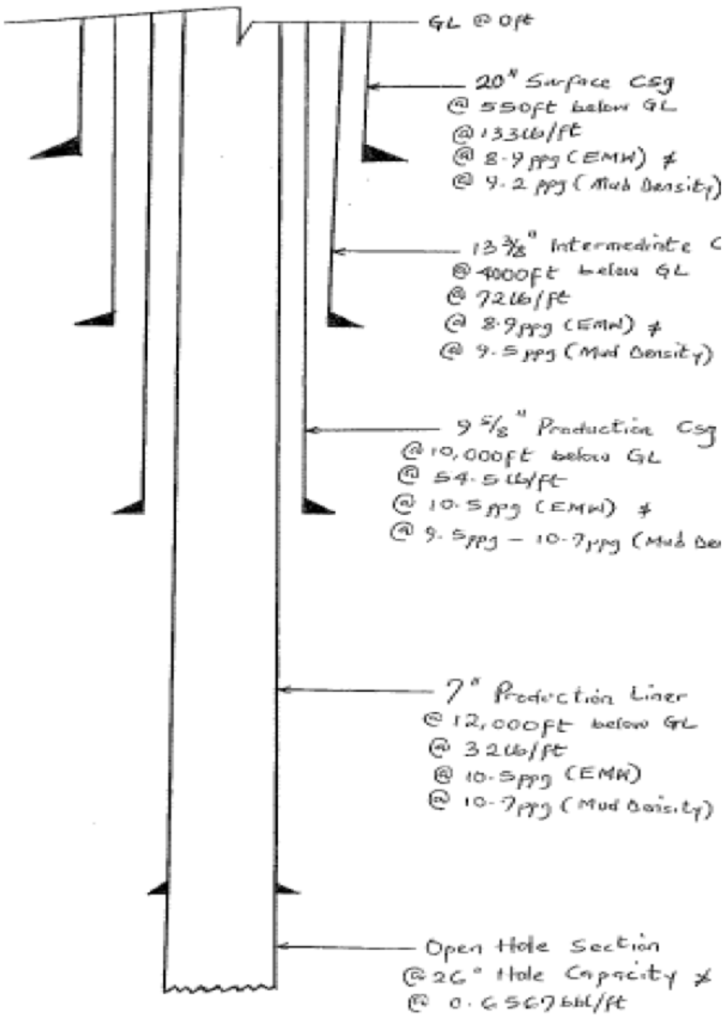

Fig3. *The Exploratory Well design schematics for reservoir B located in the Niger Delta X-Field*

3.3.1. Pressure Calculations

At a Total depth (TD) of 11750ft and a Mud Weight of 10.5ppg

Therefore, Pressure Exerted, P = 0.052 x Mud Weight x Total Depth (TD)

Hence, P = 0.052 X 10.5 X 11,750 = 6,416psi

3.3.2. Drill String and Bottom Hole Assembly (Bha) Calculations

Buoyancy Factor (BF) of the mud weight

Buoyancy Factor, BF = $1 - \frac{10.5}{65.5} = 0.8397$

Collar Length needed to achieve desired weight on bit (WOB)

Weight on bit, WOB = 50kips, Safety Factor = 0.85

Drill Collar weight (8 in x 3 in) = 147lb/ft

Assumed Stiffness Ratio (SR) = 3.5

Length of Bottom Hole Assembly, LBHA = $\frac{50 \ X \ 1{,}000}{0.85 \ X \ 0.8397 \ X \ 147} = 476.6\text{ft}$

Therefore, LBHA is approx. 477ft

Maximum Length of Drill Pipe needed with BHA is given by:

$$L_{max} = \left(\frac{(TS(1-F_{dp}) - MOP - W_{BHA})BF}{Wd_P}\right) \qquad 3.5$$

Where:

L_{max} = Maximum length of drill pipe that can be run into the hole with a specific BHA in feet,

TS = Tensile strength for new drill pipe (lb)

F_{dp} = Safety factor to correct new drill pipe

MOP = Margin of over-pull (lb)

W_{BHA} = Weight of the Bottom Hole Assembly (lb),

W_{dp} = Weight of drill pipe with tool joint (lb/ft).

Drill Pipe to be used = G105 at 19.5lb/ft

Tensile Strength of new pipe, TS = 553,800lb

Safety Factor to correct drill pipe, F_{dp} = 10%

Assumed Desired Over-pull, (MOP) = 100,000lb

Weight of BHA, (WBHA) = 50,000lb

BHA Length = 477ft (LBHA)

Weight of drill pipe with tool joint, (Wdp) = 19.5 (lb/ft)

Buoyancy Factor, (BF) = 0.8397

Hence,

Maximum Length of Drill Pipe needed with the BHA is:

$$L_{max} = \left(\frac{(553{,}800(1-0.1)-100{,}000-50{,}000)\ X\ 0.8397}{19.5}\right) = 15{,}003.5\ (ft)$$

Therefore, the Maximum Length of Drill Pipe, Lmax is approx. 15,004ft

Total Depth that can be reached with a Specific BHA in ft is given by:

$$D_T = L_{max} + L_{BHA} \qquad 3.6$$

Where:

D_T = total depth that can be reached with a specific BHA in ft,

L_{BHA} = length of BHA to be run in ft

Hence, D_T = (15,004 + 477) ft = 15,481 (ft)

Assuming a drill collar joint = 30ft

Then,

Number of Drill Collars (DCs) needed to make up the BHA is given by:

$$\frac{L_{BHA}}{DC\ joint} = \text{Number of Drill Collars needed to make up BHA}$$

$$\text{Number of DCs needed to make up BHA} = \frac{477ft}{30ft} = 15.9$$

Therefore, we will need approx. 16 DCs plus 1 drill jar and an additional 2 DCs (just in case). Hence, the BHA is made up of 19 units.

The complete BHA Design consists of the following units:

- 18 Drill Pipes
- 1 Drill Jar
- 3 Stabilizers
- 1 Float Sub

3.4.Summary of Well Design Results for the New Exploratory Well Located In the Niger Delta X-Field

Table2.0. *Well Design Results In Summary*

Well Design Parameters (units)	Niger Delta X-Field Reservoir A (Gas)	Niger Delta X-Field Reservoir B (Oil)
Pore Pressure @ 4000ft, (psi)	1,851	1,851
Pore Pressure @ 9000ft, (psi)	4,914	4,914
Pore Pressure @ TD 1750ft, (psi)	-	6,416
Total Mud Pit Capacity, (bbls)	-	4,316
Length of BHA, (ft)	-	477
Buoyancy Factor, BF	-	0.8397
Max. Length Drill Pipes, L_{max}, (ft)	-	15,004
Total BHA Depth, D_T, (ft)	-	15,481
Total Drill Collars for BHA	-	16
Total Drill Pipes Required	-	18
Number of Drill Jar(s) Required	-	1
Number of Stabilizer(s) Required	-	3
Number of Float Sub(s) Required	-	1

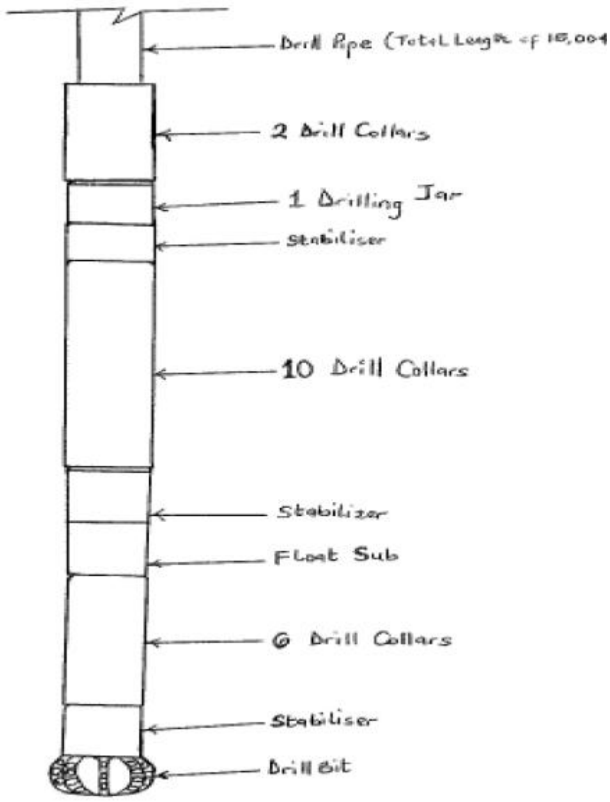

Fig4. *The complete BHA Design schematics*

4. CONCLUSION/RECOMMENDATION

The costs required to properly plan this new vertical exploratory well is insignificant in comparison to the actual drilling costs. In most cases, less than 1,000 U.S dollars is what is utilized in planning a well with a drilling cost of over 1,000,000 U.S dollars. This might only cover just one tenth of one percent of the entire well cost.

Although, many past instances can be used to illustrate that well planning costs were sacrificed or completely avoided in an effort to cut cost. Drilling companies are also reputed for cutting cost by minimizing data-collection work (even though good data can usually be obtained for small amount of money). This most times causes many well plans to be produced without the possible knowledge of drilling issues. Trying to play down expenditures during the early stages of well planning process can necessitate higher than anticipated drilling costs.

REFERENCES

[1] Drilling Engineering textbook, Institute of Petroleum Engineering, Heriot-Watt University, USA

[2] Gabolde G, Nguyen J.P (1999): Drilling Data Handbook, 7th edition, Editions Technips, Institut Francais du Petrole Publications, Paris, France

[3] Hussain Rabia: Well Engineering and Construction textbook

[4] Martin Klempa, Petr Bujok, Ludek Kovar & Co: Fundamentals of Onshore Drilling textbook

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