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Reducing Drilling Cost in Geothermal Wells by Drilling Technology Optimization

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Abstract

Sustainable production of sufficient energy to power the world's economy with a minimum environmental footprint has been one of the most significant challenges for the decades. Geothermal energy has been considered as one of the promising options to meet the world's future energy demand. The cost of drilling geothermal wells is between 35% and 50% of the total investment cost for the new high-temperature geothermal plants. This "up front" cost makes the geothermal plants more expensive to build than the conventional plants, and because of this and the perceived risk, a lot of attention has been focused on reducing this cost. This paper attempts to minimize the cost of drilling deep wells such as AG-119X, in Egypt of 20060 ft. in depths; in this well, the actual cost was more than the proposed by about five million USD. The actual cost of the drilling operation has been analyzed and compared with the proposed; by observing the cost of each drilling item, it was found that the power drive tools in the bottom hole assembly such as the downhole motor with Rotary Steerable drilling system (RSS) or turbodrill hydraulic downhole motor is the most costly element of the drilling operation in 8.5 holes, which tack thirteen trips in every trip with a new bit, and it was found that the turbodrill hydraulic downhole motor was costly effected in drilling the shush section, in this, and can save around 1756999 USD; this paper is a road map for reducing the cost of drilling geothermal wells.

1. Introduction

For decades, one of the biggest issues has been the sustainable generation of enough energy to power the global economy with the least possible environmental impact. The world relies heavily on oil and gas to provide energy, The fluctuating costof oil and gas, and environmental issues, have begun to draw people's attention.

Geothermal energy, a crucial form of alternative energy, has been viewed as one of the most viable solutions to fulfill theworld's future energy needs. It can produce large amounts of electricity with little aesthetic or environmental effect because it is a clean and renewable energy source. It has several benefits, including weather independence, dependability, stability, and thermal efficiency. [1]

Drilling accounts for almost 35% and 50% of the entire cost of Enhanced Geothermal Systems (EGS) While geothermal drilling methods can be improved through research and development (R&D) to lower costs, still, a complete analysis of the deep geothermal drilling business is lacking. For example, there is relatively little access to cost data for geothermal drilling. Additionally, there is a need for improvement in the communication between drilling contractors and project developers [2].

1.1. Geothermal drilling history

The history of geothermal drilling documents the series of attempts made by geothermal developers across the globe to include and modify drilling equipment and operating knowledge from the mining, oil, gas, and water well sectors. Both production and exploration have been made feasible by these initiatives. However, the adoption of

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recognized improvements and technological advancements has been sluggish. Drilling is a field activity that is very conventional, experience-based, and historically regarded as a private or "trade secret" activity. Because of this decreased efficacy, the almost independent learning curve leads to high upfront costs of initial development drilling. Drilling takes longer and costs more money when drilling rates are slower. The geothermal community has published outstanding research [3] that offers current data for average and range values of the generated per kilometer of dug boreholes and examines the impacts of the learning curve from around twenty large geothermal reservoirs. A wealth of documentation exists about the particular issues, studies, and advancements [4] these assessments usually concern the gradual improvement in "drilling effectiveness," or the successful avoidance and resolution of downhole issues. Furthermore, boosting "drilling performance" entails raising productivity, such as penetration rate.

The industry of geothermal energy is expanding. Global geothermal energy output surged from 6833 megawatt-hours in 1995 to 9966 megawatt-hours in 2008, and the energy it directly used in 2005 eliminated almost thirty million barrels of oil10. Although this increase, there is still very little drilling activity for geothermal in comparison to oil and gas—in the US, less than 100 geothermal wells were drilled in 2008, while over 50,000 wells were drilled for oil and gas. Considering wells for injection accounting for that present one-third of the producers, and a median geothermal well production of 6–10 MWe, there are only 1000–1600 active wells overall. Since many more wells have been dug than are now operational, this statistic can be slightly misleading. The corrosive and solids-laden brines in many geothermal reservoirs necessitate extensive workover drilling for active power plants. Numerous former productions or injection wells have been plugged and abandoned. Exploratory wells were once necessary to locate and assess the geothermal reservoirs. Despite this, the industry is currently so small that only a few drilling contractors or service providers are capable of earning a complete income from their geothermal [5]

Any downhole or surface equipment on the rig that will be subjected to high temperatures must be capable of withstanding such temperatures while digging geothermal wells. Given that drilling fluid returns are likely to be far hotter than those from traditional drilling, this could be particularly apparent Regulations in most places will mandate the use of mud coolers when returns surpass a certain temperature; however, even with coolers, drilling crew should be mindful that hot fluid will produce greater-than-usual thermal expansion forces and that any elastomer seals could be compromised by the high temperature [6].

1.2. Drilling technology

Drilling technology is the application of technology for drilling since the 1973 release of the Woodward-Clyde deep borehole design study, drilling technology has advanced dramatically. The majority of the developments have been connected to directional control, which is connected to the surge in horizontal well oil and gas drilling. The same directional drilling technology can be used to maintain borehole straightness (i.e., dogleg-severity or maximum angular deviation across a specified distance) and verticality (i.e., borehole plumpness), even when the rock structure, fabric, or fractures would tend to cause the drill bit to deviate from vertical. Deep borehole disposal is currently being investigated in vertical boreholes. By the way drilling torque is applied to the drill bit, by the way, directional control is kept, and by the kind of drill bit used and downhole tools used, we may broadly classify applicable deep drilling techniques [7].

Drilling technology has been widely used in many industries such as manufacturing, mining; oil, and gas, geothermal drilling processes are not limited to conventional methods where physical contact is made between the drill bit and the formation. Non-conventional drilling tools use transfer forms of energy such as converting the flow pressure from drilling fluid to mechanical, to generate holes in good condition [7]

Among all drilling processes, conventional drilling with drill bits without any power tools is the first operation, drilling is one of the essential operations, where the bit life can be critically affected by the quality of the drilled holes. Drilling is often considered the final machining operation during the assembly of components, where an efficient drilling process provides superior-quality drilled holes to ensure high strength and high efficiency [6] A low-quality drilling tools used can result in problems in the hole, which ultimately reduce their service lifetime and add extra costs for repair, This is why the drilling process is acknowledged as a more challenging issue during assembly and is the most common, frequent and necessary processing. Therefore, both academia and industries are highly motivated to research the applications of drilling operations.

1.2.1. Bottom hole assembly tools

Downhole tooling or bottom-hole assembly tools (BHA tools) are components of a drilling rig. It is the lowest part of the drill string refers to the tools used downhole during drilling operations. consisting of (from the bottom up in a vertical well) the bit, bit sub, a mud motor or turbine (in certain cases), stabilizers, drill collar, heavy-weight drill pipe, jarring devices ("jars"), and crossovers for various thread forms. The bottom hole assembly must provide force and power for the bit to break the rock (weight on bit), survive a hostile mechanical environment, and provide the driller with directional control of the well. Oftentimes the assembly includes a down-hole motor with a rotary steerable drilling system and turbodrill a hydraulic downhole motor drilling system and another tool [7].

1.2.1.1. Down-hole motor with rotary steerable Drilling System

Down-hole motor with rotary steerable drilling system a type of drilling technology used for directional drilling is a rotary steerable system (RSS). Specialized downhole equipment is used in place of traditional directional tools like mud motors. They are typically programmed by the measurement while drilling (MWD) engineer or directional driller who transmits commands using surface equipment (typically using either pressure fluctuations in the mud column or variations in the drill string rotation). The tool responds to these commands and slowly steers in the desired direction. In other words, a device created to prevent the need to "slide" a mud motor by drilling directionally with continuous rotation from the surface [7]. not employing bent subs to affect the angles of the hole. The angles of the hole change due to the movements of three "pads" inside the non-rotating sleeve. Inner mud-operated actuators keep the "pads" in constant connection with the formation figure 1 shows the configuration of RSS.

Rotary Steerable Systems (RSS) are the latest directional drilling systems to enter the marketplace. By providing a superior directional response, wellbore quality, and the ability to drill Extended Reach wells, usually in situations where the well's horizontal displacement to vertical depth ratio is more than 2:1. The ratio of lateral length to vertical depth may reach up to 13:1 under some circumstances. RSSs function by continuously directing the drill bit in the desired hole direction. They are found at the bottom of the drilling assembly, often measuring more than 5 km in length and rotating at speeds of up to 250 rpm [8].

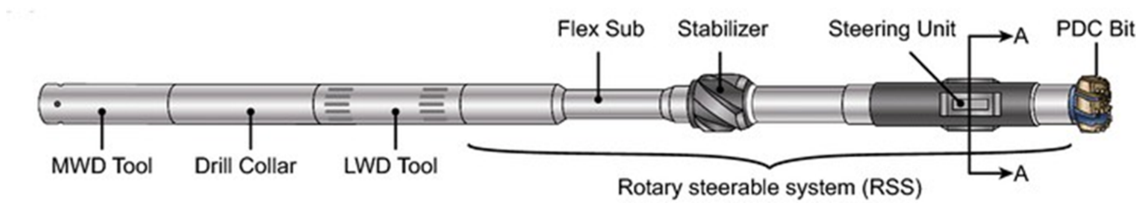

Figure 1. Rotary steerable system configuration [10].

1.2.1.2. Turbodrill

Turbodrill is a hydraulic downhole motor drilling system that imparts rotary motion to the drill bit by turning the hydraulic force given by the high-pressure injected mud into the mechanical energy. High-velocity-mud flows through the nozzles, striking the stator blades and turning the bit and outer housing. Instead of moving the entire column of rods in the well, an axial-flow multistage turbine is a working tool that converts the energy into drive force to impose rotary motion just on the drilling tool; at the bottom hole turbodrill, were used effectively for drilling the directional tangent portion of a well. As shown in Figure 2, the activity of the drilling fluid and the different turbine blade stages produces the turbodrill spinning. The rpm is directly related to the torque and fluid speed. One disadvantage is that more power is required near the surface. Certain rigs have not had enough hydraulic horsepower to run the turbodrill. Before starting the turbodrill, check the hydraulics often [9].

Some early research works and development had been done on the downhole turbines that might be used to drive the bit even before directional drilling became widely accepted. The purpose of these early instruments were to offer a substitute for the traditional rotary techniques, which required rotating the drill string total from the surface. When compared with rotary drilling for straight holes, the turbo drill did have a few benefits (a) The portion where rotary torque was needed was where it was developed; (b) More power might be produced by the turbo drill than the rotary system could provide to the bit. (c) The turbine rotational speed might be substantially quicker. (d) There was less wear and tear on the drill pipe and casing since the drill string did not need to revolve. A single-stage turbine was patented by the Cross of Chicago, but no evidence of its actual usage could be found. The 1920s saw a resurgence of interest in turbo drills, with the USA and USSR leading the development effort. Kapelyushnikov created a single-stage turbine in 1924, which was tested near Baku on the Caspian Sea. Scharpenberg deployed multi-stage turbines for the first time in California in 1926 [11]. One such machine had 30 steps and a diameter of 9 inches. With a flow rate of 550 GPM, it could generate 92 horsepower at 700 rpm. Turbo drilling, however, had a little effect in the United States, and field testing was discontinued in about 1950. The drilling activities in the USA were primarily conducted using the conventional rotary techniques; however, in the mid-1950s, Dresser imported several Russian turbo drills. However, further advancements were made in the USSR, and by 1954, turbines were drilling more than 80% of the Russian oil wells. Western Europe also showed some interest, particularly France, where Neyrfor started producing downhole turbines in 1956 [10]. Controlling the rotating speed of turbodrills, which was too rapid for traditional rock bits, was one of the main issues with their use. Reducers on the early Russian turbo drills geared down the speed from 2000 rpm to around 30 rpm. But these reducers wore out shortly [11].

Before turbo drilling would be effective in the USA, it was evident that advancements in the design of drilling bits as well as turbines were necessary. While rotary drilling was still the more cost-effective option for straight holes, turbo drilling offered some benefits for directional holes. Turbo drilling gained more traction in the Western nations in the 1960s and 1970s, due to the significant increase in the directional drilling activities. Drilling expenses increased when exploration and production shifted to the offshore regions like the North Sea and the Gulf of Mexico. Drilling directional wells from fixed platforms is expensive, thus there was a motivation to increase drilling efficiency [12]. It was shown with turbodrills that the penetration rates could be significantly raised. Turbo drilling gained popularity with more advancements in turbine design and the advent of polycrystalline diamond (POe) bits. One other factor in the success of turbo drilling was the larger, more potent mud pumps on offshore rigs that could provide higher discharge pressures. Turbodrills are a viable alternative to traditional rotary technologies for both the straight and directional wells. When determining which approach to utilize at what intervals, many operating businesses will examine the associated expenses, and evaluate the performance of both the rotary and turbine systems. One of these analyses is in this find in this paper. The turbine can span up to 50 feet, and be composed of many parts, as shown in Figure 2. For kick-offs with a bent sub, shorter turbo drills could be employed, but positive displacement motors are often the better choice for these tasks. Since significant savings may be achieved here, the lengthy tangential portion of a deviated well is the main area where turbo drills are used [13].

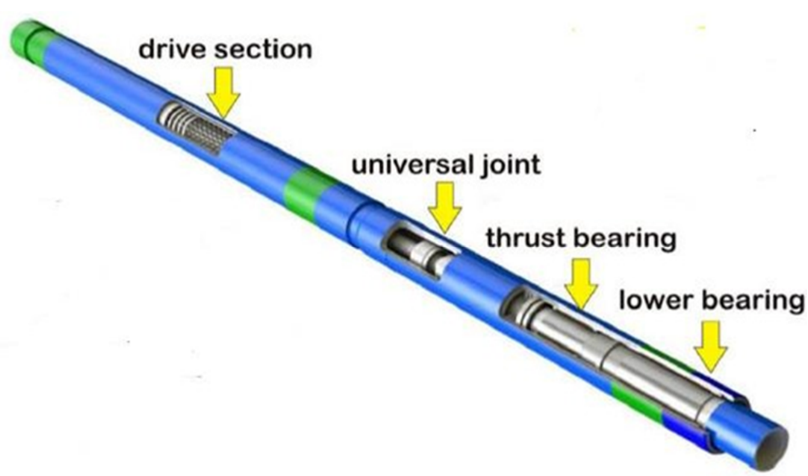

Figure 2. The Turbo drill configuration [10].

This paper attempts to solve the problem of the cost by taking a sample considered the form deepest well in Egypt AG-119X with a depth of 20,060 ft. and studying the Bottom Hole Assembly tools (BHA tools) and the factors affecting the Rate of Penetration (ROP), for the production section (Hole 8.5).

where is a section considering the difficulty in drilling and high-temperature-environment section in the well, and observes how the drilling technologies used in the downhole tools like a down-hole motor with rotary steerable drilling system and turbodrill a hydraulic downhole motor drilling system affects the bit progress and respectively the cost of drilling.

1.3. Factors affecting geothermal drilling cost

The study starts by examining the drilling cost distribution from different geothermal drilling projects around the world through a review of the literature. They were able to locate several published works that discussed the cost of geothermal drilling including those from the USA (Lukawski et al., 2016), Russia (Southon and Gorbachev, 2003), New Zealand (Hole, 2013), Saint Lucia (Bodley, 2018), Turkey (Gul and Aslanoglu, 2018), Iceland (Sveinbjornsson, and Thorhallsson, 2012), the Philippines (Southon and Gorbachev, 2003), and Kenya (Kivure, 2016; Otieno, 2016; Kipsang, 2015).

The most recent research on the cost of geothermal drilling in Indonesia was done by Purwanto et al. (2018), who compared the well expenses of 121 geothermal wells drilled between 2011 and 2018. The US Department of the Labor Bureau's Producer Price Index (PPI) was used to equalize the drilling costs, and present the comparison in the form of Geothermal Drilling Unit Cost (GDUC), which is stated in the US dollars per meter. In a different publication, Zuhro and Arif (2015) examined 86 wells that pertamina geothermal energy drilled between 2007 and 2014. A report on the statistics of the drilling costs per megawatt for 215 deep geothermal wells in Indonesia was given by Sanyal et al. (2011). According to the authors' understanding, based on many research work projects, the cost of geothermal drilling and the methods of optimization other than those already described

The drilling project is subject to the same cost regulations, as any other project, which provides that the total cost incurred is the product of the unit price multiplied by the quantity. The total cost will be higher, the higher the unit price that we agreed upon in our drilling partners' contract. In a similar vein, quantity matters the more drilling days, tools, equipment, consumables, drilling materials, and workers we use or consume, the more our project's overall drilling cost will look. Drilling rig (1), cementing (2), directional drilling (3), and casing (4) are the main four elements that affect drilling costs; these components account for about 70–80% of the entire drilling cost [6].

3.1. Drilling rig cost

The rig has to come first in this debate since it bears the brunt of the drilling expense, accounting for 40–45% of the total. The first question that comes to mind when researching this principle is always "What are the factors that influence the unit price and quantity?" because the actual geothermal project costs are not readily available. Regarding the rig cost, the quantity is the number of drilling days, and the price is the Rig Operation daily Rate (ODR) specified in the contract [6].

The primary piece of equipment in each drilling operation is the drill rig. The lead drilling engineer must accurately determine the maximum expected load and pressure to prevent purchasing an over-specified rig, which would raise the drilling project's overall cost. The 1,500 HP and 2,000 HP rigs are typically thought to have more than an adequate ability to drill standard wells or huge holes to a depth of 2,000 to 2,500 meters, depending on the load and pressure rating. However, in comparison to 1,000 HP rigs, those capabilities come with a greater ODR, a larger footprint, and a higher fuel consumption [6].

These days, the majority of drilling engineers estimate the rig ODR approximately using a number between US$18 and 22/HP, assuming that cost is a function of capacity. A 1,500 HP rig, for instance, will probably provide an ODR of about US$ 27,000–33,000/day. The selection of a drilling rig for a geothermal project involves several considerations, as Purba et al. (2019) and Hartono (2019) have explored. The right rig size and capacity must be chosen with careful consideration for the kind of well that will be built, the sub-surface risks, and the operational challenges that will arise. This is because these factors directly affect the rig's cost, in summary, the authors have gathered several variables that may have an impact on both the number of drilling days and the rig rental price (ODR) [14]

1.3.2. Cementing cost

Cementing, which comprises cement material, chemical additives, equipment, tools, and labor for cementing services, is the second cost factor included. This expense makes up about 10% of the entire cost of the drilling. Similar to rigs, the kind of well, depth, and formation characteristics (downhole temperature, pressure, subsurface risks, and gas content) greatly influence the choice of cement, additives, equipment, and personnel. The cement prices are typically not overly erratic, especially when the local products are used. The unstated expense of cementing, which is sometimes overlooked, is that the lengthier and more extensive the cementing task in a geothermal well, the longer the rig will take to complete. Poor cementing work can result in casing failure including water-trapped annulus and corrosive formation fluid/steam leaks, which ultimately reduces the well's lifespan. This is the second hidden expense [15].

Cement has two primary purposes in the building of wells: it supports and shields the casing, and stops fluid from passing through the annular space outside the casing (Bourgoyne et al. (1991). Temperature development in the downhole has a significant impact on the cement performance in geothermal wells including setting time and strength development (Kutasov and Eppelbaum, 2012). To guarantee a strong cement bonding in situ to protect the casing, meticulous planning and execution of the cement placement technique is just as important as the design of the cement slurry. The overall project economics are better, the longer the lifespan [15].

It is commonly known that geothermal wells are subjected to sub-normal sub-surface pressure in addition to high temperatures. This is the reason that even when utilizing simply fresh water as the drilling fluid, geothermal drillers frequently discover the situation of a Total Loss of Circulation (TLC). Before drilling into the deeper zone, in this case, cement is sometimes used as a downhole plug to cover the loss of circulation zone or unconsolidated formation. Nonetheless, it frequently occurs that the lost circulation state persists when the cementing engineer works on the casing cementing project. Thus, it is essential to be able to combine an appropriate cement placing technique with a slurry design that is appropriate for the task at hand. According to a study by Restrepo et al. (2019), cement voids and improper centralization will increase significant stresses in the cement and casing, which may shorten the casing's lifespan [15].

Choosing amongst different cement additives presents another difficulty for geothermal drilling experts when it comes to cement design. These additives are customized by the individual cementing companies, and are frequently not listed in general terms. Even while differences in trade names (brands) haven't been a big deal, it's still a good idea to thoroughly understand the primary purposes of any cement [15].

1.3.3. Directional drilling cost

Directional drilling comprises the tools, staff, and equipment for Directional Drilling (DD) as well as measurement, while drilling MWD services. It is the third cost component covered by the authors. This cost element makes up between 9 and 10% of the overall drilling cost. Finding flat land locations for well pad drilling is frequently quite challenging in Indonesia, as most geothermal regions are located on high-relief terrain, and are generally connected with the volcanic activity. Because of this, the directional drilling techniques are preferred in many Indonesian geothermal drilling projects, because they allow the drilling engineers to create the best possible well trajectory that will intersect or strike the subsurface target [16].

However, despite its benefits, the use of the DD and MWD tools in geothermal drilling often becomes a boomerang because of the expensive replacement costs in the case of Lost in the Hole (LIH) as a result of stuck pipe incidents that quite commonly happen in geothermal drilling operation (Purba et al. (2020b). Hartono (2019) discussed several hidden costs related to directional drilling other than the LIH cost. Same to the aforementioned cementing job, these DD and MWD services potentially create additional rig time due to (1) the reaming activities as a result of aggressive build-up rate, (2) tool make-up and calibration duration, (3) tool cooling down duration due to a high downhole temperature, (4) unnecessary gyro run, and (5) tool failure due to poor quality control. The other hidden cost is the tool/equipment standby cost resulting from unnecessary backup tools/equipment stored at the drilling site.

1.3.4. Casing cost

Casing cost is the final cost element covered by the writers. It accounts for about 8–10% of the total drilling cost. According to Hole (2008), the integrity and longevity of the well, as well as the safety and effectiveness of the well drilling operation, depend heavily on the choice of casing depths and the specifications for material weights and connections. The mapping results of the expected load that may occur during the installation of the casing typically serve as the basis for the casing requirements [17].

The size and specifications of the casing (pipe manufacturing process, material grade, weight, connection type, unique features, etc.) will typically determine the casing pricing. The quantity, however, will vary based on how many casings are required to cover each section of holes. However, choosing casing with more specifications than necessary to account for different sub-surface uncertainties can cause the overall cost to rise significantly. It is commonly recognized that, in comparison to the oil and gas formation, geothermal formation often has higher temperatures but a relatively lower pressure. As a result, when doing the casing design process, the drilling engineers must properly map the sub-surface hazards and survey the market regarding the many kinds of casings that are offered. offset data for wells, if provided, will be very helpful in determining the depth as well as the casing parameters [17].

1.4. Factors affecting ROP in a geothermal well

Because it helps to keep drilling expenses to a minimum; a Rate Of Penetration (ROP) forecast is essential to the drilling optimization. The ROP is determined by numerous factors. Drilling expertise of the rig team members' efficiency [18].

Rig efficiency minimum (rig load, pumps, and drums affect the bit performance).

Mud properties: Mud density should be maintained at a minimum value to control the formation pressure, and the mud density increase reduces the penetration rate does reduce the bit performance.

Mud viscosity: Increasing the mud viscosity reduces penetration rate does reduce the bit performance.

Water loss: Water loss prevents the direct contact between the bit and the formation, so it reduces the penetration rate relief

Solid content: The lower solid content of the mud provides a higher penetration rate, and also a good bit of performance.

Formation properties: Bit performance is affected by hardness, abrasiveness, and rock strength

Hydraulic factors such as

Circulation rate: this improves bottom hole cleaning, and increases the penetration rate.

Bit Hydraulic Horsepower (BHH) increase BHH to improve bottom hole cleaning, and increase the penetration rate.

Mechanical factors such as Bit type: must fit the mechanical properties of the formations.

Rotation speed: increasing rotation speed improves the penetration rate and the bit performance.

2. Case Study

The paper studies the drilling cost structure, and the variables that determine it. Cutting down on the time it takes to drill the well l is one strategy to lower the overall cost because the drilling rig's time charges (day rates) and related to equipment account for around half of the cost of the well. Surprisingly, little public information is available. The economic viability of producing energy from geothermal resources is mostly influenced by the expenses of drilling and finishing wells depending on the grade of the Enhanced Geothermal System (EGS) reservoir.

Estimates indicate the drilling expenses as accounting for 35% to 50% of the overall power plant costs in the EGS power plants. An earlier correlation, created by Milora and Tester [19], and later improved by Tester and Herzog [20] produced a drilling cost index based on the data from the oil and gas wells from the Joint Association Survey (JAS) on the drilling costs. This index was used to compare the cost of drilling Hot Dry Rock (HDR), and the hydrothermal wells to other types of wells.

This research work expands. Based on the real data from the Khalda Petroleum Company in Egypt is a more accurate drilling cost index that considers both the depth of a finished well and the time it was drilled. Employing the appropriate equipment, and the most recent drilling technology, comparing the actual cost to the predicted cost. This comparison is used to determine the elements that lust healthy lower-cost sheath as variations in the rate of penetration, and increases in the number of trips and runs needed increase in an increase in the rig capacity (embodied in mobilization, demobilization, and daily rental costs).

For EGS to be successful, the drilling optimization is essential, especially when there is a little drilling data available [21]. This work's ROP was calculated using the drilling data from the well, equivalent circulation of mud density, weight on bit, rotational speed, mud density, flow rate, and mud viscosity were among the input factors, in addition to identifying a few elements.

This case study will be built on a well AG-119X since this well was not drilled for geothermal. Still, it was according to the information mentioned in the research work titled "high-temperature geothermal well design" for the year 2005 [22], and since the conditions of this well are compatible with this information, and since the most important thing that distinguishes geothermal wells is the temperature. Temperatures have been recorded in this well. 340 °F. It also arrives, according to the information published in the research work entitled "exploration of geothermal resources utilizing the geophysical and Borehole data in the Abu Gharadig Basin of Egypt's Northern Western Desert "[23], which confirms that this region is considered one of the areas where geothermal energy is likely to be produced. Therefore, if we wanted to drill a well to produce geothermal energy, it would have the same conditions. The AG-119X will analyze the data regarding the factors affecting on rate of penetration (ROP) and will verify some factors and analyze others. Here is a presentation of some data and a description of the state of the well, basic well data, synopsis of the well.

2.1. Basic well information

The AG-119X is an Exploratory Vertical well drill to delineate SAFA, SAFI, and SHIFFAH reservoirs as primary targets AG-119X well is located in the heart of the AG field and will target deeper pool horizons below the traditional AG-produced horizons, the objective of the well is to explore hydrocarbons in AEB, MASAJID, SAFA, SAFI, and SHIFFAH formations, the proposed TD of 19700ft will finish in the lower SHIFFAH formation. The basic well data is shown in Table 1, Temperature gradients vary from 37 to 65 degrees Fahrenheit per kilometer, whereas the heat flows vary from 86 to 170 mW/m2 the AG-119X prospect is a massive structural culmination; the good horst is between two large northeast-southwest trending faults, each with thousands of feet of throw

Table 1. Basic well date.

Country	Egypt
Classification	Exploratory/Vertical
Region	Western Desert
Well	AG-119X
Concession	W.D Merged Conc. area (Block-30)
Rig	EDC-59
Coordinates:	Surface Lat :29° 45' 43.119" N : Surface long: 28° 30' 54.801" E X = 374642.22 m E Y = 786205.493 m N
RKB-GL	35ft
GL-MSL	308ft
RKB–MSL	343ft
Total depth: Scheduled	19700` (454ft into Basal Shifah sand FM) Actual 20060` (MD)/20043` TVD/ -19700` TVDSS
Mud data	Spud mud from surface to 1200 ft KCL salt saturated polymer from 1200 ft. to 9776 ft Oil-based mud from 9776 ft. to 20060 ft.
Casing data	:30 "Conductor from 0 to 46 ft : 20" from surface to 3608 ft : 13 ⅜ "from surface to 8909 ft : 9 ⅝" from surface to 14390 ft primary
Objective	Safa, Safi & Shaffah
Secondary objective	Alamien, AEB & Masajid
Spud date	06– October–2015
T.D. date	23– Marsh–2016

The AG-119X prospect is a massive structural culmination; the good horst is between two large northeast-southwest trending faults, each with thousands of feet of throw; AG-119X will be drilled in the heart of the AG field, and no well has tested the Paleozoic section in the AG field area only.

REVIERA SW-1X has drilled as deep as the Alamein formation. The well will be drilled vertically near the crest of the structure to optimize the various target levels.

It was planned to drill a 26 "hole to +/- 3610 ft, set 20 "casing, then drill a 17½" hole to +/-7500 ft, set 13⅜" casing, then drill 12¼" hole to +/-13950ft, set 9⅝" casing, then drill 8½" hole to +/-19700 ft, set 7 "casing (as the final total depth). The well was spud on 06–October –2015, where:

26 "hole was drilled from 46 ft to 1201 ft using spud mud, and then KCL salt saturated polymer from 1201 ft to 3608ft with maximum mud weight used, while drilling 11.5 ppg, set 20 "casing at 3608 ft.

17 ½" hole was drilled from 3608 ft to 8909 ft using KCL salt saturated polymer, with maximum mud weight used, while drilling 9.5 ppg, set 13 3/8 "casing at 8909 ft.

12¼ "hole was drilled from 8909 ft to 9776 ft using KCL polymer mud from 8909 ft to 9776 ft with maximum mud weight used, while drilling 10.6 ppg, and OBM from 9776 ft to 14389 ft section total depth with 10.95 ppg maximum mud weight used, while drilling and set 9⅝ "casing at 14390 ft.

8½ "hole was drilled from 14390 ft to 20060 ft using OBM, and the maximum mud weight was 10.55 ppg, while drilling this section total depth.

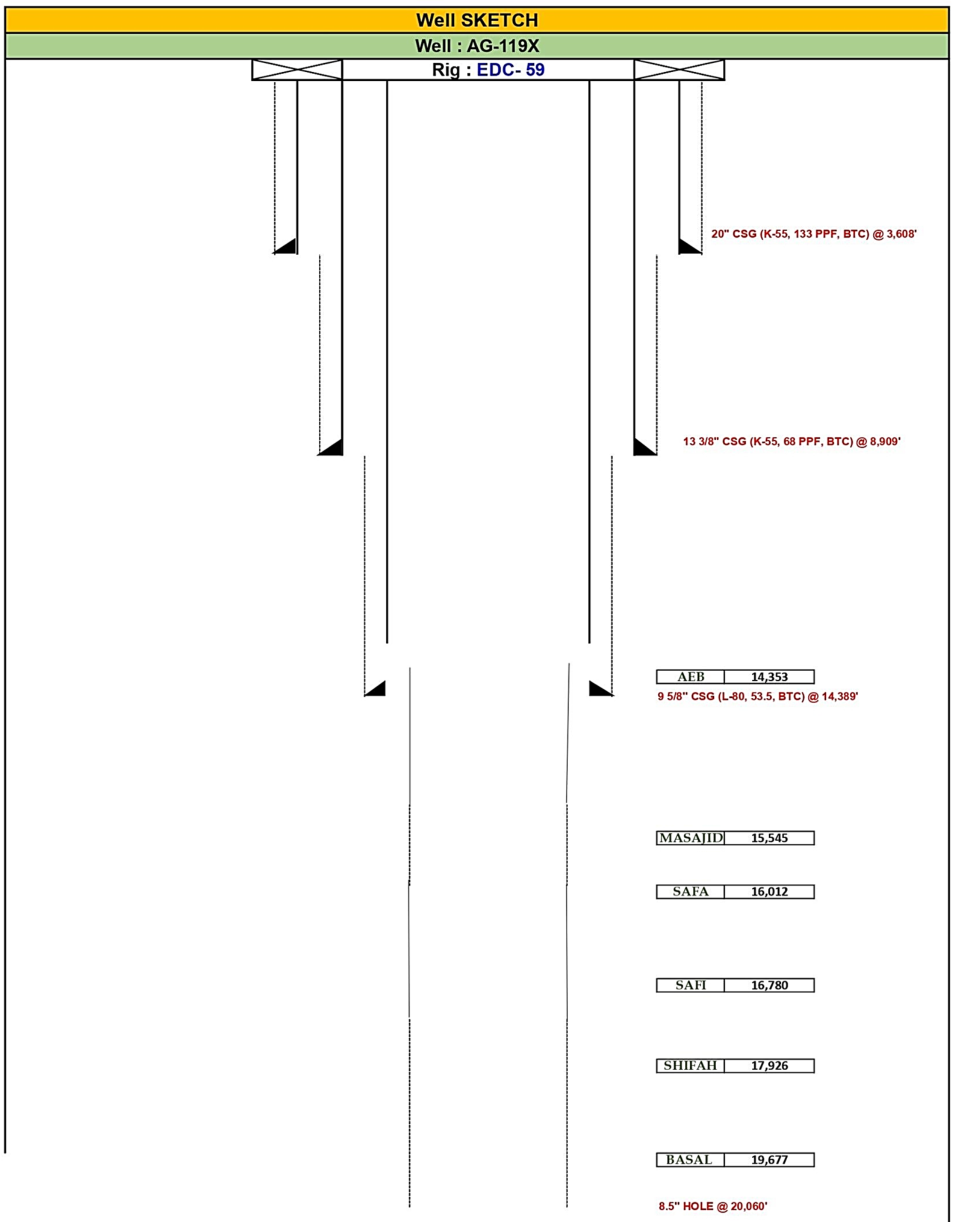

Figure 3. wellbore sketch.

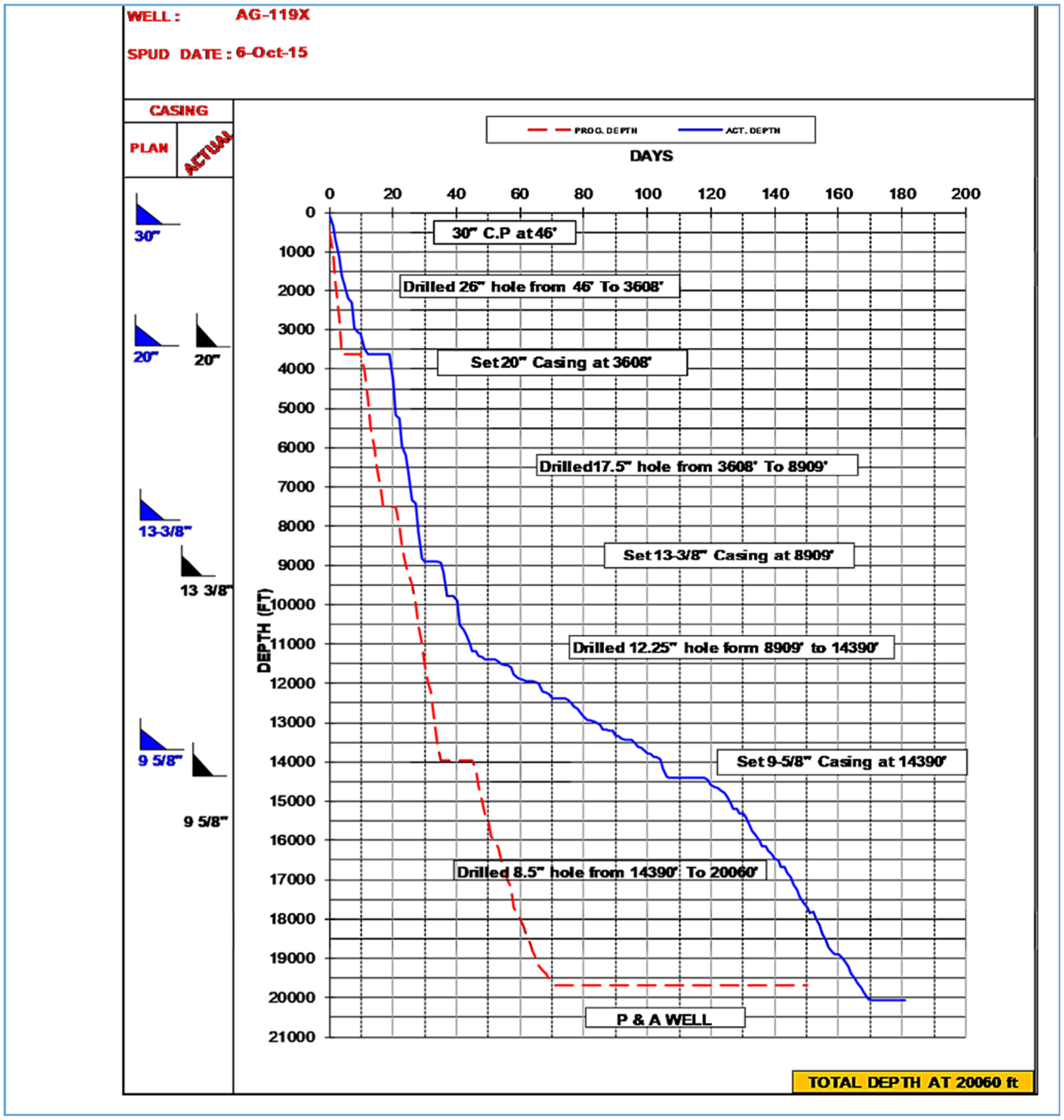

Figure 4. Progress chart

2.2. Geological information

The AG Basin is an intracratonic rift basin with an E-W trend that is 330 km long and 50–75 km broad. Due to Tethyan rifting, it was first created as a sizable half-grazed basin during the Jurassic Period and proceeded to recede over the Cretaceous Period. Then, as part of the Syrian Arc deformation that impacted northern Egypt in the Late Cretaceous, the half-graben was inverted. Within the AG Basin, three NE-SW oriented primary inversion anticlines—the Mid-Basin Arch, the AG Anticline, and the Mubarak High—are governed by the inversion of pre-existing Jurassic rift faults. With a slight dip towards the NE and SW, the AG Anticline is generally oriented NE-SW. The asymmetry of the anticline can be explained by the fact that it is locally bordered by two NE–SW running inverted faults to the southwest and northeast. At these inverted faults, the Cretaceous horizons are reverse offset. Above the tips of the inverted faults at the Late Cretaceous, Abu Roash and Khoman Formations, fault propagation folding develops. Inversion began during the Santonian period and persisted into the Campanian-Maastrichtian era, according to thickness variations and stratigraphic correlations. During the Late Eocene–Oligocene Dabaa Formation and the Paleocene–Middle Eocene Apollonia Formation's deposition, inversion persisted. Table 2 shows the age formation and depth of the layer in the lithology description for the well [24].

Table 2. Geological data for AG-119X.

	Age	Formation		MD/TVD	S.S.	Lithology
Tertiary	Miocene	Mogra		surface		Mainly sand with clay and limestone streaks.
	Oligocene	DABAA		2288	-1945	Mainly shale with siltstone and limestone streaks.
	Eocene	Apollonia	(A)	3570	-3227	Mainly limestone with shale streaks.
			(B)	4080	-3737	Mainly shale with limestone streaks.
			(C)	4240	-3897	Mainly limestone with traces of shale streaks.
			(D)	4240	-3897	Mainly limestone with traces of shale streaks.
Cretaceous	**Camp.** /Maastri	Khoman	(A)	5465	-5122	Mainly chalky limestone.
			(B)	6965	-6622	Mainly limestone.
	Turanian / Santonian	**ABU ROASH**	(A)	7278	-6935	Mainly shale with siltstone, limestone, and traces of sandstone and dolomite streaks.
			(B)	8914	-8571	Mainly limestone and shale.
			(C)	9355	-9012	Mainly shale, siltstone, sandstone, and limestone streaks.
			(E)	9456	-9113	Mainly shale with siltstone and traces of limestone streaks
			(F)	9708	-9365	Mainly Limestone.
			(G)	9843	-9500	Mainly Shale with Limestone, Sandstone, and Siltstone streaks.
	Cenomanian	**BAHARIYA**	Upper	10304	-9961	Mainly siltstone with sandstone, shale, and limestone streaks.
			Lower	10666	-10323	Mainly siltstone with sandstone, shale, and dolomite streaks.
		Kharita		11122	-10779	Mainly siltstone with sandstone, shale, and traces of dolomite, limestone, sand, and metamorphosed streaks.
Juraacic		Masajid		14138	-13795	Mainly limestone with shale and dolomite streaks.
		Khataba		14325	-13982	Mainly siltstone, sandstone, shale, sand, dimestone, dolomite, and traces of coal streaks.
Paleozoic	lle	Safi		16770/16765	-16422	Mainly siltstone, sand, shale, sandstone, limestone, and traces of coal.
		Shiffah		17900/17894	-17551	Mainly siltstone, shale, and sandstone streaks.
		Basal shiffah sand		19634/19620	-19277	Mainly Sandstone, Shale, and Siltstone with Igneous fragments.

2.3. 8 ½ "Hole section study"

This paper focuses on Analyzing this section in the well because it considers higher temperature environment and the below data for this section summers from daily drilling reports and focuses on all the details that happened during drilling the data for each trip as the section below Table 3 show summers some information about this section.

Table 3. 8 ½ "Hole section information".

Interval drilled	From 14390 ft. to 20060 ft
Drilled days	60 days
No. of bits	60 days
Open hole length	5670

2.3.1. Drilling operations summary for each run

In this section of the analysis, try to collect a lot of drilling parameters from the daily drilling reports in blow Table 4, and mention the bottom hole assembly tools to help in knowing the effect of the power tool used in each run, and recognize how this tool is better and how many bit progresses achieve. This information enables you to draw a picture or create an imagination about the nature of the ground in this sector as well as the effect of the temperature levels. We will extract some of this information in the following sections, so that you can know which tool will be better.

Table 4. Drilling parameters for each run.

Run	Depth In ft.	Depth out (ft.)	Bit type	Bit Mfg.	Nozzles	Bit grading	BHA	WOB (Klbf)	RPM (GPM)	Pump press (psi)	Temper-ature (F)	Lithology
1	14400	14410	GX-44GDXDHI	Hughess	Open	(0, 0, NO, N/A, E, I, NO, BHA)	8 ½” TRI Cone Bit, Bit Sub W/ Float, 1 X 6.5 ”DC, 8 3/8 ”string stab, 9 X 6.5” DC, JAR, 2 X 6 ½ ” DC, 24X 5” HWDP	15-25	55-70	2450	250	Sandstone, siltstone, & shale
2	14410	14473	MSXI716LWE BPX	SMITH	7X14	3, 2, WT, N-S, X, I, CT BT, PR	8 ½ "PDC Bit, ATK, MWD MOD STAB, BCPM, NM Stop sub, 8 3/8 "strinbg stab, MWD navi trak, 8 3/8 "string stab, float sub, PBL Sub, 9 X 6 ½" DC, JAR, 2 X 6 ½ "DC, 24 X 5" HWDP.	10-30	80-130	3600	260	Sandstone, siltstone
3	14473	14571	MDSXI713LW EBPX-P	SMITH	7X13	3, 2, WT, C&N, X, I, CT, PR	8 ½" PDC bit, ATK, MWD mod stab, BCPM, NM stop sub, 8 3/8" string Stab, MWD navitrak, 8 3/8 "string stab, float sub, PBL sub, 9 X 6 ½ ”DC, jar, 2 X 6 ½ "DC, 24 X 5" HWDP.	10-30	70-130	3600-4000	270	Sandstone, siltstone,& shale
4	14571	14635	RU716MCDEG UZ	ultra	7X13	3, 3, WT, S-N, X, IN, HC-BT, PR	8 ½ "PDC bit, ATK, MWD mod stab, BCPM, NM s SUB, 8 3/8" string stab, MWD Nnavitrack, 8 3/8" string stab, float sub, PBL sub, 9 X 6 ½ ”DC, JAR, 2X 6 ½ " DC, 24 X 5" HWDP.	30-35	80-135	3600-3750	280	Siltstone, Sandstone & Shale
5	14635	14777	MDZXIZ713U EBPX-P	Smith	7X13	3, 1, WT, C & N & S, X, IN, CT, PR, & PP	8 ½ "PDC bit, ATK, MWD mod stab, BCPM, NM stop sub, 8 3/8 "string stab, MWD navitrak, 8 3/8 "string stab, Float sub, PBL SUB, 9 X 6 ½ ”DC, JAR, 2 X 6 ½" DC, 24X 5"	20-30	80-100	3700-3800	280	Siltstone, Sandstone & Shale
6	14777	15183	K507QTBPXX C	SMITH	TFA = 1.4 IMPREGNATE D BIT	7, 7, RO, A, X, IN, WT, PR	8 ½ "PDC bit, bearing sec, 81/4 "stabilizer, power sect. 83/8"string stab, MWD navitrak, 83/8 "string stab, float sub. circulation sub, 9 X 6 ½ ”DC, JAR, 2 X 6½" DC, 24X5" HWDP	5-15	70-110	4100-4200	290	Siltstone, sandstone, & shale.
7	15183	15291.5	TF510D	SECURIT Y	TFA = 1.2 IMPREGN ated bit	8, 8, RO, A, X, I, WT, PR	8 ½ "PDC bit, bearing sec, 81/4" stabilizer, power sec. 83/8" string stab, MWD navitrak, 83/8 "string stab, float sub, circulation sub., 9 X 6 ½ ”DC, JAR, 2 X 6½" DC.	5-15	70-100	4100-4300	300	Siltstone, sandstone, & shale
8	15291	16272	DD5560M	REED	TFA = 1.45 IMPREGN ated bit	5, 4, HC-BB, A, X, 1/16" , LT-WT,	8 ½ "IMP bit + 6 5/8" bearing section (FBS) W/8 5/16 "sleeve + 8 1/4" S. stab + 6 5/8" power section (TSXL) + 8 3/8" STRG stab. + 6 ¾ "navitrak + 8 3/8 "STRG stab. + 6 ¾ "float sub + 6 ¾ "BPL sub + 9 X 6 ½ "D/C + 6 ½ "jar + 2 X 6 1/2" D/C + X-O + 24 X 5" HWDP	6-12	100\128 5	4300-4380	310	Siltstone, sandstone, shale, & limestone

9	16272	16510	TD408FX	HUGHES	TFA = 0.90 (6 X 14	2, 1, WT, G-S, X, I, NO, PR	8 ½ "PDC bit + 8" ATK-V + 8 3/8 "mod stab + 6 3/4" BCPM + 6 3/4" stop sub + 8 3/8 "STRG stab. + 6 ¾ "navitrak + 8 3/8 "STRG stab + 6 3/4" float sub + 6 ¾ "BPL sub + 9 X 6 ½ "D/C + 6 ½ "JAR + 2 X 6 1/2" D/C + X-O + 24 X 5" HWDP	30-35	90/100	3550-3600	310	Siltstone, sandstone, shale, & limestone
10	16510	16815	U713MCDEG UZ	ULTERRA	TFA = 0.91 (7 X 13)	1-3-WT-T,S-X-I-BT-PR/TQ	8 ½ "PDC bit + 8" ATK-V + 8 3/8 "mod stab + 6 3/4" BCPM + 6 ¾ "stop sub + 8 3/8 "strgstab, + 6 ¾ "navitrak + 8 3/8 "STRG stab + 6 ¾ "float sub + 6 ¾ "BPL sub + 9 X 6 ½ "D/C + 6 1/2" JAR + 2 X 6 1/2" D/C + X-O + 24 X 5" HWDP	25-30	90/100	2800-2900	320	Siltstone, sandstone, shale, and limestone
11	16815	17692	DD5560M	REED	TFA = 1.45 IMPREGN ated bit	8-8-WT-T,S-X-I-HC-PR/PP	8 ½ "PDC bit, bearing sec. 8 7/16 "stabilizer, power sec, 83/8 "string stab, MWD navitrack, 83/8 "string stab, float sub. circulation sub, 9 X 6 ½ "DC, JAR, 2 X 6½ "DC, .24X 5" HWDP	5-12	80/100	4250 – 4350	330	Siltstone, sandstone, shale, & limestone
12	17692	18900	DD5560M	REED	TFA = 1.45 IMPREGN ated bit	6-7-WT-A-X-1/16-HC,BT-PR	8 ½ "IMP bit (reed, DD5560M, 1.45TFA) + W/8 3/8 "sleeve6 5/8" bearing sec. (FBS) + 8 7/16 "STB + 6 5/8 "power sect. (TSXL) + 8 3/8" STRG stab" wood" + .6 ¾ "navi-trak + 8 3/8 "STRG stab "wood" + 6 ¾ "float sub + 6 ¾ "BPL sub + 9X6 ½ "D/C+6 ½ "JAR + 2X6 1/2" D/C+24 X 5" HWDP	5-12	100	4250-4400	340	Siltstone, shale, sandstone, & limestone
13	18900	20060	DD5560M	REED	TFA = 1.45 IMPREGN ated bit	4-7-WT-A-X-2/16-HC, BT-TD	8 1/2"IMP bit(reed, DD5560M, 1.45TFA) + W/8 3/8 "sleeve6 5/8" bearing sect. (FBS) + 87/16 "STB + 6 5/8 "power sect. (TSXL) + 8 3/8 "STRG stab "wood" + . 6 3/4" navitrak + 8 3/8 "STRG stab "wood" + 6 ¾ "float sub + 9X6 ½" D/C + 6 ½ "JAR + 2X6 ½ "D/C+24 X 5 "HWDP	8-10	100	4100-4300	340	Sandstone, siltstone, shale, and basement

In the run No. 1, performed a pressure integrity test to 13 pounds per gallon (ppg) Equivalent Mud Weight (EMW) with a maximum surface pressure 1870 psi, pulled out with 8½ "bottom hole assembly from 14410ft to surface, and laid down a bit".

The run No. 2 was done on a rotary steerable vertical bottom hole assembly; started a bit, drilled 8½ hole section from 14410 to 14473 ft, which had a poor ROP; tried many times to enhance ROP without success, and decided to pull out for the bit change; circulated for hole clean, slug pipe; pulled out of hole for bit change with 8½ rotary steerable vertical bottom hole assembly from 14473ft to surface and laid down bit.

The run No. 3 started a bit, from 14473 to 14571 ft, which had a poor ROP. I tried many times to enhance ROP without success, and decided to pull out for a bit of change, circulated for hole clean, slug pipe, pulled out of the hole for bit change with 8½" rotary steerable vertical bottom hole assembly from 14571 ft to surface, and laid down a bit.

In the run No. 4, it started a bit, from 14571 ft to 14635 ft, which had a poor ROP. I tried many times to enhance ROP without success, and decided to pull out for a bit of change, circulated for hole clean, slug pipe; pulled out of the hole for bit change with 8½ "rotary steerable vertical bottom hole assembly from 14635 ft to surface, and laid down a bit.

The run No. 5 started a bit from 14635 ft to 14777 ft, which had a poor ROP, had a pressure drop 200 psi, pumped slug, pulled out of a hole with 8½" rotary steerable vertical bottom hole assembly from 14777 ft to surface, and laid down a bit.

The run No. 6 tested 6 ¾ "circulating sub, was run in the hole to bottom at 14777 ft, washed and reamed from 14390 ft to bottom at 14777 ft, started a bit, reached the depth of 15183, then had a poor ROP, last 2hours, pumped slug, pulled out of the hole with 8½ turbinemotor assembly from 15183 ft to surface, and laid down a bit.

In run No. 7, washed and reamed from 14390 ft to bottom at 15183 ft, started a bit, continued drilling from 15183 ft to 15291 ft, which had a poor ROP; pumped slug, pulled out of the hole with 8½ turbine motor assembly from 15291 ft to surface and laid down a bit.

In run No. 8, washed and reamed from 15116 ft to bottom at 15291 ft, started bit, continued drilling from 15291 ft to 16272 ft, performed slow circulation rate, pumped slug, flow check, hole static pulled out of a hole with 8 ½ bit and turbine assembly to surface for change bit & bottom hole assembly, laid down bit, turbine & bottom hole assembly

The run No. 9 started a bit, continued drilling hole from 16272 ft to 16510 ft, which had a poor ROP; tried many times to enhance ROP without success, and decided to pull out for a bit change, circulated for hole clean, slug pipe, pulled out of the hole for bit change with 8½ rotary steerablevertical bottom hole assembly from 16510 ft to surface, and laid down a bit.

The run No. 10 started a bit, and continued from 16272 ft to 16815 ft, which had a poor ROP. I tried many times to enhance ROP without success, and decided to pull out for a bit of change, circulated for hole clean, slug pipe, pulled out of the hole for bit change with 8½ rotary steerable vertical bottom hole assembly from 16815 ft to surface and laid down a bit.

The run No. 11 in the hole with 8 ½ a bit, and turbo assembly to 16263 ft, washed and reamed from 16263 ft to bottom at 16815 ft, started a bit, continued drilling from 16815 ft to 16901 ft; had increased in DHCT 330 F, circulated bottom up for cooling mud, continued drilling 8.

½ vertical hole from 16954 ft to 17399 ft, circulated bottom up for cooling mud, resumed drilling 8 ½" vertical hole from 17399 ft. 17659 ft. circulated bottom up for cooling mud, resumed drilling 8½ vertical hole from 17659 ft to 17692 ft, had a poor ROP; decided to pull out for bit change, circulated for hole clean, slug pipe, pull out of the hole for bit change with 8½" rotary steerable vertical bottom hole assembly from 17692 ft. to surface, and laid down a bit.

The run No. 12 start a bit, and drilling ahead 8½ hole from 17692 ft to18900 ft, had a poor ROP; decided to pull out for a bit change, circulated for holeclean; slug pipe, flow check, pull out of the hole with 8½" rotary steerable vertical bottom hole assembly to the surface

The ran No. 13 precautionary wash and ream from 18504 ft to 18900 ft, start a bit, & drilling ahead 8½ hole from 18900 ft to 18905 ft, circulation for mud cooling, resumed drilling 8

2.3.2. Hole time distribution for section 8½

Figure 6 shows the time distribution for this section. It explains the division of time about everything like specific time taken by drilling and trips, and another observed the trips time near to half time taken by drilling

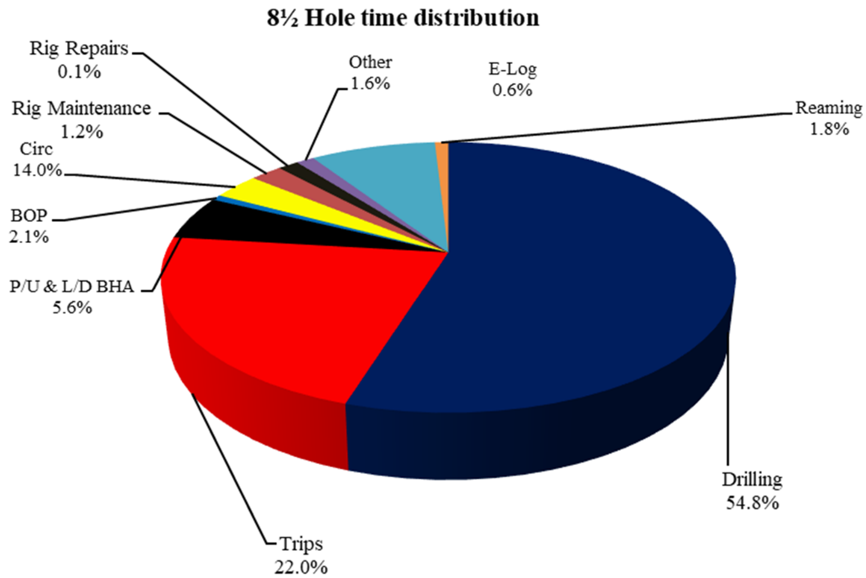

Figure 6. The time distribution for hole 8.5.

Collecting the data from each trip, in Table 5, this data is extracted from the Daily Drilling Reports (DDRs) and from well logging like rock strength abrasiveness and formation impact; this data is not memorized in the digital form, as shown in Figure 8, but can be graphically represented, and put a numerical limit.

Table 5. The parameters used in the study.

Trip Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
BHA toolusing	No	Motors RSS	Motors RSS	Motors RSS	Motors RSS	Turbine	Turbine	Turbine	Motors RSS	Motors RSS	Turbine	Turbine	Turbine
mud weight(ppg)	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
plastic viscosity (CP)	30	30	30	30	30	30	30	30	30	30	30	30	30
Yield point	22	22	22	22	22	22	22	22	22	22	22	22	22
The sum ofthe funnel viscosity	0	65	65	65	65	65	65	65	65	65	65	65	65
The sum ofrock strength	5	27	30	25	20	30	30	25	15	15	10	10	25
abrasiveness formation	50	85	70	70	85	70	85	85	85	70	85	85	100
formation impact	50	58	70	70	50	70	85	70	70	85	50	50	70

2.4. Data analysis

Can find more information about the data used, as shown in Figures 7 and 8, which the analysis done on the real data, and what happens during the drilling and obtains on rustling, and a conclusion whites focus on the downhole tools used in bottom hole assembly, like a down-hole motor with a rotary steerable drilling system and turbodrill a hydraulic downhole motor drilling, and compares between them where make elimination to the time lost relate to anther problems, as mentioned in the above in the section of data summary. For each run, analyze all the parameters gathered, as shown in Figure 12.

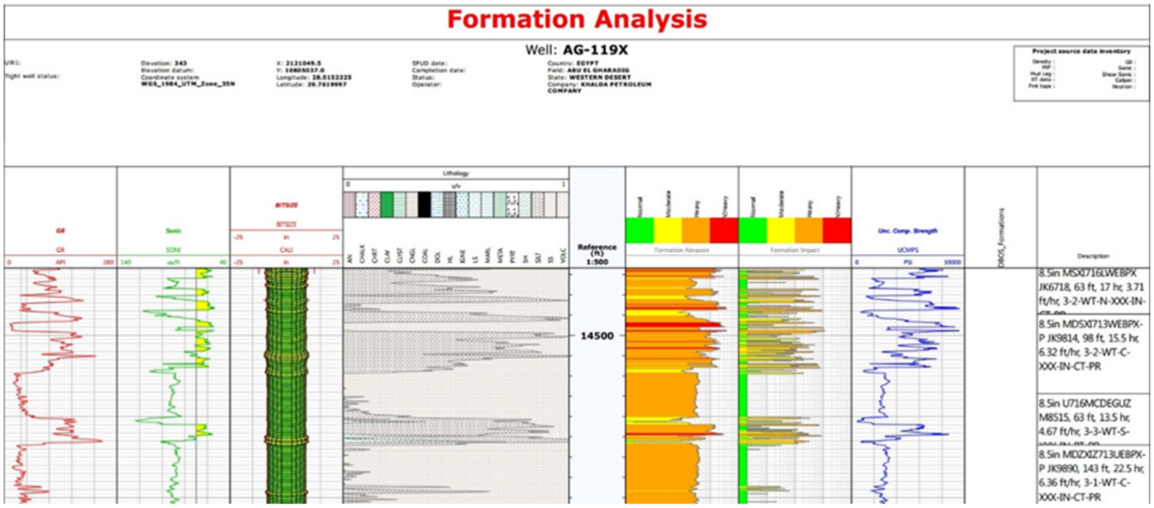

Figure 7. Sample from the well-logging data used in the study (GR-Sonic-bit size –lithology–formation impact–formation of abrasiveness- unconfined strength).

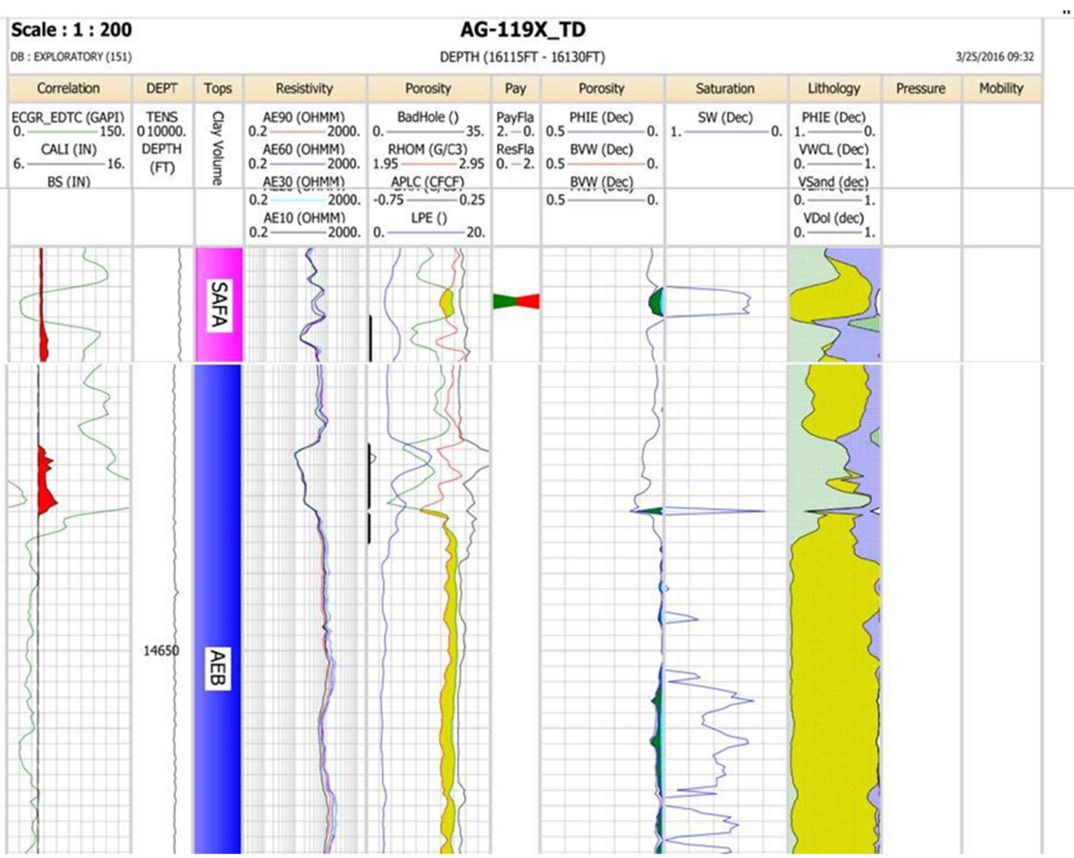

Figure 8 sample from well-logging data used in the study (lithology –correlation –porosity)

Where is the rate of penetration for the downhole tool used in the bottom hole assembly for each trip as shown in Figure9 and the data list in Table 6

Table 6. The data for the ROP for each run.

Trip Number	1	2	3	4	5	6	7	8	9	10	11	12	13
BHA tool using	No	Motors RSS	Motors RSS	Motors RSS	Motors RSS	Turbine	Turbine	Turbine	Motors RSS	Motors RSS	Turbine	Turbine	Turbine
ROP(ft/hr)	2.9	3.7	6.3	4.7	6.8	6.1	6.2	7.3	6	6.5	7.9	8	5.4

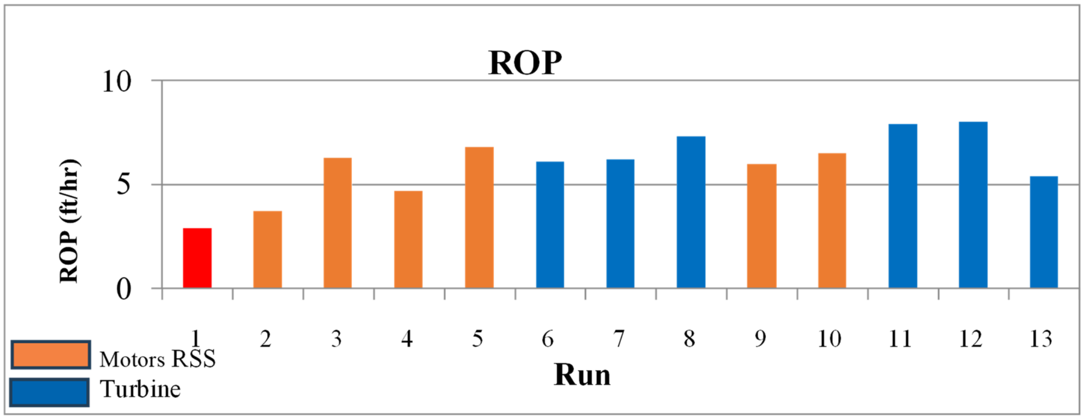

Figure 9. Shows the ROP for each run.

Then draw the bit progress for a downhole tool used in the bottom hole assembly for each run, as shown in Figure 10, and the data list in Table 7, and also the drilling time for each run, as shown in Figure 11, and the data in Table 8.

Table 7. The data for the bit of progress achieved in each run.

Run No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Bit Progress (ft)	10	63	98	64	142	405	108	981	238	305	877	1208	1160

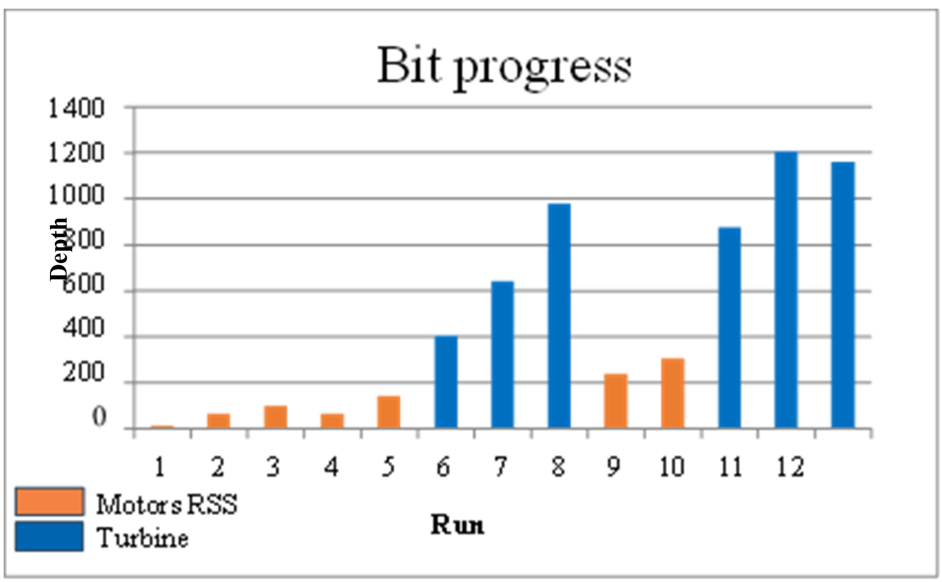

Figure 10. shows the bit of progress achieved in each run.

Table 8. The data shows the time spent on every run.

Run Number	1	2	3	4	5	6	7	8	9	10	11	12	13
Drill Time(hr.)	3.5	17	15.5	13.5	20.8	40.4	16.5	153.5	40	22	111.7	150.2	214

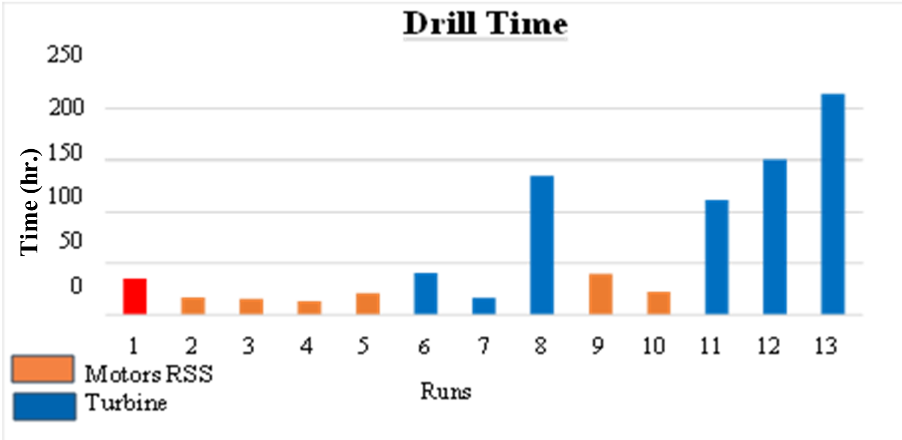

Figure 11. Shows the time spent on every run.

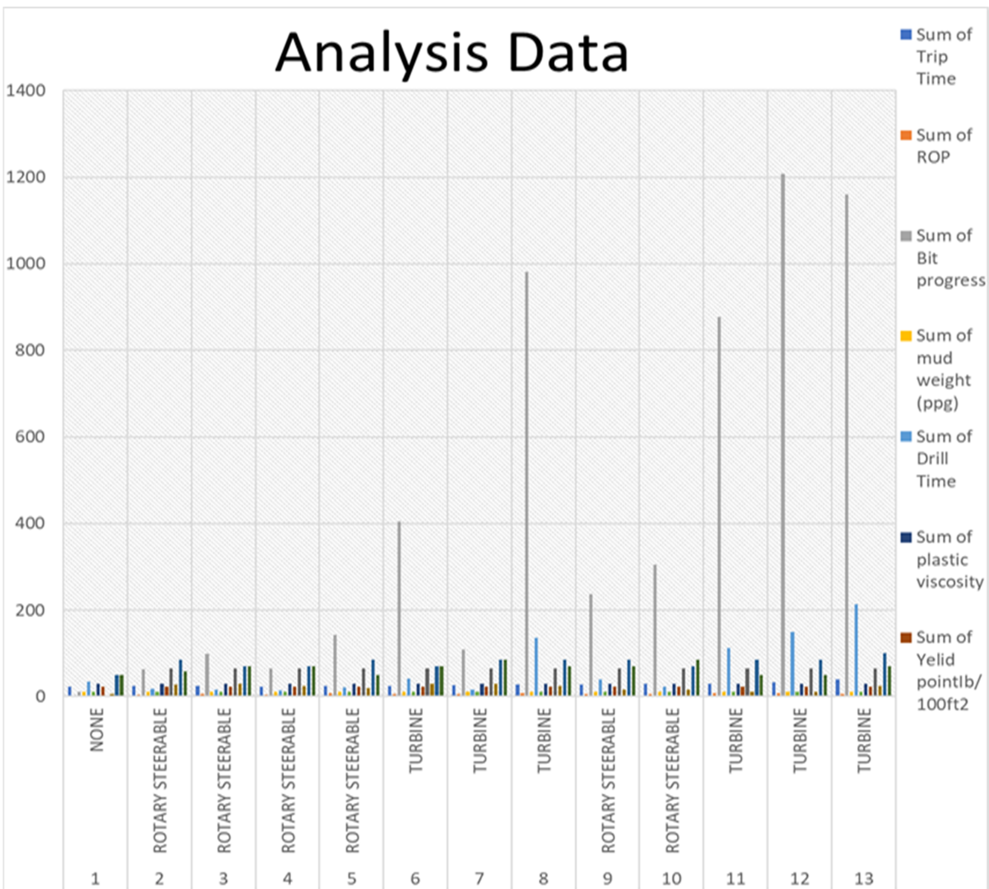

Figure 12. shows the data analysis of all parameters used in the work.

2.5. Economic analysis

This analysis happens for the well, and removes any reason that may be causing trips eliminating the time related to problems, while operating and focusing only on the rate of penetration and down-hole tools for bottom-hole assembly.

From the first look at the ROP, and a bit progress, we can estimate the difference between the motor's rotary steerable technology, and the turbodrill technology in this well; we can find this section drilled in 13 runs.

Can find this analysis in Figure 12, and from this analysis, observed the bit progress is the most common factor affected in each run; also, we observed the actives in the bit progress when using turbodrill is bigger than when using motors rotary steerable.

When looking at the cost chart in Figure 13, we can observe that this well was designed to be drilled with 8,250 million dollars but actually; it was drilled with 13.285 million dollars. When looking at the cost of the drilled 8.5 hole, we can find that this designed cost is 1735000 dollars, but take in actual 4400000 dollars. This is only for drilling, from the progress chart in Figure 4; find this section drilled in 60 days, and when make average for bit progress for each run for turbine find it around 880 ft. In this section, drilled 5670 ft, so can will drill this section in 7 runs instead of 13 runs, and if we make average for ROP for the turbine for each run, find it around 7 ft./hr. So, the expected time for each run is around 126 hr (5 days). Also, Table 9 finds the average bit price used with the turbine of 48000 dollars, and from the data, the average direction tool daily rate 22000 dollars, and we can expect the drilling for this section with turbine will take 34 days, so we will expect the cost of drilling for this section 1085048 dollars, so we can save from tool cost around 199045 dollars when compared with the actual cost for the drilling tool

(12840920 dollars), so we can observe 3115908 dollars is ex on another item like trips and rig repairs and rig up and lay down for bottom hole assembly, and make a test on blow out preventer expect the E-log; we can save the half of this number around 1557954 dollars, so if we use the turbine, we can reach to total save around 1756999 dollars

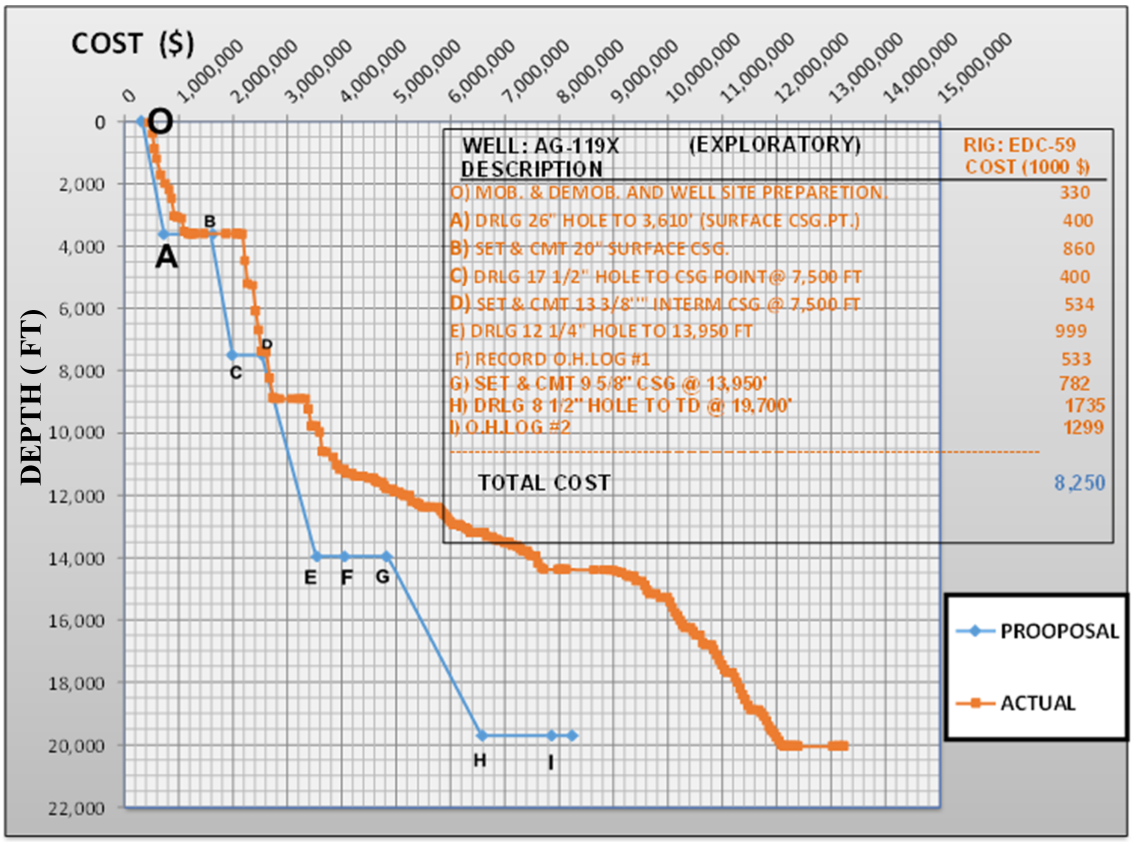

Figure 13. Shows the proposal and actual the cost of the well.

Table 9. Shows the cost of each run without adding the rig cost.

Run number	BHA type	Bit progress (ft)	Time (day)	Tool cost ($)	Bit cost ($)	Total cost ($)
1		10	0.15	$3,208	$16,709	$19,917
2	Rotary steerable	63	0.71	$15,583	$38,000	$53,583
3	Rotary steerable	98	0.65	$14,208	$38,000	$52,208
4	Rotary steerable	64	0.56	$12,375	$39,000	$51,375
5	Rotary steerable	ine142	0.87	$19,067	$55,000	$74,067
6	Turbine	405	1.68	$37,033	$58,000	$95,033
7	Turbine	645	0.69	$15,125	$20,000	$35,125
8	Turbine	981	6.40	$140,708	$48,000	$188,708
9	Rotary steerable	238	1.67	$36,667	$39,000	$75,667
10	Rotary steerable	305	0.92	$20,167	$38,000	$58,167
11	Turbine	877	4.65	$102,392	$48,000	$150,392
12	Turbine	1208	6.26	$137,683	$48,000	$185,683
13	Turbine	1160	8.92	$196,167	$48,000	$244,167
Total			34.11	$750,383	$533,709	$1,284,092

can reach the conclusion that is turbo drill technique is power better, lower cost, and achieves big progress fromthe Rotary Steerable drive type in this section at the hared formation high-temperature environment [25, 26]

3. Conclusions

Based on the analyses of the drilling of geothermal well AG-119 X, which has been drilling in the Western Desert, we can reach the following conclusion:

1. From the analysis, we can reduce the cost of drilling by using the turbodrill technology in high deep sections and high-temperature environments, where after the analysis, the actual cost for AG-119X can be reduced by around 1756999 dollars.
2. The appropriate power drive in the Bottom Hole Assembly (BHA) is the key to achieving progress in drilling. We observe that from the analysis, as shown in the above figures, when the power drive is turbine can achieve progress in drilling, more than motor RSS in the same section and lithology, and observed the tribune is more effect in a high-temperature environment.
3. Drilling rig cost is the most significant factor affecting the total well cost 80% after analysis deep section in well AG-119X find when using suitable BHA will reduce the days that take in drilling
4. Drilling rig cost is the most significant factor affecting the total well cost of 80% after analysis of the deep section in the well AG-119X find when using suitable BHA will reduce the days that take in drilling
5. In the Abu Gharadig basin, when the formation has an unconfined compressive strength greater than 40K-psi, the motor RSS does not achieve progress. This was obtained from the analysis of well-logging data for AG-119X.

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کاهش هزینه‌های حفاری در چاه‌های زمین گرمایی با بهینه‌سازی فناوری حفاری

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چکیده:

تولید پایدار انرژی کافی برای تقویت اقتصاد جهان با حداقل ردپای زیست محیطی یکی از مهم‌ترین چالش‌های دهه‌ها بوده است. انرژی زمین گرمایی به عنوان یکی از گزینه‌های امیدوارکننده برای پاسخگویی به تقاضای انرژی آینده جهان در نظر گرفته شده است. هزینه حفاری چاه‌های زمین گرمایی بین ۳۵ تا ۵۰ درصد کل هزینه سرمایه گذاری برای نیروگاه‌های جدید زمین گرمایی با دمای بالا است. این هزینه "پیش" باعث می‌شود تا ساخت نیروگاه‌های زمین گرمایی گران‌تر از نیروگاه‌های معمولی باشد و به همین دلیل و خطر درک شده، توجه زیادی به کاهش این هزینه معطوف شده است. این مقاله تلاش می‌کند تا هزینه حفاری چاه‌های عمیق مانند AG-119X، در عمق ۲۰۰۶۰ فوتی مصر را به حداقل برساند. در این چاه هزینه واقعی بیش از مبلغ پیشنهادی حدود پنج میلیون تومان بوده است. هزینه واقعی عملیات حفاری با پیشنهادی تحلیل و مقایسه شده است. با مشاهده هزینه هر آیتم حفاری، مشخص شد که ابزارهای قدرت محرک در مجموعه سوراخ پایینی مانند موتور سوراخ با سیستم حفاری چرخشی (RSS) یا موتور پایین چاه هیدرولیک توربودریل پرهزینه ترین عنصر عملیات حفاری در ۸.۵ سوراخ است که هر سیزده سوراخ جدید را می‌چسباند و هر سیزده مته جدید پیدا می‌شود. موتور داون هول هیدرولیک در حفاری بخش شوش پرهزینه بوده و می تواند در حدود ۱۷۵۶۹۹۹ دلار صرفه جویی کند. این مقاله یک نقشه راه برای کاهش هزینه‌های حفاری چاه‌های زمین گرمایی است.

کلمات کلیدی: هزینه حفاری زمین گرمایی، فناوری حفاری، توربودریل در زمین گرمایی.