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Factors Contributing to Non-Productive Time in Geothermal Drilling in Kenya: A Case of Menengai Geothermal Project

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Abstract

This research work was geared towards determining the factors that contribute to Non Productive Time (NPT) in geothermal drilling. Further, the research sought to find out the contribution of equipment breakdown to Non Productive Time, How geological challenges aid Non Productive Time, ways in which operations planning contribute to Non Productive Time, and how decision making contribute to Non Productive Time. The parameters of interest observed included; completion depth, drilling duration, well location, well design, casing design, drill rig capacity, and number of staff in the rig. A sampling frame of 32 wells was developed. The results of the study revealed enormous amount of Non Productive time associated with geothermal drilling operations in Menengai Geothermal Project. It showed that the average total Non-Productive Time is 62%, while 38% of the total drilling duration is productive time. Operations planning was the biggest contributor of Non Productive time at 41%, equipment breakdowns contributed 12%, geological challenges 8%, and decision 1%. The study provided recommendations that should be undertaken in order to cut down Non Productive Time.

Keywords: Geothermal; Drilling; Non Productive Time.

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1. Introduction

Drilling is one of the most critical, complex and costly operations in geothermal resource development projects. While drilling costs represent nearly half of well expenditures, less than half of the total drilling time is spent on actual drilling operations but rather on dealing with problems associated with the drilling operations, rig movement, equipment breakdowns and waiting periods for materials. From project management point of view, drilling operation should always be on schedule and on budget. Occurrence of drilling problems which cause delays often push drilling operation behind schedule. Once the drilling program falls behind schedule, other subsequent programs e.g. Construction of steam gathering system, construction of power plants, and ultimately injection of power to the grid falls behind schedule. Drilling a geothermal well involves planning and designing the well prior to commencement of the drilling activities. “Planning” means to list, define, schedule, and budget for all the individual activities required to drill the well, and “designing” means to specify all the physical parameters (depth, diameter, etc.) that define the well itself. Design of a geothermal well is a “bottom-up” process which is influenced by a number of factors; Location of the production zone determines the well’s overall depth, required flow rate determines diameter at the bottom of the hole – the well’s profile above the production zone is then set by iteration of the successively larger casing strings required by drilling or geological considerations, and the purpose of the well i.e. exploration, appraisal, production or reinjection [1].

The drilling action involves breaking the ground and lifting the rock cuttings from the resulting hole by suspending them in a circulating drilling fluid. The actual breaking of the ground is achieved by use of a rock bit which is rotated under controlled weight to crush and shear the surface. Drill pipes are connected to the rock bit in order to drill deeper and deeper. To prevent collapsing of the well bore walls and formation fluids invading the hole, the well is cased and cemented. Geothermal wells in Menengai field are normally drilled to a depth of about 22000m and an approximate duration of 100 days is planned to be taken. The wells are either vertical or directional depending on the objectives of the well. During the drilling process, there are numerous occurrences or eventualities that cause stoppage of drilling operations or marginal reduction in advancement of the drilling progress. Such occurrences are classified as nonproductive time (NPT). Non-Productive Time (NPT) is defined as time which drilling operation is ceased or penetration rate is very low; for example, time spent on fishing, stuck pipe, waiting on equipment repairs, tool transportation, lost circulation and tripping in/out. Non Productive Time (NPT) is the main cause of drilling project delays and huge costs overruns in drilling projects due to stand-by charges and penalties on equipment and personnel [2].

This research work sought to examine all activities that are performed during the drilling process with the aim of identifying the time spent on activities that were not in the original plan. This will help in capturing all causes of Non Productive Time during drilling of the geothermal wells. The specific objectives of this research work were to;

1. To assess contribution of equipment breakdowns to Non Productive Time

2. To determine the contribution of geological challenges to Non Productive Time

3. To examine the contribution of operations planning to Non Productive Time

4. To establish the contribution of decision making to Non Productive Time

2. Theoretical Framework

2.1. System reliability Theory

Processes, components, equipment, systems, and people are not perfect and not free from failures. Everything fails either because of events or from aging deteriorations. A natural law of entropy expresses the lowest energy state as a failure which means we must continually maintain processes and equipment to prevent disorder and failures. This requires spending time and resources to mitigating failure effects as nothing lasts forever.

Reliability is the probability that a component, system, or process will function without failure for a specified length of time when operated correctly under specified conditions. Reliability engineering is a strategic task concerned with predicting and avoiding failures. For quantifying reliability issues it is important to know why, how, how often, and costs of failures. Reliability issues are bound to the physics of failure mechanisms so the failure mechanisms can be mitigated. In the real world all potential failures are seldom well known or well understood which makes failure prediction a probabilistic issue for reliability analysis [3].

2.2. Risk Management Theory

Managing risk means not letting small problems become big ones, knowing what the risks are and when they are likely to occur. Most of the time spent drilling, and most of the cost is encountered in getting to the reservoir. Successful drilling hinges on developing a sound plan, continually updating it in light of new information and keeping the involved personnel informed on a timely basis. The plan must include procedures to follow under normal circumstances and methods for dealing with most likely and most severe problems that may be encountered. With proper training, a well-defined drilling process, sufficient data and tools for interpretation, successfully drilling a well should be a routine process [4].

2.3. Process Improvement Theory

Processes are the fundamental building blocks of all organizations, and both process understanding and process improvement form the lifeblood of total quality organizations. Processes transform inputs, which can include actions, methods and operations, into outputs. Everything we do is a process, whether it is documented or not, and in each area or function of an organization there are many processes taking place. These processes interact with other processes throughout an organization, as outputs from one process form the inputs to another. Each process is therefore part of a larger process and organizations large and small can be seen as complex networks of interconnecting processes, the highest level being the organization itself (http://www.dti.gov.uk/ quality/process).

The history of quality management, from mere 'inspection' to Total Quality Management, and its modern 'branded interpretations such as 'Six Sigma', has led to the development of essential processes, ideas, theories and tools that are central to organizational development, change management, and the performance improvements that are generally desired for individuals, teams and organizations. Continuous improvement (CI) is an array of powerful techniques that has produced substantial improvements in numerous companies and organizations. CI provides perhaps the most central and universal component of TQM (total quality management) which itself has helped many companies achieve high quality and productivity.

2.4. Decision Support systems Theory

Quite literally, organizations operate by people making decisions. A manager plans, organizes, staffs, leads, and controls his or her team by executing decisions. The effectiveness and quality of those decisions determine how successful the manager, the team, and the organization at large will be [5]. Managers are constantly called upon to make decisions in order to solve problems. Decision making and problem solving are ongoing processes of evaluating situations or problems, considering alternatives, making choices, and following them up with the necessary actions. Sometimes the decision-making process is extremely short, and mental reflection is essentially instantaneous. In other situations, the process can drag-on for weeks or even months. The entire decision-making process is dependent upon the right information being available to the right people at the right times. Case-based reasoning (CBR) is a computational method that is based on the principle of reusing past experience, that is, being reminded of similar situations and making use of decision steps made earlier, to handle new situations, shown by reference [6]. In CBR, new problems are solved by reusing the solutions of the most similar past problems stored in a case base. Furthermore, newly solved problems are stored in the case base and thus incremental and sustained learning is supported intrinsically by the reasoning method. The reasoning process can be viewed as a cyclic, four-step process often referred to as the CBR cycle [7].

3. Conceptual Framework

A conceptual framework of a research study entails the system of concepts, assumptions, expectations, beliefs, and theories that supports and informs the research [8]. Author [9] defined a conceptual framework as a visual or written product, one that "explains, either graphically or in narrative form, the main things to be studied—the key factors, concepts, or variables—and the presumed relationships among them". A conceptual framework is a product of qualitative process of theorization which interlinks concepts that together provide a comprehensive understanding of a phenomenon or phenomena [10]. The concepts that constitute a conceptual framework support one another, articulate their respective phenomena, and establish a framework-specific philosophy that defines relationships. As a visual or written product, a conceptual framework either graphically or in a narrative representation denotes the main things to be studied namely key factors, concepts or variable and the relationships among them. In this study the dependent variable was Non Productive Time in drilling operations while the independent variables were equipment failures, geological challenges, Operations Planning, and decision making.

4. Research Gaps

The Lack of Holistic approach in NPT studies presents the challenge of accurate accounting for all rig time spent on activities other than drilling operations. This is because most NPT studies are focused on select problems with the aim of getting to the root cause and coming up with ultimate solutions but not on collective problems that occur at the rig resulting to stoppages of rig operation. This is usually due to knowledge limitation of the researcher in many various drilling filed hence confining him/herself to the area of expertise. Since it almost impossible for a single individual to be fully knowledgeable in all fields of drilling operations, research can be carried out to develop a solution (e.g. computer system, manual logs) that helps in capturing NPT arising from every field of the drilling operation.

5. Constraints of the Study

This study involved review of secondary data from operations records of Geothermal Development Company. Due to the proprietary nature of the information, authority to access the records took too long to be granted.

6. Research Methodology

6.1. Research Design

The research design of this study was descriptive study with the intention of accurate determination of the amount of nonproductive time (NPT) in drilling operations for sampled wells, and to precisely portray the contribution of various factors to the total NPT. Reference [11] asserts that descriptive research is a description of the state of affairs as it exists at present and the researcher has no control over the variables.

6.2. Sampling Frame

Sampling frame is the list of elements from which the sample is actually drawn [13]. According to reference [12] sampling is the process of selecting a number of individuals for a study in such a way that the individuals selected represent the large group from which they were selected. She also recommended that a 10% to 30% sampling from every group of the population will give a more representation of the whole population. The sampling frame of this research consisted of the list of 31 wells. This sampling frame consisted of wells which were drilled to completion by similar drilling equipment hence forming a complete and correct list. To ensure minimum bias, geographic location of the wells was a key consideration parameter for selecting elements of the sampling frame. This prevented selection of wells located at the same place which could lead to systematic bias [13].

6.3. Sample and Sampling Technique

The sampling technique used in this research work was proportionate stratified sampling. 25% of the target population was used to determine the sample size. The sample frame was stratified into four strata. Stratification was done according to rig that drilled the well. Stratification of the source list according to the rigs that drilled the wells was intended to avoid biased data on NPT arising from equipment anomalies.

Table 1: Sample Frame

Drilling Equipment	**Population (Wells)**	**Sampled Number 25% (Wells)**
Rig 1	8	2
Rig 2	11	3
Rig 3	7	2
Rig 4	5	1
Total	**31**	**8**

6.4. Data Collection

Questionnaires were distributed to drilling engineers, supervisors, drillers, maintenance engineers, and maintenance technicians manning the rigs to provide the intended information. Review of secondary data was also undertaken to augment the information collected using the questionnaires. Data was entered in Data collection templates, edited in order to ensure accuracy, and where necessary classified for analysis. This guaranteed that the data was accurate, consistent with the intent of the research questions, uniformly entered, complete, and arranged to simplify coding and tabulation.

6.5. Data Processing and Analysis

Data was analyzed qualitatively and quantitatively using MS Excel and statistical results package for social science (SPSS). Descriptive statistics was used to present the results, which were tabulated in frequency distributions, percentages and graphs. For inferential statistics, the study employed regression analysis to establish the existing relationships between the independent variables (Equipment failures, Geological challenges, ope rations planning, and decision making) and Non Productive Time in drilling operations.

Regression Model

$$YP = \alpha + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \varepsilon \qquad (1)$$

Where: α and β are constants, ε represents an error term.

YP = Non Productive Time

X1 = Equipment Failure

X2 = Geological Challenges

X3 = Operations Planning

X4 = Decision Making

6.6. Data Presentation

The data was displayed by use of visual representation and graphical techniques so that flaws in the data could be detected. Bar charts were the most predominant graphical techniques that were employed in this research work. The use of percentages was also used in this research study, in order to simplify the data by reducing all numbers to a range from 0-to- 100 and to translate into a standard from with a base of 100, for relative comparison.

7. Research Findings and Discussions

7.1. Response Rate

The study administered Sixty (60) questionnaires to the target population. Fifty five (55) questionnaires were filled and returned. This represented 91% response rate making it sufficient for analysis as stated by reference [14]. The survey covered 8 wells drilled by four rigs in Menengai Geothermal Project.

7.2. General Information

The study sought to establish the distribution of the respondents among the rigs, their designation, Age bracket, highest level of education, duration of employment, and number of wells drilled.

7.3. Research Results: Descriptive Results

7.3.1. Equipment Failure

Equipment failures contributed 42%, 15%,10%, 9%, 8%, 6%, 1% Non-Productive Time in wells: MW13, MW10, MW12, MW17, MW9A, MW20, MW01A, and MW05A respectively.

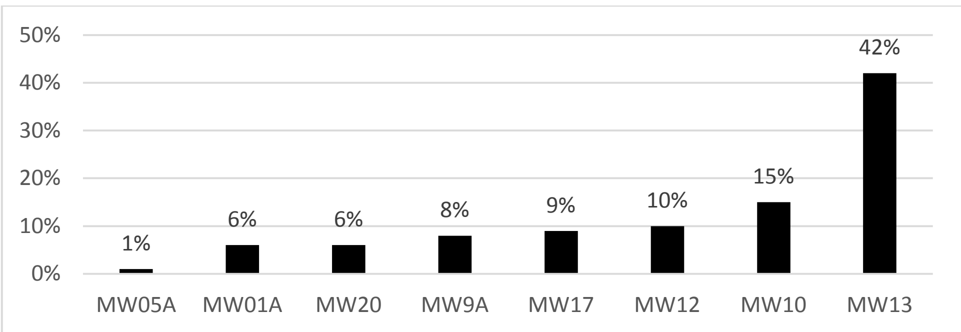

Figure 1: NPT % Due to Equipment Failure

7.3.2. Geological Challenges

Geological challenges contributed 16%, 11%, 10%, 8%, 6%, 5%, 4%, and 3% Non-Productive time (NPT) in well MW01A, MW10, MW17, MW13, MW12, MW9A, MW20, and MW05A respectively.

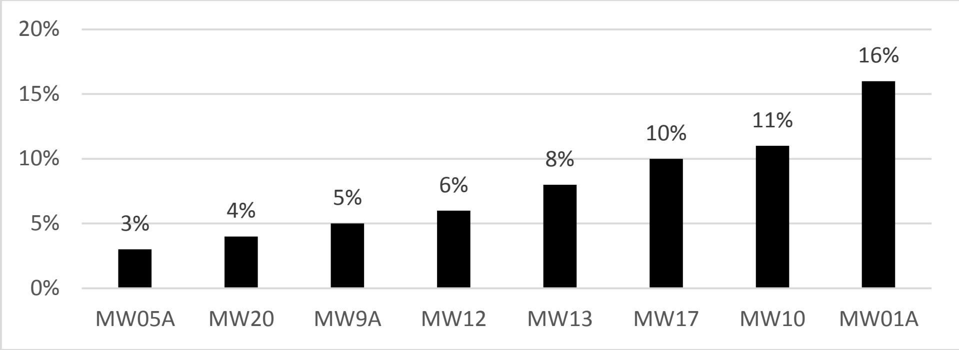

Figure 2: NPT % Due to Geological Challenges

7.3.3. Operations Planning

Operations planning contributed 51%, 49%, 45%, 42%, 39%, 37%, 34%, , and 29% Non-Productive time (NPT) in well MW01A, MW10, MW17, MW13, MW12, MW9A, MW20, and MW05A respectively.

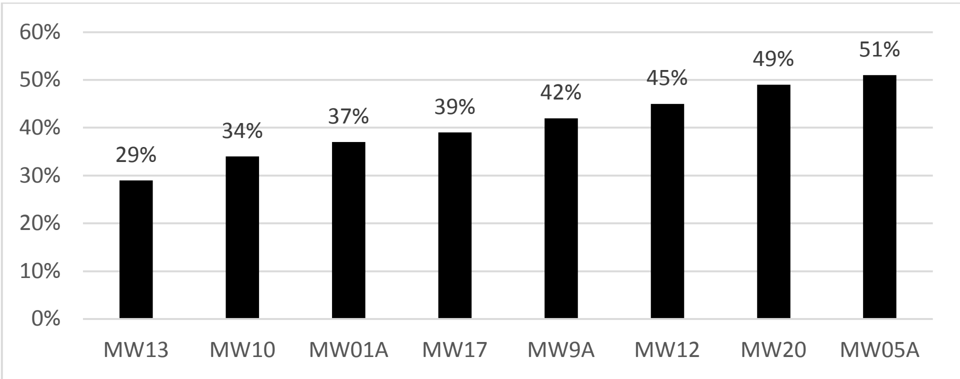

Figure 3: NPT % Due to Operations Planning

7.3.4. Decision Making

Decision making contributed 2% NPT in wells MW20 &MW01A, 1% NPT in wells MW5A, MW9A and MW13, No contribution (0%) in wells MW12, MW7, and MW10.

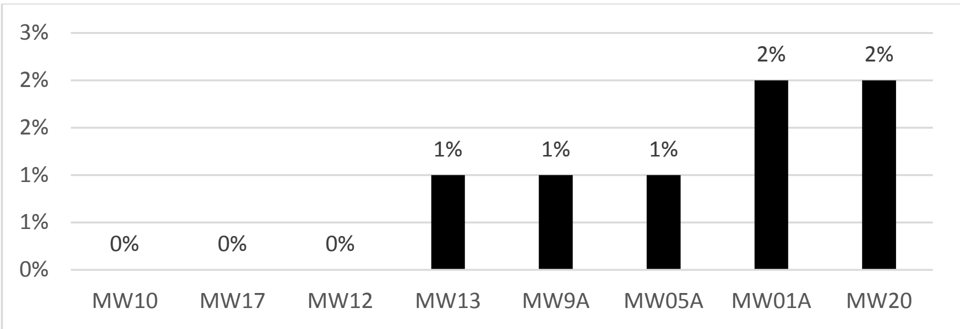

Figure 4: 4.4 NPT % Due to Decision Making

8. Conclusion

The results of this study revealed enormous amount of Non Productive time associated with geothermal drilling operations in Menengai Geothermal Project. It showed that the average total Non-Productive Time is 62%, while only 38% of the total drilling duration is productive time. In drilling operations, drilling duration and cost are proportional functions of each other; this means that there is a huge drilling cost that can be eliminated if Non Productive time can be brought down.

9. Recommendations

Identification and capturing of all causes of Non Productive Time should be carried out in all drilling operations in order to know how much of the drilling time is spend productive and unproductively.

9.1. Recommendation on Equipment Failure

Records of operating hours for all equipment in the rig should be kept on a daily basis. This will help capture and record Non Productive Time due to equipment failure/stoppage. Such records would provide useful information in determining the contribution of equipment failure to the total Non Productive Time.

9.2. Recommendation on Geological Challenges

Even though it is almost certain that geological problems will occur while drilling a well, even in the very carefully planned ones, records of all geological eventualities that result to stoppage of the drilling operations should be kept on a daily basis. This would help in determining the contribution of geological challenges to the total Non Productive Time.

9.3. Recommendation on Operations Planning

Since Operations planning is critical for any drilling operation, it should be done in a manner that no delays will be expected during execution of chain of sequential operations – the critical path – to avoid delay in project completion. In addition, keeping log of all stoppages arising from operations planning would help in determining the contribution of operations planning to the total Non Productive Time.

9.4. Recommendation on Decision Making

Recording all stoppages arising from decision making is critical to determining its to the total Non Productive Time. Use of techniques like Knowledge intensive Case Based Reasoning (KiCBR) can aid in problem solving and decision making in drilling operations.

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