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Drill-Well-on-Paper (DWOP) Utilization in Indonesia Geothermal Drilling Projects: What are the Lessons Learned?

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ABSTRACT

Drilling is one of the biggest cost contributors, both in oil and gas or geothermal projects. Therefore, geothermal developers should closely monitor the drilling cost to reduce the whole geothermal development cost. Regarding the drilling cost, many previous studies have argued that cost optimization can be achieved if the risk mitigation and optimization plan have been thoroughly formulated early in the planning phase, and then can be applied during the drilling operation.

However, drilling project is a very complex operation involving various services and activities. Those complexities make it impossible for the drilling engineers alone to address and devise mitigation plans for potential drilling problems. It requires a good and intensive communication between the personnel from various background and expertise to put together a proper drilling program. This communication and coordination process is typically known as Drill-Well-on-Paper (DWOP). DWOP is very common in oil and gas drilling projects to identify potential drilling problems that may resulted in NPT and increasing total drilling cost. But its application in geothermal drilling in Indonesia still leaves many rooms for improvement, as some may treat DWOP as just another custom in the industry without fully realizing its importance. Another crucial aspect that tends to be forgotten is that DWOP also act as a communication medium that connects the engineers who are creating the drilling program with the drilling personnel who carries out the operation on the field.

This paper summarizes the study of analyzing the DWOP practices conducted by geothermal developers and active geothermal drilling personnel in Indonesia. The research assesses the effectiveness of DWOP practices in geothermal drilling project in Indonesia. Several aspects such as the participants' awareness of the DWOP significance and objectives, the DWOP activity structure, the composition of the participants involved, facilitators' competency, and the end-product of the DWOP were evaluated. The data gathering for the research was done through literature study and distributing questionnaire / interviewing geothermal drilling personnel in Indonesia. Several best practices that are common in oil and gas industry were also compiled as comparison.

Finally, this study intends to obtain preliminary mapping of DWOP effectiveness in the current geothermal industry in Indonesia and identifying best practices in conducting DWOP. Those best practices then can be used as a guideline for conducting future DWOP, and in turn will lead to cost-optimization in drilling as well as the whole geothermal project.

1. GEOTHERMAL DRILLING IN INDONESIA

1.1 The Importance of Geothermal Exploration Projects for Indonesia

Indonesia is one of the countries that is estimated to have the largest geothermal energy potential in the world with an estimated potential of approximately 18,000-megawatt electricity (MWe). However, from that huge potential, currently, Indonesia only utilizes approximately 12% of the total potential, which is around 2,300 MWe. To increase the utilization of geothermal energy into electricity, the Government of Indonesia (GoI) is currently targeting 5,100 MWe of geothermal power plant installations by 2030.

There has been quite a number of published studies and papers discussing the issues on the challenges that the Indonesian government and the geothermal developers will face in developing geothermal projects in Indonesia. Despite those challenges, currently the exploration phase is the most critical phase that Indonesia needs to seriously take into action, in order to achieve the geothermal national target. Figure 1 shows that only few areas has been developed for geothermal power generation despite Indonesia's vast potential.

Figure 1 (Pusdatin ESDM, 2020) also shows the distribution of geothermal areas in Indonesia as according to the progress in each area. Areas that are coloured green, light green and yellow indicates areas that has been through a preliminary survey, which is commonly the 3G survey, and in some areas, surveys such as the temperature gradient hole or deep slimhole might have also been conducted. Pink indicates the areas that are ready for development, whereas red shows areas that has already been developed.

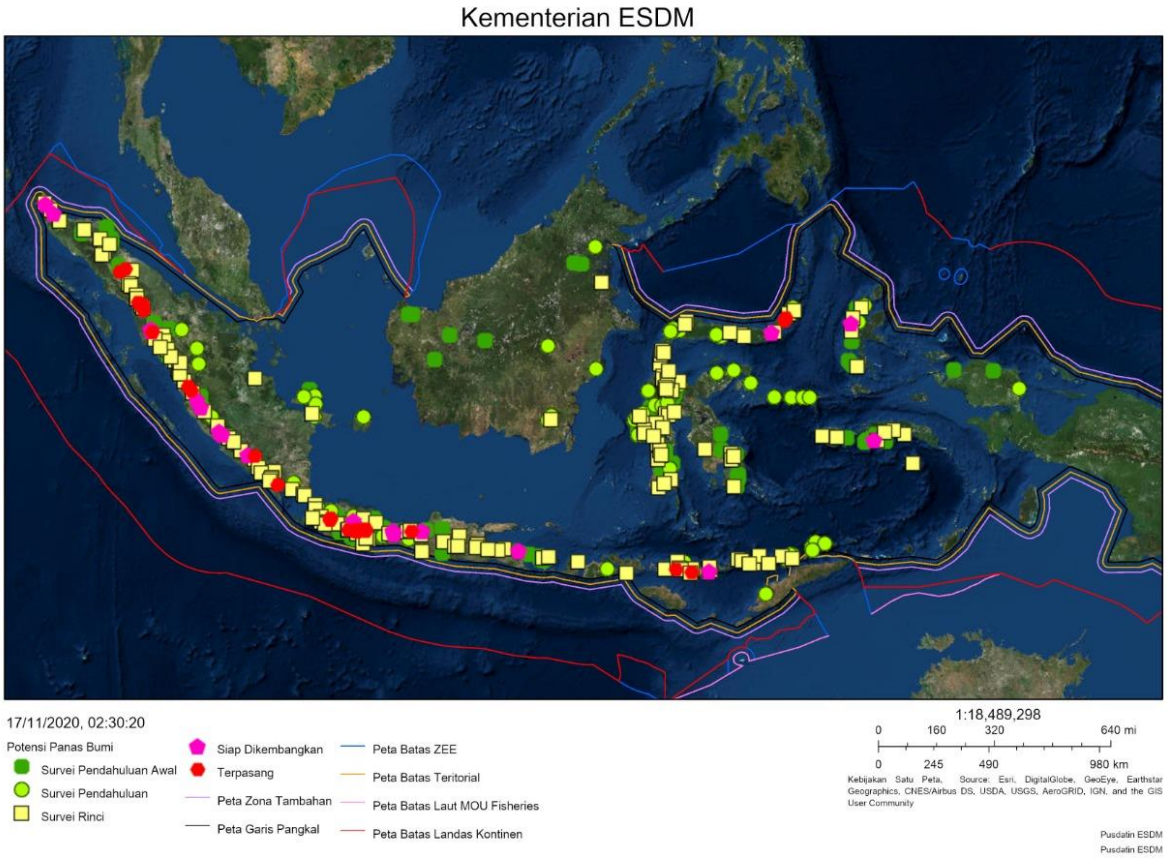

Figure 1: Maps of geothermal potential area in Indonesia with its status (Pusdatin ESDM, 2020)

While Table 1 shows that there is a total of 73 geothermal areas that are still in the exploration phase with the total potential of 3,520 MW (ESDM, 2020).

Table 1: Geothermal area status in Indonesia (ESDM, 2020)

Geothermal Area Status	Number of Area	Potential
Area Prospek Wilayah Terbuka (Prospect Area – Open)	17 prospect area	290 MW
Wilayah Penugasan Survei Pendahuluan dan Eksplorasi (Preliminary Survey)	14 PSPE area	920 MW
Persiapan Penawaran WKP dan Government Drilling (Prepared for Tender)	22 WKP	825 MW
WKP Eksplorasi Dengan Rencana Pengembangan (Exploration Area with Development Plan)	20 WKP	1,485 MW

Indonesia's geothermal energy target certainly requires collaborative efforts from all stakeholders including the government, geothermal development companies, investors, off taker, academics, researchers, affected local communities, and various institutions and companies involved in geothermal development projects. Looking at the geothermal prospects and fields map in Indonesia (Figure 1), the collaboration of these stakeholders should be focused primarily on efforts to complete the exploration phase in various prospect areas in Indonesia. It is impossible for Indonesia to achieve the geothermal national target without going through the exportation stage which is perhaps the most crucial stage and has many challenges.

The level of difficulty and risk of Indonesia's geothermal exploration phase is mainly due to combination of 2 (two) main factors:

1. The high level of uncertainty regarding the existence of economically viable geothermal resources underneath the ground (resource risk) and,
2. The high cost of drilling activity to prove the existence of these geothermal resources.

In the context of Indonesia, the challenges of geothermal exploration projects are intensified by the addition of several factors such as (Adityatama, 2020; Poernomo, 2015):

1. Geothermal prospect / exploration areas are usually located in volcanic setting with many geohazards, very minimal road access and hilly terrain.
2. There is still a lack of understanding of the local community living around the geothermal prospect area regarding geothermal projects. This often results in a low level of community acceptance on geothermal exploration projects.
3. Number of geothermal exploration experts in Indonesia, from all discipline (e.g., geoscience, drilling, environmental, social), is less than the number of exploration projects to be completed. Combined with the absence of a certification program for geothermal exploration experts, geothermal exploration projects in Indonesia are often carried out by personnel with an inadequate level of competence.

4. In the exploration phase, usually there is not yet certainty of the electricity prices, which create difficulties for investors in making decision to spend the exploration budget.

Therefore, it is very important for stakeholders in Indonesia to be able to collaborate to solve the main challenges of geothermal exploration projects that have been discussed in various publications and forums to finally achieve the national geothermal target.

1.2 Drilling as the Only Method to Prove Sub-surface Geothermal Resources

Geothermal exploration activities are generally carried out in stages starting from activities that require the least cost /effort and then increased to higher-cost activity as the level of confidence in the project's feasibility increases (Figure 2).

Figure 2 shows that exploration activities can be divided into 3 main activity groups as follow:

1. *Surface surveys / studies* – This activity is mainly including all the process of collecting subsurface data from the surface. Because the activity is carried out from the surface, the cost is much cheaper than the cost of drilling, but the data obtained generally must be interpreted first because it is not directly acquired from the subsurface. Surveys can be in the form of geological mapping, geochemical sampling, geophysical data collection (magnetotelluric, gravity, etc.), LiDAR, topographic surveys, hydrogeological surveys, social mapping, and other surveys considered necessary to support project decisions.

2. *Data interpretation and integration, conceptual modeling, and resource* assessment – These are the activities of integrating and interpreting the data obtained through the surface survey described above. These activities generally include laboratory analysis, data cleansing, data interpretation, data integration where the final product of this activity is a conceptual model that can be used to estimate the amount of commercial geothermal reserves in the prospect area. If the geothermal resource is believed attractive for further research, the project will then proceed to activities that are more complex and more expensive but can prove the existence of geothermal resources, which is called deep well drilling.

3. *Deep well exploration drilling* – This activity is commonly become the last activity in a geothermal exploration project because with the presence of a deep well the existence or absence of a commercial geothermal system below the surface can be proven. Of course, this activity is not carried out directly at the beginning of the exploration project because it has a high level of difficulty and cost.

An exploration drilling project need to be planned and executed carefully because it acts as the only way to prove the existence of a commercial geothermal system underground. Exploration well(s) will only be useful if it can reach the planned depth target where various subsurface data (e.g., formation characteristic, rock type, fluid type, permeability, temperature, etc.) can be acquired directly through various methods such as coring, cutting sampling, measurement while drilling (MWD) and wireline downhole logging.

In addition, after an exploration well is successfully completed, a flowing test may be performed which can provide more comprehensive information about the characteristics of the geothermal prospect area being explored. At the end, all data obtained from these exploration wells are significant for the decision-making process whether this prospect area is feasible for further development. Table 2 shows a list of data that is expected to be available in the end of the exploration stage to be able to conduct resource assessments and create a numerical model.

Table 2: Required data to conduct resource assessment and numerical model in the exploration phase (Nugraha, 2020; Nugraha et al., 2018; O'Sullivan & O'Sullivan 2016; O'Sullivan et al., 2015; Ratouis et al., 2015)

Data category	Data required
Geology	Topography, rock stratigraphy, lithology, regional fault structures, thermal feature location, nature of hydrothermal alteration, heat source type, location permeable zones, water table levels
Geophysics	Surface heat flow, subsurface structures, area extent and thickness of caprock/alteration zones, temperature gradient
Geochemistry	Thermal feature data: area, type, pH, temperature, chemical content, fluid type, flowrate, gas flux
Reservoir	Rock type and properties (porosity, density, resistivity, and heat capacity), temperature, fluid chemistry (type, pH, and chemical content), permeability, pressure, top of reservoir, reservoir thickness, reservoir structures, saturated and undersaturated zones
Well	Productivity/injectivity index, feed zones, downhole temperature and pressure profile, permeability, well location and trajectory

1.3 Exploration Drilling Challenges

Generally, all personnel involved in a geothermal project are aware that the existence of exploration wells is very crucial for the decision-making process towards the next stage. However, the author in this study suspects that not all personnel are well informed about the challenges faced when carrying out exploration drilling activities, either challenges from technical or from non-technical aspects, such as regulation/legal, social and environmental)

Some of the challenges in geothermal exploration drilling in Indonesia can be summarized as follows:

1. *Low accuracy of subsurface data* - at the exploration stage the available subsurface data are generally still formed based on the interpretations of surface studies so that drilling planning will be carried out based on data with very low accuracy. The challenges that will be faced are generally in the form of various surprises from formations at unexpected depths, such as massive lost zones, reactive formations, unconsolidated formations, shallow steam pockets, deeper top of reservoirs, paleosol formations, etc. Realizing that the geoscientific prognosis provided by the geoscience team may not match actual

conditions, the drilling team must make a mitigation plan for various scenarios or potential subsurface hazards that will be encountered. Failure to make a mitigation plan will result in an increase in drilling costs and the worst thing is that the drilling of the well will not be completed.

2. *Newly formed exploration team* – currently in Indonesia, companies conducting geothermal exploration activities are generally newly formed companies with a combination of several sponsoring companies. The implication of a new company is that the team is built by combining several key personnel who might be their first time working together and are not familiar with each other's working method and communication styles. Furthermore, due to the shortage of geothermal personnel, geothermal companies often recruit personnel from other similar industries such as oil and gas or mining. Although similar, the challenges of drilling in the geothermal environment are quite significant different when compared to the oil and gas and mining environments. The failure of geothermal companies to build a competent and well-communicated exploration team will cause exploration projects to run slower and ultimately increase project costs.

3. *Higher project costs compared to development stage drilling* – despite the explanation of the two points above regarding the lack of subsurface data and the exploration team being generally newly formed, the cost of exploration drilling itself is generally higher than the cost of drilling at the development stage. This is because the number of wells drilled in the exploration stage is usually less than wells drilled in the development stage. The number of these wells affects the prices proposed by the providers of rigs and supporting services. The more wells drilled, the lower the price.

4. *Low acceptance of local communities* – not only from the technical side, but exploration challenges also come from the non-technical aspect, especially those related to local communities. In the exploration stage, people living in geothermal prospect areas in Indonesia are generally have not properly educated about the benefits of geothermal projects for their livelihood. Often, geothermal companies focus too much on planning from the technical aspect and forget about engagement with local communities, resulting in community rejection.

5. *Indonesia does not yet have a geothermal drilling database* – Indonesia does not currently have a database that collects and integrates data and lessons learned from geothermal drilling activities from all geothermal development companies in Indonesia. The existence of this database will certainly make it easier for geothermal developers to learn from other developers so that the same mistakes can be avoided. In the absence of this database, each geothermal development company can only learn from their respective projects.

The various challenges above can be summarized into one word “learning curve” where in the exploration stage, which is the beginning of a geothermal development project, the team are still in the stage of learning and gathering information. Along with the increase in information, data, experience, skills and communication quality within the exploration team, the drilling success rate will generally increase as already discussed by Sanyal (2011) shown in Figure 2.

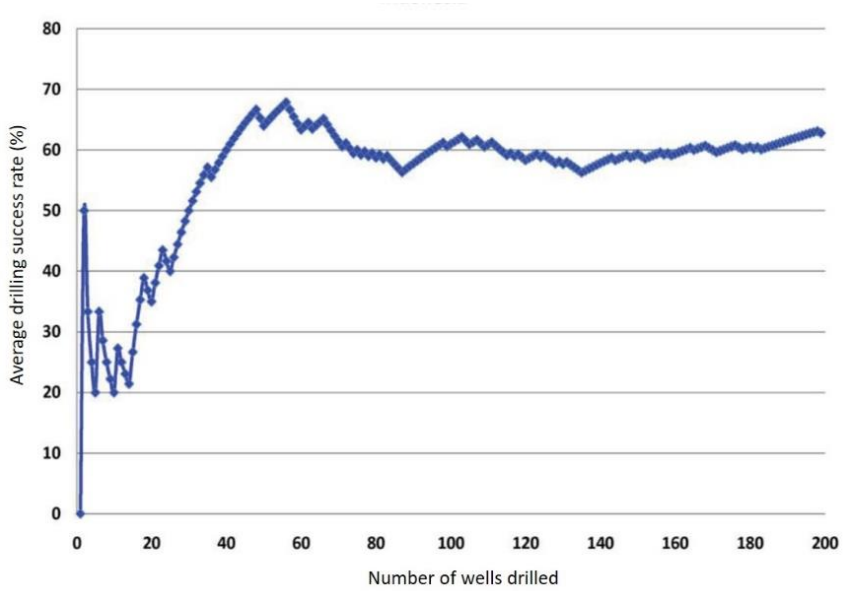

Figure 2: Average drilling success rate versus number of wells using data from Indonesia (Sanyal et al., 2011)

Failure to mitigate the various exploration challenges outlined above will lead to an increase in the cost of exploration projects which in turn increases the overall cost of geothermal development projects. Significant increase of overall project costs can eventually cause the project to become uneconomical and therefore have the potential to be discontinued.

In addition to project cost overruns, another factor that can cause an exploration project to stop is work incidents. If not managed properly, some work incidents may have an impact on the environment and residents around the project. Several incidents that have occurred in geothermal drilling projects in Indonesia recently show the level of difficulty of geothermal drilling activities in Indonesia.

1.4 Managing Geothermal Exploration Drilling Project

Like any other project management in general, the success of an exploration drilling project is largely determined by the quality of communication between stakeholders. Communication can be done in various ways where the most common way is through meetings. Some of the key meetings that are generally held in a geothermal exploration project are shown in Table 3.

Table 3: List of key meetings in a geothermal exploration project

No.	Meeting title	Short description	Typical participants
1.	Well targeting and well location meeting	This meeting aims to obtain approval from all teams involved in geothermal exploration drilling projects including drilling, civil construction, environmental, social, permitting, legal, procurement, and of course land acquisition teams. The approval in question is the location of the well and the drilling target.	All team involved in the drilling exploration project.
2.	DWOP (drill-well-on-paper) workshop	A specific meeting to have an efficient trouble-free drilling operation. The drilling task or drilling program is usually broken into several categories for discussion in a smaller group. These include but are not limited to building the team, creating an open environment for candid discussions, conveying both overall well plans and specific critical details of the well to the personnel involved, obtaining good feedback and buy-in to the project, and where needed, modifying the plan based on the feedback.	Drilling Manager, Drilling Engineer, Drilling Superintendent, Rig Manage / Superintendent, Toolpusher, Drilling Service Companies (representative from each service), Environmental and Social Specialists, Drilling Procurement Specialist, Civil Engineer, Legal Specialist.
3.	Pre-spud meeting	Pre-spud meetings would explain the upcoming well to the rig-site and office personnel involved, and alert them to any particular well hazards or difficulties anticipated. They were usually short—perhaps only a couple of hours long—and since most of the people involved already knew each other from prior work, there was nothing in the way of introductions or teambuilding (Ramsey 2019).	Drilling engineer, Drilling Superintendent, Rig Superintendent, Toolpusher, Driller, Rig Crew, Drilling Service Companies (field hands / field reps), EBTKE / government reps (occasionally), HSE personnel.

From the various meetings described in Table 1, the authors believe that Drill-Well-on-Paper (DWOP) may be one of the most important meetings with many benefits for the exploration drilling projects but have not been conducted optimally in Indonesia.

1.5 Research Objectives

With the assumption that DWOP has not been carried out optimally in Indonesia, this study seeks to find answers to the following questions:

1. What are the benefits of DWOP for geothermal exploration drilling projects?
2. How is DWOP generally done?
3. Has DWOP been carried out well in various geothermal drilling projects in Indonesia?
4. How to measure the success of DWOP against the costs incurred?
5. What actions can be taken to improve the quality of DWOP in Indonesia?

2. DRILL-WELL-ON-PAPER (DWOP)

2.1 Why DWOP?

Exploration drilling activities are complex activities because they are carried out by several companies with varied work cultures and involve multi-disciplinary personnel. The total number of companies involved in a drilling project can vary from 3 – 30 companies, depending on the contract scheme used in the project (Figure 3). This complexity clearly requires good communication between personnel so that each personnel understand their respective duties and responsibilities in realizing the goals of exploration drilling being carried out as a collective goal. Meetings are considered one of the most common methods for communicating all aspects of projects, both planned and ongoing.

DWOP as described in Table 3 is one of the important meetings that is conducted based on the following reasons (Ramsey, 2019; Taylor, 2021):

1. The geothermal developer does not carry out exploration drilling projects alone but are assisted by various parties in the form of a group of companies, contractors and agencies.
2. No geothermal drilling project is really similar. All projects can be considered unique. Therefore, in addition to industry best practices, there's always a unique set of circumstances for each project. For example, there may be environmental, cultural, political or local regulatory considerations that might get missed.
3. Geothermal exploration drilling projects, although carried out in Indonesia, generally involve international citizens, where workers come from dozens of countries and cultures, even on a single project. Rules and regulations aside, everyone needs to work in synergy.
4. An accident has implications that can spread for hundreds of miles and last for years.
5. Mistakes on a single project can result in companies going bankrupt.
6. The level of technical capability, ability and competence is exceptionally high, putting massive stress on both people and equipment.

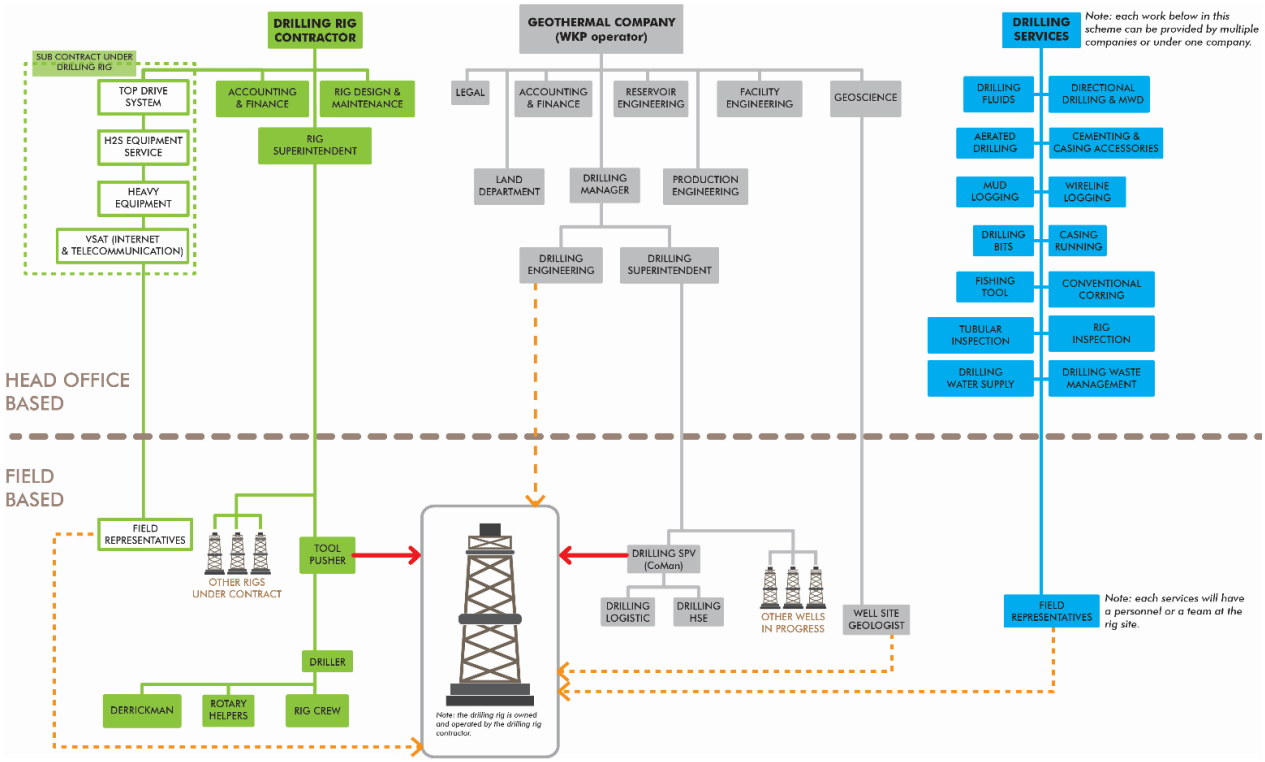

Figure 3: Typical drilling organizations in a geothermal drilling project in Indonesia (Purba et al., 2020)

2.2 DWOP Common Practice

The purpose of the DWOP can be simplified as follows:

1. Ensure all personnel involved in exploration drilling projects are “on the same page” regarding the objectives and planned drilling program and the various risks involved.
2. Provide space and time for all teams involved to express their views on the drilling program, especially if there are risks that have not been identified or have not been properly mitigated.
3. Populate all drilling risks and make a priority list of the main risks that must be mitigated accordingly.
4. Updating the drilling program so that drilling activities can run "trouble-free" and "incident-free" so that the planned wells can be realized according to the planned cost and duration.

To be able to achieve the objectives mentioned above, DWOP is generally carried out in the following ways:

Pre- DWOP (3-6 weeks before DWOP)	DWOP (2-5 days duration workshop)	Post DWOP (2-6 weeks after DWOP)
1. The drilling team as the host of the event is assisted by a facilitator (may be an external consultant) making a list of DWOP participants. 2. Distribution of the drilling program draft and drilling risk assessment to all prospective DWOP participants via email or online meeting 3. Finalizing the list of DWOP participants 4. Collecting a list of drilling risks from the initial brainstorming of the prospective DWOP participants, which is carried out individually. 5. Organizing the venue and logistic for the DWOP. 6. Distributing invitation with information of DWOP schedule and venue to all expected participants.	1. Introduction and ice breaking session to bring all participants to the “same frequency.” 2. Risk Register: all participants will be asked to submit all the risk they can think of. The risks will usually be grouped based hole section. 3. Risk Assessment: all participants will be asked to work in group to assess risk likelihood and consequences. Each group should pick the top 5 risks to be presented, including all possible action plan to reduce / mitigate the risk. The group should select the most doable action plan based on their judgment. 4. Presentation & Discussion: each group present 5 top risks of each hole section, while other groups give feedback on the assessment result.	1. The drilling team as the host will record the results of the DWOP and conduct internal meetings to follow up on various main risks that arise when the DWOP is carried out, including the proposed mitigation plan. 2. The drilling team will then report the results of the updated drilling program, including the drilling budget (if any) to high-level management for approval. 3. The updated and approved drilling program is then re-socialized to all DWOP participants and exploration drilling project stakeholders.

An example of implementation of DWOP workshop on a geothermal exploration drilling project in Indonesia can be seen in Figure 4.

Figure 4: Photos showing situation of a DWOP workshop for a geothermal exploration drilling project in Indonesia

It can be seen in Figure 4 that DWOP requires active participation from all participants and is not a one-way presentation or communication. The ability of the facilitator and the willingness of the participants to be actively involved will determine the quality and output of the DWOP session.

Ramsey (2019) mentioned that the first step to helping to build the team is to have all the key personnel physically attend the workshop/meeting. This includes the key personnel from the geothermal developer company, the drilling contractor personnel, and the specialized service company personnel involved. Different companies will have different criteria for who attends the meeting, but at a minimum it should include:

1. All operator office personnel involved in the planned operations
2. All operator rig-site key personnel
3. All drilling contractor rig-site key personnel
4. Drilling contractor rig management personnel
5. Service company rig site personnel, especially rigsite supervisory personnel
6. Health, Safety and Environment (HSE) personnel
7. Maintenance personnel
8. Other support service personnel

As one can imagine, the meetings tend to be fairly large, with a typical one having 70-100 people in attendance. Note that maximize efficiency and minimize costs associated with the “well on paper” meetings, they are typically scheduled just before a crew change, and will combine two crews in one meeting, and the other two crews will be in a second, very similar but not identical meeting.

2.3 Pitfalls of DWOP Implementation

Although DWOP theoretically appears useful on paper, in practice DWOP often does not provide optimal results. As with other types of meetings, some of the “pitfalls” to be watched out for when conducting a DWOP workshop are:

1. Meetings can become routine, boring and then unlikely to be energizing and productive.
2. A few ‘strong personalities’ tend to dominate all proceedings.
3. Key team members start to miss meetings.
4. In-house company facilitators/organizers start to resent the extra time and effort required to organize the meetings. They already have a full workload.
5. Meeting outcomes aren’t always adequately captured, and action points are not allocated to actors so aren’t closed out efficiently, if at all.

2.4 Have Indonesia Geothermal Industry Done DWOP the Right Way?

DWOP originally came from the oil and gas industry, specifically offshore drilling projects. Drilling teams who oversee the drilling projects require DWOP because typically offshore drilling costs are relatively high so that it requires continuous improvement to obtain cost-efficiency and trouble-free operation.

Similar to above explanation, in Indonesia, the drilling team that originally adapted the DWOP method was a team involved in offshore oil and gas drilling projects. Over time, the DWOP method became common for onshore drilling projects. However, currently the question arises whether this method has been well adapted by the geothermal drilling team in Indonesia? Authors find that DWOP has started to be carried out in various geothermal drilling projects in Indonesia but in a variety of programs or methods so it is difficult to know whether the DWOP carried out can achieve its main objectives.

To get answers to the questions above, the authors conducted interviews with several geothermal drilling personnel in Indonesia who had been involved in DWOP sessions in geothermal drilling projects. The results of these interviews can be seen in the following table.

Dear Reviewer(s), the interview and questionnaire team are currently still in the process of collecting data, therefore the complete result of interview and questionnaire cannot be displayed in this sub-section at this time. We will immediately update this sub-section after the data is collected completely and can be presented in the form of a table / pie chart / graph. Thank you reviewers, for understanding.

3. DISCUSSION

This paper is a preliminary study to find out the position of the geothermal drilling industry in Indonesia regarding the use of the DWOP method to support exploration drilling projects in Indonesia. Various questions in section 1.5 (points 1-2) have been answered, but for points 3-5, the authors are still in the process of collecting data.

Dear Reviewer(s), since the interview and questionnaire team are currently still in the process of collecting data, therefore the Discussion section could not be completed at this time. We will immediately update this Discussion Chapter after the data is collected completely and can be analyzed for more comprehensive discussion. Thank you reviewers, for understanding.

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