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Drill-well-on-paper (DWOP) Practice in Geothermal Exploration Drilling Project: Have We Done it the Right Way?

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ABSTRACT

Drilling is one of the most significant cost contributors in oil and gas or geothermal projects. Therefore, geothermal developers should plan thoroughly and adequately monitor the drilling cost to optimize the entire geothermal development cost. Many previous studies have argued that drilling teams can achieve cost optimization when the risk mitigation and optimization plan have been thoroughly formulated early in the planning phase and implemented carefully during the drilling operation.

However, a drilling project is a very complex operation involving various services and activities, especially in the exploration phase. Those complexities make it impossible for the drilling engineers to address and devise mitigation plans for potential drilling problems single-handedly. Creating a proper drilling program requires excellent and intensive communication between personnel from various backgrounds and expertise. One tool commonly used in this communication and coordination process is Drill-Well-on-Paper (DWOP).

DWOP is common in oil and gas drilling projects to identify potential drilling problems that may result in non-productive-time (NPT) and increase total drilling costs. However, its application in geothermal drilling in Indonesia still leaves much room for improvement, as some may treat DWOP as just another custom in the industry without fully realizing its importance. When used correctly, DWOP can serve as a solid communication media that connects the engineers creating the drilling program with the drilling personnel carrying out the operation on the field.

The importance of DWOP becomes even higher when it is associated with the large number of geothermal projects in Indonesia, which are in the exploratory drilling stage. The lack of data and lessons learned in the exploration stage makes it essential for communication sessions such as the DWOP to be held properly.

This paper summarizes the study of analyzing the DWOP practices conducted by drilling personnel in Indonesia. The research assesses the effectiveness of DWOP practices in a geothermal drilling project in Indonesia. Several aspects were evaluated, such as the participants' awareness of the DWOP's significance and objectives, the DWOP activity structure, the participants' composition, the facilitators' competency, and the end-product of the DWOP. The data gathering for the research was done through a literature study and, distributing questionnaires / interviewing geothermal drilling personnel in Indonesia.

Finally, this study intends to obtain a preliminary mapping of DWOP effectiveness in Indonesia's current geothermal industry and identify best practices for conducting DWOP. The geothermal drilling community in Indonesia can use these best practices as a guideline for conducting future DWOP, which will lead to cost optimization in exploration drilling and the whole geothermal project.

1. INTRODUCTION

Before entering a detailed discussion regarding DWOP (drill-well-on-paper), the authors need to provide, in this Introduction section, the context for developing geothermal energy and the difficulty of geothermal exploration projects in Indonesia. The author hopes that discussions regarding DWOP implementation for geothermal exploration drilling projects can become more relevant with an explicit background at the beginning.

1.1 The Importance of Geothermal Exploration Projects for Indonesia

Indonesia is one of the countries that is estimated to have the most considerable geothermal energy potential in the world, with an estimated potential of approximately 18,000-megawatt electricity (MWe). However, from that vast potential, currently, Indonesia only utilizes approximately 13% of the total potential, which is 2,356 MW installed capacity (ThinkGeoEnergy, 2023). This utilization rate is low compared to New Zealand, which used 38% of its total potential, while the United States used 21% of its total potential (Asokawaty et

al., 2020). To increase geothermal energy utilization in electricity, the Government of Indonesia (GoI) is currently targeting 5,486 MWe of geothermal power plant installations by 2030 (Direktorat Panas Bumi, 2022).

Many published studies and papers have discussed the challenges the Indonesian government and the geothermal developers will face in developing geothermal projects in Indonesia (Ibrahim et al., 2005; IGA, 2014; Poernomo, 2015; Darma, 2016; Purba, 2018; Umam et al., 2018; Purba et al., 2019; Purba et al., 2020). Despite those challenges, the exploration phase is currently the most critical phase that Indonesia needs to take into action to seriously achieve the national geothermal target. Figure 1 shows that Indonesia has only been developing a few geothermal areas for geothermal power generation despite Indonesia's vast potential.

Figure 1 (Pusdatin ESDM, 2020) also shows Indonesia's distribution of geothermal areas according to each area's progress. Areas colored green, light green, and yellow indicate areas that have been through a preliminary survey, commonly the 3G survey. In some areas, the government, academic institutions, and geothermal developers have conducted surveys such as the temperature gradient hole or deep slim hole. Pink indicates the areas ready for development, whereas red indicates areas that have already been developed.

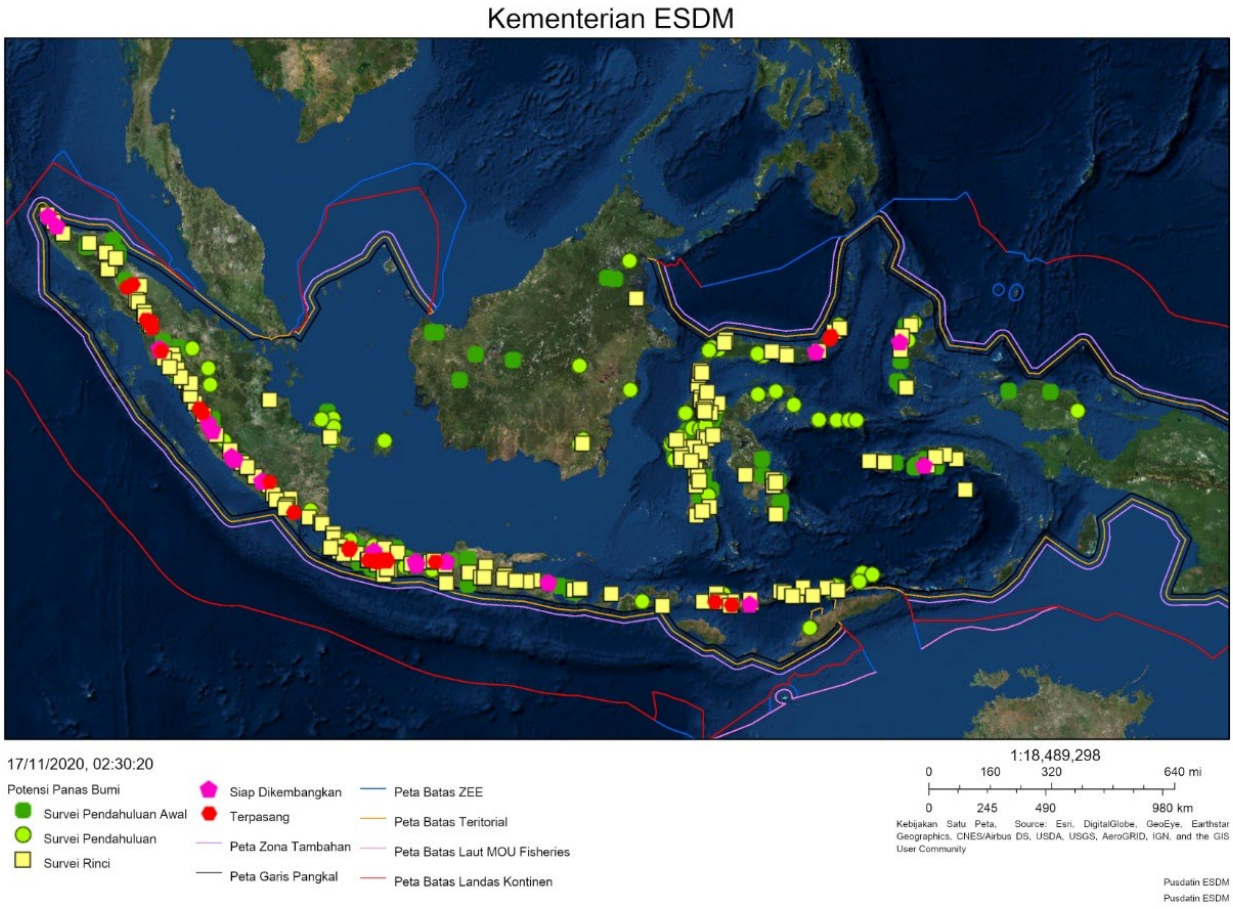

Figure 1: Maps of geothermal potential area in Indonesia with its status (Pusdatin ESDM, 2020)

While Table 1 shows the list of the 22 geothermal prospect areas or concession areas still in the exploration stage and is expected to contribute in achieving the aforementioned national geothermal target.

Table 1: List of Indonesia's Geothermal Prospect Areas/ Concession Areas in the Exploration Stage (modified from Direktorat Panas Bumi, 2022; Siahaan et al., 2023)

No	Name of the Prospect Area / Concession Area	Location	Estimated Potential Capacity (MWe)	Developer
1.	Tulehu	Maluku	31	PT PLN (Persero)
2.	Gn. Ungaran	Central Java	150	PT PLN (Persero)
3.	Atadei	East Nusa Tenggara	40	PT PLN (Persero)
4.	Songa Wayaua	North Maluku	42	PT PLN (Persero)
5.	Danau Ranau	South Sumatera	210	PT PLN (Persero)
6.	Oka Ile Ange	East Nusa Tenggara	50	PT PLN (Persero)

7.	Kepahiang	Bengkulu	254	PT PLN (Persero)
8.	Gn. Sirung	East Nusa Tenggara	152	PT PLN (Persero)
9.	Tangkuban Perahu	West Java	375	PT PLN (Persero)
10.	North Patuha (WKP Patuha)	West Java	55	PT Geo Dipa Energi
11.	Candradimuka (WKP Dieng)	Central Java	50	PT Geo Dipa Energi
12.	Candi Umbul Telomoyo	Central Java	92	PT Geo Dipa Energi
13.	Gn. Arjuno Welirang	East Java	302	PT Geo Dipa Energi
14.	Gn. Rajabasa	Lampung	283	PT Supreme Energy Rajabasa
15.	Rawa Dano	Banten	385	PT Sintesa Banten Geothermal
16.	Baturaden	Central Java	258	PT Sejahtera Alam Energy
17.	Telaga Ngebel	East Java	120	PT Bakrie Darmakarya Energi
18.	Seulawah Agam	Aceh	223	PT Geothermal Energi Seulawah
19.	Gn. Lawu	Central Java & East Java	332	PT Pertamina Geothermal Energy
20.	Kotamobagu	North Sulawesi	410	PT Pertamina Geothermal Energy
21.	Jaboi	Aceh	107	PT Sabang Geothermal Energy
22.	Gn. Talang – Bukit Kili	West Sumatera	90	PT Hitay Daya Energy
TOTAL			**4,011**	

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 and Table 1), the collaboration of these stakeholders should be focused primarily on efforts to complete the exploration phase in various prospect areas in Indonesia. Indonesia cannot achieve the national geothermal target without going through the exportation stage, which is the most crucial stage and has many challenges.

The level of difficulty and risk of Indonesia's geothermal exploration phase is mainly due to a combination of 2 (two) primary 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.

Some additional factors that intensify the geothermal exploration challenges (Utami, 2010; Chandra et al., 2021a; Umam et al., 2018; Adityatama et al., 2020; Poernomo, 2015; Purba, 2018; Purba et al., 2019) are as follows:

1. Geothermal prospect/exploration areas are usually in a volcanic setting with many geohazards, minimal road access, and hilly terrain.
2. There still needs to be a greater understanding of the local community living around the geothermal prospect area regarding geothermal projects. The low awareness often results in a higher level of community rejection of geothermal exploration projects.
3. Number of geothermal exploration experts in Indonesia from all disciplines (e.g., geoscience, drilling, environmental, social) is less than the number of exploration projects to be completed. When combining this situation with the absence of a certification program for geothermal exploration experts, many personnel with inadequate competence have the chance to run geothermal exploration projects in Indonesia.
4. In the exploration phase, there is usually not yet the certainty of the electricity prices, which creates difficulties for investors in deciding to spend the exploration budget.

Therefore, stakeholders in Indonesia need to be able to collaborate to solve the main challenges of geothermal exploration projects that have been discussed in various publications and forums to achieve the national geothermal target finally. Discussion of the challenges of geothermal exploration will be discussed in more detail in the next section.

1.2 Exploration Drilling Objective: The Only Method to Prove the Geothermal Resources in the Subsurface

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

The exploration activities can be divided into three main activity groups as follow:

1. *Surface surveys/studies* – This activity mainly includes collecting subsurface data from the surface. The assigned team performs the surveys on the surface; therefore, the cost is much cheaper than the cost of drilling a well. However, the team needs to interpret the obtained data since it does not come directly from the subsurface. The typical surface studies may include geological mapping, geochemical sampling, magnetotelluric, gravity, other geophysical data collection, LiDAR, topographic surveys, and hydrogeological surveys. It is common to conduct social mapping and environmental baseline preliminary studies 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 include laboratory analysis, data cleansing, interpretation, and integration. Integrating all relevant data will produce a final product called a conceptual model. It is a common practice in the industry to use the conceptual model to estimate the amount of commercial geothermal reserves in the prospective area. Based on the assessment, if the geothermal developer considers the geothermal resource attractive for further research, the project will proceed to more complex and expensive activities, drilling deep wells. Drilling deep wells into predicted reservoir depth can prove the existence of geothermal resources but require high capital expenses and involve higher risks.

3. *Deep well exploration drilling* – Drilling is commonly becoming the final activity in a geothermal exploration project because, with a deep well, the geothermal developer expects to prove the existence or the absence of a commercial geothermal system below the surface. Geothermal developers will only decide to perform deep well drilling if they already have various supporting information considering the high cost and difficulty of drilling.

As the only way to prove the existence of a commercial geothermal system underneath the ground, the geothermal developer must plan and execute an exploration drilling project carefully. Exploration well(s) will only be valuable if they can reach the planned depth target and acquire the targeted subsurface data. The subsurface data includes formation characteristics, rock properties, fluid characteristics, rock permeability, and reservoir temperature (Chandra et al., 2021a). It 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 completed, a flowing test may be performed, which can provide more comprehensive information about the characteristics of the explored geothermal prospect area. In the end, all data obtained from these exploration wells are significant for deciding whether this prospect area is feasible for further development. Table 2 shows a list of data expected to be available at the end of the exploration stage to conduct resource assessments and create a numerical model.

Table 2: Required data to conduct resource assessment and numerical model in the exploration phase (modified from Purba et al., 2020; 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 and Learning Curve

Theoretically, all personnel involved in a geothermal project should know that the exploration wells are crucial for the decision-making process toward the next stage. As explained earlier, the primary objective of exploration drilling in geothermal energy development is to locate, assess, and determine the size, temperature, and quality of geothermal resources in a specific area. However, not all personnel involved in a geothermal exploration drilling project may have the same understanding of the objectives of drilling exploration wells.

Therefore, the geothermal company might need to ensure their personnel has received sufficient information and training to deal with technical and non-technical challenges, such as regulation/legal, social, and environmental. Some of the challenges in geothermal exploration drilling in Indonesia can be summarized as follows (summarized from Purba et al, 2019; Chandra et al., 2021a; Utami, 2010; Chandra et al., 2021b; IGA, 2014; GeothermEx, 2010; Purwanto et al., 2018; Purba et al., 2020; Adityatama, 2020; Purba et al., 2021):

1. *Low accuracy of subsurface data* - at the exploration stage, the available subsurface data are generally still generated based upon surface studies' interpretations, so drilling planning will be carried out based on data with very low accuracy and low reliability. The drilling team may expect various surprises from formations at unexpected depths, such as massive lost zones, reactive formations, unconsolidated formations, shallow steam pockets, deeper top of reservoirs, and troublesome paleosol formations. Realizing that the geoscientific prognosis provided by the geoscience team may not match actual conditions, the drilling team must make a mitigation plan for these various scenarios or potential subsurface hazards. Failure to make a proper mitigation plan will significantly increase drilling costs and might stop the drilling team from completing the well as planned.

2. *Newly formed exploration team* – currently, in Indonesia, companies conducting geothermal exploration activities are generally newly formed with a combination of several sponsoring companies. A new company implies that the team combines several key personnel who might be their first time working together and are unfamiliar with each other's working methods and communication styles. Furthermore, due to the shortage of geothermal personnel, geothermal companies often recruit personnel from similar industries such as oil and gas or mining. Although similar, drilling challenges in the geothermal environment are

significantly different compared to the oil and gas and mining environments. The failure of geothermal companies to build a competent, experienced, professional, and coherent exploration team will cause the 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. The higher cost is because of the project scale. In terms of scale, the number of wells drilled in the exploration stage is usually less than those drilled in the development stage. The number of these wells affects the unit prices proposed by rigs and support services providers. The more wells drilled, the lower the unit price for all drilling services, equipment, and materials.

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 Indonesia's geothermal prospect areas are generally not adequately 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. If Indonesia has established this kind of database, geothermal developers in Indonesia can easily take advantage by learning from other geothermal projects and avoiding the same mistakes. Without this database, each geothermal developers can only learn from its respective projects, isolated from each other.

6. *Geohazards related to volcanic area* - Indonesia, located on the Pacific Ring of Fire, faces various geohazards that pose challenges to developing geothermal projects. These include earthquakes, volcanic eruptions, landslides, flood, phreatic eruption, and tsunamis, which can disrupt or damage power plants and infrastructure, leading to production losses and environmental impacts. Moreover, active, and potentially active volcanic systems add to the uncertainty of siting and drilling for geothermal resources. Therefore, proper assessment and management of geohazards are critical for the successful implementation and operation of geothermal projects in Indonesia and demand robust risk mitigation and response strategies to minimize their impacts.

7. *Being an archipelago country and poor infrastructures* - Indonesia faces several challenges in developing its geothermal resources as an archipelago country. The country's geography, with its numerous islands spread across vast distances, presents logistical difficulties in transporting equipment and personnel to remote locations. Additionally, the lack of infrastructure and limited access to resources such as water and power can impede the development of geothermal projects. Furthermore, diverse cultures and languages across the islands can also create challenges in gaining local community support for geothermal projects. To overcome these challenges, effective collaboration and communication with local communities and investment in infrastructure and resources are essential for the successful development of geothermal energy in Indonesia.

"Learning curve" might be suitable to describe all the challenges above. It means the team is still learning and gathering information in the exploration stage, which is the beginning of a geothermal development project. Along with the increase in information, data, experience, skills, and communication quality within the exploration team, the drilling success rate will generally increase, as Sanyal (2011) shows in Figure 2.

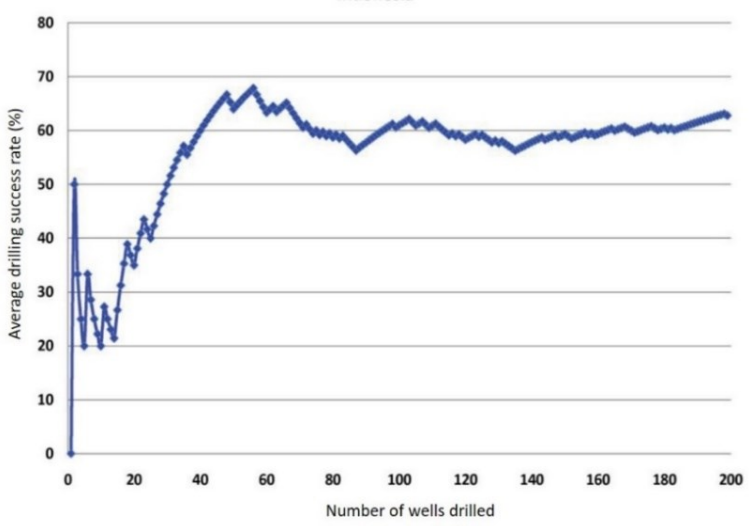

Figure 2: Average drilling success rate versus number of wells using data from Indonesia (Sanyal et al., 2011)

Geothermal developers or exploration teams need to address and mitigate the various exploration challenges outlined above to avoid an increase in the cost of exploration projects that leads to an increase in the overall cost of geothermal development projects. A significant increase in overall project costs can eventually cause the project to become uneconomical and may stop the project. The cost of geothermal exploration projects in Indonesia currently ranges from USD 15-50 million, with drilling costs as the most significant cost component (Direktorat Panas Bumi, 2022; GeothermEx, 2010; Purwanto et al., 2018; Purba et al., 2020; Siahaan et al., 2023). Based on the authors' observations, many geothermal companies in Indonesia have spent more than 50 million USD for geothermal exploration in a prospective area with inconclusive results.

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 impact the environment and residents around the project. Recent incidents in geothermal drilling projects in Indonesia (DPR RI, 2022a; DPR RI, 2022b; MCG, 2022; MCG, 2020; SOL, 2019) indicate the difficulty of geothermal drilling activities in Indonesia. Like other energy development projects, human and environmental safety must be the top priority for any geothermal drilling exploration project in Indonesia.

1.4 Managing Geothermal Exploration Drilling Project

Like any other project management, the quality of communication between stakeholders determines the success of an exploration drilling project. Communication has many forms, and the most common way is through meetings. Meetings are essential to project management as they provide a platform for stakeholders to communicate, coordinate and collaborate effectively. Meetings allow project managers to align project goals, track progress, resolve issues, and make essential decisions on time. Table 3 shows some critical meetings in a geothermal exploration drilling project.

Table 3: List of critical meetings in a geothermal exploration drilling project

No.	Meeting title	Meeting objective(s)	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 land acquisition teams. The approval in question is the location of the well and the drilling target. This meeting is critical in the early planning phase because the decision on the well location, drilling target, and well profile/trajectory will largely determine the drilling program, drilling cost, and project schedule. The impacted design includes: • the well design and materials (casings & wellhead), • the design of the drilling support infrastructure (access road, well pad, basecamp, water supply), • the type and capacity of the rig, • the list of drilling services & materials, • the area of land to be acquired. • the list of required permits, • the Social Engagement Plan • the Environmental Study (UKL-UPL, ESIA)	All team involved in the drilling exploration project: • Geoscience • Drilling • Well testing • Civil construction • Health & Safety • Social • Environmental • Land acquisition • Legal & Permit • Project control
2.	DWOP (drill-well-on-paper) workshop	DWOP is a specific meeting to have an efficient, trouble-free drilling operation. The facilitator will break down the drilling task or program 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. The goal of DWOP is to minimize risks and optimize the drilling process by anticipating and addressing potential problems before they occur.	Geoscience Manager, Exploration Project Manager, Drilling Manager, Drilling Engineer, Geoscientists, 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	The drilling team usually holds this meeting when the drilling program is final, and the drilling is ready to be carried out. Pre-spud meetings would explain the upcoming drilling program to the rig site and the office personnel involved and refresh them on the potential well hazards or difficulties. 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 team building (Ramsey, 2019).	Drilling engineer, Drilling Superintendent, Rig Superintendent, Toolpusher, Driller, Rig Crew, Drilling Service Companies (field hands / field reps), EBTKE / government reps (occasionally), Wellsite Geologist, HSE personnel.

		The meeting provides a comprehensive overview of the drilling plan, including the well design, rig mobilization, safety procedures, and contingency plans. The meeting also provides an opportunity to review and discuss the drilling schedule, equipment and materials requirements, and any regulatory requirements. The goal of the pre-spud meeting is to ensure that everyone is on the same page and that the drilling operation proceeds smoothly, efficiently, and safely.	

Meetings in Table 3 can occur several times as needed until the meeting leader achieves the meeting objectives, which are decisions regarding the next steps and actions to be taken by each related party. Meeting titles may also vary from company to company, but the general purpose of the meeting is as described.

In this study, from the various meetings described in Table 3, the authors note that Drill-Well-on-Paper (DWOP) may be one of the most important meetings with many benefits for exploration drilling projects but have yet to be conducted optimally in Indonesia. The authors based their assumption on observations of several DWOP sessions in Indonesia in which they participated.

DWOP is vital because the meeting bridges the planning and implementing/executing teams. Without the DWOP, communication between the planning and implementing teams generally only occurred through exchanging documents and e-mails.

1.5 Research Objectives and Methods

The background of this study can be summarized as follows:

1. To achieve the national geothermal target in 2030, Indonesia must focus on various exploration projects in various prospect areas spread across various islands in Indonesia. Exploration drilling activities with a high-risk level are becoming increasingly difficult in Indonesia due to various factors such as geohazards, rugged terrain, lack of local geothermal experts, absence of best practices database, local community rejection, and poor infrastructures.
2. DWOP (drill-well-on-paper) as a tool for identifying significant risks in geothermal exploration drilling projects and optimizing drilling programs to achieve the exploration project objectives by prioritizing human and environmental safety has yet to be carried out optimally in Indonesia.
3. DWOP is arguably the most critical meeting in the planning phase because it is the only meeting that involves almost all drilling personnel and other relevant stakeholders participating in the drilling project. The drilling team should conduct it in the project's early stages, providing plenty of time to make necessary improvements in the drilling program.

With this background, the authors started a preliminary study on the importance of DWOP and its current use in Indonesia by using the following research questions:

1. What are the benefits of DWOP for drilling projects?
2. How is DWOP generally done?
3. What are the pitfalls of conducting DWOP in Indonesia?
4. What actions can be taken to improve the quality of DWOP in Indonesia?

This study seeks answers to the above questions by conducting literature studies and interviewing several experts involved in various DWOP sessions during their careers in the drilling industry, both oil and gas and geothermal.

2. THE IMPORTANCE OF DRILL-WELL-ON-PAPER (DWOP)

After discussing the context of geothermal energy development in Indonesia, this study will discuss Drill-Well-on-Paper (DWOP) in more detail. DWOP refers to the process of creating a detailed plan and simulation of a drilling operation before physically drilling the well. The goal of DWOP is to minimize risks and optimize the drilling process by anticipating and addressing potential problems before they occur.

DWOP is arguably the most important meeting because it is the only meeting that involves almost all drilling personnel participating in the drilling project. Drilling personnel in the oil and gas industry have long used DWOP to anticipate and address potential problems before they occur during drilling operations. Moreover, in the recent years, based on the authors' observations, drilling teams in various geothermal projects in Indonesia also use DWOP as a risk assessment tool before well spud-in.

Interestingly, based on a literature search, the authors found only 3 (three) publications that discussed DWOP in detail (Ramsey, 2019; Nwokoma & Knobben, 2017; Lavis, 2018), but all were in the context of oil and gas drilling projects (Table 4). The authors could not find any previous publications regarding the implementation of DWOP in geothermal drilling when this paper was written. This finding is combined with the authors' observations of several DWOP sessions on geothermal projects in Indonesia which makes the authors suspect that DWOP has not been carried out optimally in various geothermal projects in Indonesia. It would be terrible if DWOP were done only to tick the box and not to achieve the drilling objectives.

Table 4: Summary of literature search related to DWOP topic.

No.	Title	Publication type	Summary	Author(s)	Year
1.	DWOPs, CWOPs, WOWOPs, and AWOPs for Fun and Profit!	Conference proceeding of 2019 AADE National Technical Conference and Exhibition in Colorado.	This paper discusses the importance of drill-well-on-paper (DWOP), complete-well-on-paper (CWOP), wait-on-weather-on-paper (WOWOP), and abort-well-on-paper (AWOP) exercises in the oil and gas industry. He notes that these exercises are essential for identifying and addressing potential problems before drilling begins. The author also highlights the importance of including all stakeholders in these exercises to ensure that everyone knows the risks and challenges that may arise during the drilling operation. This paper mentioned various considerations in implementing DWOP to achieve its main goal: efficient, trouble-free operation. The discussion includes the person who must attend, the event's structure, the distribution of group discussions, capturing of relevant input, and the actions that must be taken after the DWOP is over. Additionally, this paper also raises the importance of implementing DWOP in a fun way for participants. Finally, this paper argues that DWOPs, CWOPs, WOWOPs, and AWOPs are valuable for mitigating risk and can lead to improved operational efficiency and reduced costs. The author concludes that these exercises should be a standard part of any drilling operation to ensure success and profitability.	Mark S. Ramsey	2019
2.	Rethinking the Typical Line-Item DWOP Exercise: Does it Present a Complete Picture?	Conference proceeding of 2017 SPE/IADC Drilling Conference and Exhibition in The Hague.	The authors of this paper argue that the traditional line-item drill-well-on-paper (DWOP) exercise may need to provide a complete picture of the drilling plan. They suggest a more holistic approach, including a focus on risk management, is needed to identify potential problems better and mitigate risks during the drilling operation. The authors recommend expanding the DWOP session to include discussions on well construction design, integrity, and control. The authors also propose using a Risk Register tool to document and track potential risks and ensure that all stakeholders are aware of the risks and have the plan to manage them. By taking a more comprehensive approach to the DWOP session, the authors suggest that oil and gas companies can better prepare for drilling operations and reduce the likelihood of costly downtime, equipment failure, and other problems.	Precious Nwokoma and Xander Knobben	2017
3.	Drill Well on Paper (DWOP) – The Gift of Foresight	An article published in Drillers.com	This article argues that the "Drill Well on Paper" (DWOP) is a process that takes place before rigs and crews start drilling to create a comprehensive set of policies and procedures representing a roadmap for the perfect well. The process aims to reduce costs and drilling time while maintaining safety. The "Technical Limit" methodology is used as a backdrop for every DWOP workshop born out of the LEAN manufacturing revolution. Additionally, this paper mentioned that to push the boundaries of efficiency even further, oil companies are now bringing in independent facilitators to conduct DWOPs. These specialists bring fresh eyes and ideas and are only focused on creating additional value. Planning is needed for any commercial or infrastructure project, and for an oil and gas project, additional unique circumstances need to be taken into account.	Jason Lavis	2018

This study investigates the importance of DWOP for a drilling project through literature and interviews with 7 (seven) experienced personnel in drilling projects. Of the seven personnel interviewed, two only had DWOP experience in oil and gas, four had experiences participating in DWOP in geothermal, and only one had experience in DWOP in oil and gas and geothermal. The authors set the criteria for personnel participating in the interviews to have at least ten years of experience in the energy industry and have attended DWOP sessions at least two times during their careers. Interviews were conducted separately for each participant using the same list of questions.

In general, the results of the literature study and interviews show similarities regarding the purpose and importance of the DWOP, as summarized in Table 5.

Table 5: Summary of the importance of DWOP according to various sources.

No.	References	Why DWOP is important?
1.	Ramsey (2019).	By conducting a DWOP, drilling teams can optimize their resources, reduce downtime, and minimize the risk of accidents or delays. The author argues that DWOP is essential for effective well planning. It allows drilling teams to identify and mitigate potential issues before they arise, leading to safer, more efficient, and more cost-effective drilling operations.
2.	Nwokoma & Knobben (2017).	The authors suggest that if oil and gas companies take a more comprehensive approach to the DWOP session, it will help better prepare for drilling operations and reduce the likelihood of costly downtime, equipment failure, and other problems. They mentioned that DWOP is an accepted tool for: 1. Planning an offshore well / pre-well planning; 2. Post-drilling analysis to demonstrate tangible and potential efficiency gain.
3.	Lavis (2018).	DWOP is essential in the oil and gas industry because it allows stakeholders to come together to analyze each step of the well construction. They can brainstorm and anticipate future well drilling and completion and develop ideas to improve cost reduction, efficiency, and reduced well times while maintaining the highest levels of safety.
4.	Interview result to 7 (seven) drilling personnel in 2022.	All participants agree that DWOP, in general, aims to maximize the readiness of all teams involved and minimize surprises during drilling operations. In the interviews, this study found at least 7 (seven) reasons raised by participants on the importance of DWOP: 1. Allow engagement between personnel. DWOP allows personnel from various companies to get together and get to know each other. All respondents mentioned this reason. 2. Increase awareness of the latest agreed drilling plan. DWOP provide time to properly socialize the drilling plan to all stakeholders and personnel involved in the drilling operation. All respondents mentioned this reason. 3. DWOP provide the opportunity to collect feedback on the drilling program from relevant personnel. It provides forums for all personnel to go through the drilling program and provide feedback properly. The feedback could be on the safety aspects, drilling program effectiveness, the do-ability of the mitigation plan, and any risk that still needs to be mitigated on the program. All respondents mentioned this reason. 4. DWOP can facilitate an agreement between key stakeholders on the drilling operation target, such as well objectives, critical downhole data acquisition, the target depth and estimated drilling days. It allows all personnel to provide feedback if the target presented is feasible; if not, a more feasible target can be proposed and agreed upon. There were 5 out of 7 participants mentioned this reason. 5. It can be used to conduct the logistic check. DWOP provide sufficient time for all personnel to go through their logistics lists, such as material, equipment, tools, personnel, and schedule. DWOP can help to ensure the logistic readiness for the scheduled drilling operation. There were 4 out of 7 participants mentioned this reason. 6. 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. 7. An accident has implications that can spread for hundreds of miles and last for years. Furthermore, mistakes on a single project can result in companies get bad credit ratings or going bankrupt.

3. IMPLEMENTING DWOP: WHO, WHEN, WHERE, AND HOW?

3.1 Who Should Participate and Facilitate?

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.

Ramsey (2019) stated that the initial phase in promoting team building is to ensure the attendance of all crucial individuals in the workshop or meeting. The key personnel may include people from the oil and gas or geothermal developer company, rig/drilling contractor staff, and relevant drilling service companies. Although various companies/operators may have varying attendance criteria, the minimum requirement should be met, as listed below:

1. All operator/developer office personnel involved in the planned operations;
2. All operator/developer 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 (if any);
8. Other support service personnel;

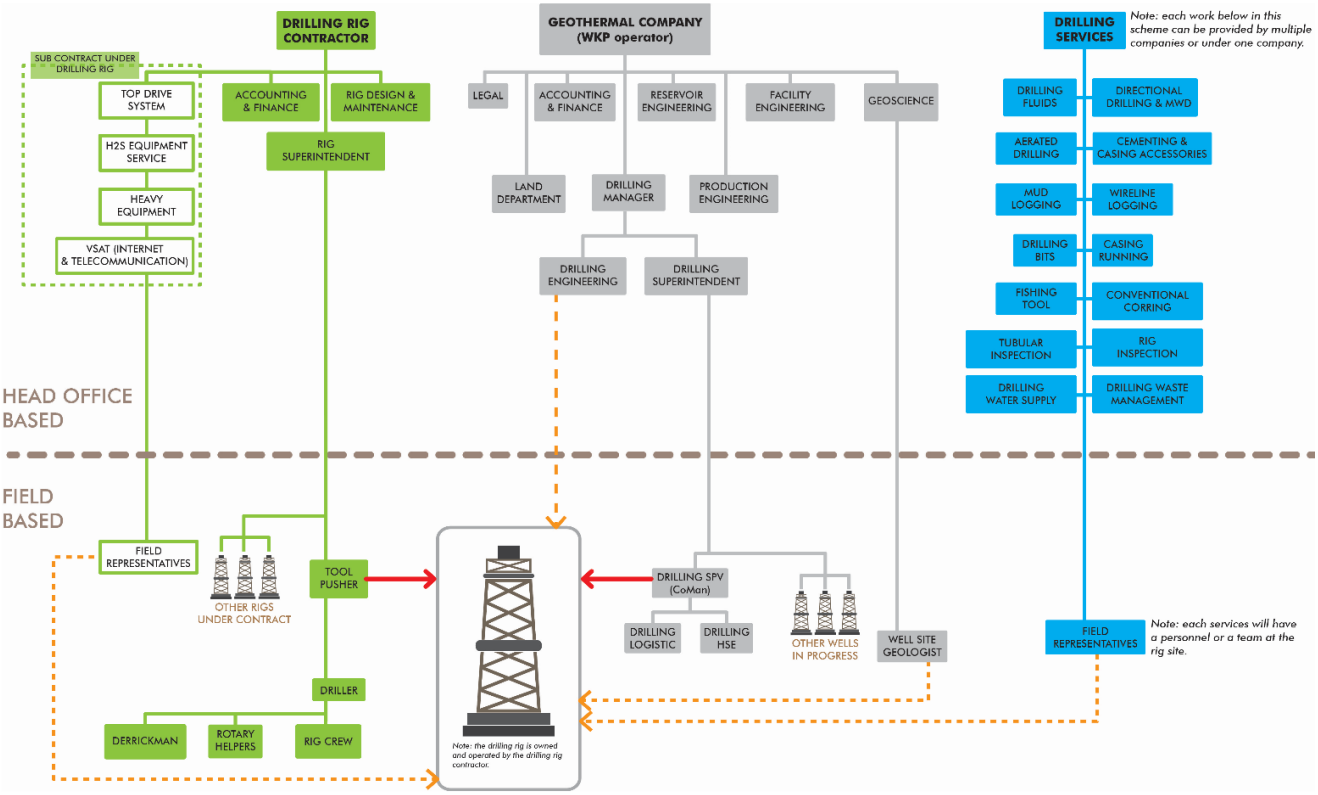

Figure 3: Typical drilling organizations in a geothermal drilling project in Indonesia (Purba et al., 2020).

With the large number of personnel involved in DWOP and coming from different corporate cultures, the role of the facilitator will be very crucial. Summarizing Ramsey (2019), Lavis (2018) and the results of interviews conducted in this study, the minimum requirements that a DWOP facilitator must meet are:

1. Have worked inside the drilling teams of the majors and have at least 15-20 years of experience in high-level engineering positions before working as DWOP facilitators.
2. Able to show a strong understanding of drilling operations and relevant industry knowledge.
3. Have experience managing complex meetings and handling conflicts constructively while maintaining a neutral position.
4. Understand and have experience in the risk assessment and mitigation process.
5. Able to organize a team of facilitators if more than one facilitator is required.

Another question Ramsey (2019), Lavis (2018), and the authors discussed is where DWOP facilitators should come from, since they may be assigned from within or outside the company. Table 6 compares the pros and cons of internal and external facilitators.

Table 6: Comparison between Internal and External Facilitators (summarized from Ramsey, 2019; Lavis, 2018 and interview results).

DWOP facilitator	Pros	Cons
Internal	1. Familiarity with the company culture, values, and goals. 2. Access to internal resources and personnel. 3. Potentially lower cost. 4. Might have more schedule flexibility.	1. They may lack objectivity and neutrality. 2. Potential conflict of interest. 3. May not have sufficient training or expertise in facilitation. 4. The internal facilitator might not want to spend the extra time and effort to organize the meetings since they already have the "routine day-to-day" workload.

External	1. They bring an outside perspective and fresh ideas. 2. Expertise in facilitation and workshop design. 3. Objective and neutral.	1. Lack of familiarity with company culture and goals. 2. They may require more time and cost for travel and preparation. 3. May not have access to internal resources and personnel. 4. They might not be flexible in terms of schedule.

In practice, DWOP can be attended by between 50-100 people, including the facilitator team, where the number of personnel will depend on the objectives of the DWOP itself. Regardless of the number of personnel involved, all respondents for this study mentioned the importance of each present understanding their role before attending the DWOP event to increase the likelihood of the event's success.

3.2 When should the DWOP be implemented?

The subsequent discussion is about when DWOP should be implemented. Ramsey (2019) suggests that DWOP should be conducted early in the well planning process before any money is spent on actual drilling operations. By conducting DWOP early, the drilling team can identify potential problems and adjust the drilling plan before drilling begins, which can help reduce costs and improve efficiency.

However, how early should the DWOP be carried out in the planning phase? Participant of interviews in this study suggested the same thing when asked at which stage the DWOP was carried out. The authors divide the planning phase into five milestones to facilitate the selection of optimal DWOP implementation points (Figure 4).

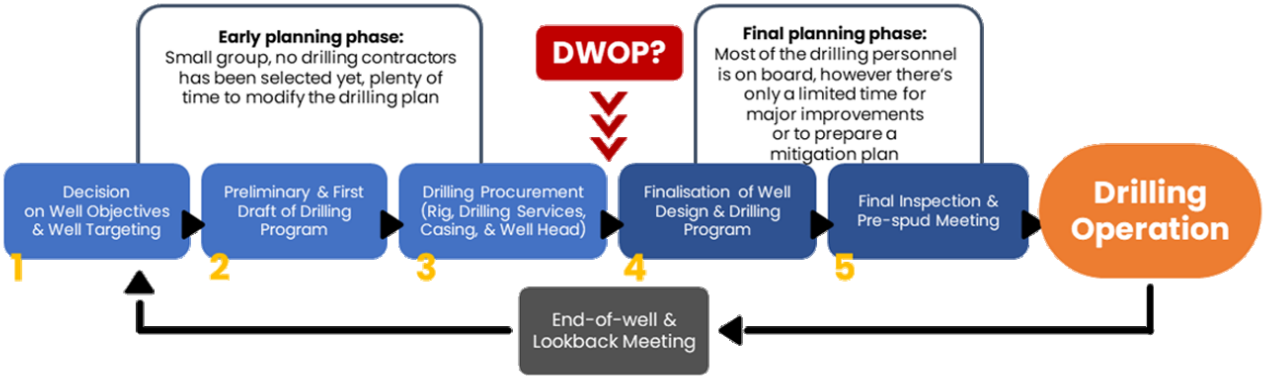

Figure 4: The timing of conducting DWOP based on drilling project milestones.

All respondents agreed that DWOP should be conducted after selecting most of the personnel involved in the operation, between box number 3 and box number 4 in Figure 4. This suggestion means that the DWOP is carried out when the procurement process for selecting rig contractor, drilling services, and other supporting services has been completed. However, the respondents also suggested that the DWOP implementation timing must still allow enough time to prepare the mitigation plan, meaning a bit further away from the spud-in date, as shown in Figure 4.

3.3 Where Should DWOP be Conducted?

There are various options for locations or venues to conduct a DWOP session. The choice of location or venue will depend on the specific needs and goals of the DWOP session, as well as factors such as team size, geographic location, and availability of technology and equipment. The authors summarize the answers from respondents regarding the best location options for holding a DWOP in Table 7.

Table 7: Pros and cons of various DWOP venues

No.	Venue option	Pros	Cons
1.	Onsite at the drilling location or rig site	1. It allows the team to have direct access to the drilling data and equipment. 2. The participants (site personnel) are in a familiar environment and can easily access relevant resources. 3. It might cost lower than rent meeting rooms in a hotel or conference building.	1. May not provide a change of scenery or a break from day-to-day operations. 2. Can be subject to distractions or interruptions.
2.	At company office or company HQ	1. The participants (office personnel) are in a familiar environment, can easily access relevant resources, and can continue working after the session is over. 2. It might cost lower than rent meeting rooms in a hotel or conference building. 3. Flexibility in setting up the room.	1. May not provide a change of scenery or a break from day-to-day operations. 2. Can be subject to distractions or interruptions.

3.	Conference center or hotel	1. Can provide a change of scenery, eliminate distractions, and allow for a more focused environment. 2. Participants mood and willingness to come to DWOP might be increase due to "out-of-office" environment.	1. Can be more expensive, may require travel or additional accommodations. 2. If the venue or hotel is not that good, it may not be as convenient for participants.
4.	Virtual/online	1. Can be more convenient for participants who are geographically dispersed. 2. Can save time and travel costs. 3. Can allow for remote participation.	1. May not provide the same level of engagement or collaboration. 2. Can be subject to technical issues or connectivity problems. 3. May not allow for the same level of interaction as an in-person session.
5.	Hybrid	1. Can facilitate all personnel who are in the office or on site or who are on service out of town. 2. Combines onsite and virtual participation, allowing for the benefits of both options.	1. Can be subject to technical issues or connectivity problems. 2. Highest cost compared to all other options.

3.4 How Should DWOP be Conducted?

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

Table 8: Series of DWOP common activities from Pre to Post.

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.

As one can imagine, the meetings tend to be fairly large, with a typical one having 50-100 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.

Therefore, ensuring that all relevant stakeholders are involved and engaged throughout the process is crucial. The stakeholders may include representatives from different departments, external contractors, and subject matter experts. Additionally, it is crucial to establish clear objectives and expectations for the DWOP, including the scope of the meeting, the desired outcomes, and any specific challenges or issues that need to be addressed.

Another critical consideration is communication, ensuring that all participants know the agenda, timelines, and relevant background information. Finally, it is essential to follow up after the DWOP to ensure that any actions or recommendations resulting from the meeting are implemented effectively and on time. Considering these considerations, it is possible to run a successful and productive DWOP that leads to improved operational performance and efficiency.

Figure 5 shows 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. Photos in Figure 5 are an example of actual implementation of DWOP workshop on a geothermal exploration drilling project in Indonesia.

Figure 5: Photos showing situation of a DWOP workshop for a geothermal exploration drilling project in Indonesia (Author's personal photo collection)

3.4.1 Agenda

Based on internet publications and interview results, there is no standard or provision regarding how to conduct a DWOP. This finding means each company can create its DWOP rundown according to project needs. However, one of the respondents mentioned that in some geothermal drilling projects, DWOP is required by the lenders as part of the loan agreement. Therefore, it might need to comply with the lender's guidance on how to conduct the DWOP. A summary of the agenda that is generally included in the DWOP agenda can be seen in Table 9.

Table 9: Main agenda in typical DWOP session based on respondent's answers.

No.	Agenda / List of Activities	Objectives
1.	Opening session & Icebreaking	To create a positive and productive atmosphere by helping participants to get to know each other, feel comfortable, and become more engaged in the meeting: a. 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. b. 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.
2.	Presentation on the latest Drilling Program (well objectives, well design, drilling procedure, drilling hazards, risk mapping, logistic plan, drilling schedule)	To 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: a. 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. b. Never assumes that everyone have the same understanding. Always check and verify.
3.	Drilling risk assessment (risk register/populate, risk rating, develop mitigation options, group presentation)	To 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. a. Populate all drilling risks and make a priority list of the main risks that must be mitigated accordingly. b. To provide an opportunity to all stakeholders to raise any red flags or any showstopper before decide progressing with the drilling operation.
4.	Drilling program update & closing session	To update the drilling program so that drilling activities can run "trouble-free" and "incident-free": a. The planned wells can be realized according to the planned cost and duration. b. Review and update the RACI (responsible, accountable, consulted and informed) matrix as a tool to identify the drilling project teams' roles and responsibilities for any task, milestone, or project deliverable. c. Ensure everybody understand each responsibility in follow up action items agreed in the DWOP.

3.4.2 Seating Arrangement

In a DWOP session, various seating arrangements can be used depending on the specific needs of the team and the project. Some common options for seating arrangements in a DWOP session include the following (Table 10):

Table 10: Various options of seating arrangement in a typical DWOP session.

No.	Seating arrangement	Description	When to use this arrangement?
1.	Theater-style or Classroom-style	In this arrangement, chairs are arranged in rows facing a screen or a whiteboard where the facilitator can present information or lead activities. This seating arrangement is useful for presentations or activities that require a more structured format.	1. At the opening session, in the very beginning. 2. During main presentation session 3. At the closing session (if intended to be a formal closing ceremony)
2.	U-shaped style	This arrangement involves arranging chairs in the shape of the letter "U" with the facilitator at the open end of the U and the team members sitting along the arms of the U.	1. During icebreaking session 2. During informal presentation 3. During group presentation 4. During closing session (informal style)
3.	Circular style	In this arrangement, chairs are arranged in a circle with the facilitator sitting amongst the team members. This seating arrangement can help to promote a sense of equality and collaboration among team members.	1. During icebreaking session 2. During informal presentation 3. During small group presentation 4. During closing session (informal style)
4.	Open seating	In this arrangement, team members are free to sit wherever they choose, and the facilitator can move around the room to interact with team members as needed. This seating arrangement can be useful for promoting a sense of informality and spontaneity.	1. During small group discussion 2. During group presentation 3. During icebreaking session 4. During risk assessment session

Ultimately, the seating arrangement chosen for a DWOP session should be based on the session's specific goals and the team's needs. Respondents of this study stated that the selection of seating arrangements for each DWOP session would determine DWOP participants' participation level and help make it easier for the facilitator team to move during the event.

4. THE COMMON PITFALLS IN DWOP

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 considered when conducting a DWOP workshop are (Table 11):

Table 11: List of common pitfalls summarized from respondent's answers.

Session	Common pitfalls
Pre-DWOP	1. Inadequate preparation: A DWOP session requires detailed preparation and organization to ensure that all aspects of the drilling plan are thoroughly discussed and evaluated. If the preparation is not adequate, the session may lack focus, be unproductive and fail to identify important issues. 2. Incomplete information: A DWOP session is only as effective as the information that is available to review. If critical information is missing or incorrect, the session may not be able to identify important issues or make informed decisions.
During DWOP	1. Lack of participation: It is important for all relevant stakeholders to actively participate in a DWOP session in order to achieve its intended objectives. If key stakeholders are not present or do not fully engage in the session, important information may be overlooked or misunderstood, leading to potential problems during the drilling operation. 2. Insufficient time: DWOP sessions can be time-consuming, and it is important to allocate enough time to allow for a thorough review of all aspects of the drilling plan. If the session is rushed or cut short, important information may be overlooked and critical issues may not be addressed. 3. Lack of objective review: A DWOP session should be an objective review of the drilling plan, and all stakeholders should be encouraged to raise questions and offer constructive criticism. 4. If the session is dominated by one or a few individuals, or if there is a lack of objectivity, the session may not achieve its intended purpose. A few 'strong personalities' tend to dominate all proceedings. 5. Meetings can become routine, boring and then unlikely to be energizing and productive. Key team members start to miss meetings.
Post DWOP	1. 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. No follow up or weak monitoring on action item plan after DWOP. 3. No written report or documentation of the DWOP.

5. ROOM FOR IMPROVEMENT

Based on the interview results, the authors found that there are several options to improve DWOP (Drilling Well On Paper) implementation, including (Table 12):

Table 12: List of suggestions from respondents regarding actions that can be taken to improve the quality of DWOP implementation in Indonesia.

Improvement areas	Related to the participants and facilitators	Related to the drilling program, risk assessment and risk mitigation	Related to the schedule, location, and duration of the events
Pre-DWOP	1. Ensure to inform and invite all companies involved in the drilling operation and stakeholders of the project. 2. Selective in selecting the DWOP facilitator and group leader(s). 3. Provide DWOP guideline in writing or video to prepare all participants before joining the event. 4. Make sure each company sending personnel with proper experiences, competences relevant to the project.	1. Distribute sufficient pre-reading material to all invited personnel with enough time to study the drilling plan. 2. Make sure that the drilling program distributed is the latest update.	1. Provide enough time for participants to get permission from the office and arrange the transportation and accommodation. 2. Choose location that is easy-to-access but still provide proper atmosphere for long meeting.
During DWOP	1. Ensuring all participants are healthy and focused on participating in the event from start to finish. 2. If necessary, each participant must sign a statement of commitment to participate in the event from start to finish. 3. Close communication with the Facilitator and Group Leader 4. Grouping of personnel need to be designed properly, not random	1. Provide the link to online storage of the most updated drilling program so participants can quickly check for the latest version. 2. Provide the most updated organization chart and RACI, so DWOP participants know where to address risk.	1. Set longer duration/more flexibility on the duration. Finish when all topics has properly discussed and agreed. 2. Proper interval/break between session to maintain participant's attention. 3. Ensuring the food menu, air circulation, and room temperature support for long meeting events.
Post DWOP	Ensure all company reps really conveying the DWOP results to all relevant personnel in their company (office and site).	1. Provide the link to online storage of the most updated drilling program so participants can quickly check for the latest version. 2. Provide the most updated organization chart and RACI, so DWOP participants know where to address risk.	Ensure to follow up the action items until all findings are closed.

6. 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 geothermal exploration drilling projects in Indonesia.

The authors begin this paper with a discussion of the current status regarding geothermal energy development in Indonesia to provide context and background on why DWOP is an important factor to pay attention to. To achieve the national geothermal target in 2030, Indonesia must focus on various exploration projects, where the exploration stages are known to have risks and a high degree of difficulty. The high level of risk and difficulty lies mainly in exploratory drilling activities. The combination of high uncertainty and drilling costs means geothermal developers must carefully plan their exploration drilling plans.

In addition, this paper also discusses various specific exploration challenges related to Indonesia. These challenges are unique because Indonesia is an archipelago country located in the ring of fire and still in progress of building supporting infrastructures on various "potential geothermal islands". The discussion regarding this challenge's uniqueness is important because DWOP was initially more widely used in offshore oil and gas drilling projects. After all, offshore drilling costs are typically relatively high, so it requires continuous improvement to obtain cost-efficiency and trouble-free operation. The authors hope that the presentation of Indonesia's current geothermal situation and the accompanying challenges at the beginning of this paper provides an introduction to the role of DWOP in the success of exploration drilling projects in Indonesia.

Furthermore, several accidents in geothermal drilling projects in Indonesia in recent years, such as blowouts, stuck pipes, and H_2S release, prove that geothermal drilling projects are complex and difficult. Planning a project that is complex and has a direct impact on human safety and the environment requires personnel with relevant competencies and good communication between stakeholders. DWOP is one of the meetings that has become a common practice among drilling teams in Indonesia. However, the authors note that even though DWOP is already common in the oil and gas drilling community, it is rare in the geothermal industry. Hence, its implementation still seems "tick-the-box" or has not been optimal.

Based on this assumption, the authors conducted a preliminary study on DWOP implementation in Indonesia by compiling several research questions. The search for answers was carried out through literature searches and interviews with 7 (seven) people who have experience as energy professionals for more than ten years and have attended DWOP sessions at least two times during their careers. The authors then summarize and compare the answers obtained from various internet publications and the respondents' answers.

The first question is related to the importance of DWOP in a drilling project. The results of literature searches and interviews show similarities. DWOP is very important in the planning phase because, if done correctly, it can optimize the drilling operation to achieve drilling goals while keeping people and the environment safe. Conversely, failure to utilize DWOP can result in high downtime or non-productive time (NPT), increase the possibility of work accidents and environmental harm, and failure to achieve the agreed drilling objectives. With the clarity regarding how vital the role of DWOP is in a drilling project, the authors are confident to continue to the next question.

The next question is about standard practice in implementing DWOP in Indonesia. The literature search results have yet to succeed in finding papers or articles that discuss DWOP implementation in Indonesia. Therefore, the authors attempt to summarize DWOP implementation practices found online to confirm with the respondents. Respondents' answers indicate that DWOP practices found on the internet are generally similar to those practiced in Indonesia. The authors then summarize the practice in tables and figures, categorized into "Who, When, Where, and How."

In short, the authors found no standard or rule for conducting a DWOP session. Any company can design a DWOP event according to the project's needs. Nevertheless, the authors have summarized each choice through a pros and cons comparison for convenience. Through these comparison tables, the authors hope readers understand the various factors to consider when designing a DWOP event.

Still related to the second question, one of the critical factors in the DWOP is the implementation timing. The authors found through interviews that DWOP is the most critical meeting in the planning phase because it is the only meeting that involves almost all drilling personnel and other relevant stakeholders participating in the drilling project. The drilling team should conduct it in the project's early stages, providing plenty of time to make necessary improvements in the drilling program but not too early when people still need to be fully onboard. The timing is essential because the DWOP will be practical and useful if all personnel involved in the drilling operation are onboard and participate in the DWOP.

The third question is to map various pitfalls when implementing DWOP. This question helps answer the fourth question, namely, how to improve the quality of DWOP to achieve the objectives of the drilling project. Through interviews and published information, the authors mapped out approximately ten common pitfalls in implementing DWOP. Understanding these pitfalls is important because implementing a DWOP will be costly and time-consuming. Modest implementation, only for the tick-the-box sake, will harm the entire drilling project.

The final question is to find the best way to improve the quality of DWOP implementation in Indonesia. With the high stakes on various exploration drilling projects, the Indonesian geothermal drilling community must continuously strive to improve the quality of communication between stakeholders, with DWOP as one of its media. The authors have summarized various points raised by respondents regarding ways to improve DWOP quality.

In closing, the authors view this paper as a preliminary study to promote DWOP implementation in the Indonesian geothermal industry. Interestingly, this paper is the first to discuss DWOP for implementation in the geothermal industry. All publications related to DWOP found when this study was conducted were in the context of oil and gas drilling projects.

As a way forward for this study, the authors plan to develop interviews with broader respondents specific to geothermal drilling projects in Indonesia. Various findings from this initial study will be used as a basis for questions in subsequent studies more sharply targeted at geothermal exploration drilling projects in Indonesia.

Authors realize that DWOP is not a silver bullet that will magically make exploration drilling projects in Indonesia run smoothly, trouble-free, and cost-effective. DWOP is the only tool trusted in the oil and gas world to optimize the planning and implementation of drilling projects. If DWOP is proven to be helpful in oil and gas industry, the geothermal drilling community must exploit its usefulness.

REFERENCES

Adityatama, D.W., Purba, D., Muhammad, F., Agustino, V., Wiharlan, H., and Pasmeputra, K. K. (2020). *Slimhole Drilling Overview for Geothermal Exploration in Indonesia: Potential and Challenges, Proceedings*, 45th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, United States.

Asokawaty, R. F., Purba, D. P., Adityatama, D. W., Muhammad, F., & Umam, M. (2020). *Indonesia's Geothermal Development Comp are to World Top Geothermal Producers*. 45th Workshop on Geothermal Reservoir Engineering.

Chandra, V. R., Asokawati, R. F., Purba, D. P. (2021a). *Common Practice of Formation Evaluation Program in Geothermal Drilling. PROCEEDINGS,* 46th Workshop on Geothermal Reservoir Engineering. Stanford University, Stanford, California, February 15-17, 2021.

Chandra, V. R., Purba, D., Nayoan, G. P. A., Fadhillah, F. R., Ramadhan, R. F., Anggara, R. (2021b). *Identifying and Assessing Geohazard in Indonesia Geothermal Area: How Difficult Is It? PROCEEDINGS,* 46th Workshop on Geothermal Reservoir Engineering. Stanford University, Stanford, California, February 15-17, 2021.

Darma, S. (2016). Indonesia: Vast geothermal potential, modest but growing exploitation. In *Geothermal Power Generation: Developments and Innovation* (pp. 609–643). Elsevier Inc. https://doi.org/10.1016/B978-0-08-100337-4.00021-8

Direktorat Panas Bumi. (2022). *Buku Pintar Umum Panas Bumi*.

DPR RI. (2022a). Live Streaming – Komisi VII DPR RI RDP dengan Kementerian ESDM RI *Terkait Penjelasan Kejadian Kebocoran Sumur Gas PT Sorik Merapi Geothermal Power pada Bulan April 2022*, retrieved from: https://www.youtube.com/watch?v=CWmqBQWGnJw&t=7826s.

DPR RI. (2022b). Live Streaming – Komisi VII RDP dengan Dirjen EBTKE KESDM RI *Terkait Penjelasan kejadian kebocoran gas dan keracunan gas beracun (H2S, S02) yang dialami masyarakat sekitar lokasi PT Sorik Marapi Geothermal Power dan PT Geo Dipa Energi (Persero)*, retrieved from: https://www.youtube.com/watch?v=VDTK9xYbkwI&t=655s.

GeothermEx (2010). *An assessment of geothermal resource risks in Indonesia*.

Ibrahim, R. F., & Fauzi, A, Suryadarma. (2005). *The progress of geothermal energy resources activities in Indonesia*. Paper presented at the *Proceeding* World Geothermal Congress 2005, 1-7.

IGA. (2014). *Best practices guide for geothermal exploration*. Bochum, Germany: International Geothermal Association.

Lavis, J. (2018). *Drill Well On Paper (DWOP) – The Gift of Foresight.* Article published in Drillers.com, 21 August 2018. Retrieved from: https://drillers.com/drill-well-on-paper-dwop-the-gift-of-foresight/#:~:text=Drilling%20the%20well%20on%20paper,and%20potential%20contingency%20action%20points.

McAndrews, K., L. (2011). *Consequences of Macondo: A Summary of Recently Proposed and Enacted Changes to U.S. Offshore Drilling Safety and Environmental Regulation. Proceedings*. SPE Americas E&P Health, Safety, Security and Environmental Conference held in Houston, Texas, USA, 21–23 March 2011.

MCG. (2022). *Studi Kelayakan Proyek Pembangkit Listrik Panas Bumi (PLTP) WKP Blawan Ijen Unit 1 – 35 MW (gross) Kabupaten Bondowoso - Jawa Timur*, PT Medco Cahaya Geothermal, (unpublished report).

MCG. (2020). *IJN 6-1 / IJN 6-1 ST 1 End of Well Report*, PT Medco Cahaya Geothermal, (unpublished report).

Nugraha, R. P., O'Sullivan, J., and O'Sullivan, M. J. (2018). *A 3D Geological Model and Natural State Simulation of Jaboi Geothermal Field, Nangro Aceh Darussalam, Indonesia*, *Proceedings*, New Zealand Geothermal Workshop, Taupo, New Zealand.

Nwokoma, P. & Knobben, X. (2017). *Rethinking the Typical Line-Item DWOP Exercise: Does it Present a Complete Picture?. Proceedings.* 2017 SPE/IADC Drilling Conference and Exhibition in The Hague.

O'Sullivan, J., Archer, R., O'Sullivan, M., Krom, T., & Williams, B. (2017). *A NEW GEOTHERMAL MODELLING WORKFLOW USING LEAPFROG AND TOUGH2*. 6th ITB International Geothermal Workshop. Bandung. (2017)

O'Sullivan, M. J., & O'Sullivan, J. P. (2016). *Reservoir Modeling and Simulation for Geothermal Resource Characterization and Evaluation*. In R. D. (Ed), Geothermal power generation: developments and innovation. Woodhead Publishing.

Purba, D.P., Adityatama, D.W., Nugraha, R. P., Ayuningtyas, R. R., Chandra, V. R., Al-Hassan, M. A., Ramadhan, R. F., Rizqy, M. M. (2021). *Resource Assessment Methods Selection for Geothermal Exploration Project in Indonesia: What Are the Considerations? Proceedings*, 46th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, United States.

Purba, D.P., Adityatama, D.W., Agustino, V., Fininda, F., Alamsyah, D., and Muhammad, F. (2020). *Geothermal Drilling Cost Optimization in Indonesia: A Discussion of Various Factors, Proceedings*, 45th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, United States.

Purba, D.P., Adityatama, D.W., Umam, M.F., and Muhammad, F. (2019). *Key Considerations in Developing Strategy for Geothermal Exploration Drilling Project in Indonesia, Proceedings*, 44th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, United States.

Purba, D.P (2018).: Energy 785 Research Project Report: *Investigation on Geothermal Resource Assessment Methods in Reducing Exploration Risk in Indonesia Geothermal System*. The University of Auckland, New Zealand. Unpublished manuscript.

Purwanto, E. H., Suwarno, E., Lukman, R. F., and Herdiyanto, B. (2018). *Geothermal Drilling in Indonesia: A Review of Drilling Operation, Evaluation of Well Cost and Well Capacity, Proceedings*, 6th Indonesia International Geothermal Convention & Exhibition, Jakarta, Indonesia.

Pusdatin ESDM. (2020): Ministry of Energy and Mineral Resources Media Center.

Poernomo, A. S. (2015). *An overview of Indonesia Geothermal Development – Current Status and Its Challenges*. Pp. 1 – 11. In: Proceedings of World Geothermal Congress, Melbourne, Australia.

Ramsey, M. S. (2019). *DWOPs, CWOPs, WOWOPs, and AWOPs for Fun and Profit!*, *Proceedings*, AADE National Technical Conference and Exhibition held at the Hilton Denver City Center, Denver, Colorado.

Ratouis, T. M., O'Sullivan, M., and O'Sullivan, J. (2015). *An Updated Numerical Model of Rotorua Geothermal Field, Proceedings*, World Geothermal Congress, Melbourne, Australia.

Relentless Pursuit of Perfection Ltd. (2023). *Our approach to DWOPs and i-DWOPs*. RP^2, retrieved from: https://rp-squared.com/services/workshop-training/our-approach-to-dwops-and-i-dwops/

Sanyal, S. K., Morrow, J. W., Jayawardena, M. S., Berrah, N., Li, S. F., and Suryadarma. (2011). *Geothermal Resource Risk in Indonesia – A Statistical Inquiry*, *Proceedings*, 36th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, United States.

Siahaan, M. F., Purba, D., Septiani, G. A., Paripurna, A. (2023). *Preparing Technical and Commercial Documents for Geothermal Exploration Project Financing in Indonesia, Proceedings*, 48th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, United States.

SOL. (2019). *Siaran Pers Kebocoran Pipa di Namora I Langit / Press Release Pipeline leakage at Namora I Langit*, Retrieved from: https://sarullaoperations.com/images/press-release/5c9e0a4d8ba6b1553861197.pdf.

ThinkGeoEnergy. (2023). *Top 10 Geothermal Countries 2022 – Power Generation Capacity (MW).* https://Www.Thinkgeoenergy.Com/Thinkgeoenergys-Top-10-Geothermal-Countries-2022-Power-Generation-Capacity-Mw/Amp/. 11 January 2023.

Umam, M., Adityatama, D., & Purba, D. (2018). *Tantangan Pengembangan Energi Panas Bumi Dalam Perannya terhadap Ketahanan Energi di Indonesia*. Swara Patra, 8(3), 48-65.

Utami, P. (2010). *High-temperature Geothermal Area and its Challenges for Civil Engineering Works*. PERTEMUAN ILMIAH TAHUNAN XIV HATTI. Indonesia.