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The Significance of Drilling Data Management to Improve Geothermal Drilling Planning and Operation in Indonesia

Daniel Adityatama[1], Dorman Purba[1], Supriadinata Marza[2], Farhan Muhammad[1], Ribka Asokawaty[1], Riviani Kusumawardani[1], Agung W. Mukti[2]

[1]Rigsis Energi Indonesia, Equity Tower 49th Floor, SCBD, Indonesia
[2]Geo Dipa Energi, Aldevco Octagon, Jakarta

daniel.adityatama@rigsis.com

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ABSTRACT

As one of the major cost components in geothermal exploration and development, an effective and cost-efficient geothermal drilling can greatly contribute to the success of the whole geothermal project. Key factors in reducing drilling costs are optimising operations, utilising human resources to its fullest potential, and benchmarking with other drilling activities to evaluate one's performance objectively. However, this is difficult if not impossible if the information of the previous drilling activities is not properly stored, thus making data query and analysis cannot be easily conducted. An optimum drilling campaign plan is difficult to create without lessons learned from previous operations.

The significance of drilling data management and analysis have been a subject of study and discussion in the petroleum industry, but it is still not that common in geothermal drilling, especially in Indonesia. The purpose of this paper is to summarise the definition and examples of drilling data management in a more well-established industry such as oil and gas from various studies in the past, assess the advantages of having a proper drilling database or data management system, and how can the data be used for potentially improving future drilling operation. A case study of converting legacy data from previous drilling campaign of two geothermal fields in Java into a database is also discussed to demonstrate how legacy drilling data can be used to evaluate drilling performance.

1. INTRODUCTION

1.1 Indonesia's Geothermal Energy Development

Indonesia's National Energy Plan (Rencana Umum Energi Nasional / RUEN) dictates that the renewable energy should reach 23% from total Indonesia's energy mix (Kementerian ESDM, 2017), in which around 7,200 MW or 16% is originating from geothermal energy (Umam et al., 2019) With the installed geothermal power plant capacity at around 1,950 MW at the end of 2018, the 5,000 MW increase in ~6 years period is a bold target to say the least (Purba et al., 2019). One of the reasons for this slow development rate is the high upfront cost required during exploration, with drilling as the main contributor. Therefore, it is important to have a lower cost per MW by having acceptable drilling cost per well (GeothermEx, 2010; Purba et al., 2019).

Drilling operation in geothermal with its many uncertainties requires a lot of experiences before reaching the most optimum condition. The heterogeneity of the subsurface condition compared to oil and gas poses another challenge for geothermal drilling, making lessons learned from previous drilling operation are invaluable to improve the whole drilling planning and operation. However, most of the time the drilling data from previous drilling campaigns are neglected, or just stored in the company's hard drive or server without proper structuring. This makes drilling analysis difficult if not impossible to carry out, as the drilling engineer must dig piles of folders and files to find some parts of information. In oil and gas industry, the awareness for having a proper drilling database and data management system is widely known and has been a popular topic for years (Hanley et al., 2011; Iyoho et al., 2005; Shi et al., 2015; Sumbal et al., 2017). However, as far as the authors' knowledge, the importance of drilling database in geothermal, let alone drilling data management system in Indonesia has not been a serious concern.

1.2 Optimising Drilling Operation

As drilling is one of the biggest contributors in total geothermal project cost, it is imperative to address the optimisation of the drilling activity, especially as drilling has high risk due to uncertainties during operation. One way to optimise drilling planning and execution is by analysing previous drilling operations, or in drilling, engineering is known as drilling analysis (Figure 1). However, Iyoho et al. (2004), assert that drilling analysis is not routinely practised as it should be. One of the main reasons that drilling analysis seems like being ignored is that most of the time the company lack of an organised knowledge-based data-management system that can seamlessly cross-correlate relevant drilling and geologic parameters.

Another concern is it is widely believed that there is a lack of knowledge retention in the oil and gas industry, with drilling in particular (Sumbal, Tsui, See-to, & Barendrecht, 2017). There is a generation gap between drilling engineers, and it is critical to have a proper record of the lessons learned and processes to ensure transfer knowledge between drilling engineers (Damski, 2014). Authors of this study believe that if in the well-established sector such as oil and gas the lack of knowledge retention is apparent, then it is safe to assume that it will be the same in the less-established industry like geothermal. Therefore, without a proper record of the lessons learned, process description, field knowledge, and a proper drilling analysis of previous drilling operations data, it will be difficult if not impossible to optimise or improve any future drilling planning.

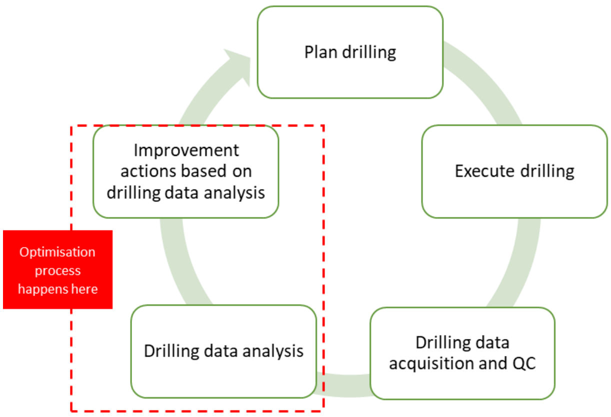


Figure 1: Drilling planning and operation cycle.

The data recorded may vary from daily activity report, bit performance, survey log, mud logging data, etc. However, more often than not, the previous drilling data and report are stored in various formats and inconsistent folder. This might lead to the following problems:

- Engineers have to manually dig in into folders and sort piles of data or report to find the information they need. This is time-consuming, and if the folder location is not consistent, other personnel who is not familiar with the availability or location of the data will have a hard time to find the information.
- Existing drilling data/report might be in a different format, making it difficult to collect, compare, and analyse.

1.3 Purpose of the Study

As discussed in the previous section, optimising geothermal drilling is not possible without learning from the previous drilling operation. However, lessons learned and data from previous campaign or operation are often neglected due to there is no proper database or data management system which in turn discourage engineers from looking up for the information or data. Therefore, the purpose of this paper is as follow:

- Summarise the drilling data management definition and concept from different kinds of literature and previous studies;
- Assessing the potential advantages of having a proper geothermal drilling database or data management system;
- Exploring how the data from previous drilling operations can be used for improving future drilling planning;
- Identifying what can be done with the legacy/historical drilling data that have not been stored properly.

Literature review regarding current geothermal drilling in Indonesia, basic drilling data management, and drilling analysis from the petroleum industry was carried out. A case study from a geothermal field in Central Java which has been drilled in the past and will be drilled for future expansion is also investigated to demonstrate how the legacy data can still be utilised for future drilling planning Figure 2.

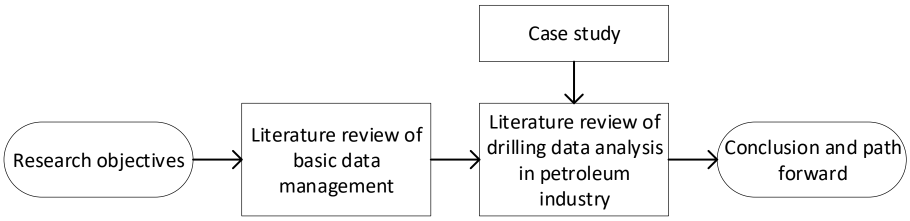


Figure 2: Methodology flowchart of this study.

2. DATA MANAGEMENT

Definition of data itself is varied depending on the source or context, but to put it, it can be defined as facts, numbers or other entities that have no context or purpose on its own. Data should be organised into a meaningful context and become **information**. The information then can be interpreted, analysed, and used for various purpose such as decision-making, evaluation, etc. and become **knowledge** (Figure 3). Hence, the data itself is practically unusable unless organised into a database or documents.

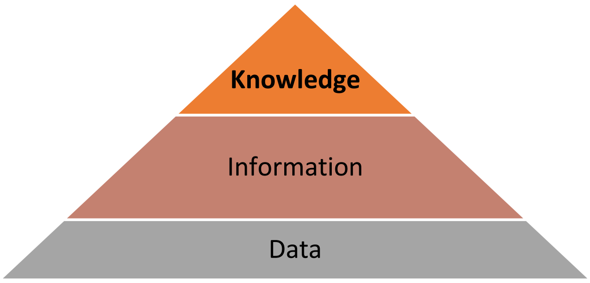


Figure 3: Illustration of data, information, and knowledge (modified from Damski, 2014).

Data management can be described as "the practice of collecting, keeping, and using data efficiently and cost-effectively" (ORACLE, 2019). However, the term data management in drilling operation is unclear, as sometimes streaming the real-time mud logging data from drilling site to the headquarter office or collecting the data (reports, mud logging data, e-log data, etc.) and storing them inside company's hard drive or server is considered enough as a form data management. Damski (2014) asserts that it is not enough in a business sense, as it is just an expense without any Return of Investment (ROI). After the information extracted from the data can be used to generate a decision to improve the business process of the company, then the cost spending for data management will become make sense. Collecting or acquisition and storing the data from previous drilling operations will only become additional cost with no value if the data is not analysed to deliver business intelligence improve the business process (productivity, safety, etc.) of the company.

However, as stated in the previous section, the business intelligence part can only be done if the data is available and easy to access/retrieve. With the readily available and processed data, the difference between two decisions is just a matter of business intelligence or data interpretation, which in turn can provide better drilling program, drilling cost estimation, etc.

2.1 Data Management in Drilling

Damski (2014) described that for drilling operation, the data management process could be summarised into the following steps **(**Figure 4**)**:

- Data acquisition
- Data QC
- Data storage
- Data retrieval
- Data analysis

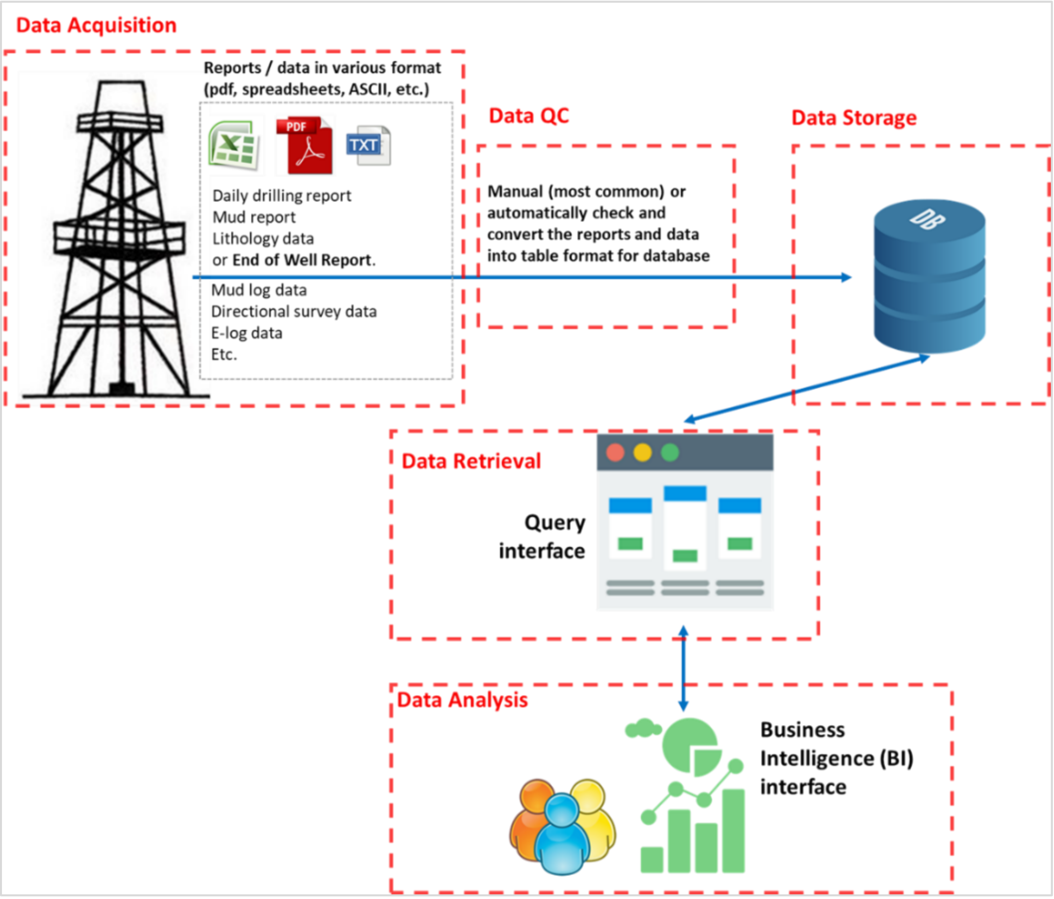


Figure 4: Steps of drilling data management.

2.1.1 Data Acquisition

Generally, there are two types of data sources in drilling; one is the manually-filled report, and the other is an automatic report from the sensors such as mud logging unit. The manual report may range from the morning meeting, daily drilling report (DDR) in the form of spreadsheet file or some sophisticated software such as Peloton's WellView™, Halliburton's OpenWells®, etc. Irrespective of the method, the manual report is involving a person in the rig to type or fill the form. This also occurred for other data records such as geology, bit, cost, drilling fluid, etc.

The electronic data from sensors, on the other hand, are collected real-time and may or may not directly transmitted to the office for storage and plotting. For both of these data types, the data reliability is crucial. This makes quality control of the data become important and will be discussed in the later section.

2.1.2 Data QC

Data Quality Assurance and Quality Control (QA/QC) process are very important due to that any bad data (inconsistent or even wrong) will also be used for analysis. There is a famous adage in the IT world "garbage in – garbage out"; where any incorrect or poor-quality input will generate nonsensical output or garbage. As stated in the Data Acquisition section, the manual report quality is highly dependent on the person on the rig site. This is more complicated than it sounds because usually the person filling the manual report (company man or drilling supervisor) must supervise the operation, and at the end of his shift, he has to create a report. If the drilling supervisor is not aware of the utilisation of the data from his report, he might miss or skimp through some information that he thinks is not important. Even if the drilling supervisor is aware or has been briefed previously on what to input in the report, based on authors experience there were a lot of occurrences when some details were missed in the report simply because of the drilling supervisor was too occupied in supervising the operation, and reporting was just become an afterthought. Similar thing in the automatic (sensor-based) report, as the faulty or not calibrated sensor, will give the wrong reading. Overall, Damski (2014) described that the most common errors in drilling database are as follow:

- Wrong datum / unit
- Inconsistency (e.g. one engineer can code one particular operation in one well and another code in the same operation in different well, making comparison difficult).
- Dispersed data source
- Outliers/anomaly
- Bad relationships between data entities.

People often overlook the QC process despite its significance. Acquiring the data relatively easily, but without proper QA/QC, the analysis result can be incorrect or misleading.

2.1.3 Data Storage

Data storage in drilling is a very interesting topic. As far as the authors know, many geothermal companies store drilling data or reports in folders inside their servers or computers. However, in IT perspectives, data such as reports, presentations, images, even excel files are considered "unstructured" data, as it is not stored in a structured manner and most of the time have a different and inconsistent format, thus making it harder to store and retrieve (Figure 5). Databases, on the other hand, are considered as "structured" data, as they possess a formal method to organise and retrieve the data (Damski, 2014).

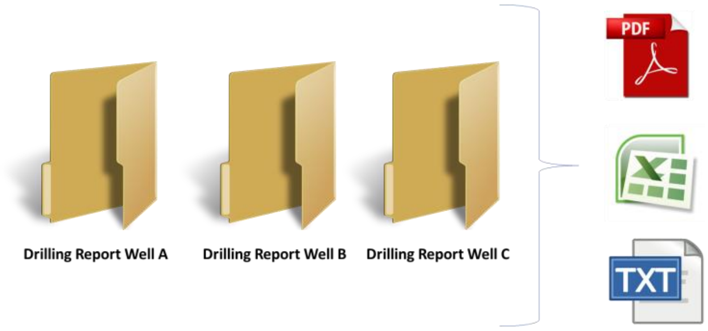


Figure 5: Illustration of common data storage in companies.

To address this, companies can obtain a database system that converts the information inside their files into a database such as provided by ORACLE, MySQL, etc. To access/retrieve the data, users or engineers can use a SQL (Structured Query Language) or use a graphic interface or application.

2.1.4 Data Retrieval

After the data is stored in some databases, the following tasks are how to retrieve it easily. In unstructured data such as reports, presentation, and images stored in folders, retrieving the data is no easy task. In a database, it can be done using a language called Standard Query Language (SQL). However, SQL itself sometimes seems like a domain for IT engineer and seems like a foreign land for a drilling engineer. Therefore, to simplify things for the user, it is important to have a graphical interface to query or retrieve the required data (Figure 6).

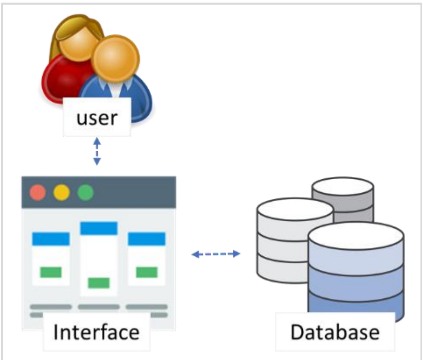


Figure 6: Simplified concept of how user access data in the database via interface/application.

2.1.5 Data Analysis

Data analysis can be described as "methods to inspect, transform and model data aiming to detect patterns, develop explanations, test hypotheses, highlighting useful information, suggest conclusions and support decision making" (Damski, 2014; Iyoho, Millheim, Virginillo, Adeleye, & Crumrine, 2004). The primary objective of the whole data management (and data analysis in particular) is how will this benefit or improve the whole business. The drilling data analysis can be used to reflect the condition in the past, present, and future (**Figure 7**). In a day-to-day drilling operation, the company will need all three of them. The past can be used as a historical basis to understand past performance, to plan future wells, and to forecast potential problems. It also helps to aid decision making in the present condition, especially if the occurring problems had occurred in the past operations.

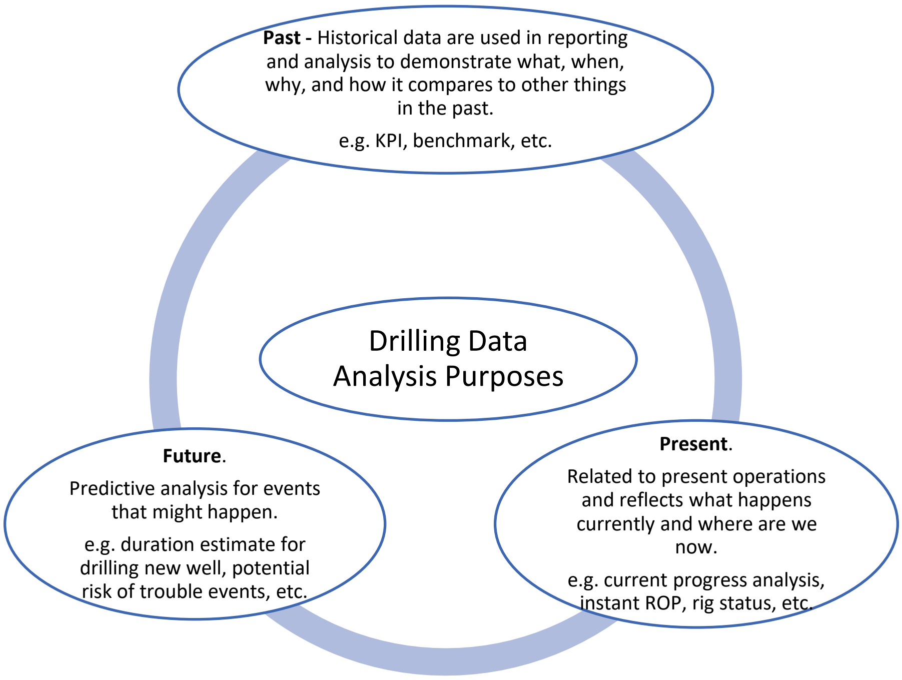


Figure 7: Basic purposes of drilling data analysis.

3. ANALYZING DRILLING DATA

3.1. Drilling Process

As stated earlier in the previous section, the drilling data (both in the past or in the current time) is crucial in every stage of well life cycle. One approach for quality management and continuous improvement is PDCA (Plan, Do, Check, Act) cycle (Johnson, 2002; Sokovic, Pavletic, & Pipan, 2010). Figure 1 illustrates the cycle of drilling a well, and it resembles the PDCA cycle. Without a proper drilling database, every stage of well life cycle will be disturbed. There will be no data, information, and lessons learned from previous drilling operation to aid in improving the next drilling plan. The execution stage will also be disturbed, as every problem encountered during operation will be a new problem since there is no record on problems in the past and how to address or mitigate them. The possible improvement and utilisation of drilling data analysis are discussed in the later section.

The drilling data is crucial in the planning and evaluation phase of the drilling operation. The engineer can use the historical data (after they are collected, organised, and quality controlled) to identify what and where problems are encountered in the past, what and where improvements can be made in future planning. There are some tools to improve drilling planning via analysis of historical data (Damski, 2014):

- Productive time analysis;
- Process control analysis;
- Non-productive (NPT) analysis;
- Best Composite Time (BCT) analysis and technical limit;
- Bit performance analysis;
- Learning curve analysis;
- Benchmark analysis.

In the oil and gas industries, several works have been carried out to propose the methodology for drilling analysis. One of them is "10-step methodology" (Figure 8) proposed by Iyoho et al. (2004). These steps are as follow:

1. **Define project objectives and scope:** In order to understand the context, targets, and design a plan. This stage should provide an answer to the following questions: where are we now? Where do we want to be? What is possible? How do we get there?
2. **Data selection and QA/QC:** The comparable sets of data are identified, compiled, and checked for their integrity prior to the subsequent analysis.
3. **Best Composite Time (BCT):** The best time recorded for each discreet sequential activity (rig up, makeup bit, run in hole, etc.) from comparable well data are identified and added up to create an "ideal well" drilling time. Then this BCT can be used for future drilling planning. Note that BCT is not a technical limit in terms of what is possible, in terms of what has been done.
4. **Best Composite Cost (BCC):** After BCT is identified, it is then converted to the total cost to analyse the financial target better.
5. **Learning Curve-Analysis:** This step is carried out to analyse the performance, progress and accomplishment in general and in specific areas of the drilling.

6. **Major Operations Analysis:** In this step, a time breakdown analysis is carried out for major operations and drilling phases to identify NPT and problems during drilling.
7. **Detailed Problem Analysis & Opportunity Identification:** This step evaluates the trouble-time duration and occurrence/repetitiveness; thus, in turn, can identify an area for improvement.
8. **Peer Review, Design Changes, and Technology Scouting:** Peer review is carried out to study the possibility of optimising drilling process through design changes, adopting new technology, etc.
9. **Economic Benefit Evaluation:** The possible improvement options from Step 8 are assessed for the most cost-effective solution.
10. **Recommendation and Follow-up:** The result from step 9 is converted into a series of recommendations and measure the financial impact as they are implemented to improve the BCT and BCC continuously.

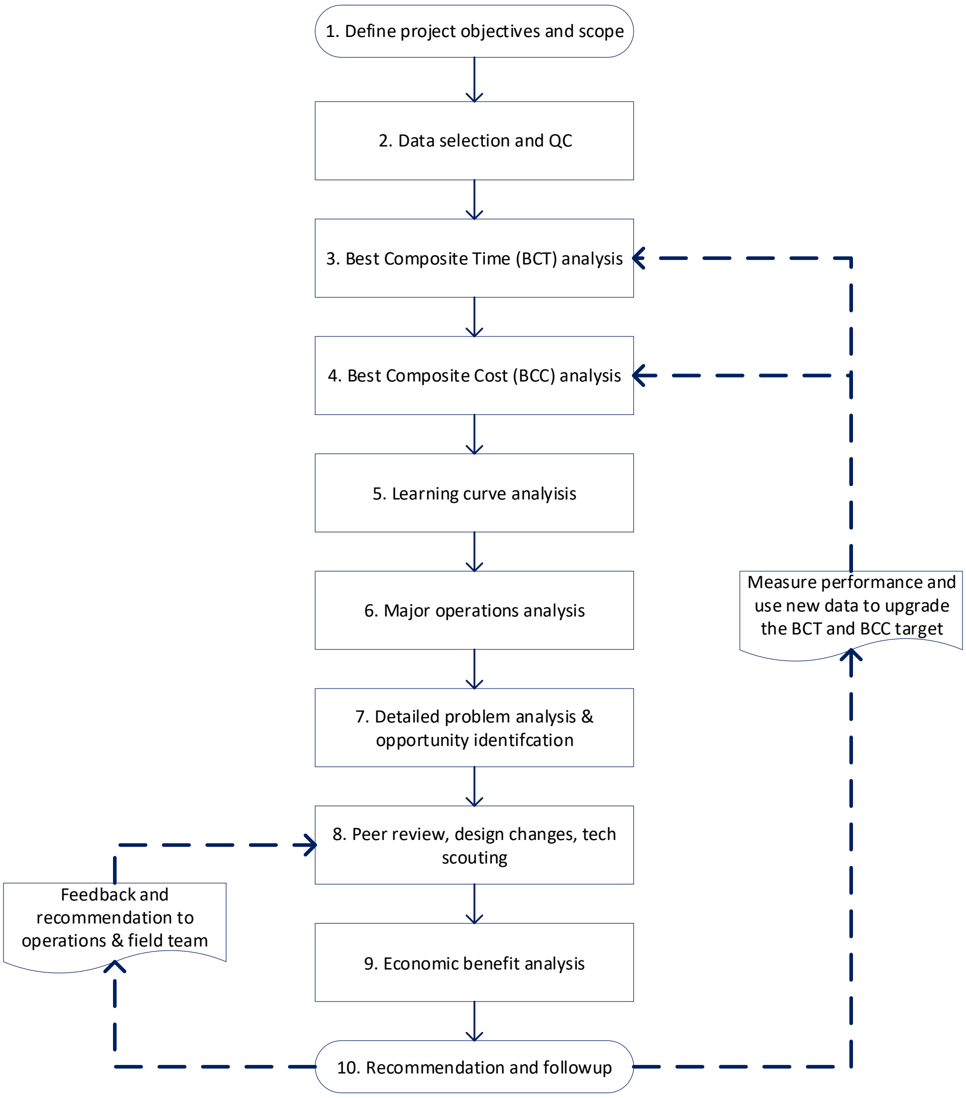


Figure 8: Ten steps of drilling analysis flowchart (modified from Iyoho, Milheim, et al. 2004).

3.2 Activity Reporting

The drilling reports, both manually-inputted daily drilling report and mud-logging or other sensor-based data, are an essential part of understanding the drilling operation and analyse it. However, most of the time, the daily report is only used for daily morning meeting, and "discarded" if there is no apparent problem during the operation. With the rise of proper drilling data management system and Business Intelligence (BI) tools, people are starting to realise the importance of this historical data.

However, even if the company realised the significance of this historical data and with the aid of sophisticated activity reporting software, sometimes it is still difficult to accurately take advantage of the information. One of the main reasons is the improper activity data reporting and the lack of operational activity coding process. (Nakagawa, Damski, & Miura, 2005). Several studies in the past have tried to identify what are the barriers that hinder the use of historical data (Figure 9) and how to mitigate it (Nakagawa, Damski, & Miura, 2005; Damski, 2014).

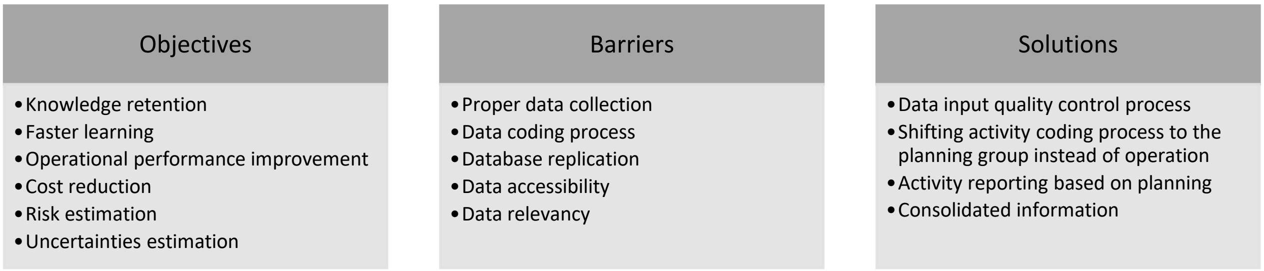


Figure 9: Barriers and the potential solution to take full advantages of historical drilling activity data (modified from Nakagawa et al., 2005).

It can be seen that the activity coding process is crucial for the historical data analysis, however, as it is not standardised in geothermal industry in Indonesia, this can cause some inaccuracies due to the following reasons:

- Not detailed enough to differentiate different activities, or excessively detailed thus making the one making the report to identify the right code;
- Inconsistent coding due to different people inputting the activity report;
- Differences on when to start/end the activity code in reporting;
- Inconsistent coding for trouble time.

Therefore, it is highly imperative that for a proper drilling activity reporting, the company should establish a dedicated team to assess their activity coding system, set standards, carry out training, and socialise the significance of proper drilling activity report throughout the organisation.

4. CASE STUDY

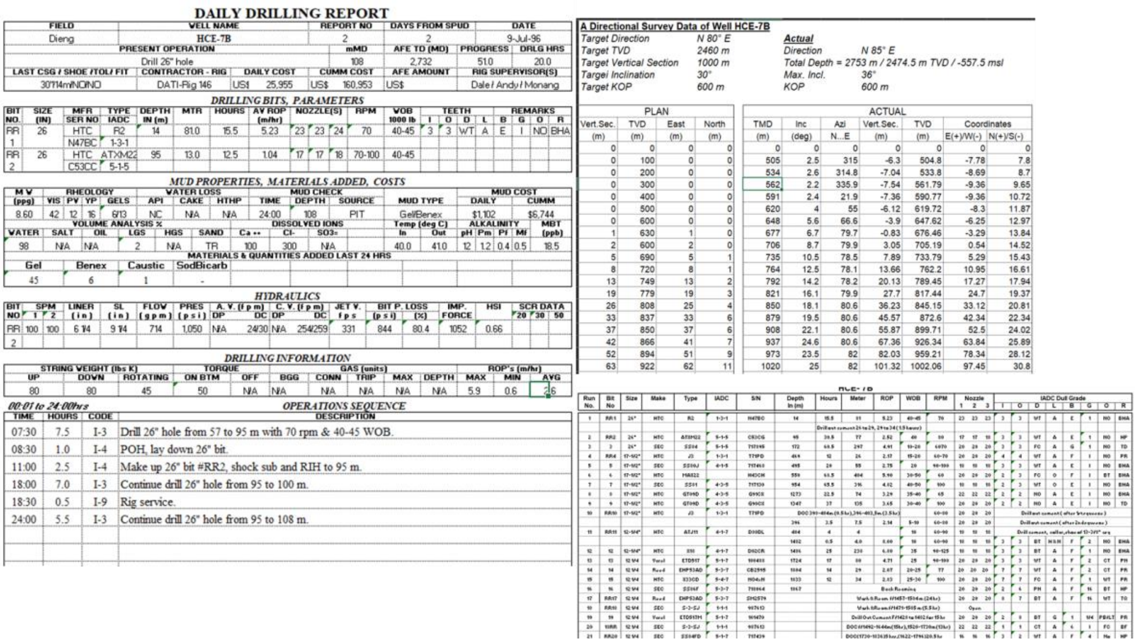
4.1 Problem

A geothermal company in Indonesia has no database of its previous drilling operation. The legacy data available just report in various format (mostly spreadsheet, and in the form of single daily drilling report with no summary). The problem arises when the company wants to carry out the next drilling campaign for power plant expansion. The inconsistent and unstructured report makes it very difficult to do drilling performance analysis.

4.2 Solution

A preliminary data management was then carried out to organise, data QC and cleansing, and implement a system to convert the spreadsheet report into one integrated historical database.

Figure 10 shows examples of the daily drilling report, directional survey, and bit performance. Note that all of the reports have not been summarised yet prior to the data management implementation. Figure 11 shows the data management flowchart for the company's legacy data.



DAILY DRILLING REPORT

FIELD	VELL NAME	REPORT NO	DAYS FROM SPUD	DATE
Dieng	HCE-7B	2	2	9-Jul-96

PRESENT OPERATION	mMD	AFE TD (MD)	PROGRESS	DRLG HRS
Drill 26" hole	108	2,732	51.0	20.0

LAST CSG / SHOE /TOL/ FIT	CONTRACTOR - RIG	DAILY COST	CUMM COST	AFE AMOUNT	RIG SUPERVISOR(S)
30"/14m/NO/NO	DATI-Rig 146	US$ 25,955	US$ 160,953	US$	Dale / Andy / Monang

DRILLING BITS, PARAMETERS

BIT NO.	SIZE (IN)	MFR SER NO	TYPE IADC	DEPTH IN (m)	MTR	HOURS	AV ROP (m/hr)	NOZZLE(S)			RPM	VOB 1000 lb	TEETH I	TEETH O	D	L	B	G	O	R
RR 1	26	HTC N47BC	R2 1-3-1	14	81.0	15.5	5.23	23	23	24	70	40-45	3	3	WT	A	E	I	NO	BHA
RR 2	26	HTC C53CC	ATXM22 5-1-5	95	13.0	12.5	1.04	17	17	18	70-100	40-45								

MUD PROPERTIES, MATERIALS ADDED, COSTS

M V (ppg)	VIS	PV	YP	GELS	API	CAKE	HTHP	TIME	DEPTH	SOURCE	MUD TYPE	DAILY	CUMM
8.60	42	12	16	6/13	NC	N/A	N/A	24:00	108	PIT	Gel/Benex	$1,102	$6,744

VATER	SALT	OIL	LGS	HGS	SAND	Ca ++	Cl-	SO3=	Temp In	Temp Out	pH	Pm	Pf	Mf	MBT (ppb)
98	N/A	N/A	2	N/A	TR	100	300	N/A	40.0	41.0	12	1.2	0.4	0.5	18.5

MATERIALS & QUANTITIES ADDED LAST 24 HRS

Gel	Benex	Caustic	SodBicarb
45	6	1	-

HYDRAULICS

BIT NO	SPM 1	SPM 2	LINER (in)	SL (in)	FLOV (gpm)	PRES (psi)	A. V. DP	A. V. DC	C. V. DP	C. V. DC	JET V. fps	BIT P. LOSS (psi)	BIT P. LOSS (%)	IMP. FORCE	HSI	SCR 20	SCR 30	SCR 50
RR 2	100	100	6 1/4	9 1/4	714	1,050	N/A	24/30	N/A	254/259	331	844	80.4	1052	0.66			

DRILLING INFORMATION

UP	DOWN	ROTATING	ON BTM	OFF	BGG	CONN	TRIP	MAX	DEPTH	ROP MAX	ROP MIN	ROP AVG
80	80	45	50	N/A	N/A	N/A	N/A	N/A	N/A	5.9	0.6	2.6

00:01 to 24:00hrs — OPERATIONS SEQUENCE

TIME	HOURS	CODE	DESCRIPTION
07:30	7.5	I-3	Drill 26" hole from 57 to 95 m with 70 rpm & 40-45 WOB.
08:30	1.0	I-4	POH, lay down 26" bit.
11:00	2.5	I-4	Make up 26" bit #RR2, shock sub and RIH to 95 m.
18:00	7.0	I-3	Continue drill 26" hole from 95 to 100 m.
18:30	0.5	I-9	Rig service.
24:00	5.5	I-3	Continue drill 26" hole from 95 to 108 m.

A Directional Survey Data of Well HCE-7B

Target Direction N 80° E; Target TVD 2460 m; Target Vertical Section 1000 m; Targei Inclination 30°; Target KOP 600 m

Actual: Direction N 85° E; Total Depth = 2753 m / 2474.5 m TVD / -557.5 msl; Max. Incl. 36°; KOP 600 m

PLAN Vert.Sec. (m)	PLAN TVD (m)	PLAN East (m)	PLAN North (m)	ACTUAL TMD (m)	Inc (deg)	Azi N...E	Vert.Sec. (m)	TVD (m)	E(+)/W(-)	N(+)/S(-)
0	0	0	0	0	0	0	0	0	0	0
0	100	0	0	505	2.5	315	-6.3	504.8	-7.78	7.8
0	200	0	0	534	2.6	314.8	-7.04	533.8	-8.69	8.7
0	300	0	0	562	2.2	335.9	-7.54	561.79	-9.36	9.65
0	400	0	0	591	2.4	21.9	-7.36	590.77	-9.36	10.72
0	500	0	0	620	4	55	-6.12	619.72	-8.3	11.87
0	600	0	0	648	5.6	66.6	-3.9	647.62	-6.25	12.97
1	630	1	0	677	6.7	79.7	-0.83	676.46	-3.29	13.84
2	600	2	0	706	8.7	79.9	3.05	705.19	0.54	14.52
5	690	5	1	735	10.5	78.5	7.89	733.79	5.29	15.43
8	720	8	1	764	12.5	78.1	13.66	762.2	10.95	16.61
13	749	13	2	792	14.2	78.2	20.13	789.45	17.27	17.94
19	779	19	3	821	16.1	79.9	27.7	817.44	24.7	19.37
26	808	25	4	850	18.1	80.6	36.23	845.15	33.12	20.81
33	837	33	6	879	19.5	80.6	45.57	872.6	42.34	22.34
37	850	37	6	908	22.1	80.6	55.87	899.71	52.5	24.02
42	866	41	7	937	24.6	80.6	67.36	926.34	63.84	25.89
52	894	51	9	973	23.5	82	82.03	959.21	78.34	28.12
63	922	62	11	1020	25	82	101.32	1002.06	97.45	30.8

Figure 10: Example of legacy drilling report (daily drilling report, survey, and bit performance).

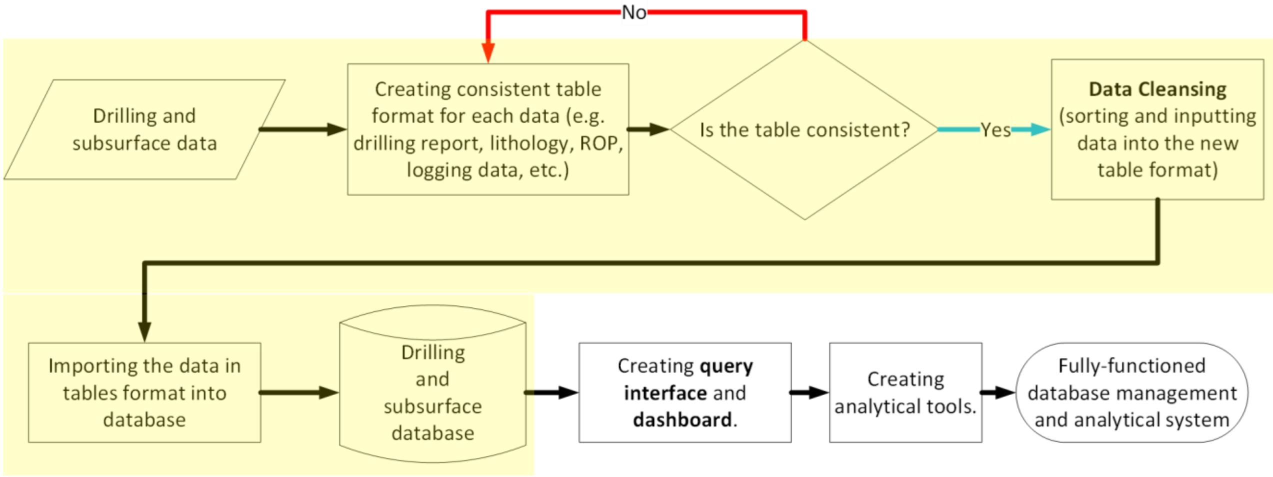


Figure 11: Data management flowchart. Current progress is highlighted in yellow.

4.3 Implementation and Challenges

The data management started with sorting and organise the reports, data quality check, creating a single format for each type of reports, and establishing a uniform activity coding system. However, as the drilling was carried out in 1998 and the original drilling team is not in the company anymore, several challenges regarding reliability of the data were faced during the process. Those challenges are described in Figure 12:

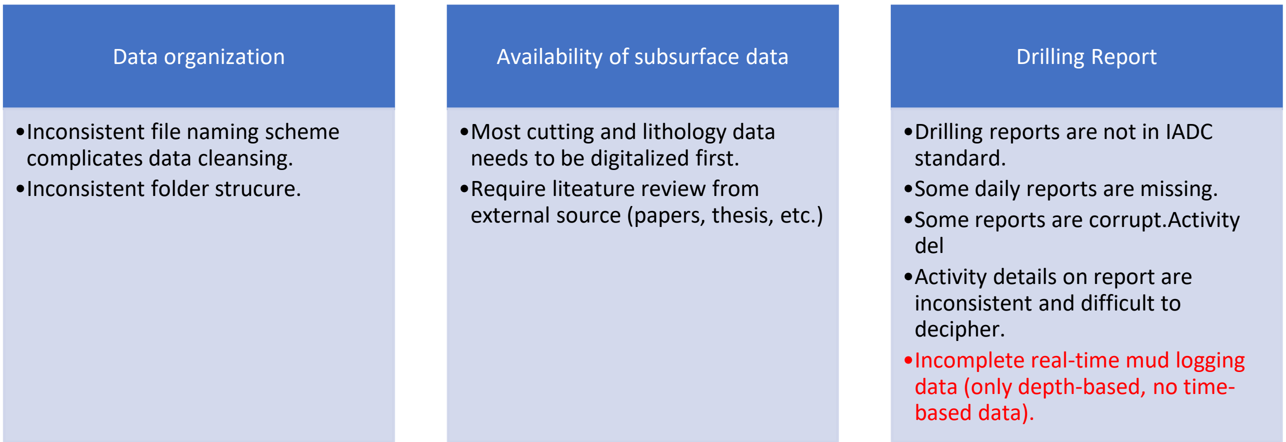


Figure 12.Challenges faced during the data management process.

The basic drilling data analysis could be conducted by BI tools such as Microsoft PowerBI or Sisense, but for the quick setup and readily available tools in the company, Microsoft Excel was then used. Several examples of the information that were extracted after the data management process are shown in Figure 13. Note that it is practically not possible to be done without data cleansing and establishing uniform activity coding process first. Figure 14 shows the interface of Microsoft Power BI dashboard that can be used to monitor drilling performance. Once the drilling operation data is saved in the company's database (most common in SQL form), it can be paired to a lot of data visualisation or data analytics/business intelligence tool.

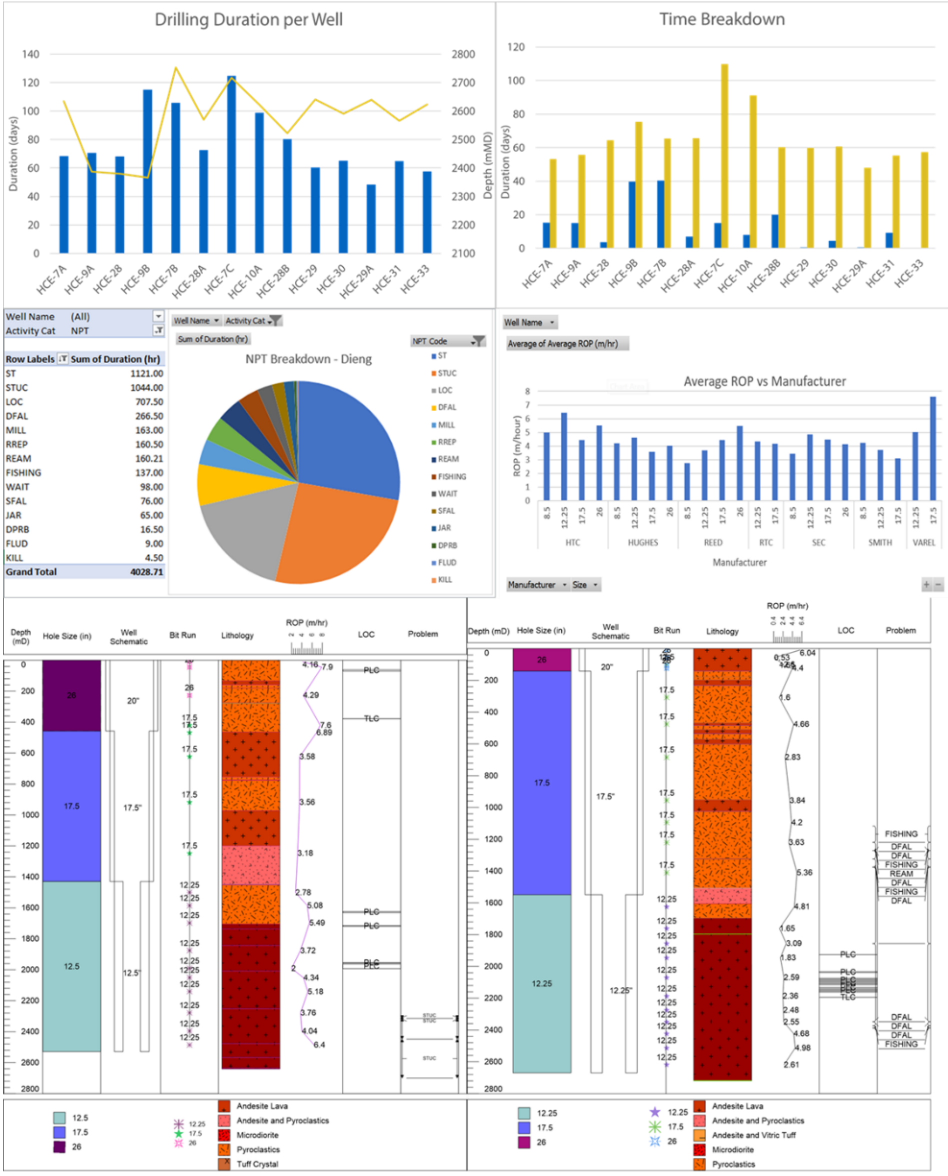


Figure 13: Several information that can be extracted after data cleansing process on the legacy data.

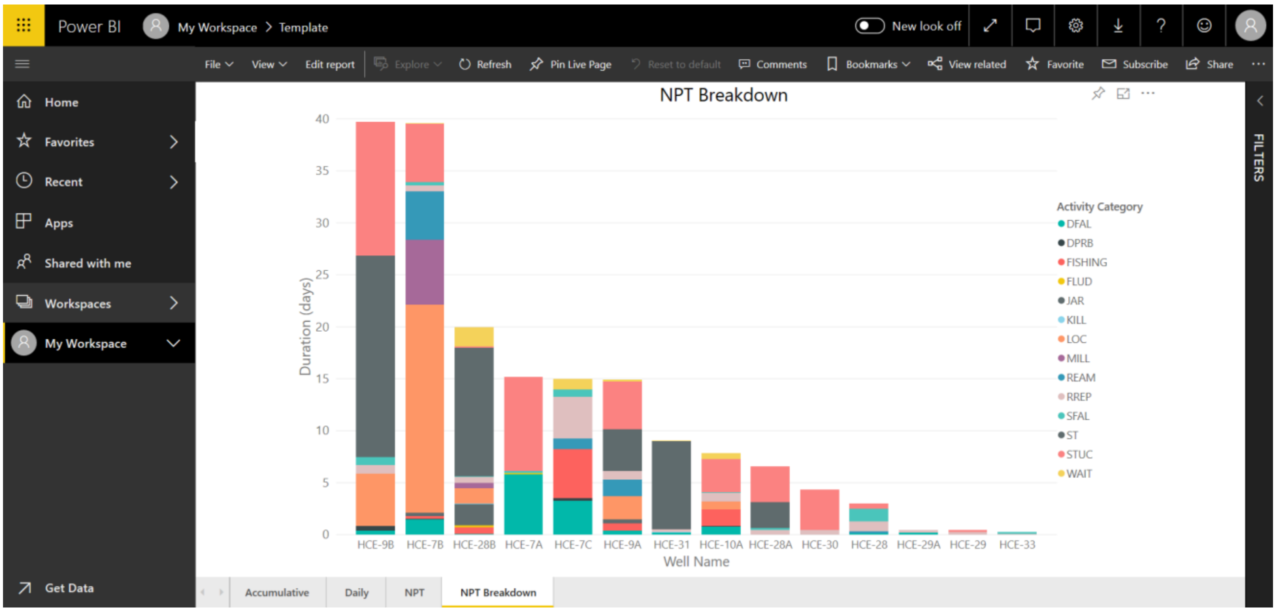


Figure 14: Example of Power BI dashboard interface to monitor drilling performance.

4.4 Results and Lessons Learned

The implementation of the data management shows that the pile of seemingly impossible to use data can be utilised to extract useful information to aid for the future drilling campaign. The format is proven to be relatively easy to use with run-of-the-mill software such as Microsoft Excel. However, to fully take benefit from the whole data management process in the future, several points of improvement are identified:

- Employ a fit-to-purpose business intelligence process to extract the critical information required for future drilling campaign decision making.
- Assess the activity code to ensure fit with the company needs.
- Utilise drilling activity reporting software or establish standardised daily drilling report spreadsheet (adopting IADC or other standards) to ease drilling report input to the database.
- QA/QC all drilling report immediately prior to inputting to the database to ensure accuracy and reliability.

5. SUMMARY

This study has summarised the drilling data management concept and advantages from various sources, mostly from more established industry such as oil and gas. From the literature study and case study, several points are obtained:

- It is important to have proper & structured drilling data in the form of a database.
- The proper database can be further developed into fully-fledged Drilling Data Management.
- A good Drilling Data Management will greatly aid in conducting drilling data analysis and business intelligence to improve business process. Without it, the whole data management will only be an extra cost with no value for the company.
- A legacy drilling data can still be used to analyse past performance and obtain lessons learned but require a lot of post-event quality control. Therefore, it is advised to apply proper quality control process from the early phase of drilling data management.
- A nation-wide proper geothermal drilling database can be used for benchmarking drilling performance, extract lessons learned from other fields (not necessarily from the same developers), and in turn, can be used to optimise future drilling campaign. The reduced drilling cost will make the geothermal energy sector more attractive to potential investors.

REFERENCES

Damski, Carlos. 2014. *Drilling Data Vortex: Where the bits meet the bits.* Australia: Genesis Publishing and Services Pty Ltd.

GeothermEx. 2010. *An Assessment of Geothermal Resource Risks in Indonesia.* Working Paper, Richmond, California: GeothermEx, Inc.

Hanley, C., J. Kubicki, M. Lumpkin, and L. Tompkins. 2011. "Development of a Global Drilling Performance Database." *SPE/IADC Middle East Drilling Technology Conference and Exhibition.* Muscat, Oman: SPE International.

Iyoho, A. W., K. K. Millheim, B. K. Virginillo, A. R. Adeleye, and M. J. Crumrine. 2004. "Methodology and Benefits of a Drilling Analysis Paradigm." *IADC/SPE Drilling Conference 2004.* Dallas, Texas: SPE International.

Iyoho, A. W., R. A. Meize, K. K. Millheim, and M. J. Crumrine. 2005. "Lessons from Integrated Analysis of GOM Drilling Performance." *Offshore Technology Conference 200.* Houston: SPE International.

Johnson, C. N. 2002. "The benefits of PDCA." *Quality Progress* (Proquest) 35 (5). https://search.proquest.com/openview/6fb24b731a9c0c8bafd90096fd751e76/1?pq-origsite=gscholar&cbl=34671.

Kementerian ESDM. 2017. "Rencana Umum Energi Nasional." *Kementerian Energi dan Sumber Daya Mineral Republik Indonesia.* Accessed June 2, 2019. https://www.esdm.go.id/id/publikasi/ruen.

Nakagawa, E., C. Damski, and K. Miura. 2005. "What is the Source of Drilling and Completion Data?" *Asia Pacific Oil & Gas Conference and Exhibition.* Jakarta: SPE International.

ORACLE. 2019. "What is Data Management?" *ORACLE.* Accessed June 5, 2019. https://www.oracle.com/database/what-is-data-management/.

Purba, D. P., D. W. Adityatama, M. F. Umam, and F. Muhammad. 2019. "Key Considerations in Developing Strategy for Geothermal Exploration Drilling Project in Indonesia." *PROCEEDINGS, 44th Workshop on Geothermal Reservoir Engineering.* Stanford: Stanford University.

Shi, X., Y. Zhou, P. Song, Q. Zhao, H. Jiang, Z. Huo, G. Yang, and X. Zhai. 2015. "Integrated Drilling Database Enables Automated Drilling Engineering Design." *SPE/IATMI Asia Pacific Oil & Gas Conference and Exhibition.* Nusa Dua, Bali: SPE International.

Sokovic, M., D. Pavletic, and K. K. Pipan. 2010. "Quality Improvement Methodologies - PDCA Cycle, RADAR Matrix, DMAIC and DFSS." *Journal of Acheivements in Materials and MAnufacturing Engineering* (International OCSCO World Press) 43 (1).

Sumbal, M. S., E. Tsui, E. See-to, and A. Barendrecht. 2017. "Knowledge retention and aging workforce in the oil and gas industry: a multi perspective study." *Journal of Knowledge Management* (Emerald) 21 (4): 907-924. doi:10.1108/JKM-07-2016-0281.

Umam, M. F., J. Susilo, D. P. Purba, and D. W. Adityatama. 2019. "Design of Geothermal Drilling Training Curriculum as the Implementation of the National Competence Standard on Onshore Drilling." *PROCEEDINGS, 8th ITB International Geothermal Workshop 2019.* Bandung: Institut Teknologi Bandung.