PROCEEDINGS, The 7th Indonesia International Geothermal Convention & Exhibition (IIGCE) 2019
Assembly Hall - Jakarta Convention Center Indonesia, August 13 - 15, 2019

THE SIGNIFICANCE OF DRILLING DATA MANAGEMENT TO IMPROVE GEOTHERMAL DRILLING OPERATION

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ABSTRACT

Drilling is one of the major cost components in geothermal exploration and development. Effective and cost-efficient drilling significantly contribute to the success of geothermal development. Key factors in reducing drilling costs are optimising operations, utilising manpower to its fullest potential, and also benchmarking with other drilling activities to evaluate one's performance objectively. This is possible if the information regarding the previous drilling activities is stored and easily gathered and analysed before making plans for the drilling campaign.

The importance of drilling data analysis and drilling data management have been a subject of study and discussion since the 1980s, 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.

INTRODUCTION

Geothermal Development in Indonesia

Indonesia's National Energy Plan (Rencana Umum Energi Nasional / RUEN) dictates that the renewable energy should reach 23% from the 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 of this slow development rate is the high upfront cost required during exploration, with drilling as the main contributor. Therefore, it is important to have 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 / server without proper structuring. This makes drilling analysis difficult if not impossible to carry out, as the drilling engineer has to dig piles of folders and files just 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, Meize, 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.

Optimizing Drilling Operation to Reduce Drilling Cost

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 is seems like being ignored is that most of the time the company lack of an organized 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 knowledge retention in oil and gas industry, with drilling in particular (Sumbal, et al. 2017). There is generation gap between drilling engineers, and it is critical to have a proper record of lesson 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 lesson learnt, process description, field knowledge, and a proper drilling analysis of previous drilling operations data, it will be difficult if not impossible to optimise / improve any future drilling planning.

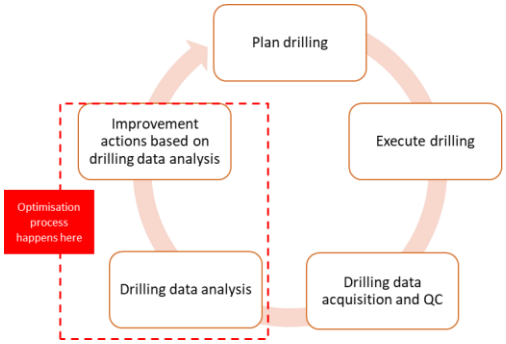


Figure 1. Drilling planning and operation cycle.

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 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 different format, making it difficult to collect, compare, and analyse.

Purpose of the Study

As discussed in previous section, optimising geothermal drilling is not possible without learning from 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 to look up for the information or data. Therefore, the purpose of this paper is as follow:

- Summarise the drilling data management definition and concept from literatures 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;
- 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 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.

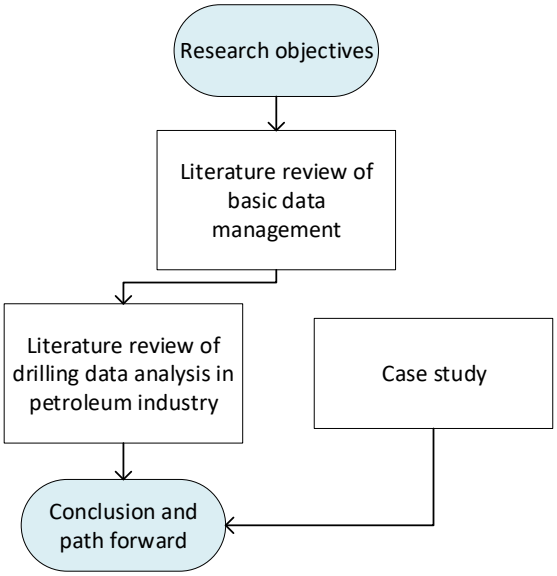


Figure 2. Methodology flowchart of this study.

WHAT IS DATA MANAGEMENT

Definition of data itself is varied depending on the source or context, but to put it simply, it can be defined as facts, numbers or other entities that has 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.** Hence, the data itself is practically unusable unless organised into a database or documents.

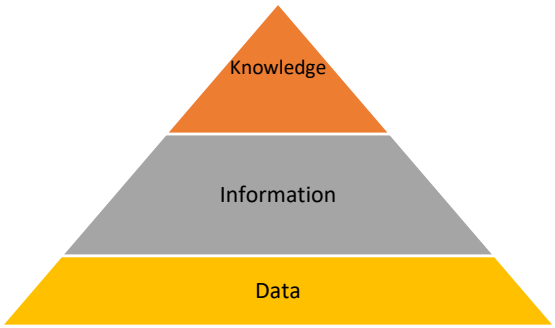


Figure 3. Illustration of data, information, and knowledge (modified from Damski, 2014).

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 decision to improve the business process of the company, then the cost spending for the data management will become make sense (Figure 4). Collecting or acquisitioning 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 business process (productivity, safety, etc.) of the company.

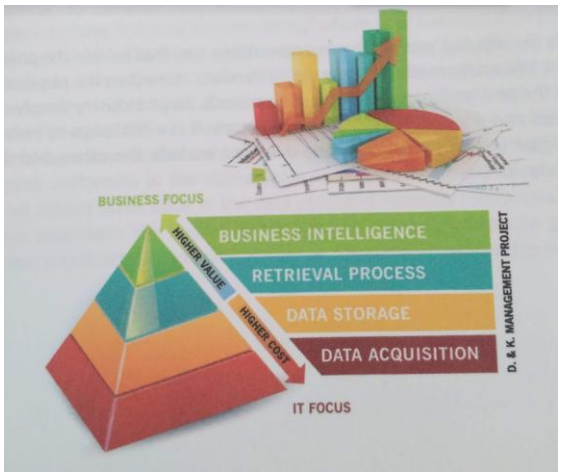


Figure 4. Cost vs value in data management (modified from Damski, 2014)

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.

Data Management in Drilling

Damski (2014) described that for drilling operation, the data management process can be summarised into the following steps **(**Figure 9**)**:

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

Data Acquisition

Generally, there are two types of data source in drilling; one is the manually-filled report and the other is automatic report from the sensors such as mud logging unit. The manual report may range from morning meeting, daily drilling report (DDR) in a 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 is also occurred for other data record 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 int the later section.

Data Storage

Data storage in drilling is a very interesting topic. As far as 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 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 formal method to organise and retrieve the data (Damski 2014).



Figure 5. Illustration of commonly 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.

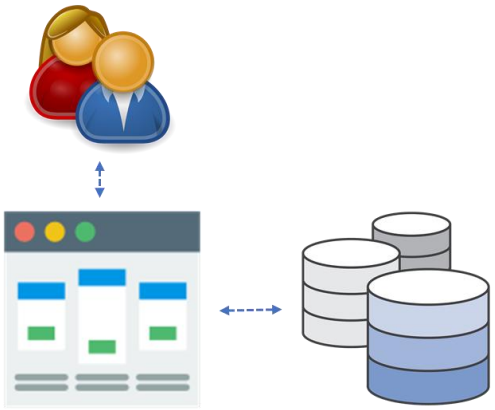


Figure 6. Simplified concept of how user access data in database via interface / application.

Data QC

Data QA/QC process is very important due to that any bad data (inconsistent or even wrong) will also be used for analysis. There is a famous adage in IT world "garbage in – garbage out"; where any incorrect or poor-quality input will generate nonsense output or garbage. As stated in the Data Acquisition section, the manual report quality is highly dependent on the person in the rig site. This is more complicated than it sounds because usually the person filling the manual report (company man or drilling supervisor) has to 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 are a lot of occurrence 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 automatic (sensor-based) report, as faulty or not calibrated sensor will give 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.

The QC process is often overlooked by people despite its significance. Acquiring the data relatively easy, but without proper QA/QC, the analysis result can be incorrect or misleading.

Data Retrieval

After the data is stored in some databases, the following tasks is how to easily retrieve it. 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 is 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 graphical interface to query or retrieve the required data.

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, et al. 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 10). In day-to-day drilling operation, the company will need all three of them. The past can be used as 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 been occurred in the past operation.

ANALYSING DRILLING DATA

Drilling Process

As stated earlier in 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 and 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 is discussed in the later section.

The drilling data is crucial in the planning and evaluation phase of 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 oil and gas industries, several works have been carried out to propose the methodology for drilling analysis. One of them is "10-step methodology" 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 answer for 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, make up 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 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 better analyse the financial target.
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 evaluate the trouble-time duration and occurrence / repetitiveness, thus in turn can identify 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 series of recommendations and measure the financial impact as they are implemented to continuously improve the BCT and BCC.

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 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 and Miura 2005). Several studies in the past have tried to identify what are the barriers that hinder the use of historical data and how to mitigate it (Nakagawa, Damski and Miura 2005, Damski 2014).

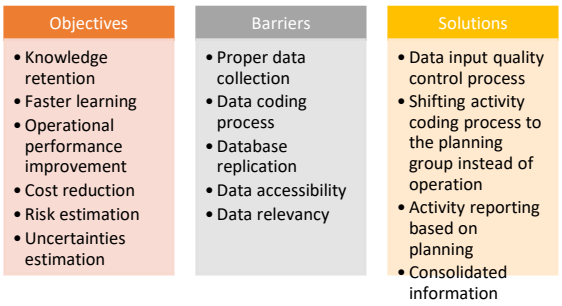


Figure 7. Barriers and potential solution to take fully advantages of historical drilling activity data (modified from Nakagawa et al., 2005).

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 socialize the significance of proper drilling activity report throughout the organization.

CASE STUDY

Problem

A geothermal company in Indonesia has no database of their previous drilling operation. The legacy data available are just reports 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 next drilling campaign for power plant expansion. The inconsistent and unstructured report make it very difficult to do drilling performance analysis.

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 12 shows the 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 13 shows the data management flowchart for company's legacy data.

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 8:

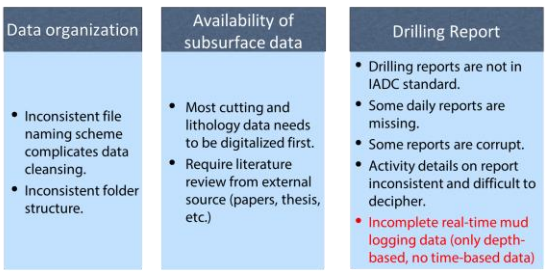


Figure 8.Challenges faced during data management process.

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 is shown in Figure 14. Note that it is practically not possible to be done without data cleansing and establishing uniform activity coding process first.

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 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 fit-to-purpose business intelligence process to extract the critical information required for future drilling campaign decision making.
- Assess the activity code to ensure that it is already 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 database.
- QA/QC all drilling report immediately prior to inputting to database to ensure accuracy and reliability.

SUMMARY AND CONCLUSIONS

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 database.
- 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.

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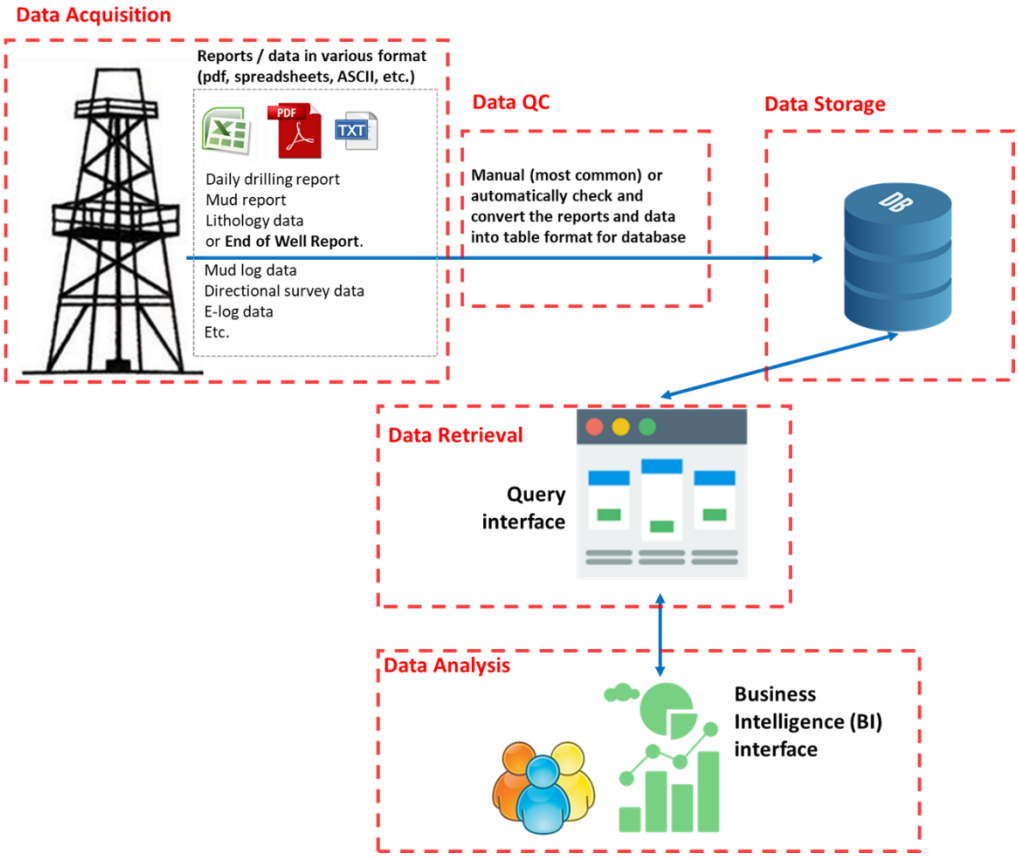


Figure 9. Steps of drilling data management. Modified from Damski (2014)

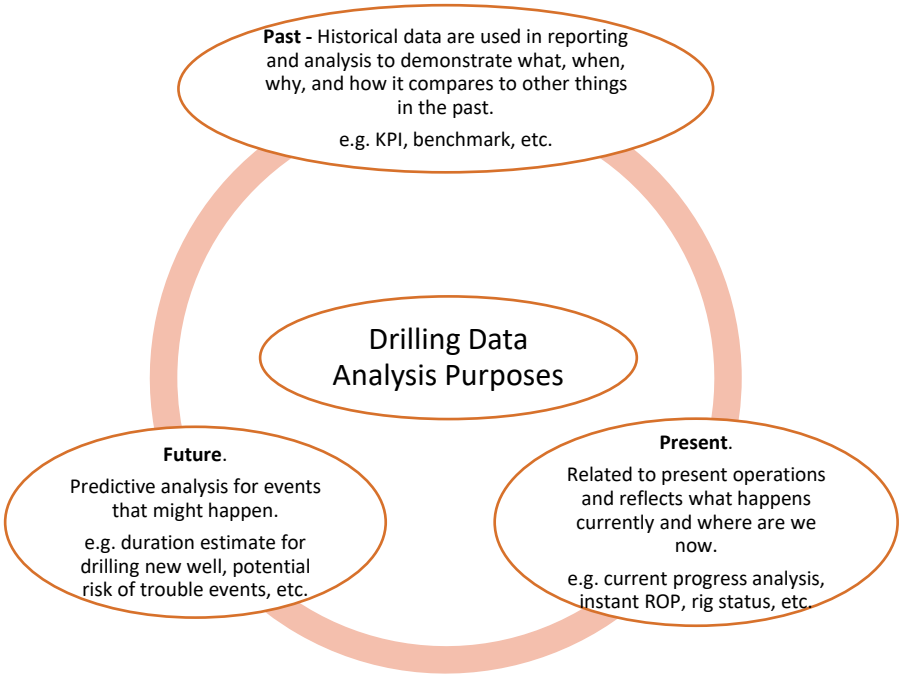


Figure 10. Basic purposes of drilling data analysis.



Figure 11. 10 steps drilling analysis flowchart (Iyoho, Millheim, et al. 2004).

DAILY DRILLING REPORT

FIELD	WELL 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"/14.mNO/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	WOB 1000 lb	TEETH I	O	D	L	B	G	O	R	REMARKS
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

MW (ppg)	RHEOLOGY YIS	PV	YP	GELS	WATER LOSS API	CAKE	HTHP	MUD CHECK TIME	DEPTH	SOURCE	MUD TYPE	MUD COST DAILY	CUMM
8.60	42	12	16	6/13	NC	N/A	N/A	24:00	108	PIT	Gel/Benex	$1,102	$6,744

VOLUME ANALYSIS % WATER	SALT	OIL	LGS	HGS	SAND	DISSOLVED IONS Ca ++	Cl-	SO3=	Temp (deg C) In	Out	ALKALINITY 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	2	LINER (in)	SL (in)	FLOW (gpm)	PRES (psi)	A. V. (fpm) DP	DC	C. V. (fpm) DP	DC	JET V. fps	BIT P. LOSS (psi)	(%)	IMP. FORCE	HSI	SCR DATA 20	30	50
RR 1	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			
2																		

DRILLING INFORMATION

STRING WEIGHT (lbs K) UP	DOWN	ROTATING	TORQUE ON BTM	OFF	BGG	CONN	TRIP	GAS (units) MAX	DEPTH	ROP's (m/hr) MAX	MIN	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*	*Actual*	
Target TVD	*2460 m*	*Direction*	*N 85° E*
Target Vertical Section	*1000 m*	*Total Depth = 2753 m / 2474.5 m TVD / -557.5 msl*	
Target Inclination	*30°*	*Max. Incl.*	*36°*
Target KOP	*600 m*	*KOP*	*600 m*

PLAN Vert.Sec. (m)	TVD (m)	East (m)	North (m)
0	0	0	0
0	100	0	0
0	200	0	0
0	300	0	0
0	400	0	0
0	500	0	0
0	600	0	0
1	630	1	0
2	600	2	0
5	690	5	1
8	720	8	1
13	749	13	2
19	779	19	3
25	808	25	4
33	837	33	6
37	850	37	6
42	866	41	7
52	894	51	9
63	922	62	11

ACTUAL TMD (m)	Inc (deg)	Azi N...E	Vert.Sec. (m)	TVD (m)	Coordinates E(+)/W(-)	N(+)/S(-)
0	0	0	0	0	0	0
505	2.5	315	-6.3	504.8	-7.78	7.8
534	2.6	314.8	-7.04	533.8	-8.69	8.7
562	2.2	335.9	-7.54	561.79	-9.36	9.65
591	2.4	21.9	-7.36	590.77	-9.36	10.72
620	4	55	-6.12	619.72	-8.3	11.87
648	5.6	66.6	-3.9	647.62	-6.25	12.97
677	6.7	79.7	-0.83	676.46	-3.29	13.84
706	8.7	79.9	3.05	705.19	0.54	14.52
735	10.5	78.5	7.89	733.79	5.29	15.43
764	12.5	78.1	13.66	762.2	10.95	16.61
792	14.2	78.2	20.13	789.45	17.27	17.94
821	16.1	79.9	27.7	817.44	24.7	19.37
850	18.1	80.6	36.23	845.15	33.12	20.81
879	19.5	80.6	45.57	872.6	42.34	22.34
908	22.1	80.6	55.87	899.71	52.5	24.02
937	24.6	80.6	67.36	926.34	63.84	25.89
973	23.5	82	82.03	959.21	78.34	28.12
1020	25	82	101.32	1002.06	97.45	30.8

HCE-7B

Run No.	Bit No	Size	Make	Type	IADC	S/N	Depth In (m)	Hours	Meter	ROP	WOB	RPM	Nozzle 1	2	3	IADC Dull Grade I	O	D	L	B	G	O	R
1	RR1	26"	HTC	R2	1-3-1	H47BC	14	15.5	81	5.23	40-45	70	23	23	23	3		WT	A	E	1	NO	BHA
								Drillout cement 24 to 29, 29 to 34 (1.5 hours)															
2	RR2	26"	HTC	ATXM22	5-1-5	D53CG	95	20.5	77	2.52	40	90	17	17	18	3		WT	A	E	1	NO	HP
3	2	26"	SEC	S224	5-1-5	7170745	172	60.5	243	4.01	10-20	1470	20	20	20	2		FC	A	G	1	NO	TD
4	RR4	17-1/2"	HTC	J3	1-3-1	T79PD	464	12	24	2.17	15-20	60-70	20	20	20	4		WT	A	F	I	NO	PR
5	5	17-1/2"	SEC	S316J	4-1-5	7174611	495	2.9	55	2.75	20	90-100	18	18	18	3		WT	A	E	I	NO	BHA
6	6	17-1/2"	HTC	HA22		H42CH	550	60.5	494	5.98	30-50	60	20	20	20	2		FC	O	F	I	BT	BHA
7	7	17-1/2"	SEC	S231	4-3-5	7170741	664	60.5	316	4.92	40-50	100	18	18	18	2		WT	O	E	I	NO	BHA
8	8	17-1/2"	HTC	GTX1D	4-3-5	GH12E	1273	22.5	74	3.29	35-40	65	22	22	22	2		NO	A	E	I	NO	BHA
9	9	17-1/2"	HTC	GTX1D	4-3-5	GH02E	1347	37	128	3.45	30-40	100	20	20	20	2		NO	A	E	I	NO	TD
10	RR10	17-1/2"	HTC	J3	1-3-1	T79PD	DOC(341~684m(0.5 hrs),395~402.5m(2.5 hrs))					60-100	20	20	20	Drillout cement (after trip sequence)							
							396	3.5	7.5	2.14	5-10	60-100	20	20	20	Drillout cement (after 2nd sequence)							
11	RR11	12-1/4"	HTC	ATJ11	4-1-7	D10DL	404	4	4		10	60-90	18	18	18	Drillout cement, collar, shoe of 13-3/4" csg							
							1402	6.5	4.0	1.88	10	60-90	18	18	18	3	3	BT	M-N	F	2	NO	BHA
12	12	12-1/4"	HTC	J11	4-1-7	D10CR	1406	2.5	220	5.28	20	90-120	18	18	18	3	3	BT	A	F	1	NO	BHA
13	13	12 1/4	Varel	ETD91	5-1-7	100401	1724	17	88	4.71	25	90-100	20	20	20	3	3	WT	A	F	2	CT	PN
14	14	12 1/4	Reed	EHP50AD	5-3-7	CB2595	1804	14	29	2.07	20-25	77	20	20	20	7	7	WT	A	F	2	CT	PR
15	15	12 1/4	HTC	X30SD	5-4-7	H04JH	1833	12	34	2.83	25-30	100	20	20	20	7	7	FC	A	F	1	WT	PR
16	16	12 1/4	SEC	S316F	5-3-7	T19964	1867			Back Reaming			20	20	20	3	5	PN	A	F	16	BT	HP
17	RR17	12 1/4	Reed	EHP50AD	5-3-7	SH2579				Work & Ream (1867~1914m (24 hr)			20	20	20	8	7	BT	A	F	16	WT	TD
18	RR18	12 1/4	SEC	S-3-SJ	1-1-1	107X13				Work & Ream (1471~1518 m (5.5 hr)			Open										
19	19	12 1/4	Varel	ETD91PH	5-1-7	101470				Drill Out Cement (1742.5 to 1802 hr 15 hr			20	20	20	2	3	BT	G	1	1/4	PR/LT	PR
20	19RR	12 1/4	SEC	S-3-SJ	1-1-1	107X13				DOC (1748.2~1846m (15hr), 1920~1930m (10hr))			22	22	22	1	1	CT	A	1	1	FC	BF
21	RR20	12 1/4	SEC	S316FD	5-1-7	T17439				DOC (1730~1836.5 hr, 1922~1946.5 hr			16	16	16	3	2	WT	A	F	4	No	BF

Figure 12. Example of legacy drilling report (daily drilling report, survey, and bit performance)

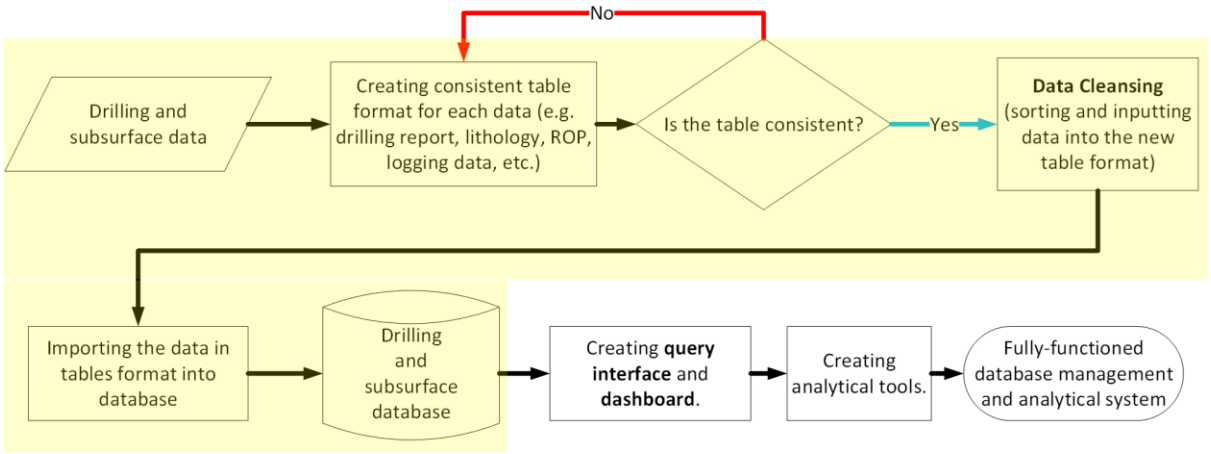


Figure 13. Data management flowchart. Current progress is highlighted in yellow.

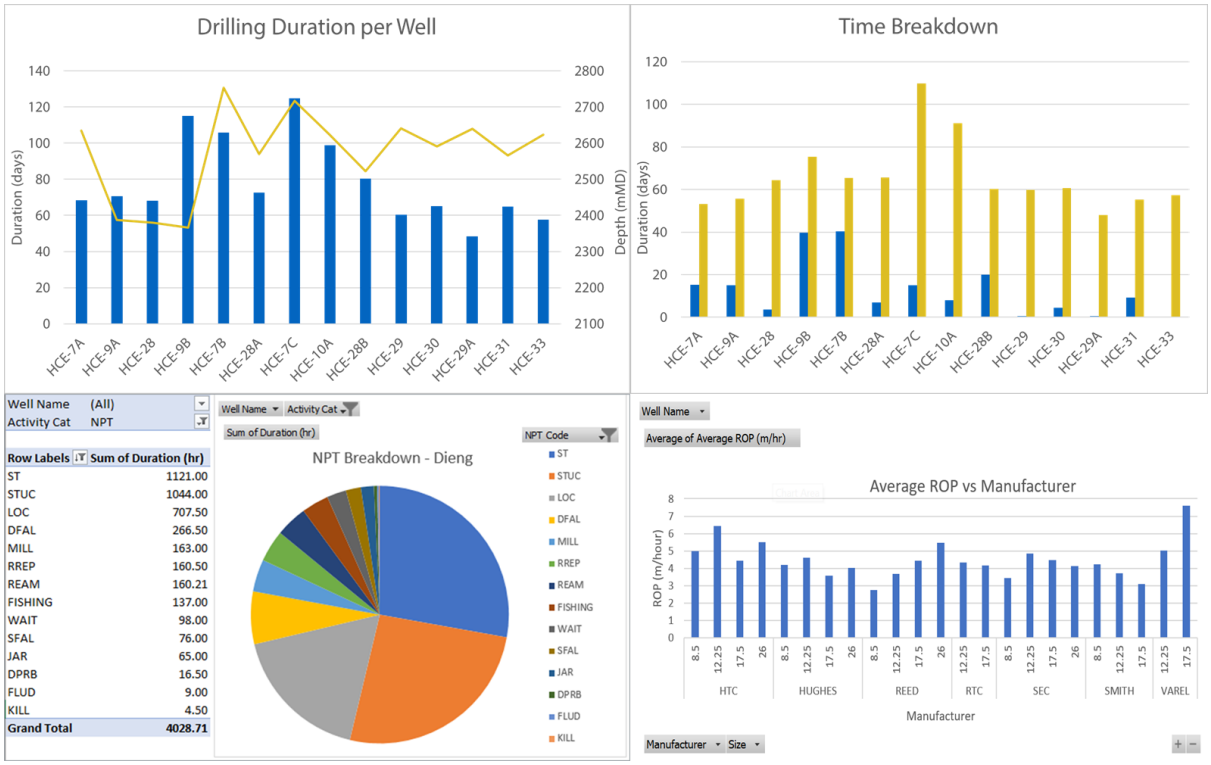


Figure 14. Several informations that can be extracted after data cleansing process on the legacy data.