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A New Approach to Risk Assessment in Well Planning and Scoping

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Abstract

With typical non-productive time of 10-30%, today's industry is effectively throwing money into holes in the ground. In hindsight, we are often able to see that the causes of non-productive time could have been predicted and subsequently mitigated had a more effective risk assessment and management process been in place in the well scoping and planning phases.

All too commonly, today's approaches to risk assessment are haphazard and dependent upon the intuition and experience of the staff making the assessment. In addition, the fact that fewer engineers are drilling more wells, results in less time being available to proactively mitigate risk. Any approach to improve on the current environment must therefore address the need for consistency, objectivity and speed.

This paper presents the results of a recent industry survey conducted by Schlumberger Information Solutions into current risk assessment practices by a wide range of operators and drilling contractors. It then discusses a new and novel approach to assessing risk in the well scoping and planning phases. This approach provides an objective and consistent set of risk indicators that are closely coupled with engineering and facilitates an understanding of risk in terms of financial exposure. Finally, this paper details a case study that demonstrates the potential benefits that can be achieved by adopting these techniques.

Introduction

Despite the wide variety of tools available to help us plan and drill wells, we all too often fail to meet one of the most important criteria for determining the success of our efforts – coming in on or under budget. A survey by Schlumberger Information Solutions indicates that more than 14% of wells drilled require a supplemental AFE because of drilling cost overruns.

With more than 40,000 wells drilled and/or completed in the United States in 2004 at a cost of almost $45 billion [1] considerable amounts of capital are being used inefficiently. Drilling cost overruns have a serious negative impact not only on the economics of an individual well, but on our organizations as a whole, increasing finding and delivery costs and reducing stakeholder confidence in our abilities. Some of the causes of cost overruns can typically be classified as resulting from [2]:

- under-estimation of cost;
- kicks;
- losses;
- stuck pipe; and
- mechanical issues.

With the clarity of hindsight we can see that many of the causes of cost overruns could and perhaps should have been anticipated. Given that methods and methodologies that could help us exist, why don't we see and mitigate these problems in advance? In *The Knowing-Doing Gap* [3], Pfeffer and Sutton give several reasons why companies fail to turn knowledge into action, which can be summarized as:

- all talk and no action;
- we've always done it this way;
- fear of failure, redundancy and retribution;
- measuring the wrong things or too complex a measuring system; and
- internal competition and rivalries.

Can we improve on our ability to anticipate and act on the causes of cost overruns? Obviously the answer must be yes. Since we can see the causes in hindsight, we are gaining knowledge into the possibility of these causes in the future. All that is needed is the implementation of effective methods and methodologies and to seek to overcome the problems of the "knowing-doing gap".

One technique that has had success in managing drilling costs is risk management. Today, drilling risk management has typically focused on real-time [4], HSE [5,6] or in AFE generation [7,8], and little if anything exists that relates to integrated engineering and cost/risk analysis in the planning and scoping phases of well construction. This work illustrates in three ways how risk assessment improves drilling success:

- analysis of an industry survey regarding risk;
- presenting a workflow using a new tool for risk analysis; and
- a case study showing how this workflow improved results.

The Survey – The survey interviewed 67 managers and executives representing 61 companies, including operators ranging from small independents to super-majors and several drilling contractors. These companies represent 18% of all the wells drilling in the United States in 2004. The questions and results of the survey can be found in the appendices, while in this paper we shall focus on some of the more interesting findings and how these demonstrate certain concepts that improve our probability of success.

The Workflow – If we consider the ability to influence the outcome of a well in a classic "pyramid" (fig. 1) then we clearly see that we need to move the risk management process into the earlier stages of identification and refinement (also known as scoping) and planning. Is this reasonable? Yes, it's intuitively obvious that the earlier we are in the engineering cycle the more we can influence the eventual outcome.

Fig. 1 – Ability to influence outcome

The workflow proposed in this paper is based upon a tool described in [9]. Several of the key features of this workflow are:

- integrated engineering;
- risk analysis;
- probabilistic time and cost; and
- ability to integrate with other decision analysis tools.

This approach allows us to move critical basis of design decisions to earlier stages of the well construction process and to solve these decisions in an iterative fashion, thereby maximizing the cost/risk/benefit solution.

The Case Study – The case study describes the challenges faced by Century Exploration New Orleans, Inc. and presents information on how the workflow is allowing Century to focus on achieving tighter AFE forecasts.

Risk Management

Before presenting the results of our analysis of the industry survey, let us first briefly review the concepts of risk management. In our discussion of risk, we will use the standard terminology for risk management as set out in [10]. Risk management is the process in which organizations address the risks of each activity in which they participate [11].

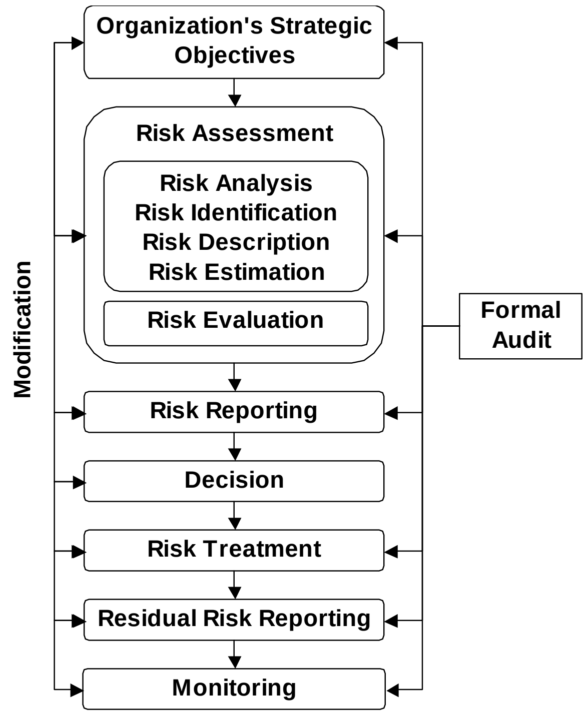

Fig. 2 – The Risk Management Process

Figure 2 shows an overview of the risk management process [11]. The workflow to be presented here focuses primarily on the risk assessment step and so, therefore, will this discussion. Risk assessment, as defined by [10,11], consists of risk analysis and risk evaluation.

Risk Analysis – Risk analysis, as Mian [12] describes it, "is any form of analysis that studies and attempts to quantify risks associated with a particular uncertain problem". As mentioned previously, most current risk analysis is focused on real-time operations, HSE or on AFE generation. When we look at the individual components of risk analysis, we will see that risk analysis is not simply about Monte-Carlo or Latin Hypercube simulations of time and cost, nor is it a process only for use during actual drilling operations. *A Risk Management Standard* reinforces this view when it states "It is important to incorporate risk management at the conceptual stage of projects as well as throughout the life of a specific project". Risk analysis itself consists of three phases: identification, description and estimation.

Risk Identification – In the process of risk identification, we seek to identify those areas in which we are subject to uncertainty. Risk can be considered the sum of a hazard and an activity. If the hazard does not exist or the activity is not undertaken, then the risk does not exist for us. A hazard in this context is any object, condition or effect that has the potential to cause harm. In risk identification we are concerned with identifying the activities we will undertake and the hazards associated with that activity.

Risk identification needs to be consistent and methodical, with communication between all relevant parties. When starting from scratch, this process can be extremely laborious and time consuming. One way to assist in this is to use a template, then examine the specific situation to augment the template with any risks that are not already identified.

Risk Description – Risk description involves presenting the previously identified risks in a structured way. This description should include, but is not limited to:

- name of risk;
- type of risk;
- description of risk;
- risk prevention plans; and
- risk mitigation plans.

It is important to differentiate between risk prevention and risk mitigation. If we are able to lower the probability of occurrence of a risk then we are seeking to prevent the risk occurring, while risk mitigation seeks to reduce the severity of the risk or to put in place plans to deal with the risk if it occurs. The purpose of this stage is to allow us to begin to prioritize those risks that will need an increased level of analysis, to ensure that we understand the nature of the risks and to help efficiently communicate them.

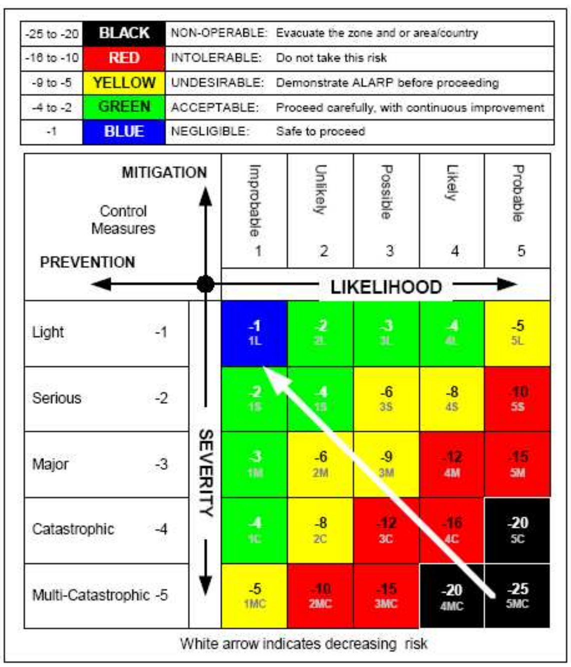

Fig. 3 – Example of a Qualitative Risk Estimation Matrix.

Risk Estimation – At this stage, we assign both the probability and the consequences of each identified and described risk. Risk probability and severity can be estimated in qualitative or quantitative terms or a combination of both. Qualitative techniques involve assigning the probability and severity of the risk in terms like low, medium or high as in figure 3, while quantitative techniques assign these as in terms of measure properties such as an 80% chance of a $2MM loss. Particular care must be taken when trying to differentiate between qualitative and quantitative risk since it is possible to present a qualitative risk as a percentage and value but from an arbitrary scale. For this reason, it is very important that each risk be defined to include the estimation type in the risk description process.

Risk Evaluation – Having completed the risk analysis, the final steps of risk assessment are to evaluate the results of the analysis and compare that with organizational criteria for those risks. We will at this point make decisions about whether to accept, prevent or mitigate the identified risks.

Analysis of the Survey

Having reviewed risk management and specifically risk assessment we ask ourselves, "What are we currently doing in the industry today?" Seeking to answer this question, Schlumberger Information Solutions commissioned a telephone survey of managers and executives of 59 operator and 2 drilling contractors, a total of 61 companies. In a detailed analysis of the survey results, several important observations appear:

- few companies are able to iterate cost/risk/benefits;
- combining qualitative and quantitative risk estimation methodologies improves results; and
- lead time impacts our results.

Ability to Iterate Solutions – Only 29% of companies stated that they were able to quickly test multiple scenarios to assess cost/risk benefits. When we look at the companies that are able to quickly test multiple scenarios, it becomes apparent that this is a very valuable process; almost 56% of companies who do this have only 10% of wells requiring a supplemental AFE.

As discussed in [13,14] iterating through drilling scenarios using computer simulation allows us to gain "artificial experience", which in turn improves the learning rate of the learning curve. Clearly, the survey shows that today most experience is still being gained through the bit and not the mouse; altogether a significantly more expensive process and one that inhibits step-changes in improvement.

Step-changes in the learning curve are almost always the result of doing something new in the drilling campaign [15]. It is more correct to say that rather than step changing the existing curve, we are creating a new learning curve with a lower technical limit. The ability to introduce these new ways of drilling the well in a computer simulation means that we learn what impact we could have on the technical limit without jeopardizing performance in the real world.

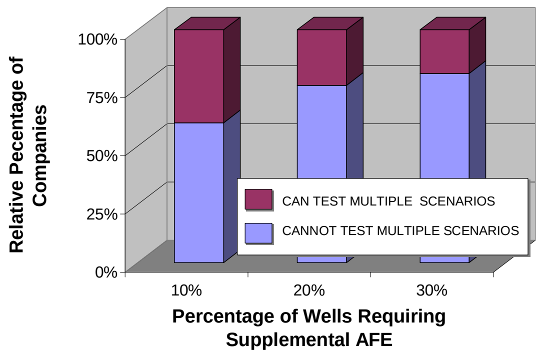

Fig. 4 – Comparison of ability to iterate solutions against supplemental AFE rates.

The ability to iterate different variations on the well is one of the most significant factors in reducing risk, not only in the sense of learning how to prevent and mitigate existing risk, but also in the sense that we can safely test new ideas without any potentially negative side effects.

***Qualitative or Quantitative Methodology* –** When we look at the type of risk methodologies employed, we see that almost 62% of companies use either qualitative or quantitative approaches. Of companies using only qualitative methodologies, only 31% achieve supplemental AFE rates of 1 in 10 wells. For companies employing only quantitative methods, only 20% achieve this same success rate. Clearly then, the type of methodology does seem to impact the success rate. Does combining these methods yield any improvement? Yes, it does; 52% of companies who use a combination of qualitative and quantitative risk assessment have supplemental AFE rates of 1 in 10 wells.

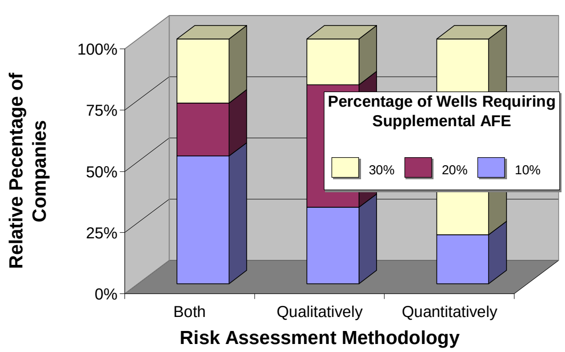

Fig. 5 – Comparison of results of differing risk estimation types

At face value, we would have expected that quantitative methods by themselves would have performed better than qualitative ones. Why then do they seem to fail? It can be conjectured that one reason is that quantitative methods do not require the engineer to examine the risks in sufficient detail; after all, if I measured it then it must be correct! Quantification also tends to use large amounts of data and data quality may also play a significant role. A more subtle effect of this data is likely to be overconfidence in the result [16,17].

Combining the techniques brings synergy to the risk assessment process, capturing the best elements of both. When using a combined approach, it is common for one or more individuals to examine the risks independently in both a qualitative and quantitative manner and then for the team to come together to review the results. The concept of “working apart and then discussing as a group” is often referred to as a “nominal group” in psychology and has proven to improve performance in tasks where overconfidence can be found [18]. Additionally, human overconfidence results in too narrow a confidence range and essentially invalid results.

***Lead Time* –** The time available to an engineer from target identification to the spudding of the well plays a significant role in cost overrun rates. Of all the wells that had a 30% probability of a supplemental AFE, 95% were planned in 1 to 3 months. Additionally, wells planned in the 1 to 3 month time frame also exhibit the largest proportion of 30% supplemental AFE rates.

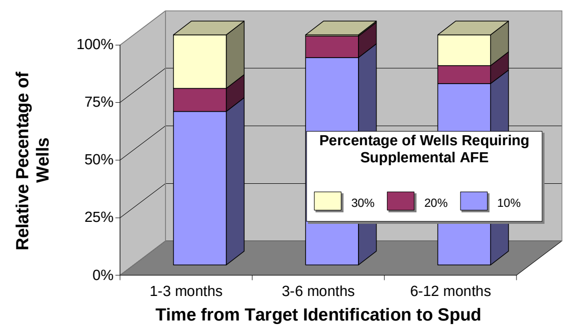

Fig. 6 – Impact of time from target identification to spudding the well

Although the survey does not reveal exactly why this shorter planning cycle should have this impact, it is a logical expectation. Disturbingly when we consider that many of the wells planned in this timeframe are “post holes” it tends to suggest that we cannot treat these as simple or routine. Furthermore, it is appropriate to suggest that the short planning cycle means that little if any iteration is being conducted.

Unexpectedly, the survey also reveals an increase in the number of wells having a potential 30% supplemental AFE rate at the longest lead-time. Again we can only speculate as to the reason for this, but several suggestions have been put forward: loss of knowledge (key personnel changing positions), loss of continuity (breaks in the planning cycle) and/or that these are technically challenging wells (deepwater, HPHT).

Introducing the Workflow

As mentioned previously, tools exist today that could help reduce unanticipated drilling costs. These tools fall into two distinct classes: spreadsheet based and commercial off the shelf software. Before we describe the tool that is the core of our workflow, we will first compare these two classes of tools.

What's Wrong With My Spreadsheet? – Many individuals and organizations have developed a variety of spreadsheets for risk assessment with varying degrees of sophistication. In addition, there are several add-ins available for popular spreadsheet applications that provide sophisticated probability distributions and Monte-Carlo simulation. With the proliferation of such spreadsheets and tools, what then is the problem with using spreadsheets?

Spreadsheets have been implicated in many serious incidents, including a recent $1 billion error in the financial statement of a major financial institution [19]. Indeed, looking at the results of several studies shows that between 24% and 91% of spreadsheets contain some form of error [20]. This is made worse by the fact that humans typically make entry errors at a rate of between 0.5% and 5%.

Before you say, "that can't happen to us", one study asked spreadsheet users if they believed their spreadsheet had errors, 18% said yes while the actual spreadsheets with errors was 81%. As mentioned before [16-18] this overconfidence is an inherent human trait. Errors occur for many reasons, including but not limited to spreadsheets are often unprotected, few have documentation, lack of revision control, entry, logic and omission errors and lack of systematic checks.

Commercial Tools **–** Commercial off the shelf tools avoid many of the errors found in spreadsheets. For example, commercial software is normally in the form of compiled code and so cannot be modified by the end user. Additionally, due to more diverse usage and rigorous testing, errors in commercial applications are generally picked up and corrected more quickly than in spreadsheets.

A New Workflow – The workflow is based upon software described in [9] which in turn was derived from the work presented in [21]. This tool provides us with a unique integrated approach to engineering and risk assessment. Each step in the workflow logically provides inputs to each subsequent step. Additionally, this workflow allows us to iterate these engineering results to refine the answers. For example, it is common to use kick tolerance to determine the casing points, but to determine kick tolerance we need to know the annular configuration, mud weight and properties – all of which are dependent upon our casing point selection. Figure 7 shows the steps within one of the available workflows. A second, more advanced workflow adds an additional step to calculate wellbore stability, but at the expense of significantly more detailed earth properties.

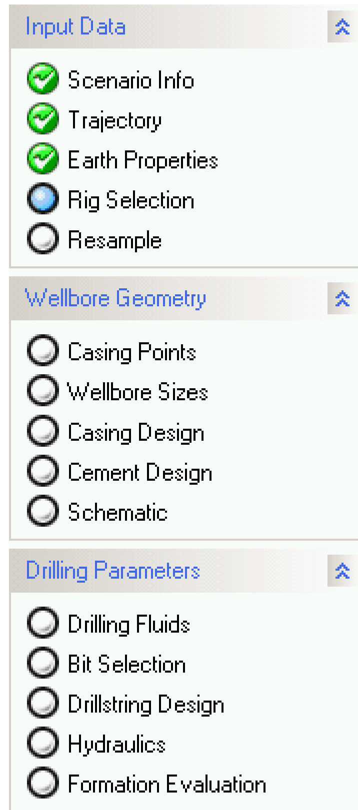

Fig. 7 – Workflow steps

Clearly, this requires considerable amounts of data to achieve. The user is isolated from this by the software through the use of configurations. Although it is possible to use a generic configuration, increased accuracy is achieved through refinement. The software permits the use of differing configurations that can be created to be dependent upon factors such as geographical location, well type or stage within the learning curve. Table 1 shows a portion of one of the many pieces of information, rig properties, which constitute the configuration.

Rig Catalog				
Rig Type	Air Gap	Motion Compensator rating	Pipe Handling	BOP Location
Rig SubType	Max Water Depth	Top Drive	Mud Pumps	BOP Size
Rig Description	Max Depth	Top Drive Max RPM	Number of Mud Pumps	Max BOP Pressure
Rig Contractor	Set back length	Top Drive Max Torque	Max Pump pressure	Riser ID
Rig Name	Liquid Mud Capacity	Rotary Table ID	Max Flow Rate	Day Rate
Rig Design	Derrick Rating	Rotary Table Max RPM	Surface Equipment Length	Spread Rate
Station Keeping	Drawworks Rating	Rotary Table Max Torque	Surface Equipment ID	Completion Spread Rate

Table 1 – An example of information within the configuration

The configuration also includes information such as casing weight, grade, connections, mud types, bits and drilling parameters. It is important to maintain this configuration information as part of the knowledge management/post well analysis process. The drilling analysis methodology [22,23] provides an ideal opportunity to make these updates, as well as to refine the results of this workflow into a finalized well plan.

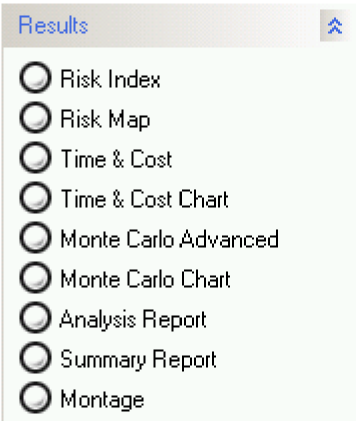

Fig. 8 – Results

The whole purpose of completing the engineering steps is to be able to use this information to base our results on true engineering. The risk index, figure 9, provides us with a measured depth based presentation of the severity of 57 hazards that are subsequently weighted and combined into the risks of gains, losses, stuck and mechanical. The hazards are qualitatively measured as low, medium or high by comparing the calculation from the engineering design with user cutoffs from within the configuration. This technique provides comprehensive, objective and consistent evaluation of the planned well.

Fig. 9 – Risk identification

These hazards are combined into risks for the whole well. In this way, the potential risk can be plotted with the actual risk and the likelihood suggested. To clarify this, consider the following – a casing risk is defined within a configuration as consisting of the following hazards:

- dogleg severity;
- well horizontal displacement;
- geothermal temperature;
- hole section length;
- casing design factors;
- casing weight;
- weight of casing string relative to rig lifting capacity;
- casing wear;
- number of casings per hole section;
- top of cement; and
- flow rate relative to pump capacity.

The potential risk is a function of the individual hazard levels when no mitigation or prevention is undertaken, while actual risk is the calculated levels of each hazard from the integrated well design. Understanding these risks allows us to work back through the engineering to see what can be done to prevent the hazards. This is often a circular argument as, for example, increasing mud weight lowers the chance of a kick but increases the chance of losses.

Prevention cannot be realistically considered without examining the cost impact of such prevention. In the workflow, the software uses a quantitative approach to assessing the risk associated with time and cost. Using the rig type, number of hole sections, hole sizes, bit parameters and other information from the engineering stage we are able to generate a detailed activity plan. This activity plan is then passed through either standard Monte-Carlo simulation with each activity being perfectly correlated, or through a more advanced Monte-Carlo simulation where a correlation matrix from the configuration is used.

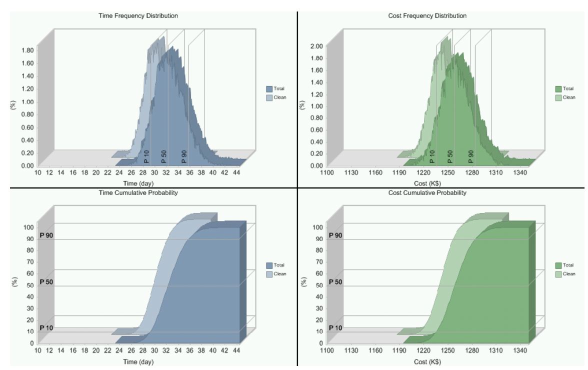

Fig. 10 – Monte-Carlo time and cost

The user combines this time and cost information along with the hazard identification to assess the cost/risk benefit of preventative measures. Any residual risk would then have mitigation plans put in place. It is important when using the results of the time and cost simulation to remember that the P50 value simply means that drilling this well an infinite number of times, the time and cost of the well would be at below this level 50% of the time and at or above it the remaining times. The P50 time and cost may not be the appropriate value to use for assessing the economic viability of the well or for the generation of the AFE [24].

Case Study

Century Exploration New Orleans, Inc. has gained extensive experience drilling in the Breton Sound area off the coast of eastern Louisiana. Wells have been drilled in both state and federal waters with water depths ranging from 8 to 50 feet. The geology of this region is fairly consistent, with a pressure transition range from 9500 to 11000 feet and mud weight from 13.0 to 17.8 ppg. A variety of rig types have been utilized in drilling these wells, including barges, jack-ups and semi-submersibles. Wells range in depth from 10000 to 17500 feet and can be classified as wildcats due to the lack of or proximity of offset control.

This drilling experience has occurred during an increasing cost environment. Rig, commodity and service costs have increased in all areas with OCTG and rig rates leading the way.

While drilling operations have been relatively trouble free, cost have varied between ± 20% of AFE amounts. Historically, approximately 30% of wells have required a supplemental AFE, with a supplemental AFE being required at 110% of the originally submitted AFE. The major factors influencing the well costs have been well configuration, lack of geological control, short planning cycles, weather and logistics. Another factor that leads to AFE underestimation is the fact that AFE estimates are typically generated 3 to 6 months ahead of the actual drilling of the well. As a result of time constraints and short planning cycle, AFE's were typically adjusted for increases in rig rate and tubular increases immediately prior to drilling the well. Other costs, such as commodity and service costs, were not captured and revised to a present day scenario.

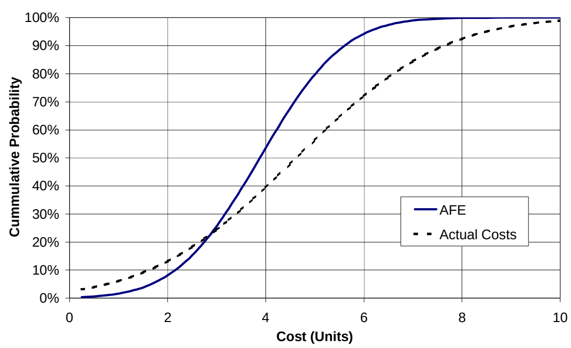

Fig. 11 – Historical cumulative cost probability distributions

Figure 11 shows one of the many of the challenges, overconfidence in the probability distribution, Century faced as a result of using subjective cost estimation, however due to Century's investment structure, it is critical that well costs are represented as accurately as possible. Investors typically want to know and plan for their maximum exposure, and as such there is not much tolerance for overspending an AFE. Management charged Century's drilling department with tightening the expenditure range from ± 20% to 0% to –10% of AFE. Figure 12 shows the cost of wells in 2002 and 2003 relative to the AFE. This chart shows that only 12.5% of these wells would meet the criteria set out for tighter AFE control.

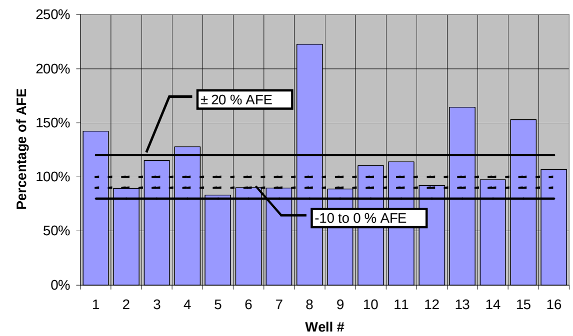

Fig. 12 – Actual costs as percentage of AFE

Previously, traditional spreadsheet risk assessment and cost generation tools involving qualitative methodologies had been used, but in order to meet the challenge of tighter expenditure ranges, it was felt that a new set of tools would be required. To that end Century chose the tool previously described in this paper. This was viewed as being able to remove the subjectivity from the cost estimating process and to provide an initial quick look at costs based on anticipated well design. It would also allow a last minute review prior to submitting AFE's for approval. This methodology also provided the flexibility to capture increasing rig, commodity and service costs.

Century Exploration New Orleans, Inc. recently drilled a 15000 feet well in the Breton Sound block 37 area. The surveyed water depth was 15 feet and the original AFE of $4.4 million to drill and evaluate the well was generated using conventional, subjective cost estimation techniques. As the rig approached the proposed location, water depth varied and the rig was subsequently grounded on a shoal. This resulted in a final rig location approximately 250 feet northwest of the proposed location. Failure to reach the planned surface location necessitated a directional correction run in the latter stages of the well to place the well path at the original intended bottom hole location. At this point, the AFE was revised to $4.93 million, again using conventional techniques, to reflect the additional time and expense of the correction run.

Evaluating the well with the workflow resulted in a P10 estimate of $4.4 million, a P50 of $6.0 million and a P90 of $7.75 million. This illustrates that the initial conventional estimate and subsequent revised AFE where on the low end of the cost distribution range. In addition, the workflow indicated a risk of both gains and losses around the intermediate casing shoe at 10476 feet and lower penetration rates in the deeper hole sections.

The final field estimated drilling costs for this well were $6.15 million. The main factors contributing to the cost overrun were a kick and subsequent lost circulation during kill operations at the intermediate casing shoe and significantly lower penetration rates than previously anticipated in the deeper 8 ½” and 6” hole sections. This placed the well at 140% of the conventionally generated AFE, significantly more than either the general ± 20% or the goal 0% to –10% ranges, although even the P50 cost estimate still results in a 3% cost overrun.

Conclusions

This work has illustrated clear gaps in today’s implementation of risk assessment within the drilling industry and presented a workflow that seeks to address those gaps. It is apparent that more study is required in this area, in particular the authors suggest:

- clarification of why combining qualitative and quantitative risk assessment appears to yield better results; and
- a quantitative approach to understanding the impact of planning time on cost overruns.

The information presented here shows that cost overruns are relatively commonplace. These are becoming increasingly unacceptable in an economic environment recovering from recent financial scandals and where corporate governance is increasingly becoming part of everyone’s job function. In part these cost overruns are due to human psychology – our poor performance in judging accurate confidence intervals – and in part the fact that we often leave risk assessment until later in the drilling lifecycle.

Our research indicates that today we are still relying on subjective and/or error prone techniques for risk assessment and have not yet fully embracing the methodologies available to assist us in making more consistent and design based decisions.

By incorporating these new tools into our workflows today, we will benefit in the future by having a proven track record of successfully controlling our costs, giving us the competitive advantage required to attract investment.

Acknowledgements

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Nomenclature

AFE = *Authorization for Expenditure*
HPHT = *High Pressure, High Temperature*
HSE = *Health, Safety and Environment*
OCTG = *Oil Country Tubular Goods*

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Appendices

Survey Results

How many wells do you plan to drill this year?

Minimum	Maximum	Mean	Median	Mode	Standard Deviation
0	2000	107.4	30	20	279.4

How many engineers do you have?

Minimum	Maximum	Mean	Median	Mode	Standard Deviation
0	200	6.8	3	1	24.4

How satisfied are you with the process of planning a new well?

Very Satisfied	Satisfied	Needs Improvement
17	34	16

What is your average turnaround time from target identification, trajectory design to spud?

1 –3 months	3 – 6 months	6 – 12 months
46	14	6

How often do you have to create a supplemental AFE for drilling overruns?

10%	20%	30%
25	22	16

Do you currently quantify risk leading to the possibility of kicks, losses, stuck pipe or mechanical failure?

Yes	No
35	31

Do your engineers analyze drilling risks qualitatively or quantitatively?

Qualitatively	Quantitatively	Both
34	5	24

Do you have the ability to quickly test multiple scenarios to find the best risk/cost tradeoff?

Yes	No
21	45

How satisfied are you with the capabilities of your current applications for risk assessment and/or drilling cost estimating?

Very satisfied	Satisfied	Needs Improvement
4	45	16

Do you feel that your current tools and resources allow you to focus on process improvement?

Yes	No
35	28