

Deepwater Well Complexity – The New Domain

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Abstract

Many of the causal factors that led to the Macondo blowout may never be resolved. Thus, it is why it is even more incumbent on the industry to recognize where serious risks exist in complex well development and to design wells which deal with the uncertainties of the safe drilling margin to address these risks. The discussions herein indicate that in some categories of complex wells, wellbore stability events are as high as 10 % of the total deepwater well time and well control incidents over four times those of “normal” wells. . This indicates that serious risk mitigation is a significant issue in drilling complex wells. As a consequence, the industry needs to better assess risks and monitor well operations. It is imperative that the industry adopt standards which ensure process safety around design and execution to ensure safe and reliable deepwater operations.

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1.0 Forward

In light of the Macondo blowout and in order to ensure safer deepwater operations this paper suggests there is an industry need to better assess risks and monitor well operations in addition to standardizing the design of complex deepwater wells.

Examining the metrics of deepwater operations in the Gulf of Mexico indicates that there routinely have been difficulties with some categories of complex deepwater wells.

Given the severe consequences of failure the Deepwater Gulf of Mexico (GOM) industry should be guided by the principles established by Professor Andrew Hopkins wherein high-performing organizations that cannot suffer failures must fully exhibit “collective mindfulness,” of major failures in conducting their work.¹

The drilling culture that has been relatively successful in taking on new technical challenges and avoiding major incidents has historically accepted some level of failure that either time or cost can mitigate. As seen by the severe consequences of the Macondo incident the approach to drilling deepwater wells has to fundamentally change. Frequently culture is called “the way we work” and in that vein the current drilling culture is fundamentally flawed when we impose a zero failure approach.

It is further evident that in some categories of deepwater wells (Section 4.0), industry performance has become worse and the final proof is the Macondo catastrophe itself. It is clearly understood that there are many causal factors around this incident. Have wellbore instability incidents become so routine that they were actually deemed normal? Did this relax the Human Controllable Factors? Did this lead to unwise management decisions? Did this result in the lack of supervision and the failure to monitor the real time data? Some of these issues may never be resolved which is why it is even more incumbent on the industry to recognize where the problems exist and design wells which deal with the uncertainties of the safe drilling margin² and address these risks accordingly. It is fundamental to understand that uncertainties drive risk and the narrower the range of uncertainties in operations, the easier to manage the risk. Risk can never be eliminated, but it can be successfully managed.

The discussions herein indicate that in some categories of complex wells, wellbore stability events are as high as 10 % of the total deepwater well time. Blowout prevention equipment was never intended to become a routine execution tool and in some of the more complex deepwater wells, time spent on the BOP's has been increasing dramatically.

2.0 The Consequence Of Failure

The Macondo catastrophe clearly indicates the industry does not fully grasp the riskiness of Deepwater nor have we adequately estimated the consequence of failure.

One of the challenges of applying traditional static risk analysis to something as dynamic and uncertain as the deepwater subsurface environment and complex operations is the lack of truly statistical meaningful data. The industry cannot continue to accept any quantifiable risk in Deepwater (DW) as miniscule.

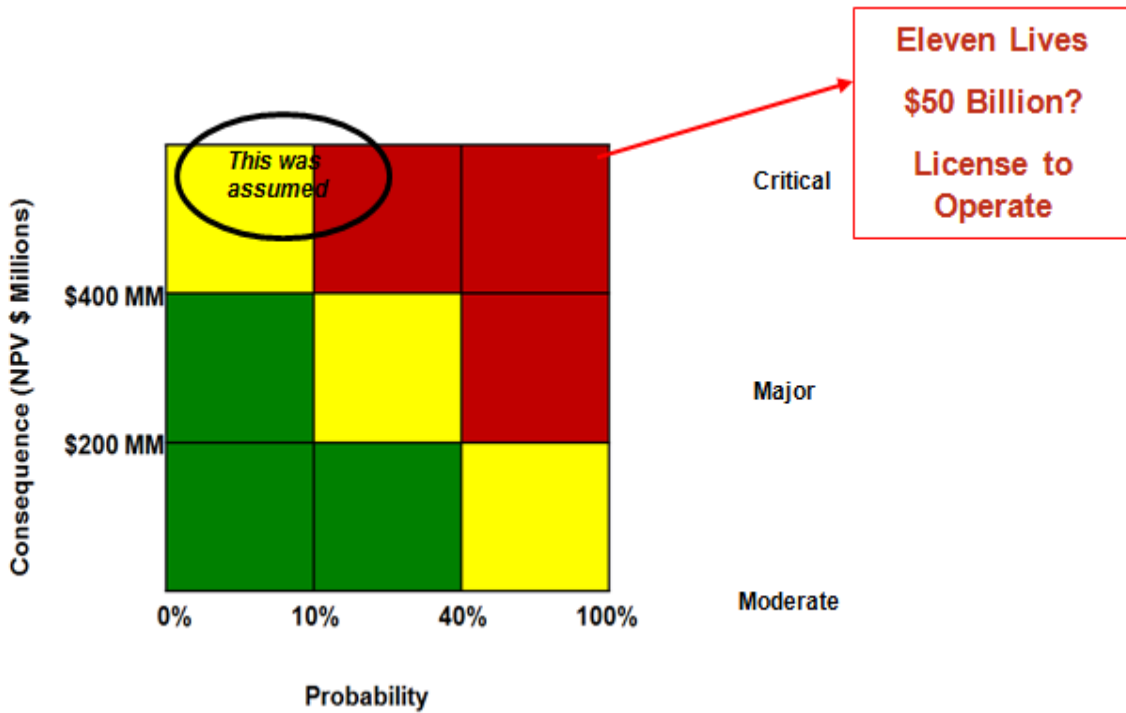


Figure 2.1 – Traditional Overview of GOM Deepwater Risk and Consequence.ⁱⁱⁱ

While it is debatable what the actual numerical value of the risk is for a major blowout in DW we have evidence it is not zero. Additionally the outcome of a full blow out, loss of rig and complete loss of well control for 87 days is a scenario no one saw as remotely possible. This appreciable risk and significant negative outcome is unacceptable and clear evidence for change.

People make rationale choices given their surroundings and perception of the risks and the possible personal consequences. With certainty, the BP employees and contractors involved did not intentionally underestimate the risk. However in hindsight there is absolute evidence many decisions were not consistent with the true risks and the potential consequences. We need no further evidence to support the need for major change.

Where does the industry begin to recognize the problem, risk and consequences – the metrics – the industries own measures of success - or failure?

3.0 The Macondo Incident And Organizational Issues

In order to think past the Macondo incident and restore confidence to the DW industry, we must consider the following: This new DW domain has no industry standards and yet is our most technically demanding.

The DW rig fleet has increased by 300 %. Has competency and reliability increased in the same manner?

ⁱⁱⁱ Kevin D. Lacy, “Restoring Integrity to the GOM Deepwater,” SPE Deepwater Drilling and Completions Conference, Presentation, Galveston, Texas, October 5-6, 2010.

There is persistently high Non-productive time in DW operations as further discussed in this paper.

- Are these challenges and warning signs being ignored?
- Why does the industry accept the current failure rate on BOP's and controls?

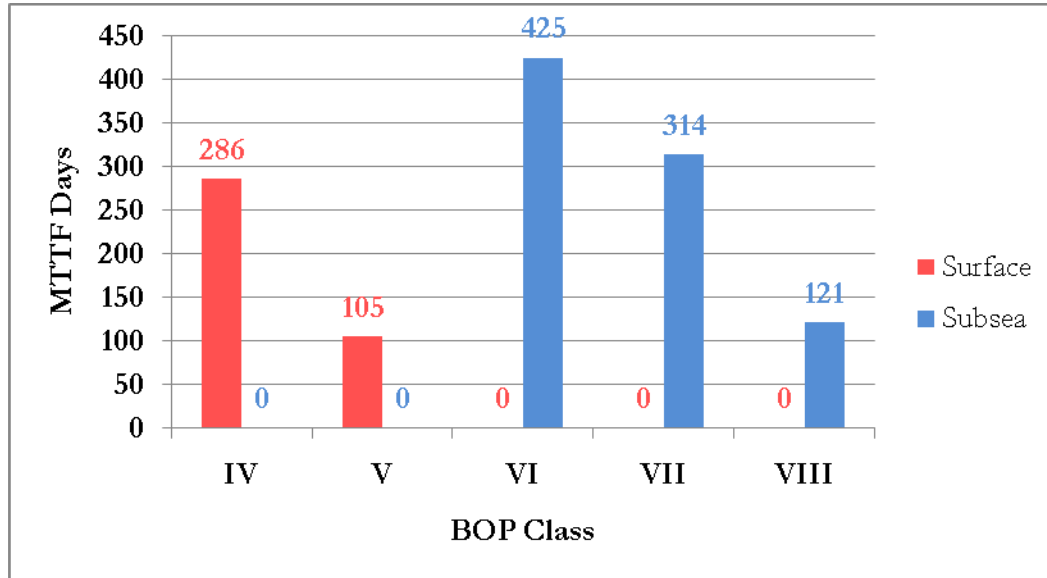


Figure 3.1 – MTTF by BOP Class.^{iv}

In 2008, several industry groups created a task force to define the work scope for a joint industry project to study BOP reliability experienced for wells drilled in the US Gulf of Mexico from 2004 to 2006. The high level result of the study indicated that even though improvements were noted over time, and that subsea systems actually had better failure rates than surface systems. Nonetheless the question must be asked and answered: Given the consequences of failure demonstrated by the Macondo incident, are the rates noted in Figure 3.1 – MTTF by BOP Class acceptable? There is also a degradation of failure rates by the more complex, deeper water systems as delineated by Class VIII systems: the most complex of deepwater systems.

Table 3.1 – BOP Systems Defined by Class.^v

Installation	Class	Annulars	Rams
Surface	IV	1	3
	V	1	4
Subsea	VI	2	4
	VII	1	6
	VII	2	5
	VIII	2	6

^{iv}: Jeff Sattler, “JIP study on BOP reliability 2004-2006: subsea control systems were most prone to failure,” Drilling Contractor, September 8, 2010, <http://drillingcontractor.org/jip-study-on-bop-reliability-2004-2006-subsea-control-systems-were-most-prone-to-failure-6875>.

^v Sattler, op. cit.

- Why are our critical systems so heavily people dependent?
- Can the industry really expect to be safe and successful with the current relationship model between:
 - Operators and Drilling Contractors?
 - The regulatory agencies being undermanned and technically thin in DW experience.?
 - Operators and other service providers?
 - Failing to recognize that the operator is in fact... the operator and fully accountable?

In regard to the regulatory agencies the relationship has now become very openly political and the “genie is out of the bottle” – it will become even more political and more prescriptive. That will be a major problem as the competency to develop a DW GOM standard does not reside within the reformed BOEMER. In fact it is already thin within Operator ranks and likely part of the root cause of the Macondo incident.

An excerpt from a portion of the BP program actually relies on default approvals, and this is not uncommon in GOM DW operations:

9.2.4 Surface Cement Plug

- 1. If cement job is not successful: (no returns or lift pressure seen).*
 - *Set wear bushing*
 - *Run IBC-CBL log*
 - *Wait on decision to do remedial work (MMS and BP)*
- 2. If cement job is successful (partial returns or lift pressure seen) or IBC/CBL log and required remedial work is completed.*
- 3. RIH to 8367' and displace to seawater:*
 - *Run 3-1/2" (1000'+) stinger x 5-1/2" DP to above the wellhead (no mule shoe I open ended pipe)*
 - *Ensure MMS Departure to set deeper plug is approved (if departure does not get approved, displacement @ 300' cement plug will be completed after LOS is set at 5800?)*
 - *Monitor well for 30 minutes to ensure no flow*
 - *Pull wear bushing if it was set*
- 4. Set a 300' cement plug from 8367' - 8067' (if approved)*
- 5. Wait on cement to set and tag top of cement with 15k down*
 - *Pump a nerf ball behind cement job*
- 6. POOH retrieve wear bushing*
- 7. Prepare to run lead impression tool and lockdown sleeve*

Note: Drilling program will be updated with actual plug depths if MMS departure is not approved.

Rev. H.

The justified motive of profits versus reliable safety standards are sometimes conflicting and a primary goal of regulations should be to enforce rigor to safety, reliability and standards. While it is commendable that operators address reliability and safety, the industry must realize “trust” is not the issue: cooperation with regulators and industry transparency to ensure a safe environment is.

The phrase “trust us” will not work and our multiple appearances in front of congressional and regulatory bodies have done little to improve our situation. All companies not just BP are no longer trusted.

The industry cannot expect to continue to make risk based decisions in DW involving well control and process safety by using traditional risk analysis and NPV or cost drivers. It should have never been that way to begin with and that is where company leadership must step up and demonstrate a new approach – in that regard, the industry has “blown it.”

Another issue which significantly impacts reliability is the natural conflicts of cost cutting and scheduling. Complex DW drilling operations must not be schedule driven.³ An excerpt from this reference:

From an organizational perspective, drilling management equals risk management. As Cunha has observed:⁴

“It is clear to me that drilling management is related closely to risk management”... and... “The correct assessment of all risks involved in drilling operations will provide better planning and will consequentially improve operational results”. Furthermore, “A proficient drilling–management process is now more important than ever. This process must permeate all phases of a project, from early planning to final execution. Risk assessment of all operations must become a routine”...

Indeed, risk assessment of all operations must become routine; however, it must also be performed in a mindful-manner – NOT as a matter of routine or with a “compliance-mentality.” Drilling performance and safety is a multidisciplinary responsibility. Managing risks begins with well planning and clearly stated objectives agreed to by all stakeholders and by setting forth clear lines of responsibility and accountability in the decision-making process.⁵

*.... It is important to fully realize how well-drilling objectives and their associated uncertainties are linked to safe drilling.... How the **Rig Schedule** plays into routinely ignoring warning signs and how risk-taking behavior can insidiously infect a risk-adverse goal. The symptoms of this infection of an otherwise healthy safety management system can lead to operator manipulation of both company design practices and also regulatory requirements and complacency. Schedule driven decisions create a dynamic characterized by a tendency to overlook or possibly ignore essential design requirements to ensure a safe drilling margin and properly manage **uncertainties and ancillary risks**. Like a virulent virus, as the contagion spreads, it can and has escalated into an unhealthy co-dependent relationship between operators and regulators, contaminating the intended system of checks and balances in favor of doing it cheaper and faster.*

Catastrophes are caused by forces that penetrate or negate protective barriers. Once that occurs it is almost always too late.

As presented by Lacy⁶:

.... “As I mentioned earlier maintaining well control and avoiding major incidents is essentially a process safety framework. It is my experience that the E&P segment has a lot to learn from our counterparts in the chemical and refining side of the business. It is also my opinion based on experience that while our drilling contractors have made good progress as it relates to personal safety they are still well behind the

Operators in that area and therefore even further behind as it relates to understanding the concepts of process safety. DW operations demand a higher standard than the norm.

“...The graphic shown is a model (Figure 3.2 – Penetration of Protective Barriers Regarding Safety and Reliability) I have used to explain to senior management the principles of well control and how it relates to process and personal safety. To keep people safe and free from major incidents we must maintain the barriers installed to safeguard against unintended releases of pressure, hydrocarbons, noxious gases, or stored energy. It is these forces that when released inadvertently or allowed to penetrate a protective barrier that result in fatalities, fires, and explosions. It needs to be pointed out that these barriers are not only mechanical such as steel, cement, and drilling fluids but also barriers that are human in terms of proper design standards, verification, quality assurance, supervision, and audits. Once the first set of barriers are penetrated we only have the vigilance of the work crews on site which must rely on their competence and training to spot and address a non routine condition, alarm, or warning sign. Finally our last failsafe is our well control equipment and fire and gas suppression systems.

The “elephant in the room” is all the mixed or unintended messages we send the crews when we are behind schedule, over cost, or behind on production. IF we don’t clearly keep personal and process safety as an unyielding value in our words and more importantly visible behaviors and decisions we ultimately will not withstand the risk or test of time and we will certainly suffer a fatality or major incident. Senior non technical management cannot allow these barriers to be breached and I offer they hold the ultimate accountability if they are breached....”

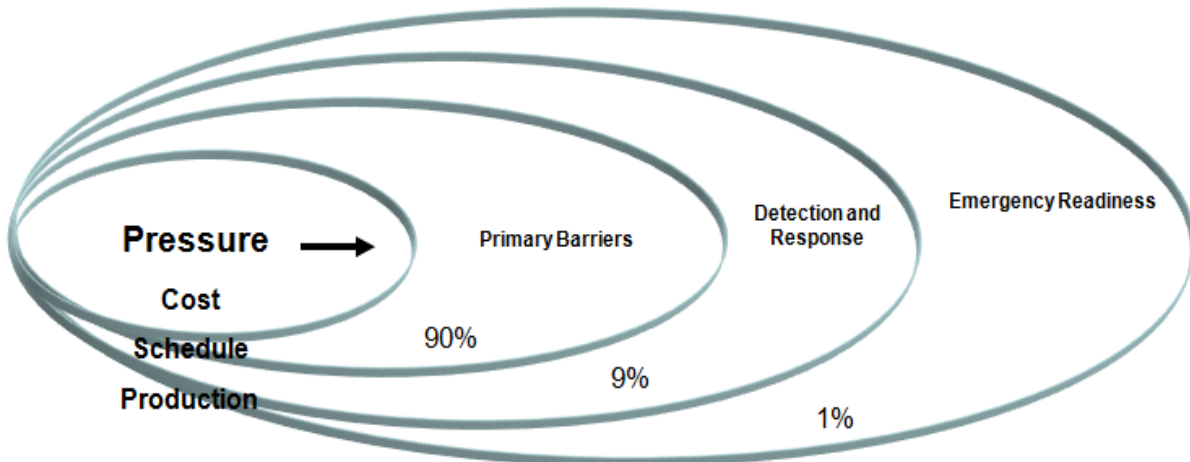


Figure 3.2 – Penetration of Protective Barriers Regarding Safety and Reliability.^{vi}

^{vi} Kevin D. Lacy, “Restoring Integrity to the GOM Deepwater,” SPE Deepwater Drilling and Completions Conference, Galveston, Texas, October 5-6, 2010, 7.

4.0 A Starting Place – The Metrics of Deepwater Drilling in the Gulf of Mexico

To establish a basis for targeting wells which have been problematic in Gulf Of Mexico Deepwater drilling, it is first necessary to understand whether or not there have been categories of wells or operations which have been problematic, and if so, what are they and to what extent. This is also important to understand and develop a robust risk profile for objective analysis.

The James K. Dodson Company has been the leading provider of metrics databases for GOM operations. This data base is populated by most operators in GOM operations. These metrics are categorized according to what Dodson has developed as the Mechanical Risk Index (MRI).⁷ Deepwater wells are bracketed according to depth of water, total well depth, numbers of casing strings, and salt penetration. The following table and figures summarize each of these categories.

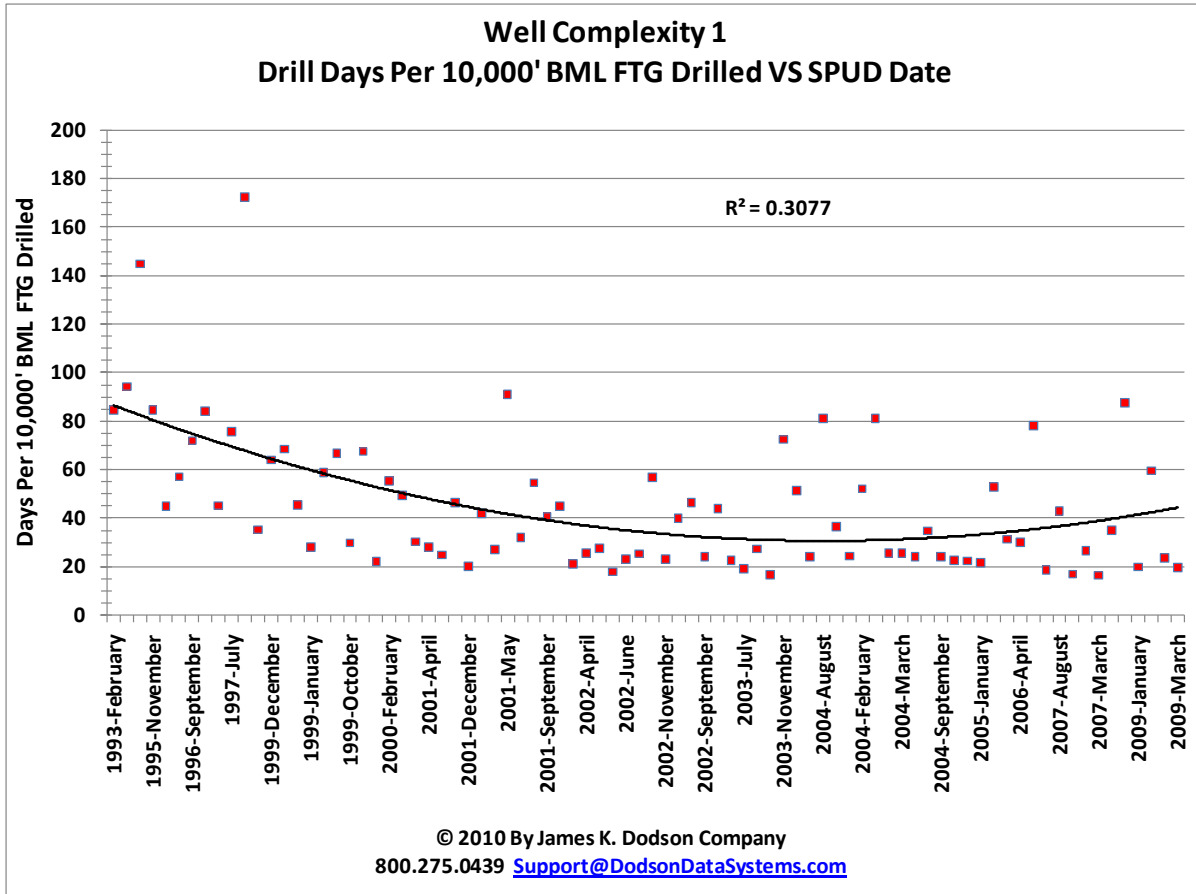
A review of the drilling performance of exploration and appraisal wells drilled in the GOM since 1993 indicates that there has not been sustained improvement in drilling performance for deepwater complex wells. Many operators have focused upon operational efficiency for improvement but, as evidenced, the expected improvement has not occurred. This has been noted in the lack of improvement in the well drill times as well as failing to achieve well objectives (Section 6.0), specifically in the highly complex wells.

Figure 4.1, Figure 4.2, Figure 4.3, Figure 4.4, and Figure 4.5 (Dodson MRI 1, 2, 3, 4, 5) illustrate clearly that as the complexity of the deepwater wells increase, learning is not occurring or at the minimum not sustained.

So, what is the problem? We often hear that “the industry has drilled 50,000 wells in the Gulf of Mexico”, implying that no real problem exists. The metrics do not support that statement and demonstrate that only Forty-three (43) MRI 3, 4, and 5 wells have been drilled through year-end 2009. These are the industries’ numbers. So what is the real risk of occurrence of catastrophic failure relative to the BP Macondo based on Figure 2.1, Figure 3.1, Figure 3.2, Figure 4.1, and Figure 4.2? Is it 1/50,000 or is it *now* 1/43? This reality poses a totally different perspective on the issue of risk management. The following figures demonstrate levels of learning across wells of higher complexity in the GOM.

Table 4.1 – Key Well Criteria for Dodson Rankings.

Dodson MRI Complexity Level	Key Well Factors - Median			
	Water Depth (WD) ft	Well Depth ft KB	Number of Casing Strings	Percent of Population penetrating salt.
1	3,200	19,000	5	78
2	4,300	23,000	5	72
3	4,400	28,000	5.5	81
4	6,000	29,500	6	85
5	6,700	30,000	7.5	100



Ref. Figure 4.1	Key Well Factors - Median			
MRI	WD ft	Well Depth ft KB	Casing Strings	% thru salt
1	3,200	19,000	5	78

Figure 4.1 – Dodson MRI 1.^{vii}

Figure 4.1 is a graph of Dodson MRI 1, indicating a slight decrease of drilling performance across this category. Learning across the general population has not been sustained.

^{vii} <https://www.dodsondatasystems.com/Default.aspx>

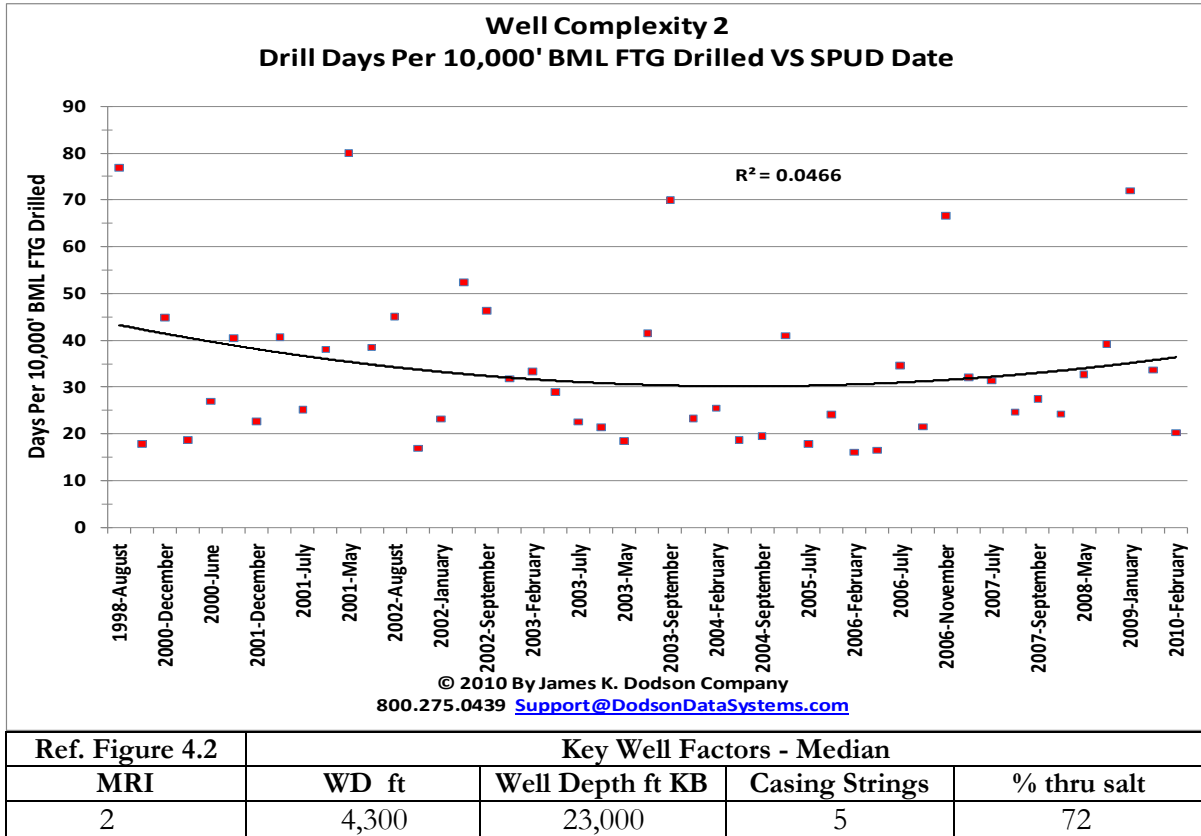


Figure 4.2 – Dodson MRI 2,^{viii}

Figure 4.2 indicates learning is scattered and at the minimum, and again, not sustained.

^{viii} <https://www.dodsondatasystems.com/Default.aspx>.

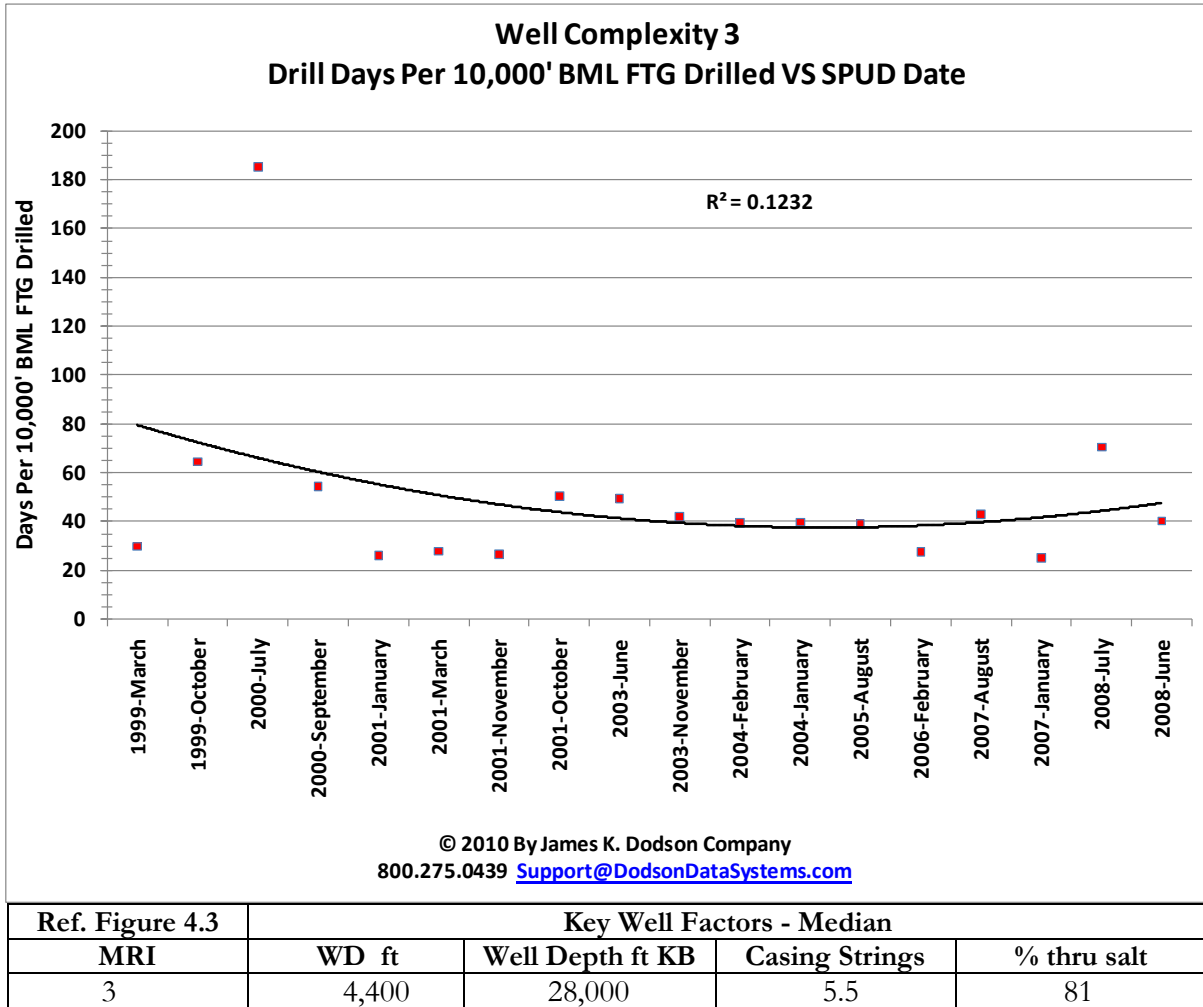
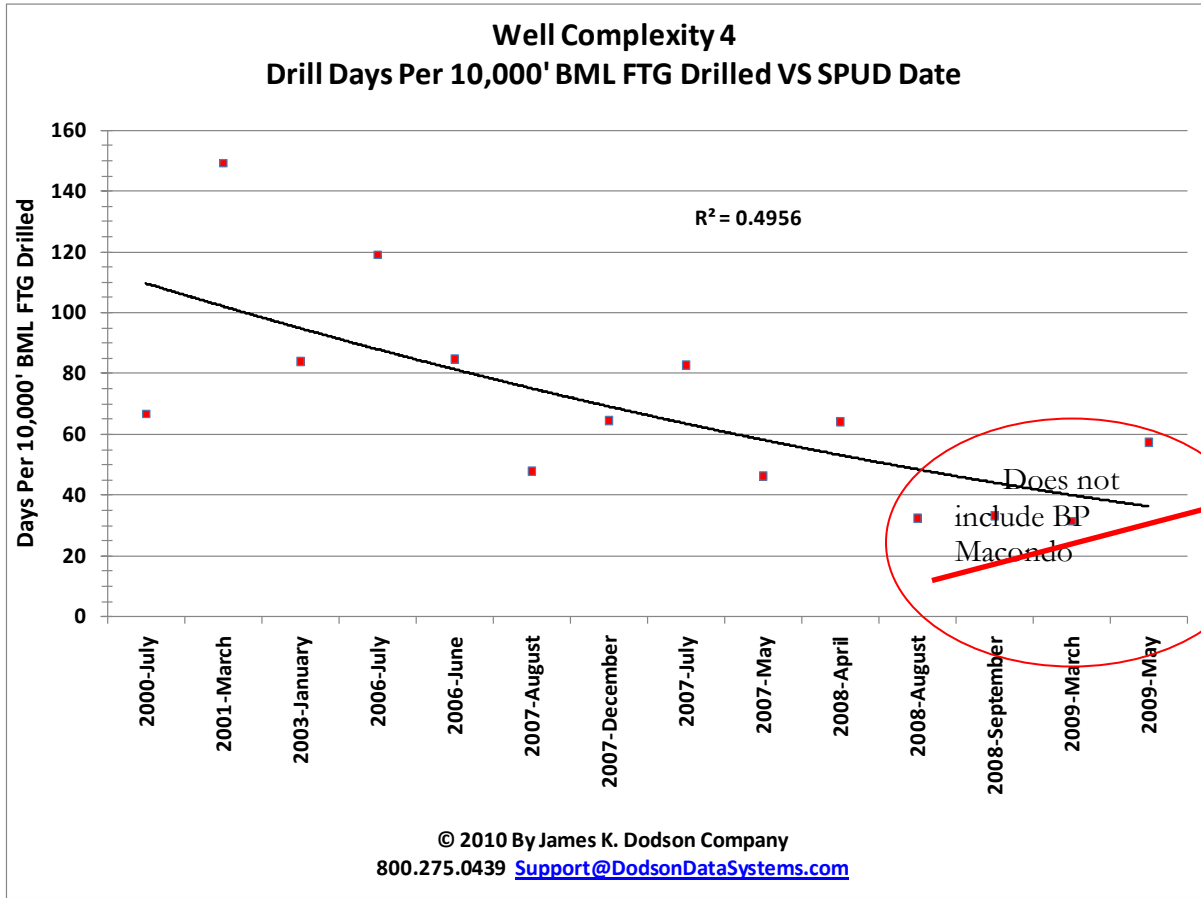


Figure 4.3 – Dodson MRI 3.^{ix}

Figure 4.3 indicates a lack of sustained learning.

^{ix} <https://www.dodsondatasystems.com/Default.aspx>.



Ref. Figure 4.4	Key Well Factors - Median			
MRI	WD ft	Well Depth ft KB	Casing Strings	% thru salt
4	6,000	29,500	6	85

Figure 4.4 – Dodson MRI 4.^x

Figure 4.4 indicates perhaps some learning, but trend reversal is beginning to show from 2008 to May 2009 (last available data). The BP Macondo well would represent between MRI levels of 3+ -4 and is not included in the above metrics.

^x <https://www.dodsondatasystems.com/Default.aspx>

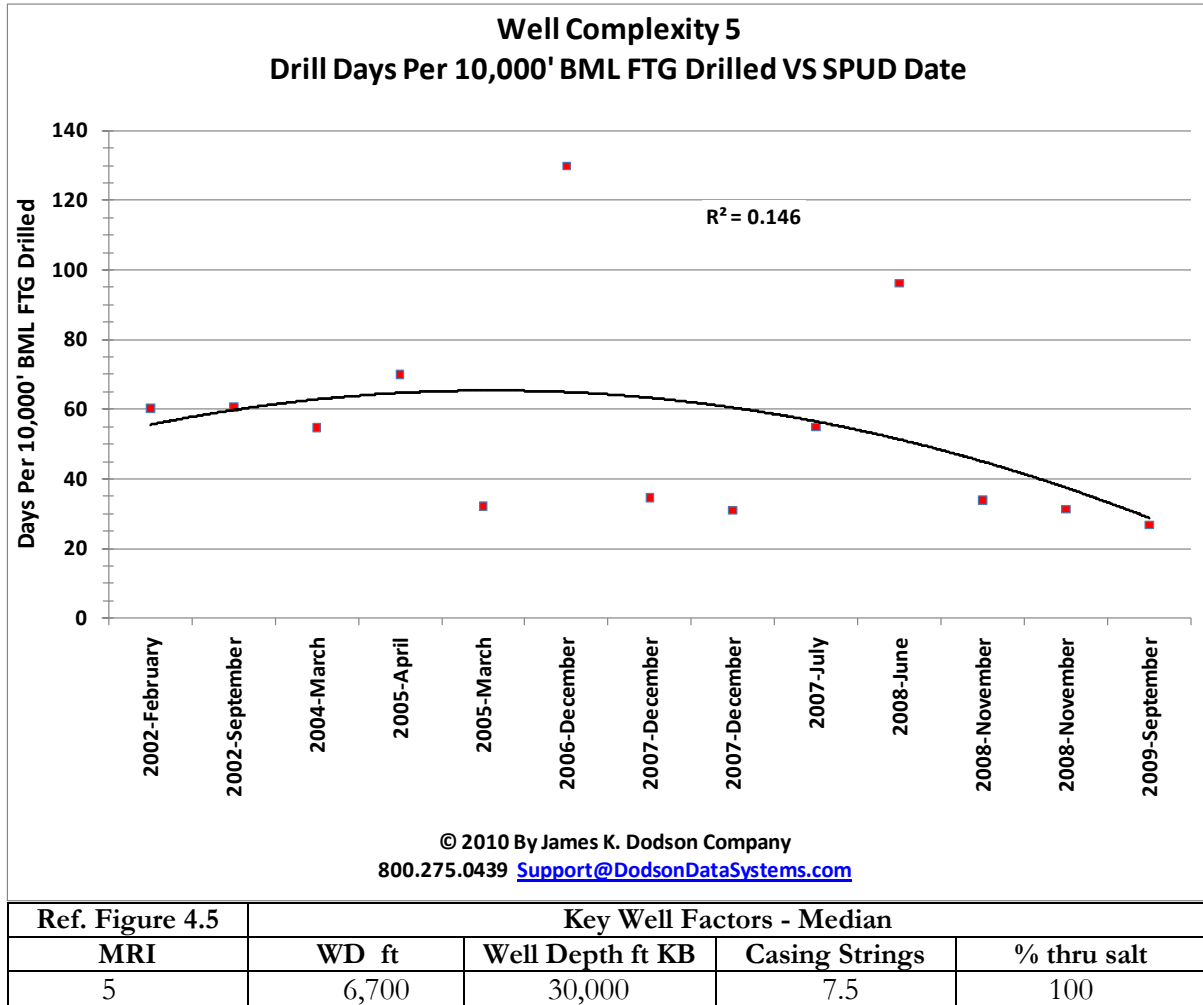


Figure 4.5 – Dodson MRI 5.^{xi}

Figure 4.5 indicates that in the most severe well complexity group, level 5, it is clear that there is a decrease in drilling performance, albeit the well population is small. The BP Macondo well would represent at least an MRI level of 3+, and the industry trend is to drill more wells of this still higher MRI 5 complexity.

5.0 Well Instability Incident Trends

For the purposes of this paper, wellbore instability incidents are considered as stuck pipe, fluid losses, and general instability. Kicks and the totality of these trends are represented in the following figure which tracks the number of wellbore stability incidents per well drilled in each MRI. This is further explained in Section 7.0.

^{xi} <https://www.dodsondatasystems.com/Default.aspx>.

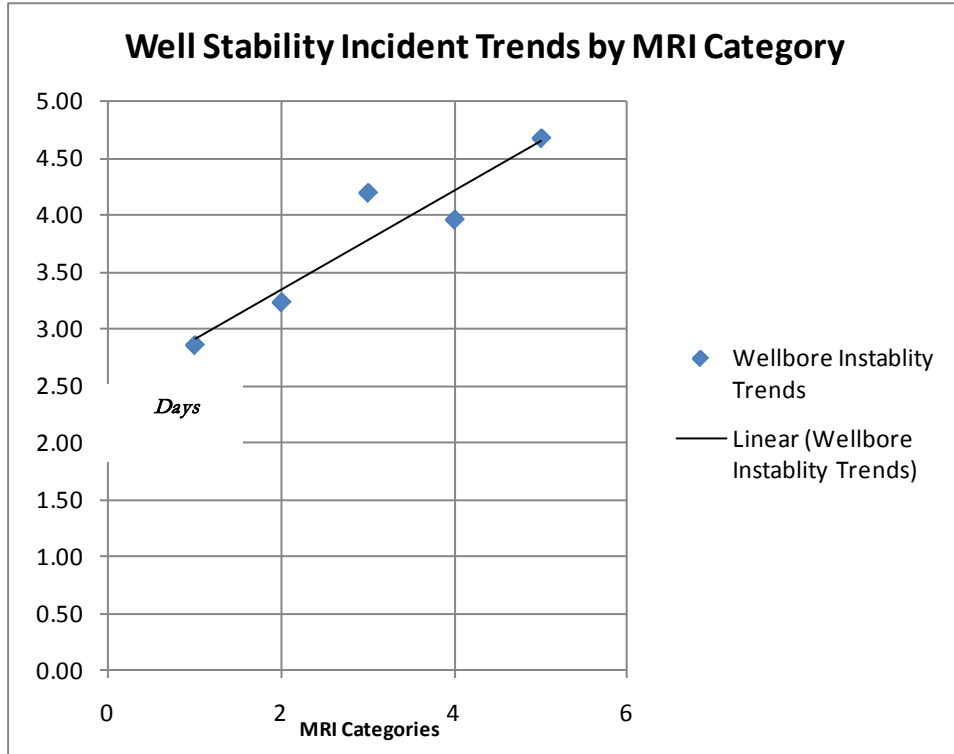


Figure 5.1 – Wellbore instability incident trends by MRI category.

Analysis of wellbore instability incident trends over the MRI populations is revealing in that the trend almost doubles from MRI 1 to MRI 5. At the minimum, these are clear indicators and warning signs of problematic wells.

6.0 Well Objectives

The drilling metrics represents only part of the problem since failure to meet well objectives is more common than it should be, and it is one of the main issues for the operator asset teams, in addition to the high cost of their wells. Failure to meet well objectives is not counted in the metrics – this is simply attributed or added to exploratory finding costs to the assets. Thus, the “metrics” are rosy and optimistic at best.

In the case of exploration wells, attaining well objectives may be more critical to the operator at that juncture than excellence in drilling performance. That is, it is more important in these wells to define the geo-scientific aspects of the well; however, this is not routinely happening in the more complex wells. Achieving objectives and excellence in drilling performance are not, and should not be mutually exclusive. The history of attaining deepwater well objectives has not been very good amongst the GOM operators. Table 6.1 is a summary of the experience of an anonymous GOM operator, which may apply to most GOM operators.

Table 6.1 – Typical well objectives achievement.

Well	Type	High		Medium		Total (High + Medium)	% Completed
		No.	Number Completed	No.	Number Completed		
GOM DW #1	Expl	Same as GOM DW#3				4	0
GOM DW #2	Expl	Same as GOM DW#3				4	0
GOM DW #3	Expl	3	1	1	0	4	25
GOM DW #4	Appr	7	5	6	6	13	85
GOM DW #6	Appr	4	2	7	3	11	45
GOM DW #7	Expl	4	2	5	4	9	67
GOM DW #8	Expl	3	3	2	2	5	100
Updated to January 26, 2009				Weighted Average Completed		56	

This data indicates that this operator accomplished only 56 % of their high and medium rated exploration well objectives. Is it acceptable to accomplish only 43 % of well objectives in an exploration program? What is the real cost of failing to achieve objectives? Are we going to continue to accept 43 % of our objectives relegated to “train wrecks”, “junked” or unusable wells?

7.0 Analyzing The Risk Of Deepwater Drilling – The Metrics Of Wellbore Instability

To further analyze the metrics of wellbore instability related events, **Error! Reference source not found.** summarizes time spent on Deepwater wells in less than 600 ft of water, the wells in non-subsalt wells in water depths greater than 3000 ft and subsalt wells greater than 3000 ft water depth. The primary bulk of MRI 3-5 wells are constituted of 65 subsalt wells in water depth greater than 3000 ft.

Table 7.1 – Days of wellbore instability as a % of total time (exclusive of weather).

Events related to Wellbore Instability	General Populations: 263 wellbores < 600 ft of water	65 subsalt wells: WD > 3000 ft	99 non subsalt wells WD > 3000 ft
Stuck pipe	2.20 %	2.90 %	0.70 %
Wellbore stability	0.70 %	2.90 %	0.90 %
Loss circulation	2.30 %	2.40 %	2.00 %
Kick	1.20 %	1.90 %	0.80 %
Total (%)	6.40 %	10.10 %	4.40 %
Total Wellbore Instability (days)	2.24 days	9.797 days	2.376 days
Total NPT Days	4	29	9
Instability % of NPT Days	56.00 %	33.78 %	26.40 %
Average Days to Drill	35	97	54
Kick Days	0.42	1.843	0.432

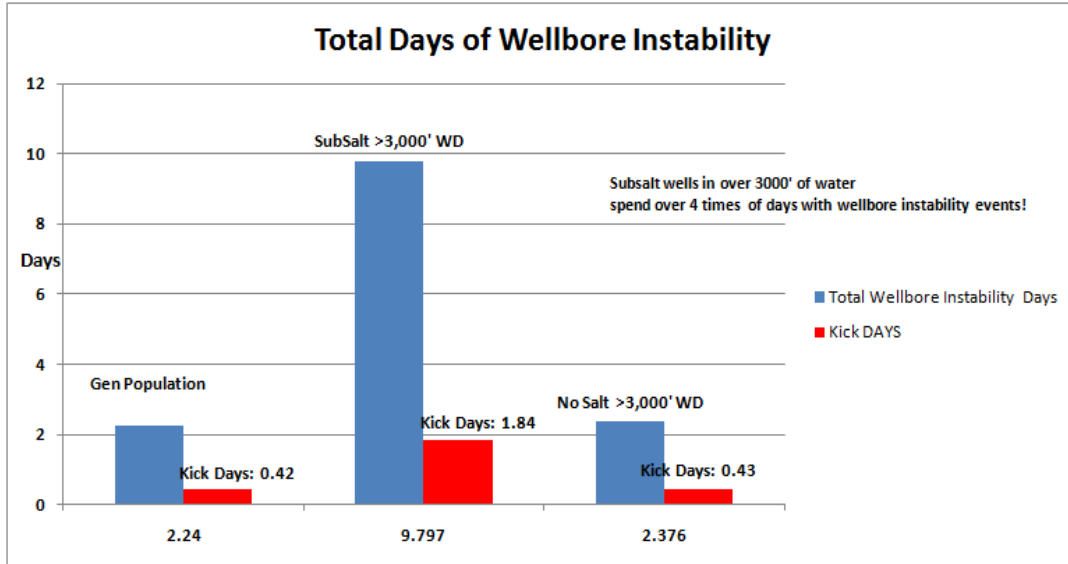


Figure 7.1 – Graphic of total days of wellbore instability.

Over four times as much time is spent on the more complex wells combating wellbore instability events. Even more revealing is that over 4 times as much time is also spent on the BOP's combating kicks.

Referencing the previous Figure 5.1, a look at the incidents indicates that there was an average of 2.85 days spent on wellbore instability for the average MRI 1 well, versus 4.67 days for MRI 5. The trend is approximately equal at MRI's 1 and 2 and jumps to over 4.1 for MRI 3.

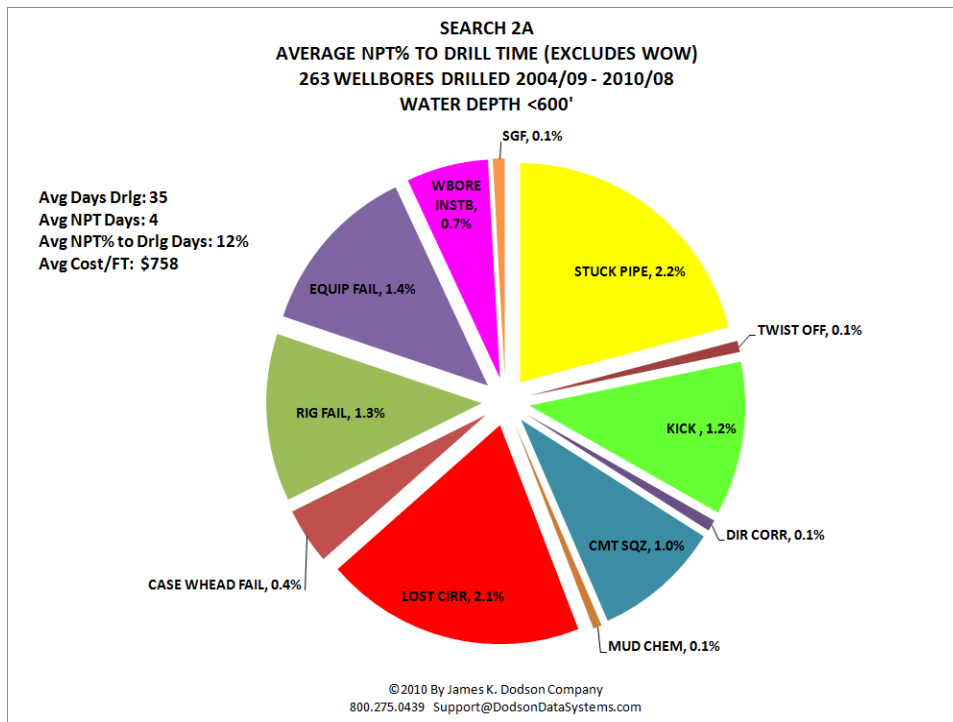


Figure 7.2 – NPT for 263 wells drilled in less than 600 ft of water.^{xii}

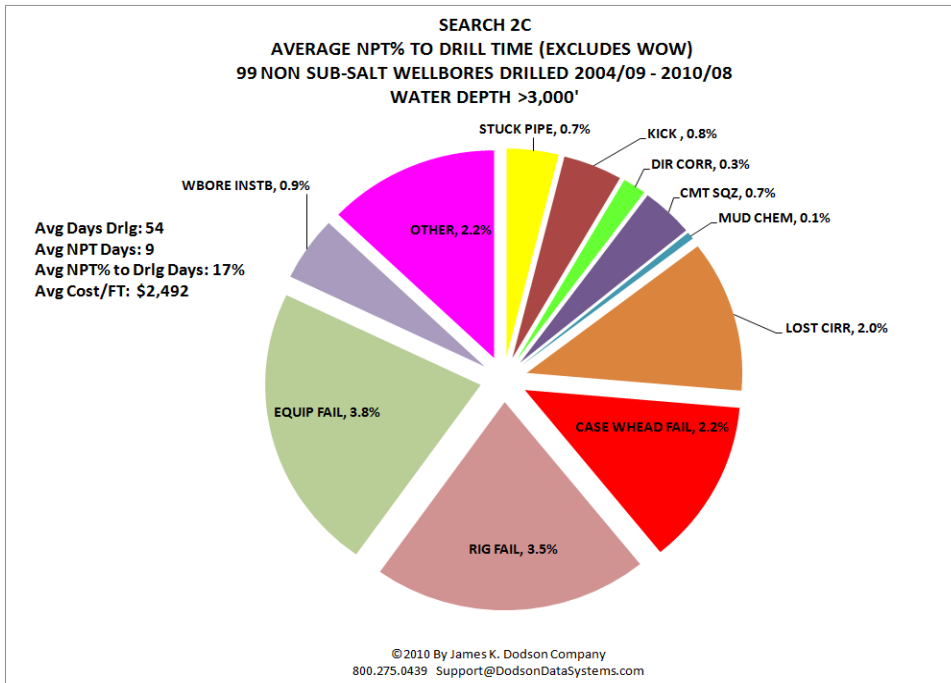


Figure 7.3 – NPT for 99 non subsalt wells drilled in greater than 3000 ft of water.^{xiii}

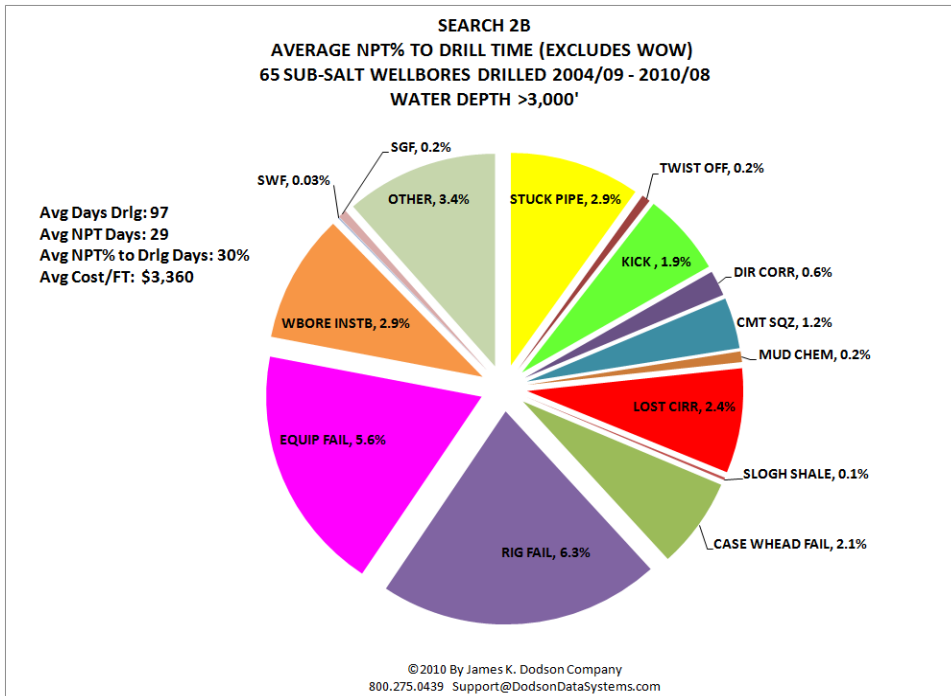


Figure 7.4 – NPT for 65 subsalt wells drilled in greater than 3000 ft of water.^{xiv}

Any event of wellbore instability has the potential of becoming a well control event.

^{xiii} Dodson, op. cit.

^{xiv} Dodson, op. cit.

8.0 Conclusion

Restoring integrity to the DW environment requires a higher standard:

- The Operator is the Operator.....
- Transparent industry standards need to be established with better verification.
- The drilling contractor must be accountable for their people, equipment, and hold each Operator to an industry standard.
- US Regulators must be assisted to be more effective.
- Dollar consequences for failure are inadequate.

It is imperative that the industry adopt standards which ensure process safety around design and execution and there are some very basic and cumulative actions which must be considered for absolute well control:

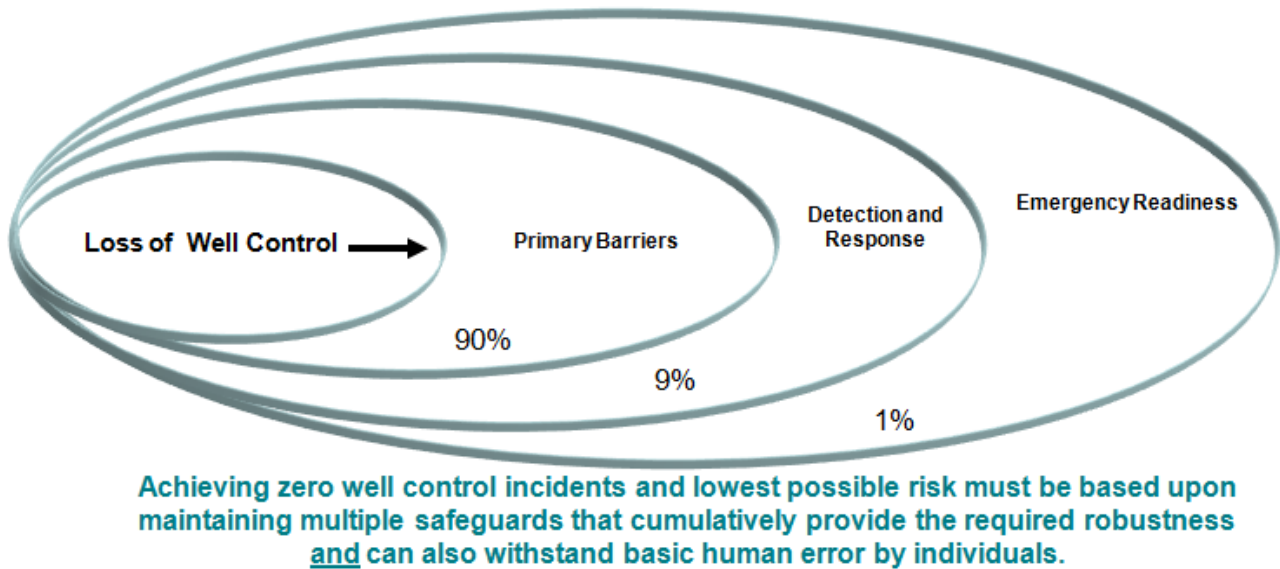


Figure 7.5 – The cumulative basics for incident free operations.^{xv}

As further pointed out by Lacy:

..... “To summarize the industry has seriously failed to adequately implement appropriate risk assessments and the standards required to mitigate the risks in DW. More importantly our industry has had a significant peer fail to adequately protect people and the environment in spite of high quality process and people and deep experience. It is a failure that was imminently preventable and therefore wholly unacceptable.

While I do expect BP to be the company that takes responsibility for the incident I fully expect the entire industry to own the learnings and the responsibility for implementing a significantly better system and way of working in highly complex environments.

^{xv} Lacy, op. cit., 9.

While the details of the incident are unique the failures are not – we know them well. We must accept responsibility for those failures. The only acceptable outcome is a new system that precludes any similar incident from happening in the future. We owe the public and the eleven families that have suffered a loss a commitment to not allow it to happen again.”

The BP tragedy in the Gulf of Mexico (GOM) has clearly revealed two major categories of the consequences of risk—the incident itself and the resultant environmental disaster. These risk consequences are quite obvious. Risk in any endeavor cannot be eliminated entirely, but it can be successfully managed if it is recognized and the consequences are fully understood.

In order to have a meaningful outcome for future deepwater drilling, the Hopkins mindsets must be addressed, and one must first understand that there is a problem, and then focus on solving the problem.

Avoiding a repeat of the current situation and changing the climate of denial can be achieved with a dose of common sense. Solutions must consider and actively apply the following:

- Look at the facts of the metrics in context of well complexity.
- Work together and collaborate as an industry.
- Recognize where the problems really are and address them from a risk management perspective.
- Focus on solving those problems and work with regulators to focus on the solutions.

The current design and exertion model must be challenged. Sound and unbiased engineering design is the fundamental precursor to process safety, sustained success and full life cycle reliability. If we solve the problem wells, then by definition of risk management, the rest of the well population is mitigated.

9.0 References

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