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**Refining the DP Watch Circle**

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# Refining the DP Watch Circle

## Abstract

This paper will discuss how the Watch Circle has evolved into a detailed technical analysis of operating limitations. Today, the Well Specific Operating Guideline is used to assess all risks to the vessel, determine which are the limiting factors, and provide a simple set of guidelines by which the DPO can minimize risk to personnel, environment, and equipment no matter what situation arises.

## 1.0 Introduction

One of the most important facets of DP Drilling Operations is minimizing risk to personnel, environment, and equipment by making sure the rig is able to disconnect from the wellhead during a loss of location. Historically, most DP vessels have used the concept of “watch circles” to clearly define when to initiate action. The basic concept of using “watch circles” is to define three critical radii around the wellhead. The outermost circle, known as the Point of Disconnect (POD), is determined by the mechanical limit of the rig equipment. If the rig hasn’t disconnected and separated from the BOP by the time it reaches the POD, either the rig equipment or the wellhead will probably sustain mechanical damage. Thus, the rig must have disconnected and separated from the BOP by the time it reaches the POD. The next smaller, or RED watch circle, is established far enough inside the POD radius to provide sufficient time to safely disconnect and separate the marine drilling riser from the BOP. The largest possible RED radius is calculated by subtracting from the POD radius the time required for the disconnect sequence (EDS) to complete and the Lower Marine Riser Package (LMRP) to lift off. In order to ensure the rig is ready to activate the EDS, a YELLOW watch circle is created inside the RED. The largest possible YELLOW watch circle is calculated by subtracting from the RED radius the time required for the driller to cease drilling operations and hang off the drill pipe.

Figure 1 below shows the relative relationship of the POD and the RED and YELLOW watch circles, plus shows a green “position alarm” set up by the DPOs to warn if the rig exceeds the normal operating envelope. Some rigs may not set up a position alarm, others may have more than one early warning.

From about 1970 to 1995, the largest possible RED circle was usually much larger than the normal operating envelope of the rig. To maintain a conservative safety margin, the YELLOW and RED were set at a distance that was larger than the normal operating envelope, but well inside the upper limits (POD). Even allowing a generous safety margin, a simple set of watch circles provided adequate time to disconnect without unnecessarily restricting drilling operations.

In the last decade, drilling operations have become more sophisticated, and DP rigs have grown larger. Watch circles based on the criteria used in 1970 do not provide adequate protection for modern DP Operations. Determining the watch circles now requires a more sophisticated understanding of operational limits to guarantee an adequate safety margin without restricting drilling operations.

Drilling contractors today perform a sophisticated analysis of many factors to determine the watch circles. Although the analysis is complex, the solution is still presented as simple YELLOW and RED watch circles. As the industry moves into ultra deep water, the watch

circles are steadily “closing in”, leaving less room before disconnect (this will be explained later). Today, for some operations the theoretical maximum RED is not significantly larger than the Normal operating envelope.

An unexpected disconnect costs about \$1 million just for lost drilling fluids, and much more if spread costs are included. If a disconnect results in a delay in the start of oil production, the cost [of disconnect] is even larger. With \$60/bbl oil, anything that causes a delay before the oil company brings a large deepwater field to market may represent significant unearned revenue. Clearly, there is sufficient financial incentive to see if we can improve performance.

This paper will discuss how the Watch Circle has evolved into a detailed technical analysis of operating limitations, how the output of this detailed analysis is presented as simple and clear guidelines for the DPO, and some ideas for further evolution of the watch circle as the industry moves into deeper water and harsher environments in our search for oil.

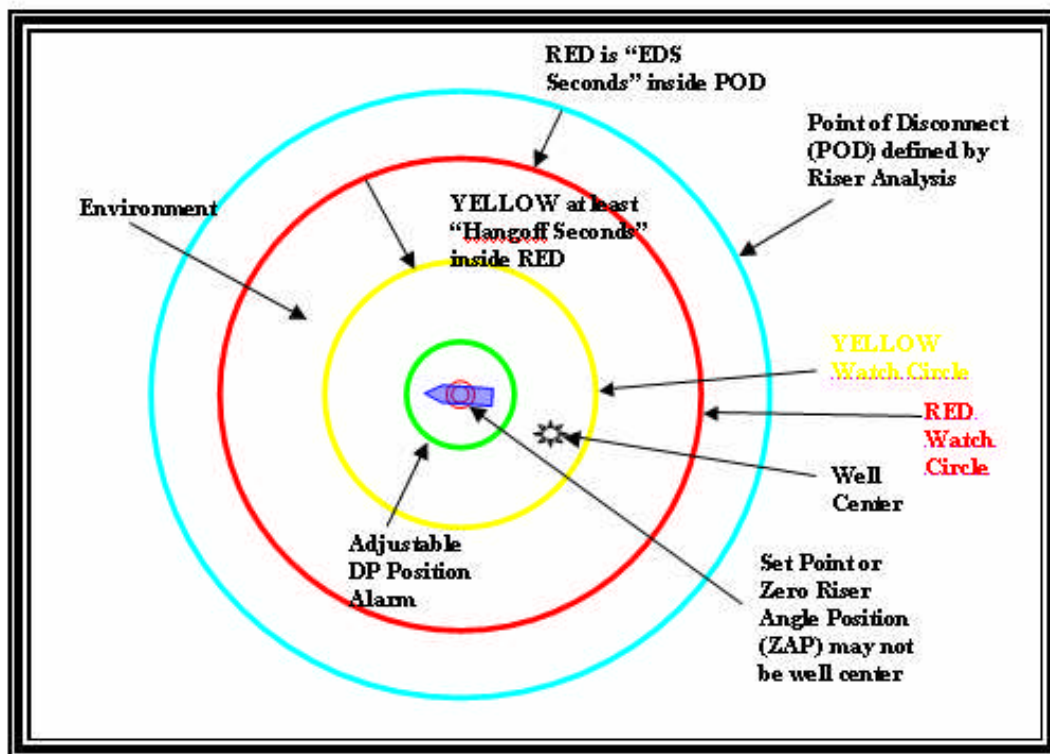


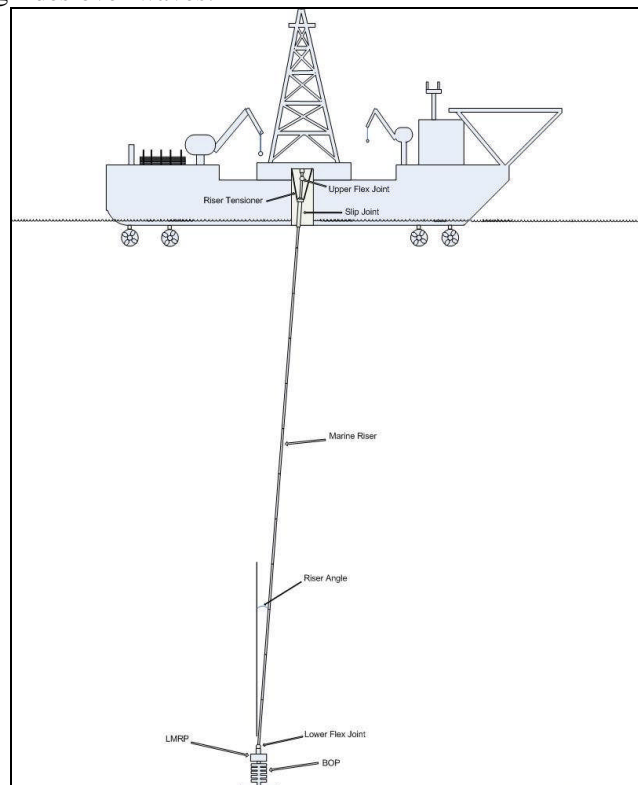
Figure 1 - Graphical Representation of Watch Circles

## 2.0 Origin of the DP Watch Circle

In order to maintain control of well bore fluids in wells on the seabed in deep water, the well bore must be extended up to the rig, where conventional drilling technology can be utilized. To make this possible, a well is constructed in the following order.

1. A wellhead is cemented into the sea floor

2. A large set of high pressure valves (known as a Blow Out Preventer or BOP) is placed on top of the wellhead. The BOP contains valves that seal the open well bore, blades that can sever the drill pipe, and hydraulic connectors to allow separation of the marine drilling riser from the BOP if the rig loses location.
3. A large diameter steel pipe, ~ 48 inch OD when fully dressed with hydraulic lines and foam floatation (known as a marine drilling riser, or riser for short) is run from the drill floor to the well control equipment (BOP) on the sea floor. The riser is used to extend the well bore from the sea floor to the rig.
4. Flexible connections are installed at the top and bottom of the marine drilling riser in order to allow the rig a limited range of motion without bending the pipe. These are called “flexjoints” and typically allow about 10 degrees of bending at the top and bottom of the riser.
5. To allow for vessel heave, a telescopic joint (or slip joint) is installed at the top of the marine drilling riser. Typically, slip joints are produced with at least 10 meters of stroke. Some newer units have 20 meters of stroke.
6. Large hydraulic cylinders, known as “riser tensioners”, are installed between the rig and the riser (just below the slip joint) to maintain the entire length of the riser in tension while the rig rides over waves.



**Figure 2 - Drilling Rig and Associated Equipment**

### 3.0 Evolution of Watch Circles 1970-1995

The first DP Oil Exploration Drilling Rig was the Sedco 445, which started drilling about 1970. Deep water in 1970 was much shallower than today. In 1974 the 445 set a world record by drilling in 600 M of water – today we routinely anchor rigs in deeper water. The limiting factor

for station keeping for these early ships was usually the maximum angle at which the riser connector [to the BOP] of 1970 would release, about 5 degrees or about 8.7% of water depth. DP systems of the time typically maintained a Normal operating envelope well under 1% of water depth. This allowed a lot of range for defining the RED watch circle. To allow time to release from the wellhead, the 20-30 second Emergency Disconnect Sequence (EDS) was activated at about 5% of water depth, or 3 degrees of riser angle. The RED watch circle was commonly set to 5% of water depth. To provide time for the driller to pick the drill pipe up off bottom and prepare for a clean disconnect, a second, "YELLOW" watch circle was set at half or two thirds of the RED diameter. As other industries adapted DP controls to their vessels, most adopted the RED and YELLOW watch circles, or something similar.

From 1970 to 1985 the industry moved into deeper water as technology improved, passing 1,200 meters by 1977 and 2,000 meters by 1985. Advancement of DP and rig equipment in this period was evolutionary rather than revolutionary. Drilling rigs in 1985 used almost the same drilling and DP equipment as in 1970. Usually, riser angle or riser tensioner stroke still established the limiting criteria, so watch circles in 1985 were similar to 1970.

Marine seismic analysis in 1970 was less sophisticated than today, thus [in the 1970s] it was actually fairly rare for DP rigs to drill into hydrocarbon reservoirs in deep water. With the main goal [of this period] being development of deepwater drilling technology rather than development of deepwater reservoirs, BOP stacks in the 1970s tended to be much lighter, shorter, and simpler than current equipment.

The period 1985-1995 was an "economic dark age" for the offshore drilling industry as depressed oil prices limited offshore drilling budgets. DP technology stagnated because there wasn't enough profit to justify improvements (the water depth record only advanced from 2,000 meters to 2,300 meters between 1977 and 1995). Between 1985 and 1995 little changed in DP.

While the drilling industry was struggling along in survival mode, cheap and powerful computers revolutionized the seismic industry. 1985-1990 was a "golden age" for seismic companies, who used cheap and fast new computer technology to dramatically improve their ability to identify oil reservoirs. The major oil companies recognized the cost saving they could achieve by avoiding drilling dry holes and poured R&D money into improving the success rate of seismic surveys.

By 1990, advanced seismic techniques allowed companies to identify hydrocarbon reservoirs with 10 times the "find ratio" of 1970. Though oil prices were still weak, enough attractive deepwater prospects were identified to keep the DP industry alive. Improved seismic made it more likely that the rig would drill into an oil reservoir, thus more likely that a loss of location could have environmental consequences. In response, watch circles were reviewed to increase confidence that the well was secured before disconnect, and the industry began discussing the need to add more functions to the BOP.

## **4.0 Evolution of Watch Circles 1995 to Present Day**

By 1995, economic recovery had increased demand for oil. Tax incentives for US offshore oil production combined with economic recovery revived interest in offshore drilling in the US GoM. Similar tax incentives and economic conditions revitalized the North Sea. At the same time, advanced seismic techniques identified immense hydrocarbon potential in the deepwater GoM, offshore West Africa, and Brazil. Economic recovery, tax cuts, seductive seismic data, and increased oil demand set the stage for increased deepwater exploration.

By 1997 economic recovery and oil demand were strong enough that the industry began to build a new series of deepwater DP drilling rigs, designed for up to 3,000 meters of water. By 2000 these new rigs were hitting the market, and encountering new challenges. The new deepwater rigs required that more factors be considered to establish the limits for watch circle determination. With these new deepwater rigs, riser angle or riser tensioner stroke were rarely the limiting factor.

On the new deepwater rigs, riser tensioner pulldown and slip joint strokeout were usually reached before maximum riser angle. Deep water operations require a longer and heavier marine drilling riser to handle the higher loadings. Riser tensioner capacity must be increased to support the heavier riser. At the same time, companies asked for more capability from BOP stacks, which made them taller and heavier. Taller BOPs and larger riser tensioners required taller and heavier drilling substructures, which in turn required larger rigs. Also, new generation BOP control systems often had EDS sequences more than twice as long as in 1970.

Taller drill floor structures raised the height of the upper flex joint above the keel, so unless the moonpool was increased in size, riser contact with the moonpool often became the limit. Higher riser tension at the BOP, combined with taller BOPs, put more stress on the wellhead and surface casing. It was now possible for the surface casing to sustain permanent damage before reaching the operating limit of the riser connector.

Larger, heavier vessels drift more slowly when DP fails, but inertia works both ways, larger vessels are harder to stop once motion starts. With larger vessels it became more likely that a vessel could achieve sufficient velocity, while still inside the RED, so that crossing the RED would be unavoidable. Thus, it became more important to consider velocity when determining the watch circles.

The simple equations of 1970 no longer worked. Determining a valid watch circle now required a sophisticated computer to sort through all the variables and find the most restrictive. Calculating watch circles today is more complex than in the past. A wide range of factors must be considered.

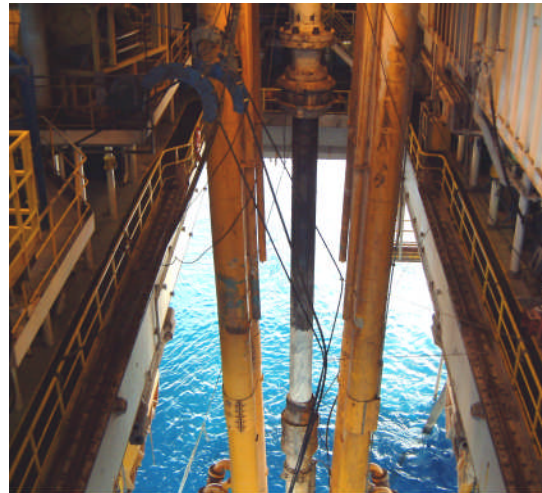
Considerations for calculating a modern watch circle include:

- Riser angle (riser connector limit)
- EDS time
- Flex joint (v. ball joint) increases moment on wellhead
- Moonpool contact
- Upper flex joint angle
- Riser tensioner pull down
- Slip Joint Extension
- Wellhead/casing yield point
- Seafloor soil yield point
- Rig velocity
- Special equipment / Operations such as production testing

Figures 3 and 4 show how careful moon pool design allows a large upper riser angle limit.



**Figure 3 - Wide Moonpool Allows  
Large Upper Angle**



**Figure 4 –Narrow Moonpool Limits Upper Angle**

In addition to these physical limits, environmental conditions must be included in the calculation, in particular if the operating region is prone to large variations in wind or current. Also, blackout restart time for the power plant is a major consideration, e.g. the time to reach terminal velocity may be less than the time to restart the power plant and stop vessel motion.

Although the limit might be determined by any of these factors, the DPO cannot remember different limits for all these factors. The watch circles must be simple and clear.

## 5.0 Detailed Analysis

Today a detailed engineering analysis of all the physical limits is performed to determine which limits affect the rig first. In order to assure a comprehensive analysis, the full range of weather conditions, currents, waves, wind, and heave for the drilling location, as well as the worst case single failure must be defined. If there is more than one EDS sequence, the analysis must be performed for the EDS sequence that is enabled. These data are subjected to a sophisticated analysis that determines the limits for all parameters.

This analysis can be performed:

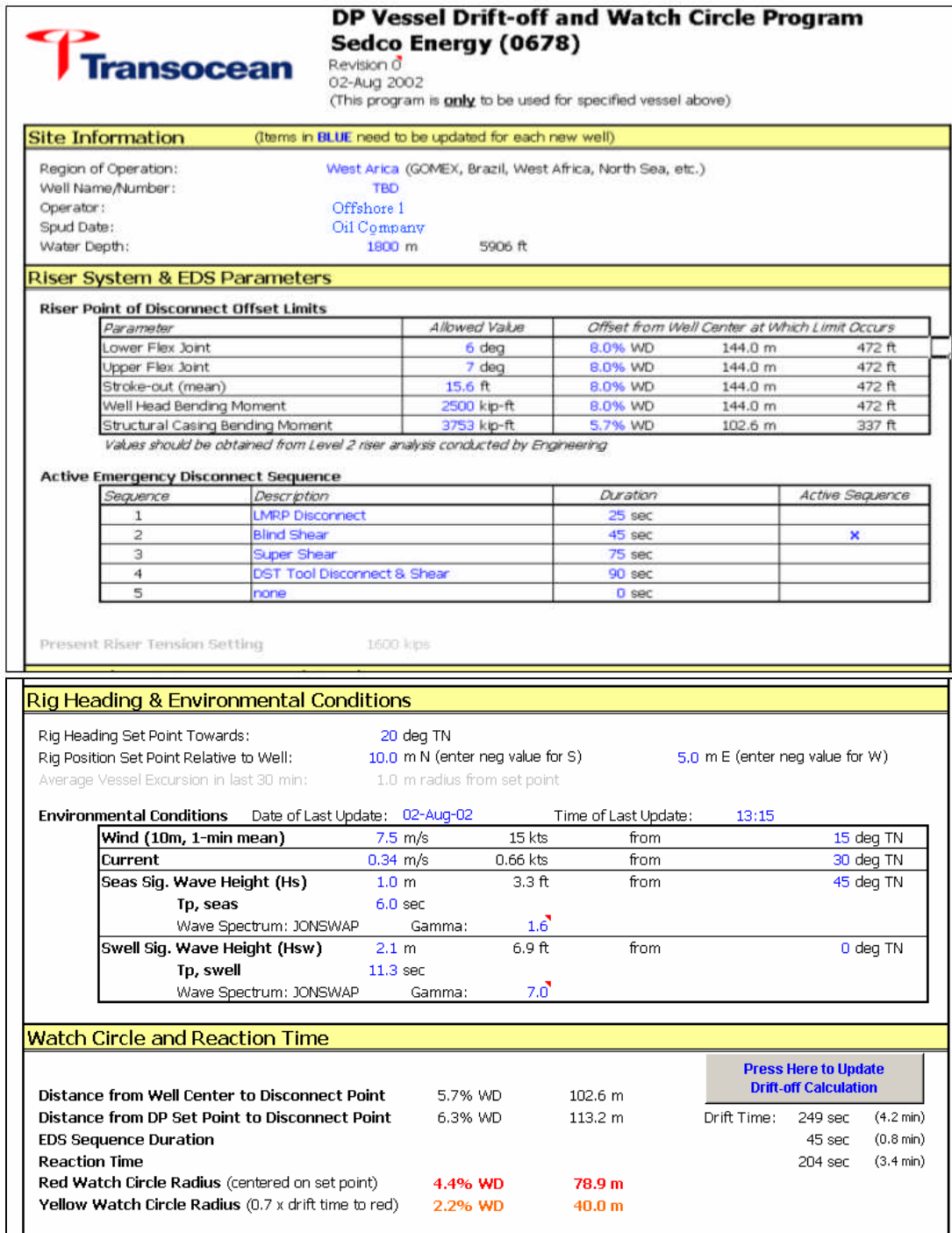
- on the rig (with specialized software)
- on shore by a dedicated department
- outsourced to a third party.

All three methods have advantages. Analysis on the rig provides the fastest answer if an unanticipated situation arises, but runs a higher risk of mistakes if the user isn't familiar with the analysis tool. Also, the analysis tool must contain sufficient expert knowledge to guide the user for all possible situations. Outsourcing to a third party has the advantage that most third parties

may have several PhDs on staff, which should produce a high quality analysis. The disadvantages are slower response time and high cost, plus the quality of the analysis is highly dependent on the quality of data provided to the consultants. Analysis in house by dedicated Engineers is somewhere in the middle. The advantages are that delivery can be fairly easily adjusted to the rig's urgency, good quality control, and is the best method to assure the analyst understands any special circumstances related to a particular rig design. The disadvantages of performing the analysis in house are that a consultancy firm may have stronger tools and deeper skill, plus, for a small company, the cost of maintaining internal expertise may be as high as outsourcing.

The analysis outputs only one set of watch circles, those determined from the physical limit which is reached first. Similar to the simple watch circles of 1970, the constraining limit is translated into a radius around the set point position.

The next figure shows the user interface of a typical rig-based analysis tool. While the analysis is quite complex, requiring several minutes of calculation, the user interface is kept very simple. All user changeable inputs are color coded and clearly marked. The output of the software analysis is presented clearly.



**Figure 5 - Rig Based Drift Off and Watch Circle Analysis Tool**

## 6.0 WSOG

In addition to calculations that determine when the rig must physically disconnect from the well to prevent damage, every location must also consider operational concerns (explained in detail below):

The rig may need to restrict operations based upon excessive risk - factors separate from the physical limits defined in the RED and YELLOW watch circles.

This analysis is known as the “Well Specific Operating Guidelines”, or WSOG. The WSOG contains the RED and YELLOW as determined by the watch circle analysis, plus a set of guidelines based upon operational considerations. These may include:

- If the DP system is unable to hold station without a gyrocompass, the WSOG will contain a line item that specifies an immediate RED if all the gyrocompasses fail, and perhaps a YELLOW if all but one fail.
- If the client wants to run a tree or some other non-standard equipment, the rig will examine this operation and modify the watch circles based on how quickly the non-standard equipment can be secured and released.
- If the well location is close to a sea floor obstruction, either man made or natural, the WSOG may specify not running casing or suspending drilling operations during periods when ambient current and wind would push the rig in that direction.
- In the GoM the WSOG may contain special considerations for hurricanes.
- Simultaneous operations (SIMOPS) by another vessel alongside the drilling rig may require special YELLOW and RED conditions related to risks associated with the SIMOPS.
- Transocean’s patented dual-activity technology, e.g. drilling one hole while running casing in another, may impose additional restrictions (limited heading changes or smaller watch circles).
- Special operations such as offloading crude oil while drilling, or production testing may impose additional restrictions (limited heading changes or smaller watch circles).

The main goal of the WSOG is to define operations and risk in sufficient detail to provide the rig with a clear set of guidelines for any situation that arises.


	FLOATING OPERATIONS MANUAL HQS-OPS-004	SECTION: 4	
		SUBSECTION: 9	
<b>DP OPERATIONS GUIDELINES</b> WELL SPECIFIC OPERATIONAL GUIDELINES			
WELL SPECIFIC OPERATIONAL GUIDELINES (WSOG)			
VESSEL: _____		DATE: _____	
LOCATION: Block: _____		WELL: _____ CLIENT: _____	
<b>ALERT STATUS</b>			
<b>Condition</b>	<b>Green</b>	<b>Advisory</b>	<b>Yellow</b>
DRIVE OFF DRIFT OFF FORCE OFF Unit offset deviation Waterdepth: meters	0 – 10m	10 – 14m	> 14m or <u>Immediately when recognized that cessation of Ops required</u>
			Immediately when confirmed that situation cannot be controlled. No later than at 50 meters offset from Initial (Pre-incident) Position.
<b>Power: Thrust/Electrical</b>			
Power consumption each network (2-split HV net)	<50%	50%	>70% or consequence alarm, whichever occurs first
Power consumption each Network (4-split HV net)	< 70%	70 %	>80% of consequence alarm, whichever occurs first
Thrust consumption each online unit ( 2- split HV net)	<50%	50%	>70% or sudden change
Thrust consumption each online unit (4- split HV net)	< 70 %	70 %	> 80 % or sudden change
<b>Footprint Alarm Settings</b>			
DP position footprint (5 min. maximum from set point)	<3m	3m	Situation specific
DP heading footprint (5 min. maximum from set point)	<3 deg.	3 – 5 deg.	5 deg. If threat to position
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REVISION DATE:	July 1, 2002	16	18

Figure 6 – Example of a WSOG Format



**Figure 7 – SIMOPS / CLOSEOPS**

## **7.0 The Future**

As the industry implements advanced drilling technologies (such as Transocean’s patented dual-activity drilling technology), the watch circles will continue to “close in”. The distance between the theoretical maximum limit (POD) and the normal operating envelope is shrinking. As we innovate to maximize performance, we naturally move closer to the operating envelope. For example, today a dual-activity rig can construct two oil wells at the same time, or construct one well while production-testing another. Drilling, production, work over, wire lining, batch setting, formation fracturing, and acid stimulation are just a few of the simultaneous activities dual-activity rigs must consider in their risk plan.

In the future, drilling technology may lead to performance advances that cannot be implemented with the current technology of station keeping. The challenge for the DP industry is to modify the technology to support the advance of drilling technology while maintaining acceptable watch circles. Here are a few ideas of ideas to increase the watch circles.

### **7.1 EDS Timing**

The single most important factor in establishing the watch circles is EDS timing. RED is specifically defined as “EDS seconds” inside the POD. Changing the POD typically

requires huge investments in capital and time, e.g. designing a new wellhead or new riser string. Shortening the EDS sequence can usually be done cheaper and faster. For example, if Rig A has an EDS time of 80 seconds, which is not unusual these days, and Rig B has an EDS time of 25 seconds, also not unusual, and they both have the same POD of 6.3% of water depth, the slower EDS time results in dramatically reduced RED watch circle for the rig with the slower EDS. Using numbers from a typical analysis, we find that Rig B would have a RED watch circle of 90 meters, but on the same well Rig A would have a RED watch circle of only 50 meters. Assuming a YELLOW of 70% of RED, Rig A will secure the well and cease operations at 35 meters, while Rig B would continue operations to 63 meters. A sudden shift in strong current, common in many places on earth, can easily cause a temporary offset of 20-30 meters. To prevent interruptions, RIG A must set the YELLOW at the theoretical maximum, while RIG B can set theirs a comfortable 30 meters inside the limit. Shortening the EDS time would prevent interruption of revenue at no cost in DP performance, and with reduced risk.

## **7.2 Stack Angle**

In deep water, the limiting factor in most cases is the soil strength, and soil strength is essentially described in terms of how large of a stack angle the rig can tolerate without damaging the soil/casing. Because flex joints are relatively stiff, when a rig offsets much of the bending force is transferred to the stack. As we move into 4,000 meters of water, likely with even heavier BOPs than we have today, stack angle may become a limiting factor, perhaps even the dominant factor.

## **7.3 Riser Tension**

Related to the previous item, soil strength is only a limit because of riser tension pulling the BOP [and wellhead] over at an angle as the rig moves off location. The bending moment would be reduced if tension at the BOP was reduced. From a DP point of view there must be enough riser tension to lift the LMRP off at disconnect – any additional tension reduces the watch circles. Eliminating excess tension directly expands the watch circles. Improved (or active?) riser tension management may be a cheap and fast way to increase the watch circles.

## **7.4 Improved riser angle management.**

The purpose of a DP system is to maintain the riser angle vertical and allow the driller to drill. Improved riser angle data may help to extend the operating envelope. There are some significant problems to solve, such as how to use a sensor that tracks rig motion with a delay of as much as 30 seconds [after the rig starts to move], and understanding how [if] this delay varies with riser tension and/or subsea currents.

## **7.5 Velocity Measurement:**

The primary performance goal of the DP control loop [on a drilling rig] is maintaining zero vessel velocity. As long as the rig maintains zero velocity, drift-off time is infinite. The RED watch circle is defined as the distance inside the physical point of disconnect at which the EDS must be initiated, and is entirely dependent on vessel velocity. Accurate rig velocity data could significantly improve the watch circle calculation.

### **7.6 Dynamic Watch Circle:**

Current watch circle analysis provides conservative watch circles. Whenever conditions are more benign than the analysis assumptions, performance is “left on the table”.

Computer technology is fast enough today to perform a dynamic watch circle calculation in real time, but it would require some key data which are presently not available, e.g. rig velocity and riser tension.

## **8.0 Conclusion**

The Watch Circle is a powerful and simple tool to define how we manage risk. Over the past three decades, Watch Circles that originally represented simple mechanical limits have maintained their simplicity despite the analysis [that defines the circles] becoming ever more complex. As we move into ever deeper water, the analysis that defines the watch circles will likely continue to grow in complexity and power, as it has for the last three decades, but it seems equally likely that we can stick with our comfortable and simple definitions of RED and YELLOW watch circles.