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Effect of Well Capping as a Blowout Risk Reduction Measure

Valentin Vandenbussche, DNV GL, Det Norske Veritas AS - Veritasveien 1 - N-1363 HØVIK - NORWAY, valentin.vandenbussche@dnvgl.com

Odd Willy Brude, DNV GL, Det Norske Veritas AS - Veritasveien 1 - N-1363 HØVIK - NORWAY, odd.willy.brude@dnvgl.com

Harald Tvedt, DNV GL, Det Norske Veritas AS - Veritasveien 1 - N-1363 HØVIK - NORWAY, harald.bjarne.tvedt@dnvgl.com

ABSTRACT 300147:

Following the 2010 Deepwater Horizon (Macondo) oil spill incident it became clear that further focus is required in order to understand and control blowout risks. The control measures are also essential in reducing potential environmental consequences given a blowout event.

The latest development in well capping techniques indicates that this might be a viable technical solution for controlling subsea oil and gas well blowouts. The limited field experience with this technology makes it however difficult to presume the effectiveness of the technology as an environmental risk reducing measure. It is assumed that successful implementation of a capping device, given a subsea blowout, would reduce the blowout duration, and thereby limit the total amount of hydrocarbons released into the environment.

By combining OPERAto, a dynamic tool for assessing environmental risks from offshore oil and gas activities, and an in-house blowout duration model, the authors have evaluated the use of capping as an environmental risk reduction measure. Uncertainties related to capping used as a solution for subsea blowouts are also discussed.

INTRODUCTION:

A number of recent oil spill incidents from offshore installations, has strengthened focus related to oil spill risk and response issues. In addition to the need to further develop knowledge and understanding about blowout risks, control measures are essential in reducing potential environmental consequences given a blowout event. The latest developments in well capping techniques indicate that this might be a viable technical solution for controlling subsea oil and gas well blowouts.

Several capping stacks and associated equipment are now available at different locations around the world (SWRP, 2014a). In the case of a subsea blowout, the equipment can be shipped or transported by air to the event location. Capping stacks can be installed on blowing wells from a construction vessel or from a rig. The device essentially fits onto the well, above the BOP. The stack is ROV operated and gradually shuts the well and reduces the hydrocarbon flow. Additional containment may be needed if the well and reservoir are unable to sustain the shut-in pressure, however in this paper it is assumed that this is not the case.

Blowout Duration and Environmental Risk Analysis (Era):

Overall blowout duration is specified as the time it takes for one or several control measures to be effectively installed, preventing further release of hydrocarbons to the surrounding environment. Historically, various control measures have been applied, with varying success. Repair of existing barriers or installations of additional barriers are standard approaches. In 52 % of the cases registered in the SINTEF Offshore Blowout Database (SINTEF, 2011), the blowouts were terminated successfully by bridging or reservoir depletion prior to any further implementation of control measures.

Historical data is used as the basis for evaluating the blowout durations used as input in Environmental Risk Analyses (ERA). The primary source for such data on the Norwegian Continental Shelf is the annual incident report issued by Scandpower (latest version 2013). The report presents blowout duration statistics separately for each well-control method: bridging and depletion, intervention on a surface blowout, intervention on a subsea blowout, and relief well. Each scheme has a specific duration distribution, usually ranging from 0 to 50-100 days depending on the solution. The relief well alternative is considered well specific and includes the following three phases: the decision to drill, mobilizing a rig, and drilling the well to successfully kill the blowout (Vandenbussche *et al.*, 2012).

In order to reflect the variations, a model has been created by DNV GL for estimating blowout durations based on historical data from Scandpower and SINTEF. The model is illustrated by the event tree in the figure below, and is further described in Vandenbussche *et al.* (2012).

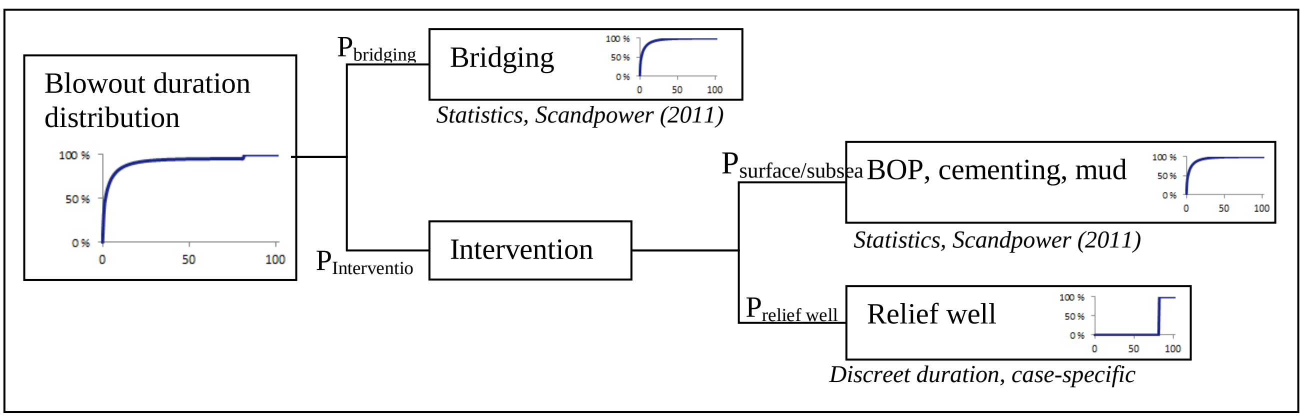

Figure 1 – Duration distributions model (Vandenbussche *et al.*,2012), duration is presented on the X axis, and probability on the Y axis.

Based on available data, 54 out of 593 incidents were reported to use “capping” as the control measure. A review of the blowout database records shows none made use of the capping stacks are described in the present paper.

The duration model provides, based on all control measures except for capping stacks, a continuous distribution of probabilities for blowout durations (**Figure 1**).

Guidelines for environmental risk assessment/ analysis for offshore installations include a step-by-step procedure to identify potential environmental consequence/risk based on a given set of criteria (OGP and IPIECA, 2013; OLF, 2008). The process includes identifying hazards and describing potential oil spill scenarios. The next step in the process is to evaluate the potential ecologic and socio-economic consequences of an oil spill. This includes the use of modelling tools for predicting the oil spill fate and trajectory. The output from fate and trajectory modelling is thereafter combined with the distribution of natural resources. This makes it possible to evaluate environmental consequences from oil spills, e.g. recovery time for populations or habitats. Risk is then established by combining the likelihood value and the potential consequence for each scenario. Depending on the risk level, additional prevention or mitigation measures may be considered. The use of a capping stack as a well control measure may constitute such an option.

Case study 1 – Norwegian Sea coastal wells:

In order to quantify the environmental risk reduction by introducing a capping stack option, a calculation of environmental risk was performed for two potential drilling locations in the Norwegian Sea, as presented in the figure below. Location N-O6 is located at 1000 meters depth and location N-O14 at 300 meters depth.

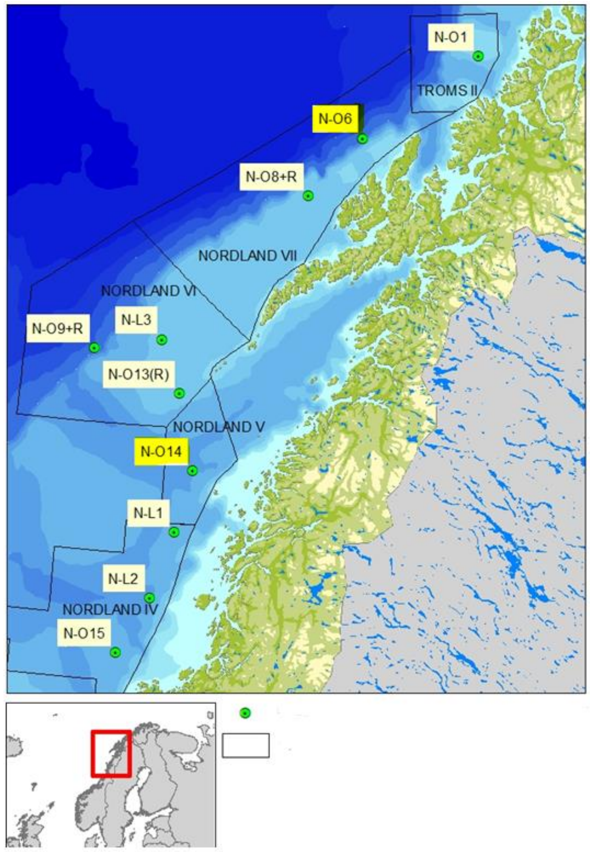

Figure 2 N-06 and N-014 potential drilling locations in the Norwegian Sea

Risk calculations were performed for a subsea blowout with the assumption that the capping stack had a 90 % probability to successfully stop the blowout. When successful, it was further assumed a 90 % probability that the well blowout would terminate within 7 days, based on 3-4 days of mobilising and transport of the capping stack to the field; and another 2-3 days for the actual capping operation. In the remaining 10 % of the cases, extensive debris clearing was assumed and 15 days were required for a successful capping operation. These assumptions change the blowout duration probability for the wells according to **Table 1**.

Table 1 Blowout duration probabilities (cumulative) for two selected wells in the Norwegian Sea with and without capping.

Blowout duration (days)	Without capping	With capping
2	42 %	42 %
7	-	94 %
15	80 %	98 %
50	100 %	100 %

The environmental risks were quantified for selected (high risk) seabird species for the two locations. The risk is calculated as probability for different environmental consequences as follows:

- minor damage (< 1 year recovery time of the species)

- moderate damage (1-3 years recovery time)
- considerable damage (3-10 years recovery time)
- serious damage (> 10 years recovery time)

Risk results are presented in **Figure 3** without (UC) and with capping (C) for the two locations.

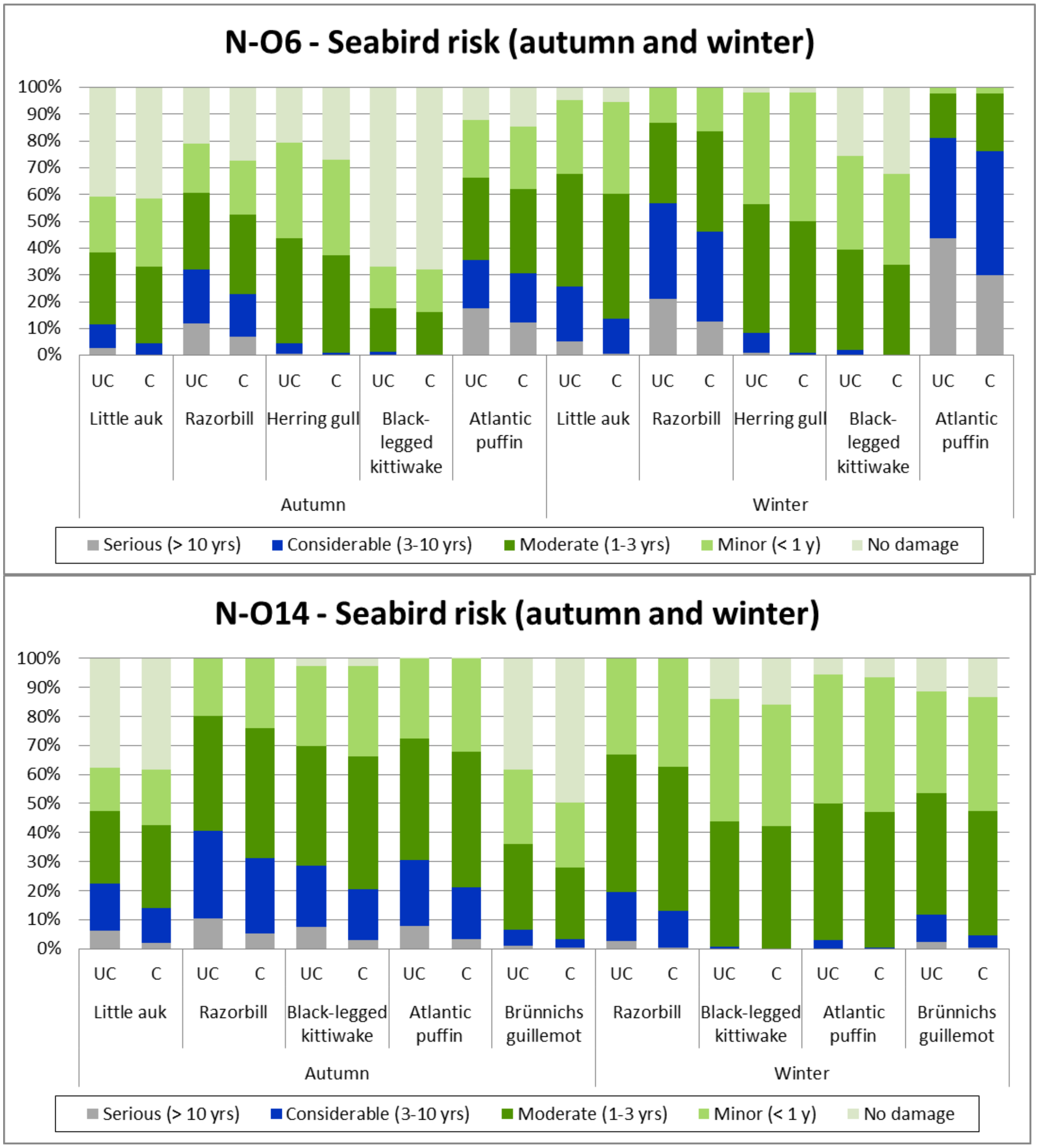

Figure 3 Environmental risk presented as probability for a given consequence category for various seabird species given a blowout in autumn or winter from the two drilling locations. Without capping is marked (UC) and with capping is marked (C).

Figure 3 shows that introduction of capping will significantly lower the probability for the highest consequence categories (considerable and serious damage) for all seabird species. This is expected as the probability for a long duration blowout is significantly reduced with capping compared to other standard procedures. This is further exemplified for the Atlantic puffin in **Figure 4** by showing the percentage change in risk introduced by capping in each consequence category for various seasons.

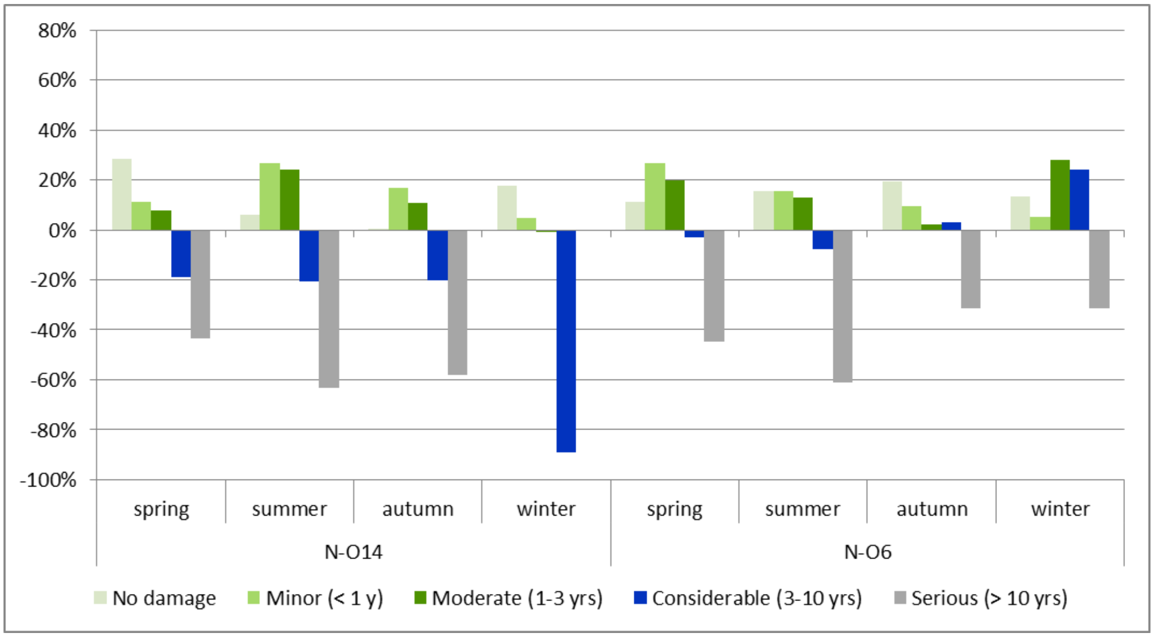

Figure 4 Percentage change in probability for different consequence categories for Atlantic puffin introduced by capping. Seasonal resolution for both drilling locations (N-O6 and N-O14).

Negative values in **Figure 4** represent a risk reduction achieved by the use of capping on the well. Conversely, positive values represent an increase in the risk level. The figure shows that introduction of capping (with the assumptions here made) reduces the probability for having a serious consequence for Atlantic puffin by 30-62 % in case of a blowout. The risk is also reduced by 20-90% in the considerable category for the drilling location N-014. The risk level is increased on the other damage categories, which is due to a shift from the more serious categories to the lower ones. Therefore it can be said that on the overall, the introduction of capping reduces the risk for Atlantic puffin at both drilling locations.

Case study 2 - OPERAto

INTRODUCTION:

OPERAto is a dynamic and interactive risk evaluation tool which, opposed to standard ERA studies, provides the user with the flexibility of adjusting an oil field's activity level as well as potential blowout rates and durations and obtain updated risk calculations promptly. The Excel-based tool presents the results graphically as well as in table format. The data are presented seasonally on two levels; for each individual activity and combined for all ongoing or planned field activities (e.g. drilling, completion, producing wells, etc.). In combination with the risk calculations, the potential oil spill influence area is illustrated seasonally, on activity level, in Google Earth. The risk is presented as damage frequency distributed among four consequence categories.

The basis for OPERAto is the establishment of a broad oil spill release rate/duration matrix in order to meet all potential scenarios linked to ongoing and future field activities. Though focus is primarily on blowout scenarios, smaller leakage scenarios are also feasible to run in the setup. Entering rates and durations values exceeding the initial matrix is not feasible, which means that the matrix has to be well planned in the initial phase of a project.

Environmental risk is assessed by connecting oil spill drift data to coastal and pelagic resources; seabirds, marine mammals and shoreline habitats. The term used for these resources is Valuable Ecological Components (VEC). In OPERAto the risk level for each VEC category is presented on activity level as well as on an overall level, providing the total environmental risk picture for a specific oil field activity level.

In addition to the risk level, the tool provides statistical data for strand mass and drift time.

Baseline risk study:

The tool was prepared for an oil field in the northern part of the North Sea including 10 oil release rates, ranging from 200 to 27 000 Sm^3/day, and 6 durations, from 2.5 hours to 110 days. The VEC category used for this study was pelagic seabirds.

The field setup consisted of a Floating Production Storage and Offloading (FPSO) unit connected to 3 subsea templates with a total of 12 oil producing wells. Drilling and completion activity for an additional oil production well was also included.

The probability split for blowout rates was determined prior to modelling **(Table 2)**. The duration probability split for a blowout is based on historical data, with longest duration being the expected time it takes to drill and operate a relief well **(Table** 3**)**.

Based on the layout of the field, the drilling and completion activity had potential for causing either a topside or subsea release while production was exclusively a seabed release.

Table 2 Blowout rates and probabilities for producing wells and drilling and completion.

Drilling and completion				Producing wells	
Topside rates [Sm^3/d] and probabilities		Subsea rates [Sm^3/d] and probabilities		Subsea rates [Sm^3/d] and probabilities	
4321	12.2 %	4262	12.2 %	5486	18.0 %
6842	26.7 %	6532	26.7 %	7351	68.0 %
8700	35.9 %	8346	35.9 %	8874	14.0 %
12350	21.7 %	12101	21.7 %		
15500	3.5 %	15321	3.5 %		

Table 3 Blowout durations including topside and subsea probability splits.

Duration (Days)	Topside	Subsea
2	54.7 %	43.5 %
5	18.2 %	16.8 %
10	11.1 %	12.6 %
15	4.5 %	6.,4 %
35	4.9 %	9.,5 %
50	0.7 %	2.3 %
80	5.9 %	8.9 %
Weighted duration (days)	*10.6*	*15.5*

Based on the input, the environmental risk levels for pelagic seabirds, in connection with production activity, was assessed to exceed a frequency of 4.0 x 10^{-5} per year for *Minor* and *Moderate* restitution time (i.e. about once every 25 000 years), and 1.1 x 10^{-5} per year and lower for the consequence categories *Considerable* and *Serious*, respectively (i.e. about once every 91 000 years) **(Figure 7)**.

Implementation of capping technology:

In order to identify the potential for reducing environmental risks by applying existing capping technologies a set of assumptions regarding capping operations were made and entered in OPERAto, as follows:

- Permanent storage of equipment 150 km from oil field – no resource limitation.
- Depending on weather conditions and logistic matters, expected on site delivery time ranged from 1 to 4 days – most likely 1.5 days.
- Well preparation work (prior to installation of capping stack) ranged from 0.5 – 10 days. The longest duration corresponds to a situation where parts of the installation have dropped onto the wellhead and debris needs to be removed. The most likely duration was estimated to 1 day.
- Stack installation and successful capping of well - 2 days. During most favourable conditions the activity could be limited to one day. It was assumed that the longest time for this activity would be 5 days.

Table 4 provides an overview of the assumptions listed.

Table 4 Time schedule (days) for capping related activities.

Activity	Minimum time	Expected duration	Maximum time
Deployment of equipment to site	1	1.5	4
Prepare well	0.5	1	10
Install equipment and successfully cap the well	1	2	5

The probability distribution for each activity was modelled with a triangle distribution curve. The overall probability distribution for capping was obtained by combining all activities. Capping was assumed to be successful in 90 % of cases. The result is illustrated in **Figure 5**.

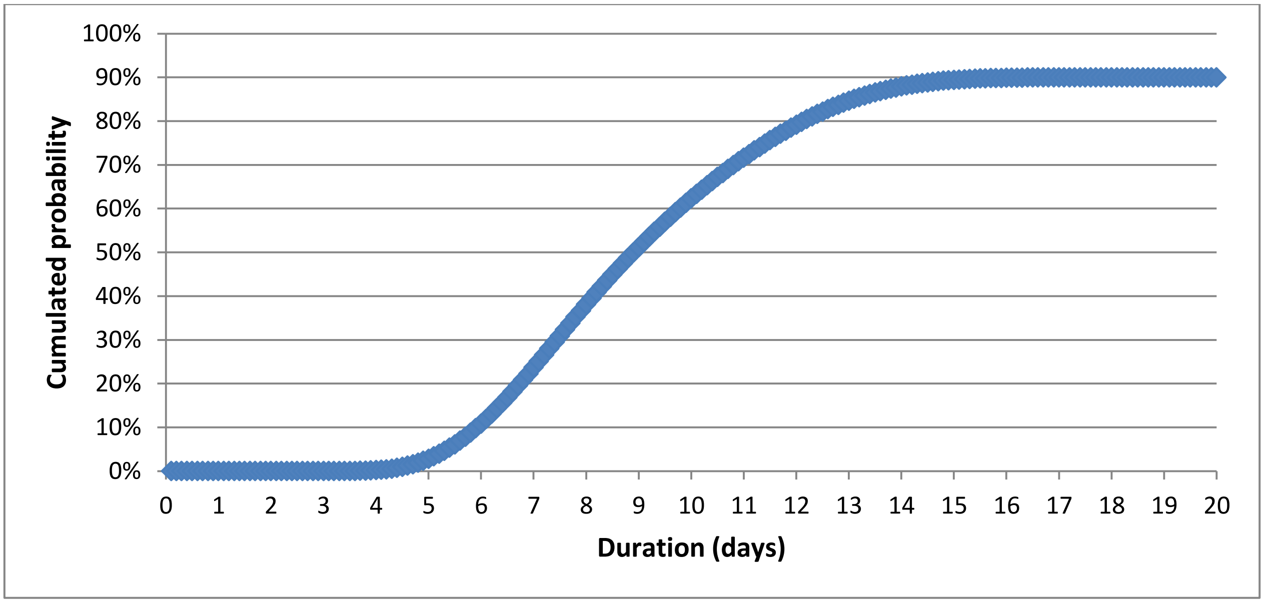

Figure 5 Cumulative probability curve for capping duration.

Capping is added to the blowout duration model. The resulting blowout duration curve is presented below.

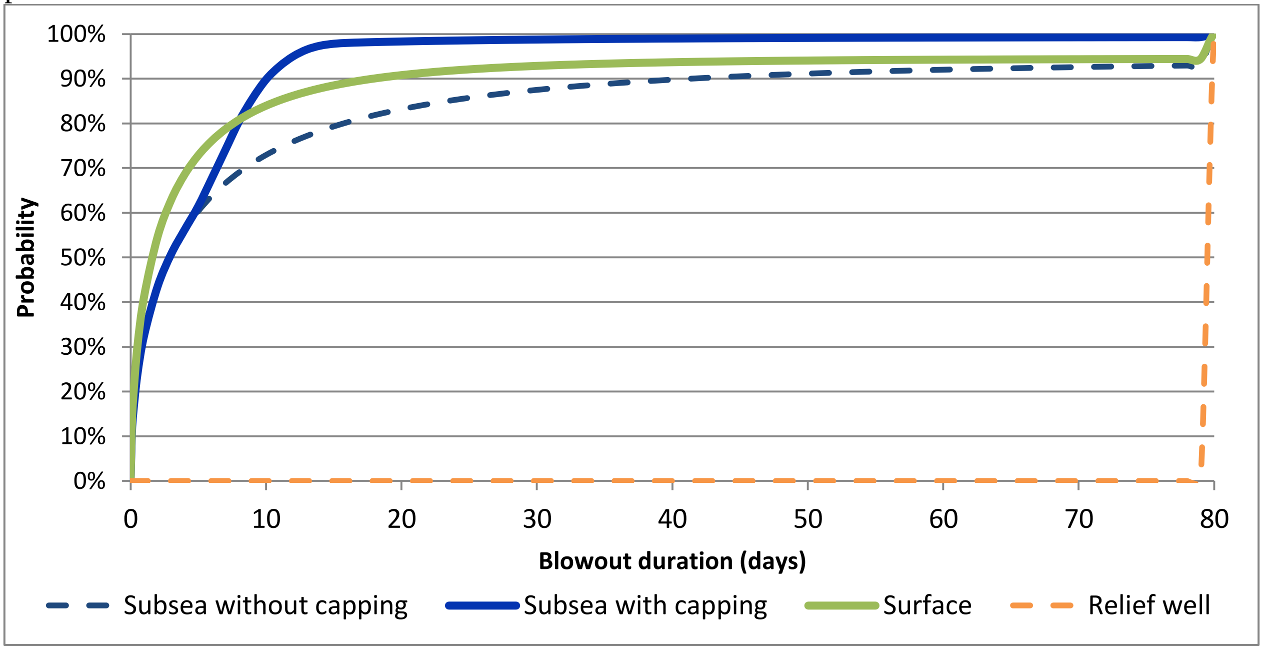

Figure 6 Blowout duration curve including use of capping stack.

Introducing capping as a blowout control measure resulted in a calculated weighted duration for a subsea blowout of 7 days, compared to 15.5 days for baseline study (blue dotted line in **Figure 6**). Based on the revised blowout duration curve, environmental consequences/risk were calculated and compared to the baseline study (**Figure 7** and

Table 5**).**

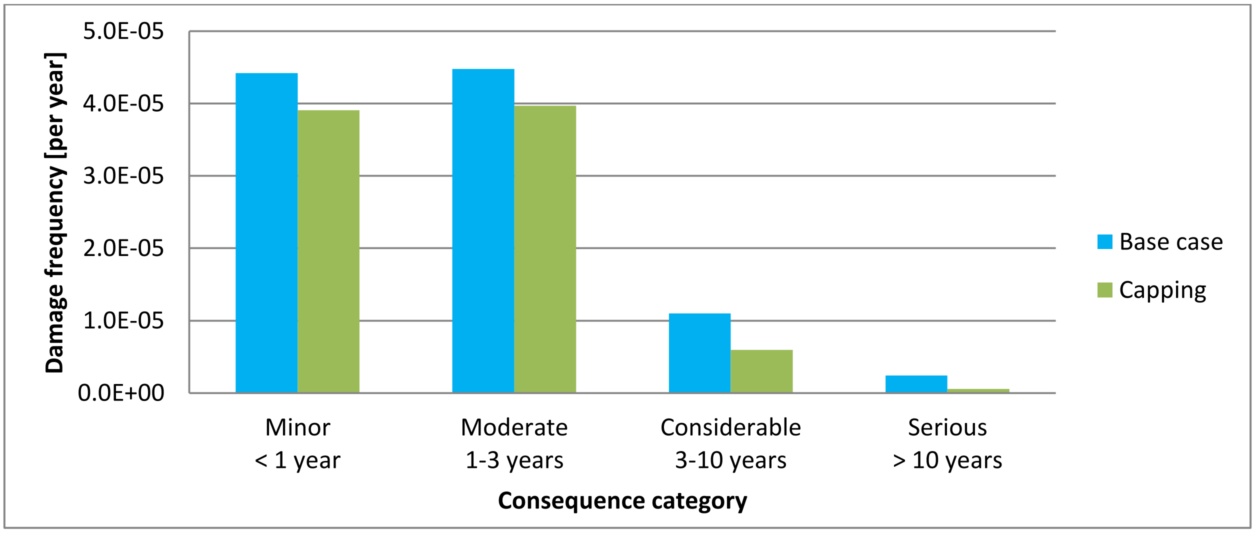

Figure 7 Assessed environmental risk level for pelagic seabirds for oil producing wells; with (green) and without (blue) capping technology.

The results from the study indicate a potential risk reducing benefit for pelagic seabird by implementing a capping device, ranging from 11 - 77 % of the baseline values. The reduction was observed highest for *Serious damage*, while lowest reduction was observed *Moderate damage*. Risk reduction (in percentage) is presented in

Table 5.

Table 5 Damage frequency for scenarios with and without capping as well as risk reduction in percentage.

Damage category	Minor < 1 year	Moderate 1-3 years	Considerable 3-10 years	Serious > 10 years
Risk reduction	12 %	11 %	46 %	77 %

DISCUSSION:

Several assumptions were taken as part of this work, since very limited data is available. This includes mobilization and installation of the capping stack as well as the success rate for capping operations.

In general, the applicability of capping will depend on site specific parameters, such as e.g. water depth, but also the course of events following the blowout, e.g. extensive damage to the wellhead could make capping less suitable as a solution. In addition, current technology requires vertical access to the wellhead for installing the capping stack. This may be a challenge when the presence of gas at the sea surface creates safety concerns. Solutions are being investigated that would allow for offset installations (SWRP, 2014b). As mentioned earlier, additional containment may also be required if the well and reservoir are unable to sustain the shut-in pressure.

Capping response time depends on technology qualification of capping stacks, maintenance and availability of equipment, training of personnel, and planning for logistics. All those parameters are important to ensure that capping can be a successful control measure as soon as possible if a blowout occurs.

Subsea application of dispersant at the well head may be a relevant mitigation measure for environmental risks prior to or in combination with capping, but use of dispersants will not limit the hydrocarbon flow from the blowing well.

Statistics used in risk analyses show that, for floaters (e.g. semi-submersible drilling rigs), in about 20 % of the cases the release location for hydrocarbons is on the topsides (sea surface). In such cases it may be an option to remove the rig from the location and turn the surface release into a subsea one in order to be able to install a capping stack if the blowout was not controlled after a few days. This solution should be considered on a site-specific basis.

For case #2, the OPERAto tool allows an instant visualisation of potential environmental risk in its Excel based spread sheet for different blowout scenarios, including generating capping scenarios without the need to run additional oil drift and fate modelling.

Based on the defined assumptions, capping could be in place and effective in controlling the blowout as early as 5 days after the initiation of an event **(Figure 5)**. Therefore, capping is a barrier for blowouts longer than 5 days. Duration statistics show that approximately 40 % of all subsea blowouts last more than 5 days **(Figure 6)**.

Environmental impacts being clearly dependent on the blowout duration, capping represents an efficient means for preventing significant environmental damage. Both case studies show that the successful use of a capping stack on a subsea blowout contributes to risk reduction, especially for the more serious damage categories requiring long recovery times.

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