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REPORT Petroleum Safety Authority

Qualitative study – causal factors and measures for well control incidents related to Norwegian petroleum activities

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Abstract:

Although the potential for major accidents on the Norwegian Continental Shelf (NCS) has steadily declined since 2005, the contribution from well control incidents has remained relatively unchanged during this period. Petroleum Safety Authority therefore initiated a study into the causal factors and measures for well control incidents related to Norwegian petroleum activities.

Information pertaining to well control incidents on the NCS was gathered from several types of sources, namely, literature review, incident reports and interviews with experienced and knowledgeable people involved in the planning and execution of drilling and well operations on the NCS.

Through the analysis of the information, four challenges have been identified for the industry to improve prevention and management of well control incidents: well control competence, learning and experience transfer, risk management and management of change.

Key word	Well control, incidents, accidents, RNNP 2022
Report no.	1074652-RE-02
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Confidentiality	Open
Revision no.	01
Date revised	30-05-2023
Pages	40

Rev. no.	Date	Reason for revision
01	30-05-23	Final report
00	24-04-23	English translation issued for client review

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1 Summary

The following report contains the work carried out by Proactima as part of Petroleum Safety Authority (PSA) RNNP 2022 report (Petroleum Safety Authority, 2023). The report is a translation of Chapter 9 in the RNNP 2022 covering the qualitative study of causal factors and measures for well control incidents related to Norwegian petroleum activities.

2 Introduction

Prevention of major accidents is a prerequisite for prudent operations. In their letter of allocation for 2022, the Ministry of Labour and Social Inclusion (AID) has set "reduced risk of major accidents in the petroleum activities" as a goal and priority area for the Petroleum Safety Authority (Ministry of Labour and Social Inclusion, 2022).

The PSA follows up companies involved in petroleum activities to ensure that they fulfil their responsibility for identifying and handling safety-critical conditions that affect major accident risk, and choosing solutions that are crucial for ensuring prudent operations. PSA also follows up developments related to possible long-term consequences for the risk level where critical functions for operation and maintenance of both on offshore and onshore facilities are affected. PSA systematically assesses and adapts any required follow-up of the industry.

In this report, the term "industry" is understood as organisations involved in drilling and well operations. The term "One Team" is also used in the report and each company may have a different approach to what this term means. In this report, "One Team" is used to describe organisational and operational forms of cooperation between companies involved in drilling and well operations.

2.1 Background for the study

The background for the study is that there has not been a significant reduction in the number of well control incidents on the Norwegian shelf since 2013; RNNP (Petroleum Safety Authority, n.d.a; Petroleum Safety Authority, n.d.b). Well control incidents are included in the assessment of the major accident potential on the Norwegian shelf. SINTEF carried out a similar study for PSA in 2011 and identified four well control challenges that the industry should follow up (Petroleum Safety Authority, 2011). The study conducted by SINTEF is hereinafter referred to as RNNP 2011. The background for the RNNP 2011 study was a negative trend in the number of reported well control incidents in the period 2008-2010, as well as an assessment of experience after the Deepwater Horizon accident in 2010. The Deepwater Horizon accident was a tragic reminder of the major accident potential associated with well control incidents.

There has also not been a significant reduction in the risk contribution from well incidents since 2012. Figure 2-1 shows the development of the major accident potential for Norwegian petroleum activities since 2005, as well as the contribution to this indicator from well incidents. The term well control incidents in this report corresponds to the term "well incidents" in RNNP.

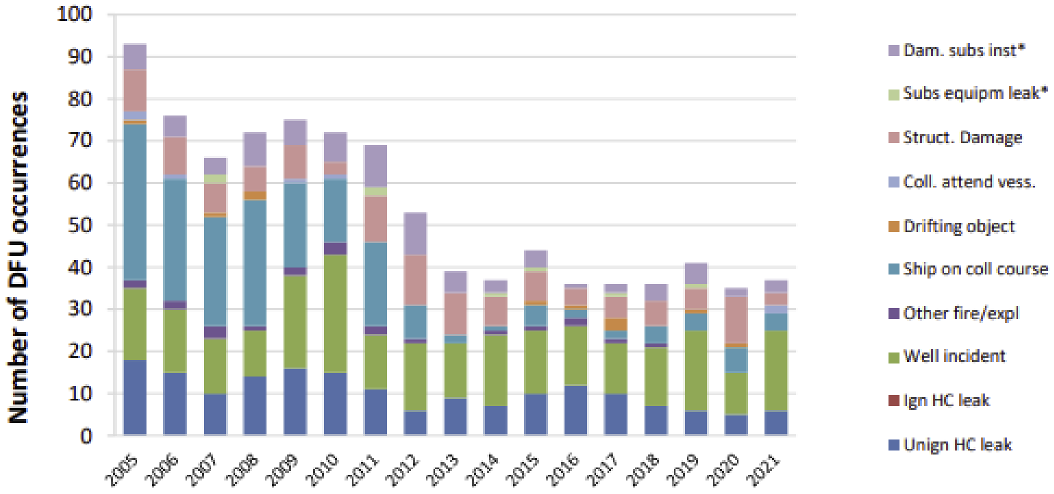


Figure 2-1 Overview of all Defined Situations of Hazards and Accident (DSHAs) with major accident potential on all facilities*

The overall indicator of major accident potential has declined since 2005, but the contribution from well control incidents has been relatively stable.

Figure 2-2 shows the number of yearly well control incidents since 2005, both for exploration wells and for production wells. Figure 2-3 shows the number of well control incidents normalized against the number of exploration and production wells per year.

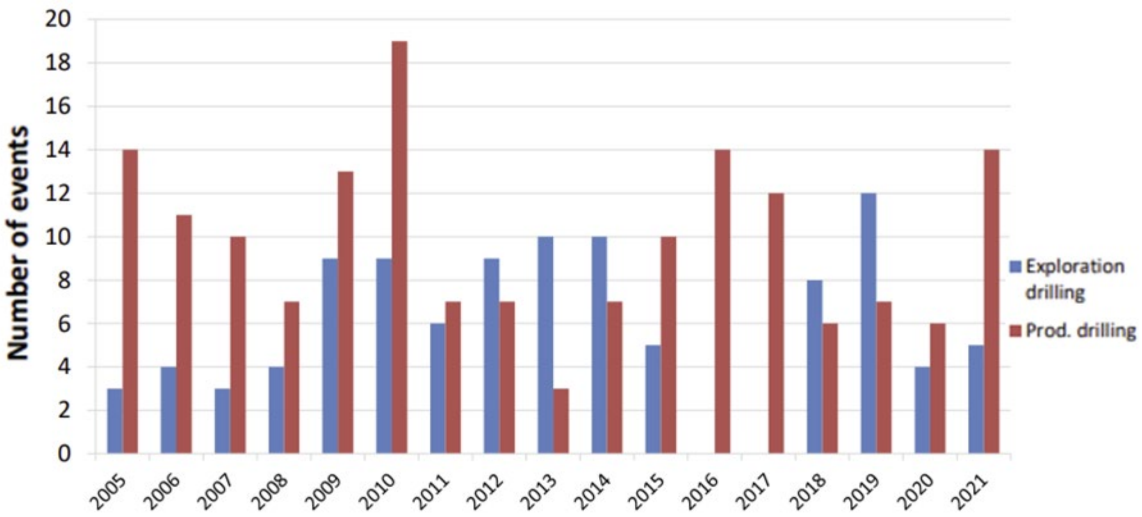


Figure 2-2 Number of well control incidents in exploration and production drilling, 2005-2021*

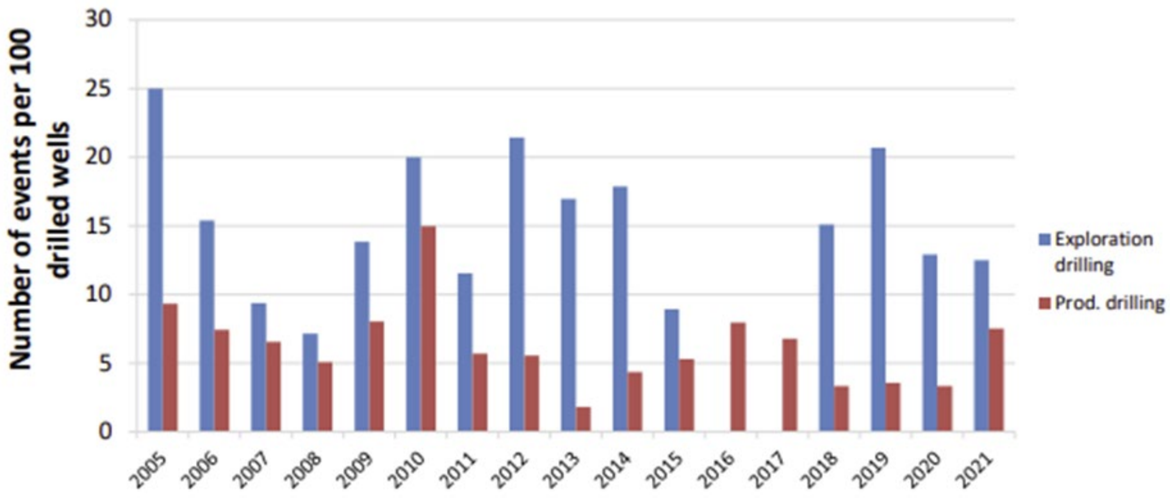


Figure 2-3 Number of well control incidents per 100 wells, exploration and production drilling, 2005-2021[*]

Figure 2-2 and Figure 2-3 show that there has been no systematic improvement in the number of well control incidents per year since 2005. These figures show only the number of well control incidents and do not include an assessment of the severity of each individual incident.

Figure 2-4 shows a risk indicator that takes into account the major accident potential from each well control incident since 2005.

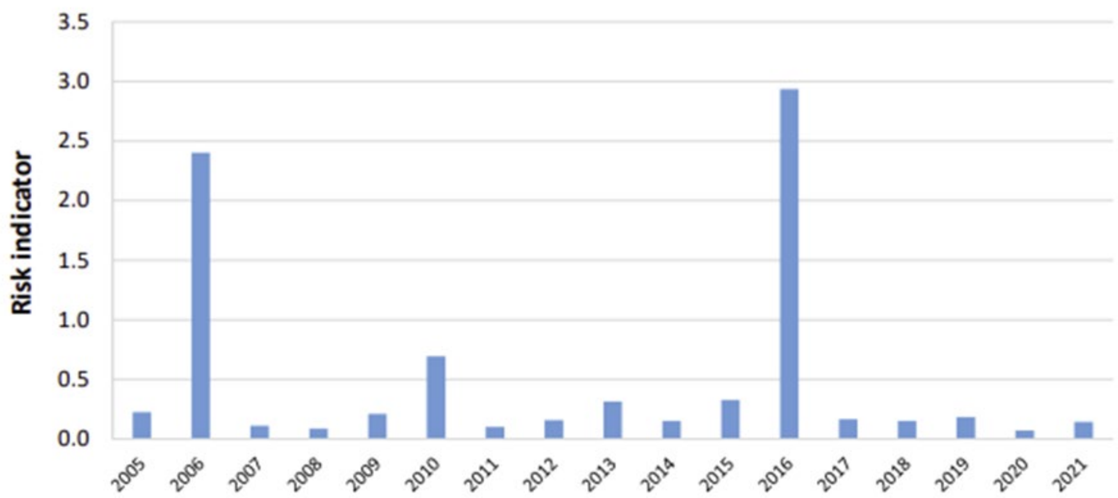


Figure 2-4 Risk indicator for well control incidents during exploration and production drilling, 2005-2021*

This risk indicator considers both the number of well control incidents and the severity of each individual incident. The high values in 2006 and 2016 are due to serious well control incidents on an exploration well on Krabbe and a plug and abandonment (P&A) operation on well G-4 on the Troll field respectively.

[*] Figure 2-1, Figure 2-2, Figure 2-3 and Figure 2-4 are from RNNP – 2021 report (Petroleum Safety Authority, 2022a)

3 Purpose and problem description

3.1 Approach

The purpose of the study is to analyse causal factors and measures related to well control incidents on the Norwegian shelf. Insight is sought into causes that have not been mapped to any great extent or for which measures have not been implemented, and which the industry can address. The study will identify challenges for the industry that can help reduce the number of well control incidents and their potential. The results will be seen in the context of the PSA's work through 'Major investment – follow-up and serious incidents' (Petroleum Safety Authority, 2022b). This study is a continuation of the study conducted under the auspices of RNNP 2011.

The design of the study is visualized in Figure 3-1.

Figure 3-1 Study design

3.2 Selection of design/analysis

The project team's experience and expertise related to drilling and well operations form a basis for the approach to the study and thus the choice of design/analysis model. The project team has chosen to use a qualitative design where information is collected based on relevant literature and interviews with relevant informants, cf. section 4. In the next sections, some academic challenges and framework conditions are highlighted that form the basis for the chosen design.

3.2.1 Well control

The main challenge in drilling and well operations is loss of well control, which can ultimately lead to a blowout of hydrocarbons. Planning and execution of drilling and well operations shall cover the following areas:

- Prevention of well control incidents
- Intervention/management of well control incidents
- Response to well control incidents in the event of escalation and spills

This study focuses on the first two of these three areas: prevention and intervention/management of well control incidents. Response is of course also an important area, but this phase is beyond the scope of this study.

3.2.2 Interaction and communication

There are several companies involved in the planning and execution of a drilling and well operation, and the activities take place both onshore and offshore. This requires a high degree of cooperation. The activities are technically demanding and involve the use of complex equipment. The companies involved must have approved technical systems and equipment, and they must have processes and procedures for carrying out the tasks in a safe and efficient manner. Personnel must understand their own role and the interaction they have with others. In this way, organisational safety is an important factor in achieving a safe and efficient operation. Involved personnel shall have both the competence and time to carry out their tasks in a safe manner.

3.2.3 Risk management

There are many uncertainties associated with drilling and well operations, for example, uncertainty in pore pressure forecasts for individual formations, and such uncertainties must be addressed in the risk management process. Risk management must be seen in relation to both individual risks and overall risk. The communication of uncertainties, risks and risk-reducing measures is of fundamental importance to ensure a prudent operation.

3.2.4 Barrier management

Establishing and verifying barriers is fundamental in both prevention and intervention of well control incidents. Barriers include technical, operational, and organisational measures.

3.2.5 Management of change

Plans for drilling and well operations often need to be changed due to inherent uncertainties, borehole challenges and challenges with drilling and well equipment. The industry is also striving for continuous improvement of safety and efficiency and reduction in costs. Such improvements require changes and a good process for managing changes.

The industry is exposed to variations in the level of activity due to changes in the price of oil. The industry is also continuously aware of how collaboration and interaction can be improved. These often lead to organisational changes that then place high demands on the management of such changes.

3.2.6 Technology Development

Technology development has been of great importance to drilling and well operations, and this development will continue in the future. This applies to drilling facilities, drilling equipment, drilling methods, interpretation of data and methods for learning and experience transfer. Technology development will also make it possible for the industry to expand the boundaries of which drilling and well operations can be carried out in a prudent manner.

3.2.7 Learning and experience transfer

Learning and experience transfer are important factors for the prevention and management of well control incidents. The industry has a great potential for facilitating experience transfer and learning at several levels, and this is central to this study.

4 Method description and assimilation of information

The project team has, in collaboration with PSA, identified three main sources of information relevant to the study that will provide a representative information base: literature review, well control incidents and interviews, see Figure 4-1 . The project team believes that these sources of information complement each other, and together these form a sufficient basis for the discussions in section 7, which is the starting point for challenges relating to focus areas for the industry in section 8.

Figure 4-1 Information sources for the study

The emphasis on these three sources of information varies to some extent in the discussions in section 7. For each discussion point, the contribution from each information source is made visible with a qualitative scale visualized using bar graphs. Figure 4-2 shows an example where the contribution from all three sources of information is considered to be equal.

Figure 4-2 Graphical representation of the contribution from each of the three sources of information

4.1 Literature review

The following literature was considered relevant to the study.

4.1.1 Deepwater Horizon blowout in 2010

A limited and targeted literature review has been conducted of national and international research and other relevant written material related to the Deepwater Horizon blowout in April 2010. The following documents were included in this review:

- PSA's final report after the Deepwater Horizon accident in 2010 (Petroleum Safety Authority, 2014a)
- Norwegian Oil and Gas (now Offshore Norge) report on the Deepwater Horizon accident

- Chemical Safety Boards (CSB) investigation into the Deepwater Horizon blowout (U.S. Chemical Safety and Hazard Investigation Board, 2016)

The following three areas were considered to be most relevant to this study and the study's discussions:

- Empirical studies on defence in depth (with a focus on technical, operational and organisational barriers)
- Organisational safety
- Methods for learning and experience transfer

4.1.2 RNNP 2011: Study on well control incidents

The background for the well control study in 2011 (Petroleum Safety Authority, 2011) was the negative trend in the number of reported well control incidents in the period 2008-2010 and experience of the Deepwater Horizon accident in 2010. The Deepwater Horizon accident was a tragic reminder of the major accident potential of well control incidents.

RNNP 2011 identified four main challenges:

- Stronger emphasis on technical measures to improve safety
- Stronger focus on barrier management and more adapted risk analyses
- Stronger focus on major accident risk – more investigations
- Creating conditions for good collaboration between operating company, contractors and subcontractors

Based on the data and information analysed in this study, an assessment has been made on how the industry has followed up the challenges highlighted in RNNP 2011.

When reviewing well control incidents, the causal categories of well control incidents, used in RNNP 2011, are shown in Table 4-1. The figure distinguishes between overall causes and specific causes. Overall causes were divided into human (H), organization (O) and technology (T). Specific causes were divided into the categories shown in Table 4-1. This classification has been used to provide greater insight into the various causes of well control incidents.

Table 4-1 Categorisation of causes of well control incidents developed by SINTEF in RNNP 2011

Overall category	Specific cause
Human (H)	Error type slip / carelessness / mistake
	Cognitive error (due to deficient expertise and/or risk understanding)
	Error directly connected to poor/deficient design
	Error connected to breach of applicable practice / procedures
Organisation (O)	Company management, facility management
	Work management
	Risk assessment / analyses (SJA, etc.)
	Planning / preparation
	Procedures / documentation
	Work practice / operational follow-up of barriers
	Workload

Overall category	Specific cause
	Inspection / check / verification
	Communication / cooperation / interfaces
	Competency / training
	Goal conflicts – safety vs. effectiveness
	Change management
Technology (T)	Technical well design (cement, plugs, casing, etc)
	Technical fault in, or inadequate detection of well kick
	Technical fault/weakness in primary barrier / drilling mud column
	Technical fault/weakness in secondary barrier / BOP
	Other technical equipment fault/weakness in safety-critical equipment
	Ergonomics / human-machine interface / design of workplace
	External causes - geology and reservoir

In RNNP 2011, direct and underlying causes were also categorised according to the categories in Table 4-1.

4.1.3 PSA audit reports

The term audit generally encompasses all activities that provide PSA with a basis for assessing and following up that the companies operating on the Norwegian Continental Shelf are conducting their operations prudently and in line with the regulations. PSA carries out audits, including revisions and verifications, and identifies areas of improvement for the industry. This study gathered and analysed information from 113 audit reports in the period 2012 to 2022 that are related to well control and cover improvement areas relevant to well control.

The audit reports describe observations related to how the companies comply with regulatory requirements. Observations can be either nonconformities or areas for improvement, and there is no distinction made between these in this study.

Observations from audit reports were assessed and categorised based on the frequency of the observations and the relevance of the study. The following categories are used:

- Well control competence requirements
- Knowledge of well control procedures
- Training, exercises, and use of previous well control incidents
- Well control equipment
- Qualification of barriers
- Roles and responsibilities related to well control
- Reporting of well control incidents

Observations from audit reports are presented in section 5.1.

4.1.4 RNNP questionnaire-based surveys

In connection with RNNP, a working environment survey is conducted every second year from 2001 onwards. This is a questionnaire survey that all employees offshore and at onshore facilities are given the opportunity to answer. There are about 6000-8000 people who respond each time.

4.2 Well control incidents

Information about well control incidents, including an understanding of what happened and how and why each incident occurred, is an important prerequisite for preventing and managing future well control incidents. Both Norwegian incidents and international incidents were considered. The International Association of Oil & Gas Producers (IOGP) is used as the source for international incidents.

4.2.1 Well control incidents in Norway

Incidents in Norway related to well control, are categorised in accordance with Offshore Norway's recommended guideline 135 (Offshore Norway, 2019.). This categorisation forms a basis for which events are included in RNNP. There are well control incidents in green, yellow and red categories included in RNNP. Well control incidents have been reported to PSA in accordance with Section 29 of the Management Regulations.

There are several sources of information on well control incidents in Norway that have been used as a basis for this study.

- Investigation reports from companies and PSA
- In-depth studies of individual events
- Offshore Norway Sharing to be Better (STBB) "one pagers" that provide a brief overview of well control incidents that have been reported
- Offshore Norway "Sharing to be Better" (STBB) detailed learning reports from selected "one pagers"

The Offshore Norway Drilling Managers Forum (DMF) performs an annual analysis of all well control incidents that have been reported. These analyses provide a summary of the incidents and an overview of the main contributing factors for the incidents.

As part of the study, 121 well control incidents in the period 2013 to 2022 in Offshore Norway's "Sharing to be Better" (STBB) database have been reviewed. These are referred to as "one pagers".

Offshore Norway prepares detailed learning reports from selected "one pagers" each year (Offshore Norway, n.d.). The information in these reports is taken from the years 2013 to 2021. A total of 22 STBB learning reports were assessed. Investigation reports and in-depth studies of well control incidents not already covered by an STBB learning report were also considered. 16 investigation reports and in-depth studies were also assessed in addition to the 22 STBB learning reports. The 22 STBB learning reports and 16 investigation reports (a total of 38 well control incidents) were used to identify causes according to the categories used in RNNP 2011.

When the operators prepare a "one pager" for a well control incident, it is noted in which phase (activity) the incident occurred. The phases used are:

- Drilling
- Tripping
- P&A/Slot recovery
- Cementing
- Completion/Workover

- Well work
- Circulation to lighter fluid

The categorisation in accordance with these phases was also used in this study.

The operators also identify direct and underlying causes for each incident according to predefined categories. Offshore Norway DMF conducts an annual review of "one pagers" and prepares a report with an overview of direct and underlying causes, improvement areas and a reflection on the development of the risk level. In the "one pager" reports, DMF identifies "main contributing factors" for well control incidents. DMF's "main contributing factors" are:

- Pore pressure prediction/ seismic uncertainty
- Equipment failure
- Swabbing
- Human error
- Incorrect mud weight
- Ballooning
- Cement
- Error in program
- Perforating
- Trapped gas P&A/ Slot Recovery

The reports from DMF in the years 2013 to 2021 were reviewed, and the areas of improvement and any actions identified by the DMF were used as input to the discussions.

4.2.2 International well control incidents (IOGP)

IOGP publishes information on well control incidents, including a description of certain incidents posted on the IOGP website, similar to that of Offshore Norway STBB. IOGP has also released a report reviewing 172 well control incidents from 2019 (IOGP, n.d.).

Prevention and management of well control incidents is important to IOGP and there is a lot of useful information about well control incidents on IOGP's website. Following the Deepwater Horizon blowout on April 20, 2010, IOGP set up a working group to learn from the Deepwater Horizon blowout and other serious well control incidents, including Montara in 2009. The group's mandate was to identify and implement measures that will help avoid such incidents in the future. The work was divided into three areas:

- Prevention: to improve drilling safety and reduce likelihood of a well incident
- Intervention: to decrease the time it takes to stop the flow from an uncontrolled well
- Response: to deliver effective oil spill response preparedness and capability

IOGP has identified the “main contributing factors” of well control incidents. These causes were compared with the causes of well control incidents in Norway to gain an understanding of whether the challenges are similar or if there are differences between the information from Norway and from IOGP. Well control incidents in STBB learning reports and investigation reports were used in this assessment.

IOGP uses seven “main contributing factors” and records the number of incidents in each category. For example, procedures are a main contributing factor in 51% of incidents.

The 38 well control incidents categorised according to the categories used in RNNP 2011 were assessed against IOGP's main contributing factors. Table 4-2 shows which categories were used in this assessment. Here, the category from RNNP 2011 that best represents each IOGP "main contributing factor" has been selected.

Table 4-2 Categories from RNNP 2011 compared to IOGP "main contributing factors"

SINTEF/RNNP 2011 category	IOGP "main contributing factor"
Risk assessment / analysis	Risk Assessment Flaws
Planning / preparation	System failures
Work supervision / management	Supervision failures
Cognitive error / misconception	Human factors
Competency / training	Competence and Resources
Technical failure of, or imperfect primary barrier / drilling mud column	Barrier failures
Wrong actions stemming from non-observance of procedures	Procedures

4.3 Interviews

The knowledge and experience of people involved in planning and execution of drilling and well operations, and who have a role and responsibility within well control, was regarded as an important source of data for the study. Several interviews were therefore organised with personnel with relevant knowledge and experience. The interviews were also used to shed light on causes of well control incidents that may not be adequately described in investigation reports, STBB learning reports and "one pagers".

The selection of informants was initially made by considering which types of companies should be involved. An important factor was to have informants who are representative of the industry and who have knowledge and experience relevant to well control. The following types of company were selected:

- Operators
- Drilling contractors
- Service companies
- Well intervention companies

Subsequently, individual companies in each company type were selected. These companies were then contacted and asked to nominate a contact person for further discussion. An introductory meeting was held with each companies' contact person where the purpose of the study and the purpose of the interviews were discussed. The project team, together with the contact person in the company in question, selected relevant people with roles and responsibilities related to well control. One of the objectives was that the selected personnel should be representative of the industry and cover roles and responsibilities related to well control across the drilling and well environment. The interviews were conducted on Teams.

The interviews were conducted with a semi-structured approach and an interview guide for the interviews was prepared in advance. The intention of the guide was to ensure consistency across the interviews, that all relevant topics were covered, and that all the informants had the same perception of the interview. The duration of the interviews was also stipulated in the supervision. The interviews included five topics that were considered appropriate for the study:

- Competence and understanding of roles related to well control
- Barriers and barrier testing
- New technical and organisational methods for drilling
- Risk management and communication
- Learning and experience transfer

Some of the interviews were conducted with individuals while others were conducted in groups. At the beginning of each interview, descriptions were given of the purpose of the study and the purpose of the interviews. Open-ended questions were used to facilitate discussion, and an important premise was that the informants expressed what they thought was important for well control. Two people from the project team participated in each interview, and efforts were made to strike a balance between what the informants wanted to highlight about each of the topics and sufficient time to cover all five topics. All informants were informed that the information and statements from the interviews would be anonymised both in the report and in all discussions with PSA.

In the interviews with the operator's drilling and well managers, the informants were given greater freedom in the discussions to highlight what they themselves believed to be the most important points with regard to well control. In the interviews with persons involved in the assessment of subsurface conditions, e.g., estimation of pore pressure during drilling, the interviews focused primarily on these subsurface factors.

All interviews were conducted by the same persons, with the exception of the interviews with informants who work with subsurface conditions where a person with expertise in this area also participated. The information that emerged in each interview was documented in minutes, and the main points from the interviews were compiled in an interview overview.

Table 4-3 shows an overview of the number of interviews and the number of people who participated in the interviews for the different types of companies. Input from the interviews provides an important basis for the discussion in section 7 and the challenges facing the industry in section 8.

Table 4-3 Overview of number of interviews and persons interviewed for each company type

Company Type	Number of interviews	Number of persons
Operator	21	27
Drilling company	7	13
Service company	4	12
Well intervention company	3	6
Total	35	58

4.4 Remarks and limitations

Both audits and investigations of well control incidents are based on an approach where faults and deviations are identified. This means that attention is focused on looking for errors and then correcting them. Information on prevention and management of well control incidents that functioned well is rarely discussed in audit reports. It is true that some investigation reports provide a description of what worked well in the handling of the incident, but this feedback has not been included in this study as it was considered that there was insufficient data to draw any conclusions. Observations from audits can be characterized by WYLFIWYF, "what you look for is what you find" (Lundberg, J. et al., 2009). This is difficult to avoid since the audit always has a theme and the people involved have their own experience and expertise. The audits may also be influenced by the PSA's main annual topic. WYLFIWYF also characterizes the investigation of incidents and the investigation team's approach to an incident. This is also highlighted in the PSA's report on the Deepwater-Horizon accident, page 100, figure 11 (Petroleum Safety Authority, 2014b; Petroleum Safety Authority, 2014c).

The basis for the comparison of the causes of incidents in Norway and IOGP "main contributing factors", as shown in section 4.2.2, has considerable uncertainty as the project team does not have access to the raw data used and how the categorisation has been carried out. Nor are the categories used in RNNP 2011 directly comparable with IOGP ”main contributing factors”. Despite the uncertainty in the basis for comparison, it was considered that the results of the comparison are worthy of highlighting, since it suggests relevant differences between the prevention of well control incidents in Norway and internationally.

The informants received information about the purpose of the study and how the interviews fit into the purpose of the study. This provided a good basis for openness and good and relevant discussions. Well control is a topic that engages most people in the drilling and well environment, and there is a good understanding that prevention and management of well control incidents is important. Despite thorough information at the start of the interviews, it is nevertheless conceivable that some of the informants may have been influenced by the fact that the study was conducted under the auspices of RNNP and PSA.

The majority of the informants are in management positions either offshore or onshore. This may influence feedback in some areas, for example for working environment factors discussed in the RNNP questionnaire survey and what the informants reported about workload. It cannot be ruled out that a different methodological choice of informants would have yielded different results.

4.5 Quality Assurance

Quality assurance is used to uncover possible sources of error and bias in the data to ensure that the analysis of information sources is as representative as possible. The quality assurance work was carried out along the way through dialogues and discussions within the project team and in meetings with the PSA. Mapping of sources of error and/or biased information has been carried out as part of the quality assurance of the report.

The information has been collated and organised so that it is possible for independent parties to replicate the categorisation from audit reports and categorisation of causes from well control incidents. The information from the interviews is organised in such a way that it is possible for independent parties to verify the interpretation of the informants' input.

4.6 Application of information

Based on an assessment of the information sources, key topics were selected and discussed, as described in section 7. These themes are then highlighted again as challenges, described in section 8.

5 Results

5.1 Audit Reports

113 audit reports with observations related to well control were assessed. In this data material there may be several observations from each individual audit. Figure 5-1 shows the number of well control observations from audit reports in each category. The choice of categories is explained in section 4.1.3.

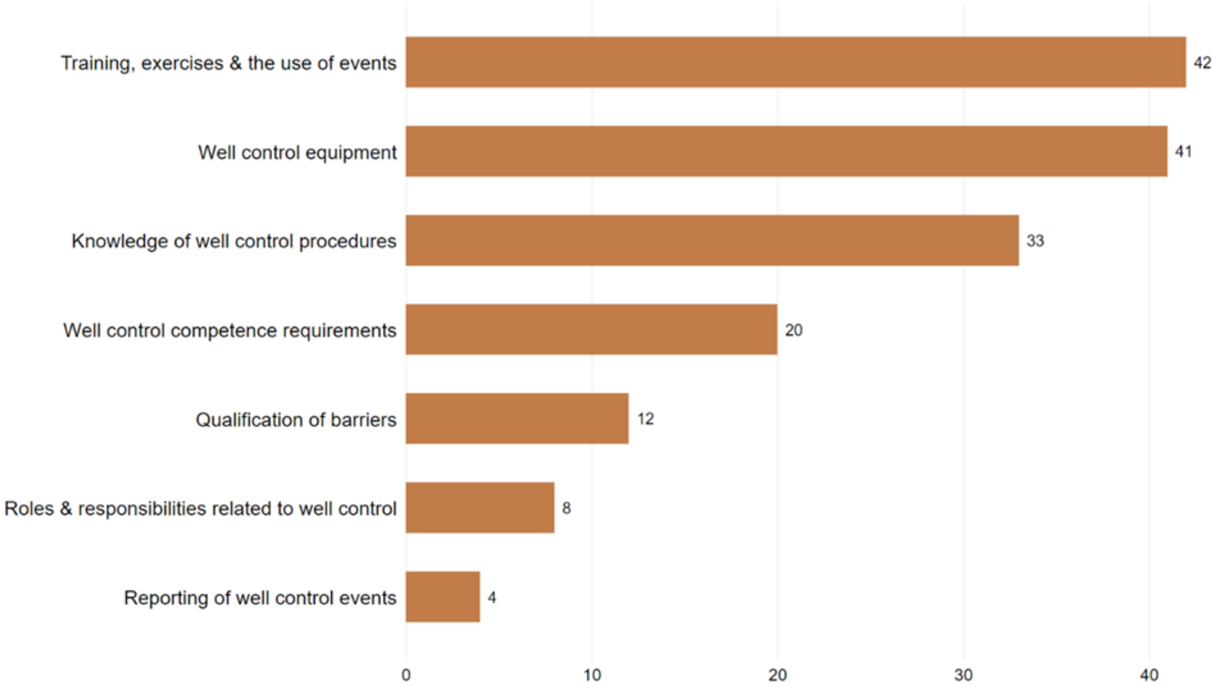


Figure 5-1 Number of well control observations from audit reports

Audit reports also provide insight into other challenges that may have an impact on the prevention and management of well control incidents. Three challenges that stand out in the audit reports are capacity and competence, risk management and organisational changes. In several audits, the PSA points out that facilitation of organisational changes is often inadequate and that the preconditions for the changes are not in place before the changes are implemented.

5.2 RNNP questionnaire-based surveys

The working environment indices 2021 were considered most relevant to the study and are presented in Figure 5-2.

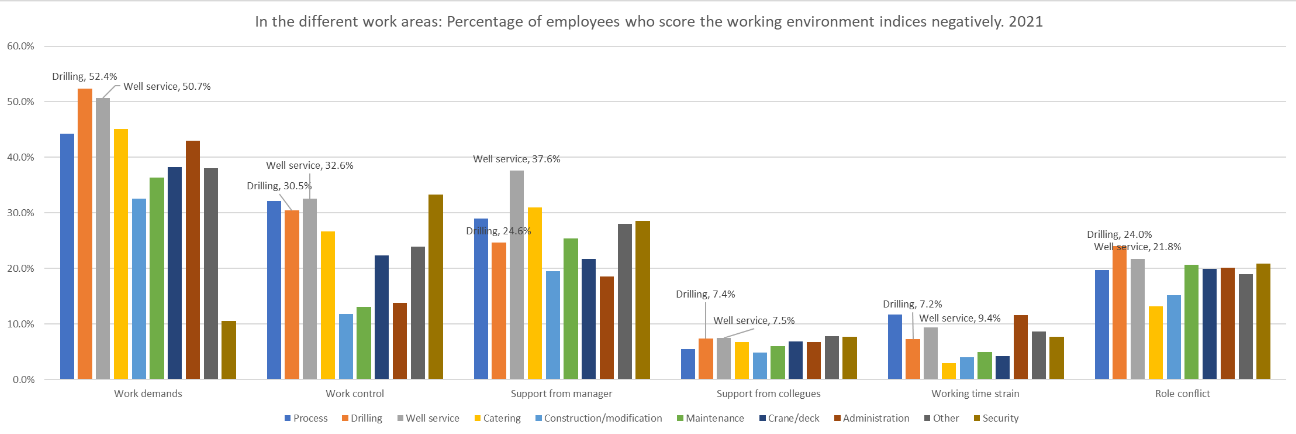


Figure 5-2 Percentage of employees that score negative on working environment-index work areas*

The RNNP questionnaire is sent out every two years to everyone who works offshore. The subjects are presented with 33 questions about their working environment. These questions constitute six indices that together can be said to provide a description of the psychosocial and organisational working environment for the individual employee. If you look at the various work areas, you get a picture of which working environment conditions stand out for each of the areas. Figure 5-2 shows the proportion of employees in each work area who have a negative score on the various indices.

The relevance of the study is related to the expectations of workers in drilling and well service and the implementation of organisational changes, e.g., the introduction of combined positions and cross-training.

5.3 Well control incidents

The causes from investigation reports between 2013 and 2022 were assessed according to categories prepared in RNNP 2011, as described in section 4.1.2; Figure 5-3. The investigation reports included in the study were selected based on the quality of the investigation reports and whether they contained an adequate description of causes. A total of 38 investigation reports from well control incidents in the period 2013-2022 were reviewed. The distribution of causes in the investigation reports is shown in Figure 5-4.

* Figure 5-2 is from the RNNP-2021 survey (Petroleum Safety Authority, 2022a)

Figure 5-3 Number of cases of well control incidents, categorised according to RNNP 2011, cf. section 4.1.2

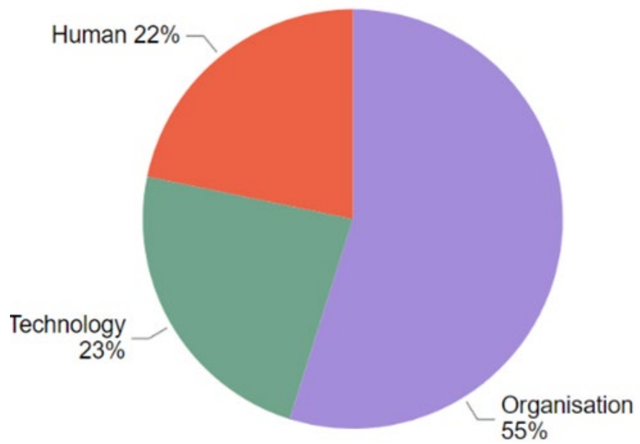


Figure 5-4 Causes of well control incidents, percentage distribution. Categorised according to RNNP 2011 (HTO)

The following human causes appear most often:

- Cognitive errors (lack of competence and/or risk understanding)
- Incorrect actions related to violations of applicable practices/procedures

The following organizational causes appear most often:

- Risk assessments/analyses
- Work practice/operational follow-up of barriers

The following technical causes appear most often:

- Technical failure/weaknesses in the primary barrier/sludge column
- External causes related to geology and reservoir*

A review of STBB learning reports and investigation reports shows that organisational reasons contribute most (55%) to well control incidents.

Figure 5-5 shows DMF's categorisation of the phases in which well control incidents occur, cf. section 4.2.1. The phases are described in section 4.2.1. The figure shows the percentage of the total number of incidents (121).

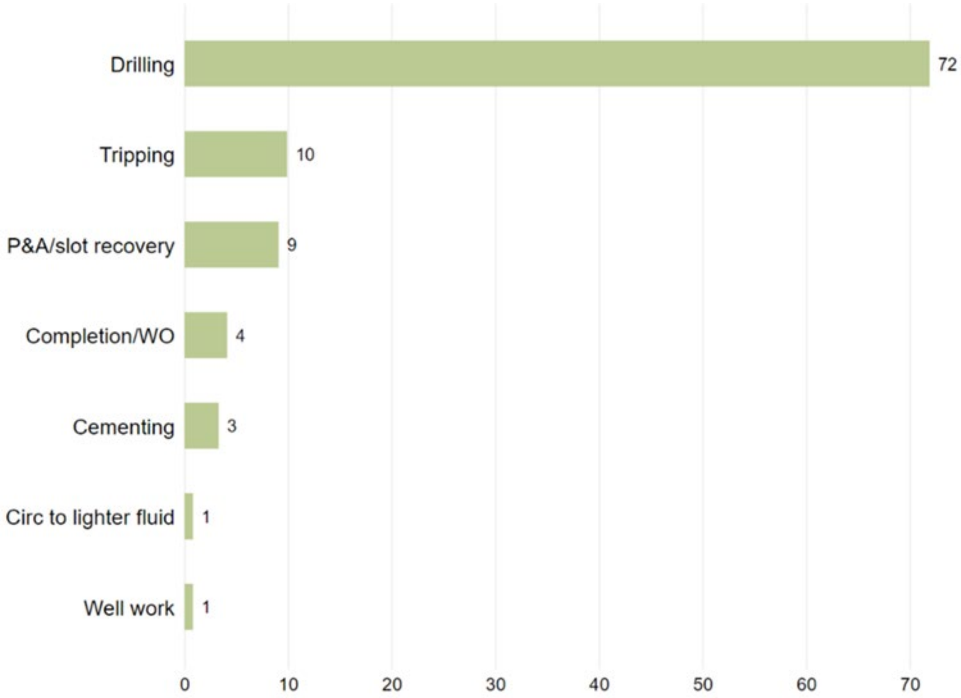


Figure 5-5 Phases in which the well control incident occurs (percentage distribution)

DMF's categorisation of "main contributing factors" to well control incidents as described in 4.2.1 is shown in Figure 5-6. In this figure, the 'main contributing factor' for each incident is shown as the percentage distribution of the total number of incidents (121).

* This also includes the uncertainty surrounding pore pressure.

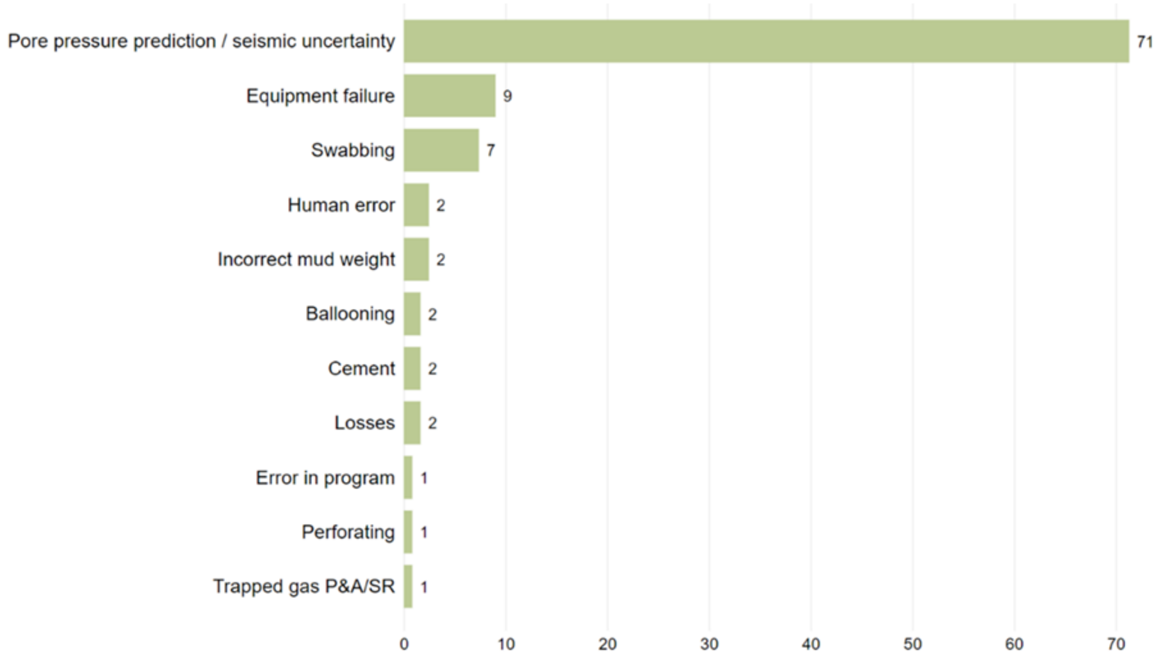


Figure 5-6 Main contribution factors of well control incidents, percentage distribution

Figure 5-3 and Figure 5-6 provide two different perspectives for the causes of well control incidents. Figure 5-6 shows that uncertainty surrounding pore pressure and subsurface conditions as the dominant cause. This is consistent with PSA findings, where investigations following well control incidents from 2018-2022 have been reviewed, and it has been identified that more than 60% of the incidents are related to pore pressure forecasts and inadequate communication of the uncertainty related to pore pressure throughout the planning phase and operation. Figure 5-3 is more nuanced and provides a more detailed picture of the causes. The basis for Figure 5-6 is all 121 well control incidents included in the study, some of which have a simple sequence of events and relatively few causes. The basis for Figure 5-3 is well control incidents that have a more complex course of events. It is these incidents that are the subject of investigations, in-depth studies and STBB learning reports.

A comparison of main contributing factors for well control incidents in Norway (38) and internationally (172) is shown in Figure 5-7. The figure shows the number of incidents for each of the seven main contributing factors. For example, procedures were a main contributing factor in 51% of IOGP incidents, and in 71% of STBB incidents. It is noted that 'procedures' in this context includes both the quality of procedures, the availability of procedures and familiarity with procedures.

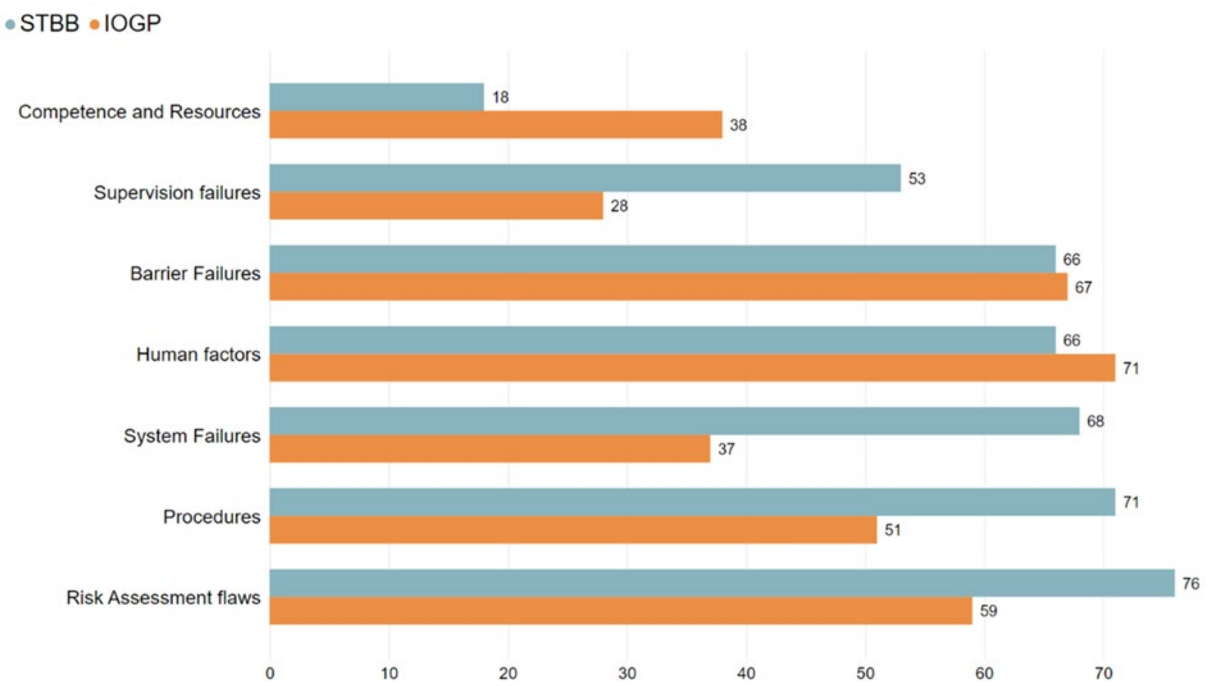


Figure 5-7 Comparison between RNNP 2011 categories and IOGP "main contributing factors"

One of the purposes of such a comparison was to assess whether there is a significant difference between the causes of well control incidents in Norway and internationally.

Based on the comparison in Figure 5-7, two main contributing factors have been selected for further consideration: 1) competence and capacity and 2) supervision failures. There was broad agreement among the informants that a lack of competence is not one of the most important causes of well control incidents in Norway. Most of the informants also state that there are sufficient resources to handle a well control incident. The difference between STBB and IOGP suggests a generally higher level of education and competence for personnel with roles and responsibilities in well control in Norway compared to other countries, e.g., qualified apprenticeship in drilling and technical college qualifications in drilling for most offshore positions with drilling contractors. Feedback from several of the informants shows that a lot is expected of frontline supervisors in terms of facilitating the work, communicating critical information and context, and expectations of being role models for the team. The investigation reports also place a lot of emphasis on the role of supervision. The project team has concluded that the difference between STBB and IOGP can be explained by higher expectations for supervision in Norway compared to other countries.

There is no basis for explaining the differences shown in "Procedures", "System failures" and "Risk assessment flaws" in Figure 5-7, as insufficient information is available from the IOGP study.

The information from the comparison described in Figure 5-7 is relevant for the assessment of human and organisational factors related to the prevention and management of well control incidents. It provides insight into organisational safety and how this affects both individuals and teams. The comparison also provides information about challenges and limitations in the organizations that may be important for the future.

5.4 Interviews

The interviews show a high degree of commitment among the informants and an interest in well control and continuous improvement related to prevention and management of well control incidents among the interviewees. Most of the informants are in management positions either offshore or onshore. For more details on the composition of informants, see section 4.

6 Follow up of the RNNP-2011 challenges

This section discusses how the industry has followed up the challenges presented in RNNP 2011. The information was obtained in the interviews using specific questions to some of the informant groups.

6.1 Stronger emphasis on technical measures to improve safety

Some of the informants stated that the industry has invested heavily in technical measures and has shown a willingness to invest in new technology and new drilling methods. The industry has also been willing to accept that the introduction of technical measures may result in increased costs and delays during the testing and introduction phases. The preparation for the introduction of new technical measures offshore is good, with involvement of relevant personnel in planning and preparation before these new measures are implemented.

According to the informants, the industry has actively used technical measures to achieve safe and efficient well and drilling operations and reduce costs. It is expected that this will continue to characterize the industry in the future.

6.2 Stronger focus on barrier management and more adapted risk analysis

The industry has increased its focus on barriers and testing of barriers after the Deepwater Horizon accident in 2010. NORSOK D-010 is considered a good standard for ensuring well integrity in drilling and well operations, and a lot of resources have been used to improve the standard since 2010. NORSOK D-010 has been revised several times since 2010 to include lessons learned from incidents and to set standards for new technology and methods. According to the informants, the principle of primary and secondary barriers is well understood, and "NORSOK D-010 Well Barrier Schematics (WBS)" are used in well planning and execution of operations.

Many of the informants stated that knowledge of, and understanding of, well barriers and barrier management is good across the industry. There has also been an increased focus on operational and organisational barriers since 2018. In this context, the PSA's barrier memo in 2017 and PSA audits have had an important influence. The informants state that establishing well barriers, testing of well barriers and understanding of well barriers remain a priority for the industry.

The informants also stated that risk analyses carried out in connection with drilling and well interventions have been improved since 2010. An important factor here is organisational development offshore. Personnel are encouraged to take the time needed to plan and execute activities, participate in discussions about safe work performance and "stop the job" if they feel that the job is not being carried out safely. Risk analysis within the planning phase remains a challenge, and this applies not least to the handling of uncertainty, especially the estimation of pore pressure.

Several of the informants pointed out a need for more expertise in carrying out risk analyses in the planning of drilling and well operations to ensure that the purpose of the analyses has been achieved and that the method is implemented as intended. Moreover, there is a need to ensure that the risk management process is adapted to both the management of individual risk and the management of overall risk. This is discussed in more detail in section 7.4.

6.3 Greater focus on major accident risk – more investigations

The industry focuses on major accident risk, and there is a broad understanding of how well control incidents contribute to this risk. Several of the informants pointed out that the quality of the investigations varies, and there is room for improvement. This is also in line with the PSA's focus on learning from incidents.

There are still examples in the investigation reports where the causes have not been adequately assessed. Some of the informants pointed out that the question 'why' is not asked often enough. The reasons often stem from vague formulations that lead to unclear measures. Human error is often referred to as a cause of incidents, and although this may be true, it in itself is of little help in finding sensible measures. The investigations need to dig deeper into human factors to understand why the people involved did what they did and why they believed the actions were acceptable and appropriate. This need is also addressed in the Safety Forum's report on Learning from incidents (Safety Forum, 2019).

In investigations, it is understandable that the investigation team focuses on what went wrong, what was not done, and what was misunderstood or misconstrued. An alternative approach to investigation is to understand what actually happened, what conditions were present and why those involved believed what they were doing was rational and acceptable.

6.4 Creating conditions (framework conditions) for good collaboration between operating companies, contractors and subcontractors

Several of the informants point out that there has been progress in cooperation and collaboration offshore, and the "One Team" concept is well anchored. The operator-supplier hierarchy is supported by better clarification of roles and responsibilities. The implementation of "One Team" facilitates good discussions and involvement. Personnel involved are encouraged to contribute with what they know and are able to stop work when it becomes unsafe. Potential offshore conflict areas are either handled offshore where offshore has the authority to make decisions or transferred onshore.

Cooperation and collaboration onshore have not had the same progress across the industry and the "One Team" concept is not as well established. Here there is a difference between the operators and how they establish and facilitate a "One Team" concept.

The informants from several companies that have contracts with the operating companies claimed that there is an unbalanced power relationship and that this is rooted in the contracts that govern framework conditions for the relationship. Poor conditions that lead to a difficult working environment are often created during the tender phases, and such contracts become less suitable for good cooperation and collaboration.

7 Discussion

Based on information from the various data sources, key topics related to prevention and management of well control incidents are discussed and analysed in this section. The discussions are the basis for challenges covered in section 8.

As mentioned in the introduction to Section 4, the weighting of the three main sources of information is shown in the bar graphs.

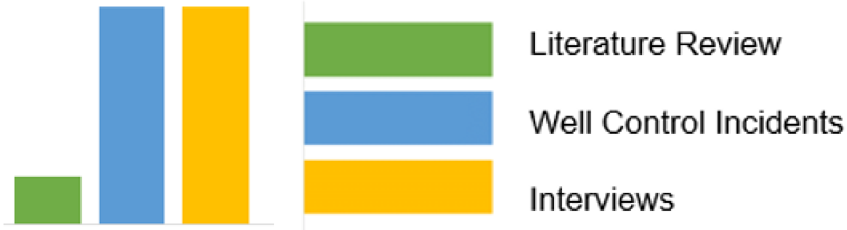
7.1 Development related to wells

Many of the informants stated that many wells have become more challenging since 2011 and that conditions for drilling and well interventions will continue to become more challenging in the future. This will affect well control. Examples of more challenging wells are HPHT, H2S, P&A, faster, deeper, and longer.

Some of the informants mentioned that the industry has access to better drilling equipment, better and more powerful drilling facilities, and has developed new and better drilling methods, and is therefore able to drill more challenging wells in a safe and efficient manner. This development will continue, and the industry will constantly redefine the boundaries of which wells are safe to drill. This of course, requires good processes for barrier management, risk management and management of change.

Some of the informants mentioned that the industry is aware of cost reduction and that this affects the design of wells. In some cases, this has resulted in less robust solutions, e.g., fewer casing strings. This requires effective risk management and good assessment of uncertainty to demonstrate that cost-effective solutions are prudent.

7.2 Development in subsurface conditions



Many of the informants stated that pore pressure will always be a challenge in exploration wells when there is limited information about subsurface conditions and few wells in the area to verify pore pressure estimates. Uncertainty about pore pressure is also the most important cause of well control incidents in Norway, cf. Figure 5-6. Some of the informants also maintained that for exploration, the information about subsurface conditions is well understood and considered in planning, but that the industry can improve the process of communicating uncertainty about subsurface conditions and how this is used in the assessment of margins in operation.

Based on the interviews, it also emerged that uncertainty about pore pressure in mature fields such as large inherent pressure variations may become a greater challenge in the future. Estimating local pore pressure in fields with water and/or gas injection can be challenging. Well planning should consider well control incidents, but this cannot be simplified to "avoid a well kick". An overall assessment must be made for each well individually to find the right balance between various factors, e.g., the balance between "avoiding a well kick" and the "possibility of loss of circulation" that could lead to a well control incident. Here, the potential for escalation and the possibility of a serious well control incident must be included in the assessment.

The information from the interviews indicates that the industry has a good understanding of the uncertainty about pore pressure and that there are serious attempts to find out how this uncertainty should be handled in the subsurface environment. Communicating uncertainty and how the inherent risk is managed remains a challenge. More challenging subsurface conditions are stated to be contributing to the trend in well control incidents since 2012.

7.3 Development of technology

Many of the informants mentioned newer drilling methods such as Managed Pressure Drilling (MPD), Dual Gradient Drilling (DGD) and Continuous Circulation Subs (CCS), which will make it possible to achieve better control of important drilling parameters and facilitate lower margins during operation. The informants pointed out that this will also make it possible to drill in more challenging downhole conditions.

Some of the informants mentioned that newer completion equipment, e.g., expandable liners, has made it possible to drill certain sections more efficiently while preventing well control incidents.

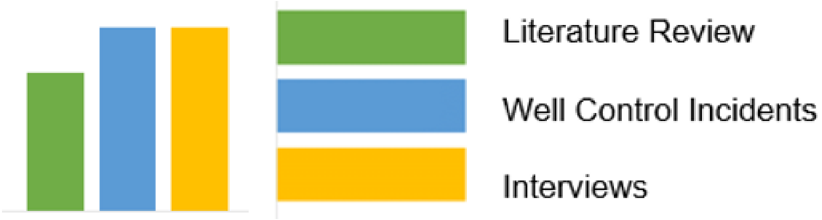
Newer drilling equipment for measuring downhole pressure, such as a wired drill pipe, which makes it possible to obtain better information about conditions in the well, especially pore pressure, was also mentioned. These provide better control over the development of downhole pressure, better well kick detection and thus improved prevention of and faster handling of a well control incident.

Information from the informants and literature indicate that improvements in remote control and communication technology may make it possible to run more operations with personnel onshore. This is a clear trend for the industry and will probably have a significant impact on drilling and well operations in the coming decades. The challenge will be good processes for risk assessments and change management that take into account human factors in cooperation and collaboration.

In the interviews, it was also highlighted that technology development, drilling automation and digitalisation can facilitate a common understanding of the situation, which is positive, but that it will also lead to greater demands on cyber security. Cybersecurity failures affecting the functioning of drilling equipment can cause a well control incident and affect the eventual handling of a well control incident.

Many of the informants mentioned ongoing processes for digitalisation of procedures for carrying out drilling and well operations. Most informants were positive to this development, but some were sceptical about a possible change. Digital procedures provide opportunities for better follow-up and documentation of operations, improvement in learning and experience transfer, and reduction in reporting. The informants are generally positive to this development, and it is clear that this is something the industry wants to focus on. As with all changes, good preparation and facilitation are important.

7.4 Risk management



The study is based on three different approaches to risk management in connection with well control:

- Risk management in the planning phase and handling of uncertainties about subsurface, drilling and well conditions
- Communication of risk and risk mitigation measures to those who perform the operations
- Risk assessments prior to operations, e.g., pre-job meeting, Safe Job Analysis (SJA), "Detailed Operating Procedures (DOP)" review etc.

Information from the informants, the review of the well control incidents and the literature reviewed indicate that risk analysis in the planning phase remains a challenge. This applies to the handling of uncertainty, particularly around the estimation of pore pressure. Pore pressure estimation is known as the greatest uncertainty in drilling operations and is the most important cause of well control incidents, see Figure 5-6. The industry has good processes for estimating pore pressure in both exploration and production drilling and a good understanding of the inherent uncertainties associated with pore pressure. The industry also has good processes for assessing other subsurface conditions, e.g., formation stability, etc. In many wells, assessing the balance between these conditions is the greatest challenge in planning.

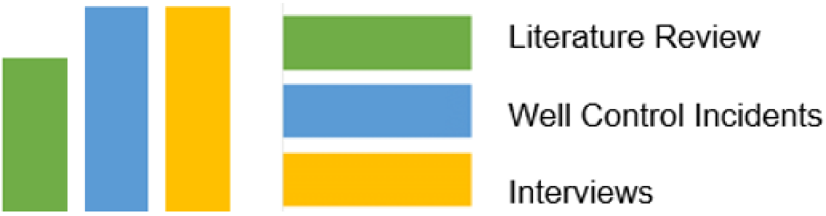
Based on the interviews, two approaches for communicating risks associated with drilling and well operations were considered. The first is the involvement of operational personnel in planning processes and through participation in risk meetings, e.g., "Drilling Well On Paper (DWOP)", "Complete Well on Paper (CWOP)" processes. This is considered positive, especially for critical wells. The second approach is dissemination through the procedures for drilling operations. Practice varies here, and the biggest challenge is how to transfer understanding of the risk picture in a way that operational personnel understand. This requires short and precise information so that recipients have the opportunity to understand what is being communicated. This is particularly important in dealing with the uncertainty surrounding pore pressure and how sufficient margins in the operation are prepared. Continuity of personnel through well planning and execution is also an important contribution to risk communication.

Many of the informants believed that the risk analyses carried out before drilling and well operations are performed have been improved since RNNP 2011. An important factor here is organisational facilitation offshore. Personnel are encouraged to take the time needed, participate in discussions about safe work performance and "stop the job" if it is not safe.

It would appear that important prerequisites for a good risk management process are that location-specific, well-specific and rig-specific factors are taken into account when assessing well control. Technology factors should be included in well-specific and rig-specific factors. There is a need for more expertise in the implementation of risk management processes to ensure that the purpose of the analyses is achieved, and that the method is implemented as intended. It is crucial that risk management processes are adapted to the management of both individual risks and the overall risk associated with the activities.

Based on information from the interviews, the industry appears to be prepared for risk management as an input to the decision and not as a process that justifies decisions. This is positive. Several examples emerged where the risk was considered unacceptable and the drilling or well operation was not carried out. This applied to both exploration and production wells with challenging subsurface conditions and challenging locations. For some fields, this has resulted in less drilling from fixed facilities and more subsea wells drilled from mobile facilities.

7.5 Barrier management



Preventing failure in primary and secondary barriers during drilling and well operations has been an important focus area for the industry since 2010.

The review process for NORSOK D-010 takes into account developments in drilling methods so that good standards and practices are developed and anchored in the industry. The industry's continued focus on testing barriers and clarifying barrier performance requirements is an important prerequisite for preventing and handling well control incidents.

Many of the informants believed that the industry, particularly during the last four years, has paid extra attention to the establishment of operational and organisational barrier elements and the establishment of performance requirements for these. This focus has been reinforced through follow-up after or because of PSA's audits. The transfer of experience in connection with operational barriers is also mentioned in recommendation 21 in OLF (now Offshore Norway) report on the Deepwater Horizon accident (Offshore Norway, 2017).

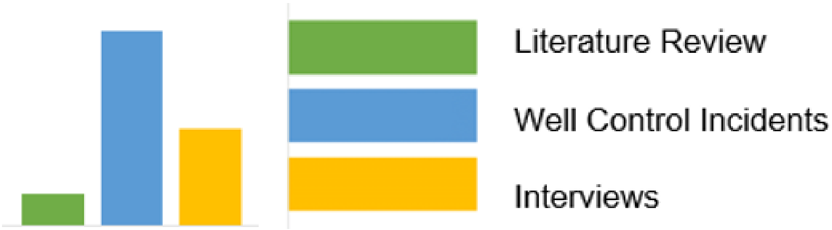
It also emerged from the interviews that the industry is developing a system for monitoring barriers so that operational personnel get a better overview of barriers that have been weakened when planning operations. This is particularly important when assessing simultaneous operations and is also a regulatory requirement.

The PSA's focus on improving barriers and barrier testing was mentioned by the informants as important for the development of barrier management.

7.6 Functionality and reliability of well control equipment

Based on the literature review and review of well control incidents, failure of well control equipment has not been identified as a significant cause of well control incidents in Norway in the period 2013 – 2022. The PSA's audit observations indicate that the industry should continue to monitor the functionality and reliability of well control equipment. Testing of barriers is an important factor and the development of technology can contribute to the verification of the performance requirements for the barriers. The Deepwater Horizon accident, the Montara accident and other serious well control incidents are important reminders of how serious the consequences of failure can be. Functionality and reliability of well control equipment will always be important for the industry, regardless of the causes identified in well control incidents.

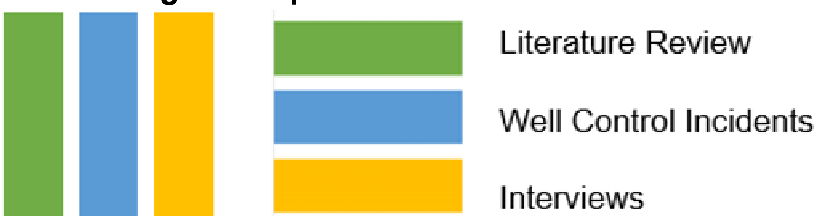
7.7 Handling of well control incidents



Many of the informants talked about good processes for establishing well control procedures that take into account well and location-specific factors (operator) and rig-specific factors (rig company). The informants also emphasised that the operators' and drilling companies' requirements and procedures are assessed and coordinated before any operation is initiated.

The handling of well control incidents is assessed as part of DMF's annual reviews and it is believed that the incidents are generally handled in a satisfactory manner. However, DMF points to inadequate follow-up of signals as an important contribution to well control incidents and has encouraged more understanding and attention among personnel and better measurement systems and methods for monitoring wells. This opinion is confirmed through the interviews.

7.8 Learning and experience transfer



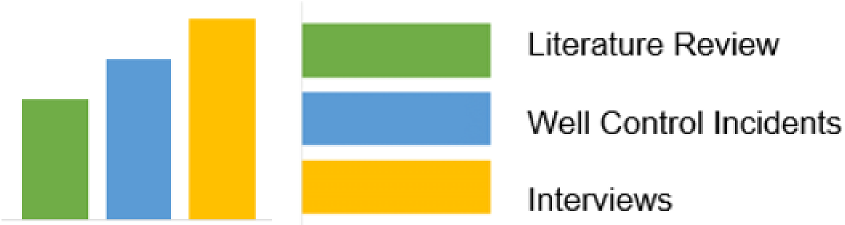
Most informants stated that learning and experience transfer have improved since 2010. The review of well control incidents and the literature also indicates that the processes for learning and transfer of experience have been improved, and that the industry ensures that information from well control incidents is made available to personnel with roles and responsibilities related to well control. Offshore Norway STBB learning reports and "one pagers" are well known and are frequently used both offshore and onshore. Many companies across the industry have established well control forums to engage their employees. Some operating companies have also established weekly offshore well control forums. In addition, some of the operators have established "Operations Excellence" processes that also include the development of well control expertise and transfer of experience. Operating companies also exchange experiences through various forums, e.g., DMF, and individual meetings on serious incidents, such as Troll G-4 in 2016. The PSA has however noted inadequate use of learning incidents as observation in their supervision.

The informants emphasised that today there is more frequent use of information about well control incidents and improved quality of the information disseminated. They also recognised the need for other means of communication to make the transfer of experience more effective, e.g., the animated film about the fatal accident at Maersk Interceptor, 7 December 2017. IOGP uses animations both for communicating information about individual incidents and for training, e.g., how to perceive weak signals, outcome bias and groupthink. Here, role-playing is also used as an educational tool. Learning from well control incidents is much improved when incidents and lessons learned are relevant to ongoing operations. In connection with audits of the companies' barrier management, the PSA also sees that several companies use real well control incidents as a starting point for scenario-based exercises that include relevant personnel, most often in the form of a table-top. Scenario-based training is also recommended in recommendation 29 of the OLF (now Offshore Norway) report from the Deepwater Horizon accident (Offshore Norway, 2017). On page 123 of their main report from the Deepwater Horizon accident, the PSA emphasizes the importance of assessing the worst possible accident scenario in risk analyses when planning drilling and well operations (Petroleum Safety Authority, 2014b; Petroleum Safety Authority, 2014c).

Most of the informants stated that the exchange of experience between the operators and from the operators to rig companies and service companies generally works well. Some operators also make their incident database available to others. In some of the interviews, however, it emerged that there was room for improvement in the exchange of experience between rig companies, service companies and well intervention companies.

The informants see the benefit of several seminars and discussion forums on well control to contribute to the development of well control competence. It is perceived that people in roles related to well control expect the industry to invest in the development of well control expertise. The informants also called for more frequent use of simulators targeting relevant well control operations, e.g., stripping and the use of relevant and realistic scenarios. Training for stripping on a simulator is particularly important since the operation in practice can lead to wear and tear on well control equipment. Training, emergency preparedness exercises and training on team cooperation are also mentioned in recommendations 29 and 30 in OLF (now Offshore Norway) report on the Deepwater Horizon accident (Offshore Norway, 2017).

7.9 Organisation, safety and culture



All informants stated that there is a good understanding of roles and responsibilities in a well control situation among the personnel involved. Clarity of roles and responsibilities is discussed as an important factor in well control incident prevention in paragraph 30 of the conclusions of the CSB's report on the Deepwater-Horizon accident (U.S. Chemical Safety and Hazard Investigation Board, 2016).

All informants stated that there is plenty of headroom for reporting incidents and adverse conditions, and an acceptance for "stop the job" in cases of uncertainty or if personnel feel unsafe. In the interviews with offshore personnel, it was stated that personnel have time to perform their tasks safely. This applies in particular to critical operations, the introduction of new methods and work on critical wells. Excessive workload was rarely highlighted as a problem by personnel in offshore positions. However, some onshore positions experienced pressures that can affect workload and work-life balance. A review of the PSA's audit reports shows that the workload is a challenge offshore.

The planning and execution of drilling and well operations is a collaboration between different companies with different expertise and experience, that together want to succeed with the technically demanding tasks that have a risk of a serious well control incident. How people work together depends on organisational factors such as openness and interaction across companies. Openness and interaction are characterized by the tone of management and what the manager is concerned about. From the interviews, it is clear that some companies are "better" than others in some areas, but this does not necessarily mean that there is one company that has the answer. There is a need for an exchange of experience with organisational factors so that the companies can learn from each other and thus achieve an improvement across the drilling and well environment in Norway.

The informants in all companies mentioned "One Team" and what this has meant for the positive development of cooperation and interaction, especially offshore.

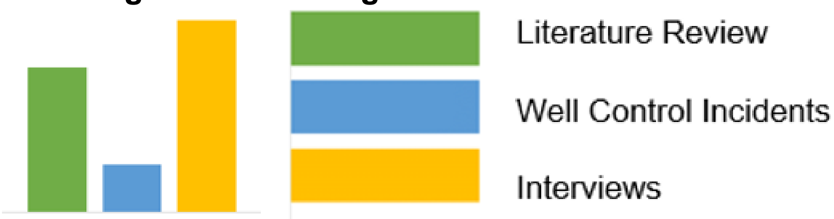
The informants stated that a major challenge with the "One Team" principles is that the framework conditions for how the companies work together are not always adapted to the companies' ambitions for interaction and cooperation. There are different approaches to dealing with this challenge. Some adapt the contracts to the principles, and some provide greater latitude in the interpretation of contract terms to operations management. In some cases, expectations are created that cannot be met due to limitations in the contracts. When the team perceives that this is not being handled in a satisfactory and fair manner, frustration is created in cooperation and collaboration. None of the informants have experienced that this has affected the prevention and management of well control incidents, but anything that undermines cooperation and cooperation can potentially contribute to creating conditions that can lead to a well control incident.

The interviews and literature indicate that managing organisational change is also a challenge for the industry, and this is discussed in section 7.10. The industry is constantly working on improvements that will lead to safer, more efficient and cheaper drilling and well operations, and this entails frequent changes.

The informants emphasised that continuity to optimise cooperation and collaboration is important. Different types of continuity were mentioned:

- Long-term contracts that make it possible to build relationships between the companies and the people in the company.
- planning and execution of drilling and well operations to ensure that important risks and uncertainties associated with the wells are followed up and to optimise the flow of information.
- carrying out critical drilling and well operations, e.g., HPHT wells, and in connection with the use of newer drilling methods, e.g., MPD. For example, that the operating companies collaborate to run a campaign on HPHT wells with the same rig, and that well intervention personnel are dedicated to HPHT intervention operations.

7.10 Management of change



The informants stated that improvements have been made in the management of changes and most companies have formal processes for identifying, risk assessing and documenting changes. This also applies to management of deviations. The informants stated that technical changes and the introduction of new methods and technology are handled in a good way. There has been a positive development in the systematic handling of changes in operational procedures and an acceptance to use the time needed for the personnel involved to become familiar with the changes.

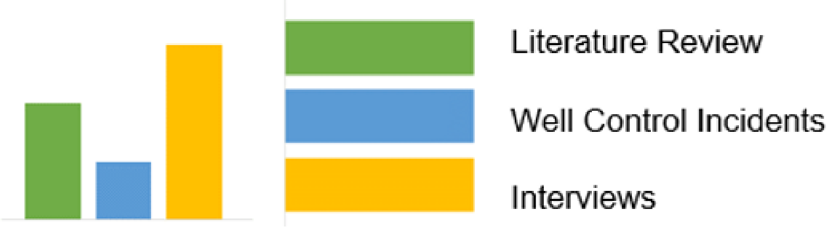
Information from the interviews and the PSA's audits indicate that the industry faces a major challenge in dealing with organisational changes. Changes are often characterised by a "trial and error" approach and the prerequisites for implementation are often not present before the change is implemented. Such assumptions are in many cases identified in advance and are thus expected to be implemented by the personnel involved. Framework conditions are often not adapted to the new organisational changes. Examples mentioned by the informants are lack of training for personnel in positions that have been moved from offshore to onshore, and contract terms that were not changed as a result of changes in workload. It is not clear whether these factors have contributed to a well control incident, but since organisational factors make an important contribution to the causes, the potential is nevertheless present.

Some informants mentioned that the introduction of cross-training and combined positions in drilling and well operations is challenging. This may explain some of the feedback in RNNP's questionnaire survey, e.g., the high negative score for 'job demands', see section 5.2 and **Error! Reference source not found.** This suggests that implementing cross-training is a challenge for the industry.

Some informants mentioned that the introduction of organisational changes has led to an increased workload on land, and some of the informants mentioned that personnel have resigned because of poor work-life balance. This will be an important factor in maintaining sufficient expertise, capacity and recruitment over time.

On page 17 of its report on the Deepwater Horizon accident, the PSA emphasizes that the industry is improving the way changes that may affect the organization's expertise and capacity are implemented (Petroleum Safety Authority, 2014b; Petroleum Safety Authority, 2014c).

7.11 Competence and competence development related to well control



Most informants are critical of the two-year certification courses from the International Well Control Forum (IWCF) and the International Association of Drilling Contractors (IADC). The IADC course was described slightly more positively than the IWCF. The informants with less experience perceived the courses more positively and emphasised the courses' contribution to understanding the basic principles of well control.

The certification courses are perceived as of little relevance to Norwegian conditions, and the equipment and systems on which the courses are based are not adapted to equipment and systems used for drilling and well operations in Norway. This applies in particular to well control equipment used for well intervention. Simulator training is considered important, but too little time has been set aside for training, and the scenarios are poorly adapted to wells in Norway. The language quality and the form of questions in the certification exam are also perceived as ambiguous.

The informants believe that certification of competence in well control is important but call for and expect a process that both verifies competence and provides competence development. The informants also believe that more use of real well control incidents for discussion, and realistic and relevant scenarios with frequent use of the simulator, is important.

The informants understand the need for verification of well control competence for personnel who have a role in well control incidents through a formal process, and both IWCF and IADC provide certification that is internationally recognised. Most informants call for more competence development than what IWCF and IADC offer today. The process should ensure two important factors:

- A confirmation that the participants understand the principles of well control and are able to perform their tasks in relation to both being able to help prevent and handle a real situation.
- A development of well control competence that takes into account learning from real incidents and the development of methods and technology.

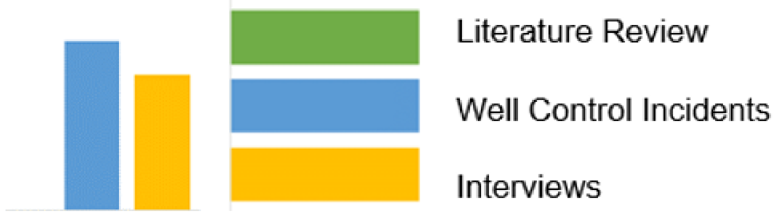
Personnel from all companies interviewed acknowledge the need for formal requirements within well control for people with tasks related to well control. Certification through IWCF and IADC courses is central to this. Many companies have their own additional requirements for competence and competence development, and the informants regard this as positive. Some companies emphasize simulator training and the use of well control incidents for learning. The operators have clear requirements for well control expertise for their own personnel and for personnel in the drilling companies. The operators do not always have clear requirements for well control expertise in the service companies, and this has been identified as an improvement area.

Detailed studies and adjustments to competence guidelines to adapt Norwegian conditions are mentioned in recommendation 28 of OLF (now Offshore Norway) report on the Deepwater Horizon accident (Offshore Norway, 2017). CBS's report on the Deepwater Horizon accident, recommendation 22, highlights the importance of "non-technical skills" in managing complex situations that can occur in a high-risk environment (U.S. Chemical Safety and Hazard Investigation Board, 2016). The recommendations from these reports emphasize the importance of continuous development of technical and organisational competence within well control.

Based on the review of well control incidents, inadequate procedures and inadequate follow-up of procedures appear to be a challenge. Updating and improving procedures is often identified as an intervention in STBB learning reports, investigation reports and in-depth studies. The development of procedures must consider the expected expertise of people involved in drilling and well operations. The information in the procedures must also consider the person's ability to absorb critical information at the available time. The informants were concerned about procedures that attempt to cover everything and all eventualities and do not take into account well-established practices and routines. This was described as a "dumbing down" of expertise and is considered an area of improvement for the industry.

The informants mentioned that for some fields with challenging subsurface conditions and high uncertainty on pore pressure, some operators have developed field-specific well control training. The informants emphasised that this training, and in particular the use of examples to highlight well control challenges, is important.

7.12 Drilling Managers Forum

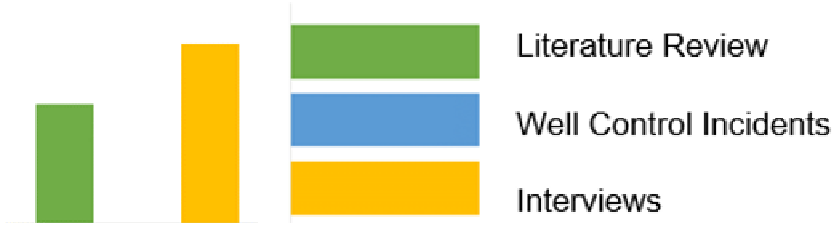


The Drilling Managers Forum (DMF) conducts an annual review of well control incidents and direct and underlying causes identified by the operating companies in “one pagers”. DMF compiles statistics that can uncover trends, identify key factors, main contributing factors, and learning points. DMF also assesses how well control incidents are handled when a well control situation occurs. Based on an assessment of the literature, it may be appropriate for the industry to develop a better system for categorising direct and underlying causes. This can contribute to more relevant learning points, especially for organisational factors.

Many of the points in this study coincide with the recommendations of DMF's annual reviews. From 2016, DMF has focused on change management, risk assessment and improvement in learning and experience transfer. From 2017, DMF has focused on the opportunities for the development of new technology and especially digitalization. From 2018, DMF has encouraged better quality of well barriers in planning, and from 2019 there was a focus on operational and organisational barriers. From 2020, the possibility of digitalisation in connection with training was promoted. DMF has also encouraged processes for better well kick detection and how new technology and digitalization can contribute to this.

Both PSA and DMF play key roles in setting the premises for the industry's improvements related to the reduction of well control incidents, and both have had a major impact on the industry's progress since 2012. Continued good cooperation between the PSA and DMF is therefore important for the industry's progress.

7.13 Future competence and capacity



All informants stated that the industry currently has good systems in place for preventing and handling well control incidents, although estimation of pore pressure was mentioned as a challenge. The informants were convinced that personnel and the organisations involved are competent. All informants mentioned availability of sufficiently competent persons as the greatest challenge for well control in the future. There is concern about a generation shift in the next few years where many experienced people will leave the industry. It is perceived that there are too few younger people with sufficient competence and experience. The industry is cyclical, and periods of uncertain future prospects and major cutbacks, in combination with challenging redundancy and lay-off rules, may have led to younger employees in wells and drilling positions leaving. Recruitment to some positions by Norwegian engineers may be more difficult in the future as there are not enough students in the relevant courses today. This can lead to the industry becoming more dependent on foreign personnel, which can present both language challenges and organisational challenges. In this case, the "One Team" concept would have to embrace more nationalities and languages, which could mean that the English language could become even more prominent in the future.

8 Challenges

Based on the findings of the study and a review of the topic for discussion in section 7, four challenges have been identified that the industry can continue to work on to improve prevention and management of well control incidents.

The challenges highlighted in this report should not be perceived as a new starting point after the report from RNNP 2011. Although good progress has been made in following up the challenges posed by RNNP 2011, the findings in RNNP 2011 are still relevant, and the industry must continue its good work on these.

8.1 Well control competence

As stated in section 7.11, there are several challenges associated with the current system for certification of well control competence. This can be improved by implementing an improvement process where future training is more relevant for drilling and well operations typical of Norway, equipment and systems used in Norway and well control procedures that are expected to be used. Such certification can be based on:

- Verification of understanding of well control principles and skills in carrying out well control tasks (especially important for new persons)
- Development of well control competence and adaptation to new methods, technology and forms of cooperation (especially for people taking refresher courses)

Such a learning plan can make use of information about real well control incidents and new techniques and technology for learning, focusing on both individuals and interaction (who does what with what equipment).

Well control expertise can also be developed by continuing frequent offshore well control forums and seminars that encourage dialogue and discussion. Here, scenario-thinking and integrated training can be useful.

The main concern about well control among personnel interviewed is the future lack of expertise and capacity, and how the industry will ensure that in the future there is access to employees with sufficient expertise and experience and who are adapted to Norwegian conditions.

Within a few years, many people may disappear from the drilling and well environment. Some will retire, some may leave due to the workload and challenge of achieving a satisfactory job/personal balance sheet, service company employees may apply to the operators since there is no longer sufficient pay gap to compensate for the higher workload, etc.

8.2 Learning and experience transfer

The industry, both in Norway and internationally, devotes considerable resources to investigating well control incidents and preparing learning points that can help prevent well control incidents. However, it remains a major challenge to communicate the lessons to the recipients. Examples of how the industry can make learning points more understandable and relevant are the use of incidents related to ongoing operations, scenario thinking, animation, virtual reality, role-playing, 'what-if' scenarios, etc. Digitalization provides greater opportunities for training through more use of virtual animated scenarios. This may become especially useful in the future as this technology is constantly evolving.

8.3 Risk management

The study shows that there is a need to further develop processes to manage the overall risk associated with drilling and well operations. This applies in particular to handling uncertainty in pore pressure and knowledge of subsurface conditions during drilling. The industry seems to understand each contributor to risk and has good processes for managing these. However, managing overall risk requires different approaches and possibly different expertise. Using scenarios in the assessment of overall risk can be a good tool.

Risk assessments are used for many different purposes, and many different risk analysis methods are used, for example when planning drilling and well operations. When there is uncertainty about the purpose of the risk assessment and the method used, there is a tendency for people to fall back on their own experience. One solution to this problem may be for selected drilling and well personnel to be trained in these methods rather than using risk experts without drilling and well expertise.

8.4 Management of change

Extensive organisational changes have been implemented within the drilling and well organisations both onshore and offshore, for example in connection with the introduction of new technology. This study points to a need to improve the process for managing organisational changes and how proposed changes affect their own organisation, partners' organisation and interaction between organisations. When cooperation between different organisations is regulated by contracts, contractual relationships must be adapted to the changes. When risk assessments prior to organisational changes identify measures that are a prerequisite for the new organisation to function, these measures should be implemented before the change is implemented.

No matter how good the change management process is, start-up challenges can arise that require adjustments. If so, it must be clear who has the authority to accept such adjustments and what is required of investigation before these are accepted.

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