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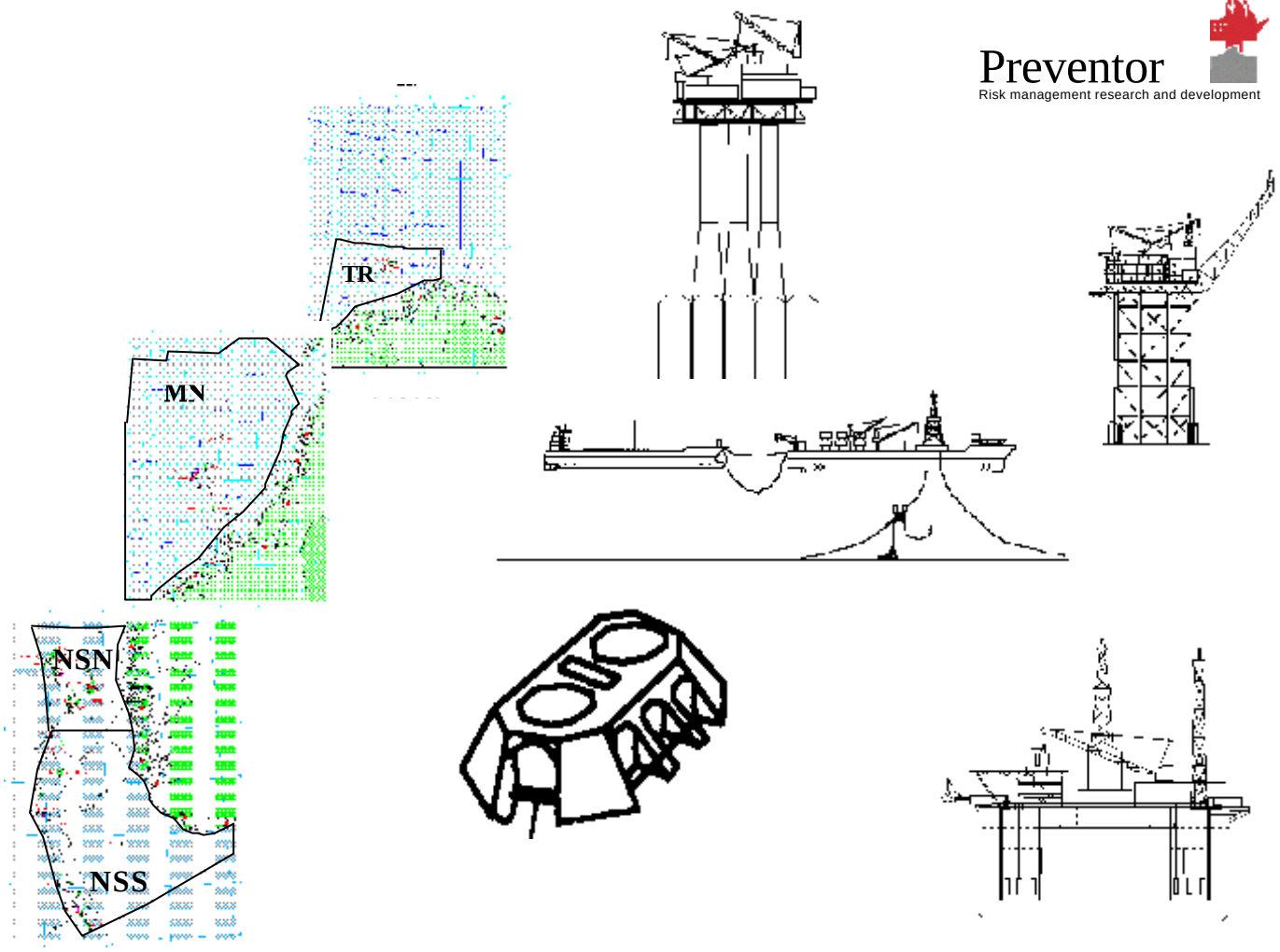

Risk Levels on the Norwegian Continental Shelf

1999 Updated Report

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The intention has been to present the historic risk levels on the Norwegian Continental Shelf during the previous 10 years, covering fatality risk to personnel, risk to the environment, risk to assets, and focused on the following types of installations and activities:

- Fixed and floating production installations
- Mobile drilling units, including transit movements
- Standby, supply vessels, anchor handling tugs, diving vessels, pipe laying, crane vessels
- Helicopter transport to and between installations
- Pipeline transportation of oil and gas, tanker transportation of crude oil.

The basis for establishing risk levels for historic periods, is a precise and detailed mapping of all activities involved in the offshore operations on the Norwegian Continental Shelf, including fixed and floating platforms, all types of vessels and barges, diving, helicopter transport and product transport by tanker or pipeline.

For personnel the most critical aspects are shown to be mobile installations and vessels, which have considerably higher risk levels than the fixed installations. It is demonstrated that the risk to personnel over the last ten years on an overall level is constant.

Index terms, English: Norsk:

Risk level	Risikonivå
Risk to personnel	Personrisiko
Risk to environment	Miljørisiko
Risk to assets	Materiell skade risiko

Contents

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1 Summary of Approach

1.1 Objectives and Scope of Work

The Main project in 1997-98 has determined the historic risk levels -mainly in the past ten years - and the expected future risk picture on the Norwegian Continental Shelf during the next ten years, covering fatality risk to personnel, risk to the environment, as well as risk to assets. The presentation in this report is focused on the following types of installations and activities:

- Fixed and floating production installations
- Mobile drilling units, including transit movements
- Standby, supply vessels, anchor handling tugs
- Diving vessels
- Pipe laying, crane vessels
- Helicopter transport to and between installations
- Pipeline transportation of oil and gas, tanker transportation of crude oil.

The basis for establishing risk levels for historic and future periods, was a precise and detailed mapping of all activities involved in the offshore operations on the Norwegian Continental Shelf, in relation to operation of the above mentioned installations and activities.

Most of the historical data was used from the ten year period, 1988 - 97. In the present updated report, the historic risk levels have been extended to include data also from 1998, implying that the ten year period which is considered is 1989-98.

A complete update of the study, also including future risk levels, is planned to be done in year 2000.

The approach used is presented in the previous report, Ref. 1. The most important terms and abbreviations are defined in Annex A.

1.2 Study Method

The study method was based on establishing comprehensive spreadsheets, with key data for all production installations individually, on the basis of the field and platform names, with main operational features on an annual basis, historically for the period 1988-97, and for the period 1999-2008.

For the other activities (i.e. exploration, pipe-laying, installation and decommissioning, use of various types of vessels), named data has not been established, but the activity levels have been modelled with respect to volume, both historically and for the future.

The consideration of risk to personnel in the study is limited to fatality risk, whereas injuries are considered only in a few cases. When fatality risk is considered, there are mainly two categories, occupational accidents and major accidents, including helicopter accidents.

1.3 Use of Risk Estimates

The risk estimates which are used in the present study, are considered to be expected values, rather than conservative estimates which often are used in risk analysis. This is considered appropriate in light of the purpose of the estimations, to present a realistic risk picture.

The present study has used an extensive amount of numbers in order to illustrate offshore safety and emergency preparedness both in the past and in the future. It is in that context vital to note the following:

- The assessment of historic frequencies is the only ***exact*** quantification of accident frequencies which is possible.
- This report presents historic frequencies for the Norwegian sector, which can be used to consider trends and important differences.
- Risk estimates provide the most explicit quantification of the uncertainty about occurrence of future accidents and related effects. The implication of this view, is that the entire report is about quantification of uncertainty. Therefore, no separate quantification of uncertainty is presented.
- The report is mainly focussed on fatality risk, fatalities are [fortunately] quite rare, implying that the data basis will always be rather limited.
- Quantitative results should always be considered in relation to qualitative evaluations of the same aspects. An explanation should always be sought when these two approaches do not match.

2 Summary of Trends - Risk to Personnel

There has been 79 fatal accidents and 265 fatalities in Norwegian offshore operations since the start of oil and gas operations in 1966, and until the end of 1998. This excludes fatalities on shuttle tankers, but includes fatalities on attendant vessel and other special vessels and barges that are used. Figure 1 shows a condensed summary of the development since the beginning of the operations in mid 1960-ties.

It should be noted that Figure 1 does not relate the number of accidents to the level of activity. This is done later in this section. The frequencies are presented for three ten year intervals, plus the 1997-99 separately, (see comment below) where the following is shown for each interval:

- Average number of fatal accidents per year
- Average number of fatalities per year

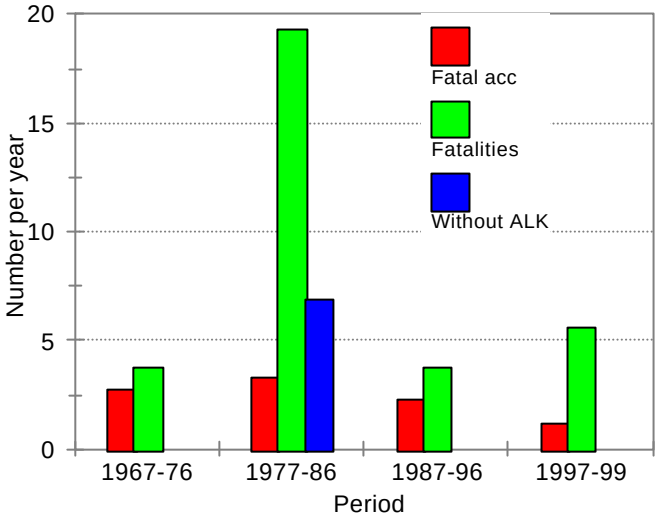

Figure 1 Overview of fatal accidents and fatalities

The second period is strongly influenced by the capsize of 'Alexander L. Kielland' in 1980. The average number of fatalities per year is 19.3 if this accident is included, 6.9 fatalities per year if excluded (see distinction made in the diagram).

The last period shown in only 2.5 years, from 1.1.1997 until 30.6.1999. Three fatal accidents have occurred during this 30 months period, with a total of 14 fatalities, including 12 fatalities from the helicopter crash into the sea in 1997. The average number of fatalities per annum is considered to be so high, because of the short period considered. The period was extended into 1999 in order to have as long a period as possible. The ten year period considered is 1.1.1989 until 31.12.1998 in all other contexts in the report.

2.1 Overview of Accidents to Personnel

The total number of fatal accidents in the period 1989 - 98 is 18 fatal accidents with 33 fatalities. These fatal accidents on the Norwegian continental shelf have occurred on the following different platform and vessel types:

- Fixed platforms:	5 fatal accidents	6 fatalities
- Mobile platforms:	5 fatal accidents	5 fatalities
- Attendant vessels:	5 fatal accidents	6 fatalities
- Crane and pipe-laying vessels:	1 fatal accident	1 fatality
- Diving:	no fatal accidents	

- Helicopter accident (platform maintenance): 1 fatal accident 3 fatalities
- Helicopter transportation (shuttling to shore): 1 fatal accident 12 fatalities

Accidents that have occurred inshore or atshore are excluded from the values considered in the report, even though in some few cases similar accidents could have occurred at an offshore location.

It should be noted that 2 fatal occupational accidents have occurred during the first half of 1999, on production installations. These are not considered for the following estimations.

A close look at the period 1.1.1977 until 30.6.1999 is shown in Figure 2 below, for production installations, mobile drilling units and attendant vessels. This overview is limited to occupational accidents, implying that the capsize of the 'Alexander L. Kielland' flotel in 1980 and helicopter accidents are not shown.

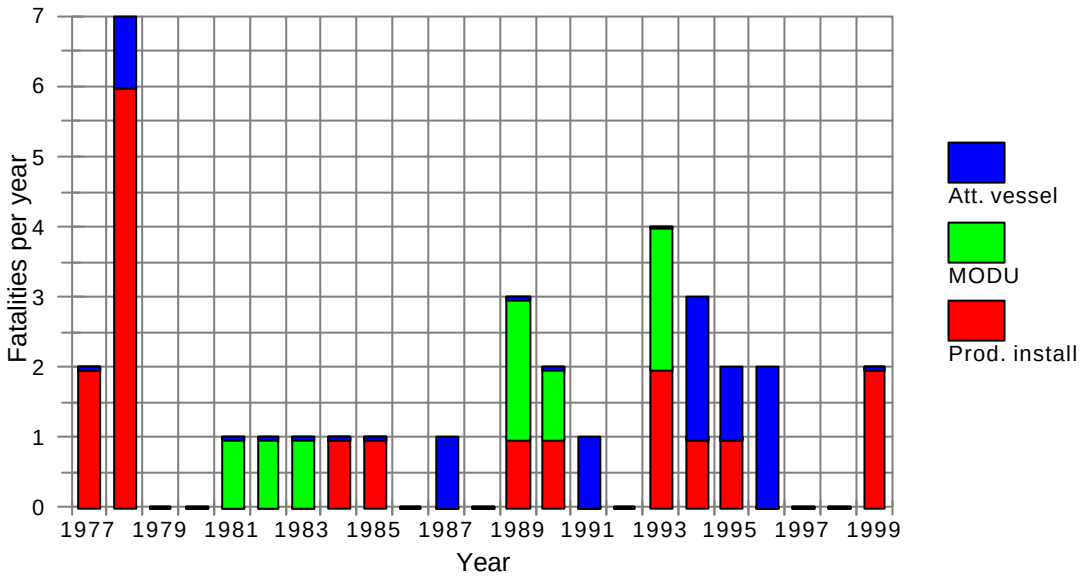

Figure 2 Overview of occupational fatalities on the Norwegian shelf, 1977 - 30.6.1999

Considering the helicopter accidents and the 'Alexander L. Kielland' accident in addition to those in Figure 2, it emerges that the following years have been free of fatal accidents after 1980:

- 1986
- 1988
- 1992
- 1997
- 1998

It can be seen that fatalities on production installations have over the last 15 years occurred roughly every second year. For mobile units and vessels, the patterns are not similarly regular, for mobile units the accidents occurred in the period 1981 - 1993. Similarly, the period with fatalities for attendant vessels is from 1987 until 1996.

2.2 Fatal Accident Rates

This section presents historic FAR levels for occupational accidents (except helicopter risk), thus based on exposure in terms of working hours for all personnel onboard, i.e. 12 hours of exposure per 24 hours of offshore stay. The following are estimates of FAR levels in the period 1989-98:

C Production installations	2.7	fatalities per 100 mill. manhours
C Production installations, including helicopter accident with three fatalities, associated with flare tip replacement	4.2	fatalities per 100 mill. manhours
C Mobile drilling units	10.8	fatalities per 100 mill. manhours
C Attendant vessels	23.8	fatalities per 100 mill. manhours
C Crane and pipe-laying vessels	16.7	fatalities per 100 mill. manhours
C Diving	0	fatalities per 100 mill. manhours
C Helicopter transport	160	fatalities per 100 mill. person flight hours
C Total for all (including helicopters)	10.1	fatalities per 100 mill. manhours
C Total (excluding attendant vessels and helicopters)	3.7	fatalities per 100 mill. manhours

No diving accidents have occurred in the period. Diving is therefore not included in any of the values given above. Except in the case of the helicopter accident in 1997 the values are limited to occupational accidents, due to the fact that no major accident with fatalities had occurred. A true risk picture therefore needs to consider additional ways to estimate risk levels. This was done for the estimation of risk for the period 1999-2008 in the 1998 version of the report.

It should be noted that there was two fatalities on production installations in the first half of 1999. If the period was taken from 1.7.1989 until 30.6.1999, the average value for production installations would be 2.9 fatalities for 100 mill. manhours.

2.3 Trends in Fatality Rates

An important aspect of the study has been to identify possible trends in historic fatality risk levels, in order to identify areas or operations where special efforts may be necessary. Trends are based on activities which are limited to the activity which takes place **on** the installations/vessels itself. Thus fatalities on Alexander L. Kielland are excluded. These trends are established separately for production installations, mobile drilling units and attendant vessels.

The fatal accidents are few in number. If just annual values were analysed, very considerable variations would have resulted, probably without the possibility to identify clear trends. The analysis has therefore been based on **rolling ten year averages** for the last ten years, (i.e. a 20 year period is considered in total) where an average FAR value is calculated based on fatalities and estimated exposure manhours (in the case of production, these values are available from NPD. For the other activities, the values are mainly derived from activity levels). The values include all fatalities that have occurred in the period. The following three diagram show three curves:

- Actual ten year rolling average values calculated for each year in the period,
- Trend curve, based on linear trend analysis.
- Previous trend curve, see comment below

The following diagrams are presented below:

- Figure 3 Production installations
- Figure 4 Mobile drilling units
- Figure 5 Attendant vessels

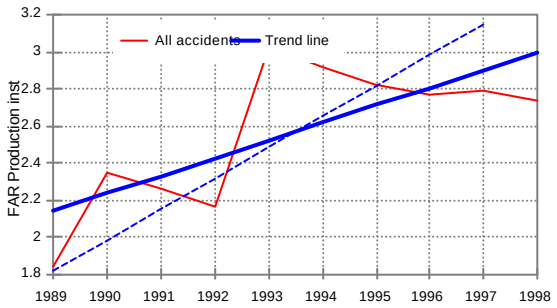

Figure 3 Trend in ten year average FAR values for production installations

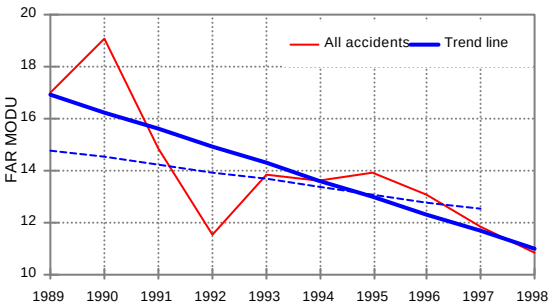

Figure 4 Trend in ten year average FAR values for mobile drilling units

The dotted lines in the three diagrams are the trend lines presented for the pervious ten year period, 1988-97, in Ref. 1.

For production installations, there is a slowly increasing trend over the last ten years. If the period is split in two five year periods, there is clear increase until 1993, after which the trend is slowly falling. No fatalities occurred on production installations in 1996, 1997 and 1998, but two fatal accidents in the first half of 1999.

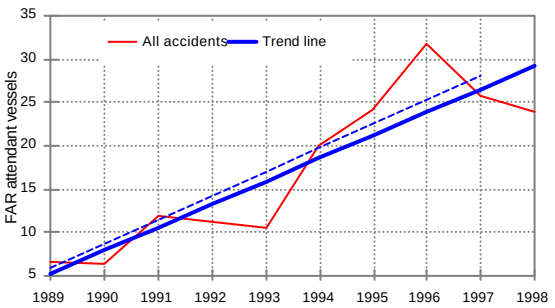

Figure 5 Trend in ten year average FAR values for attendant vessels

For mobile drilling units, there are considerable variations, but the trend analysis gives a slowly falling trend over the period.

For attendant vessels, the trend is actually the clearest, in the sense that the annual ten year averages and the analysed trend line all give an increasing trend.

It could be noted that if the trend analyses are repeated based upon **five** year rolling averages (as opposed to ten years which is used in the diagrams above), then the following trends result (not shown in the diagrams):

- Marginally increasing for production installations after 1993
- Clearly decreasing for mobile drilling units after 1993
- Strongly increasing for attendant vessels after 1993

What do these trends imply for expected future risk levels? This is uncertain, and will also depend on actions that are taken by all parties involved. It should be noted that taking the value calculated for the last year in the period, actually implies taking an average over the last ten years, due to the rolling average calculation. Taking this average may be too optimistic, where there is a clearly increasing trend. Where the trends are close to constant, this may be more realistic.

2.4 Risk Level for Helicopter Transport

The Helicopter Safety Study (by SINTEF, 1990, Ref. 2) estimated a fatal accident level of:

$$3.8 \cdot 10^{-6} \text{ per person flight hours}$$

The present study has divided the accident frequency in separate values for cruising and landing/takeoff, but a comparable value (for average flight time of 60 minutes per trip) may be given as:

$$1.61 \cdot 10^{-6} \text{ per person flight hours (29\% from landing/takeoff)}$$

This may seem as a considerable reduction in fatal accident frequency, but there are several factors that need to be given consideration in this context:

- The SINTEF study covered the period 1966-89. It has been documented in the report that the period 1975-86 was a period with more than 125 fatalities in helicopter accidents in the North Sea. After 1986 only two fatal accidents with 23 fatalities occurred until the end of 1998.
- The impact from the period 1975-86 was considerable in the Helicopter Safety Study, but the study did not attempt to consider if any trends could be identified, or whether there was basis for making distinctions between Norwegian and UK operations.
- It is an established fact that improvements were introduced in the helicopter operations in the 1980-ties because of the accidents, reduction in accident frequencies would be expected.

It might be argued that taking a ten year period after the period with the high number of fatalities leads to too optimistic an estimate. However, it would be impossible to define how much of the earlier period that would need to be included to avoid the optimism. It is also noted that one of the most severe helicopter accidents in the Norwegian sector (in 1997) is included in the period which is considered in order to establish a historic risk level.

The SINTEF study is in mid 1999 still being updated, but their statistical predictions are available from a project memo (Ref. 3). The statistical estimates are made for the period 1990-97, the intention being to address a period after that covered in the first helicopter study (1966-89). The risk estimated in average for Norwegian and UK sectors is 2.1 @ 10^{-6} per person flight hours, down from 3.8 @ 10^{-6} per person flight hours in the previous study.

The period 1990-97 is quite short in relation to an average return period of about 3 years between fatal accidents (after 1986). It could be noted that the SINTEF Memo itself refers to an average fatal accident rate of 1.5 @ 10^{-6} per person flight hours for the period 1988-98.

3 Evaluations and Conclusions

3.1 Overall Aspects

1998 was a favourable year in the Norwegian offshore operations from a fatality risk point of view. No fatal accidents occurred. There were no accidents on fixed and floating/mobile platforms in 1997 nor 1998 (if we exclude the helicopter accident in 1997). But these occurrences are somewhat random, and we should not draw too extensive conclusions based on this.

The randomness of these occurrences is clearly demonstrated by the fact that two fatal accidents have occurred on production installations in the first half of 1999.

3.2 Occupational Accidents

The FAR values presented in Section 2.2 above are somewhat lower for the 1989-98 period, when compared to the period 1988-97. The changes are small for the production installations, more notable for the mobile drilling units, vessels and barges. For these activities however, one additional fatality in the future may influence the estimations quite considerably.

The occupational accidents are so frequent that estimations of FAR levels for different installation types and vessels may be made on the basis of accident statistics. This is usually performed on the basis of Norwegian installations alone.

It is noteworthy that after the two fatal accidents on mobile drilling units (MODUs) in 1993, there have been no fatal accidents on MODUs. It should be mentioned however, that there was a serious near-miss in December, 1998, when a heave compensator failed. Once before, there has been a similarly long period without fatalities on mobile drilling units, between 5.11.1983 and 16.5.1989.

The last accident on mobile units was on 13.12.1993. This implies that the present period (until 30.6.1999) is the longest after 1980, without fatal accidents on mobile units.

3.3 Helicopter Accidents

The FAR value for helicopter transport is virtually unchanged when comparing the period considered here (1989-98) to the period previously considered, 1988-97. During the last ten years, there have been two fatal accidents during cruising (one in UK, 1992 and one in Norway, 1997), and one fatal accident during landing/take-off (UK, 1990). The total number of fatalities in these three accidents is 29, survivors are 13.

It is a fact (an unwanted one, but nevertheless a realistic one) that helicopter accidents are so frequent in the UK, Dutch and Norwegian offshore operations that a realistic estimation of FAR levels may be made from accidents statistics. Estimations are usually made taking the average in UK and Norwegian operations.

3.4 Major Accidents on Installations

Major accidents (in this context excluding helicopter accidents) are fortunately few and seldom occurrences in European offshore operations. 1988 saw two such accidents in the UK sector (Piper Alpha, Ocean Odyssey). The only potentially major accident since then in the North Sea (including Norwegian Sea and Atlantic/West of Shetland) is the collision by a passing vessel into a pipeline booster platform (see for instance Ref. 4) in the German sector in 1995 (even though it could be considered a near-miss, with virtually no damage). Shuttle tanker low energy impacts into FPSOs/FSUs are then disregarded as major accidents, and also a approximately 15 gas explosions (Ref. 5). Only one of these had an overpressure exceeding 0.2 bar. All of them caused only minimal damages. The loss of the Sleipner GBS structure in 1991 during inshore construction/testing is also disregarded.

Because the major accidents are so few in number, the only possible approach to estimation of risk levels is to use the risk assessment approach. This implies that the estimation of the risk level will be based on estimation of:

- Initiating event frequency
- Failure probabilities for safety barriers
- Probabilities for different escalation scenarios
- Failure probabilities for emergency preparedness actions
- Probabilities for different extents of consequences

The estimations are usually based on relatively generic data, possibly combined with some installation specific data, although this is much less used than what one would think. This implies that trends in risk levels never can be observed.

One way which may be used for visualisation of trends in major hazard risk is to use so-called ‘risk indicators’ or ‘performance indicators’. Some companies are using this approach, see for instance a discussion of this approach in Ref. 6. It is however, not as widely used as might be expected. There are two possible approaches to this:

- Individual indicators for each important aspect.
- Overall indicator(s) in order to reflect the combined effect of several critical aspects.

Risk indicators are not used by authorities to demonstrate what is the trends in major hazard risk levels. This could be one possible way to visualise this aspect of risk.

One of the challenges of operating offshore installations over many years, is to be able to maintain a high attention level on major accident prevention, especially if the operation has been free of major accidents or near-misses for many years. The use of risk indicators within the company is one possible way to achieve such focus.

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Annex A: Comparison of Current Risk Estimates with the Previous Estimates

The following are estimates of FAR levels in the period 1989-98 compared to the FAR estimates for the previous period, 1988-97:

	1989-98	1988-97	
C Production installations	2.7	2.8	fatalities per 100 mill. manhours
C Production installations, including helicopter accident with three fatalities, associated with flare tip replacement	4.2	4.2	fatalities per 100 mill. manhours
C Mobile drilling units	10.8	12.7	fatalities per 100 mill. manhours
C Attendant vessels	23.8	26.3	fatalities per 100 mill. manhours
C Crane and pipe-laying vessels	16.7	20.7	fatalities per 100 mill. manhours
C Diving	0	0	fatalities per 100 mill. manhours
C Helicopter transport	160	160	fatalities per 100 mill. person flight hours
C Total for all (including helicopters)	10.1	10.5	fatalities per 100 mill. manhours
C Total (excluding attendant vessels and helicopters)	3.7	4.2	fatalities per 100 mill. manhours

Annex B: Definitions, Terms and Abbreviations

Term	Definition/Interpretation	Comments
AIR	Average Individual Risk	
Attendant vessels	Taken to include standby vessels, supply vessels and anchor handling vessels	
Environ-mental damage	Direct or indirect reduction of one or several resources resulting from an accidental spill, measured in terms of recovery	
FAR	Fatal Accident Rate Fatalities per 10^8 exposure hours	Exposure hours may be based on 'on-shift' hours (12 per day) or both 'on-' and 'off-shift' hours (24 per day). The exposure hours may also relate to the entire manning complement or groups within this total, such as all personnel in so-called 'hazardous areas'. The basis for the calculation should be stated when such values are used.
Floating production unit	Includes FPSOs (see below) and other floating production units of semi-submersible type, including TLPs.	The TLP units are in some respects considered as 'fixed' installations, this is noted separately where relevant.
FPSO	Floating Production, Storage and Offloading unit	Implies use of a monohull, i.e. tanker shaped vessel.
Intervention	Is taken to imply all activities conducted in production wells other than wireline and coiled tubing operations.	
MODU	Mobile Drilling Unit	
NPD	Norwegian Petroleum Directorate.	
Personnel risk	Risk to employees on offshore installations and vessels involved in offshore operations.	The study is mainly limited to fatality risk.
QRA	Quantitative Risk Assessment	
Recovery (duration)	Time required before a resource has recove-red to the population level or condition prior to the spill, considerations given to natural variations.	The recovery time for at least one of the affected resources must be at least 1 month for the effect to be classified as environmental damage.
Risk	Expression of probability for and conse-	

	quence of one or several accidental events.	
Risk analysis	Analysis which includes a systematic identification and description of risk to personnel, environment and assets.	
Risk to assets	Risk for damage to structures and/or equipment	Limited to effects of accidents, i.e. events which may cause injury to personnel or environmental damage
Risk to Environment	Risk for damage to environmental resources	Limited to accidental spills
Special vessels	Includes vessel types such as diving vessels	
TLP	Tension Leg Platform	
WOAD	Worldwide Offshore Accident Databank	Annual 1994 report used