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Assessing The Level Of Norwegian Governmental Preparedness Using Scenarios And Model Tools In An Environmental Risk Based Approach.

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Abstract:

The Norwegian Coastal Administration (NCA) is the governmental agency responsible for governmental oil spill response preparedness in Norway. As part of this responsibility NCA has recently carried out an environmental risk based emergency preparedness analysis within the governmental area of responsibility, which is spills from vessels.

This paper gives a general introduction to how the NCA has used an environmental risk based approach to assess the oil spill contingency. The methodology and approach used an oil spill response model tool (OSCAR) to estimate the necessary level of governmental oil spill preparedness. The analysis was undertaken in two phases, phase one being the environmental risk based foundation, whereas the amount and location of equipment was the outcome of phase two which resulted in a proposal for increased budgets for equipment purchase, training and exercises. The results include the identification of specific contingency needs for six regions covering all Norwegian waters, including Svalbard. For each region a contingency level was specified based on dimensioning oil spill scenarios from vessels and national oil spill response objectives. Each contingency level is characterised by response time requirements as well as specific requirements towards oil recovery systems, chemical dispersing systems, emergency offloading systems, remote sensing and surveillance, beach cleaning capabilities and human resources.

Introduction

Recently the Norwegian authorities have conducted an assessment of the governmental contingency response capability based on environmental risk assessment. In this work a contingency planning simulation tool was used to assess spill scenarios at different locations. This paper is an abstract and compilation of the two reports that together makes the governmental risk assessment. Phase 1, the environmental risk assessment (Schreiner et al, 2000) and phase 2, the equipment location and amount (Schreiner et al, 2001).

First, an environmental risk analysis (probability of oil spill & environmental impact) was established for six regions. Then a number of "most probable" scenarios were defined in each region. For each scenario a thorough description was made, including the position of the oil spill, discharge conditions, flow rate and the total amount of oil at sea. Finally, a response plan for the simulated response operations was established for each scenario.

For each of the six scenarios, the effectiveness of oil spill response was simulated. The simulations provided us with the amount of oil recovered, naturally dispersed, stranded and evaporated. After several iterations, the response resources necessary to achieve the objectives in the response plan were identified given by the number of mechanical oil recovery systems, dispersants units and their response time, the number of shoreline cleanup teams etc.

Secondly, the recommended level of contingency was compared to the present contingency level. The results of this analysis were the need for re-location of equipment depots, purchase of more response equipment and enhanced training. In total the government needs to increase the investments in preparedness for oil spill response for approx. 110 mill. NOK over a three-year period to reach the recommended level (letter to Ministry of the Environment 17th December 2001).

Norwegian Governmental Preparedness

The Norwegian Pollution Control Act sets the responsibilities for private, municipal and governmental oil spill response preparedness. In general the private industry is responsible for spills originating from own sources, the municipalities are responsible for minor spills within the municipalities borders and the government is responsible for larger spills, especially spills originating from unknown sources and vessels. The responsible authority on behalf of the government is The Norwegian Coastal Administration (NCA). The resources at hand for the NCA are 15 equipment depots located along the Norwegian coastline and at Svalbard, 9 Coast Guard vessels with oil spill response equipment, one ETV (Emergency Towing Vessel) and 4 NCA oil spill response vessels.

In case of a large spill, e.g. from a grounded vessel, the NCA will assume responsibility for the oil spill response operations and man the operations room at its headquarters in Horten. The preparedness to do this is covered by a 24 hours, 7 days a week watch duty, in which four officers are always on duty. From this location the NCA will mobilise own resources, the municipalities resources and may mobilise resources owned by the private industry. The pollution control act gives the opportunity to mobilise all resources necessary from all parts of the society, many of the vital ones are pre-planned through agreements of assistance and trained on a regular basis. During an oil spill operation the priorities will be according to the following; 1 - life, health and security, 2 - environmental resources, 3 - economic interests.

The two phased environmental risk based approach

The environmental risk based approach has been undertaken in two phases; Phase 1 was an environmental risk analysis (probability of oil spill & environmental impact), established for six defined regions along the Norwegian coastline and Svalbard. Phase 2 was an analysis of the governmental oil spill response resources necessary to establish an acceptable preparedness level based on the environmental risk the governmental preparedness is expected to handle, phase 2 recommends the amount, types and location of oil spill response equipment in order to meet the recommendations in phase 1.

Phase 1 – The environmental risk based approach

The governmental preparedness is in general directed towards large oil spills originating from ships traffic and unknown sources. This preparedness is centred around 15 equipment depots located along the coastline, including one on Svalbard and on equipment permanently stored on board coastguard and oil recovery vessels. The structure and location of these depots has not changed significantly since the governmental oil spill response preparedness was established in the late 70's. The current structure is based on various factors, such as; reasonably nationwide coverage, close proximity to airports and other infrastructure, sailing time between depots and local needs. The structure does not build on systematic risk assessments and contingency analysis. Hence, the governmental preparedness is not risk based in the same way as the municipal and industry preparedness are, and the government had no precise knowledge whether the preparedness was reasonable compared to the risk for acute pollution represented by ships. On this background the authorities in 1999 initiated an analysis to assess whether the existing location and equipment composition correlated with the environmental risk of the governmental responsibility.

Phase 1 has primarily focused on:

- Environmental risk analysis, including the selection and location of dimensioning accident scenarios causing oil spills threatening highly prioritised environmental resources.
- Selection of response objectives and defining a response plan to handle the simulated oil spill response operation for the dimensioning accident scenarios.
- Preparedness analysis using a simulation tool (OSCAR) for the dimensioning scenarios.
- Recommendations on the preparedness level along the coastline.

The results and outcome of phase 1 has given the foundation for phase 2, in which the equipment inventories; types, amount and location of governmental equipment is assessed.

Phase 2 – Equipment types, amount and location

Phase 2 of the analysis gives a description of the types and amount of equipment needed, and the location where the equipment should be stored in order to meet the recommended preparedness level from phase 1. The preparedness level is described by a number of oil spill response systems and their response time within a defined geographical area. The oil spill response systems are divided into offshore-, coastal- and fjord systems based on booms and skimmers with necessary towing and recovery vessels, dispersants units based on helicopter borne application systems and of shoreline clean-up groups. The authorities strategies and principles for a long-term development of the governmental preparedness have had an affect on the dimensioning and location of the equipment. These principles and strategies are selected so that the most important challenges of the preparedness are taken care of. These principles and strategies are the following:

- Vulnerable environmental resources shall have better protection than economical interests.
- The governmental preparedness shall be dimensioned based on knowledge of environmental risk and not based on "worst case" scenario.
- The governmental preparedness shall be flexible and robust, and cover a broad spectre of different situations.
- The governmental preparedness and – organisation shall be an important factor in achieving good co-operation and overall use of resources within Norwegian oil spill response as a whole and nationwide preparedness.

Defining the risk for oil spills

The foundation for the assessment and the analysis has been a geographical dividing of the responsibility area of the government based on administrative and environmental criteria into six regions (Brattegard et al. 1995) and (Moe et al. 1999). These regions are

- Region 1: Skagerrak (including the counties of Østfold, Akershus, Oslo, Buskerud, Vestfold, Telemark and Aust-Agder).
- Region 2: North Sea (including the counties of Vest-Agder, Rogaland and Hordaland).
- Region 3: The North-West (including the counties of Sogn og Fjordane and Møre og Romsdal).
- Region 4: The Norwegian Sea (including the counties of Sør-Trøndelag, Nord-Trøndelag and Nordland).
- Region 5: The Barents Sea south (including the counties of Troms and Finnmark).
- Region 6: The Barents Sea north (including Svalbard and the fisheries protection zone).

Apart from the practical reasons for this division for comparative analysis, the division is also used for assessing the vulnerability of the environmental resources.

The probability for acute pollution from ships traffic along the Norwegian coastline and Svalbard has been calculated. The calculations have been undertaken in accordance with the sub-division into regions as described above, except for region 5 and 6 that have been calculated as one region due to the limited statistical information. The regions are further divided into offshore-, coastal- and harbour regions, hence a total of 15 regions are used to describe the geographical variations in the probability for acute pollution from ships.

The calculations show that the North Sea region has the highest probability of oil spills from ships both for the offshore-, coastal- and harbour regions. The Skagerrak region has very high probabilities for spills in the coastal region. On average there are more than 50 oil spills pr. year in the North Sea region. Furthermore an oil spill from vessels in the proximity of the two oil-loading terminals in the region (Mongstad and Sture) is expected every 13 years. Spills originating from offshore shuttle tanker loading have the highest probability in the North West region, where an oil spill is expected every 40 years (Johannesen et al. 1999).

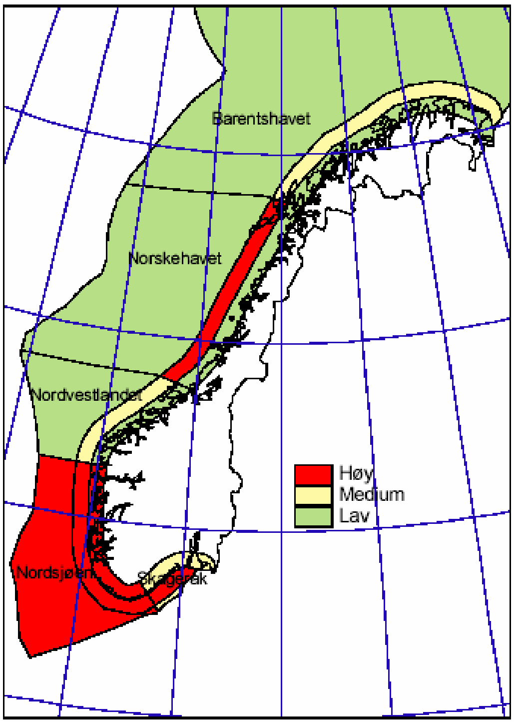

Figure 1. Geographical distribution of probability for oil spills from vessels. The probability is divided into low (< 5 spills/year), medium (5-10 spills/year) and high (> 10 spills/year).

The probability for oil spills show good correlation with the traffic density along the coastline as described by the amount of goods transported via the ports. The probability shows a less obvious connection with the distribution of ships accidents. The most common oil types in these accidents are diesel and slops that together represent more than 60% of the spills. In 84% of the cases the amount of spilled oil is less than 1 tonnes. Bunker oils and diesel are the most common oil types in the larger spills. The accident statistics for all accidents show that fishing vessels are the single largest contributor by more than 40% of the incidents followed by smaller coastal cargo vessels with 24%. All these vessels mainly use diesel fuel.

Environmental Sensitivity

The environmental sensitivity analysis has been undertaken with reference to the work carried out in the MOB (SFT and DN, 1996) and the Special Environmental Sensitive areas (SMO) and offshore petroleum-activity (Moe et al. 1999). In the latter an SMO area is defined as geographical area with one or more special types of natural resources that are vulnerable to acute oil pollution, and that will need time to rehabilitate to a natural level after being damaged by a spill. Any damage to a population, habitat or society with a rehabilitation time of more that 10 years qualify to an SMO if at least one of the following criteria is fulfilled:

- Annihilation of species and habitats, i.e. a reduction of the number of reproductive organisms to less than 1% of the level before the damage occurred, within a limited geographical area.
- More than 5% reduction in the total population, where the North-Eastern Atlantic population will be the baseline.
- More than 10% reduction in the Norwegian population, Svalbard included.

- More than 20% reduction in a regional population.

Based on the identified SMO areas on national/international level, supported by the regional level where appropriate, an assessment of the geographical and seasonal variations in the environmental sensitivity has been done. For this work, the seasonal variations are sub-divided into half years; autumn/winter (October – March) and spring/summer (April – September).

In the summertime, breeding areas are the dominant factors for the relative regional variations in the environmental sensitivity. In general the largest colonies and populations are found in the northern areas, hence these areas have the highest sensitivity. In the wintertime however, it is the dense populations of migratory birds in wintering areas that dominate. Based on the differences in environmental sensitivity the six regions are divided into three classes of potential environmental damage.
However this division is done on a level where the purpose only is to identify any differences between the geographical regions. Hence, the term "low" damage potential is only relevant in comparison with other regions. It does not mean that acute oil pollution in this region represents low damage.

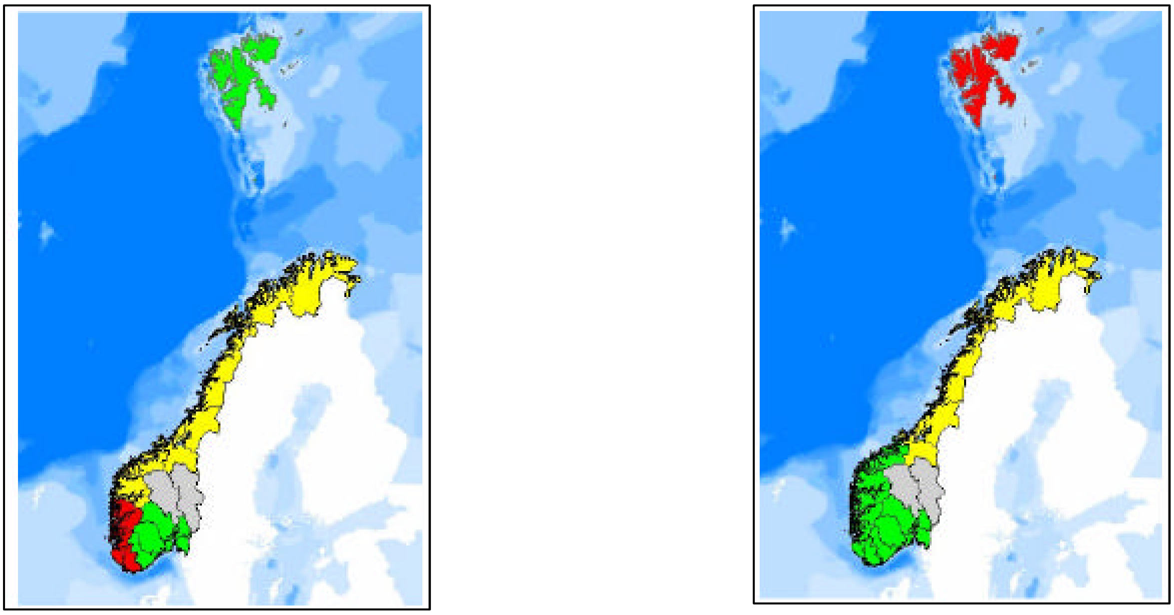

Figure 2. Potential damage classes for each region, winter - left and summer - right. Colour codes are red: high, yellow: moderate and low: green.

In the wintertime, region 2 is evaluated to have a high damage potential, regions 3, 4 and 5 to have a moderate damage potential and regions 5 and 6 to have a low damage potential.

In the summertime region 6 is evaluated to have a high damage potential, regions 4 and 5 a moderate damage potential and regions 1,2 and 3 to have a low damage potential.

The scenarios – representing probable spills from vessels

By combining the relative values for both probability of oil spill from vessels and environmental sensitivity, a complete relative environmental risk matrix is drawn up for both summertime and wintertime. This matrix is shown below.

Relative classes of damage		**Summer**			**Winter**		
	High	Region 6					Region 2
	Moderate		Region 5	Region 4		Region 3 Region 5	Region 4
	Low		Region 3	Region 1 Region 2	Region 6		Region 1
		Low	***Moderate***	***High***	***Low***	***Moderate***	***High***
		Relative probability for discharges			**Relative probability for discharges**		

Table 1, Risk matrix combining relative probability for accidents with relative environmental sensitivity.

The risk matrix above is used to define the time and location for the dimensioning scenarios based on the sub-division of six regions. Combinations shoving low probability/low consequence, medium probability/low consequence or low probability/ medium consequence is not evaluated further. The combinations of probability and consequence used to define the scenarios are highlighted in the figure above. This geographical selection with one dimensioning scenario in each region at a time where the environmental risk or the challenge for the oil spill preparedness is highest will furthermore cover the whole of the governmental area of responsibility.

Without taking the worst-case scenario into consideration, the selected scenarios as summarised in table 2. shall be defined so that if the preparedness is covered in an acceptable way in the assessed situations, this will cover the majority of other incidents within the region. The total governmental preparedness needs, will according to this be the sum of the needs for each scenario corrected for resources that may be used across the geographical regions and for incidents where other types of resources will be needed. The total amount of resources will be brought in from the governmental depots, the municipalities, the private industries and from international agreements on assistance.

The incidents that are the foundation of the scenarios are chosen based on knowledge of traffic pattern and accident statistics. Each incident is described by:

- Type and time of incident.
- Spill type (oil type), total amount and spill rate.
- Dimensioning environmental resource based on the SMO location(s) that was instrumental in the regional sub-division of relative environmental risk.

Table 2. presents a compiled description of the defined incidents.

Region nr/name	Incident	Oil type	Spilled amount/ rate	Time	Dimensioning environmental resource
1/Skagerrak	Spill following grounding in outer Oslofjord of a 126 400 DWT shuttle tanker en route to Exxon refinery at Slagentangen. Hole in three cargo tanks and bunker tanks. Cargo: 137 000 m^3 crude oil. Bunkers: 1500 tonnes bunker C and 80 tonnes diesel fuel.	Balder crude oil. Bunker C.	Spill of 15 000 tonnes crude oil and 300 tonnes bunker C after two hours. Further spill prevented by the water pressure.	Summer/ June	Hvaler and ajecent sea area. National SMO, including Black Guillemot. Important hatching area for Alcids. The total population of Lesser Black-backed Gulls in Skagerak has international value. Important moulting area for Eiders. Recreational area for many people.
2/North Sea	Spill following a collision between a 126 400 DWT shuttle tanker and a container vessel. Three cargo tanks on the tanker are ruptured in the waterline. Shuttle tanker loaded with 137 000 m^3 crude oil.	Balder crude oil.	After two hours: 20 000 tonnes crude oil has leaked out. Further spill prevented by the water pressure.	Winter/ January	Sea areas off Jæren. National SMO containing Velvet Scoter. Important wintering area for Eiders, Black Guillemots and Velvet Scoters. Jæren nature reserve. Recreational area.
3/ North West	Spill following the grounding of a 2 600 DWT coastal tanker. Bunkers: 200 tonnes diesel. Cargo: 500 tonnes petrol, 900 tonnes diesel and 900 tonnes fuel oil no 4.	Petrol, diesel and fuel oil no. 4.	After two hours: 10 tonnes petrol 20 tonnes diesel and 20 tonnes fuel oil no 4. Followed by 3 tonnes/hour of all the products.	Spring/ March-April.	Runde with adjacent sea areas. Runde is one of the largest “bird mountains” in Norway. International protection value. Many species hatch in large numbers.
4/ Norwegian sea	Spill following a grounding of a 100 000 DWT bulk ore carrier. Bunkers: 1500 tonnes bunker C and 70 tonnes diesel fuel.	Bunker C and diesel fuel.	After two hours: 100 tonnes bunker C and 20 tonnes diesel. Followed by 3 tonnes/ hour.	Late summer/ autumn.	Vega and adjacent islands and sea areas. One of the most important hatching and moulting areas for sea birds in Scandinavia. Large populations of Eiders, Black Guillemots and Cormorant.
5/ Barents Sea south	Spill following a grounding of a crude oil tanker. Tanker loaded with: 100 000 tonnes Russian crude oil, 1200 m^3 bunker C and 80 tonnes diesel fuel.	Russian crude oil (similar to Balder crude).	Over a period of 12 hours 21000 tonnes of crude oil is released.	Spring/ April.	Karlsøy and adjacent islands and sea areas. The area is of national protection value due to the geology and environment. There are large populations of sea birds in the area.
6/ Barents Sea north	Spill following a grounding of a coal carrier en route to Svea (van Mijenfjord, Svalbard). Bunker 300 tonnes IF 30	IF 30	After two hours 50 tonnes IF 30. Followed by 4 tonnes/hour.	Summer/ July	The areas north of Bellsundet are important moulting and feeding areas for Eiders and Northern Geese and fulfil the criteria for national SMO.

Table 2. Compiled description of the defined dimensioning scenarios.

The Methodology for dimensioning the governmental preparedness

This chapter gives a description of the methodology used to analyse the governmental preparedness level. The approach is twofold; first the need for equipment is set for each of the dimensioning scenarios, second the need for equipment is assessed as a whole for each of the six regions. The analysis only focuses on the need for equipment and required response time. How this correlates to the current equipment inventory is described in the chapter "recommended level of preparedness".

Methodology for defining the necessary oil spill response equipment in the dimensioning scenarios

For each of the dimensioning scenarios a response plan and response objectives was established following standard NCA procedures. The response objectives take into account the priorities described in the chapter "Norwegian governmental preparedness". Due to the locations of the scenarios, at sea response is not sufficient by itself to achieve the objectives and even the most environmental sensitive areas will be affected. The objectives are still set quite stringent because they are essential for the selection of response strategy and prioritising the use of spill response equipment. Hence fulfilment of the objectives has to be evaluated for the whole of the simulated response operation, where all the different phases of the operation is evaluated together.

In all the dimensioning scenarios the response operations start with an at sea recovery and dispersants operation. The effectiveness and the results of the at sea response will be vital for the use of resources in the other phases of the response operation. In an ideal situation, without limitations in the amount of available resources for at sea operations, the operations will reach a level where additional use of equipment will have limited effect on achieving the environmental objectives or result in unrealistic costs. This limit is the "breaking point" as illustrated in figure 4. Allocating equipment up to this level is seen as the optimal dimensioning of the seagoing response operation. In large-scale incidents where the availability of floating oil on the sea surface does not represent a limiting factor for the effective use of resources, this breaking point will represent a number of response units that are totally unrealistic. This will, e.g. be the case for scenario no.1 where the simulations show that 15 offshore recovery systems can be allocated within a response time of 24 – 36 hours before the overall recovery effectiveness of each system is reduced. In such cases a lower (more realistic) use of seagoing recovery systems is chosen.

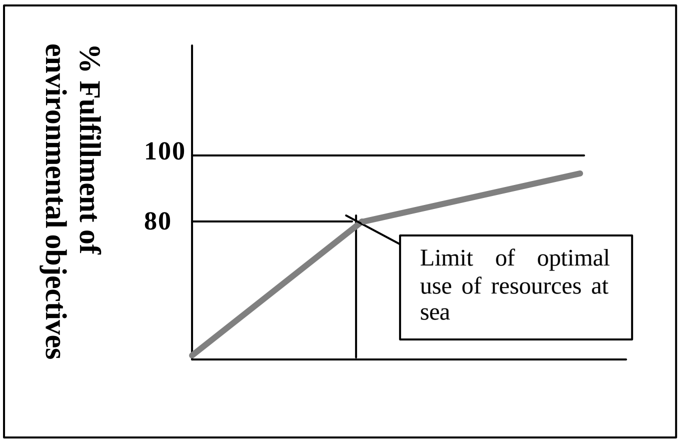

Figure 3, The breaking point

The use of equipment is described as

complete systems for; offshore, coastal, fjord, shoreline and use of dispersants. For offshore, coastal and fjord each system is comprised of a boom, a skimmer, and two towing vessels (recovery vessels). For each of the systems the simulations are undertaken by adding experience based figures of effectiveness, hence the systems are downgraded by a given number correlating to wave height, darkness, time loss by offloading recovery vessels, mechanical breakdown etc.

The fulfilment of the objectives of the seagoing part of the response operation is expressed as a reduction in the amount of oil reaching the environmental sensitive areas as compared to the amount of oil reaching the same areas with no seagoing response operation. In addition the total amount of treated (recovered or dispersed) oil, the reduction of oil volume and affected metres of shoreline are assessed as part of the evaluation for the seagoing response operation.

In each of the dimensioning scenarios, the amount of resources for the seagoing response operation was simulated using the Sintef Oscar model. These simulations where done in several iterations on three different levels for each scenario. The initial level, level 0, was run without the use of any spill response equipment until all oil has stranded or weathered away. Subsequently two simulations where run in which variations in use of resources, response time and selection of strategy were varied (level 1 and level 2). Level 1 is an optimistic approach to the current situation where all activities in general are specified within the framework of the current level of governmental preparedness supplied with available resources from the private industry (NOFO), the municipalities and through international agreements. In level 2 the use of resources is intensified and/or use of other response strategies are enhanced (e.g. the use of dispersants).

For the different phases of the oil spill response operation, the following is documented for each scenario:

- Distribution of oil at sea and on shoreline at the end of simulation
- Total mass balance for the spilled oil (oil at sea, evaporated, dispersed and beached)
- Distribution of recovered or dispersed oil between the different systems and dispersants units.

On the based of the information obtained above, the composition and size of the resources, including the response time, is decided for the at sea response operations in each scenario. Although an enhanced number of simulations are desired for deciding the optimal allocation of resources at-sea, the analysis will give a sufficient indication of when the cost-benefit of allocating an increased amount of resources will not reduce the amount of oil beaching in sensitive areas or the volume of recovered/ treated oil significantly.

One outcome of the OSCAR model (see below) is the amount of beached oil both in sensitive areas and in total for the chosen level of at sea operation. At the time of the simulations the OSCAR model did not give an output in terms of area-calculations for the beached oil. Furthermore there is no available data on what types of beach that are affected within the areas of beached oil. Hence the total metres of contaminated shorelines are stipulated with basis in the oil drift calculations from the OSCAR simulations and from information obtained the ContAct-database (Alpha 1999). The latter gives information on the total shoreline length, the number of islands and distribution of sea and land area within a grid net of 10 x 10 km covering the whole Norwegian coastline.

For each scenario an assessment of the distribution of free floating oil close to the shoreline, drifting on and off the beach with the tide, and oil permanently fixed to the beach is made. The free-floating oil is expected to be contained in bays and inlets and recovered from the seaside using coastal- and fjord systems (booms and skimmers). For each scenario the necessary number of this type of equipment is calculated with basis in the established objectives for the simulated oil spill response operation.

Based on experience from previous oil spill response operations and the length of contaminated shorelines, the necessary resources in terms of equipment and personnel needed to remove oil drifted onshore is estimated so that the established response objectives are met. This estimation is made based on standard shoreline cleanup teams, and their capability of cleaning 100 metres of shoreline pr. day based on standard shoreline type (combination of sand and stones) and standard oil type (medium heavy bunker oil). The estimation is compensated for the volume of oil on the shoreline and the shorelines capability for self-cleaning by wave action etc. In addition the estimation is enhanced to compensate for sticky emulsions (by a factor of 1,5) or to compensate for high percentage of sticky emulsion (by a factor of 2). The beach's capability for self-cleaning is assessed based on the exposure to waves etc, this information is obtained from the ContAct database.

Method for establishing the necessary governmental preparedness

The necessary governmental preparedness is assessed for each region based on the geographical dividing of the responsibility area into six regions as described previously. The necessary amount of equipment is based on the outcome of the simulations for each of the regional scenarios and the assumption that the scenarios are representative so that if the preparedness is adequate in the analysed scenarios, it will also be adequate (dimensioning) for the majority of other incidents within the planning area (hence the region).

To assess the requirements for the response time, each region is classified into response time classes, ref table 3. The response time classes are risk based, and established with background in the risk matrix, ref table 1. The risk matrix is separated into winter and summer time. For the selection of response time classes the time of year with the highest risk is used as the selection point for the required response time.

Environmental consequences	***High***	Region 6 (HL)		Region 2 (HH)
	Medium		Region 3 (MM) Region 5 (MM)	Region 4 (MH)
	Low			Region 1 (LH)
		Low	***Medium***	***High***
		Probability for accident		

Table 3. Response time classes

From table 3 the following response time classes are established:

- Response time class 1: HH – Region 2
- Response time class 2: HL, MM, MH - Regions 3,4 and 6
- Response time class 3: LH – Region 1

In region 2, the only region within response time class 1, no area shall have longer response time for equipment than the dimensioning scenario. For the other regions falling into response time class 2 and 3, an increase in the response time for equipment of + 1,5 compared to the dimensioning scenario is accepted. These response times will be applied to equipment that is expected to be at the incident site within 48 hours. For other types of equipment the same response time as in the dimensioning scenarios will apply. A correction is made in the amount of equipment and services that may not be specifically connected to a regional distribution of response resources, that will be common for all regions, or for incidents where other types of equipment that are not covered by this assessment is needed. In general this applies for certain types of oil skimmers (e.g. special skimmers for very high viscosity emulsions).

Type of equipment	**Dimensioning response time**
Boom and oil recovery systems	To handle recovery of spilled oils ranging from diesel to heavy bunker oil (response time is established in the dimensioning scenario and adjusted according to response time class).
Emergency offloading system	Response time 48 hours
Dispersants systems	Response time 6 hours
Aerial surveillance	Response time 6 hours

Table 4. Dimensioning response time for all regions

Hence, each scenario has resulted in a table summarising the recommended level of preparedness in terms of amount and type of equipment resources for the specified region.
The requirements for response time will primarily apply to incidents close to the coast, although the responsibility to act will apply in the whole Norwegian economic zone and the fisheries protection zone around Svalbard. To fully cover this responsibility within the recommended response time, an unrealistic number of offshore recovery vessels are needed to have preparedness for accidents with very low probability and very low cost/ benefit.

The overall recommended amount of resources (equipment etc) as part of the governmental resources will be the sum of the amounts in all regions minus the following (taking the response time demand into account):

- Governmental resources that may be utilised in more than one region.
- Municipal resources.
- Private resources
- Resources from international agreements on assistance.

This is exemplified below in the Oslofjord scenario.

OSCAR Model Description

SINTEF's OSCAR model system has been developed to supply a tool for objective analysis of alternative spill response strategies. Key components of the system are:

- a data-based oil weathering model,
- a three-dimensional oil trajectory and chemical fates model,
- an oil spill combat model,
- exposure models for fish and ichthyoplankton, birds, and marine mammals and

- tools for exposure assessment within GIS polygons (delineating, for example, sensitive environmental resource areas).

OSCAR has been applied to the analysis of oil spill response strategies for both offshore platforms and coastal terminals. OSCAR provides, for alternative spill response strategies, a basis for comprehensive, quantitative environmental impact assessments in the marine environment. The model calculates and records the distribution in three physical dimensions plus time of a contaminant on the water surface, along shorelines, in the water column, and in the sediments. The model is embedded within a graphical user interface in Microsoft Windows, which facilitates linkages to a variety of standard and customized databases and tools. These latter allow the user to create or import wind time series, current fields, and grids of arbitrary spatial resolution, and to map and graph model outputs. Oil and chemical databases supply physical-chemical and toxicological parameters required by the model. Results of model simulations are stored at discrete time-steps in computer files, which are then available as input to one or more biological exposure models.

OSCAR employs surface spreading, advection, entrainment, emulsification, and volatilization algorithms to determine transport and fate at the surface. In the water column, horizontal and vertical advection and dispersion of entrained and dissolved hydrocarbons are simulated by random walk procedures. Partitioning between particulate-adsorbed and dissolved states is calculated based on linear equilibrium theory. The contaminant fraction that is adsorbed to suspended particulate matter settles with the particles. Contaminants at the bottom are mixed into the underlying sediments, and may dissolve back into the water. Degradation in water and sediments is represented as a first order decay process. Algorithms used to simulate the various processes controlling physical fates of substances are described in Aamo *et al*. (1993) and Reed *et al*. (1995 and 2004). It should be noted, however, that the model is undergoing continuous development, and that some of the algorithms may have been updated since these papers were published.

Parameters defining the response capabilities for mechanical recovery and dispersant application systems can be supplied by the user or taken from a database. Mechanical recovery systems include specific units such as booms, skimmers and towboats (response vessels), as well as loading barges for storage of recovered oil. Each unit is characterised by parameters such as boom swath, tow velocity, skimmer rate, transfer velocity, loading capacity and loading time. Recovery efficiency is assumed to depend on sea state (significant wave height, which in OSCAR is computed as a function of wind speed, fetch, and water depth). Under ideal conditions, a maximum percentage of the oil entering the boom can be recovered, with the remaining leaking under the boom. Effectiveness is reduced as wave height increases, and goes to zero at a user-supplied threshold wave height. The user can also specify whether operations continue at night (for example if infrared monitoring equipment is available). OSCAR computes sunrise and sunset from latitude and longitude and calendar day.

Chemical dispersant system may be either helicopters or fixed wing aircraft or spray boats, each characterized by parameters such as transfer and operational velocities, endurance (maximum duration of each trip), onboard storage volume of dispersants, spray swath and spray rate. The surface oil mass that can be treated per unit time depends on the spray rate and the dispersant-to-oil ratio, while the dispersing rate (amounts of oil mixed into the water column per unit time as a result of treatment) is supposed to improve with increasing wind. However, dispersant operations are supposed to be limited by a system dependent threshold wind speed.

Each oil spill combat system is located at a certain base station and is given a certain mobilization time. The arrival time of the system at the spill site is thus a sum of the mobilization time and the transfer time – the latter given by the transfer speed and the distance from the base to the spill site.

OSCAR allows the assignment of specific operational strategies to each boom-skimmer or dispersant application system being simulated. A standard strategy for blowout situations is to position mechanical recovery equipment as near the source as possible to increase the potential encounter rate between booms and oil. If all units follow this strategy, then oil that escapes this initial response action will continue to drift unhindered. Unless dispersed naturally or by a directed dispersant action, this oil can later threaten natural resource areas 'down-stream' of the source. The oil response scenarios sometimes therefore employ a mixed strategy, wherein some skimmers work near the source, and others collect oil threatening identified natural resource areas. Dispersant application units can be deployed in similar ways.

Example – Oslofjord Scenario

The following scenario is taken from the assessment of the governmental contingency response capability based on environmental risk assessment as described above.

The incident

15 000 tonnes of Balder crude oil and 300 tonnes of bunker C is spilled in two hours as a result of a shuttle tanker of 126 400 DWT running aground. The incident occurs close to the shoreline with an estimated shortest drift time of 18 hours for the first oil to reach the shoreline. The Balder crude oil is generally categorised as an asphaltenic crude oil with a density of 914 kg/m^3. Based on oil weathering studies less than 20% will evaporate and the oil will have reduced dispersablility after 24 hours (at summertime an 5 m/s wind). The weathering characteristics of the oil do not imply difficulties for conventional oil skimmers. When stranded, the oil will have a water content of 80%.

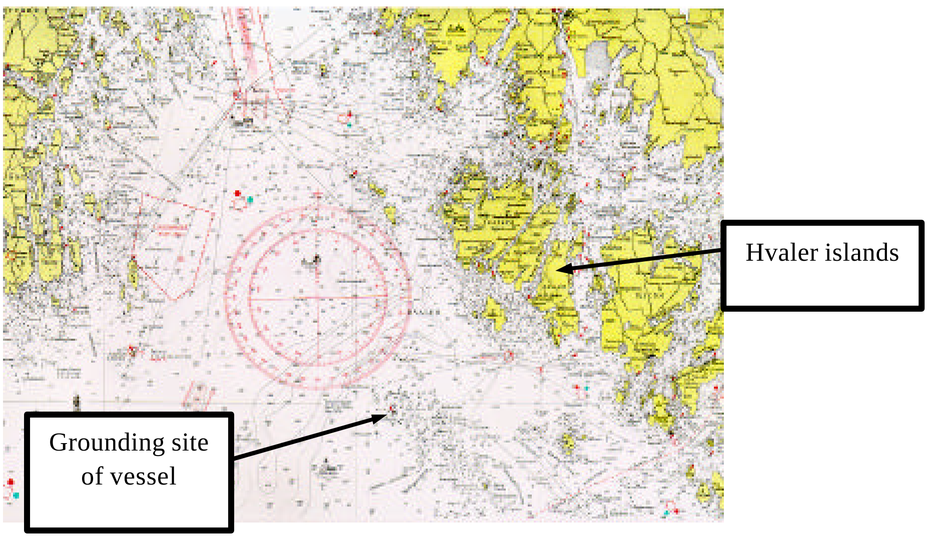

Figure 4. Grounding site of vessel (map extract of Outer Oslo fjord).

Dimensioning environmental resources and oil spill response objectives

The possible influence area for the spill includes the Hvaler islands with adjacent sea areas that qualify the requirements for national SMO. The area is an important hatching area for Alcids and Gulls. The total amount of Lesser Black-backed Gull on the coastline of Skagerak has international protection status. The area is a very important moulting area for Eider, and the whole area is important as recreational area for many people around the Oslofjord.

Response objectives

A) In the combat phase of the response operation

1. Hinder/reduce oil to affect the highest prioritised environmental sensitive areas according to MOB A and MOB B (ref figure 5.)
2. Hinder secondary pollution/ remobilising oil from infected beaches.
3. No free-floating oil at sea after three weeks.
4. Plan for shoreline cleanup to be implemented within three weeks.
5. Environmental monitoring to be established within three weeks.

The dimensioning of the necessary equipment will primarily be based on response objective 1, 2 and 3.

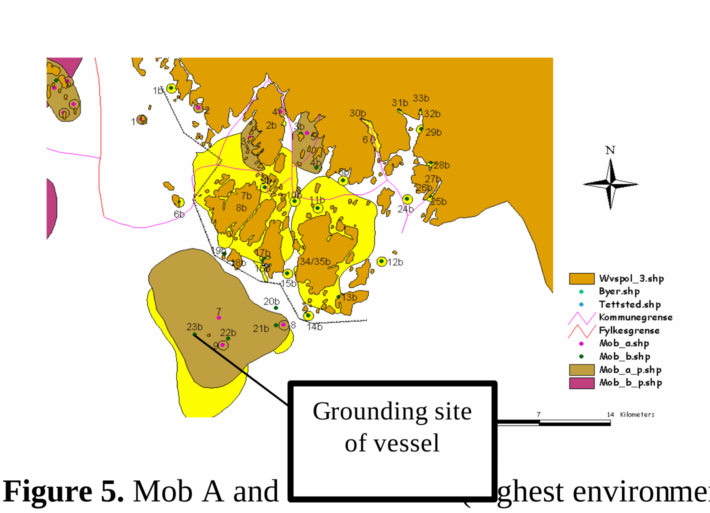

Figure 5. Mob A and (... ghest environmental priority)

B) In the shoreline cleanup phase of the operation

1. The most important moulting and wintering areas for sea birds shall within X months have a degree of cleanness that normal use of the areas does not harm the birds (hence no oil on sea- or land surface).
2. The most important breeding areas shall before the next breeding season have a degree of cleanness that normal use of the areas does not affect the birds.
3. The recreational areas for people shall before the next summer season have a degree of cleanness that does not affect normal use.

Simulation with no response efforts

With the spill location, spill rate and type of oil defined, various test runs were made with the OSCAR model to obtain a scenario that would cause serious damage to the most vulnerable resources in the area in the season of concern. The simulations were based on an estimated mean surface current pattern in the area (background currents), supplemented with historical wind data for several years. Figure 7a shows results from the chosen scenario 5 days after a presumed spill start in June 22, 1991. This simulation was performed without any response efforts. After two days 3000 tonnes of oil are in the littoral zone. Total contaminated beach line is 75 km, of which 25 km are within the MOB A and MOB B priority areas. After 5 days all oil, i.e. 11000 tonnes pure oil corresponding to 60000 m^3 of emulsion, is within the littoral zone. At this time approximately 200 km of shoreline are contaminated.

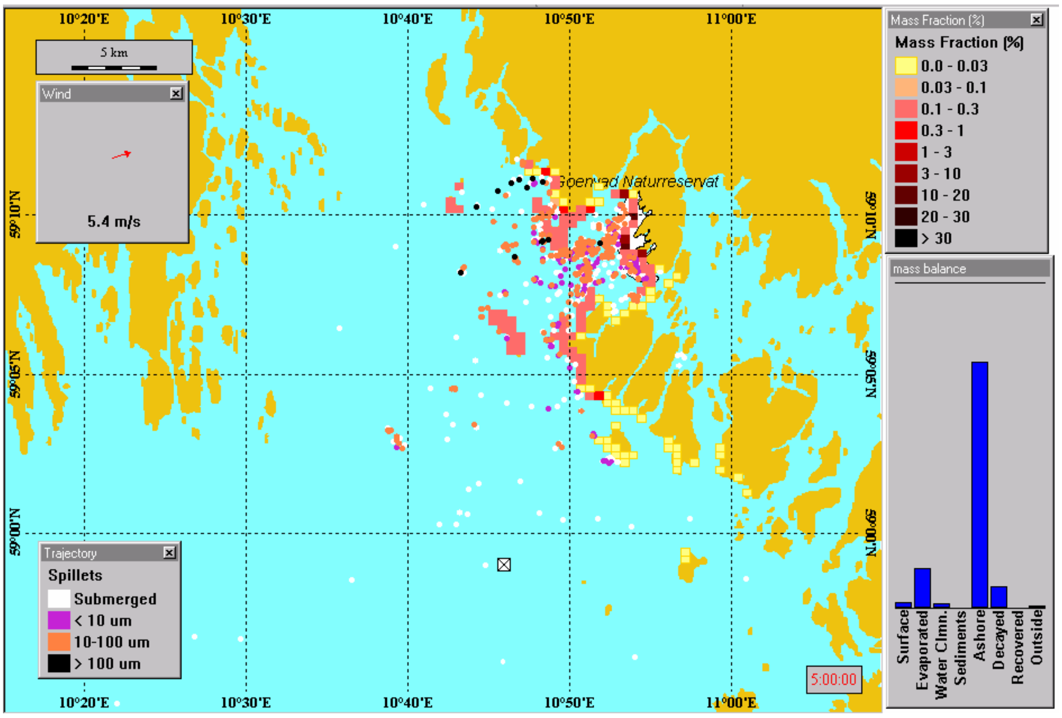

Figure 7a

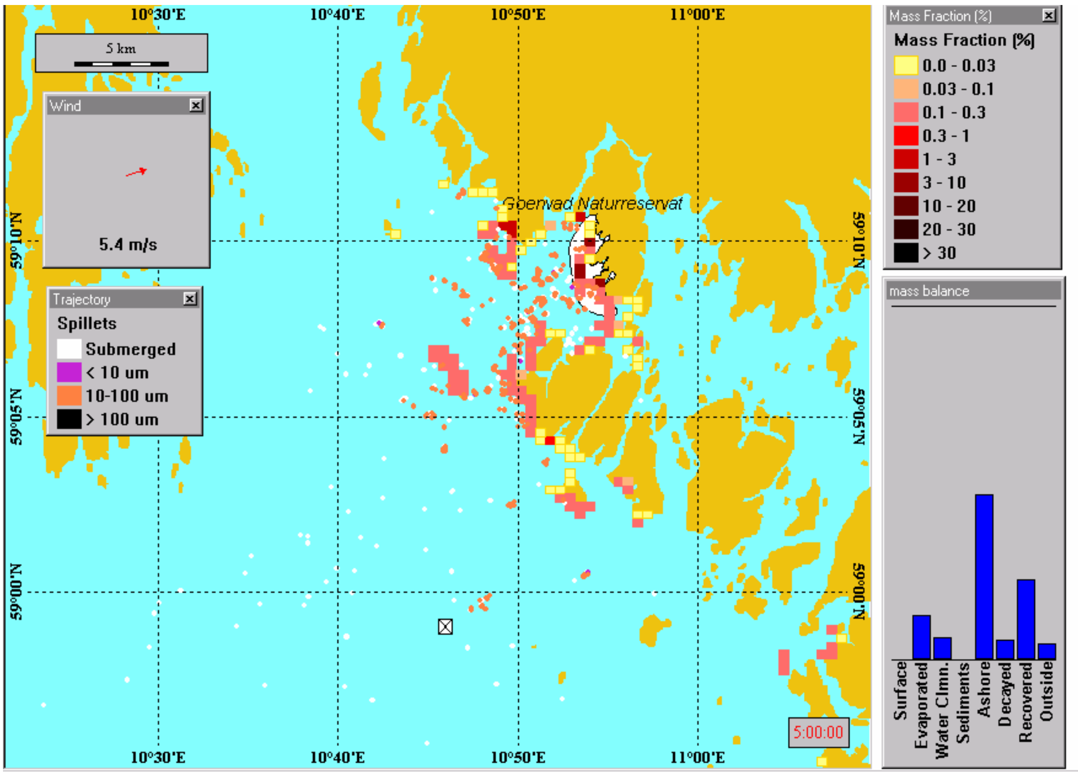

Figure 7b

Figure 7a and b. OSCAR simulations of the Oslofjord scenario: The maps show the distribution of oil on sea and on shoreline without (a) and with (b) oil spill combat measures 5 days after start of the release. The bar chart to the right of the map indicates the oil mass balance in terms of fractions of oil that is remaining on the sea surface, evaporated, stranded, or recovered. The extent of the area with the most vulnerable resources is indicated on the map (Goenvad wildlife reserve).

Simulations with oil spill response efforts

In these simulations, oil spill response efforts (mechanical recovery and use of dispersants) were used in two ways. The first based on an optimistic approach as to availability and response time, the second based on enhanced use of dispersants and shorter response time for the first mechanical recovery systems. The different response methods were downgraded by the use of net benefit response factors. Figure 7b shows results from the OSCAR model 5 days after spill start for the first simulation with response efforts. Table 4 illustrates the results of the different simulations in terms of amount of pure oil in the littoral zone (free-floating and beached).

Simulation 2 gives a reduction of 1600 tonnes pure oil in the littoral zone (on and close to shoreline) compared to simulation 1. This corresponds to a reduction in the highest sensitive areas of 500 tonnes. The main reason for this reduction is shorter response time for two of the offshore recovery systems and increased time on location due to adding emulsion breakers reducing the offloading time for the recovery vessels. Due to the limited benefit of the enhanced response efforts in simulation 2, simulation 1 is used for dimensioning the seagoing mechanical oil spill response preparedness.

	No response	Simulation #1 with response	Simulation #2 with response
Amount of recovered and dispersed oil (tonnes)	0	4800	6800
Total amount of oil in the littoral zone (tonnes)	11000	7200	5600
Amount of oil in highest sensitive areas (tonnes)	9000	4000	3500

Table 5. Comparison of the simulations. All numbers are given as pure oil.

Recommended level of preparedness – location and amount of equipment

Based on the assumptions above, and similar estimations of the need for shoreline cleanup systems, dispersants systems, coastal and fjord recovery systems, at total compilation of the recommended resources is given below. The left column represents response times to handle this scenario; the column to the right represents response times for other areas within this region (ref chapter "Method for establishing the necessary governmental preparedness" above).

Oil spill response system	**Response time Hvaler scenario (hours)**	**Response time other areas within the region (hours)**
Offshore system 1	10	15
Offshore system 2	18	27
Offshore system 3	22	33
Offshore system 4 and 5	36	48
Dispersants unit 1	4	6
Dispersants unit 2	5	6
Coastal system 1 and 2	6	9
Coastal system 3	11	17
Coastal system 4	20	30
Coastal system 5 and 6	36	48
Coastal system 7 – 15	168	168
Fjord system 1 – 3	6	9
Fjord system 4 – 6	18	27
Fjord system 7	30	45
Fjordsystem 8 – 45	168	168
Beachcleaning group 1 – 5	168	96
Beachcleaning group 6 – 26	168	168
Surveillance system	6	6
Emergency offloading	48	48

Figure 6. Total resources recommended

From figure 6 the necessary resources needed within the region and the corresponding response time is deducted. Based on these figures a correlation is made with the existing equipment within this region and other regions from which equipment may be transferred within the response time. In this region there is one main governmental depot in Horten.

The closest in the next region is Kristiansand. Only lesser adjustments of the equipment inventory of these depots is necessary. Equipment resources from the Exxon Refinery at Slagentangen will be used. In addition a smaller equipment depot has to be established between the two main depots in order to achieve the desired response time for the middle section of the region. This depot must consist of two coastal systems, each of 300 metres boom and one skimmer.

The table below summarizes the equipment types that must be added within this region to reach the necessary response times.

Equipment type	At depot in Horten	Other resources	Need for new equipment
Offshore systems, booms and skimmers	1200 metres boom 3 skimmers	Coast Guard and Supply vessels	No
Coastal systems, booms and skimmers	900 metres boom 4 skimmers	Exxon refinery Swedish Coast Guard From other regions	Yes – two systems located in Kragerø.
Fjord systems, booms and skimmers	1100 metres boom 3 skimmers	Private companies Municipalities From other regions	Yes – two skimmers at Horten depot
Dispersants systems	None	Exxon refinery From other regions	Yes – bucket and 10 m^3 of dispersants.

Table 6. Equipment types to be added in region 1**.**

Similar assessments have been made for all six regions resulting in a nationwide need for new equipment in the order of approx. 60 mill. NOK, and the relocation of one NCA depot from Fedje to Florø (both on the west coast of Norway). The new equipment will in part be added to existing equipment at NCA's 15 depots, and there will be established 9 secondary equipment depots under Intermunicipal care between the main governmental depots. The total equipment inventory of NCA will need to be adjusted by transferring surplus equipment in one region to another equipment with shortcomings. This adjustment will come in addition to the need for investment in new equipment.

Conclusions

The assessment of the level of Norwegian governmental preparedness as described in this paper was the foundation for recommendations to The Ministry of the Environment regarding the development of the preparedness for the 10-year period from 2001 to 2010. Part of this recommendation was the proposal for increased budgets over at three-year period in the order of 110 mill. NOK to invest in new equipment and enhanced training and exercises to establish a higher level of preparedness. Current budgets have not fulfilled the intentions of the recommendation to a full degree, but the budgets have been increased following the preparedness analysis. By the end of 2004 all nine secondary equipment depots will have been established, the NCA depot will have been transferred from Fedje to Florø, and the relocation of equipment between NCA depots will have started. The implementation of a governmental dispersants preparedness is still pending budgets as well as investments in certain types of booms and skimmers to enhance the inventory at existing NCA depots.

References

Aamo, O. M., M. Reed, P.S. Daling, and Ø. Johansen(1993): A Laboratory-based weathering model: PC version for coupling to transport models. Proceedings of the 1993 Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, pp.617-626.

Alpha Miljørådgivning (1999): "Risikobasert planlegging av statlig beredskap mot akutt forurensning –miljøressurser og konsekvenser." *Notat nr.: GMS090599-1,* Alpha Miljørådgivning as, 05-99. (In Norwegian only).

Beredskap mot akutt forurensning - MOB (SFT&DN 1996)

Brattegard, T., Holthe, T. (editors.) (1995): "Kartlegging av egnede marine verneområder i Norge. Tilråding fra rådgivende utvalg. Utredning for DN Nr. 1995 - 3. Direktoratet for naturforvaltning. 179 pp (In Norwegian only).

Johannesen, B.O. (1999): "Sannsynlighet for akutte utslipp av olje fra skipstrafikk langs norske kysten" - Rapport nr. BOJ/99AAACXW, Det norske Veritas 3. mai 1999.(In Norwegian only).

Moe, K.A., Anker-Nilssen, T., Bakken, V., Brude, O.W., Fossum, P., Lorentsen, S.H., Skeie, G.M. (1999): "Spesielt Miljøfølsomme Områder (SMO) og petroleumsvirksomhet. Implementering av kriterier for identifikasjon av SMO i norske farvann med fokus på akutt oljeforurensning." Alpha Miljørådgivning - Havforskningsinstituttet - Norsk institutt for naturforskning - Norsk Polarinstitutt. Alpha Rapport 1007-1. Alpha Miljørådgivning. 51 pp. (In Norwegian only).

Reed, M., O. M. Aamo, and P. S. Daling (1995): Quantitative analysis of alternate oil spill response strategies using OSCAR. Spill Science and Technology Bulletin, Vol. 2, pp. 67-74.

Reed, M. et al. (2004): DREAM: A dose-related exposure assessment model - Technical description of physical-chemical fates components. Journal Marine Systems, Vol. 45 (in press).

Schreiner, Ø., Hansen, O., Lenes, G., Bratfoss, B., Hansen, T.W., Bertheussen, H., Reinertsen, A.R.: " Risikobasert dimensjonering av statlig beredskap mot akutt forurensning, Fase 1: Miljørettet risiko og beredskapsanalyse" SFT-report 1755/2000 (in Norwegian only), Horten December 2000.

Schreiner, Ø., Hansen, O., Lenes, G., Bratfoss, B., Hansen, T.W., Bertheussen, H., Reinertsen, A.R.: " Risikobasert dimensjonering av statlig beredskap mot akutt forurensning, Fase II: Behov og plassering av utstyr langs kysten" SFT-report 1848/2001 (in Norwegian only), Horten, December 2001.