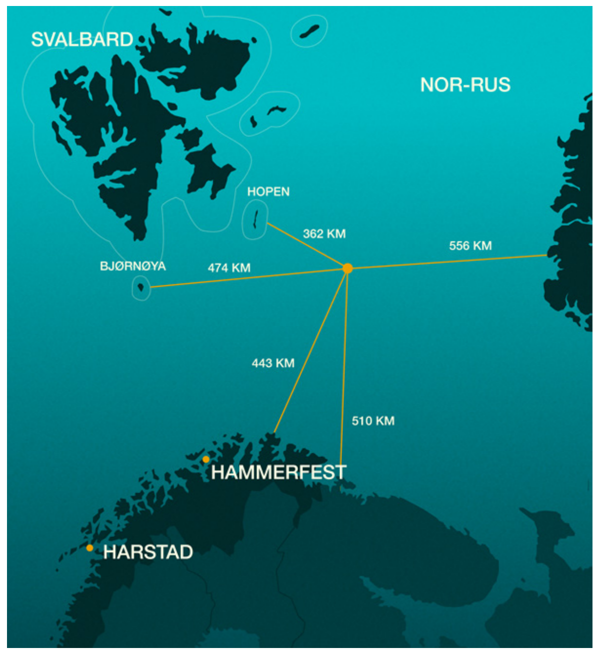
Miljørisiko og oljevernberedskap i Barentshavet sørøst

Barents Sea Exploration Collaboration (BaSEC) er et industrisamarbeid for å forberede leteoperasjoner i Barentshavet. Barentshavet har vært åpent for petroleumsaktivitet siden 1980, men industrien beveger seg nå inn i nye områder av dette havområdet. BaSECs siktemål er derfor å koordinere operatører og komme med anbefalinger om tiltak som kan danne grunnlag for sikker og effektiv letevirksomhet i Barentshavet. BaSEC har 17 medlemmer, alle operatører på norsk sokkel. BaSEC bygger sine rapporter på beste tilgjengelige kunnskap og på den brede erfaring disse 17 selskapene har fra operasjoner i Barentshavet, andre steder på norsk sokkel og i andre områder med tilsvarende forhold.

Sammendraget dekker tre rapporter om tre tema: miljørisiko, oljevernberedskap og status for oljevern i is. De tre rapportene er laget med utgangspunkt i blokk 7435/9 som inngår i lisens PL859. Rapportene ble utarbeidet i forkant av vårens tildelinger i 23. konsesjonsrunde. Lisensgruppen som nå har ansvaret for lisens PL859 vil utarbeide miljørisikoanalyser når de bestemmer seg for hvor og når man skal bore letebrønner i denne lisensen.



Figur 1: Lokalisering av brønn for miljørisikoanalysen

Blokk 7435/9 ligger midt i Barentshavet med stor avstand til land. Nærmeste landområde er Hopen som er 380 km unna, det er 440 km til fastlandet (Nordkapp) og ca. 500 km til Bjørnøya. Dette er en viktig forutsetning for de vurderingene som gjøres i miljørisikoanalysen. I tillegg er det viktig å merke seg de funn som er gjort i BaSECs rapport om «Fysisk miljø i Barentshavet sørøst», som ble offentliggjort tidligere i 2016. Videre har rapporten brukt en generell sannsynlighet for utblåsning på 0,014 % eller 1 gang per 7092 letebrønner. Det er forventet at denne risikoen vil være lavere ved senere analyser på grunn av reservoarenes lave trykk og lave temperatur.

Rapporten er laget av DNV GL og har anvendt best tilgjengelige data, slik som Seapop og SEATRACK for å kunne si noe om risikoen ved en eventuell oljeutblåsning. Anerkjente analyseverktøy som OSCAR for oljedriftsimulering er også brukt. Rapporten har også for første gang gjennomført en dynamisk simulering av olje i drift i forhold til den marginale issonen og vurdert sårbarheten til dyrelivet i området definert som polarfronten.

Hovedfunnene knyttet til miljørisiko ved en oljeutblåsning fra blokk 7435/9 kan oppsummeres med at:

- Oljen fra en utblåsning vil ikke nå land
- Så lenge aktiviteten foregår i henhold til myndighetenes krav om en 50 kilometers buffersone er det svært lite sannsynlig at oljen fra en eventuell utblåsning vil nå inn i iskantsonen
- En oljeutblåsning vil i hovedsak påvirke sjøfugl på åpent hav – det er mer enn 70 % sannsynlighet for ingen skade og inntil 30 % sannsynlighet for en skade hvor bestanden vil være gjenvunnet i løpet av 1-3 år
- Det er ikke funnet bestandseffekter på sjøpattedyr eller på fisk
- Eksisterende oljevernutstyr vil kunne benyttes med betydelig effekt

Hvor stor er sannsynligheten for en oljeutblåsning?

Selv om Barentshavet ligger langt mot nord, viser erfaring og kunnskapen om geologien i området at det ikke er mer komplisert å bore der enn andre steder på sokkelen. I Barentshavet er det ikke høyt trykk i reservoarene, i motsetning til enkelte steder i Nordsjøen og i Norskehavet. Det lave trykket innebærer at det er liten sannsynlighet for en ukontrollert utblåsning. En eventuell utblåsning vil derfor ha et begrenset skadepotensiale.

I denne rapporten har BaSEC likevel, basert på relevant historisk statistikk, brukt en generell frekvens risiko for oljeutblåsning tilsvarende 1 utblåsning for hver 7092 letebrønn. Dette tilsvarer en sannsynlighet for utblåsning på 0,014 prosent. Det antas at dette er en høyere risiko enn den man vil se i de forskjellige boremålene i de tildelte lisensene.

Siden 1969 er det boret om lag 1500 letebrønner totalt på norsk sokkel, hvorav ca. 130 brønner i Barentshavet.

Vil oljen kunne nå kysten?

Leteblokk 7435/9 i Barentshavet sørøst (en del av lisens PL859) ligger 380 km fra nærmeste landområde på Hopen og hele 440 km nord for fastlandet på Finnmarkskysten. Avstanden til den maritime grensen mellom Norge og Russland er 30 km. En eventuell oljeutblåsning ved leteboring i området vil derfor ikke nå kysten.

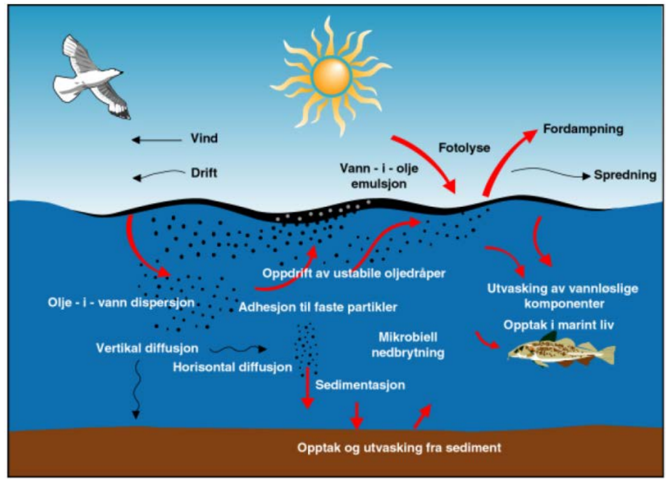
Skrugard-olje, som er oljetypen valgt for området ved blokk 7435/9, har en relativt kort levetid – 2 døgn – på sjøen ved mye vind og høye bølger, men kan holde seg en drøy uke på havoverflaten under rolige værforhold.

Fordampningen og nedblandingen ved en eventuell oljeutblåsning eller et eventuelt oljeutslipp, starter like etter oljen legger seg på havoverflaten. Da iverksette tre prosesser fra naturens side som alle bidrar til at oljeflaket brytes opp og forsvinner.

Første fase. De lette delene av oljen fordamper. Hvor fort det skjer, avhenger av værforhold og oljens konsistens. Forventet olje i Barentshavet sørøst kjennetegnes ved å være lett. Konsistensen gjør at fordampingen vil skje raskere der enn i de fleste andre havområder.

Andre fase. Oljen blandes ut med vann. Dette kan øke volumet på oljeflaket selv om konsentrasjonen av olje synker.

Tredje fase. Den viktigste prosessen er den naturlige oppløsningen av oljen. Oppløsningen skjer i hovedsak ved at vind og bølger brekker opp oljeflaket i små oljedråper. Jo større bølger og jo kraftigere vind, desto fortere brytes oljeflaket opp. Disse dråpene blandes så inn i vannet under havoverflaten. Ganske raskt synker da konsentrasjonen av giftige stoffer til under nivået som påvirker levende organismer. På det tidspunktet kan ikke lenger oljen skade livet i havet.



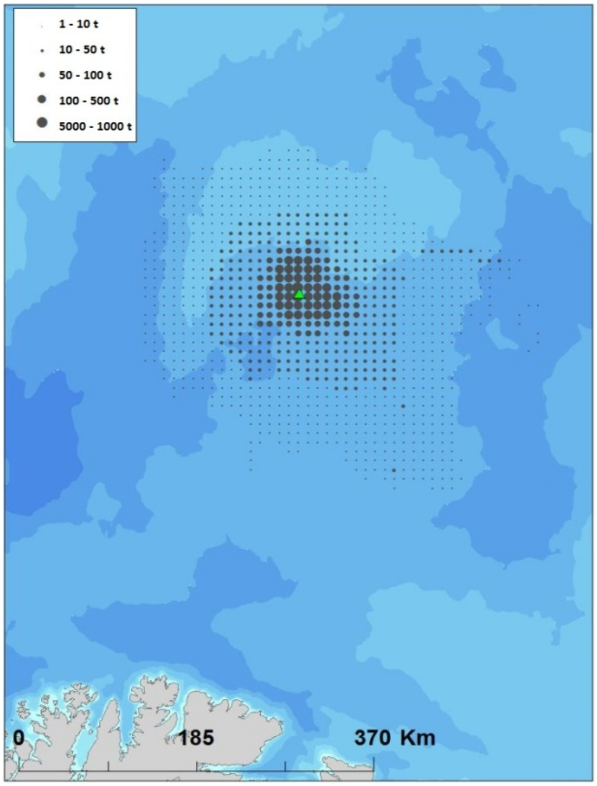
Figur 2: Naturlig nedbryting av olje på havoverflaten. Kilde: SINTEF

Antatt levetid på overflaten for olje i Barentshavet sørøst er fra to dager til en drøy uke. I tillegg til dette vil det være oljeverntiltak som tar opp olje fra havoverflaten og/eller øker nedbrytingen av oljen i vannet. Det er strenge krav til å være forberedt på slike situasjoner, og alle operasjoner i Barentshavet har og vil ha en god beredskap for oljevern.

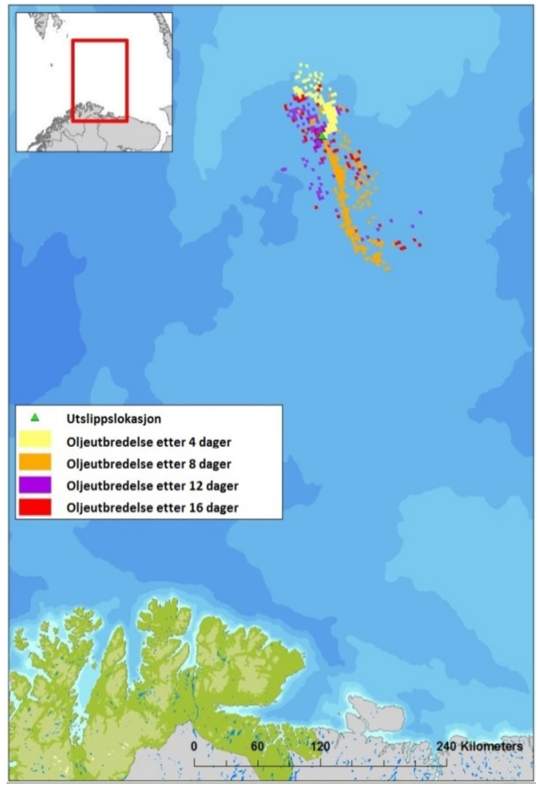
Oljedriftsberegninger viser at oljen fra en utblåsning er forventet å bre seg inntil 100 km fra utslippspunktet, men at oljen i noen tilfeller kan drive så langt som 200-250 km på havet før den er fordampet og nedblandet i vannmassene. Jo lengre oljen kommer vekk fra utblåsningspunktet, jo mindre er konsentrasjonen av oljen og mulige miljøeffekter avtar i takt med reduksjon i konsentrasjon.

Figur 3 (på neste side) viser hvor oljemengdene fra en utblåsning i blokk 7435/9 i hovedsak kan havne. Et enkeltutslipp vil dekke et mye mindre område, men vil ikke gå utenfor det merkede området. Figuren er en simulering av hvor et stort antall oljeutslipp kan drifte under ulike historiske vind- og strømforhold.

Figur 4 (på neste side) viser hvordan et enkeltutslipp vil bevege seg over en 16-dagers periode. Dette er en tilfeldig utvalgt simulering.



Figur 4: Vektet oljemengde i tonn per 10x10km ved en overflateutblåsning



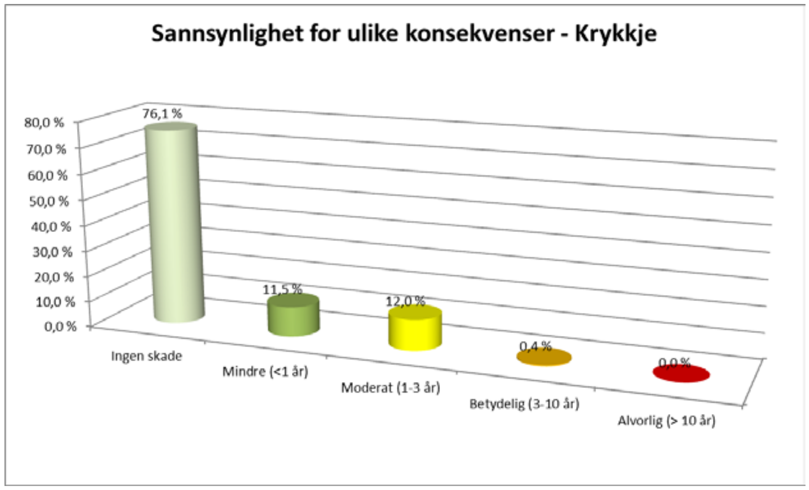
Figur 3: Utbredelse av olje på havoverflaten over en periode på 16 døgn i en tilfeldig valgt utblåsningssimulering

Vil oljen kunne nå iskanten?

Oljedriftsberegningene som er utført for blokk 7435/9 i lisens PL859 viser at det er svært lite sannsynlig at olje driver inn til en iskant som er mer enn 50 km unna. Beregningene viser en samvariasjon som gjør at selv om man forventer at olje kan drive 100 km så driver den som regel i samme retning som isen, dvs. når isen rykker sørover driver også oljen sørover og når isen trekker seg tilbake vil oljen drive nordover igjen.

Overgang fra åpent hav til islagt hav (iskanten) har variabel karakteristikk fra dag til dag, fra måned til måned og fra år til år. Forvaltningsplanen for Barentshavet og Lofoten benytter derfor en definisjon på iskanten som det området hvor mer enn 15 % av havflaten er dekket av sjøis i mer enn 30 % av dagene i april. Typisk ser man da på sannsynlighet basert på mange år med historiske isutbredelser (10-30 år med data). Blokk 7435/9 ligger cirka 150 km sør for det iskantområdet etter denne definisjonen. Regelverket tilsier at dersom iskanten kommer nærmere enn 50 km fra borelokasjonen skal en leteboringsoperasjon settes på vent inntil isen igjen er mer enn 50 km unna.

Hvordan vil en oljeutblåsning påvirke sjøfugl og sjøpattedyr på havet?



Figur 5: Sannsynlighet for effekt på krykkje

Analysene som er utført for blokk 7435/9 viser at det er sjøfugl som vil kunne bli mest berørt. Dette inkluderer arter som krykkje, lunde og polarlomvi. Selv om enkeltindivider vil kunne dø er det beregnet at det er over 70 % sannsynlighet for at en eventuell oljeutblåsning ikke vil medføre skade (mer enn 1 % tap) på sjøfuglbestandene i Barentshavet. Det er mindre enn 1 % sannsynlighet for å få en betydelig miljøskade, som vil medføre 3-10 års restitusjonstid for bestanden av krykkje i Barentshavet (se figur 6).

Beregningene er utført basert på data fra Seapop (seapop.no) som har utarbeidet kart som viser artenes utbredelse på åpent hav om sommeren, høsten og vinteren.

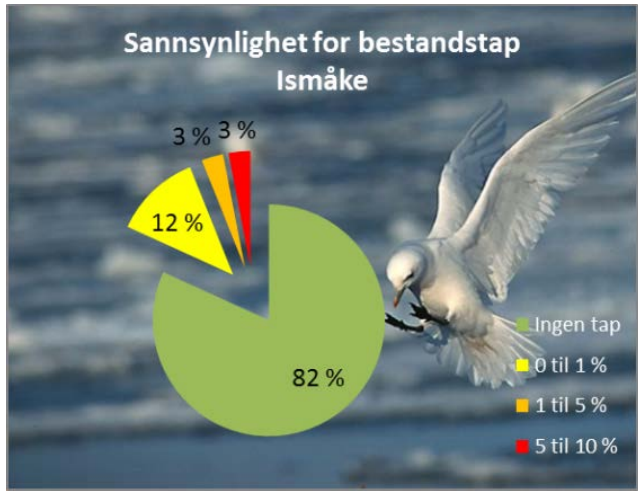
Generelt kan vi si at det er svært stor variasjon i hvilke konsekvenser en oljeutblåsning vil få for sjøfugl og sjøpattedyr avhengig av værforholdene når et utslipp skjer og hvor mye sjøfugl og sjøpattedyr det er i området. Konsekvensen vil også variere med hvor sårbare ulike individer er for olje, men også hvor sårbare ulike bestander er i forhold til en nedgang i populasjonen.

Et annet usikkerhetsmoment er Polarfronten – skillet mellom varmt atlantisk vann og kald arktisk vann og hvilke biologiske ressurser som finnes der. Datasettene er for grove til å fange opp større tettheter av fugl i polarfronten. Hvis man likevel analyserer en utblåsningseffekt på en hel bestand som skulle befinne seg i umiddelbar nærhet av utblåsningen, forventer vi at bestandstapet fremdeles er på under 10 %. Bestanden vil da i løpet av 1-3 år gjenvinne størrelsen. Dette er innenfor det som på norsk sokkel er en akseptabel risiko. Igjen er det viktig å huske på at sjansen for en utblåsning i seg selv er på 0,014 %.

Hvordan vil en oljeutblåsning påvirke dyrelivet i iskanten?

Borelokasjonen ligger et stykke unna iskanten, og det er beregnet en lav sannsynlighet for at olje vil berøre iskanten ved en eventuell oljeutblåsning. Det forventes derfor ikke at dyrelivet i iskanten vil bli vesentlig berørt. Oljen i denne delen av Barentshavet har relativt kort levetid (2 døgn) på sjøen ved mye vind og høye bølger. Den kan holde seg i en drøy uke på havoverflaten under rolige værforhold.

Beregninger utført for ismåke viser at selv i vinter- og vårsesongen, hvor iskanten er nærmest borelokasjonen, så er det ved en utblåsning mer enn 80 % sannsynlighet for at man ikke får konsekvenser på ismåkebestanden (se figur 7). Det er generelt lite spesifikke datasett tilgjengelig som viser utbredelsen av dyrelivet i iskantsonen. For å vurdere mulige konsekvenser på sjøfugl ble det derfor opparbeidet et datasett på utbredelse av ismåke, en høyarktisk art som har tilhold i isfylte farvann hele året. Datasettet er dynamisk og viser utbredelsen i områder med 20 til 50 % is.



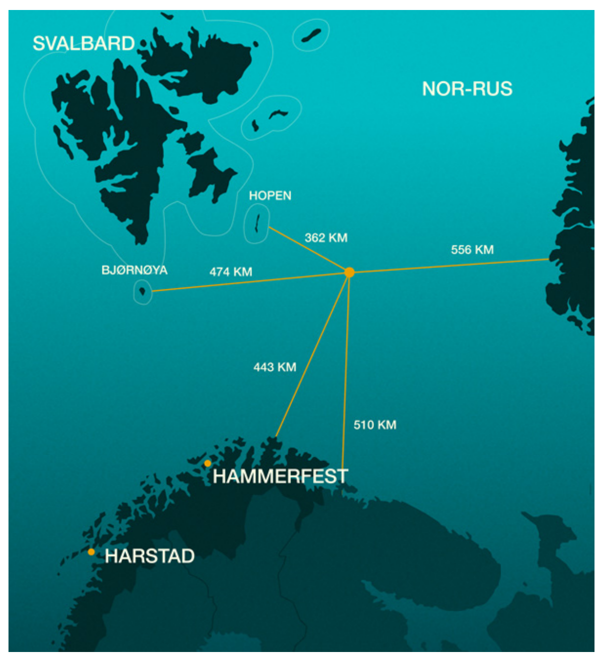
Figur 6: Sannsynlighet for bestandstap av ismåke

Dataene om ismåke baserer seg på GPS-logger-studier i SEATRACK. Dette er et helhetlig og langsiktig overvåkings- og kartleggingsprogram for norske sjøfugler. Datasettet kan også være relevant for andre arter i den marginale issonen slik som for eksempel sel.

Hvordan vil en oljeutblåsning påvirke dyrelivet i kyst- og strandsonen?

Risikoen for en utblåsning er på 0,014 %. I og med at borelokasjonen i blokk 7435/9 er mer enn 380 km fra nærmeste landområde på Hopen og mer enn 440 km fra Finnmarkskysten, så vil ikke olje fra en eventuell utblåsning leve så lenge på havoverflaten at den vil kunne nå land. Det vil derfor ikke være noen bestandseffekter på dyrelivet i kyst- og strandsonen.

Oljen i denne delen av Barentshavet har relativt kort levetid (2 døgn) på sjøen ved mye vind og høye bølger. Den kan holde seg en drøy uke på havoverflaten under rolige værforhold. Enkelte sjøfuglarter, som for eksempel lunde kan fly så langt som 100 km ut fra hekkekolonien for å finne mat. Individer av enkeltarter som er basert langs land forventes derfor i svært begrenset grad å bli påvirket av en utblåsning fra denne blokken.



Figur 7: Lokalisering av brønn for miljørisikoanalysen

Hvordan vil en oljeutblåsning påvirke fisk og livet i havet?

Ved en eventuell oljeutblåsning vil bølger føre til at noe av oljen naturlig blandes ned i vannsøylen. Det vil imidlertid være en rask fortynning i tid og rom i av de giftige oljekomponenter i vannsøylen som kan gi effekter på livet i havet. Det er først og fremst fiskeegg- og larver som er mest sensitive for oljepåvirkning. Det er ikke vist til særlig stor konsentrasjon av fiskeegg- og larver i området rundt borelokasjon 7435/9 og modellerte oljekonsentrasjoner i vannsøylen er lave. Det vil kunne være dødelighet av egg- og larver i nærområdet 20-30 km rundt en utblåsning, men dette forventes ikke å føre til målbare konsekvenser for fiskebestander i Barentshavet.

Det er i cirka 250 meters vanndyp på borelokasjonen og skulle en utblåsning skje på sjøbunnen og ikke på overflaten, forventes det allikevel at gass og reservoartrykk vil føre oljen raskt opp til overflaten for så å spres på samme måte som et overflateutslipp.

Hvilken effekt kan vi forvente av oljevernberedskap i dette området?

En oljevernberedskapsanalyse er utført for et utblåsningsscenario fra blokk 7435/9 i lisens PL859. Størst beregnet effekt har en kombinasjon av mekanisk opptak med lensesystemer og dispergering fra fly. En slik kombinasjon vil kunne redusere oljen på overflaten med inntil 75 % under optimale forhold i løpet av de første fem dagene. Av de vurderte teknikkene er det mekanisk opptak som viser størst potensiale i iskonsentrasjon opp til 30 %. Det vurderes imidlertid som svært lite sannsynlig at et eventuelt oljesøl vil nå iskanten.

På tross av lav sannsynlighet for oljepåslag i is, tar studien for seg ulike beredskapsteknikker både i åpent hav og i isfylte farvann. Den belyser hvilke teknikker som kan fungere best på en eventuell utblåsning i dette området. Dette omfatter både mekanisk opptak med både konvensjonelle og aktive lensesystemer, kjemisk dispergering både fra fly og fra fartøy, brenning og undervannsdispergering. I tillegg er det sett på et konsept for et fartøy som kan utføre flere typer oljeverntiltak i isfylte farvann opp til 30 % iskonsentrasjon.

Målet er at flest mulig av disse beredskapsteknikkene er tilgjengelige og kan benyttes basert på hvilke forhold det til enhver tid er rundt utslippet. Beredskapen vil være sammenlignbar med effektiviteten andre steder på norsk sokkel. Den viktigste forskjellen er at forskjellen i effekt mellom sommer og vinter er større enn på andre deler av sokkelen. Dette skyldes blant annet lysforhold.

Flere øvelser har blitt utført i Finnmark vinteren 2015. En øvelse ble også gjennomført i iskanten senvinteren 2015. Øvelsene har gitt verdifull informasjon og erfaringer om norsk oljevernberedskap i kaldt klima og is, og underbygger de utførte beregninger. Øvelsen demonstrerte bl.a. at et vanlig NOFO-system kan settes ut og opereres etter dagens prosedyrer. Anti-is middel (glykol) kan benyttes på sentrale komponenter for å motvirke ising.

For isfrie farvann er eksisterende og tilgjengelige løsninger på norsk sokkel for oljedeteksjon dekkende, men datakommunikasjon kan være en begrensende faktor så langt nord. Tiltak for å forbedre digital kommunikasjon fra skip viser gode resultater, og digitale downlink-systemer fra fly fungerer også godt.

Dersom et oljeutslipp skulle drive inn i Russisk farvann er det etablert en overenskomst mellom Norge og Russland angående samarbeid om bekjempelse av oljeforurensning i Barentshavet. I medhold av avtalen er det utarbeidet en felles Norsk-Russisk beredskapsplan for oljevernaksjoner i Barentshavet. Planen regulerer samarbeid mellom myndigheter i de to landene når det gjelder aksjoner mot oljeutslipp, gjennomføring av øvelser og jevnlige møter.

OIL SPILL RISK ASSESSMENT AND RESPONSE RELATED TO EXPLORATION DRILLING I BARENTS SEA SOUTH-EAST

Oil spill response in the Barents Sea South East - Status document

Statoil ASA

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Table of contents

EXECUTIVE SUMMARY 4

NORSK SAMMENDRAG 6

DEFINITIONS AND ABBREVIATIONS 8

1 INTRODUCTION 11
1.1 Background 11
1.2 Scope of work 11

2 NATIONAL FRAMEWORK FOR OIL SPILL RESPONSE 15
2.1 Legal framework 15
2.2 Acute pollution from petroleum activities on the Norwegian Continental Shelf 15
2.3 Norwegian international cooperation 15

3 RESPONSE TACTICS IN COLD CLIMATE AND ICE 16
3.1 Behaviour of oil in water and ice 16
3.2 Response measures 18
3.3 Additional Considerations 31

4 RESPONSE EFFICIENCY IN COLD CLIMATE AND ICE 34
4.1 Experiences from exercises 34
4.2 Quantitative efficiency assessments 39

5 OIL SPILL RESPONSE STRATEGIES AND CONCEPTS FOR BARENTS SEA SOUTH EAST 43
5.1 Barrier strategies 43
5.2 Current barrier elements/response systems 46
5.3 Future barrier elements/response systems 49
5.4 Cross border issues 53

6 RESULTS FROM OSCA 56
6.1 Conclusions 56
6.2 Operational feasibility 57

7 EXISTING RESPONSE CAPACITIES AND RESOURCES 58
7.1 NOFO resources 58
7.2 Resources through NOFO agreements 58
7.3 Relevant resources based on Governmental international agreements 60
7.4 Rules and regulations for vessels operating in the Barents Sea 61

8 DISCUSSION AND RECOMMENDED ACTIONS 66
8.1 Discussion 66
8.2 Recommended actions 68

9 REFERENCES 69

APPENDIX 71

EXECUTIVE SUMMARY

This report has been prepared together with an Environmental Risk Analysis (ERA) and an Oil Spill Contingency Analysis (OSCA) for the Barents Sea Exploration Collaboration (BaSEC). The status document summarizes key elements in oil spill response for cold climate and ice infested waters with emphasis on areas included in the 23. Licensing round in the Barents Sea, and serves as a basis document for the OSCA.

When oil is spilled at sea natural processes are spreading, evaporation, dissolution, biodegradation and formation of emulsions. Low temperatures and ice will influence an oil spill differently compared to temperate regions. Especially low temperatures and dampening of waves due to ice lead to reduced oil spreading, evaporation, emulsification and dispersion.

There are several response measures to oil spill in an arctic marine environment. The main response options are remote sensing, mechanical recovery, dispersant application and in-situ burning. Each category can be split in several sub-categories depending on specific response context, platform for deployment and configurations of components. The response measures are described, including the potential impacts generated from cold climate and ice. Additional considerations such as logistics, training, planning and HSE are outlined.

Results and experiences from relevant exercises are presented and discussed as a part of evaluation of response efficiency in cold climate and ice. Several exercises with deployment of response equipment have been carried out in Finnmark in winter 2015. An exercise was also carried out in the marginal ice zone late winter 2015. The exercises provide valuable information and experiences for oil spill response in cold climate and ice.

A quantitative methodology for assessment of response efficiencies is proposed. The methodology is based on an analysis that combines defined limitations for oil spill response with a comprehensive metocean dataset. The methodology enables calculation of average efficiencies for the main response measures in the Barents Sea and adjacent areas due to environmental conditions such as wind, waves, ice, temperature, visibility and darkness. In the BaSEC location block 7435/9 vessel-based dispersant application is expected to have the highest general regularity through the year, closely followed by mechanical recovery. A significantly lower regularity is expected for In situ burning. A calculation tool has been developed were metocean conditions as well as system- and spill-specific information can be added (ORCA - Oil spill response calculator). This tool has been used for calculating oil spill response in ice in the separate oil spill contingency analysis (OSCA).

A general oil spill response barrier strategy for the study area is outlined, organizing relevant elements and functions in barrier 1a and 1b. Six oil spill response concepts are identified and described (response to oil on sea surface). Three of the systems are currently implemented in existing preparedness – mechanical recovery, vessel-based dispersion application and aerial dispersion application. Three future systems are defined and described based on their potential benefits in cold climate, ice or relatively remote areas; In situ Burning in open water, mechanical recovery with active boom system and a multi-purpose vessel for oil spill response in ice. The selected response measures are further analyzed in the OSCA. Subsea dispersant injection is also included (response to oil in the water column), but operational issues regarding logistics and deployment are not evaluated.

Block 7435/9 is in close proximity to the Norwegian Russian boarder which creates a high degree of likelihood for cross-boundary pollution in case of a blowout. Currently Norway and Russia cooperate on acute pollution preparedness based on an agreement signed by the Governments of Norway and

Russia in 1994. The agreement regulates cooperation, communication and effective use of available oil spill resources, and is also the basis for the joint Norwegian-Russian contingency plan for oil spill response in the Barents Sea. According to the contingency plan Russia have relevant response resources. Response vessels etc. are not by default allowed to cross the border unless this is decided by the national authorities. According to current procedures a spill from the Norwegian to Russian waters is likely to prompt a Norwegian governmental intervention in the management of the response.

The main results are taken in from the OSCA report and indicate that active mechanical recovery systems in combination with dispersants are the most effective for the given scenario. Passive mechanical recovery systems and in situ burning in open water are the least effective. The amount of treated oil is generally higher in summer than in the winter season due to seasonal variations in weather conditions. Response measures also have a greater effectiveness on the topside blowout compared to subsea blowout.

SINTEF's OSCAR model does not enable modelling of oil spill response in ice. The ORCA tool has been applied to assess the effect of the multipurpose response vessel for oil recovery in ice-infested waters. The system is primarily set up for operations in ice up to 30 % and comprises of kits for mechanical recovery, in situ burning and dispersant application in ice. Calculations were based on input from single scenarios modelled in OSCAR. The results indicate that mechanical recovery is the most effective response technique in ice-infested waters since dispersion and ISB have limited effect due to the high water uptake of the Skrugard oil. A combination with chemical dispersion and in-situ burning could potentially broaden the operational window if operating on fresh oil in ice – although this is unlikely to occur at the selected location.

An overview of existing and available oil spill resources is provided, with focus on resources most relevant for the Barents Sea. This includes resources from depots in Norway and internationally, and from public and private resource owners. The focus is on main equipment and systems. NOFO (Norwegian Clean Seas Association for Operating Companies) is the key resource provider, but several major additional sources are available in Norway and internationally based on agreements or as commercial services.

A key resource for oil spill response is the Oil Recovery (OR) vessels. Rules and regulations for vessels operating in the Barents Sea are described, including ice class, the Polar Code and winterisation of ships. It is suggested that vessels going to be operated all year in the northern part of the area included in 23rd licensing round should have a proper ice class and winterization. Further recommendations are to establish a winterisation standard for response equipment, and operating procedures for cold climate and ice. A template for spare parts and equipment for NOFO operations in northern waters should also be prepared and a training program for oil spill operations in cold climate and ice should be developed. The study indicates that active mechanical recovery systems for offshore conditions should be considered as an addition to existing recovery systems. The concept is well proven in coastal water, and offshore versions have proven promising in realistic tests. Active booming systems normally enable higher encounter rates than passive systems, which is the primary factor in a successful recovery. Other benefits are increased manoeuvrability and that the system can be operated in a single boat configuration. Other areas that need attention are planning and testing of logistic chains in remote areas.

NORSK SAMMENDRAG

Denne statusrapporten, samt en miljørisikoanalyse (MRA) og en miljørettet beredskapsanalyse (BA), er utarbeidet for "The Barents Sea Exploration Collaboration" (BaSEC). Statusdokumentet oppsummerer sentrale elementer i oljevernberedskapen for kaldt klima og farvann der det kan forekomme sjøis med vekt på områder som er inkludert i 23. lisensrunde i Barentshavet. Statusdokumentet er et grunnlagsdokument for beredskapsanalysen.

Når olje kommer på sjøen inntrer en rekke naturlige prosesser som spredning, fordampning, dispergering, biologisk nedbryting og dannelse av olje-vann emulsjoner. Lave temperaturer og is vil kunne påvirke disse prosessene sammenlignet med mer tempererte områder. Blant annet vil lave temperaturer og demping av bølgeaktivitet på grunn av is føre til redusert oljespredning, fordampning, emulgering og spredning.

Det er flere aktuelle oljeverntiltak for å bekjempe oljeutslipp i arktiske marine miljøer. De viktigste alternativer er fjernmåling, mekanisk oppsamling, kjemisk dispergering og in-situ brenning. Hver av disse kategoriene har flere varianter, og avhengig av bl.a. utslippsrelaterte forhold kan ulike tiltak bestå av og settes sammen med ulike egenskaper og tilpasset ulike forhold. De mest aktuelle tiltakene er beskrevet herunder innvirkning av kulde og is. Andre momenter slik som logistikk, øving/trening, planlegging og HMS er også skissert.

Erfaringer fra relevante oljevernøvelser blir presentert og diskutert som en del av diskusjonen om oljevernberedskapens effektivitet i kaldt klima og is. Flere øvelser har blitt utført i Finnmark vinteren 2015. En øvelse ble også gjennomført i iskanten senvinteren 2015. Øvelsene har gitt verdifull informasjon og erfaringer om norsk oljevernberedskap i kaldt klima og is.

En kvantitativ metode for vurdering av oljevernberedskapens sesongmessige og geografiske anvendbarhet blir foreslått. Metodikken er basert på en analyse som kombinerer definerte begrensninger for oljevernberedskap med omfattende metocean data. Metodikken muliggjør beregning av relative, gjennomsnittlige effektiviteter for de mest aktuelle responstiltakene i Barentshavet i forhold til begrensende miljøparametere slik som vind, bølger, is, temperatur, sikt og mørke. Det er utført særskilte vurderinger knyttet til blokk 7435/9 hvor det kommer fram at fartøybasert dispergering forventes å ha den høyeste generelle anvendbarheten gjennom året, tett fulgt av mekanisk oppsamling. En vesentlig lavere anvendbarhet er forventet for in-situ brenning. Et beregningsverktøy (ORCA) er utviklet hvor også utslippsspesifikke og utstyrsspesifikke forutsetninger kan spesifiseres. Dette verktøyet har blitt benyttet i beredskapsanalysen til å beregne effektiviteten av ulike beredskapsløsninger ved isfylte farvann.

En generell barriere strategi for oljevern er skissert, herunder organisering av relevante elementer og funksjoner i havgående barrierer (1a og 1b). Seks tiltaksalternativer for bekjempelse av olje på sjøoverflaten er beskrevet. Tre av alternativene er implementert i eksisterende beredskap - mekanisk oppsamling, fartøysbasert dispergering og dispergering med fly. Tre fremtidige tiltaksalternativer er beskrevet basert på potensielle fordeler i kaldt klima, is eller relativt avsidesliggende områder; in-situ brenning i åpent vann, mekanisk oppsamling med aktive lensesystemer og et flerbruks fartøy for oljevern i is. Disse tiltaksalternativene er videre analysert i beredskapsanalysen. Undervannsdispergering (SSDI) er i tillegg vurdert.

Blokk 7435/9 ligger nært til den norsk russiske grensen noe som gir en høy sannsynlighet for grenseoverskridende forurensning i tilfelle en utblåsning. Norge og Russland samarbeider om beredskap mot akutt forurensning basert på en avtale fra 1994. Avtalen regulerer samarbeid, kommunikasjon og effektiv bruk av tilgjengelige ressurser, og er også grunnlaget for en felles norsk-russisk beredskapsplan som er etablert for Barentshavet. Ifølge beredskapsplanen har Russland relevante oljevernkapasiteter. Oljevernfartøy under oljevernaksjoner vil ikke kunne operere over grensen mindre dette er besluttet av de respektive nasjonale myndigheter. I henhold til gjeldende norske prosedyrer for vesentlige, grenseoverskridende utslipp er det sannsynlig at staten ved Kystverket i så fall vil overta ledelsen av oljevernaksjonen.

Hovedkonklusjonene fra beredskapsanalysen indikerer at aktive mekaniske lensesystemer i kombinasjon med dispergeringsmidlene er de mest effektive for de definerte scenarioene (utblåsning med Skrugard råolje). Passive mekaniske utvinning systemer og in-situ brenning (ISB) i åpent vann er de minst effektive. Mengden av behandlet olje er generelt høyere om sommeren enn om vinteren på grunn av sesongmessige variasjoner i værforhold. Oljevernberedskapen er også mer effektiv på overflateutslipp enn på sjøbunnsutslipp.

SINTEFs OSCAR-modell muliggjør ikke modellering av oljevern i is. ORCA verktøyet har blitt brukt for å vurdere effekten av et flerbruks fartøy i is. Dette tiltaksalternativet er spesifisert for å kunne gjennomføre oljeverntiltak i inntil 30 % iskonsentrasjon, og består av tilpassede enheter for mekanisk oppsamling, ISB og dispergering. Beregningene er basert på modellerte enkeltscenarier i OSCAR. Resultatene indikerer at tilpasset mekanisk oppsamling er det mest effektive tiltaksalternativet i is for disse scenariene, noe som skyldes at dispergering og ISB påvirkes negativt av det relativt høye vannopptak i Skrugard råolje. En kombinasjon med kjemisk dispergering og brenning kan potensielt utvide operasjonsvinduet hvis man opererer på ferskere olje i is - selv om dette er lite sannsynlig på den gitte lokasjonen.

En oversikt over eksisterende og tilgjengelige oljevernressurser er gjengitt, med fokus på de ressursene som er mest aktuelle for Barentshavet. Dette inkluderer ressurser fra depoter i Norge og internasjonalt, og fra offentlige og private ressurs eiere. Fokuset i kartleggingen er på hovedutstyr og systemer. NOFO (Norsk Oljevernforening For Operatørselskap) er den sentrale ressurseieren, men flere andre ressurser er tilgjengelige i Norge og internasjonalt basert på avtaler eller som kommersielle tjenester.

En viktig ressurs for oljevernberedskap er OR-fartøy (Oil Recovery-fartøy). Regelverket for fartøy som opererer i Barentshavet er beskrevet, inkludert krav til isklasse, Polarkode og vinterisering av skip. Det foreslås at fartøy som skal brukes året rundt i den nordlige delen av området inkludert i 23. runde bør tilfredstille krav til isklasse og vinterisering. Ytterligere anbefalinger er å etablere en vinterisering standard for oljevernutstyr, og driftsprosedyrer for dette i kaldt klima og is. En mal for reservedeler og utstyr for NOFO operasjoner i nordlige farvann bør også være forberedt, samt at det bør utvikles et treningsprogram for oljevernaksjoner i kaldt klima og is. Studien indikerer at aktive mekaniske opptaks-systemer for offshore forhold bør vurderes som et tillegg til eksisterende opptaks-systemer. Konseptet er godt utprøvd i kystnære farvann, og realistiske offshore tester har vist lovende resultater. Aktive lensesystemer kan gi høyere oppsamlingsrate enn passive lensesystemer, noe som er en suksessfaktor ved mekanisk bekjempelse. Andre fordeler er økt manøvrerbarhet og at systemet kan opereres med ett fartøy. Andre områder som bør følges opp er planlegging og testing av logistikk-kjeder i avsidesliggende områder.

DEFINITIONS AND ABBREVIATIONS

Biodegradation	The breaking down of substances by microorganisms, which use the substances for food and generally release harmless by-products such as carbon dioxide and water.
Boom	A temporary floating barrier used to contain an oil spill. Conventional/passive boom systems are usually towed in U- or J-formation by two vessels. Active boom systems can be towed at higher operational speeds by one vessel.
Chemical dispersion	Oil spill response strategy which involves the application of oil dispersants to help breaking oil into small droplets.
cP	Centipoise
Crude oil	Naturally occurring liquid mixture of hydrocarbons found in reservoirs in the bedrock and extracted as raw materials in the petroleum industry.
Dispersants	Chemicals that are used to break down spilled oil into small droplets.
Dispersion	A system in which particles are dispersed in a continuous phase of a different composition (or state).
Deployment	Strategic placement of equipment and personnel
DOR	Dispersant to oil ratio
Encounter rate	Rate at which a response system encounters an oil slick. It includes three components: sweep width, encounter speed, and oil film thickness.
Emulsion	A mixture of small droplets of oil and water.
Emulsification:	The formation of a mixture of two liquids, such as oil and water, in which one of the liquids is in the form of fine droplets and is dispersed in the other.
Evaporation	The physical change by which any substance is converted from a liquid to a vapour or gas.
Environmental risk	Refers to a product of the probability of an accident to occur and the environmental consequences expressed as restitution time
Environmental vulnerability	The capacity of an environmental resource to cope with different pressures
ERA	Environmental risk assessment
Fate	The outcome; the fate of an oil spill is what happens to the oil.
Influence area	Oil/chemical affected area (a number of grid cells) which the radius of

	the area is defined from the relevant product and mass category
Ice-concentration	Defined according to the WMO nomenclature; i.e. as the percentage of the sea surface covered by ice.
In-situ burning	In situ burning, or ISB, is a technique sometimes used by people responding to an oil spill. In situ burning involves the controlled burning of oil that has spilled from a vessel or a facility, at the location of the spill.
Key species	A species that is critical for maintaining the relationship of an ecosystem
Natural dispersion	Dispersion (see *dispersion*) of oil due to the effect of breaking waves.
Oil slick	A layer of oil floating on the surface of water.
Oil Spill Contingency plan	A document that describes a set of procedures and guidelines for containing and cleaning up oil spills.
Oil spill contingency system	System used in oil spill contingency operations- such as a system for application of chemical dispersants (usually one boat or aircraft) or a system for mechanical recovery (usually includes one OR-ship and a towing boat, including boom and skimmer equipment).
Oil spill response	Measure implemented in the acute phase of an oil spill with the aim of preventing the spreading of the oil.
OR vessel	Oil recovery ship. The main ship in a mechanical oil recovery system, containing storage tank and equipment such as skimmer and boom.
OSCA	Oil Spill Contingency Analysis
OSCAR	Oil Spill Contingency and Response model (SINTEF).
Pour point	The pour point of a liquid is the temperature at which it becomes semi solid and loses its flow characteristics.
Recovery system	A system for mechanical recovery of oil, which normally includes one OR-ship and a towing boat, including boom and skimmer equipment.
Response time	Time a response system needs until it is on scene and start the operation. This includes mobilization time, transit time, and deployment time of equipment.
System capacity	Anticipated recovery rate in m^3/d for a response system, including contact time, encounter rate etc.
Skimmer	Device used to remove oil from water surface.
Viscosity	Having a resistance to flow; substances that are extremely viscous do not flow easily.

Vulnerability	The ability of an environmental resource to deal with types of exposure
Vulnerability for oil	The ability of an environmental resource to deal with oil pollution
Vulnerability value	Relative ranking of resource vulnerability
Water column	An imaginary cylinder of water from the surface to the bottom of a water body; water conditions, temperature, and density vary throughout the water column.
Weathering	Action of the wind, waves, and water on a substance, such as oil, that leads to disintegration or deterioration of the substance.

1 INTRODUCTION

1.1 Background

This report has been prepared for the Barents Sea Exploration Collaboration (BaSEC). The BaSEC collaboration focus on solving operational tasks related to petroleum exploration in the Barents Sea.

This document has been prepared together with an Environmental Risk Analysis (ERA) (DNV GL, 2015a) and an Oil Spill Contingency Analysis (OSCA) (DNV GL, 2015b).

1.2 Scope of work

The status document summarizes key elements in oil spill response for cold climate and ice infested waters with emphasis on areas included in the 23. Licensing round in the Barents Sea. The scope of work is:

- To establish a structured and consensual approach to assumptions, basis for analysis, response/combat measures, and overall strategies for oil spill response in ice infested waters and cold climate.
- To collocate a description of relevant response measures, tactics and techniques, and identify existing response resources (main equipment, depots/stockpiles) – in Norway and internationally.
- Suggest seasonal capacity/efficiency numbers for applicable response measures.
- To address challenges for currently existing equipment, both technical, operational and HSE related challenges.
- Describe requirements for ships for ice infested waters, and make an assessment of applicability for relevant ships.
- Give a description of relevant system for detection and surveillance.
- Outline additional topics e.g. Russian cross border issues and logistics.
- The document will reflect the Arctic response technology JIP, and further focus on information relevant for the study area, e.g. experiences from NOFO exercises in Finnmark during winter 2015 and the NOFO test in the marginal ice-zone in April 2015.
- The document serves as input for the OSCA.
- The document aims to establish operational response concepts, e.g. solutions for practical implementation.

The scope covers multiple areas of expertise and science. A complete review of all relevant material exceeds the frames of the project. Several of the issues that are addressed in the status document are also relevant for other types of spills such as spills from ship incidents and also other areas with cold climate or ice, but this is generally not specified in the document.

The report reflects defined assumptions for location, oil type and discharge rates. The assessments in the report may vary if the selected conditions changes.

1.3 Study area

The context and focus for this study is potential oil spills from exploration drilling in the Barents Sea South-East. The defined scenario is an exploration drilling operation at block 7435/9 (see Figure 1-1), using a semi-submersible rig.

The well location is in a remote area, at a distance of approximately 440 km from mainland Norway; Nordkinnhalvøya in Finnmark. The island Hopen, in the south-eastern part of the Svalbard archipelago, is the closest land area, about 380 km to the northwest of the well location. The distance to Spitsbergen, the largest island at Svalbard, is longer with about 470 km. The distance to the coastal areas of Russia exceeds 500 km, and the distance to Novaya Zemlya is about 530 km. The water depth at the location is 228 meters MSL.

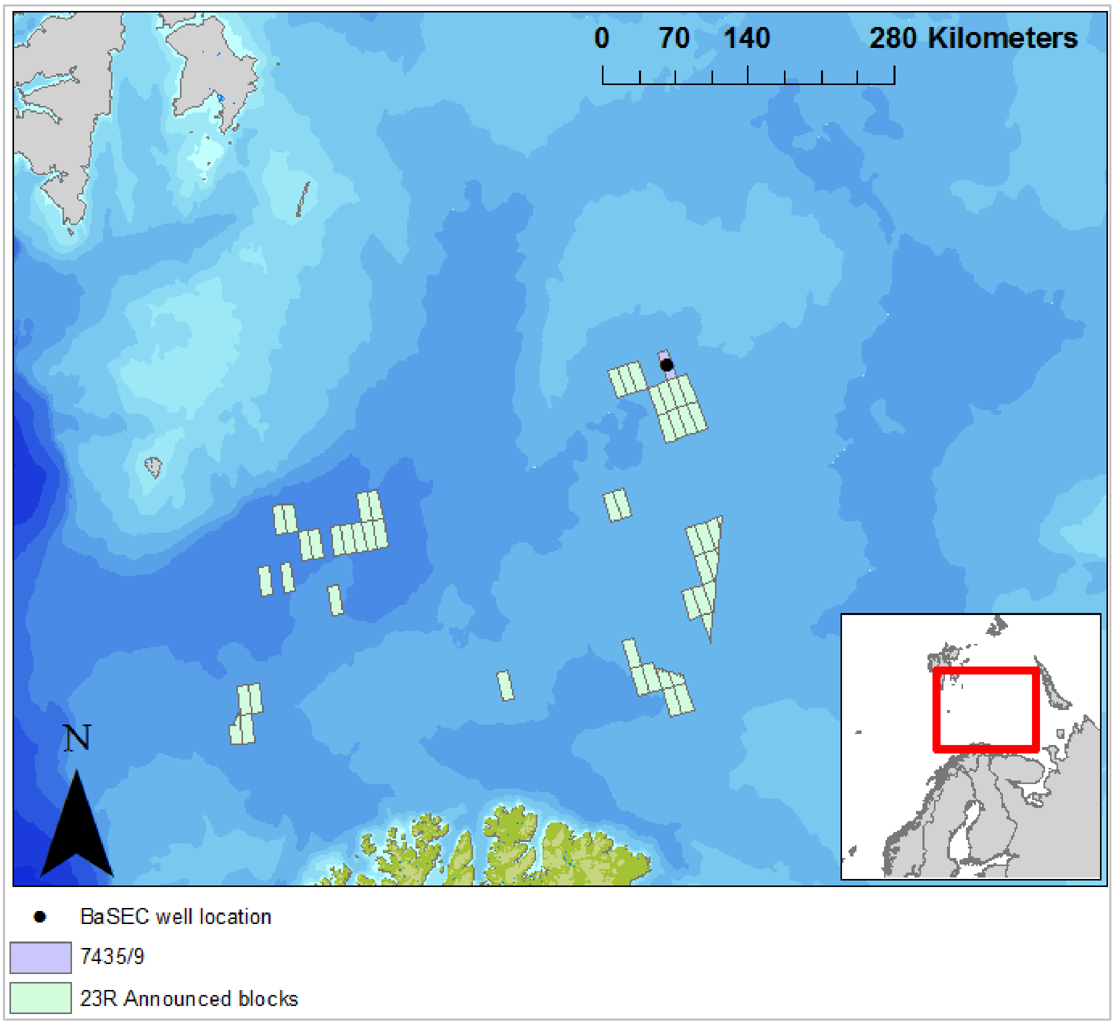


Figure 1-1 *Announced blocks in the 23rd licencing round. Well location and block 7435/9 are highlighted.*

The report focuses on oil spill in cold climate and ice, but it should be emphasized that the presence of high concentrations of sea ice is not common at the specific location. DNV GL has developed a tool (*Ice Mapper*) to map the occurrence of sea ice at different concentrations at different times of the year, based on statistical satellite data from the period 2003-2014 (University of Bremen). This tool is used in the evaluation of possible oil exposure in the marginal ice zone after a blowout from the well location.

According to the updated Management plan for the Barents Sea the *marginal ice zone* is defined as the area of ≥ 15 % ice concentration in more than 30 % of the time (Klima - og Miljødepartementet, 2015). The results are shown as frequency for ice concentrations > 15 % and > 50 % in each month from January-June in Figure 1-2 and Figure 1-3. Throughout the summer and autumn the ice is expected to retreat further north, before advancing once again with decreasing temperatures entering the winter season. The figures show that there is a 10-20 % probability for ice concentrations > 15 % within a 50-100 km range north of the well location in the period January to March. In April-June the probability is reduced to < 10 %. For the higher ice concentrations (> 50 %) the results are similar in the period January-March, while decreasing rapidly in April-May, to no probability within the area in June.

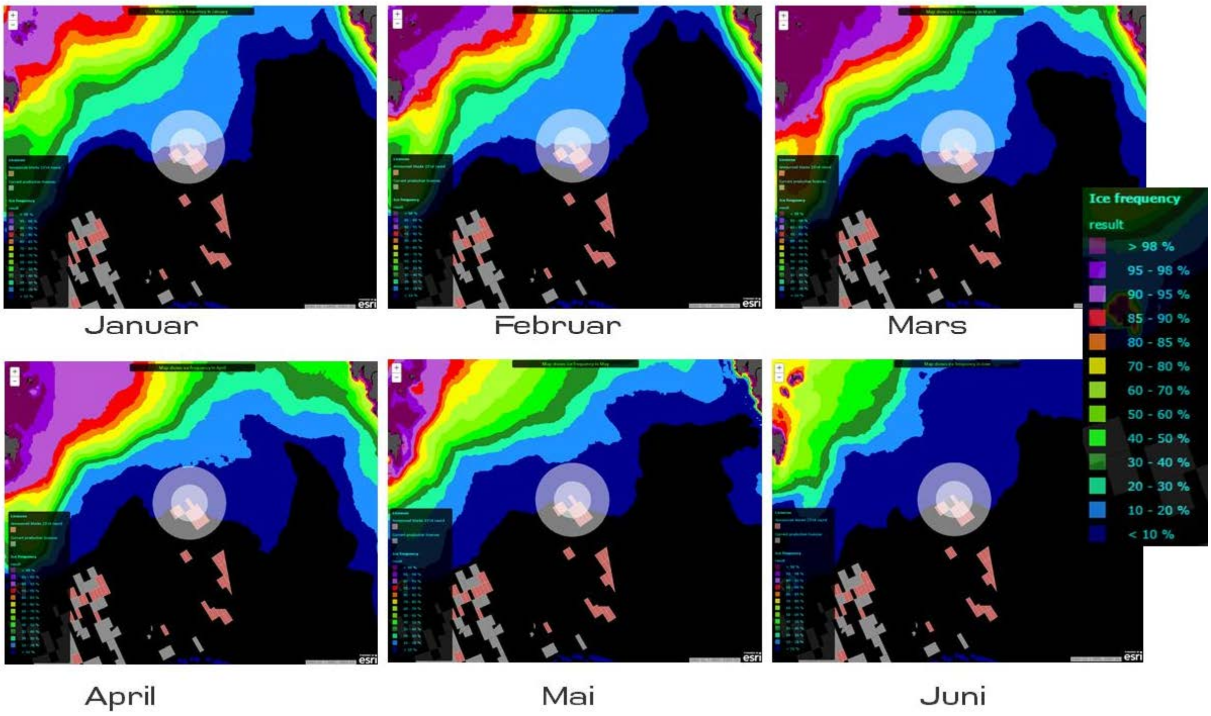


Figure 1-2 *Frequency for > 15 % ice concentration in each month from January to June, based satellite on data from 2003-2014 (University of Bremen). The well location is centred in the light circles, with a 50 km and 100 km buffer zone surrounding it.*

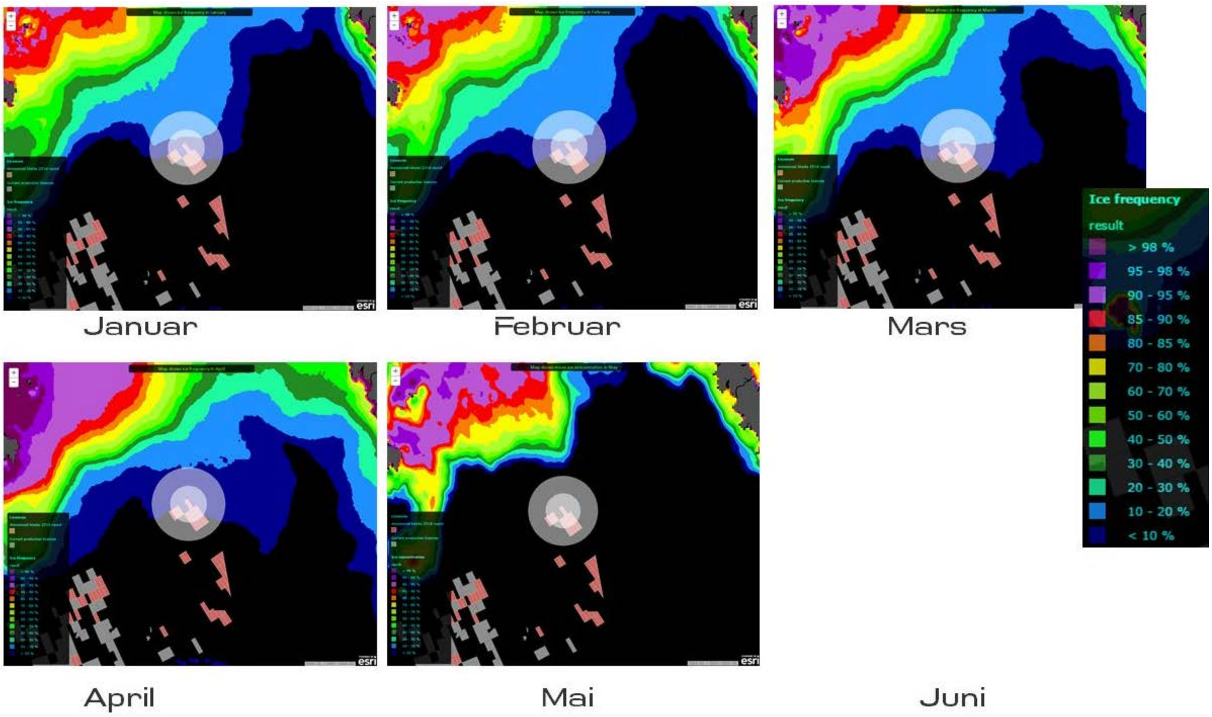


Figure 1-3 *Frequency for > 50 % ice concentration in each month from January to June, based on satellite data from 2003-2014 (University of Bremen). The BaSEC well location is centred in the light circles, with a 50 km and 100 km buffer zone surrounding it.*

1.4 Work process and deliverables

The project started out with a kick-off workshop outlining the key elements of study. SINTEF participated with their competence and experience. Later the response measures for the OSCA were proposed and discussed with NOFO and BaSEC.

The status document and the OSCA are linked. The status document serves as basis for the OSCA e.g. by identifying which systems to include in the analysis, and the system specifications. The results from the OSCA are included in the status document as a basis for evaluation of the current situations and suggested actions.

2 NATIONAL FRAMEWORK FOR OIL SPILL RESPONSE

2.1 Legal framework

The legal basis for emergency preparedness acute pollution or risk of acute pollution in Norway is:

- The Pollution Act and regulations (including HSE regulations for petroleum operations) and individual administrative decisions (including contingency requirements)
- The Harbour Act
- The Svalbard Environmental Protection Act

2.2 Acute pollution from petroleum activities on the Norwegian Continental Shelf

Any party engaged in activities which may lead acute pollution, should ensure a necessary preparedness to prevent, detect, stop, remove or limit the impact of pollution (Pollution Act § 40). Operating companies on the Norwegian Continental Shelf (NCS) have responsibility for acute pollution caused by their own activity. The preparedness against acute pollution shall be based on environmental risk.

If an acute pollution occurs the responsible operator will notify Petroleum Safety Authority (PSA) and the Norwegian Coastal Administration (NCA), and contact between relevant parties will be established. The operator establishes an Incident Action Plan for prevention or mitigation of potential environmental consequences. The operator mobilizes Norwegian Clean Seas Association for Operating Companies (NOFO) who carries out the response on behalf of the operator based on the Incident Action Plan. NCA have a supervisory role during a response, and see to that relevant and adequate measures are initiated by the operator including monitoring and surveillance. NCA will also be able to provide assistance to operator through the agreements concluded between NCA and NOFO.

2.3 Norwegian international cooperation

The Barents Sea South-East is legislatively affected by the Norwegian/Russian boarder. As documented in the ERA report a dimensioning spill from Block 7435/9 would likely reach the Norwegian/Russian maritime boarder, making cross border issues for oil spill response relevant. Norway and Russia have signed agreements on, among other issues, mutual notification, drills and combating acute oil spills in the Barents Sea which establishes a framework for this scenario (Governments of Norway & Russia, 1994). This framework is further discussed in chapter 5.4.

It should also me mentioned that Norway participates in other international forums and agreements such as with the Arctic Council, the International Maritime Organization (IMO), European Maritime Safety Agency (EMSA), the Bonn agreement, Norbrit agreement and Copenhagen agreement. Description of these agreements can be found at www.kystverket.no.

3 RESPONSE TACTICS IN COLD CLIMATE AND ICE

This chapter provides general descriptions of oil behaviour and oil spill response in cold climate and in ice infested waters.

3.1 Behaviour of oil in water and ice

When oil is spilled at sea, a number of natural processes produce changes in the physical and chemical properties of the oil and in the oil's behaviour at sea. These natural processes are spreading, drifting, evaporation, dissolution, photolysis, biodegradation and formation of oil-in-water and water-in-oil (w/o) emulsions. A common term for all of these natural processes is weathering. The relative contribution of each process varies during the duration of a spill, and large variations in oil properties cause them to behave differently when spilled at sea. The behaviour of spilled crude oils and petroleum products depends on:

- The oils physical and chemical properties
- The release conditions (the rate and amount of spilled oil, surface release or underwater release, presence of gas etc.)
- The environmental conditions (e.g. temperature, waves, wind, currents)

In principle, if the oil is well characterized and the environmental conditions of wind speed, sea-state, currents, salinity and temperature are known, it is possible to predict the rates of many of the weathering processes and thus establish how the properties of the oil changes with time. This can be important information for oil spill response planning.

A main challenge for oil spill response operations is the spreading of the oil on the sea surface. The spreading can be very fast and is frequently the dominant process in the initial stages of a spill, although its importance decreases with time. High density and viscosity of the oil will decrease the spreading. The oceanographic conditions (current, waves and wind and ice if present) are the dominating effect on the spreading of oil. This can lead to thin layers of oil films covering large areas, which has to be allocated and encountered in order to get a sufficient oil thickness to be able to perform e.g. mechanical recovery or in-situ burning.

3.1.1 Behaviour of oil in cold climate and ice

Oil weathering processes affected by cold and sea ice are presented in Figure 3-1 and Table 3-1. Low temperatures and ice will influence an oil spill differently compared to temperate regions. Especially low temperatures and dampening of waves due to ice lead to reduced oil spreading, evaporation, emulsification and dispersion (Brandvik et al., 2010).

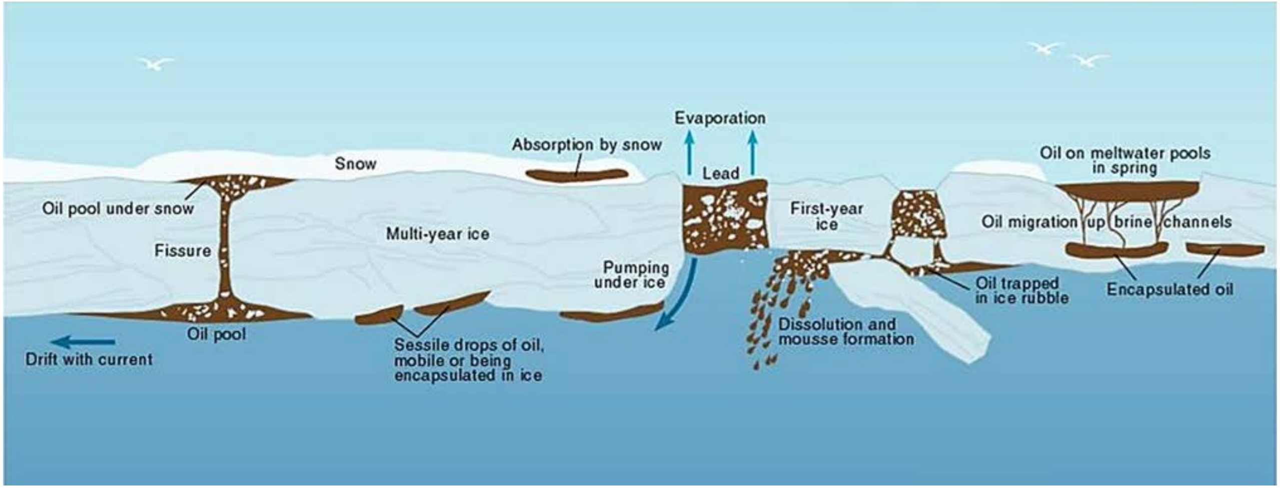


Figure 3-1 *Weathering processes of oil spilled in ice infested environments (Wilson et al., 1998).*

During freezing, ice grows downwards and may encapsulate oil lying beneath it. Once the oil becomes fixed within the ice, it moves only as the ice moves. Oil entrapped in ice may therefore be very difficult to track, especially during the winter darkness. This can results in a secondary discharge situation on new and unexpected locations during the spring season.

Table 3-1 *Oil Weathering Processes Affected by Cold and Sea Ice (NUKA 2010).*

Process	Open Water	Extreme Cold or Ice
Spreading and Dispersion	A thick layer of oil grows thinner and covers a larger area of water (depending on the oil)	Ice acts as a physical barrier (broken Ice) or retardant (grease ice); oil does not spread or disperse as far and ends up in a new thicker layer
Drift	Oil moves with wind/current	Oil will drift separately from ice at less than 30 % ice coverage. With ice concentrations at 60 to 70 % (or greater) the drift of oil will follow the ice drift.
Evaporation	Relatively fast (thin oil films)	Slower where oil spills are thickened.
Emulsification	Higher in areas with breaking waves. Rate of emulsification, total water uptake, and stability of emulsion depending on oil type.	Total water uptake and rate of uptake may be lower as a result of reduced wave activity because of the presence of ice.

3.2 Response measures

There are several possible ways to respond to an oil spill in an arctic marine environment. This section describes the main response tactics, with emphasis on internationally established and proven solutions. Operational challenges in cold climate and ice is elaborated for each tactic in Appendix D. The system specifications applied in this study for the OSCA is described in chapter 5.2.

The main response options are (Figure 3-2):

- Remote sensing
- Mechanical recovery
- Dispersant application
- In-situ burning

Within these categories there exists a variety of technical platforms, components and units with different applicability in various settings and conditions. Here; emphasis is given on offshore conditions that are relevant for the BaSEC study area.

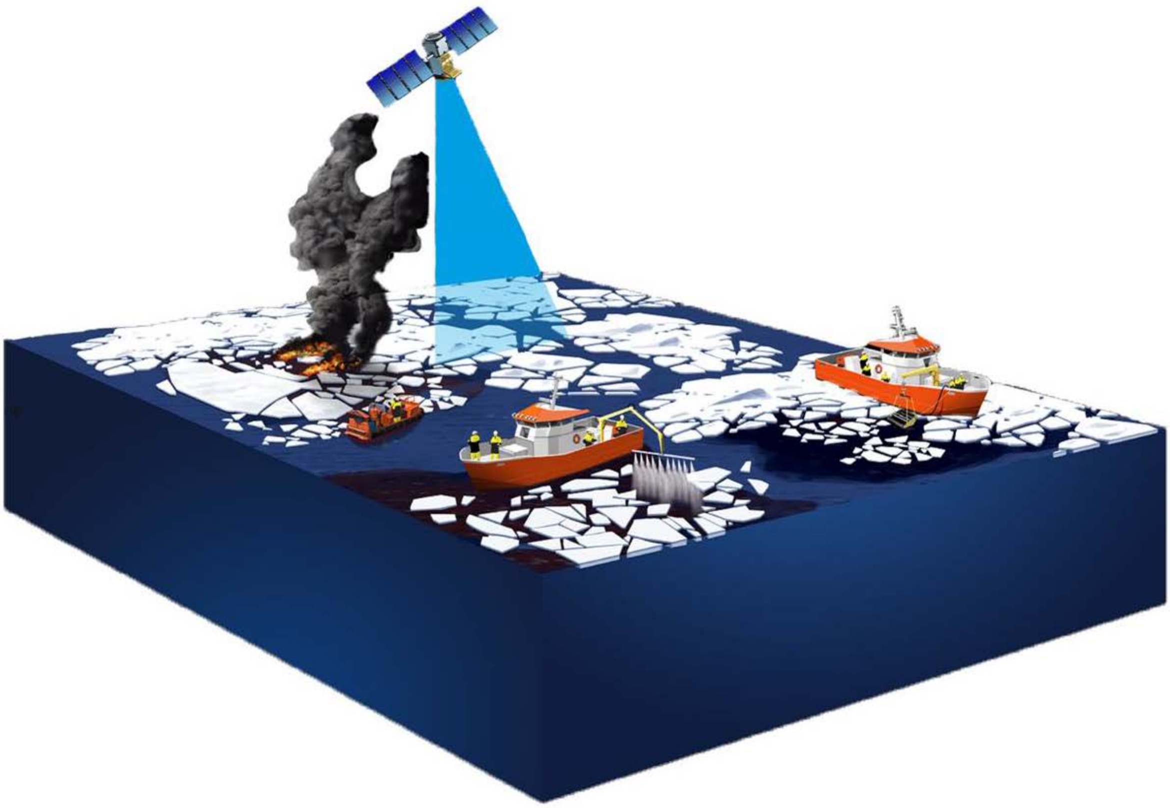


Figure 3-2 *The main response techniques for arctic conditions (source: Arctic Response Technology JIP).*

3.2.1 Mechanical recovery

The term mechanical containment and recovery refers to a number of response techniques that aims to physically collect and remove the spilled oil from the environment. This principle can be applied on land, on water and in snow and ice. The term “containment and recovery” may also be used, especially for marine operations, as it indicates the two main processes involved. Before the oil can be effectively removed from the water surface, normally with a skimming device, it must first be encountered, collected and concentrated. In open water this is usually done by use of containment booms. For the purpose of this study it is deviated between “active” and “passive” containment systems. The active systems enable effective containment at towing speeds up to 3 – 5 knots depending on conditions, while the passive systems only will work effectively up to ca. 1 knot. This gives active systems a potentially higher encounter rate than passive systems – especially if the oil is scattered. The recovered oil must then be stored in a tank, barge or bladder and transported out of the area for appropriate waste management.

In operative mode, mechanical recovery comprises multiple pieces of equipment, vessels and operators, configured as a containment and recovery system. A traditional system configuration consists of 1–3 boats/vessels, a containment boom, an oil skimmer with a pump, and a storage tank or device (Figure 3-3). Normally the containment and recovery system will also highly benefit from information from surveillance and remote sensing in order to be able to locate the oil and its optimal position for recovery.

In an environmental protection perspective, mechanical recovery is usually considered as the most favorable response option as it can remove spilled oil from the environment (Potter et al., 2012).

Figure 3-3 *Open-ocean mechanical recovery systems (Source: NOFO).*

3.2.2 Dispersants

The use of chemical dispersants is a response technique which does not physically remove the oil from the water, but enhance the natural dispersion of oil by creating a higher number of oil droplets that are small enough to be permanently captured in the water column and resist resurfacing. Due to that a higher fraction of the oil slick will be dispersed from the sea surface into the water column.

Dispersants are usually sprayed or applied onto oil slicks by vessels or aircrafts (Figure 3-4). They are applied using spray nozzles, pumps and hoses. Dispersants operations are usually monitored from aircraft to make sure that the application is on target. The *time-window-of-opportunity* is usually relatively limited as the effect from dispersants normally decreases with oil weathering. The effectiveness of dispersants will vary and depends on the type and properties of the spilled oil.

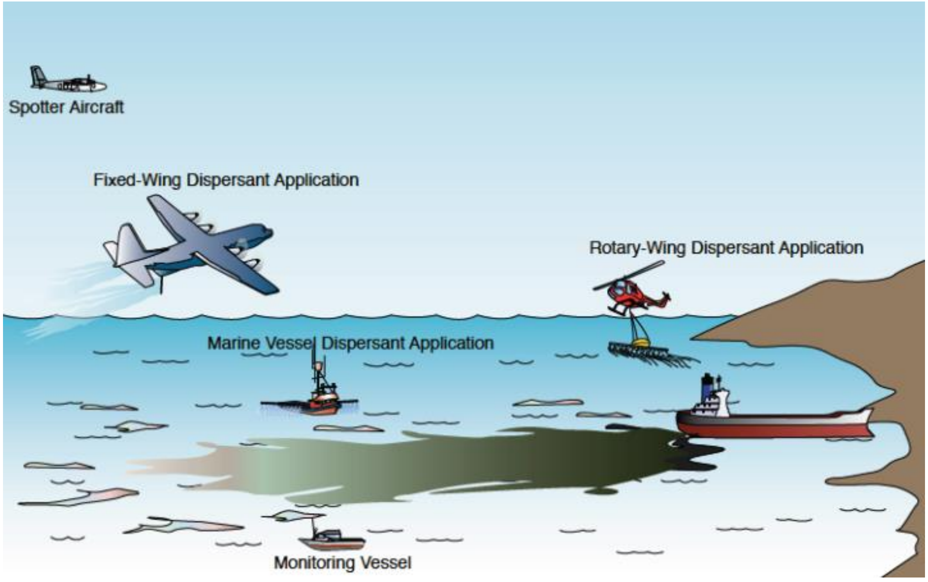


Figure 3-4 *Dispersant application and monitoring operations (Source: NUKA 2010)*

3.2.2.1 Subsea dispersant injection (SSDI)

Subsea dispersant injection (SSDI) is a response technique to a subsea release by injecting chemical dispersants into the subsea plume. The Deepwater Horizon accident off the Gulf of Mexico in 2010 has shown that SSDI can be an effective response technique for subsea oil and gas blowouts.

SSDI can have many advantages over the strategy of responding to the released oil only when it reaches the sea surface (IPIECA-IOGP, 2015). For example, SSDI:

- treats oil released at the point of release
- requires less dispersant compared to surface oil treatment
- Reduces the exposure of responders to the health and safety hazards of VOCs and oil
- Can be conducted continuously, day and night and in practically any weather conditions, unlike response techniques on the sea surface.

On the other hand, the potential risk of SSDI is the increased exposure of marine organisms in the deep sea water column as smaller oil droplets will be produced within the water column. Furthermore, SSDI is most feasible at great water depth. During a subsea blowout, a plume of small oil droplets, gas bubbles and entrained water will initially rise rapidly in the form of a buoyant plume, with the gas providing the dominant source of lift and buoyancy. Studies showed that at oil and gas releases from subsea blowouts in water less than 500 meters depth, the gas is not likely to totally dissolve in the water and the buoyant plume of gas and oil is likely to rapidly arrive at the sea surface. A relatively short distance between seabed and water surface thus limits the contact period between oil and dispersion particles which ultimately will affect the effectiveness of SSDI as a response strategy (IPIECA-IOGP, 2015).

The logistics of conducting SSDI require considerable specialist equipment, trained personnel and support. Multiple ROVs will be required with dedicated offshore supply vessels and a logistical supply chain for dispersant stocks. Subsea dispersant use requires subsea monitoring to assess whether it is being effective and where the subsea plumes of oil would be transported by the prevailing deep water currents.

3.2.3 In-situ burning

In-situ burning (ISB) is the term used for controlled burning of oil "in the original place" and refers to that spilled oil is ignited and burned directly on the water surface or in broken ice. In order to burn oil spilled on water, three elements must be present: fuel, oxygen and a source of ignition. The oil must be heated to a temperature at which sufficient hydrocarbons are vaporized to support combustion in the air above the slick.

ISB is generally a response technique that is considered to have a high potential for the removal of oil spills in arctic conditions, especially for fresh oil in in snow and ice. ISB is well proven and established as part of the oil spill contingency in many arctic areas. The effectiveness of ISB is verified by previous field experiments performed in the US, Canada and Norway, showing removal efficiencies over 90 % (Sørstrøm et al., 2010). The suitability of ISB depends on the initial oil characteristics (oil type, film thickness) and the weathering state of the oil. The rule of thumb for minimum ignitable thickness for relative calm conditions is at least 1 mm for fresh, crude oil; 3-5 mm for diesel fuels and unemulsified crude; 10 mm for residual fuel oil (Buist et al., 1999).

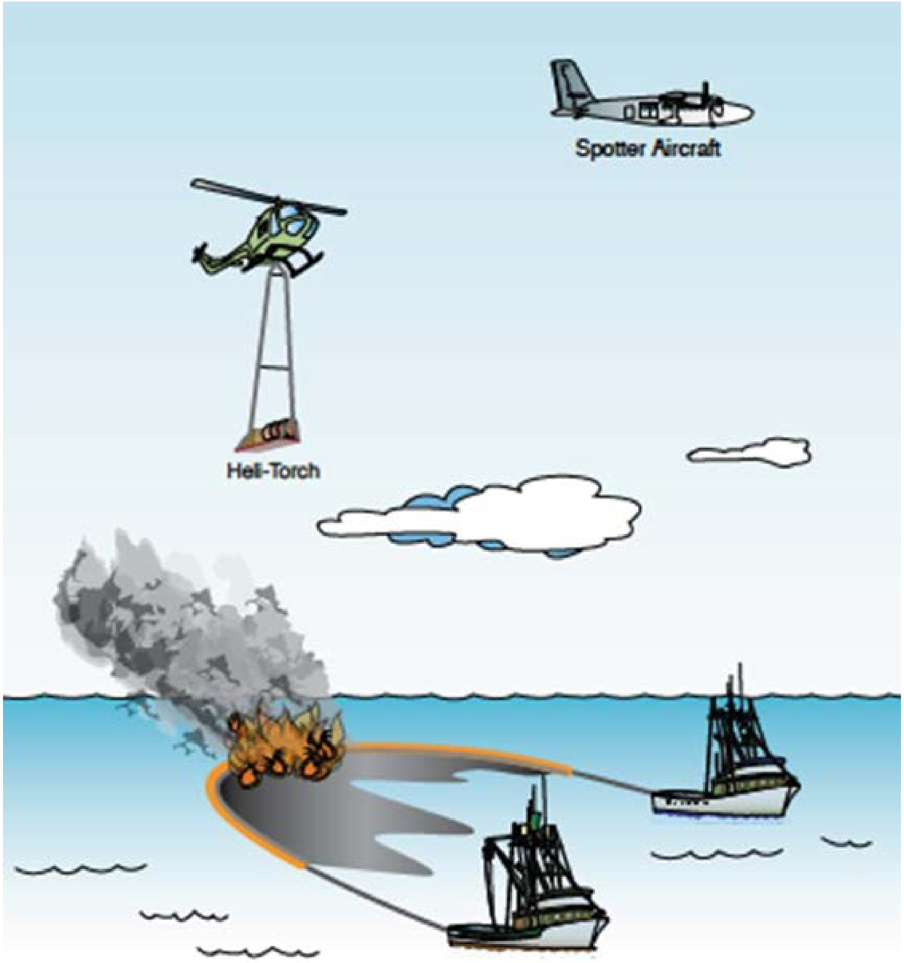


Figure 3-5 *Typical offshore in-situ burning operations (Source: NUKA 2010).*

ISB is usually performed by the use of fireproof booms to capture, thicken, and isolate a portion of the spilled oil followed by ignition by releasing a burning, gelled fuel from a helicopter or from a vessel (Figure 3-5). The oil might also be encircled by a stationary fire boom or within ice edges. Once the oil is ignited, most oil will burn off the surface of the water or ice, but some nonvolatile compounds will remain. These residues may float or sink, depending on the oil type and burn conditions (Arctic Response Technology JIP, 2013). However in comparison with mechanical recovery, operational aspects like transfer, storage, treatment and disposal of recovered oil are not given or are present at a minor extent.

Figure 3-6 *In-situ burning test conducted within the JIP Oil in Ice (Copyright: SINTEF).*

3.2.3.1 Field research using herders to advance in situ burning

Herders use surface active agents to thicken slicks without the need to collect the oil in a physical boom. They are effective in the open sea, with or without the presence of ice, up until there are breaking waves present. An ongoing multi-year research project initiated in 2004, is studying oil-herding surfactants as an alternative to booms for thickening slicks in light ice conditions for in situ burning (ISB) burning (S.L. Ross, 2015), including field testing as a part of The Arctic Response Technology JIP. An objective of the field releases is to validate the use of herders in combination with in-situ burning (ISB), when both are applied by helicopter. The aim is to develop a rapid response aerial system that enhances responders' ability to use offshore ISB in drift ice conditions ranging from limited ice cover (1 to 3/10) to ice-free waters.

A significant potential advantage of using herders in drift ice conditions is the possibility that the entire operation could be carried out using helicopters, or possibly even an unmanned aircraft, to spray herders on the water around slicks and then ignite the thickened oil with aerially-deployed igniters. With aerial application of both the herding agent and ignition source (igniter), the herder/burn combination becomes an extremely rapid and effective new response tool, lessening the need for vessel support. This combined aerial response maximizes the use of resources and minimizes the number of personnel required to remove a surface slick from the marine environment where it can do the most harm. In addition, the entire response operation becomes safer by reducing the exposure of response personnel to marine operations such as boom deployment and recovery under challenging conditions. The slower weathering of oil slicks in ice and cold water can also extend the window of opportunity for such a tool. The ongoing research is promising, but more work needs to be done in order to operationalize the concept. In the following, concept is thus not evaluated closer.

3.2.4 Remote sensing

Remote sensing plays a major part in oil spill recovery as it gives crucial information about the location and spreading of the oil. It will normally act as an information source in order to support effective combat of oil, and not a sole response measures in itself. This chapter summarizes the main challenges and solutions for remote sensing of oil spills in arctic waters and in ice conditions. Developing technologies are mentioned, and a recent summary of state-of-the-art technologies and solutions is rendered.

3.2.4.1 General description

Remote sensing of oil spills includes detection, monitoring and tracking of oil. By the use of sensors, oil can to various degrees be detected on the water surface, under the ice, within the ice sheet, or on top of the ice. The sensors can be mounted on a variety of platforms such as satellites, aircraft, helicopters, autonomous underwater vehicles, etc.

Remote sensing is generally required for an effective oil spill response. Information about the oils location and spreading provides key input for choosing appropriate response tactics, both for combatting and protective measures. The ability to forecast oil movement is equally important, as it makes it possible for the responder to plan ahead and adapt the response objectives and tactics to the expected conditions ahead in time.

3.2.4.2 Challenges in cold climate and ice

In remote areas the capability to perform remote sensing becomes increasingly important due to limited direct access and also restricted visibility due to fog, precipitation, snow drift and seasonal lack of daylight. The presence of ice also inflicts on remote sensing, and may both facilitate and complicate the tasks of monitoring, detecting, and tracking oil. Practical experience from remote sensing in ice is limited, but in general broken ice slows down the spreading of oil on the sea surface, which makes the location and movements of the oil more predictable compared to open water. This may reduce the need for e.g. frequent observations. If oil is located under ice or snow, it will generally be more challenging for remote sensing.

3.2.4.3 Current Technologies

Through the Arctic Oil Spill Response Technology Joint Industry Program (JIP) a qualitative evaluation of state-of-the-art of surface remote sensing technologies has recently been published through this program (Puestow et al., 2013) as well as a report on the detection of oil spills under sea ice from underwater vehicles (Wilkinson et al., 2013). The main types of remote sensing platforms are:

- Satellite platforms
- Airborne platforms
- Surface platforms and
- Subsea platforms.

Figure 3-7 The Norwegian surveillance aircraft LN-KYV (picture: Håkon Jacobsen).

Satellite Platforms

Satellites are widely used for general remote sensing, and are also applicable to oil spill purposes. Sensors may include high-resolution optical imagers and synthetic aperture radar. The advantages for using satellites include wide area coverage, and when combined with radar imagery, it is also independent from cloud cover, fog or darkness. Satellite technology is considered most efficient in lower ice concentrations.

Airborne Platforms

Several arctic nations such as Norway have sophisticated pollution surveillance aircrafts to search for oil spills (Figure 3-7). These aircrafts normally have very large operational range and carry a suite of sensors that complement one another to differentiate thin from thick slicks, identify oil type and operate in conditions of low visibility.

Surface Platforms

Surface systems refers to systems that may be deployed either from the surface of the water, by vessel, or from the surface of the ice. Sensors may differ from Low-cost, non-cooled, hand-held IR systems, to Ground Penetrating Radar (GPR). GPR have also been tested successfully from aircraft platforms. Trained dogs have also been successfully tested by SINTEF, confirming that dogs can be used to detect oil spills covered with snow and/or ice (Brandvik and Buvik, 2009).

Subsea Platforms

The technology for unmanned underwater vehicles (AUVs) is rapidly developing, representing a potential platform for sensors that can overcome the specific limitations associated with many of the other systems, especially when it comes to penetrating sea ice.

Related technologies; integrated systems, modeling and forecasting

Tracking and forecasting the position of spilled oil, based on integrating remote sensing information, environmental data, and numerical modeling will provide important information in planning and execution of the response. Several technologies aim to provide combinations of information of multiple sensors combined with advanced navigation and plotting technologies. These systems may also provide valuable tools for other applications such as marine search and rescue as well as for oil spill detection (Potter et al., 2012, Aptomar, 2013).

3.2.5 Evaluation of remote sensing technologies

Table 3-2 summarizes the strengths and weaknesses of different technologies evaluated in relation to the changing operating environments, scenarios and potential challenges for remote sensing of oil spills in the Arctic (Puestow et al., 2013).

It should be emphasized that for the geographical focus area in this study, open water will be the dominating condition. In table 3-2, *open water conditions* falls within the category of ice concentration < 30 %.

Table 3-2 *Remote sensing technology evaluation (source: Puestow et al. (2013)).*

	Expected Detection Performance							
Technology	Open Water and Among Pack Ice			On ice	Under Ice/Snow or encapsu-lated	Low visibility		
	Ice concentration							
	< 30%*	30-60%	>60 %			Blowing snow	Darkness	Rain or fog
Optical sensors (Cameras, multi/hyperspectral sensors, UV sensors)							Active Systems	
Thermal and infrared sensors								
Microwave radiometers								
Radar sensors (SLAR/SAR systems, marine radar)								
Ground-penetrating radar								
Fluorosensors								
Tunable Diode Laser Systems								
Laser-ultrasonic system								
LIDAR								
Acoustic sensors								
Dogs								

**Open water and pack ice < 30 %*

Color coding

The light green color indicates that the technology is proven and fully validated, and that its performance and limitations are well understood.

The dark blue color indicates that the technology is potentially applicable and that partial validation may have taken place, but the technology has not been comprehensively validated for performance under the given scenario.

The white color indicates that the likely performance of the technology is unknown, as it has never been tested under the given scenario.

The light red color indicates that the technology is not applicable to the given scenario.

As the evaluation reveals, the changing nature of the operational conditions for remote sensing in the arctic confirms that no single sensor system yet meets all needs for oil detection, tracking, and monitoring in ice environments.

A robust and flexible response strategy for arctic conditions should therefore require a combination of airborne, satellite-based, and surface-based technologies, with multiple sensor capacities.

The main challenge still to be technically overcome is related to oil that is encapsulated or located under ice/snow. Recent evaluations describe promising future potential for combinations of sensor technology and Autonomous Underwater Vehicles (AUVs) that may narrow this gap (Wilkinson et al., 2013). For logistical considerations, flexibility of deployment and range, AUVs are likely the most promising underwater platform for oil spill detection. The absence of a tether makes them easier to deploy and recover than a Remotely Operated Vehicles (ROV), and importantly extends the range of the vehicle. However, the autonomy of the AUVs introduces a range of technical issues that must be considered, including real-time data analysis, accurate navigation in complex, drifting ice conditions, and the possible need for collision avoidance techniques if operating close to the ice underside or in shallow water. As technology develops, hybrid systems, with an autonomous vehicle connected to the surface by a very long fiber-optic tether, may be an appropriate approach to allow more control of the vehicle and improved data telemetry, while at the same time permitting relatively long-range missions.

3.2.6 Summary of environmental conditions and potential impact on oil spill response options

A summary of potential impacts on oil spill response due to environmental conditions in cold climate is presented in table Table 3-3. A specific description for each of the response measures (mechanical, dispersants and ISB) in included in Appendix A.

The operational limitations applied in the quantitative assessment/response gap analysis (see chapter 4.2) are included in Appendix B.

Table 3-3 *Environmental Conditions and potential impact on oil spill response options (adapted from NUKA (2010)).*

	POTENTIAL IMPACTS TO SPILL RESPONSE				
ENVIONMENTAL CONDITION	**All response options**	**Mechanical recovery**	**Dispersants**	**In-situ burning**	**Remote Sensing**
Sea ice	**Challenges:** Difficult for vessel to access spill site. Difficult to sense or track movement of oil in, on or under ice. Ice-class vessels required in higher ice concentrations. Experienced vessel operators must be familiar with ice. Ice conditions may change suddenly and create dangerous conditions. **Benefits:** Oil may weather and spread more slowly.	**Challenges:** Ice may tear, lift or move containment boom. Reduced encounter rates for skimmers. Ice may clog pumps or cause them to fail. Limited manoeuvrability may prevent or delay skimmer and boom deployment. Ice must be separated from recovered oil. **Benefits:** Ice may contain oil in pools for small-batch recovery.	**Challenges:** Cannot access oil under ice. Ice reduces mixing energy. Dispersants generally less effective in lower salinities.	**Challenges:** Certain ice conditions may reduce burn effectiveness or impede ignition. Difficult to deploy fire boom. Difficult to track and recover residue. **Benefits:** Ice may provide containment for burning.	**Challenges:** Can make remote sensing generally difficult, difficult to locate and track ice, depending on ice development, ice coverage, or ice drift.
Cold temperature	**Challenges:** Potential for hypothermia among responders. Unsafe to work at extreme low temperatures. Cold may cause brittle failure in metals. Cold air may freeze sea spray, creating ice surfaces- Icing conditions make vessels unstable. Natural bio-degradation of oil slowed. **Benefits:** Oil may weather more slowly, increasing window of opportunity for response	**Challenges:** Skimmers freeze up. Sea spray may freeze on boom, causing it to fail. Pumps may freeze up. Increased oil viscosity makes soil difficult to recover and pump.	**Challenges:** Increased oil viscosity may reduce dispersant effectiveness.	**Challenges:** Ignition more difficult. Oil may burn more slowly or less completely.	**Challenges:** Low temperatures/high wind chill factor can be a challenge for surface systems.
High winds	**Challenges:** Unsafe to operate vessels and deploy equipment during high winds. Aircrafts cannot fly above	**Challenges:** High winds can move boom or tear it from anchor. Difficult to keep vessels and equipment on station.	**Challenges:** Difficult to accurately spray dispersants Aerial spraying not safe during high winds	**Challenges:** Difficult to ignite oil in high winds. Aircraft cannot deploy heli-torches in high winds.	**Challenges:** Causes snow drift on snow covered sea ice. generally a challenge for surface systems

	POTENTIAL IMPACTS TO SPILL RESPONSE				
ENVIONMENTAL CONDITION	**All response options**	**Mechanical recovery**	**Dispersants**	**In-situ burning**	**Remote Sensing**
	certain wind thresholds. High winds drive sea state, may enhance wave height or create choppy seas. High winds may combine with low temperatures to create wind chill. **Benefits:** Strong directional wind may drive wind away from sensitive areas.	Crew unable to work on deck, equipment deploy-ment and retrieval impeded	Cannot conduct application monitoring form aircraft **Benefits:** Wind-driven sea states will provide mixing energy for dispersants and oil	High winds may drive plume. ISB is generally not safe or feasible in high winds	
Sea state (high waves, strong winds)	**Challenges:** High waves limit small boat operations. Strong currents challenge vessel operations. **Benefits:** High sea states can increase natural dispersion.	**Challenges:** Booms and skimmers do not function well at high sea states. Short, choppy waves can be more limiting than longer wave periods. Moderate to high currents cause boom to fail.	**Challenges:** Vessel-based application limited by sea state based on vessel size **Benefits:** Sea state should not inhibit aerial application (assuming no high winds) High sea state typically enhance the effectiveness of chemical dispersants	**Challenges:** High sea states make containment and ignition difficult and unsafe.	**Challenges:** Severe sea states can be a challenge for surface systems. Can also cause submersion of oil from sea surface. **Benefits:** Several sensors register the oil damping effect on waves, making the presence of waves necessary for remote sensing
Limited visibility (including darkness)	**Challenges:** Limit or precluded safe vessel operations. Aerial operations typically not conducted during darkness, heavy fog or low ceiling. Difficult to see, track or locate oil spill.	**Challenges:** Cannot conduct mechanical recovery in darkness or low visibility unless work lights can be used.	**Challenges:** Darkness or low visibility Limits aerial application and observation Vessel application requires visual confirmation of slick location.	**Challenges:** Cannot conduct in-situ burning during darkness Aerial operations (heli-torch, herders) may be limited	**Challenges:** Low visibility caused by darkness, fog, precipitation, snow drift or low clouds is a challenge for passive optical sensors.

3.3 Additional Considerations

3.3.1 Health, Safety and Environment (HSE)

An obvious challenge for the working environment in the arctic is related to low temperatures, as these have a significant influence on working conditions. Cold air temperature in combination with wind leads to a perceived decrease in air temperature felt by the human body on exposed skin. The wind chill effect at low ambient temperatures will reduce the working periods outside the accommodation (Table 3-4). Accidental immersion in the cold water involves a serious risk of drowning and/or hypothermia.

Through winterization of vessels more of the manual work can be done indoors. Outdoors activities require high quality work clothing. Clothing may reduce dexterity which could lead to longer time needed to perform certain work tasks and thus may need a larger work force due to limited work periods caused by wind chill effects.

Table 3-4 *Impact of wind chill and wind chill factor (adapted after (CAPGO, 2013)).*

Wind Chill	Wind Chill Factor (w / m^2)	Impact on Human Comfort
above -13 °C	<700	None
below -13 °C, above -24 °C	700 to 1200	Unpleasant
below -24 °C, above -33 °C	1200 to 1600	possible frost nip
below -33 °C, above -50 °C	1600 to 2700	frostbite likely
below -50 °C	>2700	exposed skin will freeze in 30 seconds

3.3.2 Logistics and Infrastructure

In an oil spill response operation of a certain proportion, logistics will be a major issue. This reflects the fact that a response normally involves rapid mobilization of multiple types and quantities of resources like e.g. ships, aircrafts, oil spill equipment and personnel to the spill site and surrounding areas. As the response passes the initial phase, the need for support, resupplying or detachment will occur at some point. In total this calls for a wide range of assets and services, such as:

- **Supply** - Receive, store, issue, and resupply materiel for conducting operations.
- **Maintenance** - Actions necessary to preserve, repair, and ensure continued operation and effectiveness of recovery systems, components and task forces.
- **Transportation** - The movement of units, personnel, equipment, and supplies from the point of origin to the final destination.
- **Engineering** - Provide damage repair and maintenance of facilities.
- **HSE Services** - Support the health and well-being of personnel.
- **Other Services** - Provide administrative and personnel support to keep response organization fully operational. Includes internal and external communication systems.

The geographical focus area for this study is illustrated in Figure 3-8. To keep an oil spill response operation going for some time at such a location without unnecessary hesitations, delays or malfunctions will requires a highly skilled response organization as well as appropriate preparations and plans.

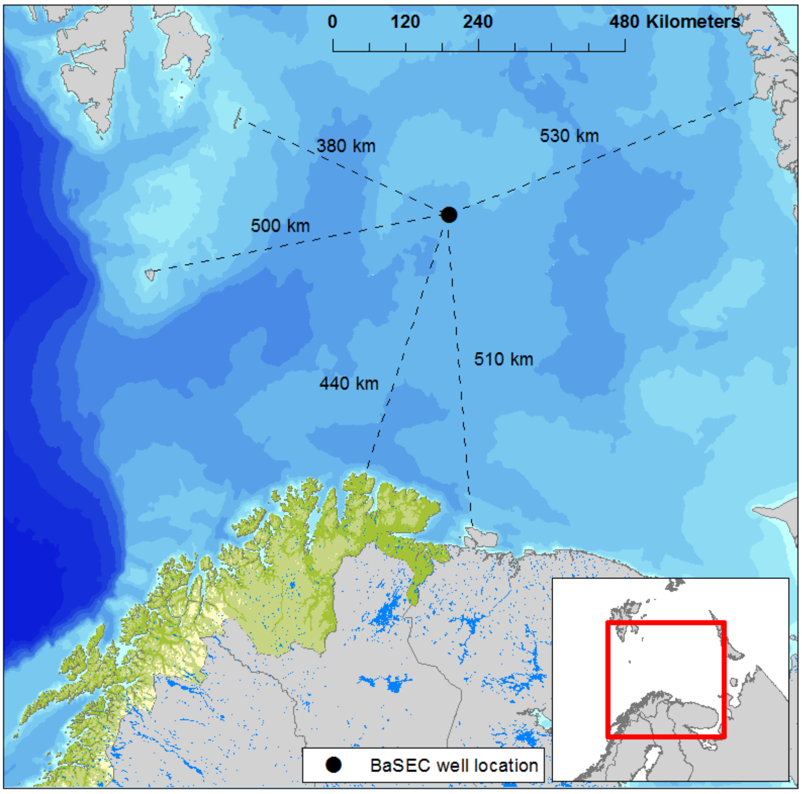


Figure 3-8 *Distances to nearest land areas from the well location in block 7435/9.*

3.3.3 Key planning issues

All logistical challenges and solutions will in some way be of a site specific nature, and no standard solution is therefore applicable. Still the following principles, functions, and elements of the logistic process represent a universal approach, and should be considered.

- **Responsiveness** - Providing the right support at the right time, at the right place.
- **Simplicity** - Avoiding unnecessary complexity in preparing, planning and conducting logistic operations.
- **Flexibility** - Adapting logistic support to changing conditions.
- **Economy** - Employing logistic support assets effectively.
- **Attainability** - Acquiring the minimum essential logistic support to begin mitigating/recovery operations.
- **Sustainability** - Providing logistic support for the duration of the operation.
- **Robustness** - Ensuring that the logistic infrastructure prevails.

3.3.4 Training

A well-functioning pollution preparedness presupposes that the personnel have received adequate training. To ensure that instruction is ensured in a satisfactory manner, the national curriculum for preparedness against acute pollution used. The actors who conducts training according to the curriculum should approved by the Norwegian Coastal Administration (NCA). Training and exercises will be important to ensure that the parties know their responsibilities and powers at such events. NCA conducts regular training and exercises to ensure that the parties' responsibilities and roles in national preparedness have a clear understanding of this.

NOFO is planning to establish a training program for cold climate in cooperation with The Norwegian Fire Protection Training Institute (NBSK). NOFO has also started to do special training and testing in cold climate and ice. This is outlined in the next section.

4 RESPONSE EFFICIENCY IN COLD CLIMATE AND ICE

In this chapter results and experiences from relevant studies and exercises are presented as a fundament for assessments of response efficiency in cold climate and ice.

4.1 Experiences from exercises

NOFO has increased the focus on oil spill response in cold climate and ice, and has during 2015 carried out several activities supporting this. This focus addresses all elements in their preparedness and response organization – the equipment, R&D (Oljevern 2015 – technology program), competence, training and international dialog and cooperation. NOFO has prepared a report that summarizes activities and experiences from 2015 (NOFO 2015), and suggests new activities towards 2015 (NOFO 2015).

4.1.1 Exercise Ice Breaker 2015

The Ice Breaker 2015 exercise was conducted in the waters northeast of Bear Island April 16 to 17, 2015 in good weather and moderate temperatures.

The exercise objectives were:

- To gain experience from operations in waters of occurrence of ice.
- Observe possible effects of climatic conditions on the equipment, as well as safeguarding the health and working environment during operations in the northern Barents Sea.

The exercise was carried out by NOFO and the BaSEC cooperation, and organized as ordinary NOFO oil spill exercise including testing of equipment. It was not made technical modifications of any kind, and all equipment used exists in NOFO standard mechanical response systems. The surveillance plane LN-KYV participated in the exercise.

Figure 4-1 *Testing Norlense 1200 containment boom in combination with weir- and heavy oil skimmer from Framo.*

Findings:

- The NOFO system is functional in areas if ice and in slush ice, if higher concentrations of ice in the boom system are avoided. A key element during an operation is to avoid higher concentrations of ice.
- The skimmer can also get clogged with ice in the inlet. If this occurs it can be handled by blowing skimmer clean, with or without using steam. Overall a reduced efficiency of the skimmer should be expected.
- For operations high north with long distances to a base a specific evaluation of spare parts and auxiliary equipment should be carried out. A template for spare parts and equipment for NOFO operations in northern waters should be prepared.
- During the test the aerostat had an emergency landing in the sea due to high winds; a phenomenon called "Low Level Jet's" that occurs particularly in the Arctic when wind from the open sea goes into the ice-covered areas. Specific Arctic operating procedures for the aerostat will be developed as a result of the incident, including practical methods for assessment of wind in height (smoke, measuring equipment, etc.).
- Autonomous solutions that reduce exposure of workers to HSE challenges should have focus in technology development – as already defined in the technology program Oljevern 2015.
- An increasing number of support systems rely on access to the internet. Vsat onboard ships have clear limitations. Establishment of 4G around producing fields will be helpful, but oil spill preparedness should adapt to the limitations that Vsat has through smart solutions such as messenger apps, systems that adapt to available bandwidth and redundant solutions (Iridium).
- The existing systems for remote sensing such as Aptomar SECurus/TCMS, Rutter OSD and LN-KYV worked satisfactory during the IceBreaker exercise.
- Kongsberg Seatex digital downlink functioned satisfactory. Stable reception was observed over a time period of 2 x 1 hour (two of flights) at distances from 0 to 150 km, which are considered to be highly effective. The system enables reliable transfer of large amounts of data between devices.

Exercise Ice Breaker proved that NOFO equipment, vessel and crew worked well under prevailing conditions. The equipment is too large to be used in solid ice, but resistant to a certain extent collected mixture of ice and slush. High ice coverage can destroy a NOFO system, so the strategy must be to avoid the ice, i.e. manoeuvre alongside higher concentrations of ice. For such operations more agile booms, for instance Current Busters, can be beneficial.

4.1.2 Exercises in Finnmark 2015.

Three exercises were held in the Porsanger fjord in week 6, 7 and 9 in various winter conditions. The exercises included nearshore response systems such as Current Buster 2 and 4 (active boom systems), a variety of skimmer types, Oil bag (primary storage) Ocean Eye aerostat and vessels from the nearshore vessel-pool. Popcorn was partly used as test simulant during the exercises.

The conditions encountered during the exercises varied from cold temperatures (minus 13 degrees Celsius) in combination with moderate gale, via moderately calm winter conditions to strong gale/storm conditions (exercise halted). The ice conditions were characterized by a defined ice edge accompanied with a zone of broken ice and slush towards open water. Due to wind, sea spray and cold significant icing occurred on vessels and equipment (Figure 4-2).

Figure 4-2 *Oil spill exercise in Finnmark winter 2015 (Photo: NOFO).*

The exercises were carried out with ordinary operational procedures. Both general and more specific experiences and findings were recorded.

Findings:

- Builds up ice on the valves of Oil Bag and joints and light on booms
- Booms become unstable and tilt to the side in the water
- Skimmer Pump and hoses freezes on deck and equipment is more easily destroyed
- Power-packs located on decks in the cold will not start
- Ice clogging in the inlet to the Current Buster
- During deployment of equipment is advised to deploy a safety vessel

- Work in the cold is heavier than usual, and crew tire more easily
- Frostbite occurs readily on bare skin.

An important experience is that even oil spill operations may be feasible, all operations normally will become significantly more time consuming in freezing temperatures and when encountering ice. An overall decrease in effectiveness due to technical and operational challenges is thus to be expected. These factors should be mitigated by establishing adapted operational procedures, and winterization measures for equipment.

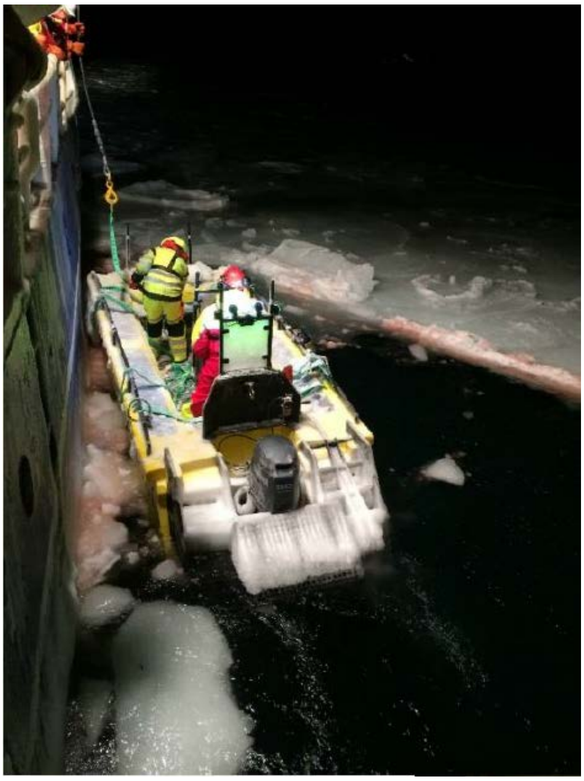


Figure 4-3 *Oil spill exercise in Finnmark winter 2015 (Photo: NOFO).*

4.1.3 Oil on Water Exercise (OOW)

The annual Oil on Water (OOW) exercise arranged by NOFO and NCA have for several years been a main international event in terms of full scale testing. The crude oil releases require a release permit issued by the Norwegian Environmental Agency. The OOW exercise provides testing of oil spill response equipment under realistic off-shore conditions, and therefore provides important knowledge even though the tests are not cold climate and ice specific.

The Oil Spill Response 2010 development program, carried out in 2009-13, resulted in a number of new products and services. In response to the call for proposals in January 2009, some 170 project ideas were received in the form of brief outlines – dubbed White Papers. Through a phase of developing project specifications and financing plans, 20 of these were finally selected and projects initiated. A number of the projects have resulted in commercially available products. NOFO and the Norwegian Coastal Administration (NCA) have launched a new technology development program under the name Oil Spill Response 2015. This will challenge the industry in Norway and internationally to present new ideas and proposals for developing commercially available products which can improve and enhance the efficiency of oil spill response operations in Norwegian waters – including the far north, along the coast and in the beach area.

4.1.4 Other training and competence measures

NOFO aims to establish a competence partnership with arctic responders and attend courses in dealing with oil in ice. NOFO also aims to develop competence and course activities at The Norwegian Fire Protection Training Institute (NBSK).

4.2 Quantitative efficiency assessments

DNV GL has conducted a comprehensive assessment of oil spill response conditions in the Barents Sea and adjacent areas (DNV GL 2014). The study area is presented in Figure 4-4. The Response Gap methodology quantifies the monthly average response applicability for mechanical recovery, dispersant application and in situ burning techniques, caused by environmental factors such as wind, sea state, ice, temperature and visibility. It must be emphasised that response applicability in this context refer to the possibilities to actually deploy and perform a response – not evaluation of the volumetric efficiency in terms of treated oil.

Figure 4-4 *Area for the response gap analysis.*

High resolution historical data at a large spatial scale - grids of 10 x 10 km have been used. Based on best available technology, factual knowledge and expert judgment, a set of criteria for the environmental factors known to limit oil spill response has been established (see appendix A1). The results enable visualization of the percentage of time when the response conditions are favourable, impaired or ineffective on a monthly basis for each response technique, or for multiple techniques.

The response gap analysis provides a good basis for general assessments of response applicability for the Barents Sea, as it combines high resolution metocean data with operational challenges and limitations for relevant offshore response techniques. Geographical and seasonal variations are reflected in the results for each technique and technique variation. As an example the distribution of favourable response conditions for mechanical recovery is illustrated in Figure 4-5.

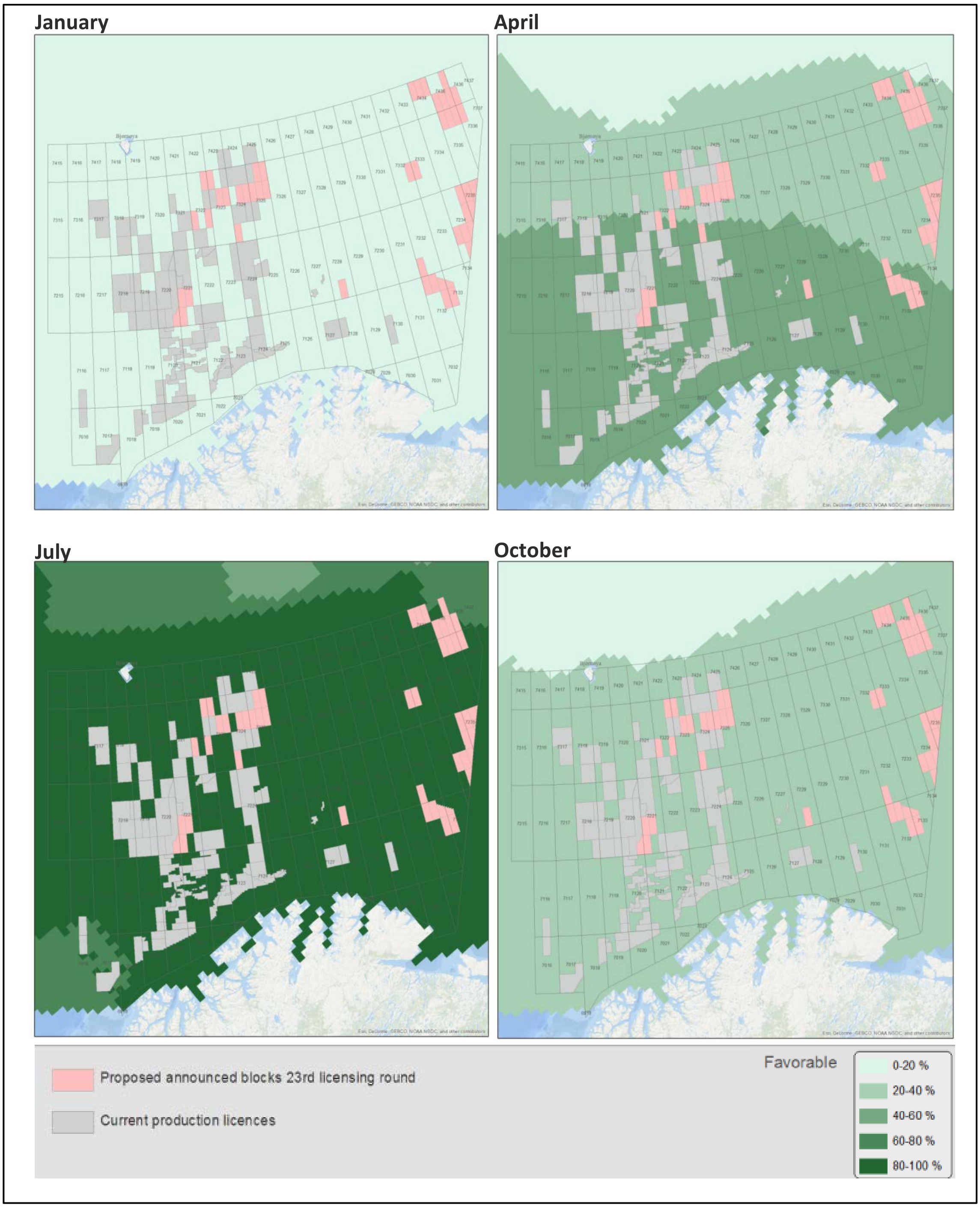


Figure 4-5 *Favorable metocean response conditions for mechanical recovery. Percentage of time in January, April, July and October***.**

Based on this methodology the relative applicability for each response measure at a given location can be calculated. Monthly and seasonal averages for response applicability for mechanical recovery, vessel based dispersion and in-situ burning for the BaSEC location (block 7435/9) is presented in percentages in Table 4-1 and Table 4-2.

The average response applicability of the response measure is calculated by subtracting the recorded percentage of time with inefficient response conditions. The remaining time consists of favourable and impaired response conditions. In the calculation the efficiency in favourable conditions is set to 100 %, and in impaired conditions to 50 %. This means that mechanical recovery in March will have an average efficiency of 37 % due to metocean conditions.

Table 4-1 *Average response applicability due to metocean conditions throughout the year*

	Mechanical recovery	Vessel-based dispersion	In-situ burning
January	33 %	39 %	7 %
February	35 %	40 %	7 %
March	37 %	40 %	11 %
April	46 %	49 %	18 %
May	53 %	55 %	33 %
June	68 %	69 %	44 %
July	83 %	84 %	45 %
August	77 %	78 %	43 %
September	64 %	66 %	22 %
October	50 %	53 %	15 %
November	43 %	47 %	10 %
December	38 %	43 %	11 %

Table 4-2 *Average system applicability due to metocean conditions for each season*

	Mechanical recovery	Vessel-based dispersion	In-situ burning
Spring (March - May)	45 %	48 %	21 %
Summer (June - August)	76 %	77 %	44 %
Autumn (September – November)	52 %	55 %	16 %
Winter (December – February)	38 %	43 %	9 %

The results reveal that the applicability for mechanical recovery and vessel-based dispersion at this location are very similar, while In-situ burning is significantly less applicable. This is due to how the operational limitations for the techniques are defined, as the metocean conditions are identical. The defined limitations are listed in Appendix B.

The response gap study does only address the potential for deploying the defined response systems related to metocean conditions, hence cannot alone define system efficiencies in terms of treated oil volumes. In order to do that it is necessary to include scenario-related and system-related parameters and assumptions in the calculation:

- Oil spill scenario related parameters e.g. spill volume or oil properties
- System/operational related parameters e.g. system encounter rate

For the purpose of this study an alternative, quantitative methodology is proposed that combines the data from the response gap analysis with system and scenario assumptions. This approach has been applied with a DNV GL in-house calculator ORCA (Oil spill response Calculator) to assess the effect of oil recovery in ice-infested waters in the OSCA report (DNV GL, 2015b), since this is not possible in the OSCAR model. A schematic setup of the ORCA methodology is illustrated in Figure 4-6.

In order to calculate the efficiency in terms of recovered volumes, both system and scenario information needs to be added. These options are also included in the ORCA tool.

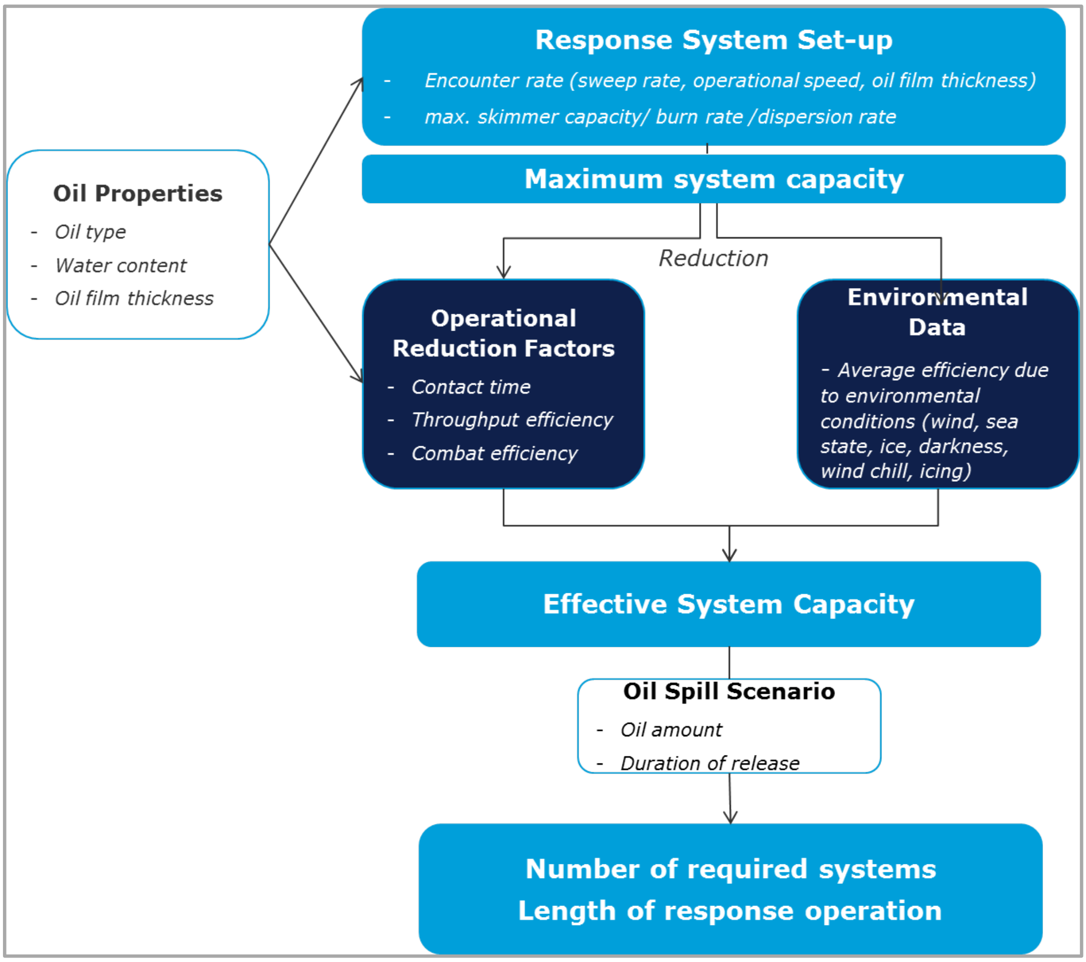


Figure 4-6 *Schematic setup of the ORCA methodology.*

It must be emphasized that in a real oil spill response the actual result of the response in terms of effectively treated oil will depend on a wide range of factors that cannot be fully predicted in models. In reality each spill and response will be unique, and hence any efficiency calculation method represents a simplification that considers a limited number of factors. It can still provide valuable information in risk evaluations and for planning purposes.

The ORCA model demonstrates that efficiency calculations are especially sensitive to assumptions about the weathering of the oil, the distribution of oil and the systems abilities to encounter the oil. These factors are generally also difficult to predict with a high accuracy, especially for exploration drilling. With regards to metocean conditions both the ORCA calculations and the OSCAR modelling approach generally address statistical trends (e.g. seasonal averages), although response conditions in reality may vary significantly within any month of the year.

In practice oil spill preparedness, especially connected exploration drilling, should be robust and agile in order to work in a variety of conditions and spill scenarios.

5 OIL SPILL RESPONSE STRATEGIES AND CONCEPTS FOR BARENTS SEA SOUTH EAST

In this chapter the most relevant strategies for oil spill response in the study area are identified and described at a generic level. This serves as input for the OSCA that is performed by the OSCAR simulations for open water conditions and the ORCA tool for ice conditions. In addition cross border issues are discussed, and the existing bilateral framework is outlined.

5.1 Barrier strategies

Oil Spill Response can in principle be defined as a set of consequence reducing barriers, which aim to stop or reduce negative effects of acute pollution to the environment. The Offshore Industry in Norway has developed common barrier strategies accompanied by a set of minimum requirements (NOROG, 2013) for this purpose. These include:

Barrier 1a: Combat of oil offshore, near the source of the spill

Barrier 1b: Combat of oil offshore, downstream from the source of the spill

Barrier 2: Combat of oil in the coastal and near shore zone

Barrier 3a: Combat of mobile oil by the shoreline

Barrier 3b: Shoreline cleaning

Due to the results of the modelled oil drift the only relevant barriers for this study are 1a and 1 b. An overview of relevant strategies, functions, elements and requirements for oil spill response in barrier 1a and 1b are listed in Table 5-1 (open water) and ice infested waters

As the primary objective of an oil spill response is to safely undertake actions to minimize the overall environmental and socio-economic damages that are caused by an incident, it can be beneficial to evaluate the advantages and disadvantages of different response strategies, including natural recovery. The process of choosing response options that result in the least ecological and socio-economic damage is called Net Environmental Benefit Analysis (NEBA). The output of NEBA-based considerations is guidance on tactical deployment of strategies in the specific context of the operation's setting (IPIECA and OGP, 2013)

The NEBA generally is an evaluation process that may be used during pre-spill planning or during a response, which incorporates the following steps (IPIECA and IOGP, 2015):

1.) Compile and evaluate data to identify an exposure scenario and potential response options, and to understand the potential impacts of that spill scenario.

2.) Predict the outcomes for the given scenario, to determine which techniques are effective and feasible.

3.) Balance trade-offs by weighing a range of ecological and/or socio-economic benefits and drawbacks resulting from each feasible response option.

4.) Select the best response options for the given scenario, based on which combination and tools and techniques will minimize impacts.

Table 5-1 *The barrier principles applied to oil spill response in the study area – open water*

Barrier strategies	Barrier functions	Barrier elements	Functional requirements	Considerations
Subsea Well Incident Intervention (All conditions)	Reduce spill by source control	• Capping system • Relief well • Subsea dispersants	• Contracted availability • Logistical solution/plan • Competence and training	• Water depth • Volatile oil/gas at sea surface
Combat of oil – open ocean (Ice free conditions)	Reduce spreading of spill by containment and recovery of combatable oil on sea surface	• NOFO offshore system, conventional boom • NOFO offshore system, active boom	• Cold weather functionality • Rapid deployment and uploading • Containment capacity with heating	• Oil properties • Operational conditions/limitations • One vessel systems
	Reduce spreading of oil on sea surface by use of chemical dispersants	• Vessel based dispersant system • Fix-wing based dispersant system	• Plan for field resupply of dispersants to vessels • Competence and training • Response time	• Oil properties • Operational conditions/limitations • Increased volume of dispersants on vessels
	Reduce spreading of spill by containment and In situ burning (ISB) on sea surface	• ISB system/kit onboard offshore response vessel (fire booms, igniters)	• Response time • Training and competence • System adapted to relevant vessels	• Oil properties • Hazards • Operational conditions/limitations • ISB system/kit must be fitted to offshore response vessel • Permission application regime

Table 5-2 *The barrier principles applied to oil spill response in the study area – ice infested water*

Barrier strategies	Barrier functions	Barrier elements	Functional requirements	Considerations
Combat of oil – ice infested waters	Concentrate efforts upstream towards the spill source and in ice free conditions, to avoid/reduce oil entering ice infested waters	• Relevant offshore elements listed above • Monitoring of ice	• Real time monitoring of ice	• Applicability of existing concepts
	Combat oil near or in ice infested waters	• Relevant offshore elements listed above with adapted tactics to ice: o Crane and grab o Feasible skimmers o Dispersant application with added energy o ISB o Water cannon for mechanical dispersion of thin oil film	• Feasible vessels for ice • Cold weather functionality • Competence and training	• Apply best practice • Oil properties
Additional strategies - all barriers	Surveillance and monitoring	• Multiple sensors from o Satellites o Aerial (fix wing) o Helicopter with Down link o Drones o Vessels o Aerostat	• Key functionality • Response time • Sustainability/robustness • Interactivity	• Coverage • Data communication capacity
	Response capability	• Common Operation Picture (COP) • Logistics • Operational stamina	• Cold weather functionality • Competence and training	• Applicability of existing concepts
	Post-response assessments	• Procedures • Experts	• Contracted availability • Response time	• Applicability of existing concepts
No combat of oil	Natural dispersion, wave flushing and degradation of oil in open ocean and at exposed shorelines	• Surveillance and monitoring	• NEBA	• Feasible tactic if natural degradation processes are more effective than other tactics • May also be only feasible tactic due to personnel safety

5.2 Current barrier elements/response systems

5.2.1 Open water mechanical recovery with passive boom system (MechP)

The system type is established and generally well proven on the NCS. The system requires a second vessel for the boom operation. A general description with key capacities is presented below.

Mechanical recovery with passive boom system

Oil spill open ocean response vessels Esvagt Aurora. Source: DNV GL.

Description:

Response measure MechP equals a modern OR stand-by or supply vessel with detection capacity (IR and oil radar), an open ocean containment boom and a high capacity skimmer and primary storage capacity (NOFO system). Towing vessels for could be daughter crafts or a second vessel (eg. fishing vessel/NOFO Pool).

Key capacities	
Response system:	1 open-ocean containment and recovery vessel
Travel speed:	14 knots
Mobilisation time:	2 hours
Travel time:	Dependent on scenario location
Response measure:	Mechanical recovery
Oil storage capacity:	1500 m^3
Boom swath width:	130 m
Skimmer uptake capacity:	High viscosity skimmer (100 m^3/h)
Operational speed:	0.7 knots
Operative in darkness:	Yes, with reduced effectiveness (0.65)
Winterisation:	Yes, with sheltered storage of equipment, tank/pump heating glycol ready, working environment/HSE

5.2.2 Open water vessel based dispersion system (DispV)

The system type is established and generally well proven on the NCS. A general description with key capacities is presented below.

Open water vessel based dispersion system

Oil spill open ocean response vessels Stril Barents. Source: Eni Norge.

Description:

Response measure DispV equals a modern OR stand-by or supply vessel equipped for chemical dispersion. The concept consists of detection capacity (IR and oil radar), spray booms and dispersant fluid.

Key capacities

Response system:	1 open-ocean dispersant system (ship)
Cruise speed:	14 knots
Mobilisation time:	2 hours
Travel time:	Dependent on scenario location (see table)
Response measure:	Dispersant application
Operational speed:	5 knots
Operative in darkness:	Yes, with reduced effectiveness (0.65)
Dispersant volume:	100 m3
Dispersant name	Dasic Slickgone
Application rate and ratio:	120 l/min, 1:25
Spraying width	26 - 34 m
Winterisation:	Yes, with sheltered storage of equipment, heating, glycol ready, working environment/HSE

5.2.3 Open water aerial dispersion system (DispA)

The system type is established and generally well proven on the NCS. A general description with key capacities is presented below.

Open water aerial dispersion system

© U.S. Air Force – Tech. Sgt. Prentice Colter

Description:

Response measure DispA equals a fixed-wing dispersant aircraft (e.g. *OSRL Boeing 727*) for aerial dispersant application. The system will have a dispersant capacity of 17,500 litres and a range of 2,500 nautical miles in five hours.

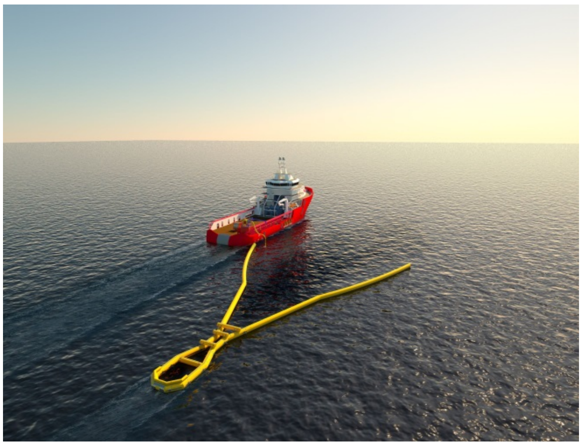
Key capacities

Response system:	1 Fixed-wing aircraft (OSRL Boeing 727)
Travel speed:	200 knots
Travel time:	24h
Response:	Dispersant application by aircraft
Dispersant name	Dasic Slickgone
Application rate and ratio:	1000 l/min, 1:50
Spraying width:	50 m
Operational speed:	140 knots
Operative in darkness:	No
Spotter plane:	Yes

5.3 Future barrier elements / response systems

5.3.1 Open water mechanical recovery with active boom system (MechA)

The concept is existing and proven, but not implemented for offshore response on NCS. It has been included in this study because of its potential benefits due to its manoeuvrability, speed and single boat configuration.

Open water mechanical recovery with active boom system	
 *Active Boom, one boat system. Source: NOFI Tromsø AS.*	***Description:*** Response measure MechA equals an open ocean containment and recovery system (Response measure MechP), but operates an active boom system (e.g CB6/CB8) with a high capacity skimmer and primary storage capacity.
Key capacities	
Response system:	1 open-ocean containment and recovery vessel
Travel speed:	14 knots
Mobilisation time:	2 hours
Travel time:	Dependent on scenario location
Response measure:	Mechanical recovery
Oil storage capacity:	1500 m^3
Boom swath width:	50 m
Skimmer uptake capacity:	High viscosity skimmer (100 m^3/h)
Operational speed:	4 knots
Operative in darkness:	Yes, with reduced effectiveness (0.65)
Winterisation:	Yes, with sheltered storage of equipment, tank/pump heating glycol ready, working environment/HSE

5.3.2 Open water in-situ burning system (ISB)

The concept of in situ burning in open water is existing and proven, but has not been implemented for offshore response on NCS. It has been included in this study because of its potential benefits due to potentially high effectiveness paired with its relatively simplicity in logistics.

Open water in-situ burning system	
	***Description:*** Response measure ISB equals a future response concept for In Situ Burning in open ocean. These resources are based on a modern OR stand-by or supply vessel with oil detection capacities (IR and oil radar) and carries an additional ISB kit. The kit contains of fire booms and a surface ignition system. Towing vessels could be daughter crafts or fishing vessels.
Key capacities	
Response system:	1 open-ocean vessel with fire boom, surface ignition system
Travel speed:	14 knots
Mobilisation time:	2 hours
Travel time:	Dependent on scenario location
Response measure:	In Situ Burning in open water with fire boom (multiple booms for prolonged operation)
Boom swath width:	30 - 50 (150 m fire boom)
Max water content (for ignition):	50 %
Burn rate:	150 m3/h
Operational speed:	0.7 knots
Operative in darkness:	No (in reality: Onsite assessment)

5.3.3 Multipurpose response vessel for ice-infested waters (IceRV)

This concept and the tools it includes, exists separately in different configurations but is not implemented for response on NCS. It has been included in this study as a specific response tool for ice conditions.

Multipurpose response vessel for ice-infested waters

Multipurpose response vessel system (Hylje). Source: Finnish Environment Institute.

Description:

Response measure IceRV equals a multipurpose vessel system equipped for combating oil in ice infested waters. The system is primarily set up for operations in ice up to ~30 %, and comprises of kits for 1) mechanical recovery, 2) ISB and 3) dispersant application in ice.

Key capacities	
Response system:	1 open-ocean containment and recovery vessel
Travel speed:	11 knots
Mobilisation time:	2 hours
Travel time:	Dependent on scenario location
Response measure 1:	Mechanical recovery
Oil storage capacity:	1500 m^3
Boom swath width:	0 – 50 m
Skimmer uptake capacity:	High viscosity skimmer (100 m^3/h)
Operational speed:	0 – 4 knots
Operative in darkness:	Yes, with reduced effectiveness (0.65)
Response measure 2:	Chemical dispersion
Operational speed:	0 - 5 knots
Operative in darkness:	Yes, with reduced effectiveness (0.65)
Dispersant volume:	100 m3
Dispersant name	Dasic Slickgone

Application rate and ratio:	50 l/min, 1:20
Spraying width	5 – 10 m
Response measure 3:	In Situ Burning
Boom swath width:	0 - 25m
Max water content (for ignition):	50 %
Burn rate:	150 m3/h
Operational speed:	0.7 knots
Operative in darkness:	No

5.3.4 Subsea dispersion (DispS)

Subsea dispersant injection is not currently a standard feature in the OSCAR model. In this study an adapted methodology has been applied by modelling the subsea blowout with decreased interfacial tension between oil and water. This approach does not implement any technical or operational considerations or specifications, which means that the modelling results are independent of a specific system setup or assumptions.

5.4 Cross border issues

5.4.1 Probabilities and emulsion volumes

The close proximity of Block 7435/9 including the “BaSEC well” to the Russian maritime boarder creates a high degree of likelihood for cross-boundary pollution in case of blowout from the well.

5.4.2 Cooperation Norway–Russia

Currently Norway and Russia cooperate on acute pollution preparedness based on the following agreements and plans:

1.) Agreement for Oil Spill Combatment of Oil Pollution in the Barents Sea, signed by the Governments of Norway and Russia in 1994 (Governments of Norway & Russia, 1994):

   a. In case of acute oil pollution from the Norwegian continental shelf should spread across the Russian border, there has been prepared a cooperation agreement to improve cooperation, communication and effective use of available oil spill resources.

2.) Joint Norwegian-Russian contingency plan for oil spill response in the Barents Sea (NCA & MRS 2014):

   a. Under the Agreement of 1994, the Joint Norwegian-Russian Contingency Plan for Oil Spill Response in the Barents Sea (annually updated) was developed. These documents provide a framework for cooperation between the responsible national authorities in the two countries regarding actions against oil spills, execution of joint exercises and regular meetings (usually twice a year).

   b. Implementation of the plan is a shared responsibility between the Norwegian Coastal Administration (NCA) and the Marine Rescue Service of Rosmorrechflot (MRS) under the Department of Maritime Transport - of the Ministry of Transport - of the Russian Federation. The two agencies are defined under article 2 in the agreement.

   c. The annual joint exercise is called “Exercise Barents” and the responsibility for implementing the exercise alternates between the two countries. The exercise is held once a year combined with the annual joint SAR exercise. The Joint Norwegian-Russian Contingency Plan is a basic training element in the exercise. One of the annual cooperation meetings between the two countries is the planning meeting for this annual exercise.

3.) International Convention on Oil Pollution Preparedness, Response and Co-Operation (OPRC 1990):

a. Norway and Russia are both parties to the 1990 international OPRC convention. The convention gives a framework for cooperative measures related to oil spill incidents. The convention outlines that trained crew and appropriate oil spill equipment must be on board ships and offshore installations to implement their oil pollution emergency plans to effect damage repair and mitigate pollution, including responding to ice damage. OPRC also calls for the establishment of stockpiles of oil spill response equipment, implementation of oil spill response exercises and establishment of oil spill contingency plans. State Party which has signed the convention has also committed themselves to assist other states in case of pollution emergency situations.

4.) Agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic (Arctic Council 2013):

a. The objective is to strengthen cooperation, coordination and mutual assistance among the Parties on oil pollution preparedness and response in the Arctic in order to protect the marine environment from pollution by oil.

The Russian oil pollution contingency system in the Barents Sea area consists of state and municipal systems. The state contingency system is responsible for oil spill response to large spills of oil or oil products from any vessel or object, regardless of ownership or flag. The most relevant authorities in Russia are the Ministry of Transport of the Russian Federation represented by its rescue and emergency response unit, the Northern Branch of the Maritime Salvage Service. The Ministry for Emergency Situations (EMERCOM) is the key authority regarding shoreline oil spill response.

5.4.3 Government takeover in extreme pollution events

NCA and the Oil Industry have established a bridging document describing roles and responsibilities related to extreme pollution incidents, and where NCA partially or completely will take over the incident Command according to the Pollution Control Act § 46, paragraph 3. Such full or partial takeover does not change the operators responsibilities for own resources, responsibility for the incident itself or responsibility for the consequences of this. A decision on partly of full takeover will be based on an assessment of established criteria. One of these criteria is cross border pollution.

6 RESULTS FROM OSCA

This chapter summarizes the conclusions in the OSCA report and discuss their operational feasibility and implementation. All results from the OSCA are described in detail in a separate document (DNV GL, 2015b).

6.1 Conclusions

- **Response measures are general more effective during summer season compared to the winter period.** This is due to harsher environmental conditions as well as oil properties such as viscosity or oil film thickness.
- **Response measures are more effective given a topside blowout compared to a subsea blowout.** Oil which reaches the surface after a subsea blowout is more difficult to recover/treat as it has changed its properties, e.g. increased water uptake or thinner oil film thickness.
- **Shortened response time by using a second standby-vessel has limited effect at the end of the simulation.** The additional increase of recovered or dispersed oil is < 5 % and there is no or very limited further decrease in population loss probability. The effect of shortened response time is marginal due to the long spill duration. Shorter spill durations would probably result in greater differences in the mass balance.
- **Active mechanical recovery systems have a greater capacity to recover oil from surface than passive mechanical recovery systems due to higher encounter rate.** Results showed that 5 active systems recovered more than twice the amount of oil as 5 passive systems. The high encounter rate is mostly influenced by the higher operational speed of the active systems, which is nearly 6 times higher than the operational speed of a passive system.
- **Dispersant application with 5 vessels showed to have a better effect on reducing population loss than application of the same amount of dispersant fluids by one aircraft.** Population loss could be reduced by 17 percentage points by dispersant vessels during summer season compared to 8 percentage points by aerial application. This is most likely due to the ability to operate on different oil slicks at the same time.
- **Mechanical recovery systems in combination with aircraft dispersant systems contribute to the highest decrease of oil on surface.** Surface oil could be decreased by 75 % within the first 5 days after a topside blowout in the summer season. This shows that the flexibility of the active systems plus the high efficiency of aerial dispersion is a good combination in combatting an oil spill.
- **In-situ burning in open water is regarded as a less favourable response option.** Operational feasibility is limited by high seas states and darkness in winter time. Furthermore, due to the oil properties of the Skrugard crude oil (high and rapid water uptake), the burn efficiency is assumed to be very limited.
- **Subsea dispersion has limited effect in the model.** The amount of dispersed oil in the water column was increased by 14 %, while the probability of population loss was reduced by 2 percentage points. This is most likely due to the low water depth at the release location resulting in a rapid raise of the plume to the water surface. Single simulations revealed a travel time of ~10 minutes to the water surface. Due to the methodology of modelling subsea dispersion in OSCAR there are some uncertainties in the results and these have thus to be considered with care.

- **Mechanical recovery is the most feasible response technique for an oil spill within the marginal ice zone up to 30 % ice concentration.** Due to the oil properties of the Skrugard oil (high and rapid water uptake), the efficiency and system capacity of dispersion and in-situ burning systems will be reduced or is close to zero. The efficiency of ISB is very dependent on the oil type and properties and might be more effective on other oil types.

The study showed that by using combination of several response techniques and implementing new response systems to the “toolbox” the operational time window can be widened and the environmental damage and impact can be reduced.

6.2 Operational feasibility

For mechanical recovery in open water the passive systems are currently the most common. The passive systems are well tested and have its benefits also in areas with cold climate and ice. For instance it is easy to empty the boom for ice if necessary, by turning it or by making a temporary opening between the boom and the ship. The booms are also self-inflatable and can be deployed with few personnel. The skimmer works well with the boom concept, and can even handle ice.

The active systems have traditionally been used in coastal areas, but the concept has also been developed further into more offshore capable systems. The three main benefits with these concepts over the static systems are 1) they don't depend on a second towing vessel, 2) their increased towing speed and 3) increased manoeuvrability. These benefits actualize the active systems as a part of a mechanical response strategy. Still issues with ice drainage from systems needs to be addressed. Both concepts are depending on external storage capacity after primary storage is full.

Vessel based dispersant application systems are established and proven concepts. It has also been implemented as winterized solutions. Integrated systems are in general more robust towards problems related to exposure to cold climate compared to concepts like the BV spray (BoomVaine operated hose with nozzles). This concept can be relevant, as it gives a wider application width.

For dispersants, a continuous vessel based application will depend upon a logistical chain of resupply. It is also possible for the vessels to bring more dispersants, but unless integrated tanks are modified in advance these will have to be stored as 1m^3 tanks on deck.

Aerial dispersion is a relevant measure and must for the time being be based on the Hercules L-382 aircraft. The Hercules is a versatile and effective platform. A project to convert two Boeing 727s has been underway by OSRL. The Boeing 727 is planned for delivery in the third quarter of 2015 and will be relevant also for the scenario in this study.

In-situ burning is not currently implemented in Norway, and the results from the OSCA do not indicate it as a main response option, mainly due to the quick water uptake of the Skrugrad oil. A concept comprising of aerial application of herders and ignition may be interesting to assess further.

The OSCA indicates that a multitool option for ice conditions including mechanical recovery, dispersants and ISB has a potential in certain conditions, and may even be the only option in times with extreme ice extensions. Overall it still seems most relevant as a supplementary capacity to open water strategies, since the modelling indicates that the probability of oil in ice is very low.

7 EXISTING RESPONSE CAPACITIES AND RESOURCES

This chapter gives an overview of existing and available oil spill resources, with focus on resources most relevant for the Barents Sea. This includes resources from depots in Norway and internationally, and from public and private resource owners. The focus is on main equipment and systems. Further details regarding locations, type, numbers and capacities are listed in Appendix C and D.

7.1 NOFO resources

NOFO is the primary responder for operating companies on the Norwegian Continental Shelf. Key NOFO assets are:

- An Emergency Response Centre with state-of-the-art technology. Can communicate with NCA emergency response centre when needed.
- 25 oceangoing systems for mechanical recovery, of which 11 of these systems are permanently placed on board in OR vessels on permanent standby.
- 31 OR vessels with corresponding number of towing vessels. Se Appendix C for information regarding availability due to upcoming regulations in arctic waters
- 21 High Speed Coastal recovery systems (Current buster 4) available from NOFO bases and NOFO depot in Havøysund and Hasvik
- Five spill response bases with 100 equipment operators. Can serve logistical issues in connection with oil spill operations and the most relevant bases for operations in the Barents Sea are located in Sandnessjøen and Hammerfest.
- Permanent dispersant capacity on 12 vessels on permanent standby
- Access to 804 m3 dispersant according to:
    - o 537,5 m3 on 12 vessels on permanent standby
    - o 267 m^3 on stock in 4 bases
- Oil-radar system (OSD) and infrared sensors (IR) on vessels on permanent standby for detection of oil, SLAR radar, FLIR (forward looking infrared camera) and established procedures
- Dispersing BV spray concept
- Three aerostats for operational remote sensing
- Access to a MOS Sweeper. The system handles both high waves and stronger power than traditional booms and represent in reality the 26th oceangoing system.

7.2 Resources through NOFO agreements

Agreement with Norwegian Coastal Administration (NCA) for access to:

- 16 Governmental depots (materials and depot personnel) and a smaller depot located in Ny-Ålesund. Available equipment from the Northernmost depots are listed in appendix C
- Emergency tug vessels suitable for towing of offshore recovery systems (NSO Crusader and Beta).

- Coast Guard vessels KV Harstad, KV Barentshav, KV Sortland and KV Svalbard which are most relevant based on response time and available oil spill equipment on board. KV Harstad, KV Barentshav and KV Sortland are permanently equipped with NO800 R oil boom. KV Barentshav and KV Sortland are equipped with a multi-skimmer, for different oil viscosities and oil thicknesses. KV Harstad is equipped with an oil skimmer for medium to very high viscosity oil such as heavy bunker oils and weathered crude oils under low temperature. The skimmer works inefficiently on diesel and other low viscous products. ORO tanks has a capacity of around 1000-1100 m3 and has an integrated heating system for keeping the oil flowing and pumpable in the tank. KV Svalbard has however no ORO tank capacity and only minor oil spill equipment. All vessels have oil detection radar.
- The 3 coast guard vessels in Nordkapp class (KV Nordkapp, KV Andenes and KV Senja). They have no oil spill response capacity, but can work well as a platform for On Scene Coordinator or other similar tasks. The vessels also have helicopter capacity.
- MS Polarsyssel (Governor of Svalbard)
- 3 new generation multi-purpose oil spill vessels from NCA (OV Utvær, OV Skomvær and OV Bøkfjord (2016)) and in near future additional 3 new vessels will be available.
- Reconnaissance airplane (LN-KYV).

Agreements with OSRL:

- Agreement between OSRL and NOFO, which gives access to dispersant aircraft and 100 m3 dispersant.
- Several operators have agreements that go beyond the NOFO agreement with OSRL where they get access to extensive resources. This includes:
    - Offshore oil spill equipment
    - Dispersant systems
    - Higher amounts of dispersants
    - SWIS Capping Stack System & Subsea Incident Response Toolkit
    - In situ burning equipment
    - Competent personnel

Agreement with global Response Network (GRN) with access to operational teams with expertise on key functional areas of oil spill response techniques including:

- Dispersants
- In-situ Burning
- Remote sensing
- Ice-covered Waters
- Shallow Water/Onshore
- Offshore

GRN is a network of the following responder organisations:

- Alaska Clean Seas (ACS)
- Australian Marine Oil Spill Centre (AMOSC)
- Easter Canada Response Corporation (ECRC-SIMEC)
- Marine Spill Response Corporation (MSRC)
- Oil Spill Response Limited (OSRL)
- Western Canada Marine Response Corporation (WCMRC)

Other NOFO agreements:

- Agreement with Teekay for access to shuttle tankers for use caching collected oil emulsion
- Agreement with KSAT8 about remote monitoring of the continental shelf

7.3 Relevant resources based on Governmental international agreements

- Vessels from the Icelandic Coastguard based on Copenhagen Agreement. Especially one vessel (KV Thor) is of interests with dimensions similar to KV Harstad. The vessel is equipped with NO 800 boom and Lamor LFF 400 skimmer and with an ORO capacity of 640 m3
- EMSA increased satellite coverage (EU agreement with KSAT)
- Russian resources based on the Norway – Russia agreement and the Joint Norwegian-Russian Contingency Plan for Oil Spill Response in the Barents Sea. Most relevant resources are oil recovery equipment of the state contingency system in Murmansk. Main equipment consist of:
    - 5 offshore oil recovery vessels
    - Coastal booms
    - Different skimmer types

7.4 Rules and regulations for vessels operating in the Barents Sea

Generally, there are no additional mandatory rules for vessels operating in the Barents Sea today. From 1st January 2017, IMO will introduce a mandatory Polar Code for vessel operating in the polar areas as defined north of the line shown in Figure 7-1 below. After 1st of January 2017 all vessel that today have to comply with SOLAS and MARPOL requirements will have to comply with the Polar code which is an add-on to both SOLAS and MARPOL.

The code will apply to all ships except:

  - o ships below 150 gross tonnage engaged on any voyage;
  - o ships below 500 gross tonnage not engaged on international voyages; and
  - o fishing vessels
- Ships operated by or on behalf of the authorities or navy vessels

This means that all standby and emergency rescue and recovery vessels (NOFO fleet and ORO vessel) operating within the IMO Polar Code area will have to comply with the code, while the fishing vessels and SAR vessels are not required to comply.

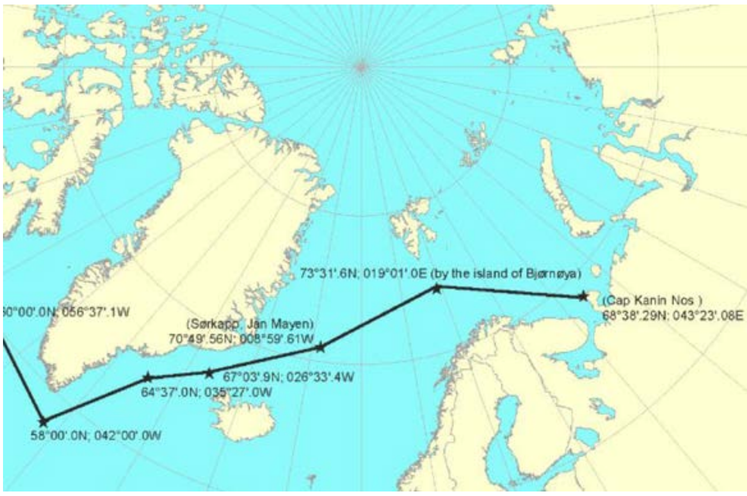


Figure 7-1 *Border for IMO Polar Code in Barents Sea*

7.4.1 Ice conditions and cold climate challenges

The offshore installations in the Barents Sea will have to be designed according to NORSOK. According to NORSOK "Sea Ice – shall be taken into account in parts of Barents sea". The ice data in NORSOK are based on satellite information of sea ice with concentration more than 10%-20%.

Figure 7-2 below shows the probability for ice in the Barents Sea as defined in NORSOK 2007. The yellow area is the same area as included in the 23rd round and the two lines shows the limits for the probability of 10^{-2} and 10^{-4}. Note that NORSOK is under revision and that some minor modifications to the limits are proposed.

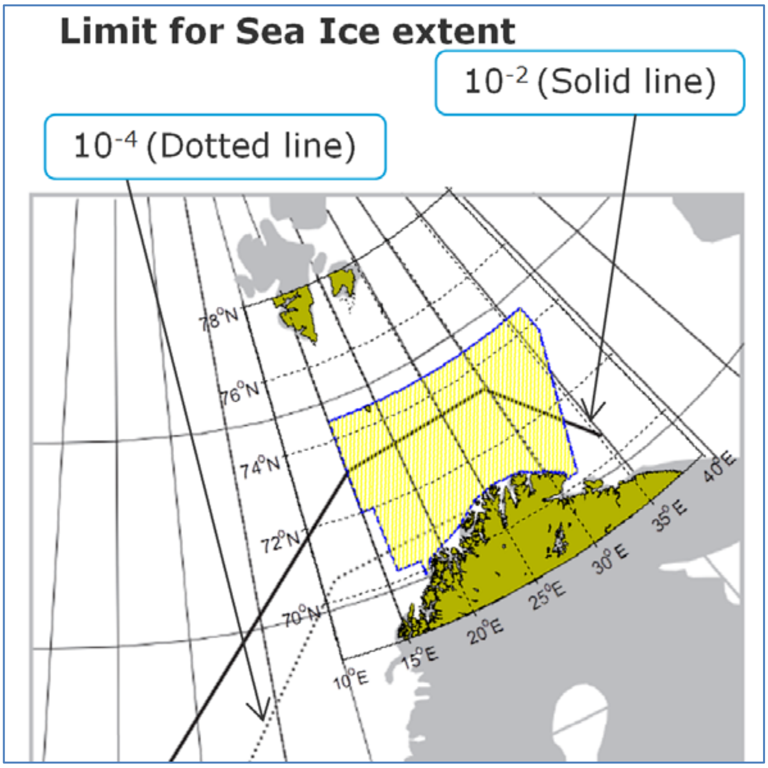


Figure 7-2 *NORSOK probability of ice in the Barents Sea. Area for 23rd round indicated in yellow.*

The supporting vessels should be designed for the same ice conditions as the offshore units based on the actual location and NORSOK/ice information. This is relevant for year round operation, while for seasonal operation, the actual condition should be considered. This means that for seasonal summer operation, the effect of ice does not need to be considered.

7.4.2 Ice class – existing vessels

The requirement for an ice class is independent of the Polar Code, as it is *"the responsibility of the captain to operate the vessel within the design limits for the actual ice and weather conditions"*.

The few vessels in the NOFO list constructed with an ice class either have the low ice class ICE - C or the lowest Baltic ice class ICE-1C. Ice class ICE-1C is limited for operation in light first year broken ice with a corresponding level ice thickness of 0.4 m. This ice class is not for vessels intended to break ice.

For vessels going to operate year around in the northern part, a significant higher ice class will be required as a minimum. Considering the list of NOFOs standby vessels, only a few of these have a sufficient ice strengthening/ice class relevant for year round operation. As these vessels will be the last vessels to leave the site, they should be designed for the worst ice condition expected to occur in the actual area.

Generally for vessels operating in areas where ice is present is that the vessel will try to find the easiest way through and avoid the heaviest ice and ridges. For a vessel located as a standby/support to an offshore unit, it will have to be present close to the unit all the time. This will require that the vessel should be defined for the worst case ice condition.

In case the offshore installation will require ice management, the supporting/ice management vessels will have to be designed with a higher ice class including ice breaking capability, i.e. an ice breaker notation. The evaluation of the possible need for ice management has to be considered separately for the actual operation where the different needs have to be considered.

The lowest Baltic ice classes only have some requirement to additional strengthening in the bow area, while the higher ice classes also have requirements to additional strengthening in the mid ship and stern area. A stand-by, rescue and oil recovery vessel will not only operate ahead with the bow first and hence a higher ice class should be considered. The additional strengthening mid-ships is manly included to avoid damages when exposed to sideways pressure from drifting ice.

If the operators will require to apply the same ice condition, as defined in NORSOK, for the vessels as for the offshore units, significant higher ice classed vessel will be required.

In the list of vessels, only KV Svalbard with a POLAR-10 notation will satisfy year round operation in the northern part of the area taking the worst probably ice conditions into consideration.

More detailed requirements to ice class depending on actual position/latitude should be studied more in detail by based on more detailed ice information and operation profile for the actual position.

7.4.3 IMO Polar Code requirements to ship structure

The goal of IMO Polar Code is to provide for safe ship operation and the protection of the polar environment by addressing risks present in polar waters and not adequately mitigated by other instruments of the Organization.

The code is a further development of previous issued voluntary guidelines which now has been developed further and will be mandatory.

The Code consists of an Introduction, part I and part II. The Introduction contains mandatory provisions applicable to both part I and part II. Part I is subdivided into part I-A, which contains mandatory provisions on safety measures, and part I-B containing recommendations on safety. Part II is subdivided into part II-A, which contains mandatory provisions on pollution prevention, and part II-B containing recommendations on pollution prevention.

According to the IMO Polar Code, the functional requirements to the scantlings of ice-going vessels “shall be designed to resist both global and local structural loads anticipated under the foreseen ice conditions”. The Code utilizes three Categories as thresholds for various requirements:

- Category A ship means ships designed for operation in polar waters at least in medium first-year ice, which may include old ice inclusions
- Category B ship means a ship not included in category A, designed for operation in polar waters in at least thin first-year ice, which may include old ice inclusions
- Category C ship means a ship designed to operate in open water or ice conditions less severe than those included in Categories A and B.

The scantlings of the different category ships shall “be approved by the Administration, or a recognized organization accepted by it, taking into account standards acceptable to the Organization or other standards offering an equivalent level of safety”.

In the draft Code, the “standards acceptable to the Organization” are generally referring to the IACS Unified Requirements for Polar Ships, and considers the ice classes PC1-PC5 applicable for Category A ships and PC6-PC7 applicable for Category B ships, respectively.

Ships with other ice classes than Polar Classes can be assigned a Polar Code category, but these vessels will need to be evaluated to confirm equivalency with the IACS strengthening and safety levels.

Except from KV Svalbard, all the NOFO vessels will fall in Category C.

Content of the Code, Part I - Safety measures

An extract of some of the main requirements from each chapter in the IMO Polar code are described below:

- A Polar Water Operational Manual has to be developed prior to polar operations
- The hull structure has to be evaluated in order to establish the equivalent IACS Polar Ice Class and ship category (A, B or C)
- The stability with ice accretion in intact condition has to be checked
- Means to prevent icing at doors and hatches shall be provided. Well documented operational procedures including the measures to be applied should be sufficient for this vessel.
- The part of the machinery installations which may be exposed to ice, icing and low temperatures have to be checked the avoid blockage of air and sea water intakes.
- A risk assessment for the actual operation shall be carried out
- Life Saving Appliances and Fire Fighting equipment to be reviewed in order to avoid problems with icing and freezing.
- Immersion suites to all passengers shall be provided and the life boats have to be partly or totally enclosed. Equipment for survival shall be provided for the minimum expected time of rescue. (Expected time of rescue is min 5 days)
- Mandatory to have equipment for receiving ice maps and weather forecast. The navigation equipment and systems shall retain their functionality under the expected environmental conditions.
- The vessel shall be able to communicate and send/receive data at all positions along the route. This also includes equipment for communication with/between life boats and rafts as well as equipment for transmitting distress calls.
- A detailed voyage plan has to be developed for the planned operation. Several functional requirements to the content are included in the Code.
- Masters, chief mates and officers in charge of a navigational watch shall be qualified in accordance with chapter V of the STCW Convention and Code

Content of the Code, Part II - Pollution prevention measures

This part is divided into five chapters with the same objective to prevent pollution. Generally the requirements include documentation of means to reduce and to the extent practicable prevent harmful impacts from oil, noxious liquids, harmful substances in packed form, sewage and garbage. The documentation shall include plans, manuals, records, procedures and means to avoid environmental impact.

7.4.4 Winterization

In addition to the possible ice in the northern part of the area, the temperatures will be low during the winter season and create challenges for the operation. In combination with low water temperature and wind, there will be periods with high probability for sea spray icing. Atmospheric icing can also be a problem under certain conditions, but the sea spray icing is expected to be the main challenge for the vessels going to support the offshore operations in the area during the winter season. As the vessel has to be present at given positions, the possibility to avoid the weather and reduce the icing by changing heading, speed etc. is limited.

In addition, the vessels have to be designed to avoid problems with the low temperatures, i.e. avoid freezing of liquids and water and sufficient heating where temperatures above freezing is required. Special attention has to be given to the firefighting equipment, rescue and oil recovery equipment.

The vessels going to operate in this area during the winter should be winterized to avoid the adverse impact from sea spray icing and low temperatures in general.

Some of the vessels have the old DEICE notation and some of the newer vessels have the present WINTERIZED notation.

A proper ice class and winterization should be minimum requirements for vessels going to be operated year around in the northern part of the area included in 23rd round.

For vessels only supporting summer operations, the actual condition has to be considered. If the summer operation is extended, some winterization and a proper ice class should be considered for the northernmost areas, as these vessels are the first to enter the area and the last to leave after a drilling operation. As presence of ice in these areas is limited, it is assumed that the summer season drilling period will include periods early in the season and late in the season with low temperatures. Hence a proper winterization to avoid freezing and negative effects from sea spray icing should be considered. Prior to the operation, an evaluation based on available meteorological data for the actual area should be carried in order to identify the need for winterization.

8 DISCUSSION AND RECOMMENDED ACTIONS

8.1 Discussion

A part of the scope in this project has been to collocate descriptions of relevant response measures, tactics and techniques relevant for cold climate and ice. Each of these topics is in fact comprehensive and complex topics in its own right, and the focus in this work has been set to a conceptual rather than technical level. For in-depth descriptions and discussions the reference list, including the recent results from the Arctic response technology JIP, should be consulted.

Obvious as it may seem, it should be emphasised that oil spill preparedness and response in cold weather and even in ice is not unique for the study area. Low temperatures represent in fact a normal condition for the NCS in wintertime. Presence of ice is in wintertime also quite normal in fjords at the mainland and in Svalbard. It should be noted that what in the existing literature often is described in general terms as e.g. harsh arctic conditions are quite normal conditions in Norwegian waters, which means that our responders and other involved parties generally have fundamental cold weather competence.

The response concepts addressed in this study comprises of both existing concepts and future concepts. These categories are not absolute as most of the tactics and technical components already exist, but are not implemented on NCS. In situ burning is in general the tactic with the least implementation and practice. Although often referred to as a key option in arctic conditions, this study indicates that ISB both in open water and in ice has a limited potential compared to mechanical recovery and dispersants. This is mainly due to the oil properties for the Skrugard oil, with relatively rapid water uptake that makes ignition a bottleneck. For open water emerging technologies with aerial operated herder application and ignition systems are promising. In a statistically possible, but not likely scenario for this location where a blowout occur close to or in ice, in situ burning can also represent an important and effective response measure. In general the ice specific options described in the multi-tool response concept should only be regarded as a supplementary resource to open water capacities.

The results from OSCAR modelling and the ORCA tool indicate quite clearly that mechanical recovery with active boom systems and dispersant application has the biggest potential. The concept of active boom systems are well established and proven in coastal waters, but to a less degree implemented in offshore preparedness. The obvious benefits of active boom systems are increased mobility and hence increased encounter rate and recovery rate in most situations. Other relevant benefits are the lack of need for a second towing vessel, and the relatively high manoeuvrability of the system. Potential weaknesses are clogging of ice, and also difficulty with getting rid of ice. Current systems are also not self-inflating, which requires manual handling during deployment. Freezing of valves can also be a week point. In comparison the passive boom systems have proven functional for a variety of conditions, also in the presence of ice. We believe active and passive boom systems can be supplementary in cold climate and ice, as both concepts have pros and cons. There is also a potential for further innovation and development in ice deflection to mitigate ice clogging.

As testing has revealed skimmers are likely to be affected if the boom is filled with slush or broken ice. The may lead to an interruption of the recovery operation in order to remove ice accumulations in the skimmer head with hot water (steam) or by reversing the pump direction. The reduced efficiency because of such interruption will be decided by ice concentrations and temperature. Anti-ice (glycol) used in key components will be necessary at low temperatures. The experiences actualize a winterization standard for oil spill response equipment, operational procedures and an associated training program.

The OSCA study indicates that dispersants have a significant potential both in cold weather conditions and in ice. Winterized solutions have been implemented in later years. Operationally, dispersant application requires a simpler, “one-way” supply chain compared to mechanical recovery, as the need for waste management is eliminated. With the standard set-up a vessel based dispersant system may be self-supported with dispersant fluid for around 2-3 days of operation depending on the scenario and conditions. After that, resupply of dispersants will be necessary, if the dispersing should continue. Currently there is no established concept for resupplying of dispersant fluid offshore, as the currently implemented concepts are based on resupplying the vessels by an onshore base. Dispersants are generally not a pre-planned response option for exploration drilling since the oil properties from a spill normally are not certain.

Aerial dispersant application is in comparison with vessel based concepts more sensitive to environmental conditions, especially darkness when aviation regulations generally prohibit dispersion operations. On the other hand it has an extended operational reach in a short time. The OSRL Boing 727 program is expected to represent a general improvement in this response concept, although operational details have currently not been announced. Dispersants are also effective in combination with mechanical recovery, both deployed from aerial platforms or vessels at sea level. To have the ability to perform both mechanical recovery and dispersion, in parallel or as subsequent strategies also increases the flexibility.

An objective in the project has been to document experiences from NOFO exercises in Finnmark during winter 2015 and the NOFO test in the marginal ice-zone in April 2015. The available documentation has provided valuable input to the work by documenting practical challenges, possibilities and limitations. It has also documented the diversity of conditions that can be expected, varying from benign to extreme conditions. Further testing and exercises should follow this project to gain more experience, and should include winter offshore conditions. This will further address challenges for currently existing equipment, both technical, operational and HSE related challenges. Logistics and supply-chains become increasingly important with longer distances to onshore bases. As a consequence oil spill logistics should be one of the focus areas in both exercises and preparedness planning for these areas.

In order to establish a structured and consensual approach to assumptions and basis for analysis for cold climate and ice, this project has established an approach and methodology that is applicable for the whole Barents Sea and adjacent areas due to a high resolution metocean dataset. This methodology enables quantitative assessments of system capacities for mechanical recovery, dispersants and in situ burning. The methodology is applicable in both open water and ice conditions, and combines system related factors, scenario related factors and metocean factors. The approach is transparent, flexible and comprehensive, but has its limitations compared to modelling. Still it provides a useful reference point when it comes to comparing the relative effectiveness of different systems and response measures as long as modelling of response effectiveness in ice is not possible.

Existing response resources (main equipment, depots/stockpiles) in Norway and internationally have been identified. For the defined scenarios we believe that existing resources from NOFO, NCA, OSRL and Russia will be key. GRN may also provide important expertise in extreme ice conditions. Related areas for improvement is, as mentioned earlier, is to establish winterization standard for oil spill response equipment, operational procedures and an associated training program.

Generally, there are no additional mandatory rules for vessels operating in the Barents Sea today. This will change from primo 2017 when the Polar Code is mandatory. The current number of OR vessels with ice class and winterisation is limited, and it should be prioritized to extend the number of suitable vessels.

Meteorological conditions in northern waters may present challenges for remote sensing: Quick changes of wind speed (aerostat) and reduced visibility (far more common in northern waters than further south). Autonomous solutions that do not expose personnel HSE challenges should be developed, which is the focus of the technology development program Commenced Oil spill in 2015. An increasing number of operational services are dependent on Internet communication. Vsat systems on ships have. 4G surrounding fields will improve this somewhat, but the oil spill response must adapt to the limitations VSAT provides through smart solutions: Systems that adapts to available bandwidth (Oil Spill Response 2015 project with Aptomar), use of App messaging and redundant solutions (Iridium) in case loss of VSAT. The established remote sensing systems such as Aptomar SECurus / TCMS, Rutter OSD and LN-KYV are proven concepts. Maritime Robotics OceanEye Aerostat represents a very good capacity, but precaution needs to be taken related to rapid shift in wind. Kongsberg Seatex digital downlink works well and will be able to function both as a transmission medium for information between devices locally, and transfer of information between aircraft and ships and from ship to shore via aircraft.

8.2 Recommended actions

Oil spill response is an area of constant improvement and development. In this study the focus is primarily conceptual rather than technical. Key areas for further development are:

- A proper ice class and winterization should be minimum requirements for vessels going to be operated year around in the northern part of the area included in 23rd licensing round. For vessels only supporting summer operations, the actual condition has to be considered.
- A winterisation standard for response equipment should be established. Response equipment needs as a minimum a defined set of operating procedures for cold climate and ice.
- Active boom systems for offshore conditions should be considered, as a supplement to existing containment and recovery systems.
- A template for spare parts and equipment for NOFO operations in northern waters should be prepared.
- A training program for oil spill operations in cold climate and ice should be established.
- Planning of logistical supply chains in remote offshore areas should be conducted well in advance of operations.
- More training, tests and exercises in cold climate and ice, including mid-winter offshore conditions should be conducted.

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APPENDIX

- Appendix A – Operational challenges for response tactics in cold climate and ice
- Appendix B - Operational limitations applied in the response gap analysis
- Appendix C - Overview of NOFO vessels
- Appendix D - Existing oil spill equipment

Appendix A
Operational conditions and challenges for response tactics

Mechanical recovery - Operational conditions and challenges

The basic challenge for mechanical recovery in a marine environment is that oil generally spreads quickly and form thin and broken slicks on the surface of the water. The main strategy for mechanical recovery is therefore to operate relatively close to the source of the spill, where high encounter rates are more likely than further away from the spill source.

In ice the spreading of oil may be reduced significantly, depending on the ice concentration, working to the potential benefit for mechanical recovery. But presence of ice will typically also complicate e.g. detection and accessibility, which may counteract these benefits. In conclusion the issue regarding low encounter rates seem to remain the fundamental challenge for mechanical recovery both in open water and in ice (Potter et al., 2012).

Wind, sea state and current

Combinations of these factors have major impacts on the spreading of oil, which as emphasized represents the fundamental challenge of mechanical recovery. Strong winds can also make it difficult to keep the vessels at correct position and towing speed, which e.g. may lead to loss of oil from booms. Wind can also make it difficult or unsafe to work on ship decks and manage the equipment, depending on the vessel (NUKA, 2010).

The effectiveness of mechanical recovery is generally sensitive to sea states. The booms ability to contain oil will generally decrease with more energy in the water, as the oil in higher sea states will start to submerge, resulting in more oil escaping under the boom. Wave action can also cause splashes over the boom, or result in a complete boom failure. Oil escaping from the boom will occur if towing speed or currents exceed 0.5 - 1 knots for conventional booms. The wave height, wave length and the wave pattern will give varying influence, with shorter or braking waves as the main challenge.

Low temperatures

When air temperatures drop below the freezing point, several operational and technical challenges occurs. The same applies for sea temperature. There is a potential for icing on vessels and recovery equipment due to water splash, fog or precipitation. The general operation of equipment becomes more difficult and skimmers and pumps may freeze. The oil viscosity will also increase which makes it more difficult to handle, including storage and transfer.

Ice coverage

Ice coverage or sea ice concentration normally describes the ice conditions in a larger area with ice floes from several meters up to several hundreds of meters in width. However, the type of ice is an equally important parameter with regards to oil spill. If there is a solid sheet of ice on the sea surface, the oil spill response will depend on whether the oil has been spilled on or under the ice. If there is only a partial ice cover on the sea surface, the response will be affected by the amount of coverage and the properties of the ice. The success of, for instance, mechanical recovery is dependent on whether there are pockets of ice-free water between the larger ice floes, or if these are filled with small pieces of ice or slush ice.

A conventional booming strategy can be the most effective in open water and ice concentrations up to 10 %, but could also be used with some effectiveness in concentrations up to 30 % especially by deflecting the ice with active ice management. A single vessel recovery skimming systems with short sections of boom attached to the sweep arms could manoeuvre between large ice floes and operate in higher ice concentrations than a conventional boom. If ice concentrations increase beyond 70 % the ice provides a barrier against oil spreading, and in dense ice, it will completely prevent oil from spreading and thinning out. This natural containment can be an advantage because the oil will tend to be concentrated in a smaller area in "pockets" that are more easily recovered than thin, widespread slicks. Furthermore, the presence of ice also modifies the wind-induced wave action at sea because short waves are damped by the presence of ice. In the absence of breaking waves, oil between ice floes will not weather as fast as it would do in open water where emulsified and weathered oil can have significantly higher viscosity.

The ice concentration will also influence operation of the skimmers. The most challenging conditions for skimmer operations are the presence of small ice floes and pieces of ice combined with slush ice. It is also necessary to handle low temperatures, and the skimmers should therefore be protected and/or heated to avoid freezing. In ice coverage up to 30 %, normal, open-water skimmers can be used, but with a risk of damage due to moving ice. If the ice coverage is between 30 % and 70 %, special ice skimmers are normally required. To facilitate movement among ice blocks, the skimmers should have their own propulsion system or the possibility to enhance movements by the crane of the supporting vessel.

The properties of the recovered oil are also an important factor. Specialized pumps and heating coils for storage tanks may be required to permit the recovered product to be removed.

Visibility

Reduced visibility due to darkness, fog, low clouds and blowing snow is generally a challenge, although modern technologies have reduced the impact considerably. Still, reduced visibility in combination with other factors may impose safety considerations and measures that limit the response operation.

Logistics & HSE

Mechanical recovery is a relatively logistic intensive tactic as it both depends on a logistical chain for the response systems and for the recovered oil. In contact with ice the boom fabric and the skimmers are relatively fragile and may be damaged or destroyed. Freezing temperatures also increase the vulnerability of e.g. hoses, valves and other components. In operations far from onshore bases it is important to bring sufficient reserves and gear to repair damages to reduce downtime. In order to reduce the specific impact from oil storage that can subsequently lead to downtime for the system it is important to reduce the amount of recovered water as much as possible. In cold climate it is also important that storage tanks are prepared in a way that avoids freezing in the tanks.

Dispersant - Operational conditions and challenges

Dispersant use can be an effective oil spill response option in many oil spill scenarios, but several considerations have to be made before dispersion is used:

- Expected effectiveness of the dispersant on the particular oil type and weathering degree
- Natural resources threatened by the drifting surface oil slick (e.g. bird/seal habitats)
- Natural resources affected by the dispersed oil plume before being diluted (e.g. fish eggs/larvae)

- Is the existing water depth and water circulation sufficient for rapid dilution of dispersed oil?

Wind, sea state and current

Waves are the driving force for the dispersion of dispersant-treated oil spills. When breaking waves are present, the crest of a breaking wave passing through a dispersant-treated oil slick possesses sufficient shearing action to convert the oil into small-sized droplets. Even a small vertical advection within the water column is sufficient to maintain the oil droplets in the water column and prevent the oil droplets from resurfacing. This process of natural dispersion can be enhanced by the adding of dispersants.

High waves and winds are thus favorable for the dispersion of oil in water; however they can pose safety risks for crew and equipment. High winds especially make it difficult to accurately spray dispersants and aerial spraying and monitoring will not be safe. Vessel based applications are mainly limited by high sea states.

Very low sea states on the other hand (as they can occur in ice infested waters) results in reduced mixing energy compared to open water, thereby reducing oil droplet formation. If dispersants are sprayed onto spilled oil from a vessel, mixing energy can be added by, e.g. the use of the vessel's propellers or the use of high pressure water systems. The intention of using additional energy after dispersant application is to create small oil droplets with a very low rising velocity, thus allowing the prevailing local currents to dilute the cloud of dispersed oil.

Low temperatures

Low temperatures do not inhibit dispersants effectiveness directly; however they increase the viscosity of the oil which limits effective dispersion. Dispersants remain effective for most unemulsified oils as long as the oil viscosity does not exceed 20,000cP and the pour point of the oil is lower than the ambient water temperatures (Belore et al., 2009). Current research is aimed at modifying dispersant formulations to increase their effectiveness on viscous oils. In particular, the development of a new "gelled" dispersant has been promising in increasing the time that the active ingredient in the dispersant remains in contact with the oil (Nedwed et al., 2011).

Ice coverage

The presence of ice modifies the wind induced wave action at sea; short waves are damped by the presence of ice, while long swells from open water persist in the outer regions of broken ice fields.

Thus, weathering processes of oil such as evaporation and emulsification are slowed down under cold temperatures and low wave action which on the one hand can lead to an increased window-of-opportunity (Daling et al., 2010). On the other hand, the energy input from breaking waves may be almost zero, and in cases like these, it will be necessary to enhance the dispersion process by adding extra mixing energy (e.g. by using small propeller boats or large azimuthal-driven icebreakers) (Daling et al., 2010).

Visibility

Low visibility will restricts the use of dispersants as it does for any of the other response techniques described earlier. Aerial application of dispersants requires good visibility and dispersants cannot be applied during darkness.

Logistics and HSE

A logistical benefit for chemical dispersants is that the treatment of oil happens In-situ, and that no capacity is needed for treated oil. Freezing temperatures may increase the vulnerability of e.g. hoses, valves and other components. In operations far from onshore bases it is important to bring sufficient reserves and gear to repair damages to reduce downtime. The main logistic issue is the resupply of dispersant fluid. Currently a significant volume of dispersant fluids are available in Norway and internationally, but no standard procedure exists for resupplying OR vessels with chemical dispersant off shore. Without resupply the tanks will eventually become empty (given a response of more than 2 – 4 days). For aircrafts the logistic issue is mainly about resupplying the airport. In Finnmark the main resource is Lakselv airport (Porsanger municipality) which according to NOFO is well suited for such operations.

In Situ Burning (ISB) - Operational conditions and challenges

Wind, sea state and current

ISB performed on open water with the use of fireproof booms and towing vessels face the same challenges as mechanical recovery e.g. tearing and movement of booms due to strong winds, or failing due to high waves and currents. The suitability of ISB depends on oil's initial characteristics (physical and chemical properties) and weathering state. Swell/waves and wind conditions are important factors for a successful burning (Buist et al., 1999).

A potential challenge for ISB is a successful ignition of the oil in windy conditions. Wind driven, short-period waves and currents can lead to reduction of flame spreading due to reduced film thickness and blending of cold, underlying oil. Usually it is not the combustion which pose a challenge, it is the ignition that becomes difficult or impossible at high winds (Allen, 2013).

However, once ignited ISB can be enhanced due to wind through transport of fresh oil to the fire. The maximum wind speed for successful ignition of large burns has been determined to be 10-12 m/s. High winds can also drive the smoke plume posing a risk for safety and health for workers and downwind sensitive areas. On the other hand, low winds (as little as 2 m/s) and currents can have the advantage that they can hold a slick against a barrier, such as the ice edge or a towed boom, thus thickening the oil for burning (Buist et al., 2013).

Due to the weight of materials used for fireproof booms, the weight per unit is generally much higher than for conventional booms. This results in lower wave thresholds.

Wind protection and shielding of the burn region (e.g. lee side of a large structure/vessel) can be a measure to deal with and reduce these limitations. In general, the application of ISB under high winds and rough sea states is often a safety issue, posing a high risk to the responders.

Low temperatures

Low temperatures in both air and on the sea surface are a general challenge for operative personnel. Low temperatures could also make the ignition of the oil difficult and oil may burn more slowly and less completely.

Ice coverage

ISB can be performed in various ice conditions, and as long as the oil slick is thick enough to be ignited, there are no limitations on ice coverage and ice type (Buist et al., 2013). The window of opportunity is generally extended for spills in ice affected conditions, compared with open water, due to decreased oil spreading and lower rates of emulsification (Sørstrøm et al., 2010).

In open water to approximately 30 % ice coverage the oil's spread and movement will not be greatly affected by the presence of ice and open water ISB techniques may be possible. Oil spills can spread and become too thin to ignite, requiring collection and thickening of the oil slick of oil with fireproof booms. Tests made during the SINTEF Oil in Ice JIP (Figure 3-6) have shown that fire resistant booms may also be used with good effect in low ice conditions, but is not considered feasible in higher ice concentrations (Potter and Buist, 2010). The use of specific chemical surface-active agents (oil herders) to contain oil slicks on open water has been previously studied. Small quantities of these surfactants (50 mg/m^2) will quickly clear thin films of oil from large areas of the water's surface, contracting the oil into thicker slicks (Buist et al., 2007).

In 30 to 70 % ice coverage, the ice will reduce the spreading and movement of the slick, but not completely containing the oil. Deployment and operation of booms in these ice concentrations are difficult. There might be situations were fire booms can be deployed at very low speeds or they can be manoeuvred between ice floes, permitting an effective concentration and burning of the oil (Buist et al., 2013).

In pack ice (70 – 90 % ice coverage) ice floes can contain the oil and slicks are often thick enough to be ignited. ISB is also considered as the best option of treating oil on top of solid ice or oil that pools on top of melting ice in the spring (Potter et al., 2012). Oil spilled in pack ice during break-up in spring will likely be easier to treat than during freeze-up conditions. In autumn, the sea ice is constantly freezing, which generates significant amounts of slush ice which can severely hamper containment. Thickening of slicks for burning and logistics become increasingly difficult with the onset of winter. In general, for larger oil spills in ice, helicopters deploying igniters would be used. For smaller spills, manual ignition could be employed (Potter et al., 2012).

For spills that occur under ice during freeze-up or during winter and oil which is encapsulated within the ice, the response technique is usually to track the oil through the winter months and to apply ISB when it appears on the surface again. In this case the response could be deferred for several months (S.L.Ross, 2011).

Visibility

Low visibility (due to fog, ceiling, precipitation, or darkness) generally impacts ISB for safety reasons. The ability to operate vessels, aircrafts, or other equipment needed to sustain operations and position is crucial and if visibility is too low operations have to be stopped. Solutions and adaptations to those challenges lie within the constant improvement of surveillance techniques.

Logistics & HSE

Main challenges of oil spills in ice for ISB are general logistical issues e.g. accessibility to the oil, operation and manoeuvrability within ice which requires successful ice-management. Also the use of a helitorch igniter system is regarded as a risk due to its flammability and a potential risk for the pilots of the aircraft. ISB of oil spills in remote areas pose a severe problem as remote ignition systems which are effective and safe are not in place yet.

Emulsification of oil

Emulsification of oil negatively affects in-situ ignition and burning, because of the uptake of water. Emulsion water contents are typically in the 60-80 % range. For weathered crude that has formed a stable water-in-oil emulsion, the upper limit for successful ignition is about 25 % water (Buist et al., 1999). The oil in the emulsion cannot reach a temperature higher than 100 °C until the water is either boiled off or removed. Further studies are needed on the emulsification of fuel oil, but it is known that the emulsification varies in summer and winter conditions and the properties of oil (viscosity). A two-step process is often applied to burn emulsions: "Breaking" of the emulsion, and boiling off the water (by the heat of the igniter) to form a layer of unemulsified oil floating on top of the emulsion slick; and subsequent combustion of this layer. Emulsion breakers, chemicals commonly used in the oil industry may also be applied. Compared to unemulsified slicks, emulsions are much more difficult to ignite, and once ignited, display reduced flame spreading and more sensitivity to wind and wave action. For stable emulsions, the burn rate declines significantly with increasing water content.

Burn residue

Although a number of scientific studies have confirmed that burn residues that remain after in-situ burning are less toxic than the original oil, burn residues can still have an ecological impact and should be removed from the marine environment if possible. Floating burn residue may be picked up with large strainers, nets or hand tools, sorbents or oil skimmers. The recovery of sinking burn residues is currently not a standard technique, but there are recommendations to suspend a net along the bottom of the containment boom to catch the residues as they begin to sink (NUKA, 2010).

Appendix B

Operational limitations applied in the response gap analysis

The following tables show the operational limitations set for each tactic:

Table A: Mechanical recovery

Table B: In-situ burning

Table C: Dispersant application

Table A - Limitations applied for mechanical recovery

	MECHANICAL RECOVERY WITH BOOMS			**MECHANICAL RECOVERY WITHOUT BOOMS**		
Environmental parameter	**Favorable**	**Impaired**	**Ineffective**	**Favorable**	**Impaired**	**Ineffective**
Wind W_s (m/s)	$W_s < 15$	$15 \leq W_s \leq 20$	$W_s > 20$	$W_s < 15$	$15 \leq W_s \leq 20$	$W_s > 20$
Significant wave height H_s (m); average wave period T_m (s)	$H_s < 3$ or $3 \leq H_s \leq 4$ *and* $T_m > 6$	$3 \leq H_s \leq 4$ *and* $T_m \leq 6$	$H_s > 4$	---(1)	---(1)	---(1)
Ice coverage	0-10 %	10-40 %	> 40 %		40-90 %	0-40 % *or* 90-100 %
Light conditions	Daylight	Darkness	---(2)	Daylight	Darkness	---(2)
Superstructure icing Ici_{rat} (cm/h)	$Ici_{rat} < 0,7$	$0,7 \leq Ici_{rat} \leq 2$	$Ici_{rat} > 2$	$Ici_{rat} < 0,7$	$0,7 \leq Ici_{rat} \leq 2$	$Ici_{rat} > 2$
Wind Chill T_{wc} (W/m^2)	$T_{wc} < 1000$	$1000 \leq T_{wc} \leq 1600$	$T_{wc} > 1600$	$T_{wc} < 1000$	$1000 \leq T_{wc} \leq 1600$	$T_{wc} > 1600$

(1) No wave data available for ice concentrations > 40 %

(2) Visibility and operational light conditions are considered as impaired only as lighting equipment and infrared sensors can be used to locate oil spills

Table B - Operational limitations applied for in-situ burning

Environmental parameter	IN-SITU BURNING WITH BOOM			IN-SITU BURNING WITHOUT BOOM		
	Favorable	Impaired	Ineffective	Favorable	Impaired	Ineffective
Wind W_s (m/s)	$W_s < 8$	$8 \leq W_s \leq 10$	$W_s > 10$	$W_s < 15$	$15 \leq W_s \leq 20$	$W_s > 20$
Significant wave height H_s (m); average wave period T_m (s)	$H_s < 1$	$1 \leq H_s \leq 1{,}8$	$H_s > 1{,}8$	---(1)	---(1)	---(1)
Ice coverage	0-40 %	40-70 %	> 70 %	70-100 %	40-70 %	0-40 %
Light conditions	Daylight	Darkness	---(2)	Daylight	Darkness	---(2)
Superstructure icing Ici_{rat} (cm/h)	$Ici_{rat} < 0{,}7$	$0{,}7 \leq Ici_{rat} \leq 2$	$Ici_{rat} > 2$	$Ici_{rat} < 0{,}7$	$0{,}7 \leq Ici_{rat} \leq 2$	$Ici_{rat} > 2$
Wind Chill T_{wc} (W/m^2)	$T_{wc} < 1000$	$1000 \leq T_{wc} \leq 1600$	$T_{wc} > 1600$	$T_{wc} < 1000$	$1000 \leq T_{wc} \leq 1600$	$T_{wc} > 1600$

1. No wave data available for ice concentrations > 40 %

2. Visibility and operational light conditions are considered as impaired only as lighting equipment and infrared sensors can be used to locate oil spills

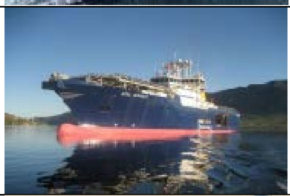
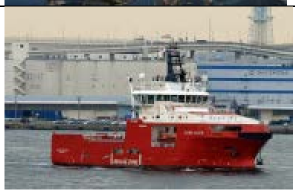
Table C - Operational limitations applied for application of dispersants

Environmental parameter	DISPERSANTS APPLICATION BY SHIP			DISPERSANTS APPLICATION BY AIRCRAFT		
	Favorable	Impaired	Ineffective	Favorable	Impaired	Ineffective
Wind W_s (m/s)	$W_s < 15$	$15 \leq W_s \leq 20$	$W_s > 20$	$W_s < 15$	$15 \leq W_s \leq 20$	$W_s > 20$
Significant wave height H_s (m); average wave period T_m (s)	$H_s \leq 5$		$H_s > 5$	$0{,}3 \leq H_s \leq 5$	$H_s < 0{,}3$	$H_s > 5$
Ice coverage	0-40 %	40-70 %	> 70 %	0-10 %	10-40 %	> 40 %
Ceiling				> 300m		≤ 300m
Light conditions	Daylight	Darkness	---(2)	Daylight	Darkness	---(2)
Superstructure icing Ici_{rat} (cm/h)	$Ici_{rat} < 0{,}7$	$0{,}7 \leq Ici_{rat} \leq 2$	$Ici_{rat} > 2$	-	-	-
Wind Chill T_{wc} (W/m^2)	$T_{wc} < 1000$	$1000 \leq T_{wc} \leq 1600$	$T_{wc} > 1600$	$T_{wc} < 1000$	$1000 \leq T_{wc} \leq 1600$	$T_{wc} > 1600$

Appendix C

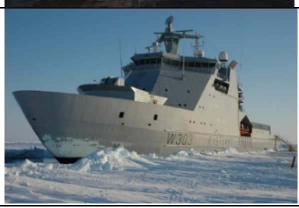
Overview of NOFO vessels

The table below shows the vessels included in the NOFO fleet today. The table also include KV Svalbard. The two columns to the right show if the vessels have an ice class or a WINTERIZED notation.

Name/Location	Picture of vessel	Class Notations	Ice Class	Winterize
Esvagt Aurora – c/s OYPV2 ENI – Goliat		1A1 Fire fighter(I, II) Standby vessel(S) Tug BIS Clean(Design) COMF(V-3) DEICE-C DYNPOS(AUTR) E0 HL(2.5) Ice(1C) NAUT(OSV(A)) OILREC SF Winterized(Basic) Built 2012	X	X
Stril Poseidon – c/s LMDC Statoil - Haltenbanken		1A1 Fire fighter(I, II) Tug Clean COMF(V-3) DYNPOS(AUTR) E0 HELDK(H, S) OILREC SF Built 2003		
Stril Herkules – c/s LAJD Statoil - Tampen		1A1 Fire fighter(II, I+) Standby vessel Tug Clean(Design) COMF(V-3) DYNPOS(AUTR) E0 HELDK(H, S) OILREC SF Built 2008		
Ocean Alden - c/s 3YAG GdFSuez - Gjøa		BV I + Hull + MAC, Clean Ship Super AWT, STBY- and Supply vessel, Tug, DP II, SDS damage stability, AUT UMS, FIFI 1, Water Spray, SYS-NEQ-1, Oilrec and NOFO 2500, ROV. Built 2011 in China		
Havila Troll – c/s LMKL Statoil – Troll/Oseberg		1A1 Fire fighter(I, II) Tug Clean COMF(C-3, V-3) DYNPOS(AUTR) E0 HELDK(H, S) OILREC SF Built 2003		
Esvagt Stavanger - c/s OYGC2 Statoil – Troll/Oseberg		1A1 Fire fighter(I+) Standby vessel Tug BIS Clean(Design) COMF(V-3) DYNPOS(AUTR) E0 HL(2.5) NAUT(OSV(A)) OILREC SF TMON Built 2012		
Stril Power - c/s LINO ExxonMobil – Balder/Jotun		1A1 Fire fighter(II) Supply vessel Tug DK(+) DYNPOS(AUTR) E0 Ice(C) OILREC SF Built 1997	X	

Esvagt Bergen - c/s OYCI2 Statoil – Sleipner/Volve		1A1 Fire fighter(I+) Standby vessel Tug BIS Clean(Design) COMF(V-3) DYNPOS(AUTR) E0 HL(2.5) NAUT(OSV(A)) OILREC SF TMON Built 2011		
Stril Mariner - c/s OZ2083 BP – Ula/Gyda		1A1 Fire fighter(I+) Clean(Design) COMF(V-3) DK(+) DYNPOS(AUTR) E0 HL(2.8) LFL(*) NAUT(OSV(A)) OILREC SF Built 2009		
Skandi Hugen – c/s LEJI CoPNo – Ekofisk		1A1 Offshore service vessel SPS Standby vessel Clean(Design) COMF(V-3) DK(+) DYNPOS(AUTR) E0 HL(2.8) NAUT(OSV(A)) OILREC SF Built 2013		
Stril Merkur – c/s 9HA2720 Statoil - Avløserfartøy		1A1 Fire fighter(II, I+) Standby vessel Tug Clean(Design) COMF(V-3) DYNPOS(AUTR) E0 HELDK(H, S) OILREC SF Built 2011		
Stril Barents – c/s LDMA ENI – PSV Goliat/Hammerfe st		1A1 Fire fighter(I, II) Offshore service vessel(Supply) Clean(Design) COMF(V-3) DK(+) DYNPOS(AUTR) E0 Gas fuelled HL(2.8) Ice(C) LFL(*) NAUT(OSV(A)) OILREC SF TMON Winterized(Basic) Built 2015	X	X
Viking Avant - c/s LMSZ Statoil - Hammerfest		1A1 Standby vessel Clean COMF(V-3) Container DEICE-C DK(+) DYNPOS(AUTR) E0 HL(2.5) Ice(C) LFL(*) OILREC SF Built 2004	X	(X)
Island Chieftain – c/s LALR BP - Sandnessjøen		1A1 Supply vessel(Basic) Clean(Design) COMF(V-3) DK(+) DYNPOS(AUTR) E0 HL(2.8) Ice(C) LFL(*) NAUT(OSV(A)) OILREC SF Built 2009	X	
Olympic Energy - c/S 3YWS Statoil - Kristiansund		1A1 Clean(Design) COMF(V-3) DK(+) DYNPOS(AUTR) E0 Gas fuelled HL(2.8) Ice(C) LFL(*) NAUT(OSV(A)) OILREC SF Built 2012	X	
Skandi Mongstad – c/s LALP Statoil - Mongstad		1A1 Fire fighter(II) Standby vessel(S) Supply vessel Tug Clean(Design) COMF(C-3, V-3) DK(+) DYNPOS(AUTR) E0 HL(2.8) LFL(*) OILREC SF Built 2008		

Siem Symphonie – c/s LCKH Total - Stavanger		1A1 Fire fighter(II) Offshore service vessel(Supply) Standby vessel(S) BIS Clean(Design) COAT-PSPC COMF(C-3, V-3) DK(+) DYNPOS(AUTR) E0 Gas fuelled HL(2.8) LFL(*) NAUT(OSV(A)) OILREC SF Built 2014		
Viking Queen – c/s LNAB Lundin Stavanger		1A1 Fire fighter(II) Supply vessel Clean(Design) COMF(V-3) DK(+) DYNPOS(AUTR) E0 Gas fuelled HL(2.8) Ice(C) LFL(*) OILREC SF Built 2008	X	
Torsborg - c/s OZ2130 BG - Kristiansund		1A1 Clean(Design) COMF(C-3, V-3) DK(+) DYNPOS(AUTR) E0 HL(2.8) LFL(*) NAUT(OSV(A)) OILREC SF Built 2012	X	
Rem Fortress – c/s LCOR Shell - Kristiansund		1A1 Standby vessel(S) Clean(Design) COMF(C-3, V-3) DK(+) DYNPOS(AUTR) E0 HL(2.8) Ice(C) LFL(*) NAUT(OSV(A)) OILREC SF Built 2011	X	
Troms Arcturus – c/s LKNL Statoil - Kristiansund		1A1 Clean(Design) COMF(C-3, V-2) DK(+) DYNPOS(AUTR) E0 HL(2.8) Ice(C) LFL(*) NAUT(OSV(A)) OILREC SF Winterized(Basic) Built 2014	X	X
Skandi Gamma – c/s LCML Statoil - Kristiansund		1A1 Standby vessel Clean(Design) COMF(C-3, V-3) DK(+) DYNPOS(AUTR) E0 ESV(DP[HIL]) Gas fuelled HL(2.8) LFL(*) NAUT(OSV(A)) OILREC SF Built 2011		
NS Orla – c/s LEKK Dong - Stavanger		1A1 Offshore service vessel(+, Supply, Towing) BIS Clean(Design) COMF(C-3, V-3) DK(+) DYNPOS(AUTR) E0 F(A, M) HL(2.8) LFL(*) NAUT(OSV(A)) OILREC SF VIBR Built 2014		
Far Serenade – c/s LAQC Statoil - Mongstad		1A1 Supply vessel(Basic) Clean(Design) COMF(V-3) DK(+) DYNPOS(AUTR) E0 HL(2.8) Ice(C) LFL(*) NAUT(OSV(A)) OILREC SF Built 2009	X	
Energy Swan – c/s LFUR Wintershall – Mongstad		1A1 Clean COMF(V-3) DK(+) DYNPOS(AUTR) E0 HL(2.8) Ice(C) LFL(*) OILREC SF Built 2005	X	

Havila Foresight – c/s JWQD Statoil - Mongstad		1A1 Supply vessel Clean COMF(V-3) DK(+) DYNPOS(AUTR) HL(2.8) LFL(*) NAUT(OSV(A)) OILREC SF Built 2008		
Stril Luna – c/s LEHE Statoil - Stavanger		1A1 Offshore service vessel(Supply) Standby vessel BWM(T) Clean(Design) COMF(C-3, V-2) DK(+) DYNPOS(AUTR) E0 HL(2.8) Ice(1C) LFL(*) NAUT(OSV(A)) OILREC SF Winterized(Basic) Built 2014	X	X
Strilmøy – c/s LMYV ExxonMobil - Stavanger		1A1 Clean COMF(V-3) DK(+) DYNPOS(AUTR) E0 HL(2.0,2.8) LFL(*) OILREC SF Built 2005		
Stril Orion – c/s 3YUU Det Norske - Stavanger		1A1 Clean(Design) COMF(C-3, V-3) DK(+) DYNPOS(AUTR) E0 HL(2.8) Ice(C) LFL(*) NAUT(OSV(A)) OILREC SF Built 2011	X	
Stril Mermaid – c/s LGVY Det norske - Stavanger		1A1 Fire fighter(I) Clean(Design) COMF(V-3) DK(+) DYNPOS(AUTR) E0 HL(2.8) LFL(*) NAUT(OSV(A)) OILREC SF Built 2010		
Island Challenger – c/s LALR Talismann - Stavanger		1A1 Supply vessel(Basic) Clean COMF(V-3) DK(+) DYNPOS(AUTR) E0 HL(2.8) LFL(*) NAUT(OSV(A)) OILREC SF Built 2007		
KV Svalbard		Polar-10 Icebreaker DEICE	X	X

Oljevernfartøy i NOFO-pool Barriere 1 og 2 Pr. 01.06.2015

Ankerfisk – c/s LHAG		
Asbjørn Selsbane – c/s LDGP		
Arnøytind – c/s LJZH		
Bøen – c/s LJSY		
Cetus – c/s LLYM		
Gularøy – c/sLIQO		
Hovden Viking – c/s JWLM		

Krossøy – c/s LIZI		
Kvitungen – c/s LGPZ		
Lise-Beate - c/s LLYL		
Meløyfjord – c/s 3YUG		
Piraja – c/s LMTJ		
Segla – c/s LLZL		

Toya – c/s LK8222		
Vestbris – c/s LMCW		
Vestviking – c/s JXAM		
Willassen - LDIW		
RS 110 Reidar von Koss		
RS 111 Peter Henry von Koss		

RS 115 Ulabrand III	
RS 113 Erik Bye	
RS 114 Bergen Kreds	
RS 125 Det Norske Veritas	
RS 126 Harald V	
Rs 132 Gjert Wilhelmsen	

RS 136 Halfdan Grieg		
RS 137 Kristian Gerhard Jebsen		

APPENDIX D

Existing oil spill equipment

Resporces at Svalbard, Coast Guard and NCA vessels

Depot	Utstyrsbetegnelse	Kapasitet	Utstyrstype	Utstyrsundertype	Antall
Kystverket Svalbard	Lenser Lett		NOFI 250EP 4x25m i pakkramme		4 stk
Kystverket Svalbard	Lenser Lett		NOFI 350EP 4x25m I pakkramme		7 stk
Kystverket Svalbard	Lenser Lett		NO 35 F 4x25m I pakkramme		8 stk
Kystverket Svalbard	Lenser-T/M		Expandi 4300 152 m på pall		2 stk
Kystverket Svalbard	Lenser-T/M		NOFI 500EP 100m i container		4 stk
Kystverket Svalbard	Lenser-T/M		Current Buster 4		1
Kystverket Svalbard	Lett lensesystem		Current Buster 2		1
Kystverket Svalbard	Absorberende lenser		med skjørt		1200 m
Kystverket Svalbard	Absorberende lenser		uten skjørt		450 m
Kystverket Svalbard	Oljeopptaker	30 m3	Uniskim Multiskimmer 30		2 stk
Kystverket Svalbard	Oljeopptaker		Lamor LWS 500 m/børste/skive		1 stk
Kystverket Svalbard	Oljeopptaker		Desmi Terminator	Overløpsskimmer	1 stk
Kystverket Svalbard	Oljeopptaker		Foxtail VAB 4-9	I trsp.cont	1 stk
Kystverket Svalbard	Oljeopptaker		Foxtail VAB 2-9	I trsp.cont	1 stk
Kystverket Svalbard	Oljeopptaker		Foxtail VAB 2-6	I trsp.cont	2 stk
Kystverket Svalbard	Pumper		Rabbit P265 brannpumpe		1 stk
Kystverket Svalbard	Pumper		Elro slangepumpe		1 stk
Kystverket Svalbard	Oljecontainer	10 kbm	Unibag		3 stk
Kystverket Svalbard	Oljecontainer	25 kbm	Unibag/Oilbag		1stk
Kystverket Svalbard	Hydraulikk aggregat	39kw Fast	Henriksen 150-110-D		1 stk
Kystverket Svalbard	Hydraulikk aggregat	26kw Fast	Henriksen 140-90-D		1 stk
Kystverket Svalbard	Hydraulikk aggregat	26kw Fast	Henriksen 120-60-D		1 stk
Kystverket Svalbard	Hydraulikk aggregat	35 kw Fast	Lamor LPP-35L		1 stk
Kystverket Svalbard	Kjøretøy		Løfteåk for gaffeltruck		1 stk
Kystverket Svalbard	Nødlossepakke for bunkersoljer		Nødlossepakke for bunkersoljer		1 stk
Kystverket Svalbard	Strandrens		Barkspreder	Foxblower	1 stk
Kystverket Svalbard	Akuttfase strand		Container 1		1 stk
Kystverket	Akuttfase strand		Container 2		1 stk

Svalbard					
Kystverket Svalbard	Akuttfase strand		Container 3		1 stk
Kystverket Svalbard	Akuttfase strand		Container 4		1 stk
Kystverket Svalbard	Strandrens		Barkspreder	Melbu Oilfighter	1 stk
Depot	**Utstyrsbetegnelse**	**Kapasitet**	**Utstyrstype**	**Utstyrsundertype**	**Antall**
Kystverket Svalbard	Strandrens		Nilfisk Alto. Dieseldrevet		1 stk
Kystverket Svalbard	Strandrens		Oljebark	Absorbent	927 sekk
Kystverket Svalbard	Diverse		Dregger: 5x36 kg, 5x25m tau		5 sett
Kystverket Svalbard	Diverse		Expandi pakkemaskin	for E4300	1 stk
Kystverket Svalbard	Diverse		Karmkasse	Liten utgave	3 stk
Kystverket Svalbard	Diverse		Prøvetakingskoffert		1 stk
Kystverket Svalbard	Personlig verneutstyr				50 sett
Kystverket Svalbard	Vaskestasjon			mobil for personell	2 stk
Sysselmannen, Longyearbyen	Båter	2 x 1560 HK 71,6 m	M/S Nordsyssel	Isgående (mai-desember)	1 stk
Sysselmannen, Longyearbyen	Båter	140 HK 21 ft	Vaktbåt (Polarcirkel)	Eier SMS	1 stk
Sysselmannen, Longyearbyen	Båter	130 HK 19 ft	Fjordtor 1 (Polarcirkel)	Eier SMS	1 stk
Sysselmannen, Longyearbyen	Båter	130 HK 19 ft	Fjordtor 2 (Polarcirkel)	Eier SMS	1 stk
Sysselmannen, Longyearbyen	Båter	130 HK 19 ft	Fjordtor 3 (Polarcirkel)	Eier SMS	1 stk
Sysselmannen, Longyearbyen	Båter	40 HK 3,7 meter	Zodiac	Eier SMS	5 stk
Sysselmannen, Longyearbyen	Helikopter		Super Puma	Airlift AS	2 stk
Sysselmannen, Longyearbyen	Beltevogn				2 stk
KV Svalbard	Lenser T/M		Expandi 4300	430 mm fribord, selvoppblåsende	304 m
KV Svalbard	Oljeopptaker		Foxtail VAB 2-6	VAB Oil Skimmer. 2 bånd à 6 tommer	1 stk
KV Svalbard	Lagrings tank	25 m3	Unibag		2 stk
KV Svalbard	AIS Drivbøye			4950A AAnderaa	1 stk
KV Svalbard	Karmkasse		Stor utgave		1 stk
KV Svalbard	Prøvetakingskoffert				1 stk
KV Svalbard	Oljedeteksjonsradar				1 stk
KV Harstad	Tunge lenser		NO 800 R 300m på trommel	m/krysshanefot innfestning	1 stk
KV Harstad	Mellomtunge lenser		Expandi 4300 152m på pall		2 stk
KV Harstad	Oljeopptaker		Foxtail VAB 4-9	VAB Oil Skimmer. 4 bånd à 9 tommer	1 stk
KV Harstad	Oljeopptaker		Trans Rec 125 Hi Visk		1 stk
KV Harstad	Pumpe		TK 150 lossepumpe	For lasteolje	1 stk
KV Harstad	Lagrings tank	1116 m3	tank		1 stk

KV Harstad	Lagrings tank	25 m3	Unibag		1 stk
KV Harstad	AIS drivbøye			4950A-AAnderaa	1 stk
KV Harstad	Doppler log system			4900 Aanderaa	1 stk
KV Harstad	Karmkasse		Stor type		1 stk
KV Harstad	Oljedeteksjonsradar				1 stk
KV Harstad	Prøvetakingskoffert				1 stk
Depot	**Utstyrsbetegnelse**	**Kapasitet**	**Utstyrstype**	**Utstyrsundertype**	**Antall**
KV Barensthav	T/M lenser		NO-800-R 152m på trommel	m/krysshanefot innfestning	1 stk
KV Barentshav	T/M lenser		Expandi 4300 152 m på trommel		2 stk
KV Barensthav	Oljeopptaker		NORMar 200TI		1 stk
KV Barentshav	Oljeopptaker		Foxtail VAB 4-9	I transportcontainer	1 stk
KV Barensthav	Tankkapasitet	1075 m3			
KV Barentshav	AIS drivbøye			4950A-Aanderaa	1 stk
KV Barentshav	Doppler Log System			4900 Aanderaa	1 stk
KV Barentshav	Havarisett			MIKO	1 stk
KV Barentshav	Karmkasse		Stor type		1 stk
KV Barentshav	Oljedeteksjonsradar			Rutter	1 stk
KV Barentshav	Prøvetakingskoffert				1 stk
KV Sortland	T/M lenser		NO-800-R 300m på trommel	m/krysshanefot innfestning	1 stk
KV Sortland	T/M		Expandi 4300 152m på på pall		2 stk
KV Sortland	Oljeopptaker		NORMar 200		1 stk
KV Sortland	Oljeopptaker		Foxtail VAB 4-9	i transportcontainer	1 stk
KV Sortland	Tankkapasitet	1075 m3			
KV Sortland	AIS drivbøye			4950A-Aanderaa	1 stk
KV Sortland	Doppler Log System			4900 Aanderaa	1 stk
KV Sortland	Havarisett			MIKO	1 stk
KV Sortland	Karmkasse		Stor type		1 stk
KV Sortland	Oljedeteksjonsradar			Rutter	1 stk
KV Sortland	Prøvetakingskoffert				1 stk
MS Polarsyssel	Mellomtung lense	300 m	EP 350		1 stk
MS Polarsyssel	Oljeopptaker		Foxtail VAB 4-9	VAB Oil Skimmer.	1 stk
MS Polarsyssel	Oljeopptaker	40 m^3	Foxtail		1 stk
MS Polarsyssel	Tankkapasitet	1500 m^3			
MS Polarsyssel	IR Kamera				1 stk
NSO Crusader	Pumpe	50 m^3/h	Flugt		1 stk
NSO Crusader	Tankkapasitet	1000 m^3			
NSO Crusader	Oil Detection Radar.				1 stk
NSO Crusader	Securs IR system				1 stk
NSO Crusader	Light Salvage package				1 stk
Beta	Pumpe	50 m^3/h	Flugt		1 stk

Beta	Tankkapasitet	1000 m^3			
Beta	Oil Detection Radar.				1 stk
Beta	Securs IR system				1 stk
Beta	Light Salvage				1 stk
Depot	**Utstyrsbetegnelse**	**Kapasitet**	**Utstyrstype**	**Utstyrsundertype**	**Antall**
OV Skomvær	Lenser T/M	152m	Expandi 4300		2 stk
OV Skomvær	Lenser	200m	NO 450S		1 stk
OV Skomvær	Opptaker		Lamor Bucket Skimmer	LRB 150W	1 stk
OV Skomvær	Opptaker		Foxtail VAB 4-9	VAB oil skimmer	1 stk
OV Skomvær	Opptaker		Lamor	LORS D4C	1 stk
OV Skomvær	Tankkapasitet	160 kbm			
OV Skomvær	AIS drivbøye			4950A-Aanderaa	1 stk
OV Skomvær	Doppler log system			4900 Aanderaa	1 stk
OV Skomvær	Havarisett		MIKO		1 stk
OV Skomvær	Karmkasse		Stor utgave		1 stk
OV Skomvær	Securus IR		Dagslyskamera		1 stk
OV Skomvær	Oljedeteksjonsradar		Rutter		1 stk
OV Skomvær	Prøvetakingskoffert				1 stk
OV Utvær	Lenser T/M	152m	Expandi 4300		2 stk
OV Utvær	Lenser	200m	NO 450S		1 stk
OV Utvær	Opptaker		Lamor Bucket Skimmer	LRB 150W	1 stk
OV Utvær	Opptaker		Foxtail VAB 4-9	VAB oil skimmer	1 stk
OV Utvær	Opptaker		Lamor	LORS D4C	1 stk
OV Utvær	Tankkapasitet	160 kbm			
OV Utvær	AIS drivbøye			4950A-Aanderaa	1 stk
OV Utvær	Doppler log system			4900 Aanderaa	1 stk
OV Utvær	Havarisett		MIKO		1 stk
OV Utvær	Karmkasse		Stor utgave		1 stk
OV Utvær	Securus IR		Dagslyskamera		1 stk
OV Utvær	Oljedeteksjonsradar		Rutter		1 stk
OV Utvær	Prøvetakingskoffert				1 stk
Svea	Mellomtunge lenser		Ro-Boom 1500	Ledelense	350 m
Svea	Lette lenser		Ro-Boom 200		300 m
Svea	Oljeopptaker		Desmi Terminator	Belteskimmer, på taubåten	1 stk
Svea	Lagrings tank	10 m3	Unibag		1 stk
Svea	Lagrings tank	25m3	Ro-tank m/slepesett	På taubåten	1 stk
Svea	Lagrings tank	40m3	Tank m/slepesett	På taubåten	1 stk
Svea					
Svea.Store Norske/LNSS	Lette lenser		Havnelense,		300 m
Svea.Store Norske/LNSS	Lette lenser		Ledelense Ro-boom 1500		600 m
Svea.Store Norske/LNSS	Lagrings tank	6 tonn	Portable tank		2 stk
Svea.Store	Lagrings tank	10m3	Lagrings tanker 10m3		30 stk

Norske/LNSS					
Svea.Store Norske/LNSS	**Lagrings tank**	**100 l**	**Polypropylene big bags**		**10 stk**
Svea.Store Norske/LNSS	**Lagrings tank**	**10m3**	**Fleksibel flytende lagrinsbag**		**1 stk**
Svea.Store Norske/LNSS	**Pumper**		**Sjøvannspumpe BGM 5 m/tilbehør**		**2 stk**
Svea.Store Norske/LNSS	**Personlig verneutstyr**		**Personlig verneutstyr**		**15 sett**
Depot	**Utstyrsbetegnelse**	**Kapasitet**	**Utstyrstype**	**Utstyrsundertype**	**Antall**
Svea.Store Norske/LNSS	**Absorbenter**		**Oljebark 50.ltr sekker**		**300 stk**
Svea.Store Norske/LNSS	**Båter**		**20', fritidsbåter**		**4 stk**
Svea.Store Norske/LNSS	**Båter**		**arbeidsbåter**		**2 stk**
Svea.Store Norske/LNSS	**Pumper, (Sigyn og Bonden)**		**Desmi Dop-160,**	**screw off loading pump**	**1 stk**
Svea.Store Norske/LNSS	**Båt (på Sigyn og Bonden)**		**MP-741 Springer mob.båt, vannjet**	**Beredskapsbåt**	**1 stk**
Ny-Ålesund	**Lette lenser**		**NO35 F**	**34cm fribord m/fast flytelegeme**	**300 m**
Ny-Ålesund	**Båter**	**375 HK**	**aluminumsbåt**	**Kings Bay AS**	**1 stk**
Ny-Ålesund	**Båter**	**100 HK**	**PVC**	**Kings Bay AS**	**1 stk**
Ny-Ålesund	**Båter**	**40 HK**	**aluminumsbåt**	**Velferden**	**1 stk**
Ny-Ålesund	**Båter**	**40 HK**	**aluminumsbåt**	**Velferden**	**1 stk**
Ny-Ålesund	**Båter**	**40 HK**	**aluminumsbåt**	**Velferden**	**1 stk**
Barentsburg	**Absorberende lenser**		**BL-BOM 20/25/12,5**	**200 mm, 200 m med skjørt**	**400 m**
Barentsburg	**Oljeopptaker**		**NORMar Multi**		**1 stk**
Barentsburg	**Lette lenser**		**NO35F**	**35cm fribord m/fast flytelegeme**	**400 m**
Barentsburg	**Båter**		**Polarcirkel 760**		**1 stk**
Barentsburg	**Oljeopptaker**		**NorMar 15**	**multiskimmer**	**1 stk**
Barentsburg	**Diverse**		**fortøyningssett**		**16 stk**
Barentsburg	**Personlig verneutstyr**		**Personlig verneutstyr**		**10 sett**

Resources available from depots in Norway

Depot	Utstyrsbetegnelse	Kapasitet	Utstyrstype	Utstyrsundertype	Antall
Kystverket Vadsø	Lenser-T/M	300m på trommel	Norlense NO-800R		1 stk
Kystverket Vadsø	Lenser-T/M	200m på trommel	NO 450 S		1 stk
Kystverket Vadsø	Lenser-T/M	152m på pall	Expandi 4300	selvoppblåsende.	4 stk
Kystverket Vadsø	Lenser-T/M	10	Current Buster 4	10' container.	1 stk
Kystverket Vadsø	Lenser-T/M	5	Current Buster 2	10' container m/paravan	1 stk
Kystverket Vadsø	Lette lenser		NOFI 350EP	4x25 m i pakkramme	3 stk
Kystverket Vadsø	Diverse		Expandi Pakkemanskin	for EP 4300	1 stk
Kystverket Vadsø	Olje opptagere	9	Foxtail VAB 2-6	adhesjons skimmer	1 stk
Kystverket Vadsø	Olje opptagere		KLK402	Trommelskimmer	1 stk
Kystverket Vadsø	Olje opptagere	30	Desmi	Overløpsskimmer	1 stk
Kystverket Vadsø	Olje opptagere		KLK602/Foxdrum	m/transportcontainer	1 stk
Kystverket Vadsø	Olje opptagere		Lamor LWS 500	m/børste/skive	1 stk
Kystverket Vadsø	Olje opptagere		Foxtail VAB 2-6	m/transportcontainer	1 stk
Kystverket Vadsø	Absorberende lenser		med skjørt		1850 m
Kystverket Vadsø	Absorberende lenser		uten skjørt		1200 m
Kystverket Vadsø	Pumper		Rekord/Vogelsang R 120		1 stk
Kystverket Vadsø	Pumper	20	Elro-Honda slangepumpe	Bensin	1 stk
Kystverket Vadsø	Spylepumpe		Rabbit P265M	Brannpumpe.	1 stk
Kystverket Vadsø	Kjøretøy		Løfteåk for gaffeltruck		1 stk
Kystverket Vadsø	Hydraulikk		Henriksen 150-110-D 39kW Fast	Diesel	1 stk
Kystverket Vadsø	Hydraulikk		Henriksen 120-60-D 26 kW Fast	Diesel	1 stk
Kystverket Vadsø	Hydraulikk		Lamor LPP-35L 35kW Fast		2 stk
Kystverket Vadsø	Hydraulikk		Rexroth 50kW Fast		1 stk
Kystverket Vadsø	Strømaggregat		Honda E2500 Bensindrevet		2 stk
Kystverket Vadsø	Oljecontainer	$25m^3$	Container 25m3	Unibag/Oilbag	1 stk
Kystverket Vadsø	Oljecontainer	$10m^3$	Container $10m^3$	Desmi RO-tank	2 stk
Kystverket Vadsø	Båt	80	Arb.båt	Rana 20	1 stk
Kystverket Vadsø	Dregger		Oppankringsutstyr	5x36kg,5x25m tau	3 sett
Kystverket Vadsø	Diverse		Grabb for operasjon i kran		1 stk
Kystverket Vadsø	Diverse		Karmkasse, liten		3 stk
Kystverket Vadsø	Diverse		Prøvetakingskoffert		1 stk
Kystverket Vadsø	Strandrens		Akuttfase Strand - Container 1	10-fots akuttfase strandutstyr	1 stk
Kystverket Vadsø	Strandrens		Akuttfase Strand - Container 2	10-fots akuttfase strandutstyr	1 stk

Kystverket Vadsø	Strandrens		Akuttfase Strand - Container 3	10-fots akuttfase strandutstyr	1 stk
Kystverket Vadsø	Strandrens		Akuttfase Strand - Container 4	10-fots akuttfase strandutstyr	1 stk
Kystverket Vadsø	Strandrens		Barkspreder	Foxblower	1 stk
Depot	Utstyrsbetegnelse	Kapasitet	Utstyrstype	Utstyrsundertype	Antall
Kystverket Vadsø	Strandrens		Barkspreder	Melbu Oilfighter	1 stk
Kystverket Vadsø	Strandrens		Nilfisk Alto.	Dieseldrevet	1 stk
Kystverket Vadsø	Strandrens		Absorbent	Oljebark	1576 sekker
Kystverket Vadsø	Nødlosse utstyr		Nødlossepakke for bunkersolje		1 stk
Kystverket Hammerfest	Lenser-T/M	300m lagret på trommel	Norlense NO- 800 - R		1 stk
Kystverket Hammerfest	Lenser-T/M	200m lagret på trommel	NO-450S		1 stk
Kystverket Hammerfest	Lenser-T/M	$10m^3$	Current Buster 4		1 stk
Kystverket Hammerfest	Lenser-T/M	$5m^3$	Current Buster 2		1 stk
Kystverket Hammerfest	Lette lenser		NOFI 350 EP 4x24m	Fast flytelegeme, i pakkramme	3 stk
Kystverket Hammerfest	Oljeopptagere	30	Foxtail VAB 4-9	Vertikal Adhesjon Band	1 stk
Kystverket Hammerfest	Oljeopptagere	9	Foxtail VAB 2-6	Vertikal Adhesjon Band	3 stk
Kystverket Hammerfest	Oljeopptagere		KLK402	Trommelskimmer	1 stk
Kystverket Hammerfest	Oljeopptagere		Uniskim Multiskimmer 30	Multiskimmer	1 stk
Kystverket Hammerfest	Oljeopptagere	40m3/time	Lamor Minimax 40	Børsteskimmer	1 stk
Kystverket Hammerfest	Oljeopptagere		KLK 602 / Foxdrum m/ trsp.cont	Multiskimmer	1 stk
Kystverket Hammerfest	Oljeopptagere		Lamor LWS 500 m/ børste/skive	Multiskimmer	1 stk
Kystverket Hammerfest	Oljeopptagere		Desmi Terminator. Skive/børste	Multiskimmer	1 stk
Kystverket Hammerfest	Oljeopptagere		Desmi Terminator. Overløp	Overløpskimmer	1 stk
Kystverket Hammerfest	Pumper		Rabbit P265 Brannpumpe		1 stk
Kystverket Hammerfest	Pumper		Elro-Honda slangepumpe	Bensindrevet.	1 stk
Kystverket Hammerfest	Pumper		Honda WB20XT	Spylepumpe	1 stk
Kystverket Hammerfest	Kjøretøy		Toyota 7FBMF25. El.drift. 2,5t		1 stk
Kystverket Hammerfest	Kjøretøy		Toyota 7FDF45. Dieseldrevet		1 stk
Kystverket Hammerfest	Kjøretøy		Løfteåk for gaffeltruck		1 stk
Kystverket Hammerfest	Diesel Hydraulikk aggregate	60	Henriksen 120-60-D 26 kW Fast		1 stk
Kystverket Hammerfest	Diesel Hydraulikk aggregate	40	Henriksen 150-200-D 53kW Fast		1 stk
Kystverket Hammerfest	Diesel Hydraulikk aggregate	19	Markleen DHPP 40kW		1 stk
Kystverket Hammerfest	Diesel Hydraulikk aggregate	9	Markleen DHPP 60kW		1 stk
Kystverket	Diesel Hydraulikk	53	Lamor LPP-35L		1 stk

Hammerfest	aggregate		35kW Fast		
Kystverket Hammerfest	Diesel Hydraulikk aggregate		Rexroth 50kW Fast		1 stk
Kystverket Hammerfest	Båt		Arbeids/insp.båt	T650KYV 22ft	1 stk
Kystverket Hammerfest	Båt		GB Cat arbeidkatamaran	m/ kran	1 stk
Kystverket Hammerfest	Oljecontainer	25 m3	Unibab / oilbag		1 stk
Depot	**Utstyrsbetegnelse**	**Kapasitet**	**Utstyrstype**	**Utstyrsundertype**	**Antall**
Kystverket Hammerfest	Oljecontainer	1000 liter	IBC-container		2 stk
Kystverket Hammerfest	Oljecontainer	10 m3	Desmi RO-tank		1 stk
Kystverket Hammerfest	Dregger		Oppankringsutstyr	5x36kg, 5x25m tau	6 sett
Kystverket Hammerfest	Diverse		Karmkasse, liten		3 stk
Kystverket Hammerfest	Diverse		Prøvetakingskoffert		1 stk
Kystverket Hammerfest	Diverse		Expandi Pakkemanskin	for EP 4300	1 stk
Kystverket Hammerfest	Strandrens		Akuttfase Strand - Container 1	10-fots akuttfase strandutstyr	1 stk
Kystverket Hammerfest	Strandrens		Akuttfase Strand - Container 2	10-fots akuttfase strandutstyr	1 stk
Kystverket Hammerfest	Strandrens		Akuttfase Strand - Container 3	10-fots akuttfase strandutstyr	1 stk
Kystverket Hammerfest	Strandrens		Akuttfase Strand - Container 4	10-fots akuttfase strandutstyr	1 stk
Kystverket Hammerfest	Strandrens		Barkspreder	Foxblower	1 stk
Kystverket Hammerfest	Strandrens		Barkspreder	Melbu Oilfighter	1 stk
Kystverket Hammerfest	Strandrens		Nilfisk Alto.	Dieseldrevet	1 stk
Kystverket Hammerfest	Strandrens		Absorbent	Oljebark	1152 sekker
Kystverket Hammerfest	Strømaggregat		Honda E2500 Bensindrevet		2 stk
Kystverket Hammerfest	Nødlossing		Nødlossepakke for bunkersolje		1 stk
Kystverket Tromsø	Lenser-T/M	300m på trommel	Norlense NO-800R		1 stk
Kystverket Tromsø	Lenser-T/M	152m på pall	Expandi 4300		3 stk
Kystverket Tromsø	Lenser-T/M	200m på trommel	NO-450S		1 stk
Kystverket Tromsø	Lenser-T/M		NOFI 500 EP	50cm fribord	4 stk
Kystverket Tromsø	Lenser-T/M	10m3 tank	Current Buster 4		1 stk
Kystverket Tromsø	Lenser-T/M	5m3 tank	Current Buster 2		1 stk
Kystverket Tromsø	Lette lenser		NOFI 350 EP	4x25m i pakkramme	3 stk
Kystverket Tromsø	Absorberende lenser		Abs. lense med skjørt		850 m
Kystverket Tromsø	Absorberende lenser		Abs. lense uten skjørt		1600m
Kystverket Tromsø	Oljeopptagere	30	Foxtail VAB 4-9	Adhesjon	2 stk
Kystverket Tromsø	Oljeopptagere		Foxtail VAB 2-6	Adhesjon	1 stk
Kystverket Tromsø	Oljeopptagere		Sandvikband	Transportbånd	1 stk
Kystverket Tromsø	Oljeopptagere		KLK 602	Trommelskimmer	1 stk

Kystverket Tromsø	Oljeopptagere		KLK 402	Trommelskimmer	2 stk
Kystverket Tromsø	Oljeopptagere		Desmi Terminator. Belte		1 stk
Kystverket Tromsø	Oljeopptagere		Desmi Terminator.	Overløpskimmer	2 stk
Kystverket Tromsø	Oljeopptagere	65	Foilex TDS 200	Overløpskimmer	2 stk
Kystverket Tromsø	Oljeopptagere		Lamor LWS 500 m/ børste/skive	Multiskimmer	1 stk
Kystverket Tromsø	Pumper		Rabbit P265 Brannpumpe		1 stk
Kystverket Tromsø	Pumper	20	Elro-Honda slangepumpe	Bensindrevet.	1 stk
Depot	**Utstyrsbetegnelse**	**Kapasitet**	**Utstyrstype**	**Utstyrsundertype**	**Antall**
Kystverket Tromsø	Pumper		Rekord/Vogelsang R120		1 stk
Kystverket Tromsø	Kjøretøy		Løfteåk for gaffeltruck		1 stk
Kystverket Tromsø	Kjøretøy	El.drift.2,5 ton	Toyota 7FBMF25.		1 stk
Kystverket Tromsø	Kjøretøy		Caterpillar	V120/140 Diesel	1 stk
Kystverket Tromsø	Kjøretøy		Akuttfase strand	Container 6	1 stk
Kystverket Tromsø	Diesel Hydraulikk	39kwF	Henriksen 150-110-D 39kW Fast		1 stk
Kystverket Tromsø	Diesel Hydraulikk		Henriksen 120-60-D 26 kW Fast		1 stk
Kystverket Tromsø	Diesel Hydraulikk	53kwF	Henriksen 150-200-D 53kW Fast		1 stk
Kystverket Tromsø	Diesel Hydraulikk		Lamor LPP-35L 35kW Fast		1 stk
Kystverket Tromsø	Oljecontainer	10m3	Desmi RO-Tank		2 stk
Kystverket Tromsø	Oljecontainer	25m3	NOFI oljelekter 25kbm		1 stk
Kystverket Tromsø	Båt		Arbeids/insp.båt Rana 20ft	påhengsmotor	1 stk
Kystverket Tromsø	Dregger		Oppankringsutstyr	5x36kg, 5x25m tau	5 sett
Kystverket Tromsø	Diverse		Karmkasse, liten		3 stk
Kystverket Tromsø	Diverse		Prøvetakingskoffert		1 stk
Kystverket Tromsø	Diverse		Expandi Pakkemanskin	for EP 4300	1 stk
Kystverket Tromsø	Diverse		Mooring 500kg		10 sett
Kystverket Tromsø	Diverse		Grabb for operasjon i kran		1 stk
Kystverket Tromsø	Strandrens		Akuttfase Strand - Container 1	10-fots akuttfase strandutstyr	1 stk
Kystverket Tromsø	Strandrens		Akuttfase Strand - Container 2	10-fots akuttfase strandutstyr	1 stk
Kystverket Tromsø	Strandrens		Akuttfase Strand - Container 3	10-fots akuttfase strandutstyr	1 stk
Kystverket Tromsø	Strandrens		Akuttfase Strand - Container 4	10-fots akuttfase strandutstyr	1 stk
Kystverket Tromsø	Strandrens		Barkspreder	Foxblower	1 stk
Kystverket Tromsø	Strandrens		Barkspreder	Melbu Oilfighter	2 stk
Kystverket Tromsø	Strandrens		Nilfisk Alto.	Dieseldrevet	1 stk
Kystverket Tromsø	Strandrens		Absorbent	Oljebark	1000 sekker
Kystverket Tromsø	Strandrens	20 ft	Bekledningscontainer		1 stk
Kystverket Tromsø	Strømaggregat		Honda E2500		2 stk

			Bensindrevet		
Kystverket Tromsø	Nødlosse utstyr		Nødlossepakke for bunkersolje		1 stk
NOFO Hammerfest	Tunge lenser		NOFO system		6 stk
NOFO Hammerfest	Mellomtunge lenser		Current Buster 4	m/Paravan	3 stk
NOFO Hammerfest	Dispergeringsmiddel		Dascic Slickgone NS		53m3
NOFO Sandnessjøen	Tunge lenser		NOFO system		2 stk
NOFO Sandnessjøen	Mellomtunge lenser		Current Buster 4	m/Paravan	3 stk
NOFO Kristiansund	Tunge lenser		NOFO system		2 stk
NOFO Kristiansund	Mellomtunge lenser		Current Buster 4	m/Paravan	3 stk
NOFO Kristiansund	Dispergeringsmiddel		Dascic Slickgone NS		52m3
NOFO Mongstad	Tunge lenser		NOFO system		2
Depot	**Utstyrsbetegnelse**	**Kapasitet**	**Utstyrstype**	**Utstyrsundertype**	**Antall**
NOFO Mongstad	Mellomtunge lenser		Current Buster 4		3
NOFO Mongstad	Dispergeringsmiddel		Dascic Slickgone NS		70m3
NOFO Stavanger	Tunge lenser		NOFO system		2
NOFO Stavanger	Mellomtunge lenser		Current Buster 4	m/Paravan	3
NOFO Stavanger	Dispergeringsmiddel		Dascic Slickgone NS		92m3
OB Haltenbanken	Tunge lenser		NOFO system		1
OB Haltenbanken	Dispergeringsmiddel		Dascic Slickgone NS		52m3
Barentshavet	NOFO system		NOFO system		1
Barentshavet	Dispergeringsmiddel		Dascic Slickgone NS		50m3
Hammerfest	Dispergeringsmiddel		Dascic Slickgone NS		50m3
Gjøa	Tunge lenser		NOFO system		1
Gjøa	Dispergeringsmiddel		Dascic Slickgone NS		45m3
Statoil Avløserfartøy	Tunge lenser		NOFO system		1
Statoil Avløserfartøy	Dispergeringsmiddel		Dascic Slickgone NS		33m3
Tampen	Tunge lenser		NOFO system		1
Tampen	Dispergeringsmiddel		Dascic Slickgone NS		62m3
Troll-Oseberg II	Tunge lenser		NOFO system		
Troll-Oseberg II	Dispergeringsmiddel		Dascic Slickgone NS		48,5m3
Troll-Oseberg I	Tunge lenser		NOFO system		
Troll-Oseberg I	Dispergeringsmiddel		Dascic Slickgone NS		46m3
OB Balder	Tunge lenser		NOFO system		1
OB Balder	Dispergeringsmiddel		Dascic Slickgone NS		60m3
Sleipner/Volve	Tunge lenser		NOFO system		1
ULA/Gyda/Tamber	Tunge lenser		NOFO system		1
ULA/Gyda/Tamber	Dispergeringsmiddel		Dascic Slickgone NS		33m3
Ekofisk	Tunge lenser		NOFO system		1
Stavanger	Dispergeringsmiddel		Dascic Slickgone NS		18m3

Main Oil recovery equipment from the state contingency system in Murmansk:

Type	Quantity
Mobil oil recovery vessels:	
m/v «Spasatel Kavdeykin»	1
m/v "Kapitan Martyshkin"	1
m/v “Viktor Petrov”	1
m/v "Markab"	1
m/v ”Agat”	1
Booms:	
Expandi 4300	243m
NOAS KL-8D	400m
NOAS XF-11	400m
Ro-Boom 2000	1000m
Ro-Boom 3500	1200m
BPP-1100	4085m
BPP- 830	1000m
BPP-1100(Fi-Fi)	100m
Sorbent booms(for land)	270m
Ro-Sweep	2x52m
Ro-Boom 1500	500m
Expandy 1500	243
Elastec Velboom 1500	200
PL-1000/35	1
Skimmers:	
Foxtail 4-9	1
Foxtail 2-6	1
Desmi 250	2
Transrec skimmer-250	1
Transrec skimmer-350	3
Desmy-Minimax	3
Walosep W-2	2
Desmy Polar Bear	2
Desmy Helix	2
ElastecTDS136	1
Framo (TK-5, TK-8)	2
Other:	
Dispersant system	1
Sorbent (Vermikulit)	250kg
Sorbent (Vivant)	100kg
Sorbent (Sorbonaft)	2500kg

Gas detector	3
Ro-Clean cleaning system	1
Ro-Set	1
Portable VHF Furuno Fm-55	12
Motorboat	3
Portable container 1cb.m cpst	4
Ro-Tank 25	8
Ro-Tank 25	2

About DNV GL

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