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Technical sub-report 3: Impact Assessment

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The Greater North Sea and its wider approaches is one of the busiest and most highly used maritime areas in the world. With the ever-increasing competition for space comes an increased risk of accidents that could result in marine pollution.

Currently the area has no overall risk assessment for marine pollution; risk is mapped with a variety of national risk assessments which are undertaken with differing methodologies; thus reducing comparability.

The BE-AWARE project is therefore undertaking the first area-wide risk assessment of marine pollution using a common methodology that allows the risk to be mapped and compared under different scenarios.

The project outcomes will be sub regional risk management conclusions, which will identify priority future risk reduction and response scenarios for each sub region, oil impact and damage assessments and a region wide environmental and socioeconomic vulnerability analysis.

The project is a two year initiative (2013-2015), co-financed by the European Union (DG ECHO), with participation and support from the Bonn Agreement Secretariat, Belgium, Denmark, France, Germany, Ireland, the Netherlands, Norway, Sweden and the United Kingdom.

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1. Summary

In the present report, the results of the oil drift model and the impact model are given. In the BE-AWARE I project, the distribution of accidents throughout the Bonn Agreement area was calculated. Along with the accident distribution, the likelihood of oil spills at these accident locations was also calculated. The first step of the risk assessment process in BE-AWARE II was on the modelling of the drift, fate, and oil recovery of these spills. This was included in the process of calculating the impact of oil, i.e. the area affected by the oil spills. The method used in BE-AWARE II is given in the Method Note, (BE-AWARE, 2015b).

Oil impact distribution mapping was one of the significant outcomes of the BE-AWARE project, which allows the Bonn Agreement Contracting Parties to see the most critical areas with respect to oil impact and on this basis enabling them to make decisions about the future focus of risk reducing measures and emergency response. In Figure 1-1 the oil impact distribution is given. The impact is given as *g oil/km²* and it expresses the amount of oil from accidental spills that on average is present in each km² of the North Sea. The average amount of oil includes contributions from all kinds of spills, including small spills that occur relatively often as well as large spills that occur relatively rarely. In addition, different oil types and accident types are included.

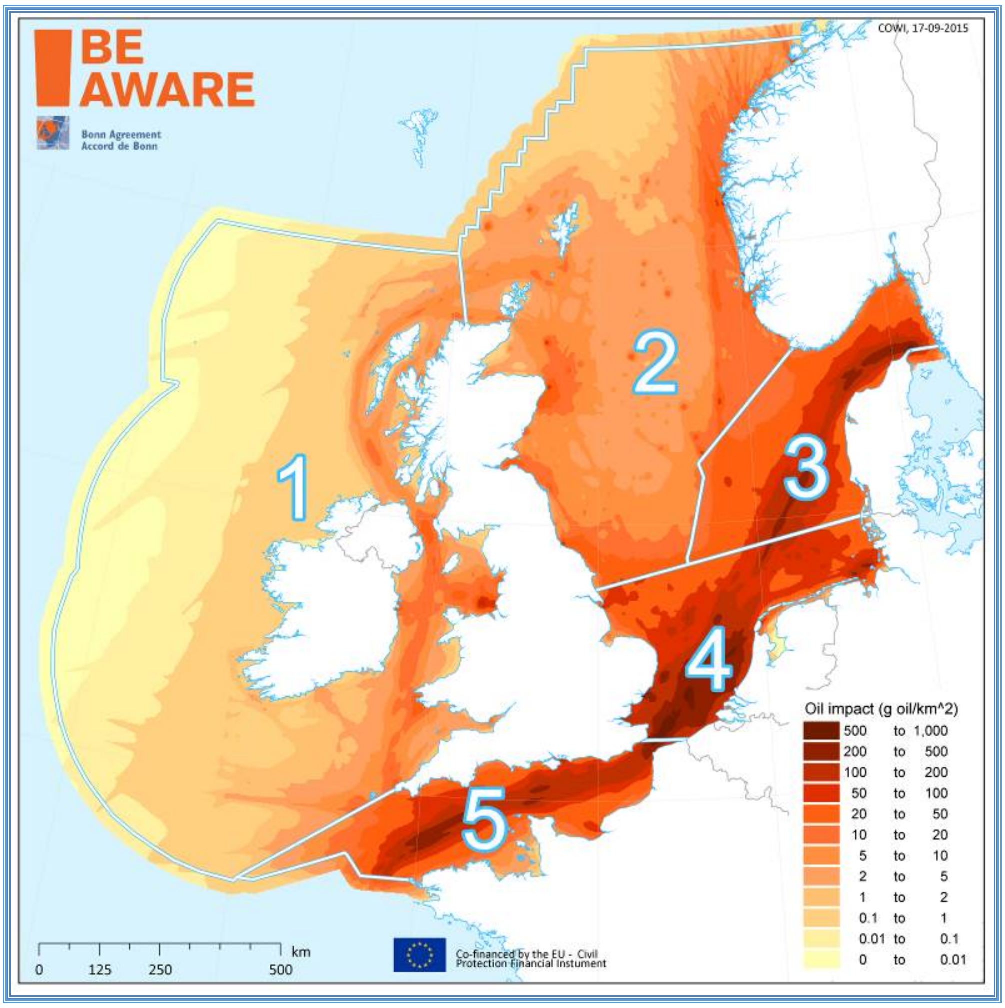


Figure 1-1 Base scenario 2020: Oil impact (on water)

In Table 1-1 the probability distribution of oil in the regional waters and on the coastline in the region for the base scenario is given.

Table 1-1 Oil impact in the sub-regions – Base case

Base Scenario	Region 1	Region 2	Region 3	Region 4	Region 5
Oil on coast [t]	39,00	137,73	70,15	158,84	78,43
Oil on water [t/y]	1,25	3,20	8,33	14,97	7,68
Dispersed oil in water [t/y]	0,18	0,41	0,00	1,38	1,54

By combining the oil impact maps with the environmental and socioeconomic vulnerability maps, (BE-AWARE, 2015d), the combined environmental and socioeconomic damage was calculated, i.e. the damage that the oil impact gives rise to in a specific area. Due to the diverse vulnerabilities seen in the Bonn Agreement area, the damage maps are somewhat different from the oil impact maps. For example the highest vulnerabilities are seen in the German Bight and Wadden Sea, and due to this, these areas have the highest damage, although the greatest oil impact is along the main shipping routes.

The damage maps enabled the Contracting Parties to evaluate current response based on a one-parameter approach that included a wide range of features. By introducing the single parameter damage approach the results of the impact analysis became clear, unambiguous and directly comparable. This made it possible to carry the damage results further in the analysis and base the risk management conclusions and the cost-benefit analysis on them. The damage map for the base case (used as reference for the different scenarios) can be seen in Figure 1-2.

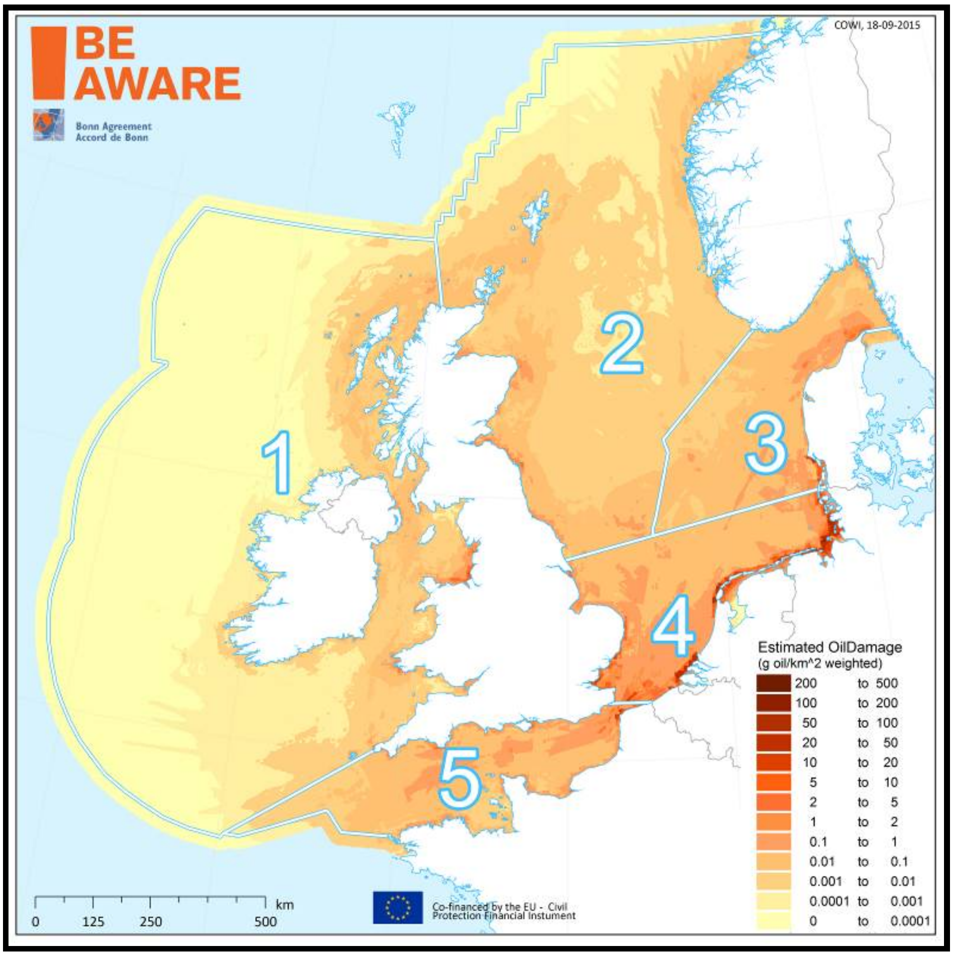


Figure 1-2 Base scenario 2020: Oil damage

The clear differences seen between Figure 1-1 and Figure 1-2 indicate the large variations found in the Bonn Agreement area within the environmental and socioeconomic vulnerabilities. Less vulnerable areas, e.g. far from shore, typically get less damage relative to the oil impact, and highly vulnerable areas, such as the Wadden Sea, show more damage relative to the oil impact.

In Table 1-2 below the damage index integrated within each sub-region is given.

Table 1-2 Damage index in the sub-regions – Base case

Base Scenario	Region 1	Region 2	Region 3	Region 4	Region 5
Damage index [Non-dimensional]	8969	9393	20068	194383	20781

The non-dimensional damage number is a function of the oil impact, summarised in Table 1-1, and the environmental and socioeconomic vulnerability. The summation of damage in region 1 and 2 are comparable in size. The summation of damage in region 3 and 5 are also comparable but twice the size of region 1 and 2. Region 4 is the high-risk area with a damage index approximately 10 times higher than the results from region 3 or 5.

These regional differences in severity should be taken into consideration when looking at the full Bonn Agreement Area. A number of scenarios were run to test various risk reducing measures and oil spill response measures. The purpose of the scenario runs was to test the effect of these measures in relation to the base case scenario. The comparison parameters were oil impact (on the surface as well as in the water column), amount of oil on shore and environmental and socioeconomic damage. These results fed into the risk management conclusions report where the effect and the cost were evaluated and recommendations on possible future measures were given.

An overview of the various scenarios is given in Table 1-3.

Table 1-3 Scenario overview

Scenario name	Risk Reducing Measure	Response Measure
Vessel Traffic Services (VTS)	X	
Traffic Separation Schemes (TSS)	X	
AIS alarm (Wind turbines)	X	
E-navigation	X	
New Emergency Towing Vessels (ETVs)	X	(X)[1]
Improved night detection capability		X
Further use of dispersants		X
50% increase in response equipment		X

The results were summed up per sub-region in order to make it possible to conclude on the effectiveness in the different regions. This was essential as the regions were different with respect to traffic, vulnerability and response equipment and the effect of the individual scenarios reflected this. The outcome of the analysis was given per sub-region on this basis. The results in terms of oil impact are listed below:

[1] The ETV has emergency towing capability that could prevent an accident from escalating and response equipment for responding to a spill event, and is therefore listed under both categories.

Table 1-4 Effect of the scenario on the amount of oil in water compared to the base case

Oil on water - effect					
Scenario	Region 1	Region 2	Region 3	Region 4	Region 5
VTS	-0,19%	-3,12%	-30,95%	-21,70%	-0,86%
TSS	-0,34%	-5,20%	-51,84%	-3,06%	0,00%
AIS Alarm	-0,79%	-0,18%	-0,95%	-2,79%	-0,34%
E-navigation	-25%	-25%	-25%	-25%	-25%
ETV in Ireland	-1,78%	0,00%	0,00%	0,00%	-0,02%
Night vision	-0,73%	-0,09%	-0,44%	-1,06%	-1,30%
Dispersants	-1,01%	-0,06%	3,73%	6,35%	3,01%
+50% resp.	-1,19%	-1,22%	-1,73%	-2,01%	-1,78%

Table 1-5 Effect of the scenario on the amount of oil on the coast compared to the base case

Oil on coast - effect					
Scenario	Region 1	Region 2	Region 3	Region 4	Region 5
VTS	-0,27%	-0,63%	-27,56%	-14,87%	-3,43%
TSS	-0,40%	-0,20%	-31,09%	-0,97%	-0,01%
AIS Alarm	-0,33%	-0,05%	-0,45%	-1,16%	-0,62%
E-navigation	-25%	-25%	-25%	-25%	-25%
ETV in Ireland	-2,10%	0,00%	0,00%	0,00%	0,00%
Night vision	-0,85%	-0,07%	-0,13%	-0,53%	-0,50%
Dispersants	-0,64%	-0,03%	-5,82%	-3,86%	-3,73%
+50% resp.	-1,14%	-1,23%	-1,06%	-1,20%	-0,83%

Table 1-6 Effect on dispersed oil in the water column compared to the base case

Dispersed oil in water column - effect					
Scenario	Region 1	Region 2	Region 3	Region 4	Region 5
VTS	0,00%	-0,14%	-19,49%	-27,11%	-0,70%
TSS	0,00%	0,00%	0,00%	0,00%	0,00%
AIS Alarm	-0,61%	-0,15%	-0,13%	-0,72%	-0,14%
E-navigation	-25%	-25%	-25%	-25%	-25%
ETV in Ireland	-0,09%	0,00%	0,00%	0,00%	0,00%
Night visibility	0,00%	0,00%	0,00%	0,00%	0,00%
Dispersants	43,66%	59,61%	1428[2]	292,77%	119,50%
+50% response	0,00%	0,00%	0,00%	0,00%	0,00%

[2] Given as a factor and not a percentage. The dispersants only scenario gives high figures as dispersants are not currently used in region 3 and the chemically dispersed oil in the base case therefore is limited spill over effects from other regions.

The impact of the scenario on the damage, i.e. including both the environmental and socioeconomic features is given below:

Table 1-7 Effect of the scenario on the damage in the region compared to the base case

Damage effect					
Scenario	Region 1	Region 2	Region 3	Region 4	Region 5
VTS	-0,17%	-1,28%	-26,58%	-10,74%	-3,18%
TSS	-0,26%	-1,04%	-41,62%	-2,82%	-0,01%
AIS Alarm	-1,74%	-0,26%	-1,31%	-1,61%	-0,31%
E-navigation	-25%	-25%	-25%	-25%	-25%
ETV in Ireland	-1,63%	0,00%	0,00%	0,00%	-0,01%
Night visibility	-1,25%	-0,09%	-0,22%	-0,94%	-0,71%
Dispersants	1,45%	3,10%	32,80%	15,12%	27,07%
+50% response	-1,68%	-1,34%	-1,97%	-1,91%	-1,29%

Large variations in the effectiveness of the different scenarios were seen in the various regions. Some of the scenarios were primarily introduced in one or two regions; the effect elsewhere was therefore very limited as this was only caused by the difference in the amount of oil drifting into the region. I.e. the ETV in Ireland reduces very slightly the amount of damage cause by oil in region 5 by reducing the amount of oil from region 1 drifting into region 5. Other scenarios were more generic and e.g. linked to the intensity of the traffic, and this again caused a great variation based on the variations in the traffic intensity.

2. Introduction

2.1 Background

The Greater North Sea and its wider approaches is one of the busiest and most highly used maritime areas in the world. Currently the area has no overall risk assessment for marine pollution and risk is mapped with a variety of national risk assessments, which are undertaken with differing methodologies, thus reducing comparability.

In 2010, the Bonn Agreement recognised the need for an area-wide risk assessment and the associated benefits (Bonn Agreement Dublin Declaration). The Bonn Agreement Secretariat, in collaboration with Bonn Agreement Contracting Parties, undertook the BE-AWARE I and II projects with part funding from the EU Civil Protection Mechanism, to achieve this aim.

The BE-AWARE I project (2012-2014), assessed the risk of oil pollution both now (2011) and in the future (2020) and the likely size of any spills. However in order to assess which methods and technologies will be most effective in reducing and responding to oil pollution further analysis were required.

The BE-AWARE II project was a two year initiative (2013-2015), co-financed by the European Union (DG ECHO), Ireland, the Netherlands and Germany, with participation from the Bonn Agreement Secretariat, Belgium, Denmark, France, Germany, Ireland, the Netherlands, Norway, Sweden and the United Kingdom.

2.2 Content and structure of report

This report describes the results of the impact assessment of oil spills carried out as part of the BE-AWARE II project. The analysis covers the North Sea, the Skagerrak, the English Channel, the Irish Sea and the waters west of Scotland and Ireland, in the report termed the BA area.

The structure of the report is as follows:

Chapter 3 outlines the methodology used for the impact assessment.

In chapter 4 the results of the oil impact analysis are given. The drift, fate and recovery are taken into account to calculate the period during which the oil from each spill point and size has been in each cell. This produces a probability distribution for the area giving the likelihood of having oil present in each cell.

The results of the damage analysis are given in chapter 5. Here the oil impact given in chapter 4 was combined with the ecological and socioeconomic vulnerability from (BE-AWARE, 2015d) to give a one-parameter damage result. This was the amount of damage that the oil impact distribution gave rise to, along with the impact distribution, this was a key parameter for determining how future response should be planned.

2.3 Regional division

The project area was divided into 5 areas to enable separate conclusions to be drawn based on the different results for the areas. The regional division is given in Figure 2-1.

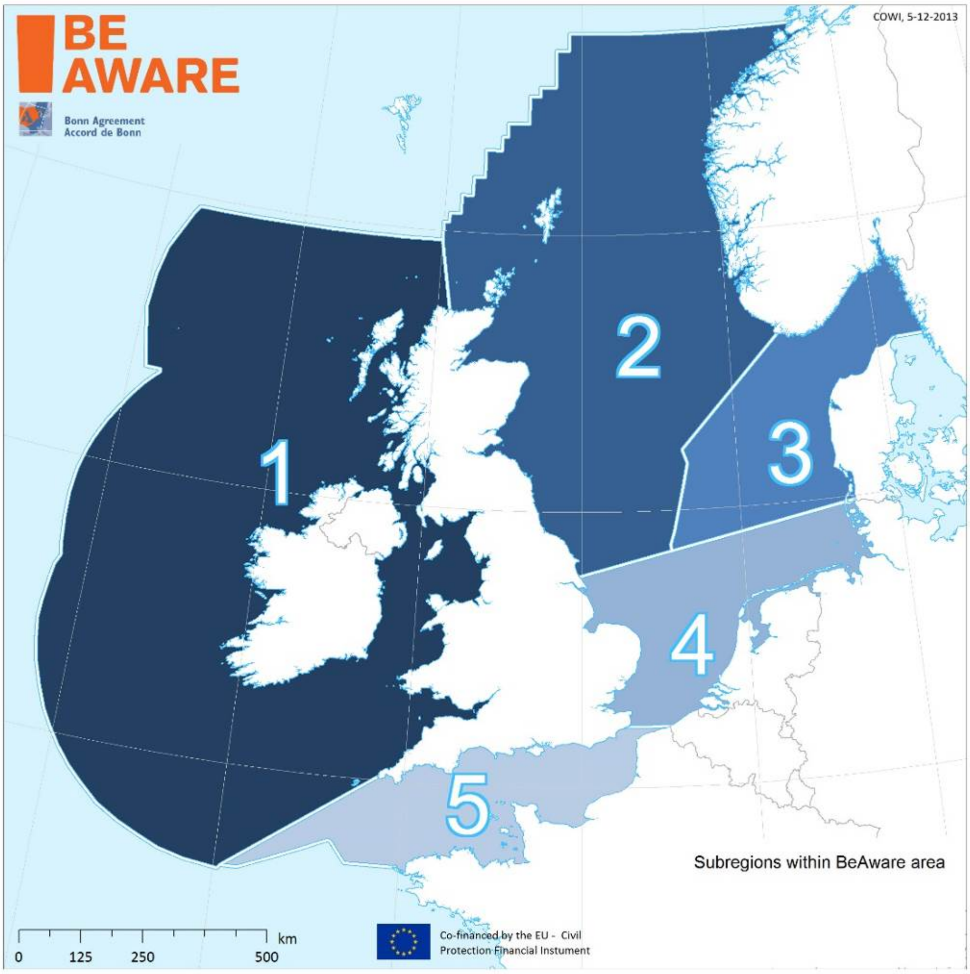


Figure 2-1 Sub-regional division of the Bonn Agreement area (sub-regions shown in five colours)

3. Methodology

Detailed information about the applied methodology can be found in the methodology note, (BE-AWARE, 2015b). In the current chapter, an overview of the various outcomes of the model is given, along with a description of the process to get there.

3.1 Purpose of the impact assessment

The impact assessment serves as a basis for the risk management conclusions that are the principle outcome of the BE-AWARE II project. Several elements are required in order to provide this input. These are:

- Establishment of the oil drift and spread model.
- Determination of the impact of oil from various scenarios. The oil impact for open sea areas as well as for stretches of coastline is given.
- Determination of the environmental and socioeconomic damage by combining the impact of oil with the environmental sensitivity for all scenarios

3.2 Procedure

The principal results for the various stages in the calculations are given below:

1. Accident frequency (type of accident, location, vessel characteristics, season)
2. Spill frequency (location, type, size, season)
3. Impact (season, coastline, cell)
4. Damage (cell)

Steps 1 and 2 were results from the BE-AWARE I modelling process. Some risk reducing scenarios required recalculation of these steps but the calculation procedure established in BE-AWARE I, was not altered. The results from step 3 are given in section 4. Here the impact of the spills calculated under step 2 was determined by simulation of the drift and fate of the oil and the mechanical recovery. Under step 4, the impact of oil from step 3 was coupled with the environmental and socioeconomic vulnerability to determine the damage. The results in section 5 are given for both the base case and the various scenarios.

3.3 Scenario overview

An overview of the scenarios with the options on Risk Reducing Measures or Response Measures compared to the base scenario is given below:

Table 3-1 Scenario overview

Scenario name	Risk Reducing Measure	Response Measure
Vessel Traffic Services (VTS)	X	
Traffic Separation Schemes (TSS)	X	
AIS alarm (Wind turbines)	X	
E-navigation	X	
New Emergency Towing Vessels (ETVs)	X	(X)[3]
Improved night detection capability		X
Further use of dispersants		X
50% increase in response equipment		X

In the schematic overview given below the modules changed in the scenarios are marked with orange circles.

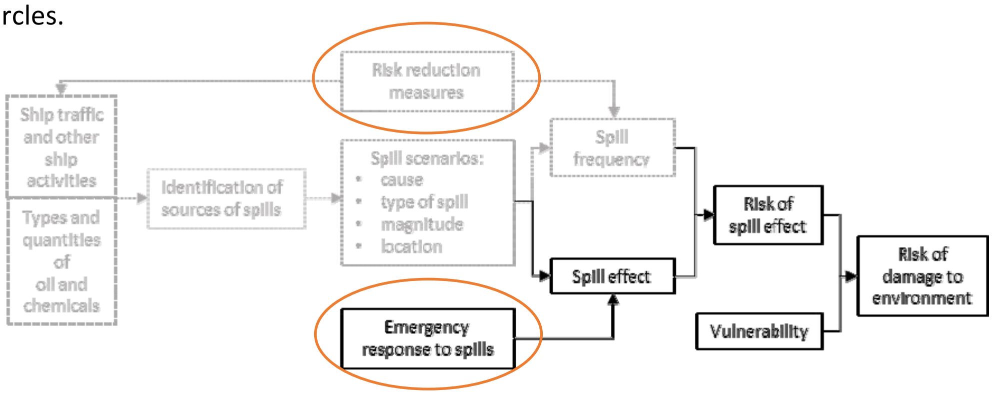


Figure 3-1 Schematic overview of the modelling process and marking of the modules where the changes in the scenarios apply in the modelling process.

[3] The ETVs has emergency towing capability that could prevent an accident from escalating as well as response equipment for responding to a spill event, and are therefore listed under both categories.

Background information about the different scenarios can be found in the methodology note, (BE-AWARE, 2015b). Some scenarios include general risk reducing or response measures implemented in all regions. In other scenarios, the reducing or response measure is limited to specific vessels or specific locations and the implementation is therefore limited to those specific regions. The scenarios can however effect a region without any implementation proposed due to the spill over effect, i.e. oil drifting from region to region. In Table 3-2 the overview of the regional implementation of scenario measures is given.

Table 3-2 Regional implementation of scenario measures

Scenario	Region 1	Region 2	Region 3	Region 4	Region 5
Vessel Traffic Services (VTS)	X	X	X	X	X
Traffic Separation Schemes (TSS)	X	X	X	X	
AIS alarm (Wind turbines)	X	X	X	X	X
E-navigation	X	X	X	X	X
New Emergency Towing Vessels (ETVs)	X				
Improved night detection capability	X	X	X	X	X
Further use of dispersants	X	X	X	X	X
50% increase in response equipment	X	X	X	X	X

4. Oil spill and drift

4.1 Procedure

At the beginning of the BE-AWARE II project the locations most prone to oil spills were determined. For each of these points the probability of oil spills occurring in eight different sizes and four different oil types was established. Each location had a distinct combination of sea temperature, prevailing wind direction, prevailing current and proximity to the coastline; therefore the oil drift pattern varied for each location. The spill points, along with a definition of the applied meteorological and tidal areas in the Bonn Agreement area, are given in Figure 4-1.

The transformation from representative points to the modelled spill points from BE-AWARE I was done by superposition of the calculated drift pattern. The result was a complete map of the region with the distribution of the oil load. Furthermore the amount of oil was summed up per region and the amount of oil that reached the coastline was also given.

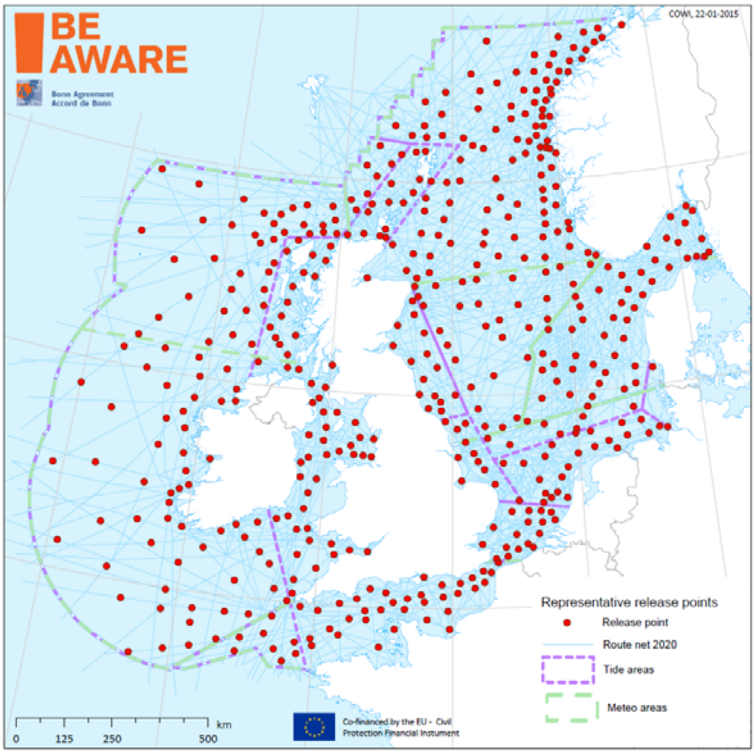


Figure 4-1 Simulated release point in the Bonn Agreement Area

The oil impact is the amount of oil in each cell coming from all oil types and sizes of oil spills. For this calculation the duration when oil has been in the cell is taken into account, i.e. the frequencies of the originating event and the amount of oil from this event staying in a particular cell is multiplied with the duration for which oil from this specific event stayed in the particular cell. This therefore results in a unit of grams of oil per square km (*g oil/km*^{2}). Oil dispersed in the water column is aggregated with the same procedure, knowing that the depth that the dispersed oil affects in this situation is an important factor.

Each of the cells has a distinct value that is carried forward in the damage analysis. The graphical representation gives an overview of the magnitudes of the impact on a region wide scale and makes it possible to focus on hotspots in the regions.

4.2 Base case scenario

The procedure outlined in section 4.1 was applied for several scenarios. The reference scenario given in this section was the basis for all comparisons.

The visual representations of all of the scenario runs are given in Annex 1.

In the reference scenario the already agreed response capabilities and risk reducing measures were applied to give an estimate of planned measures. Further to providing the best estimate of the future situation, the base case was also used as a reference scenario, which all other scenarios can be compared to. The primary base scenario is for the year 2020. All measures that had already been agreed in national plans were included in this scenario. The impact maps, i.e. risk of spill effect for the base case is seen in Figure 4-2 and Figure 4-3

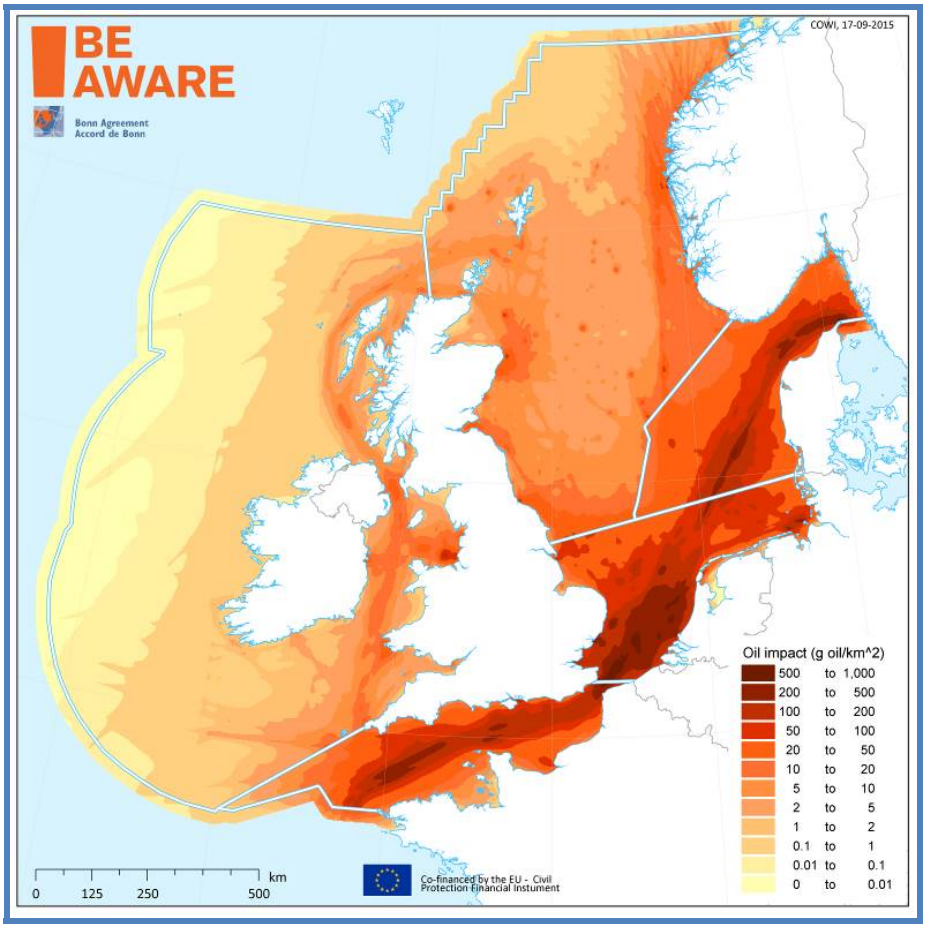


Figure 4-2 Base scenario 2020: Oil impact (on water)

The probability distribution of oil in the regional waters and on the coastline in the region for the base scenario is given in Table 4-1.

Table 4-1 Oil impact in the sub-regions – Base case

Base Scenario	Region 1	Region 2	Region 3	Region 4	Region 5
Oil on coast [t]	39,00	137,73	70,15	158,84	78,43
Oil on water [t/y]	1,25	3,20	8,33	14,97	7,68
Dispersed oil in water [t/y]	0,18	0,41	0,00	1,38	1,54

The results presented in Table 4-1 were used as a benchmark in the analysis, and other scenarios were measured against this. The oil amounts were a result of all sizes of oil spills and thereby the variations in the underlying incident return periods were very large. This means that the impact came from both frequent small spills and from very large and very infrequent spills.

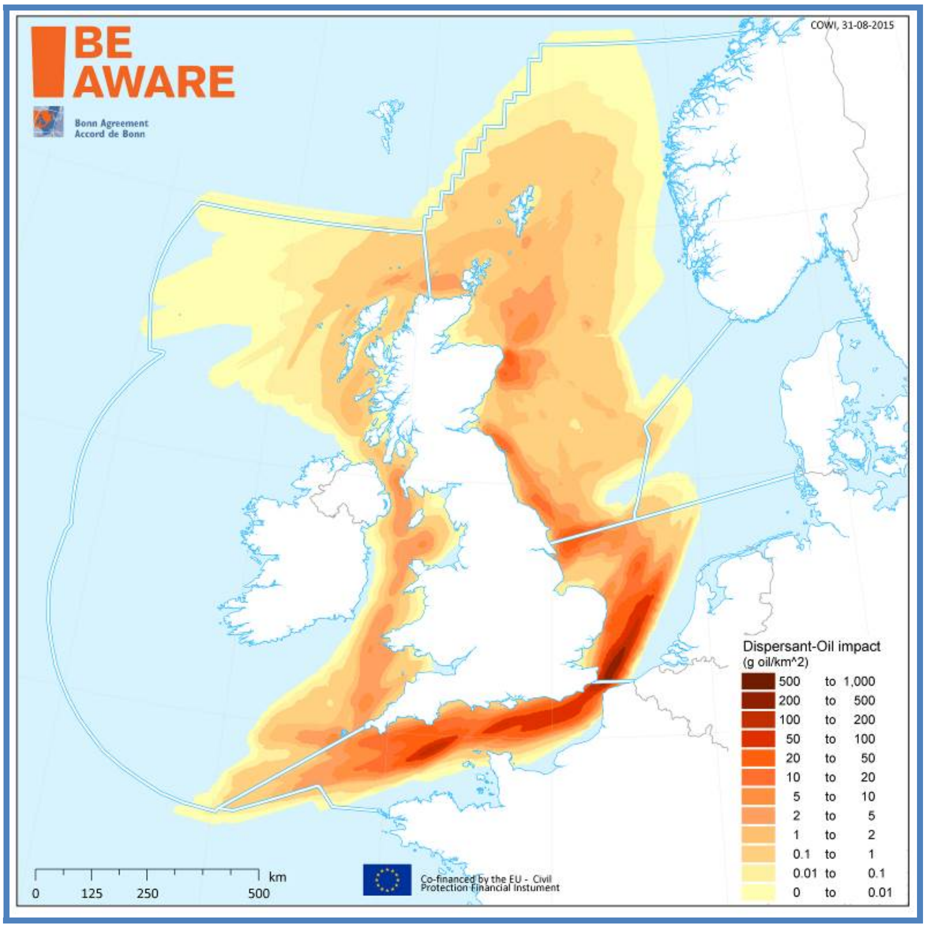


Figure 4-3 Base scenario 2020: Oil impact (dispersed in water)

The use of dispersants as the primary response measure is modelled only in the UK waters and this is the reason for the localised impact of dispersed oil seen in Figure 4-3.

4.3 Region wide effectiveness of scenarios

The effectiveness, i.e. the difference in the total impact of oil by introducing the measures modelled in the scenarios can be seen below. The effectiveness was aggregated over each sub-region to generate an overview of the difference in effectiveness for oil coming from various spill sizes. The percentages given in Table 4-2 to Table 4-16 are the relative changes compared to the base scenario and the values given in Table 4-1.

4.3.1 Region 1

Region 1 includes Ireland and the UK. In Table 4-2 the amounts of oil on the coastline are given for the different scenarios.

Table 4-2 Relative change in the amount of oil on the coast

Region 1 - Oil on coast			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-0,39%	-0,08%	-0,27%
TSS	-0,55%	-0,15%	-0,40%
AIS Alarm	-0,14%	-0,65%	-0,33%
E-navigation	-25%	-25%	-25%
ETV in Ireland	-0,03%	-5,54%	-2,10%
Night visibility	-1,07%	-0,49%	-0,85%
Dispersants	-0,78%	-0,40%	-0,64%
+50% response	-1,16%	-1,10%	-1,14%

In Table 4-3 the relative changes in the amounts of oil on the water are given.

Table 4-3 Relative change in the amount of oil on water

Region 1 - Oil on water			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-0,39%	-0,04%	-0,19%
TSS	-0,69%	-0,08%	-0,34%
AIS Alarm	-0,33%	-1,12%	-0,79%
E-navigation	-25%	-25%	-25%
ETV in Ireland	-0,06%	-3,02%	-1,78%
Night visibility	-1,00%	-0,54%	-0,73%
Dispersants	-1,38%	-0,75%	-1,01%
+50% response	-0,98%	-1,35%	-1,19%

In Table 4-4 the relative changes in the amounts of oil in the water column are given.

Table 4-4 Relative change in the amount of oil in the water column

Region 1 - Dispersed oil in water			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	0,00%	0,00%	0,00%
TSS	0,00%	0,00%	0,00%
AIS Alarm	-0,34%	-1,46%	-0,61%
E-navigation	-25%	-25%	-25%
ETV in Ireland	-0,07%	-0,14%	-0,09%
Night visibility	0,00%	0,00%	0,00%
Dispersants	47,51%	31,54%	43,66%
+50% response	0,00%	0,00%	0,00%

The 3 most effective scenarios for both oil on water and oil on the coast are the same. However, there are differences between the scenarios in terms of impact. The scenario with the use of dispersants only gives the 4th largest reduction in the oil on the coastline but does not have any limiting effect on the amount of oil on water, let alone the amount of dispersed oil in the water column where a significant increase is found. Several scenarios effects in the region is only a "spill over" effect from neighbouring sub-regions, i.e. the scenario affects an adjacent area and the effect of the scenario is caused by the changes in the oil impacts from this area being able to drift into region 1.

4.3.2 Region 2

Region 2 includes the UK and Norway. In Table 4-5 the variation in the amount of oil on the coastline is given.

Table 4-5 Relative change in the amount of oil on the coast

Region 2 - Oil on coast			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-0,68%	-0,42%	-0,63%
TSS	-0,11%	-0,58%	-0,20%
AIS Alarm	-0,01%	-0,23%	-0,05%
E-navigation	-25%	-25%	-25%
ETV in Ireland	0,00%	0,00%	0,00%
Night visibility	-0,07%	-0,08%	-0,07%
Dispersants	0,03%	-0,33%	-0,03%
+50% response	-1,00%	-2,25%	-1,23%

In Table 4-6 the variation in the amount of oil on the water is given.

Table 4-6 Relative change in the amount of oil on water

Region 2 - Oil on water			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-3,09%	-3,15%	-3,12%
TSS	-4,21%	-6,21%	-5,20%
AIS Alarm	-0,17%	-0,18%	-0,18%
E-navigation	-25%	-25%	-25%
ETV in Ireland	0,00%	0,00%	0,00%
Night visibility	-0,02%	-0,16%	-0,09%
Dispersants	0,16%	-0,28%	-0,06%
+50% response	-0,45%	-2,00%	-1,22%

In Table 4-7 the variation in the amount of oil in the water column is given.

Table 4-7 Relative change in the amount of oil in the water column

Region 2 - Dispersed oil in water			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-0,13%	-0,15%	-0,14%
TSS	0,00%	0,00%	0,00%
AIS Alarm	-0,07%	-0,57%	-0,15%
E-navigation	-25%	-25%	-25%
ETV in Ireland	0,00%	0,00%	0,00%
Night visibility	0,00%	0,00%	0,00%
Dispersants	55,61%	81,23%	59,61%
+50% response	0,00%	0,00%	0,00%

The ranking of the scenarios based on the different measuring criteria: oil on the water, dispersed oil in the water column and oil on the coast, is comparable in many ways, but there are significant differences. The VTS and TSS scenarios give rise to significant reductions in the amount of oil on the water, but very limited effect in the amount of oil in the coastline. The shipping routes, and thereby spill probabilities affected by these measures are in this region far from the coastline and this distance from the coast explains for these differences.

4.3.3 Region 3

Region 3 includes Norway, Sweden, Denmark, Germany and the Netherlands. In Table 4-8 the variation of the oil on the coastline is given.

Table 4-8 Relative change in the amount of oil on the coast

Region 3 - Oil on coast			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-27,06%	-28,27%	-27,56%
TSS	-22,42%	-43,55%	-31,09%
AIS Alarm	-0,51%	-0,35%	-0,45%
E-navigation	-25%	-25%	-25%
ETV in Ireland	0,00%	0,00%	0,00%
Night visibility	-0,15%	-0,11%	-0,13%
Dispersants	-7,59%	-3,27%	-5,82%
+50% response	-1,19%	-0,86%	-1,06%

In Table 4-9 the variation in the amount of oil on the water is given.

Table 4-9 Relative change in the amount of oil on water

Region 3 - Oil on water			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-31,59%	-30,53%	-30,95%
TSS	-53,24%	-50,92%	-51,84%
AIS Alarm	-0,80%	-1,04%	-0,95%
E-navigation	-25%	-25%	-25%
ETV in Ireland	0,00%	0,00%	0,00%
Night visibility	-0,18%	-0,61%	-0,44%
Dispersants	8,98%	0,32%	3,73%
+50% response	-1,10%	-2,14%	-1,73%

In Table 4-10 the variation in the amount of oil in the water column is given.

Table 4-10 Relative change in the amount of oil in the water column

Region 3 - Dispersed oil in water			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-20,33%	-15,36%	-19,49%
TSS	0,00%	0,00%	0,00%
AIS Alarm	-0,16%	-0,01%	-0,13%
E-navigation	-25%	-25%	-25%
ETV in Ireland	0,00%	0,00%	0,00%
Night visibility	0,00%	0,00%	0,00%
Dispersants	1385%	1642%	1428%
+50% response	0,00%	0,00%	0,00%

The most effective scenarios in this region are the extended TSS, the extended VTS area and the more generic e-navigation scenario. The TSS scenario has very limited effect on the oil dispersed in the water column as the TSS is applied in an area that does not apply dispersants as a primary response measure. The dispersants only scenario gives high figures as dispersants are not currently used in region 3 and the chemically dispersed oil in the base case therefore is limited spill over effects from other regions.

4.3.4 Region 4

Region 4 includes Germany, the Netherlands, Belgium, France and the UK. In Table 4-11 the variation in the oil on the coastline is given.

Table 4-11 Relative change in the amount of oil on the coast

Region 4 - Oil on coast			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-14,30%	-15,45%	-14,87%
TSS	-1,01%	-0,94%	-0,97%
AIS Alarm	-1,17%	-1,15%	-1,16%
E-navigation	-25%	-25%	-25%
ETV in Ireland	0,00%	0,00%	0,00%
Night visibility	-0,01%	-1,08%	-0,53%
Dispersants	-4,62%	-3,08%	-3,86%
+50% response	-0,89%	-1,51%	-1,20%

In Table 4-12 the variation in the amount of oil on the water is given

Table 4-12 Relative change in the amount of oil on water

Region 4 - Oil on water			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-22,41%	-21,21%	-21,70%
TSS	-3,83%	-2,52%	-3,06%
AIS Alarm	-1,61%	-3,61%	-2,79%
E-navigation	-25%	-25%	-25%
ETV in Ireland	0,00%	0,00%	0,00%
Night visibility	-0,04%	-1,77%	-1,06%
Dispersants	10,21%	3,65%	6,35%
+50% response	-1,04%	-2,68%	-2,01%

In Table 4-13 the variation in the amount of oil in the water column is given.

Table 4-13 Relative change in the amount of oil in the water column

Region 4 - Dispersed oil in water			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-29,57%	-22,36%	-27,11%
TSS	0,00%	0,00%	0,00%
AIS Alarm	-0,45%	-1,24%	-0,72%
E-navigation	-25%	-25%	-25%
ETV in Ireland	0,00%	0,00%	0,00%
Night visibility	0,00%	0,00%	0,00%
Dispersants	264%	349%	293%
+50% response	0,00%	0,00%	0,00%

In region 4 the most efficient scenarios depends to a high degree on the chosen measurement parameter. VTS and e-navigation have very large risk reducing effects.

4.3.5 Region 5

Region 5 includes the UK and France. In Table 4-14 the variation in the amount of oil on the coastline is given.

Table 4-14 Relative change in the amount of oil on the coast

Region 5 - Oil on coast			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-3,97%	-3,05%	-3,43%
TSS	-0,02%	-0,01%	-0,01%
AIS Alarm	-0,38%	-0,79%	-0,62%
E-navigation	-25%	-25%	-25%
ETV in Ireland	0,00%	-0,01%	0,00%
Night visibility	-0,15%	-0,75%	-0,50%
Dispersants	-4,14%	-3,44%	-3,73%
+50% response	-0,55%	-1,02%	-0,83%

In Table 4-15 the variation in the amount of oil on the water is given.

Table 4-15 Relative change in the amount of oil on water

Region 5 - Oil on water			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-1,18%	-0,72%	-0,86%
TSS	0,00%	0,00%	0,00%
AIS Alarm	-0,19%	-0,41%	-0,34%
E-navigation	-25%	-25%	-25%
ETV in Ireland	0,00%	-0,04%	-0,02%
Night visibility	-0,74%	-1,56%	-1,30%
Dispersants	6,80%	1,31%	3,01%
+50% response	-0,88%	-2,18%	-1,78%

In Table 4-16 the variation in the amount of oil in the water column is given.

Table 4-16 Relative change in the amount of oil in the water column

Region 5 - Dispersed oil in water			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-0,78%	-0,60%	-0,70%
TSS	0,00%	0,00%	0,00%
AIS Alarm	-0,10%	-0,18%	-0,14%
E-navigation	-25%	-25%	-25%
ETV in Ireland	0,00%	0,00%	0,00%
Night visibility	0,00%	0,00%	0,00%
Dispersants	101%	145%	120%
+50% response	0,00%	0,00%	0,00%

The most effective scenarios in this region are the generic e-navigation scenario, the VTS scenario and the +50% response. For the surface oil parameter the Night visibility scenario has also shown effect and for the parameter of dispersed oil in the water column the AIS alarm scenario gave a minor limiting effect.

4.3.6 Regional impact overview

The 3 most effective scenarios for the impact parameters measured, oil on the coast, oil on water and oil dispersed in the water column are given in Table 4-17.

Table 4-17 Listing of the 3 most effective scenarios with regards to impact in each region.

Regional overview – 3 most effective scenarios															
Region		1			2			3			4			5	
Parameter (coast, surface, dispersed)	c	s	d	c	s	d	c	s	d	c	s	d	c	s	d
Scenario VTS				3	3	3	2	2	2	2	2	1	3		2
Scenario TSS					2		1	1			3				
Scenario AIS Alarm			2			2			3			3			3
Scenario E-navigation	1	1	1	1	1	1	3	3	1	1	1	2	1	1	1
Scenario ETVs	2	2	3												
Scenario Night visibility														3	
Scenario Dispersants															
Scenario +50% response	3	3		2						3			2	2	

5. Oil Damage

5.1 Procedure

Oil damage is the combination of the oil impact, i.e. the amount of oil in each cell, and the environmental and socioeconomic vulnerability. It is given in terms of a non-dimensional distribution of the damage caused by oil throughout the region.

5.2 Base case scenario

The procedure outlined in section 5.1 is applied for all scenarios similar to the impact given in section 4. The reference scenario given in this section is the basis for all comparisons.

All of the visual representations of all of the scenario runs are given in Annex 2.

The oil damage map for the base case is seen below:

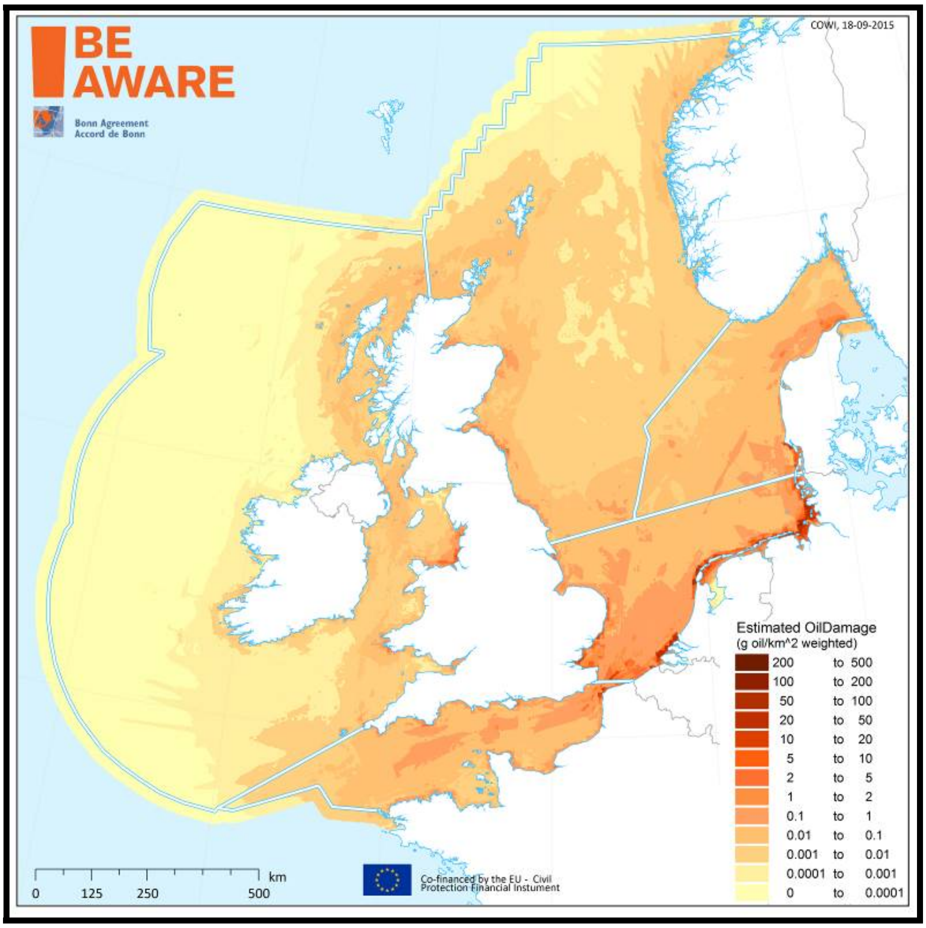


Figure 5-1 Base scenario 2020: Oil damage

Significant changes can be seen when comparing the damage maps to the oil impact maps and highly vulnerable areas such as the Wadden Sea show relatively higher damage compared to the variations seen in the impact maps.

In Table 5-1 below the damage amounts in the different regions are given.

Table 5-1 Damage index in the sub-regions – Base case

Base Scenario	Region 1	Region 2	Region 3	Region 4	Region 5
Damage index [Non-dimensional]	8969	9393	20068	194383	20781

The summation of damage in region 1 and 2 are comparable in size. The summation of damage in region 3 and 5 are also comparable but twice the size of region 1 and 2. Region 4 is the high-risk area with a damage index approximately 10 times higher than the results from region 3 or 5. These regional differences in severity should be taken into consideration when looking at the full Bonn Agreement Area. The results given in Figure 5-1 were used as a benchmark in the analysis against which all other scenarios were measured against. The total damage was a result of all sizes of oil spills and therefore the variations in the underlying return periods were very large. Furthermore, they were a product of the aggregation of all the environmental and socioeconomic features. In order to differentiate between smaller and more frequent events and larger less frequent events the variation in damage was given for spills smaller and larger than 5000t.

5.3 Region wide effectiveness of scenarios

5.3.1 Region 1

Region 1 includes Ireland and the UK. In Table 5-2 the variation in the damage in the region is given

Table 5-2 Relative change in damage in region 1

Region 1 - Damage			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-0,27%	-0,04%	-0,17%
TSS	-0,41%	-0,08%	-0,26%
AIS Alarm	-0,47%	-3,34%	-1,74%
E-navigation	-25%	-25%	-25%
ETV in Ireland	-0,12%	-3,52%	-1,63%
Night visibility	-1,74%	-0,63%	-1,25%
Dispersants	2,23%	0,47%	1,45%
+50% response	-1,91%	-1,39%	-1,68%

5.3.2 Region 2

Region 2 includes the UK and Norway. In Table 5-3 the variation in the damage in the region is given.

Table 5-3 Relative change in damage in region 2

Region 2 - Damage			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-1,13%	-1,52%	-1,28%
TSS	-0,70%	-1,60%	-1,04%
AIS Alarm	-0,12%	-0,49%	-0,26%
E-navigation	-25%	-25%	-25%
ETV in Ireland	0,00%	0,00%	0,00%
Night visibility	-0,04%	-0,18%	-0,09%
Dispersants	4,18%	1,29%	3,10%
+50% response	-1,04%	-1,85%	-1,34%

5.3.3 Region 3

Region 3 includes Norway, Sweden, Denmark, Germany and the Netherlands. In Table 5-4 the variation in the oil on the coastline is given.

Table 5-4 Relative change in the damage in region 3

Region 3 - Damage			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-24,66%	-28,57%	-26,58%
TSS	-34,87%	-48,64%	-41,62%
AIS Alarm	-1,68%	-0,93%	-1,31%
E-navigation	-25%	-25%	-25%
ETV in Ireland	0,00%	0,00%	0,00%
Night visibility	-0,13%	-0,31%	-0,22%
Dispersants	52,75%	12,07%	32,80%
+50% response	-2,22%	-1,72%	-1,97%

5.3.4 Region 4

Region 4 includes Germany, the Netherlands, Belgium, France and the UK. In Table 5-5 the variations in the damage for the simulated scenarios are given.

Table 5-5 Relative change in the damage in region 4

Region 4 - Damage			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-12,42%	-9,37%	-10,74%
TSS	-3,33%	-2,39%	-2,82%
AIS Alarm	-1,96%	-1,32%	-1,61%
E-navigation	-25%	-25%	-25%
ETV in Ireland	0,00%	0,00%	0,00%
Night visibility	-0,02%	-1,69%	-0,94%
Dispersants	17,73%	13,00%	15,12%
+50% response	-1,98%	-2,67%	-1,91%

5.3.5 Region 5

Region 5 includes the UK and France. In Table 5-6 the variation in the damage is given.

Table 5-6 Relative change in the damage in region 5

Region 5 - Damage			
Scenario	Spill<5000t	Spill>5000t	Total
VTS	-3,84%	-2,71%	-3,18%
TSS	-0,01%	0,00%	-0,01%
AIS Alarm	-0,24%	-0,36%	-0,31%
E-navigation	-25%	-25%	-25%
ETV in Ireland	0,00%	-0,01%	-0,01%
Night visibility	-0,14%	-1,11%	-0,71%
Dispersants	37,43%	19,69%	27,07%
+50% response	-0,70%	-1,71%	-1,29%

5.3.6 Regional damage overview

In Table 4-17 the 3 most effective scenarios for the parameters measured, oil on the coast, oil on water and oil dispersed in the water column are given.

Table 5-7 Listing of the 3 most effective scenarios with regards to limiting damage in each region.

Regional overview for damage – 3 most effective scenarios					
Region	**1**	**2**	**3**	**4**	**5**
Scenario VTS		3	2	2	2
Scenario TSS			1	3	
Scenario AIS Alarm	2				
Scenario E-navigation	1	1	3	1	1
Scenario ETV in Ireland					
Scenario Night visibility					
Scenario Dispersants					
Scenario +50% response	3	2			3

The most effective scenarios listed in Table 5-7 gives an overview the regional differences within the Bonn Agreement area. The prioritised list of the effectiveness in limiting the damage from oil spills is does not factor in the cost of the implemented measures. The cost-benefit considerations are discussed in the Risk management conclusion report (BE-AWARE, 2015e).

6. References

/BE-AWARE, 2015b/ Technical Sub Report 1:Methodology note. BE-AWARE II project. COWI 2015

/BE-AWARE, 2015d/ Technical Sub report 2: Environmental and socioeconomic sensitivity and vulnerability mapping. BE-AWARE II project. COWI 2015

/BE-AWARE, 2015e/ Technical Sub Report 4: Risk management Conclusions. BE-AWARE II project. COWI 2015

1. Annex Impact Maps

In this section the oil impact maps for the different scenarios are given

1.1 About

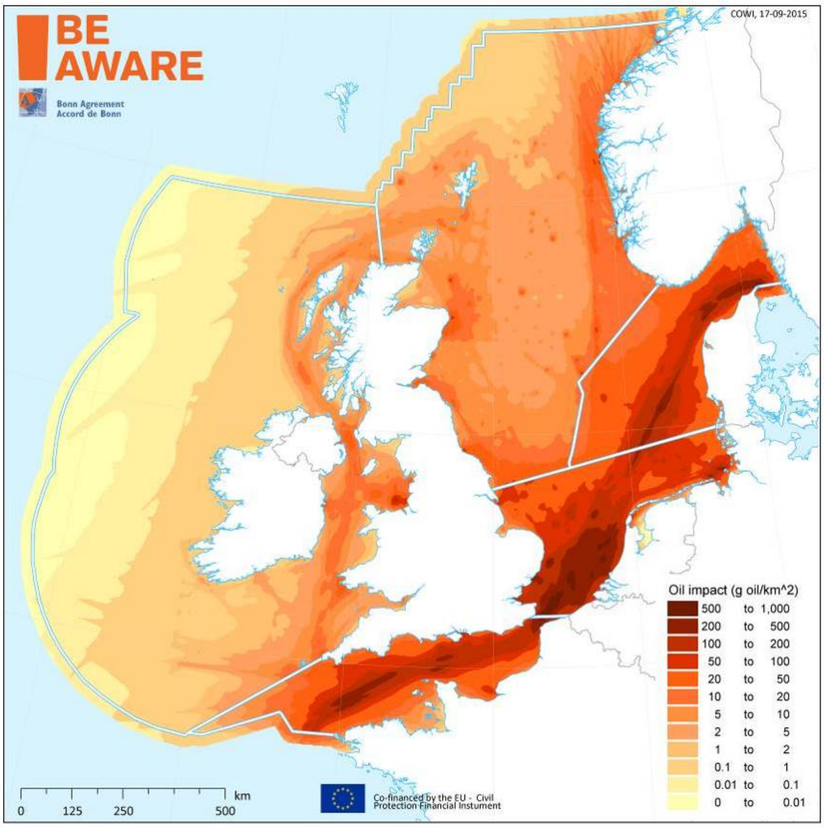
The impact maps given below this section show the variation from scenario to scenario. For some scenarios, the change is limited and can be found on a cell-to-cell basis, but for other scenarios, the impact is visible on a region wide scale.

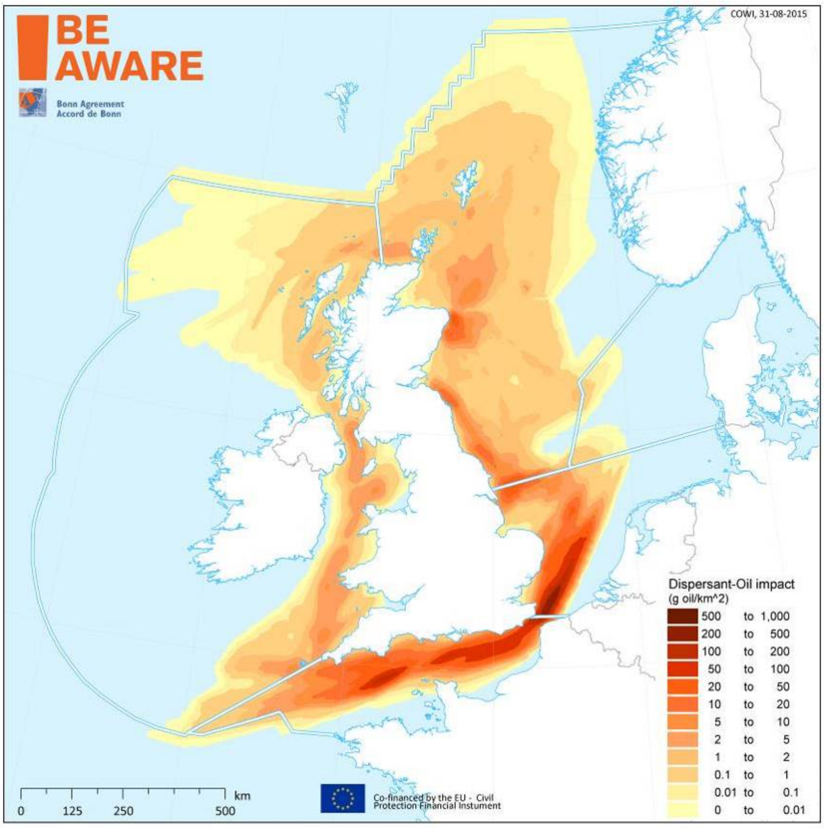
1.1.1 Impact definition

The oil impact is the amount of oil in each cell coming from all oil types and sizes of oil spills. As the duration when oil has been in the cell is taken into account, i.e. the frequencies of the originating event and the amount of oil from this event staying in a particular cell is multiplied with the duration for which oil from this specific event stayed in the particular cell. This therefore results in a unit of grams of oil per square km ($g\ oil/km^2$). Oil dispersed in the water column is aggregated with the same procedure, knowing that the depth that the dispersed oil affects in this situation is an important factor.

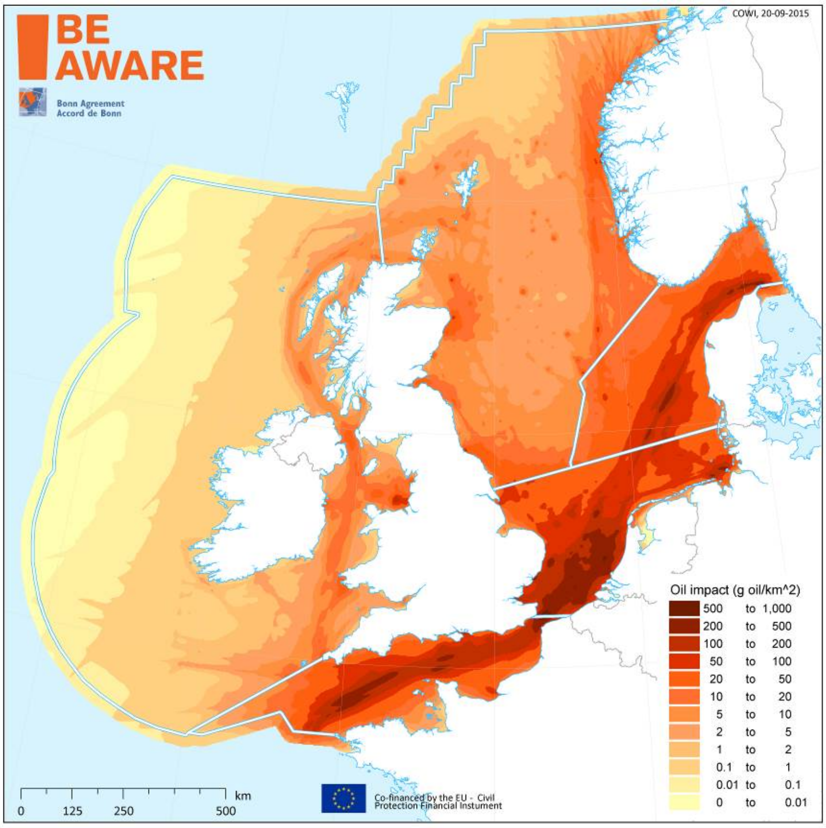
Each of the cells has a distinct value that is carried forward in the damage analysis. The graphical representation gives an overview of the magnitudes of the impact on a region wide scale and makes it possible to focus on hotspots in the regions.

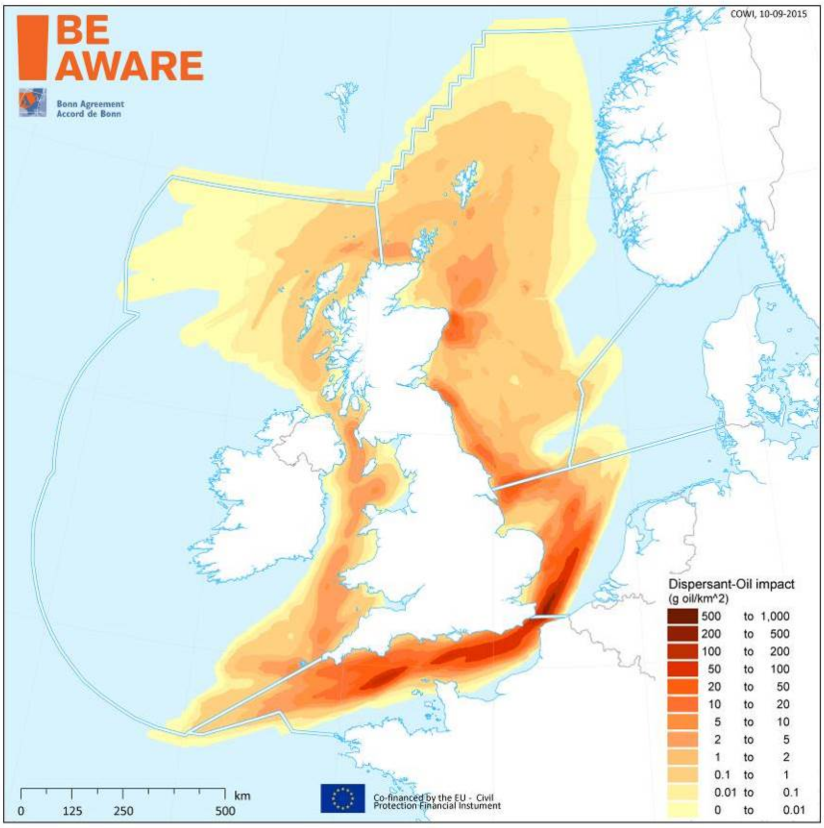
1.2 Base Case


COWI, 17-09-2015
BE AWARE
Bonn Agreement
Accord de Bonn
Oil impact (g oil/km^2)
500 to 1,000
200 to 500
100 to 200
50 to 100
20 to 50
10 to 20
5 to 10
2 to 5
1 to 2
0.1 to 1
0.01 to 0.1
0 to 0.01
0 125 250 500 km
Co-financed by the EU - Civil Protection Financial Instument

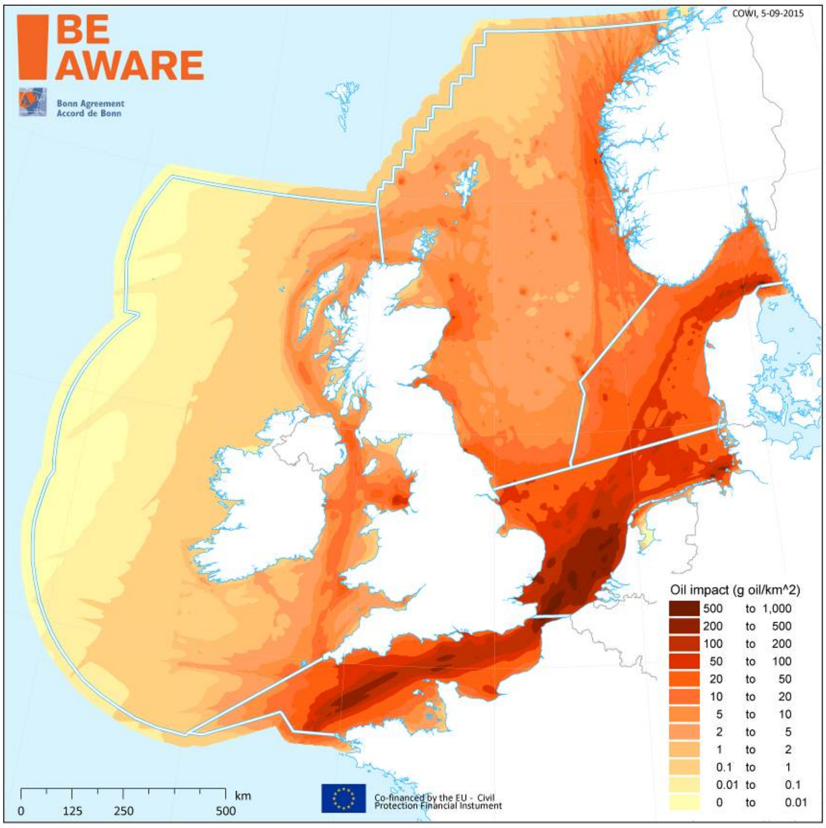

COWI, 31-08-2015
BE AWARE
Bonn Agreement
Accord de Bonn
Dispersant-Oil impact (g oil/km^2)
500 to 1,000
200 to 500
100 to 200
50 to 100
20 to 50
10 to 20
5 to 10
2 to 5
1 to 2
0.1 to 1
0.01 to 0.1
0 to 0.01
0 125 250 500 km
Co-financed by the EU - Civil Protection Financial Instument

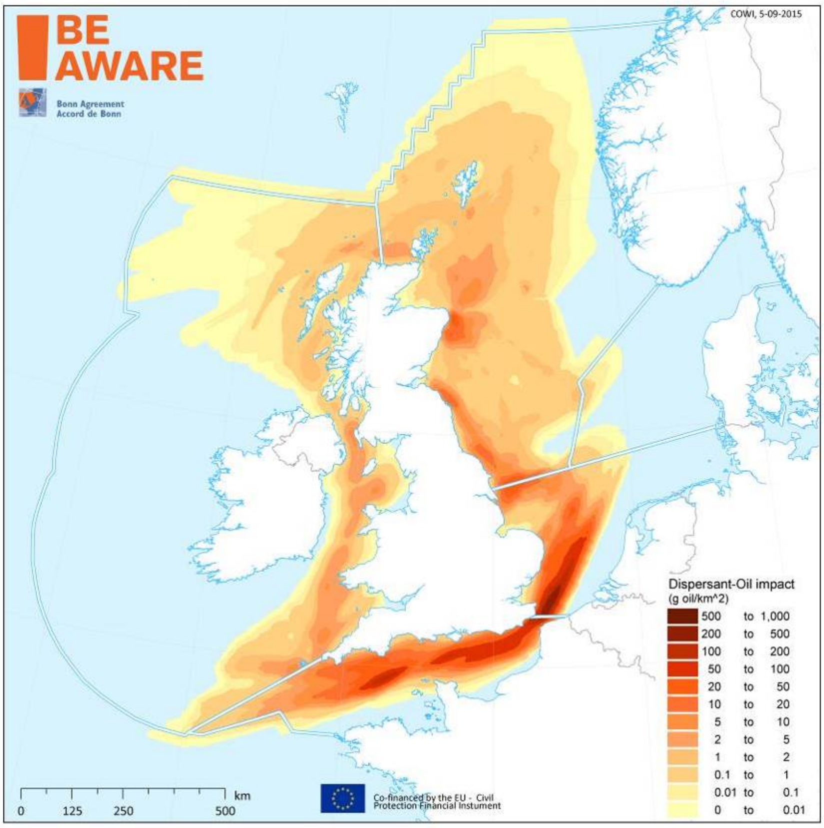
1.3 VTS scenario



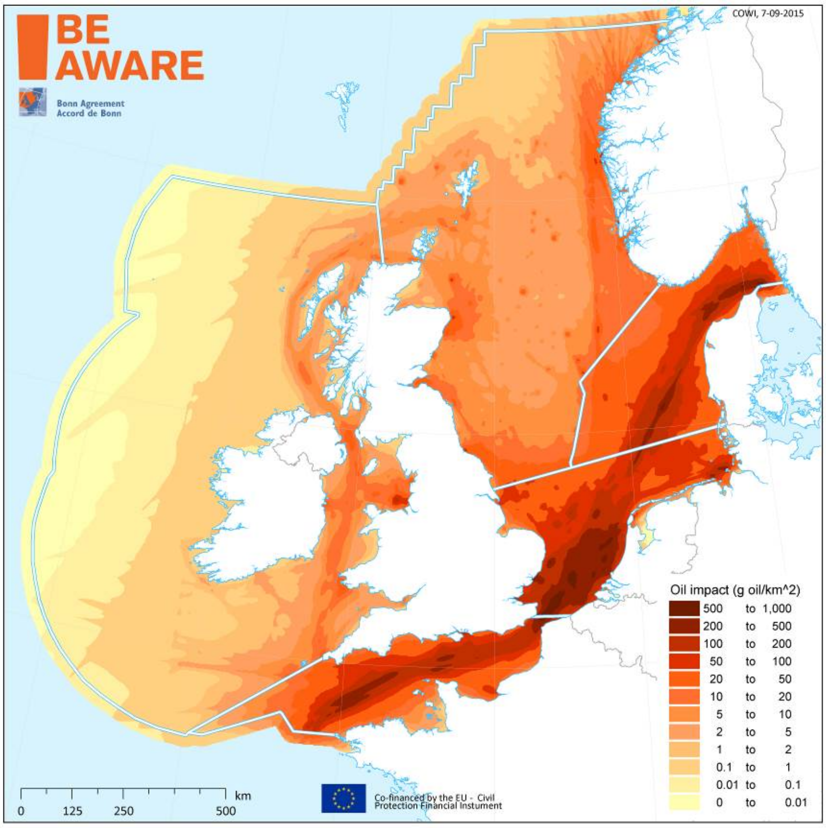


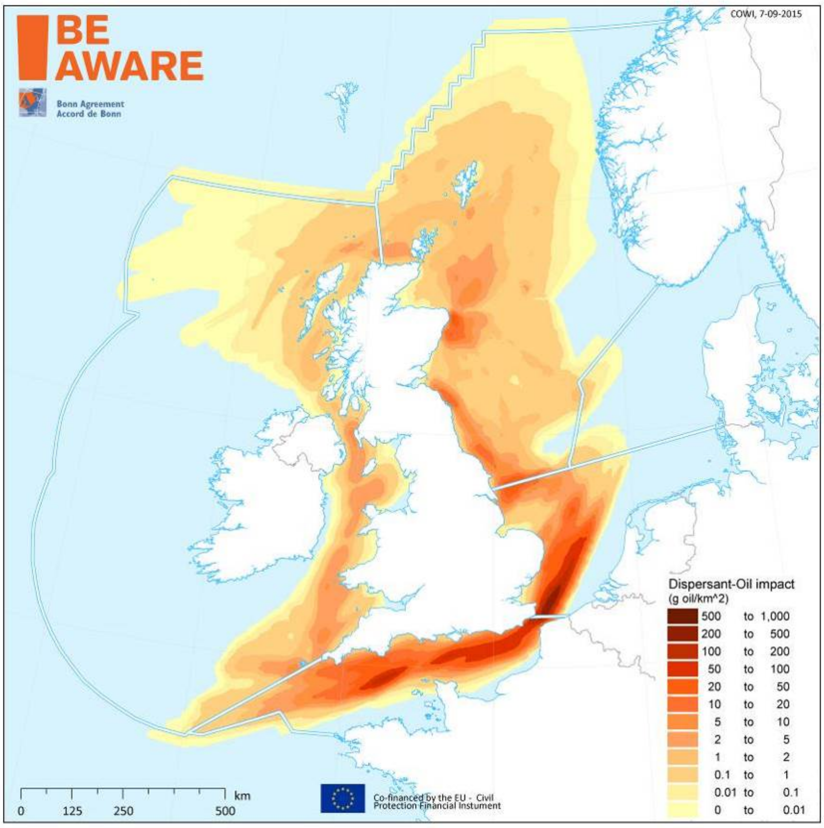
1.4 TSS scenario



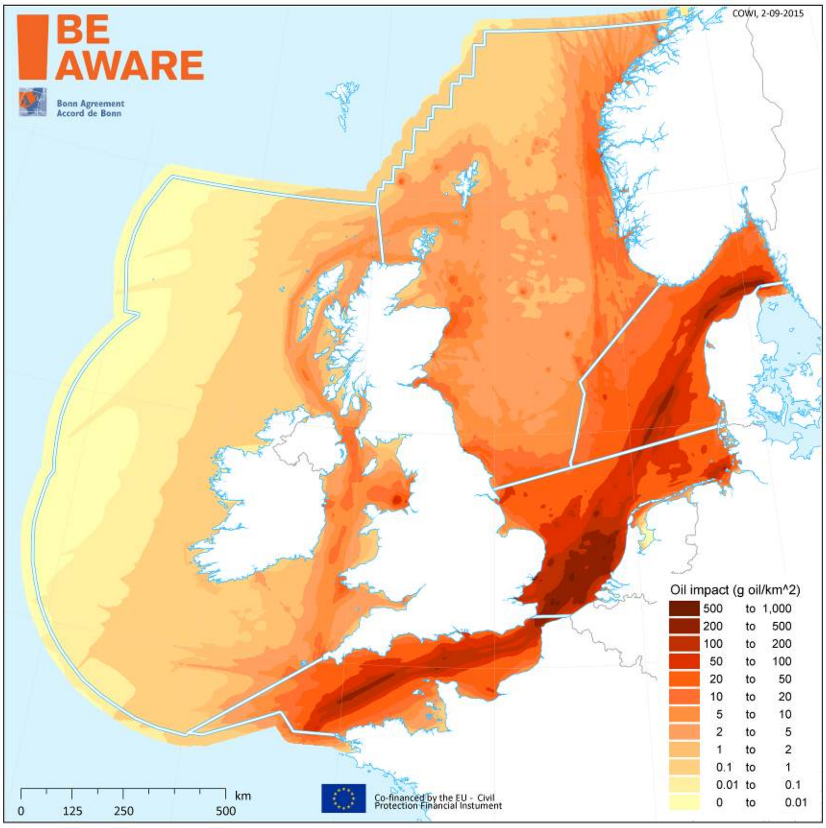


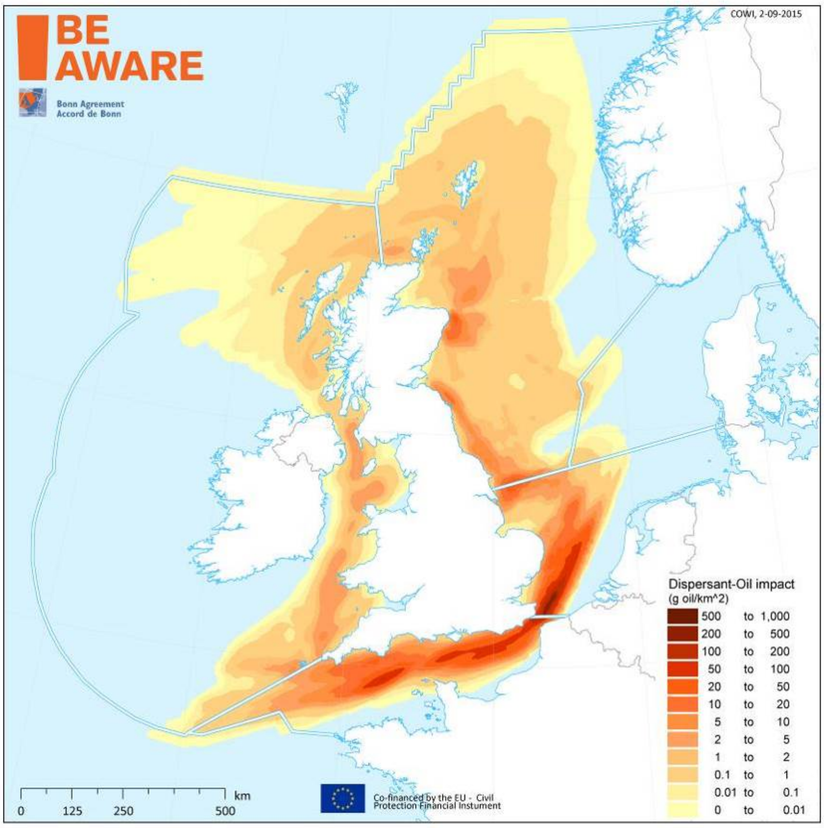
1.5 AIS alarm


BE
AWARE
Bonn Agreement
Accord de Bonn
COWI, 7-09-2015
Oil impact (g oil/km^2)
500 to 1,000
200 to 500
100 to 200
50 to 100
20 to 50
10 to 20
5 to 10
2 to 5
1 to 2
0.1 to 1
0.01 to 0.1
0 to 0.01
0 125 250 500 km
Co-financed by the EU - Civil Protection Financial Instument

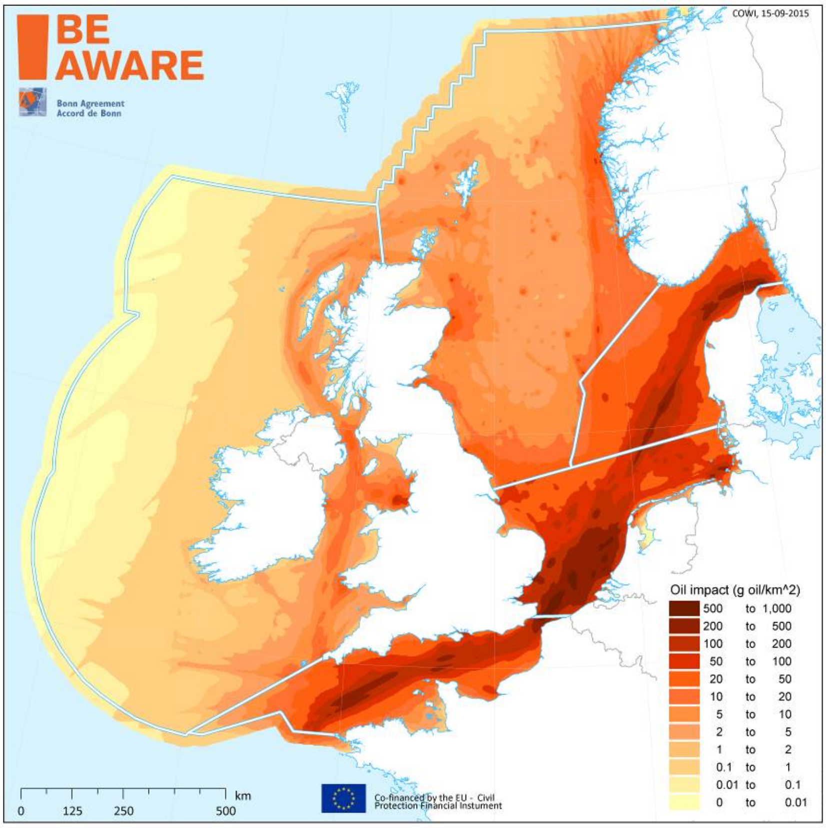

BE
AWARE
Bonn Agreement
Accord de Bonn
COWI, 7-09-2015
Dispersant-Oil impact (g oil/km^2)
500 to 1,000
200 to 500
100 to 200
50 to 100
20 to 50
10 to 20
5 to 10
2 to 5
1 to 2
0.1 to 1
0.01 to 0.1
0 to 0.01
0 125 250 500 km
Co-financed by the EU - Civil Protection Financial Instument

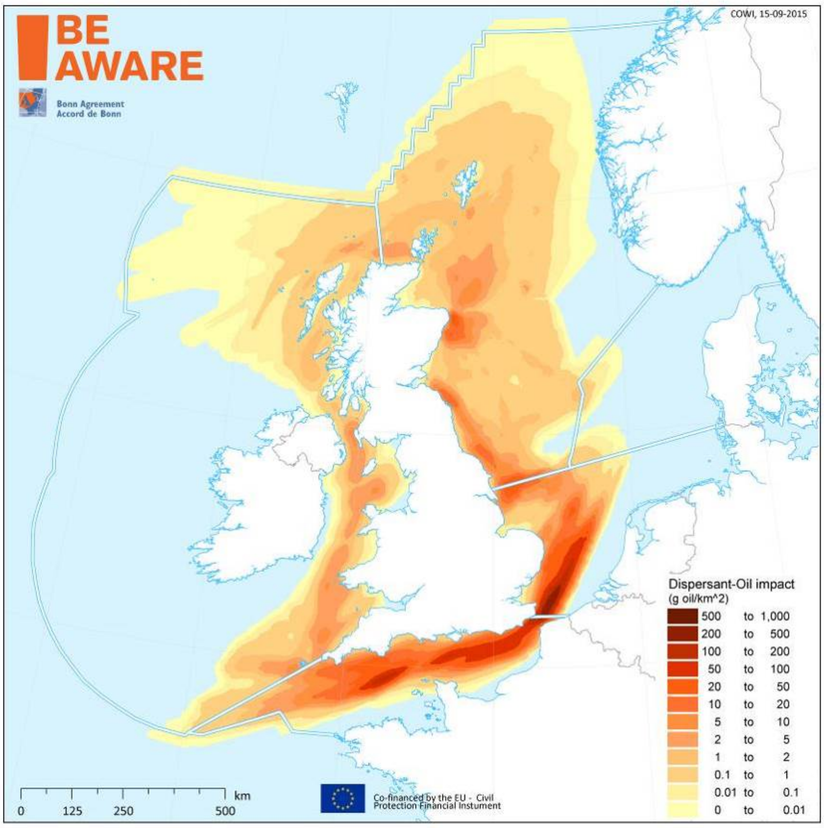
1.6 E-navigation



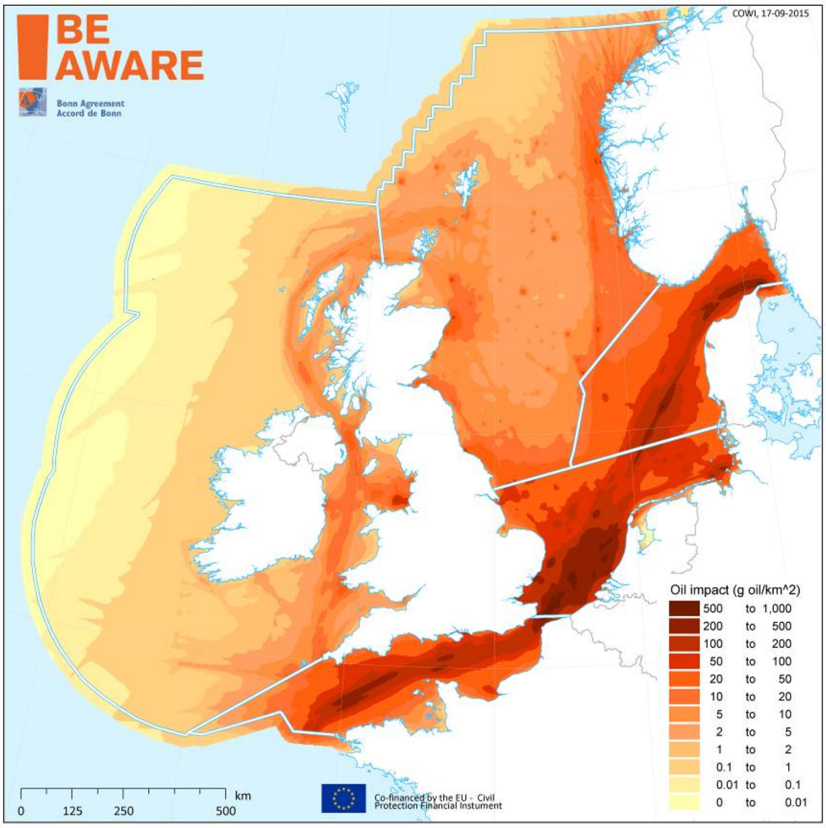


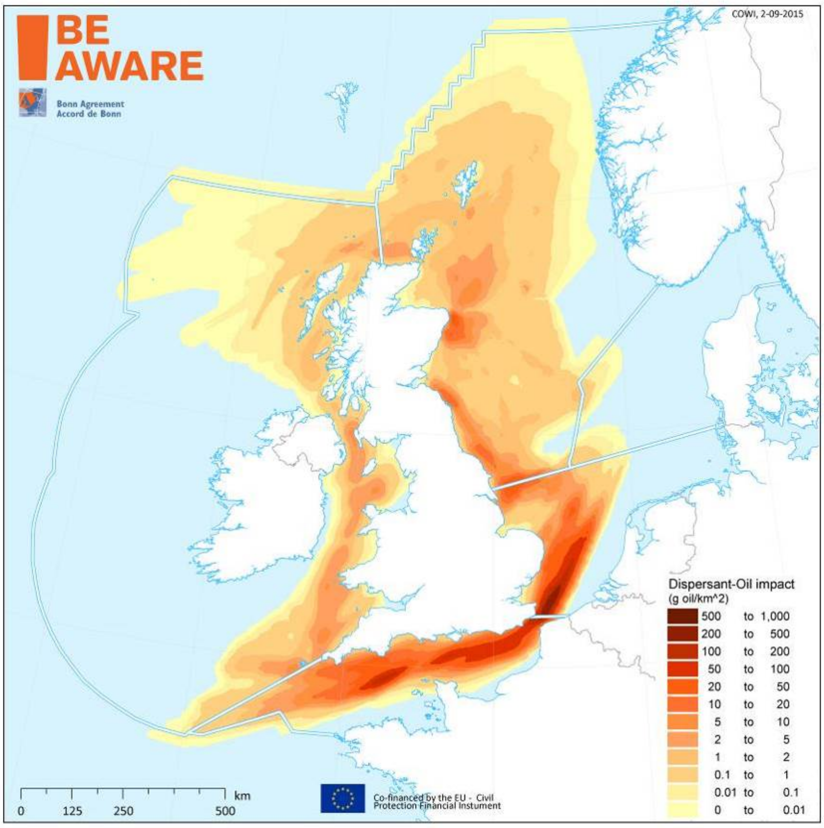
1.7 ETV in Ireland



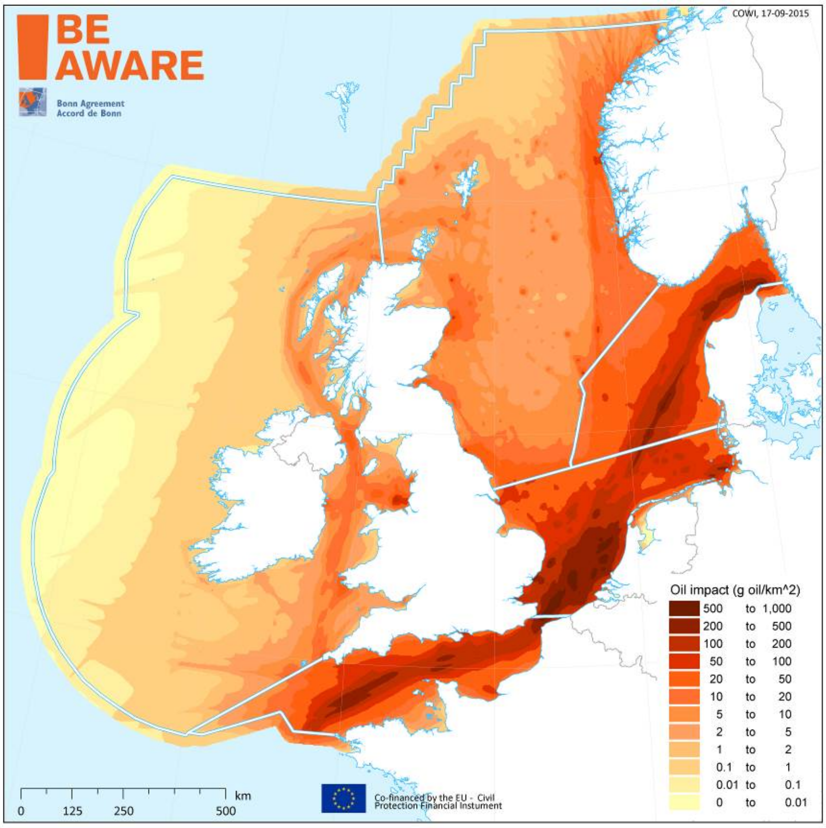


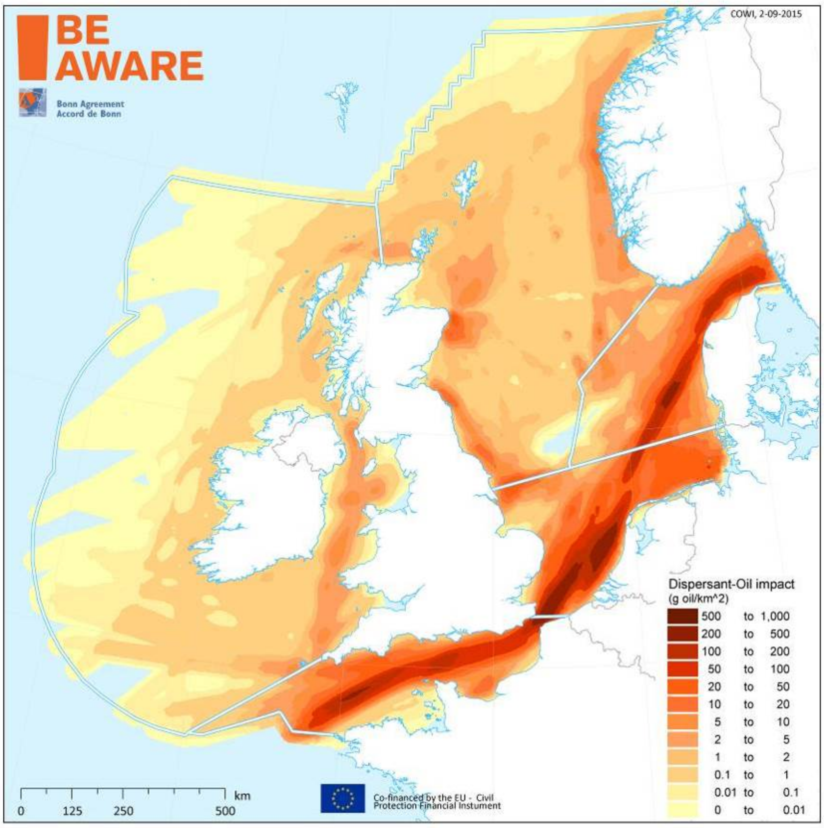
1.8 Improved night detection capability.



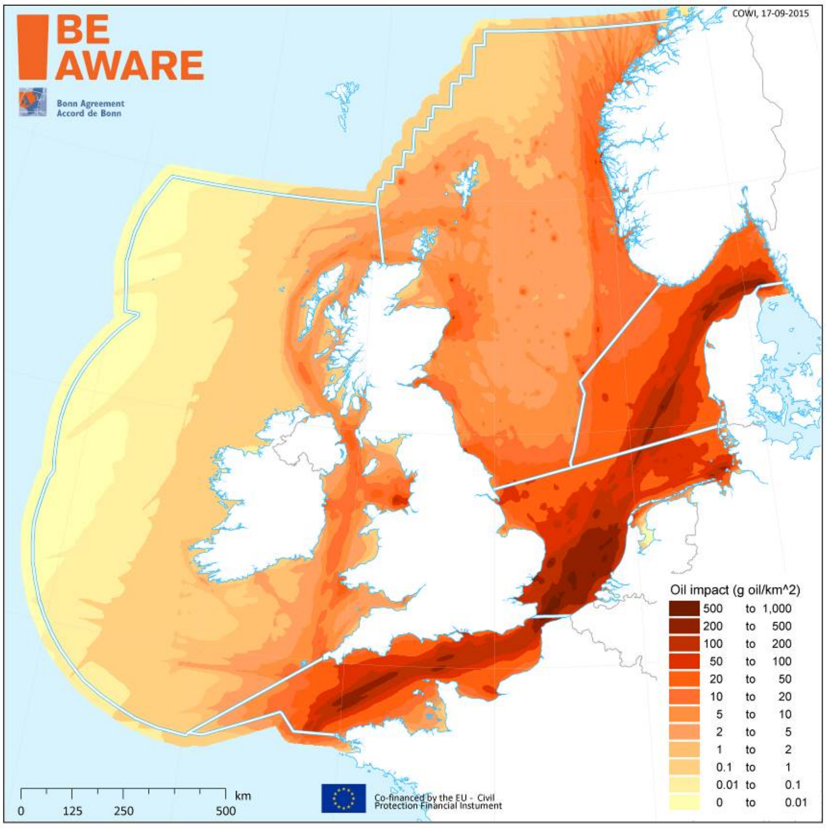


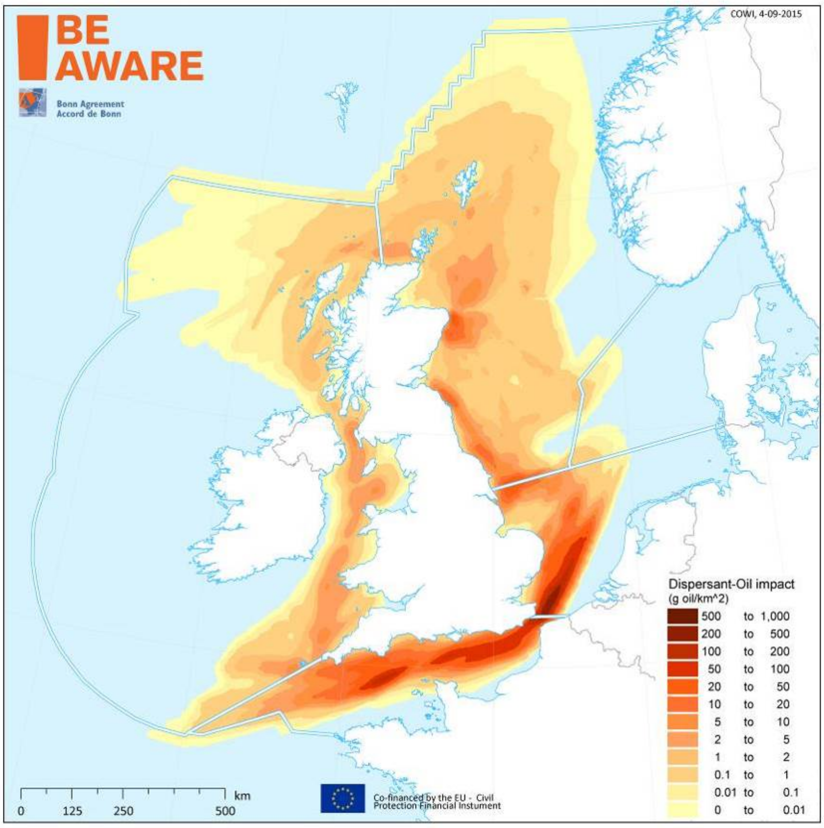
1.9 Further use of dispersants





1.10 50% increase in response equipment





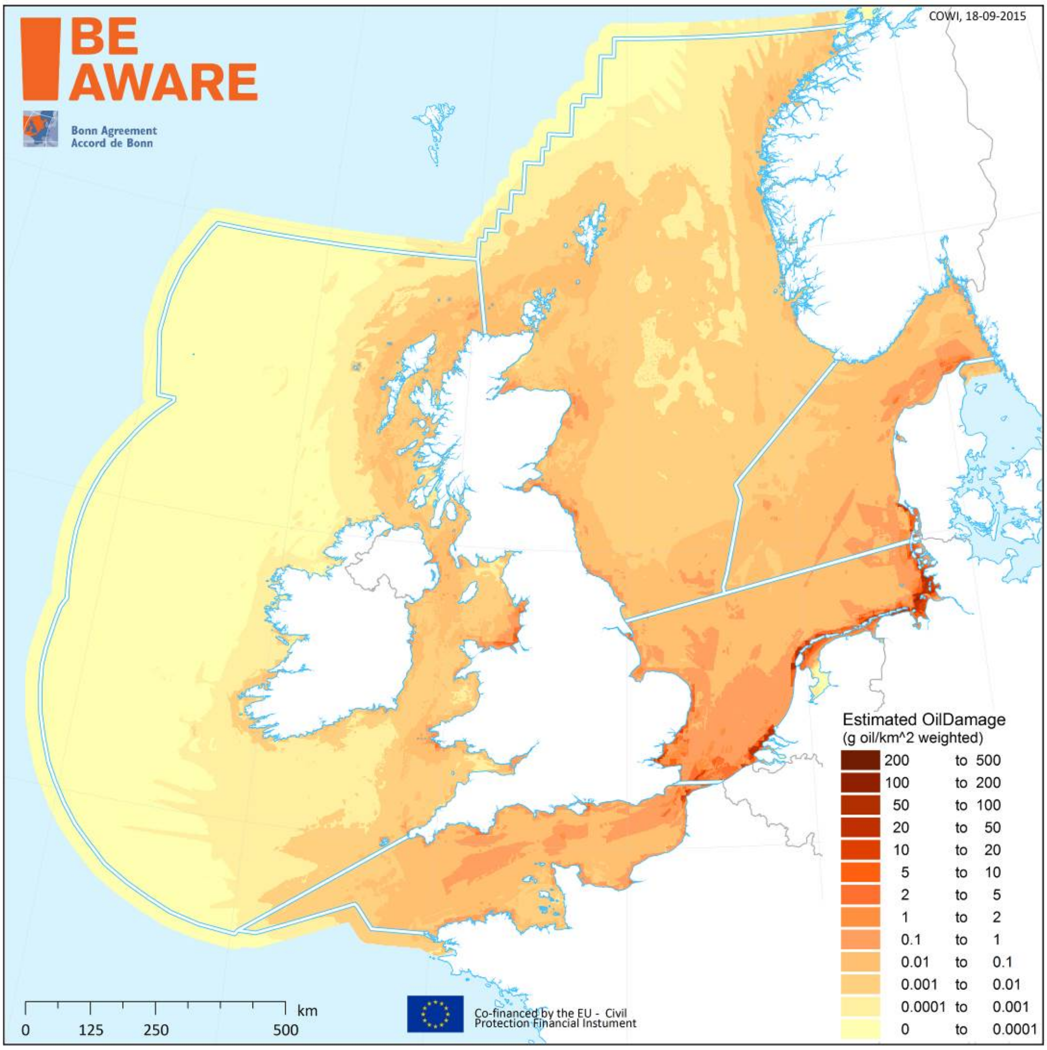
2. Annex Damage Maps

In this section the damage maps for the different scenarios are given

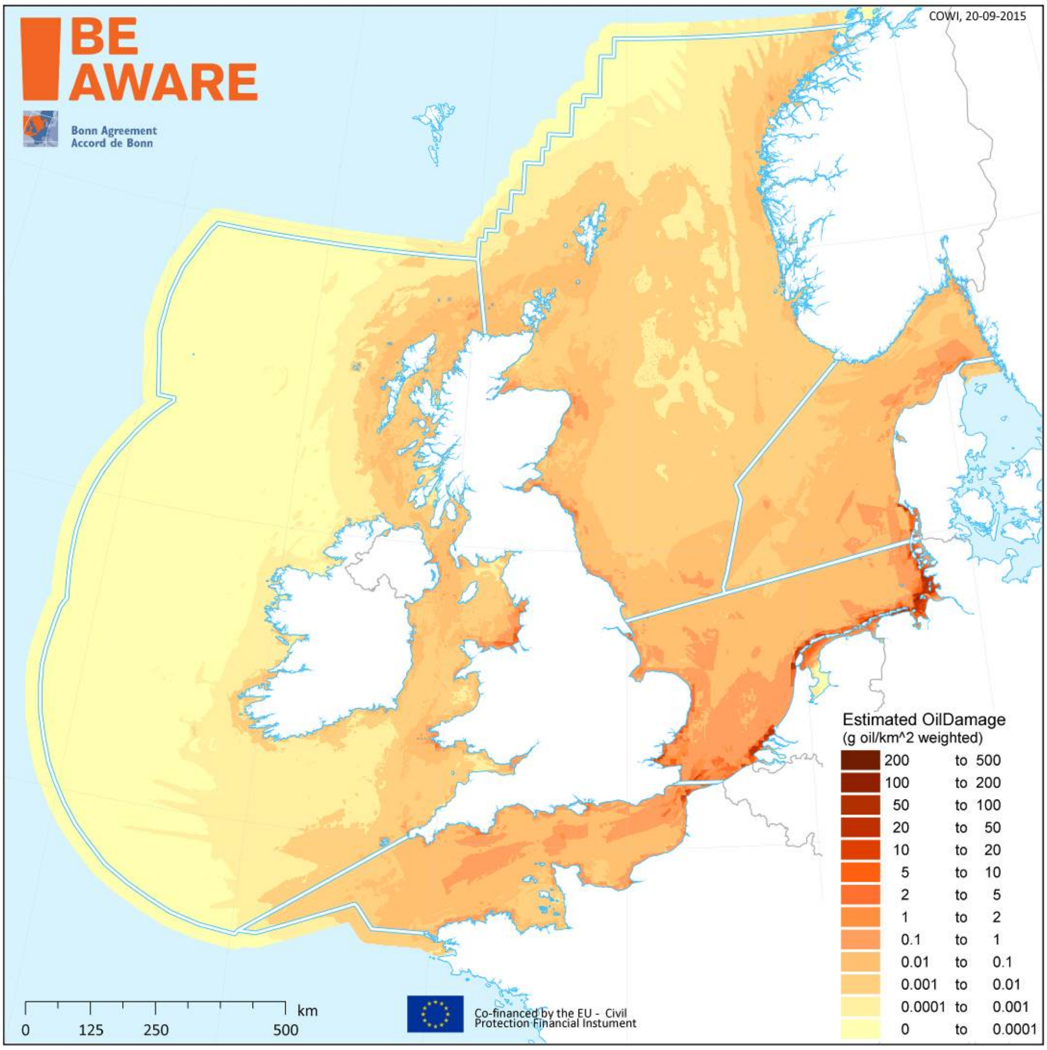
2.1 About

The damage maps given hereunder this section show the variation from scenario to scenario. For some scenarios the change is limited and can only be found on a cell-to-cell basis, but for other scenarios the impact is visible on a region wide scale.

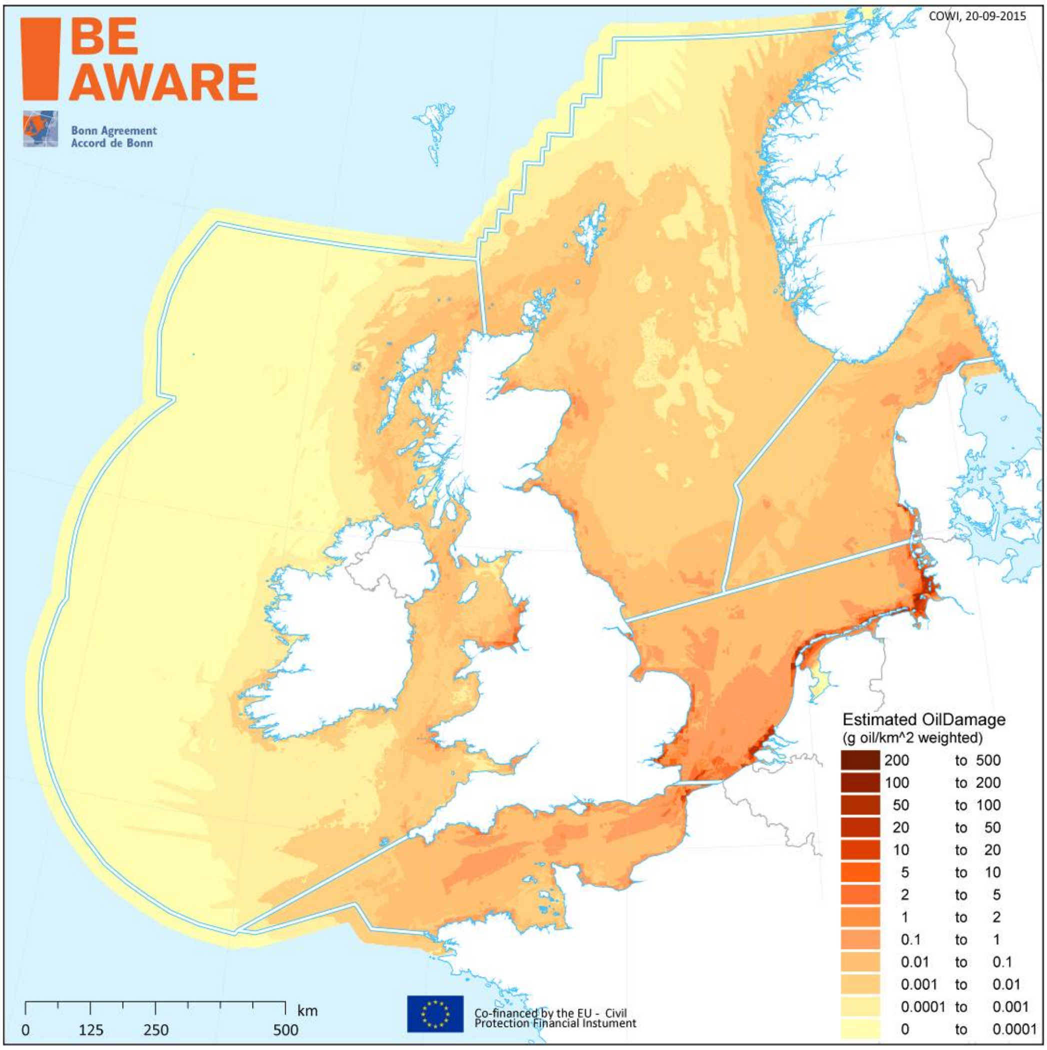
2.2 Base Case



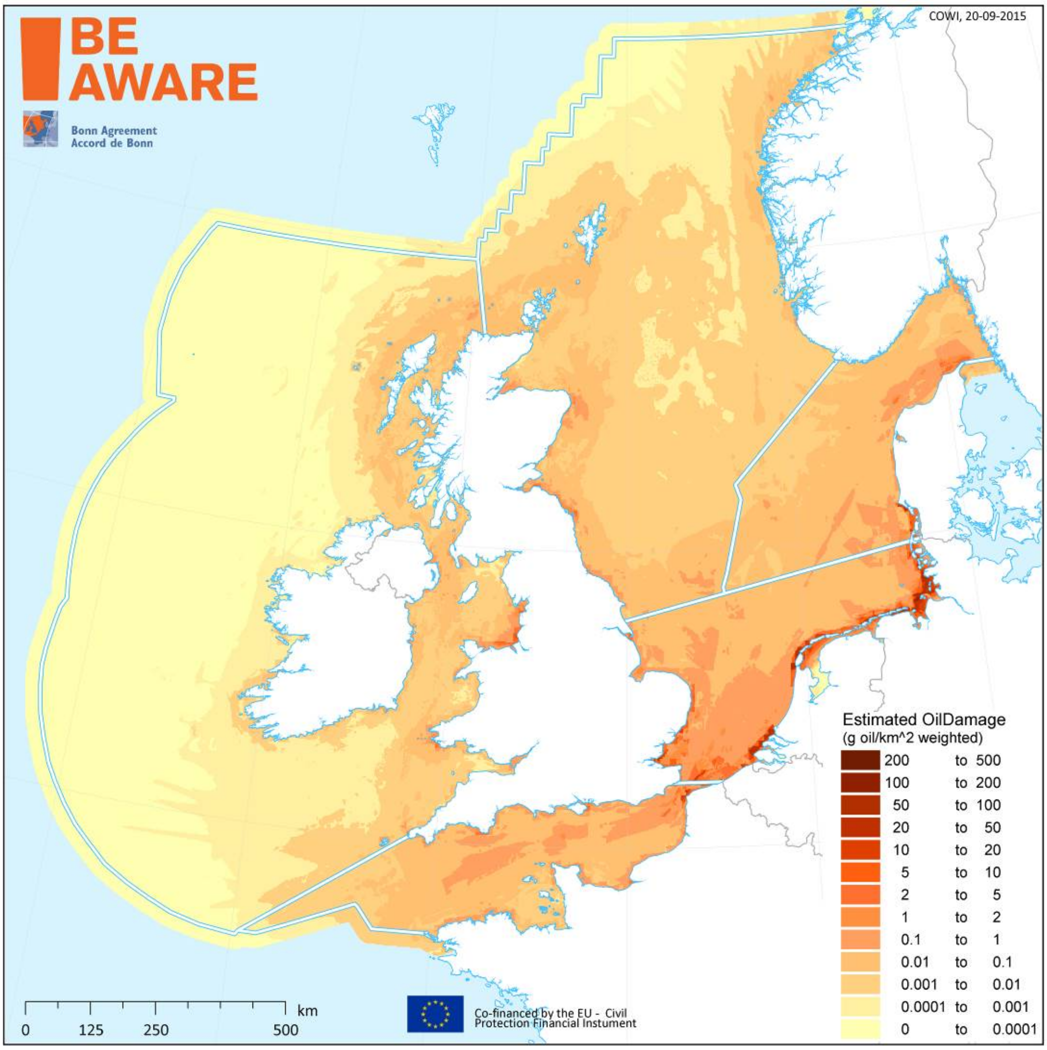
2.3 VTS scenario



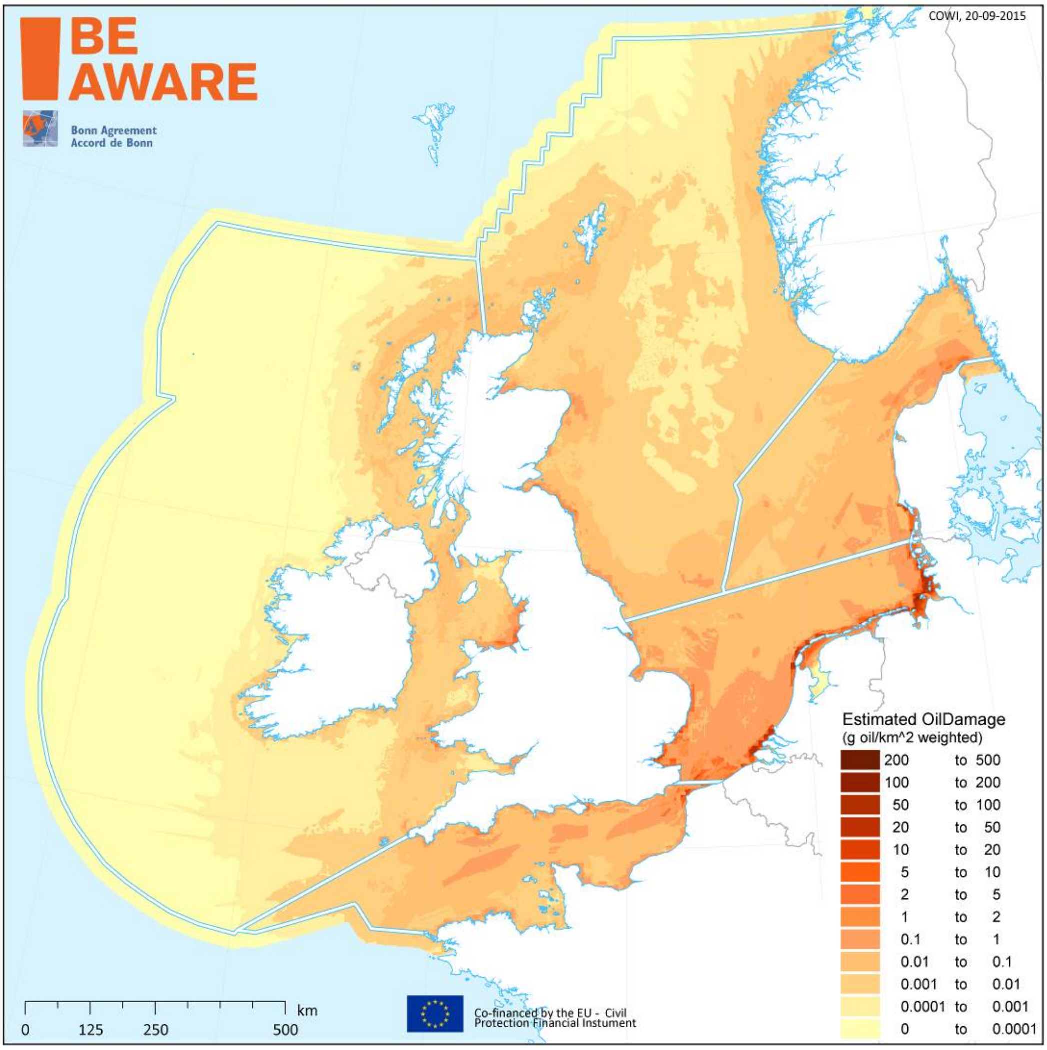
2.4 TSS scenario



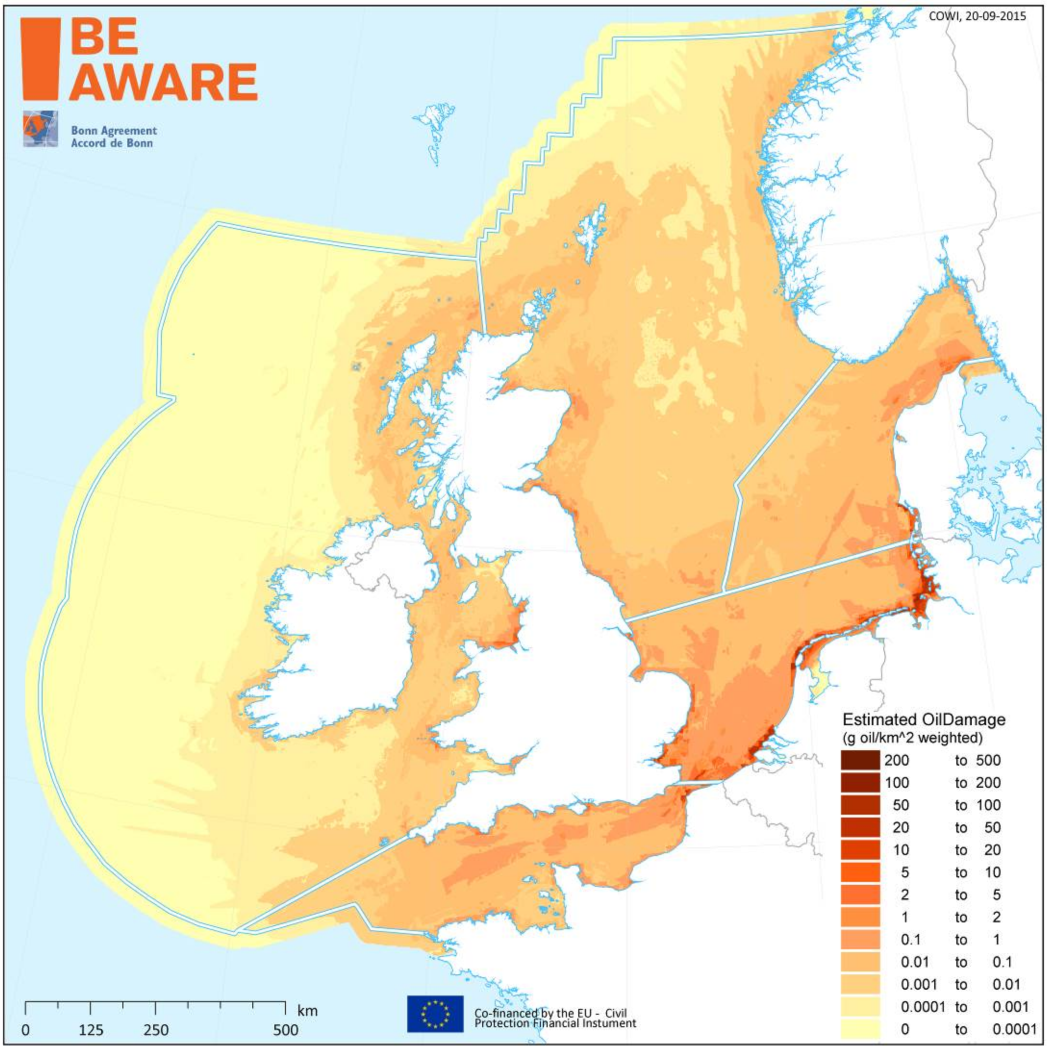
2.5 AIS alarm


COWI, 20-09-2015
BE AWARE
Bonn Agreement
Accord de Bonn
Estimated OilDamage
(g oil/km^2 weighted)
200 to 500
100 to 200
50 to 100
20 to 50
10 to 20
5 to 10
2 to 5
1 to 2
0.1 to 1
0.01 to 0.1
0.001 to 0.01
0.0001 to 0.001
0 to 0.0001
0 125 250 500 km
Co-financed by the EU - Civil Protection Financial Instument

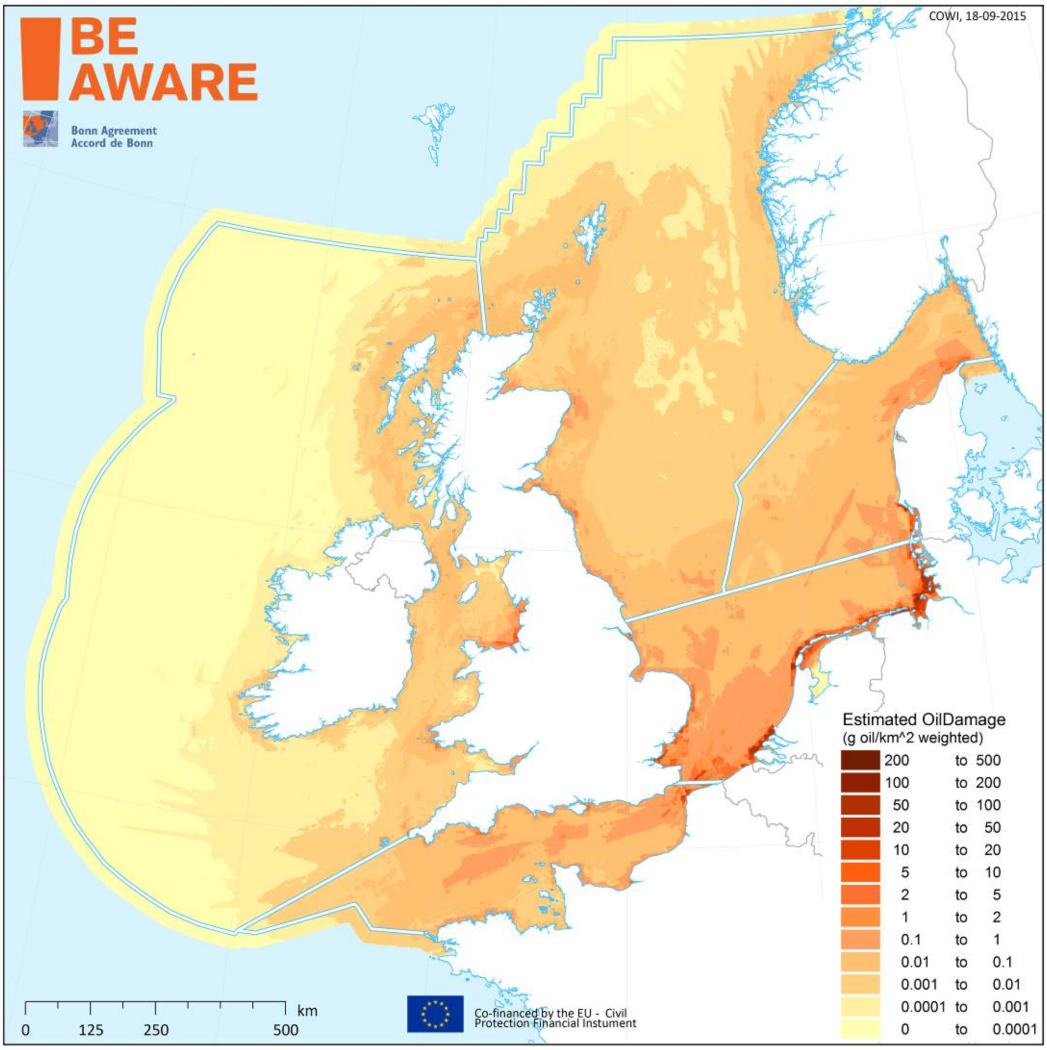
2.6 E-navigation



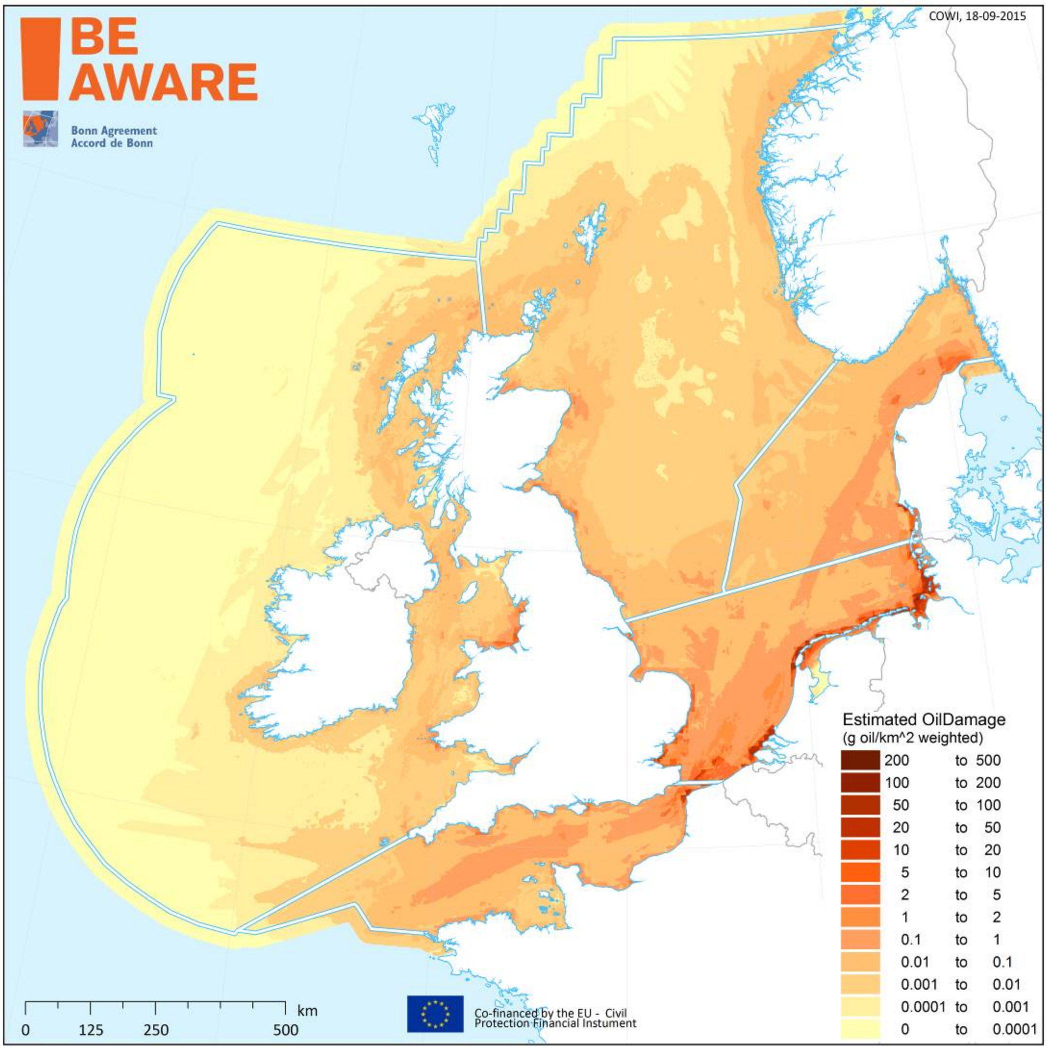
2.7 ETV in Ireland



2.8 Improved night detection capability.



2.9 Further use of dispersants



2.10 50% increase in response equipment