Admiral Danish Fleet HQ,
National Operations, Maritime Environment

# Sub-regional risk of spill of oil and hazardous substances in the Baltic Sea (BRISK)

Numerical calculation

December 2011

Part-financed by the European Union
(European Regional Development Fund)

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# 1 Introduction

## 1.1 BRISK Project setup

The project is defined in response to an increased concern about accidents and environmental damage in the Baltic Sea due to the significant increase of ship traffic, particularly the oil tanker traffic. Major oil spills can affect the economy of several countries and are hence a trans-national problem. The increased risk of oil spills is of great concern in the whole Baltic Sea region.

The objective of the project is to identify specific proposals for increased co-operation. The project will result in increased preparedness of authorities to respond to medium size oil spills and enhanced sub-regional co-operation. The network of responsible persons will be further developed. The project will promote building partnerships and co-operations among trans-national, national and regional authorities that are responsible for emergency and response operations in the Baltic Sea.

The BRISK project is partly financed by EU´s Baltic Sea Regional Programme 2007-2011with 3.3 million EUR for the period 2009 to 2012.The co-financing varies between 15 % and 25 %, depending on the home country of Project Partner.

The project partnership consists of the national authorities responsible for oil spill preparedness around the Baltic Sea together with HELCOM. The countries involved are: DK, SE, FI, EE, LT, LV, PL, DE, plus HELCOM. Russia in involved indirectly through the BRISK-RU project, which is financed by the Nordic Council of Ministers with 200.000 EUR. A list of the contracting authorities and the contact persons involved is given in the appendix.

The project activities are divided into the following 6 Work Packages (WP):
WP1: Management, responsible: LP (Lead Partner, Denmark)

WP2: Communication and information, responsible HELCOM

WP3: Risk assessment: Common methodology, unified data collection, common risk model, common assessment of risk of pollution and impact, Identification of additional response resources needed, resp. LP

WP4: Agreements: Development of proposals to remove administrative obstacles to the efficient response, resp.: LP

WP5: Investment plans: Preparation of integral and comparable investment plans for response resources, resp.: LP.

The structure of the project reports is given in below

*Table 1-1 Document list of the BRISK project*

| **Document number** | **Document Title** |
|---|---|
| 70618 3.1.1 | Method Note |
| 70618 3.1.2.1 | Data Collection Note |
| 70618-3.1.2.2 | Data Collection Report |
| 70618-3.1.3.0 | Model Note,0- Introduction |
| 70618-3.1.3.1 | Model Note,1-Traffic |
| 70618-3.1.3.2 | Model Note,2- Transport |
| 70618-3.1.3.3 | Model Note,3- Vulnerability |
| 70618-3.1.3.4 | Model Note,4- Frequency |
| 70618-3.1.3.5 | Model Note,5- Spreading |
| *70618-3.1.3.6* | *Model Note,6- Numerical calculations* |
| 70618-3.1.3.7 | Model Note,7-Model modification |
| 70618-3.2.1 | Model scenarios |
| 70618-3.2.2 | Model results |
| 70618-3.3 | Response Resources |
| 70618-4 | Agreements |
| 70618-5 | Investment plans |

# 2 Numerical calculations

The present chapter gives a tentative presentation of the principles of the numerical aggregation for the integrating risk assessment.

## 2.1 Introduction

This chapter addresses the numerical calculation involved in the *Simple Spill Effect Calculation Model* and the *Integral Model*. In Figure 2-1 the relevant part of the overall model complex is shown.

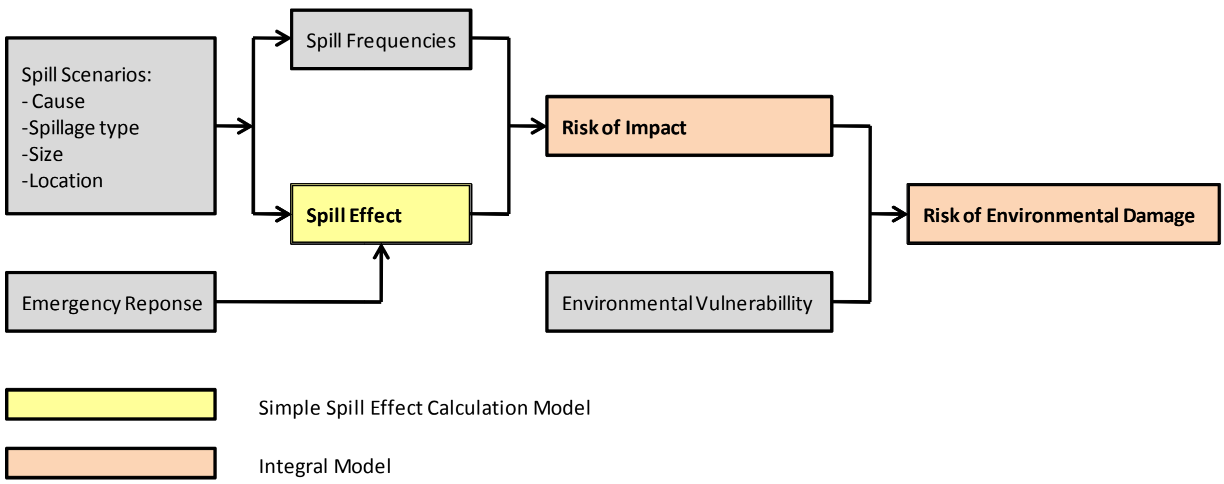



*Figure 2-1 Relevant part of the overall model complex*

As can be seen, the *Simple Spill Effect Calculation Model* addresses the element *Spill Effect*, while the *Integral Model* addresses the elements *Risk of Impact* and *Risk of Environmental Damage*.

The *Simple Spill Effect Calculation Model* calculates a lot (literally millions) of scenarios using a simplified (parameterized) description of the processes involved during a spill.

The *Integral Model* combines the results from the many scenarios calculated using the *Simple Spill Effect Calculation Model* with the spill frequencies to give the risk of impact. In addition the *Integral Model* combines these results of risk of impact with the vulnerability of the environment to give the risk of damage to the environment. The format of the results is tables as well as maps.

These 2 numerical models will be described in more details in the following.

In a project like this, naturally a lot of numerical calculations are involved. This chapter does not intend to describe the specific numerical calculations regarding the *Ship Traffic*, *Transportation*, *Environmental Vulnerability*, *Spill* or *Spreading and Containment*. Refer to these chapters for more details.

## 2.2 Simple Spill Effect Calculation Model

The *Simple Spill Effect Calculation Model* uses a simplified (parameterized) description of the processes involved in a spill together with a description of the scenario and the emergency response to simulate a spill, see Figure 2-2.

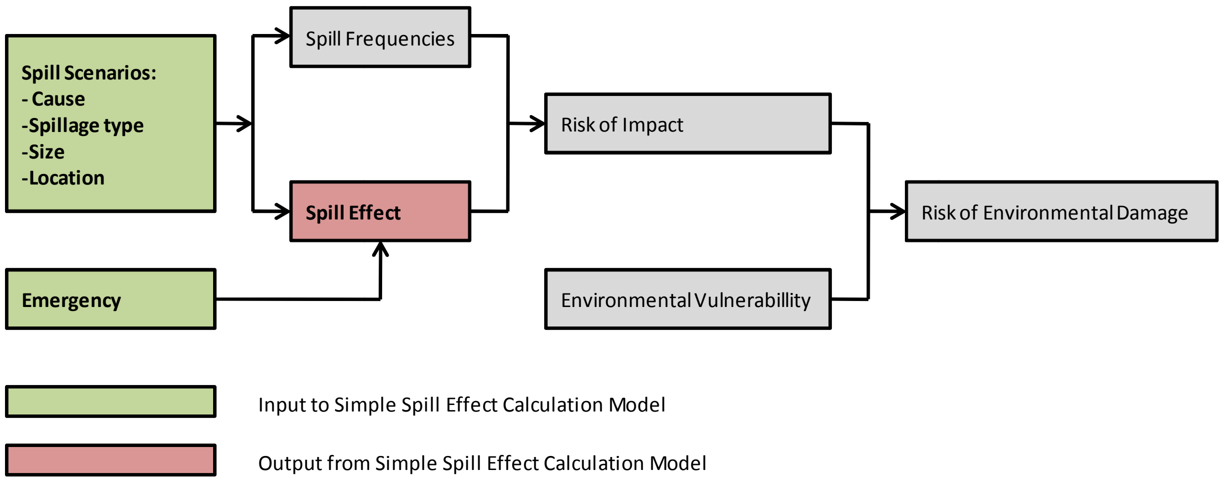



*Figure 2-2 Input to and output from the Simple Spill Effect Calculation Model*

An important aspect of the *Simple Spill Effect Calculation Model* is the independency of the spill frequencies. That is, if some of the frequencies are changed, for instance to model another year or to model modified risk reducing measures, it is not necessary to recalculated all the scenarios of the *Simple Spill Effect Calculation Model*. The new results for the impact and damage are obtained using the *Integral Model* which combines the new frequencies with the old spill effect calculations.

2 different models have been developed depending on the characteristics of the substances in question:

- *Model for Oil and Floating Chemicals*
- *Model for Soluble Chemicals*

Each of these 2 models will be addressed in the following.

The *Simple Spill Effect Calculation Models* are developed in *Microsoft Visual Basic* using *Microsoft Excel* as a platform and communicating with *Microsoft Access* regarding the management of input and output.

### 2.2.1 Model for Oil and Floating Chemicals

In the chapter *Spreading and Containment* the processes involved when oil or floating chemicals are spilled in the sea are analysed in details.

These detailed investigations of the relevant processes, refer Figure 2-3, have been summarized into parameterized models.

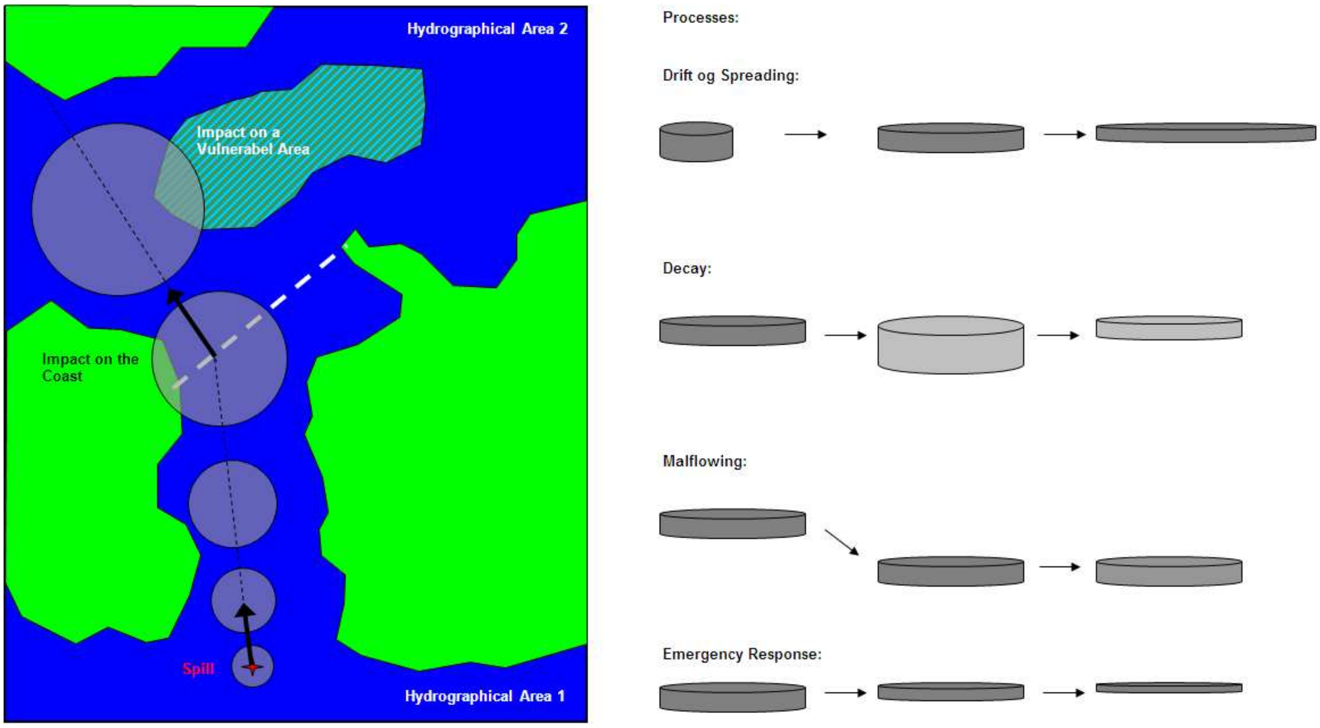



*Figure 2-3 Fundamental sketch of the relevant processes*

This parameterization makes it possible to simulate a vast number of scenarios.

The exact number of scenarios is not yet established, but to get an indication of the order of magnitude, these are the scenarios used in the project /Oil spill DK, 2007/:

- 4 seasons
- 8 substances (actually 7 but one of the substances was *re-surfacing* ("*mal-fydning"*)
- 5 spill sizes (the 5 largest spill sizes)

- 80 release points
- 2 emergency responses (no emergency response and full emergency response)
- 12 wind directions
- 3 wind speed classes

This adds up to 921.600 scenarios.

In the BRISK project we operate with 6 seasons:

| SeasonID | Season | Months |
|---|---|---|
| 1 | Winter with ice | Jan, Feb |
| 2 | Spring with ice | Mar, Apr |
| 3 | Spring without ice | May |
| 4 | Summer | Jun, Jul, Aug |
| 5 | Autumn | Sep, Oct, Nov |
| 6 | Winter without ice | Dec |

And due to the larger geographical area covered in the BRISK project the number of release points is expected to be larger than in the project /Oil spill DK, 2007/.

Therefore the number of scenarios is expected to be millions.

To effectively simulate the scenarios the geographical area of interest is divided into cells of 2 km by 2 km. Each cell in this grid is then marked as *Sea*, *Coast*, *Land* or *Sea border* (cells in Kattegat between Denmark and Sweden). Refer Figure 2-4for an example of how Bornholm is modelled.

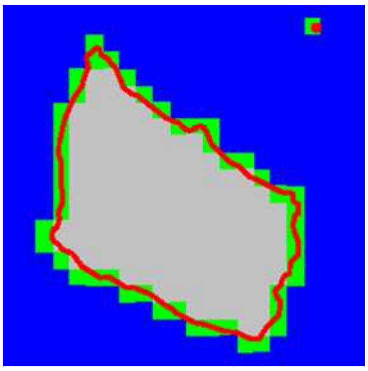


*Figure 2-4 Example of the geographical modelling of Bornholm into cells of the type Sea, Coast and Land.*

This results in approximately 110.000 *Sea* cells and 20.000 *Coast* cells.

In addition the whole geographical area of interest is divided into a number of administrative areas (sub regions) and hydrographical areas.

The output of a simulation of one scenario is simply a number of affected cells. The actual result for an affected cell depends on the type of the cell. For a *Sea* cell the amount of oil/chemical multiplied by the time the oil/chemical was in the cell is registered. For a *Coast* cell (and a *Sea border* cell) the total amount of oil/chemical is registered.

In addition the total amount collected by the emergency response is registered for each scenario.

The result of a simulation of one scenario can be illustrated as in Figure 2-5.

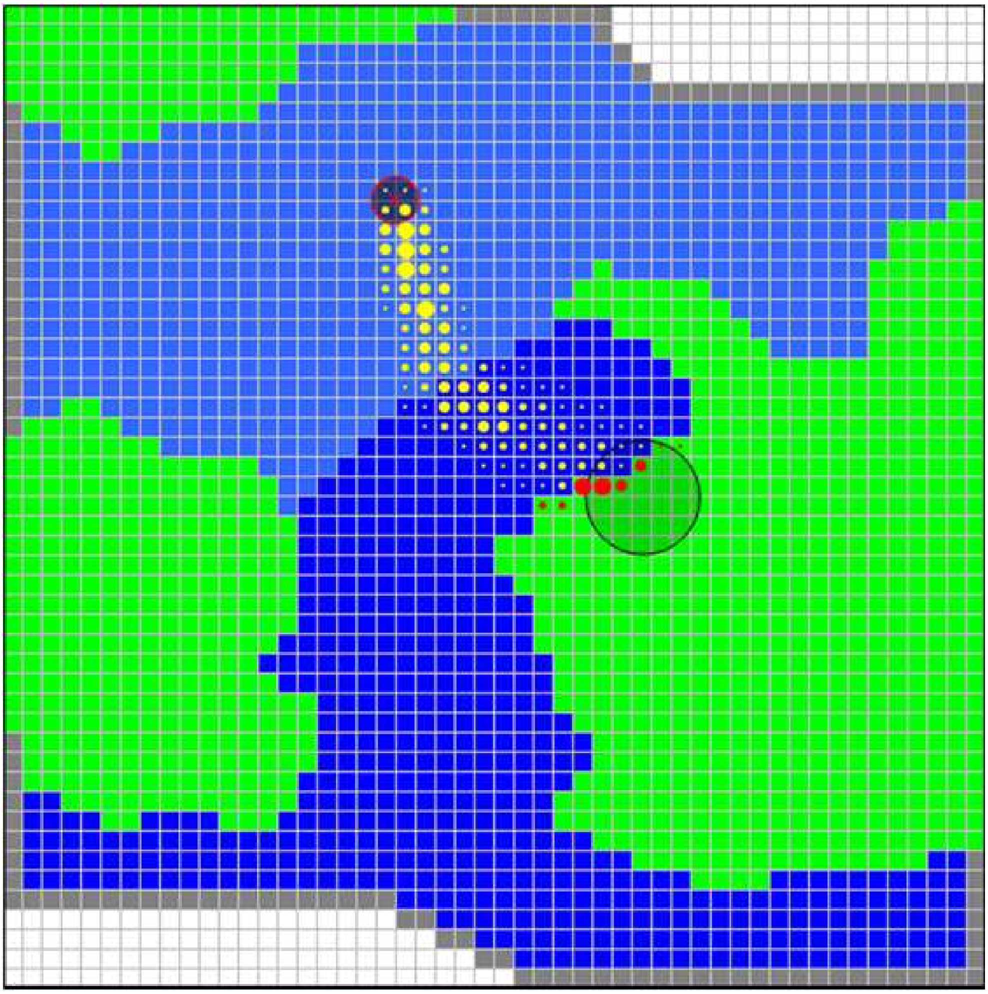


*Figure 2-5 Example of a simulation of a scenario. The release point and the size of the original spill and the final spill size is indicated.*

### 2.2.2 Model for Soluble Chemicals

The *Model for Soluble Chemicals* applies the PEC/PNEC model, which is abbreviation for *Predicted Effect Concentration/Predicted No Effect Concentration*; see Figure 2-6 for a fundamental sketch of this model.

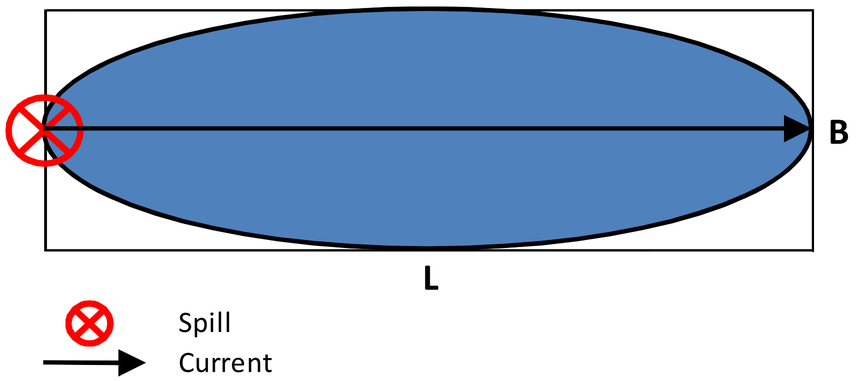



*Figure 2-6 Fundamental sketch of the PEC/PNEC model*

The PEC/PNEC model is described in more details in the chapter *Spreading and Containment*. For the purpose of the numerical calculations of soluble chemicals it is sufficient to say that:

- The PEC/PNEC model was developed to determine the effect of spill from the offshore industry
- The PEC/PNEC model calculates a downstream distance of effect
- This distance of effect depends on the size of the spill, the water in question and the substance (the environmental toxicity)

As for the *Model for Oil and Floating Chemicals*, this simplified model makes it possible to simulate a vast number of scenarios.

The exact number of scenarios is not yet established, but to get an indication of the order of magnitude, these are the scenarios used in the project /Oil spill DK, 2007/:

- 4 seasons
- 3 substances
- 5 spill sizes (the 5 largest spill sizes)
- 1497 release points
- 1 emergency responses (no emergency response)
- 12 wind directions
- 1 wind speed classes (the PEC/PNEC model predict no influence of the wind speed)

This adds up to 1.077.840 scenarios.

As for the *Model for Oil and Floating Chemicals* more seasons and more release points indicate the expected number of scenarios for the *Model for Soluble Chemicals* to be millions.

The same geographical grid is used for the *Model for Soluble Chemicals* as for the *Model for Oil and Floating Chemicals*

Conservatively the *Simple Spill Effect Calculation Model* uses the rectangle in stead of the ellipse for the affected area.

That is for a specific scenario, the cell of the spill in question is located, se Figure 2-7.

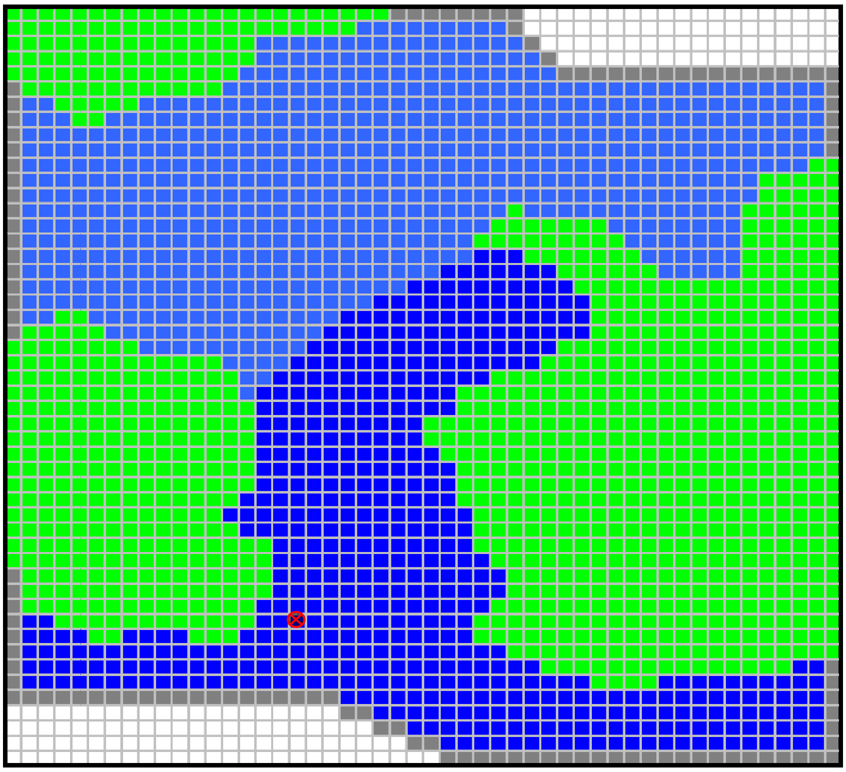


*Figure 2-7 Example of a spill (release point) in a cell*

Next the rectangle of the affected area is determined, se Figure 2-8.

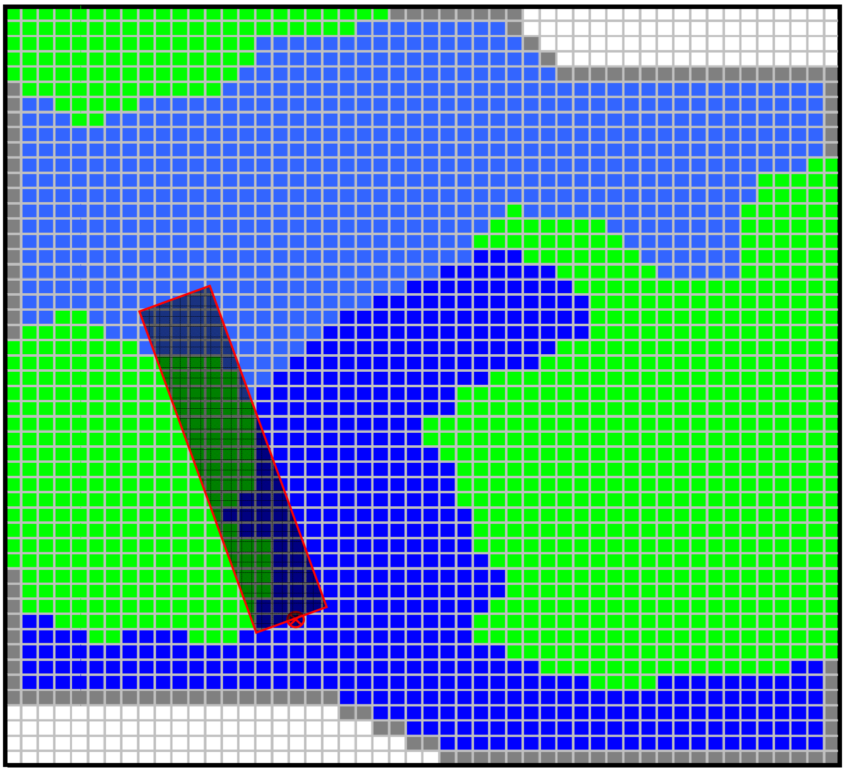


*Figure 2-8 Rectangle of effected cells calculated using PEC/PNEC*

And finally the actual cells affected are marked taken into consideration a possible shadow effect by the coast, see Figure 2-9.

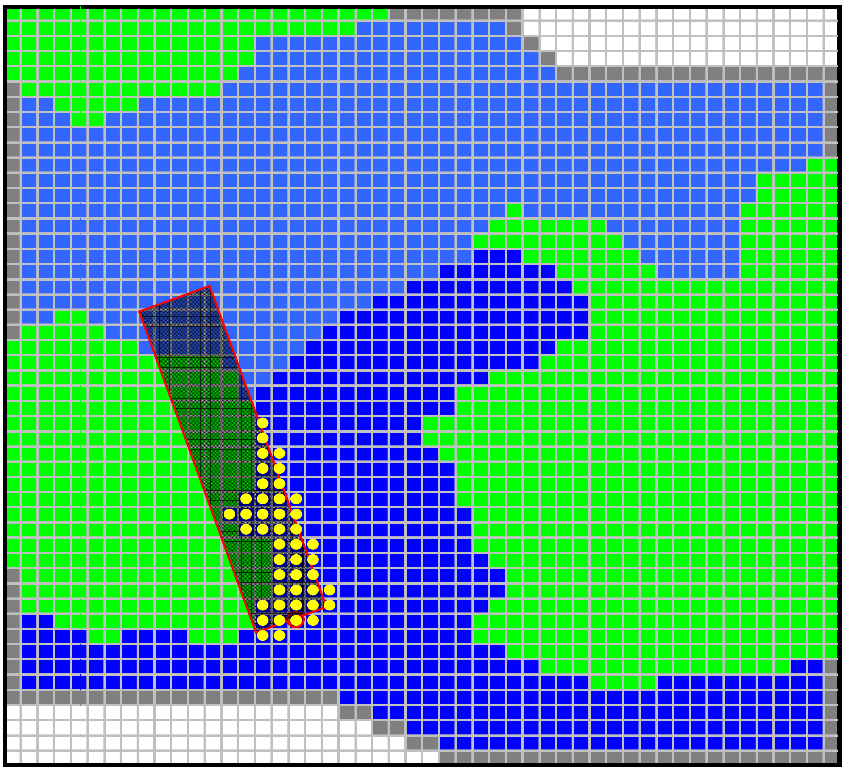


*Figure 2-9 Affected cells taking into consideration a possible shadow effect*

Conservatively a cell touched by the rectangle is considered as an affected cell.

The output of a simulation of one scenario is simply a number of affected cells (the cells hit).

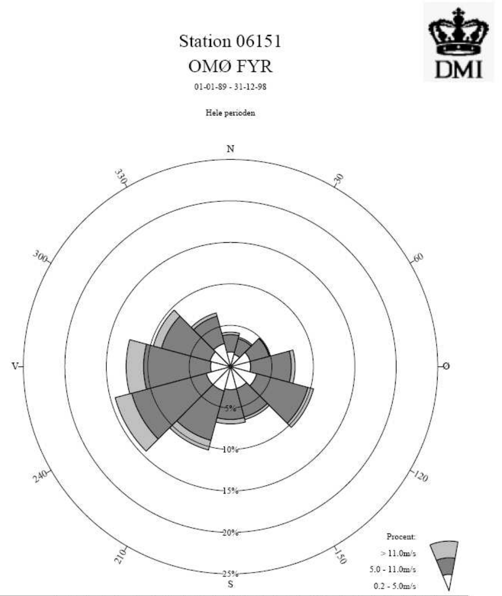
### 2.2.3 Wind Aggregation

With so many single-cell results to be combined with frequencies, proper data management is required. On one hand aggregation of the data before combination with the frequencies is advantageous because of the reduction of the number of single-cell results. On the other hand the possibility to "ask" about the influence of the different parameters (spill size, season etc.) is advantageous because of the flexibility of the *Integral Model*.

This trade-off results in an aggregation of the results with respect to the wind direction and wind class (wind speed).

The purpose of wind aggregation is thus twofold:

- Reduction of the number of single cell results by integrating the probability of the wind (direction and speed) for the different seasons for the relevant hydrographical areas, see Figure 2-10.




| | N | 30 | 60 | Ø | 120 | 150 | S | 210 | 240 | V | 300 | 330 | Ialt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | 4.2 | 3.7 | 4.9 | 7.8 | 10.4 | 6.6 | 6.9 | 10.4 | 14.4 | 12.6 | 9.6 | 6.7 | 98.3 |
| % 0.2-5.0m/s | 1.8 | 1.5 | 2.5 | 2.4 | 3.3 | 2.7 | 2.8 | 3.0 | 3.1 | 2.4 | 2.6 | 2.9 | 31.0 |
| % 5.0-11.0m/s | 2.1 | 2.0 | 2.4 | 4.9 | 6.4 | 3.6 | 3.6 | 6.2 | 9.3 | 8.1 | 6.1 | 3.4 | 57.9 |
| % > 11.0m/s | 0.3 | 0.2 | 0.1 | 0.4 | 0.7 | 0.3 | 0.5 | 1.2 | 2.1 | 2.1 | 1.0 | 0.4 | 9.3 |
| Middel hastighed | 5.9 | 5.7 | 5.0 | 6.3 | 6.4 | 5.8 | 6.1 | 6.9 | 7.5 | 7.8 | 7.1 | 5.7 | 6.6 |
| Største hastighed | 20.6 | 16.5 | 15.4 | 20.6 | 17.5 | 17.5 | 20.6 | 25.7 | 36.0 | 27.7 | 23.7 | 20.6 | 36.0 |

Totalt antal observationer = 60155 Kilde: DMI
Vindstille defineret som hastighed <= 0.2m/s
Antal observationer med vindstille/varierende vind: 1028 = 1.7%

*Figure 2-10 Example of wind statistics from a light used in the project /Oil spill DK, 2007/*

- Modelling the real emergency response by proper weighting no emergency response and full emergency response depending on the wind speed class (transferred into a significant wave height), see Figure 2-11.

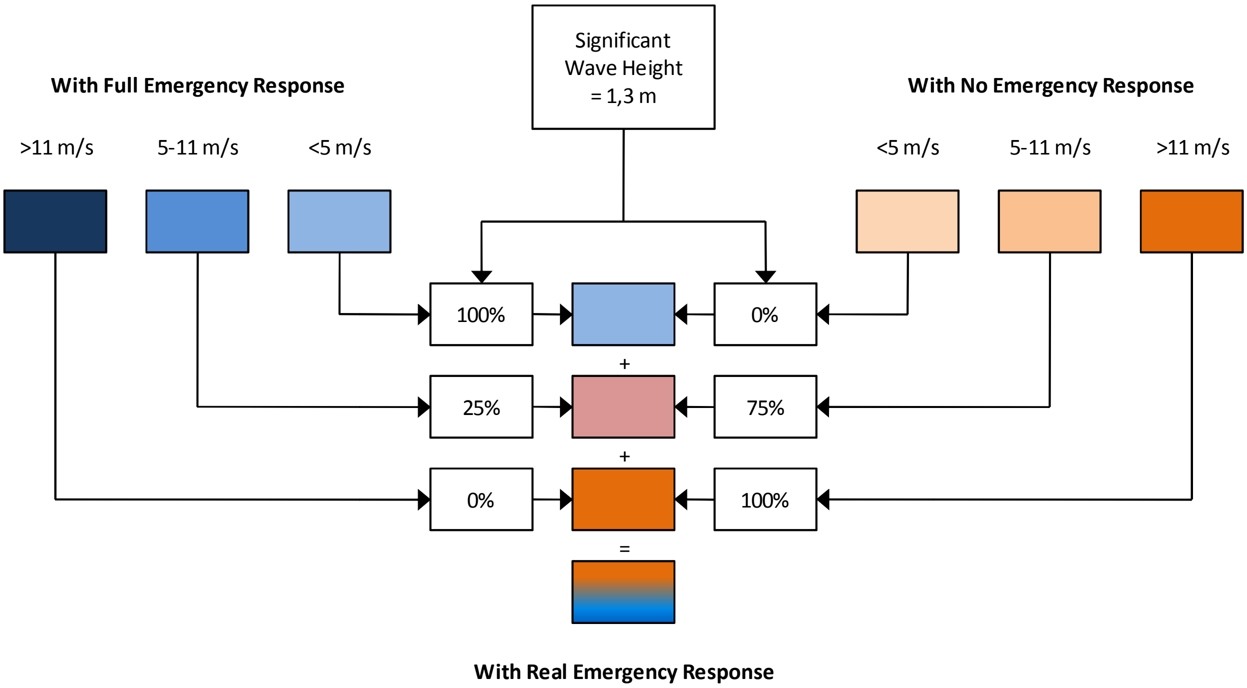



*Figure 2-11 Wind aggregation to determine the emergency response (the figures is taken from the project /Oil spill DK, 2007/)*

### 2.2.4 Model Modifications

Compared with the project Oil spill DK, 2007/the *Simple Spill Effect Calculation Model* in this BRISK project has been subject to the following modifications:

- General update (new versions of the development platforms)
- Management of a new and much larger geographical grid (including a different kind of transformation/projection due to the much larger north-south distance)
- More season (due to the possibility of ice cover)
- Distinguishing between drift in ice cover and in no ice cover

## 2.3 Integral Model

The *Integral Model* combines the huge amount of single-cell results from the *Simple Spill Effect Calculation Model*s with the spill frequencies and the vulnerability of the environment to deliver tables and maps of the risk of impact and the risk of environmental damage, see Figure 2-12.

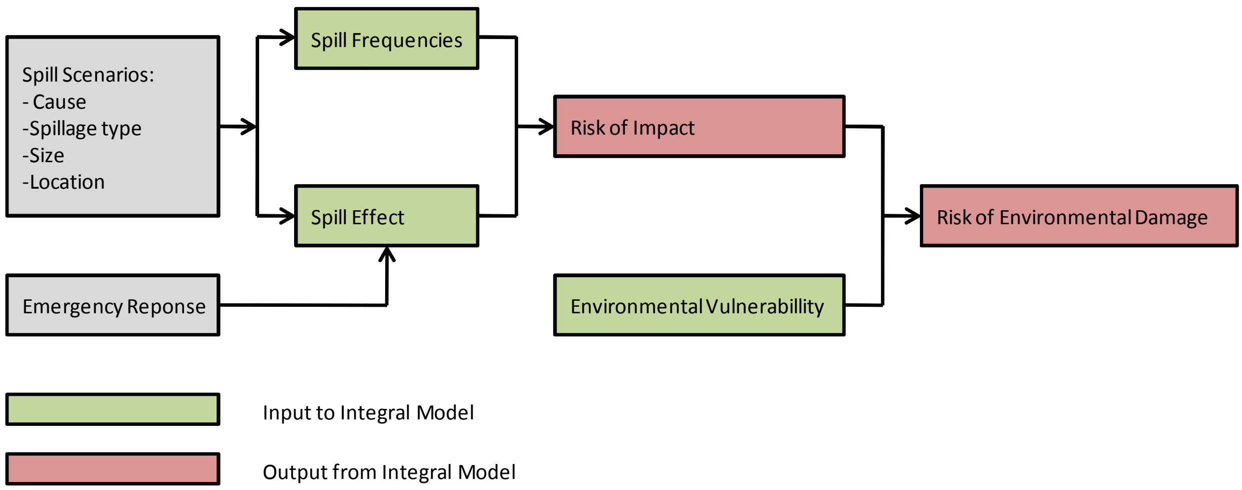



*Figure 2-12 Input to and output from the Integral Model*

The *Integral Model* is developed in *Microsoft Visual Basic* using *Microsoft Excel* as a platform and communicating with *Microsoft Access* regarding the management of input and *Pitney Bowes MapInfo* regarding the production of maps.

### 2.3.1 Model Modifications

Compared with the project Oil spill DK, 2007/the *Integral Model* in this BRISK project has been subject to the following modifications:

- General update (new versions of the development platforms)
- Handling of the new geography
- Handling of the new kind of scenarios (for instance the new seasons)

# 3 References

Oil spill DK, 2007: "*Risikoanalyse: Olie- og kemikalieforurening i danske farvande" (Risk analysis: Oil and chemicals pollution in Danish waters)*, prepared for Danish Ministry of Defence by COWI, COWI report 63743-1-01, October 2007