BE AWARE

Bonn Agreement
Accord de Bonn

Technical Sub Report 10: Case Study

Bonn Agreement
Accord de Bonn

Co-financed by the EU –
Civil Protection Financial Instrument

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COWI

MARIN

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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 improve disaster prevention by allowing North Sea States to better focus their resources on areas of high risk.

The project is a two year initiative (2012-2014), co-financed by the European Union, with participation and support from the Bonn Agreement Secretariat, Belgium, Denmark and the Netherlands, with co-financing from Norway.

Contents

Executive Summary

The main objective of the BE-AWARE project was to conduct an area-wide risk assessment in the spillage of oil and HNS in the North Sea. The approach followed is described in the Method note and the risk assessment was performed for the years 2011 and 2020.

Within the BE-AWARE project a multi model approach similar to that used in the BRISK Project was chosen. This model is developed and used by COWI for the calculation of the frequencies of collisions and groundings in the BE-AWARE area. Some Contracting Parties have also used the SAMSON model, developed and used by MARIN, in their national risk assessments and this was also used for the assessment of the risk for offshore installations, being platforms and wind turbines in the project.

The purpose of this Technical Sub report is to benchmark the result of the BE-AWARE risk assessment against the SAMSON model for a high risk area. This would allow Contracting Parties that use SAMSON nationally to take these differences into consideration when comparing the BE-AWARE results against national studies. The comparison was done for the case study area, a high intensive traffic area off the Belgian and Dutch coasts. The following comparisons were performed.

- Comparison of the BE-AWARE route structure with the SAMSON schematization.
- Assessment of the accident frequencies: ship – ship collisions and groundings.
- Assessment of the spill frequencies and sizes.

The models for collision risk in BE-AWARE and SAMSON have the same basis. The number of encounters is calculated based on the traffic database consisting of links with the number of ship movements. Each link has its own lateral distribution. SAMSON uses a fixed domain around the ship that will be kept free of other ships and BE-AWARE a distance of 20 ship lengths. BE-AWARE uses one causation factor for the transit of encounters to collisions. SAMSON uses a ship type and size dependent casualty rate, because there is a difference in casualty sensitivity between ship type and ship size classes. The casualty rates are also different for the three types of encounters. The casualty rates of SAMSON are derived from the world wide casualty database with focus on the North Sea.

The models for grounding are also different. As SAMSON has detailed accident data for the Dutch region it uses two models for the contact risk for an object or grounding: one for the ramming risk, a grounding with normal speed after a navigational error, and one for the drifting grounding after a technical failure. For BE-AWARE this data was not available for the whole Bonn Agreement region and therefore it used parameters derived from historical casualty data.

The purpose of risk models is that they describe what happens as effectively as possible in an objective way. Risk models are very useful in indicating differences between scenarios or quantifying the effect of measures. Risk models are less precise in predicting absolute values of certain occurrences.

The comparison of the results of the BE-AWARE and the SAMSON model with respect to collisions and groundings in the Case Study area has delivered overall figures that are in the same order of magnitude. Of course a closer fit would have been nicer but the differences shown are acceptable.

The BE-AWARE and SAMSON models are too different from each other to make a detailed comparison of the results possible. Some causes for the differences are described in detail in this report.

The largest difference has been found for the probability and volume of bunker spills. The probability and the volume of a bunker spill seem to be high in BE-AWARE with respect to the number of ships involved in collisions and the fuel capacity of the ships.

1. Introduction

The main objective of the BE-AWARE project is to conduct an area-wide risk assessment in the spillage of oil and HNS. The approach followed is described in the BE-AWARE Methodology note. The risk assessment is performed for the years 2011 and 2020. The final risk in a certain area is the result of several steps:

1. Determination of the traffic intensity and composition in ship type and size classes;
2. Determination of the substances carried by the ships;
3. Determination of the probability of all possible incidents;
4. Determination of the probability of a spillage of oil or HNS given a certain type of incident;
5. Impact of the spillages on the environment.

The first four steps are addressed in the BE-AWARE project. The last step will be addressed in the BE-AWARE II project.

Because the probability of a shipping incident is low while the risk has to be spread over the whole geographic area, models are necessary that can predict the probability of an incident in a limited area based on the traffic, layout and external conditions.

The BE-AWARE project chose a multi model approach. The multi model approach is developed and used by COWI for the calculation of the frequencies of collisions and groundings in the BE-AWARE area. A similar model is SAMSON, developed and used by MARIN. Within the BE-AWARE project the SAMSON model has been used for the assessment of the risk for offshore installations, being platforms and wind turbines.

Risk Assessment Models predict probabilities of incidents in the order of 10^{-6} or even less. The predictions are based on models with many parameters which describe the influencing factors. It is impossible to determine accurate values for all these parameters and to describe the real impact of all parameters. For the same reason it is difficult to validate a risk model. However, a risk assessment model is the only option for a study like BE-AWARE.

As both the BE-AWARE and SAMSON approach have been used by Bonn Agreement Contracting Parties in their national risk assessments it was felt that the methodology used in BE-AWARE should be compared against the SAMSON model for a high risk area. This would allow Contracting Parties to consider the differences between the models when comparing the results of BE-AWARE with their national assessments.

More details regarding the SAMSON model can be found at: http://www.iala-aism.org/wiki/iwrap/index.php/SAMSON

Purpose of the report
The purpose of Task I, subject of this sub-report, is to make a comparison between results of the BE-AWARE model and the SAMSON model. The comparison will be done for the case study area presented in Figure 1-1. The following comparisons will be performed.

- Comparison of the BE-AWARE route structure with the SAMSON schematization.
- Assessment of the accident frequencies: ship – ship collisions and groundings.
- Assessment of the spill frequencies and sizes.

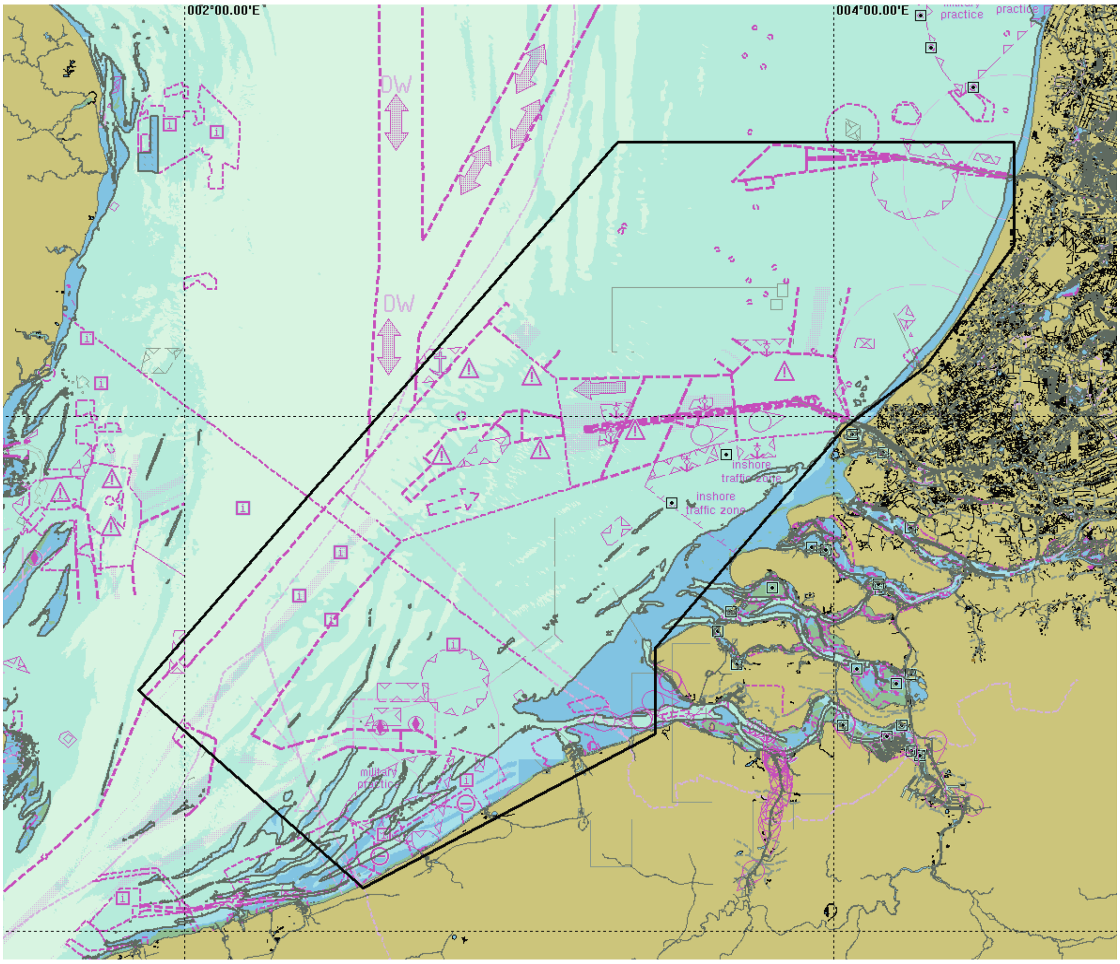

Figure 1-1 Case study area

2. Comparison of the traffic database 2011

Within the BE-AWARE project two traffic databases have been prepared, for 2011 and 2020. As the case study is executed for the 2011 situation, differences in the 2011 database between BE-AWARE and SAMSON are discussed here and in the Annex. There were also some remarks regarding the 2020 database and these are included in the Annex.

The traffic database for 2011 is prepared by COWI based on the AIS data within the BE-AWARE area, described in Technical Sub-report 1: Ship Traffic. The result is presented in Figure 2-1. Each link represents traffic in two directions. The thickness of the line increases (not linearly) with the intensity of shipping.

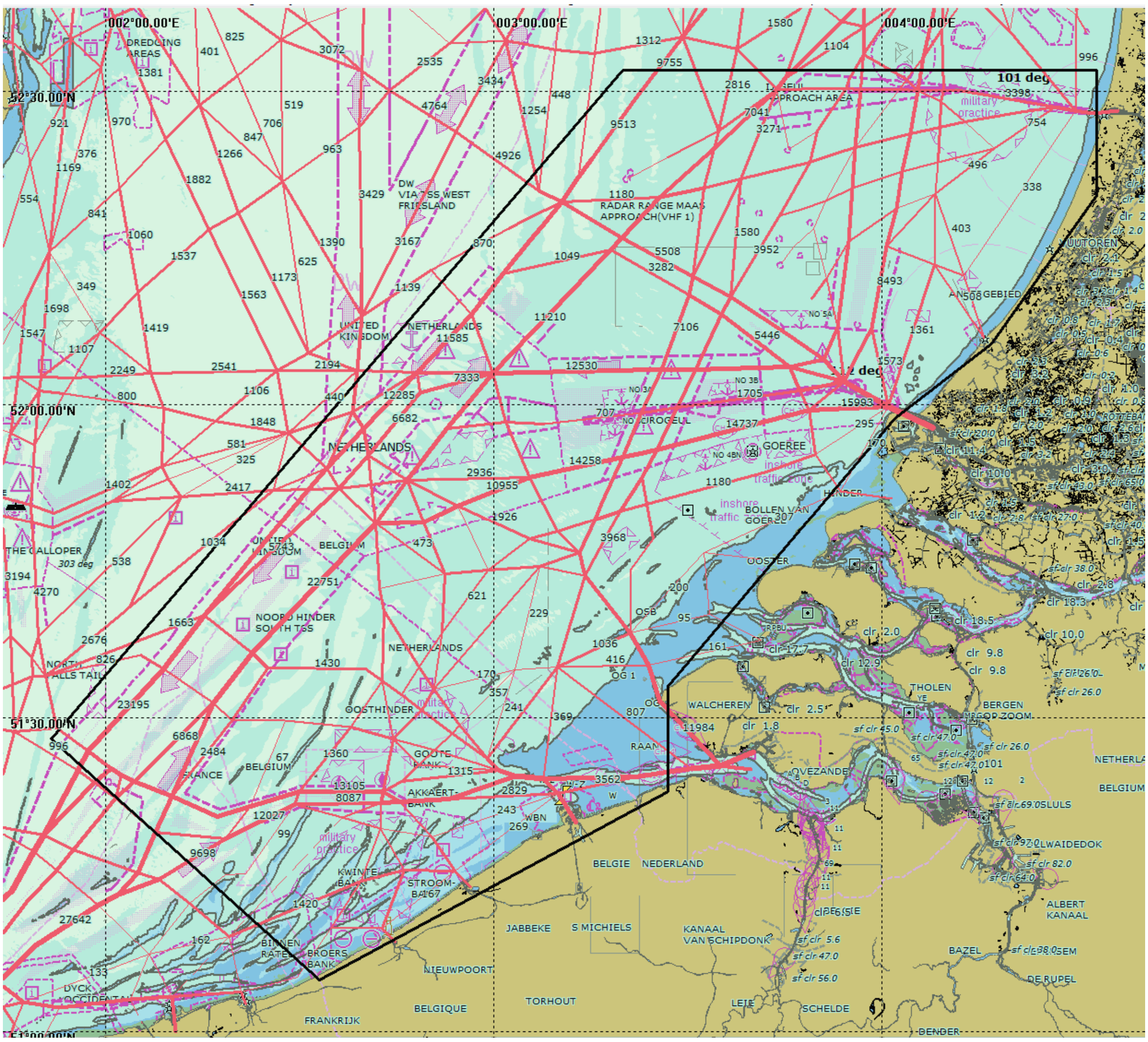

Figure 2-1 **Traffic database for 2011 of BE-AWARE**

Figure 2-2 contains the SAMSON traffic database of 2008. The traffic database is based on all voyages in 2008 and the routes are checked with the AIS data. The thick black lines are the borders of the case study area. The other black lines are shipping routes with very low intensities.

The determination of the traffic database is different from the approach of BE-AWARE. The route database is created by reconstructing the journeys of all voyages of 2008 from port to port over the North Sea using shortest route principles and following navigation rules thus respecting existing TSS, rather than based on actual AIS plots of the vessels.

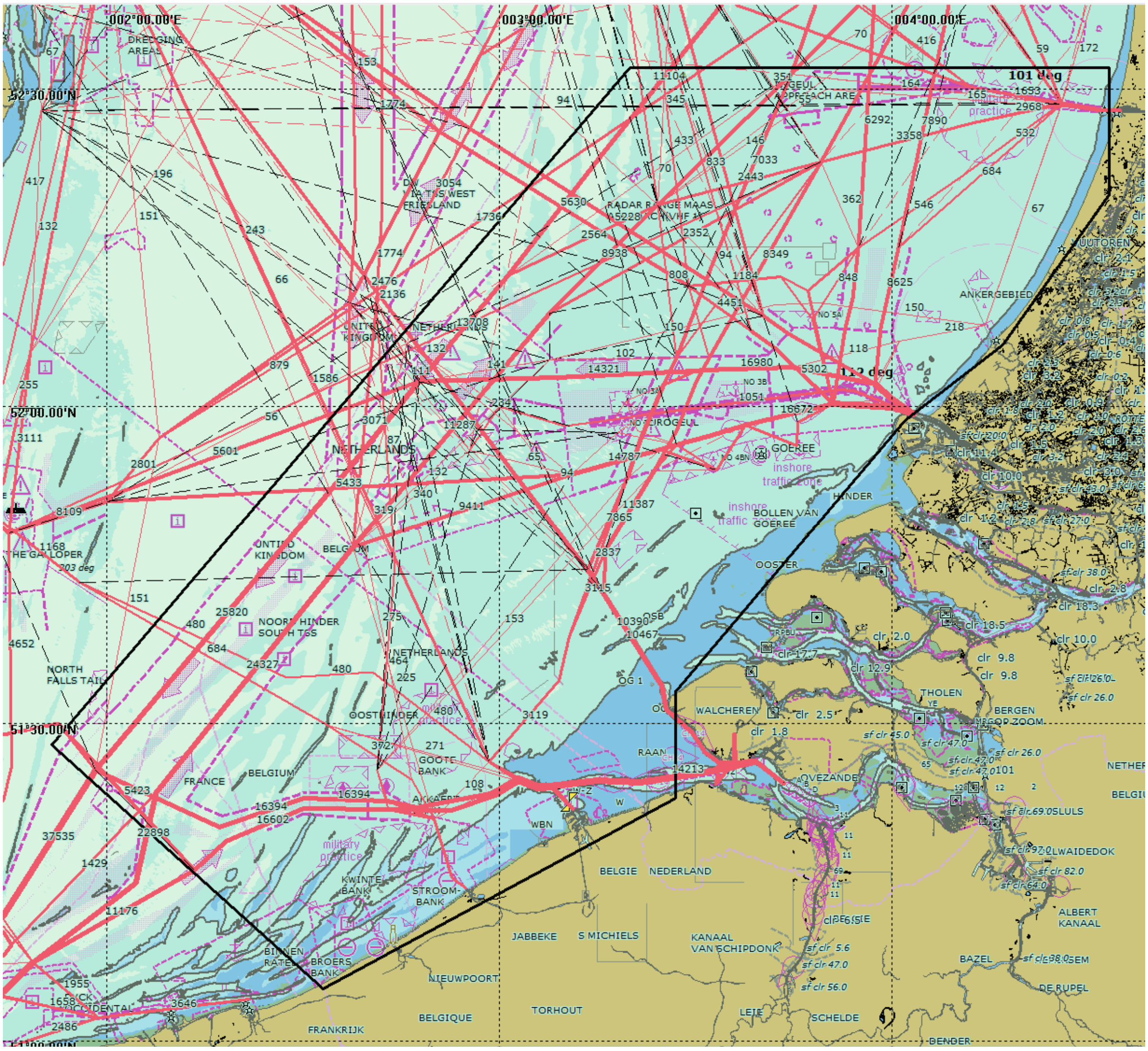

Figure 2-2 **Traffic database for 2008 of SAMSON**

Of course it is impossible to detail and analyse all differences between the two databases. The purpose of this case study is to indicate the most important differences. For example when looking at Figure 2-1 and Figure 2-2 it is clear that the SAMSON database has more links. These extra links have generally low intensities.

The two models also treat the anchorage areas differently. The SAMSON database contains links to and from the anchorage areas while in the BE-AWARE database anchoring ships are assigned to the closest route. Because these movements introduce additional risk, it is important to include them. However, this case study indicates that this will have only a small impact on the total risk in the BE-AWARE area.

In the BE-AWARE database traffic is automatically allocated to the nearest route leg by an algorithm, based on the underlying traffic distribution, as given that there are nearly 10,000 route legs in the whole North Sea area it is impossible to allocate them manually. In the SAMSON model they are allocated strictly in line with the TSS. This has led to some differences between the traffic databases as is the case for the area outlined below in Figure 2-3 where the BE-AWARE traffic database has some vessels going against the flow of the TSS in the northern lane and the SAMSON one does not.

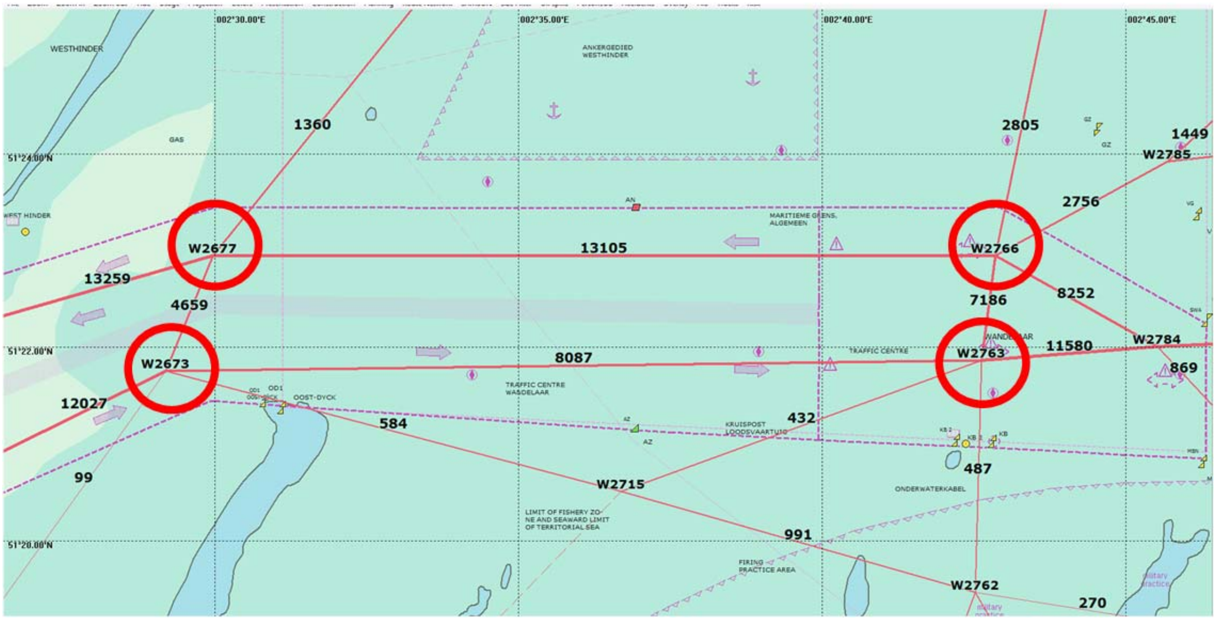

Figure 2-3 **Links in the Westhinder TSS for the Western Scheldt in the BE-AWARE traffic database of 2011**

However as Figure 2-4 shows the traffic situation in this area is extremely complicated due to the anchorage area to the north of the TSS with traffic sometimes crossing the opposite lane in the wrong direction which could account for some of the differerence.

The assignment of this crossing traffic to the west-going traffic lane of the TSS in the BEAWARE traffic database delivers a result in SAMSON for that link of 0.0068 ships involved in head-on collisions per year and 0.0032 ships in overtaking collisions per year and 0 in crossing collisions. In reality a proportion of the 0.0068 head-on collisions should be crossing collisions, however this depends on the angle at which they cross the other TSS lane.

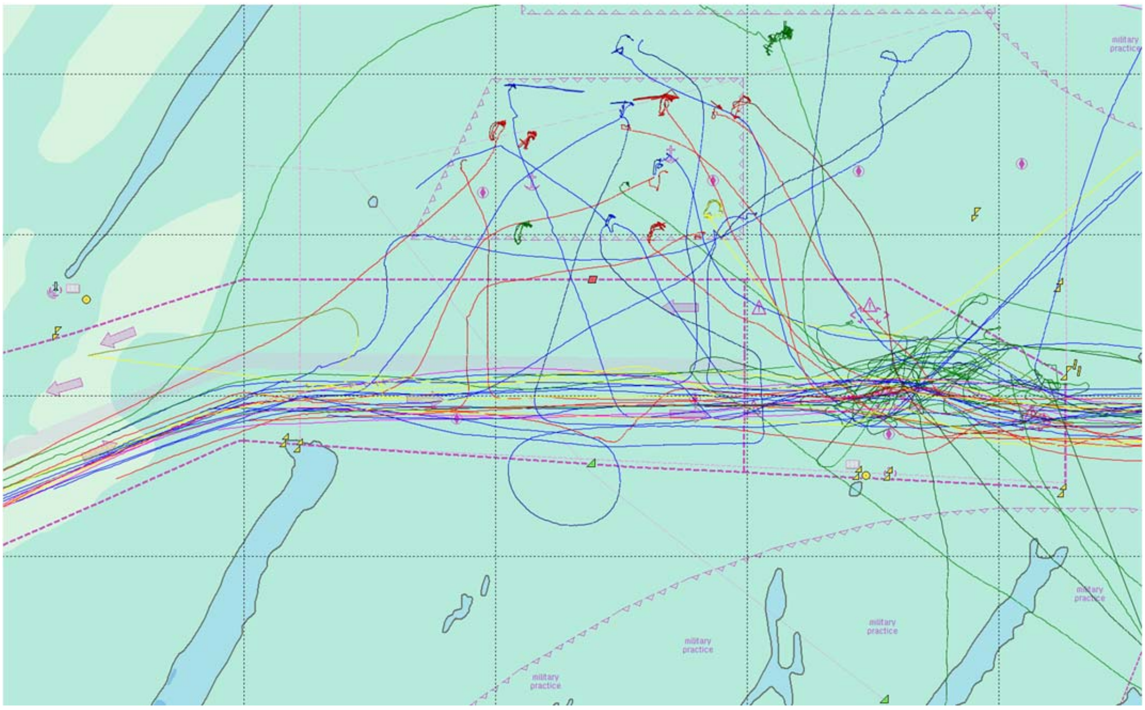

Figure 2-4 AIS tracks in the Westhinder coming from southwest for one day

As already mentioned, there are other differences in the traffic modelling. Although these differences seem to have little impact on the overall result they can play a role when the results are analysed in greater detail. For this reason an overview of the differences found is included in the Appendix. These findings can be used to make future improvements to the traffic databases.

3. Comparison of calculated risk for the Case Study area

3.1 Introduction

BE-AWARE has calculated the collision risk for all links and nodes of the traffic database and the probability of grounding assigned to a number of grounding points. In this chapter the results of BE-AWARE for the Case Study area are compared with results of calculations made by MARIN using the SAMSON model. The SAMSON calculations have been performed with the BE-AWARE traffic database of 2011 and the SAMSON traffic database of 2008 scaled to the traffic intensity of 2011. The results of the collision risk are compared in 3.2 and those of the grounding risk in 3.3.

3.2 Comparison of collision risk

The results of the collision risk are presented in Table 3-1.

Table 3-1 Predicted number of Ships involved in collisions and spill frequencies for 2011

	1	2	3
	Results of BE-AWARE, based on nodes and links in Case Study area	SAMSON with BE-AWARE database of 2011	SAMSON with SAMSON database updated to 2011 intensity
on route / head-on + overtaking	1.96	2.53	1.34
in nodes / crossings	0.51	2.89	2.53
total collisions	2.46	5.42	3.87
bunker spills	0.35	0.05	0.04
cargo oil spills	0.02	0.09	0.05
total spills	0.37	0.14	0.09
bunker oil spilt [t]	334.1	18.7	12.7
cargo oil spilt [t]	320.9	1464.7	803.9
total oil spilt [t]	654.9	1483.4	816.6
Average size bunker oil spill [t]	956	344	327
Average size cargo oil spill [t]	14495	16696	16617

The table contains the results of 3 cases that are described in more detail. The same cases are used when comparing the grounding risk in 3.3. It should be noted that the total amount of accidents in the case study area is roughly 25% of the incidents in the total BE-AWARE area. This is due to the very dense traffic flows in this area. The oil spilt in the Case Study area is about 30%.

Case 1: The table contains the frequencies for collisions for the nodes and the route links that are located within the Case Study area and for groundings. For each incident also the frequency of a spill is given for bunker oil and a number of cargo substances carried in bulk. The frequencies of BE-AWARE for the routes that are partly located in the Case Study area are multiplied with the fraction that is within the Case Study area.

Case 2: The traffic database for 2011 of BE-AWARE is converted to a traffic database for SAMSON. Next the collision risk is calculated with the SAMSON collision risk and spill models.

Case 3: Is based upon the SAMSON database for 2008 converted to match the traffic situation for 2011 to allow a direct comparison with the BE-AWARE results.

Table 3-1 also contains the frequencies and amounts of oil spilt. The substances included in cargo oil spills in the SAMSON model are given with the number of calls in 2008 with these substances on board. BE-AWARE has distinguished 4 types of bulk spills (19 crude oil, 20 fuel oil, 21 gasoil, diesel petroleum, jet fuel and heating oil, 22 petrol). The classification of oil in the BE-AWARE and SAMSON model correspond sufficiently for the comparison.

Comparison:

The collisions calculated by BE-AWARE are divided over collisions on route and collisions in the nodes. The collisions on route contain ships sailing on the same route (node to node = link in SAMSON) in the same or opposite direction. The “collision on route” does not include collisions between ships from different routes that are located close to each other, as the ships will be allocated to each route depending on their underlying distribution.

The collisions calculated by SAMSON are divided into head-on, overtaking and crossing collisions depending on the absolute course difference between the two ships, 60° for overtaking, 150°-180° for head-on and 60°-150° for crossing.

In the tables the on route collisions of BE-AWARE are compared with the head-on and overtaking collisions of SAMSON and the node collisions of BE-AWARE with the crossing collisions of SAMSON. It is doubtful if such a comparison is relevant due to the differences in the definitions. For this reason the most relevant comparison is the comparison of the totals.

The following statements can be made when different cases of Table 3-1 are compared:

- **BE-AWARE model versus SAMSON model:** Case 1 and Case 2 contain results for the same traffic database of BE-AWARE for 2011 but calculated with respectively the BE-AWARE and SAMSON models. The total number of ships involved in collisions with the SAMSON model is with 5.42 thus 2.2 times the 2.46 of BE-AWARE. The main difference is in the number of crossing collisions 2.89 for SAMSON and 0.51 for BE-AWARE. The latter might be affected by the difference in definitions of both collisions. Further the predicted number of bunker spills by SAMSON is much lower.
- **BE-AWARE traffic database versus SAMSON traffic database:** Case 2 compared with Case 3 shows the difference between using the BE-AWARE traffic database and the SAMSON database. Using the SAMSON database the number of head-on and overtaking collisions is 1.34 per year compared with 2.53 for the BE-AWARE database. The difference in crossing collisions of 2.89 per year for the BE-AWARE database and 2.53 per year for the SAMSON database is negligible.
- **BE-AWARE vs SAMSON:** However when you compare the two models in their entirety including the traffic databases and models the results are very similar with only minor differences in the number of crossing collisions and the amount of bunker oil spilt. The predicted spill frequency by the BE-AWARE models is much higher for bunker oil and much lower for cargo spills than predicted by the SAMSON models. The average size of a cargo oil

spill is nearly the same for both models. While the average spill of bunker oil is 956 tonnes much larger than the 344 tonnes calculated by SAMSON the average size of the cargo spills 14495 tonnes and 16696 tonnes respectively are very similar.

3.3 Comparison of grounding risk

The results of the grounding risk calculations are presented in Table 3-2. The same cases are used as for the collision risk calculations described in 3.2. The grounding risk calculated by BE-AWARE is concentrated on representative 'grounding points'. Three grounding points of the 96 in total are located in the Case Study area. The results of these grounding points are summarized for the comparison with the SAMSON calculations.

The SAMSON model uses a 5 m, 10 m and 20 m depth line for the calculation of the grounding probability. The line used depends on the size of ship. The three grounding points of BE-AWARE and the three stranding lines used in SAMSON are plotted in Figure 3-1.

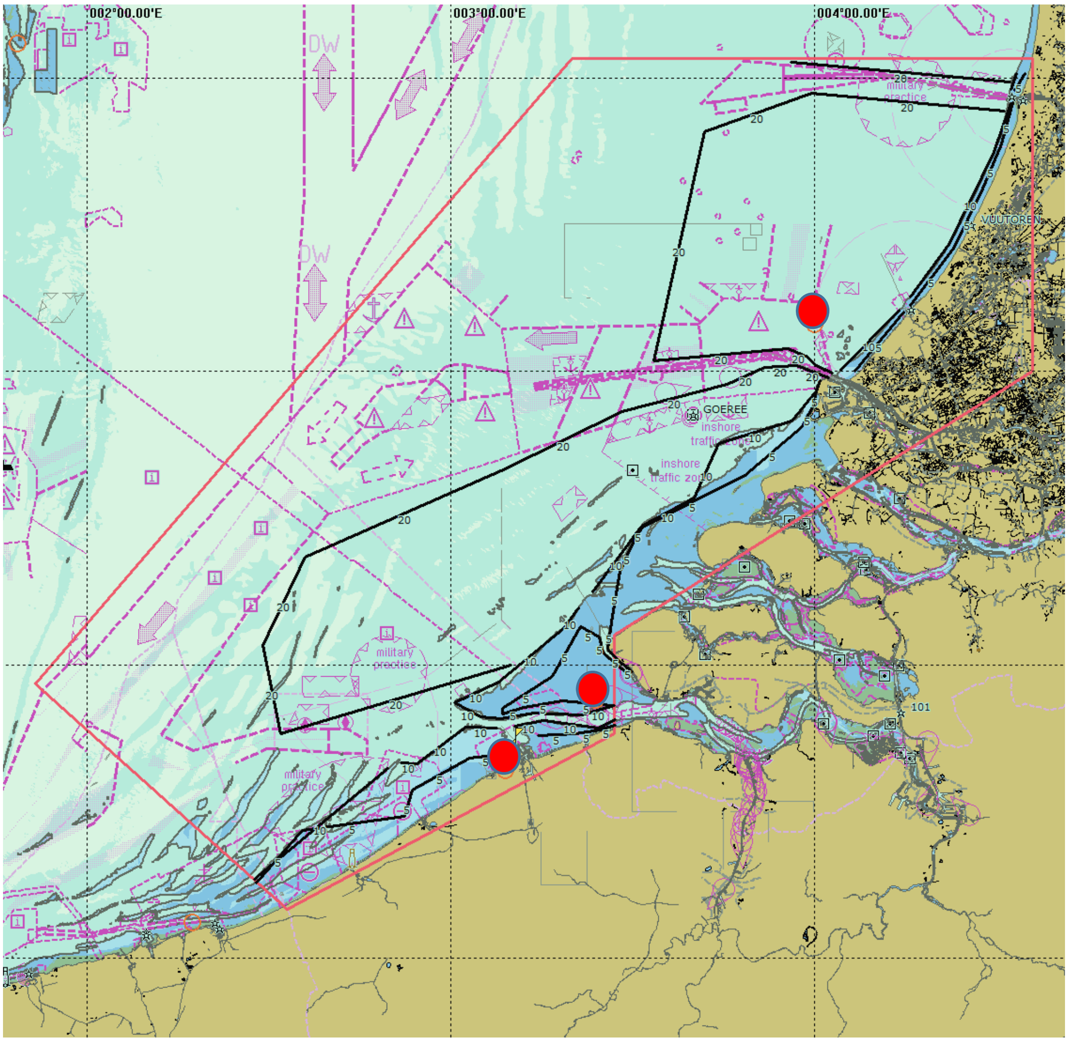

Figure 3-1 Grounding points of BE-AWARE and stranding lines of SAMSON in the Case Study area

Table 3-2 Predicted number of ships involved in groundings in 2011

	1	2			3		
	BE-AWARE, groundings points in Case-Study area	BE-AWARE traffic database of 2011 with SAMSON grounding lines and models			SAMSON with SAMSON database updated to 2011 intensity		
		drift-ing	ram-ming	total	drift-ing	ram-ming	total
Total	0.732	0.772	1.513	2.285	0.676	1.522	2.198

Only 3.3% of the grounding incidents of the total BE-AWARE area occur in the Case Study area. This is much less than the 25% for collisions. The oil spilt is even less and can be neglected. This is realistic as the coast in this area consists of a sandy seabed with no hard structures which will not result in damage to the containment system. The following statements can be made when different cases of Table 3-2 are compared:

- **BE-AWARE model versus SAMSON model:** Case 1 and Case 2 contain results for the same traffic database of BE-AWARE for 2011 but calculated with respectively the BE-AWARE and SAMSON models. The grounding incidents predicted by the SAMSON model are 2.285, thus 3.1 times as high as the 0.732 of BE-AWARE.

- **BE-AWARE traffic database versus SAMSON traffic database:** Case 2 compared with Case 3 shows the difference between using the BE-AWARE traffic database and the SAMSON database. The predicted grounding incidents are 2.198 for the SAMSON database, which is similar to 2.285 for the BE-AWARE database. The difference is small because the grounding probability depends on the distance ships sail and is not sensitive to small variations in that value.

4. Explanation of the comparison BE-AWARE and SAMSON

The BE-AWARE model and SAMSON models for quantifying risk are different.

The models for collision risk in BE-AWARE and SAMSON have the same basis. The shared approach involves the number of encounters calculated based on the traffic database consisting of links with number of movements. Each link has its own lateral distribution. The differences are that SAMSON uses a fixed domain around the ship that will be kept free of other ships and BE-AWARE a distance of 20 ship lengths. BE-AWARE uses one causation factor for the transit of encounters to collisions. SAMSON uses a ship type and size dependent casualty rate, because there is a difference in casualty sensitivity between ship type and ship size classes. The casualty rates are also different for the three types of encounters. The casualty rates of SAMSON are derived from the world wide casualty database (sensitivity on ship type and size) and the absolute level is based on what has occurred on the North Sea (encounters and collisions).

The models for grounding are different. SAMSON uses two models for the contact risk for an object or grounding: one for the ramming risk, thus a grounding at normal speed after a navigational error, and one for the drifting grounding after a technical failure. For BE-AWARE this data was not available for the whole Bonn Agreement region and therefore it used a single model. The parameters for both models are derived from historical casualty data.

The differences in the modelling mean that the results will differ. However that will always be the case when the results of risk calculations are compared. The reason is that the total risk is the sum of millions of probabilities that occur often with a probability of less than once in a million cases. The real probabilities are impossible to determine with high accuracy as some of the statistical evidence is lacking. In fact the predicted absolute risk is never completely accurate.

The purpose of risk models is that they describe what happens as effectively as possible in an objective way. Risk models are very useful in indicating differences between different scenarios or quantifying the effect of measures. Risk models are less precise in predicting absolute values of certain occurrences.

The comparison of the results of the BE-AWARE and the SAMSON model with respect to collisions and groundings has delivered overall figures that are in the same order of magnitude. Of course a closer fit would have been nicer but the differences shown are acceptable.

All overall probabilities of collisions and groundings are of the same order of magnitude. The largest difference is found for the probability and volume of bunker spills. This is analysed in more detail. Table 4-1 contains the average fuel capacity of ships in the different size classes. The fuel capacity is divided over four fuel tanks, two tanks on each side. On each side there is one tank of 35% and one tank of 15% of the total fuel capacity. When using this division the average capacity of a fuel tank is 348 tonnes, which corresponds quite well with the average bunker oil spill of 344 and 327 predicted by the SAMSON model. The average spill of 956 tonnes by BE-AWARE seems to be high.

There is a better correspondence in the predicted cargo spills. The average size of a cargo oil spill is very similar in both models. The SAMSON model predicts more spills, but predicts also more ships involved in collisions.

Table 4-1 Capacity of fuel tanks in shipping database

Size class in GT	Number of ships in shipping database	Total fuel capacity [t]	Global division of total capacity over the fuel tanks of the ship	
			Largest tank 1 on SB and 1 on BB [t]	Smallest tank 1 on SB and 1 on BB [t]
0-1000	8838	282	99	42
1,000-1,599	1720	390	136	58
1,600-5,000	6128	432	151	65
5,000-10,000	3275	831	291	125
10,000-30,000	5670	1844	645	277
30,000-60,000	3506	3401	1190	510
60,000-100,000	1314	5992	2097	899
>100,000	557	7958	2785	1194
Average size	**31008**		**488**	**209**
Average size all tanks			**348**	

5. Conclusions

The purpose of risk models is that they describe what happens as effectively as possible in an objective way. Risk models are very useful in indicating differences between different scenarios or quantifying the effect of measures. Risk models are less precise in predicting absolute values of certain occurrences.

The comparison of the results of the BE-AWARE and the SAMSON model with respect to collisions and groundings in the Case Study area has delivered overall figures that are in the same order of magnitude. Of course a closer fit would have been nicer but the differences showed are acceptable.

The largest difference is found for the probability and volume of bunker spills. The probability and the volume of a bunker spill seem to be high with respect to the number of ships involved in collisions and the fuel capacity of the ships. However the overall impact on total spill size, taking into account the modelled spills from cargo oils, would not be significant.

Glossary of Definitions and Abbreviations

N-ship A non-route-bound ship. This ship mostly has a mission at sea, such as fishing vessels, supply vessels, working vessels and pleasure craft.

NCS Netherlands Continental Shelf

Probability The probability (or number per year) is generally provided to a large number of decimal places. This does not necessarily mean that the accuracy is very large, but the larger number of decimal places is used to make comparison possible between different items, also when the absolute values are small.

QRA Quantitative Risk Assessment

R-ship A route-bound ship. It is a merchant ship or ferry sailing along the shortest route from one port to another.

SAMSON Safety Assessment Model for Shipping and Offshore on the North Sea

TSS Traffic Separation Scheme

Annex

In section 2.1 of this reported it is noted that the traffic modelling in the Westhinder TSS shows differences with traffic observations in the area. Also at some other locations differences were found mostly due to the way the BE-AWARE model automatically allocates ships to the closest route based upon their underlying distribution. These differences are included in this Appendix so this information can be used to make future improvements in the traffic databases.

Traffic database 2011

Figure 0-1 shows the links to and from the TSS Maas NW. Node W3001 needs special attention. This waypoint is on the route to TSS Maas NW, meant for traffic from the UK (Hull area) not Rotterdam. However 3282 ships come from a route from the UK to this waypoint instead of via link W3011-W3001.

To get insight into what happens in node W3011, the number of movements over each link to node W3011 and from W3011 is presented in Table 0-1 Movements to and from node W3001.

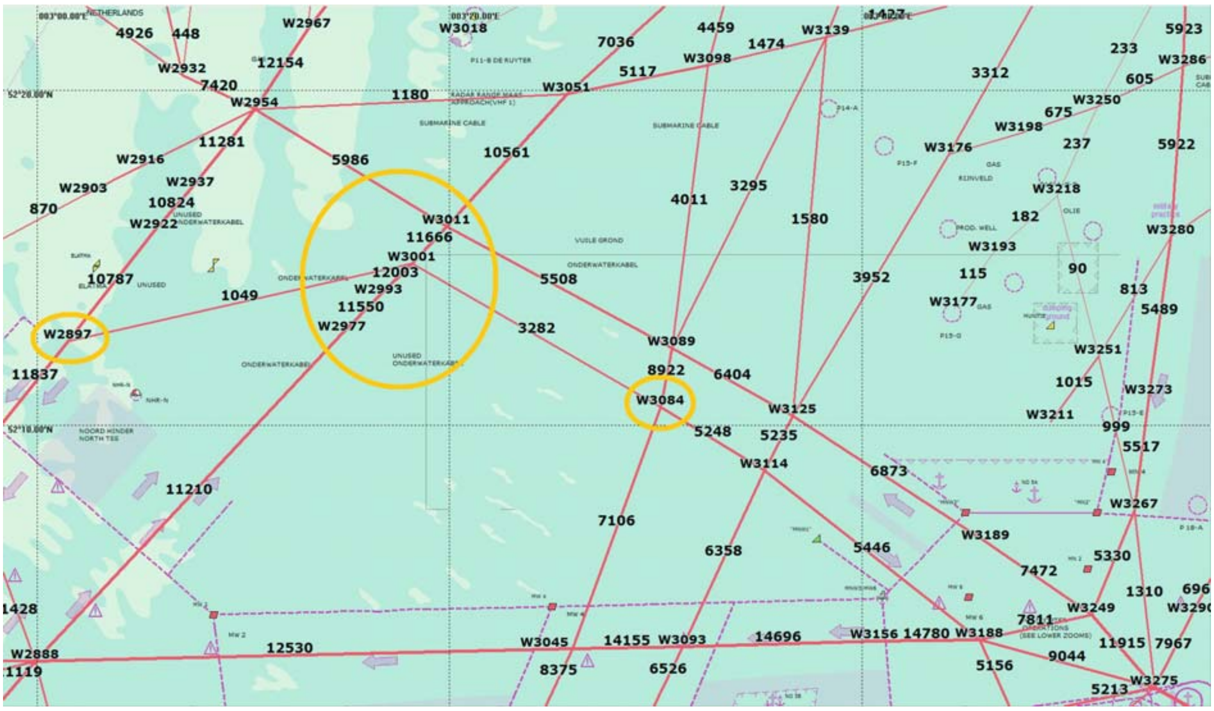

Figure 0-1 Links to the Maas-NW TSS in the COWI traffic database of 2011

Table 0-1 Movements to and from node W3001

From node	To node	Movements in traffic database of COWI for 2011	Comment
W2897	W3001	156	Route is very unlikely
W2993	W3001	12003	Main traffic route from TSS Noord Hinder North to TSS Texel
W3011	W3001	4565	Due to their underlying distribution in the AIS data these ships have been allocated against the main traffic from TSS Noord Hinder North to TSS Texel
W3084	W3001	242	Route is very unlikely
All	W3001	16966	
W3001	W2897	1049	
W3001	W2993	965	Due to their underlying distribution in the AIS data these ships have been allocated against the main traffic from TSS Noord Hinder North to TSS Texel
W3001	W3011	11666	Main traffic route from TSS Noord Hinder North to TSS Texel
W3001	W3084	3282	These movements had to come from a route from the UK to this waypoint instead of via link W3011-W3001
W3001	All	16962	

The Eurogeul to Rotterdam is meant for deep draft vessels that follow the Eurogeul from Maas West Outer TSS. The number of movements through the Eurogeul is 707 in Maas West Outer TSS and 1705 in Maas West Inner TSS. Only 539 of the 707 ships and 830 of the 1705 movements are ships above 60,000 GT. This means that many smaller ships have also been routed through the Eurogeul; however this could be complicated by the nearby anchorage areas. It also means that other large ships of size class 8 to Rotterdam are routed through other lanes to Rotterdam.

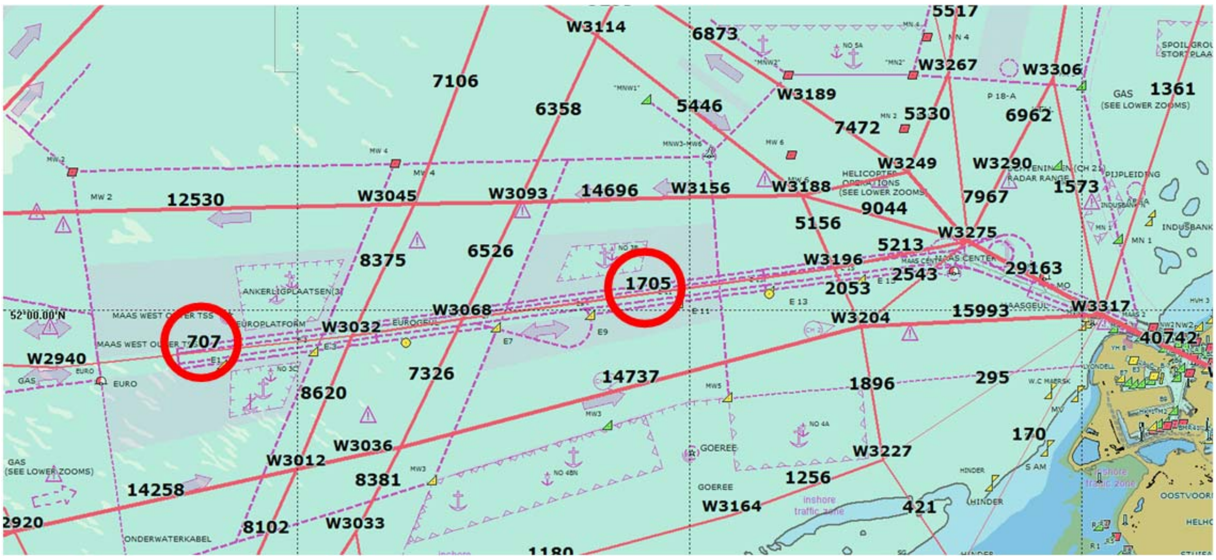

Figure 0-2 Eurogeul with movements in traffic database of COWI of 2011

Traffic database 2020

The traffic database for 2020 is generated from the traffic database of 2011. The changes in shipping are modelled by growth factors for each ship type and ship size. In August 2013 there has been a major change in the traffic flows west of the Dutch coast, due to the changes in the Traffic Separation Schemes. Therefore the route net of BE-AWARE in that part of the North Sea is adapted. The traffic database of COWI for 2020 is presented in Figure. Generally the new TSSs (black lines) are followed. However, some of the traffic links east of Maas North TSS that are not allowed, e.g. the inshore route via way point W3804 to Rotterdam.

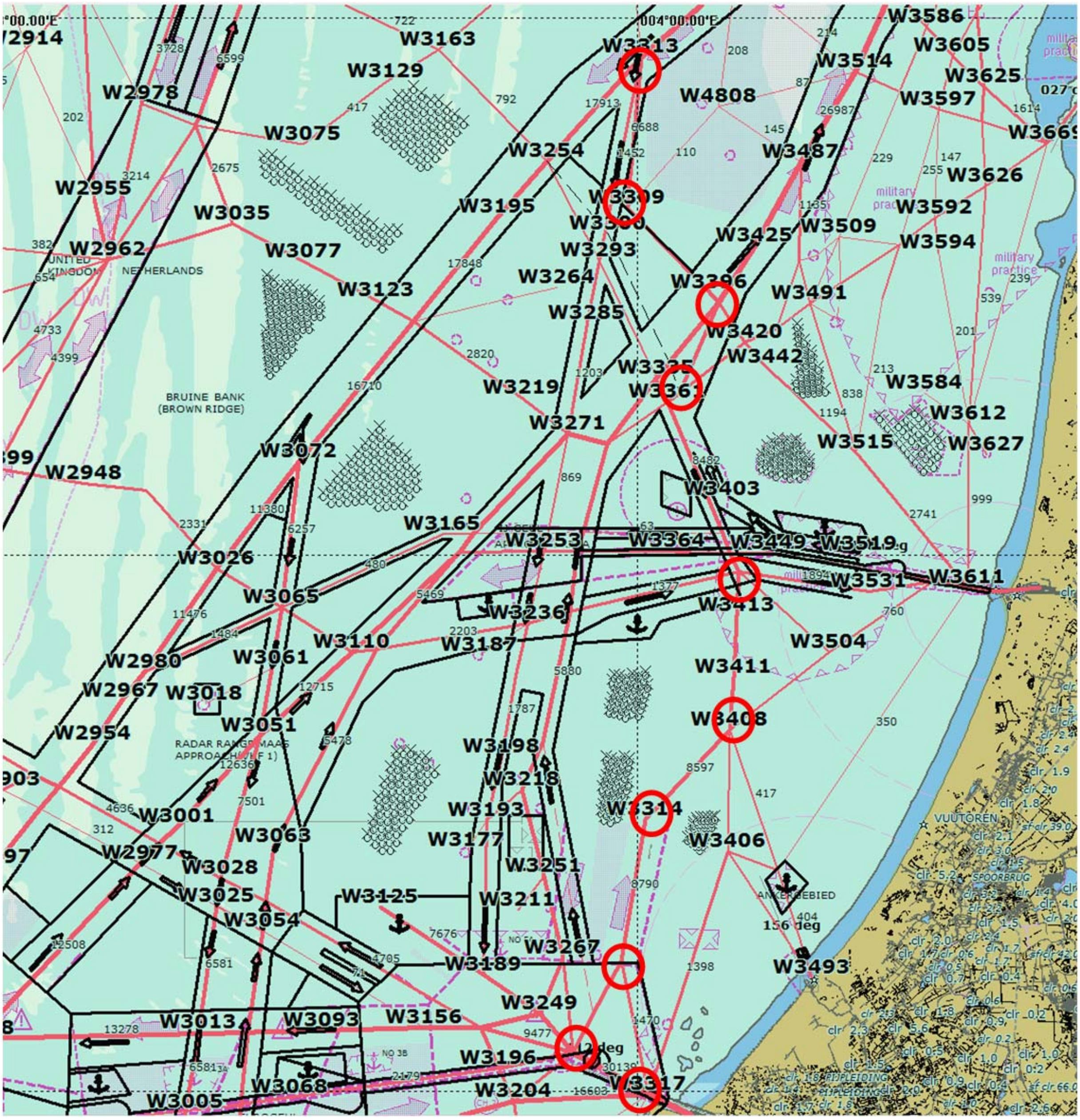

Figure 0-3 Traffic database of COWI for 2020 through the TSSs in force since August 2013

The TSS near IJmuiden also has an anomaly. The outgoing traffic has to sail through the northern lane. Merchant vessels have to follow this lane to TSS Texel. However in the traffic model some of this traffic has been routed along the coast.

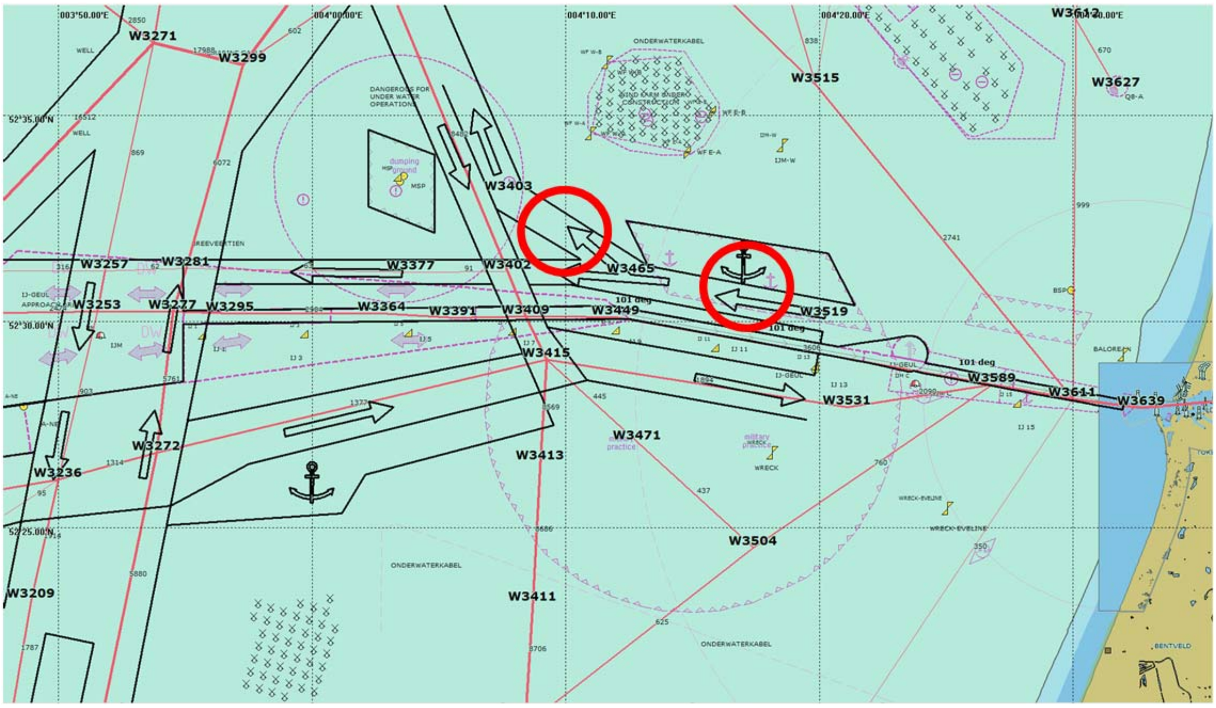

Figure 0-4 Traffic database of COWI for 2020 and the TSS near IJmuiden in force since August 2013

- The remarks made for the 2011 traffic database can also be made for the 2020 traffic database.

Impact of Wind turbines

The expected growth of offshore wind farms will have impact on the traffic flows. The number of wind turbines grows from 1010 in 2011 to 11703 in 2020. This is modelled by deleting the links through the wind farm areas as illustrated in Figure and Figure. A ship that crosses a wind farm area in 2011 is rerouted in the 2020 traffic database over links around the wind farm. This is not always the most logical route as ships do not sail right up to wind farms and then around the wind farm to the other side, see for example the link W2672-W2574 in Figure. In reality the shortest route will be followed, thus a new route will be chosen well before the approach to the wind farm to avoid the situation described. This means that other routes will appear.

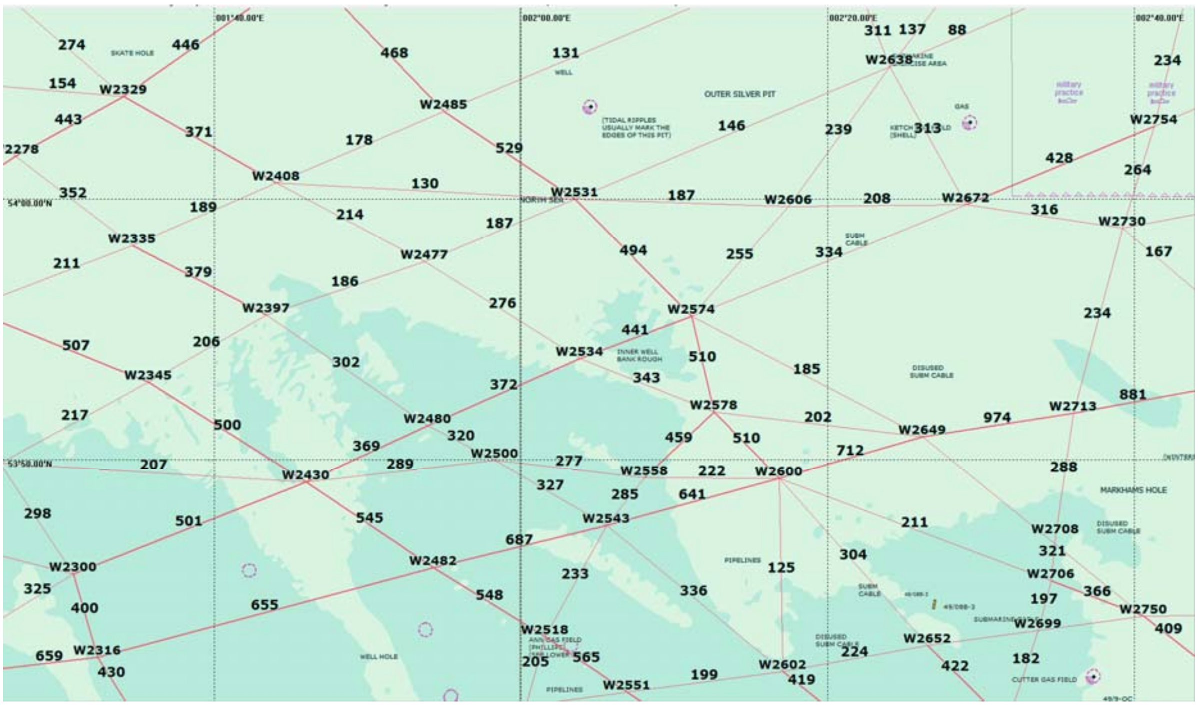

Figure 0-5 **Traffic database of COWI for 2011**

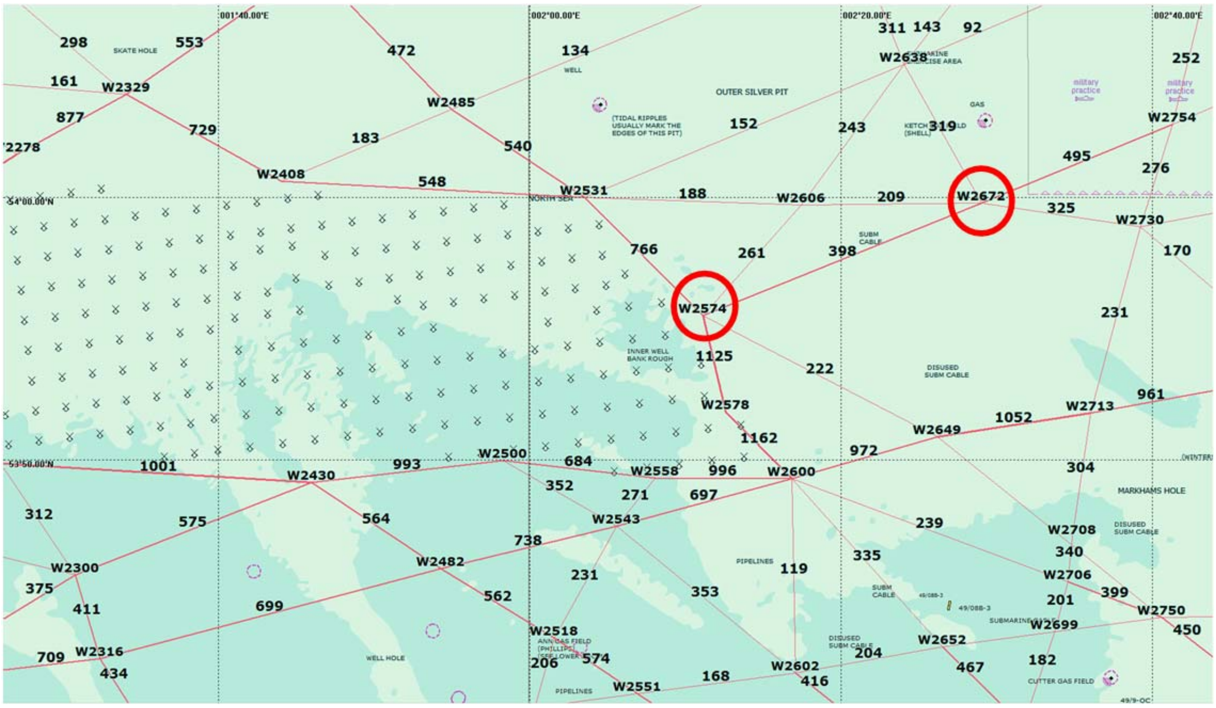

Figure 0-6 **Traffic database of COWI for 2020**