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Horns Rev 3 Offshore Wind Farm

NAVIGATIONAL RISK ANALYSIS

FEBRUARY 2014

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Horns Rev 3 Offshore Wind Farm

NAVIGATIONAL RISK ANALYSIS

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1. SUMMARY AND CONCLUSIONS

The objective of the present report is to provide the navigational risk analysis for the wind farm Horns Rev 3 located north of the existing wind farm Horns Rev 2.

A general procedure for carrying out the navigational analysis has been established between DNV and COWI. This was made in order to ensure that the same procedures were applied for the wind farms Horns Rev 3 and Kriegers Flak. This procedure contains the following steps:

Step 0:	Establishing the method and procedure for carrying out the navigational risk analysis
Step 1:	Implementation of the frequency analysis. The analysis is presented to the Danish Maritime Authority
Step 2:	If the Danish Maritime Authority is not able to approve the risk based on the frequency analysis, a consequence analysis shall be carried out. The updated navigational risk analysis with both the frequency and the consequence analysis, i.e. the risk, is presented to the Danish Maritime Authority
Step 3:	If the Danish Maritime Authority is not able to approve the risk estimate an analysis of risk reduction measures shall be carried out. The updated navigational risk analysis with the risk reduction measures is presented to the Danish Maritime Authority

The present report is the result of the established method and procedure (Step 0) and contains the frequency analysis given as Step 1 in the procedure listed above. Furthermore an overview the consequences have been given on order to evaluate significant contributions to the risk.

As the final location of the wind farm is not established at the time of this analysis the worst case of a number of different wind farm layouts has been investigated. On this basis the frequencies calculated in the present analysis are considered conservative. The analysis shall be updated when the final layout of the wind farm is known. The primary focus of the analysis is the operational phase of the park, as information about the construction and decommission of the farm, e.g. number of installation vessels, installation procedure, ports used etc. is to be decided at a later stage by the developer. The navigational impacts in the construction and decommissioning phase are therefore treated on a more general basis.

A detailed analysis of collisions has been carried out and the frequency of ship – turbine collisions has been calculated. The frequency analysis is based on robust mathematical models and the parameters used in the model are based on general accident statistics. The mathematical models used have been developed to estimate the probability of collisions with bridges but have later been applied on various offshore wind farms as well as collisions with other offshore installations.

As a basis for the frequency model the ship traffic in the area of the Horns Rev 3 Offshore Wind Farm has been investigated. The ship traffic patterns in the area have been established on the basis of AIS data. AIS transmitters are required for all ship larger than 300 GT but they are used to some extent by smaller ships as well. The traffic is modelled based on all ships carrying an AIS transmitter. Vessels not carrying an AIS transmitter e.g. smaller fishing vessels and leasure crafts have therefore not been included in the traffic model. After the park is finished the number of fishing vessels within the park area is expected to be very limited and although eventual leasure crafts are expected in the park area this number is not expected to be large and the risk comming form these vessels are therefore limited. The traffic is modelled using a number of traffic routes and the observed ship tracks are used to estimate the transversal distributions of the ships on the individual routes.

Using the traffic model the frequency of collisions between planned wind turbines and ships has been calculated.

Looking at individual route contributions the largest contribution to ship collisions with the wind farm comes from drifting ships from the main traffic route west of the wind farm. This contribution is around three times larger than the second largest contribution to drifting collisions coming from the large route going east/west from Esbjerg. The third largest contribution from drifting ships comes from vessels that are currently passing through the park in a north/south direction, but which after the establishment of the park are assumed to pass just off the eastern side of the park.

For the powered collisions the largest contribution comes from the vessels that are currently passing through the park north/south, but which after the establishment of the park are assumed to pass just off the eastern side of the park. This contribution is nearly three times larger than the powered contribution from vessels on the main route vest of the park.

Looking at the vessel types the contributions from drifting collisions primarily come from merchant and offshore vessels whereas merchant vessels, dredgers other ship types have significant contributions to the frequency of powered collisions.

The return period for collision between wind turbines and a drifting ship has been calculated to be 70 years and collision between wind turbines and a powered ship has an estimated return period of 141 years. The return period for all the considered collisions is on this basis 47 years.

The return period of 47 years is smaller than e.g. the return periods of 84 and 230 years that has been calculated for two investigated locations of Horns Rev 2. The investigated "worst case" layout of the Horns Rev 3 gives the largest contributions to the frequency from the turbines located on the western side but also considerable contributions from the turbines located most easterly. Significant reductions to the collision frequency can be expected if the turbines located furthest to the east and west were moved away from the critical routes.

The largest contribution to the collision frequency that comes from drifting ships from the main route west of the wind farm has been compared to grounding frequencies caused by drifting in the Great Belt. The numbers are of comparable size

In the present version of the navigational risk analysis the consequences have been assessed on an overall level in order to differentiate the contribution from various sizes and types of vessels. It is seen that both the size and the amount of tankers vary significantly for the investigated park, but the largest contributor to the risk both in terms of frequency and consequences comes from the main traffic route west of the park and is comparable with existing wind parks in the area.

It is expected that emergency procedures to shut down production in the event that a ship is on collision course with the wind farm will be developed. Further differentiation of the consequences and risk reduction measures (steps 2 & 3) has not been deemed necessary at this stage.

2. SAMMENFATNING

Denne rapport indeholder en analyse af sejladssikkerhed forbundet med vindmølleparken Horns Rev 3, der skal opføres nord for den eksisterende vindmøllepark Horns Rev 2.

En generel procedure, etableret mellem DNV og COWI, er benyttet for at gøre analysen for Horns Rev 3 sammenlignelig med risikoanalysen for vindmølleparken Krigers Flak. Proceduren indeholder implementering af frekvens analyse, som efterfølgende skal godkendes af Søfartsstyrelsen. Kan projektet ikke godkendes på denne basis foreskriver proceduren en konsekvens analyse og i sidste instans risikoreducerende tiltag.

Denne rapport inkluderer frekvens analysen samt en oversigt over konsekvenser for at evaluere de mest betydelige bidrag. Da den endelige beliggenhed af vindmølleparken endnu ikke er fastlagt, er analysen baseret på et "worst case" scenarie, og de udregnede frekvenser skal derfor anses som konservative. Analysen skal opdateres, når et endeligt layout for vindmølleparken er fastlagt.

En detaljeret analyse af kollisioner er udført og frekvensen af skib – vindmølle kollisioner er udregnet. De benyttede modeller er oprindeligt udviklet til udregning af kollisioner mod broer men er efterfølgende anvendt på forskellige offshore vindmølleparker samt andre offshore installationer. Ulykkesstatistikker er baggrund for de anvendte parametre i modellen.

Skibstrafikken i området omkring Horns Rev 3 vindmølleparken er benyttet som basis for frekvens modellen. Mønstre i skibstrafikken er identificeret baseret på AIS data. AIS sendere er påkrævet for skibe større end 300 GT men bruges i nogen omfang også af mindre skibe.

Trafikken er modelleret vha. af et antal definerede trafikruteelementer og de observerede skibsbevægelser er brugt til at estimere den tværgående fordeling af skibe på de enkelte ruteelementer. Ud fra disse fordelinger er frekvensen af kollision mellem vindmøller og skibe beregnet.

De største bidrag til skibskollisioner med vindmøller kommer fra drivende skibe fra hovedtrafikåren vest for parken. Skibskollisioner fra drivende skibe på andre ruter er signifikant mindre. Det største bridrag for motoriserede skibe kommer fra fartøjer, der for nuværende passerer gennem parken og som efter opførsel af parken, forventes at passerer øst for parken. I forhold til skibstype vil kollisioner med drivende skibe primært være offshore og handelsskibe hvorimod de motoriserede kollisioner primært er handelsskibe og uddybningsfartøjer.

Returperioden for kollisioner mellem drivende fartøjer og vindmøller blev udregnet til 70 år og 141 år for motoriserede fartøjer. Den samlede returperiode for alle kollisionstyper blev fundet til 47 år. Denne returperiode er noget lavere end for Horns Rev 2, men en del af forskellen skyldes formodentlig, at det er "worst case" scenariet, der her er analyseret. Signifikant færre kollisioner må forventes, hvis parken bliver rykket længere væk fra de mest kritiske ruter.

I relation til konsekvensbetragtningen kommer det største bidrag fra hoved trafikken vest for parken. Sammenlignet med andre vindmølleparker i området er både frekvens og konsekvens i samme størrelsesorden

Det er forventet, at der skal udvikles en nødlukningsprocedure for vindmøllerne i tilfælde af, at et skib er på kollisionskurs med vindmølleparken.

3. INTRODUCTION

3.1. Background and scope

This report contains a navigational risk analysis of the planned offshore wind farm Horns Rev 3 off the Danish west coast, Figure 3-1. The analysis is one of the parts of a comprehensive environmental impact analysis (EIA) of this wind farm.

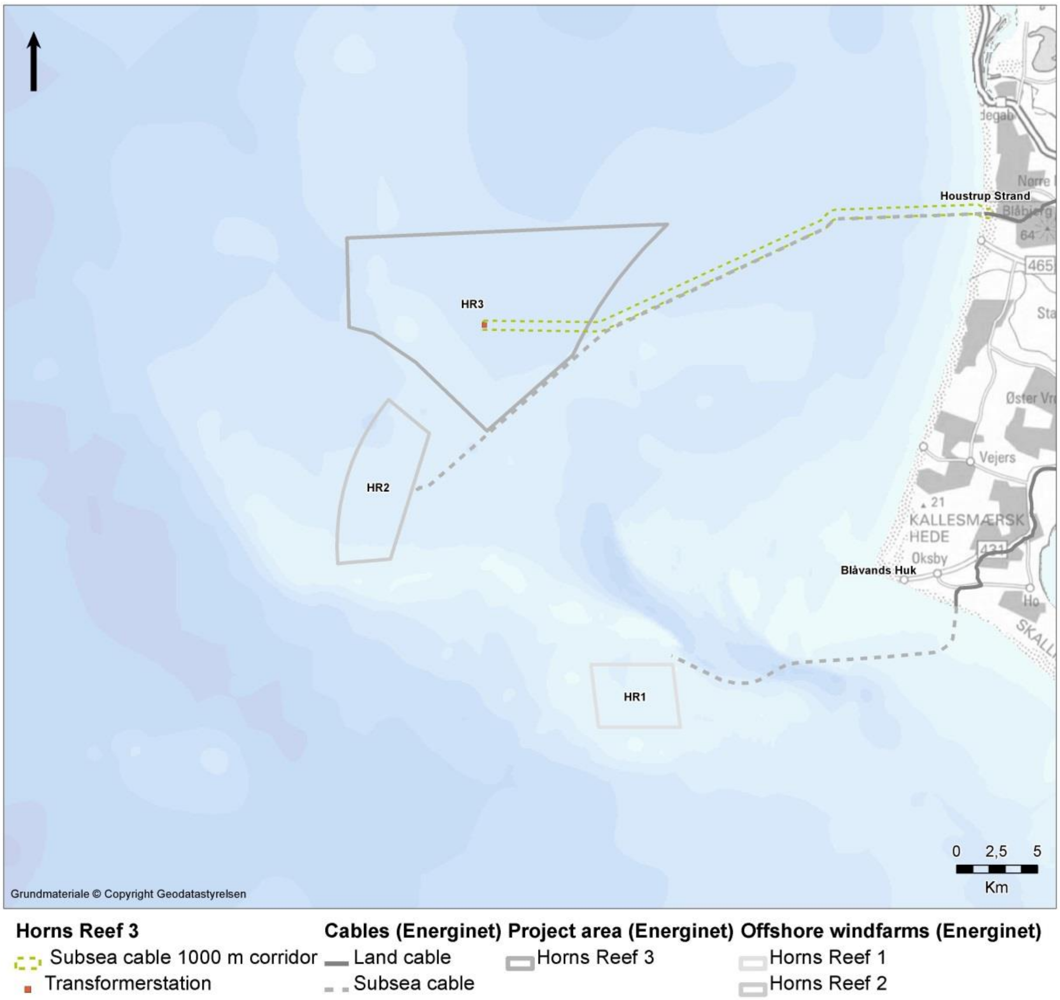

Figure 3-1. Horns Rev 3 Offshore Wind Farm - project area.

The analysis deals with navigational risks that are caused or altered by the presence of a future wind farm.

Navigational risks due to the construction process are covered, although on a more general basis. This is mainly due to the lack of knowledge of the expected construction set-up and procedure at this early stage.

3.2. Procedure

The analysis is based on the Guidelines for Formal Safety Assessment (FSA) issued by the International Maritime Organization (IMO) /IMO, 2002/.

An FSA consists of the following five steps

1. Identification of hazards
2. Risk analysis
3. Risk control options
4. Cost-benefit assessment
5. Recommendations for decision-making

In the present case, step 4 is not based on a cost-benefit assessment in the strict sense, i.e. damages will not be converted into monetary units. Instead, more general concepts will be used in order to compare different types of damages with each other.

The specific procedure applied for carrying out the navigational analysis has been established between DNV and COWI, see /JV, 2013/. This was made in order to ensure that the same procedures were applied for the wind farms Horns Rev 3 and Kriegers Flak. This procedure contains the following steps:

Step 0:	Establishing the method and procedure for carrying out the navigational risk analysis
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The present report is the result of the established method and procedure (step 0) and contains the frequency analysis given as Step 1 in the procedure listed above. Furthermore an overview the consequences have been given on order to evaluate significant contributions to the risk.

As the final location of the wind farm is not established at the time of this analysis the worst case of a number of different wind farm layouts has been investigated. On this basis the frequencies calculated in the present analysis are considered conservative. This is described in further detail in Chapter 3 that contains the basis for the analysis.

3.3. Structure of report

Table 3-1 shows how the chapters of this report match the individual FSA steps.

Table 3-1 Report structure.

Chapter	Title	Corresponding FSA step
5	Hazard identification	1
6	Traffic model	2
6-8	Collision frequency during operation, construction and decommissioning	2

The report is divided into three parts. In chapter 4 and 5 the analysis basis is described and so forming the basis part of the report. This includes description of the data applied in the analysis and assumptions about the location of the individual turbines. In the model part of the report, chapter 6 and 6, the approaches used to model the ship traffic and the results in the form of collision frequencies and general consequences are given. In chapter 7 and 8 the construction and decommissioning phase is addressed.

4. BASIS

4.1. Project description

The planned Horns Rev 3 OWF (400 MW) is located north of Horns Rev (Horns Reef) in a shallow area in the eastern North Sea, about 20-30 km northwest of the westernmost point of Denmark, Blåvands Huk. The Horns Rev 3 pre-investigation-area is app. 190 km2. The Horns Rev 3 area is to the west delineated by gradually deeper waters, to the south/southwest by the existing OWF named Horns Rev 2, to the southeast by the export cable from Horns Rev 2 OWF, and to the north by oil/gas pipelines (Figure 4-1).

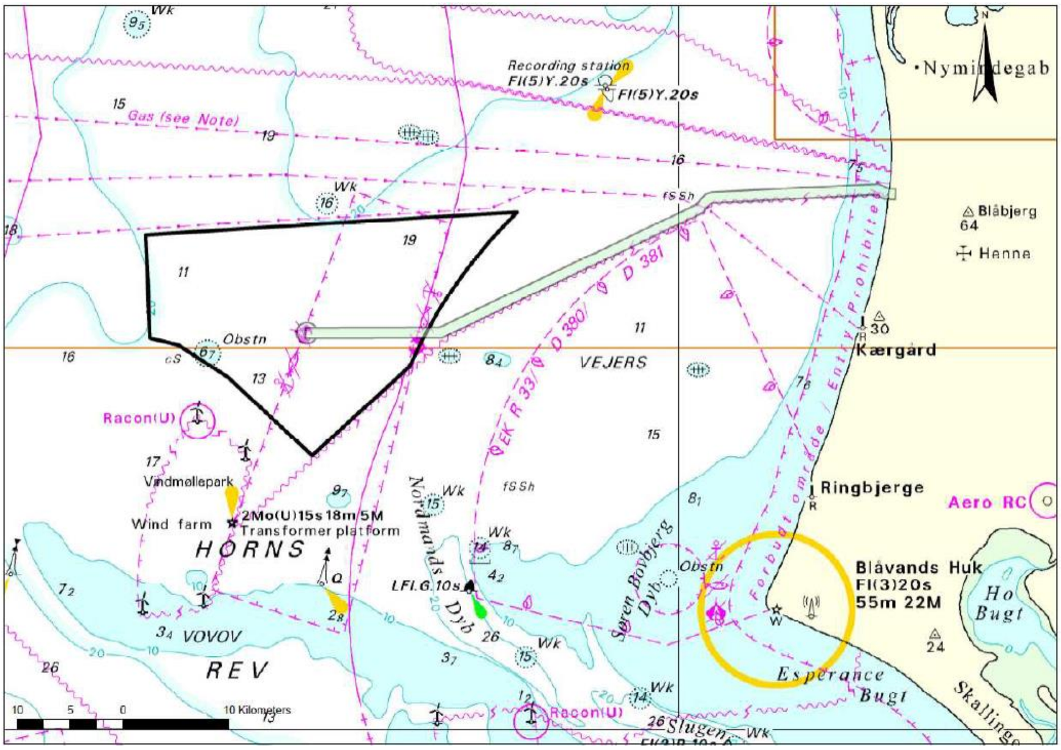

Figure 4-1 The project area (black solid line contour) in the North Sea off the coast of Jutland (the existing wind farm Horns Rev 2 and the northernmost part of Horns Rev 1 are outlined as well).

4.2. Hydrography and meteorology

The water depths in the Horns Rev 3 area vary between app. 10-21 m. The minimum water depth is located on a ridge in the southwest of the site and the maximum water depth lies in the north of the area. In the ship collision analysis the effect of vessels grounding before the wind farm is reached is due to the relative large water depth not taken into account.

The winds at Horns Rev are predominantly westerly throughout the year. The wind and wave climate can be rough year round, but especially during fall and winter. A comprehensive site specific metocean analysis is currently being conducted, but this data is not yet available. The meteorological basis for this study is taken from a study conducted for Horns Rev 1 in 2002, /HR, 2002/. It is expected that basic wind conditions at the location of Horns Rev 3 will not vary significantly from the obtained basis. Local variations can be expected but as vessels within a distance of 15 nautical miles from the site are treated with similar meteorological conditions minor local variation will not be significant for the results.

4.3. Wind Farm Layout

The Technical Project Description /Energinet, 2013/ defines 3 basic wind farm layouts (A, B and E) and 3 wind turbine sizes (3, 8 and 10 MW), resulting in a total of 9 layouts, see Appendix B. These do not necessarily represent the exact locations of the turbines as the final location of the individual turbines will be decided by the developer based on optimisation on a variety of parameters.

The three basic layouts are a north-west (A), a west (B) and an east (E) layout. From a navigational safety point of view, basic layout A in combination with 3 MW turbines is deemed to be the worst-case layout, see Figure 4-2. With this layout the wind farm is going to be situated close to both the main traffic on the west side of the reef and on the traffic to/from Slugen. Vessels going south from Hvide Sande are forced to plan a new route further north than presently. It can be expected that they will pass as far north as necessary, i.e. as close to the turbines as possible. Furthermore the 3 MW turbine size is deemed most critical because more turbines will be located within a predetermined area and on this basis cause a (slightly) higher probability of collisions.

All considerations in the remainder of this report are based on this layout.
Appendix B provides a comparison and discussion of the nine layouts.

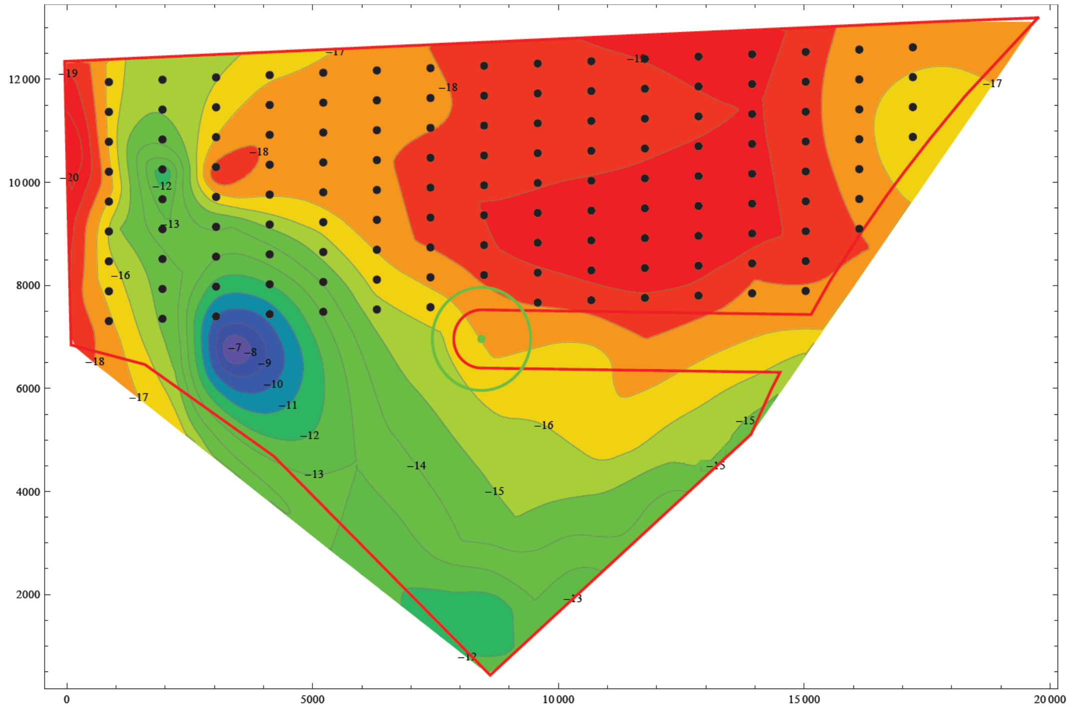

Figure 4-2 The worst-case wind farm layout (A-3MW) seen from a navigational point of view (illustration: /Energinet, 2013/.

(Note that the hazard identification (HazID) workshop was held before the 9 layouts were defined. The HazID protocol in Appendix A does thus not reflect the worst-case layout or any other of the 9 layouts. Instead, a number of preliminary layouts were used. See discussion in Chapter 5).

4.3.1 Dimensions of structures

The exact dimensions of the structures (turbines/substation platform) at the wind farm will depend on the types of substructures applied, the final dimensions of transition pieces and the turbines. The foundations can be made as monopoles, concrete gravity based structures or steel jackets. The Danish Maritime Authority requires that the foundations used shall have a collision-friendly design. Furthermore it is required that the wingtip of the turbine at all times is more than 20 meters above Highest Astronomical Tide (HAT). Although generally very different the size of the various structures in relation to ship collisions does not vary significantly for the investigated size of turbines. For larger turbines the difference between the different types of foundations could vary more. This has no immediate impact as the overall collision frequency will be smaller due to the reduction in the number of turbines; see the previous section and discussion in Appendix B. In the model conservative assumptions have been applied in order not to underestimate the frequency of collisions due to the size of the structures.

In the analysis it is assumed that the wind turbines have a diameter of 6 meters. Small changes in this parameter does however not have a great influence on the results as either the ship length or the ship width will dominate the determination of whether the turbine has been hit for the drifting and the powered collisions. For the transformer platform marked with a green dot in Figure 4-2 the dimensions are assumed to be 24x24m.

Other subsea structures in the area, with no probability of collisions, such as cables have not been treated in the navigational risk analysis.

4.3.2 Aids to Navigation

Aids to Navigation (AtoN) including marking with light on the turbines in relation to shipping and navigation is expected to comply with the following description. All turbines placed in the corners and at sharp bends along the peripheral (significant peripheral structures = SPS) of the wind farm, shall be marked with a yellow light. Additional turbines along the peripheral shall be marked, so that there will be a maximum distance between markings of 2 nautical miles.

The lights shall be visible for 180 degrees along the peripheral and for 210-270 degrees for the corner turbines (typically located at a height of 5-10m). The light shall be flashing synchronously with 5 flashes per 10 second and with an effective range of at least 5 nautical miles. Within the wind farm the individual turbines will not be marked. It can be required to place a RACON on one or more of the turbines. In this case the RACON on Horns Rev 2 shall be removed

Indirect light will be illuminating the part of the yellow painted section with the turbine identification number.

If the transformer station will be situated outside the wind turbine array, the transformer station will most likely be requested to be marked by white flashing lanterns with an effective reach of 10 nautical miles. The exact specifications of the marking shall be agreed with the Danish Maritime Authority in due time before construction.

During construction the complete construction area shall be marked with yellow buoys with yellow light with a range of at least 2 nautical miles. Details on the requirements for the positions and number of buoys shall be agreed with the Danish Maritime Authority.

For the frequency calculation it is assumed that the described Aids to Navigation does not influence the frequency compared to other wind farms in the area, i.e. no reduction of the collision frequency has been made on the basis of the markings.

4.3.3 Installation

Although offshore contractors have varying construction techniques, the installation of the wind turbines will typically require one or more jack-up barges.

The wind turbine components will either be stored at an adjacent port and transported to site by support barge or the installation vessel itself, or transported directly from the manufacturer to the wind farm site by barge or by the installation vessel. The wind turbine will typically be installed using multiple lifts. A number of support vessels for equipment and personnel jack-up barges may also be required.

4.4. Ship traffic data

AIS data from 2012 has been used as the basis for the analysis. Furthermore VMS data has been investigated in order to identify fishing vessels in the area not carrying an AIS transmitter.

4.4.1 AIS data

Passing vessel traffic statistics were obtained by means of AIS (Automatic Identification System). Every vessel above 300 GT is required to carry an AIS transponder on board, which sends information about vessel ID (IMO number, MMSI number and name), position and several other parameters. This information can be received by all nearby AIS units. In the present case, the AIS data, from /SFS/, has been recorded during the period from January to December 2012[1].

4.4.2 IHS World Shipping Encyclopaedia

Once the IMO-number of a vessel is known, it is possible to search for all relevant vessel properties in IHS World Shipping Encyclopaedia, /IHS, 2013/. The properties include

1 At the time when the HazID was carried out only 2011 AIS data was available. This was therefore used as a basis for the HazID. In the detailed analysis of the traffic 2012 data has been used.

vessel dimensions, maximum speed and dozens of other parameters. Combining the information from AIS and the encyclopaedia provides a very comprehensive picture of the ship traffic in an area.

4.4.3 VMS data

Vessel monitoring system data (VMS) is a Global Positioning System (GPS) used in commercial fishing to monitor the location of fishing vessels. VMS data for the period January to December 2012 has been examined in the area of the park. From 2012 data should cover all fishing vessels longer than 12m. Although the VMS basis provides some information about the whereabouts of fishing vessels in the area it has not been applied directly in the analysis. The navigational risk analysis carried out has focused on the large fishing vessels that carries an AIS transponder, but it is seen from other studies, /Orb, 2013/, that the smaller vessels are typically fishing along the same routes that have been defined based on AIS data. The frequencies obtained for fishing vessels are therefore limited to the fishing vessels equipped with AIS. A total of 73 distinct fishing vessels have been observed in the area based on VMS. The number of fishing vessels from AIS is limited to 32. Some fishing vessels will not have been categorised as a fishing vessel in the AIS data and will be presented under the category "Other types". The number of fishing vessels that is established on the basis of AIS data has therefore not been adjusted on the basis of the received VMS data.

4.4.4 Data on leisure crafts

Specific data on leisure crafts not covered by AIS have not been obtainable. It is known that leisure crafts approach from the German, Dutch and Belgium waters towards and along the western coast of Denmark and vice versa. These vessels can pass through the investigated area, although it is believed that due to the existing parks Horns Rev 1 and 2, the amount of these vessels taking a route through the area is limited. The influence of the new park will on the basis of this also be limited. Telephone interviews with the harbour in Hvide Sande and the marina on Fanø have been carried out. Although leisure crafts are present in the general area no significant reasons for them passing through the project area have been found. As the area has several wind farms it is assumed that the whereabouts of the parks are investigated before proceeding into the area. The presence of an additional park will therefore only have minor impacts on leisure crafts. When the park is constructed it can be expected that some leisure crafts will proceed towards the area to see the wind farm, however these leisure crafts will be aware of the presence of the wind turbines and is not expected to significantly increase in frequency compared to e.g. what can be seen for Horns Rev 1 and 2.

4.4.5 Additional data on beach nourishment vessels (Dredgers)

Beach nourishment vessels have been identified from AIS data in the area. The Danish Coastal Authority has informed that no dredging is carried out by beach nourishment vessels in the project area. The dredgers are merely passing to other areas. The project area and the worst case wind farm layout will make it necessary for the North-South going vessels to make a detour around the wind farm. The Danish Coastal Authority questioned the placement of the wind farm that makes a detour necessary and pointed out that this can be avoided with other locations. Besides the longer route no additional effects of the new wind farm was identified for the beach nourishment vessels.

4.4.6 Additional information related to German ships

At the HazID meeting German stakeholder were invited to supply specific viewpoints related to German vessels in the area. No concerns requiring additional analysis have been raised and the AIS data for the area that contains all types of vessels carrying an AIS transmitter has been found representative for the vessels in the area.

5. HAZARD IDENTIFICATION

The hazard identification (HazID) meeting was held at the Scandic Olympic Hotel in Esbjerg on 5 February 2013. It involved 26 participants, including navigators, fishermen, pilots, port operators, wind farm operators, military representatives as well as project staff from Energinet, Orbicon and COWI. A detailed HazID protocol is provided in Appendix A.

The outcome of the hazard identification meeting can be grouped into the following results:

- Identification and qualitative evaluation of the ship accident scenarios on each of the existing shipping routes (including re-routing towards other existing or future routes)
- Identification of the accident consequences
- Identification of possible risk-reducing measures

At the time the HazID meeting was held the worst-case turbine arrangement had not been defined yet. Thus, the participants were asked to assess all hazards in the light of a number of different possible turbine arrangements. The worst-case scenario was defined at a later stage, see Section 4.3.

It was at the HazID meeting generally agreed that the main hazard due to the park was related to ship collisions with the wind farm. The influence of the park with regard to ship groundings and ship-ship collisions was considered to be less significant. The following scenarios are therefore considered in the navigational risk analysis:

- Ship – Turbine collision due to drifting vessels
- Ship – Turbine collisions due caused by human error and/or radar failure (powered collisions)

Collisions could lead to damage of both the turbine and the ship. The consequences of this could be damage or loss of material, personal injuries and economic losses (both direct and indirect).

In the construction phase additional activities is carried out in the park area. This leads to increased vessel activity in the area and furthermore there will e.g. be exposed foundations that can be difficult to see. This can lead to increased probabilities of collision during this period. The process and procedures to be applied in the construction phase is not currently defined but it must be ensured that adequate precautions are taken during this phase to ensure the safety for ships in the area.

6. TRAFFIC MODEL

The impact frequency from passing vessels is in chapter 6 considered separately for powered vessels and for drifting vessels. As a prerequisite for the assessment of both, the ship traffic of passing vessels needs to be analysed and described.

The traffic model is based on the observed traffic in the area. The source of the data is described in section 4.3. The traffic model applies data on ship movements around the proposed wind farm to model the observed traffic patterns by means of routes and the amount of and distribution of traffic on these routes.

Figure 6-1 shows the vessel activity in the vicinity of the proposed wind farm. The density plot has been obtained by considering cells of size of 25m x 25m. Depending on the number of ships counted within each cell during the observed period, the cell is inked with a colour indicating the activity in the cell. If no ship was observed in the considered period, then the cell remains transparent.

The figure shows the density plot of all vessels from which AIS signals have been received. The investigated area is limited by the larger of the green outlines 15 nautical miles from the wind farm /JV, 2013/, the project area where wind turbines are considered is indicated by the smaller green shape and finally the treated worst case layout of the turbines is marked with black dots. The wind turbines are not in scale.

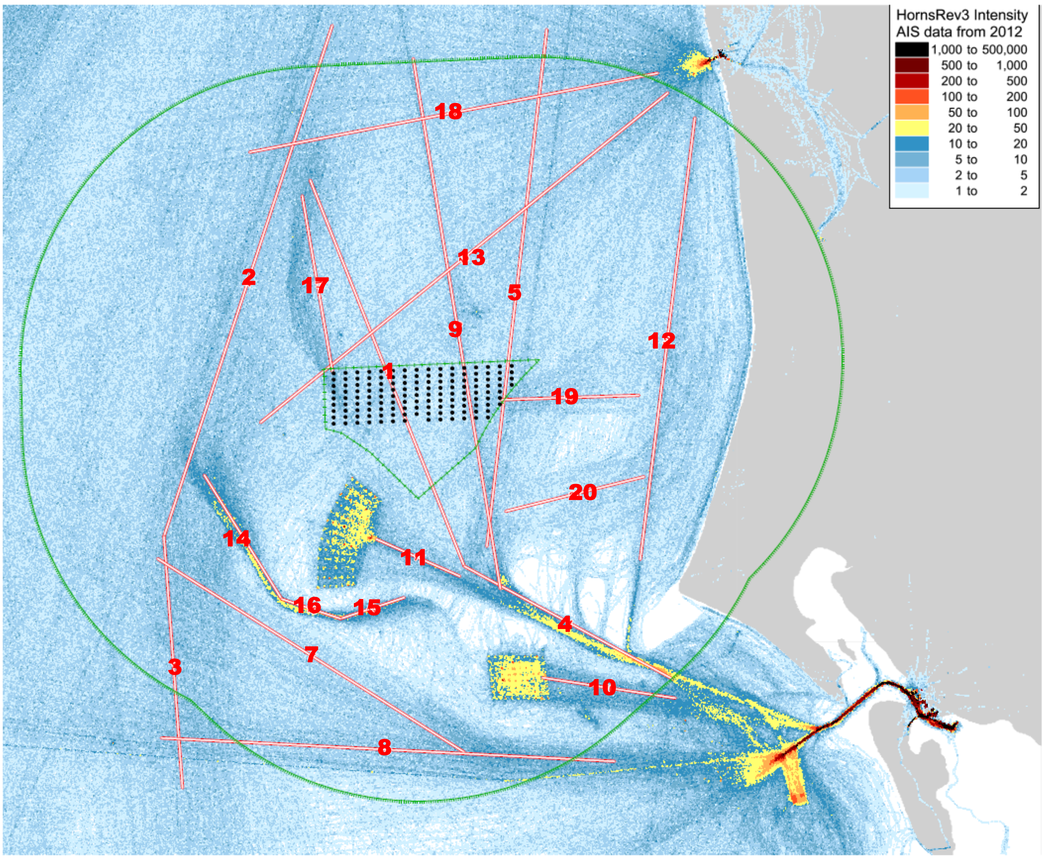

Figure 6-1 Observed traffic in the project area. Routes applied to measure and model the traffic is indicated with red lines and the route numbers are indicated. The intensity is given for 25x25m sections.

6.1. Re-routing

The worst case layout investigated in this analysis requires that some traffic is re-routed due to the placement of the wind farm. This is dependent on the vessel type and the individual routes.

6.1.1 Routes going through the park

The majority of the traffic going through the park consists of north/south going beach nourishment vessels and some merchant vessels. It is likely that these vessels will take the smallest possible detour around the eastern side of the park. This will be on the new route 1 around the park and further north following route 5 and 9 as indicated in Figure 6-2. It is expected that these vessels will pass very close to the park as the wind farm will give these vessels a longer trip and as a result they will presumably minimise this by passing as close as possible to the park. The distribution of the vessels on the new routes are assumed to follow the GL-distributions, see /GL, 2010/.

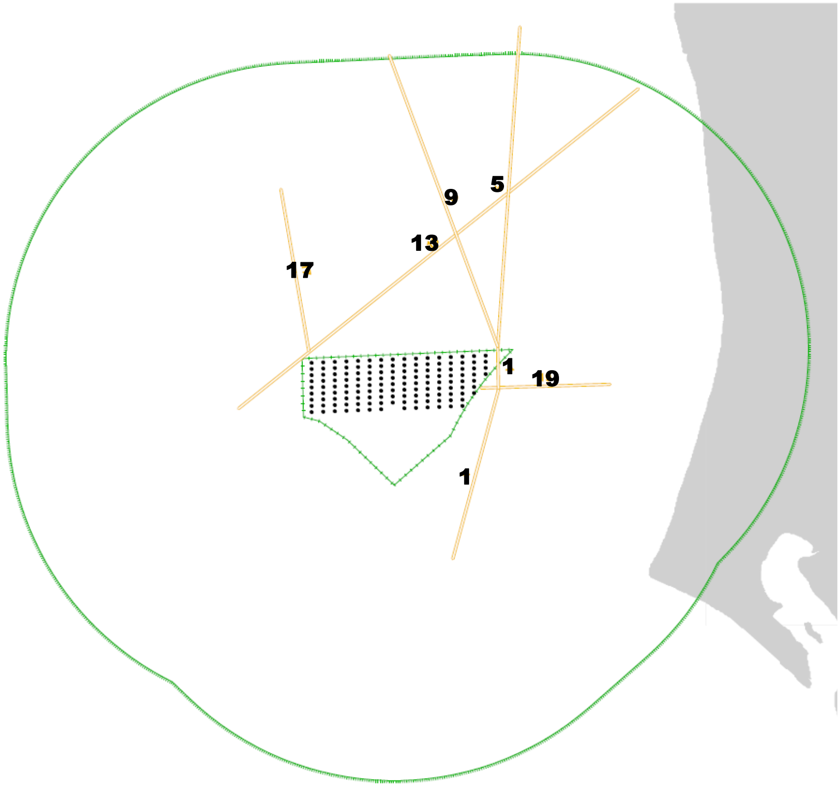

Figure 6-2 New routes after construction of the wind farm

6.1.2 Routes going close to the park

Fishing vessels do currently trawl within the proposed park area based on the 2012 data. Route 17 and 19 will be shortened when the park is built as trawling will not be permitted within the park perimeter. It is expected that fishing vessels will still be present on the shortened routes but only enter the park area by accident if they forget to turn or if they start to drift into the park area due to a motor/steering failure.

Vessels going to and from the harbour in Hvide Sande on route 13 are assumed to follow the GL-distributions, see /GL, 2010/, post installation. Furthermore the route centreline has been moved outside the park perimeter.

6.2. Route fitting

For the routes that have not been moved the transverse distribution is fitted to the current data. This is done by applying crossing lines for each of the routes. For each of the crossing lines the location where vessels crossed the crossing line in each direction can be obtained from AIS data. Figure 6-3 shows raw AIS data and the fitted distributions for the transversal distribution.

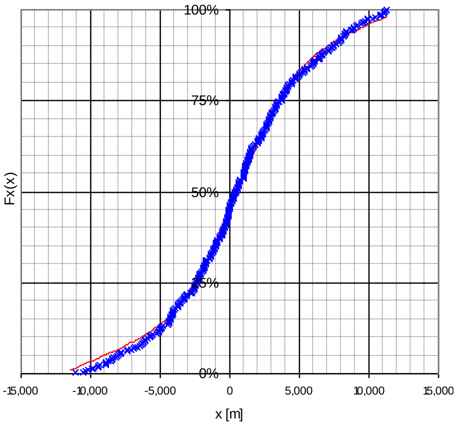

Figure 6-3 Typical fit of transversal distribution for a route.

6.3. Route overview

The ship properties are based on average ship properties for the considered ship type and size. Number of ships versus routes is presented in Table 5.1. The total number of vessels in 2012 in the area cannot be taken as the sum of all routes as some vessels are passing through several routes on one journey.

Table 6-1 Overview of the 2012 traffic on the routes in both directions (Based on AIS.)

Route number	Traffic (vessels per year)						
	Merchant	Offshore	Military	Dredger	Fishing	Other	Total
1	416	200	14	268	28	286	1212
2	3608	40	34	0	12	68	3762
3	2162	0	14	0	12	68	2256
4	416	1400	14	268	52	286	2436
5	396	80	14	40	14	260	804
7	276	286	20	0	8	340	930
8	598	1280	34	0	34	676	2622
9	20	0	0	228	20	26	294
10	0	1300	0	0	0	240	1540
11	0	1280	0	0	0	0	1280
12	52	62	0	20	64	64	262
13	14	40	0	44	100	60	258
14	0	0	0	0	70	0	70
15	0	0	0	0	80	0	80
16	0	0	0	0	70	0	70
17	0	0	0	0	106	0	106
18	24	0	0	100	44	40	208
19	0	0	0	0	36	26	62
20	0	0	0	0	40	0	40
Total	7982	5968	144	968	790	2440	18292

7. COLLISION FREQUENCY DURING OPERATION

The impact frequency from passing vessels during operation of the park is considered for powered vessels and for drifting vessels.

7.1. Drifting vessels

7.1.1 Impact frequency

The impact frequency for drifting vessels is evaluated given the following equation:

$$P(I) = \Sigma_{i,j,k}\, N_i\, P(D)\, P(NR_{j,k})\, P(D\alpha_{j,k})\, P(T_j)\, P(L_j)$$

where:

i …	Index specifying a ship of a given type and size.
j …	Index specifying a specific point of the net of a defined route.
k …	Index specifying a specific drifting speed.
N_i …	Number of passages of a vessel of a given type and size.
$P(D)$ …	Probability of a vessel to start drifting on the defined route.
$P(NR_{j,k})$…	Probability that the failure leading to the blackout cannot be repaired.
$P(NF_{j,k})$…	Probability that the vessel cannot use the anchor.
$P(D\alpha_{j,k})$…	Probability that the drifting vessel is on collision course given a specific drifting speed.
$P(T_j)$ …	Transversal probability.
$P(L_j)$ …	Longitudinal probability.

Figure 7-1 shows the principle of the procedure applied in the model. The possible position of a ship is defined by the position along the route and the offset from the route. The route is defined from points P1 to P2. With the geometrical extent of the transverse distribution and the length of the route a net can be generated. Based on the longitudinal distribution and the transversal distribution, the likelihood for a given position can be evaluated. The transversal distribution P(T) is based on distributions fitted on the basis of AIS data and the longitudinal distribution P(L) is assumed to follow a uniform distribution.

The drifting probability P(D) is based on a blackout frequency of $2.5 \cdot 10^{-4}$/h given in /GL, 2010/. P(D) is calculated for each route based on the length of the route and the average vessel speed.

Probability of no repair P(NR) is one minus the probability that the blackout can be repaired. Based on drifting speed and the distance to the structure the time available for repair t can be calculated. /GL, 2010/ recommends using the following function for no repair:

$f(t)=1$	for $t<0.25$h
$f(t)=1/(1.5(t-0.25)+1)$	for $t>0.25$h

Figure 7-2 shows the distribution of the probability of no repair. The probability of anchor failure P(NF) is given in Figure 7-3. The distribution is taken directly from /GL, 2010/.

Finally, $P(D\alpha_{j,k})$ is the probability of the vessel drifting towards the object of consideration. This is depending on the geometry as illustrated in Figure 7-1. Given the two shown angles from a vessel to the object position the object the directional probability can be evaluated, given a drifting rose has been evaluated, see Section 7.1.2. For the geometrical evaluation the object length and width as well as its orientation is requested together with ship geometry.

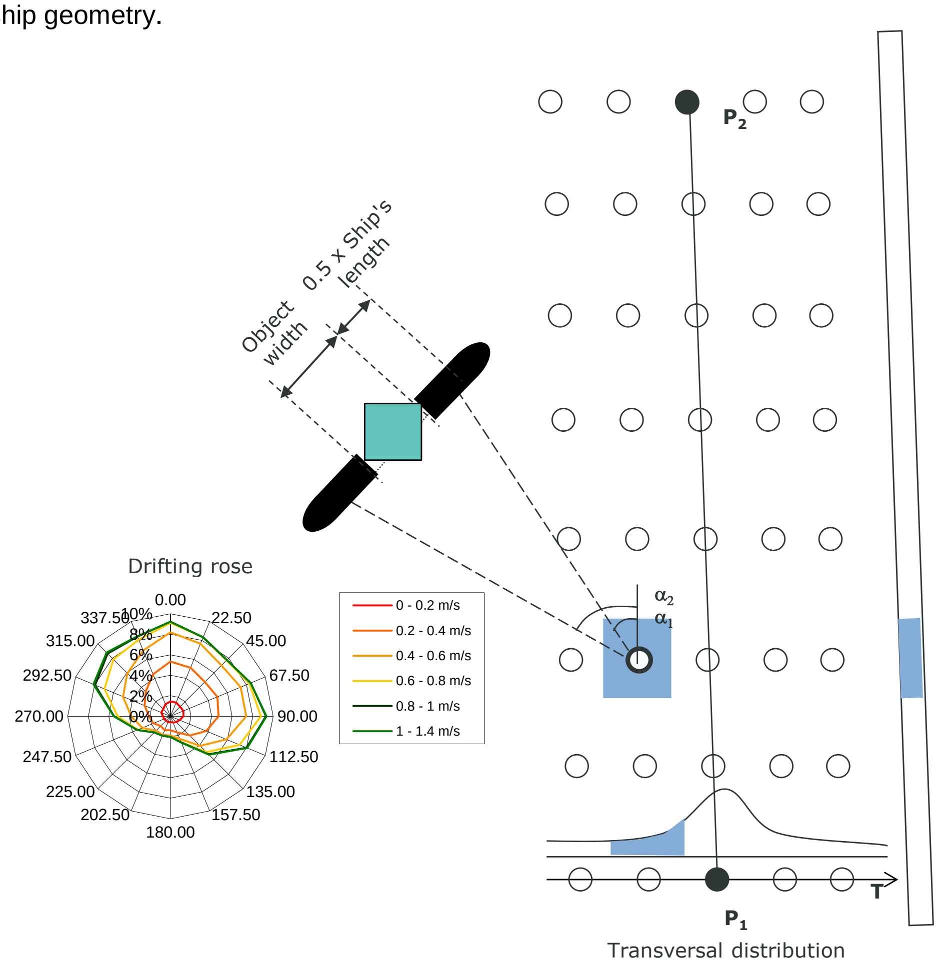

Figure 7-1 Geometric evaluation for the collision frequency for drifting collisions from possible positions in transverse and longitudinal direction.

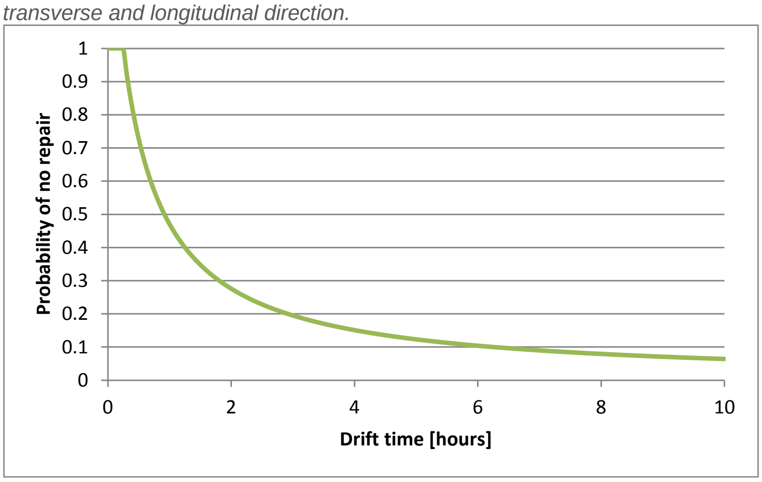

Figure 7-2 Distribution of the repair time, /GL, 2010/.

Wind [bft]	Probability of anchor failure
0	0.01
1	0.01
2	0.01
3	0.01
4	0.035
5	0.07
6	0.126
7	0.21
8	0.35
9	0.49
10	0.63
11	0.7
12	0.7

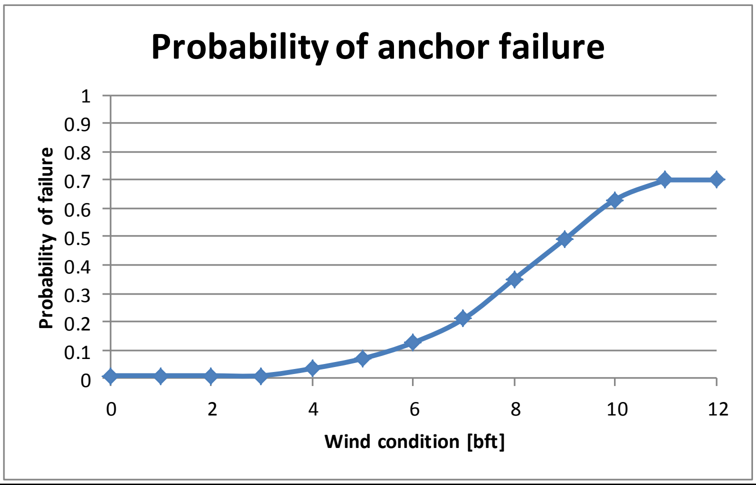

Figure 7-3 Anchor failure function, from /GL, 2010/.

7.1.2 Drifting rose

A drifting rose describes the drifting behaviour of ships by means of the drifting direction, the drifting speed and the associated likelihood of this scenario. In the following it is described how the drifting rose has been established.

The drifting rose is calculated based on:

- Wind rose
- Model for the drifting direction due to wind
- Drifting speed as a function of the wind speed
- Current

The applied drifting speed as a function of the wind speed is based on a relation given in /Vinnem, 2007/ for merchant vessels between 5,000 and 15,000 DWT. For smaller as well as larger vessels, drifting speed is generally lower. Therefore, applying the wind speed distribution is a slightly conservative assumption. In fact, wind speeds do not differ much for the other size categories.

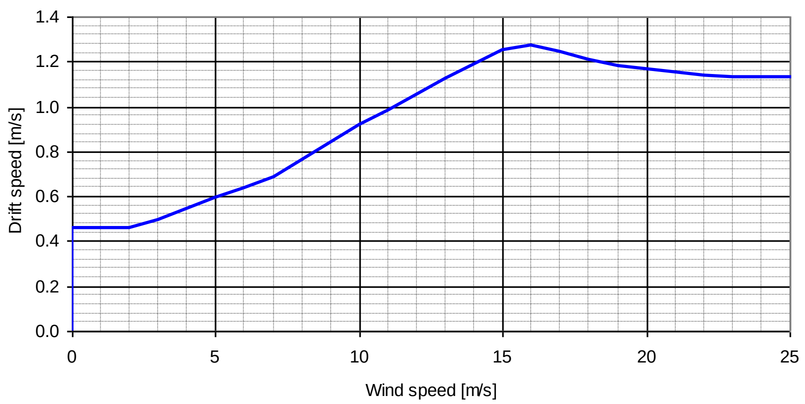

Figure 7-4 Applied drifting speed as a function of the wind speed according to /Vinnem, 2007/.

In /ICS OCIMF, 1998/ the results of drifting experiments and calculations are reported. Figure 7-5 shows that this report considers the drifting direction due to wind as a function of whether the wind comes from the starboard or the port side of the ship. Moreover, /ICS OCIMF, 1998/ reports the many influencing parameters which in the end cannot be modelled explicitly, such as rudder, trim, list etc. and many more. As a result of this and based on the findings reported in /ICS OCIMF, 1998/, the angle B shown in Figure 7-5 is taken as 160°±20°. Within this range, all angles are considered as equally likely. In addition, if the angle between wind and the longitudinal axis of the vessel is smaller than 23° it is assumed to be equally likely for the wind to come from port or from starboard. Already the uncertainty in the wind data provides room enough for this assumption. If the angle is larger than 23°, the weighting is 90% to 10% in favour of the dominating side.

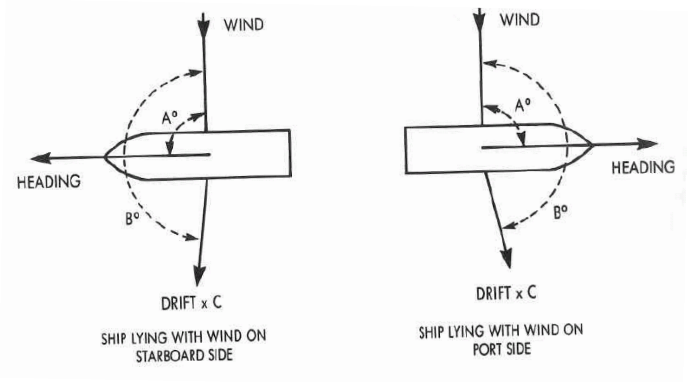

Figure 7-5 Drifting direction of ships due to wind, taken from /ICS OCIMF, 1998/.

The current in the area around Horns Rev 1 is quite low and average very close to zero. This is also assumed to be the case for the investigated wind farm. On the basis of this and in agreement with the assumption applied on other wind farms in the area, e.g. /HR2, 2006/, the current vector is taken to be zero.

Based on the information described above, the drifting direction for a given wind direction can be calculated. Moreover, for a discrete wind speed the average drifting speed due to wind is obtained. The final drifting direction and speed is then obtained by means of a vector addition of the drifting vector due to wind and the drifting vector due to the current as shown in Figure 7-6.

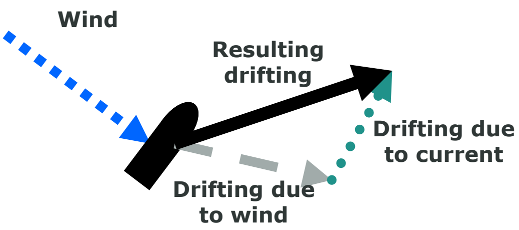

Figure 7-6 Evaluation of drifting direction and speed.

Subsequently, all combinations of wind direction and wind speed, current direction and current speed are considered and weighted accordingly. The finally obtained direction and drifting speed is then mapped into a scheme consisting of 6 drifting speed classes and 16 directions. Figure 7-7 shows the drifting rose for a ship with a course over ground equal of 0°.

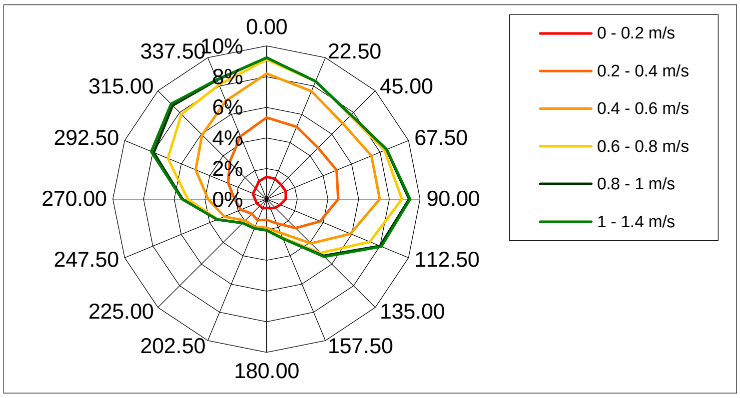

Figure 7-7 Drifting rose for 6 drifting speeds and 16 drifting courses for vessel course over ground 0°.

7.2. Powered collisions

7.2.1 Impact frequency

The impact frequency is evaluated by the equation below, whereas the geometrical outline is illustrated in Figure 7-8.

Nc=Ns Pg Pc R

where:

Nc	…	The frequency of severe ship impact, i.e. number of severe ship impacts per year.
Ns	…	The annual number of ship passages on the route.
Pg	…	The geometrical probability of a ship is heading towards the structure
Pc	…	The causation probability of a ship failing to avoid an impact accident, e.g.. by failing to correct to a safe course, P_C=3.0x10^{-4} /GL, 2010/ .
R	…	Risk reducing factors arising from, e.g. VTS, pilotage, AIS, and electronic navigation charts (ECDIS).

The principle of the model is illustrated in Figure 7-8. A route is here defined by the three points P_1 and P_2 and P_3.

The likelihood of a vessel colliding with an object, either because the ship master forgets to turn at P_2, or simply because the ship is not on its intended course close to an object is based on the transversal distribution. The transversal distribution is based on AIS data for which distributions are fitted based on a Gaussian and a uniform distribution.

P_g is calculated using the ship width and the projected width of the considered object. The projected width of the object is calculated in turn on the length and width of the object and its orientation. Finally the transversal distribution is used to evaluate the likelihood of being on a collision course.

No specific risk reducing measures have been considered in the area.

Forget to turn scenario

The causation probability applied to estimate the fraction of ships omitting to turn at the bend is taken as: $1.25{\cdot}10^{-4}$. This value is taken from the Great Belt Update, where analysis of incidents was used to modify the base value previously applied.

After forgetting to turn, some of the ships may identify the mistake and correct the course. This is modelled on basis of the following assumptions for ships without pilot on board:

- 90% of the ships are assumed to check their position every 8 ship lengths with a failure probability of 0.01. Furthermore, it is assumed that no checking is done if the distance to the bridge structure is less than 8 ship lengths.
- 10 % of the ships continue without checking their position because of failure of duty. It is assumed that 5 % —"wake up" per 8 ship lengths.

For ships with pilot on board failure of check of position is assumed to be 0.005 and failure of duty is 1%. 5% are assumed to "wake up" per 8 ship length in case of failure of duty with pilot on board.

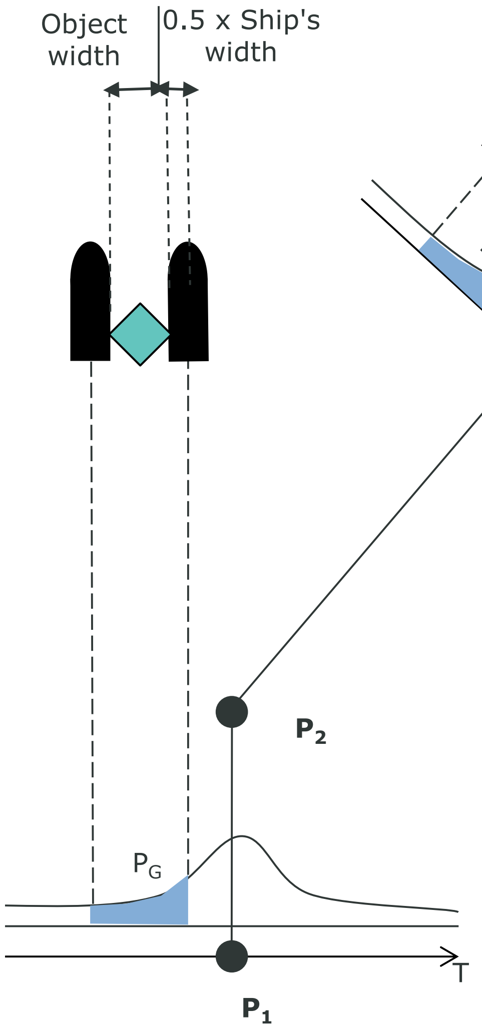

Figure 7-8 Geometric evaluation for the collision frequency for powered collisions for the normal powered collisions and the forget to turn scenario.

7.3. Shielding

7.3.1 Within the park

A colliding vessel, powered or drifting, can have a collision path where it will collide with several turbines. A large ship could impact and damage several turbines, but smaller vessels will often be stopped after a collision and therefore not impact more than one.

To estimate the effect of shielding the geometric shielding factor from each turbine is calculated. This means that if a vessel will have impacted another turbine before hitting the considered turbine it will not be counted twice. For each of the turbines all possible angles from where a ship impacting will not have impacted other turbine beforehand are established based on the geometrical layout of the wind farm. As the ships movement direction varies dependent on if it is a powered ship or a drifting ship the effect of shielding varies between these two categories. The effect of shielding has on this basis been calculated and is described by the following reduction factors for the examined park lay-out:

$Shield_{drift}$= 0.57

$Shield_{power}$=0.92

The factors describes the average geometric shielding effect of all of the turbines compared to freestanding objects with no shielding, i.e. compared to a situation where the turbines have zero impact capacity.

7.3.2 Other wind farms and the reef

Other wind farms in the area will have a geometric shielding effect similar to the turbines within the park itself described in section 7.3.1. Horns Rev 1 is quite far away from the area and is therefore assumed to have a small effect in relation to shielding. Horns Rev 2 is however just south of the investigated wind farm. The 91 2.3 MW turbines at Horns Rev 2 will have a shielding effect especially on the routes west and southwest of the park. Large vessels on the routes south and southwest of the park, i.e. route 3, 7 and 8 will furthermore be influenced by the reef itself. The large vessels can have a draught larger than the water depth at the reef and will therefore ground before reaching the area of the wind farm.

7.4. Summary of collision frequencies

7.4.1 Drifting collision

For drifting collisions the contributions to the collision frequency from the various vessel types is given in Table 7-1

Table 7-1 *Frequency of drifting collisions for the various vessel types on the routes in the area. Route 1, 5 and 9 are new routes as described in chapter 5 and route 13, 17 and 19 have been offset or shortened.*

Route number	Frequency drifting collisions						
	Merchant	Offshore	Military	Dredger	Fishing	Other	Total
1	7.09E-04	3.39E-04	2.36E-05	4.45E-04	4.45E-05	4.71E-04	2.03E-03
2	6.34E-03	6.98E-05	5.91E-05	0.00E+00	1.97E-05	1.15E-04	6.60E-03
3	3.83E-04	0.00E+00	2.46E-06	0.00E+00	1.99E-06	1.17E-05	4.00E-04
4	2.97E-04	9.92E-04	9.88E-06	1.86E-04	3.46E-05	1.97E-04	1.72E-03
5	2.18E-04	4.37E-05	7.61E-06	2.14E-05	7.18E-06	1.38E-04	4.36E-04
7	1.15E-04	1.18E-04	8.24E-06	0.00E+00	3.10E-06	1.37E-04	3.81E-04
8	4.84E-06	1.03E-05	2.72E-07	0.00E+00	2.56E-07	5.28E-06	2.09E-05
9	1.32E-05	0.00E+00	0.00E+00	1.47E-04	1.23E-05	1.66E-05	1.89E-04
10	0.00E+00	3.28E-06	0.00E+00	0.00E+00	0.00E+00	5.88E-07	3.86E-06
11	0.00E+00	7.23E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.23E-04
12	5.02E-05	5.94E-05	0.00E+00	1.88E-05	5.75E-05	5.97E-05	2.46E-04
13	6.52E-05	1.85E-04	0.00E+00	2.00E-04	4.34E-04	2.70E-04	1.15E-03
14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.13E-05	0.00E+00	3.13E-05
15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.44E-05	0.00E+00	1.44E-05
16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.23E-05	0.00E+00	1.23E-05
17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E-04	0.00E+00	1.18E-04
18	5.51E-06	0.00E+00	0.00E+00	2.24E-05	9.41E-06	8.87E-06	4.61E-05
19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.15E-05	6.11E-05	1.43E-04
20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.50E-05	0.00E+00	3.50E-05
Total	8.20E-03	2.54E-03	1.11E-04	1.04E-03	9.16E-04	1.49E-03	1.43E-02

An overview of the contributions from drifting collisions from the different routes is shown in Figure 7-9.

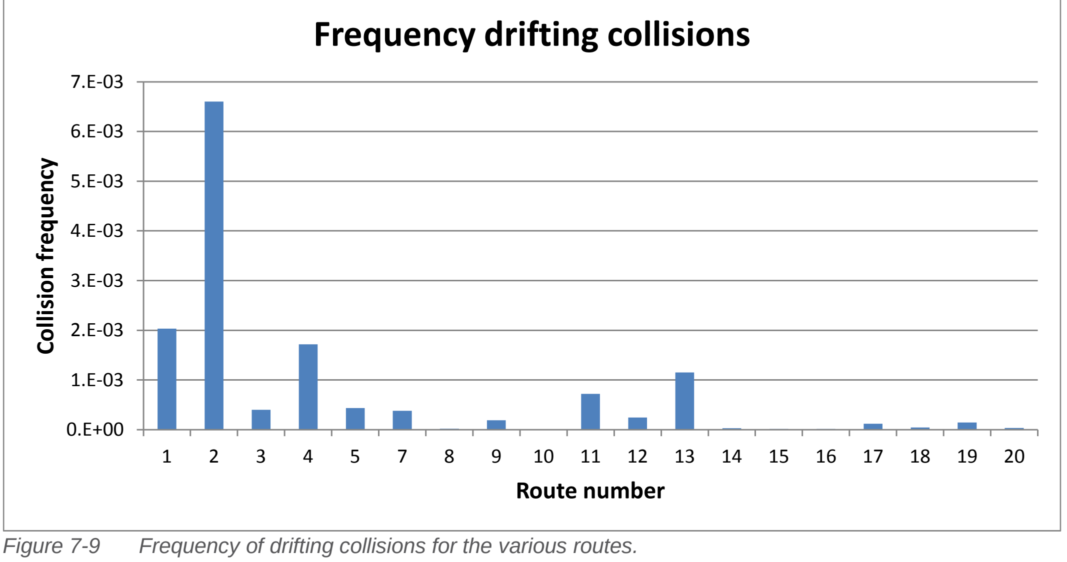

Figure 7-9 *Frequency of drifting collisions for the various routes.*

The return period for drifting collisions for all routes considered is 70 years. The largest of the individual contributions comes from drifting collisions from route 2, which is the main traffic route west of the park. The primary traffic on the route is merchant vessels. This route is located very close to the park and has the highest amount of traffic in the area. If a vessel begins to drift, the drift direction will most often be towards the turbines and as the distance is small the possibility of repairing the vessel is limited.

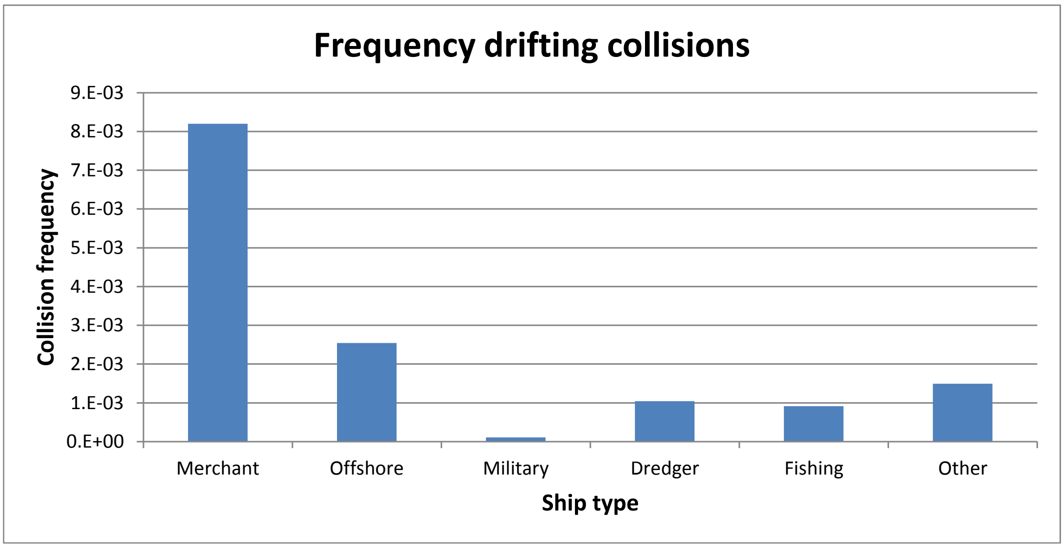

Figure 7-10 Frequency of drifting collisions for various ship types.

In Figure 7-10 it is seen that merchant vessels and offshore vessels gives the largest contribution to the collision frequency from drifting vessels.

7.4.2 Powered collisions

For powered collisions the contributions to the collision frequency from the various vessel types is given in Table 7-1

Table 7-2 Frequency of powered collisions for the various vessel types on the routes in the area. Route 1, 5 and 9 are new routes as described in chapter 20 and route 13, 17 and 19 have been offset or shortened.

Route	Frequency powered collisions						
number	Merchant	Offshore	Military	Dredger	Fishing	Other	Total
1	1.67E-03	6.88E-04	5.62E-05	1.08E-03	7.76E-05	9.84E-04	4.55E-03
2	1.46E-03	1.40E-05	1.38E-05	0.00E+00	3.43E-06	2.38E-05	1.51E-03
3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5	1.01E-04	9.17E-06	2.02E-06	5.72E-06	1.06E-06	2.98E-05	1.49E-04
7	3.24E-64	2.90E-64	2.34E-65	0.00E+00	6.65E-66	3.45E-64	9.89E-64
8	2.51E-237	4.55E-237	1.43E-238	0.00E+00	9.65E-239	2.41E-237	9.71E-237
9	1.51E-06	0.00E+00	0.00E+00	7.35E-06	2.90E-07	6.41E-07	9.79E-06
10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
11	0.00E+00	3.98E-37	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.98E-37
12	2.82E-38	2.89E-38	0.00E+00	1.08E-38	2.41E-38	2.98E-38	1.22E-37
13	4.01E-05	9.93E-05	0.00E+00	1.26E-04	2.04E-04	1.49E-04	6.18E-04
14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.94E-47	0.00E+00	3.94E-47
15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.62E-194	0.00E+00	3.62E-194
16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.10E-05	0.00E+00	5.10E-05
18	1.67E-131	0.00E+00	0.00E+00	6.96E-131	2.12E-131	2.38E-131	1.31E-130
19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.07E-05	1.10E-04	1.80E-04
20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.07E-25	0.00E+00	4.07E-25
Total	3.27E-03	8.11E-04	7.20E-05	1.22E-03	4.08E-04	1.30E-03	7.08E-03

An overview of the contributions from powered collisions from the different routes is shown in Figure 7-11

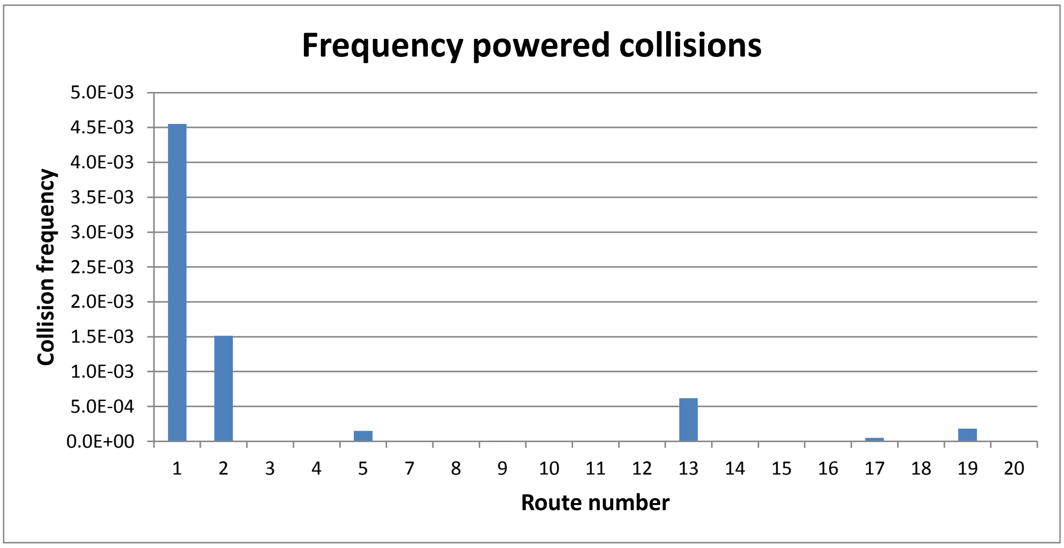

Figure 7-11 Frequency of powered collisions for the various routes.

The return period for all powered collisions is 141 years. The largest individual contribution from the powered collisions comes from route 1. This is a new route leading vessels around the eastern side of the park. These vessels will have to make a detour compared to the route that they are currently using, and it is expected that they will minimise the distance that they shall cover and, thus, will not be take a larger detour around the turbines, than absolutely necessary. The contribution from this route comes primarily from merchant vessels and dredgers. The scenario of forgetting to turn that is governing for route 5, 17 and 19 does not give significant contributions.

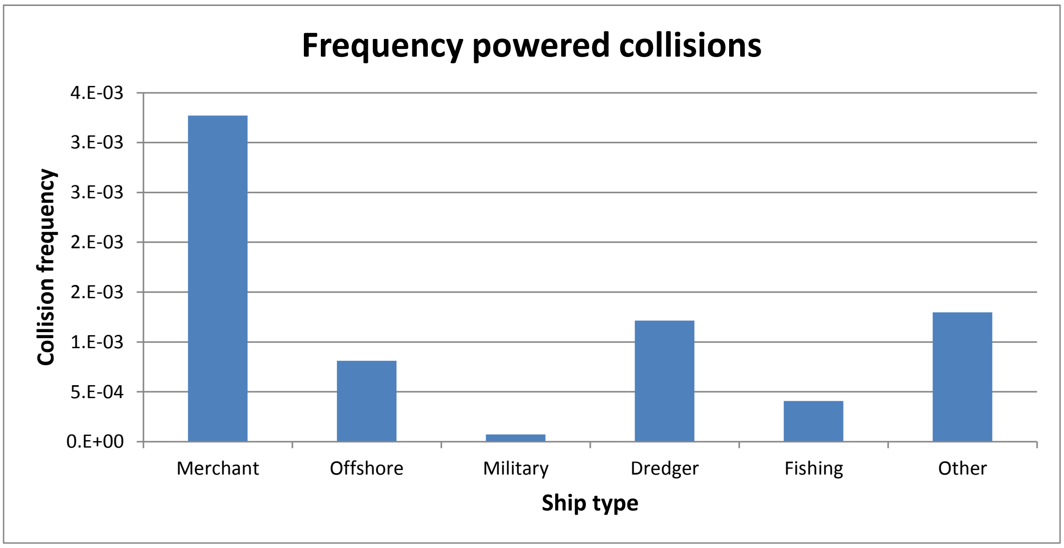

Figure 7-12 Frequency of powered collisions for the various ship types.

In Figure 7-12 it is seen that the largest contribution to the frequency of powered collisions from all routes comes from merchant vessels followed by the categories Other types and Dredgers

7.4.3 Total collision frequency during operation of the wind farm

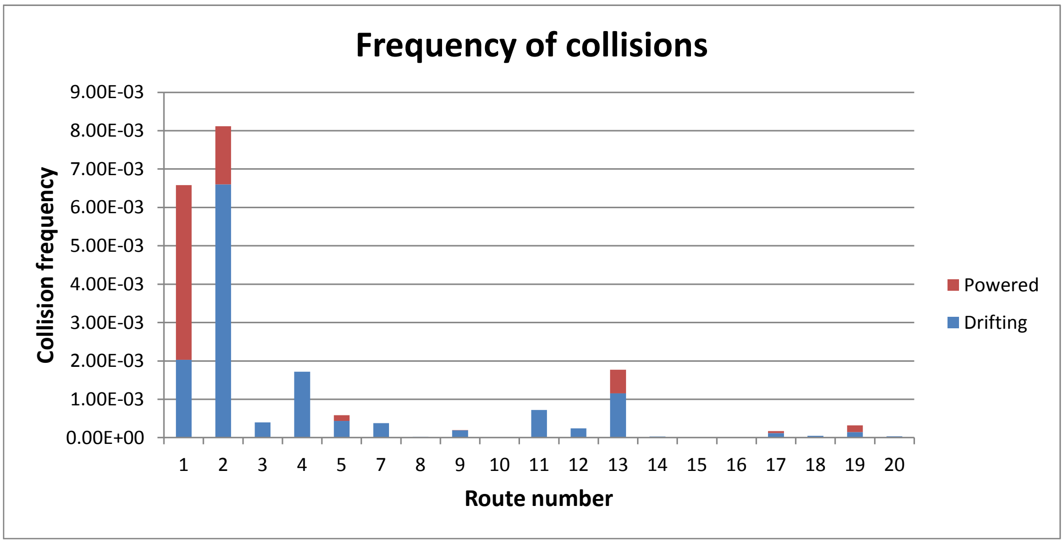

Figure 7-13 Frequency of collisions for the various routes.

The collision frequency for both drifting and powered collisions is corresponding to a return period of 47 years. The largest of the individual contributions comes from drifting collisions from the main traffic route west of the park. This route is located very close to the park and has the highest amount of traffic in the area. If a vessel begins to drift, the drift direction will most often be towards the turbines and as the distance is small the possibility of repairing the vessel is limited. The second largest individual contribution comes from powered collisions from powered vessels that will need to go around the eastern side of the park. These vessels will have to make a detour compared to the route that they are currently using. Aggregated route 2 gives the highest contribution to the collision frequency closely followed by route 1. Further significant contributors are route 13, 11 and 4.

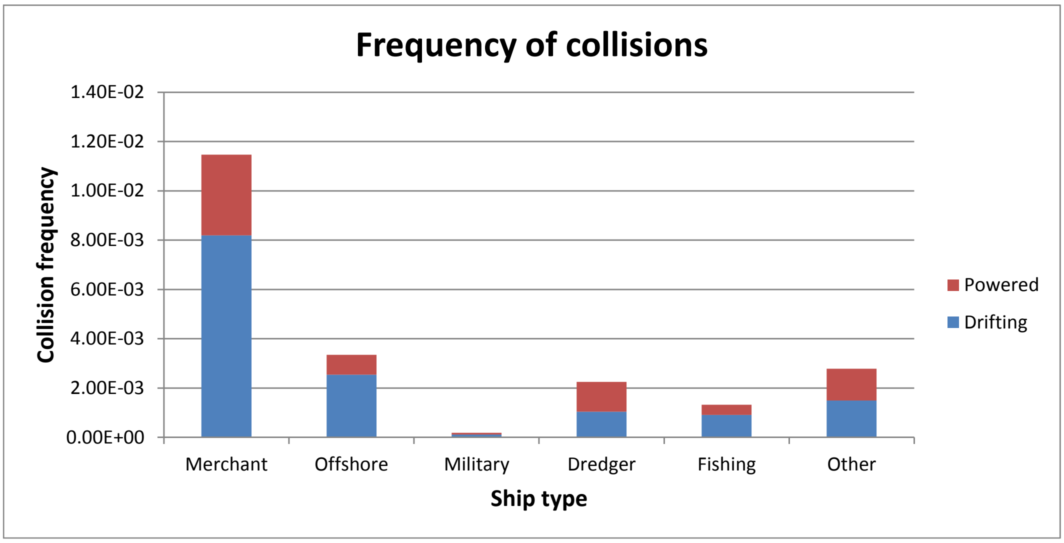

Figure 7-14 Frequency of collisions for the various ship types.

The contributions from drifting collisions primarily come from merchant vessels whereas both merchant vessels, dredgers and other types have significant contributions to the frequency of powered collisions. The calculated frequencies are based on the fully developed wind farm. Aggregated on the different ship types the merchant and offshore vessels are most critical.

The transformer platform is located very far away from both route 1 and 2. The primary contribution to the collision frequency at this location is drifting. A collision frequency of $3.6 \cdot 10^{-5}$ corresponding to a return period of approximately 27500 years have been calculated for the transformer platform.

The investigated worst case layout of the wind farm will be a conservative estimate of the risk for collisions from ships in the area. The main contribution to the frequency comes from drifting ships where the impact velocity in average and thereby the damages caused by the collision is limited compared to powered collisions.

In order to validate the results the calculated collision frequencies have been compared with the average probability of a ship grounding elsewhere. However, the amount of powered collisions cannot directly be compared to historical data of powered grounding as the historical data will contain a substantial amount of collisions with subsea reefs. This type of human error will not be governing at the wind farm as the turbines are visible and not only subsea. Comparing the frequency of powered collisions against the park with statistics about powered groundings in general does therefore not give any validation of the results.

The frequency of collisions due to drifting can however be compared with the average probability of a ship grounding elsewhere. Based on /DNV, 2011/, drift groundings comprise approximately 13% of the total amount of groundings. For the BRISK project, /Brisk, 2011/ the grounding probabilities per nm were calculated for various locations. For the Great Belt the historical grounding probability is $4.7 \cdot 10^{-6}$ per nm, for the Sound the grounding probability is $3.7 \cdot 10^{-6}$ per nm and for Little Belt the grounding probability is $1.7 \cdot 10^{-6}$ per nm. If the traffic on route 2 was located in the Great Belt and the critical length of the route was say 10 km the return period for a drifting grounding would be 82 years. If the grounding probabilities from the Sound or Little Belt are applied the return period for drifting groundings would be 105 and 228 years respectively. The calculated drifting collision frequency with the wind farm from route 2 is 151 years. The numbers are therefore of the same order of magnitude which is expected as the fundamental behaviour is comparable.

Although no direct validation of the frequency of powered collisions has been carried out the frequency of powered collisions is approximately the same order of magnitude as the frequency of drifting collisions and this is also expected.

7.4.4 Comparison with other wind parks

Other wind parks have been investigated prior to being constructed. At the wind park at Anholt the collision frequency was assessed to have a return period varying between 172-217 years, /ANH, 2009/, depending on the investigated layout at the preliminary stage. For the wind park Horns Rev 2 the return period for collisions was assessed to be between 84-230 years, /HR2, 2006/, dependant on the layout.

The total return for an impact against Horns Rev 3 of 47 years is smaller than e.g. the return period that has been calculated for Horns Rev 2. The investigated layout of the wind farm gives the largest contributions to the frequency from the turbines located on the western side but also considerable contributions from the turbines located most easterly. Significant reductions to the collision frequency can be expected if these turbines were moved further away from these routes. This is primarily possible for route 2. For the wind park Horns Rev 2 the contribution to the collision frequency from route 2 is comparable with the investigated wind park. The reason the total frequency is higher than for Horns Rev 2 is due to route 1 and 13 where vessels need to go around the new wind park. The vessels on this route is however typical smaller and the consequences are therefore limited compared to collisions from route 2. This is described further in chapter 7.5.

7.5. Collision consequences

The consequence of a collision with the wind farm can lead to a variety of outcomes. Both the turbines and the vessel involved in a collision could be damaged and furthermore personal injuries can occur if a vessel is damaged or capsizes. Environmental damage could arise if bunker oil is released or if a chemical or oil taker has a spill from the storage tanks. The outcome of a collision is dependent on a variety of parameters. Some of these are listed below:

Impact energy

The outcome of a collision is dependent on the speed of the vessel and the mass of the vessel. A large vessel would most likely damage the turbine significantly whereas a fishing vessel or minor recreational vessel could impact the turbine without damaging the turbine itself. Damage could however occur to the vessels in the event of an impact;

however the requirement for a collision-friendly design of the foundation does limit the probability of this.

The impact angle of a collision with a turbine can also influence the consequences. A sliding collision with the turbine will make a vessel glide of the turbine with a minimum of energy transferred to the structure, whereas a direct hit would maximise the energy transferred to the structure, and therefore have a significant higher probability of severe consequences such as hull damage. The impact zone is also of relevance for the collision consequences. In a sideways collision, i.e. a drifting vessel, the energy can be transferred to the structure over a significant height but with a direct collision with the bow the energy most likely would be transferred over a smaller area, i.e. the bow or bulb of the vessel. This could result in different failure modes both for the turbine and the vessel. The foundation design and the shape of the impacting vessel do all influence the type of failure. The required collision-friendly design of the foundations does limit the probability of damaging the vessel in the event of an impact.

V**essel type/characteristics**

In the case of a collision the environmental consequences is dependent on the size of spills from the vessel. All vessels can in the event of a collision have a spill of the bunker oil carried. Some vessels have bunker protection and are therefore less likely to have these spills. More severe environmental consequences could occur in the event of a large chemical or oil tanker colliding with the park. The various chemical and oil products carried on these vessels can be leaked in the event of a collision damaging the tanks. The probability of having a breach of the tanks on an oil carrier or chemical tanker is influenced by the design of the vessel. The share of double hull tankers have over the last decades increased and today nearly all tankers have a double hull. This has a positive effect on the probability of having a leakage in the event of a collision with a tanker.

7.5.1 Overview of size of vessels

The traffic on the routes in the area of Horns Rev 3 varies significantly. Some routes are only used by smaller fishing vessels and other routes are used by large merchant vessels. An overview of the distribution of the vessel sizes on the various routes can be found in Table 6-3

Table 7-3 Overview of the size class of the vessels on the routes near Horns Rev 3.Typically fishing vessels and other smaller vessels are not included in the IHS Fairplay database. The overview is based on the vessels that can be identified and fishing vessels and other smaller vessels in the area are therefore not included. Routes where no vessel size distributions are given is only used by these smaller vessels.

Route	Size of vessels (DWT)							
number	< 1000	1000 - 3000	3000 - 5000	5000 - 10000	10000 - 20000	20000 - 40000	40000 - 80000	> 80000
1	7%	50%	11%	31%	1%	0%	0%	0%
2	2%	12%	30%	27%	14%	11%	2%	1%
3	2%	12%	26%	28%	16%	13%	2%	1%
4	43%	34%	4%	19%	0%	0%	0%	0%
5	11%	43%	15%	30%	1%	0%	0%	0%
7	14%	30%	29%	20%	5%	1%	1%	0%
8	12%	17%	58%	8%	2%	2%	1%	0%
9	2%	61%	4%	33%	0%	0%	0%	0%
10	77%	17%	0%	6%	0%	0%	0%	0%
11	94%	0%	3%	3%	0%	0%	0%	0%
12	38%	48%	15%	0%	0%	0%	0%	0%
13	72%	23%	4%	0%	0%	0%	0%	0%
14	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-
18	65%	19%	12%	0%	3%	1%	0%	0%
19	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-

It is seen that the largest vessels are present on route 2 and 3 where ships over 80000 DWT are found. Route 1 that contributes with a collision frequency comparable to route 2, comprise significant smaller vessels, with a maximum below 20000 DWT. This is also the case for route 13 where the largest vessel is under 5000 DWT. The larger vessels are typically taking the north/south routes 2 and 3 and if going to Esbjerg route 7 and 8 far away from the park is used.

7.5.2 Fraction of chemical and oil tankers

The environmental consequence in the event of a collision depends on the type of vessel involved. The most severe environmental consequences could arise if an oil tanker or chemical tanker collides with a turbine and this collision causes a leak in the storage tanks on the vessel. The fraction of the merchant vessels on the routes that are categorised as oil or chemical tankers is given in Table 6-4

Table 7-4 Fraction of merchant vessels categorised as chemical or oil tankers

Route number	Fraction of chemical and oil tankers in merchant vessels
1	7%
2	10%
3	15%
4	5%
5	9%
7	28%
8	33%
9	2%
10	0%
11	0%
12	4%
13	4%
14	-
15	-
16	-
17	-
18	15%
19	-
20	-

The significant contributors to the collision frequency come from route 1 and 2. However as route 2 have approximately 9 times as many merchant vessels and the larger fraction of oil and chemical tankers the consequences of a collision from this route is deemed more critical from an environmental point of view than the contribution from route 1. It should be notes that 90% of the merchant vessels on route 2 are not oil or chemical carriers and that the oil related environmental consequences from these therefore primarily relate to spill of bunker oil.

Route 7 and 8 with a relative large share of oil and chemical tankers are located far away and therefore does not give any significant risk contribution even though the consequences would be higher.

7.5.3 Summary of collision consequences

Impacts from route 2 will likely have the highest consequence as this route has the highest fraction of large vessels. Besides the size of the vessels on route 2 the fraction of oil and chemical tankers is larger than other significant routes and this could give rise to more significant environmental consequences in the event of a collision.

The typical size of vessels on route 1 is significantly smaller than on route 2 and furthermore the amount of tankers on route 1 is limited. Smaller vessels and a smaller fraction of tankers gives lower consequences for route 1 compared with route 2. Route 13 that has the third highest collision frequency has even smaller vessels and fewer tankers.

8. COLLISION FREQUENCY DURING CONSTRUCTION

The process and procedures to be applied in the construction phase is not currently defined in any detail. Thus no collision frequency during construction and decommissioning of the wind farm can be calculated. Various parameters will however influence the frequency of collisions in the construction phase.

8.1. Ship-Ship collisions

In the construction phase a number of construction vessels are present in the area. The number and type of vessels and the duration where the vessels are present in the area is very dependent on the e.g. the chosen type of foundation and the procedure applied for construction. A number of construction vessels will, however, need to go to and from the site. This will give additional probability of ship-ship collisions on the routes used. If narrow navigational routes, e.g. from Esbjerg through Slugen and to the site, is used it will give a higher probability of ship – ship impacts than on routes that does not have these limitations e.g. from Hvide Sande.

8.2. Ship - Turbine collisions

During the construction phase a safety zone of 500m is expected to be established around the main construction sites in order to protect the project, the safety of personnel and the safety of third parties. It is intended that third parties will be excluded from the safety zone during the construction period, and that the zone(s) will be marked in accordance with the requirements from the Danish Maritime Authority. The temporary markings will include yellow light buoys with an effective range of at least 2 nautical miles. All buoys will further be equipped with yellow cross sign, radar reflector and reflector strips. It is expected that one or more guard vessels will be required in the construction phase. Regular Notice to Mariners will be issued in advance and as construction progresses.

It is expected that during some of the construction phases there could be an increased probability of collisions. Disregarding impacts from the construction vessels working on the park this could be caused by a number of factors:

- Marking of the site can be overlooked
- Partly constructed turbine cannot be seen on radar
- The vessels are used to taking a specific route and not used to the presence of the park

The ship – turbine collision frequency during construction can be higher for powered collisions than in the operational phase. The powered collisions are generally caused by human errors and as temporary marking can be overlooked there could be a higher probability of collisions during this phase.

The frequency of drifting collisions from the regular traffic will most likely be smaller or maximum the same size in the construction phase compared to the operational phase. The turbines are erected gradually and as number of turbines is increasing the probability of a drifting vessel impacting the farm will also increase. The routes currently going through the park could give an additional contribution to the probability of drifting collisions during this phase however the established safety zones could make the vessels chose another route and the presence of tug boats in the area can reduce the probability of impacting the turbines if used to assist a drifting vessel

9. COLLISION FREQUENCY DURING DECOMMISSIONING

The lifetime of the wind farm is expected to be around 25 years. It is expected that two years in advance of the cease of the production the developer shall submit a decommissioning plan. The method for decommissioning will be to follow best practice and the legislation at that time. The deconstruction of the turbines will be done in reverse order compared to construction. From a navigational point of view the collision frequencies with the turbines in the deconstruction phase for passing vessels, is expected to be lower than in the construction phase. As the wind park has been present in the area for approximately 25 years at the time when decommissioning is initiated, the ship traffic will be fully aware of the presence of the wind farm and as the number of turbines will be reduced throughout the decommissioning process the risk of impacting them will gradually decrease. It is expected that a safety zone will be enforced in the decommissioning process in line with what is required during the construction process.

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APPENDIX A: HAZID PROTOCOL

The HazID (hazard identification) meeting was held at the Scandic Olympic Hotel in Esbjerg on 5 February 2013.

The meeting was conducted in Danish. Therefore, the following HazID protocol is in Danish.

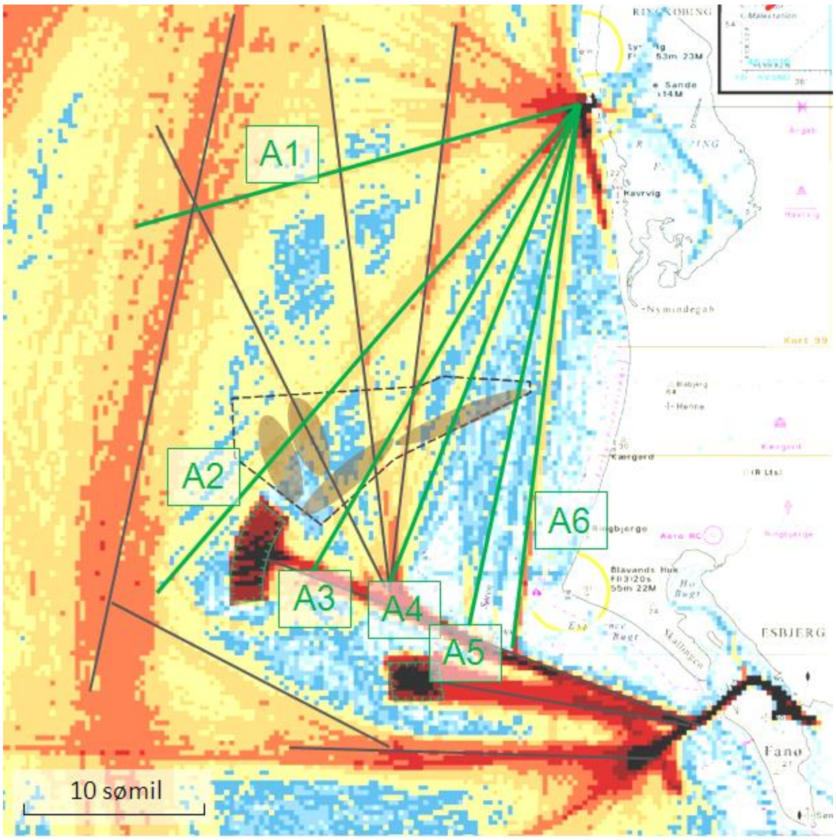
A.1 Deltagere

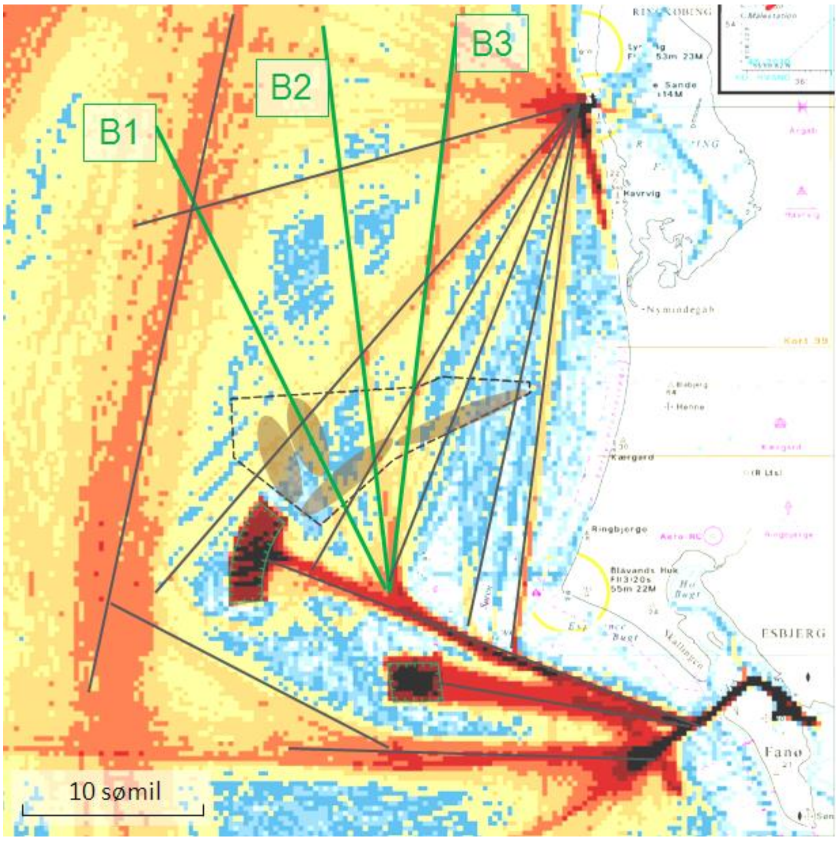
Navn	Stilling	Firma/institution
Jesper Juul Larsen	Formand	Sydvestjysk Fiskeriforening/ Danmarks Fiskeriforening
Torben Jensen	Maritim chef	Esbjerg Havn
Flemming S. Sørensen	Nautisk specialkonsulent	Søfartsstyrelsen
Peter Dam	Nautisk specialkonsulent	Søfartsstyrelsen
Henrik S. Lund	Marin biolog	Danmarks Fiskeriforening
Kurt S. Madsen		Danmarks Fiskeriforening
Per Stenholt	Head of Offshore Development	Vattenfall Vindkraft A/S
Lars Bie Jensen	Environment & Consents Manager	DONG Energy
Mads Vangaard	Financial Analyst	DONG Energy
Leif Jensen	Havnechef	Thorsminde Havn
Steen Davidsen	Havnechef	Hvide Sande Havn
Henning Yde	Havnemester	Hvide Sande Havn
Jens Henrik Sørensen	Kontorchef	Forsvarets Bygnings- og Etablissementstjeneste
Søren Malle	Major	Forsvarets Bygnings- og Etablissementstjeneste
Bjarke Fyhring Sørensen	Lods	DanPilot - Esbjerg
Hilmar Larsen	Kaptajn	DFDS
Jens Heine Grauen Larsen	Orlogskaptajn	Forsvarskommandoen, nationale operationer
Michael Tolstrup	Orlogskaptajn	Søværnets Operative Kommando, nationale operationer
Niels Rosenberg Andersen	Overmekaniker	Søværnets Frømandskorps, explosive ordnance disposal
Lene Schepper	Seniorspecialist, risikoanalyse	COWI A/S
Anne Mette Kjeldsted Olsen	Ingeniør, risikoanalyse	COWI A/S
Albrecht Lentz	Specialist/delprojektleder, risikoanalyse	COWI A/S
Anders Nielsen	Projektleder Kriegers Flak	Energinet.dk
Sif Zimmermann	Projektleder HR3	Energinet.dk
Kristian Nehring Madsen	Projektleder HR3	Orbicon A/S
Simon Blauenfeldt. Leonhard	Projektleder HR3	Orbicon A/S

A.2 Definition af sejlruterne i området

Sejlruterne i området omkring den planlagte vindmøllepark er baseret på AIS-data, der beskriver skibstrafiktætheden. Dataene er indsamlet over hele kalenderåret 2011, dvs. 01.01.-31.12.

Sejlruterne er defineret med formålet om at forenkle kommunikationen mellem HazID'ens deltagere. Derudover tjener de som overordnet struktur, dvs. ruterne diskuteres den ene efter den anden.

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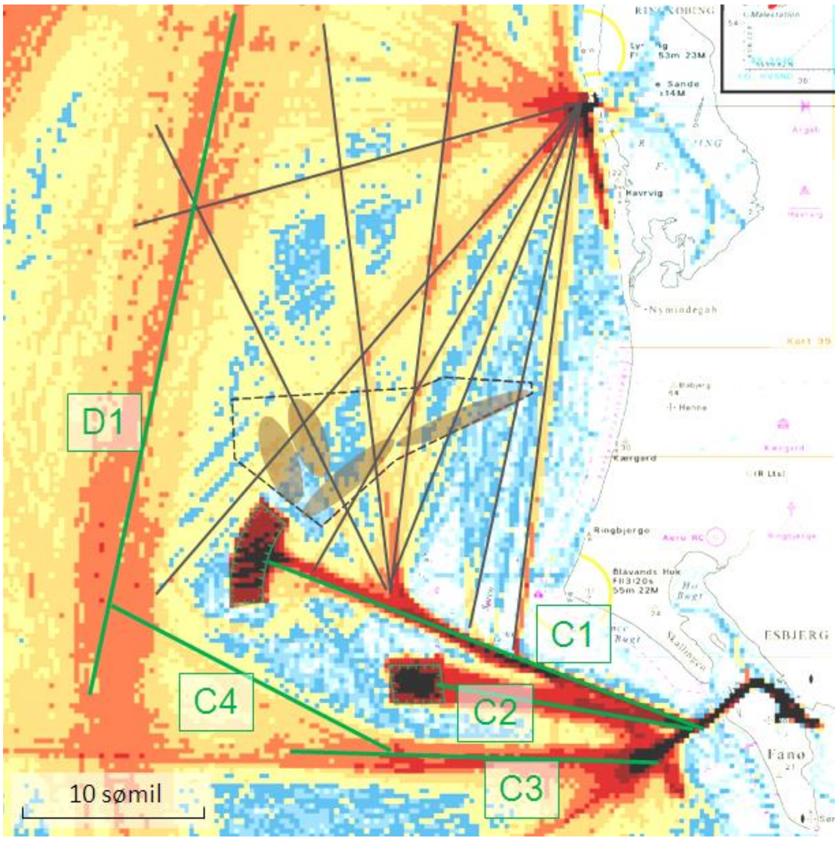
Nymindegab
Ringbjerge
Blåvands Huk
ESBJERG
Fanø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C2
C3
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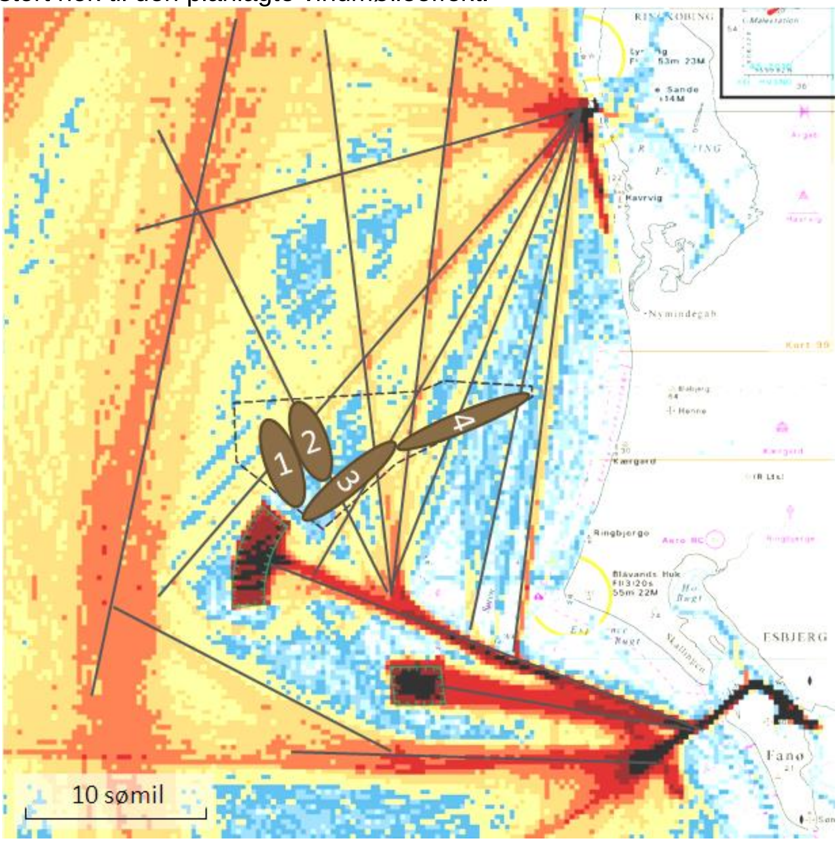
10 sømil
Havrvig
Nymindegab
Ringbjerge
Blåvands Huk
ESBJERG
Fanø

A.3 Definition af mulige mølleopstillingsscenarier

Denne risikoanalyse af sejladsforholdene indgår som led i den overordnede vurdering af virkningen på miljøet (VVM) for havmølleparken Horns Rev 3. VVM'en tager udgangspunkt i worst-case-opstillingsscenariet. Dette scenario havde imidlertid ikke været fastlagt endnu, da HazID-mødet fandt sted. Derfor opereres der med fire hypotetiske opstillingsscenarier (1 til 4), der er defineret specifikt til dette HazID-møde. De er valgt således, at de udnytter områderne med lavt og gennemsnitligt dybt vand bedst, mens de ikke benytter sig af de dybeste områder.

Det skal bemærkes, at der skal flere af scenarierne til samtidig for at opnå et areal, der er stort nok til den planlagte vindmølleeffekt.



A.4 Fareidentifikationsprotokol vedr. sejladsforhold i driftsfasen

For at holde processen simpel, blev fareidentifikationen brudt ned til to hovedtrin:

1. Identificering af alle sejladsrelaterede farer, der kan tænkes i forbindelse med tilstedeværelsen af en ny vindmøllepark

2. Identificering af de specifikke farer på de enkelte ruter, inkl. kommentarer til deres hyppighed, alvor og mulige sikkerhedsforanstaltninger

A.4.1 Generel gennemgang af sejladsrelaterede farer i forbindelse med vindmølleparken

Fare	Konsekvens	Alvor	Kommentar
Påvirkning af risikoen for skib-skibskollisioner	- Personskader - Oliespild		
Påvirkning af risikoen for grundstødninger	- Oliespild		Skibsbrand kan være medvirkende til, at et skib begynder at drive.
Kollisioner med vindmøller	- Oliespild - Strømslag (personskade) - Faldende møllekomponenter (personskade)	Strømslag anses ikke som relevant, da skibet jo altid er jordet (skroget ligger i vandet)	

A.4.1 Gennemgang af sejlruterne i området

Fire typer af hasarder vil være repræsenteret i analysen for hver sejlrute (hvis relevante):

- Drivende skib kolliderer med mølle (som følge af drift eller motorstop)
- Kollision mellem eksisterende skibe som følge af trafikomlægning
- Risiko for grundstødning som følge af trafikomlægning

Under fremdrift af skibe vil navigationsfejl indgå som risikoscenarie for alle ruter og kommenteres derfor generelt ikke i protokollen.

Rute/Scenario	Beskrivelse af uheld	Sikkerhedsforanstaltninger	Hyppighed	Konsekvens	Kommentar
Generelt	Sejlende skib kolliderer med vindmølle under normal fremdrift			Svigt af møllen pga. den høje kinetiske energi.	Dette scenarie gælder samtlige ruter, der går tæt på møllerne og gentages derfor ikke for de enkelte ruter nedenfor i tabellen.
A1	Drivende skib kolliderer med vindmølle	- Skibe skal drive langt for at nå møllerne men der er ofte vestenvind. - SOK vil hurtigt blive kontaktet og andre skibe kan hjælpe. - Ved en afstand på ca. 15 sømil vil kollision højst sandsynlig kunne afhjælpes men tættere på kan det være svært at nå at iværksætte beredskabsprocessen. - Der kan kastes anker men stor sandsynlighed for det ikke vil holde under hårde vindforhold.		Skibene kan godt gøre skade på en mølle.	Få handelsskibe. Drivende skibe kan være fiskeskibe eller mindre tankskibe. Længde på skibe kan være ca. 100m og 2500 tons. Drivhastighed kan være op til 4 sømil/h.
A2-1	Drivende skib kolliderer med vindmølle	- I forhold til opstillingsscenarie 1 og 2 er afstanden måske for lille til at nå iværksættelse af beredskabs-manøvre – mindre reaktionstid. - SOK vil hurtigt blive kontaktet og andre skibe kan hjælpe. - Der kan kastes anker men stor sandsynlighed for det ikke vil holde under hårde vindforhold.	- Større sandsynlighed end A1 pga. afstanden til opstillingsscenarie 1 og 2. - Scenarie 3 og 4 kan skibet drive til ved vestenvind som ofte forekommer.	Samme som A1-1	Samme skibe som A1.
A2-2	Kollision mellem skibe som følge af trafikomlægning	- Skibe over 300 GT sejler med AIS (internationalt krav)	- Ændring af indflyvningspunkt fra rute D1 anses ikke at have be-	Skibene kan godt gøre skade på hinanden ved kollision	Skibene vil tvinges til at sejle nord om møllerne i tilfælde af opstillings-

Rute/Scenario	Beskrivelse af uheld	Sikkerhedsforanstaltninger	Hyppighed	Konsekvens	Kommentar
			tydning for kollisionsrisiko da ruten er kendt.		scenarie 1 og 2. Der er ikke trafikseparation ved indfletning.
A2-3	Risiko for grundstødning som følge af trafikomlægning	- Kun mindre skibe går tæt på revet med vanddybder ned til ca. 7,5 m. - Større ruter skal have korridor på 3-4 sømil. - Passagemuligheder for indtil 2 sømil.	Risikoreducerende at kun mindre skibe går tæt på revet.		
A3-1	Drivende skib kolliderer med vindmølle	- I forhold til opstillingsscenarie 3 og 4 er afstanden måske for lille til at nå iværksættelse af beredskabs-manøvre – mindre reaktionstid. - SOK vil hurtigt blive kontaktet og andre skibe kan hjælpe.	- Større sandsynlighed for kollision med mølle i scenarie 3 og 4 pga. afstanden - Scenarie 1 og 2 kan skibet drive til ved østenvind. - Servicefartøjer sås på ruten i 2011, men et andet mønster kan ses nu.	Konsekvensen reduceres ift. rute A1 og A2 pga. størrelsen af skibene.	- Skibe der sejler på ruten er små trawlere med hastighed på 3 knob. -A3 er ikke reelt blivende trafik. Servicefartøjer udgik fra Hvide Sande til Horns Rev 2 i vinteren 2011 (kunne ikke sejle til/fra Esbjerg, fordi isforholdene skaber problemer for waterjet-fremdriftssytemet) .
A3-2	Kollision mellem skibe som følge af trafikomlægning	- Indfletning fra rute C1 anses ikke at have betydning for kollisioner da ruten er kendt. - Fra Anholt er der gode erfaringer med at ændrede sejlruter overholdes. Ingen tilfælde af afvisninger af større skibe, kun lystfartøjer. - Introduktion af nye waypoints giver koncentration af trafikken. Hvis trafikken på A3 omledes ad A4, giver det tværtimod færre krydsningssituationer mellem	- Risikobidraget ved evt. knæk af ruten er minimalt da møllerne etableres over en årrække og således er kendte.	Ikke så stor konsekvens pga. skibenes størrelse og hastighed.	Skibe der sejler på ruten er små trawlere med hastighed på 3 knob og servicefartøjer. A3 er ikke reelt blivende trafik.

Rute/Scenario	Beskrivelse af uheld	Sikkerhedsforanstaltninger	Hyppighed	Konsekvens	Kommentar
		skibe samlet set. -SOK har radarstation ved Blå-vand/Esbjerg. - Skibe under 300 GT sejler generelt ikke med AIS.			
A4-1	Drivende skib kolliderer med vindmølle	- I forhold til opstillingsscenarie 3 og 4 er afstanden måske for lille til at nå iværk-sættelse af beredskabs-manøvre – min-dre reaktionstid. - SOK vil hurtigt blive kontaktet og andre skibe kan hjælpe.	- Større sandsynlighed for kollision med mølle i opstillingsscenarie 3 og 4 pga. afstanden - Opstillingsscenarie 1 og 2 kan skibet drive til ved østenvind.		Ruten forbinder Slugens nordvestlige ende med Hvide Sande. Skibe der stikker mindre dybt end at kan følge rute A6 (f.eks. rejefiske-re). Transit.
A4-2	Kollision mellem skibe som følge af trafikom-lægning	- Indfletning fra rute C1 ændrer sig ikke, da dens position er fastlagt ved fysiske forhold (Slugen). - SOK har radarstation ved Blå-vand/Esbjerg.	- Risikobidraget ved evt. knæk af ruten er mini-malt da møllerne etable-res over en årrække.		Der vil sejles vest om opstillingsscenarie 4.
A5-1	Drivende skib kolliderer med vindmølle	Der er størst kollisionsrisiko ved østen-vind.	- Der vil sejle ca. 600 skibe årligt (ud fra 2006-data)		Fiskere og mindre skibe. Skibe der stikker meget lidt. Lidt større dybgang end skibe der benytter A6-ruten.
A5-2	Kollision mellem skibe som følge af trafikom-lægning	- Lokale fiskere kender til de specifikke forhold, bl.a. den meget snævre rende Søren Bovbjergs Dyb der benyttes af rejefiskere. -SOK har radarstation ved Blå-vand/Esbjerg.			Under skydeaktiviteter benyttes A4. VMS data vil indgå i analysen.
A6-1	Drivende skib kolliderer med vindmølle	- Ruten ligger uden for mølleområdet. - I forhold til opstillingsscenarie 4 er afstanden måske for lille til at nå iværk-sættelse af beredskabs-manøvre – min-			Små skibe – sandpum-pere. Hvis drivning af skibene skal udgøre en risiko,

Rute/Scenario	Beskrivelse af uheld	Sikkerhedsforanstaltninger	Hyppighed	Konsekvens	Kommentar
		dre reaktionstid. - SOK vil hurtigt blive kontaktet og andre skibe kan hjælpe. - Skibe under 300 GT sejler generelt ikke med AIS.			skal de drive for østen-vind.
A6-2	Kollision mellem skibe som følge af trafikom-lægning	-SOK har radarstation ved Blå-vand/Esbjerg.			
B1-1	Drivende skib kolliderer med vindmølle	- Større skibe kan få hjælp af skibe fra den større sejlrende (få tusinde) - Drivende skibe er højst sandsynlig for tæt på parken til at en beredningsma-nøvre kan nå at igangsættes i tide. - Konsortiet har egne beredskabsplaner. Der kan f.eks. etableres nødstop på møllerne (jf. Rødsand 2).	Ca. 600 skibe om året (ud fra 2006-data).		- Ruten bruges af større skibe. - Søfartsstyrelsen kræ-ver en åben korridor i nord/syd-retning.
B1-2	Kollision mellem skibe som følge af trafikom-lægning	- Skibene der sejler gennem opstillings-scenarie 1 og 2 vil skulle omlægges. - For at få skibene til at sejle øst om, kan møllerne afmærkes så skibene kan på-virkes til at følge en rute. - Ved fravælgelse af B1 tvinges skibene over på dybere vand (rute B2), hvilket er godt. - Skibe over 300 GT sejler med AIS (internationalt krav)	Ind- og udfletning er intet problem med 2-3 skibe om dagen.		- Søfartsstyrelsen kræ-ver en åben korridor i nord/syd-retning. - B1, B2 og B3 kan læg-ges sammen.
B1-3	Risiko for grundstødning	- Ved fravælgelse af B1 tvinges skibene over mod rute B2 på dybere vand, hvilket er risikoreducerende.			
B2-1	Drivende skib kolliderer med vindmølle	- Drivende skibe er højst sandsynlig for tæt på parken til at en beredningsma-	- Mere trafik end B1. Trafikken øges ved		- Ruten bruges af større skibe.

Rute/Scenario	Beskrivelse af uheld	Sikkerhedsforanstaltninger	Hyppighed	Konsekvens	Kommentar
		nøvre kan nå at igangsættes i tide. - Konsortiet har egne beredskabsplaner. Der kan f.eks. etableres nødstop på møllerne.	sammenlægning med B1 og B2 - Kollision med møller kan ske ved både ve-stenvind og østenvind.		
B2-2	Kollision mellem skibe som følge af trafikom-lægning	- Erfaring med sammenlægning af ruter viser at der kommer naturlig trafiksepara-tion i det øjeblik, hvor en klar sejlrute eller –korridor defineres. - Skibe over 300 GT sejler med AIS	- Ved sammen-lægning med B1 og B3 vil trafik-ken øges. - Naturlig separation giver mindre kollisionsri-siko - Vil indfletninger kan trafikken øges.		- Ruten bruges af større skibe
B2-3	Risiko for grundstødning		Ikke øget		
B3-1	Drivende skib kolliderer med vindmølle	- Kollision med møller i opstillingsscena-rie 1 og 2 kræver østenvind. - Drivende skibe er højst sandsynlig for tæt på parken til at en redningsmanøvre kan nå at igangsættes i tide.	- Største kollisionsrisiko (dvs. sammen med B1 og B2) - Vindmøllerne introdu-cerer større risiko for fysisk brud på gasled-ningen ved nødankring.	Største konsekvens ved kollision på denne rute og de øvrige B-ruter (B1 og B2)	- Ruten bruges af større skibe. - Skibe på vej fra Den tyske Bugt til Skagen og Vestnorge (og modsat) sejler tæt på kysten ("fjernsynsruten")
B3-3	Kollision mellem skibe som følge af trafikom-lægning	- Grundet trafikken skal ruten så vidt muligt ikke knækkes i nærheden af møl-lerne - Kan samles med B1 og B2 - Der skal indsendes beredskabsplaner (der kan f.eks. etableres nødstop på møllerne).	- Ved sammen-lægning med B1 og B3 vil trafik-ken øges. - Naturlig separation giver mindre kollisionsri-siko		

Rute/Scenario	Beskrivelse af uheld	Sikkerhedsforanstaltninger	Hyppighed	Konsekvens	Kommentar
C1-1	Drivende skib kolliderer med vindmølle	- Meget stærk strøm i Slugen. - Servicebåde kan ikke bruges til slæbning - Nødankring kan højst sandsynlig ikke holde skibet pga. strømmen - Servicebåde kan drive i sydlig vind. - Der er altid fartøjer i området til hjælp ved havari.	- Risiko reduceret for servicebåde da de ikke sejler ud ved højere bølger end 1,5 m. - Risiko større for fiskerskibe og større handelsskibe som kan gå ud i al slags vejr. Disse skibe vil til gengæld nok støde på grund, hvis de begynder at drive i Slugen (= østlig del af rute C1).	Servicebådene kan ikke gøre stor skade på møllen. Mere farligt for mandskabet ombord.	- Går gennem Slugen til Horns Rev 2. Bliver ikke påvirket i sejlmønstret. - I gn.snt. 8-10 servicefartøjer ligger i Esbjerg og sejler ud dagligt til Horns Rev 1 og 2. - Strømmen i Slugen følger dens orientering. Uden for Slugen (nord og syd for revet) gør strømmen i nord-syd retning. Det drejer sig om tidevandsstrøm. Strømmen ved revet (dvs. syd for windparken Horns Rev 3) er stærkere end nord for vindparken.
C1-2	Kollision mellem skibe		Trafikken øges med den nye trafik til mølleparken		Ruten forventes ikke at blive påvirket i sejlmønstret
C1-3	Risiko for grundstødning		- Større drivende skibe gennem slugen vil højst sandsynlig gå på grund (jf. scenario C1-1)		
C2-1	Drivende skib kolliderer med vindmølle	- Ruten ligger forholdsvis langt væk fra HR3 og derfor kan beredskabsmanøvre højst sandsynlig igangsættes i tide.			Små skibe (servicebåde til Horns Rev 1).

Rute/Scenario	Beskrivelse af uheld	Sikkerhedsforanstaltninger	Hyppighed	Konsekvens	Kommentar
C2-2	Kollision mellem skibe som følge af trafikom-lægning		Ingen forøget risiko da ruten ikke er påvirket betydeligt af trafik til Horns Rev 3.		Trafik til Horns Rev 1. Det antages ikke at ruten skal omlægges.
C3-1	Drivende skib kolliderer med vindmølle	- Ruten ligger forholdsvis langt væk fra HR3 og derfor kan beredskabsmanøvre højst sandsynlig igangsættes i tide.		Drivninger vil snarere ende med grundstødning end møllekollision	Større kommercielle fartøjer og offshore skibe går herfra op gennem Slugen
C3-2	Kollision mellem skibe som følge af trafikom-lægning				
C3-3	Risiko for grundstødning			- Større drivende skibe vil højst sandsynlig gå på grund	
C4-1	Drivende skib kolliderer med vindmølle			Et drivende skib kan lige så vel ramme HR2	
C4-2	Kollision mellem skibe som følge af trafikom-lægning				
C4-3	Risiko for grundstødning				
D1-1	Drivende skib kolliderer med vindmølle	- Strøm er ikke problematisk i nord-syd retning men vestenvinden kan være problematisk.	Årlig passage vurderes til ca. 5000 skibe.		Er en del af hovedruten mod nord som samles ved Skagen. Samme forhold er gældende som for Horns Rev 2. Der er observeret 4500 bevægelser i 2006.
D1-2	Kollision mellem skibe som følge af trafikom-lægning				Trafikken forventes ikke at skulle omledes da afstanden til møllepar-ken er stor.

Generelle kommentarer

- Vindmøller er ikke designet til kollision, hvilket vil sige at alle kollisioner bortset fra meget små skibe med lav hastighed kan betragtes som uønskede.

- Generelt har Søfartsstyrelsen ikke fået nogen indberetninger om vindmøllekollisioner i Danmark.

- Generelt vil Søfartsstyrelsen kræve en passageafstand til møllerne på 3-4 sømil (til hovedskibsruter).

- Søfartsstyrelsen ønsker ikke møllerne opstillet gennemgående fra øst til vest uden gennemsejlingskorridor.

- Forsvaret holder fast i, at det er en væsentlig påvirkning af militærets aktiviteter hvis parken lægges her. Der varsles en måned før der skydes inden for skydeområderne og skydeaktiviteterne indberettes til Søfartsstyrelsen. Der skydes 6-36 gange om året over en 6-årig periode.

- Farvandet er ikke VTS-overvåget

- Søværnet oplyser om, at søkortet har været forkert således at mølleparken kolliderer med skydeområdet. Fikspunkt og afstand fra fikspunkt må have været forkert. I tilfælde af at mølleparken kommer til at kollidere med skydeområdet, skal Forsvaret flytte øvelsesområdet til Canada. Der skydes i dag inden for en radius på 25 km målt fra Oksbøl Skydeterræn. Det officielle søkort og definitionen af projektområdet er derimod baseret på en radius på 20 km. Denne uoverensstemmelse løses på overordnet plan (dvs. ikke som del af sejladsrisikoanalysen). Den konkrete løsning, der måtte blive fundet, vil dog potentielt påvirke sejladsrisikoanalysen.

- Vindmølleparkens tilstedeværelse kan føre til nødankringsmanøvrer af drivende skibe. Derfor øges risikoen for, at gasledningen (løber langs projektområdets nordlige grænse) eller ilandføringskablet fra Horns Rev 2 (løber langs projektområdets sydlige grænse) beskadiges af et anker.

Generelle risikoreducerende tiltag kan være:

- Beredskabsplaner: Operatøren har deres egen beredskabsplan der dog kun omfatter egen bemanding. Hvis denne ikke slår til vil SOK træde til med det formål at redde menneskeliv og ikke materiel. Beredskabsplan for koncessionshaver skal godkendes af ENS.

- Nødstop af møller: Møllerne kan nødstoppes ved kollision så risiko og konsekvens kan reduceres. Det er ikke omkostningsfuldt at stoppe møllen i forhold til produktionen, men det kan tage år af møllens levetid.

- Alarm og AIS: Alarmer og AIS kan sættes op, men vil ikke tage alle skibe. Kun skibe over 300 GT er forpligtet til at anvende AIS (internationalt krav).

A.5 Fareidentifikationsprotokol vedr. sejladsforhold i anlægsfasen

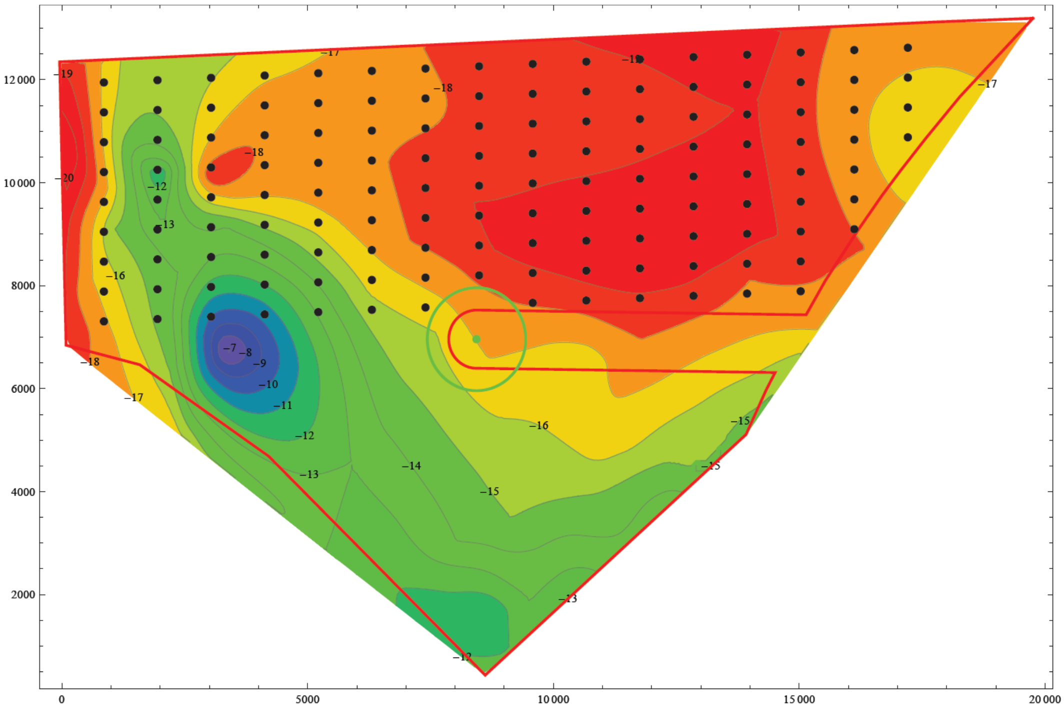
Beskrivelse af uheld	**Sikkerhedsforanstaltninger**	**Hyppighed**	**Konsekvens**	**Kommentar**
Tredjepartsskib påsejler konstruktioner og byggefartøjer i byggeområdet	- Afviserfartøj - 24 timers overvågning under byggefasen. - Radar sættes på monopiles. - Byggefartøjer sejler ikke under dårlige vejrforhold. - God ide at etablere området i god tid så skibene vender sig til området. Men heller ikke for tidligt så de vender sig til der ikke sker noget og bare sejler igennem. Find passende niveau for etablering. - Gennemsejlingskorridoren vil blive afmærket. Hvis et kabellægningsskib skal krydse korridoren er særlige fartøjer tilstede og særlige restriktioner. Der kan lukkes i nogle timer.			- Mange fundamenter og fartøjer som er svære at se. Monopæle kan rage 1,5 m over vandoverfladen, er rustrød og kan ikke ses. Flere hindringer man kan ramme. Ellers samme mulighed for drivende skibe osv. som i driftsfasen. - Lige som i driftsfasen vil der aldrig lukkes for den øvrige trafik i hele byggeområdet, dvs. der vil altid være en gennemsejlingskorridor.

	Ankringsforbud på 200 m på hvert side af kablet.			
Tredjepartsskib eller byggefartøj driver ind i byggeområdet	- Skibe kan hjælpe og beredskabskæden kan hurtigt sættes i gang. Slæbebåde, dykkerskibe og crewboats til stede. Kun til stede ved godt vejr. Ellers er der ingen til stede. - Jack-up- fartøjer vil søge ly i havn under dårlige vejrforhold.			- Nye generationer af jack-up-fartøjer vil primært være drevet af vind, pga. a stor overbygning/dæksfaciliteter.
Byggefartøj og tredjepartsskib kolliderer uden for byggeområdet				Tunge fartøjer lastes både i Hvide Sande og Esbjerg.
Byggefartøjer kolliderer indbyrdes	- Byggefartøjer sejler ikke under dårlige vejrforhold.			
Byggefartøj rammer møllefundamenter, møller og andet udstyr	- Byggefartøjer sejler ikke under dårlige vejrforhold. Sejlafstanden er så kort så man venter hvis vejret er dårligt og til gode vejrmeldinger. - Skibe i problemer kan hjælpes af andre skibe – risikoreducerende.		- Specielt avorligt, når der drejer sig om større byggefartøjer. - Mindre byggefartøjer: Er i mindre omfang til fare for byggepladsen.	

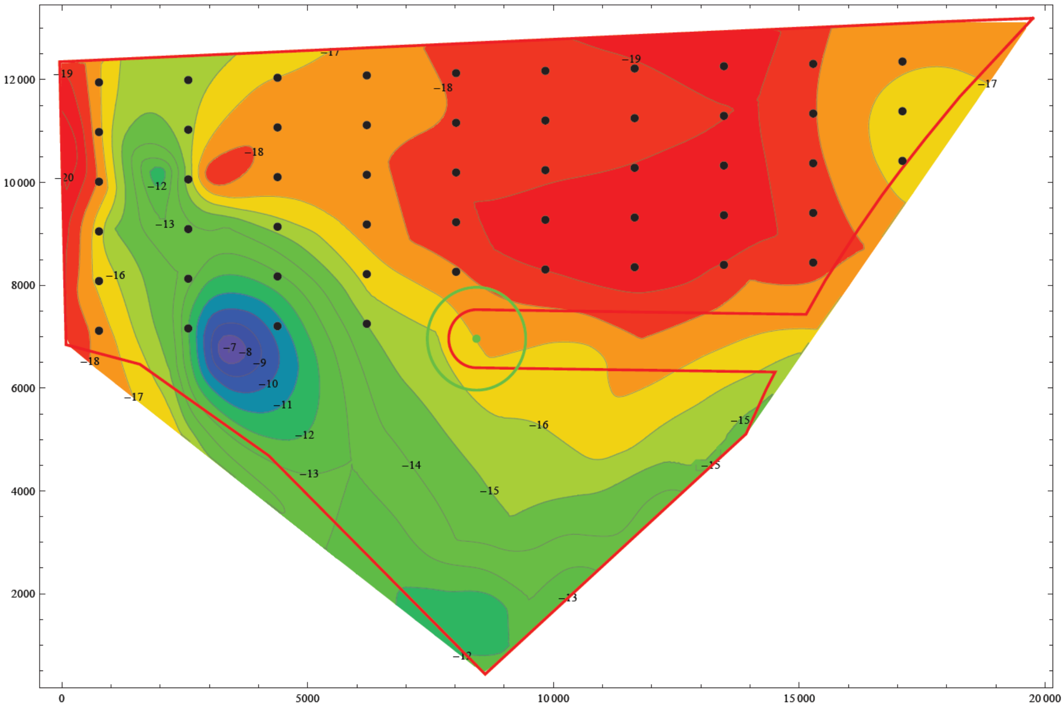
APPENDIX B: IDENTIFICATION OF THE WORST-CASE WIND FARM LAYOUT

B.1 Suggested wind farm layouts

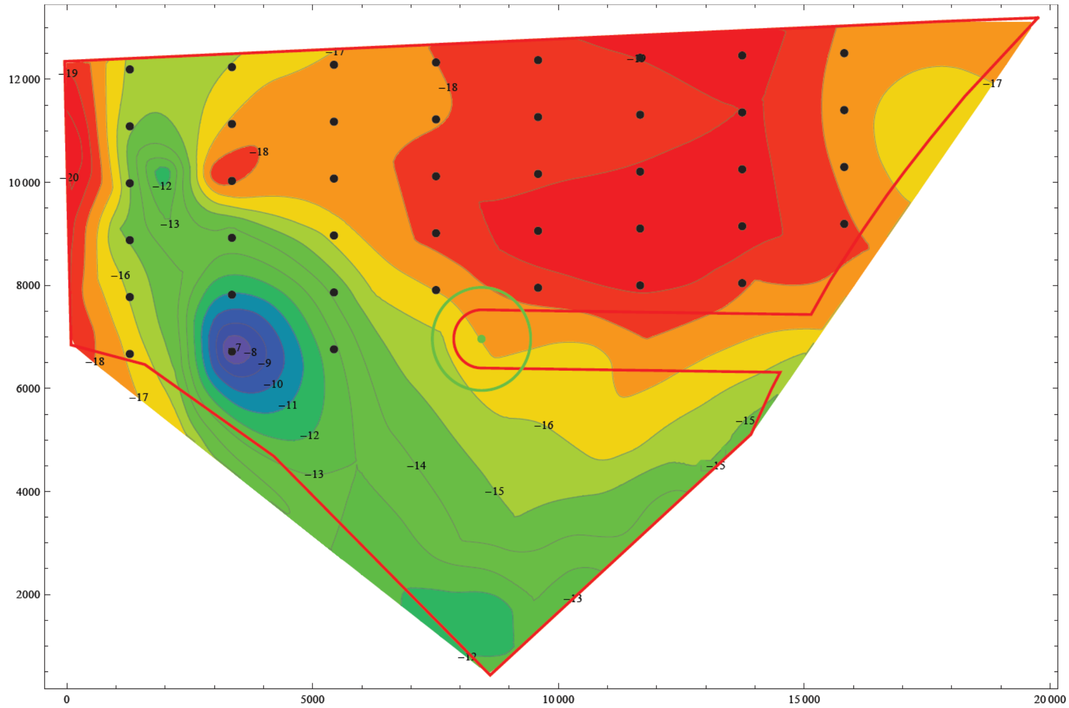
Scenario A – 3 MW



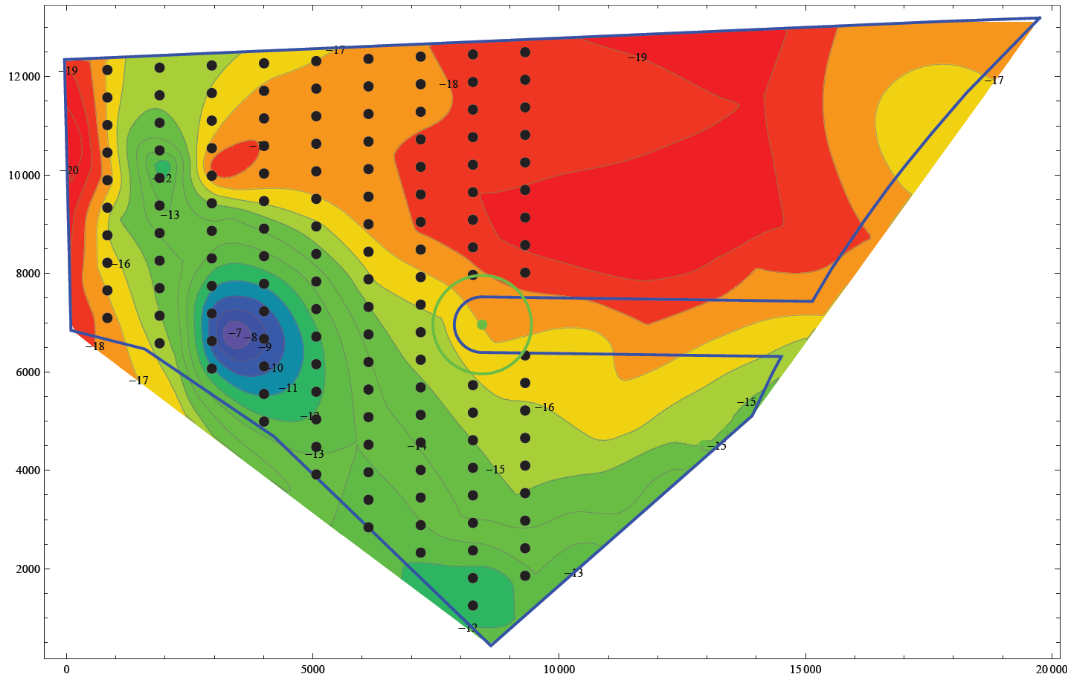
Scenario A – 8 MW



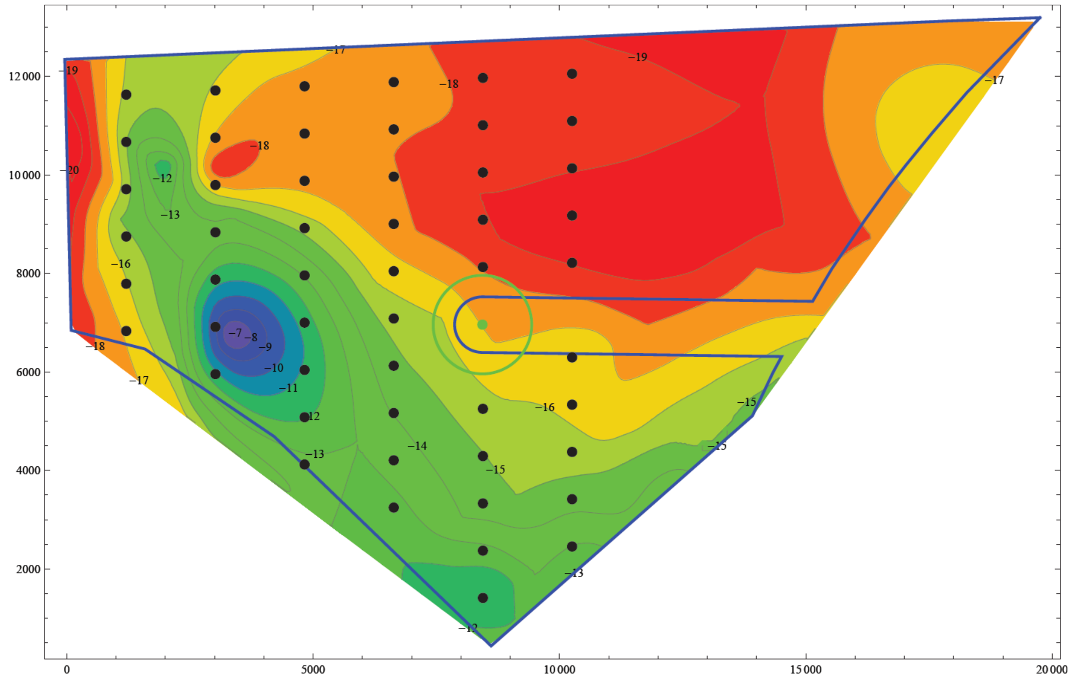
Scenario A – 10 MW



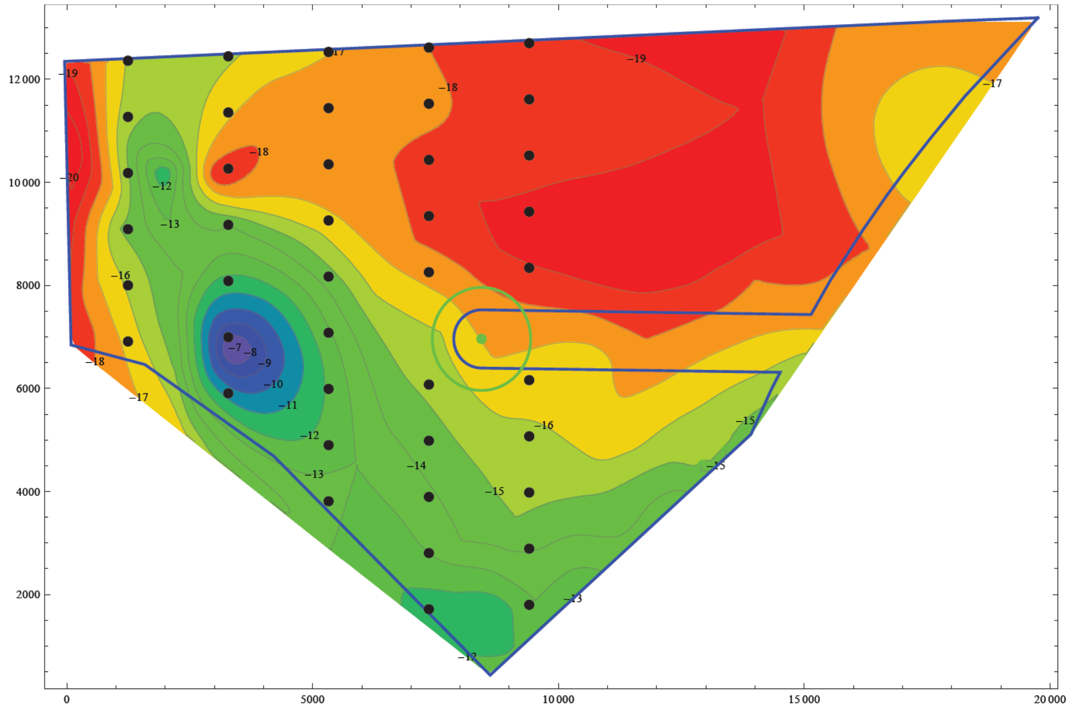
Scenario B – 3 MW



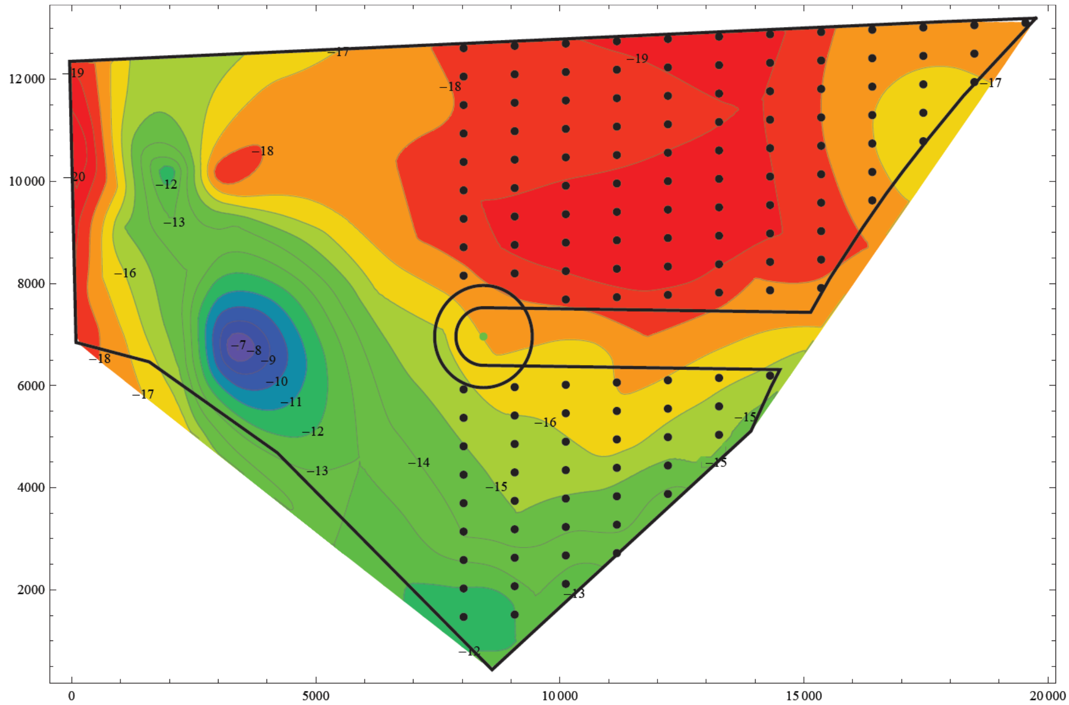
Scenario B – 8 MW



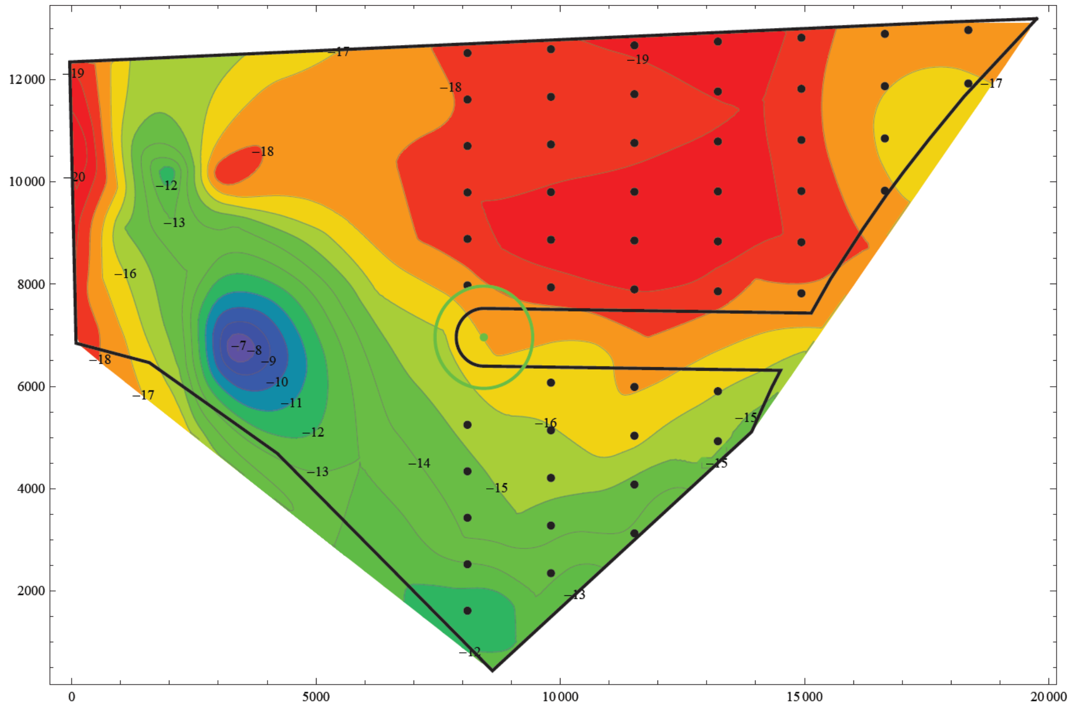
Scenario B – 10 MW



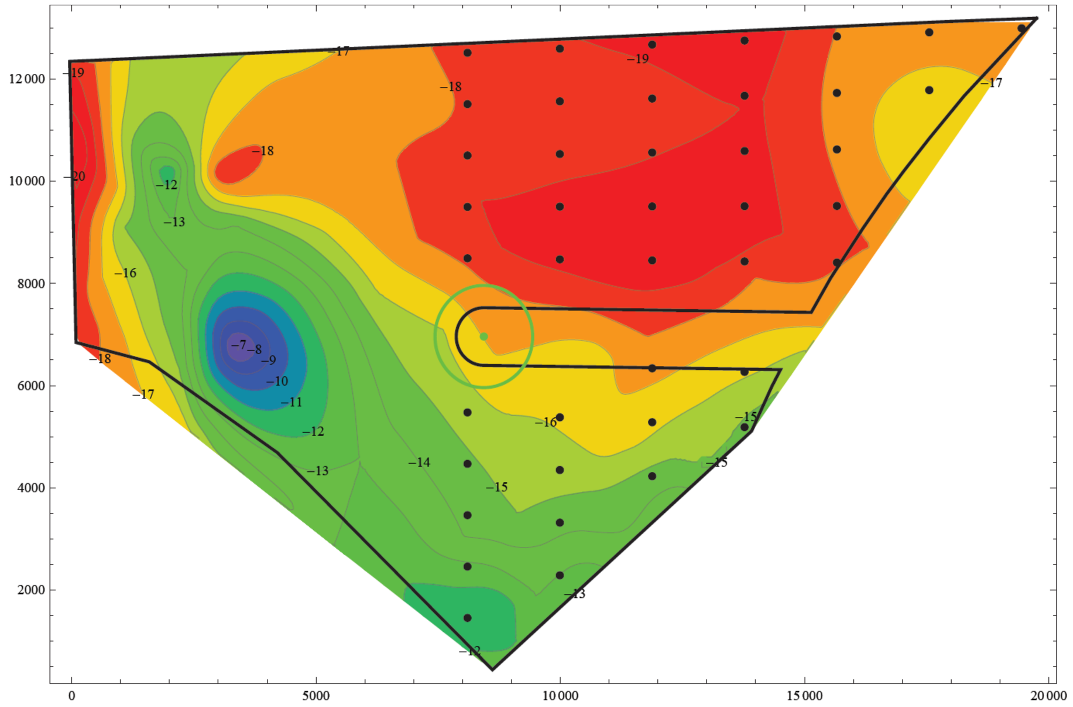
Scenario E – 3 MW



Scenario E – 8 MW



Scenario E – 10 MW



Further discription of the layouts can be found in /Energinet2, 2013/

B.2 Selection of the worst-case layout from a navigational safety point of view

General considerations about the selection of the worst case scenario:

- The 3 MW-turbines are more problematic than the larger 8 and 10 MW-turbines; because more turbines will be located within a predetermined area and on this basis cause a (slightly) higher probability of collisions. Therefore only the 3 MW-turbines are considered in the worst-case-considerations.
- Scenario A is going to be situated close to both the main traffic on the west side of the reef and on the traffic to/from Slugen.
- Scenario B is located as close to the main traffic as scenario A, but is further away from the traffic to/from Slugen. The area that is only present in B (area towards Horns Rev 2) is only slightly exposed to drifting ships coming from west. The reef and Horns Rev 2 will to some extent shield. No ships currently sail close to the area mentioned.
- For both scenario A and B vessels going south from Hvide Sande is forced to plan a new route further north than presently. It can be expected that they will sail as far north as necessary, i.e. as close to the turbines as possible
- Scenario E forces the traffic from Slugen to sail vest of the turbines. It can be expected that they will sail as close to the turbines as possible. On the other hand scenario E is furthest away from the main traffic. Ships from Hvide Sande, that needs to go around the reef does not come close to the turbines either. Towards east the turbines will come close to the coastal traffic, but due to the predominant westerly winds this will hardly influence the collision frequency.

Summarising the findings, it is seen that scenario A and B are most problematic. Scenario A is chosen as the worst case scenario due to the fact that is closer to the route to/from Slugen. On the other hand the marginally increased contribution from the main route (west of the reef) present at scenario B is not problematic to the same degree.

Conclusion: Worst case Scenario A with 3 MW-turbines, see section B1 for a layout of the wind farm. The 3 MW-turbines have an outer diameter of up to 6.0m and a hub hight abouve MSL of 79m.

The offshore substation platform will consist of a foundation structure and topside. The dimensions of the platform's foundations are expected to be 24m long and 20m wide, with a height of app. 13m above sea level. It is expected that the topside will have length of 40m, a width of 30m and a height of 30 – 35m above sea level. The lower deck (cable deck) is expected at a level of 13 m above sea level.