Netherlands Enterprise Agency

Site Studies Wind Farm Zone Borssele

Unexploded Ordnance (UXO) desk study

>> *Sustainable. Agricultural. Innovative. International.*

Author REASeuro

Offshore wind energy Netherlands

Site Data Borssele wind farm zone

Unexploded Ordnance (UXO) - Desk Study
REASeuro

Site data Borssele wind farm zone

Unexploded Ordnance (UXO) – Desk Study
REASeuro

Project number	: 71992
Location	: North Sea, the Netherlands
Order	: UXO – Desk Study
Client	: The Netherlands Enterprise Agency
Place and date	: Riel, 9th December 2014
Label	: 20141209_SDB_REASeuro_UXO-desk study_EvdBerg_V03_D
Author	: Mr. E. van den Berg BSc., Senior advisor
Checked by	: Mr. J. Bakker BSc., Project manager International Projects
Approved by	: Mr. A.P.A.M. van Riel, CEO

REASeuro	**Rijksdienst voor Ondernemend Nederland**
…	…
J. Bakker, BSc Project manager International Projects	H.B. van Eck Team manager

Illustration front page: Horns Rev wind farm (Denmark). Source: www.innwind.nl

Table of Contents

Page

Summary

The Ministry of Economic Affairs has requested The Netherlands Enterprise Agency to prepare and collect all required site data required for the selection of an appropriate site within the Borssele wind farm zone. In this context The Netherlands Enterprise Agency has commissioned this UXO Desk study. The UXO desk study consists of a historical research and a UXO risk assessment.

Historical research
The Borssele wind farm zone and its surrounding areas were the scene of many war related activities in World War I and World War II. Due to the following facts the entire Borssele wind farm zone is to be considered a UXO risk area:

- In both world wars a large number of naval mines were deployed in the North Sea. In World War II a total of six known minefields were (partially) located within the Borssele wind farm zone. The presence of mines, due to secret offensive mine laying operations can't be ruled out. Of the mines that were laid in WWII, only around 15 - 30% were countermined after the war, there are no records for minesweeping following WWI, so recovery is likely to have been even lower [27].
- The Borssele wind farm zone is located in the main flight path of Allied bomber raids. As a consequence a large number of aircrafts are crashed in the North Sea and many bombs were dropped in the North Sea.
- Since April 2005 25 UXO [20] were reported by fisherman within the Borssele wind farm zone.
- The seabed is very dynamic by nature, due to strong tidal streams and the movement of sand banks. For this reason UXO can be moved from their original position.
- In the post war period the seabed was intensively used. Due to intensive fishing (trawling) UXO were moved. Until 2005 most of the UXO that were encountered in fishing nets were simply put overboard, often in the direct vicinity of known shipwrecks. These locations were normally avoided because of the risk of damaging the fishing nets, thus offering a gathering place of remnants of war.

Based upon the described source material the following UXO are likely to be encountered:

- Naval mines;
- Bombs;
- Depth charges;
- Naval mine destruction charges;
- Torpedoes;
- Grenades.

UXO risk assessment
The UXO likely to be encountered can be sensitive to hard jolts, change in water pressure, and acceleration with an amplitude > 1 m/s^2. Within the Borssele wind farm zone several intrusive activities will be conducted. These activities may cause a UXO to detonate. Because of the often large calibre UXO a detonation will have a devastating effect on nearby vessels, equipment, foundations, crew members and surroundings. A detonation forms an intolerable risk.

The possible presence of UXO in the area, however, is no constraint for offshore wind farm related activities. With proper UXO Risk Management the risks can be reduced to a level that is as low as is reasonably practicable (ALARP).

The duty in health and safety law is to eliminate the risk if possible or reduce it to a level that is ALARP. The level of ALARP can only be determined during the design and engineering phase of the wind farm development.

Recommendations
To manage UXO related risks recommendations are given for the preparation phase, execution phase and the operational phase of the wind farm development.

Preparation phase

- A geophysical (bathymetric) survey is recommended in preparation for a dedicated UXO survey, consisting of at least a high resolution multibeam and side scan sonar. The multibeam generates high quality and high resolution data of the seabed. This data will be used for morphologic research and assessment of the movement of sand dunes. The side scan sonar must be able to identify objects > 1m. The generated data is used to identify objects, debris, debris fields and wrecks. Optional the additional conduction of sub bottom profiler can be considered.
- It's recommended to provide this UXO-Desk Study to the contractor of the geophysical survey.
- An awareness training (or kick-off meeting) before conducting the geophysical survey is recommended.
  It is recommended to conduct an intrusive and/or non-intrusive survey (depending on the local conditions) at each CPT/bore hole and sample location.
- It's recommended to train and certify the key personnel managing the geotechnical investigations to the level "Basic OCE".
- During the metocean measurements potential UXO risks occur. To constrain this risks an awareness training (or kick-off meeting) before conducting the measurements is to be recommended.
- As regards the Met mast installation, intrusive activities will be conducted. Before installation, the area effected by the intrusive activities has to be cleared from UXO. The clearance operations have to be conducted by a certified EOD-company.
- It is highly important to assess the mobility of sand waves (banks and ridges) by comparing current bathymetry results with historic data. Thereafter the effects of the mobility of sand waves on the burial depth of UXO need to be determined.
- There is a possibility wrecks need to be removed in order to construct the wind farm. From most wrecks, wreck remains and foul areas specific information lacks. It is recommended to investigate the known wrecks to gather additional information.

Execution phase

- It is recommended to reassess the UXO related risks based on the first draft of the design for the wind farm. Possibly adaptations in the design can be made to mitigate a part of the risks. For the remaining (intolerable) risks a detailed UXO risk mitigation strategy needs be worked out. The required risk mitigation actions will include search and safe removal of UXO within a further to assess part of the wind farm zone. The size of the survey area will be determined in the detailed UXO mitigation strategy.
- Prior to the search operations a detailed dedicated UXO survey has to be developed. The information gathered during the geophysical survey is to be used as input for the survey plan.
- Because the validity of the collected data (geophysical survey) is limited in time, it's recommended to minimize the time lapse between the survey and the actual installation works.
- The UXO survey plan needs to address the following subjects:
  - the elevation differences of the seabed;
  - the maximal burial depth of UXO;
  - the types and calibres of UXO (e.g. German GC naval mines, with limited ferromagnetic materials);

- locations of wrecks and wreck remains;
- elements and objects disruptive to the UXO survey data such as cables and pipelines.
- Etc.

- It is recommended to conduct the UXO search and removal operations at short notice prior to the construction activities. The validity of the collected magnetometer survey data in regards to tidal streams, mobility of sand waves and seabed usage has to be taken into account when planning the survey and construction operations. Time lapse between project phases has to be limited as much as possible.

Operational phase

- Because of tidal streams, mobility of sand waves and seabed usage the possibility that UXO are moved within the wind farm zone after completion of the construction activities has to be taken in to account.
- It is recommended to write a maintenance and monitoring plan. This plan needs to provide safe working protocols for future maintenance operations and a monitoring strategy. To constrain this risks an awareness training (or kick-off meeting) before conducting maintenance operations is also recommended.

Samenvatting

Het Ministerie van Economische Zaken wil partijen concessies geven voor het bouwen van windparken op vooraf aangewezen locaties. Selectie gaat via een tenderprocedure. De Rijksdienst voor Ondernemend Nederland gaat ten behoeve van de tenderprocedure de fysieke omstandigheden zoals gesteldheid van de bodem, golven, stroming, aanwezigheid van Niet Gesprongen Explosieven (NGE of UXO in het Engels), etc. in kaart brengen. In dit kader heeft de Rijksdienst voor Ondernemend Nederland voorliggende bureaustudie naar NGE opgedragen. Deze bureaustudie bestaat uit een historisch vooronderzoek en een risicoanalyse.

Historisch vooronderzoek
Het windgebied Borssele en het omliggende gebied waren het toneel van vele oorlog gerelateerde gebeurtenissen gedurende zowel de Eerste als de Tweede Wereldoorlog. Ten gevolge van de volgende feiten moet het volledige windgebied als NGE-risicogebied worden aangemerkt:

- In beide wereldoorlogen werden grote hoeveelheden zeemijnen ingezet in de Noordzee. In windgebied Borssele waren zes bekende mijnenvelden (WOII) aanwezig. De aanwezigheid van zeemijnen in de overige delen van het windgebied kan, ten gevolge van het in het geheim leggen van offensieve mijnenvelden niet worden uitgesloten. Van alle mijnen die tijdens de Tweede Wereldoorlog werden gelegd is slechts 15% tot 30% geruimd [27]. Er zijn geen gegevens van het ruimen van mijnen na de Eerste Wereldoorlog. Waarschijnlijk was het percentage geruimde mijnen na de Eerste Wereldoorlog nog geringer.
- Het windgebied Borssele ligt binnen de belangrijkste vluchtroutes van geallieerde bommenwerpers. Ten gevolge hiervan zijn een groot aantal vliegtuigen neergestort in de Noordzee en zijn grote hoeveelheden bommen afgeworpen in de Noordzee
- Sinds april 2005 zijn door vissers bij de kustwacht 25 NGE aangemeld binnen het windgebied Borssele.
- De zeebodem is erg dynamisch ten gevolge van getijdestromingen en de beweging van zand duinen. Hierdoor kunnen NGE zijn verplaatst, waardoor ze niet meer op hun oorspronkelijke positie liggen.
- In de periode na de oorlog is de zeebodem intensief gebruikt. Ten gevolge van intensieve visserij zijn NGE verplaatst. Tot 2005 werden de meeste NGE na aantreffen weer terug in zee geworpen. Dit gebeurde vaak in de buurt van bekende scheepswrakken. Deze locaties werden veelal vermeden om schade aan de netten te voorkomen en vormden zodanig vaak een verzamelplaats voor NGE.

Op basis van het aangetroffen bronnenmateriaal kunnen de volgende soorten NGE in het windgebied Borssele zijn terechtgekomen en achtergebleven:

- Zeemijnen;
- Vliegtuigbommen;
- Dieptebommen;
- Mijn vernietigingsladingen;
- Torpedo’s;
- Granaten.

Risico analyse
De NGE die mogelijk zijn achtergebleven in het windgebied Borssele zijn gevoelig voor toucheren, bewegen, veranderingen in waterdruk en versnellingen groter dan 1 m/s^2. Binnen het windgebied Borssele worden diverse grondroerende activiteiten uitgevoerd. Deze activiteiten kunnen een detonatie van een aanwezig NGE veroorzaken. Vanwege het vaak grote kaliber van de te verwachten NGE heeft een detonatie een vernietigende werking op vaartuigen, materieel, funderingen, personeel en de omgeving. Een detonatie vormt daarom een niet toelaatbaar risico.

De mogelijke aanwezigheid van NGE in het windgebied vormt echter geen belemmering voor de realisatie van het windgebied. Met goed NGE-risicomanagement kan het risiconiveau tot een aanvaardbaar niveau worden teruggebracht.

De wetgeving op het gebied van veiligheid en gezondheid schrijft voor dat de risico's zo veel mogelijk gereduceerd moeten worden. Het aanvaardbare risiconiveau kan echter pas worden vastgesteld tijdens de ontwerpfase van het windgebied.

Aanbevelingen
Ten einde de NGE gerelateerde risico's te beheersen, zijn aanbevelingen gegeven voor de voorbereidende fase, de uitvoeringsfase en de exploitatiefase van het windgebied.

<u>Voorbereidende fase</u>

- Aanbevolen wordt een uitgebreid geofysisch (bathymetrisch) onderzoek uit te voeren ter voorbereiding op een specifiek op NGE gerichte detectie. Dit geofysisch onderzoek dient ten minste te bestaan uit hoge resolutie multimeam en side scan sonar metingen. De multibeam metingen dienen te resulteren in een hoge kwaliteit data met een hoge resolutie. Deze data worden gebruikt voor het morfologisch onderzoek en de beoordeling van de verplaatsing van zandduinen. Met side scan sonar worden objecten met een grootte van meer dan 1 m geïdentificeerd, teneinde de aanwezigheid van objecten, vervuilde gebieden en wrakken vast te stellen.
- Aanbevolen wordt dit rapport ter beschikking te stellen aan het bedrijf dat het geofysisch onderzoek gaat uitvoeren.
- Aanbevolen wordt het personeel dat het geofysisch onderzoek gaat uitvoeren een bewustwordingstraining te laten volgen.
- Het geotechnisch onderzoek dient door een gecertificeerd opsporingsbedrijf te worden begeleid. De locaties van grondroerende werkzaamheden dienen voorafgaand aan het geotechnisch onderzoek te worden vrijgegeven.
- Geadviseerd wordt het personeel dat betrokken is bij het geotechnisch onderzoek op te leiden en te certificeren op het niveau "Bastiskennis OCE".
- Tijdens de weerkundige en oceanografische onderzoeken kunnen zich NGE-gerelateerde risico's voordoen. Om deze risico's te beheersen wordt een bewustwordingstraining voor het betrokken personeel aanbevolen.
- Met betrekking tot de installatie van de Met mast vinden grondroerende werkzaamheden plaats. De locaties van de grondroerende activiteiten dienen voorafgaand aan het plaatsen van de mast door een gecertificeerd opsporingsbedrijf te worden onderzocht en vrijgegeven.
- Het is van groot belang om de mobiliteit van de zandduinen in het windgebied vast te stellen. Vervolgens dient het effect van de beweging van de zandduinen op de diepteligging (verzanding) van de te verwachten NGE te worden vastgesteld.
- Er is een kans dat de aanwezige wrakken worden verwijderd om realisatie van het windgebied mogelijk te maken. Van de meeste wrakken, restanten van wrakken en verontreinigde gebieden ontbreekt specifieke informatie. Geadviseerd wordt de bekende wraklocaties nader te onderzoeken.

<u>Uitvoeringsfase</u>

- Aanbevolen wordt de NGE-risicoanalyse te herijken op basis van het ontwerp van het windgebied. Mogelijk kunnen aanpassingen in het ontwerp worden doorgevoerd om een deel van de risico's te mitigeren. Voor de overige risico's dient een gedetailleerde risicoanalyse te worden uitgevoerd. Op basis hiervan dient een NGE onderzoeksstrategie te worden ontwikkeld. Rekening moet worden gehouden met het opsporen en ruimen van NGE in een nader te bepalen deel van het windgebied. De omvang van het te onderzoeken gebeid wordt vastgesteld in de gedetailleerde risicoanalyse gebaseerd op het ontwerp.

- Voorafgaand aan de opsporing dient een maatwerk detectieplan te worden opgesteld. Dit plan dient mede te worden gebaseerd op het uitgevoerde geofysisch onderzoek.
- Het detectieplan dient in te gaan op de volgende onderwerpen:
  - Hoogteverschillen van de zeebodem in het windgebied;
  - De maximale penetratiediepte van de te verwachten NGE;
  - De types en kalibers van de te verwachten NGE (bijvoorbeeld de Duitse GC mijn die een beperkte hoeveelheid ferro-houdend materiaal bevat);
  - De locaties van wrakken en restanten van wrakken;
  - Detectie verstorende objecten in het windgebied, zoals kabels en leidingen.
  - Etc.
- Aanbevolen wordt de opsporing en ruiming van NGE zo kort mogelijk voorafgaand aan de constructiewerkzaamheden te plannen. De houdbaarheid van de detectiedata is ten gevolge van de getijdestromingen, de beweging van zand duinen en het gebruik van de zeebodem beperkt. De verschillende projectfasen dienen derhalve aaneensluitend te worden gepland en uitgevoerd.

Exploitatiefase

- Vanwege getijdestromingen, de mobiliteit van zandduinen en het gebruik van de zeebodem bestaat de mogelijkheid dat NGE worden verplaatst tot in het windgebied nadat het windgebied is gerealiseerd. Bij het uitvoeren van onderhoudswerkzaamheden moet met dit risico rekening worden gehouden.
- Aanbevolen wordt een onderhouds- en monitoringsplan te schrijven. In dit plan moeten veilige werkprotocollen voor de toekomstige onderhoudswerkzaamheden worden vastgelegd. Tevens wordt geadviseerd een bewustwordingstraining te verzorgen voor personeel dat betrokken is bij het uitvoeren van onderhoudswerkzaamheden.

1. INTRODUCTION

The Ministry of Economic Affairs has requested 'The Netherlands Enterprise Agency to prepare and collect all site data required for the development of offshore wind farms in Borssele offshore wind farm zone'. In this context The Netherlands Enterprise Agency has commissioned this UXO Desk study. In this chapter a general introduction on offshore wind energy is given. Subsequently the area of research for this UXO-Desk Study and the purpose and main objectives are set.

1.1. GENERAL INTRODUCTION TO THE OFFSHORE WIND ENERGY IN THE NETHERLANDS

This paragraph provides a general introduction to the offshore wind energy in the Netherlands.

1.1.1. Offshore wind farms in the Netherlands

The first two wind farms that were built in the Dutch part of the North Sea are the offshore Wind Farm Egmond aan Zee and the Princess Amalia Wind Farm.
Wind Farm Luchterduinen is currently (2014) under construction and the wind farms Buitengaats and Zee-Energie (the so-called Gemini wind farms) are expected to be built in 2015-2016. These wind farms have a total capacity of some 1,000 MW.

1.1.2. The Energy Agreement for Sustainable Growth

In the Energy Agreement for Sustainable Growth (Energieakkoord voor duurzame groei), more than forty organizations have laid the basis for a robust, future-proof energy and climate policy for the Netherlands, enjoying broad support.

An important part of this agreement is scaling up offshore wind power to 4,450 MW, operational in 2023. In addition to this, a total of 3,450 MW will be contracted for by means of phased tender procedures commencing in 2015.

1.1.3. Wind farm zones

In the Netherlands, the spatial planning of the North Sea has been laid down in the "National Water plan" (Nationaal waterplan). This plan provides a description of the current use of the Netherlands part of the North Sea and the vision on future utilization of the North Sea in the Dutch sector. In the National Water plan the following wind farm zones have been designated (see Figure 1):

- Borssele;
- Hollandse Kust;
- IJmuiden ver;
- Ten Noorden van de Waddeneilanden.

Only within these wind farm zones developments can take place.

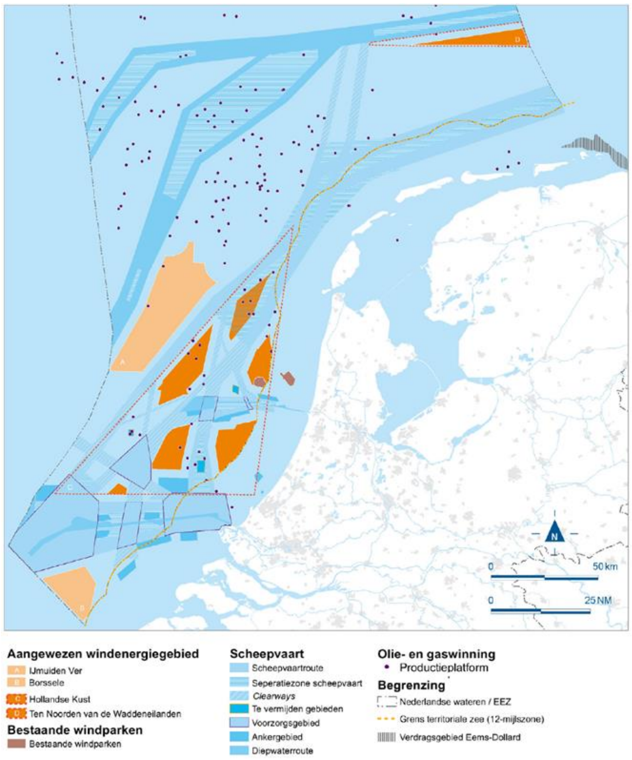


Figure 1: Designated wind farm zones at the Dutch continental shelf

1.1.4. Wind farm sites

In the new offshore Wind energy bill (Wet windenergie op zee), which is expected to enter into force in Q3 2015, the legislative framework for the development of offshore wind farms in the Netherlands will be changed. By then new wind farms are only allowed to be constructed at sites within one of the wind farm zones.

The Ministries of Economic Affairs and of Infrastructure and Environment will take the Wind farm site decisions (kavelbesluiten). A wind farm site decision includes the contours of the site and the conditions under which wind farms can be constructed and operated. A wind farm site decision is subject to an Environmental Impact Assessment (EIA).

For the deployment of new offshore wind farms until 2023, the Dutch government has decided to select developers according to the schedule shown in Table 1.

Tendering		Wind farm zone
Year	Capacity	
2015	700 MW	Borssele
2016	700 MW	Borssele
2017	700 MW	South Holland coast wind farm zone
2018	700 MW	South Holland coast wind farm zone
2019	700 MW	North Holland coast wind farm zone

Table 1: Schedule for tendering wind farms

1.1.5. Selection of developers

Developers who can build and operate wind farms on the sites will be selected by tender procedures in which respectively the grant and the permit for constructing and operating a wind farm can be awarded. To facilitate developers in competitive bids for the tenders, site data on the wind, water and soil conditions will be made available.

1.1.6. Site data

The Netherlands Enterprise Agency makes site data available. This site data includes:

- Geological, morphodynamical and geomorphological data;
- Archaeological and UXO analysis;
- Metocean data;
- Geophysical and geotechnical data (based on surveys).

The investigations for this data will also be used for the EIA. Investigations relevant for the design basis will be certified according to DNV-OS-J101 or equal.

1.2. Area of research

The Borssele wind farm zone is located at the southern part of the Dutch sector, just outside the 12 nautical mile zone, neighbouring the Belgian Border. In Figure 2 the Borssele wind farm zone and surrounding areas are shown.

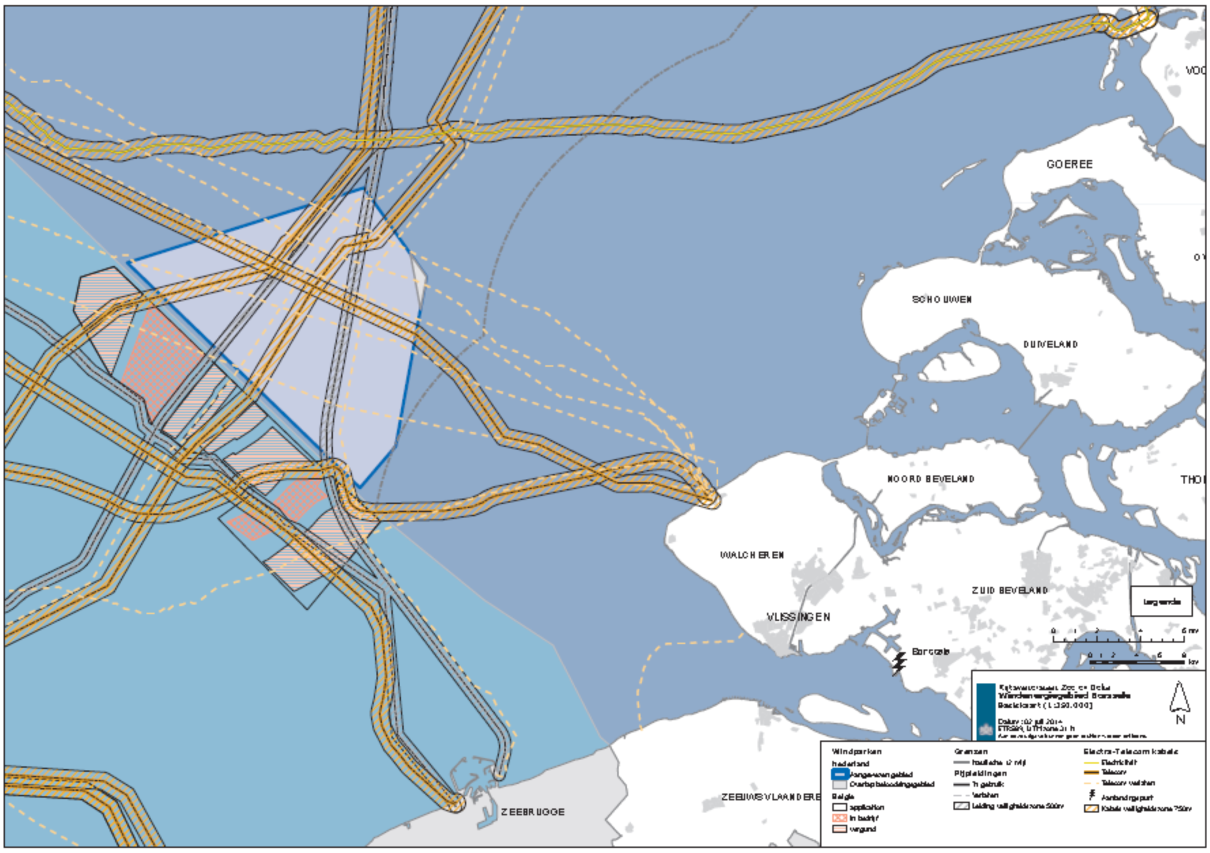


Figure 2: The Borssele wind farm zone and surrounding areas

The Borssele wind farm zone is shown in Figure 3. Within the wind farm zone, 4 wind farm sites have been defined. It is foreseen that at each wind farm site an offshore wind farm of approximately 350 MW will be developed. Concessions to develop the wind farm sites will be tendered together with a permit and grant through a tender which is currently under preparation by the Ministry of Economic affairs.

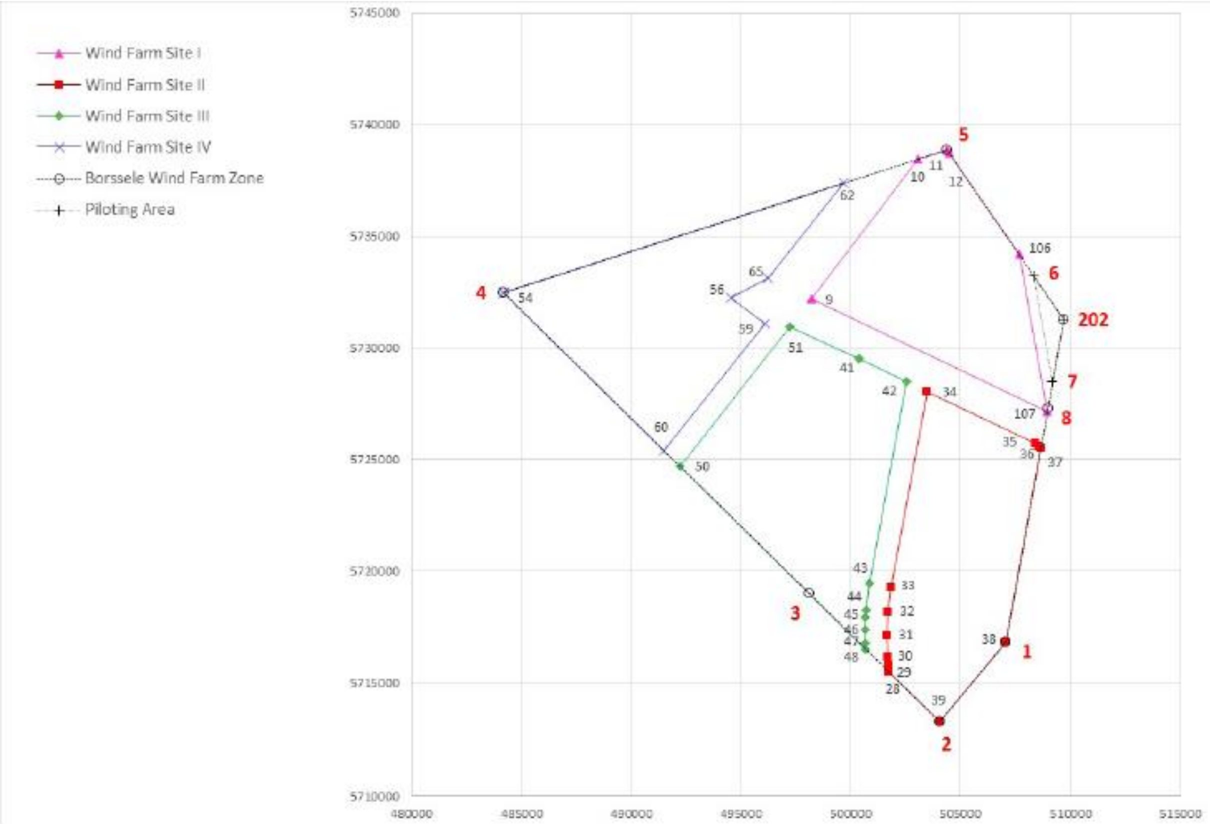


Figure 3: Overview of the Borssele wind farm zone and wind farm sites

The coordinates of the positions that demarcate the boundary of the Borssele wind farm zone are shown in Table 2. The numbers shown in the first column of Table 2 correspond to the numbers with the red colour.

PointNr	Geographical coordinates (ETRS89)		UTM (ETRS89, zone 31)	
	Degrees N	Degrees E	Easting	Northing
1	51,60230	3,10233	507087,05	5716811,66
2	51,57027	3,05828	504039,56	5713246,09
3	51,62197	2,97263	498105,40	5718993,72
4	51,74303	2,77085	484178,55	5732482,80
5	51,80073	3,06343	504373,70	5738878,38
6	51,74985	3,12080	508338,99	5733222,40
7	51,70735	3,13312	509197,84	5728498,93
8	51,69642	3,12985	508974,49	5727282,45
202	51,73228	3,14055	509706,86	5731271,30

Table 2: Coordinates of the Borssele wind farm zone

The area of research for this study also includes an additionally area of several kilometres around specified Borssele wind farm zone.

1.3. PURPOSE AND MAIN OBJECTIVES

The purpose of the UXO desk study is to get insight in the areas in the Borssele wind farm zone with an increased risk of encountering unexploded ordnances (UXO's).

The main objectives of this study are:

1. Identify constraints for offshore wind farm related activities in the Borssele wind farm zone as a result of the presence of UXO's.
2. Identify areas within the Borssele wind farm zone that should preferably not be used for the installation of offshore wind farms and/or cables.
3. Identify requirements from UXO perspective that should be taken into account for:
   a. Determining the different concession zones in the wind farm zone.
   b. Carrying out safe geophysical & geotechnical investigations.
   c. Safe installation of wind turbine foundations.
   d. Safe installation of cables.

1.4. STRUCTURE OF THE REPORT AND TOPICS ADDRESSED IN EACH CHAPTER

This report describes the first two phases of the UXO risk management process. The UXO risk management process is shown in Figure 4 (see Figure 26 for a larger image).

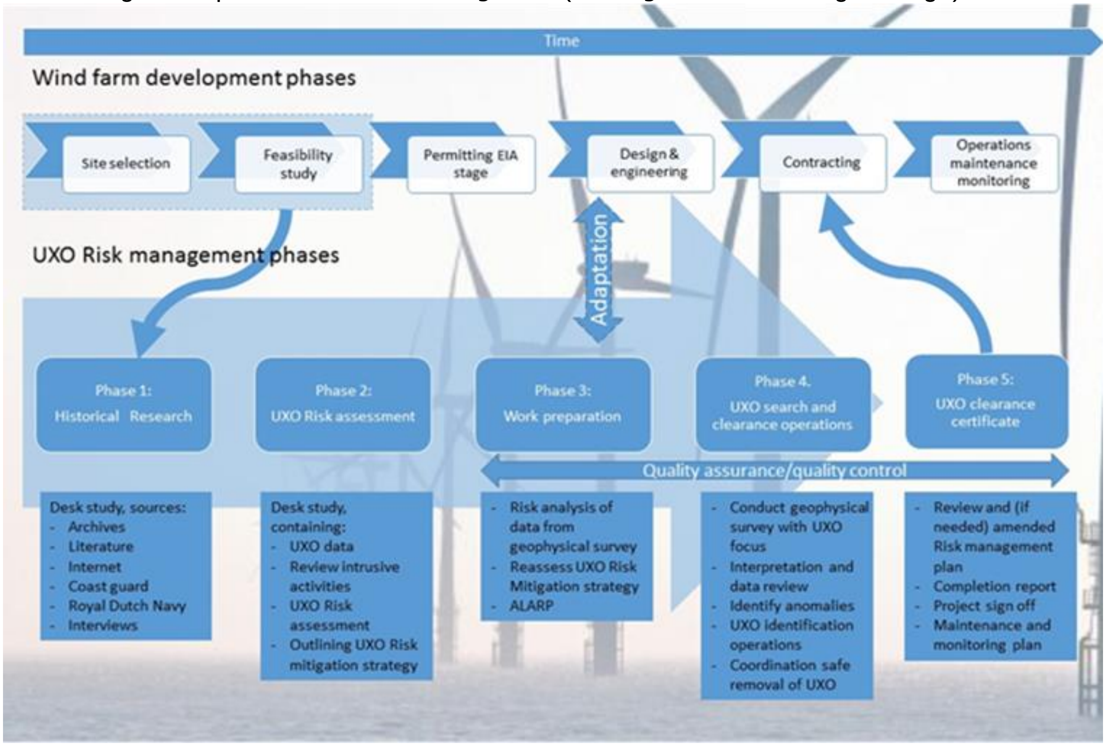


Figure 4: UXO risk management phases

The structure and content of this report is as follows:

- Chapter 2:
  At first a historical research is conducted to determine if UXO are to be expected in the Borssele wind farm zone as a result of war related activities and to define the type of UXO to be expected.

- Chapter 3:
  In this chapter the types of UXO likely to be encountered are described. This information is crucial for defining the hazards and effects of the expected UXO due to the intrusive activities needed to realize the wind farm.
- Chapter 4:
  In this chapter the effects of underwater detonations and chemical warfare agents are given. These effects on vessels, equipment, constructions, crew members and surroundings will determine the level of risk during the preparation phase (site investigations), execution phase (construction works) and operational phase (maintenance) of the wind farm development.
- Chapter 5:
  The level and nature of UXO risks will amongst other things, depend upon the intrusive activities in the area and the nature of the proposed works. Therefore all possible intrusive survey, construction and maintenance activities during the preparation, execution and operational phases of the Borssele wind Farm zone are summarized.
- Chapter 6:
  This chapter provides the characteristics of the wind farm zone relevant for defining the UXO mitigation strategy and the selection of appropriate survey techniques.
- Chapter 7:
  The possible presence of UXO in the wind farm area, is no constraint for offshore wind farm related activities. With proper UXO Risk Management the risks can be reduced to a level that is as low as is reasonably practicable (ALARP). Chapter 7 provides the outline of the UXO risk mitigation strategy.
- Annex 1
  This annex provides an overview of the war related events as described in chapter 2.
- Annex 2
  This annex contains a dictionary for “Wind op Zee”.

2. HISTORICAL RESEARCH

In this chapter the results of the desktop study will be presented. Although the Netherlands remained neutral during the First World War, also this war was of influence for the Borssele wind farm zone. Therefore both wars are described in this chapter. The information is drawn from literature, open source information, military information, information derived from the client and archives (for references see chapter 8).

Goal of the historical research is to determine if UXO are to be expected in the Borssele wind farm zone as a result of war related activities. The objective is to identify (if possible) areas within the Borssele wind farm zone that should preferably not be used for the installation of offshore wind farms and/or cables. The secondary objective is to define the type of UXO to be expected. This information is crucial for defining the hazards (see chapter 3) and effects of the expected UXO (see chapter 4).

2.1. World War I

World War I, also known as the First World War or the Great War, was a global war centred in Europe that began on 28 July 1914 and lasted until 11 November 1918.

During the war, the Netherlands remained neutral. Zeeland bordered to German-occupied Belgium. Especially the naval warfare on the North Sea has been of influence to the surroundings of the Borssele wind farm zone, especially due to the laying of naval mines in the North sea and the Westerschelde. There is little specific information on war related activities in (the direct vicinity of) the Borssele wind farm zone. The only activities that can be traced back to the area of research are a sea battle in the night of 30th of April 1915 (see paragraph 2.1.2) and the aerial attack on the Dutch vessel 'Cornelis' on Thursday the 29th of July (see paragraph 2.1.3).

2.1.1. Naval mines

Naval Warfare in World War was mainly characterized by the efforts of the Allied Powers, with their larger fleets and surrounding position, to blockade the Central Powers (Germany, the Austrian-Hungarian Empire, the Ottoman Empire and Bulgaria) by sea, and the efforts of the Central Powers to break that blockade or to establish an effective blockade of the United Kingdom and France with submarines and raiders. The North Sea was the main theater of the war. The British Grand Fleet took position against the German High Seas Fleet. Britain's larger fleet could maintain a blockade of Germany, cutting it off from overseas trade and resources. Germany's fleet remained mostly in harbor behind their screen of mines, occasionally attempting to lure the British fleet into battle. It was the blockade of German commerce through the North Sea, which ultimately starved the German people and industries and contributed to Germany seeking the Armistice of 1918.

During World War I, mines were used extensively to defend coasts, coastal shipping, ports and naval bases around the globe. The Dutch blocked the 'Westerschelde' with navel mines to stop intruders. The Germans laid mines in shipping lanes to sink merchant and naval vessels serving Britain. The Allies targeted the German U-boats in the Strait of Dover and the Hebrides. In an attempt to seal up the northern exits of the North Sea, the Allies developed the North Sea Mine Barrage. During a period of five months from June of 1918 almost 70,000 mines were laid, spanning the North Sea's northern exits. The total number of mines laid in the North Sea, the British East Coast, Straits of Dover, and Heligoland Bight is estimated at 190,000 and the total number during the whole of WWI was 235,000 sea mines [11]. Figure 5 shows a naval mine map dated 1918.

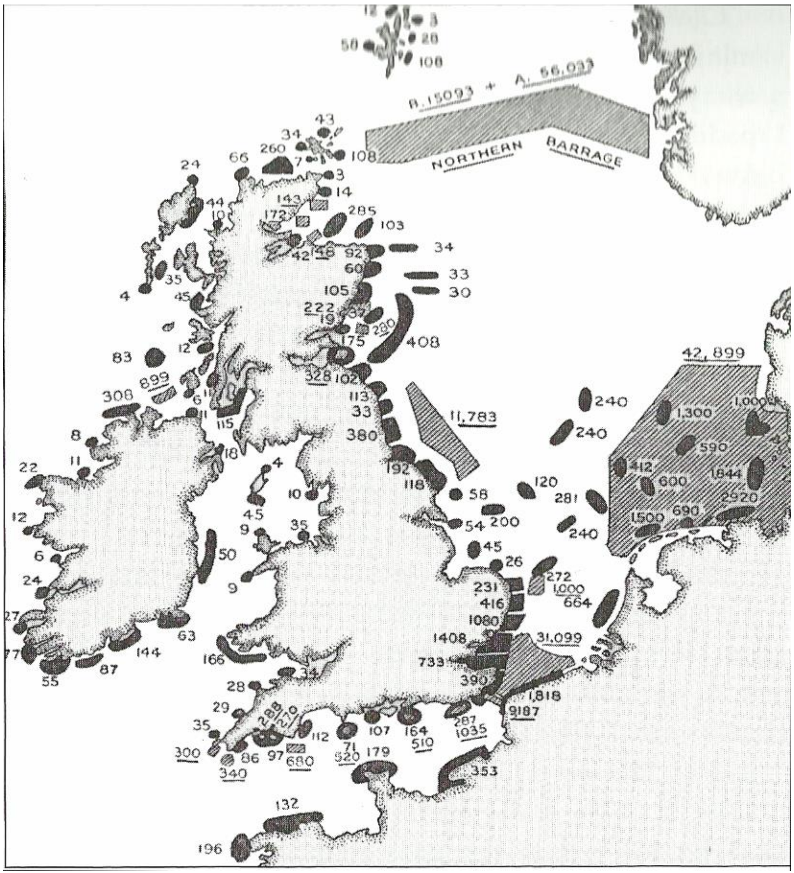


Figure 5: Map of mines laid during World War I [16]
Black shapes denote the German laid mines. Grey shaped denotes the Allied laid mines. Underlined numbers are the number of mines laid by the Allies, the other are German number of mines.

During the four years of war a total number of 6,450 mines washed up on the beaches of ‘Zeeland’ [10]. Many mines exploded on beaches, shores and dikes, killing several civilians. During the war 175 fishing vessels are lost and 862 crewmembers are killed [10]. The beaching of naval mines is a global problem that still exist nowadays and causes casualties on a regular bases.

Despite the intense mine clearing operations in the post war period even today naval mines from World War I are encountered regularly.

2.1.2. Naval warfare

In the night of 30th of April 1915, a sea battle took place in the proximity of the lightship 'Noord-Hinder' [10]. This lightship was anchored near the sandbank 'Noord-Hinder', at the south west side of the wind park zone Borssele. This battle claimed several ships and lives at both sides of the battling forces. A German airplane crashed. The crew was rescued by the crew of the lightship.

2.1.3. Aerial attacks on ships

During the war several vessels were attacked by Allied and German aircrafts.

For example the Dutch vessel 'Cornelis'. On Thursday the 29th of July 1915 this ship was heading for England. At the latitude of the lightship Schouwenbank an unknown seaplane occurred. The plane dropped four bombs on the vessel, none of which hit the target. Fragments of the exploding bombs landed on deck of the ship. On one of the fragments a number was present. This number indicated that the bombs were German.

On the 2nd of October 1917, in front of the coast at Cadzand, a Dutch guard ship opened fire on an unknown double-decker plane. The plane circled around the ship and dropped four bombs. The plane was suspected to be a German plane, thought to bomb 'Duinkerke'.

2.1.4. UXO dump site Paardenmarkt [21]

After World War I an estimated 35,000 tons of war material was dumped on the "Paardenmarkt", a shallow sand flat just off the Belgian coast (see Figure 6). Probably about one third consists of chemical munition. The dumping site extends over 3 km^2, ranging in water depth between 1.5 and 5.5 m. The munition has been sagging and is largely covered under accumulating fine-grained sediments, mainly due to the construction of the outer port of Zeebrugge.

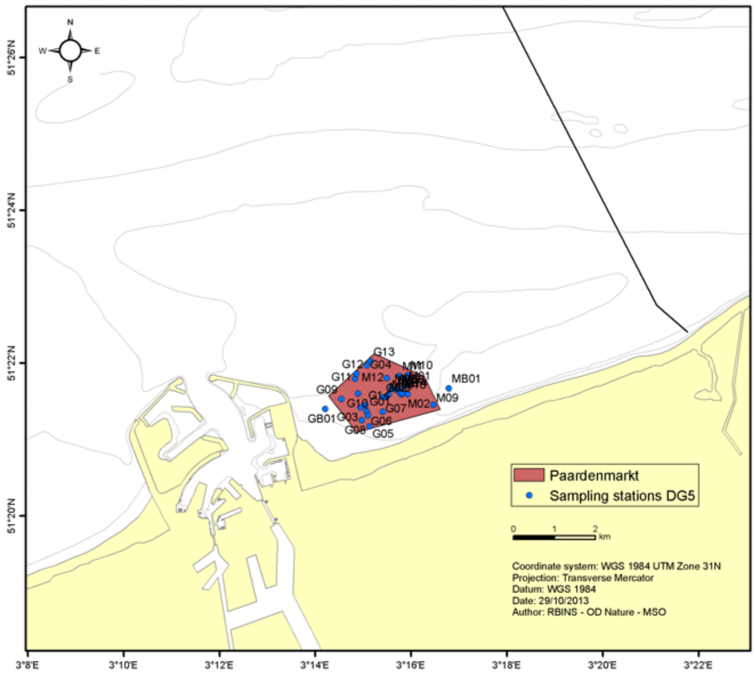


Figure 6: Location Paardenmarkt dump site [31]

The dump site is located approximately 25 kilometre southeast of the wind farm zone. Due to fishing activities UXO can be moved over great distances. The presence of UXO originating from the dump site Paardenmarkt in the wind farm zone can't be ruled out. There also is a possibility lumps of mustard gas leaked and were transported within the wind farm zone by sea currents.

2.2. WORLD WAR II

The Second World War, also known as the World War II, was a coalescence of several initially separate military conflicts. The war was fought between the Allied forces and the Axis powers on a global scale in the period from 1939 until 1945. During the war several activities took place that could be relevant for the wind park zone Borssele.

2.2.1. Air warfare

Air warfare was a major component of World War II. Germany and Japan depended on air forces that were closely integrated with land and naval forces; they downplayed the advantage of fleets of strategic bombers, and were late in appreciating the need to defend against Allied strategic bombing. By contrast, Britain and the United States took an approach that greatly emphasized strategic bombing, and to a lesser degree, tactical control of the battlefield by air, and adequate air defenses. They both built a strategic force of large, long-range bombers that could carry the air war to the enemy's homeland.

An around-the-clock campaign attacked Germany, with British bombers at night and U.S. aircraft during the day. From 1942 onward, the intensity of the British bombing campaign against Germany became less restrictive, increasingly targeting industrial sites and eventually, civilian areas. By 1943, the United States had significantly reinforced these efforts. The controversial fire bombings of Hamburg (1943), Dresden (1945), and other German cities followed (see Figure 7).

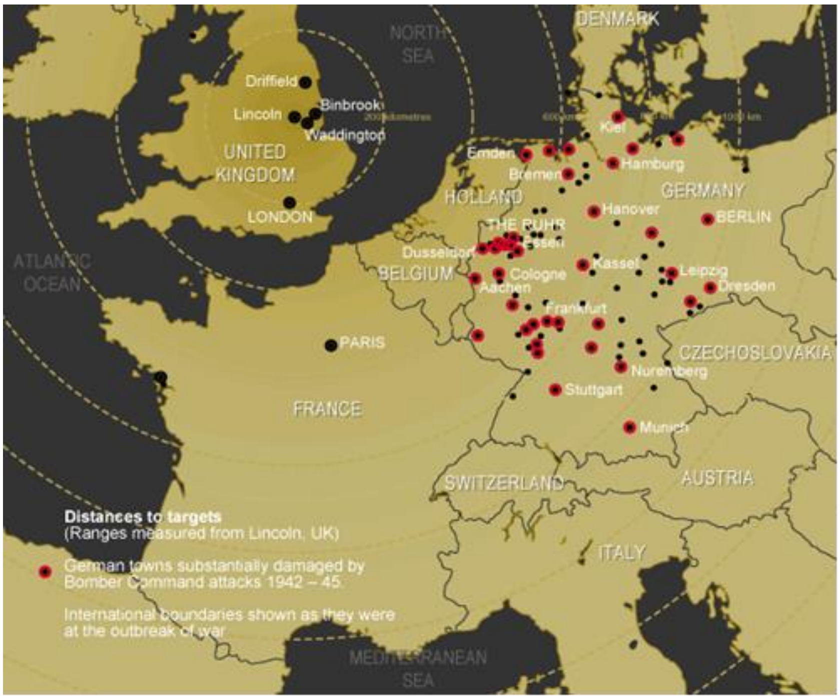


Figure 7: German towns bombed by Bomber Comand

The German ‘Ruhrgebied’, al large industrial zone, was a main target in many Allied bombings. Therefore the wind park zone Borssele is located within the main flight path of the Allied bomb raids (see Figure 8). The Allied aircrafts were attack by German Night Fighters, FLAK (abbreviation of Flugabwehrkanone) ships and intensive FLAK on the Dutch coast line. As a consequence a large number of airplanes were shot and crashed in the North Sea. Also many bombs were dropped above the North Sea, for example by Bombers damaged by FLAK or German Night hunters or aircrafts returning to England who still had bombs aboard. Planes were not allowed to land with a bomb load.

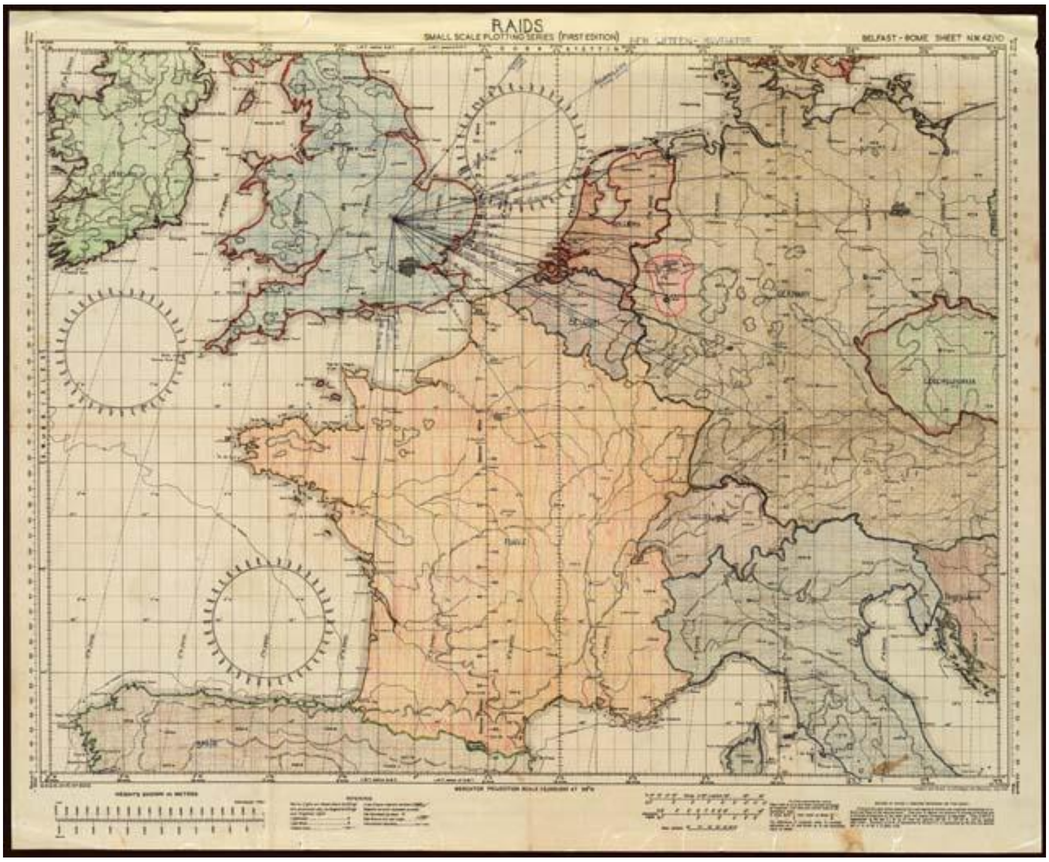


Figure 8: Flight paths Allied bomber raids [17]

The consulted literature describes a large number of aerial reconnaissance missions in the North Sea area. On several occasions vessels were attacked with bombs, rockets or canons. The literature doesn’t mention coordinates or exact locations of these attacks. Figure 9 shows the rockets of a Hawker Typhoon, fired at a tug in the Scheldt estuary. Next to the ship the impact of 20 mm grenades from the planes canons are visible.

Figure 9: A British Hawker Typhoon's rockets raining down on a tug caught in the Scheldt estuary, September 1944 [22]

2.2.2. Airplane crashes

The Borssele wind farm zone is located in the approach path of allied bombers. During the war many bombers crashed in the North Sea. The ‘Studiegroep Luchtoorlog 1939-1945’ provides online data on aircraft losses that are somehow related to the Netherlands [6]. The on-line database remains a work in progress. It still is not complete, and there is a lot of data not yet entered into the database. At this moment (August 2014) the database holds some 7,000 aircraft registrations, including some 1,200 damaged aircraft (mostly German) considered to be repairable and almost 22,000 registrations on aircrew. In total 759 aircrafts are reported to be crashed in the North Sea. Several aircrafts are crashed near ‘Zeeland’. Exact coordinates of the crashed planes are not available.

The book ‘En nooit was het stil’ [8] also mentions a great number of aircraft that crashed in the North Sea.

The website ‘Wings to Victory’ also provides a database of aircraft losses known in the province Zeeland. In total 623 known losses are present in the database. The number of losses in the North Sea totals 144. Exact coordinates of the crashed planes are not available. Based on the number of crashed aircrafts the possibility of encountering (parts of) aircrafts has to be taken into account. An example is given in Figure 10. It shows a Dornier-17 bomber in the English Channel.

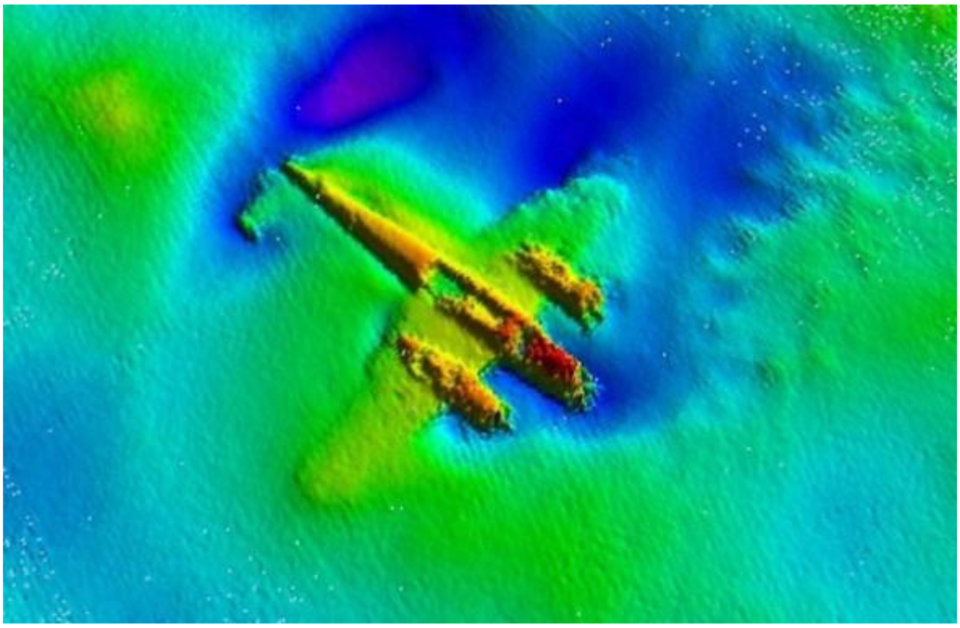


Figure 10: A scan of the sea bed in the English Channel shows the Dornier-17 German bomber, buried under sand since World War Two

2.2.3. Naval warfare

At the beginning of the war much of the early action by German forces involved mining convoy routes and ports around Britain. For defensive purposes Britain laid extensive minefields along the British coast.
Initially, contact mines were employed, usually tethered at the end of a cable just below the surface of the water. By the beginning of World War II, most nations had developed mines that could be dropped from aircraft and floated on the surface, making it possible to lay them in enemy harbors.

A large quantity of mines were used in the North Sea and the Dover Barrage. Figure 11 shows the British and German declared mine areas at the beginning of World War II.

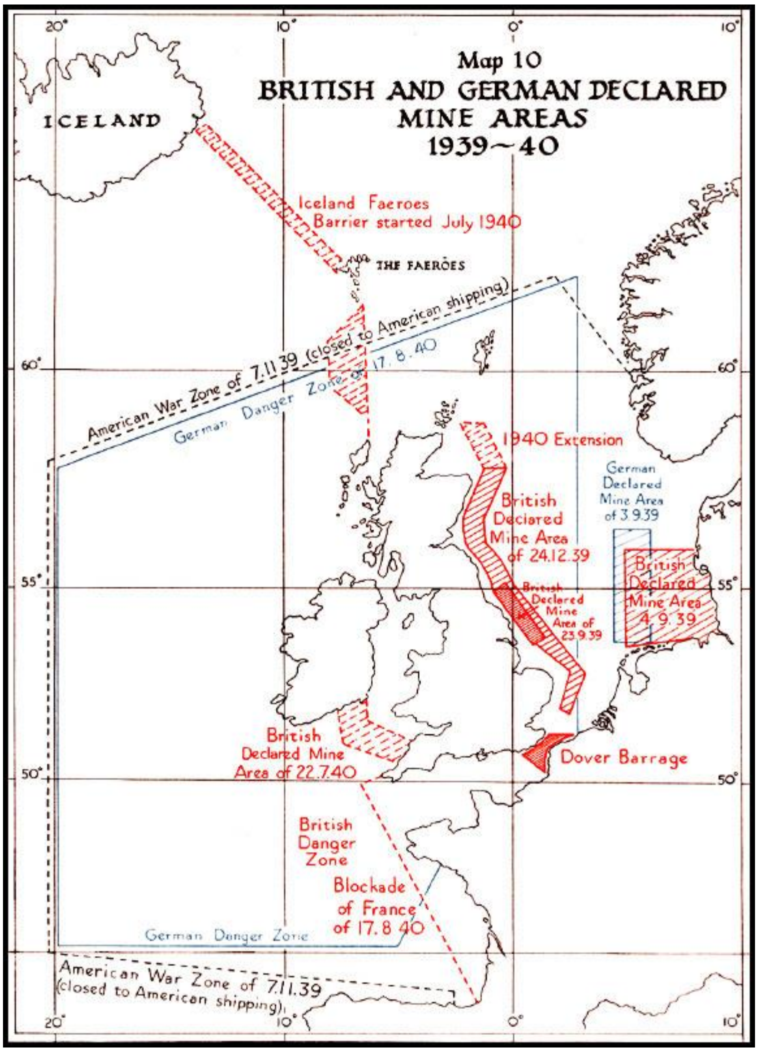


Figure 11: British and German declared mine areas 1939-1940

Six known mine fields were situated in the Borssele wind farm zone. These mine fields are shown in Figure 12.

For offensive purposes, especially during World War II, many non-declared minefields were laid, e.g. aerial dropped German mines in the Thames estuary. Offensive mining proved to be much more successful then defensive mining. Therefore a large number of mines were laid by aircraft, surface ships and submarines.

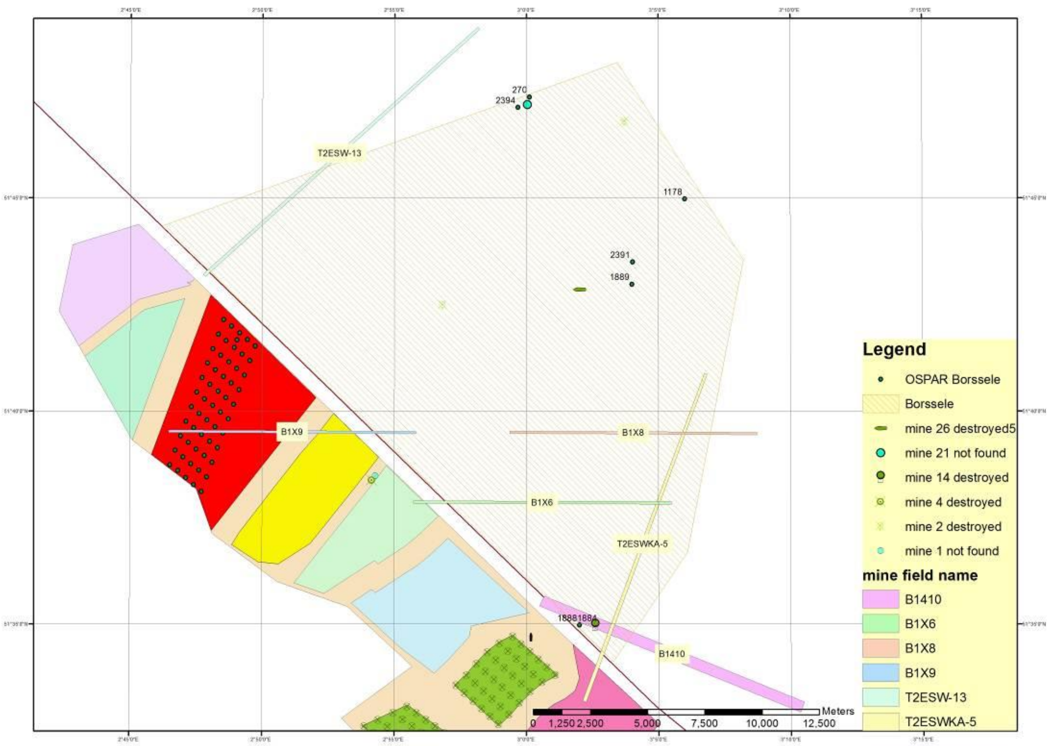


Figure 12: Known mine fields and encountered mines within the Borssele wind farm zone

The numbers in the legend in Figure 12 (for example mine 26) correspond with the numbers on the ´Explosievenkaart´ from the Dutch Coastguard (also see paragraph 2.3). Annex 1 shows that a number of naval mines were encountered in the vicinity of the known mine fields.

The Second World War was, in terms of naval warfare, again mostly a submarine war on the German side. However, this time the main action was not in the North Sea but rather the Atlantic. Also different from the first war, the North Sea was no longer the exclusive territory of the Allies. Rather, it was, especially in the first years of the war, the stage for an intensive coastal war, featuring mainly small vessels like submarines, minesweepers, and Fast Attack Craft. These vessels used torpedoes, depth charges and grenades during the war on the North Sea. As a result quit large quantities of torpedoes, depth charges and grenades are encountered in the North Sea.

2.2.4. Ship wrecks

During the wars a large number of ships sunk in the North Sea. The 'Wrakkenkaart' [7] and the 'Wrakkenregister' [32] provide an overview of known ship wrecks. The following known ships sunk in the vicinity of the Borssele wind farm zone because of war related activities:

- Tubantia
  On the 16th of March 1916 the Tubantia was heading from Amsterdam to Buenos Aires. At a few miles distance from the light ship 'Noord Hinder' it anchored because of dense fog. There it was discovered by the German

submarine UB-13. The ship was torpedoed at the level of the engine room. All persons on board were rescued by Dutch torpedo ships.

- Christiaan Huygens
  This Dutch passenger ship hit a sea mine when travelling from Antwerpen to Rotterdam on the 26th of August 1945. It sunk on the 5th of September 1945. The wreck is located 14 miles of 'Neeltje Jans' at a depth of 15 meters.
- SS Vecht
  This cargo vessel was sunk by the German submarine U-14 on the 7th of March 1940. All 22 crewmembers perished. The wreck lays on a depth of 25 meters.

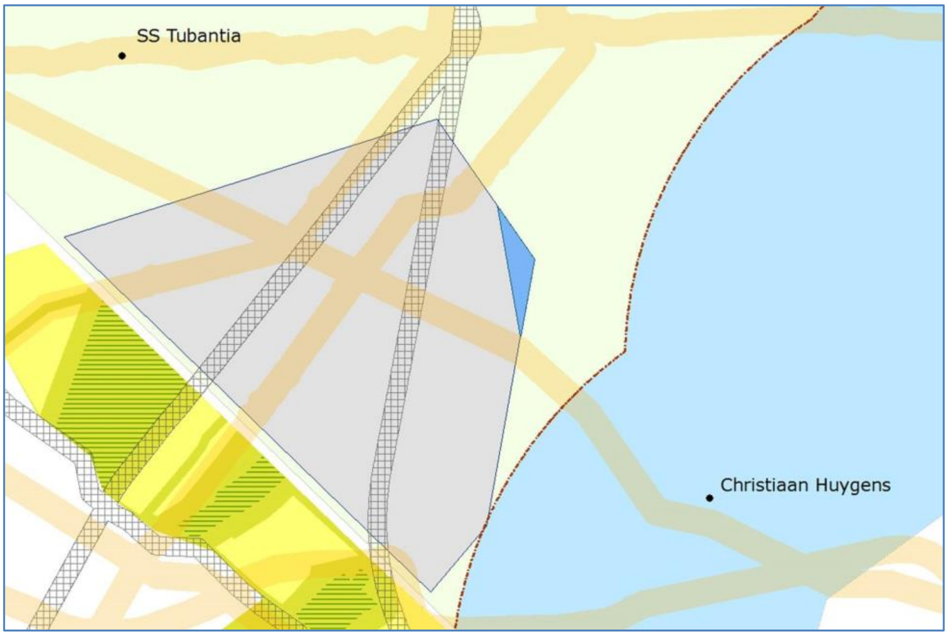


Figure 13: Location Christiaan Huygens and SS Tubantia [7]

The locations of mentioned ship wrecks are shown in Annex 1.

2.3. DUTCH COAST GUARD

Since the Second World War the Dutch fishing fleet almost weekly encounters UXO (Unexploded ordnance) in fishing nets. To compensate fisherman for the loss of income in case they encountered UXO, a deficiency payments regulation was defined. Due to the height of the payments, fisherman deliberately fished for UXO when fishing was poor. As a consequence large amounts of UXO were brought ashore each year. This UXO were demilitarised by the Dutch EOD (Explosive Ordnance Disposal).This situation eventually led to the abolishment of the compensation.

The following period no UXO were reported. However, this doesn't mean no UXO were encountered, all UXO were simply put overboard. This often led to dangerous situations.

On April the 6th 2005 three crewmembers of the vessel OD-1 'Maarten Jacob' (a fishing boat) were killed after an airplane bomb detonated at the deck of the vessel. This event led to a change in the handling of UXO by fisherman. The Dutch Coast Guard developed the "Bijstands- en bijdrageregeling" [4]. The primary goal of this regulation was to reduce the risks due to the encountering of UXO as much as possible.

The regulation provides guidelines for fisherman and professional support from the Coast Guard and EOD. To prevent fisherman to dump the UXO back in sea a financial compensation was implemented.

After the tragic event with the OD-1 a detailed administration is kept regarding encountered UXO in the North Sea. In total 1.569 UXO were reported to the coast guard, Royal Netherlands Navy and other authorities. The Royal Netherlands Navy Mine Counter Measures Service destroyed 1.173 of the reported UXO, 394 could not be found. In the Dutch/Belgian area, 2 UXO are not yet destroyed [6]. The Borssele wind farm zone is located in this area.

Within the wind farm zone 25 UXO were reported since April 2005. In the vicinity of the wind farm zone another 36 UXO were reported. Table 3 shows the reported types and numbers of UXO. The locations of the reported UXO are rendered in Annex 1. Annex 1 shows that most UXO were reported in the deep parts of the wind farm. The overview [20] of reported UXO, provided by the Royal Netherlands Navy Mine Counter Measures Service, does not mention if the reported UXO were recovered/destroyed or could not be found. Therefore mr. Bezemer (Head ABNL Naval Mine Warfare Mission Support Centre) was interviewed. This interview did not provide further information upon the overview of reported UXO.

UXO type	Number in wind farm zone	Number in vicinity of wind farm zone
Naval mine	7	28
Bomb	12	1
Torpedo	3	2
Depth charge	1	1
Unknown	2	4
Total	**25**	**36**

Table 3: Types and numbers of UXO reported within and near the Borssele wind farm zone [20]

The registration kept since April 2005 shows that UXO are present in the entire Dutch part of the North Sea. Concentrations of UXO are present in the following areas:
- The approach path of allied bombers.
- UXO dump sites.

In particular on the ‘Schouwenbank’,’Noord Hinder’ en ‘Schaar’ many UXO are reported. The Borssele wind farm zone is located in the vicinity of these locations (sandbanks) and in the main flight path of Allied bomber raids (see Figure 14). The UXO encountered in, and in the vicinity of the wind farm zone (see Table 3) make up approximately 4% of the total amount of UXO reported in the Dutch coastal waters.

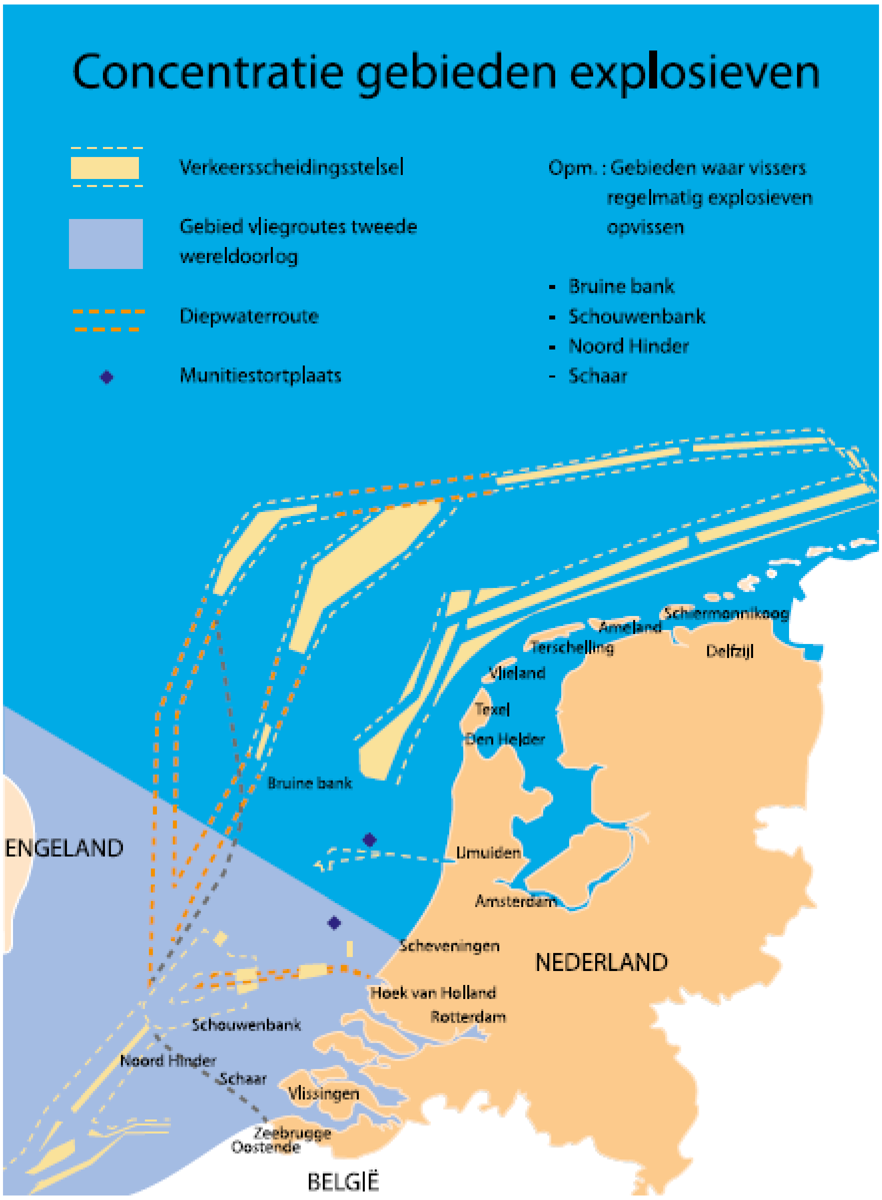


Figure 14: Areas with concentrations of UXO [5]

2.4. Outlining UXO risk area

There are several factors of main importance for outlining the UXO risk area:

- The Borssele wind farm zone is located in the main flight path of Allied bomber raids. As a consequence a large number of aircrafts are crashed in the North Sea and many bombs were dropped in the North Sea.
- In World War I and II a large number of naval mines were deployed in the North Sea. Mine fields were installed by submarines, ships and aircrafts. In World War II a total of six known minefields were (partially) located within the Borssele wind farm zone. The presence of mines, due to secret offensive mine laying operations can't be ruled out. Of the mines that were laid in WWII, only around 15 - 30% were countermined after the war, there are no records for minesweeping following WWI, so recovery is likely to have been even lower [27].

- Since April 2005 25 UXO [20] were encountered by fisherman within the Borssele wind farm zone.
- The seabed is very dynamic by nature, due to strong tidal streams and the movement of sand banks (also see paragraph 6.3). For this reason UXO can be moved from their original position.
- In the post war period the seabed was intensively used. Due to intensive fishing (trawling) UXO were moved. Until 2005 most of the UXO that were encountered in fishing nets were simply put overboard, often in the direct vicinity of known shipwrecks. These locations were normally avoided because of the risk of damaging the fishing nets, thus offering a gathering place of remnants of war.

Due to the stated factors a large part of the seabed of the North Sea must be considered a UXO-risk area. Because the Borssele wind farm zone was located in the middle of the flight path of Allied bombers and the fact that several minefields were present and mines were encountered, the entire location must be considered a UXO risk area.

2.5. TYPE OF EXPECTED UXO

Based upon the described source material the following UXO are likely to be encountered:

- Naval mines (see Figure 15)
  British and German naval mines from World War I and II can be present. Since 2005 7 naval mines[1] were encountered within the Borssele wind farm zone. Because a large number and variety of mines were deployed the presence of other types of mines can't be ruled out.

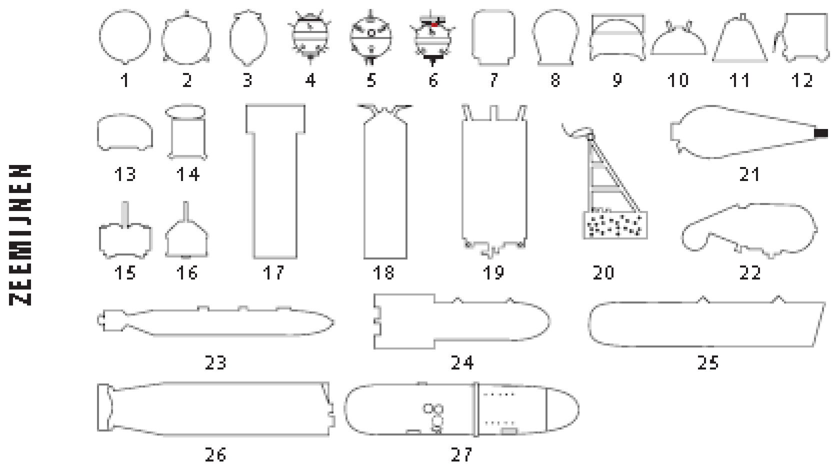


Figure 15: Cropping from the explosives chart regarding Naval mines [4]

- Bombs (see Figure 16)
  The likelihood of encountering bombs is high. Both German and British bombs may be encountered. Since 2005 most of encountered UXO in the North Sea concern Allied bombs. Within the Borssele wind farm zone 7 bombs were encountered.

[1] Fisherman report encountered UXO to the coast guard. They report the location and the number of the resembling picture in the identification chart. The number is used by the coast guard for a first identification in subgroups. This helps planning the disposal operation.

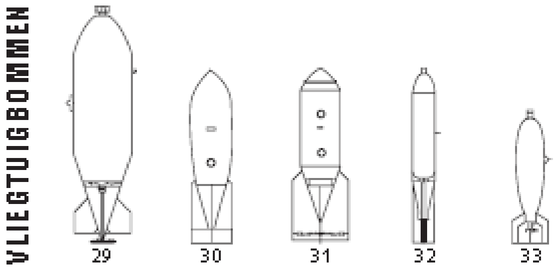


Figure 16: Cropping from the explosives chart regarding bombs [4]

- Depth charges (see Figure 17)
  A depth charge is an anti-submarine warfare weapon intended to destroy or cripple a target submarine by subjecting it to a powerful hydraulic shock. According to the overview with encountered UXO depth charges are encountered on a regular base. Since 2005 2 depth charges were encountered within the Borssele wind farm zone.

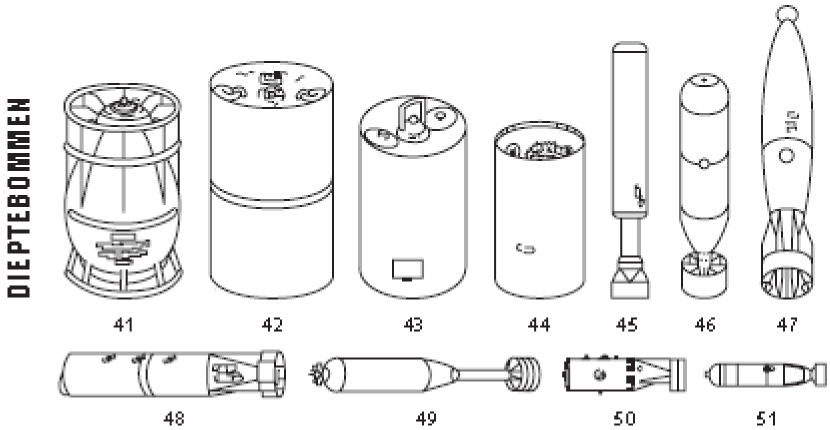


Figure 17: Cropping from the explosives chart regarding depth charges [4]

- Naval mine destruction charges (see Figure 18)
  These charges were used to destroy mines. The shockwave created by these charges causes nearby naval mines to detonate.

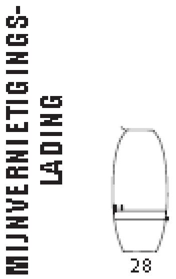


Figure 18: Cropping from the explosives chart regarding mine destruction charges [4]

- Torpedoes (see Figure 19)
  Torpedoes were widely used in the First and Second World War, both against shipping and against submarines. Germany disrupted the supply lines to Britain largely by use of submarine torpedoes. Britain and its allies also used torpedoes throughout the war. U-boats themselves were often targeted. Up until three or so years into WW2, German designed torpedoes were notoriously unreliable and commonly either exploded prematurely or failed to detonate at all. Failed torpedoes will fall to the seabed with their warhead intact when they run out of propellant fuel. Since 2005 2 torpedoes were encountered within the Borssele wind farm zone.

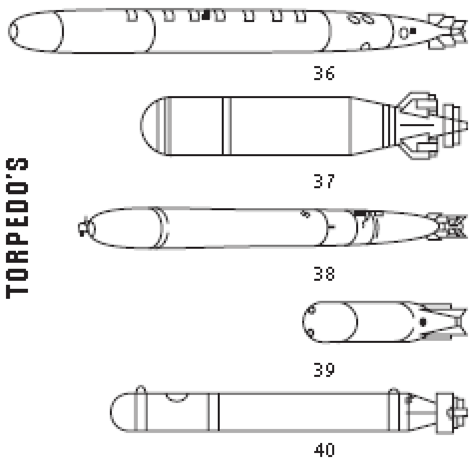


Figure 19: Cropping from the explosives chart regarding torpedoes [4]

- Grenades (see Figure 20)
  Grenades were used for anti-aircraft purposes and naval warfare. Due to incidents of naval combat, aerial attacks and/or dumping operations grenades may be encountered. Since 2005 no grenades were encountered within the Borssele wind farm zone.

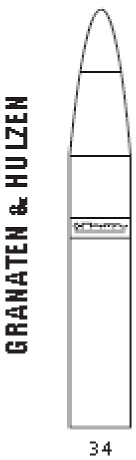


Figure 20: Cropping from the explosives chart regarding grenades [4]

2.6. State of expected UXO

The expected UXO are likely to be armed. This means that the safety devices preventing the UXO to detonate to early, e.g. during handling, are removed. Therefore the triggering sequence, also called an explosive train, is in line. The triggering sequence is a sequence of events that culminates in the detonation of explosives. The triggering sequence starts with the firing pin hitting the blasting cap. The highly sensitive explosives in the blasting cap detonate, causing the main charge to detonate.

In case of bombs dropped by aircrafts in danger the bombs were often dropped safe by dropping the devices with safety features still in place.

Some of the expected UXO, e.g. naval mines, may be encountered in very poor condition as the thin skin has been severely eroded. The high explosive fill within (usually TNT or occasionally Hexonite) however, will not have significantly deteriorated and the explosive capability will remain more or less undiminished. Stability of the device is also likely to deteriorate with age.

The exact state of encountered UXO can only be determined after positive identification by an EOD-expert.

2.7. Other remnants of war possibly to be encountered

It can't be ruled out entirely that (parts) of crashed airplanes are present, since a large number of planes crashed in the North Sea bordering 'Zeeland'. The available information regarding the crash sites often is not very accurate.

Several crewmembers of the crashed aircrafts were never found. This means there's a possibility of encountering human remains.

Due to the presence of the dump site 'Paardenmarkt' (see paragraph 2.1.4) at approximately 25 kilometres from the wind farm zone, there's a small possibility of encountering lumps of Yperite (mustard gas).

3. HAZARDS OF UXO LIKELY TO BE ENCOUTERED

In this chapter the types of UXO likely to be encountered are described. The given information, together with the impact of UXO and other remnants of war (see chapter 4), the planned intrusive activities (see chapter 5) and the specific characteristics of the site (see chapter 6) forms the input for outlining the UXO mitigation strategy (see chapter 7).

3.1. AERIAL BOMBS

An aerial bomb is a type of explosive weapon intended to travel through the air with predictable trajectories, designed to be dropped from an aircraft. As with other types of explosive weapons, aerial bombs are designed to kill and injure people and destroy materiel through the projection of blast and fragmentation outwards from the point of detonation. Therefore most bombs were accommodated with an explosive charge, although incendiary bombs were also put to use.

The used fuzes are of main importance for the likelihood of a bomb to detonate as a consequence of seabed activities. Fuzes have two purposes, one is to cause the bomb to explode, and the other to prevent the bomb from detonation before it has left the aircraft and at close range of the aircraft.

The fuzes are armed during and after the bombs are dropped. When the bomb makes impact, the fuze has a spike or electrical circuit that detonates the bomb. If the fuze has a spike, that spike is driven into a small detonation charge that sets off the main bomb charge. An electrical fuze uses a spark to set off the detonation charge.

Fuzes can have various timers built into them to make the blast more effective. Some go off at a given time after arming, e.g. chemical long delay fuzes such as tail fuze no. 37 MkI (see Figure 21). More common are short delay or instantaneous timers to delay the detonation for a few fractions of a second.

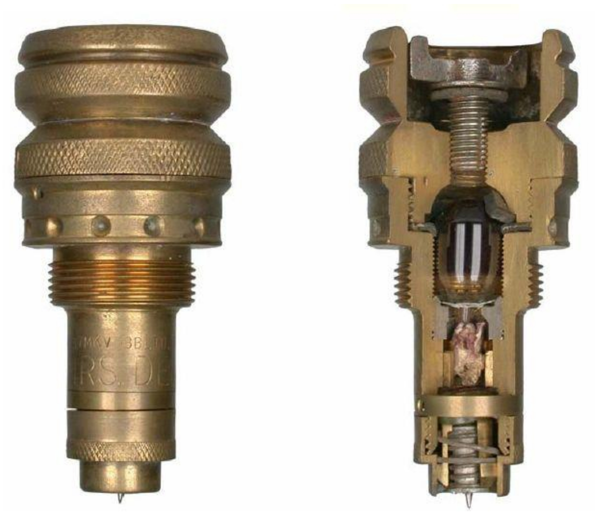


Figure 21: Tail fuze no. 37 MkI

Once a fuze is armed, any hard jolt can set it off causing the bomb to detonate. Fuzes, and chemical long delay fuzes in particular, are sensitive to accelerations with an amplitude > 1 m/s^2 in the surrounding soil. This kind of accelerations can occur as a consequence of vibrations causes by any kind of piling operations.

3.2. DEPTH CHARGES

A depth charge is an anti-submarine warfare weapon intended to destroy or cripple a target submarine by subjecting it to a powerful hydraulic shock. Most depth charges are fitted with conventional high explosives and a fuze set to cause detonation at a preselected underwater depth. Depth charges can be dropped by ships and patrol aircraft.

Depth charges were detonated by a spring-loaded firing pin released by a water pressure driven bellows system. The mechanism could be set to various depths based on the attacking vessel's estimate of the depth of the submarine. A late war variant included a magnetic detonator which automatically exploded the depth charge when it reached the proximity of a submarine. The change of encountering this type of fuzing is estimated to be low.

3.3. TORPEDOES

A torpedo is a self-propelled weapon with an explosive warhead, launched above or below the water surface, propelled underwater towards a target, and designed to detonate either on contact with its target or in proximity to it. Proximity fuzes were later developed in World War II. The change of encountering this type of fuze is estimated to be low.

A proximity fuze is a fuze that detonates an explosive device automatically when the distance to the target becomes smaller than a predetermined value, which can also take place when the fuze and the target pass by each other.

3.4. NAVAL MINES

Naval mines may be classified into three major groups (Contact, Remote and Influence Mines).

3.4.1. Contact mines

The earliest mines were usually of this type. They are still used today, as they are extremely low cost compared to any other anti-ship weapon and are effective, both as a terror weapon and to sink enemy ships. Contact mines need to be touched by the target before they detonate, limiting the damage to the direct effects of the explosion and usually affecting only the single vessel that triggers them.

Contact mines are often equipped with Hertz Horns (or chemical horns) or switch horns. These fuzes work reliably even after the mine has been in the sea for several years. The mine's upper half is studded with hollow lead protuberances, each containing a glass vial filled with chromium acid. When a ship's hull crushes the metal horn, it cracks the vial inside it, allowing the acid to run down a tube and into a lead–acid battery which until then contains no acid electrolyte. This energizes the battery, which detonates the explosive.

During the initial period of World War I, the British Navy used contact mines in the English Channel and later in large areas of the North Sea to hinder patrols by German submarines. Later, the American antenna mine was widely used because submarines could be at any depth from the surface to the seabed.

This type of mine had a copper wire attached to a buoy that floated above the explosive charge which was weighted to the seabed with a steel cable. If a submarine's steel hull touched the copper wire, the slight voltage change caused by contact between two dissimilar metals was amplified and detonated the explosives.

3.4.2. Remotely controlled mines

Frequently used in combination with coastal artillery and hydrophones, controlled mines (or command detonation mines) can be in placed in peacetime, which is a huge advantage in blocking important shipping routes. The mines can usually be turned into "normal" mines with a switch (which prevents the enemy from simply capturing the controlling station and deactivating the mines), detonated on a signal or be allowed to detonate on their own.

3.4.3. Influence mines

These mines are triggered by the influence of a ship or submarine, rather than direct contact. Such mines incorporate electronic sensors designed to detect the presence of a vessel and detonate when it comes within the blast range of the warhead. The fuzes on such mines may incorporate one or more of the caused by the proximity of a vessel. There were also a small amount of other specialised devices but these were few in number and are unlikely to be encountered.

Even as far back as the Second World War it was possible to incorporate a "ship counter" facility into mine fuzes e.g. set the mine to ignore the first two ships to pass over it (which could be mine-sweepers deliberately trying to trigger mines) but detonate when the third ship passes overhead, which could be a high-value target such as an aircraft carrier or oil tanker.

3.5. GRENADES

Grenades were deployed by aircraft (20 mm), submarines and warships. It's also possible that grenades are encountered that were initially used on land and dumped into sea as a matter of clearance. Grenades can be deployed with different kinds of artillery fuzes.

An artillery fuze is the type of munition fuze used with artillery munitions, typically projectiles fired by guns (field, anti-aircraft, coast and naval), howitzers and mortars. A fuze is a device that initiates an explosive function in a munition, most commonly causing it to detonate or release its contents, when its activation conditions are met. This action typically occurs a preset time after firing (time fuze), or on physical contact with (contact fuze) or detected proximity to the ground, a structure or other target (proximity fuze).

3.6. ANTI HANDLING DEVICES

Some fuzes, e.g. those used in air-dropped bombs and naval mines may contain anti-handling devices specifically designed to kill bomb disposal personnel. Generally, the more sophisticated the mine design, the more likely it is to have some form of anti-handling device fitted in order to hinder clearance. The technology to incorporate booby-trap mechanisms in fuzes has existed since at least 1940 e.g. the German ZUS40 anti-removal bomb fuze.

3.7. SELF-DESTRUCTION DEVICES

The Hague Conventions of 1907 [28] states that is forbidden (article 1):

- to lay unanchored automatic contact mines, except when they are so constructed as to become harmless one hour at most after the person who laid them ceases to control them.

- to lay anchored automatic contact mines which do not become harmless as soon as they have broken loose from their moorings.
- to use torpedoes which do not become harmless when they have missed their mark.

As a consequence of The Hague convention naval mines were presumed to be equipped with a deactivating or self-destruction device. These devices often didn't work properly. In case a self-destructing device malfunctioned the UXO holding the device is to be considered highly sensitive to handling (movement). Because washed up mines were falsely considered safe they claimed many casualties during and after the wars. Despite of the prohibitions of The Hague conventions, naval mines and torpedoes must be considered dangerous at all times.

4. EFFECTS OF DETONATION AND CHEMICAL WARFARE AGENTS

In this chapter the effects of underwater detonations and chemical warfare agents are given. These effects on vessels, equipment, constructions, crew members and surroundings will determine the level of risk during the preparation phase (site investigations), execution phase (construction works) and operational phase (maintenance) of the wind farm development.

4.1. EFFECTS OF UNDERWATER DETONATIONS

The damage that may be caused by an underwater detonation depends on the "shock factor value", a combination of the initial strength of the explosion and of the distance between the target and the detonation. When taken in reference to ship hull plating, the term "Hull Shock Factor" (HSF) is used, while keel damage is termed "Keel Shock Factor" (KSF). If the explosion is directly underneath the keel, then HSF is equal to KSF, but explosions that are not directly underneath the ship will have a lower value of KSF [12]. The effect of a detonation mainly depends on the amount of explosive content (Net Explosive Weight) of the UXO and the type of explosive content (e.g. TNT, Torpex, etc.). The type of explosive is of less importance.

4.1.1. Direct damage

Direct damage can occur to vessels and platforms that come into contact with e.g. a contact mine. Direct damage is a hole blown in the ship or platform. Among the crew, fragmentation wounds are the most common form of damage. Flooding typically occurs in one or two main watertight compartments which can sink smaller ships or disable larger ones. Contact mine damage often occurs at or close to the waterline near the bow, but depending on circumstances a ship could be hit anywhere on its outer hull surface.

It is unlikely that direct damage occurs due to seabed activities. Present UXO are most likely to be present in or on the seabed.

4.1.2. Bubble jet effect

The bubble jet effect occurs when a mine or bomb detonates in the water under (e.g. on the seafloor), or a short distance away from a ship. The explosion creates a bubble in the water, and due to the difference in pressure, the bubble will collapse from the bottom. The bubble is buoyant and so it rises towards the surface. If the bubble reaches the surface as it collapses it can create a pillar of water that can go over a hundred meters into the air (a "columnar plume"). If conditions are right and the bubble collapses onto the ship's hull the damage to the ship can be extremely serious; the collapsing bubble forms a high energy jet that can break a meter wide hole straight through the ship, flooding one or more compartments, and is capable of breaking smaller ships apart. The crew in the areas hit by the pillar are usually killed instantly. Other damage is usually limited.

4.1.3. Shock effect

If a mine or bomb detonates at a distance from the ship, the change in water pressure causes the ship to resonate. The whole ship is dangerously shaken and everything on board is tossed around. Engines rip from their beds, cables from their holders, etc. A badly shaken ship usually sinks quickly, with hundreds, or even thousands of small leaks all over the ship and no way to power the pumps. The crew fare no better, as the violent shaking tosses them around [12], [14]. This shaking is powerful enough to cause disabling injury to knees and other joints in the body, particularly if the affected person stands on surfaces connected directly to the hull (such as steel decks).

In Table 4 the distances on with a certain amount of shock damage is expected is shown for the common types of Allied bombs. The distances are calculated by TNO. Leakage is to be expected in case of a Hull Shock Factor (HSF) > 0,3 kg $^{0.5}$/m. Damage to equipment is to be expected in case of a HSF > 0,02 kg $^{0.5}$/m [14].

NEW [kg]	Leakage of working vessels [m]	Damage to equipment [m]
51 (e.g. bomb 250 lbs	29	430
105 (e.g. bomb 500 lbs)	41	617
270 (e.g bomb 1,000 lbs)	66	989

Table 4: Distances for shock damage due to detonation [14]

Table 4 shows that in case a UXO detonates, it is highly likely severe damage to the equipment and foundations and injury of personnel will occur.

4.1.4. Shredding effect or spalling

In case of a shock wave with a peak pressure of 37,2 bar and higher reflecting against the water surface, this will generate a cracking effect on this water surface. The water particles in the surface layer will be thrown out into the air with great force. This phenomenon, where a shock wave travels from a dense medium (water) into a less dense medium (air) and thus creating a distortion of the surface layer between water and air, is called the “shredding effect” or “spalling”.

The mechanism of wounding a human body can be explained by this shredding effect. A shockwave travelling through a human body will cause severe damage to tissue around air compartments like ears, lungs and intestines.

Gas containing organs can be harmed by the shock wave transferring from the water environment to the air environment. Specifically the transfer of the shock wave energy between water and air causes ruptures in the lungs and other gas containing organs. These ruptures can be fatal in the worst cases.

4.1.5. Lethality of fragments

Fragments from explosives charges in water quickly loose energy. A scientific study on the effects of fragments travelling under water after detonation, is used by the Dutch EOD for calculating the safe distances [13].

In the Borssele wind farm zone UXO with explosive weights over 200 kg TNT can be present. To detain all fragments a water depth > 10 m is needed. Because of the actual water depths at the site (> 16 m) it is unlikely that lethal fragments are ejected above the surface of the water (see Figure 22).

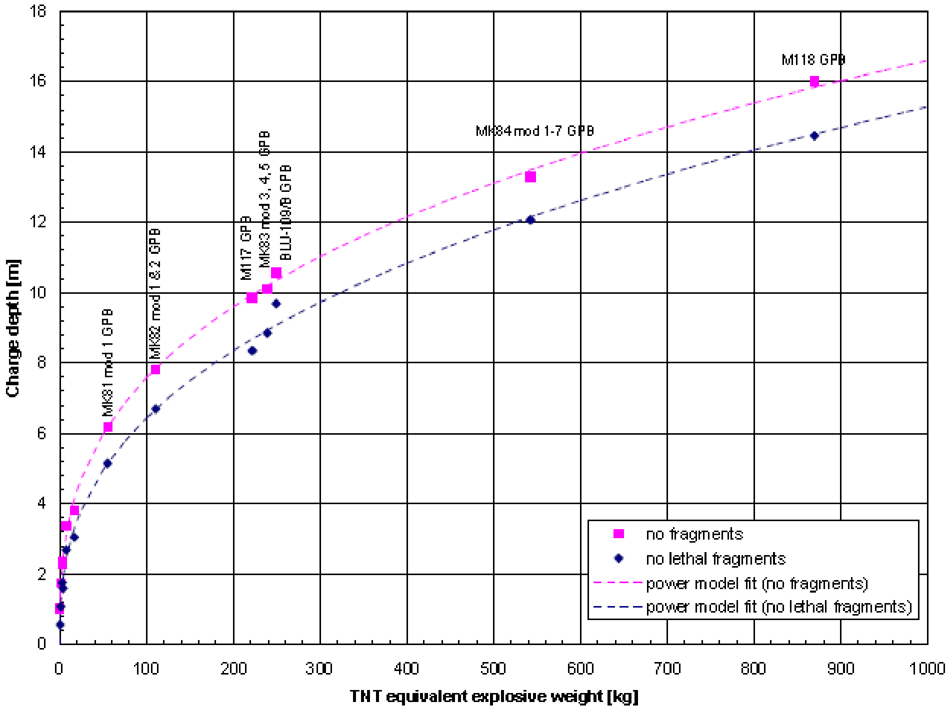


Figure 22: Minimal water depth to detain fragmentation of explosives with a Net Explosive Weight of 0-1000 kg TNT equivalent

4.2. SAFE DISTANCES

The Dutch EOD regulation provides formulas for calculating the safe distances in case of a controlled demolition of UXO in water. In case of a controlled demolition of UXO in water in the stated area [13]:

a) $R = 270\ 3\sqrt{W}$ diving is not allowed;
b) $R = 24\sqrt{W}$ civilian shipping is not allowed;
c) $R = 36\sqrt{W}$ tankers are not allowed;
d) $R = 12\sqrt{W}$ warships are not allowed.

R : Radius in meters
W : Net Explosive Weight (NEW) in kg. TNT-equivalents

In Table 5 the safe distances for UXO with a net explosive weight of 100, 200 and 300 kg TNT are given. The safe distances are calculated with the formulas stated above. This explosive weights are representative for the types and calibres of UXO likely to be present in the wind farm area (e.g. naval mines bombs, depth charges and torpedoes).

W [NEW]	Diving [m]	Civilian shipping [m]	Tankers [m]	Warships [m]
100 kg	1,253	240	360	120
200 kg	1,579	339	509	170
300 kg	1,807	416	624	208

Table 5: Safe distances for controlled demolition [13]

4.3. EFFECTS OF CHEMICAL WARFARE AGENTS

Over the last decades a number of accidents related to sea-dumped chemical weapons have been reported in the North Sea. Most accidents involved fishing crews; in some cases complete lumps of Yperite (mustard gas) were fished up, often resulting in serious burning wounds.

The possible presence of lumps of Yperite can't be ruled out completely, but is assessed to be low. The possibility of skin contact with Yperite is also assessed to be low. Of all personnel divers are most likely to come into contact with Yperite. Divers however are well protected by their diving suits. Therefore specific safety measures regarding the possible presence of Yperite are not necessary.

5. INTRUSIVE ACTIVITIES

The level and nature of UXO risks will depend upon the wartime and post war activity in the area, any previous construction works, intrusive activities in the area and the nature of the proposed works.

In this chapter all possible intrusive survey, construction and maintenance activities during the preparation, execution and operational phases of the Borssele wind Farm are summarized. Since, in the current stage of the project, an execution plan is not yet available the needed information is derived from the report 'Windpark Borssele, Geological desk study' [26] and information provided by the ordering party [30]. Therefore the activities described in this chapter only provide a range of possible activities that could occur. Not all activities could be required or additional activities could be planned.

For each intrusive activity the relevant effects for the UXO risk assessment are given. In general the presumption is made that magnetic sensors on present influence mines became ineffective. Therefore the presence of large steel constructions is not considered relevant for the UXO risk assessment.

5.1. PREPARATION PHASE

Preliminary site investigations are planned to be conducted, comprising of:

- Geophysical investigations:
  - multibeam echo sounder;
  - side scan sonar;
  - magnetometer;
  - sub bottom profiler.
- Geotechnical investigations:
  - cone penetration tests, covering the whole area;
  - a limited number of boreholes for sampling purposes;
  - grab samples.
- Metocean measurements:
  - FLIDAR (offshore meteorological station) installation;
  - Wave buoy installation;
  - Installation of Met mast.

<u>Potential UXO risks</u>

Potential UXO risks are:

- Direct contact between a UXO and jacks, anchors and/or suction anchors of the vessels conducting the site investigations.
- Direct contact between a UXO and the cone or drill during the geotechnical investigations.

5.1.1. Met mast

In order to optimize the energy output from a wind farm, detailed statistical information on wind direction, speed and altitude is desirable. In order to collect this information, a Met mast can be installed prior to the development of the wind farm itself. A Met mast is a slender structure containing measurement equipment. As the Met mast becomes redundant after fabrication of the wind farm, the Met mast is normally removed. For the UXO risk assessment only the realization and removal of the foundation of the Met mast is relevant.

Potential UXO risks

Potential UXO risks are:

- Direct contact between a UXO and jacks, anchors and/or suction anchors of the vessels installing the foundation.
- Direct contact between a UXO and dredging equipment and/or gravel or rock during the removal of obstructions, the preparation of the seabed and/or gravel/rock dumping.
- Direct contact between a UXO and the foundation during the placement of the foundation.
- Accelerations with an amplitude > 1 m/s^2 in the surrounding soil during the placement or removal of the foundation (depending on the type of foundation, there are techniques that are vibration-free).
- Direct contact between a UXO and jacks, anchors and/or suction anchors of the vessels conducting the investigations.
- Direct contact between a UXO and divers during cable connection operations.
- Direct contact between a UXO and divers/ROV's during inspections and as-built checks.

5.2. EXECUTION PHASE

A wind farm contains a variety of structures. The following elements are identified and briefly described:

- Wind turbines.
- Converter- and transformer stations.
- Scour protection.
- Cable routes (internal and external).

5.2.1. Wind turbines

A wind turbine consist of a nacelle with rotor blades, a support structure and a foundation. For the UXO risk assessment only the realization of the foundation is relevant. There are several suitable foundation options. The decision for a foundation type will be based on a range of factors, including water depth; tidal, wind and wave conditions; logistical practicalities; commercial factors; ease of construction and installation; and the type and size of turbine chosen. Figure 23 shows three possible foundation types. Suction anchors may also be a suitable solution.

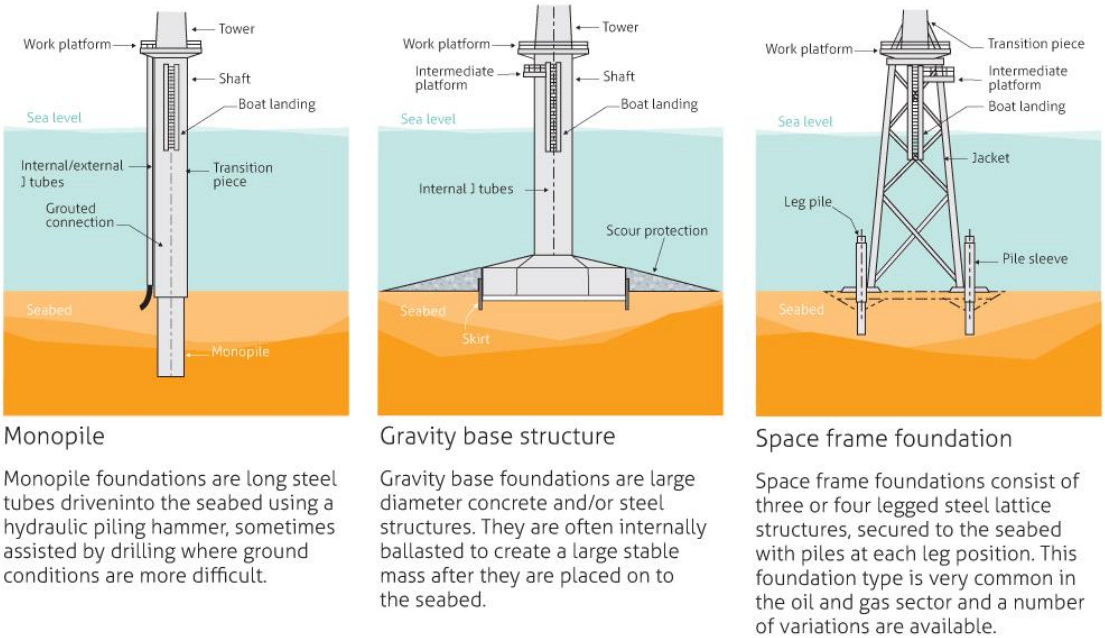


Figure 23: Example of suitable foundation types [29]

<u>Potential UXO risks</u>

Potential UXO risks are:

- Direct contact between a UXO and jacks, anchors and/or suction anchors of the vessels installing the foundation.
- Direct contact between a UXO and dredging equipment and/or gravel or rock during the removal of obstructions, the preparation of the seabed and/or gravel/rock dumping.
- Direct contact between a UXO and the foundation during the placement of the foundation.
- Accelerations with an amplitude > 1 m/s2 in the surrounding soil during the placement or removal of the foundation (depending on the type of foundation, there are techniques that are vibration-free).
- Accelerations with an amplitude > 1 m/s^2 during operation of the turbines.
- Direct contact between a UXO and divers during cable connection operations.
- Direct contact between a UXO and divers/ROV's during inspections and as-built checks.

5.2.2. Converter- and transformer stations

In order to deliver a constant flow of electricity to shore, all generated electricity is collected in one point and transformed to the predetermined voltage and frequency. The transformer station size can be compared with medium-sized oil and gas facilities, which is why its structure is mostly found equivalent. For the UXO risk assessment only the realization of the foundation of the transformer station is relevant.

Potential UXO risks

Potential UXO risks are:

- Direct contact between a UXO and jacks, anchors and/or suction anchors of the vessels installing the foundation.
- Direct contact between a UXO and dredging equipment and/or gravel or rock during the removal of obstructions, the preparation of the seabed and/or gravel/rock dumping.
- Direct contact between a UXO and the foundation during the placement of the foundation.
- Direct contact between a UXO and divers during cable connection operations
- Direct contact between a UXO and divers/ROV's during inspections and as-built checks.
- Accelerations with an amplitude > 1 m/s^2 in the surrounding soil during the placement or removal of the foundation (depending on the type of foundation, there are techniques that are vibration-free).

5.2.3. Scour protection

Sandy soils, such as present in the Borssele wind farm zone, can be more or less susceptible to a type of erosion called scour. Due to tidal currents, a significant section of the soil around the piles can be removed, due to the effect of the foundation on the local flow pattern and velocities. Therefore, depending on the local conditions and the chosen type of foundation, scour protection may be needed. A common way of scour protection is rock dumping around the piles. Typically, the scour protection will be realized using layers of natural, crushed rock, increasing in size when going up from the seabed. The lowest layer of rock, which is small enough to restrain the soil, may be replaced by a geotextile. Prior to applying the scour protection seabed preparation may be needed.

Potential UXO risks

Potential UXO risks are:

- Direct contact between a UXO and jacks, anchors and/or suction anchors of the vessels installing the scour protection.
- Direct contact between a UXO and dredging equipment and/or gravel or rock during the removal of obstructions, the preparation of the seabed and dumping of gravel/rock.
- Direct contact between a UXO and divers/ROV's during inspections and as-built checks.

As a consequence of scour buried UXO in the vicinity of the piles can change position or even get moved by tides. This risk can occur in the operational phase of the wind farm (see paragraph 5.3).

5.2.4. Cable routes

In order to transport the generated power from the turbine to the transformer station, cables are installed (in-field cables). The electricity is transported from the transformer station to shore through the export cables. To avoid damage by scratching anchors or fish nets, cables are to be buried below the sea bed. In most cases, cables are buried beneath the seabed to a set target depth in conjunction with a stone protection.

Trenching operations
Cables are buried in a narrow trench cut by water jet or plough. The usual and most efficient burial method is by use of a subsea cable plough which is towed on the seabed behind the cable ship or subsea crawler. The cable passes through the plough and is buried into the seabed. The plough lifts a wedge of sediment so that the cable can be inserted below, thus minimizing seabed disturbance to a very narrow corridor.

Before the main laying and ploughing operations take place, a seabed Route Clearance operation and a Pre Lay Grapnel Run (PLGR) operation is carried out. This is to remove items of debris such as abandoned fishing nets, wires, abandoned cables, hawsers etc. Removal of any debris ensures a clear route for the plough to negotiate so that burial can be maximized.

Following plough burial, a post lay burial and inspection is normally carried out in areas where the plough could not bury, such as at cable and pipeline crossings, locations where the plough may have been recovered for repairs etc. This burial is carried out by a Remotely Controlled Vehicle (ROV), which buries the cable to the same target depth as the main lay plough but by use of water jetting. At pipeline crossings, due to pipelines often being situated proud of the seabed, further protection to the cable and pipeline is normally made by means of a post lay rock placement operation.

Potential UXO risks
Potential UXO risks are:
- Encountering UXO during the Pre Lay Grapnel Run and Route Clearance.
- Direct contact between a UXO and the cable plough during the installation of the cables.
- Movement of a UXO as a consequence of water jetting during the installation of the cables.
- Direct contact between a UXO and rocks during rock placement operations.
- Direct contact between a UXO and divers/ROV’s during inspections and as-built checks.

5.3. OPERATIONAL PHASE

The North Sea is a highly dynamic system. The action of the tides and the waves constantly move objects on the sea bed and over a period of time an area which was previously cleared may no longer be so. In 2011 a good example of the dynamic nature of the North Sea was shown when a WW2 1,000 lbs high explosive bomb was discovered lying against the side of the monopile base of a UK offshore wind farm under construction [27]. This bomb had clearly drifted towards the monopile from elsewhere. Another noticeable example is a torpedo being discovered in 2002, having drifted against a North Sea oil pipeline [27].

During the operational phase of the wind farm maintenance activities will be needed onwards. Intrusive activities may be conducted, e.g. cable laying and anchoring of working vessels. Because of the likelihood of a UXO drifting in an offshore wind farm (previously cleared), these intrusive activities may cause safety and exploitation risks.

Potential UXO risks

Potential UXO risks are:

- Direct contact between a UXO and jacks, anchors and/or suction anchors of vessels conduction maintenance operations.
- Direct contact between a UXO and dredging equipment and/or gravel or rock during the maintenance of scour protection.
- Direct contact between a UXO and divers/ROV's during inspections.

6. SPECIFIC CHARACTERISTICS OF THE WIND FARM ZONE

The Borssele wind farm zone is located at the southern border of the Dutch Exclusive Economic Zone (EEZ); 0.5 km from the Belgium EEZ. At the south east side of the wind farm zone the Belgian dedicated offshore wind zone is located. The surface of the wind farm zone is ~344 km^2, it is expected that the zone will be split up into four sites where four wind farms can be realized with a total capacity of 1,400 MW. The first two sites, for two wind farms with a total capacity of ~700 MW are expected to be tendered by the end of 2015.

At the South-East side of the wind farm zone a sand extraction area is located and at the east side the zone a pilotage zone is located. Anchoring areas and a shipping lane are located at the North side of the zone.

In this chapter provides the relevant characteristics of the wind farm zone for defining the UXO mitigation strategy (chapter 7) and the selection of appropriate survey techniques.

6.1. COMPETENT AUTHORITIES

The 'Ministerie van Infrastructuur en Milieu, Dienst Zee en Delta' is the competent authority regarding the public security. This authority needs to approve the project plan according to the applicable regulation [34].

For the industrial safety the Dutch Working Conditions Act is applicable. The 'Inspectie SZW' (Labour Inspectorate) is responsible for the enforcement of the legislation.

The royal Dutch Navy is responsible for the removal of all UXO encountered. If any UXO are encountered they must be reported to the Coast guard. Removal of reported UXO will generally take up to about a week, depending on the priority given and the availability of Mine Counter Measures Vessels.

6.2. SPECIFIC CHARACTERISTICS OF THE WIND FARM ZONE

In Table 6 the specific characteristics of the Borssele wind farm are specified.

Characteristics	
Water depth	≈16 to ≈38 m
Distance from shore	22.2 km (12 nm)
Surface area (incl. safety zone)	344 km^2

Table 6: Characteristics of the Borssele wind farm zone

6.3. WATER DEPTH AND SAND BANKS

A bathymetric survey was conducted. This survey shows that within the Borssele wind farm zone several sand banks are present. The sand banks are visible in light green in Figure 24. The height of the sand banks is about 20 meters [24].

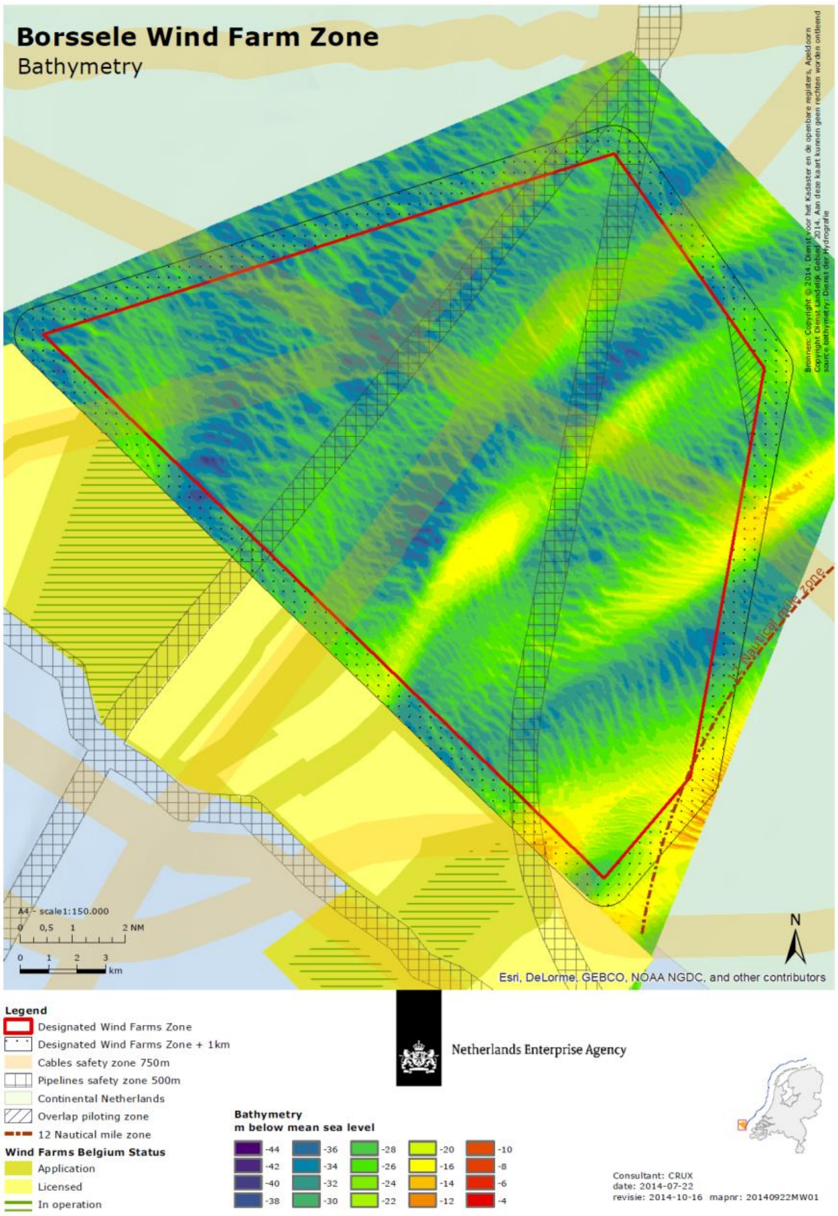


Figure 24: Bathymetry Borssele wind farm zone [24]

The sand banks in the North Sea slowly travel north with speeds reaching a maximum of approximately 20 meters a year [23]. The actual mobility of the sand banks in the Borssele wind farm zone is unknown. It is recommended to assess the mobility of sand waves (banks and ridges) by comparing current bathymetry results with historic data, as the (in) mobility of the sea bed largely dictates feasibility of foundation types and cable trenching, therefore wind farm development [26]. The outcome of this assessment is of great importance for a clearing operation in the area. Because of the movement of sand waves UXO can be buried underneath a thick layer of sand (see paragraph 6.6).

The minimal depth in the area is approximately 16 meters. The maximum depth is about 38 meters. This means that in case divers are needed for the clearance a decompression tank is needed.

6.4. Tidal streams

The average tidal streams during average weather conditions (wind south-west force 3 to 4) reaches speeds up to 1,2 kts (1,9 kts at spring tides) [25].

The given speeds of tidal streams are the average calculated speeds. The actuals speeds depend upon a large number of variables. Therefore the actual speeds may be higher than the calculated speed.

Depending on the wave height, water depth, visibility, experience of the divers, type of activities, etc. diving within tidal waves must be taken into account.

6.5. Geology

In general the Borssele wind farm zone comprises of an area of Pleistocene and Holocene sands in the top 10 to 40 meters, which includes large sand banks of about 20m height, underlain by stiff clays.

The areas in the North-West as well as the smaller area in the South-East seem homogeneous, but any further discretization of the Borssele zone is not possible, due to lack of critical information. As a result, a preliminary site investigation is proposed to be performed.

6.6. Burial of UXO on impact

Any object will descent at a steady velocity water depth dependant. Burial on impact typically depends on the type of sediment and its associated “sheer strength”.

Due to the present water depths the burial on impact is considered to be minimal. The kinetic energy of air dropped UXO (bombs) will be totally adsorbed by the water. When UXO reach the seabed they won’t have sufficient energy to penetrate the seabed.

Critical factor in the process of “mine burial” is surface wind causing waves and turbulence of the water volume [33].

Due to the travelling of sand banks UXO can be buried underneath several meters of sand. Since World War I and II sand dunes may have travelled up to 2,000 meters. The sand banks have heights up to 20 meters.

Therefore the possibility must be taken into account that UXO are present at depths beneath the seabed outside the detection range of survey equipment.

6.7. Existing infrastructure

The wind farm zone is crossed by several in-use cables / pipelines. Further, several abandoned cables/pipelines run through the Borssele area. Figure 2 (page 13) shows the Borssele wind zone and infrastructure crossing the zone.

Burial depth, if any, is unknown at this stage and would need to be thoroughly documented.

In case detection is conducted the disruptive effect of the cables / pipelines on the detection data must be taken into account. The disruptive influence will occur up to 20 meters distance of the cables / pipelines.

6.8. WRECKS, WRECK REMAINS AND FOUL AREA'S

Within the Borssele wind farm zone eleven known wrecks, remains of wrecks and/or foul areas are known. These wrecks, remains of wrecks and/or foul areas are listed in Table 7. In the vicinity another twenty-four wrecks and/or foul areas are known.

Wreck no.	Geographical coordinates (ETRS89)		Name	Specification
	Degrees N	Degrees E		
1703	51,61167	2,97833	Alca Torda	Belgian trawler, further details unknown
1714	51,68333	2,86833	Unknown	Details unknown
1723	51,70167	3,01000	Unknown	Least depth by sounding 26,5 m
1738	51,75667	3,02667	Unknown	Least depth by sounding 23,5 m
3644	51,72333	2,84833	Unknown	Remains of wreck or other foul area, no longer dangerous for navigation but to be avoided by vessels anchoring, trawling, etc.
3645	51,73167	2,85667	Unknown	
3646	51,76167	2,90000	Unknown	
3657	51,63167	3,08833	Unknown	Remains of wreck or other foul area, no longer dangerous for navigation but to be avoided by vessels anchoring, trawling, etc.
3658	51,61167	3,02167	Unknown	
3666	51,69000	2,96667	Unknown	
3671	51,72500	3,08500	Unknown	

Table 7: Known wrecks and/or foul areas in the Borssele wind farm zone

In case detection is conducted the disruptive effect of the wrecks, wreck remains and/or foul areas on the detection data must be taken into account.

7. OUTLINING THE UXO MITIGATION STRATEGY

Because the Borssele wind farm zone was located in the middle of the flight path of Allied bombers and the fact that several minefields were present and mines were encountered within the wind farm zone, the entire location must be considered a UXO risk area.

The possible presence of UXO in the area, however, is no constraint for offshore wind farm related activities. With proper UXO Risk Management the risks can be reduced to a level that is as low as is reasonably practicable (ALARP).

7.1. ALARP

The possible effects of a detonation of a UXO on vessels, equipment, wind farm structures and personnel (including divers) form an intolerable risk. The likelihood of a detonation of a UXO is low to medium, but the consequence/harm is high to severe. This means mitigation measures are needed to reduce the risks to a tolerable level.

The duty in health and safety law is to eliminate the risk if possible or reduce it to a level that is ALARP. This recognises that it may not be possible or reasonable to search for, or remove or make safe every device within a total construction area, however it is essential to consider whether the actions taken are sufficient, taking into account the cost, time and effort required to reduce any further, the risk of harm to people. If such costs, time and effort required are grossly disproportionate to any risk reduction achieved then they may be deemed as 'not reasonably practicable'.

The level of ALARP can only be determined during the design and engineering phase of the wind farm development. Fine-tuning of the UXO Risk management strategy based on the design is needed. If not, there is the potential for the risk to either be set too low, exposing the project to physical risk and delay, or too high, and then developers may incur significant costs for unnecessary investigation. Figure 25 shows the ALARP triangle to illustrate the risk mitigation principle.

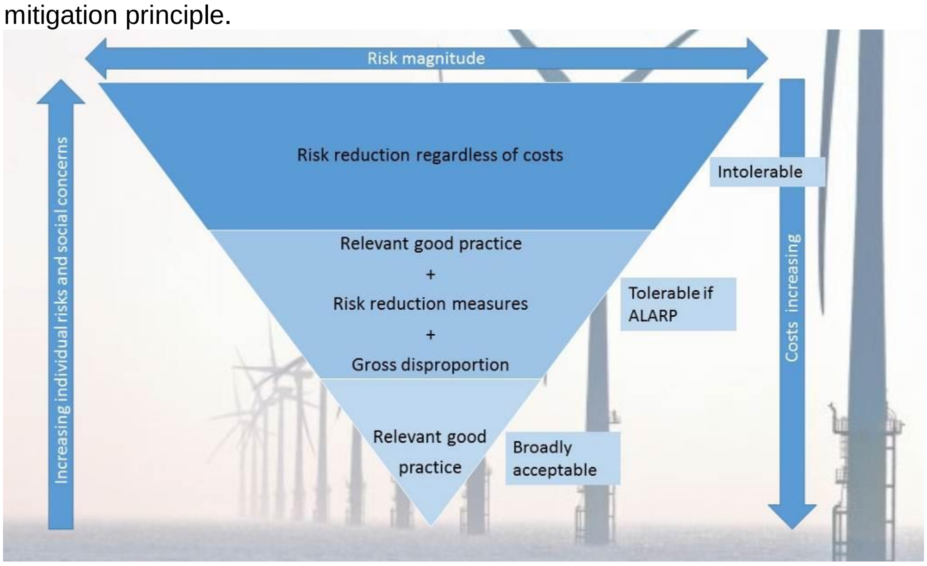


Figure 25: ALARP triangle

The required actions will presumably consist of search and safe removal of UXO, training of personnel and deployment of safe working protocols.

7.2. PREPARATION PHASE

During the preparation phase site investigations (geophysical and geotechnical investigations and metocean measurements) will be conducted in order to provide future commercial developers to prepare a competitive subsidy bid for the Borssele wind farm zone.

Although this report gives the general outline of the UXO threat for wind farm development the character and extent of present anomalies (magnetic objects and therefore possible UXO) remains unknown for the time being.

7.2.1. Geophysical survey

It is recommended to conduct a non-intrusive geophysical (bathymetrical) survey consisting of at least:

- Multibeam echo sounder;
- Sidescan sonar.

The multibeam echo sounder generates high quality and high resolution data of the seabed. This data is will be used for morphologic research and assessment of the movement of sand dunes. The side scan sonar must be able to identify objects > 1m. The data generated with side scan sonar is used to identify objects, debris, debris fields and wrecks. Optional the additional conduction of sub bottom profiler can be considered.

The collected data needs to be reviewed by a team of experts. After review of the data a dedicated UXO survey plan can be drawn up (see paragraph 7.3). Due to the highly dynamic nature of the seabed it is of main importance to minimize the time lapse between the geophysical survey and the execution of the dedicated UXO survey. Due to tidal streams, the mobility of sand waves and the use of the seabed (e.g. fisheries) the validity of the collected data is limited in time.

It's recommended to provide this UXO-Desk Study to the contractor of the geophysical survey. An awareness training (or kick-off meeting) before conducting the survey is also to be recommended.

7.2.2. Geotechnical investigations

Because the burial depth of UXO is unknown in this phase of wind park development, it may not be possible to guarantee a safe working environment by non-intrusive magnetometer survey on its own. This means the risk of a detonation during the geotechnical survey (CPT's, bore holes and sample grabbling) cannot be mitigated.

Therefore it is recommended to conduct an intrusive and/or non-intrusive survey (depending on the local conditions and burial depth of UXO) at each CPT/bore hole and sample location. Suitable techniques are for example magnetometer based surveys (non-intrusive), CPT with magnetometer cone (intrusive), Pulse Induction Metal Detectors (non-intrusive). In case an anomaly is detected it is recommend to move the location of the CPT/bore hole or sample to a location that is free of anomalies. In this case clearance operations in the preparation phase can be avoided.

According to the applicable regulation, the minimum requirement is to have all personnel, directly involved in UXO-search and removal projects, to hold a certificate "Basic OCE". This certificate assures that all personnel is properly trained and aware of the safety regulations involved with UXO-clearance. Therefore it's recommended to train and certify the personnel involved with the geotechnical investigations to the level "Basic OCE"

7.2.3. Metocean measurements

During the metocean measurements potential UXO risks occur. To constrain this risks an awareness training (or kick-off meeting) before conducting the measurements is to be recommended.

As regards the Met mast installation, intrusive activities will be conducted. Before installation, the area effected by the intrusive activities has to be cleared from UXO. The clearance operations have to be conducted by a certified EOD-company (see paragraph 7.6).

7.2.4. Research into mobility of sand waves

It is highly important to assess the mobility of sand waves (banks and ridges) by comparing current bathymetry results with historic data. Thereafter the effects of the mobility of sand waves on the burial depth of UXO need to be determined. Subsequently the effects of the determined burial depth on the risk assessment and survey possibilities must be assessed. A dedicated UXO survey plan (see paragraph 7.3) can only be drawn up after the maximal burial depth of UXO is determined[2].

7.2.5. Research into the origin of wrecks, wreck remains and foul area's

There is a possibility wrecks need to be removed in order to construct the wind farm. From most wrecks, wreck remains and foul areas specific information lacks. It is recommended to investigate the known wrecks to gather additional information. This information is relevant for the removal of the wrecks/wreck remains and the UXO risk assessment. For wreck removal the possible presence of UXO always has to be taken into account. The geophysical survey may provide important data on the locations of wrecks and wreck remains.

7.3. EXECUTION PHASE

In this UXO-Desk Study the design and engineering is considered to be part of the execution phase. The reason for this assumption is that the design and engineering is the responsibility of the commercial participating in, or winning the subsidy tender.

7.3.1. Design and engineering

It is recommended to reassess the UXO related risks based on the first draft of the design for the wind farm. Possibly adaptations in the design can be made to mitigate a part of the risks. For the remaining (intolerable) risks a detailed UXO risk mitigation strategy needs be worked out.

The required risk mitigation actions will include search and safe removal of UXO within a further to assess part of the wind farm zone. The size of the survey area will be determined in the detailed UXO mitigation strategy.

[2] Mine burial is a process of multiple parameters and quite complex. Therefore it is recommend to estimate the burial depth based on the assessment of the mobility of sand waves.

Prior to the search operations the development of a detailed dedicated UXO survey has is recommended. The information gathered during the geophysical survey is to be used as input for the survey plan.

Because the validity of the collected data (geophysical survey) is limited in time, it's recommended to minimize the time lapse between the survey and the execution of works.
The UXO survey plan needs to address the following subjects:

- the elevation differences of the seabed;
- the maximal burial depth of UXO;
- the types and calibres of UXO (e.g. German GC naval mines, with limited ferromagnetic materials);
- locations of wrecks and wreck remains;
- elements and objects disruptive to the UXO survey data such as cables and pipelines;
- Etc.

7.3.2. Execution

It is recommended to conduct the UXO search and removal operations at short notice prior to the construction activities. The validity of the collected magnetometer survey data in regards to tidal streams, mobility of sand waves and seabed usage has to be taken into account when planning the survey and construction operations. Time lapse between project phases has to be limited as much as possible.

7.4. Operational phase

Because of tidal streams, mobility of sand waves and seabed usage the possibility that UXO are moved within the wind farm zone after completion of the construction activities has to be taken in to account.

Therefore it is recommended to write a maintenance and monitoring plan. This plan needs to provide safe working protocols for future maintenance operations and a monitoring strategy. To constrain this risks an awareness training (or kick-off meeting) before conducting maintenance operations is also recommended.

7.5. General outline of the UXO Risk mitigation strategy

UXO Risk mitigation is a staged process, consisting of 5 sequential phases. The level and extent of activities in each following phase will generally depend upon the findings of the preceding phase. For example, the extent of activities needed to be able to provide a UXO risk sign of to ALARP, can only be estimated after reassessment of the UXO mitigation strategy in regards to the design of the wind farm and a dedicated UXO survey and review of the data. This makes UXO risk management projects particularly hard to manage. Therefore a phased approach is needed. This approach is aimed at decreasing the amount of project management risks (especially time and money) in each following phase of the UXO risk management process. Figure 26 shows the wind farm development phases in comparative to the UXO Risk Management phases. This report consists of the phases 1 and 2 of the UXO risk management phases.

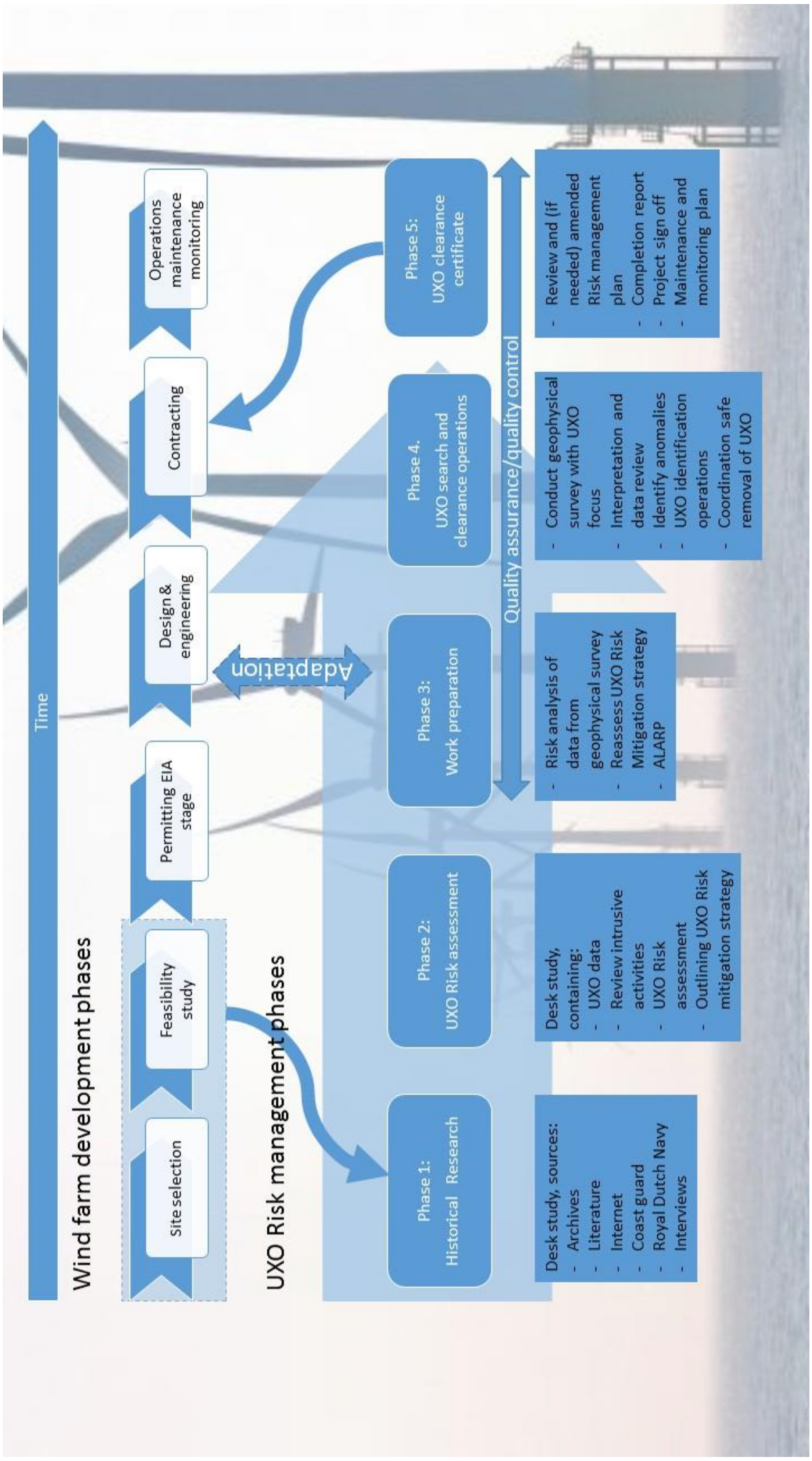


Figure 26: General outline UXO risk mitigation strategy Borssele wind farm zone

7.6. REGULATION AND STANDARDS

The applicable regulation on all EOD-operations is the “Werkveld Specifiek Certificatie Schema – Opsporen Conventionele Explosieven (WSCS-OCE)” [34]. According to the WSCS-OCE all EOD-companies must be certified for ‘scope A’ and/or ‘scope B’. A scope a certified EOD-company is responsible for all UXO search and clearance operations. A ‘scope B’ company can be responsible for supporting the operations on the level of civil engineering.

<u>Minimal standards EOD-personnel [34]</u>
The minimal standards for EOD-personnel are:
- Senior OCE-expert level UXO-clearance certificate (UXO-Supervisors);
- OCE-expert level UXO-clearance certificate (UXO-divers).

<u>Minimum standards for other personnel [34]</u>
According to the WSCS-OCE the minimum requirement is to have all personnel, directly involved in UXO-removal projects, to hold a certificate “Basic OCE”. This certificate assures that all personnel is properly trained and aware of the safety regulations involved with UXO-clearance.

<u>Minimum dive standards</u>
The International Marine Contractors Association (IMCA) is the international trade association representing offshore, marine and underwater engineering companies [35]. IMCA guidelines and standards are applicable to the offshore industry. Though not mandatory, use off the IMCA guidelines and standards is advised.

All divers have to comply with the Dutch certificate B [36].

8. REFERENCE DOCUMENTS

[1] Nationaal Waterplan 2009-2015, december 22nd 2009
[2] Ontwerp-Rijkstructuurvisie Windenergie op Zee, december 2013
[3] Beleidsnota Noordzee 2009-2015, december 22nd 2009
[4] Bijstands- en bijdrageregeling opgeviste explosieven, november 2009
[5] Digitaal Verliesregister Studiegroep Luchtoorlog 1939-1945
[6] http://www.kustwacht.nl/nl/explosieven.html
[7] http://beschermeenwrak.nl/wrakkenkaart/
[8] En Nooit was het Stil. Kroniek van een Luchtoorlog (2 dln. & supplement), zonder datum
[9] http://www.wingstovictory.nl
[10] http://www.geschiedeniszeeland.nl/
[11] http://en.wikipedia.org/wiki/Naval_mine
[12] The Response of Surface Ships to Underwater Explosions. DSTO-GD-0109, september 1996
[13] VS 9-861, Voorschrift Opruimen en Ruimen van Explosieven, 29th september 2010
[14] TNO-rapport Beveiligd 'baggeren Maas, stuwpand Sambeek', 11th may 2012
[15] http://en.wikipedia.org
[16] http://www.navalhistory.net
[17] http://www.loc.gov
[18] http://newswatch.nationalgeographic.com
[20] Excel file with since april 2005 encountered UXO (scource: Duik en Demonteergroep)
[21] Chemical munition dump sites in coastal environments, 2002
[22] http://www.ahctv.com
[23] http://www.natuurinformatie.nl
[24] 20141016_SDB_RVO_Borssele_CRUX_Bathymetry_A4_20140922MW)v2
[25] HP33, Waterstanden en stromen 2014, 2014
[26] Rapport [RE14254a3], Windpark Borssele Geological desk study, 23-07-2014
[27] Unexploded Ordnance Risk, Considering Unexploded Ordnance Risk on and around the British Isles, 27-04-2011
[28] Laws of War: Laying of automatic submarine contact mines (Hague VIII), 18-10-1907
[29] www.navitusbaywindpark.co.uk
[30] Site Studies Wind Farm Zone Borssele, offshore wind development, construction and operations, 29-08-2014
[31] www.mumm.ac.be
[32] HP 39, Wrakkenregister, Nederlands continentaal plat en Westerschelde, 2014
[33] Storm influence on the burial of objects in a shallow sandy shelf environment, 2014
[34] Staatscourant 2012 nr. 4230, 16 maart 2012
[35] IMCA International Code of Practice for Offshore Diving, February 2014
[36] Arbeidsomstandighedenregeling, artikel 6.3, 01-01-2007

Annex 1 Overview war related events

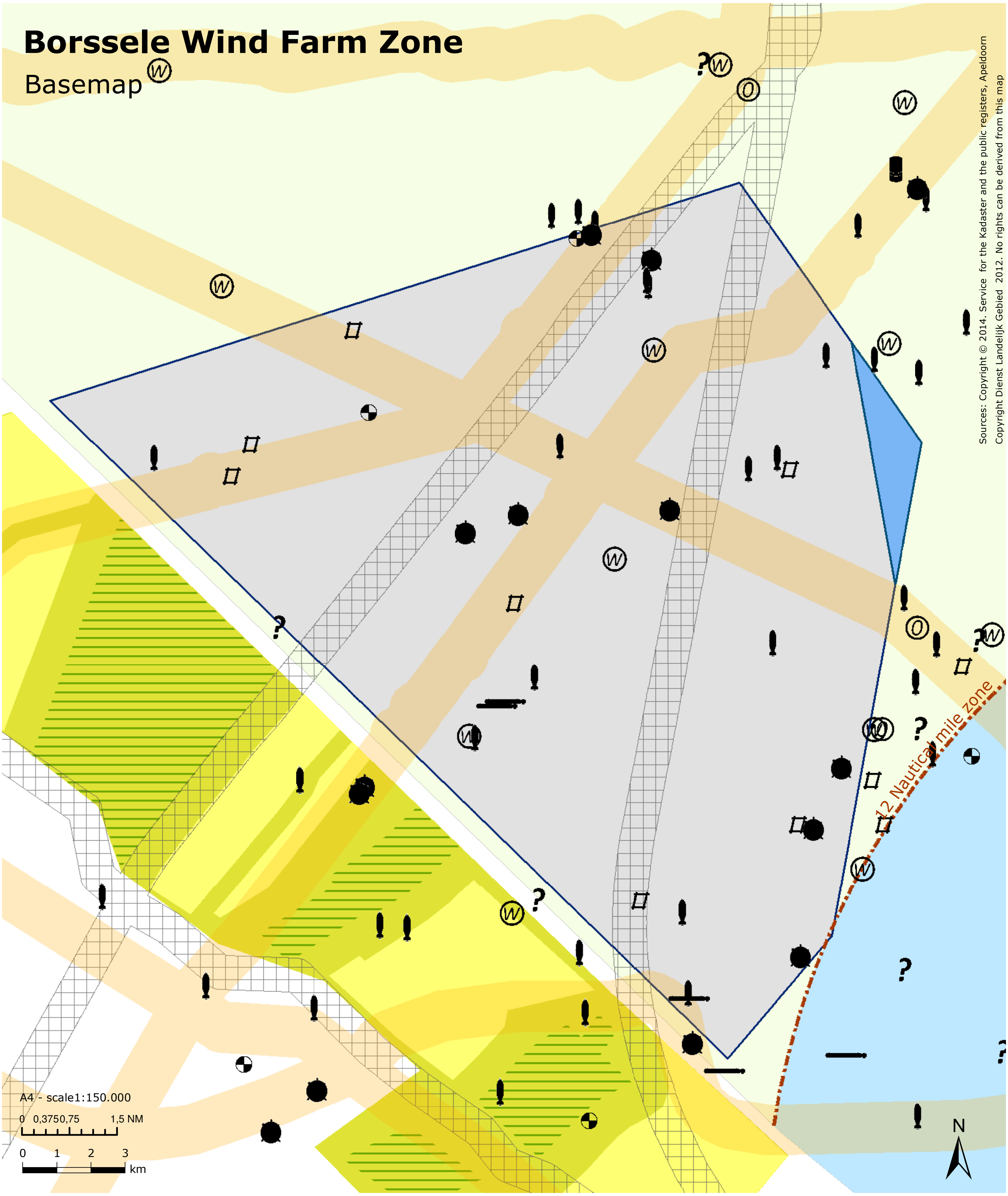
Annex 2 Dictionary Wind op Zee

Dutch	English
De Nederlandse overheid	The Dutch Government
Rijksdienst voor Ondernemend Nederland	Netherlands Enterprise Agency
TenneT	The national electricity transmission system operator TenneT (TSO)
Energieakkoord voor duurzame groei	Energy Agreement for Sustainable Growth
Nationaal Waterplan	National Water Plan
Kavel	Wind farm site
Windgebied	Wind farm zone
Windgebied Borssele	The Borssele wind farm zone
Windgebied Zuid-Hollandse Kust	The South Holland coast wind farm zone
Windgebied Noord-Hollandse Kust	The North Holland coast wind farm zone
tender (inschrijving)	call for tender
subsidie	grant
subsidiebeschikking	grant decision
beschikken	to grant
Kavelbesluit	Wind farm site decision
Wet Windenergie op Zee	Offshore Wind Energy Bill
Flora en fauna wet	Dutch Nature Conservation Act
Netbeheerder op zee	Offshore grid operator
De Nederlandse Exclusieve Economische Zone	The Dutch Exclusive Economic Zone (EEZ)
Beloodsingsgebied	pilotage zone
Milieu Effect Rapportage	Environmental Impact Assessment
MER	EIA
Notitie Reikwijdte en Detailniveau	Memorandum Scope and Level of Detail
Passende beoordeling	Appropriate assessment
Vergunningen (concreet, 1 specifieke vergunning)	Permit
Vergunningen (algemeen, ook: formele toestemmingen en ontheffingen)	Consent
Vergunning verleend	Consented
geofysische studie	geophysical study
geotechnisch onderzoek	geotechnical survey
Technische projectbeschrijving	technical project description
Sondeertest	Cone Penetration Test (CPT)
kabel naar vaste land	export cable
kabels binnen windpark	in field cables OR inter array cables
gondel	nacelle
fundering	foundation
rotorbladen	rotor blades
mast	tower
officiële publicaties	official notices
bodemonderzoek	soil investigations
Ministeriële regeling	Ministerial regulation
SDE+	stimulation of sustainable energy production
basisbedrag	base amount (ook wel strikeprice genoemd)
basisenergieprijs	base energy price (ook wel floor genoemd)
correctiebedrag	correction Amount
voorlopig correctiebedrag	provisional correction amount
in aanmerking komen (voor subsidie)	eligible

Colophon
Netherlands Enterprise Agency
P.o. box 8242
3503 RE Utrecht, Netherlands
T +31 (0) 88 042 XX XX
E …@rvo.nl
www.rvo.nl
www.###.nl

Date of publication
This is a publication realized for the Ministry of Economic Affairs

Mission text
Netherlands Enterprise Agency (RVO.nl) is an agency of the Dutch Ministry of Economic Affairs. Netherlands Enterprise Agency implements policy for various ministries in to the areas of sustainability, agricultural, innovation and international business and cooperation. Netherlands Enterprise Agency is the contact point for businesses, knowledge institutions and government bodies. For information and advice, funding, networks and legislation and regulations.



Legend

Wind Farm Belgium Status (situation 2014)
- Application
- Licensed
- In operation

- Territorial sea
- Exclusive Economic Zone of the Netherlands
- Cables safety zone 750m
- Pipelines safety zone 500m
- Overlap piloting zone
- 12 Nautical mile zone
- Designated Wind Farm Zone

Cleared UXO
- Bomb
- Depth charge
- Naval mine
- Torpedo
- Unknown

Wreck locations
- Obstruction
- Remains
- Unknown
- Wreck

Consultant:
date:
revision: 2014-12-09 mapnr: 20141209MW01

Location TenneT platforms, safety zones export cables and helicopter approach routes not yet included
This geographical information is based on the data available on October 28th 2014.
Updates will be made available on www.rvo.nl

This website is managed by the Netherlands Enterprise Agency, an agency of the Dutch government concerned with international business and cooperation. Whilst a great deal of care has been taken in compiling the contents of this site, the Agency can not be held liable for any damages resulting from any inaccuracies and/or outdated information.

Contacts
Netherlands Enterprise Agency (RVO.nl)
Croeselaan 15 | 3521 BJ | Utrecht
P.O. Box 8242 | 3503 RE | Utrecht
www.rvo.nl / http://english.rvo.nl

Netherlands Enterprise Agency (RVO.nl) | December 2014