Netherlands Enterprise Agency

UXO Desk Study
-Unexploded Ordnance-

Ten noorden van de Waddeneilanden Wind Farm Zone

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Document title: UXO Desk Study – Unexploded Ordnance

Document subtitle: Site Data Ten noorden van de Waddeneilanden (TNWWFZ)

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Project ID RVO.nl: WOZ2180092
Number of pages: 87 pages

Version	**Approved for public disclosure by contract manager RVO.nl**	**Approved for public disclosure by project manager offshore wind RVO.nl**
Final	**Name** Cynthia Mors **Signature** **Date** 23 July 2019	**Name** Ruud de Bruijne **Signature** **Date** 2019-07-24

UXO Desk Study

Unexploded Ordnance

Ten Noorden van de Waddeneilanden Wind Farm Zone (TNW WFZ)

73458 / RO-190129
July 12th, 2019

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UXO Desk Study

Unexploded Ordnance

Ten Noorden van de Waddeneilanden Wind Farm Zone (TNW WFZ)

Client	:	Rijksdienst voor Ondernemend Nederland
Reference	:	73458 / RO-190129 version 1.0 Final version
Place, date	:	Riel, July 12th, 2019
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SUMMARY

This unexploded ordnance (UXO) desk study is part of the site data on the Ten Noorden van de Waddeneilanden Wind Farm Zone. This UXO desk study consists of a historical research and a UXO risk assessment.

Historical research

The Ten Noorden van de Waddeneilanden Wind Farm Zone (TNW WFZ) and its surrounding areas were the scene of several war related events during World War I and World War II. Among these are the major German convoy routes which traversed the WFZ and the presence of minefields during both World Wars. Due to these events the entire TNW WFZ is to be considered a UXO risk area. The UXO items considered most likely to be present within the investigation area are shown in the overview below. Note that the overview shows the expected likelihood of presence of generic UXO types within the site based on the evidence gathered about potential UXO sources.

UXO type	Likelihood of presence	Subtype / calibre	Remarks
Allied aerial bombs	Probable	Ranging from 4 lbs up to and including 4,000 lbs	Research shows that at least one allied airstrike took place in the area of investigation. Given the presence of convoy routes in the area of investigation more airstrikes may have taken place. Beside airstrikes, allied aircraft often jettisoned bombs over the North Sea. Not many direct indications have been derived from the historical sources, but indirect indications are plentiful.
Naval mines	Certain	WWI: Mark I, Mark II and Mark III contact mines (UK) WWII: EMC and EMD contact mines (German), A Mark I-IV and A Mark V ground mines (UK)	The area of investigation is situated in the larger German Bight area, which was a major theatre of mine warfare during both World Wars. The sheer number of naval mines and the rudimentary methods with which they were swept after the war, leads to the conclusion that the evidence of the presence of naval mines is indisputable.
Artillery shells	Feasible	20 mm up to and including 8.8 cm	German ships passing through the area of investigation are known to have fired on allied aircraft on at least two occasions. The intensity of flak fire, which is tantamount to more modern 'spray and pray' tactics, may have led to the presence of artillery shells of common flak calibres in the area of investigation.

Table 1: UXO items likely to be encountered in the WFZ.

SAMENVATTING

Deze studie is onderdeel van de site data voor het windgebied Ten Noorden van de Waddeneilanden. De bureaustudie bestaat uit een historisch vooronderzoek en een risicoanalyse.

Historisch vooronderzoek

In het windgebied Hollandse Kust (west) en de omgeving daarvan hebben zich in de Eerste en de Tweede Wereldoorlog diverse oorlogshandelingen voltrokken. Zo liepen belangrijke Duitse konvooiroutes door het onderzoeksgebied, en zijn zowel in de Eerste als in de Tweede Wereldoorlog mijnenvelden in en rond het onderzoeksgebied gelegd. Ten gevolge van deze oorlogshandelingen moet het gehele gebied als verdacht gebied worden beschouwd. De soorten Niet Gesprongen Explosieven (NGE) die mogelijk zijn achtergebleven zijn weergegeven in onderstaande tabel. Opgemerkt wordt dat in de tabel de waarschijnlijkheid van aanwezigheid van de verschillende soorten NGE is weergegeven. Deze waarschijnlijkheid is gebaseerd op het verzamelde historische feitenmateriaal.

Soort NGE	Waarschijnlijkheid van aanwezigheid	Subsoorten en kalibers	Opmerkingen
Geallieerde vliegtuigbommen	Waarschijnlijk	Van 4 lbs tot en met 4,000 lbs	Historisch onderzoek wijst uit dat minimaal één luchtaanval plaatsvond binnen het onderzoeksgebied. Gezien de Duitse konvooiroutes door het onderzoeksgebied kunnen meer aanvallen niet worden uitgesloten. Naast intentionele aanvallen werden ook noodafworpen uitgevoerd boven de Noordzee.
Zeemijnen	Zeer waarschijnlijk	WOI: Mark I, II en III Britse contactmijnen (GB) WOII: EMC en EMD contactmijnen (Duits), A Mark I-IV en A Mark V grondmijnen (GB)	Het onderzoeksgebied is gelegen in de Deutsche Bucht, een belangrijk strijdtoneel van beide wereldoorlogen. Het grote aantal mijnen en de rudimentaire veegmethoden van na de oorlogen leiden tot de conclusie dat zeer waarschijnlijk zeemijnen aanwezig zijn.
Geschutmunitie	Aannemelijk	20 mm tot en met 8.8 cm	Duitse schepen die het onderzoeksgebied passeerden hebben tenminste twee maal met boordgeschut geallieerde vliegtuigen onder vuur genomen. De intensiteit van het vuur en de hoeveelheid verschoten munitie leidt tot de conclusie dat mogelijk NGE van geschutmunitie in het onderzoeksgebied zijn achtergebleven.

Table 2: NGE die mogelijk zijn achtergebleven in het windgebied Hollandse Kust (west).

1 GENERAL INFORMATION

The Netherlands Ministry of Economic Affairs has requested "The Netherlands Enterprise Agency" (RVO.nl) to prepare and collect site data for the development of offshore wind farms in the Ten Noorden van de Waddeneilanden Wind Farm Zone (TNW WFZ). In this context The Netherlands Enterprise Agency (RVO.nl) 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, the purpose, and main objectives are detailed.

1.1 TEN NOORDEN VAN DE WADDENEILANDEN WIND FARM ZONE (TNW WFZ)

TWN WFZ is situated 56 km from the Frisian Island of Schiermonnikoog. This desk study deals with the western part of the WFZ, situated approximately 60 km north of Terschelling and Ameland. The investigation area as indicated by RVO.nl is shown in Figure 1. The investigation borders an existing wind farm.

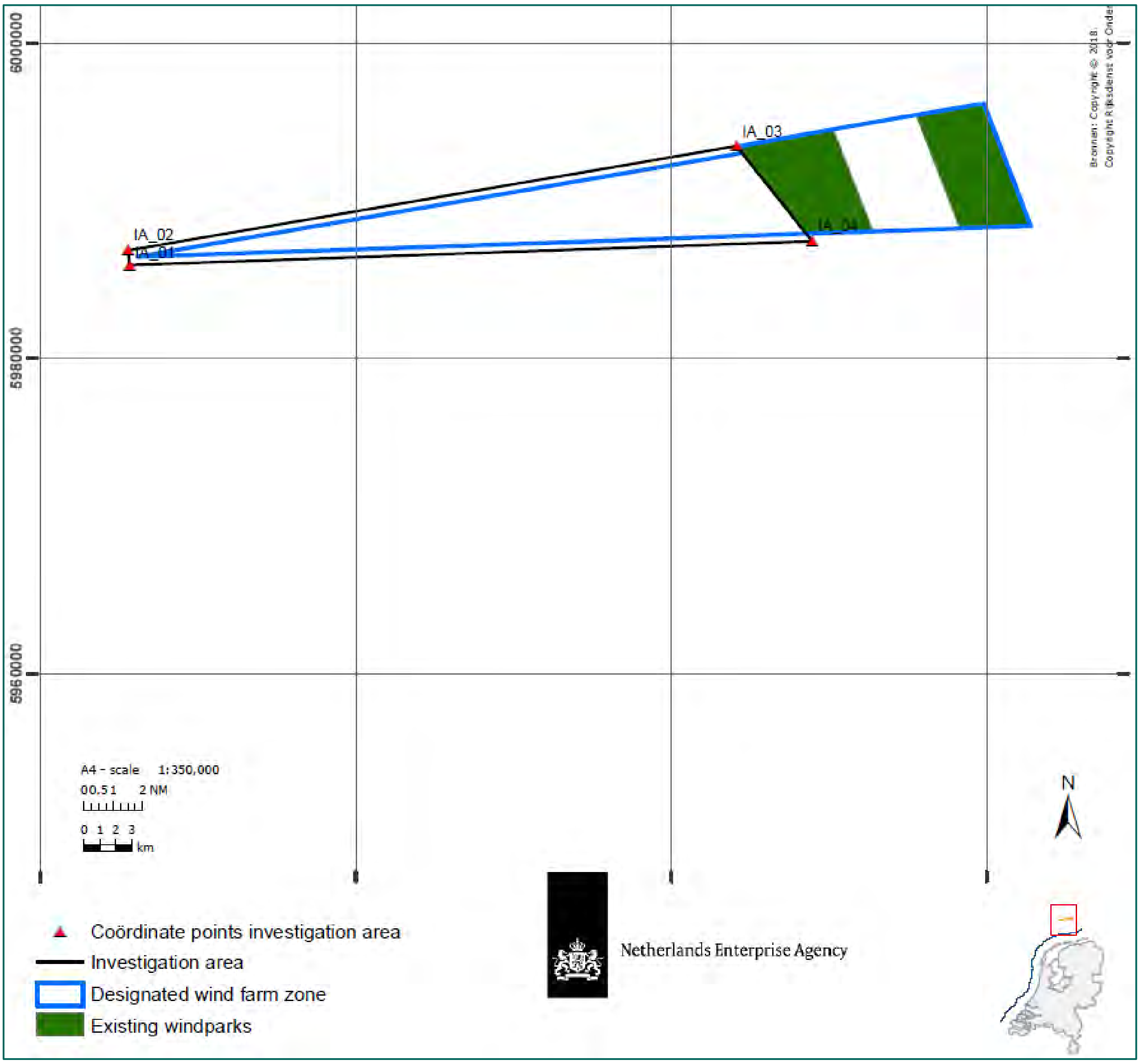

Figure 1: TNW WFZ, as indicated by RVO.nl.

1.2 WORKING AREA AND AREA OF INVESTIGATION

The investigation area is mentioned as the 'working area' in this report, as future development works will take place in this area. The area of investigation also includes a buffer area of 5,000 meters around the working area. This buffer is necessary to gain full insight in the working area during the First and the Second World War.

The given buffer is based on the inaccuracies inherent to conducting offshore desk research. The positions of naval minefields, air strikes and crashes and convoy routes in historical sources are given only rudimentary, since navigation equipment was not nearly as accurate as its contemporary counterparts. The most common method of noting locations during the World Wars was based on decimal degrees, which were accurate down to 1 naval mile (1.852 meters). Another way of noting positions is found in German sources, which are based on the German Naval Grid (*Kriegsmarine Quadranten*), with a grid size of 6x6 naval miles. Historical sources based on this grid thus position war related events in an area of 123 square kilometers.

Besides these inherent inaccuracies from historical sources, one must take into account the displacement of UXO on the sea bed. Bottom trawling and recent developmental activities may have caused this displacement. The working area and the area of investigation are shown in the figure below.

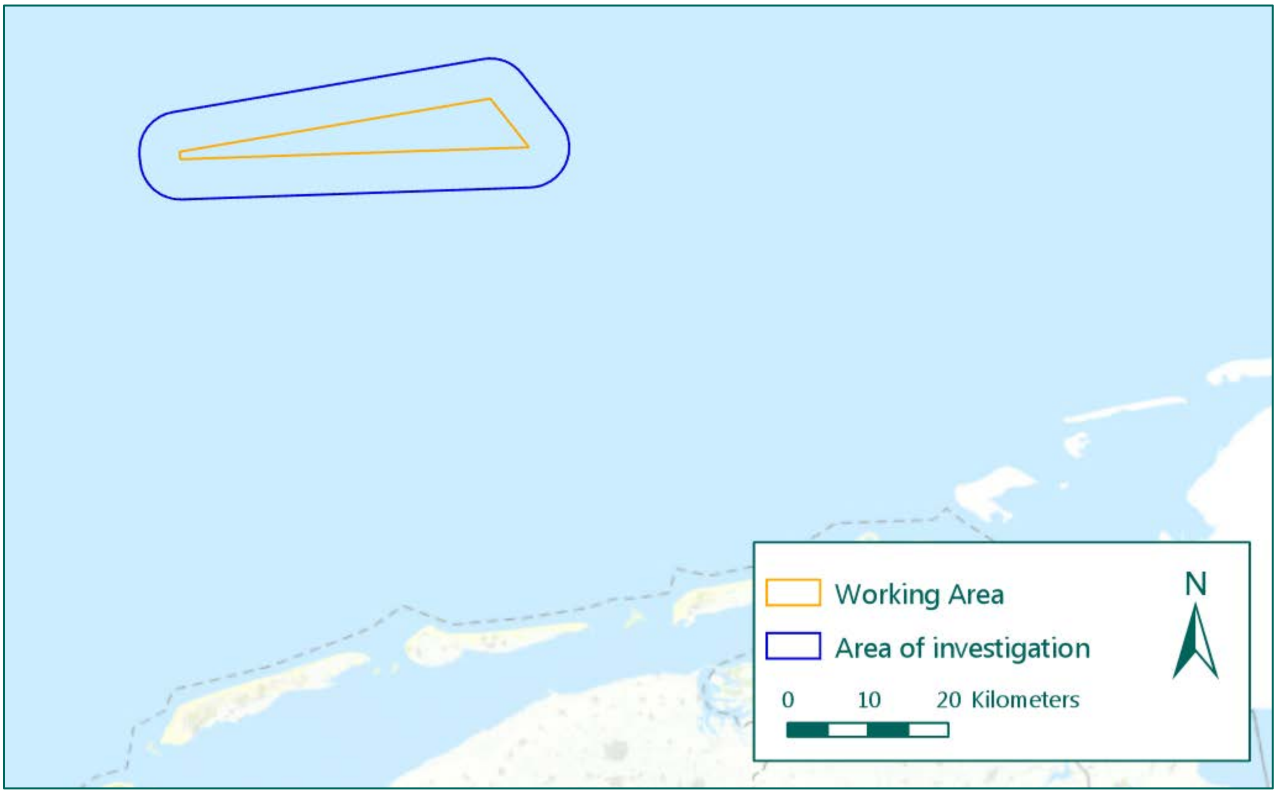

Figure 2: Working area and area of investigation (Source of base map: ESRI).

1.3 PURPOSE AND MAIN OBJECTIVES

The purpose of the UXO desk study is to detail the areas within the TNW WFZ which present an increased risk of encountering unexploded ordnance (UXO).

The main objectives of this study are:

1. Identification of possible constraints for offshore wind farm related activities in the TNW WFZ as a result of the possible presence of items of UXO.
2. Identification of areas within the TNW WFZ that may be avoided when considering the layout of offshore wind farms and/or cables.
3. Identifying the requirements from an 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. Installation of wind turbine foundations.
    d. Installation of cables.

1.4 STRUCTURE OF THE REPORT

This report describes phase I (historical research) and phase II (UXO risk assessment) of the UXO risk management process. These phases are rendered within the red highlighted area within Figure 3: UXO risk management phases.. The full UXO risk management process is also described in Figure 3 (see annex 2 for a larger image). The execution of the following phases of the UXO risk management process is the responsibility of the future developer.

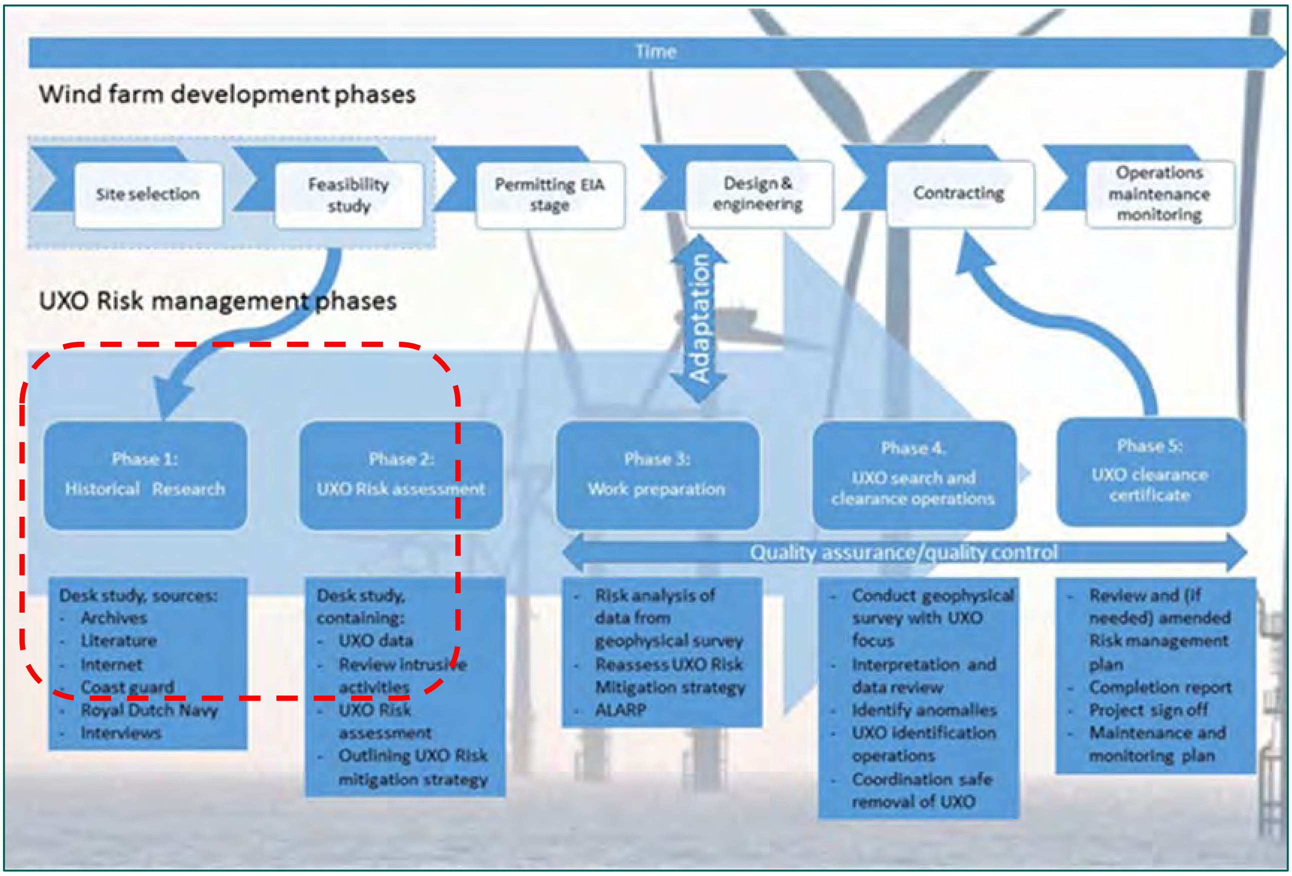

Figure 3: UXO risk management phases.

This UXO desk study exists of two main parts, according to phase I and phase II of the UXO risk management process. Each part contains specific detailed chapters. An overview of the chapters in each part is given in Table 1. A glossary of terms, additional figures and the elaboration of consulted sources are included within the annexes.

Phase of the UXO risk management	Chapters
Phase I: Historical research	- Chapter 2: Appraisal of historical sources - Chapter 3: Analysis of war related events - Chapter 4: Gaps in knowledge and UXO risk area
Phase II: UXO risk assessment	- Chapter 5: UXO burial assessment - Chapter 6: UXO migration assessment - Chapter 7: Hazards of UXO likely to be encountered - Chapter 8: Effects of detonations - Chapter 9: Intrusive activities - Chapter 10: UXO risk assessment - Chapter 11: Outlining the UXO mitigation strategy - Chapter 12: Geophysical survey methodologies - Chapter 13: Threshold levels to be applied

Table 1: Phases of the UXO risk management and related chapters in this report.

2 METHODOLOGY AND HISTORICAL SOURCES

This chapter describes the consulted sources. Detailed information extracted from each source is included within the annexes. Information extracted from the sources, results in an overview of relevant war events. These events are the starting point for the review and analyses of sources in chapter 3 of this historical research.

2.1 METHODOLOGY OF HISTORICAL RESEARCH

This research report is conducted in accordance with the Dutch WSCS-OCE regulations for UXO research and REASeuro's internal standards for offshore desk top studies. War related events that took place in the area of investigation are derived from historical sources, and subsequently analysed. Based on this analysis a UXO risk area may be demarcated.

The WSCS-OCE regulations are mostly applicable to land-based research. This desk top study thus departs from these regulations when necessary. Examples in which the WSCS-OCE cannot be applied are the demarcation of risk areas, obligated sources and interpretation of aerial photography. In these cases, REASeuro's own internal standards are applied.

The research has been conducted by a historian / UXO advisor, a GIS-specialist, a civil technician and a Senior UXO expert. Page 1 of this report mentions the involved experts. ArcGIS Pro version 2.3.2[1] has been used as a tool to conduct this research. Historical maps and other information have been gathered and projected in this geographical information system for analysis. GIS is also used to position and clarify the relevant war related events mentioned in the list of war related events in paragraph 2.3.

2.2 SOURCES

The following table shows the obligated sources according to the WSCS-OCE regulations, and the sources consulted for this DTS.

Source	Obligated according to the WSCS-OCE	Consulted for this DTS
Literature	□	■
Dutch archives		
Municipal archives	□	N/A[2]
Provincial archives	□	N/A
Nederlands Instituut voor Militaire Historie (NIMH)		■
NIOD Instituut voor Oorlogs-, Holocaust- en Genocidestudies (NIOD)		N/A
Nationaal Archief (NA)		■
Explosieven Opruimingsdienst Defensie (EOD) • UXO clearance reports • Minefield map collection • MMOD[3]-archives	 □ □ □	 N/A N/A N/A
Collections of Aerial Photography		
Wageningen University library	□	N/A
Kadaster Topographical Department (Zwolle) • Aerial photography collection • Allied military map collections	□	N/A
The National Collection of Aerial Photography (NCAP, Edinburgh)		N/A
Luftbilddatenbank (Estenfeld)		N/A
International archives		
The National Archives (London, UK)		■

[1] Mentioned as 'GIS' throughout this report.
[2] Not applicable sources are exclusively relevant for land-based research, and have thus not been consulted.
[3] MMOD was the Mine and Munitions clearance service, one of the predecessors of EOD.

Source	Obligated according to the WSCS-OCE	Consulted for this DTS
Bundesarchiv-Militärarchiv (Freiburg, DE)		■
National Archives and Records Administration (College Park (MD), US)		■
Library and Archives Canada (Ottawa, CA)		N/A
Sources specific to offshore research		
Royal Netherlands Navy Hydrographic service		■
Dutch Coast Guard		■
Map collection of the Dutch Navy Museum		■
Noordzeeloket		■
UK Hydrographic Office		■
Other sources		
Crash Database of the Studiegroep Luchtoorlog 1939-1945		■
Cultural Heritage Agency of the Netherlands		■

Table 2: Consulted sources.

Literature

An overview of used literature can be found in annex 3. A variety of local, national and international books were consulted. These books have been studied for descriptions and events which might be relevant to the area of investigation. The resulting events are shown in chronological order in the tables in annex 3. The references (book and page) for each event are included in the tables.

Crash Database

The Dutch Air War Study Group 1939-1945 (Studiegroep Luchtoorlog 1939-1945) maintains an online database of all military airplane losses in the Netherlands during WWII. This record is checked and the results are presented in Annex 3.

Nederlands Instituut voor Militaire Historie (NIMH) in Den Haag

The NIMH is the institute for military history of the Dutch armed forces. This institution maintains several archives concerning Dutch military history. The Collection 035: Volkers (coastal mines) and 092: Navy Mongraphy have been checked for any relevant events in the area of investigation. Research in the NIMH did not yield relevant results.

Nationaal Archief (NA) in The Hague

The Dutch National Archives have been consulted for more information on the dumping of explosives, naval minefields and minesweeping, shipwrecks and other relevant information for the area of investigation. Annex 4 contains the relevant information from the National Archives.

Post-war UXO clearance: Coast Guard and OSPAR

The area of investigation is situated in the North Sea, 12 Nautical Miles off the Dutch coast. Therefore, the UXO-related interventions of the Coast Guard [4] and the database of the OSPAR Commission[5] were consulted. No munition clearance activities are shown in these databases.

The National Archives (TNA) in Londen

The National Archives have been consulted for information on naval minefields, air strikes, naval combat, bomb jettisons and other relevant war related events. The Admiralty, War Cabinet and Air Ministry archives have been consulted for this information. Annex 5 contains relevant results from TNA.

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[4] The Royal Netherlands Navy keeps a detailed registration on UXO encounters in the Dutch and Belgian part of the North Sea. The registration provides information on UXO encounters since 2005.

[5] The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR-convention) provides a framework for reporting encounters with conventional and chemical munitions in the OSPAR maritime area.

Bundesarchiv-Abteilung Militärarchiv (BAMA) in Freiburg

The German military archives were severely damaged during World War II. What remains of the archives is kept and maintained in the Bundesarchiv in Freiburg. The archives of the German navy (*Kriegsmarine*) survived the war relatively well compared to the other service branches. These have been consulted for this desk top study, as well as the German Air Force (*Luftwaffe*) archives, from which only 2% of the documents survived the onslaught of the war. Annex 5 contains the relevant information from the BAMA.

National Archives and Records Administration (NARA) in College Park (MD)

Research has been conducted in the US National Archives and Records Administration. The NARA has been consulted for documents from the US Army Air Forces (USAAF) and for the collection of captured German records.

Noordzeeloket

The Noordzeeloket contains information on military usage of the North Sea, and has thus been consulted for information on the area of investigation. This yielded no relevant results.

Royal Netherlands Navy Hydrographic service

This has been consulted for recent naval charts of the area of investigation. These naval charts show wrecks and other obstructions on the seabed. Information on wrecks has also been derived from the wreck register (HP39). Annex 7 contains information from the Hydrographic Service.

Cultural Heritage Agency of the Netherlands

The Cultural Heritage Agency has been consulted for more information on wrecks and explosives encountered during archeological research. To gain this information, REASeuro has access to the Archis (archeological information system) which contains archeological finds, studies and areas of interest. Consulting Archis yielded no relevant results.

UK Hydrographic Office

The UK hydrographical office maintains a collection of historical naval charts, including charts that contain minefields and convoy routes. Naval charts showing the area of investigation have been consulted and are shown in Annex 6.

Marinemuseum, Den Helder

The Navy Museum ('Marinemuseum') holds a collection of Royal Netherlands Navy maps and charts. The collection includes maps of post-war minesweeping operations. The relevant information is added in Annex 6.

Navy Museum, Den Helder

The Navy Museum ('Marinemuseum') holds a collection of Royal Netherlands Navy maps and charts. The collection includes maps of post-war minesweeping operations. The relevant information is added in Annex 4.

2.3 WAR RELATED EVENTS

The consulted historical sources (see Annexes) indicate several war related events within the area of investigation. The following table shows the war related events derived from the historical sources. A primary analysis divides the events between events considered relevant and not relevant for the area of investigation. Relevant events are subsequently referred to a paragraph for further analysis.

Event		**Historical sources**			**Primary analysis**	
Date	Details	Literature	Dutch archives	International archives	Relevant?	Paragraph
1914-1918	The German and British laid numerous minefields in the German Bight. Over the course of WWI, multiple naval mines washed up on the coasts of Ameland and Terschelling. The mines were, without exception, British Mark I, II and III contact mines.	CRO BEZ 1, SCHE	NA, 2.12.18-275	BaMa, RM5-4721K, TNA, ADM 234/561	Yes, indications of WWI minefields in the area of investigation.	3.4.1
27 December 1915	The Dutch fishing vessel Y.M.88 sank after hitting an allied mine.		NA, 2.05.32.09-44.		Yes, mine hit just south of the area of investigation.	3.4.1
1939-1940	The Royal Dutch Navy laid minefields to protect vital shipping lanes against German aggression.	BUR			No, no indication of Dutch interbellum minefields in the area of investigation.	-
September 1939	German minelayers placed minefield C3 with EMC contact mines in the area of investigation.			BaMa, ZA 5-44	Yes, indication of a minefield in the area of investigation.	3.4.2
1940-1945	Allied bombers traversing the North Sea jettisoned bombs in the water over the entire course of the war.			THAN, AIR 14/110	Yes, indication covering the entire North Sea.	3.2.3
	Several German convoy routes crossed the area of investigation over the course of the war.			UK Hydrographic Office, OCB MO 6590 TNA ADM 234/561	Yes, convoy routes were considered a target by allied air forces and navies.	3.1
28 May 1940	One Hudson attacked four stationary MTBs, 50 km North of Terschelling.	ZWA 1			No, location is not sufficiently known.	-
27 March 1941	Aerial mining ("Gardening Field") 'Nectarines' was commissioned, encompassing the entire area between the river Elbe en Terschelling. The area was extended further seawards in 1942, becoming the heaviest mined garden in the North Sea.			TNA, ADM 234/560, ADM 234/561, BaMA, ZA5/27	Yes, indication of minefield containing British aerial mines around the area of investigation.	3.4.2
28 June 1941	Short Stirling bomber crashed 60 kilometers north of Terschelling.	ZWA 1			Yes, possible crash in the area of investigation.	3.3
28 September 1941	The freighter 'Aspe' sank north of Ameland after setting off a British aerial mine.	ROW			Yes, indication of the presence of British aerial mines near the area of investigation.	3.4.2

Event		Historical sources			Primary analysis	
Date	Details	Literature	Dutch archives	International archives	Relevant?	Paragraph
14 June 1942	The freighter 'Taiwan' sank after setting off a British aerial mine north of Ameland.	ROW			Yes, indication of the presence of British aerial mines near the area of investigation.	3.4.2
July 1942	Minefield C3 was partially swept by German minesweepers.			BaMa, ZA 5-44	Yes, minesweeping is not equal to mine clearance. Mines may be left at the seabed after clearance.	3.4.2
16 October 1942	A Coastal Command Bristol Beaufighter reported a floating mine in the area of investigation.			TNA, AIR 25/342	Yes, indications of minefields in the area of investigation.	3.4.2
30 November 1942	A Coastal Command Bristol Beaufighter reported a floating mine in the area of investigation.			TNA, AIR 25/343	Yes, indications of minefields in the area of investigation.	3.4.2
2 February 1943	A Coastal Command Bristol Beaufighter spotted a convoy in the area of investigation, and was subsequently fired upon by the ship's flak.			TNA, AIR 25/346	Yes, indications of fire contact between surface vessels and aircraft in the area of investigation.	3.2.1
26 February 1943	Coastal Command Beaufighter was fired upon by German armed trawlers in the area of investigation.			TNA AIR 25/346	Yes, indications of fire contact between surface vessels and aircraft in the area of investigation.	3.2.1
19 July 1943	The Swedish steamer 'Vidar' sank after setting off a mine north of Terschelling.	ROW			Yes, indication of the presence of British aerial mines near the area of investigation.	3.4.2
27 July 1943	A Dornier 24 flying boat was shot down by a British Beaufighter 36 miles north of Ameland	ZWA 1		TNA, AIR 25/351	Yes, dogfight and possible crash in the area of investigation.	3.3
26 September 1943	German minesweepers of the 1st Security Division clear an English aerial mine			BaMa, RM67-12	Yes, indication of the presence of British aerial mines near the area of investigation.	3.4.2
October 1943	Minefield C3 was definitively swept by German minesweepers.			BaMa, ZA 5-44	Yes, minesweeping is not equal to mine clearance. Mines may be left at the seabed after clearance.	3.4.2
18 July 1944	Coastal Command aircraft attacked radar contact in the area of investigation.			TNA, AIR 25/363	Yes, attack on shipping in the area of investigation.	3.2.2
1945-1972	Multiple maps indicate the presence of a large 'mine danger area' around the area of investigation. The area is roughly similar to the 'Nectarines' garden.		NA, 2.12.56-955, Navy museum map collection		Yes, indications of WWII minefields still present after the conflict.	3.4.2

Event		Historical sources			Primary analysis	
Date	Details	Literature	Dutch archives	International archives	Relevant?	Paragraph
September 1946	Several mines washed up on the shore of Ameland and were subsequently destroyed by the Dutch Navy.		NA, 2.12.19-703		Yes, indications of WWII minefields North of Ameland.	3.4.3

Table 3: War related events.

3 ANALYSIS OF WAR RELATED EVENTS

The war related events that are considered relevant in paragraph 2.3 are analysed in this chapter. Objective of this analysis is to investigate whether UXO may be present in the working area as a result of these events. Based on the historical sources, there is evidence of the following war related events in the area of investigation:

- Airstrikes on shipping
- Wrecks of ships and aircraft
- Naval minefields

A short background is provided in order to gain more understanding of the events during World War I and World War II. The events are subsequently analysed, followed by a conclusion.

3.1 BACKGROUND

A major element of the allied forces strategy during World War I was an economic blockade of the German empire by the mass employment of naval forces. The German navy was to be confined to the North Sea, while the movement of merchant vessels had to be brought to a complete halt. The German Bight, in which the area of investigation is situated, was a major theatre in which this strategy was implemented by the mass deployment of naval mines.

The area north of the Frisian Islands was a major theatre of naval warfare during the Second World War. German convoy routes were situated closely to the islands, which offered sanctuary against the onslaught of allied air forces against German shipping during the day. The convoy routes were heavily mined, while allied aircraft attacked the convoys from the air whenever possible. German minelayers laid minefields outside the convoy routes to protect the routes against raiding British surface vessels. Another major aspect of this theatre of war were the flight routes crossing over the area of investigation. Thousands of light, medium and heavy bombers used flight routes over the area of investigation over the course of the war. Many bombers were forced to jettison their bombs in the water when damaged, chased by enemy fighters or when they were simply unable to land their plane with the payload still in the plane.

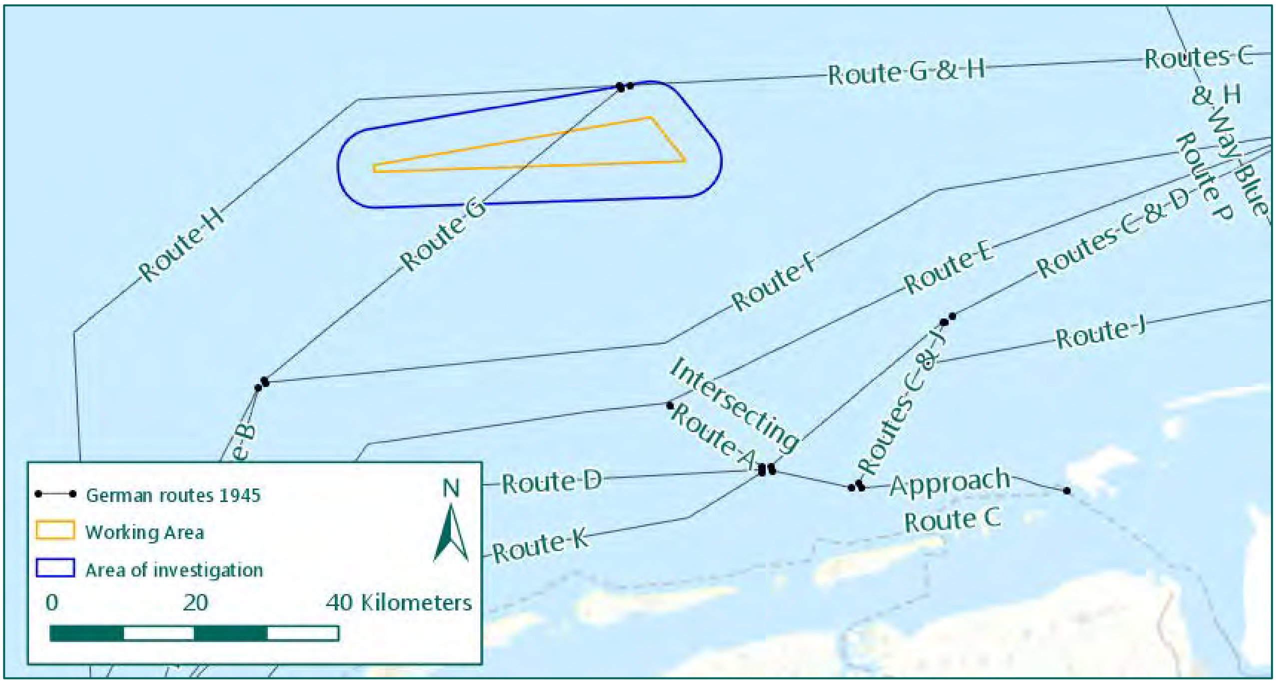


Figure 4: German convoy routes north of the Frisian Islands, situation 1945 (Based on UKHO, chart MO6590).

Warfare in the area of investigation, during World War I as well as during World War II, mainly revolves around the presence of strategically vital convoy routes. The following paragraphs analyse the consequences of the aerial attacks, wrecks and naval minefields in the area of investigation.

3.2 AERIAL WARFARE

Coastal Command and Bomber Command Operations Record Books (ORBs) of aerial warfare over the North Sea from between 1942 and 1945 are available to REASeuro. The ORBs from the period between 1940 and 1942 contain location references in cypher, which have only partially been decoded. According to these documents, several events related to aerial warfare took place in the area of investigation. RAF ORBs mention anti-aircraft artillery (AAA or flak) firing, airstrikes on shipping and jettisons by bombers. These events are analysed in the following paragraphs, followed by a general conclusion.

3.2.1 Anti-aircraft artillery

According to documents from 16 Group of Coastal Command (see Annex 5), responsible for coastal patrols roughly from the Channel to the Dogger Bank, patrolling aircraft were fired upon by German flak mounted on ships. On 2 February 1943, two coasters fired machine guns and AAA at two Coastal Command aircraft flying at low altitude. A similar event took place on 26 February, when a Bristol Beaufighter was engaged with fairly accurate flak by German ships. German ships were equipped with AAA of calibres ranging between 20 mm up to and including 8.8 cm.

3.2.2 Airstrikes

Of the airstrikes that may have taken place in the area of investigation, one can be positioned in the area of investigation with a sufficient degree of certainty. Coastal Command documents (see Annex 5) mention one airstrike that took place in the area of investigation. On 18 July 1944, a Vickers Wellington equipped with radar attacked a radar 'blip' with five 500 lbs *Medium Capacity* bombs from a height of 3,500 feet. No results were observed.

3.2.3 Jettisons

Several major allied flight routes crossed over the area of investigation (see Annex 5). Hundreds of allied light, medium and heavy bombers used these flight routes to navigate to targets in Germany. These bombers often experienced mechanical problems, attacks by German fighters or situations in which they were not able to drop their bombs on target. When these situations occurred, bombs were often jettisoned. While the policy was to jettison the bombs 'safe' as shown in the figure above, they were often dropped 'live'. Jettisons were only sporadically noted in the ORBs. When a jettison was noted in the ORBs, locations were often not mentioned, as shown in the figure below.

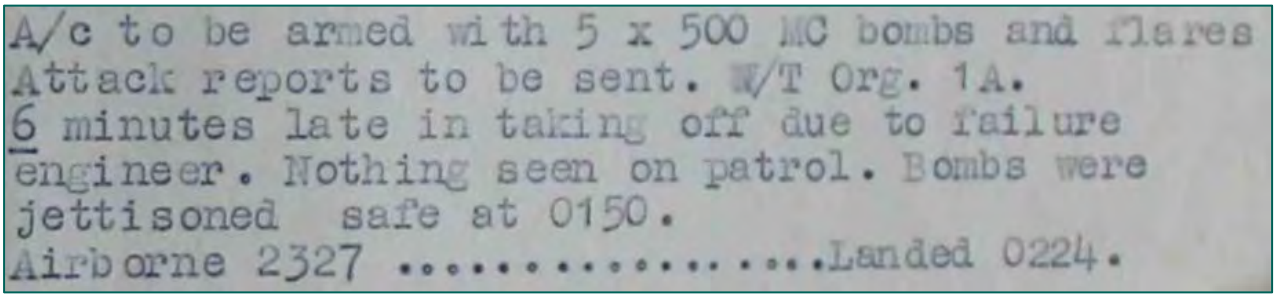

A/c to be armed with 5 x 500 MC bombs and flares
Attack reports to be sent. W/T Org. 1A.
6 minutes late in taking off due to failure
engineer. Nothing seen on patrol. Bombs were
jettisoned safe at 0150.
Airborne 2327 ....Landed 0224.

Figure 5: Jettison of bombs on an unknown location by Coastal Command on 28 April 1944 (Source: TNA, AIR 25/360)

Since a major accident with the OD-1 'Maarten Jacob' fishing trawler, in which an aerial bomb fell out of the net on the deck and subsequently detonated, the Dutch Coast Guards keeps track of munitions encountered offshore. Of the over 1.600 UXO encountered since 2005, approximately 60% were aerial bombs.

3.2.4 Conclusion

Several relevant incidents took place in the area of investigation. Flak fired on aircraft inside the area of investigation on multiple occasions, at least one airstrike was carried out against German shipping and there are indirect but plenty indications that jettisons may have taken place in the area of investigation.

3.3 WRECKS

The consulted sources mention the presence of wrecks and parts of wrecks of aircraft and ships in the area of investigation. The Wreck Register of the Royal Navy Hydrographic Service (HP39, see Annex 6) shows 11 wrecks and obstructions in the area of investigation, of which only two are known by name.

The consulted literature resulted in information on several ships sunk by naval mines. Exact locations of these ships are not mentioned, however. Beside ships, there are indications of a Short Stirling bomber shot down 60 kilometers north of Terschelling (see Annex 3). The location is not known by coordinate and cannot be positioned in the area of investigation with sufficient amount of certainty.

The ORBs of 16 Group Coastal Command mention the crash of a German Dornier 24 flying boat after a dogfight with a Bristol Beaufighter in the area of investigation on 27 July 1943. The Dornier was hit multiple times by the Beaufighter's cannon shells, after which it burst into flames and crashed into the sea. While the dogfight took place in the area of investigation, the crash location is not exactly known.

Figure 6: Dornier 24 in its original Luftwaffe markings (World War 2, colorized).

While several sources indirectly indicate the presence of wrecks in the area of investigation, no known wrecks can be related directly to war related events. It's possible that some of the wrecks and obstructions in the area of investigation are caused by these events. However, there is no concrete historical evidence available to proof this.

3.4 NAVAL MINEFIELDS

The historical sources indicate the presence of several minefields in the area of investigation. These minefields were laid during World War I and World War II. The minefields from these wars are analysed, followed by an analysis of the results of post-war mine clearance operations and a general conclusion.

3.4.1 World War I minefields

As described in paragraph 3.1, the German Bight was a major theatre of naval warfare during World War I. British forces laid 42.899 naval mines in the Bight, while three minor German minefields were laid around the area of investigation according to information derived from literature. This information is confirmed by archival documents from the German Bundesarchiv and The National Archives in the United Kingdom (see Annex 5). Many of these mines broke loose over the course of the war, ending up floating towards the beaches of the Frisian Islands. Dutch contemporary sources (see Annex 3 and 4) mention only English naval mines washing up the shores of the islands. This was not the only violation of Dutch neutrality during the First World War. On 27 December 1915, the Dutch ship Y.M. 88 sank after hitting a mine just south of the area of investigation. The Y.M. 88 was one of many Dutch civilian ships that sank because of allied and German mines.

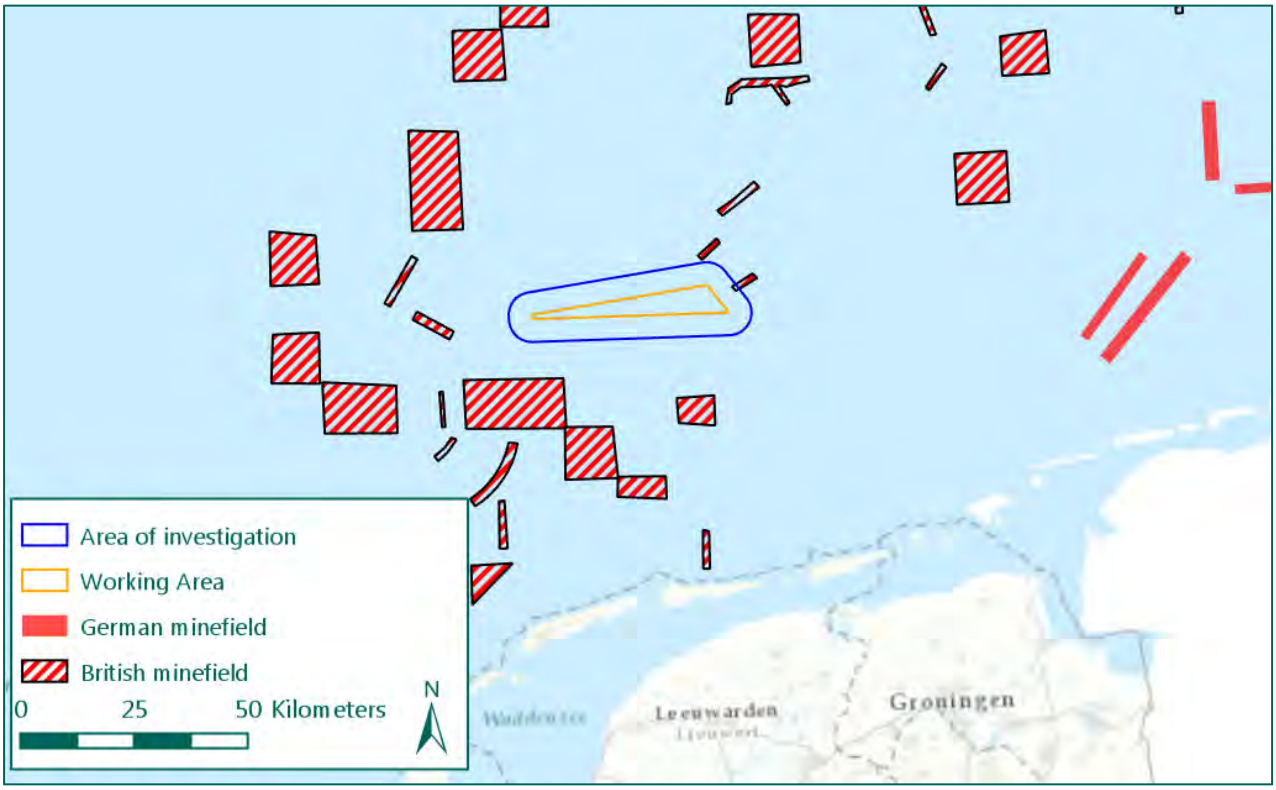


Figure 7: Positions of German and British minefields around the area of investigation (Source: Literature, SCHE 288).

3.4.2 World War II minefields

The area north of the Frisians was once again a theatre of mine warfare during World War II. British offensive minelaying was aimed against the plethora of German convoy routes passing through the German Bight, while the German Navy laid defensive minefields against allied ships intruding into the Bight. British minelaying was carried out by aircraft, while German minelaying was done by surface vessels.

The British aerial minelaying campaign was codenamed 'Gardening'. Minefields were given names of plants, flowers, vegetables, fruits and small animals. When the RAF mentioned planting nectarines, they laid mines in the area north of the Frisians. This major garden was authorized in March 1941 and incorporated all waters within the ten-fathom line between the Elbe River and Terschelling. The 'garden' was later extended further seawards. According to information from The National Archives and the Bundesarchiv, 12,072 A

Mark I-IV and A Mark V ground mines were planted by Bomber and Coastal Command in the garden and its proceeding gardens, Zinnia, Xeranthemum and Mussels. According to literature and British sources, the ground mines caused many German casualties. German documentation from the 1st Naval Security Division mention at least one cleared British aerial mine. The Nectarines mine garden is shown in Figure 8. Since the ground mines were notoriously hard to sweep, the area was declared a danger area until well into the 1960s.

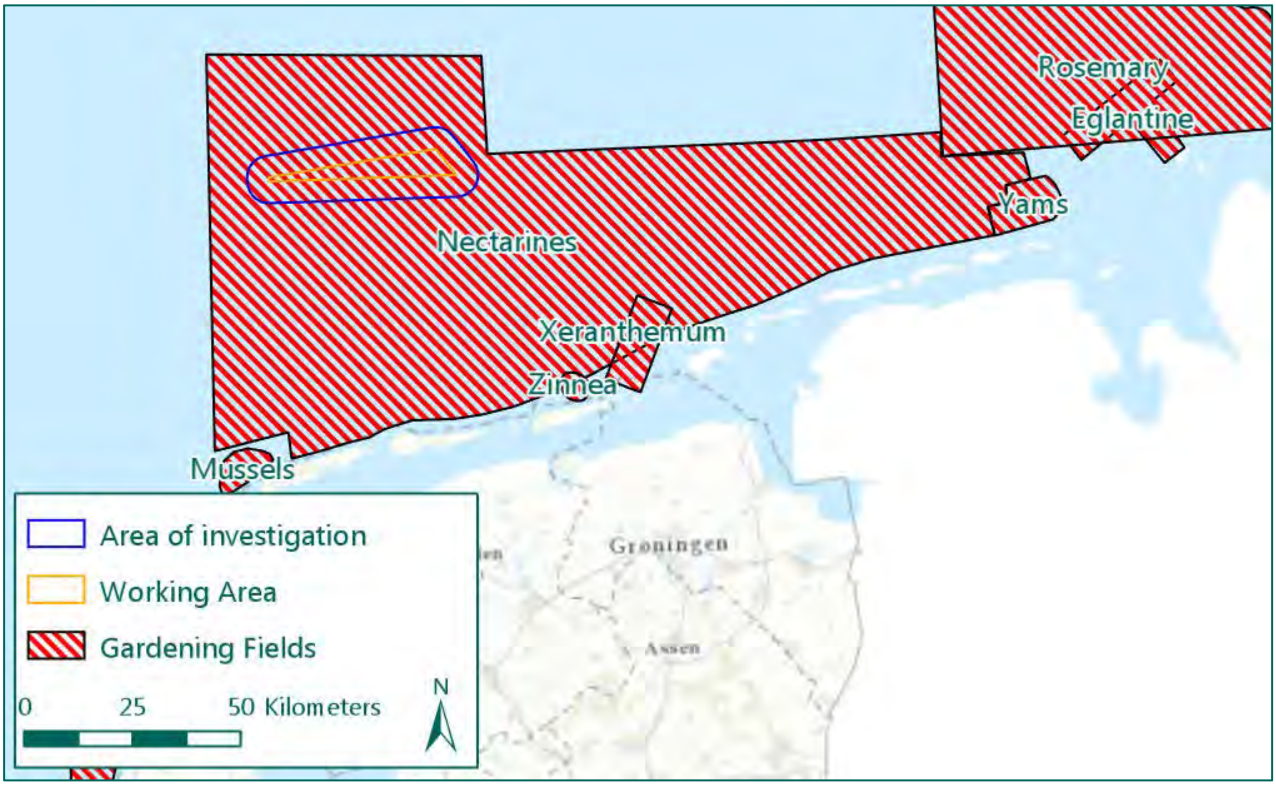


Figure 8: Nectarines mine garden and its predecessors Mussels, Xeranthemum and Zinnia (Source: TNA, ADM 234/561).

The German employed more ‘conventional’ minelaying north of the Frisian Islands. The minefields were defensive and almost exclusively contained moored contact mines of the EMC/EMD type. Surface vessels laid the fields shortly after the allied declaration of war against Germany in 1939. One minefield, coded C.3 in the post-war Summary of Enemy Minelaying (see Annex 5), intersects the area of investigation. The minefield contained 174 EMC and EMD mines, paired with 202 explosive floats. Accuracy of the minelaying was poor, resulting in an estimated inaccuracy of 1.5 miles. The field was partially swept in July 1942, with the remaining part being swept in October 1943.

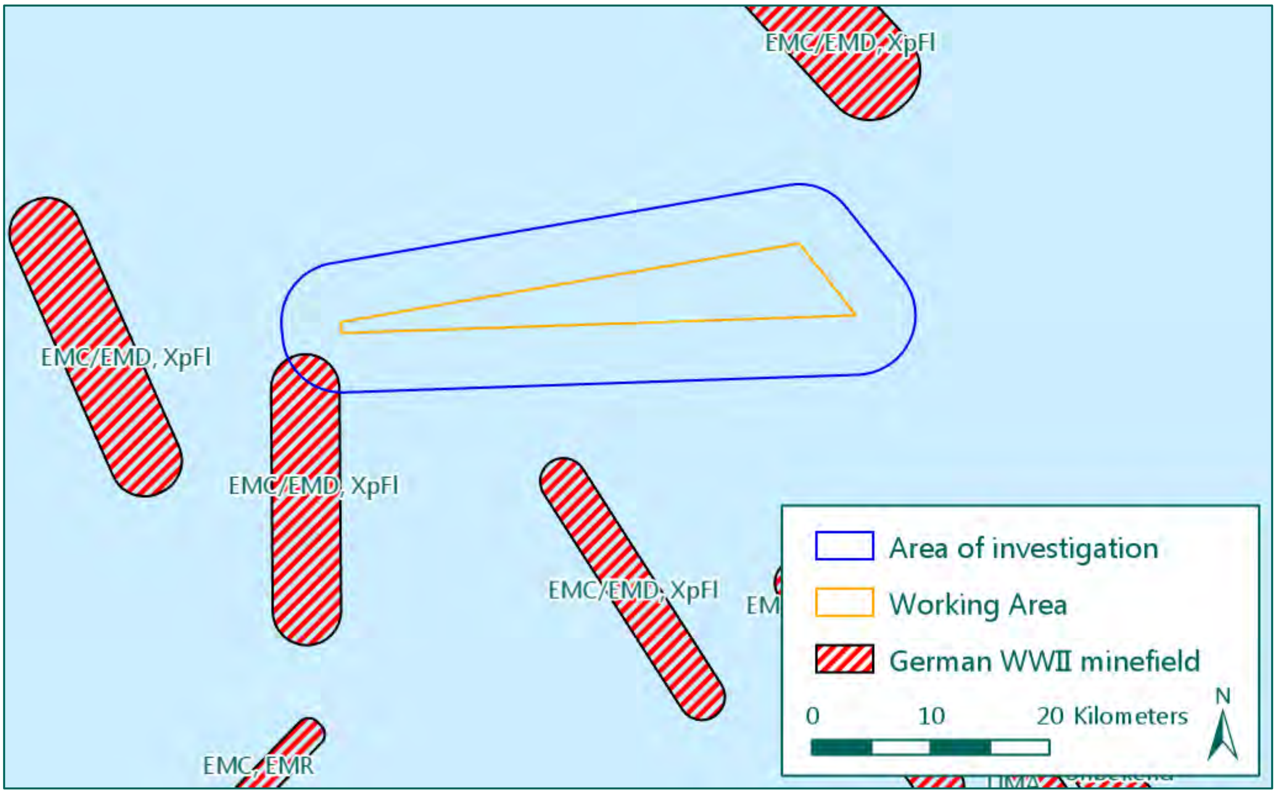
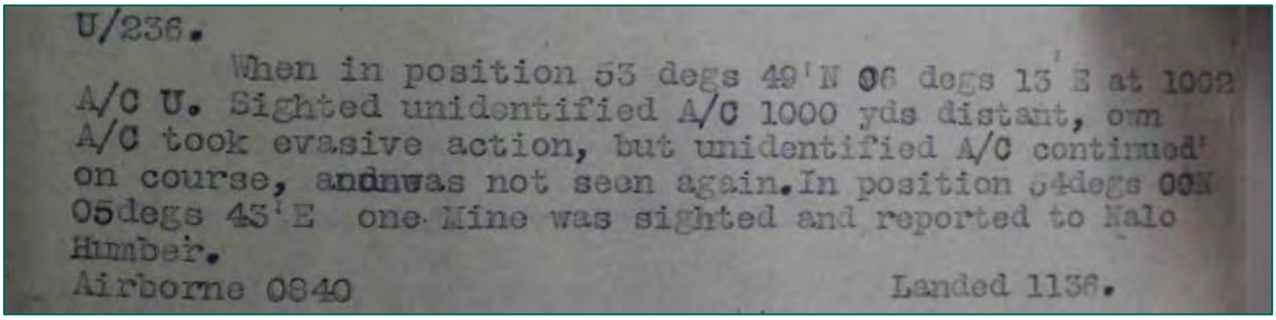


Figure 9: German minefields near the area of investigation (Source: BaMa, ZA 5/44).

Coastal Command patrol aircraft spotted several floating mines, according to the 16 Group ORBs. On 16 October and 30 November 1942, floating mines were spotted and reported to the Humber mine intelligence unit (see Annex 5).



U/236.
When in position 53 degs 49'N 06 degs 13 E at 1002 A/C U. Sighted unidentified A/C 1000 yds distant, own A/C took evasive action, but unidentified A/C continued on course, andnwas not seen again. In position 54degs 00N 05degs 43'E one Mine was sighted and reported to Nalo Humber.
Airborne 0840 Landed 1136.

Figure 10: Mine observation of 30 November 1942 (Source: TNA, AIR 25/343).

3.4.3 Postwar mine clearance

After World War I, a large effort was made to clear shipping lanes of naval mines. It took several months and a fleet of minesweepers to clear the mine fields. Sweeping was carried out by sweeping a cable with anchors below the water surface. The cable was dragged by two ships.

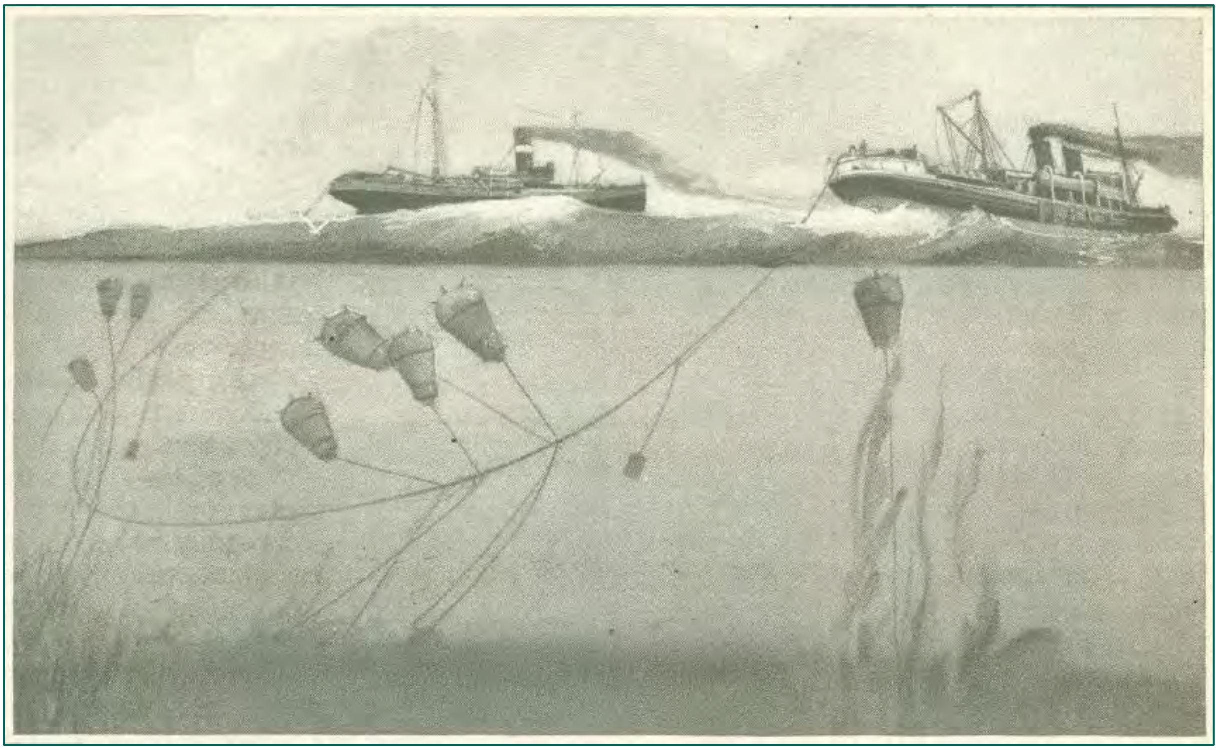


Figure 11: Post WWI-mine sweeping. (Source: http://www.digitalhistoryproject.com/2012/06/submarine-mines-in-world-war-i-byleland.html).

Mines also continued to pose a danger to shipping after World War II. In order to combat this threat, a large scale minesweeping campaign was set up. The area of investigation was situated in the Dutch sweeping zone. Charts of the Marinemuseum (see Annex 6) show that the entire area was a designated danger area. Minesweeping was conducted with a variety of methods. Moored mines were usually swept with Oropesa sweeping gear[6].

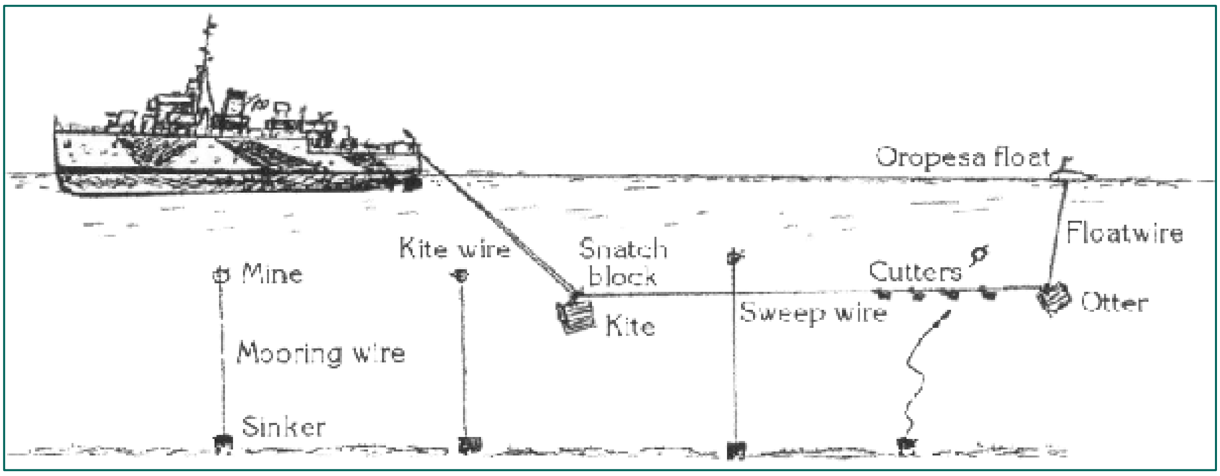


Figure 12: Oropesa sweeping (source: ‘The 'Art' of Minesweeping’, 27 May 2013, http://www.minesweepers.org.uk/sweeping.htm, consulted 6 December 2016).

The moorings of the mines were cut with cutters dragged on a wire behind a ship. Cutting the mooring wires/cables caused the mines to float to the surface, where the mines could easily be shot with cannon or rifle fire. Shooting the mines caused them to sink or to detonate. Ground mines were swept with acoustic hammer boxes, triggering the acoustic mines, or by magnetic sweeping gear to trigger magnetic mines.

[6] So named after the World War I trawler in which the technique was first developed. Till then all sweeping was done using two ships joined by a single wire.

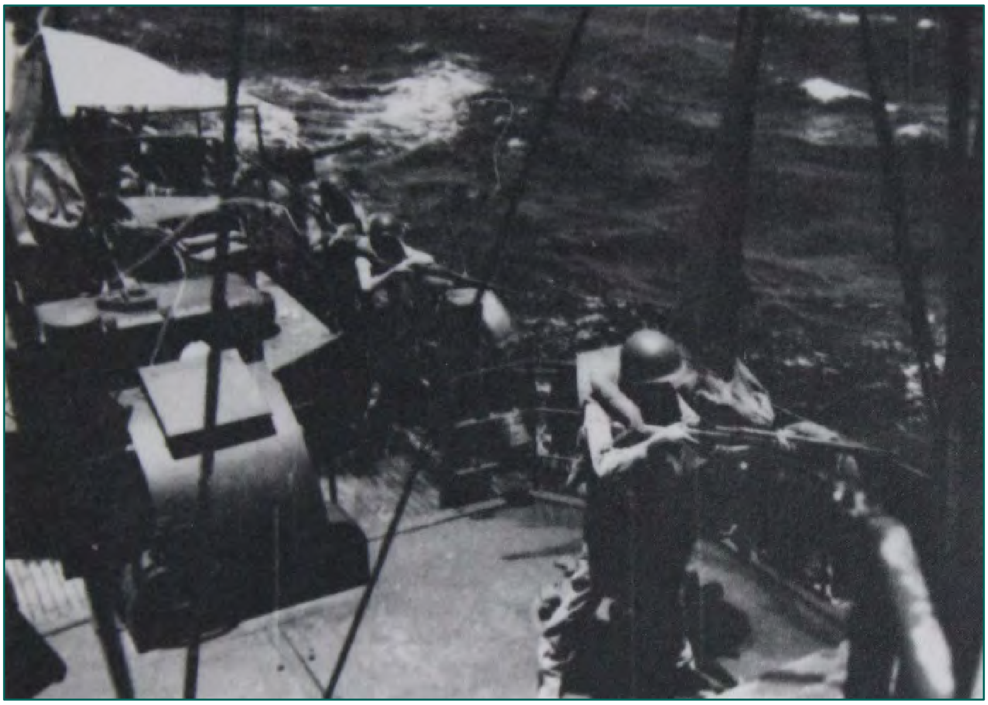


Figure 13: Mine disposal team preparing to fire on swept mines. (Source: TNA, ADM 199/154).

Minesweeping was not synonymous to mine clearance. Objective of the operations was to clear the shipping lanes for navigation. The sea bottom is still littered with unexploded mines, including swept and sunken moored mines, self-sterilized mines[7] and ground mines with empty batteries. Nowadays, fishermen and dredging ships still encounter these naval mines on a regular basis.

As a cause of clearance operations, tidal and other weather conditions, moored mines could break loose from their anchor and migrate. Furthermore, due to extensive pair and beam trawling there is often no clear relation between the positions of encountered mines and the locations of historical minefields. This observation is confirmed in documents from the Dutch National Archives, in which several washed up mines are mentioned on the island of Ameland.

3.4.4 Conclusion

The area of investigation intersects several historical minefields. During World War I, the area of investigation was situated in a British mining area which contained almost 43,000 moored contact mines. German minefields were situated around the area of investigation as well. During World War II, the large Nectarine garden was put into place. More than 11,000 ground mines were laid in this minefield by Bomber Command and Coastal Command aircraft. Not only British, but also German forces laid mines in and around the area of investigation. These German mines were exclusively moored contact mines, paired with explosive floats as sweeping obstructions. Postwar minesweeping succeeded in securing the shipping lanes, but did not manage to clear all mines. Many mines still litter the seabed, with mechanical fusing mechanisms still in place. Sweeping, trawling and extreme tidal and weather conditions caused these mines to migrate over the years, resulting in a situation in which there is no longer a clear link between the original minefields and the current positions of naval mines.

[7] According to international laws, mines are to be equipped with mechanisms to automatically disarm or 'self-sterilize' them after a set time. Moored mines were to sink to the seabed after a given time through, for example, a soluble plug, while ground mines disarmed automatically through a timing mechanism or simply at the end of their battery life. These mechanisms move the mine out of harm's way, but do not disable mechanical fusing mechanisms like *herz horns* and anti-handling devices.

4 GAPS IN KNOWLEDGE AND UXO RISK AREA

4.1 GAPS IN KNOWLEDGE

During the analysis and review of historical sources some gaps in knowledge occurred that could not be filled in with the consulted sources:

- Knowledge of previous UXO clearance operations is often absent. Therefore, it is not fully known if during the period 1914-2016 UXO were encountered in and/or removed out of the investigation area, e.g. it is not known if UXO were encountered during installation of the part of the TNW WFZ that is already in place.
- Compared to land, the North Sea offers few reference points. Therefore, specific information about locations is often lacking. Furthermore, it must be noticed that specific information can be inaccurate.
- Information on naval combat during World War I is only sparsely available.
- Because of the systematic destruction of the *Luftwaffe* archives, there is only sporadic information available on German Air Force activity.
- There is no specific information about crashed airplanes in the vicinity of the site.
- There is no exact information about the locations, amounts, conditions and types of dropped bombs during aerial attacks or jettisons above the North Sea.

4.2 UXO RISK AREA

Based upon the analysis of historical sources it is evident that different war related events took place within and nearby the area of investigation. Because of these events it's expected that UXO are present in the area of investigation.

The following UXO are likely to be encountered within the area of investigation:

- Artillery shells
- Aerial bombs
- Naval mines

Figure 14 presents an overview of all identified war related events near the area of investigation. The likelihood of presence and state of the expected UXO is elaborated in paragraphs 4.2.1 and 4.2.2 of this report.

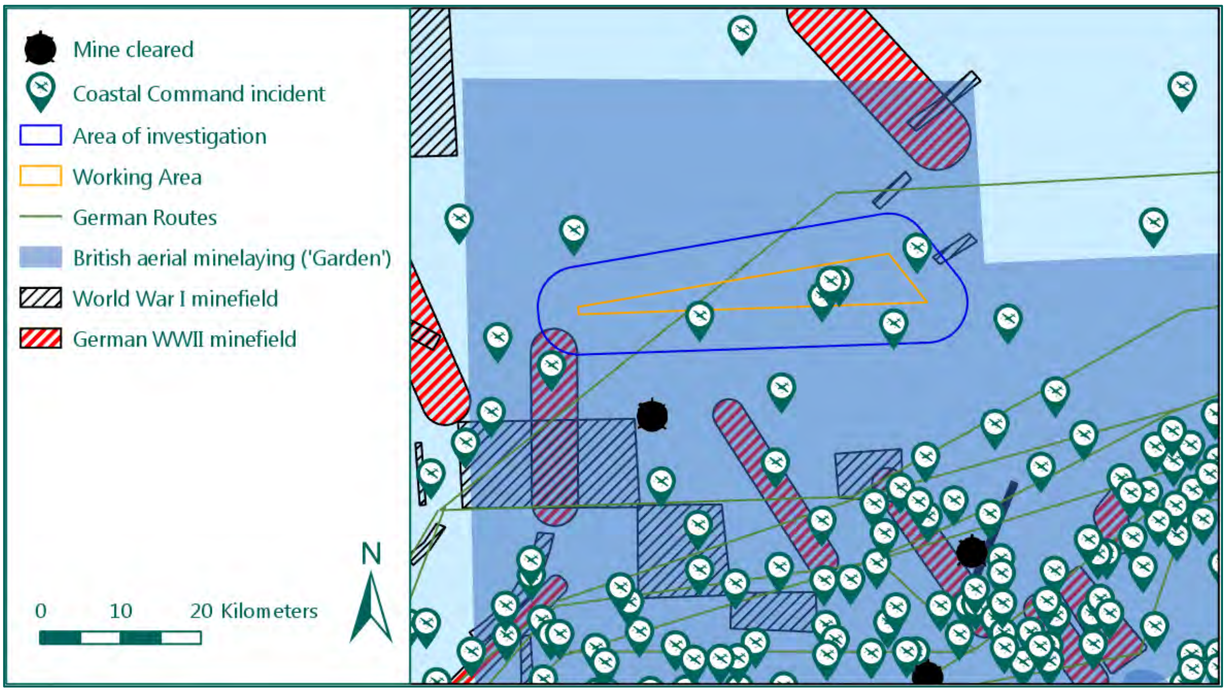


Figure 14: Overview of war related events.

4.2.1 Defining the UXO risk area

The UXO items considered most likely to be present within the area of interest are shown in Table 5. Note that the table shows the probable presence of generic UXO types within the site based on the evidence gathered about potential UXO sources. It's important to recognise that the presence of a UXO type does not necessarily mean that it will be encountered. The likelihood of encounter (i.e. a positive interaction with the UXO during a specific project activity), will generally be less than the probability of items of that particular UXO type being present across the whole area of interest; given that the actual footprint of wind farm installation operations will be less than the total investigation area volume. In Table 4 the terminology is shown, Table 5 is used to indicate the likelihood of presence of a specific type of UXO in the investigation area.

"Presence" Term	Meaning
Negligible	No evidence pointing to the presence of this type of UXO within an area but it cannot be discounted completely.
Remote	Some evidence of this type of UXO in the wider region but it would be unusual for it to be present within the area of study.
Feasible	Evidence suggests that this type of UXO could be present within the area.
Probable	Strong evidence that this type of UXO is likely to be present within the area.
Certain	Indisputable evidence that this type of UXO is present within the area.

Table 4: Definitions of terminology used for the likely presence of UXO.

UXO type	Likelihood of presence	Subtype / calibre	Remarks
Allied aerial bombs	Probable	Ranging from 4 lbs up to and including 4,000 lbs	Research shows that at least one allied airstrike took place in the area of investigation. Given the presence of convoy routes in the area of investigation more airstrikes may have taken place. Beside airstrikes, allied aircraft often jettisoned bombs over the North Sea. Not many direct indications have been derived from the historical sources, but indirect indications are plentiful.
Naval mines	Certain	WWI: Mark I, Mark II and Mark III contact mines (UK) WWII: EMC and EMD contact mines (German), A Mark I-IV and A Mark V ground mines (UK)	The area of investigation is situated in the larger German Bight area, which was a major theatre of mine warfare during both World Wars. The sheer number of naval mines and the rudimentary methods with which they were swept after the war, leads to the conclusion that the evidence of the presence of naval mines is indisputable.
Artillery shells	Feasible	20 mm up to and including 8.8 cm	German ships passing through the area of investigation are known to have fired on allied aircraft on at least two occasions. The intensity of flak fire, which is tantamount to more modern 'spray and pray' tactics, may have led to the presence of artillery shells of common flak calibres in the area of investigation.

Table 5: Summary of UXO likely to be present within the investigation area.

4.2.2 Condition of expected UXO

The majority of the expected UXO are likely to be in an armed condition. This means that the safety devices preventing the UXO from premature detonation, e.g. during handling, are removed. Therefore, the explosive train, is in line. The explosive train is a sequence of events that culminates in the detonation of explosives.

- In the case of aerial bombs which were dropped by aircraft in distress situations, the bombs could have been dropped with safety features still in place, however they still present an explosive risk, e.g. as a result of corrosion of vital safety features.

- Some of the expected UXO, e.g. naval munitions, contain a large quantity of explosives and may be encountered in very poor condition as the thin metal casings may have been severely eroded. In many cases, the explosive capability could remain more or less undiminished. Some explosive charges neither absorb nor dissolve in water, and some charges do. However, stability of the munition may have deteriorated with age.
- Naval contact mines from the period of interest typically contained a dry cell battery with an electrical detonating circuit which was connected to external conventional switch horns. These batteries will have now deteriorated and no longer have the ability to supply sufficient power to function the mine. However, the condition of the explosives can be highly sensitive.
- Contact mines with Hertz Horns were also common from WWI onwards. Each horn contains a container of acid. Heavy contact with the horn can breach the acid container within, which subsequently energizes a battery and functions the main charge. Therefore, this type of mine must be handled with extreme caution.

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

5 UXO BURIAL ASSESSMENT

In dynamic sediment conditions, UXO items are likely to become buried; the depth of burial is depending on a number of variables that will be explored below. In the offshore marine environment, UXO burial is predominantly due to one or a combination of the following three mechanisms:

- Initial impact
- Scour
- Bedform migration

5.1 BURIAL ON IMPACT

The first mechanism for UXO burial to consider is that due to initial impact. In the marine environment, a bomb or air-delivered ground mine's kinetic energy is rapidly attenuated by the water it passes through and its geometry is changed substantially. The depth of water, therefore, is also an important factor in estimating the likely burial depth on impact.

Experiments on Mk 84 bombs show that the trajectory of a bomb falling into water at an angle of entry of ~90° is rapidly altered by the new medium. The bomb rotates and orientates to near parallel to the seabed by a water depth of around 5 meter[8] (see Figure 15). Its burial in sandy soils due to impact will be minimal in water depths over 5 meter. Burial on impact of a large air dropped ground mine will also be minimal at larger water depths. The water depth within the investigation area varies from 15.0 to 34.5 meter (LAT), with an average of 22.6 meter (LAT). Burial on impact is therefore assessed to be null.

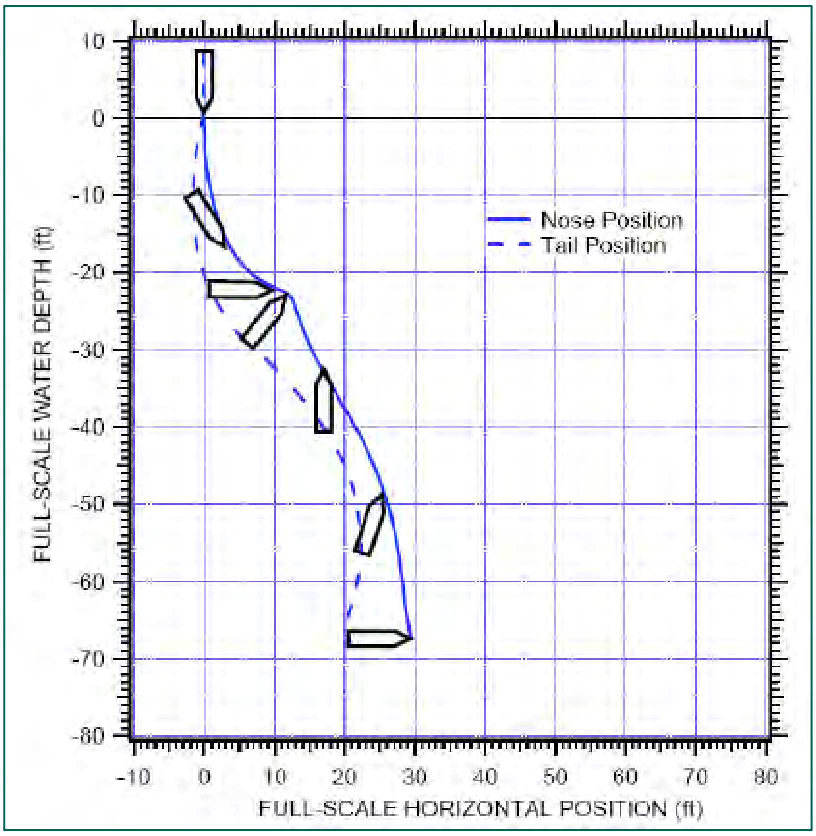


Figure 15: Trajectory of Mk 84 with no tail section and water-entry velocity of 296 m/s.

[8] Chu P.C. et al, *Semi Empirical Formulas of Drag/Lift Coefficients for High Speed Rigid Body Manoeuvring in Water Column*, May 2008.

5.2 SCOUR

Scour[9] is the change in bed configuration due to the change in flow pattern around an object such as a UXO placed on or near the surface of a movable bed. The presence of the object modifies the flow pattern around the object, generating vortices that locally increase and decrease the bottom flow stresses. The vortices cause depressions and mounds to form on the bed surface. Objects placed on beds where the flow was causing no apparent motion can locally increase the bed stress behind the object and induce bed motion and scour.

Studies of mines placed on sandy bottoms show that subsequent burial occurs through a series of scour events followed by rolling or sliding of the mine into the scour depression. It has been shown that the amount and rates of scour and burial of objects on the sea floor under the influence of waves and currents is a function of their size, weight, and shape. Shape is an essential variable because scour is related to the intensity of the vortex system that forms around the object as the current flows past it. Thus, streamlined bodies scour less rapidly than bluff (blunt) bodies. Once scour depressions develop around a UXO, the object is buried incrementally by moving into the depressions formed by the scour process, either by rolling or sliding (see Figure 16).

In general, small UXO items scour and bury deeper relative to their diameters than large UXO, while absolute burial as measured from sediment surface to UXO keel is greater for large UXO. Furthermore, three-dimensional UXO (ovoids and hemispheres) bury more slowly than two-dimensional (cylindrical) UXO.

The scour process stops when the UXO is at a depth where it's protected against the scour. Experiments and modelling have shown this depth to be approximately 0.6*diameter for large objects in sandy sediments. UXO burial due to scour to the maximum scour depth is to be expected in the investigation area. The largest UXO possibly to be present is a German EMC moored mine. This mine has a diameter of 1.2 meter and can be buried due to scour up to approximately 0.7 meter below seabed.

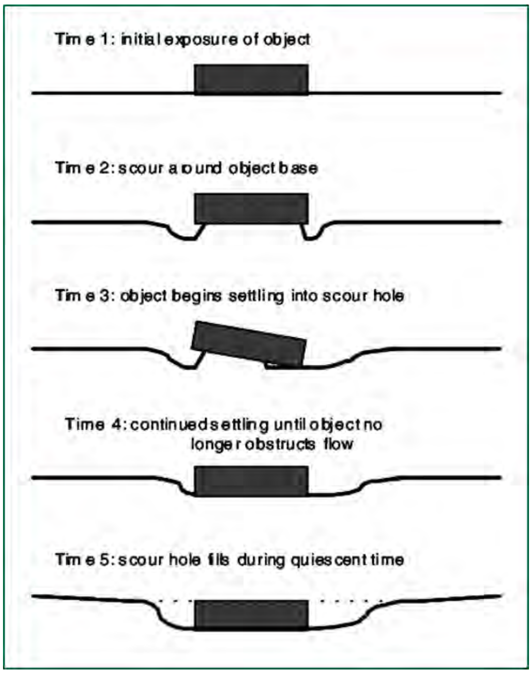


Figure 16: Scour mechanism[10].

[9] Source: Douglas L. Inman et al., Scour and burial of bottom mines, A Mine Burial Primer, September 2002.
[10] Source: www.researchgate.net

5.3 BEDFORM MIGRATION

Assessment of possible UXO burial requires insights in the behaviour of the mobile morphological features within the investigation area. UXO burial (and exposure) may be caused by the formation and migration of bedforms. The spatial scale of the bed forms ranges from several meters to several kilometres and migration speeds range from < 1 m/year to > 100 m/year. Table 6 summarizes the six different types of bed forms can be distinguished at the Dutch continental shelf.

Bed form	Length (m)	Height (m)	Migration speed (m/year)	Evolution time scale
Ripples	0.1 - 1	0.01 – 0.1	100 – 1,000	Hours
Mega ripples	1 – 10	0.1 – 1	100 – 1,000	Hours – days
Sand waves	100 – 1,000	1 – 5[11]	1 – 10	Decades
Long bed waves	1,500	5	Unknown	Centuries
Shore face connected ridges	5,000 – 8,000	1 – 5	1 – 10	Centuries
Tidal sand banks	5,000 – 10,000	1 – 5	< 1	Centuries

Table 6: Overview of bed forms located at the Dutch continental shelf.[12]

The ripples and mega ripples are too low to be of major importance for the burial assessment. Long bed waves, shore face connected ridges and tidal sand banks migrate too slow to be of importance for the burial assessment. Due to their height and migration rates sand waves are the predominant bed forms in regards to the burial depth of UXO.

At the time of the composing of this report a detailed study on seabed morphology was not yet available. This study will be undertaken by RVO.nl at a later stage. Based on the information currently available[13] the burial depth of UXO due to the migration of bedforms is assessed to be negligible.

5.4 CONCLUSIONS

Based on the mechanisms outlined in the previous paragraphs, the likely maximum burial depth (MBD) for an item of UXO can be calculated using the basic formula:

MBD = (0 (burial on impact)) + (0.6 x 1.2 (UXO diameter)) + (0 (height of bedform)) = **0.7 meter**

This calculation is based on data available at the moment of conducting this risk assessment. The calculation should be verified when more information on bedform height becomes available.

[11] Average values. The maximum height/depth ratio observed to be about 1/3.
[12] Menninga J., 2012. Analysis of variations in characteristics of sand waves observed in the Dutch coastal zone: a field and model study. MSc dissertation thesis. Utrecht University, 2012.
[13] Rijkswaterstaat, Bathymetry 2017. Online Viewer www.informatiehuismarien.nl/open-data.

6 UXO MIGRATION ASSESSMENT

In preparation for the geophysical UXO survey, the potential migration of UXO needs to be assessed. UXO migration is highly relevant in determining the maximum permissible safe time interval between the conclusion of a geophysical UXO survey, UXO clearance operations and the commencement of construction works.

Migration can occur due to environmental and natural causes and also human activity. In this chapter the possible migration of UXO is assessed.

6.1 MIGRATION BY NATURAL CAUSES

Migration by natural causes may occur due to hydrodynamics and/or morphodynamical behaviour.
In this paragraph these aspects will be assessed.

6.1.1 Hydrodynamics in the wind farm zone

The hydrodynamics within the wind farm zone is characterized by tide and wind generated currents and waves. The tide is predominantly semi-diurnal tide. Table 7 presents the mean tidal water levels at Nes to illustrate the tidal characteristics. The mean tidal range is 2.22 meter, with a mean high water of NAP+1.06 meter and a mean low water of NAP-1.16 meter.

Tide	HW [m NAP)	LW (m NAP)	Tidal range (m)
Mean tide	1.06	-1.16	2.22
Spring tide	1.19	-1.33	2.52
Neap tide	0.88	-0.94	1.82

Table 7: Tidal water levels L9 Platform.[14]

The average tidal streams during average weather conditions (wind south-west force 3 to 4) reaches speeds up to 0.2 kts (0.7 kts at spring tides)[15]. The given speeds of tidal streams are average calculated speeds. The actual speeds depend on a large number of variables. Therefore, the actual speeds may be higher than the calculated speed.

The shapes, dimensions and weights of the UXO that can be expected in the investigation area are such that they are not likely to be transported over long distances by normal wave and tidal conditions. Due to water depth, influence of storm loading is considered negligible. The forces on the objects are relatively low and the objects are not likely to migrate a great distance from their original resting position. In contrast, scour will develop around the object and this may result in burial.

6.1.2 Morphodynamical behaviour

The migration of objects is also not likely to be influenced by morphological changes in the area. Because of the minimal geomorphic activity of the seabed the risk of UXO getting unburied in the slopes of sand waves is assessed to be negligible. Therefore, UXO migration due to morphodynamical behaviour is not a factor to consider in the determination of the maximum permissible safe time interval between the conclusion of a geophysical UXO survey, UXO clearance operations and the commencement of construction works.

6.2 MIGRATION DUE TO HUMAN ACTIVITY

Human activity may have a more significant impact on UXO migration than natural causes. Especially dredging and fishing activities have the capacity to move items of UXO.

[14] Rijkswaterstaat, Kenmerkende waarden getijgebied 2011.0, July 22, 2013.
[15] HP33, Waterstanden en stromen 2014, 2014. Mentioned speeds are current speeds at the surface.

Particularly in areas where beam and pair trawling are prevalent. Currently the investigation area is fished several times a year[16]. It's expected that some trawlers may have unintentionally moved UXO. These UXO items may have been transported with the movements of the vessel's nets for considerable distances before they are returned to the seabed. In such circumstances, fishing nets have been known to move UXO up to 30 miles (48 km) from their original location[17].

Wind farm zones are not navigationally controlled. After completion the wind farm zone may be crossed by vessels smaller than 24 m. Therefore, the risk of UXO being moved unintentionally by fisherman after conduction of the UXO survey and completion of the wind farm remains.

It is not possible to quantify the UXO migration due to human interaction. Therefore, human interaction is not a factor in the ALARP sign off certification process. This migration factor is part of the baseline residual risk. If a large calibre UXO is unintentionally dragged into the area of investigation by fisherman, it will lie on the seafloor. Therefore, it will most likely be visible in for example SSS data.

6.3 MAXIMUM PERMISABLE SAFE TIME INTERVAL

In general, due to the possibility of UXO migration, the time periods lapsed from completion of the geophysical survey, UXO/anomaly investigation, UXO disposal phase and installation operations, must be kept to an absolute minimum. This is to ensure that UXO migration cannot nullify the validation period of the final ALARP clearance certification. It is therefore imperative to manage and plan the phases of the project, in an educated and calculated manner. This can be achieved by ensuring that vessel planning, vessel availability, weather windows, vessel/contractor capability, project phase execution and management are carefully planned and implemented to guarantee that the operations are carried out within the specified time scale reflective of the UXO migration assessment information.

For the investigation area horizontal migration of UXO is most likely to occur due to human interference. However, it proved not to be possible to quantify the horizontal migration rate.

The maximum permissible safe time interval between the conclusion of a geophysical UXO survey, UXO clearance operations and the commencement of construction works is assessed to be approximately two years. This is a widely accepted industry standard.

[16] http://www.clo.nl/indicatoren/nl2093-ecologische-duurzaamheid-bodemvisserij, Visserij Intensiteit op het Nederlands Continentaal Plat, 2007-2011 (no longer available, historic data used)
[17] Unexploded Ordnance Munitions Migration Assessment, Report Number: P3872-E3MMA, August 2014

7 HAZARDS OF UXO LIKELY TO BE ENCOUNTERD

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 8), the planned intrusive activities (see chapter 9) and the specific characteristics of the site forms the input for outlining the UXO mitigation strategy (see chapter 11).

7.1 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 enemy materiel through the projection of blast and fragmentation outwards from the point of detonation. Therefore, most bombs were accommodated with a high explosive charge, although incendiary bombs were also put to use.

The deployed fuses are highly important for the likelihood of a bomb to detonate as a consequence of seabed activities. Fuses 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 pistols/fuses are armed during and after the bombs are dropped. Upon impact, the pistol/fuse has a striking pin or electrical circuit that detonates the bomb. If the fuse has a striking pin, that pin is driven into a small firing cap that sets off the explosive train, and thus the main charge. An electrical fuse uses an electrical detonator to set off the detonation charge.

Fuses can have various timer devices to make the timing of the blast more effective. Some function at a given time after arming, e.g. chemical long delay pistol such as tail pistol no. 37 Mk. I (see Figure 17). More common are short delay or instantaneous pistol/fuses to delay the detonation for a few fractions of a second.

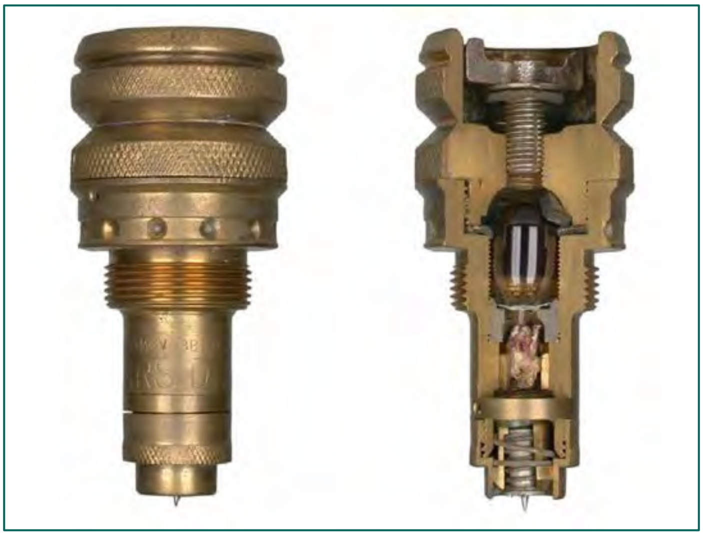


Figure 17: Tail fuze no. 37 Mk. I.

Once a fuse is armed, shock, movement or manipulation can cause the bomb to detonate. Fuses, and chemical long delay fuses in particular, are sensitive to movement and accelerations with an amplitude > 1 m/s^2 in the surrounding soil. This kind of accelerations can occur as a consequence of vibrations caused by piling operations.

7.2 NAVAL MINES

Naval mines can be classified into three major groups: contact, remote and influence mines. Naval mines can be subdivided by appearance or the way they are positioned in the water column, such as:

- Moored mines
- Ground mines
- Drifting mines
- Oscillating mines
- Crawling mines
- Limpet mines

Moored mines and ground mines are the most commonly used. Practice mines exist as variants of all types of war type naval mines with only absence of the warhead and extra equipment such as floats for marking the position and initiation of the exercise mine. The presence of explosives components with a small explosive payload in practice mines cannot be ruled out.

7.2.1 Contact mines

The earliest mines were usually of this type. They are still in use today, as they are extremely low cost compared to any other anti-shipping weapon and are effective in sinking 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.

Based on the different firing systems, one can summarize the following types of contact mines:

- Mechanical: upon contact a firing pin will function the detonator initiating the explosive train.
- Electrical: contact mines with an electrical firing system are often equipped with Hertz Horns (or chemical horns), switch horns or galvanic horns.
    - Hertz Horn: these fuses work reliably even after the mine has been in the sea for several years. The mine's upper and/or lower 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.
    - Switch Horn: this horn acts as the switch in the electrical circuit. Closing this circuit will set off the electrical detonator initiating the explosive chain. An internal battery is needed for the supply of the electrical power.
    - Antenna or Galvanic Horn: this type of horns works on the principle of creating battery power based on the salt water environment. A copper antenna or horn fitted to the mine casing acts as positive electrode. When another metallic object (i.e.: ships hull) makes contact with the antenna or horn.

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 between the surface and 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 ignited the explosives.

7.2.2 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. There was 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.

7.3 ARTILLERY SHELLS

Artillery shells were deployed by aircraft (20 mm), FLAK, submarines and warships. It is possible that Artillery shells could be encountered, initially used on land and dumped at sea as a matter of clearance. Artillery ammunition can be deployed with different kinds of artillery fuzes.

The types of fuzes most commonly used would cause the shell to detonate or release its contents when its activation conditions were met. This action typically occurred on time after firing (time fuze), on physical contact with a target (contact fuze) or a detected proximity to the ground, a structure or other target (proximity fuze).

7.4 ANTI-HANDLING DEVICES

Some fuzes, e.g. those used in air-dropped bombs and naval mines may contain anti-handling or anti withdrawal 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 or the earlier mentioned Pistol No. 37.

7.5 SELF-DESTRUCTION DEVICES

The Hague Conventions of 1907[18] 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 did not 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 the prohibitions of The Hague conventions, naval mines and torpedoes must be considered dangerous at all times.

18 Laws of War: Laying of Automatic Submarine Contact Mines (Hague VIII); October 18, 1907.

8 EFFECTS OF DETONATIONS

In this chapter the effects of underwater detonations 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.

8.1 EFFECTS OF UNDER WATER 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/vessel 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/vessel will have a lower value of KSF[19]. 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.

8.1.1 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 ship/vessel direct damage will occur due to seabed activities, unless operating in very shallow water. For this area if investigation, UXO will only be present in or on the seabed, unless otherwise brought to the surface.

8.1.2 Bubble jet effect

The bubble jet effect occurs when a mine or bomb detonates in the water under (e.g. on the seabed), 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 expand from the bottom. The bubble is buoyant and 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 at the ship's hull the damage to the ship can be extremely serious, flooding one or more compartments, is capable of breaking smaller ships apart and causing fatalities to the crew within the affected areas.

8.1.3 Shock effect

If a UXO 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 and equipment can be dislodged from their positions etc. A ship which experiences a large shock effect 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[20]. 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 8 the distances on with a certain amount of shock damage is expected are 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 $kg^{0.5/m}$[21].

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19 The Response of Surface Ships to Underwater Explosions. DSTO-GD-0109, September 1996
20 TNO-rapport Beveiligd 'baggeren Maas, stuwpand Sambeek', 11th may 2012
21 TNO-rapport Beveiligd 'baggeren Maas, stuwpand Sambeek', 11th may 2012

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 8: Distances for shock damage due to detonation18.

Table 8 shows that in case a UXO detonates, it is highly likely severe damage to the equipment and injury of personnel will occur. Furthermore, damage to foundations (mono piles) cannot be ruled out, depending on the distance between the detonation and the foundation.

8.1.4 Shredding effect or spalling

A shock wave with a peak pressure of 37.2 bar and higher reflecting against the water surface, 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 filled cavities such as ears, lungs and intestines.

8.1.5 Lethality of fragments

Fragments from explosives charges in water quickly lose 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[22].

In the TNW WFZ UXO with explosive weights (TNT equivalent explosive weight) up to 1,000 kg can be present. To detain all fragments a water depth > 16 m is needed. Because of the actual water depths at the site (> 15 m) it is unlikely that lethal fragments are ejected above the surface of the water (see Figure 18).

22 VS 9-861, Voorschrift Opruimen en Ruimen van Explosieven, 29th september 2010

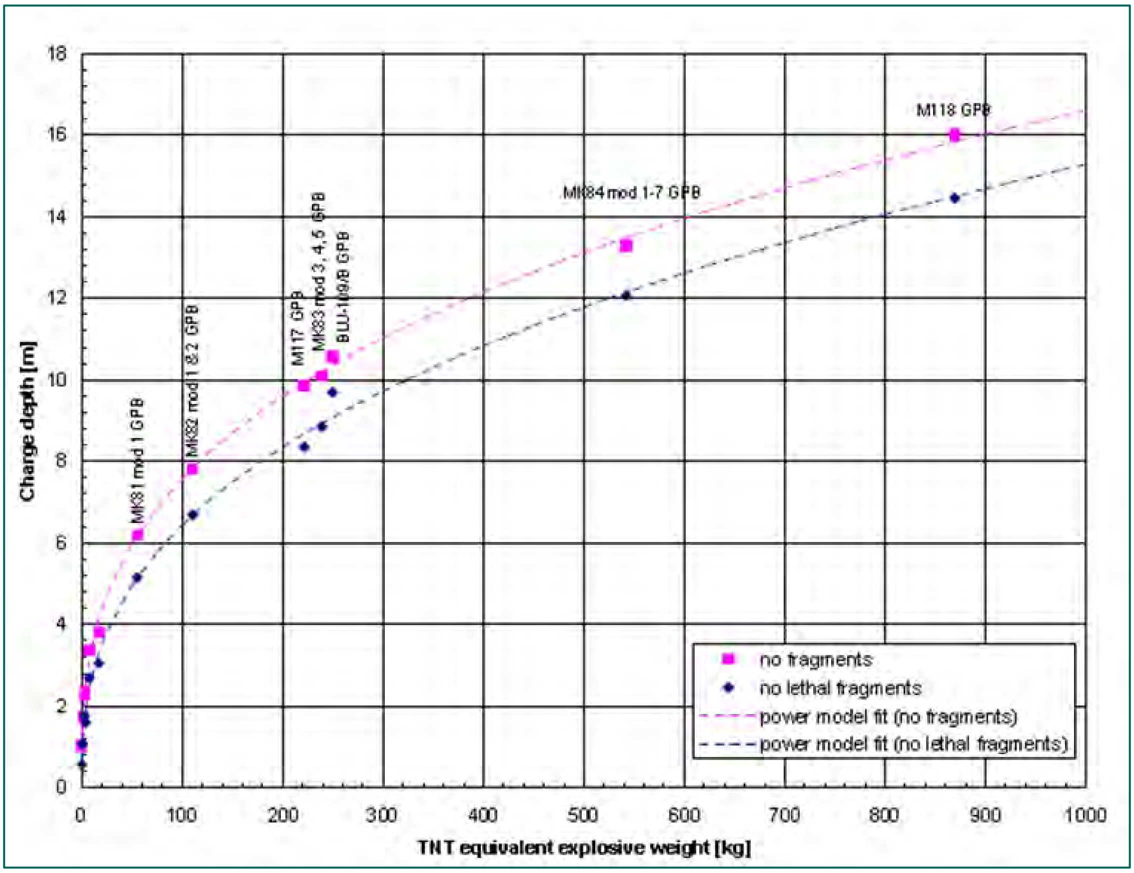


Figure 18: Minimal water depth to detain fragmentation of explosives with a Net Explosive Weight of 0-1,000 kg TNT equivalent [12].

8.2 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[23]:

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

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

In Table 9 the safe distances for UXO with a net explosive weight of 100, 200, 300 and 1,000 kg TNT are given. The safe distances are calculated with the formulas stated above. The explosive weights are representative for the types and calibres of UXO likely to be present in the wind farm area (e.g. naval mines, aerial 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
1,000 kg	2,700	759	1,138	380

Table 9: Safe distances for controlled demolition.

23 VS 9-861, Voorschrift Opruimen en Ruimen van Explosieven, 29th september 2010

9 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 TNW WFZ are summarized. Since, in the current stage of the project, an execution plan is not yet available, the needed information is derived from open sources. 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 assumption 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.

9.1 PREPARATION PHASE

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

- Geophysical investigations:
  - multibeam echo sounder;
  - side scan sonar;
  - magnetometer;
  - metal detector;
  - sub-bottom profiler.
- Geotechnical investigations:
  - cone penetration tests, covering the whole area;
  - a limited number of boreholes for sampling purposes;
  - grab samples.
- Metocean measurements:
  - metocean buoy installation.

<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.

9.1.1 Metocean measurements

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 metocean campaign is started by RVO.nl. A metocean buoy is installed in the area. The buoy is kept in place with a bottom weight. For the UXO risk assessment only the intrusive activities of the metocean campaign are relevant.

<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 metocean buoy and conducting the investigations.
- Direct contact between a UXO and divers/ROV’s during inspections and as-built checks.

9.2 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).

9.2.1 Wind turbines

A wind turbine consists of a nacelle with rotor blades, a support structure and a foundation. For the UXO risk assessment only intrusive activities (all activities that influence the soil) are 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 19 shows three possible foundation types. Suction anchors may also be a suitable solution.

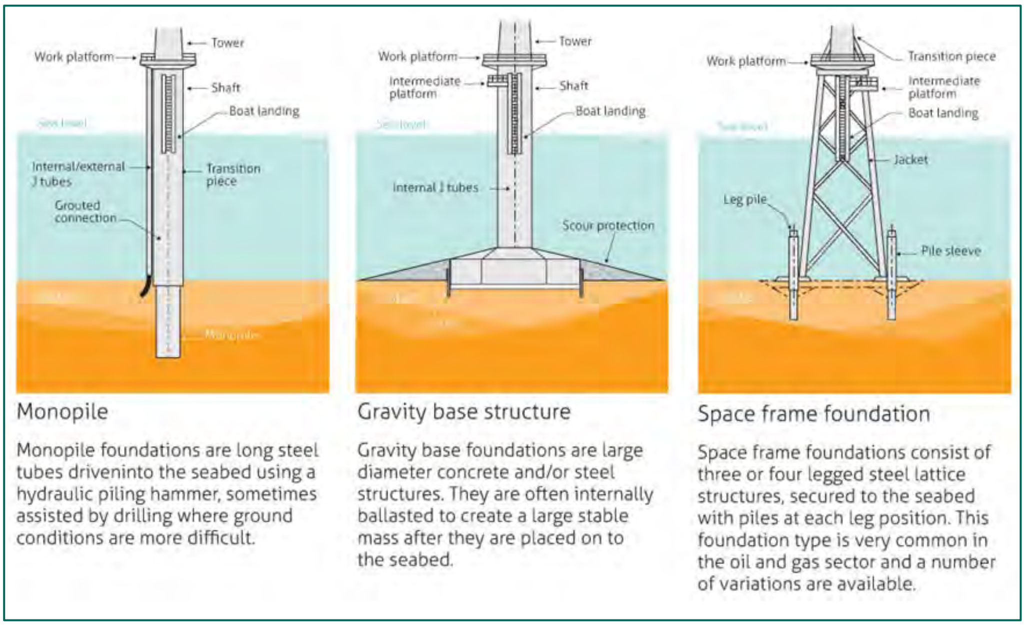


Figure 19: Example of suitable foundation types.[24]

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 soil surrounding a UXO 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 in the soil surrounding a UXO 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.

24 Source: www.navitusbaywindpark.co.uk

9.2.2 Converter- and transformer stations

In order to deliver a constant flow of electricity to shore, all generated electricity is collected on substations 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 soil surrounding a UXO during the placement or removal of the foundation (depending on the type of foundation, there are techniques that are vibration-free).

9.2.3 Scour protection

Sandy soils, such as present in the TNW WFZ, 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).

9.2.4 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 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. 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 Operated Vehicle (ROV), which buries the cable on 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.

9.3 OPERATIONAL PHASE

The North Sea is a highly dynamic morphological 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 deemed to be clear. In 2011 a good example of the dynamic nature of the North Sea was shown when a WWII 1,000 lbs high explosive bomb was discovered lying against the side of the monopile base of a UK offshore wind farm under construction[25]. This bomb had drifted towards the monopile from elsewhere. Another noticeable example is a torpedo being discovered in 2002, having drifted against a North Sea oil pipeline[22].

During the operational phase of the wind farm maintenance activities will be required throughout. 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.
- High energetic fields which can possibly influence electrical detonators.

25 Unexploded Ordnance Risk, Considering Unexploded Ordnance Risk on and around the British Isles, 27-04-2011

10 UXO RISK ASSESSMENT

In assessing the overall UXO risks for the project a Semi Quantitative Risk Assessment (SQRA) process was applied. SQRA is widely considered best practice in the offshore industry. The risk factor values assigned in the SQRA are determined by UXO experts and are consequently subjective and open to different interpretation.

In this assessment the following parameters were assessed:
- Source, Pathway and Receptor,
- Likelihood of Presence,
- Type of encounter,
- Likelihood of Occurrence,
- Hazard severity.

Chapter 8 provides a brief description on the effects of a detonation.

10.1 RISK ASSESSMENT MATRIX

The following matrix is used to quantify the risk. Each generic UXO hazard is assessed for severity and likelihood of occurrence. This model is generally considered best practice for assessing risk in the marine environment, although it has been modified where required to ensure it is UXO centric.

		Hazard Severity				
		1 = Negligible	2 = Slight	3 = Moderate	4 = High	5 = Very High
Likelihood of Occurrence	1 = Very Unlikely	1 LOW	2 LOW	3 LOW	4 LOW	5 LOW/MODERATE
	2 = Unlikely	2 LOW	4 LOW	6 LOW/MODERATE	8 MODERATE	10 MODERATE/HIGH
	3 = Possible	3 LOW	6 LOW/MODERATE	9 MODERATE	12 MODERATE/HIGH	15 HIGH
	4 = Likely	4 LOW	8 MODERATE	12 MODERATE/HIGH	16 HIGH	20 HIGH
	5 = Very Likely	5 LOW/MODERATE	10 MODERATE/HIGH	15 HIGH	20 HIGH	25 HIGH

(red)	Unacceptable
(orange)	ALARP with reduction measures
(yellow)	ALARP
(green)	Acceptable

Table 10: UXO risk assessment Matrix.

The high probability, high severity combinations are ranked in the category 'Unacceptable'. This means mitigation measures are required to reduce the risk to a level that is considered ALARP. The mitigation measures for this category of risks are mainly source orientated. The source of the risk is eliminated usually by survey, avoidance was possible, identification of objects that cannot be avoided and removal of positively identified UXO that cannot be avoided.

The medium probability, medium severity combinations are ranked in the category 'ALARP', or 'ALARP with reduction measures'. ALARP essentially means the risk is accepted at the present level.

'ALARP with reduction measures' means risk reduction measures may be required to achieve ALARP. The risk reduction measures for this category are mainly aimed at mitigating the effects. This can be achieved by e.g. procedural measures, applying shrapnel protection, etc.

The low probability, low severity combinations are ranked in the category 'Acceptable'. This indicates the risk of an event is not high enough to legitimize mitigation measures, or that the risk is sufficiently controlled. No action is usually taken for this category.

10.2 RISK ASSESSMENT RESULTS TEN NOORDEN VAN DE WADDENEILANDEN WIND FARM ZONE

Table 11 shows the UXO risks within the TNW WFZ prior to the conduction of mitigation measures. The resulting risk for each source item is a function of the 'Likelihood of Occurrence' and the 'Hazard Severity'. The 'Likelihood of Occurrence' is the product of the 'Likelihood of Presence' and the likelihood of initiation of an item of UXO. The values assigned to each factor in the risk calculation are subjective and based on many variables, which themselves are difficult or impossible to quantify. Data for a statistical analysis is not available. Therefore risk calculation results must be treated with caution and an understanding of their origin.

UXO risk is generally considered a low probability but very high consequence event, therefore it is the latter factor that usually dictates the overarching risk score. The potential consequence of a UXO detonation is by far the dominant factor in the calculation.

Severity of consequence, for example, will depend on the precise circumstances of the receptor (construction, equipment/personnel, vulnerability, depth of water, lay-back etc.). Likelihood of encounter will be governed by, inter alia, whether the UXO is likely to be completely buried, and to what depth, measured against the depth of intrusion into the sediment of a particular activity. The values assigned cannot be absolute or based upon statistical data (for example, of previous occurrences) because the data is not generally available and there are a great many permutations of the factors involved. The UXO specialist provides a professionally informed judgement based upon empirical, qualitative and anecdotal evidence employed in a consistent approach.

The purpose of the risk calculation at this stage is only to produce a relative order of merit to provide input for the Risk Mitigation Strategy. Nevertheless, despite its limitations, the risk assessment matrix as currently used is suitable for adequately assessing and grading Health and Safety (H&S) risk, which is generally mandated by legislation as well as individual company policy. It is also a robust tool for assessing project risk tolerability.

RISK ASSESSMENT RESULTS

Ten Noorden van de Waddeneilanden Wind Farm Zone (TNW WFZ)

Source	Likelihood of Presence	Pathway	Receptor	Type of encounter	Likelihood of Occurrence	Hazard Severity	Risk Result
Allied aerial Bombs	Probable	See appendix 11	Personnel Equipment	Primary Secondary	3 = Possible	5 = Very High	15 = HIGH
Naval mines	Certain	See appendix 11	Personnel Equipment	Primary	3 = Possible	5 = Very High	15 = HIGH
Artillery shells 20 mm up to 8,8 cm	Feasible	See appendix 11	Equipment Personnel	Primary Secondary	2 = Unlikely	1 = Negligible	1 = Negligible

Table 11: Risk assessment results for the TNW WFZ.

There is sufficient and indisputable evidence that Naval mines are present within the investigation area. There is also strong evidence indicating the presence of aerial bombs in the area. The planned construction works may cause an aerial bomb or naval mine to detonate. A detonation is assessed to be 'possible' and may be initiated by e.g. crushing with a cable trencher during cable lay operations, a kinetic energy created during pile foundation operations, etc.

In case of a detonation under water, the water column provides protection against fragmentation. The bubble jet and shock effect however, may cause serious damage to the vessel, compromising the integrity of the ship. Also personnel may be injured or killed due to the shock or sinking of the vessel.

Artillery shells originating from naval attacks or dumping are feasible to be present. These shells do not pose a significant threat for installation operations.

11 OUTLINING THE UXO MITIGATION STRATEGY

In strategic terms, the UXO risk on the project can either be:
- Accepted by all parties and no further proactive action is taken.
- Mitigated with measures to contain, and/or eliminate the UXO risks (by reducing the probability or consequences).
- Carried with the balance of any residual risk transparently exposed to those parties involved with site works.

Although mitigation is generally the most cost effective and efficient option for dealing with UXO risks, a balanced blend of the options is usually required to comply with best practice. This desk based study and risk assessment has shown that the risk from UXO to the proposed operations are 'Low', 'Moderate' or 'High'. Mitigation is required to reduce the 'Moderate' and 'High' risks to ALARP. All operations with a 'Low' risk level do not require mitigation measures. It is recommended to accept the residual risk and conduct the operations as planned.

11.1 AIM OF THE RECOMMENDED UXO RISK MANAGEMENT STRATEGY

Research for this study has established that there is a UXO hazard as the following three components are present:
- Source – a UXO hazard that exists,
- Pathway – a mechanism that may cause UXO to detonate,
- Receptors – these would be at risk of experiencing an adverse response following the detonation of a UXO.

The purpose of hazard mitigation is to take action to address one or more of these components to reduce the probability of the problem occurring or to limit the impact of the problem if it does occur. Thereby eliminating the hazard or reducing the hazards to an acceptable level. When considering the hazards associated with UXO the most logical approach is to employ measures to reduce the probability of an event occurring. For the TNW WFZ this is best achieved by addressing the source of the hazard.

The primary aim of the recommended UXO risk management strategy is to reduce the health and safety risk to personnel to ALARP. The objectives of the mitigation strategy, are:
- Reduce the H&S risks to ALARP,
- Ensure it is technically robust within the bounds of available technology,
- Take account of the potential for buried UXO,
- Provide a solution that is pragmatic and at best value to the future developer.

11.2 METHODOLOGY

The conducted historical research has shown that several calibres of aerial bombs, naval mines and depth charges could be present within the investigation area. The possible effects of a detonation on vessels, equipment, personnel, and surroundings may form an intolerable risk. This means mitigation measures are required to reduce the risks to as low as reasonably practicable (ALARP). It is recommended to address the source of the hazard by performing a UXO geophysical survey prior to any intrusive works.

The mitigation measures consist of UXO survey, identification of potential UXO objects and disposal of actual UXO objects.

12 UXO SURVEY METHODOLOGIES

The conducted historical research and this additional historical research has shown that several types of UXO could be present within the entire TNW WFZ. Due to the types and sizes of UXO likely to be present there is no "silver bullet solution" for the UXO geophysical survey.

In order to reduce the risk to ALARP, a dedicated UXO geophysical survey must be carried out to identify objects on the seabed that could potentially be UXO. This chapter briefly considers the types of technology that may be used in such a survey and the key issues that should be considered during the planning phase. Following the survey, data interpretation, contact avoidance and contact investigation/disposal (where avoidance is not feasible) should be the sequential phases of UXO mitigation prior to wind farm development.

UXO survey techniques that might be considered for the TNW WFZ are as follows:

- Magnetometry (MAG);
- Electro Magnetic (EM);
- Side scan sonar (SSS);
- Multibeam echo sounding (MBES);
- Seismic sub bottom profiling (SBP).

There are a number of other technologies available to profile the seabed but are yet considered to be either unproven in the commercial sector or employed by the military and cost-prohibitive.

12.1 MAGNETOMETRY

Magnetometry is generally considered the most reliable and common method of UXO geophysical survey. The method relies upon the UXO causing a spatial variation in the Earth's magnetic field. Since the majority of WWI and WWII munitions were constructed from iron or steel and were relatively large, this technology is seen as a prime methodology for offshore UXO detection. Either gradiometers or total field sensors can be used. The aim is to detect and interpret objects that meet the determined threshold criteria to the required depth below the seabed (burial depth or depth of the intrusive activities). Large ferrous objects (e.g. large calibres air dropped bombs or a ferrous ground mine) can be detected up to 5-8 m distance to the MAG sensors (dependent on the type of sensors).

12.1.1 Gradiometers

Vertical gradiometers (such as fluxgate magnetometers) require careful vertical alignment. To have good gradiometer data, the system must be stable, with all the sensors keeping their position on the respective axis. This is why gradiometers are usually deployed from a stable platform such as a Remotely Operated Vehicle (ROV). The gradiometer determines the gradient of the "Z component" of the Earth's magnetic field. Motion must be compensated for on all axes in order to be able to re-estimate the proper gradient axis, particularly roll and pitch effects. The Z axis still has to be compensated (altimeter pressure sensor for marine applications) to keep a same reference level.
Gradiometers have shown that they can offer a high degree of immunity from diurnal and external influences in the ambient magnetic field; they can enhance near-surface, small or weak magnetic anomalies; and they can provide obvious improvements in spatial resolution over the total field measurement alone.

12.1.2 Total Field Magnetometers

A total field magnetometer is a single sensor magnetometer that measures the actual magnetic field strength at any given position. The majority of towed marine magnetometers are total field systems, using either proton or caesium vapour detectors. The latter have a higher resolution and sampling rate than proton magnetometers. There are a range of types, configurations and deployment methods of magnetometer systems currently used in the market, which will incorporate different sensitivities, towing characteristics and array mountings. A determination of which configuration is "best for UXO detection" is not easily achieved from a desk based exercise. The choice of the appropriate instruments depends on the individual site conditions and the UXO hazard in question.

12.2 ELECTRO MAGNETIC

Electromagnetic (EM) systems have the ability to detect all types of conductive metallic materials by observing the induced secondary electromagnetic field produced when the target is stimulated by a primary electromagnetic field. On land these systems are used for the detection of non-ferrous ordnance. However in seawater the presence of a highly conductive media surrounding the transmitter and receiver coils can substantially reduce the effectiveness of the system. The limiting factors imposed by saline conditions however can be solved by some technological modifications to the system. With these modifications large UXO items can be detected up to approximately 2-4 m distance from the coils.

12.3 SIDE SCAN SONAR

Side scan sonar, when used for UXO detection, is a proven and capable remote sensing tool. The low grazing angle of the side scan sonar beam over the target and sea floor results in distinctive shadows being cast behind objects proud of the seabed. For relatively flat and featureless terrain, high resolution side scan sonar will allow the discrimination and identification of large UXO items proud of the seabed. However, the more irregular the seabed morphology as present in the TNW WFZ, the more difficult it becomes to identify man-made debris. Partial burial of objects, short wavelength bedform fields (ripples/mega ripples) and heavy concretion on UXO may also make identification difficult. For detection of relatively small UXO, such as bombs and projectiles, where conditions are suitable a high frequency side scan sonar should be employed; typically, a dual frequency tow fish with a minimum frequency of 500 KHz (nominal value) for UXO identification. The swath width should be set to ensure always 200% data coverage, with the side scan sonar profiles being run in two mutually perpendicular directions to ensure that any targets are illuminated by the sonar from two directions. This technology will ensure that large UXO items (if present) are detected if the seabed conditions are suitable and the objects are on the seabed or partly buried. SSS on its own is not considered to be a reliable system to mitigate the risks of the presence of large UXO items. This system should always be combined with other survey techniques, for example MAG and EM survey.

12.4 MULTIBEAM ECHO SOUNDER (MBES)

MBES, unlike side scan sonars, have their transducers rigidly mounted to the hull of the survey vessel, eliminating almost all chances of casting shadows. Using MBES for object detection requires a focus on the resultant bathymetry rather than shadows. The resolution of a multibeam echo sounding system in shallow coastal waters is such that gridding of data at the 0.2 m bin is required for the detection of potential UXO on the seabed.

The results of a high resolution multibeam bathymetric survey can provide very useful information to assist with the interpretation of side scan sonar imagery, in particular providing improved accuracy for coordinates of targets. However, as an acoustic system, the efficacy of MBES for discriminating targets is also degraded in uneven seabed environments.
MBES on its own is not considered to be a reliable system to mitigate the risks of the presence of large UXO items. This system should always be combined with other survey techniques, for example MAG and EM survey.

12.5 SEISMIC (SUB BOTTOM PROFILING)

Seismic sub bottom profiling systems are commonly used for geological profiling but can locate and determine the burial depths of pipelines. Pipeline detection systems rely on wide beam width systems, usually pingers, to produce diagnostic hyperbolic reflections from pipeline structures. High resolution, narrow beam systems such as parametric sources produce very small search footprints on the seabed, which therefore requires greater line density to detect small targets such as UXO. Reflections from features are created by sharp changes in acoustic impedance (product of acoustic velocity and density); metallic objects provide a very strong contrast in acoustic impedance when buried in sediments. Despite this theory, in reality, discrimination between geological and manmade features is difficult when interpreting seismic information. Recent advances in 3D chirp technology have made SBP a much more effective tool in UXO detection. With SBP it is possible to detect large UXO items that are on the seabed or partly buried but SBP on its own is not considered to be a reliable system to mitigate the risks of the presence of large UXO items. This system should always be combined with other survey techniques, for example MAG and EM survey.

12.6 COMPARISON OF SURVEY TECHNIQUES

In Table 12 a comparison of the survey techniques explained in the previous paragraphs is provided. The strengths and limitations of the different techniques are given. In general magnetometry is the most suitable technique for detecting ferrous UXO. In order to enhance the data evaluation it is recommended to preform survey operations with a spectrum of survey techniques, for example MAG, SSS and MBES. To enhance the evaluation process it is recommended to correlate the data obtained with the different survey techniques.

Method	Strengths	Limitations
Magnetometry	• Will detect ferrous UXO either buried or below the seabed (within bounds). • Not as susceptible to weather as other methodologies. • Ability to model the source target using the anomaly response. • Can detect larger ferrous objects at deeper depths than EM methods. • Multiple systems can be linked together in an array to enhance production rates and increase efficiency. • Data can be analysed to estimate target size and depth.	• Influenced by some geological features and manmade features. • Small survey footprint per magnetometer. • Will not detect non-ferrous UXO. • Instrument response may be affected by nearby power lines and cultural features.
Electro Magnetic	• Advanced systems have multiple frequency and time gates. • Ability to detect all types of metallic munitions (ferrous and non-ferrous). • Additional data can provide information on target shape, orientation, and material properties. • Multiple sensors can be linked together in an array to enhance production rates and increase efficiency. • EM systems are less susceptible to cultural noise sources, such as utilities, than magnetic methods.	• Smaller detection range than a magnetometer. • Only specialist organisations operating with the equipment. • Could be affected by saline conditions.

Method	Strengths	Limitations
Side Scan Sonar	• Large swath of data can be captured per run line. • Side scan sonar is the most suitable tool when searching for debris lying on the seabed. • A wide range of equipment and different frequency tow fish are commercially available. • Likely to identify large NEQ items of UXO. • 200% coverage allows contact position to be improved.	• Data quality influenced by marginal weather and water turbidity. • If USBL positioning is compromised then the positioning accuracy of seabed contacts may be limited. • Length dimensions may be exaggerated by a number of reasons including tugging. • Will not identify buried UXO. • Difficult to distinguish between UXO and other seabed feature such as boulders.
Multi Beam Echo Sounder	• Ability to identify UXO size targets on the seabed, with better accuracy than the side scan sonar. • Positional accuracy is very good, especially as the equipment is hull mounted. • Option of exceptionally high sounding accuracy, and a dense pattern of soundings to cover the seafloor in order to reveal small seabed features. • In addition to the soundings, the multibeam echo sounders produce seabed image data similar to a side scan sonar image (backscatter).	• Will not detect buried UXO. • A multibeam system can produce excellent results in this application only when positioned very close to the seabed. • The option to use echo sounder backscatter data analysis to characterise the seabed is complex and not commonly used for UXO identification. • Discrimination performance is degraded in rocky, uneven seabed conditions.
Seismic Sub Bottom Profiling	• Potential to detect buried UXO. • Option for LMB threat.	• Small survey footprint. • Difficult to discriminate between manmade and geological features.

Table 12: Comparison of survey techniques.

For a dedicated advice regarding survey techniques to be applied for TNW WFZ see chapter 13.

13 THRESHOLD LEVELS TO BE APPLIED

The SQRA has shown that certain types of UXO necessitate mitigation measures to reduce the risks to as low as reasonably practicable (ALARP). The mitigation measures consist of UXO survey, avoidance of significant objects[26], Identification of potential UXO objects that cannot be avoided and disposal of actual UXO objects that cannot be avoided.

In order to set the scope of work for the UXO survey, appropriate threshold level(s) for modelling of anomalies detected by a UXO survey in TNW WFZ need to be determined. This chapter provides the provisional thresholds needed to mitigate the risk to a level that is considered ALARP. The threshold levels need to be reassessed based on the preliminary design and proposed installation methodologies.

13.1 SPECIFICATIONS OF UXO THAT REQUIRE MITIGATION MEASURES

Table 13 provides the known specifications of the UXO likely to be present that require mitigation measures.

Category	Type	Calibre	Origin	Diameter (cm)	Length (cm) (without / with tail section)	Weight in air (kg)	NEQ (kg) (dependent on type of charge)	Ferrous mass (dependent on main charge)
Aerial bomb	GP MK I-III	250 lbs	UK	26	70 / 140	112	28.6 / 30.8	83.5 / 81
Aerial bomb	Demolition	300 lbs	US	27.7	100 / 123.4	124	62	62
Aerial bomb	GP	500 lbs	US	36	118.4 / 150	227	120	107
Aerial bomb	GP	1.000 lbs	UK	41	133.4 / 180 or 220	486	151 / 171.5	335 / 314.5
Aerial bomb	MC	250 lbs	UK	26	70 / 133.4	102	37	65
Aerial bomb	MC	500 lbs	UK	32.8	94.5 or 104 / 145 or 179	226	92 / 101	124 / 125
Aerial bomb	MC	1.000 lbs	UK	45	133.4 / 183	549	215 / 238	334 / 311
Aerial bomb	HC	4.000 lbs	UK	76	189 / 279	1707	1006 / 1102	701 / 605
Aerial bomb	SAP	250 lbs	UK	23	802 / 125	111	19	92
Aerial bomb	SAP	500 lbs	UK	33.5	106 / 156	222	41	181
Aerial bomb	Fragmentation	260 lbs	US	21.5	82 / 111	118	15	103
Underwater ordnance	Moored mine	n.a.	UK	79	n.a.	255	145 / 204 / 227	110 / 51 / 28
Underwater ordnance	Moored mine UMB	n.a.	GER	84	n.a.	40	190	150
Underwater ordnance	Moored mine EMC and EMD	n.a.	GER	120	n.a.	630	300	330

Table 13: Specifications of UXO possibly to be present.

13.2 THRESHOLD LEVELS FERROUS UXO

Taking the results of the SQRA into account, it is assessed that the 250 lb bomb is deemed the smallest ferrous threat item for an ALARP sign-off. These items are cylindrical/tear-drop in shape, made of steel and, depending on the variant, contain between 30 and 60 kg of HE. The ferrous weight can range from 50 to 83 kg dependent on the make, modification and type of munition. Assuming these items can be successfully

26 Objects that meet the set survey thresholds.

detected and identified within the geophysical datasets, larger objects will also be detectable. The provisional magnetometer (MAG) threshold is set on 50 kg ferrous mass. This threshold is also sufficient to detect ferrous naval mines which are likely to be present in the area. The risk also posed by the possible presence of depth charges, torpedoes and large calibre artillery shells will be mitigated sufficiently by applying the recommended threshold value.

13.3 REQUIRED DETECTION RANGE

The required detection range for UXO is to the intended installation depth +0.5m (interarray cables) or the assessed MDB (turbine and platform foundations).

13.4 AREAS TO BE SURVEYED

The size of the exclusion zones and the areas to be surveyed is dependent on the actual design, installation methodologies and geophysical parameters. The size of the areas to be surveyed needs to be assessed in an additional risk assessment based on the (provisional) design of the wind farm and the relevant site data. The exact scope for the survey, identification, removal and disposal operations needs to be determined in a detailed UXO mitigation strategy.

13.5 VALIDATION OF GEOPHYSICAL UXO SURVEY EQUIPMENT

It is not recommended to prescribe a certain technique in the specifications for the UXO geophysical survey. The selection of the appropriate detection techniques and devices is the full responsibility of the contractor. It is mandated by the WSCS-OCE that all detection devices used during the geophysical UXO survey are to be subjected to a thorough UXO validation. The purpose of the validation is to establish the maximum detection range limits for the specified thresholds of objects. This detection range threshold may then be used to check for achieved detection depths below seabed and/or ‘coverage achieved’ on completion of the data acquisition. The variables which influence the degree of coverage are primarily sensor altitude, horizontal separation between adjacent lines, distance between the sensors and clearance requirements as specified by the wind farm zone developer.

The relevant survey parameters such as sensor altitude and line spacing can only be determined on the validation results of the actual survey equipment (combination between survey array and vessel/ROV). The survey contractor needs to assess the line spacing required based on the applicable thresholds, the required detection depth, the proposed MAG/EM system and the validation results of these systems.

13.6 REGULATION AND STANDARDS

The applicable regulation on EOD-operations in the Netherlands is the “Werkveldspecifiek Certificatie Schema – Opsporen Conventionele Explosieven (WSCS-OCE)”. According to the WSCS-OCE all UXO clearance companies must be certified for ‘scope A’ and/or ‘scope B’. A ‘scope A’ certified UXO clearance 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.

The International Marine Contractors Association (IMCA) is the international trade association representing offshore, marine and underwater engineering companies. IMCA guidelines and standards are applicable to the offshore industry. Though not mandatory, use of the IMCA guidelines and standards is recommended.

14 CONCLUSIONS

Based on the results of the historical research and UXO risk assessment the research questions are answered as follows:

- *Identification of possible constraints for offshore wind farm related activities in the TNW WFZ as a result of the possible presence of items of UXO.*

  Based upon the analysis of historical sources, it's evident that different war related events took place within and nearby the area of investigation. Due to these events the entire area of investigation is to be considered a UXO risk area. A large variety of UXO are likely to be present which include artillery shells, aerial bombs and naval mines. The likely presence of UXO in the area, however, is not a constraint for offshore wind farm development. With applying professional UXO risk management these risks can be reduced to a level that is considered As Low As Reasonably Practicable (ALARP).

- *Identification of areas within the TNW WFZ that could preferably not be selected for the installation of offshore wind farms and/or cables.*

  Within the proposed area there are no UXO risk free areas identified, however since the entire TNW WFZ is to be considered a UXO risk area and the risks posed by the presence of UXO can be sufficiently mitigated to ALARP, the entire TNW WFZ can be selected for the installation of offshore wind farms and/or cables.

- *Identifying the requirements from a 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. Installation of wind turbine foundations
  d. Installation of cables

  The conducted historical research has shown that several calibres of aerial bombs and naval mines could be present within the investigation area. The possible effects of a detonation on vessels, equipment, personnel, and surroundings may form an intolerable risk. This means mitigation measures are required to reduce the risks to ALARP. It´s recommended to address the source of the hazard by performing a UXO geophysical survey prior to any intrusive works. The mitigation measures consist of UXO survey, identification of potential UXO objects, re-routing or re-location of cables and structure if possible and disposal of UXO items if required.

Evaluating the results of the SQRA, it's assessed that the 250 lbs Air Dropped Bomb is deemed the smallest ferrous threat item for an ALARP sign-off. The ferrous weight of these bombs can range from 50 kg to 83 kg dependent on the make, modification and type of munition. Assuming these items can be successfully detected and identified within the geophysical datasets, larger objects will also be detectable. The provisional magnetometer (MAG) threshold is set on 50 kg ferrous mass. This threshold is also sufficient to detect ferrous naval mines which are likely to be present in the area.

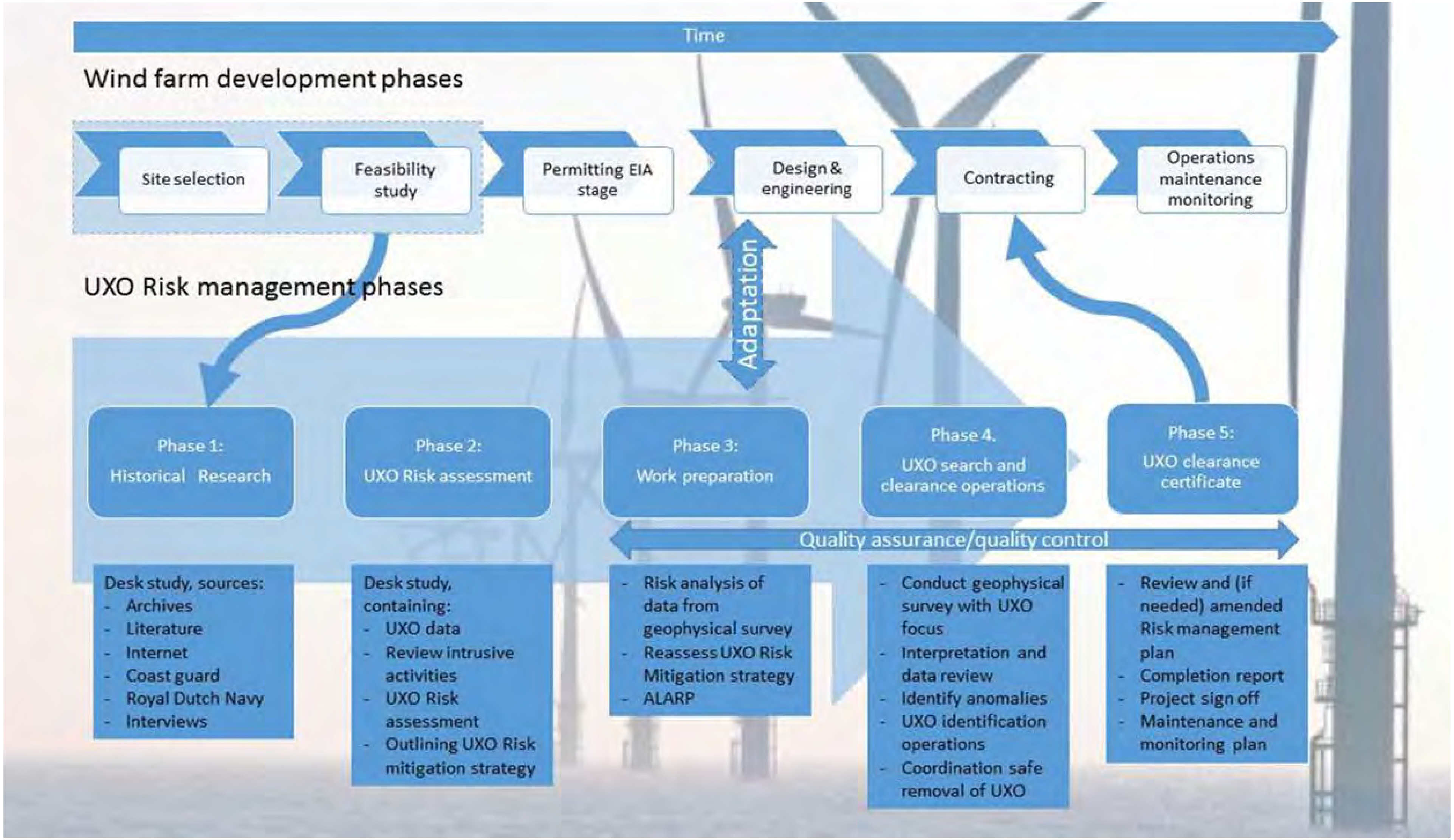
15 ANNEXES

ANNEX 1 GLOSSARY OF TERMS

Begrip	Definitie
Bijdragebesluit / Gemeentefonds	Regeling voor Rijksfinanciering van (een deel van) de kosten voor het NGE-bodemonderzoek.
Conventionele Explosieven (CE)	Elk explosief dat niet als geïmproviseerd, nucleair, biologisch of chemisch kan worden aangemerkt. Bij het opsporingsproces wordt aan CE gelijkgesteld en als zodanig behandeld: - CE die geen explosieve stoffen (meer) bevatten; - Restanten van CE die door leken als zodanig herkenbaar zijn; - Voorwerpen die door leken kunnen worden aangemerkt als CE; - Wapens of onderdelen daarvan.
Historisch Vooronderzoek – Niet Gesprongen Explosieven (HVO-NGE)	Bureaustudie waarin de oorlogshandelingen van de periode 1940-1945 (incl. naoorlogse munitieruimingen en opsporingsactiviteiten) worden geanalyseerd. Doel is om vast te stellen of in het analysegebied sprake is van een NGE-Risicogebied in relatie tot het onderzoeksgebied. Het HVO-NGE bestaat uit: - Rapportage. - Positief of negatief advies. - In het geval van een positief advies: Horizontale afbakening NGE-Risicogebied(en). - NGE-Risicokaart.
Negatief advies	Op basis van de analyse van het bronnenmateriaal wordt niet verwacht NGE aan te treffen in het analysegebied. Een vervolgstap van het NGE-bodemonderzoek wordt niet geadviseerd. De geplande werkzaamheden kunnen regulier worden uitgevoerd.
Niet Gesprongen Explosieven (NGE)	Door REASeuro gehanteerd begrip waaronder wordt verstaan: alle explosieven of onderdelen/restanten van explosieven die niet of gedeeltelijk hebben gefunctioneerd. Onder NGE vallen: - Conventionele Explosieven (CE); - Geïmproviseerde explosieven; - Explosieven voor civiel gebruik; - Chemische explosieven; - Biologische explosieven; - Nucleaire explosieven.
Niet Gesprongen Explosieven – Bodemonderzoek (NGE-Bodemonderzoek)	Werkwijze van REASeuro waaronder wordt verstaan: de integrale totaalaanpak voor de NGE-problematiek bestaande uit vijf afzonderlijke fasen. Hierdoor kan de opdrachtgever per fase een weloverwogen besluit nemen en zijn vervolgacties plannen met als doel dat de opdrachtgever de regie over het project in handen houdt. De vijf fasen zijn: 1. HVO-NGE (Historisch Vooronderzoek NGE). 2. PRA-NGE (Projectgeboden Risicoanalyse NGE). 3. Projectplan-NGE. 4. Uitvoering-NGE. 5. PvvO-NGE (Proces-verbaal van Oplevering).
Niet Gesprongen Explosieven – Risicogebied (NGE-Risicogebied)	Gebied waar op basis van historisch bronnenmateriaal een risico op het aantreffen van NGE bestaat naar de situatie van 1940-1945 (inclusief naoorlogse munitieruimingen en opsporingsactiviteiten). Het NGE-Risicogebied is horizontaal afgebakend, waarin zijn opgenomen: - Eventuele onzekerheden en onnauwkeurigheden uit het bronnenmateriaal (o.a. cartografische onnauwkeurigheden). - De maximale horizontale verplaatsing van NGE in de bodem.

Begrip	Definitie
Niet Gesprongen Explosieven – Risicokaart (NGE-Risicokaart)	Cartografische weergave van het (de) NGE-Risicogebied(en).
Analysegebied	Gebied waarop het HVO-NGE zich richt. Het analysegebied is ruimer dan het onderzoeksgebied om een zo compleet mogelijk beeld te krijgen van de situatie in oorlogstijd.
Oorlogshandeling	Gebeurtenissen die kunnen hebben geleid tot de aanwezigheid van NGE. Voorbeelden van oorlogshandelingen zijn: - Bombardementen - Artilleriebeschietingen - Munitiedump - Munitieongevallen - Vliegtuigcrashes - Aanwezigheid van verdedigingswerken
Opsporingsgebied	Het verdachte gebied binnen het onderzoeksgebied waar voorafgaand aan de reguliere werkzaamheden de opsporing naar NGE wordt geadviseerd.
Positief advies	Analyse van het bronnenmateriaal heeft aangetoond dat NGE kunnen worden aangetroffen in het analysegebied. Een vervolgstap van het NGE-bodemonderzoek wordt geadviseerd. Tevens vormt een positief advies de legitimatie voor het indienen van een Raadsbesluit t.b.v. van een Rijksbijdrage.
Projectgebonden Risicoanalyse – Niet Gesprongen Explosieven (PRA-NGE)	Bureaustudie waarin het verdachte gebied binnen het NGE-Risicogebied wordt afgebakend. Daarnaast worden de risico's van de voorgenomen reguliere werkzaamheden in relatie tot de aan te treffen NGE vastgesteld. De PRA-NGE bestaat o.a. uit: - Indien nodig het opvullen van leemten in kennis van het HVO-NGE. - De horizontale en verticale afbakening van het verdachte gebied. - Een NGE-Risicoanalyse. - Het bepalen van aanvaardbare risico's. - Het opsporingsadvies. - De mogelijkheid tot een proefdetectie.
Reguliere werkzaamheden	Alle door de opdrachtgever voorgenomen niet NGE-gerelateerde werkzaamheden. Enkele voorbeelden zijn civieltechnische, milieutechnische en archeologische werkzaamheden.
Verdacht gebied	De horizontale en verticale afbakening van het NGE-Risicogebied. Bij de afbakening is o.a. rekening gehouden met: - Het vaststellen van de horizontale verplaatsing van de NGE in de bodem (inkaderen NGE-Risicogebied). - De mogelijke inperking van de onzekerheden en onnauwkeurigheden uit het bronnenmateriaal. - De naoorlogse werkzaamheden (zoals ontgravingen, ophogingen etc.). - De bodemkundige parameters (zoals grondsoort en draagkracht van de grond).
Onderzoeksgebied	Het door de opdrachtgever aangegeven gebied waarbinnen reguliere werkzaamheden (niet NGE-gerelateerd) uitgevoerd gaan worden of waar een functieverandering wordt doorgevoerd.
Werkveldspecifiek certificatieschema voor het systeemcertificaat Opsporen Conventionele Explosieven (WSCS-OCE)	Het WSCS-OCE is het Werkveldspecifiek certificatieschema voor het opsporen van Conventionele Explosieven. Hierin zijn onder andere richtlijnen, proceseisen en deskundigheidseisen opgenomen. Het WSCS-OCE is sinds 1 juli 2012 de opvolger van de Beoordelingsrichtlijn Opsporen Conventionele Explosieven (BRL-OCE) en is wettelijk verankerd in de Arbowet. Om het maatschappelijk belang – veiligheid en gezondheid van en rondom de arbeid – te waarborgen, is door de overheid gekozen voor een wettelijk verplichte certificatieregeling voor de borging van de kwaliteit/veiligheid van het opsporen van conventionele explosieven.

ANNEX 2 UXO RISK MANAGEMENT PHASES



Time
Wind farm development phases
Site selection
Feasibility study
Permitting EIA stage
Design & engineering
Contracting
Operations maintenance monitoring
UXO Risk management phases
Adaptation
Phase 1: Historical Research
Phase 2: UXO Risk assessment
Phase 3: Work preparation
Phase 4. UXO search and clearance operations
Phase 5: UXO clearance certificate
Quality assurance/quality control
Desk study, sources:
- Archives
- Literature
- Internet
- Coast guard
- Royal Dutch Navy
- Interviews
Desk study, containing:
- UXO data
- Review intrusive activities
- UXO Risk assessment
- Outlining UXO Risk mitigation strategy
- Risk analysis of data from geophysical survey
- Reassess UXO Risk Mitigation strategy
- ALARP
- Conduct geophysical survey with UXO focus
- Interpretation and data review
- Identify anomalies
- UXO identification operations
- Coordination safe removal of UXO
- Review and (if needed) amended Risk management plan
- Completion report
- Project sign off
- Maintenance and monitoring plan

ANNEX 3 LITERATURE

For this research the following literary sources are consulted:

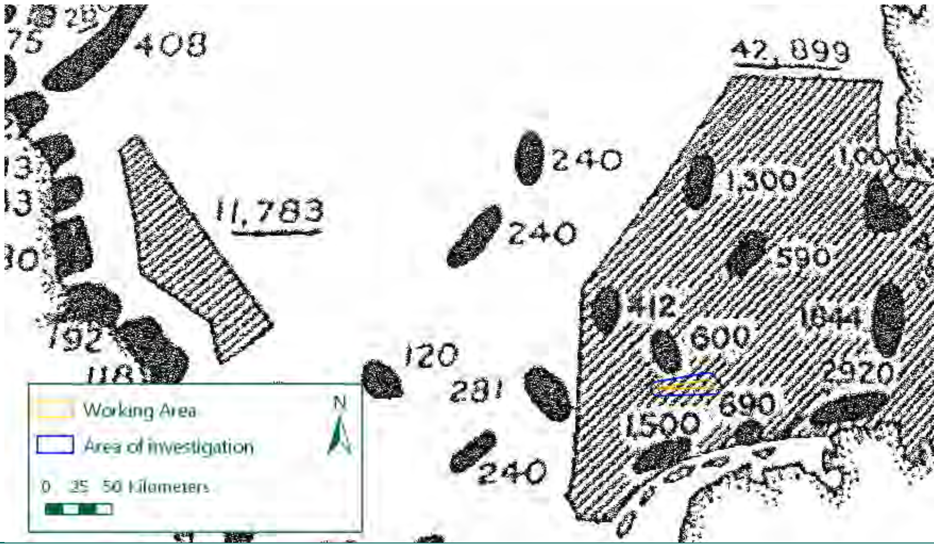
Abbreviation	Author	Title	Relevant
BER	Bertijn, F. (red.),	*Voor een veilige zee* (Naarden 1982).	No
BEZ 1&2	Bezemer, K.W.L.	*Geschiedenis van de Nederlandse Koopvaardij in de Tweede Wereldoorlog* (2 dln.; Amsterdam).	Yes
BOS	Bosman, A.V.A.J	*Een gemeente in oorlogstijd : Velsen 1940-1945* (Santpoort 1995)	No
BOW	Bowyer, Ch.	*Coastal Command at War* (1979).	No
BRO	Brongers, D.	*Op tegengestelde koersen. De kustvaart in oorlogstijd* (Deventer 1996).	No
BUR	Burg, G. van	*Oorlogsstorm over zee en havens. IJmuiden 1939-1946* (Schoorl 1995).	Yes
CRO	Crossley, J.	*The Hidden Threat. The story of mines and minesweeping by the Royal Navy in World War I* (South Yorkshire 2011).	Yes
DIS	Dissel, A. van e.a.	*De Nederlandse koopvaardij in oorlogstijd* (Amsterdam 2014).	No
DUR	Durrieu, A. e.a.	*Atlantic Wall. Its most incredible remains.*	No
KUR	Kurowski, F.	*Seekrieg aus der Luft. Die Deutsche Seeluftwaffe im Zweiten Weltkrieg* (Herford 1979).	No
MID	Middlebrook, Ch.	*The Bomber Command War Diaries. An operational reference book 1939-1945* (Leicester 1996).	No
MVL	Ministerie voor Luchtvaart	*Coastal Command speurt, beschermt, valt aan* (London, z.j.)	No
NES	Nesbit, R.C.	*The Strike Wings. Special Anti-Shipping Squadrons 1924-45* (London 1995).	Yes
ROE	Roetering, B.,	*90 jaar Mijnendienst: Feiten Verhalen En Anekdotes Uit Het Negentigjarig Bestaan Van De Mijnendienst Van De Koninklijke Marine* (Z.P. 1997).	Yes
ROO	Roosenburg, L. e.a. (red.)	*De Zee. Tijdschrift gewijd aan de belangen der Nederlandsche Stoom- en Zeilvaart* (Rotterdam 1916).	Yes
ROW	Rohwer, J., en G. Hümmelchen	*Chronik des Seekrieges 1939-1945* (Stuttgart 2007) via https://www.wlb-stuttgart.de/seekrieg/chronik.htm.	Yes
SCH	Schroeder, W, Kutzleben, K. von	*Minnenschiffe. Marinekleinkampfmittel* (1974).	No
SCHE	Scheer, R.,	*Germany's High Sea Fleet In The World War* (London 1920)	Yes
SGLO	Studiegroep Luchtoorlog	*Crash database. Dutch Air War Studygroup. http:www.verliesregister.studiegroepluchtoorlog.nl*	Yes
VER	Verbeek, J.R.	*Kustversterkingen 1900-1940* (Wassenaar 1988).	No
ZWA 1&2	Zwanenburg, G.J.,	*En Nooit was het Stil. Kroniek van een Luchtoorlog* (2 dln. & supplement; Oldemarkt).	Yes

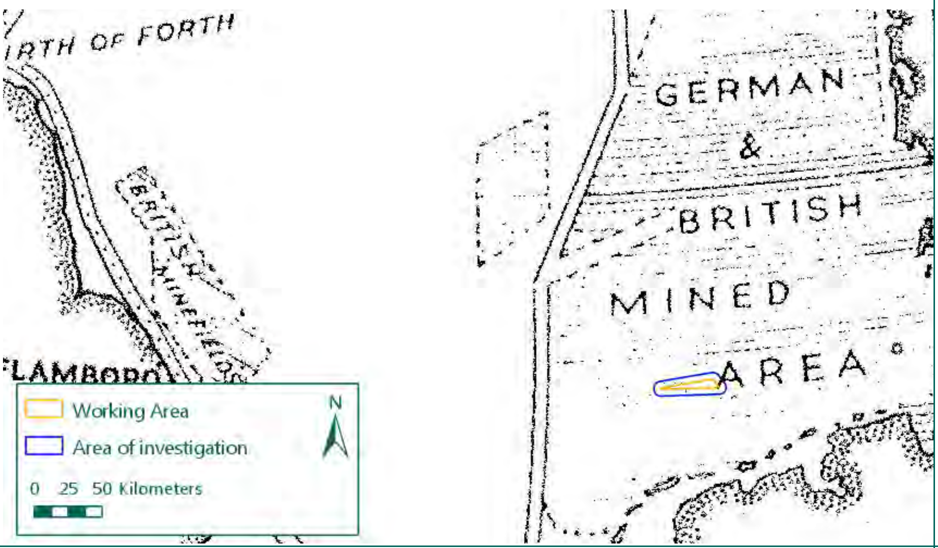
Table 14: References to literature.

The annexes in this table contain the events that are considered relevant for the area of interest. To guarantee authenticity, the sources in Dutch, English, French and German have been quoted in their original language.

First World War mobilization and interbellum, 1914-1939

The First World War forced the Dutch armed forces to mobilize. Coastal guns were installed to protect strategic positions on the coast. The Netherlands maintained a policy of neutrality. However, Dutch shipping took considerable damage from mine and U-boat warfare. Dozens of Dutch merchant vessels were sunk by the thousands of mines laid by the German and British navies. Large scale efforts to clear the minefields after the First World War did not succeed in clearing all these mines. The following literature is relevant for this period:

Date / year	Event	Source	Page
1914-1918	British, German and American mines laid during the war. The German minefields are in black, whereas the Allied fields are shaded. The underlined figures are numbers of Allied mines, and other figures are numbers of German mines. With their vastly greater resources, the Allies laid far more mines in the latter part of the war placing them strategically where they would effectively trap the maximum numbers of U-boats. German mines were placed mainly close to headlands where ships would make landfalls and around the approach to major ports. From 1916 onwards, most of the German mines were laid by submarines, whereas the Allies were able to use surface ships, especially fast destroyer-minelayers, to operate close to enemy coasts. The chart gives an idea of how dangerous mine laying and minesweeping operations were as both enemy and friendly mines might be laid in the same areas. *Hatched areas in the figure below indicate allied minefields, solid areas indicate German minefields. Three German minefields with a total of 2.790 naval mines surround the area of investigation, while the larger allied minefield contains a total of 42.899 naval mines.* 	CRO	62
Augustus 1914	Tot de onbeperkte Duitse onderzeebootoorlog in februari 1917 begon, vormden mijnen de voornaamste oorzaak van onze koopvaardijverliezen. De Duitse regering deelde al in augustus 1914 mede, dat zij zich waarschijnlijk genoodzaakt zou zien mijnen te leggen voor de operatiebases der vijandelijke vloten en voor havens waar troepen van de tegenstander zouden worden ingescheept of ontscheept. In oktober volgde een Britse bekendmaking dat een mijnenveld in een nader omschreven deel der Noordzee was gelegd, maar er bleef een geul over voor de scheepvaart. In de loop van de oorlog werden steeds meer geallieerde en Duitse mijnen gelegd in uitgestrekte delen van de zee, die beide partijen tot oorlogs- of gevaarlijke zones hadden gedeclareerd en verliezen onder de neutrale scheepvaart konden hierdoor moeilijk uitblijven. Er werden hoofdzakelijk verankerde mijnen gelegd die als ze van hun verankering lossloegen, onschadelijk werden. Zo hoorde het althans, maar de praktijk wees herhaaldelijk anders uit. Gedurende de oorlog spoelden ruim 6.000 mijnen alleen al op de Nederlandse kust aan, meest Engelse, namelijk 4.981 stuks (tegen 431 Duitse, 81 Franse en ruim 500 van onbekende oorsprong). Vele ervan kwamen echter toch tot ontploffing. Eind 1916 waren in totaal 29 Nederlandse schepen door mijnen gezonken. Ongeveer een derde deel daarvan was op mijnen gelopen door U-boot-mijnenleggers gelegd, zoals eerst vele jaren na de oorlog bleek. Hoewel navigatorisch geen eenvoudige	BEZ 1	24-25

Date / year	Event	Source	Page
	operatie, met het kleine type onderzeeboot hiervoor meestal gebruikt, wisten de Duitse onderzeebootcommandanten bijzonder nauwkeurig, in aansluitende vakken, mijnenvelden te leggen.		
2 November 1914	Op 2 november 1914 had Engeland de gehele Noordzee tot oorlogsgebied verklaard. Het overschrijden van een lijn, lopend van de noordpunt der Hebriden tot Ijsland, werd ontraden in termen die met een verbod gelijk stonden, met de bedoeling de neutrale scheepvaart te dwingen de weg door Het Kanaal te nemen.	BEZ	18
1915	By this stage in the war it had become clear that the best strategy to deal with German mines was not to try to sweep them all, as a German offensive minefield could equally well serve as a British defensive one, once it was properly charted and buoyed. Rather, it was determined to keep open a swept channel along the east coast, which would be routinely swept daily by trawlers (see Chart 1). The procedure was soon followed in the English Channel and elsewhere. Shipping would be held in a safe area until the daily sweep was completed.  	CRO	55
27 December 1915	Op 27 December 1915 heeft een ontploffing plaats gehad op of bij den stoorukorder „Erin" YM. 88, waarbij persoonlijke ongelukken te betreuren waren. Op 24 December 1915, des middags ongeveer 12 uur vertrok het schip, bemand met 11 koppen, ter vischvangst van Ymuiden , gestuurd werd tot 4 uur n.m. Noord per kompas, vervolgens tot 10 uur des avonds N.O.t.O., in het totaal waren toen ongeveer 75 mij1 afgelegd. Daarna werd gestopt en met de vischvangst een aanvang gemaakt, men bleef bij voortduring op de zelfde plaats visschen, ten hoogste zal het schip ongeveer 15 mijlen Oostelijker zijn gekomen. Op 27 December tusschen half twaalf en 12 uur voormiddags, terwijl men bezig was aan bakboord het net in te halen, en de borden juist voor waren, riep de matroos de Munnik den schipper toe, dat een mijn aan het bord hing. Op hetzelfde oogenblik had een hevige ontploffing plaats. De schipper, de stuurman en de matroos de Koning waren gewond en bloedden hevig, de matrozen Olyrook, de Munnik en Slagveld vielen getroffen neder op het dek, de stoker Jan Alders kwam te water. Het voorschip was deerlijk gehavend en de kop van het vaartuig dook in zee, de B.B.galg was door midden, de mast ping aan S.B. zijde over boord en aan de boeg aan B.B. zijde was een groote deuk zichtbaar. De eerste machinist, getuige Hoonson, die met den tremmer in de machinekamer was en bij de ontploffing naar dek was gesneld, en de kok Maarten Ouwehand wierpen Alders dadelijk een touw toe en trokken hem aan boord. Fluitseinen werden gegeven om de aandacht te trekken van de in de nabijheid visschende stoomkorders. Bevreesd, dat het schip zou zinken, zette men de boot uit en begaf men zich daarin, na den ernstig gewonden schipper, die vrijwel bewusteloos was, en den niet minder gekwetsten stuurman en matroos de Koning er in gelaten te	ROO	221 - 222

Date / year	Event	Source	Page
	hebben. De eerste machinist begaf zich nog naar de machinekamer waar niets beschadigd was, de tweede-machinist, getuige Akkerman, ging naar de drie op het dek liggende matrozen, bovengenoemd, die sporen van zware verwondingen vertoonden; bij riep hen maar kreeg geen antwoord, terwijl zij evenmin eenig ander teeken van leven gaven. Inmiddels werd de positie van de boot gevaarlijk, daar zij ander het achterschip lag en tegen het schip aansloeg ; vertrek was noodzakelijk. Wel werd er over gedacht de 3 matrozen mede te nemen, maar men was overtuigd, dat zij dood waren en ook de toestand der drie gewonden noopte zoo spoedig mogelijk aan boord van een ander schip te komen waar zij althans voorloopig verbonden konden warden, terwijl bovendien gevreesd werd. dat de „Erin" zou zinken. De eerste-machinist kwam het laatst in de boot, men stiet of en bereikte den stoomkorder „Aecacia", welke met den stoomkorder „Olivia" nader was gekomen. Aan boord van de „Accacia" werden de drie gekwetsten verbonden, dit schip voer zoo dicht mogelijk langs de „Erin", fluitseinen werden gegeven maar de drie matrozen bleven onbewegelijk op het dek liggen. In verband met den ernst van de verwondingen van de drie gekwetsten en spoedde de „Accacia" zich naar IJmuiden, waar men 27 uren later aankwam. Van de „Clivia" was men aan boord van de „Erin" gekomen en men bevond, dat alleen de matroos olyrook nog eenig levensteeken gaf ; hij werd naar de „Olivia" overgebracht maar overleed voor dat men IJmuiden bereikte. Schipper, stuurman en matroos de boning werden opgenomen in het ziekenhuis en hun herstel mag worden verwacht. De oorzaak van het ongeval is het ontploffen van de mijn, welke met het ophalen van het net werd opgevischt. In aanmerking genomen de omstandigheden, waarin de bemanning van de „Erin" verkeerde en de toestand van de drie gewonden, welke een onmiddellijke verzorging vereischte, mag men genoemde bemanning geen verwijt er van waken, dat zij van boord is gegaan zonder de drie matrozen van wier dood zij overtuigd was, mede te nemen.		
Na 1918	Later when hostilities were over, it was possible to use drifters by themselves to sweep shallow fields near the Dutch and Belgian coasts where the water was very shallow and even mines sitting on the bottom were a danger. These all had to be painstakingly trawled up and exploded. There was also the dangerous job of exploding the many mines that became washed up on shore. This work was undertaken by a small flotilla of drifters based on Ostend.	CRO	154
1918	Mines, of course, remain deadly irrespective of peace treaties or armistices. No fewer than 240,000 mines were scattered about the seas, some in their original position, some having dragged their moorings and settled in a new location, and some drifting freely. These constituted a major danger to shipping after the end of the war. To clear them up an international committee was formed, which included most belligerent and neutral countries, and was eventually joined by the defeated powers. This was called the International Mine Clearance Committee (IMCC) and was organized principally by the Royal Navy. All members carried out mine clearance activities and reported regularly to the IMCC, who issued regular charts and updates showing safe areas and known danger zones. The main part of the clearance work was divided between the maritime nations, Germany being responsible for sweeping Heligoland Bight, France the waters off the French and Belgian coasts, America the Northern Barrage and the UK, most of the rest, working through a new organization called the Mine Clearance Service. The service was manned mainly by Royal Navy personnel and fishermen and consisted of 14,500 men and 700 officers at its peak. A particular danger when clearing dense fields was what was known as 'counter mining'. This occurred when exploding one mine would set off others in the vicinity – possibly dangerously close to the sweeper involved. Normally, deep fields were left until last, as they did not constitute a serious danger to shipping, but sometimes some of the mines were laid incorrectly and finished up close to the surface. It was determined to skim of any of these shallow mines first, and the sweep began in the normal way.	CRO	149 - 160

Date / year	Event	Source	Page
	The intensive mining of the eastern North Sea also contributed to Germany's to such an extent that it could not even undertake exercises safely, the British offensive mining campaign contributed to the collapse of fleet discipline and hence to the popular revolt against the Kaiser's government, which resulted in the Armistice.		
1918		SCHE	288

Table15: Overview of events World War 1 – Interbellum.

Mobilisation and German invasion, 1939-1940

When the inevitability of the Second World War became clear in August 1939, the Dutch army once again mobilized to prepare for an imminent attack. While serious naval threats were not foreseen, preparations also took place on the coast and the sea. Coastal guns were once again installed, and vital waterways were mined.
In the morning of May the 10th, 1940, the German army invaded the Netherlands. One of the first steps of the German military was to mine the Dutch ports. Major clashes between naval forces did not take place however.

Date / year	Event	Source	Page
1939-1940	Het ontwerpen van de nodige versperringen werd in vredestijd reeds voorbereid bij de staven der diverse oorlogscommandanten, t.w. bij de Commandant van de Stelling den helder, de Commandant der Vesting Holland en de Commandant in Zeeland, waarbij het uitwerken van de geprojecteerde versperringen geschiedde door officieren van de mijnendienst. De versperringen droegen in het algemeen een defensief karakter en het doel dat beoogd werd, was het voor vijandelijke strijdkrachten bemoeilijken van de toegang tot de territoriale wateren in het algemeen en de diverse toegangswegen tot havens in het bijzonder. De mijnversperring was hierbij de feitelijke hindernis, welke aan de vijandelijke schepen in de weg werd gesteld, terwijl de spertonnen slechts ten doel hadden, het opruimen van de versperring door de vijand te bemoeilijken of het gebruik van de beveiligingstuigen onmogelijk te maken. De ontworpen en uitgewerkte versperringen waren vastgelegd in de zeer geheime bijlagen van de "Aanwijzingen voor de Mijnversperringen", en werden eerst bij tel.B of zoveel eerder als voor het leggen der versperringen nodig was, aan de desbetreffende commandanten uitgereikt. In 1938 kwam in de organisatie van de mijnendienst een wijziging. Tot dat jaar had de regering zich op het standpunt gesteld dat het doel van de moederlandse verdediging aan de zeezijde beperkt zou blijven tot een afsluiting der zeegaten en andere toegangen van uit zee door mijnversperringen, die door bewakingsvaartuigen en kustbatterijen tegen opruimen door licht materieel ener tegenpartij zouden worden beschermd.	BUR	12-13

Date / year	Event	Source	Page
	In 1939 werd echter dit standpunt enigszins gewijzigd en werd door de Minister van Defensie voor het eerst vastgelegd dat Nederland voortaan ook zou moeten bijdragen tot de beveiliging ter zee, zodat de voedsel en grondstoffentoevoer in oorlogstijd, mede door Nederlandse oorlogsschepen zou kunnen worden beschermd.		

Table 16: Overview of events mobilization – Dutch capitulation.

The occupation, May 1940 - June 1944 (D-Day)

Occupation followed the capitulation of the Dutch army. The North Sea became the frontline between Great-Britain and occupied mainland Europe. Fast attack craft from the Royal Navy coastal forces attacked German shipping close to the coast and laid mines to further hamper German navigation of the North Sea. Patrolling allied aircraft attacked convoys, submarines and surface vessels with all possible means, while heavy bombers dropped even more mines in the waters around The Netherlands. To make matters worse, thousands of aircraft flew over the North Sea on route to targets in Germany, jettisoning their bombs in the sea when they encountered German fighters.

Date / year	Event	Source	Page
28 May 1940	Coastal Command Een Hudson deed een aanval op vier stilliggende motortorpedoboten, 50 km ten noorden van Terschelling, waarbij de bommen tien meter voor het doel vielen. Schade werd niet geconstateerd.	ZWA 1	41
28 June 1941	Bomber Command Achttien Blenheims en zes Stirlings doelen in NW Duitsland, alle voortijdig terug. Eén Stirling ca. 60 km ten noorden van Terschelling door Bf-109's in zee neergeschoten. Noot. De Stirling was van No. 7 Squadron. F/ Lt. Collins en zijn bemanning kwamen om en zijn tot op heden nog vermist. Overigens hadden de Stirlings ook raak geschoten, want een gloednieuwe Bf-109 moest wegens treffers een noodlanding op zee maken en ging verloren.	ZWA 1	215
12 September 1941	Angriffe des RAF Coastal Command auf Schiffsverkehr. In norw. Gewässern wird am 2.9. die dt. Oslebshausen (4989 BRT) bei Stavanger mit Lufttorpedo und am 12.9. die finn. Tauri (2517 BRT) vor Bergen durch Bomben versenkt. Am 17.9. wird der kleine norw. Tanker Vard durch Bomben beschädigt. — In der südl. Nordsee gehen am 15.9. die dt. Johann Wessels (4659 BRT) bei Norderney durch Luftangriff verloren, am 12.9. wird die Narvik nördlich von Ameland durch Luftangriff beschädigt.´	ROW	-
28 September 1941	Erfolge brit. Luftminenverseuchung: Am 2.9. geht in der Osterems Bergungsschlepper Peter Wessels (135 BRT) verloren. Am 19.9. sinkt östl. Grenaa (Kattegatt) der Fischdampfer Bunte Kuh (262 BRT) beim Fischfang. Am 28.9. wird die norw.? Aspe (xxx BRT) nördl. Ameland durch Luftminentreffer beschädigt.	ROW	-
14 June 1942	Verluste durch brit. Luftminen. In der Nordsee sinken am 4. 6. Katharina Dorothea Fritzen (7843 BRT) bei Langeoog, am 11.6. die norw. Haugarland (6042 BRT) bei Terschelling, am 16.6. die Plus (2451 BRT) und am 21.6. der schwed. Erzfrachter Ekno (1847 BRT) in der Wesermündung, am 28. 6. die Frielinghaus (4339 BRT) bei Borkum. Beschädigt werden am 14.6. die norw. Taiwan (5502 BRT) nördlich Ameland und am 16.6. der neue dt. Frachter Alsterdamm (3764 BRT) bei Borkum. In der Ostsee sinkt am 12.6. die schwed. Bojan (1046 BRT) vor Saßnitz. Am 4.6. wird die Ingerseks (4969 BRT) östl. Arkona beschädigt.	ROW	-
9 November 1942	Vor Lowestoft greifen die dt. 2., 4. und 6. S-Flottille mit 20 Booten (F.d.S. an Bord von S 83) ein Nordgeleit an. Im Gefecht mit den Geleitschiffen erhält S 113 mehrere Treffer im Vorschiff und muß eingeschleppt werden, S 112 muß ebenfalls einige Treffer einstecken. S 64 wird durch den Zerstörer Vesper, S 101 (Oblt.z.S. Miljes †) durch ML 201 und MGB 103 beschädigt. Im Wehrmachtsbericht vom 11.11. wird die Versenkung von 4 Schiffen mit 11.000 BRT , die Beschädigung eines Bewachers und 2 weiterer Dampfer gemeldet. In Wirklichkeit war der Erfolg wesentlich geringer. Versenkt wurde der norw.	ROW	-

Date / year	Event	Source	Page
	Frachter Fidelio (1843 BRT) und torpediert der brit. Dampfer Wandle (1482 BRT). — Brit. MTB torpedieren aus einem deutschen Konvoi nördlich von Terschelling den schwedischen Frachter Abisko (3139 BRT). Das Schiff wird nach Emden eingebracht und repariert.		
19 July 1943	Minenoffensive des RAF Bomber Command: in 15 Nächten 297 Einsätze gegen Häfen der Biskaya, Küste der Bretagne, die niederländische, friesische Küste sowie die Elb-Mündung. Dabei gehen 6 Flugzeuge verloren. — Im Juli gehen folgende große Schiffe auf (Luft-)Minen verloren: am 8.7. Sperrbrecher 165 / Gebweiler vor Gjedser Odde (Ostsee), am 19.7. der schwed. Dampfer Vidar (2140 BRT) nördlich von Terschelling, am 23.7. Minensucher M 152 in der Gironde (Ergänzung).	ROW	-
27 July 1943	Coastal Command 05.59 uur. Door een Beaufighter op verkenning langs de Nederlandse kust, werd 36 mijl ten noorden van Ameland een Do-24 neergeschoten.	ZWA 2	47
14 May 1944	Der dt. Minensucher M 435 wird nördlich Ameland von Beaufighters des RAF Coastal Command angegriffen und schwer beschädigt. Es sinkt während eines Bergungsversuches durch M 369. Im gleichen Zuge wird nördlich von Terschelling der dt. Frachter Vesta (1854 BRT) versenkt.	ROW	-

Table 17: Overview of events German occupation to D-Day.

June (D-Day) – May 1945 (liberation)

One June 6th an allied invasion force landed in Normandy, rapidly advancing to Germany. German forces desperately attacked the allied convoys transporting vital resources for the advancing armies, forcing the British navy to aggressively patrol the shipping lanes. This situation continued until the capitulation of the German military in May 1945.

Date / year	Event	Source	Page
Augustus 1944	By August 1944, the Germans had been forced to cease sending convoys by day along the Dutch coast. The toll taken by the Allied air forces had become too heavy. The only possible tactic was to sail the convoys by night, in short hops from port to port, sheltering in heavily defended harbours during the long daylight hours. In response, Coastal Command tried to attack the convoys at night, employing the Torbeaus of the Strike Wings. These squadrons were joined by two bomb-carrying squadrons based at Bircham Newton in Norfolk, the Wellingtons of 524 Squadron and the Avengers of 855 (Fleet Air Arm) Squadron. During moonlit nights these aircraft would roam along the Dutch coast on patrols called Rovers, taking off singly at set intervals and seeking 'targets of opportunity'. On dark nights, they would sometimes adopt more involved tactics, known as Operation Gilbeys. These were combined bombing and torpedo attacks, and the method had been worked out as early as January 1944, based on experiments carried out by the Torbeaus of 254 Squadron at North Coates.	NES	181

Table 18: Overview of events D-Day – May 1945.

Post-war period

Immediately after the war, the reconstruction of the Netherlands began. Defensive works, bunkers and remaining NGE were cleaned up. German prisoners of war were used to clear the thousands of minefields.
No relevant information has been found for this period.

ANNEX 4 DUTCH ARCHIVES

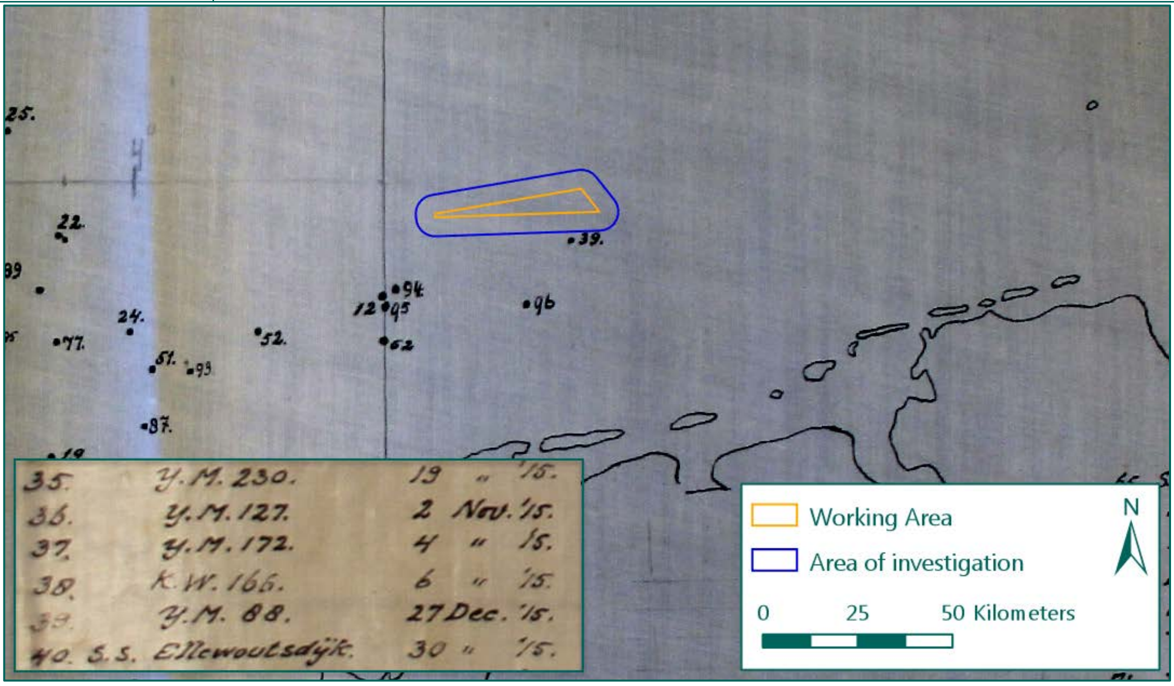
Several Dutch archives have been consulted for this desk top study. The Dutch National Archives (Nationaal Archief) contains relevant results for this study. These results are shown in this annex.

The following records have been consulted in the Nationaal Archief:

- Toegang 2.05.32.09 BuZa/Zeeoorlogschade [*Foreign relations / naval warfare damage*]
- Toegang 2.12.18 archief van de Koninklijke Marine: Chef van de Marinestaf te 's-Gravenhage, 1886-1942 [*Chief of the Navy staff, 1886-1942*]
- Toegang 2.12.19 Marinestaf, 1945-1948 [*Navy Staff, 1945-1948*]
- Toegang 2.12.27 Marine / Tweede Wereldoorlog, 1940-1945 [*Navy during the Second World War*]
- Toegang 2.12.56 Marine na 1945 [*Navy after the Second World War*]
- Toegang 2.13.114 Marinestaf van het Ministerie van Defensie, 1948-1984 [*Navy staff of the Ministry of Defence*]

Relevant files from the record groups mentioned above are shown in the following tables:

Toegang 2.05.32.09 BuZa/Zeeoorlogschade	
Inventaris 44	Kaart van de Noordzee met opgave van de plaatsen waar verankerde mijnen lagen, waarop Nederlandse schepen zijn gevaren in de jaren 1914-1916, op linnen, zonder datum



Ship sank after mine hit on 27 December 1915.

2.12.18 archief van de Koninklijke Marine: Chef van de Marinestaf te ''s-Gravenhage, 1886-1942	
Inventaris 275	Stukken betreffende het onschadelijk maken van mijnen. 1914-1940
Reports of beached naval mines over the course of the First World War. Only Mk. I, Mk. II and Mk. III British mines were found and subsequently cleared on the beaches of Terschelling and Ameland.	

2.12.18 archief van de Koninklijke Marine: Chef van de Marinestaf te ''s-Gravenhage, 1886-1942

1 September 15 Engelsche myn type II. De myn ligt op het Noordzeestrand by paal 22 te Ameland.

Merken : N
Ltd.
M.S.
Mark II
1910
No 4575.

Brengen eene springlading van 4 blokjes/tegen het mynlichaam tot ontploffing. De springlading van de myn detoneert. Myn is vernietigd. [pikrinezuur]

1 December 15 Engelsche myn type II liggende op het Noordzeestrand by paal 12 op het eiland Schiermonnikoog.

Merken : M.A.R.K.III
1914
No 9485.

Brengen eene springlading van vier blokjes pikrinezuur tegen het mynlichaam tot ontploffing. De myn detoneert en is vernietigd. Deze myn werd onschadelyk gemaakt door den Torpedomaker-majoor E.L. Hangard, stamb. no 25175.

Toegang 2.12.19 Marinestaf, 1945-1948	
Inventaris 703	Commandement Marine Willemsoord/Den Helder januari - september 1946, 1 omslag

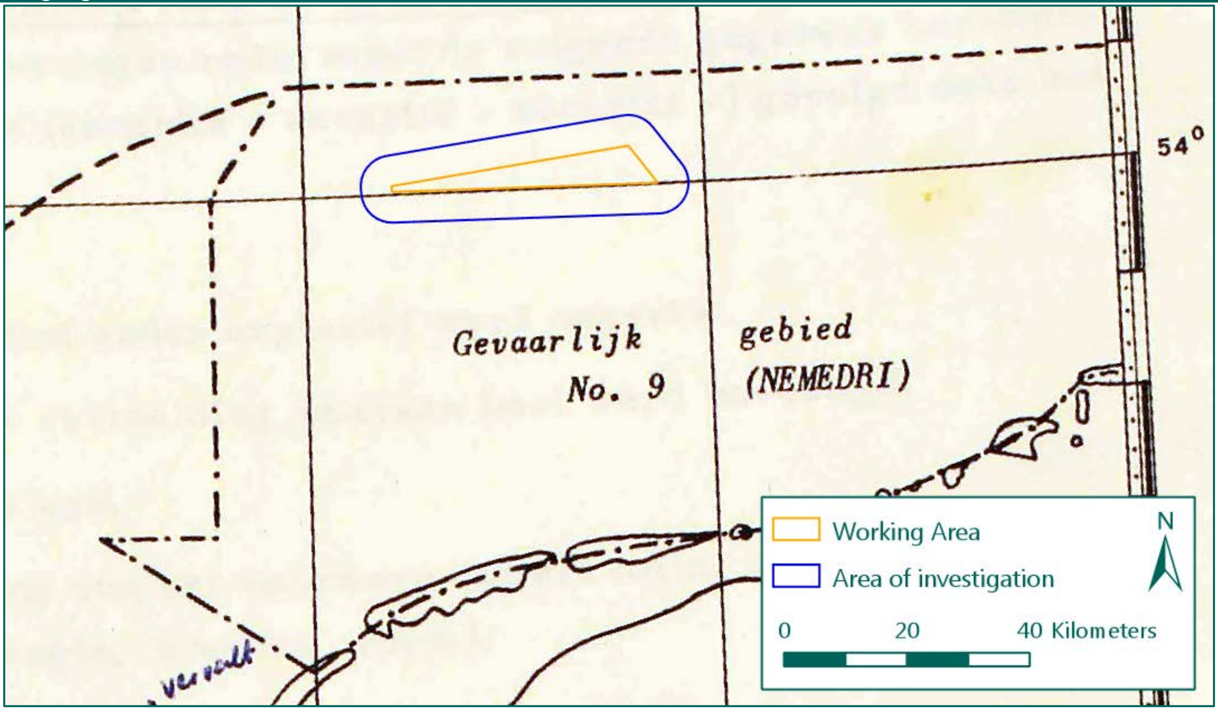
Several floating mines were found on the beach and detonated by Royal Netherlands Navy personnel.

Op Ameland : 1 drijvende Duitsche mijn door te exploderen.
1 drijvende Duitsche mijn GY - gedemonteerd en lading verbrand.
1 Engelsche mijn MK XVII - gedemonteerd en lading verbrand.

Toegang 2.12.27 Marine / Tweede Wereldoorlog, 1940-1945
No relevant files in this series.

Toegang 2.12.56 Marine na 1945	
Inventaris 955	Tijdig publiceren van mijnenoefeningen en het aangeven van de oefengebieden, 1957, 1960, 1967-1972

The area of investigation was situated in 'Dangerous area no. 9 (NEMEDRI)' in 1968. Fishing was allowed in this area, but completely on the responsibility of the fishermen and without any possible compensation for damages.

Toegang 2.12.56 Marine na 1945


2.13.114 archief van de Marinestaf van het Ministerie van Defensie, 1948-1984
No relevant files in this series.

ANNEX 5 INTERNATIONAL ARCHIVES

Several international archives have been consulted in order to gain information on the war related events in the area of investigation. The REASeuro database contains a large quantity of documents from the British, American and German archives. The following international archives yielded relevant documents for this desk top study:

- The National Archives (TNA) in London, UK.
- National Archives and Records Administration (NARA) in College Park (MD), United States.
- Bundesarchiv-Militärarchiv (BaMa) in Freiburg, Germany.

The National Archives

The National Archives (TNA) have been consulted for more information on maritime and aerial warfare in the area of investigation. This annex contains relevant information from TNA. Information regarding maritime and aerial warfare is mentioned consecutively.

Admiralty series

The admiralty series (ADM) have been consulted for information concerning wrecks, naval combat, minefields and air strikes. Consulting these series yielded several files containing relevant information. These files are shown in the tables below.

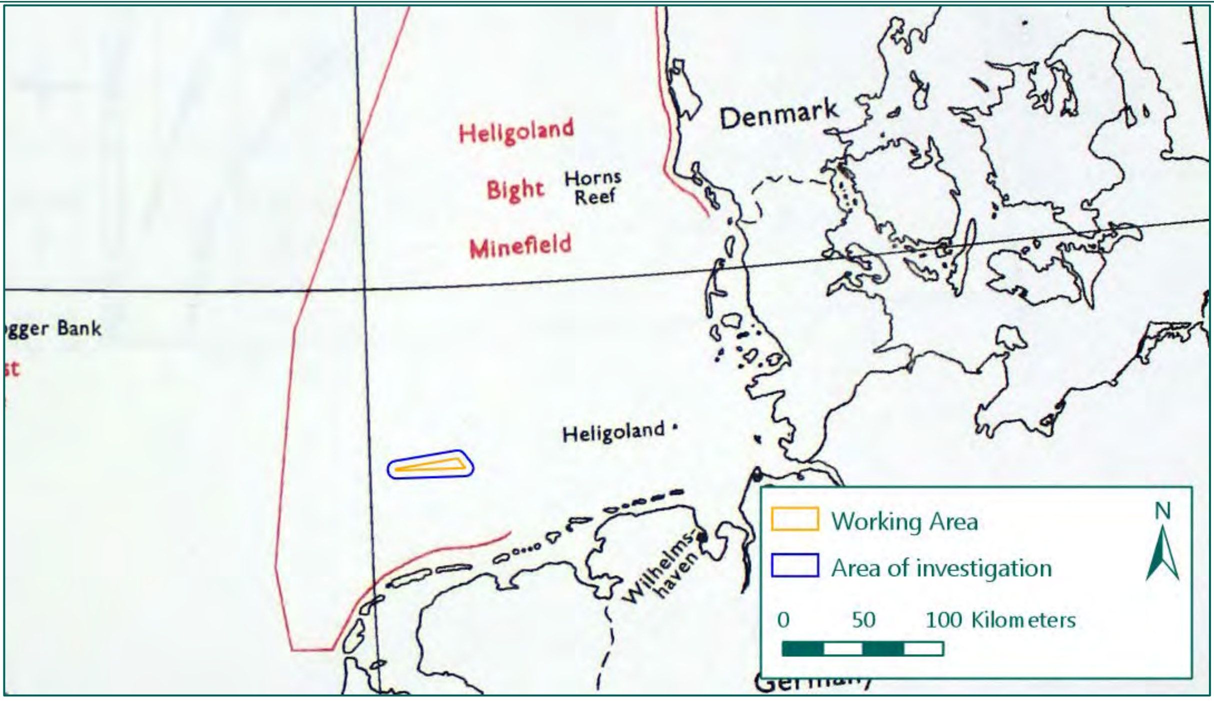
Admiralty, and Ministry of Defence, Navy Department: Correspondence and Papers (ADM)	
ADM 234/560	British mining operations 1939-1945: Vol 1.
"On 27th March [1941] a large new area was authorised for air minelaying in the North Sea, incorporating all waters within the ten-fathom line lying between the Elbe River and Terschelling [Nectarines]. While the original smaller 'gardens' contained therein were still regarded as individual targets, the mining of this new area was calculated to extend the enemy's sweeping resources considerably, besides providing a useful dumping ground for pilots who had been unable to lay on their specified eastern targets because of enemy opposition. It was first visited by No. 816 Squadron at the end of March and was later sub-divided, numerically, for ease of recording: in February 1942 "Nectarines" was extended further to seaward and became one of the more heavily planted 'gardens'." Information indicates the area of investigation was situated in a large 'mine garden', in which aerial mines were laid. The following further information is relevant: Garden name: Nectarines (formerly Xeranthemum, Zinnia and Mussels) Mine types: Ground mines A Mk I, A Mk. I-IV and A Mk. V. Total: 12,072 ground mines Casualties: 146	

AREA 4

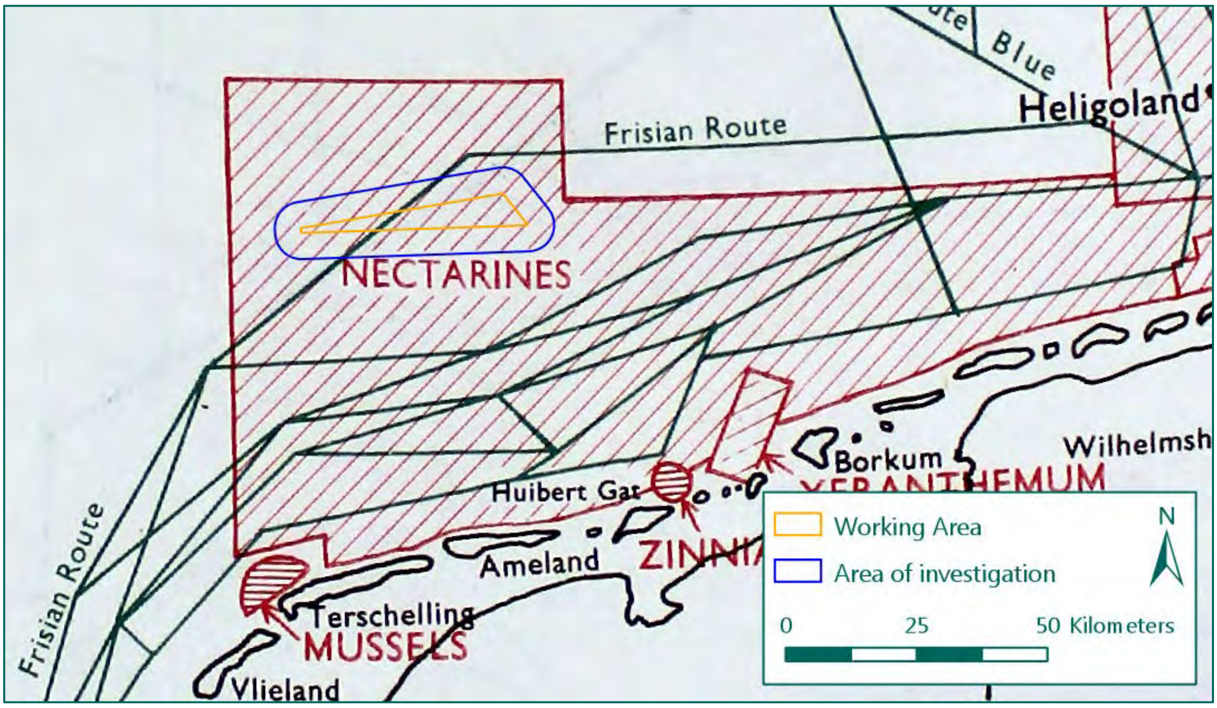
ANALYSIS OF OPERATIONS

		DANISH COAST Hawthorn Rosemary	ELBE & WESER Eglantine Yams	GERMAN COAST & FRISIAN Is. Xeranthemum Zinnia Mussels Nectarine	DUTCH WEST COAST Limpets Whelks Trefoil	HOOK OF HOLLAND Oysters Iris V	SCHELDT Newts Juniper Iris II Flounders	ALL AREAS
1940	Mines	-	139	127	45	60	70	441
	Casualties	-	8	10	10	7	5	40
	Ratio	-	1:17	1:13	1:4.5	1:8.5	1:14	1:11
1941	Mines	37	116	268	-	2	-	423
	Casualties	1	11	18	4	2	-	36
	Ratio	1:37	1:10.5	1:15	∞	1:1	-	1:11.7
1942	Mines	698	133	3,921	170	-	-	4,922
	Casualties	18	10	67	4	-	-	99
	Ratio	1:39	1:13	1:58	1:42	-	-	1:49.5
1943	Mines	156	63	6,288	372	-	-	6,879
	Casualties	12	4	32	-	-	-	48
	Ratio	1:13	1:16	1:197	∞	-	-	1:143
1944	Mines	1,800	150	1,468	491	88	252	4,249
	Casualties	53	11	19	8	5	8	104
	Ratio	1:34	1:13.6	1:77	1:61	1:18	1:31	1:41
1945	Mines	296	361	-	-	-	-	657
	Casualties	1	14	-	2	-	-	17
	Ratio	1:296	1:26	-	∞	-	-	1:39
OVERALL	Mines	2,987	962	12,072	1,078	150	322	17,571
	Casualties	85	58	146	28	14	13	344
	Ratio	1:35	1:16.6	1:83	1:38.5	1:10.7	1:25	1:51

ADM 234/561	British mining operations 1939-1945: Vol 2.;



British First World War minefields in the German Bight.



Minelaying gardens en shipping routes (green lines), situation of July 1944.

Air Ministry series

The Air Ministry series (AIR) contain information on aerial warfare during the Second World War. The Operations Record Books (ORBs) of units that operated in or near the area of investigation have been consulted:

- Headquarters Coastal Command, 1940-1945 (AIR 24/372 t/m AIR 24/427)
- 16 Group Coastal Command, 1940-1945 (AIR 25/313 t/m AIR 25/374)
- Headquarters Bomber Command, 1940-1945 (AIR 24/217 t/m AIR 24/319)
- Intelligence on USAAF missions (AIR 40)

16 Group Coastal Command patrolled the North Sea, attacking German shipping and conducting rescue operations. ORBs from this unit contain location of air strikes, jettisons, aircraft wreckages and Anti-Aircraft Artillery (AAA). Until halfway 1942 the locations were noted in Coastal Command cypher which has only partially been decrypted by REASeuro. From 1942 onwards the ORBs mention locations in coordinates, based on decimal degrees. One must take into account that Coastal Command operated during the night as well, severely restraining navigational accuracy. When possible, war related events mentioned in the Coastal Command records have been coupled with records from the German point of view, resulting in more accurate positioning based on multiple sources.

REASeuro digitalized all the relevant latitude/longitude coordinates from Coastal Command ORBs and plotted these coordinates in GIS. This results in a comprehensive database of Coastal Command activity that may have results in the presence of UXO in the area of investigation. Coastal Command activity in and around the area of investigation is shown in Figure 20.

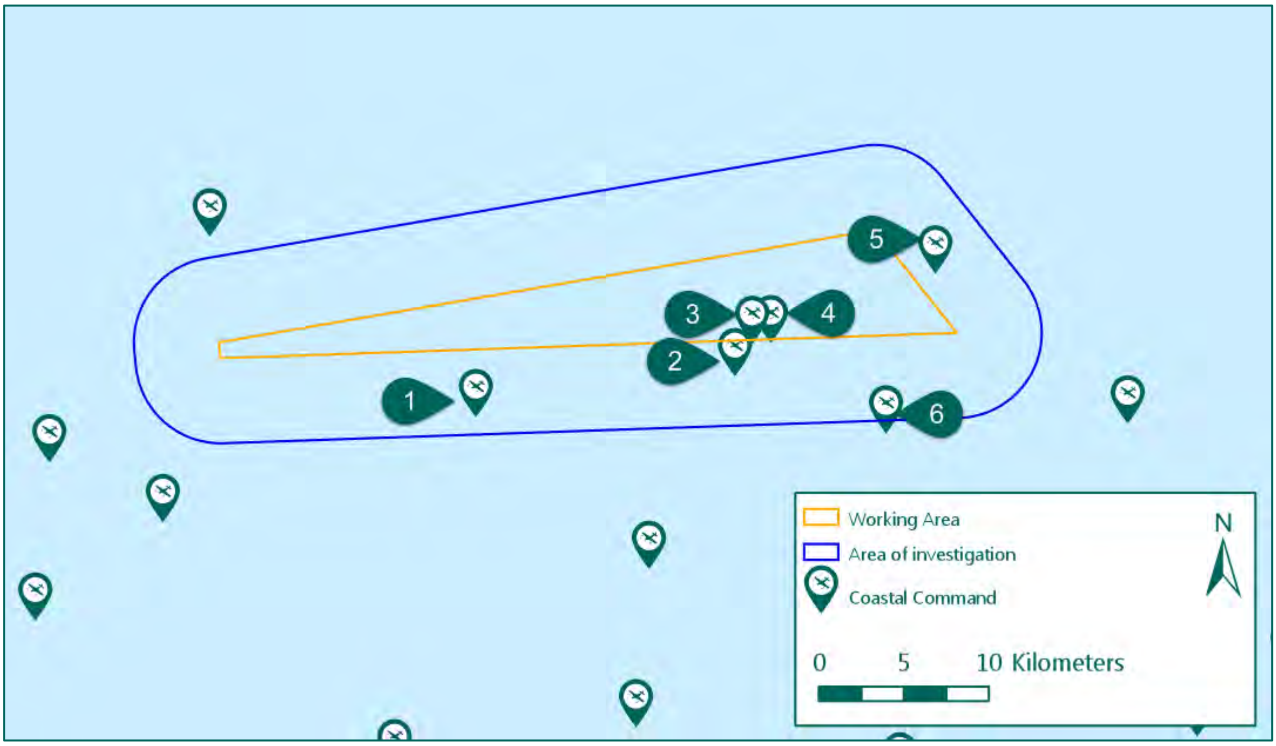


Figure 20: Locations of Coastal Command operations, based on 16 Group logs.

Coastal Command operations			
No.	Date	Event	Sources
1	2 February 1943	U/143: At 1332 in position 53 39 N 05 02 E, sighted 2 Coasters about 4-500 tons, very close together, heading NE apparently stationary or moving very slowly. Leading vessel was emitting much black smoke from funnel. There were no balloons. The vessel in rear opened fire with machine gun and three black shell bursts. Fire was from amidships of vessel and fell astern of aircraft. H.E. bursts were also above altitude of aircraft, which was 50 feet.	AIR 25/346
2	27 July 1943	V/254: At 0559 hrs in position 53 59 N 05 41 E sighted enemy aircraft – Dornier 25 – 600 ft above own aircraft bearing 030 course 090, 4000 yards distant. 'V' closed in to 800 yds and gave enemy aircraft two bursts. Strikes were seen on tail. Dornier 24 replied from turret effecting slight damage to 'V''s port main plane. 'V' closed to 200 yds and using more deflection, gave second burst. This appeared to put front turret of enemy aircraft out of action and strikes were seen along bottom of hull and sponsons. Enemy aircraft burst into flames attempted to climb, then plunged into the sea,	AIR 25/351

		enveloped in flames and smoke. Patrol was completed at 50 ft, but no shipping sighted.	
3	18 July 1944	Armed with 5x 500 lb. MC tail fused 14 seconds delay bombs – 25x Mk. V flares No. 3 capsules, and fitted with Radar Mk. II, this a/c was airborne as instructed. [...] At 02.34 hours they climbed and homed. Attack was then made on Radar at 0239 hrs in position 54 00 N 05 42 E from height of 3,500 ft apart from five bomb flashes seen through cloud nothing else was observed.	AIR 25/363
4	30 November 1942	U/236 [...] In position 54 00 N 05 43 E one mine was sighted and reported to Nalo Humber.	AIR 25/343
5	26 February 1943	Beaufighter 'Q' flew his patrol at 50 feet. At 1821 hrs in Position 54 02 N 05 52 E, 2 armed Trawlers were seen travelling at a speed of 6 knots, they fired light flak, with red and white tracer, proving unsuccessful, but fairly accurate for height and direction.	AIR 25/346
6	2 February 1943	P/143 [...] 1334 in position 53 57 N 05 49 E two armed trawlers were sighted, course NE, speed 5 kts. These trawlers fired inaccurate flak at P/143. Nothing else sighted except mines.	AIR 25/346
N/A[27]	16 October 1942	W/236 Completed patrol, which was flown at 50 feet, but nothing was sighted except a horn type mine in position VVLE 5856 [*53 58 N 05 56 E*], and this was reported to NALO Humber.	AIR 25/342

Table 19: Coastal Command operations, based on 16 Group ORBs.

Bomber Command, Coastal Command's famous land-based counterpart, was also active against German shipping during the first years of the war. Besides intentional bombing, Bomber Command aircraft also jettisoned bombs when in trouble. The jettisons preferably took place over sea, since this dramatically reduced the chance of collateral damage. Bomber Command coordinates have been digitalized and imported in GIS as well. Coordinates in and around the area of investigation are shown in Figure 21.

[27] Coordinates based on Royal Navy coded grid system cannot be shown in GIS.

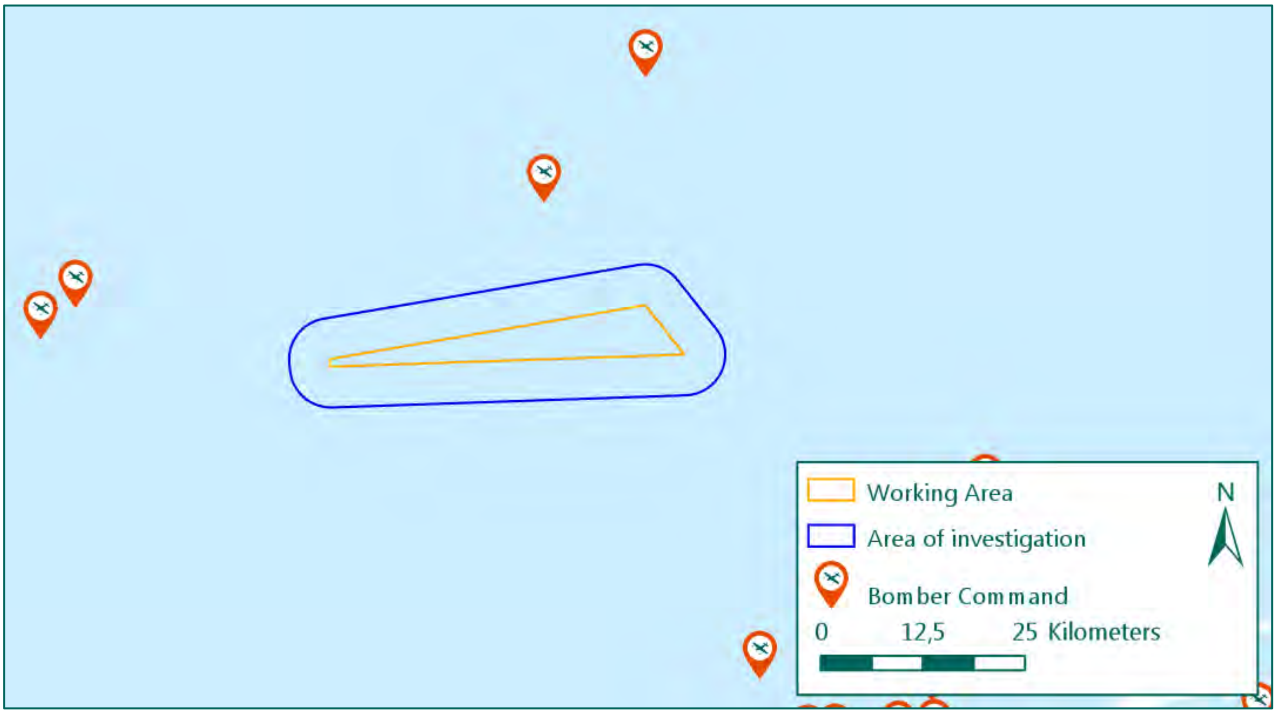


Figure 21: Bomber Command operations against convoys and jettisons.

The figures shown above only show war related events that were noted with traceable coordinates. Not all events were noted in the ORBs with a coordinate. Many locations of attacks and jettisons are not or only vaguely noted. The following figures show examples of attacks and jettisons without a traceable location.

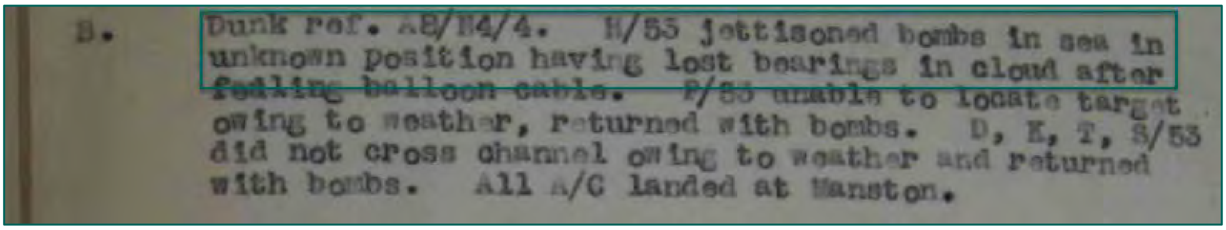

B. Dunk ref. A8/B4/4. H/53 jettisoned bombs in sea in unknown position having lost bearings in cloud after fouling balloon cable. P/53 unable to locate target owing to weather, returned with bombs. D, K, T, S/53 did not cross channel owing to weather and returned with bombs. All A/C landed at Manston.

Figure 22: 5 October 1940: Blenheim bomber jettisons bombs on an unknown location in the North (Source: TNA, AIR 24/375).

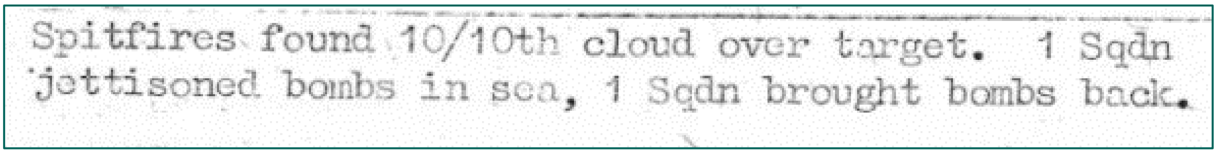

Spitfires found 10/10th cloud over target. 1 Sqdn jettisoned bombs in sea, 1 Sqdn brought bombs back.

Figure 23: 20 May 1944: A squadron of Spitfires jettisons bombs after being unable to locate its target (Source: TNA, AIR 37/713).

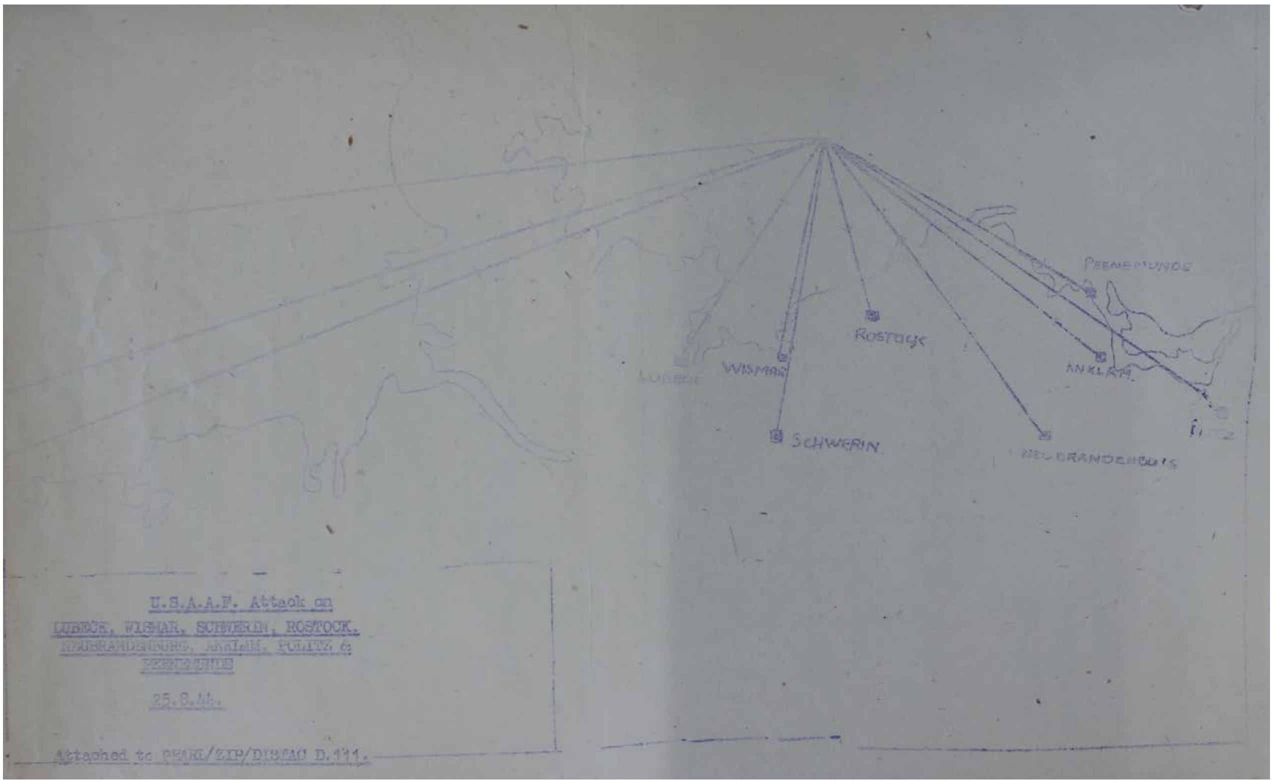
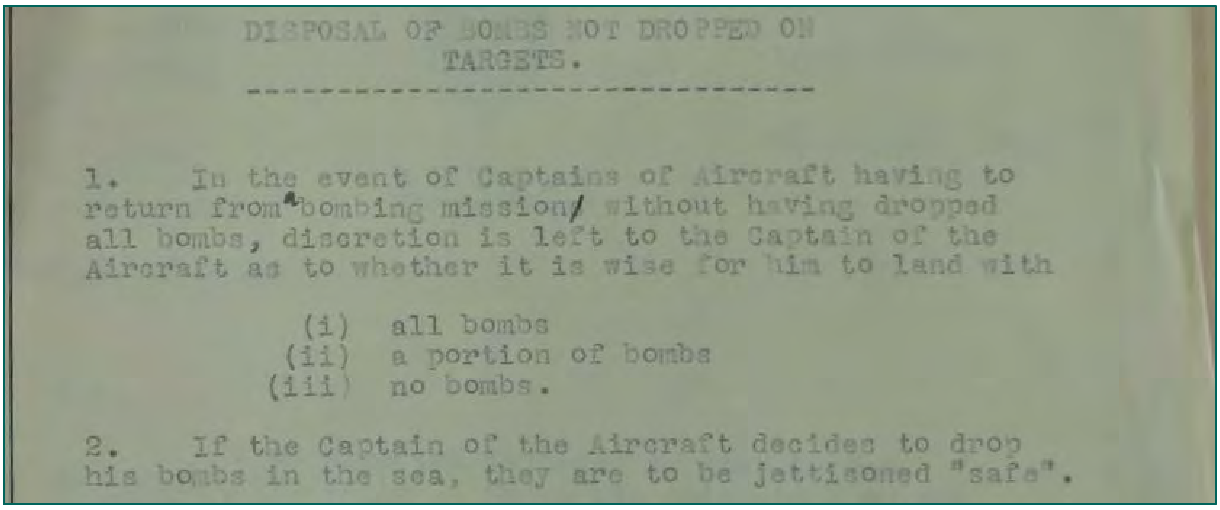


Figure 24: Track chart of USAAF bombers, flying over the Area of Investigation (Source: TNA, AIR 40/720).

Research in TNA also yielded policy documents mentioning jettisoning. Document from AIR 14/110 (Disposal of bombs not dropped on allotted targets) describe the procedure of jettisoning bombs:



DISPOSAL OF BOMBS NOT DROPPED ON TARGETS.

1. In the event of Captains of Aircraft having to return from bombing missions without having dropped all bombs, discretion is left to the Captain of the Aircraft as to whether it is wise for him to land with

(i) all bombs
(ii) a portion of bombs
(iii) no bombs.

2. If the Captain of the Aircraft decides to drop his bombs in the sea, they are to be jettisoned "safe".

Figure 25: Extract from AIR 14/110 (Disposal of bombs not dropped on allotted targets).

National Archives and Records Administration

The following Record Groups have been consulted in the NARA:

- Record Group 18: Mission Reports.
  The mission reports contain detailed information on allied bombing raids, including height, air speed and the deployed munitions.
- Record Group 242: Captured German Records
  The Captured German Records are microfilmed German army records captured after the German capitulation. In several instances the captured records are more complete than the records maintained by the Bundesarchiv.
- Record Group 342: Records of U.S. Air Force Commands, Activities, and Organizations
  Record Group 342 contains additional details not mentioned in Record Group 18.

Record Group 242: Captured German Records	
The German 5. *Sicherungsdivision* (fifth security division) was responsible for safeguarding convoy routes along the Dutch coast. The area of investigation partially fell under the responsibility of the division. Digital copies of the *Kriegstagebücher* (war diaries) of this division have been ordered at the National Archives and Records Administration. The copies are not yet available to REASeuro at the time of this research, however.	
T1022R, roll 3557 and 3558	KTB and Anlagen 5. Sicherungsdivision 12 March 1942 – 31 December 1942.
Not yet available at the time of this research.	
T1022R, roll 3593-3595	KTB and Anlagen 5. Sicherungsdivision (1 January 1943 – 15 January 1945)
Not yet available at the time of this research.	

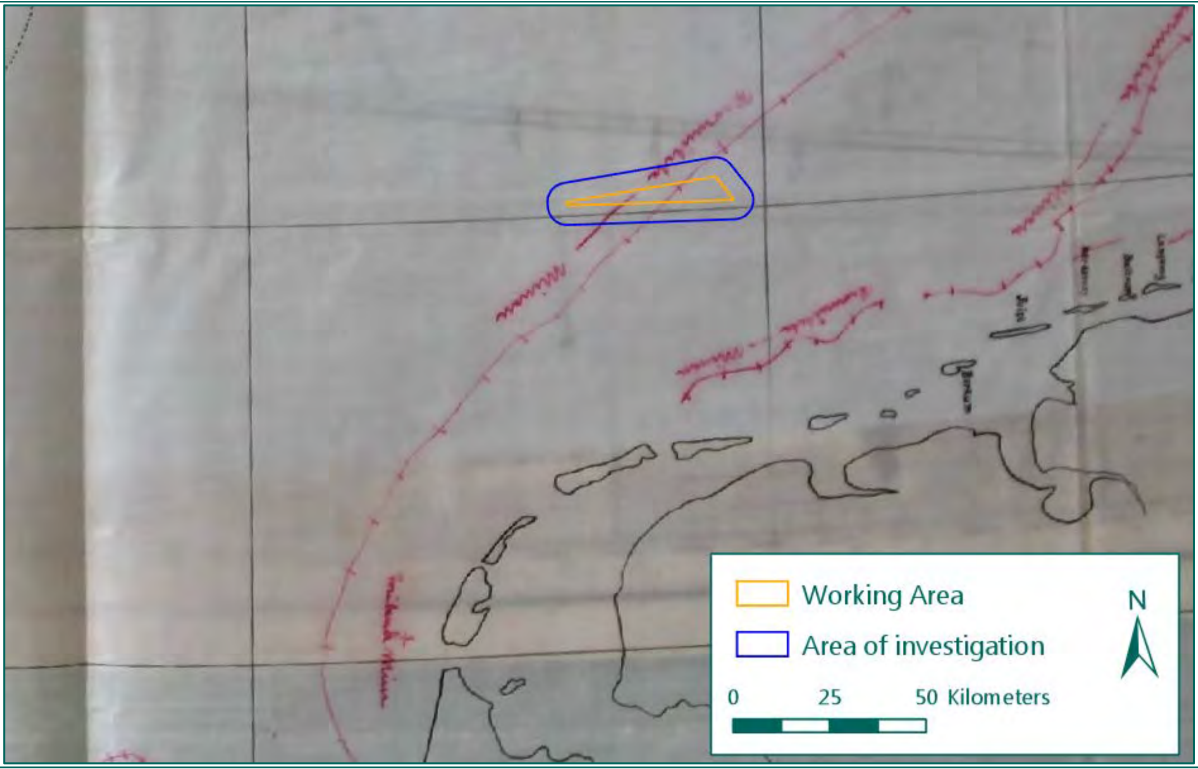
Bundesarchiv-Militärarchiv (BAMA)

The German military archives have been consulted in the BAMA in Freiburg. This archive contains the documents from the German military in the Second World War. The following record groups have been consulted by REASeuro to gain more information about the German perspective of naval warfare in the area of investigation:

- RM 2: Kaiserliches Marinekabinett.
- RM 5: Admiralstab der Marine / Seekriegsleitung der Kaiserlichen Marine.
- RM 7: Seekriegsleitung der Kriegsmarine.
- RM 8: Kriegswissenschaftliche Abteilung der Marine (Marinearchiv).
- RM 35-II: Marinegruppenkommando West der Kriegsmarine.
- RM 45-II: Dienststellen und Kommandostellen der Kriegsmarine im Bereich Deutsche Bucht und Niederlande.
- RM 67: Sicherungsdivisionen der Kriegsmarine.
- ZA 5: Deutscher Minenräumdienst (German Minesweeping Administration).

The following documents have been found relevant for the area of investigation:

RM 5: Admiralstab der Marine / Seekriegsleitung der Kaiserlichen Marine.	
The Admiralty of the Imperial Navy was the highest level of command of the German Navy during the First World War. Record Group RM5 contains documents from the admiralty. The following documents are considered relevant for the area of investigation.	
RM 5/4721K	Kommando der Hochseestreitkräfte: "Zusammenstellung der bisher bekannten Minensperren und minenverdächtigen Gebiete". Druck, 3.3.1915
Map showing known and suspected allied minefields, situation March 1915. The area of investigation was situated in an area which was suspected to be mined.	



RM 67 Sicherungsdivisionen der Kriegsmarine	
The area of investigation fell under the joint responsibility of the 1st and the 5th *Sicherungsdivision* (Security Division) of the German Navy. These security divisions escorted convoys through convoy routes, protecting them from attacks by surface vessels and aircraft and clearing mines along the way. Significant events were noted in the war diaries, referring to *Quadrant*-based locations. War diaries from the 1st *Sicherungsdivision* are available to REASeuro.	
RM 67/12	Kriegstagebuch 1. Sicherungsdivision
26 September 1943: 7. Minensuchflottille cleared one ELM/A [*Englischen Luftmine A*] mine in AN 6973.	

ZA 5 Deutscher Minenräumdienst (German Minesweeping Administration)	
The German Minesweeping Administration was responsible for post-war mine clearance of German waters. This administration also summarized and mapped all German minefields laid during the Second World War.	
ZA 5/27	Im Kriege geworfene Minensperren in der Ost- und Nordsee etc.
Information on Gardening field Nectarines. 11.449 ground mines were laid in this gardening field.	
ZA 5/44	Summary of Enemy Minelaying, The Admiralty, United Kingdom (Großformat)
Detailed information concerning German minefields. This summary contains all relevant information that forms the basis for chart ZA 5/48, including mine types, rows, accuracy and coordinates. Minefield C.3 intersects the area of investigation. German minelayers laid the minefield in September 1939 between coordinate 53 47.5 Northing 05 10 0 Easting and 53 57.6 Northing 05 10.4 Easting. The accuracy was poor, resulting in a degree of accuracy of 1.5 miles. 174 EMC contact mines together with 202 explosive floats were placed in the minefield. The field was partially swept in July 1942, with the remaining part being swept in October 1943.	

C3	3	9/39	53 47.5 N 05 10.0 E 53 57.6 N 05 10.4 E	1.5	174 EMC and EMD 202 XpFl	M M	4-15 35-40			Half with AE Switch at 15 feet. Half without AE Switch at 4 feet. Swept part in July 1942. Remainder October 1943.

ZA 5/48	Chart C The North Sea.- Southern Sheet
Naval chart showing numbered German minefields. This map has not been used for this historical research, because the coordinates given in ZA 5/44 are used to more accurately position the minefield.	

ANNEX 6 CARTOGRAPHIC MATERIAL

This historical research made extensive use of cartographic material from a plethora of sources. Relevant cartographic material includes historical coordinate systems, minefields and contemporary naval charts. Cartographic material from the following sources has been consulted.

- Latitude/longitude coordinates
- German Quadrantkarte
- Defence overprint
- Noordzeeloket
- Royal Netherlands Navy Hydrographic service
- Navy Museum Den Helder
- UK Hydrographic Office
- Library of Congress

Latitude/longitude coordinates

Naval locations in historical sources are often noted in decimal degrees and minutes. One minute is equal to one naval mile, or 1,852 meters.

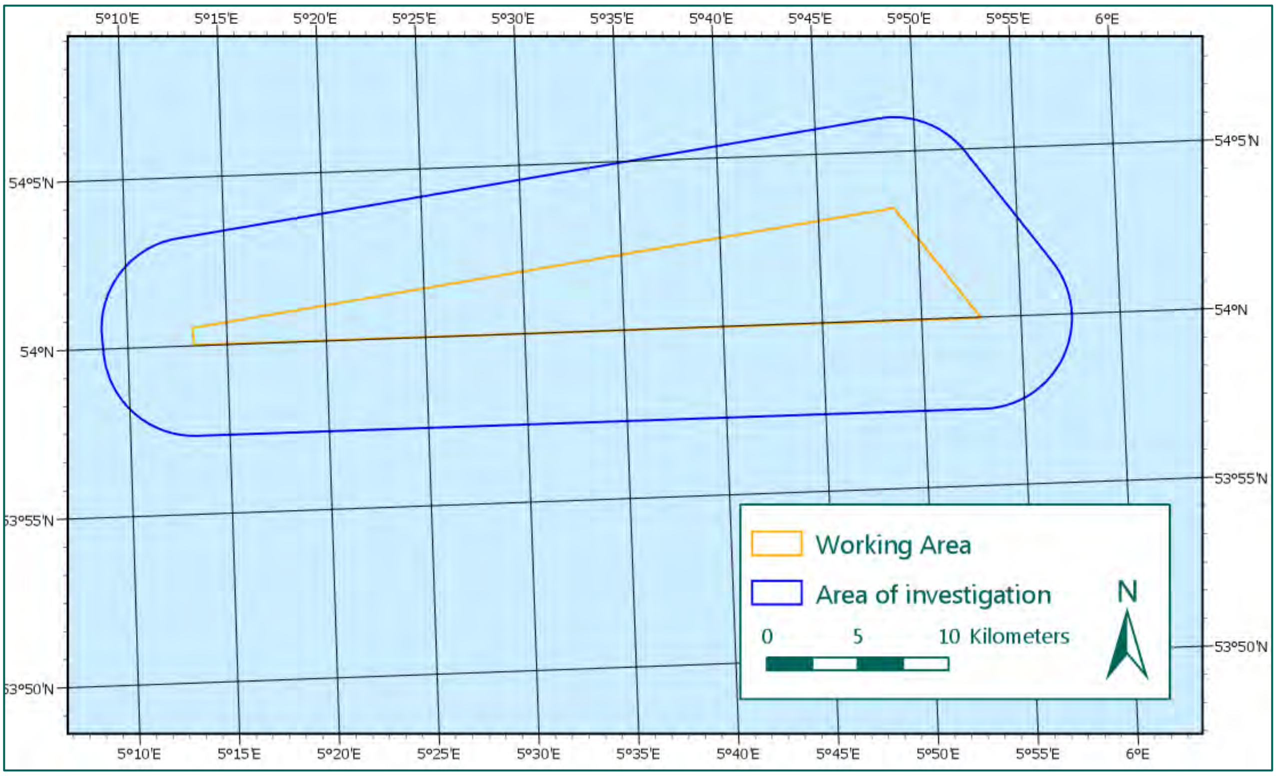


Figure 26: Latitude/longitude grid.

German *Quadrantkarte*

The German Kriegsmarine (war navy) used the so-called *Quadrantkarte* as an aid to note naval locations. The grid square (*Quadranten*) measured 6x6 naval miles and were determined with a geographic formula. REASeuro digitalized the German grid in the GIS system to accurately establish the relevant grid squares for the area of investigation. The following grid squares are relevant:

- AN 6947, AN 6948, AN 6949, AN 6957, AN 6958, AN 6959, AN 6971, AN 6972, AN 6973, AN 6981, AN 6982 and AN 6983.

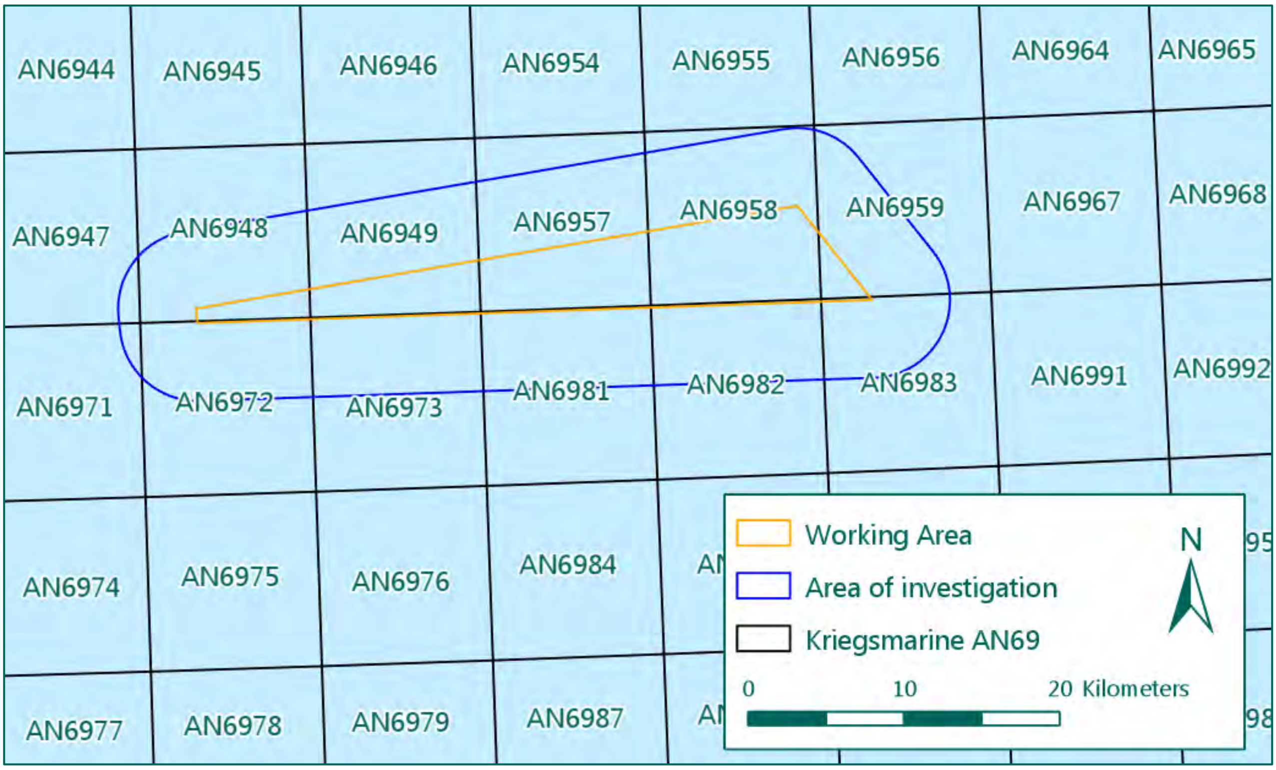


Figure 27: German grid squares relevant for the area of investigation (Source base map: ESRI)

Royal Netherlands Navy Hydrographic service

Naval charts of the area of investigation have been acquired through the Hydrographic Service. Besides naval charts the HP39 (wreck registry) publication has been consulted to gain information on possible wrecks in the area of investigation.

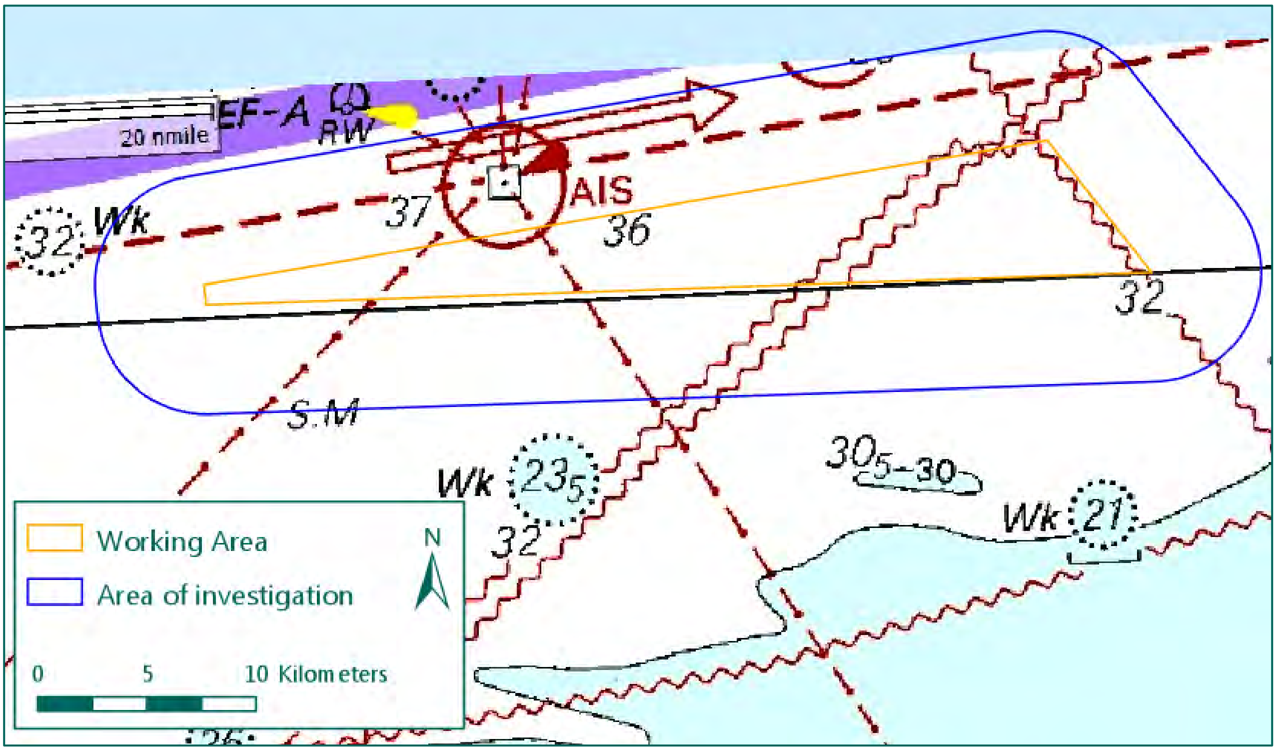


Figure 28: Naval chart of the area of investigation. No significant objects are shown in the area of investigation.

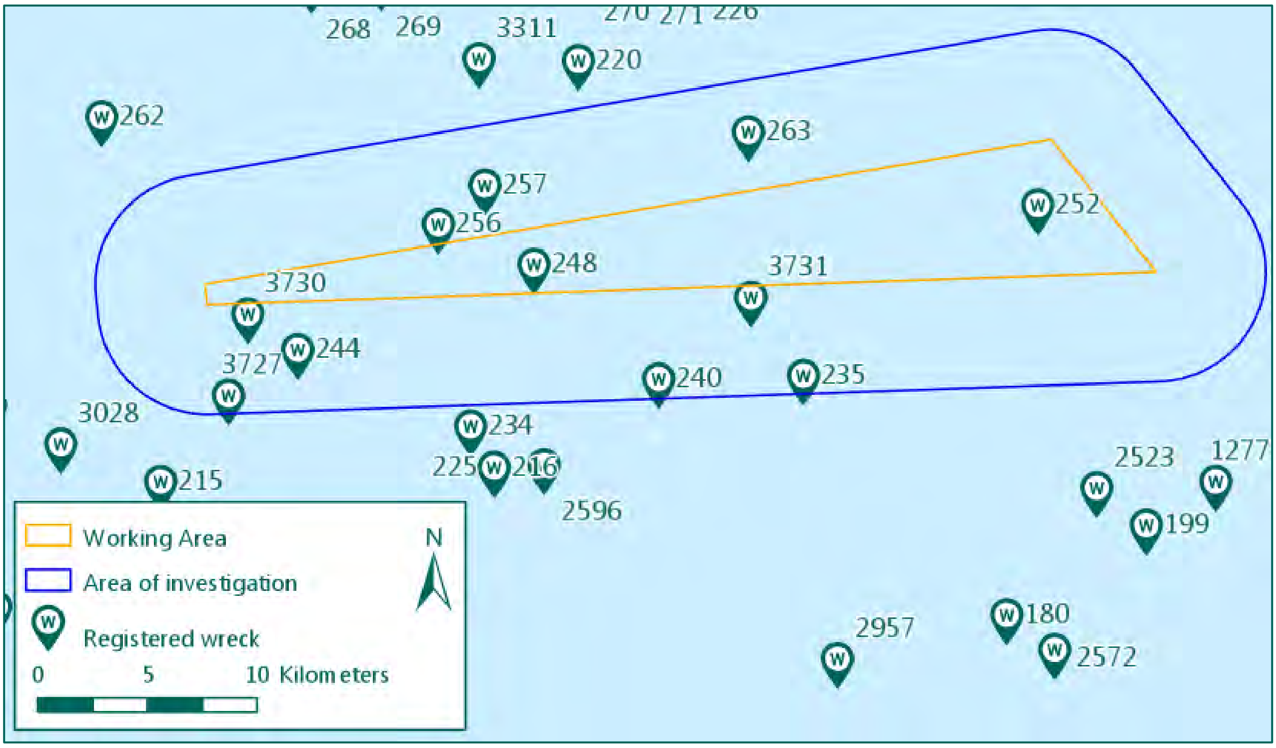


Figure 29: Registered and numbered wrecks.

No.	Type	Name	Details
235	Wreck	M41	N/A
240	Unknown	-	-
244	Wreck	-	-
248	Wreck	-	-
252	Wreck	Insulaner	N/A
256	Wreck	-	-
257	Wreck	-	-
263	Wreck	-	-
3727	Wreck	-	-
3730	Wreck	-	-
3731	Wreck	-	-

Table 20: Wrecks in the area of investigation.

Navy Museum Den Helder

The map collection of the Navy Museum (Marinemuseum) in Den Helder has been consulted. NEMEDRI-maps were found in this collection. These maps offer information on minesweeping after the Second World War. The following figures are extracts of the NEMEDRI maps, showing the area of investigation shortly after the war. The area of investigation is consequently shown in a ubiquitous Danger Area, owing to naval mines.

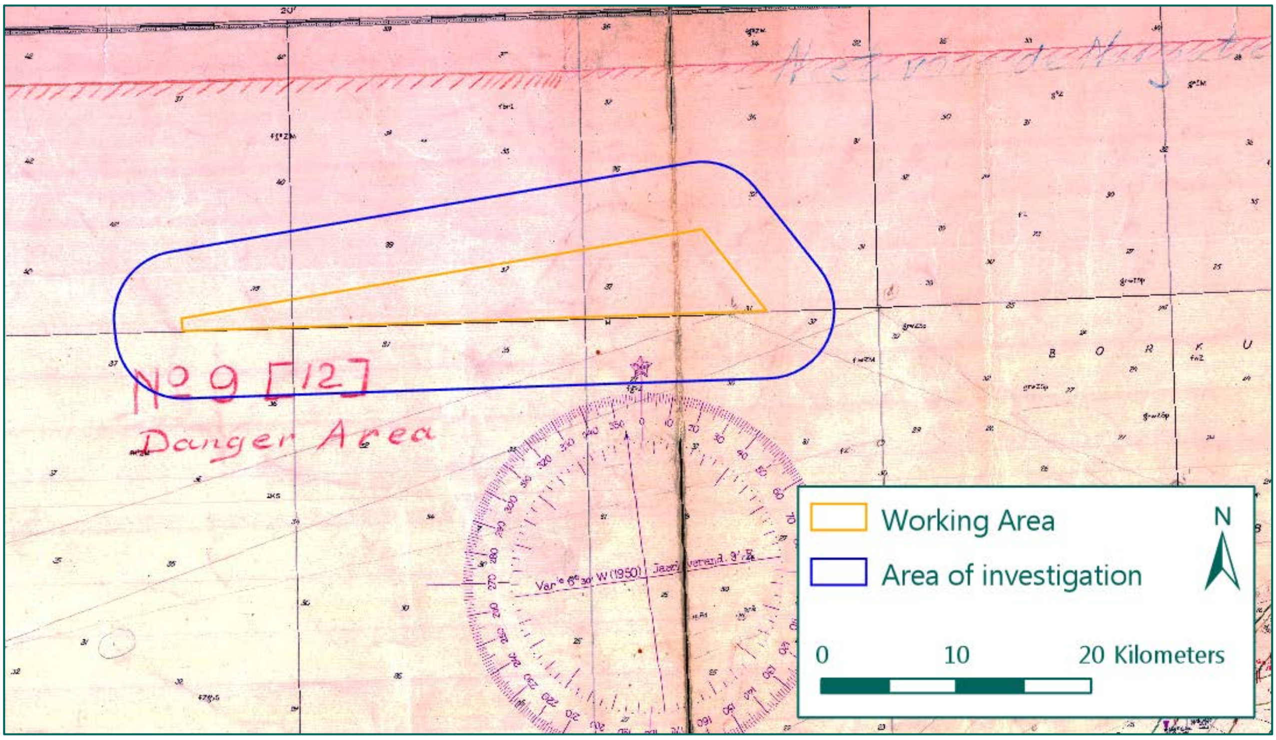


Figure 30: Zeekaart Noordzee Nederlandse en Duitse kust van IJmuiden tot de Weser; NEMEDRI 226; mijnenveegoperaties 1949-1963. [1949] (Source: Marinemuseum Den Helder inventaris A/007/132).

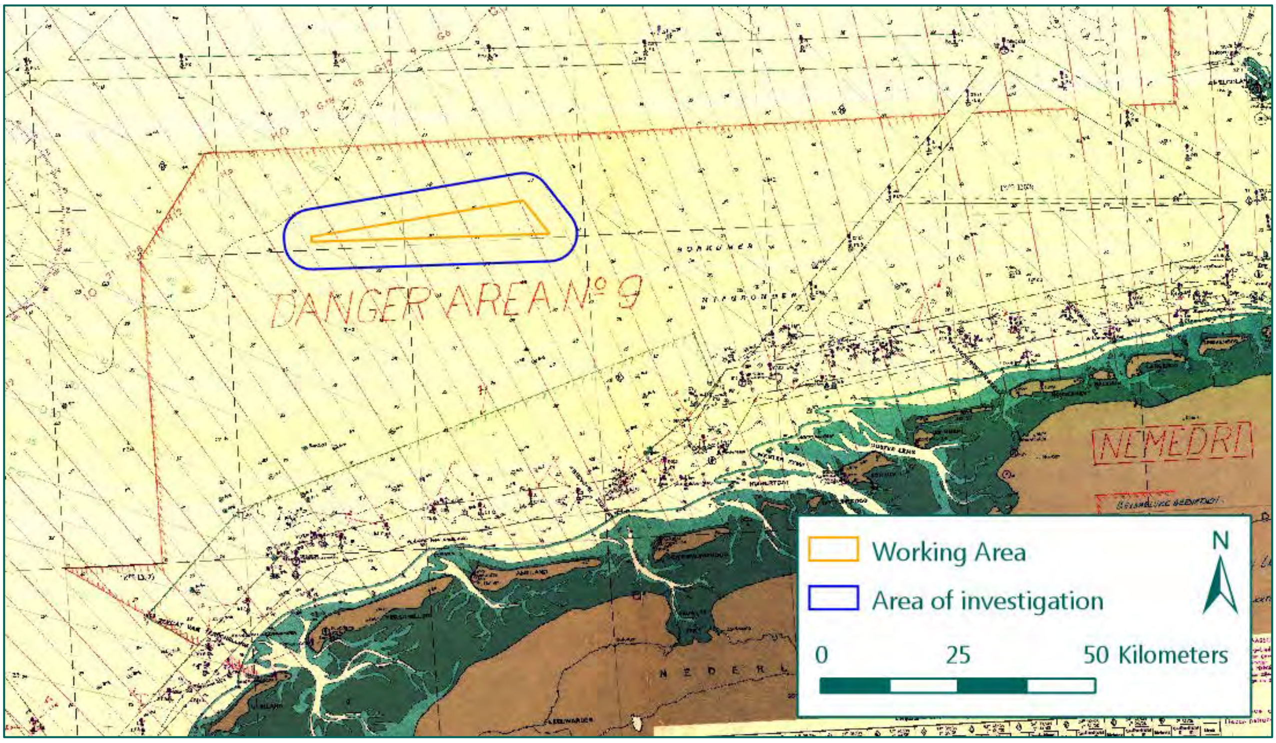


Figure 31: Zeekaart Noordzee Texel tot Die Elbe en Lister Tief; NEMEDRI 1037; mijnenveegoperaties 1965-1969. (Source: Marinemuseum Den Helder, inventaris A/007/134).

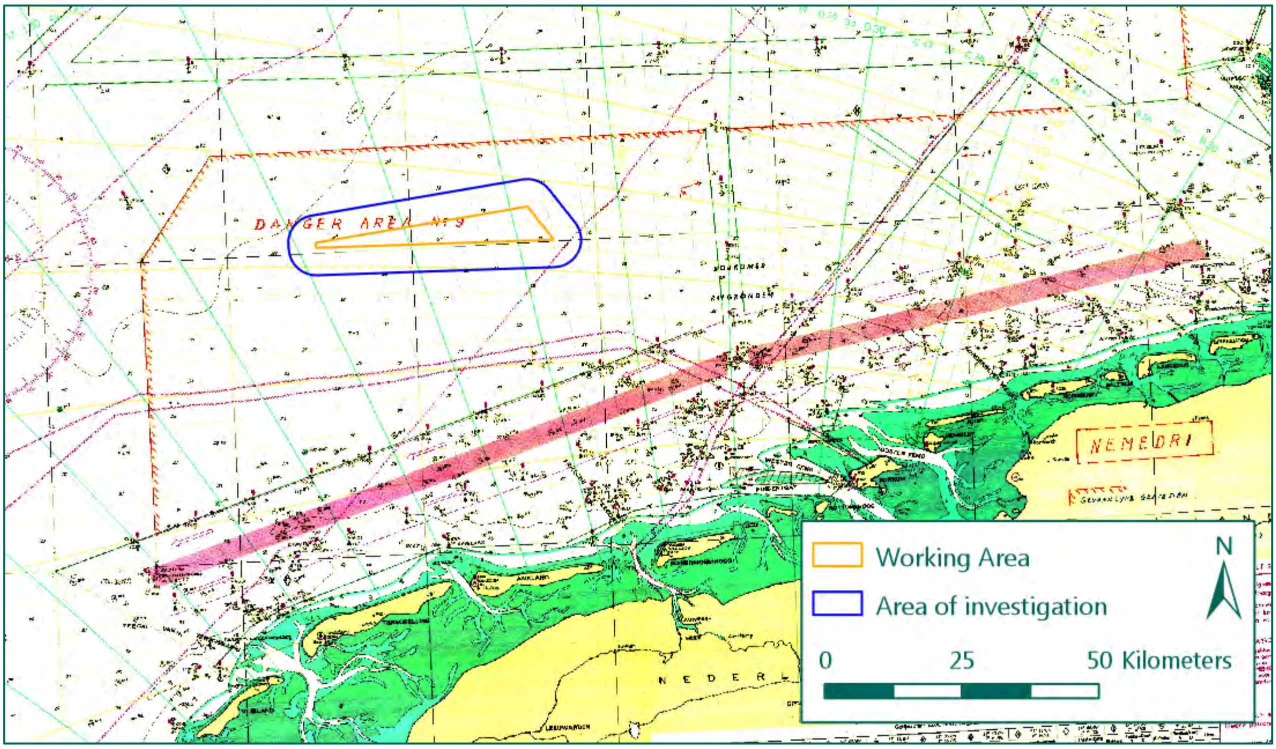


Figure 32: Zeekaart Noordzee Texel tot Die Elbe en Lister Tief; NEMEDRI 1037, 1971 (Source: Marinemuseum Den Helder, inventaris A/007/135).

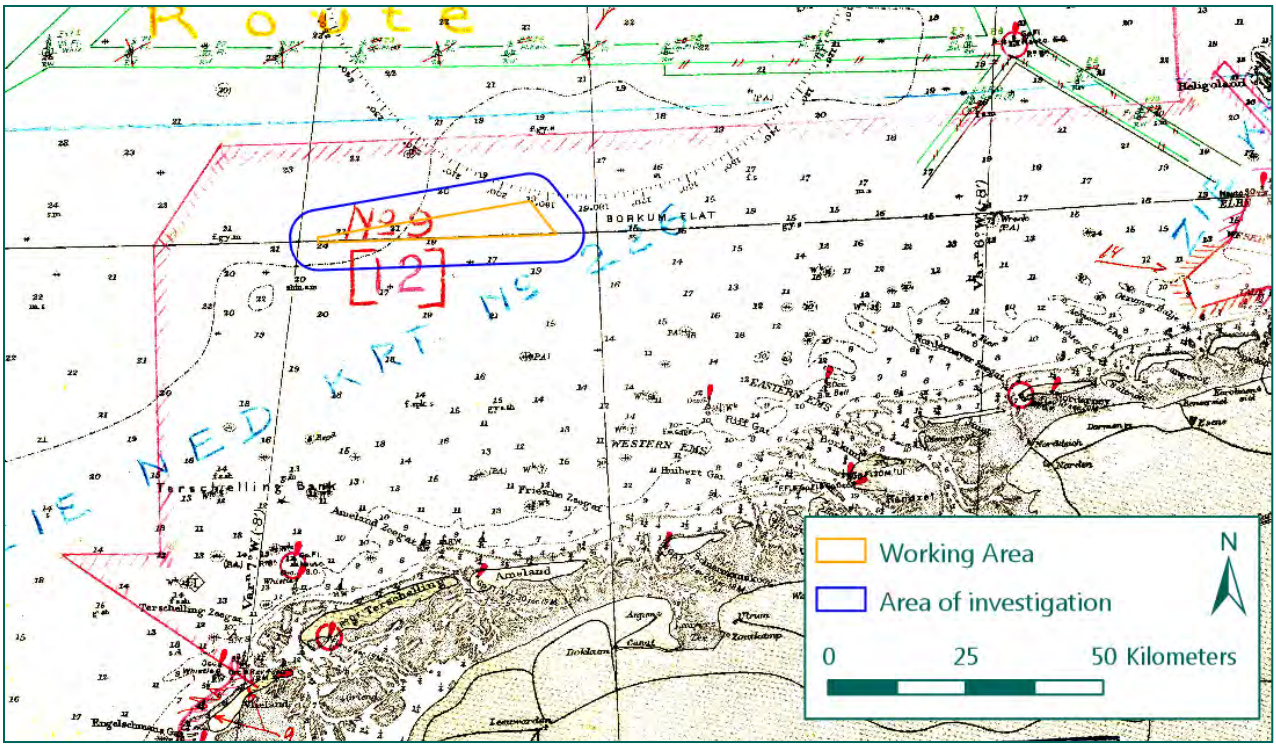


Figure 33: Zeekaart The North Sea Southern sheet; NEMEDRI 2182a; mijnenveegoperaties 1950-1951. (Source: Marinemuseum Den Helder, inventaris A/007/138).

UK Hydrographic Office (UKHO)

The UK Hydrographic Office maintains a large collection of historical nautical charts, including a collection of mine charts. These mine charts have been consulted, resulting in a map with known active minefields and German convoy routes at the moment of drawing. The map is a secret reproduction of a German map, obtained through intelligence work.

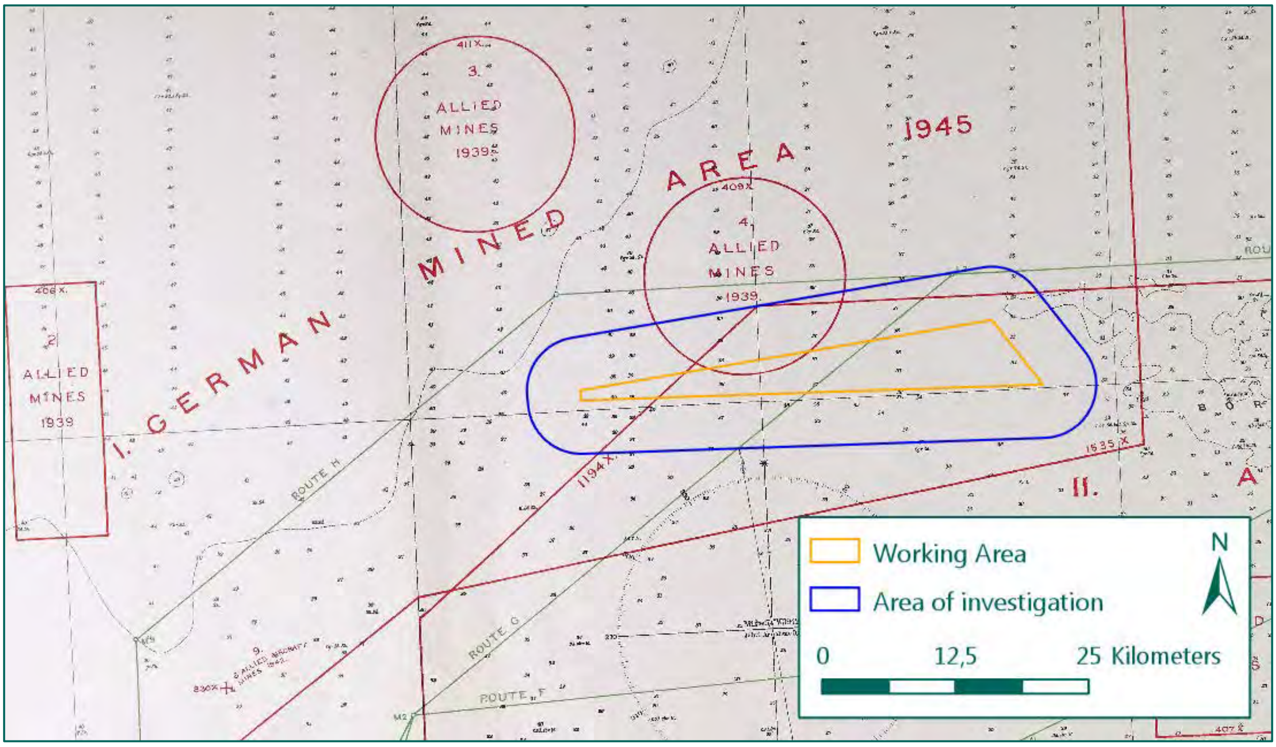


Figure 34: OCB MO 6590 Texel bis Cuxhaven, 1945 (Source: UKHO, Shelf 35). Green lines indicate convoy routes, red polygons indicate minefields.

Library of Congress

A map of known minefields on August 18, 1918 is available on the website of the Library of Congress. This map shows the area containing British minefields.

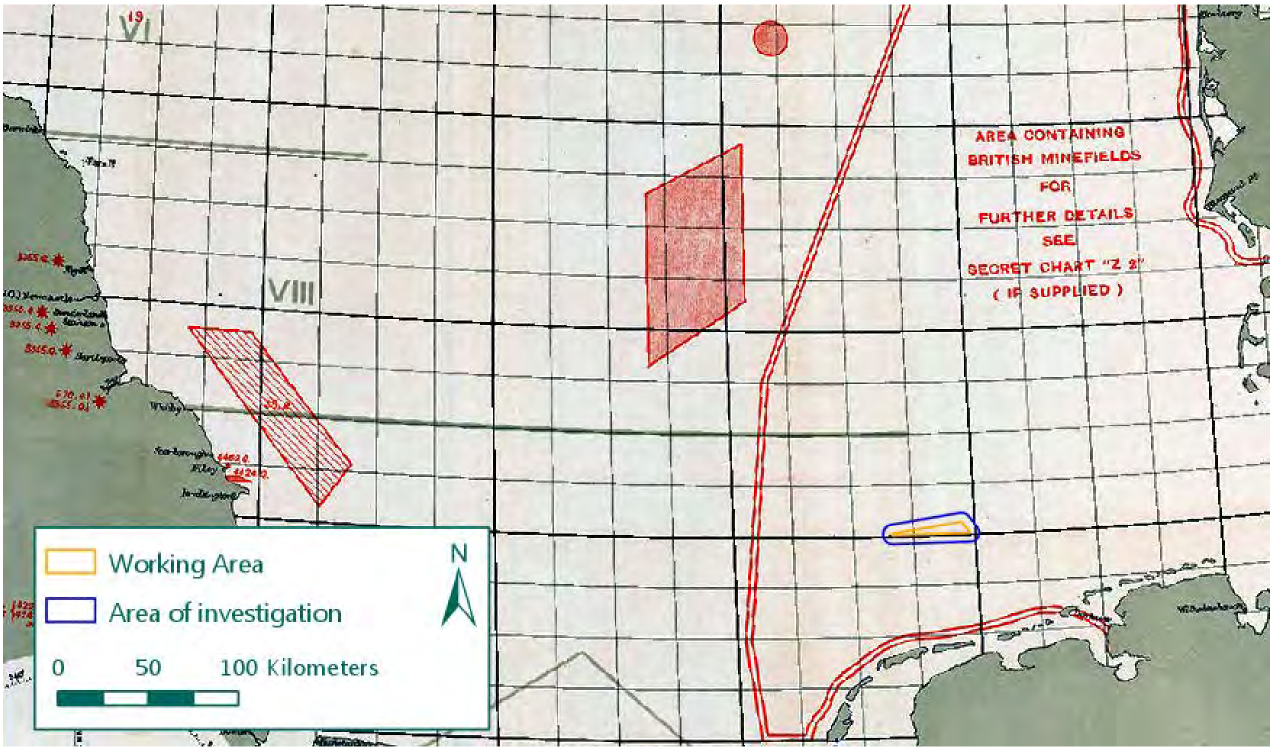


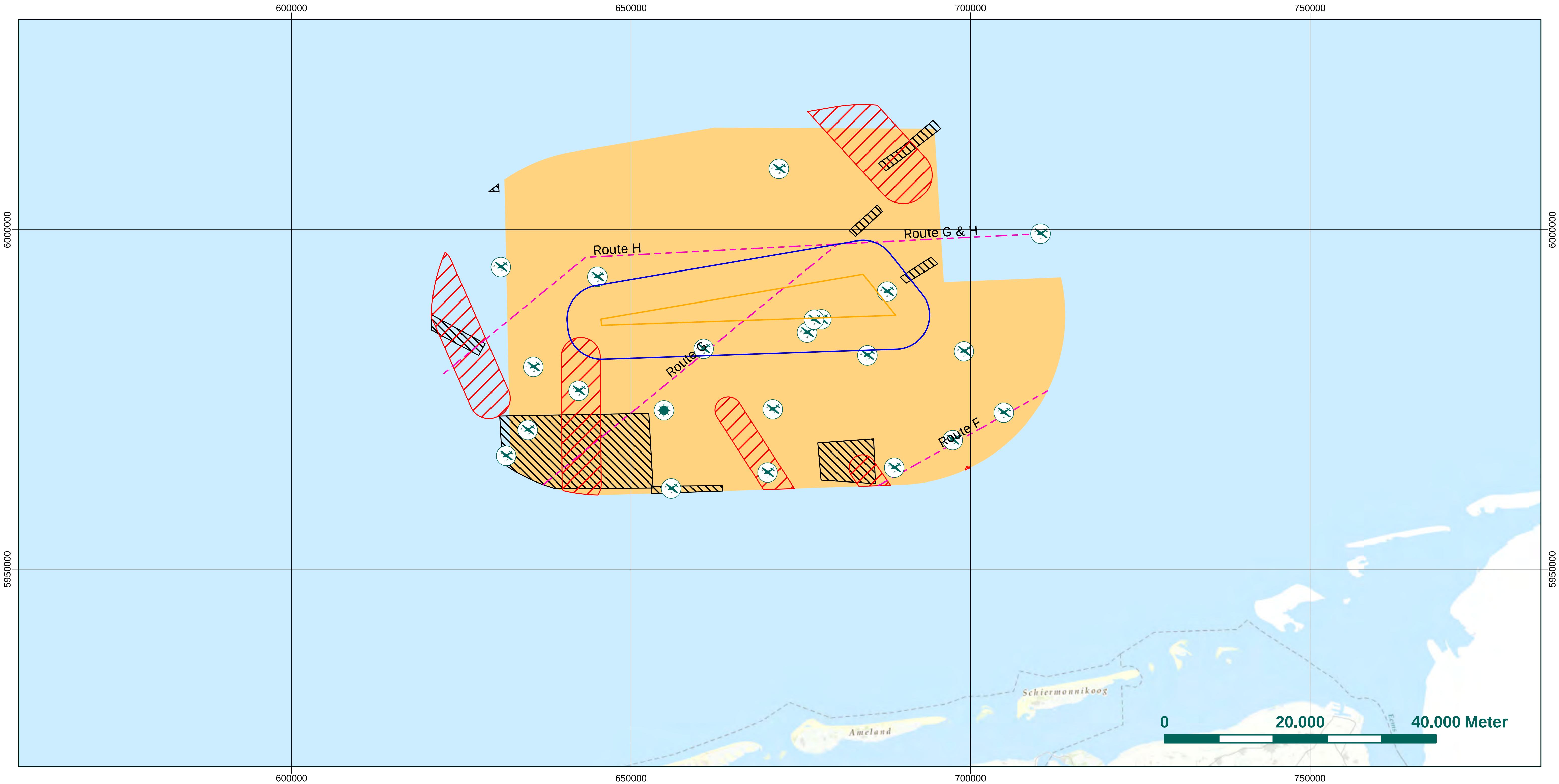
Figure 35: Library of Congress map (Source: Library of Congress, G5701.S65 coll .F8).

ANNEX 7 FACT MAP (LOOSE-LEAF ATTACHMENT)

REASeuro

Ten Noorden van de Waddeneilanden

Factmap



- Area of Investigation
- Working area
- Mine cleared
- Coastal Command incident
- German routes 1945
- World War II minefields
- World War I minefield
- British aerial minelaying ('Garden')

Ten Noorden van de Waddeneilanden

Factmap

Rapportnummer RO-190129

Getekend:	M. van Lelieveld	6-6-2019	Tekening no: 73458-01-01
Gecontroleerd:	L. Arlar	6-6-2019	
Akkoord:	M. Taks	6-6-2019	

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Netherlands Enterprise Agency (RVO.nl) | July 2019