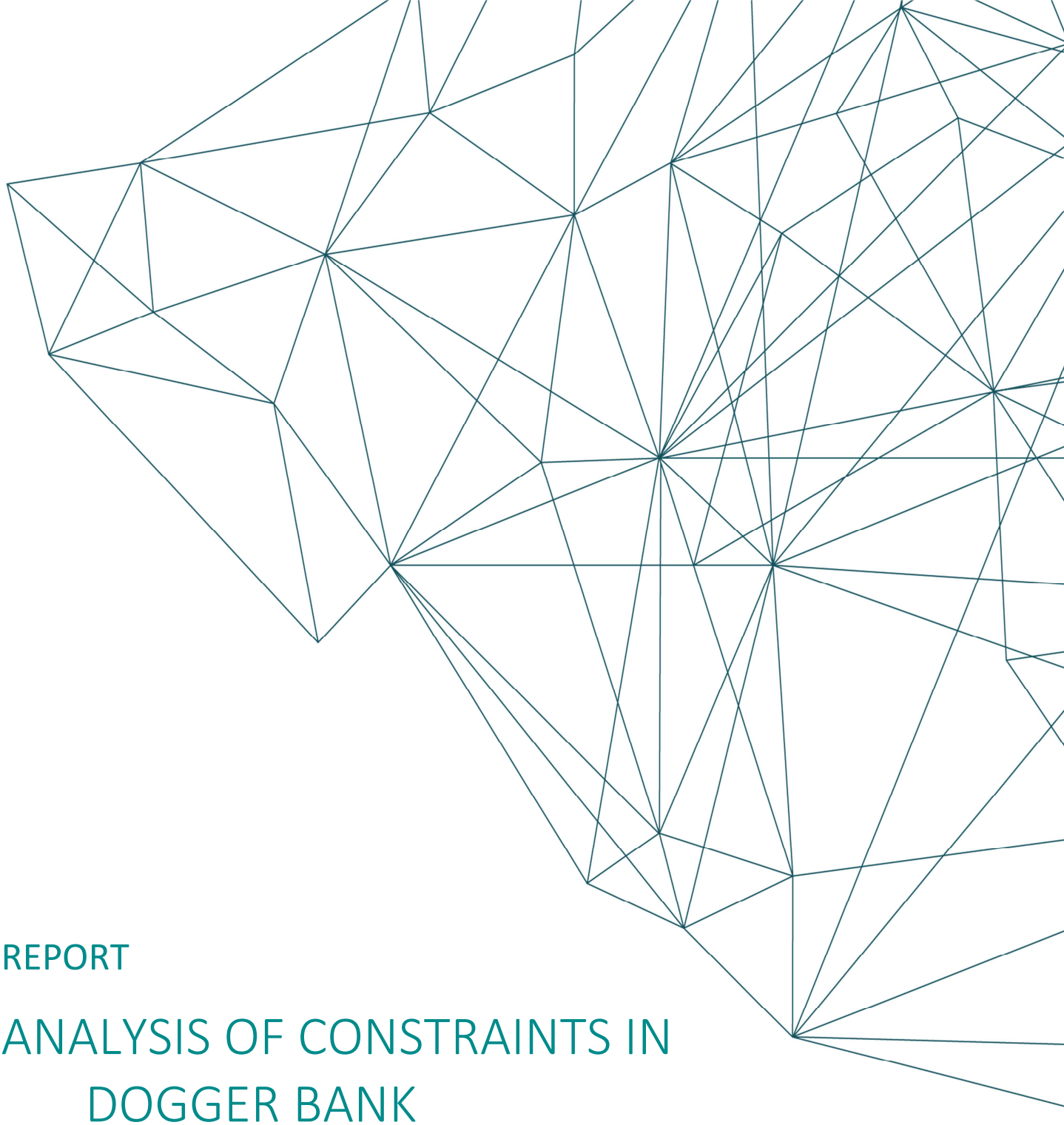

REPORT

ANALYSIS OF CONSTRAINTS IN DOGGER BANK

Preliminary assessment of geology and ecology for the NSWPH-project in Danish EEZ

November 2017 – internal report

Dok. 17/07686-5 - Delvis

ENERGINET

Contents

EXECUTIVE SUMMARY

A preliminary desk-top study with a quick scan of the geology and ecology of the Dogger Bank area in the Danish EEZ have been performed in order to identify potential constraints for the NSWPH-project in regards to further in-depth ecological studies that will be carried out in 2018 and 2019.
Key initial studies need to be performed before the project can move into further developing phases. This includes a specification of maximum water depth for feasibility of the NSWPH-project in order to determine potential gross areas for the project.

From the geological desk-top study it was observed that the Dogger Bank, in the Danish EEZ, is found at water depths of approximately 40 meters with an area of 1,400 km^2. More detailed studies were made of the flanks of the Dogger Bank in the Danish EEZ, as these may be of special ecological importance. No steep flanks were observed from the data available, and no conclusions can be made on their potential significance for the ecology in the area. Identified constraints relating to the geology includes large bedforms, sea-level fluctuations and tectonic activity in the area.

From the ecological desk-top study the importance of the bank for resting birds, harbour porpoise and fish have been estimated. The Danish area generally has few official designations relating to ecological values, and no areas of the Dogger Bank in the Danish EEZ are part of the Natura 2000 network. Identified potential constraints for the NSWPH-project relating to the ecology includes possible biodiversity hotspots at the slopes of the bank, the significance for birds, harbour porpoises and fish. Furthermore clarity is needed on the legal process relating to Natura 2000 in the Germany, Netherlands and UK and general cross border coordination.

Other key constraints for the NSWPH-project include the extensive oil and gas activities in the Danish Dogger Bank area, future wind farms projects not related to the NSWPH-project, as well as archaeological and fishery interests.

Elaboration of project scope and relation to offshore wind farms is furthermore needed in order to design and perform more detailed studies and surveys.

1. Introduction

This document contains a preliminary assessment of potential constraints for the NSWPH-project (North Sea Wind Power Hub) identifying other interests at the Dogger Bank, with special focus on geology and the environment. The assessment mainly addresses the Danish part of the Dogger Bank, but includes information on the geology of neighbouring waters (UK, German and Dutch) as well as a preliminary assessment of possible conflicts with the Natura 2000-network in German waters.

The Dogger Bank is a large sand bank located in Danish, German, Dutch and UK waters (Figure 1).
The extent of Dogger Bank is in this document defined at a depth of approximately 40 meters below sea level, according to a bathymetry map by Ramboll (2014) (Figure 5).

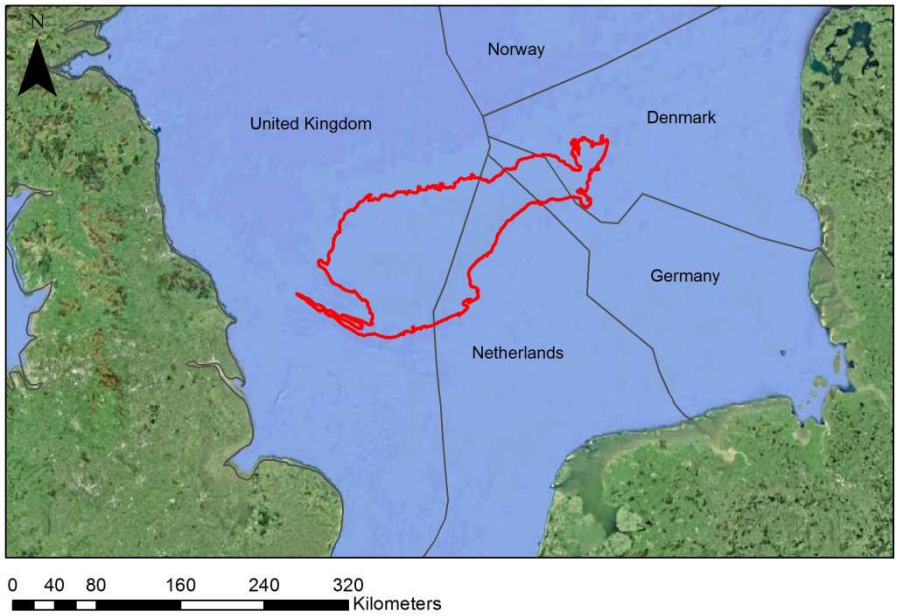

Figure 1: Outline of the Dogger Bank (in this document the outline of the bank is defined at a depth of approximately 40 meters below sea level). Satellite image from Google Earth, 2017. Outline is drawn in ArcMAP.

2. Purpose

The purpose of this document is to serve as a first identification of the issues which need to be investigated further as the project moves into more detailed developing phases.
The focus is to identify potential conflicts and constraints including ecological interests which need to be assessed further and the identification of further studies to be carried out.
The sub-aims of the chapter on geology and ecology respectively are defined below.

For the chapter on geology the aim is to obtain a geological understanding of the extent of the Dogger Bank, especially placement/definition of the flanks of the Dogger Bank in the Danish area, as these are preliminarily assessed to be of special ecological importance. By understanding the general geology of the area, including elements such as geological setting, sedimentology, stratigraphy, seabed dynamics, sea-level fluctuations and tectonic activity, it is further-

more possible to assess potential interests and conflicts the geology may have for the NSWPH-project.

For the chapter on ecology the aim is to obtain a basic understanding of the ecology of the Dogger Bank and to identify areas of the bank which are especially sensitive towards the project. This includes a preliminary assessment of the conflicts especially with protections relating to the Natura 2000-network. In addition, the aim is also to identify gaps in the knowledge about the ecology which need to be further addressed as the project moves into more detailed developing phases.

3. Brief Project Description

The NSWPH-project is still at an early stage, which means that only a very rough project description is available. This also means that the NSWPH-project will be designed under observation of the conflicts and constraints identified in this document and the further studies mentioned.

The purpose of the NSWPH-project is to provide an efficient, affordable and reliable energy export system in the North Sea, which will contribute to both European and national climate and energy targets. The project consortium will investigate the feasibility of a North Sea Wind Power Hub established as one or more artificial islands or constructions with energy-infrastructure in the North Sea focusing on Dogger Bank in Danish, German and/or Dutch EEZ. The size of the island(s) and/or construction will depend on several factors, including the maximum capacity of the offshore wind farms which in the future will be connected to the island and potential other energy sources.
The assumption for this document is that the wind farms are not as such a part of the present project as they will be built by external parties, but it is a point of observation to clarify how future wind farms can be placed in the vicinity of the island(s) as it will depend on placement and lay-out of the island(s).How this is to be managed in relation to legislation is to be clarified with the relevant authorities when more details on the project are available.

The island(s) is expected to contain a large amount of energy infrastructure as the purpose of the island(s) is to serve as a hub for energy transport in the North Sea. The energy infrastructure possibly includes a port and an airstrip as well as living quarters for workers and visitors and a large amount of HVDC stations which can transform AC-energy from the offshore wind farms to DC-energy which is better suited for long distance transport.
More information on the project design as well as information on expected construction time, construction methods etc. is needed for carrying out further detailed studies on the environment and other interests.

Presently two very basic cases relating to the size of the island have been set up:

- Case 1. Island capable of handling 16 GW Wind power
  Island size: 378 ha (3.78 km^2)
  Size of offshore wind farms: 296,000 ha (2,960 km^2)

- Case 2. Island capable of handling 30 GW Wind power
  Island size: 501 ha (5.01 km^2)
  Size of offshore wind farms: 555,000 ha (5,550 km^2)

The land use on the island based on Case 2 can be seen in

Table 1.

Table 1 Estimated land use on an island of 5 km^2 (500 ha)

Areas	501	ha
Port basin	59	ha
Port Area	62	ha
HVDC stations	113	ha
Nature/Green areas	100	ha
Living areas/ recreational facilities	25	ha
Runway/airstrib	63	ha
(Remaining/others/additional)	62	ha
Roads	18	ha

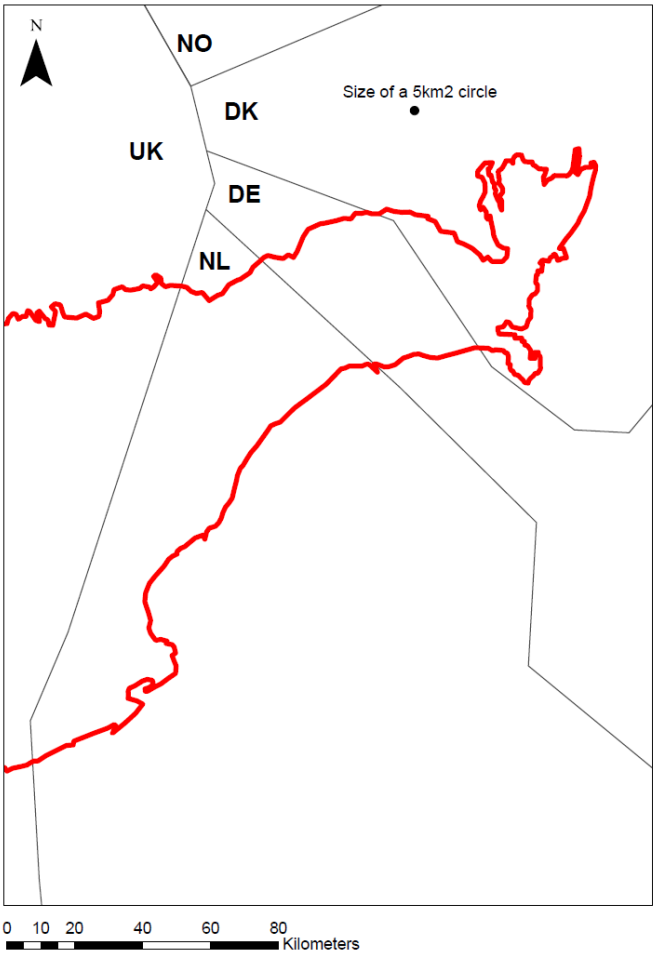

Figure 2: Size of a potential 5 km^2 island (black circle) compared to the Dogger Bank (red outline). The area of the bank in Danish waters is approximately 1,400 km^2 which means that the island will take up approx. 0.4 % of the bank. The outline of the bank represents a depth of approximately 40 meters below sea level

4. Geology of the Dogger Bank Area

The Dogger Bank is an isolated topographic relief located in the central part of the southern North Sea, extending into UK, German, Danish and Dutch waters (Figure 1). It is a large sand bank named after an old type of Dutch fishing boats called "Doggers", and has for centuries been a productive fishing bank (Britannica, 2017). The area of the bank is approximately 20,700 km^2 (assuming an outline of the bank at a depth of approximately 40 meters below sea level)[1]. The bank is elongated in shape and extends approximately 300 km in a NE-SW trending direction. It varies in width between 25 km to approximately 130 km. In Danish waters the bank is approximately 70 km long in a NE-SW trending direction, and it varies in width from 10 to 50 km. The area of the bank in Danish EEZ is approximately 1,400 km^2.

4.1 Previous Studies

The Dogger Bank has been recognized for many years and several well-known geological studies of the bank have been performed since the 1950'ies (e.g. Stride, 1959; Veenstra, 1965). However, it is not until recent years that detailed studies of the bank; including detailed seismic imagery, 3D seismics as well as large-scale depositional modelling have been performed (Fitch et al., 2005; Cotterill et al., 2017). These studies are mainly limited to the British part of the bank, and have primarily been driven by the recent interest of the bank as a potential site for future offshore wind farms (e.g. Cotterill et al., 2017; Forewind, 2017). As a result of this interest, regional geophysical surveys were conducted in the British part of the Dogger Bank in 2010 and sub-bottom profiles, Magnetometer, Sidescan sonar and Multibeam datasets were furthermore compiled. As only little has been investigated prior to the study on the sediments deeper than 6 m, boreholes and Cone Penetration Tests were also performed (Cotterill et al., 2017).

Similar studies have yet to be published in the Danish part of the Dogger Bank, and published geological information is limited to mostly shallow (< 5 m) geotechnical borehole-data, general sedimentological maps and bathymetric data. The Dogger Bank in the Danish area has been of great geological interest for several decades, due to the existence of several large oil and gas reservoirs in the region on and around the Dogger Bank, and several geophysical, geological and geotechnical studies have been performed in that regard. It should be expected that detailed datasets of the Dogger Bank geology exists for the Danish area, but that these are not published and most likely confidential. These datasets are expected to have been compiled in relation to the exploration for oil and gas as well as for the construction of oil and gas platforms and pipelines.

4.2 Geological Setting

The geological evolution of the North Sea area, since its formation approximately 250 million years ago has been complex. The geological timespan relevant for this study however, only covers the last 2.5 million years and the setting can be characterized by Quaternary aged series of marine – intertidal – deltaic – proglacial – subglacial – marine cycles, with evidence of three glaciations (BGSS, 1989; 1991; Cameron et al., 1992). In the Dogger Bank area the Quaternary sediments are up to 800 m thick (Cotterill et al., 2017).

[1] Area, length and width of the Dogger Bank have been measured in ArcMap.

In early Pleistocene (approximately 2.5 m.y.a.) shallow water, deltaic to distal environments were dominating the southern North Sea (Figure 3a and 3b) (Balson and Cameron, 1985). Sediments were transported from the Rhine and other rivers from the Baltic into a deltaic system that originated out from the Netherlands in to the southern North Sea. River systems originating from the UK furthermore transported sediments into the North Sea contributing to the overall sediment deposition in the area. The sediments deposited in this depositional environment mainly constituted fine to medium sand (Cotterill et al., 2017).

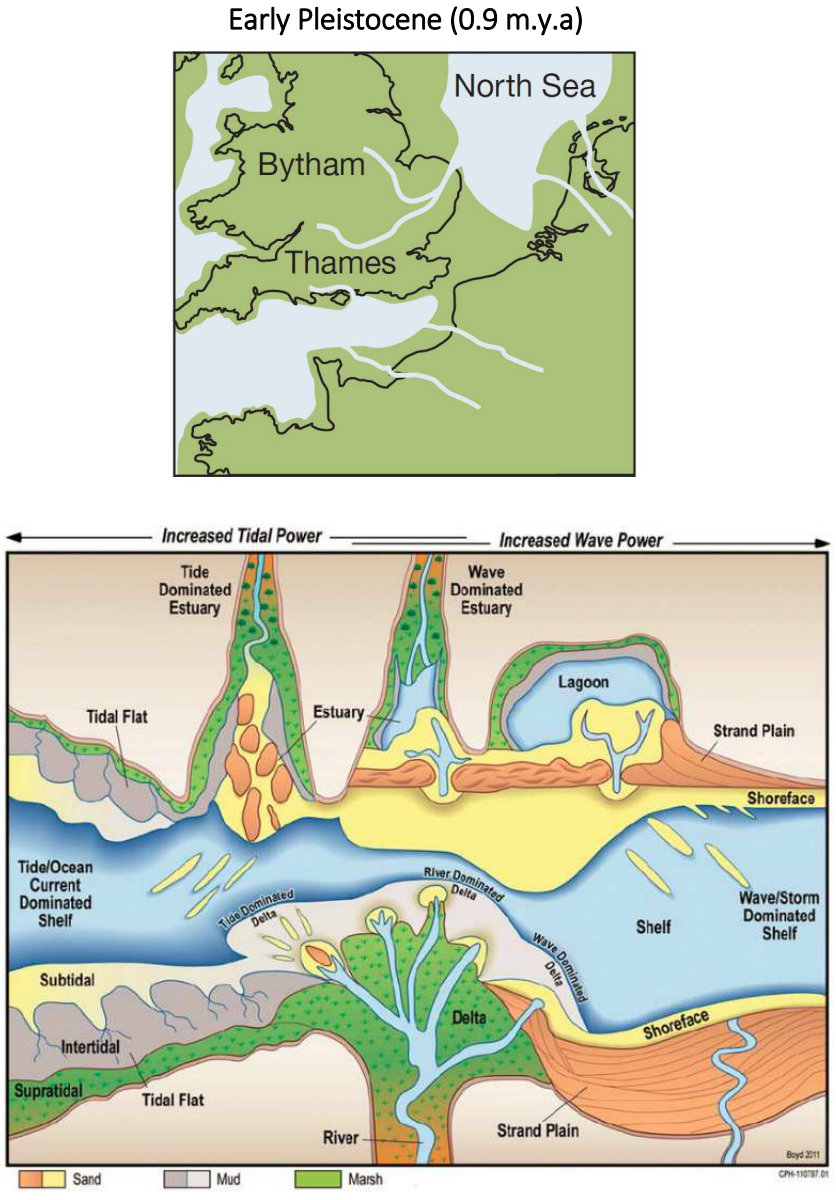

Figure 3a: Palaeogeographic map of early Pleistocene. The southern North Sea can be characterized by consisting of shallow water and deltaic to distal environments. Sediments were transported from rivers originating from the Rhine, the Baltic and UK. From Parfitt et al., 2010.

Figure 3b: A schematic overview of common shallow-water depositional environments. Especially deltaic, fluvial and intertidal depositional environments dominated the Quaternary of the Dogger Bank area. From Steel & Milliken, 2013.

During the rest of the Pleistocene (approximately 0.4 – 0.011 m.y.a), thick deposits of pro-glacial and subglacial sediments were deposited as part of three glacial cycles (the Elsterian, Saalian and Weichselian glaciation), and as a result, several incised tunnel valley systems were formed. The sediments deposited during the glacial cycles were mainly the clay diamicton of the Dogger Bank Formation, interbedded with lenses of silt, sand and gravel (Fitch et al., 2005; Cotterill et al., 2017).

The glacial cycles were replaced by a fluvial to intertidal environment in late Pleistocene to early Holocene (approximately 11000 years ago). The Dogger Bank area consisted of a complex meandering river system and sediments characterizing the period were clay, peat and muddy fine sand (Figure 4) (Fitch et al., 2005; Forewind, 2014).

Figure 4. A hypothetical map of "Doggerland". Figure from on Coles, 2000.

The Dogger Bank was submerged around 7500 years ago and the environment eventually became marine. Today the area is dominated by modern sand waves, and the deposition of fine to medium sand with angular to rounded shell fragments and clay, gravel and silt intercalations (Fitch et al., 2005; Cotterill et al., 2017).

4.3 Methodology

In order to understand the extent and topography of the Dogger Bank, the bathymetry of the area will be outlined. This is followed by a sedimentological and stratigraphic review, which will describe and discuss the composition of the bank.

Paragraphs on seabed dynamics, tidal currents, sea level fluctuations and tectonic activity in the Dogger Bank area will furthermore be presented as these may also be of importance for the NSWPH-project.

4.4 Extent and Topography of the Dogger Bank

The first element of the study is to define the extent of the Dogger Bank.. By using this bathymetric map in combination with elevation profiles generated in Google Earth, it is possible to make a comment on important topographical features. This include a presentation of the slope of the flanks bordering the Dogger Bank, and potential elevation differences across the bank, that should be taken into consideration during the developing stages of the NSWPH-project.

4.4.1 Bathymetry

There is not a common definition of where and how the boundaries of the Dogger Bank should be placed. In this study the outline of the bank is defined at a depth of approximately 40 meters below sea level to align with bathymetric datasets (Figure 5). Further studies are to be done to define and present the spatial extension of Dogger Bank assuming the bank delimited by WD 30 m and WD 20 m, as it could be argued whether the boundary should be placed at a more shallow depth (heavily limiting the extent of the bank in the Danish area) or be made even deeper (expanding the bank by several 100 km^2 in the Danish area), which is discussed in section 4.4.3.

The Dogger Bank varies in elevation across EEZ boundaries and the highest point of the bank is situated in UK and Dutch waters where it can be as shallow as 10 to 19 meters below sea level. In both German and Danish waters the Dogger Bank is situated approximately 40 to 35 meters below sea level (Figure 5).

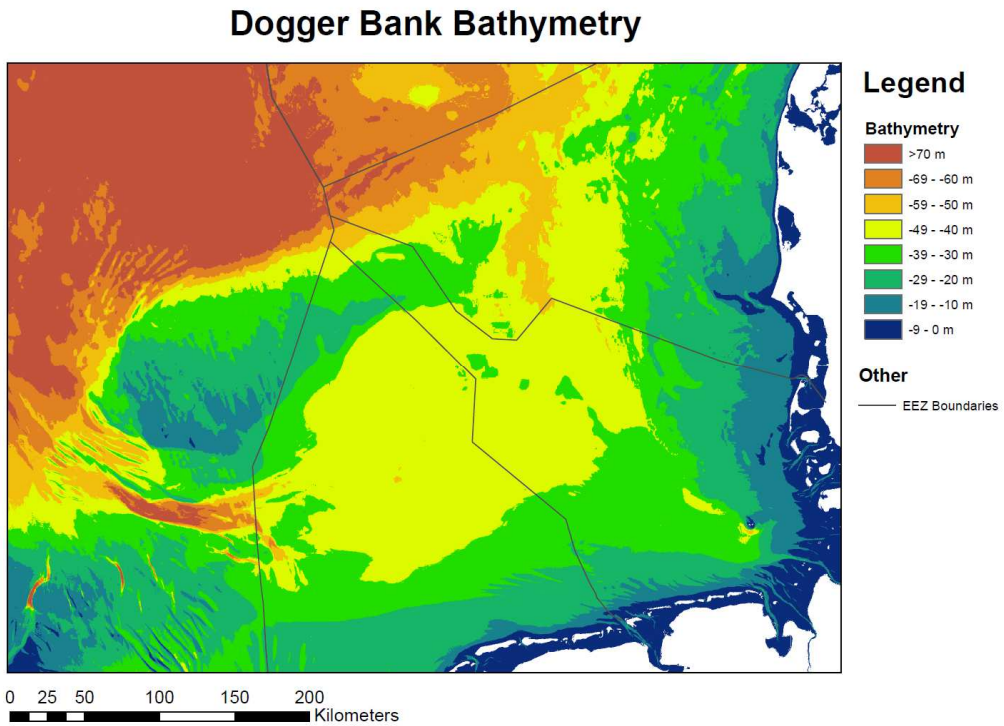

Figure 5: Bathymetric map of the southern North Sea. The map is made with GIS-data from the European Marine Observation and Data Network.

4.4.2 Cross Sections

From Google Earth it was possible to create simple elevation profiles of Dogger Bank in the Danish Area (Figure 6 and 7). Although inaccuracies at a meter scale are expected, they can still be used during the initial geological evaluation. [2]

A grid of 15 lines and 15 cross lines were created in order to investigate the bathymetry of the Bank. The data showed that the Dogger Bank in the Danish Area is generally flat with only few topographic differences (Figure 7B and 7C) resulting in slopes of < 1 % across the bank. At the flanks, angles are found to also be < 1 % (Figure 7A).

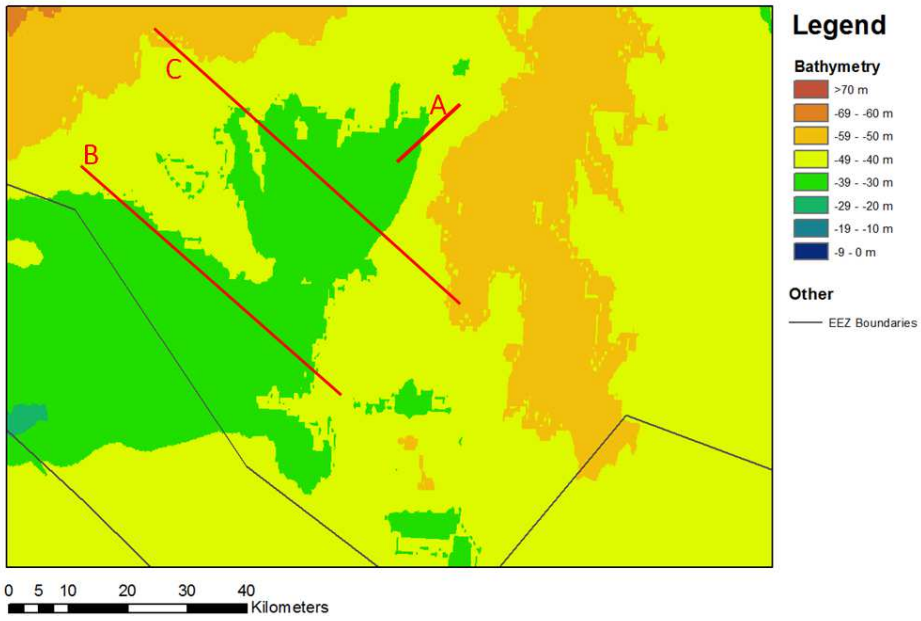

Figure 6: The boundary between the yellow and green represents the boundary of the Dogger Bank at 40 meters below sea level. 15 Lines and 15 cross-lines for the entire Dogger Bank in Danish waters have been created in order to look at the slope of the flanks. Bathymetry data from the European Marine Observation and Data Network.

4.4.3 Defining Dogger Bank (input for the Environmental Assessment)

The seabed within the defined Dogger Bank in this study is almost flat, and it could therefore be discussed whether the defined outline of the Dogger Bank may be too narrow. This discussion is of great importance as potential steep-angle flanks may prove to host rich eco-systems. Furthermore, should the boundary of the Dogger Bank be redefined later in the process it is essential to know of potential environmental barriers, which may be in the form of eco-rich flanks, for the NSWPH-project. Additional lines and cross-lines were therefore created extending further into the southern North Sea (Figure 8). The results from this show that although water depths increase away from the Dogger Bank, the slopes do not exceed 1 % (Figure 9a and 9b). No steep flanks are recognized in this study, however steeper flanks may be present in the area as the calculation has some inaccuracies and may differentiate some meters, and more detailed studies would be needed to address this issue.

[2] Google Earth mostly uses GEBCO Gridded bathymetry data, which only have inaccuracies at a m-scale (+/- 10 m).

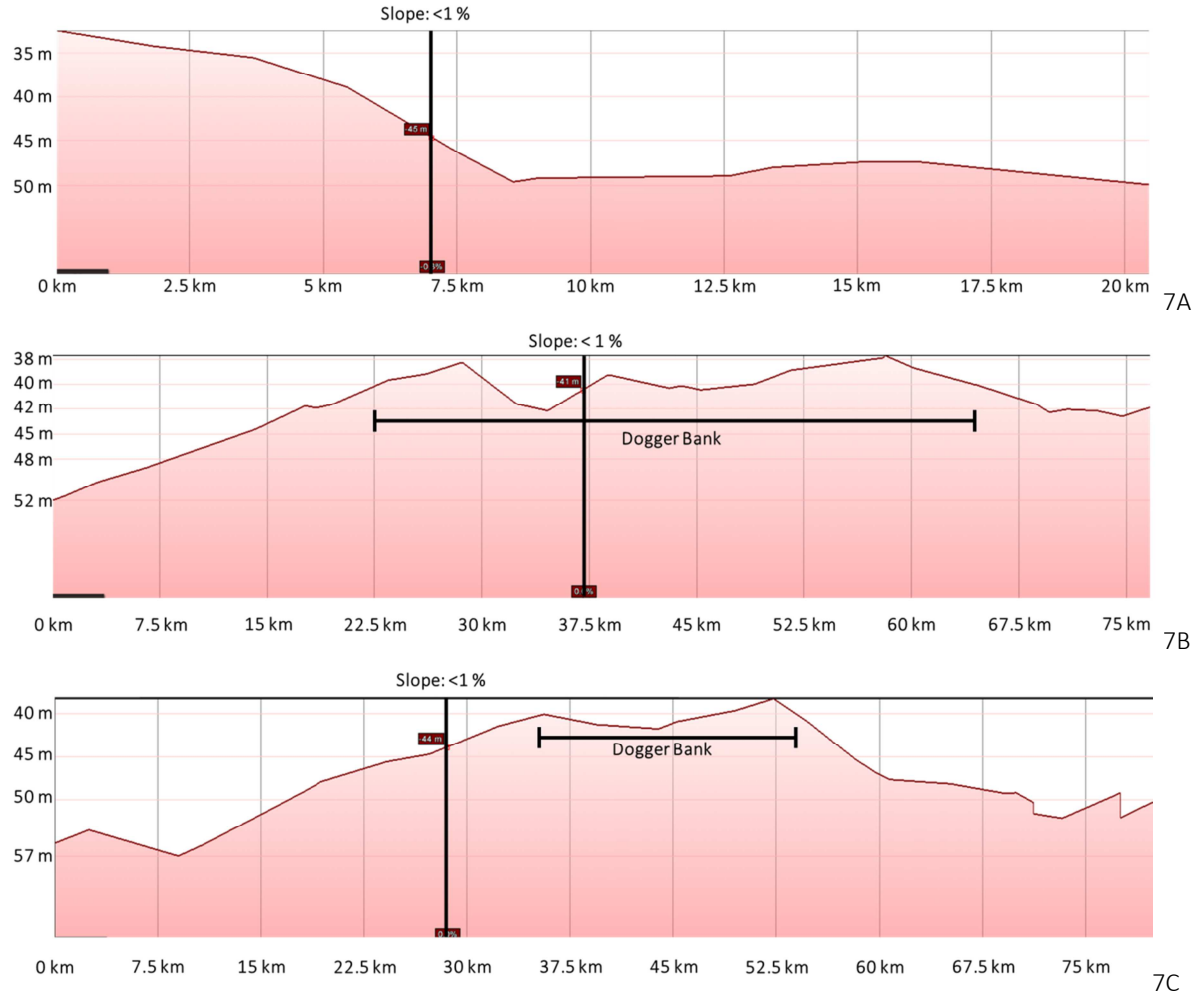

*Figure 7: Cross section (**A**). The flanks of the Dogger Bank in the Danish Area slopes < 1 %. In the example above the flank has a slope of < 1 %. Even though the drop is from 40 m to 50 m it is over a distance of approximately 2.5 km, resulting in a very low angle decline. Both cross section (**B**) and (**C**) presents examples of topographic variations within the bank. They show that there are topographic variations within the bank, but due to the size of the bank, slope angles never exceed 1 %. They furthermore contribute to evidence that slopes of the flanks do not exceed 1 %. From Google Earth 2017.*

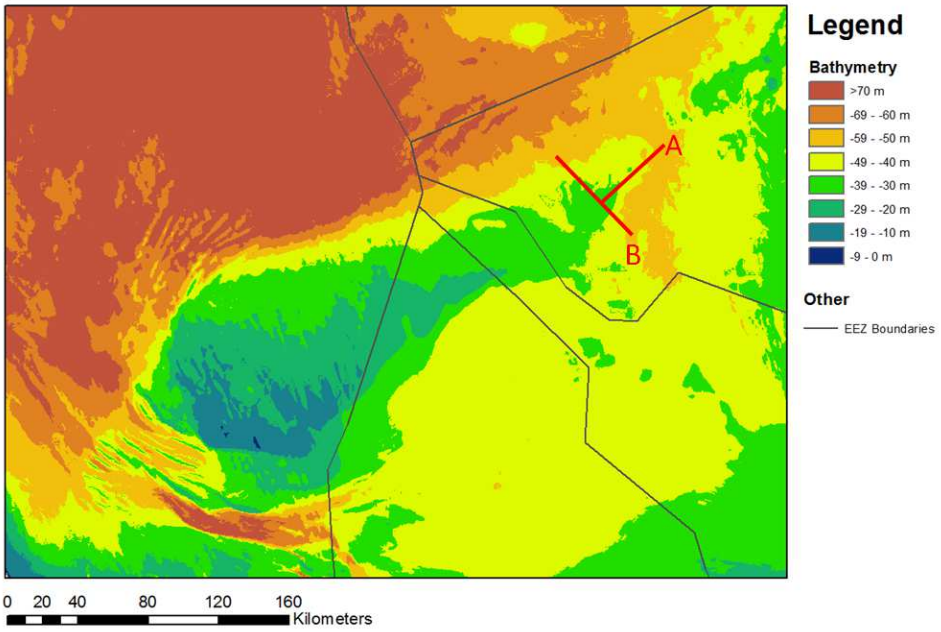

Figure 8: Selected cross-lines used to establish potential steep flanks further away from the Dogger Bank. Two representation cross-line chosen to use in this study. Bathymetry data from the European Marine Observation and Data Network.

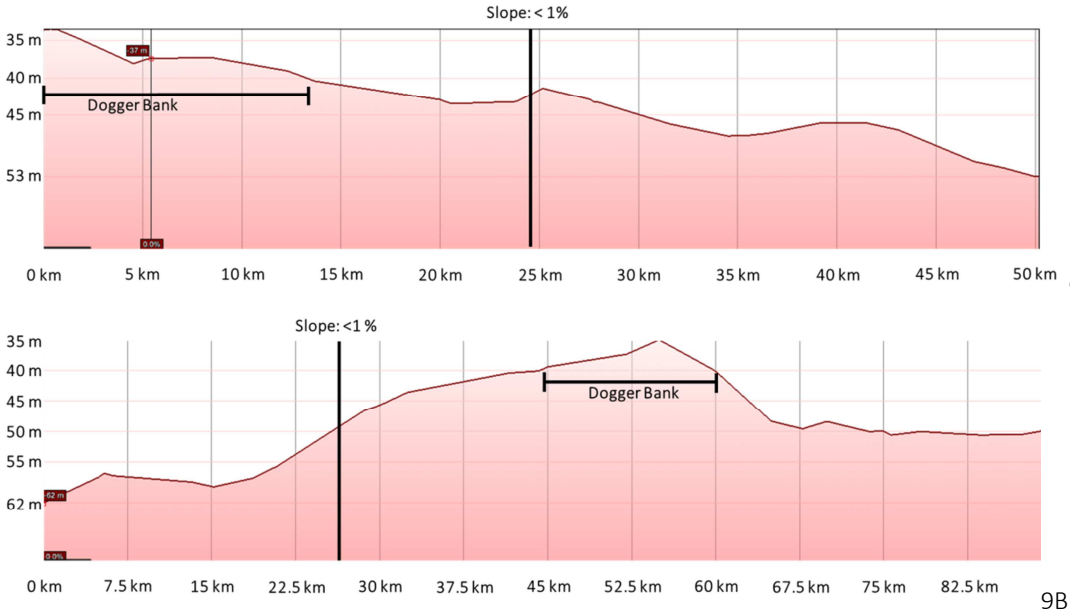

*Figure 9: Cross-section (**A**) presents a NE-SW trending line with the Dogger Bank in the SW corner of the line. The slopes do not exceed 1 %, and maximum water depth reaches 53 meters. Cross-section (**B**) presents a NW-SE trending line with the Dogger Bank at the centre of the section. Although water depths reach approximately 60 meters toward NW the slope does not exceed 1%. From Google Earth 2017.*

4.5 Sedimentology and Stratigraphy

The sedimentological and stratigraphic review of the Dogger Bank in the Danish area is based on a study by Cotterill et al. (2017), published borehole-data from the Jupiter-database (GEUS)

as well as data from an offshore sedimentological map presented by GEUS (2015). Although the study by Cotterill et al. (2017) only focuses on the UK part of the Dogger Bank, it is assumed that description of the general geology will also be valid for the Danish, Dutch and German parts of the bank.

The top 200 m of the Dogger Bank is dominated by sediments deposited in the periods of Pleistocene and Holocene of the Quaternary (Forewind, 2014).

Laminated dark grey clays to fine grained sands belonging to several formations can be recognized approximately 40 meters below seafloor (Figure 10) (for further detail see Cotterill et al., 2017 figure 2 and table 3). These sediments were deposited in marine, intertidal and deltaic environments that dominated the southern North Sea in early Pleistocene.
They are overlain by the up to 35 meter thick Dogger Bank Formation, which predominantly consists of a clay-rich diamicton with multiple intercalating sand-rich and gravel-rich layers (Cotterill et al., 2017). This formation was deposited in a periglacial to glacial environment during the rest of the Pleistocene, marking the various glacial cycles recognized in this geological time period. The Dogger Bank furthermore contains loess deposits, desiccation surfaces and channels from this period, and evidence of southerly directed folding and thrusting as a result of glacitectonic deformation has furthermore been documented (Cotterill et al., 2017).
The uppermost approximately 5 meters of sediments, are mostly Holocene of age, and they represent a transgressional setting, which began in late Pleistocene with deposition of peat in a fluvial environment. As the setting transgressed in to an intertidal, then shallow marine and finally a marine environment, sediments became dominated by marine fine- to medium grained sands containing angular to rounded shell fragments and intercalations of clay and gravel.

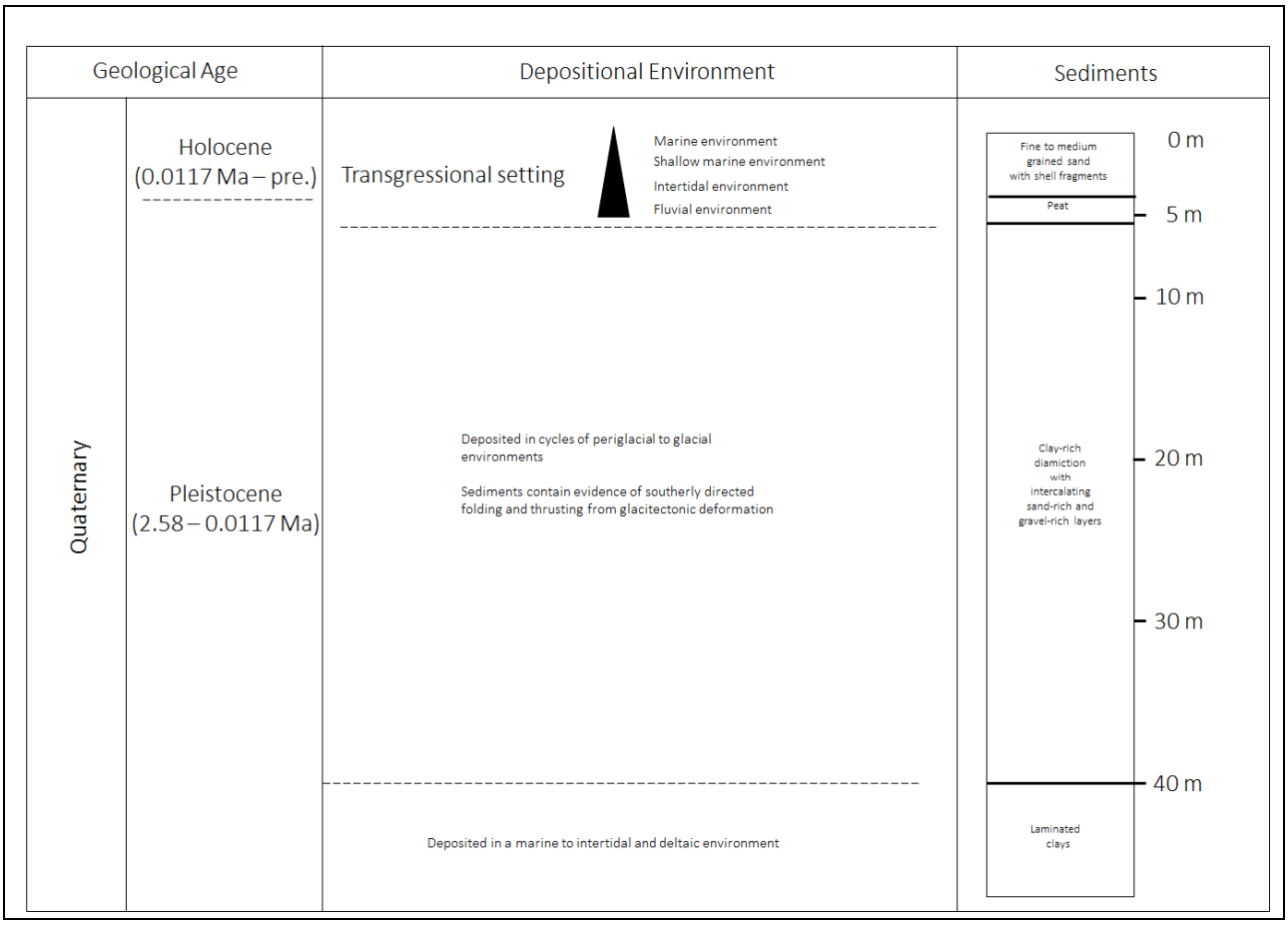

Figure 10: A schematic overview of the sedimentology and stratigraphy of the upper 50 meters of the Dogger Bank. The scheme is based on data from Cotterill et al., (2017) and the GEUS Jupiter Database, and lateral variations of thicknesses of the different sediments should be expected across the Dogger Bank.

The results from the study by Cotterill et al. (2017) are generally in good coordination with the borehole data from the Jupiter-database (GEUS, 2017) and the map of seabed sedimentology presented by GEUS (2015), which show a varying sedimentology across the southern North Sea in the Danish Area (Figure 11). From Figure 11 it is evident that the seabed in the Dogger Bank area comprises several types of sediments ranging from; sand to muddy sand as well as patches of clay- and gravel-rich sediment. From borehole-data the sand in the uppermost 5-10 meters are described as fine to medium grained sand with some angular to rounded shell fragments. Some boreholes furthermore recognize gravel, clay layers, silt layers, peat and organic traces interbedded within the sand.

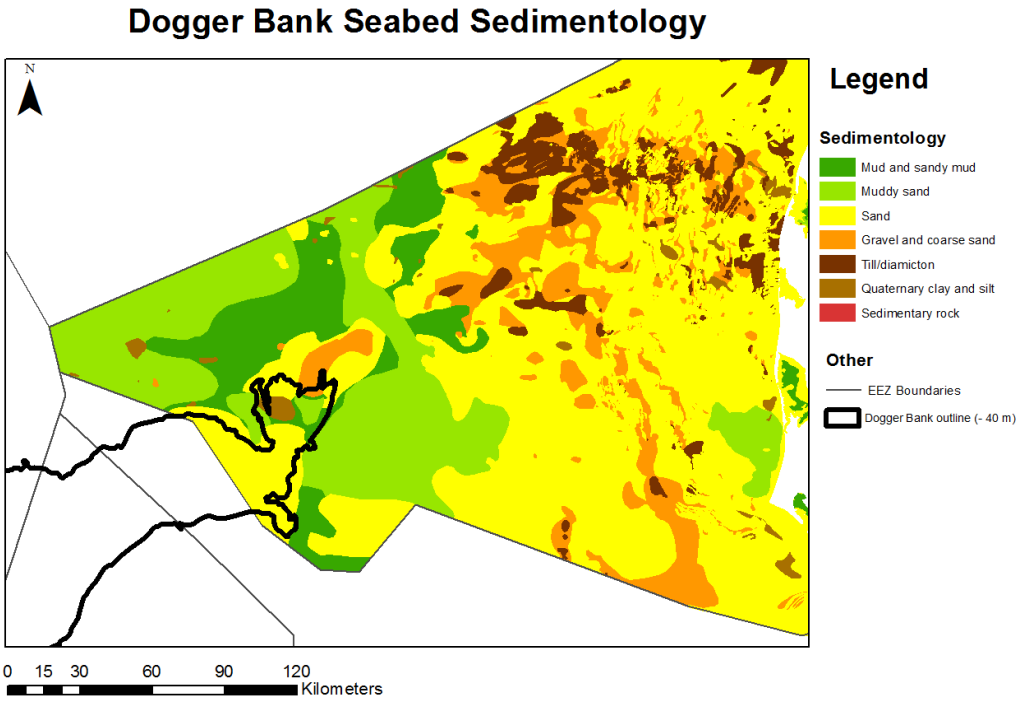

Figure 11: Seabed sedimentology in the Dogger Bank area. It is evident that the seafloor in the Dogger Bank area comprises a differentiating sedimentology of sand to muddy sand as well as patches of clay- and gravel-rich sediment Map from GEUS (2015)

4.6 Seabed Dynamics

Recognized features on the seabed comprise mega ripple structures[3]. These mega ripples are recognized with wavelengths between 0.5 to 25 meters and amplitudes from 1.4 to 2.2 meters and they are aligned NNW-SSE and N-S (Gardline, 2013a; Forewind, 2014).

4.7 Tidal Currents and Wave Conditions

In the UK sector of the Dogger Bank only weak (less than 0.4 m/s) current velocities have been measured (Forewind, 2014). Mathiesen and Nygaard (2010) have in a study made estimates of extreme tidal current velocities in the Dogger Bank area at return periods of one (0.88 m/s), ten (0.98 m/s) and 100 years (1.11 m/s).

Simulations in the southern North Sea have been made for Energinet by Ramboll (2014), and they show that wave heights at a sustained wind speed of 20 m/s from west would be up to 7 meters in the Dogger Bank area. Spring tidal amplitudes are in the same report estimated to be approximately 0.25 – 0.5 meters.

4.8 Sea-level Fluctuations

From satellite measurements in the period 1992-2014, it has been calculated that the southern North Sea has experienced an absolute rise in sea-level of 2-3 mm/year (EEA, 2016). It should be taken in to consideration how future sea-level changes will affect a potential artificial island.

[3] Mega ripples are large-scale sedimentary structures created from wave activity on the seabed.

4.9 Tectonic Activity

In 1994 an earthquake with a magnitude of 4.4 on the Richter magnitude scale occurred just south of the Danish part of the Dogger Bank. The Dogger Bank furthermore experienced an earthquake in the British part in 1931. It had a magnitude of 6.1 on the Richter magnitude scale and a small tsunami was formed as a result (British Geological Survey). Although earthquakes do happen in the southern North Sea, they rarely exceed a magnitude of 4.4 on the Richter magnitude scale, and they generally seem to be located outside the outline of the Dogger Bank used in this study. It should be taken in to consideration how the project if realised, could be affected by potential earthquakes.

5. Ecology of Dogger Bank

The Dogger Bank is the largest sand bank in the North Sea.
The water column above the Dogger Bank is constantly mixed, since warm water with low salinity from the English Canal to the south meets cold water with high salinity from the North Sea to the north.
This means that an oceanographic front is created with high production of phytoplankton which serves as basis for high biomass at higher levels of the food chain and fish spawning grounds (JNCC, 2011 c.f. Energistyrelsen, 2012). The front is located just south of the Dogger Bank and stretches north along 5 degrees eastern length (Munk et al., 2009).
The shallow and flat top occupies a large proportion of the bank and experiences turbulent hydrodynamic conditions. The surrounding slopes offer a more stable environment. Clean sands dominate the Dogger Bank, but muddy and stony grounds are present as well. The combination of location and range of habitats of the wider Dogger Bank results in a centre of biodiversity. Due to the presence of fronts the Dogger Bank is a year-round source of food for fish, birds as well as marine mammals.
The flat top of the Dogger Bank is dominated by small characteristic endobenthic species, well adapted to disturbances. Larger epibenthic species also occur in this part of the bank, but these are ubiquitous in the southern North Sea. The collected society of endobenthic species at the Dogger Bank has been defined as an Amphiura/spiophanes-society by ICES (Energistyrelsen 2012). As such, the present community does not seem particularly vulnerable to fisheries with bottom gears.
The slopes and deeper areas in the vicinity of the Dogger Bank harbour important natural values. Sand eel (*tobis*) is especially abundant in sandy areas on the slopes.
The fish are caught by industrial fisheries, but also serve as staple food for several (commercial) fishes, birds and marine mammals. Consequently, these species tend to concentrate on the borders of the bank as well, for example the Harbour porpoise (*marsvin*).
Large and long-lived bivalves such as Flat oyster, Ocean quahog and Horse mussel have disappeared or are still present in low densities. Rays have also been known to concentrate near the Dogger Bank and the wider area is known as a spawning ground for several fish species (Van Moorsel, 2011).

5.1.1.1 Significance for the Project

The impact on ecology of placing the island near the slopes could be greater than a placement on the top of the bank. This is because the slopes harbour a more stable and valuable community which will react stronger to disturbances in contrast to the top where the communities are

more used to disturbances. Especially the southern slope of the bank appears to be of importance, but this needs to be further investigated.

Based on the conclusions regarding geology, the slopes are difficult to define geographically as they are very gentle. A dialogue with interested parties should be initiated to find out more about the exact placement of the biodiversity hotspots at and near the bank. At the present knowledge stage it is recommended to look more into a placement of the project on a more central part of the bank and avoiding placement near the slopes (Figure 1).

5.2 Protected Natura 2000 areas

5.2.1 Danish Area

The Danish part of Dogger Bank is not designated as a Natura 2000-area.
The nearest Danish Natura 2000-areas are Sydlige Nordsø N246 (both SCI (F113), SAC (H255)) and Jyske Rev/Lillefiskerbanke N248 (only SAC (H257)). These areas are located approximately 140 km east of Dogger Bank (Figure 12).

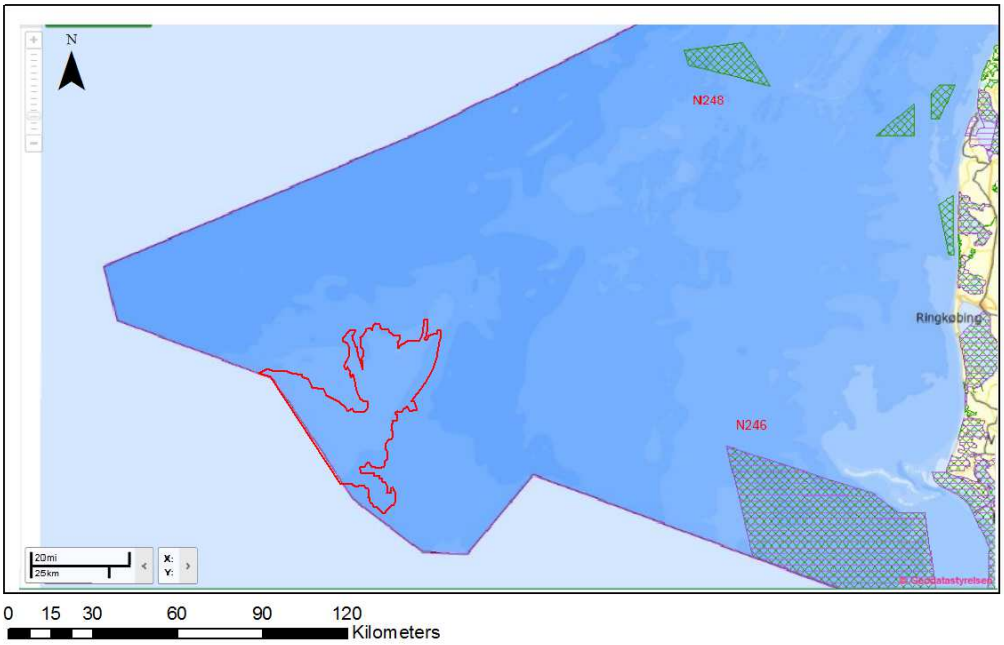

Figure 12: The Danish part of the North Sea with all Natura 2000-areas shown approx. 140 km from Dogger Bank (SCI in pink and SAC in green).

In Denmark no mapping of habitat types outside the designated Natura 2000-areas has been carried out. It is therefore unknown to what extent the Danish part of the Dogger Bank is the habitat type 1110 (Sandbanks which are slightly covered by sea water all the time). This is the only relevant type, and is the reason for designation of the Dogger Bank in UK, German and Dutch waters.
The habitat type 1110 is on a national Danish scale assessed as being in unfavourable ecological condition, but it is improving. The assessment is based on expert opinion (Fredshavn et al, 2014).

Danish marine areas containing this habitat type is e.g. the SAC Sydlige Nordsø (mentioned above). This area has a total surface area of 2,463 km^2 (246,296 ha) of which 12,000 ha are mapped as the habitat type 1110.

The habitat type 1110 is in the Atlantic region of Denmark assessed to cover an area of 1,313 km^2 (131,300 ha). The main threats to this habitat type are eutrophiation, fisheries and invasive species. Also pollution is a problem.

5.2.1.1 Significance for the Project

There is no official designation in the Danish part of the Dogger Bank area and therefore no legal protection. It is unknown whether the Danish part of Dogger Bank contains the habitat type 1110, but it is likely that it does and that the habitat-type covers most of the bank area. The total area of the Danish part of Dogger Bank is defined to be 1,400 km^2 of which most of the area is probably habitat type 1110. The island will cover up to 500 ha, which means that the island will take up approx. 0.4 percentage of the bank.
A more in depth analysis of the potential impact by removing up to 500 ha of the nature type could be carried out.

5.2.2 German Area

The German Natura 2000-Site "DE1003301 Dogger Bank" was proposed in May 2004 and designated as an SCI in November 2007 (Figure 13). It is a 100 % marine area covering 1,699 km^2. The only habitat type in the area is 1110 (Sandbanks which are slightly covered by sea water all the time) which covers 162,370 ha (1,623 km^2). The data quality is assessed as *good* meaning that it is based on surveys.
The area is described as a representative German part of unique sandbanks in the North Sea and the largest in Germany. It has a high diversity of biotypes which are markedly different from the areas in German Bight. The conservation status is assessed as *C*, but the total assessment as *A*.
Dogger Bank is a biogeographical divide with cold-adapted benthic species to the north and life forms preferring more temperate waters to the south. Sandy areas of the site are colonised by a special offshore form of a community of fine sand and seafloor species. Some 38 species on the German Red Lists have so far been recorded in the Dogger Bank area. The slopes are the least impacted areas of the German Dogger Bank.

There are regular observations of mother-calf groups of harbour porpoise.
Larus fuscus (The lesser black-backed gull, Sildemåge), *Phoca vitulina* (Common seal, spættet sæl) and *Rissa tridactyla* (The black-legged kittiwake, Ride) are present in concentrations at the site while *Fulmarus glacialis* (Northern fulmar, Mallemuk), *Morus bassanus* (Northern gannet, Sule), *Phocaena phocaena* (Harbour porpoise, Marsvin) and *Uria aalge* (Common guillemot, Lomvie) are present.
The species which are conservation objectives for the site are *Phoca vitulina* (Common seal, spættet sæl) *and Phocaena phocaena* (Harbour porpoise, marsvin). The population of *Phocaena phocaena* is 501-1000 while *Phoca vitulina* is a foraging visitor with current population statistics at the site.
In addition, a long list of invertebrates as well as one fish (*Echiichthys vipera*, lesser weever, lille fjæsing) are mentioned as important species at the site. (European Environment Agency. 2017b and BfN, 2017)

The bases for designation of the area are the following nature types and species:

- 1110 Sandbanks which are slightly covered by sea water all the time
- 1351 Phocoena phocoena (Harbour porpoise, Marsvin)
- 1365 Phoca vitulina (Common seal, Spættet sæl)
- Fulmarus glacialis (Northern fulmar, Mallemuk)
- Larus fuscus (The lesser black-backed gull, Sildemåge)
- Morus bassanus (Northern gannet, Sule)
- Rissa tridactyla (The black-legged kittiwake, Ride)
- Uria aalge (Common guillemot, Lomvie)

General conservation objectives have been set as follows for the sandbank habitat type by which the site is defined, and for harbour porpoise and common seal as species requiring special protection:

- Maintenance and restoration of the site's specific ecological functions, biological diversity and natural hydrodynamics and morphodynamics
- Maintenance and restoration at favourable conservation status of habitat type Code: 1110 (sandbanks which are slightly covered by sea water all the time) together with its characteristic and endangered ecological communities and species
- Maintenance and restoration at favourable conservation status of the following Habitats Directive species and their natural habitats: Harbour porpoise and common seal

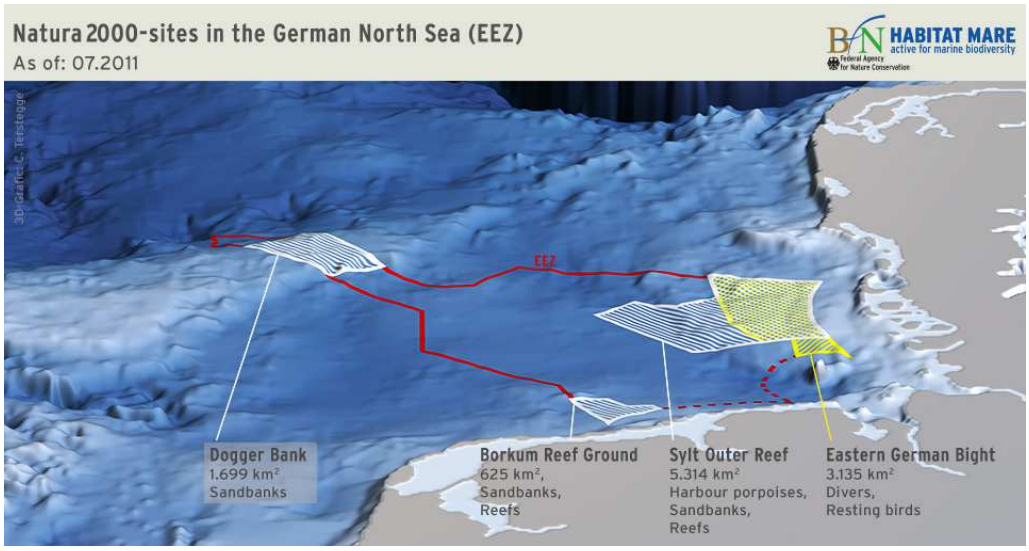

Figure 13: Map showing the German marine Natura 2000-areas. (BfN, 2017)

5.2.2.1 Significance for the Project

The German part of the Dogger Bank is designated as a Natura 2000-site and with the habitat type 1110 covering almost the whole area (96 %).
In Germany thresholds are used in relations to impacts on Natura 2000-nature types.
Placement of an island in the German area would mean an impact of 5 km^2 out of a total of 1,623 km^2 corresponding to 0.3 % of the Natura 2000-area. To qualify this impact as non-significant a number of assumptions have to hold true. One of them is that the permanently impacted area has to be less than 2.5 ha. (Lambrecht and Trautner, 2007).
This is not the case and therefore it is preliminarily assessed that the impact will be qualified as significant. Further assessment of the mentioned assumptions has to be carried out if placement in Germany is to be assessed in more detail.

5.2.3 Impacts into Dutch, German and UK Natura 2000 area

In relation to assessments of Natura 2000, impacts outside the designated area which can have an affect into the area also have to be taken into account. Effects into the German, Dutch and English Natura 2000 areas therefore have to be assessed even though the island is placed in Danish waters, outside the Natura 2000-designation. Likewise a placement in one of the Natura 2000-areas also has to take impacts on the other Natura 2000-areas into account.
The UK area is UK0030352 Dogger Bank and the Dutch area is "NL2008001 Doggersbank".

The basis for designation in Dutch waters is:

- 1110 Sandbanks which are slightly covered by sea water all the time
- 1351 Phocoena phocoena (Harbour porpoise, marsvin)
- 1364 Halichoerus grypus (Grey seal, gråsæl)
- 1365 Phoca vitulina (Common seal, spættet sæl)

The basis for designation in UK waters is:

- 1110 Sandbanks which are slightly covered by sea water all the time

5.2.3.1 Significance for the Project

A possible way to coordinate the assessment of impacts across international borders also on the Natura 2000-network is through an Espoo-hearing. The process for this has to be agreed with the relevant authorities and should be coordinated with the EIA-process.
To be able to carry out the needed assessment of impacts in the Natura 2000-areas, it may be necessary with investigations of how species which are protected in the Natura 2000-areas are using the wider Dogger Bank area (common seal, grey seal and harbour porpoise).

5.3 Annex IV-species (EU Habitat Directive)

Under the EU Habitat Directive Annex IV Harbour porpoise is the only species relevant for the area (Figure 14). Only data for the Danish area has been included here, but an assessment of the impacts on the species in a wider area encompassing areas in all four countries has to be included in the final assessment for the project.

The highest concentration of this species in Danish waters has been found in Skagerrak, near Skagen, in the Wadden Sea, near the Natura 2000 area 'Sydlig Nordsø' and around Dogger Bank (Theilmann et al, 2008).
Harbour porpoise is especially abundant in the inner Danish marine areas. Only few observations have been made in the North Sea. The sightings are concentrated around the Dogger Bank which is probably an important feeding area for the species in Denmark as well as in the other countries. The slopes have been mentioned as the most important areas for the species, but other areas may also be of importance.

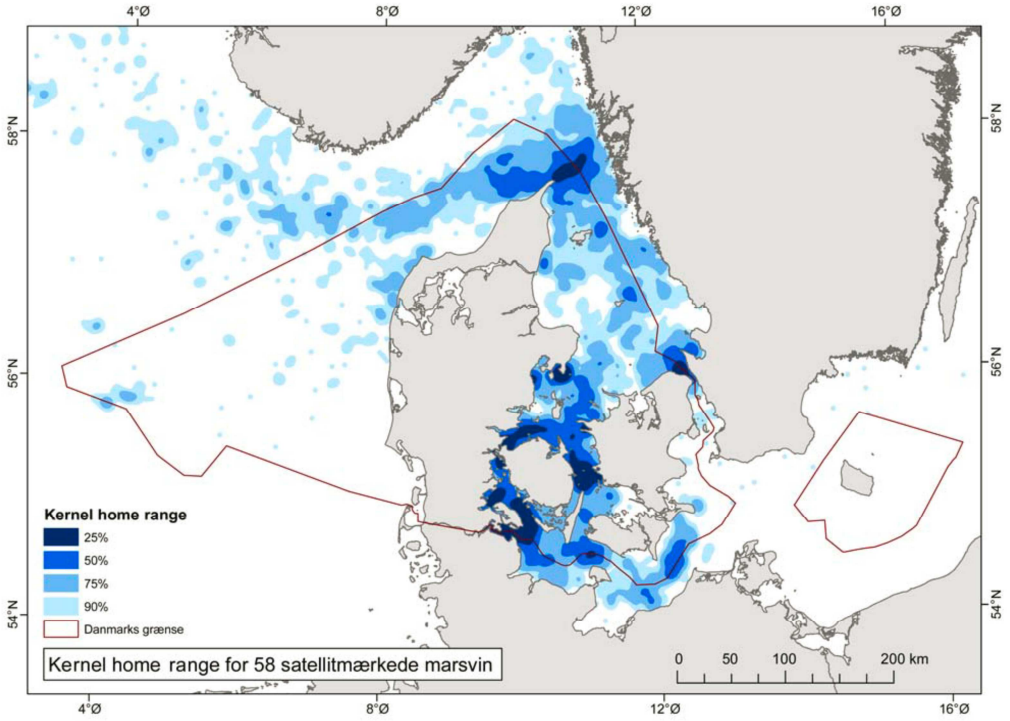

Figure 14: Core areas for harbour porpoise in Denmark (Søgaard and Asferg, 2007)

5.3.1.1 Significance for the Project

It is important to notice that Harbour porpoise is both on annex II and IV of the EU Habitats Directive.
In relations to annex II, an assessment for the species has to be carried out for the UK and German Natura 2000-area respectively, see chapter above.
In relations to annex IV an assessment for the species has to be made irrespective of Natura 2000-areas and country borders. How this is to be handled has to be clarified with the authorities in all four countries and could be handled in the Espoo process, in coordination with the assessment relating to Natura 2000-areas.

A thorough investigation of potential impacts on harbour porpoise will be needed. It is important that placement of the island is planned so that areas at the bank which are of special value for the species are not influenced - both during construction where sedimentation can be a problem and during operation due to the permanent loss of area. It is assessed as very likely that mitigation measures will be needed during construction.
The need for field investigations during the EIA-process and permitting process has to be clarified as well as the need for monitoring during and after construction.

DCE, Aarhus University (Danish Centre for Environment and Energy) should be contacted in order to obtain all existing knowledge about the species and the importance of the area. They are responsible for the map shown in Figure 14 and therefore have data for the area. Likewise similar institutions in the UK, Germany and Netherlands should also be contacted.

5.4 Birds

Only data for the Danish area has been included here. For further information see the report made for the Dutch area of Dogger Bank.
There is no official designation at or near the Danish part of the Dogger Bank relating to birds (SPA (Natura 2000), IBA (Important Bird Areas) or Ramsar (protection of wetlands for migrating birds)).
It is however certain that Dogger Bank is an important area for a number of marine birds, who feed on the fish along especially the slopes of the Dogger Bank. E.g. Dogger Bank is an important area for *Alle alle* (little auk, søkonge) with maybe 100.000 birds wintering in the area (DOF, 2005). Numbers have also been assessed higher, up to 1 million (DOF, 2016).
In the UK and German part of the bank, large numbers of the British population of *Uria aalge* (common guillemot, Lomvie) has been found, but not as a regular occurrence. There are also indications of high densities of *Gavia stellata* (red-throated diver, rødstrubet lom) in the UK and German part of the bank and overwintering populations of *Gavia adamsii* (yellow-billed loon, hvidnæbbet lom)(Energistyrelsen, 2012).

5.4.1.1 Significance for the Project

Contact to the Danish Ornithological Society (DOF) is recommended to clarify the importance of the site for birds. In addition a more thorough literature review should be carried out. Based on these, the need for field investigation should be assessed. It is likely that an island will also create benefits for birds.
Effects on birds in German, UK and Dutch waters also have to be assessed, and contact to the relevant NGOs in these countries should be made.

5.5 Nature Conservation Sites

No nature conservation sites have been appointed near the Dogger Bank in either country. Nature conservations zones are here defined as Nature reserves (DE), Biosphere Reserve Zones (DE), Nature reserves (DK) and Recommended marine conservation zones (UK). The closest are Recommended marine conservation zones for Fulmar in UK (Ramboll, 2014).

The Dogger Bank in The Netherlands, UK and Germany has been appointed as an OSPAR marine protected area (Ramboll, 2014).
The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention, 1992) is the current legislative instrument regulating international cooperation on environmental protection in the North-East Atlantic.
A network of marine protected areas has been designated, with the aim of:

- protecting, conserve and restore species, habitats and ecological processes which have been adversely affected by human activities;
- preventing degradation of, and damage to, species, habitats and ecological processes, following the precautionary principle;
- protecting and conserve areas that best represent the range of species, habitats and ecological processes in the maritime area.

In relations to OSPAR, priority habitats have been appointed. None of these are present at the Dogger Bank, but mappings have been made north of the area, in Norwegian EEZ.

5.6 Maritime Spatial Planning

Maritime spatial planning is a tool for the management and protection of the marine environment, offering an integrated, ecosystem-based approach to managing the multiple and potentially conflicting uses of the sea.
In the EU, the Directive for Maritime Spatial Planning (2014) should help Member States develop plans to better coordinate the various activities that take place at sea, ensuring they are as efficient and sustainable as possible. By 2016, Member States are required to transpose the Directive into their national legislation. The plans themselves will need to be established by 2021.
A large area including Dogger Bank and its surroundings has been designated as Marine Spatial Planning (European Commission, 2017 and Ramboll, 2014).

5.7 Fish and Commercial Fishing

The Danish part of Dogger Bank is along with other shallow water sand banks in the eastern part of the North Sea the primary location for trawl fisheries for Sand eel (*Tobis*). The amount of Sand eel caught each year depends on quotas and in some years fishing can be very intensive at selected locations. The population fluctuates quite a lot which means the same for quotas. In 2017 the population has been in growth and the resulting quotas are therefore high (Miljø- og Fødevareministeriet, 2017).
Sand ell is an important commercial species, but also an important species for the food web in the North Sea.
It is important to secure recruitment of young fish also for the populations of sea birds. Therefore fishing after Sand eel has been banned near the coast in the northwestern North Sea. Fishing is however not the only factor controlling the populations and other factors may be important.

Dogger Bank, eastern North Sea, southern Skagerrak and western Baltic Sea are all important areas for fishing Plaice and Cod with “Snurrevod” (Danish seines). Locally the intensity can be quite high and large amounts of the species are landed each year. For the North Sea in 2012 it was 646 tons for cod and 3277 tons for plaice.

Dogger Bank has a high occurrence of fish eggs and larvae, especially from cod, plaice and American plaice. Eggs and larvae have been found at all stages which indicates that the bank both serves as a spawning and rearing ground with only little transport from surrounding areas (Munk et al. 2009).

The distribution of four key commercial fish (cod, herring, sand eel and plaice) in the North Sea has been mapped as part of the Danish basis analyses for EU marine strategy framework directive (Figure 15) (Naturstyrelsen and Ramboll, 2014). Cod, herring and plaice are present in the entire study area, while sand eel is mostly distributed along the Dogger Bank and central North Sea.

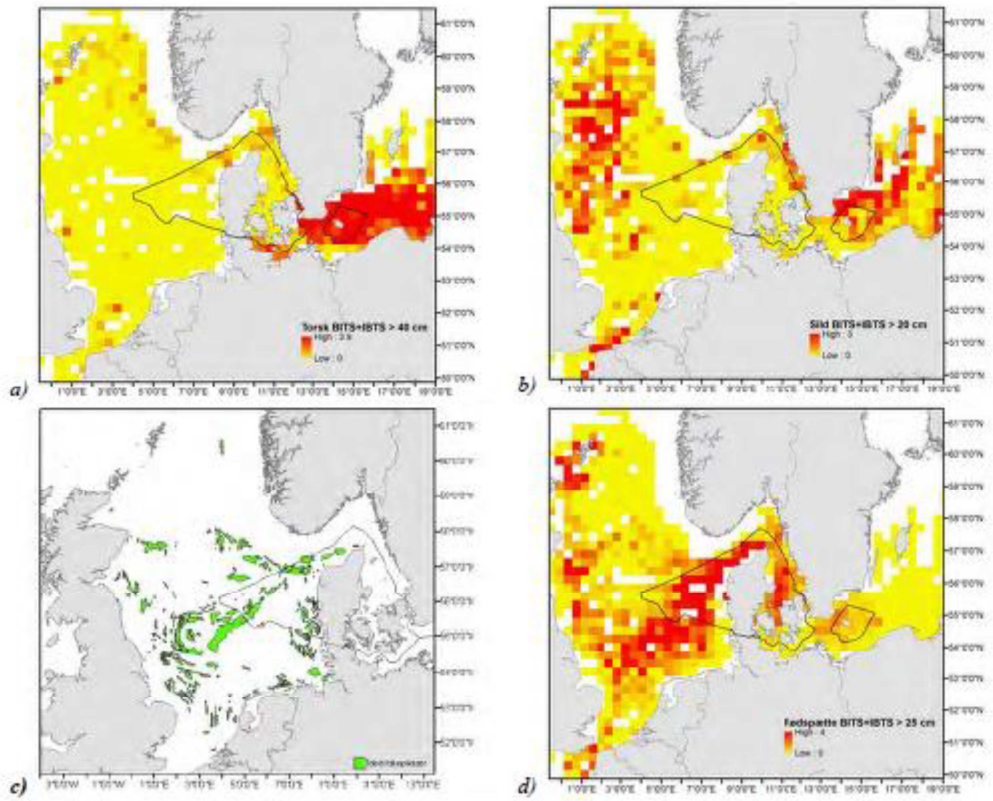

Figure 15: Important distribution areas for a) cod, b) herring, c) sandeel, d) plaice

5.7.1.1 Significance for the Project

It is recommended to liaise with the Danish Fishing Association to clarify a potential impact on the economic interests connected to Sand Eel, Plaice and Cod, and possibly other species. Also it should be investigated to which extend breeding areas for Sand eel are affected. The project should preferably be located centrally on the Dogger Bank and not on the slopes which are the most important breeding areas.

6. Other Constraints

6.1 Raw Materials

There are no interests related to extraction of sand gravel etc. in the Danish part of Dogger Bank. All existing and potential areas are located much closer to the coast as can be seen on figure 16.

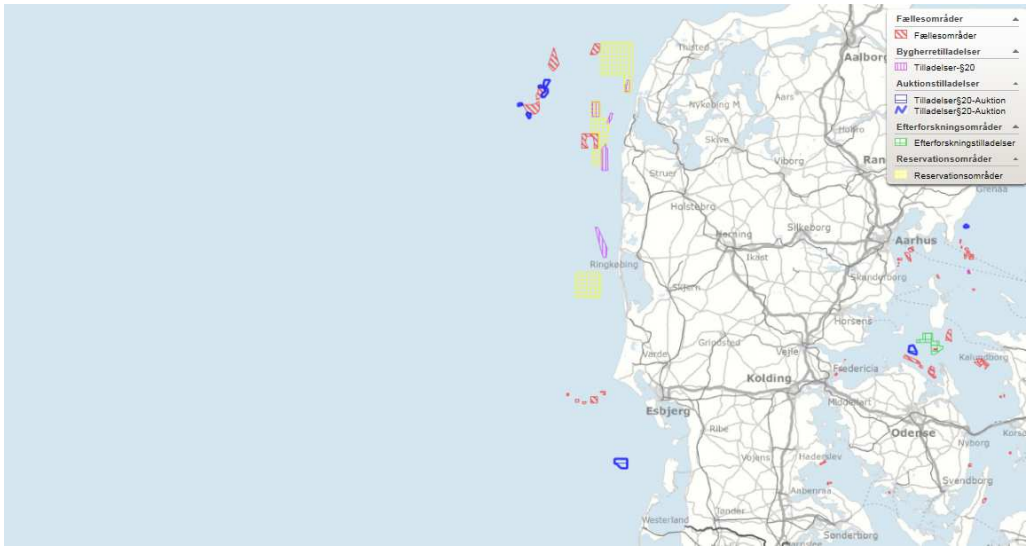

Figure 16: Current and potential areas for raw material extraction in Denmark

6.2 Oil and Gas Activities

The Dogger Bank overlay several oil and gas reservoirs, that are situated approximately 2000 meters below the seafloor, and therefore several oil and gas fields are located within the Danish part of the Dogger Bank (e.g. the Tyra Gas Field, Rolf Oil Field, Dagmar Oil Field, Skjold Oil Field and Gorm Oil Field) (Figure 17). Extensive oil and gas activity in the Danish area of the Dogger Bank may influence the placement of a 5 km^2 artificial island. Potential future oil and gas projects must furthermore be taken into consideration and the current status based on the strategic environmental assessment carried out by Energistyrelsen in 2012 should be investigated (Energistyrelsen, 2012).

It should also be noted that a pipeline with a 200 m protection zone crosscut the Dogger Bank in the Danish Area. Other pipeline connections may furthermore exist in the area, and these should be identified. Ship activity is furthermore expected in the areas between and around the oil fields. Oil and gas activities should also be taken into account in relation to future offshore wind farms expected to be placed near and to be connected to the energy hub.

For this study only oil and gas activities in the Danish part of the Dogger Bank area have been considered. Oil and gas activities for the Dutch, German and UK parts of the bank should be outlined and mapped in order to obtain a better understanding of what influence these activities will have as a whole for the NSWPH-project.

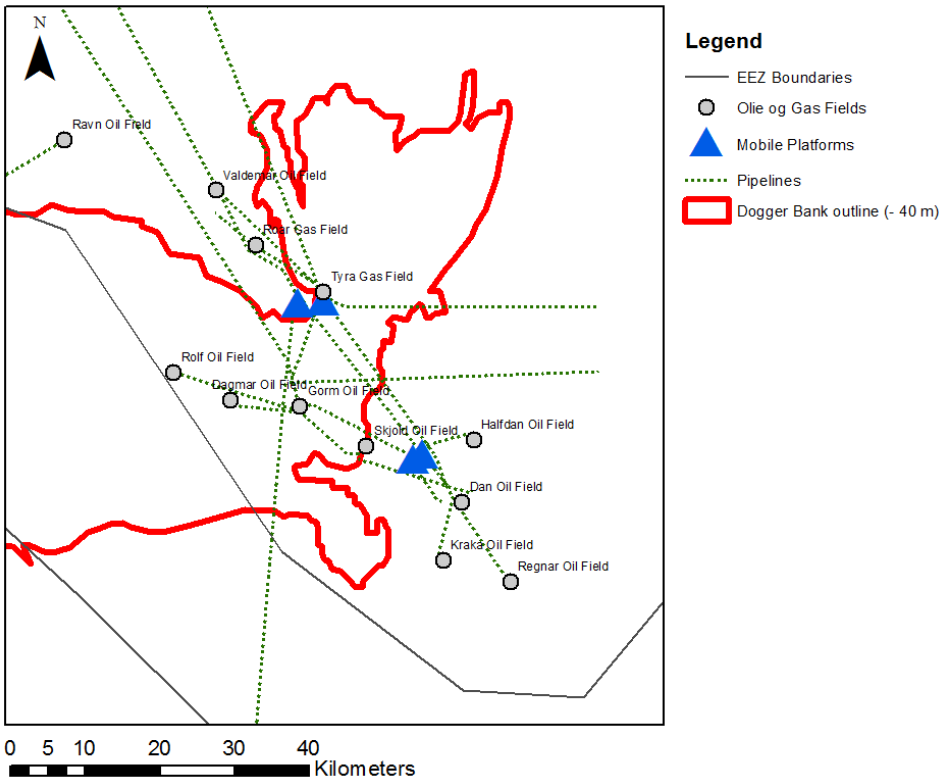

Figure 17: Some of the Oil and Gas activities in the southern North Sea. More activities may exist and needs to be identified.

6.2.1 Gas Seepage

In the Dutch area, gas emission activity has been recognized at the rim of the Dogger Bank (Römer et al., 2017). The gas seepage is known as 'the Dutch Dogger Bank Seep Area' and it is believed to originate from a gas reservoir approximately 600 meters below sea level. It should be analysed whether a similar condition could prevail in other parts of the Dogger Bank relevant to the NSWPH project and whether these can create conflicts.

6.3 Other Energy Activities

Other activity in the Dogger Bank may limit the placement of the energy hub. Examples could be existing cables-routes and wind farms and these should be investigated further. Future planned projects may furthermore have an effect on the NSWPH-project.

6.4 Archaeology

The Dogger Bank has proven interesting for archaeologists as several remains from the Mesolithic period (approx. 12,000 to 7,000 years ago) have been found by beam trawling and fishery. Remains of aurochs, woolly rhino and other animals are some of the evidences of a pre-existing landmass, named Doggerland, that connected the UK to the mainland of Europe approximately 9000 years ago (Figure 4) (Spinney, 2013). Sites of archaeological value need to be assessed further to clarify the possible constraints is may have for the project. It should be clarified with the relevant authorities for each jurisdiction how the legal requirements are for archaeology in the EEZ.

6.5 Obtaining the Needed Material for Construction of the Island

Very large quantities of material will be needed to construct the energy hub whether it being an island or some other construction. In order to assess the feasibility of the project, a preliminary assessment of the potential volumes of material needed and where it can be obtained should be made. The ecological impact of the extraction of raw material even if from other places has to be assessed in more detail at an early stage and at least during the EIA- and permitting processes.

6.6 Wind Farms Surrounding the Island

The feasibility of the project depends to a large extend on the offshore wind farms connected to the energy hub. Once the placement of the energy hub island is defined, the area of placement of wind farms is also defined, since the distance from the connection point will have economic significance. It has to be clarified how the process of identifying the area to place the NSWPH-project should be coordinated with the resulting fixation of placement of wind farms and whether a separate Strategic Environmental Assessment is needed for the planning of the wind farms.

7. Conclusion and Constraints

7.1 Geology

The Dogger Bank in the Danish Area mainly consists of clays and sands that have been deposited in a cycles of marine, intertidal, deltaic, proglacial, subglacial to marine depositional environments during the Pleistocene and Holocene periods. Although data on Dogger Bank sedimentology in Danish EEZ is limited, borehole data from the Jupiter database is in good coordination with the study by Cotterill et al., 2017.

The boundary for the Dogger Bank has in this study been defined at approximately 40 meters below sea level, which is in accordance with bathymetric maps and some geological literature. However, it could be argued whether the chosen boundary is the correct one, or if it should be defined as a deeper (making the extent of the Dogger Bank in the Danish area larger) or shallower (making the extent smaller) depth point. The size of the Dogger Bank in the Danish Area has from the defined parameters been calculated to have an area of approximately 1,400 km^2, which is a significant size that enables the installation of a 5 km^2 energy hub. By examining the flanks of the Dogger Bank, as these may be important for the environmental assessment, it is evident that they are generally very low-angled with slopes < 1 %. Although no steep flanks are recognized in this study, they may be present as inaccuracies at a m-scale may occur, and more detailed studies would be needed to address this issue.

7.2 Ecology

There are significant biological values at the Dogger Bank. Based on the current knowledge these are assessed to be mainly located near the slopes of the bank, but further analyses have to be carried out to ascertain this in more detail.
The Danish Area generally has few official designations relating to ecological values.
An important conclusion is the cross border effects which have to be taken into account and handled in a coordinated procedure during the permitting process.
There will most certainly be a need for field investigations and monitoring, but these should not be carried out now, but await further definition of the project and dialogue with interested parties. It is however very important that the project is further detailed under observation of

the potential impacts on the environment and in a way that minimizes these. Therefore different placements of the energy hub should preferably be investigated in the EIA process and in pre-assessments.

7.3 Identified constraints

Several potential constraints related to establishment of an artificial island in the NSWPH-project on the Dogger Bank have been identified in this report and are listed below:

Oil and Gas activities:

- The location of several oil and gas platforms (and the connection of these) on the Dogger Bank is a constraint for the placement of an artificial island (Figure 17).
- Oil and Gas activities in the German, Dutch and UK parts of the Dogger Bank should furthermore be mapped and taken into consideration.
- Future planned activities as assessed in the Strategic Environmental Assessment carried out by Energistyrelsen in 2012
- Pipelines cross-cutting the Dogger Bank in Danish waters
- Marine activity from ships in relation to oil and gas activities in the Dogger Bank area.
- Gas seepage

Other energy activities:

- Potential cable-routes in the Dogger Bank area
- Future placement of offshore wind farms unrelated to this project in the UK part of the Dogger Bank
- Placement of wind farms related to this project and the potential need for a Strategic Environmental Assessment of this or to include assessment of these in the EIA process for the artificial island

Geological constraints:

- Large bedforms and their migration could be considered a constraint for the NSWPH-project
- Tectonic activity
- Sea-level fluctuations
- Water depth in the Danish area (approximately 40 meters)

Ecological constraints:

- Biodiversity hotspots at the slopes of the bank
- Significance of the bank for resting birds and harbour porpoise
- Legal process relating to Natura 2000 in Germany, Holland and UK and general cross border coordination

Other constraints:

- Archaeological interests
- Fishing interests
- Obtaining the material needed for the island

8. Further Studies and Activities Needed

In order to increase the knowledge base for assessing the ecological impact of the project the below mentioned steps have been identified. A timeframe is difficult to set up, but the permitting process including the EIA- and Espoo-process is anticipated to take at least 2 years when the project is mature enough to enter this stage. The time frame for the permitting process is especially due to field investigations and surveys to obtain the necessary data for the assessments. The following listed items needs to clarified or initiated for further assessments:

1. Project Scope to be defined
2. Relation to offshore wind farms
3. Mapping out required permits
4. Working definition of Dogger Bank to be used in this project has to be defined. This could be one based on the maximum depth for feasibility of placement of island, or in dialogue with interested parties, based on the findings in this report.
5. Obtaining in more detail existing knowledge about birds, harbour porpoise and fish spawning grounds at Dogger Bank by contacting external experts. For the Danish area e.g. DOF, WWF, Danish Fishermen Association, authors of cited literature.
6. Completion of desk study with focus on existing and planned infrastructure (e.g. oil and gas activity, pipelines, cables, wind farms etc). Must include a maintenance component due to the time-span of the NSWPH project. Must include a GIS component.
7. Evaluation of knowledge base and need for further desktop studies before process with authorities and stakeholders are initiated. At least the following studies are required
    - Metocean
    - UXO
    - Infrastructure
    - Geology and hydrography
    - Archaeology
    - Traffic
    - Fishing
8. Dialogue with relevant environmental authorities in Denmark to clarify permitting process to which permits the project requires etc. (Miljøstyrelsen, Energistyrelsen, Trafik-, Bygge- og Boligstyrelsen…). Possible dialogue with environmental authorities in England, Germany and Holland to align.
9. Preliminary site investigation of selected potential sites of significant value. Not very detailed, but to get an idea of feasibility. Scope, extend and timing of this has to be defined (MetOcean, geophysics)

When the above mentioned among other technical considerations have been carried out it is expected to have obtained enough knowledge to define the project and then initiate the permitting process for energy hub here under starting the EIA process. The next steps are then expected to include:

10. Initiation of EIA-process and permitting process (including clarity if the project is going to be subject to PCI process under the TEN-E regulation as this needs to be coordinated in the permitting process)

11. Field investigation program for birds, harbour porpoise, (fish) and bottom-organisms on Dogger Bank. Preferable two seasons to be used for Environmental Impact Assessment
12. Writing EIA documentation, permit application etc.
13. Permit – including EIA permission
14. Detailed geotechnical investigation of selected site(s)
15. Baseline study of ecological importance of selected site prior to installation
16. Monitoring program for selected site set up
17. Construction and monitoring program
18. Post-construction monitoring program

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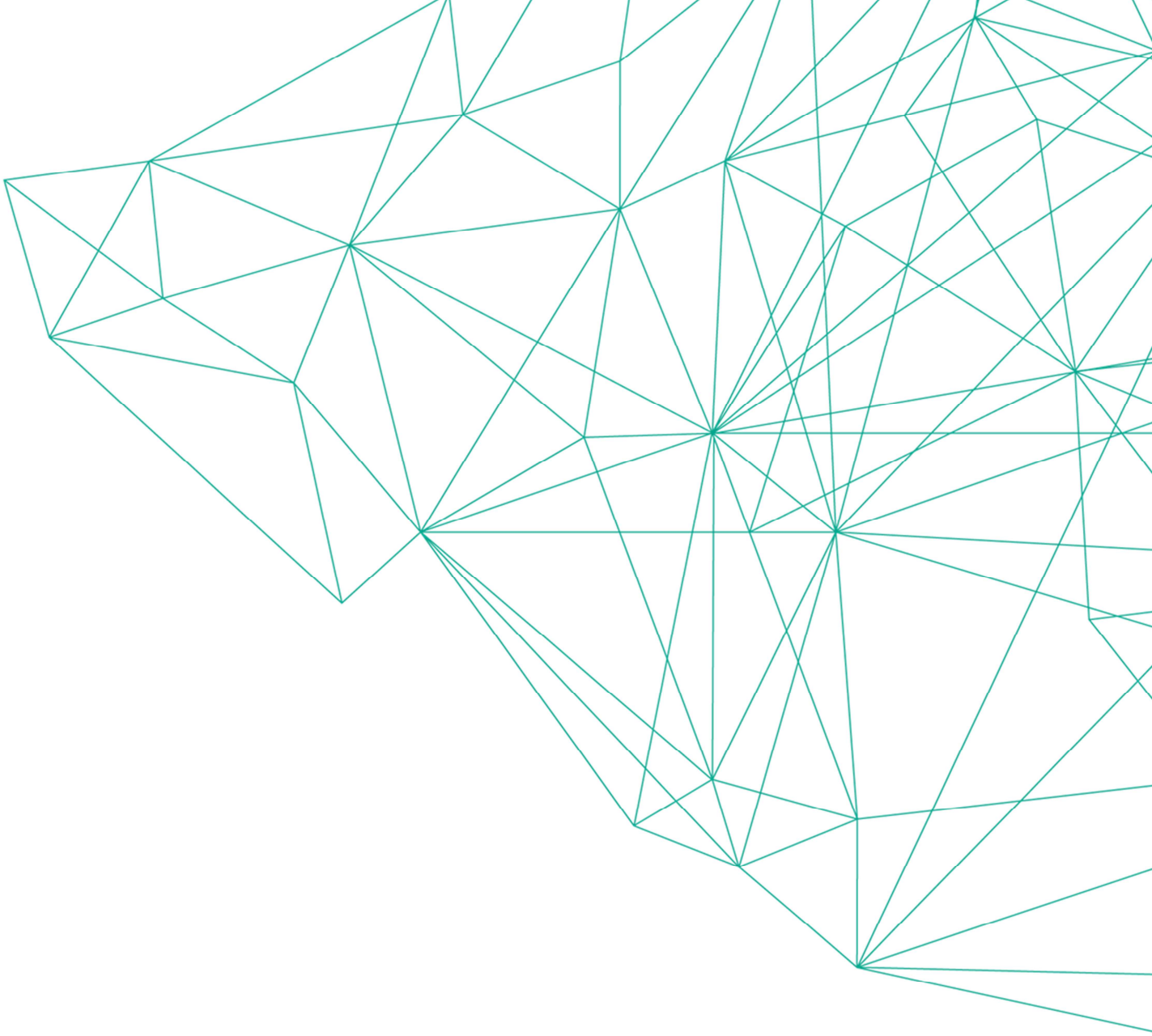

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