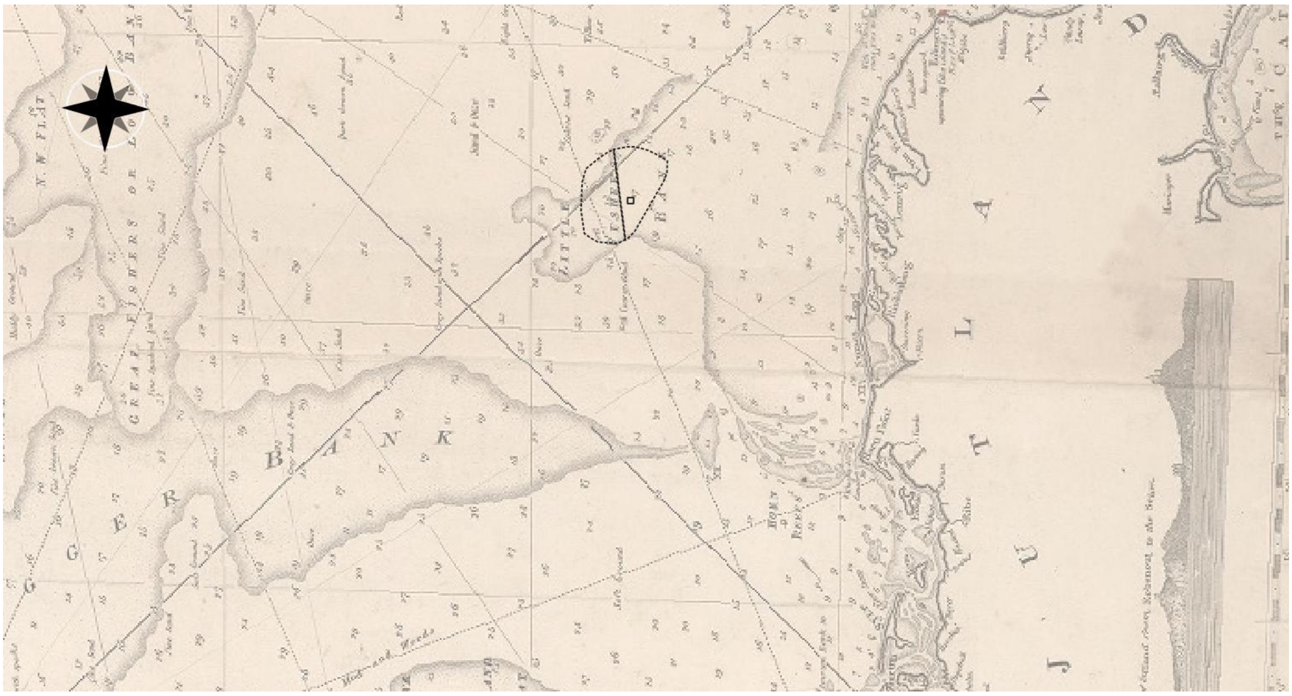
Energy Island
Maritime archaeology
Geo-archaeological analysis, report



2022

Marinarkæologi Jylland

Final version for publication

Nordjyllands Kystmuseum

MOMU Moesgaard Museum

De Kulturhistoriske Museer Holstebro Kommune

1. Summary

This report comprises a Phase II desk-based geophysical analysis of the Energy Island location with regards to submerged cultural heritage impact assessment. Based on the geoarchaeological analysis, it was concluded that there is little (but not zero) risk that the project will destroy Stone Age sites or shipwrecks.

The most important reasons that destruction of Stone Age sites is considered unlikely are:

- The depth to the sea bottom (minimum -27masl) and -40masl to horizon H10 suggests the area was inundated ca. 9000-8500 BC. Therefore, the area was not inhabitable for most of the Holocene. The presence of Late Palaeolithic settlement cannot be excluded, but because population density was so low there is only a slight probability that any evidence of prehistoric activity remains in the area. Therefore, it is deemed unlikely that a Phase III marine archaeological survey would identify possible traces of Late Palaeolithic/Early Mesolithic settlements.
- Based on the seismic data, it is not possible to identify areas with an increased archaeological potential. Horizons H05, H10 and H20 occur in the proposed Energy Island location, but they do not have the characteristic elements (shorelines, lakes, islands, etc.) that often accompany the presence of prehistoric activities. Therefore, it is difficult to construct topographic models that suggest likely hotspots for further investigation.
- The seismic data (and the horizons interpreted from them) suggest the presence of a massive sediment layer (U05 and U10) that formed when the area was inundated. In most of the area where the island will be it has a thickness of 10-15m, making it extremely difficult to access horizons which might contain prehistoric remains. Assuming an effort was made with, for example, dredging, any possible finds would have limited context information which greatly reduces their scientific value.
- None of the 105 CPTs and cores contain traces of Holocene peat layers. In other words, the bore samples contained no certain evidence of archaic land surfaces that could have been occupied while the area was dry land. On the other hand, peat layers were identified in other locations in the OWF area.

In summary, it cannot be excluded that settlement remains from the Late Palaeolithic or Early Mesolithic occur in the proposed island area. However, based on the factors stated above, the presence (and location) of preserved archaic landscapes suitable for prehistoric occupation is highly uncertain. Furthermore, the presence of a thick sediment layer that formed after the area was submerged makes it very unlikely that any possible traces of prehistoric activity could be found. The bore samples and geophysical data collected from the surrounding area of the OWF indicate that there might be a better basis for archaeological investigations there. Thus, in connection with the geoarchaeological analyses that will be done before establishment of the OWF and its associated cable routes, an evaluation will be made as to whether there is justification for marine archaeological investigations in these areas.

The review and analyses of the geophysical survey has not shown any clear large-scale shipwrecks, shipwreck debris or wrecks of aircraft or submarines in the area. Three SSS anomalies were identified as debris associated with shipwrecks and of interest for submerged cultural heritage, but all are outside of the EI site. 59 magnetic anomalies were identified as above the threshold (50nT) MAJ considers relevant for objects of maritime archaeological interest. These magnetic anomalies have been investigated by the EOD mitigation survey and one target is of archaeological value, where removal is recommended.

Figure 1 Cover picture: Position of the Energy Island and OWF on a historical chart by Imray 1852

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List of abbreviations and definitions

BCE	Before Current Events
BH	Borehole
BSU	Base Seismic Unit
CE	Current Events
CPT	Core Penetration Test
DKM	De Kulturhistoriske Museer I Holstebro Kommune
EI	Energy Island
EOD	Explosive Ordnance Disposal
GEUS	Geological Survey of Denmark and Greenland
GIS	Geographic Information System
HF	High Frequency
LF	Low Frequency
MAG	Magnetometer
MAJ	Marinarkæologi Jylland
MASL	Meters Above Sea Level
MBES	Multibeam Echo Sounder
MMO	Man Made Object
MOMU	Moesgaard Museum
NKM	Nordjyllands Kystmuseum
OWF	Offshore Wind Farm
ROV	Remotely Operated Vehicle
SBP	Sub-Bottom Profiler
SLIP	Sea Level Index Point
SLKS	Slots- og Kulturstyrelsen
SOW	Scope Of Work
SSS	Side Scan Sonar
UXO	Unexploded Ordnance
WWI	World War One
WWII	World War Two

2. Introduction

2.1. Project information

Energinet is establishing offshore energy infrastructure in the Danish North Sea to supply offshore wind energy to the Danish mainland and to neighbouring countries via an offshore energy hub - an artificial Energy Island about 100 km outside of Thorsminde, off western Jutland.

The construction of the Energy Island and the erection of wind turbines may impact maritime archaeological find locations. Furthermore, anchoring and jacking-up of vessels used during construction work can damage cultural heritage in the affected areas. The project site for the artificial Energy Island itself is 2.5 km x 2.5 km and the work could potentially endanger maritime archaeological objects such as shipwrecks, wreckage and Palaeolithic and Early Mesolithic find locations.

Energinet has asked the maritime archaeological museums in the collaboration Maritime Archaeology Jutland (MAJ) to carry out a Phase I and Phase II desk based cultural heritage impact assessment of the proposed construction area of the Energy Island to evaluate the extent to which this project will affect objects and areas protected by Section 28 of the Danish Museum Act. Although the area of investigation lies outside of Danish territorial waters and thus the Danish Museum Act does not have jurisdiction, an agreement was made between Energinet and MAJ, with the involvement of SLKS, that the archaeological investigation will proceed according to the above legal framework. This analysis seeks to determine the presence of cultural heritage, such as traces of human activity from the Palaeolithic period or cultural-historical objects such as shipwrecks.

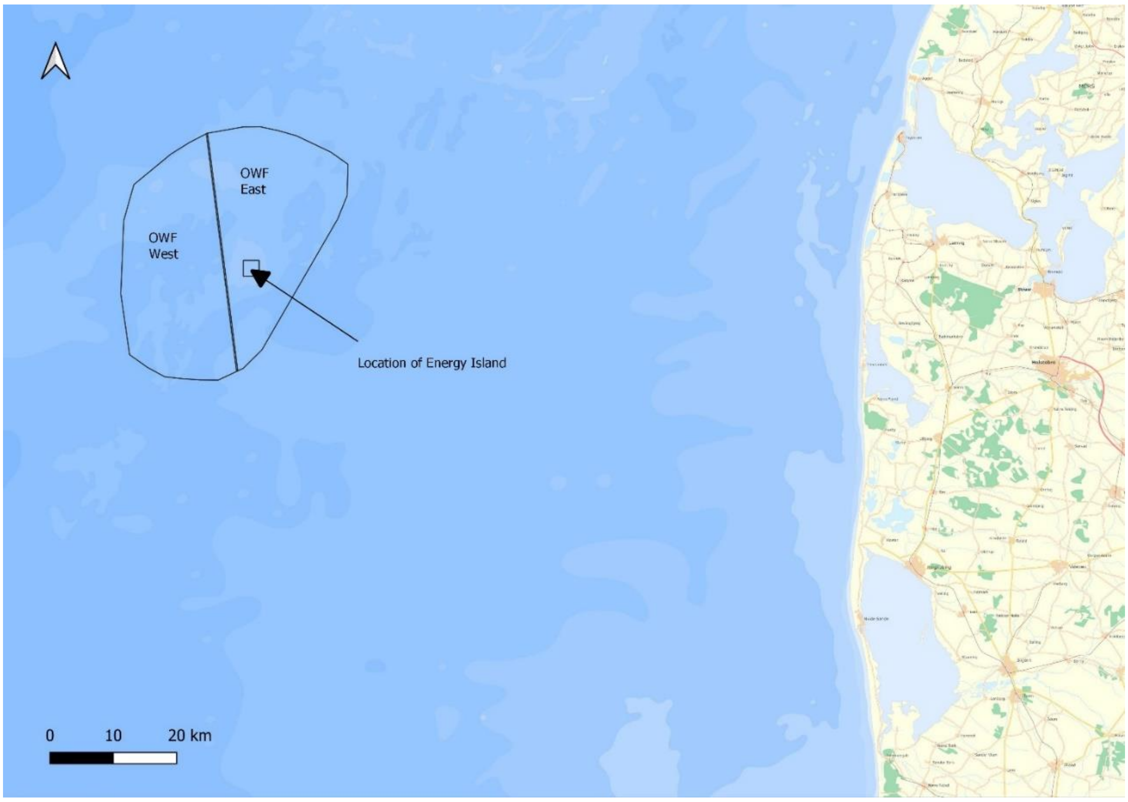


Figure 2 Position of Energy Island

2.2. Administrative and other data

Accountable museum:	Marinarkæologi Jylland (MAJ)
Museum contact:	PMA
Report responsibility:	DD + PMA
Report finish date:	
Participating archaeologists:	PMA (MM), AJ (DKM), JHL (NJK), DD (MM)
Stone Age responsibility:	PMA
Historical archaeology responsibility:	AJ, JHL, DD
Name of site:	Energiø, Nordsøen
Site and location number (FF):	400110a Nordsøen V: 106
MAJ collaboration case no.:	MAJ2021-50 Energiø, Nordsøen
DKM case no.:	DKM 21007
SLKSs case no.:	
Approved budget incl. sales tax:	
Date of approval of budget:	
Type of budget:	Geoarchaeological analysis
Period of investigation:	
Date of project description	
Contractor name	Energinet
Contractor address	Tonne Kjærsvej 65, 7000 Fredericia
Contractor type	Public
Contractor CVR no.	
Coordinates:	X 346581.0 Y 6267032.0
Geographic coordinate system:	Euref89 UTM zone 32N
Water depth:	
Area of investigation:	6.25km^2

2.3. Assessment objectives

The object of this Phase II cultural heritage impact assessment is to review and analyse the survey data collected by MMT and Fugro and provided by Energinet. The report should provide an accurate analysis of encountering and damaging cultural heritage and the character of this cultural heritage during the construction of the EI.

Archaeological study phase	Description
Phase I	Desk based background study of maps, historic records, archives, previous project results and databases.
Phase II	Geoarchaeological analysis of survey results, and if not provided by the client, gathering of data using non-intrusive methods.
Phase III	Survey excavation of potential locations.
Phase IV	Full scale excavation.

2.4. Scope of work

The cultural heritage impact assessment should be performed in 2022 and completed by 30th September 2022. The report should cover the full area of investigation and include all available data.

2.4.1. Deviations to scope of work

The deadline for the delivery of the report was extended to December 2022 to await C14 dating results.

2.5. Purpose of document

The purpose of this document is to provide an overview over submerged cultural heritage at the EI site and serve as the base document for further archaeological investigations as well as to outline risks in connection with the construction for Energinet.

2.6. Reference documents

Document Number	Title	Author
103783-ENN-MMT-SUR-REP-SURWPA-A REVISION A	GEOPHYSICAL SURVEY REPORT – ENERGY ISLAND	MMT
103783 GS All Blocks 2021_10_15	GRAB SAMPLE REPORT	MMT
103783-ENN-MMT-WPA-EI-MAG-Anomaly-List	MAGNETIC ANOMALY LIST	MMT/ENERGINET
103783-ENN-MMT-WPA-EI-MBES-SSS-Contact-List_Images	SIDE-SCAN SONAR ANOMALY LIST	MMT/ENERGINET
EES1228-Energy Island-RPS-UXO-MTL_00	UXO ANOMALY LIST	RPS/ENERGINET
1306_uxo_threat_and_risk_assessment_artificial_island	DESK STUDY FOR POTENTIAL UXO CONTAMINATION ENERGY ISLAND - NORTH SEA ARTIFICIAL ISLAND	RPS

1307_uxo_survey_report.pdf	UXO SURVEY REPORT – ARTIFICIAL ISLAND PROJECT SITE	RPS
1302_marine_archaeology_archaeological_analysis_desk_study.pdf	ARKIVALSK KONTROL OG ARKÆOLOGISK ANALYSE AF ANLÆGSOMRÅDET FORUD FOR ETABLERING AF ENERGI-Ø MED TILHØRENDE VINDMØLLEPARK I NORDSØEN	MAJ
1308_104087-enn-mmt-sur-rep-wpduxo-a	INSPECTION AND REMOVAL REPORT – ARTIFICIAL ISLAND PROJECT SITE	MMT
1309_risk_sign-off_documentation_report.pdf	ENERGINET - ENERGY ISLAND – NORTH SEA ALARP CERTIFICATE	RPS/ENERGINET

3. Survey methods and data gathering

This report is based on the geophysical survey data delivered by Energinet in accordance with PROJEKTBESKRIVELSE AF ARKÆOLOGISK OG GEOARKÆOLOGISK ANALYSE I FORBINDELSE MED ENERGIØ OG 3 GW HAVVINDMØLLEPARK I NORDSØEN. 21. JUNI 2021 J. NR. MAJ2021-50.

A detailed report on the methods for geophysical data acquisition, processing, transformation and interpretation is found in GEOPHYSICAL SURVEY REPORT WP-A ENERGY ISLAND | 103783-ENN-MMT-SUR-REP-SURWPAEI JANUARY 2022 by MMT.

MAJ received the data collected by MMT and Fugro from Energinet as seen in Table 1.

The location of the Energy Island was based on as defined in Artificial_Island_Site_PTS.xlsx.

For the analysis of Stone Age potential the following databases were reviewed among others:

- Danish central register of cultural historical properties, Fund og Fortidsminder, Slots- og Kulturstyrelsen, https://www.kulturarv.dk/ffreg/
- National boringsdatabase (Jupiter) (geus.dk)

For the historical cultural heritage analysis the following databases were reviewed among others:

- Danish central register of cultural historical properties, Fund og Fortidsminder, Slots- og Kulturstyrelsen, https://www.kulturarv.dk/ffreg/

- Danish sports divers´ wreck database, Vragguiden, https://www.vragguiden.dk
- Royal Navy Loss List database, MAST Maritime Archaeology Sea Trust, https://www.thisismast.org/research/royal-navy-loss-list-search.html
- Royal Navy Wooden Shipwrecks Database (V1.3 07 Jul 2018), 3H Consulting, http://www.3hconsulting.com/rnshipwrecks.html

Raster geodatabase:	Bathymetry - Gridded soundings, 0.25m resolution
	Bathymetry - Gridded soundings, 1.00m resolution
	Bathymetry - Gridded soundings, 5.00m resolution
	Bathymetry - backscatter 32bit geotiff stored in esri file geodatabase (amplitude populated channels)
	Generated elevation grids relative to vertical datum for each interpreted horizon in 5 m resolution
	Generated depth below seabed (BSB) grids for each interpreted horizon in 5 m resolution
	Generated Isochore (layer thickness) grids for each interpreted soil unit in 5 m resolution
File geodatabase	Track plots for all instruments as TSG object TRACKS_LIN, indicate equipment carrier and equipment type in attributes.
	Bathymetry - Bathymetric contour curves with 50cm interval, as TSG object CONTOURS_LIN
	SSS Anomaly target list, as TSG object SSS_ANOMALY_PTS, anomaly characteristics provided in attributes.
	MAG Anomaly target list, as TSG object MAG_ANOMALY_PTS, anomaly characteristics provided in attributes
	SBP and UHRS Anomaly target list, as TSG object SBP_ANOMALY_PTS, anomaly characteristics provided in attributes.
	Seabed Surface Geology, as TSG object SEABED_GEOLOGY_POL, indicate surface geological unit in attributes
	Seabed Surface Features, as TSG object SEABED_SURFACE_PTS, indicate surface forms in attributes
	Seabed Surface Features, as TSG object SEABED_SURFACE_LIN, indicate surface forms in attributes
	Seabed Surface Features, as TSG object SEABED_SURFACE_POL, indicate surface forms in attributes
	Seabed Substrate type, as TSG object SEABED_SUBSTRATE_POL, indicate substrate type in attributes.
	Man-Made-Objects, as TSG object MMO_PTS, indicate MMO type in attributes.
	Man-Made-Objects, as TSG object MMO_POL, indicate MMO type in attributes.
	Man-Made-Objects, as TSG object MMO_LIN, indicate MMO type in attributes.
	Grab sample positions, as TSG object GEOTECHNIC_PTS, indicate sampling characteristics in attributes.
Bathy data	Bathymetry - Gridded soundings, 0.25m resolution, (X,Y,Z) values in ASCII format (tiled following the UTM grid).
	Bathymetry - Gridded soundings, 1.00m resolution, (X,Y,Z) values in ASCII format (tiled following the UTM grid).
	Bathymetry - Gridded soundings, 5.00m resolution, (X,Y,Z) values in ASCII format (untiled).
SSS data	Side scan sonar data as XTF-files with corrected navigation, High frequency
	Side scan sonar data as XTF-files with corrected navigation, Low frequency
	Navigation files, CSV-format
	Target Catalogues
	SonarWiz 7 project including the bottomtracked and suitably processed .XTF files and SSS and Magnetometer targets
Mag data	MAG measurements, CSV-format
SBP & 2DUHRS data	Interpretation of the processed seismic data. These data include interpretation points for digitized horizons identified in the seismic recordings (point list file in CSV-format).
	Generated elevation grids relative to vertical datum for each interpreted horizon in 5 m resolution as (X,Y,Z) values in ASCII format (Z as the horizon elevation in meter)*
	Generated depth below seabed (BSB) grids for each interpreted horizon in 5 m resolution as (X,Y,Z) values in ASCII format (Z as the horizon depth BSB in meter)*
	Generated Isochore (layer thickness) grids for each interpreted soil unit in 5 m resolution as (X,Y,Z) values in ASCII format (Z as the layer thickness in meter)*
Grab sampling data	Grab sample classification, MS-Excel spread sheet
	Grab sample laboratory analysis, overview table and result tables, MS-Excel spread sheet.
Report	Operations Report
	Geophysical site survey Report (charts as enclosures)

Table 1 List of MBES, SSS, MAG, SBP, 2D UHRS, interpretations data delivered to MAJ

4. Historical overview of the Energy Island and OWF site

Stone Age

Archaeological, as well as geoarchaeological research, indicate that the area that is now covered by the North Sea was part of a large prehistoric plain, until ca. 9000 BCE. The area, termed Doggerland, stretched from what is today Denmark to the British Isles. Debate is ongoing as to how rapidly, and whether gradually or in a catastrophic event, but the area was flooded and became inhabitable and the sea impenetrable during the Palaeolithic and Mesolithic periods. During the period of possible occupation Doggerland provided open hunting and fishing grounds for prehistoric humans, an area of seasonal or permanent settlement and a migration route to and from the British Isles and Scandinavia.

Antiquity

There are little to no records on seafaring on the North Sea in the pre-Roman Germanic periods. The Roman geographer and historian Pliny the Elder wrote in the 1st century AD about the northern European region. In his Book 4 Chapter 27 he describes today´s northern German coast as well as some regions of Scandinavia (Pliny, 1.4.27). The activity of the Roman Empire in Germania during the Julio-Claudian period and the extensive archaeological evidence for trade with the northern barbarians and movement of goods and people throughout the region make it clear that there was seafaring along Jutland´s west coast and thereby the construction area. The wreck of a Roman seagoing merchant vessel, Blackfriars I, was discovered in London in 1962. In 2018, a Roman anchor was discovered during survey works for Scottish Power Renewables´ East Anglia ONE OWF, 40km from the English coast in the North Sea (Scottish Power 2022).

Maritime finds from this period outside of the Mediterranean are nevertheless rare and any such finding is considered highly unlikely. Their rarity however, makes them incredibly valuable to science.

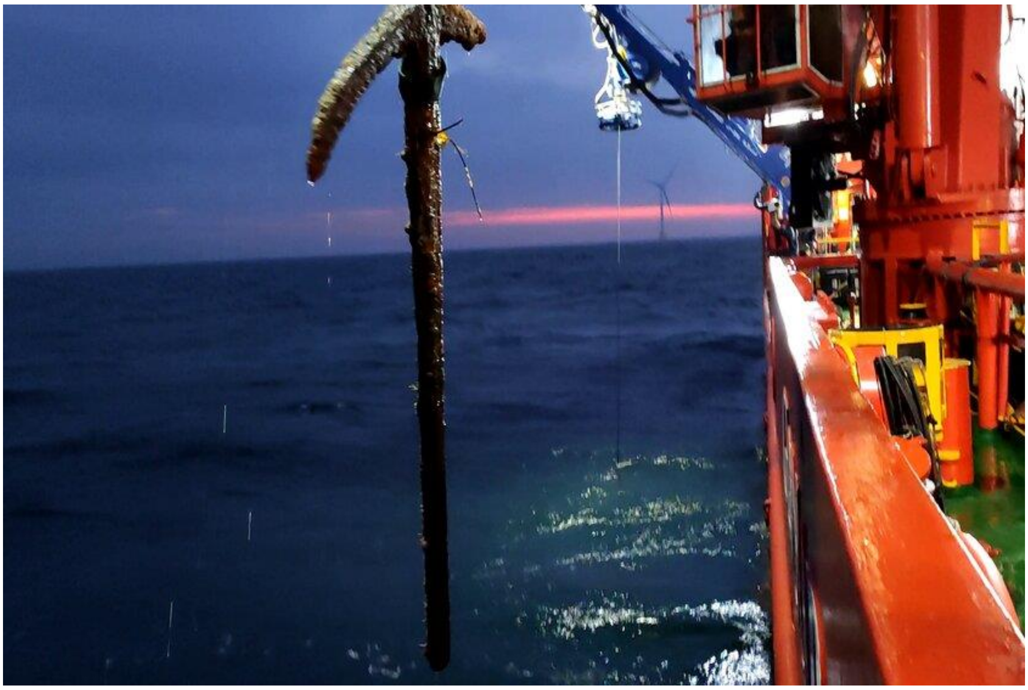


Figure 3 Recovery of the Roman anchor in the North Sea (Scottish Power 2022)

Post-Roman Iron Age

Trade and mobility declined after the fall of the Roman Empire and there is unlikely to have been any substantial maritime transport in the area.

Viking Age

The first documented Scandinavian raid on the British Isles was on Lindisfarne in 793 CE. There are substantial archaeological and historical arguments for offshore seafaring before this date as well in the period. The 9th-11th centuries were characterized by a large amount of maritime transport across the area. Large Viking fleets left Scandinavia for the British Isles, and the Islands of the North Atlantic (Faroe Isles, Iceland, Greenland) were settled and incorporated into the maritime trade network. The number of vessels and wreckings are difficult to estimate, but range in the hundreds. Wrecks in the deeper offshore part of the area are likely to have been destroyed upon impact with the seabed, leaving behind a scattered debris field, especially if the ship sustained structural damage in a violent storm. Near the coast, shipwrecks could have been covered by sediment. As some Viking ships, especially of the Norwegian types, contained mostly wooden fasteners (dowels, trenails and joints), they are likely not to give a magnetic anomaly signal or a very weak one if they are buried in the sediment. Especially the area around Thyborøn and the entrance to Limfjorden can be interesting, as this was an important landing point already during the Viking Age. Nevertheless, the chances of a wreck from the Viking period surviving in these conditions are small and finding such a wreck is deemed unlikely.

Medieval Period

Seafaring on the North Sea in the Middle Ages was dominated by the Hanseatic League, which controlled most of the trade in and out of the Baltic Sea. Throughout the period following the Norman conquest of Britain the Dutch cities started to gain in importance for the North Sea trade and the Hanseatic League gradually lost its power from the 15th century onwards. The main ship types of the era were the hulks and the cog. Examples of these are scarce and of immense scientific and cultural historical value. Considering the volume of trade across the North Sea in this period with these vessels, it is likely there are wrecks and debris fields in the North Sea but stumbling upon them would be exceptional. The large oak timbers and the iron fasteners of these vessels would probably show up on a magnetometer survey.

Post-medieval and Renaissance Period

After the decline of the Hanseatic League various actors took over the trade across the North Sea, mainly the Dutch, but also the Danes. Despite the ever-changing political situation and wars, trade steadily increased and grew in volume. Advances in shipbuilding technology meant an increasing amount and size of ships. With the 16th century new routes opened up to and from the Americas. Navigation and charts became steadily better in the period, as well as records of shipping and wrecking and the administrative and legal frameworks concerning these. This is the first period where, if a wreck were found, its identification would be possible.

19th century

At the opening of the 19th century, the North Sea was dominated by the British Royal Navy and politically by the Napoleonic Wars. Very detailed records on North Sea seafaring exist from this period onwards which can give us a good indication of the number of ships lost in the area, probably numbering in the low thousands. Among the most famous are the grounding of HMS St George and HMS Defence on the Danish west coast (Dalicsek 2016). Vessels from the 19th century, especially the larger ones, should be visible on the magnetometer survey and potentially on the SSS survey as well. From the wide scale introduction of the steam engine the boilers of these ships are usually detectable on bottom surveys.

Figure 4 Chart showing the strandings on the coasts of Denmark and on the Swedish coast between Marstrand and Carlskrona during the period from 1st January 1858 to 31st December 1885 (Hohlenberg 1885)

20th century

Although according to the Danish Museum Act, the cut-off date for a historical wrecking is 100 years prior to current date, this timeframe now encompasses WWI and, during the project scope of EI OWF, WWII as well. It is also without question that shipwrecks and wrecks of aircraft from WWII have an important role in international cultural heritage and their management shouldn´t be neglected. It is mostly these military vessels that are of archaeological concern, as well as they fall within the scope of the UXO survey. Their identification is almost entirely possible and as anomalies they should be visible both on SSS and magnetometer surveys. They pose a challenge in the management aspect as they can fall within special legal categories international, whereby disturbing or removing them should be closely monitored and cleared with relevant authorities at home and abroad. One of the most important naval battles of the 20th century took place in and around the EI area. The Battle of Jutland took place during the 31st of May to 1st of June 1916 and resulted in the loss of 25 warships, where the last wrecks were identified as late as 2016 (Jakobsen 2018).

The wrecks of the later 20th century probably make up more than any other category, as the increase in trade and deep-sea fishing resulted in increased traffic in the region. These wrecks in themselves are not protected by the Danish Museum Act, however their registration and inspection are important for maritime archaeology. They represent examples of decay processes and the natural site transforming effects can be recorded on them, thereby helping the protection, management and exploration of historical shipwrecks. Therefore, in the case of such wrecks an ROV dive survey would be utmost beneficial, both for the cultural heritage and the environmental impact assessments.

5. Overview of previous works in the area

There have been several large-scale offshore wind farm projects surrounding the area. Beside these, there are various underground cables crossing the planned construction zone. The area has been an important fishing ground and since the 20th century industrial scale trawling has had a major destructive impact on the seabed. The recent decades also saw dredging for raw material extraction offshore.

To the south of the proposed construction zone lie the offshore wind parks Horns Rev 1-3. There were no comments regarding underwater cultural heritage for the construction of Horns Rev 1. A desk-based phase I cultural heritage impact assessment was conducted for Horns Rev 2, but no findings were made. The construction was permitted under the condition, as specified in the Danish Museum Act, that in case of accidental finds during construction works the relevant museum and the Agency for Culture and Palaces (SLKS) will be informed, and the works stopped immediately (Tilladelse til etablering af elproduktionsanlæg samt internt ledningsnet ved Horns Rev 2 19. Marts 2007 J.nr. 022531/78033-0007). A similar process was followed for the construction process of Horns Rev 3, but here a phase II instrumental survey and a phase III preliminary search were made. This resulted in a single anomaly that was then protected by a 200m radius exclusion zone. (Tilladelse til etablering af elproduktionsanlægget Horns Rev 3 samt internt ledningsnet (etableringstilladelse) 21. maj 2015)

At the inshore minor wind park Rønland at Thyborøn the desk-based study did not show shipwreck finds, despite archival examples of loose finds in the area. (Godkendelse af 8 vindmøller på havet ved Rønland 19. juli 2002 J.nr. 5337-0022)

At the coastal wind park Vesterhav Nord, south of Thyborøn, the desk-based study showed possible wrecks and other anomalies in the area, where further inspection and/or exclusion zones were recommended. (Kulturhistorisk vurdering af geofysiske data vedr. Vesterhavet Nord Havvindmøllepark 2014 DKM 20.697, KUAS 2013-7.26.01-0009)

To the southeast of the proposed construction are lies the Thor offshore wind park, currently under construction. During the planning and permission process the archaeological analyses found 430 anomalies. The Agency for Culture and Palaces recommended further inspection and/or exclusion zones in the case of 292 of them. Areas of Stone Age potential were also identified and the relocation of individual windmills within the are avoided these sites (Thor offshore wind farm, North Sea, Archaeological analysis 30. august 2019 DKM 20.959 MAJ 2019-21 SLKS 19/04719).

Planned wind parks in the area include Odin, immediately to the north of the windmill area and Jyske Banke to the northeast. Both of which await a cultural heritage impact assessment.

The closest area for raw material extraction from the seabed is 562-LC Jyske Rev A, where no archaeological finds were made as of yet as a result of the works. (Primær tilladelse til indvinding af råstoffer i fællesområde 562-LC Jyske Rev A 1. december 2015 J.nr. NST-7322-01889)

In 2018 an archaeological screening of geophysical data was carried out prior to the laying of the transatlantic fibre cable Havfruen. MAJ identified two potential archaeological objects on the seabed and these were mitigated by the establishment of exclusion zones of 100m radius around the anomalies, in order to secure that no archaeological objects were damaged. (Havfruekabel, Nordsøen, Geoarkæologisk analyse af geofysiske data for transatlantisk fiberkabel: Rev 0 Marts 2019 DKM 20.942 MAJ 2018-69 SLKS 18/10175)

The Royal Danish Navy has following WWII demined the area, but there is still a high potential for UXO. In their process of disposing of underwater hazards, both the navy and the maritime authority have likely destroyed some historic wrecks, or wrecks that would today be considered of importance to cultural heritage studies.

Gert Norman Andersen and his commercial diving company JD-Contractor A/S have been an unalienable part of the development of Danish maritime archaeology. They have been active in exploring the seabed for historic shipwrecks, especially those of the two World Wars. In 2015, nautical archaeologist and historian Dr

Innes McCartney of Bournemouth University joined JD-Contractor A/S when they identified the last remaining wrecks from the Battle of Jutland as well as carrying out dives and high resolution multibeam imaging.

6. The Energy Island´s impact on potential underwater heritage

Artificial islands have a long history and are usually constructed by reclamation. This has been extensively employed in the southern part of the North Sea by the Netherlands since at least the 16th century. It involves building up the island by encircling the area and depositing soil, sand, or other construction materials until the water surface is penetrated and an island created. To protect such reclaimed artificial islands or peninsulas, protection of the sides with stone or concrete, containment of reclamation material within concrete walls is usually employed. Similarly, to improve the footing of the island, foundation improvements by cement hardening of bottom material, sand and structural piling, or sand and gravel foundation carpet placements are used. Such artificial islands have been used as storm barriers, offshore fishing bases, foundations for offshore gun placements for coastal protection, lighthouse foundations, and more. In more recent years, reclaimed artificial islands have been constructed to serve as solid waste depositories or fills, sites for toxic industrial activities, nuclear power plants, refineries, marinas, and airports. A large-scale land reclamation is currently underway outside of Copenhagen, Denmark. The Energy Island will be a ground-breaking project by constructing such a large-scale island so far offshore in such hostile conditions. This is a land reclamation project without comparison. To evaluate the projects impact on submerged cultural heritage in the form of wreckage the enormous mass of the deposited sediment and the impact of the construction machinery in the form of vessels and jack-up rigs must be considered. It is thus obvious, that any shipwreck, wreck of submarines or aircraft or parts of wreckage on the Energy Island location will be threatened with complete and irreversible destruction and the loss of archaeological information.

7. Submerged Stone Age potential (PMA)

7.1. Registered cultural heritage finds

“Doggerland” is the designation given to the now submerged landscape between England, Denmark, and the Netherlands. Some of the first evidence that sea levels in the North Sea were once lower came in the form of tree stumps and peat layers in the tidal zone along the English coasts (Reid 1913). Based on these observations, Reid produced some of the first maps of how the area might have appeared during the Stone Age. In 1931 a fisherman made one of the first archaeological finds that confirmed humans had once lived in the area that is now the North Sea when he recovered a 10,000-year-old, fine-toothed bone point in a clump of peat ca. 25 km from the English coast at Norfolk (Coles 1998). This type of evidence convinced archaeologists that the North Sea area was once occupied by people and since then investigation of these submerged landscapes has proceeded apace. Geophysical data and bore samples produced by the oil industry provided the basis for interdisciplinary projects/collaborations such as the Paleolandscapes Project (Gaffney, Thomson, and Fitch 2007) and Lost Frontiers (Gaffney et al. 2017), which aimed to reconstruct the submerged landscapes and clarify their archaeological potential.

In recent years multiple investigations have been conducted in Danish parts of the North Sea in conjunction with raw material extraction and the construction of offshore wind parks and gas pipelines. Our knowledge of the inundated Stone Age landscapes and contemporary coastlines has progressively increased as a result of these investigations (especially geoarchaeological studies). However, it is still unclear what the coasts were like during the Stone Age. Were there large, broad, exposed sandy beaches (like today), or were there more sheltered coasts resembling those of the inner Danish waters? Presumably, the area holds great archaeological potential, even though investigations are still in their early stages and have not yet produced in situ archaeological remains.

There are no prehistoric finds registered in the central register of culture-historical properties (Fund og Fortidsminder) in the area proposed for the island. However, a Danish fisher brought up a worked antler tool from a depth of 30-40m (Figure 5), dated to around 7040-6700 BCE. The precise findspot is unknown (Andersen 2005). A lightly water-rolled flint blade was also found during sand pumping near Horn’s Reef, though its precise find location is also unknown.

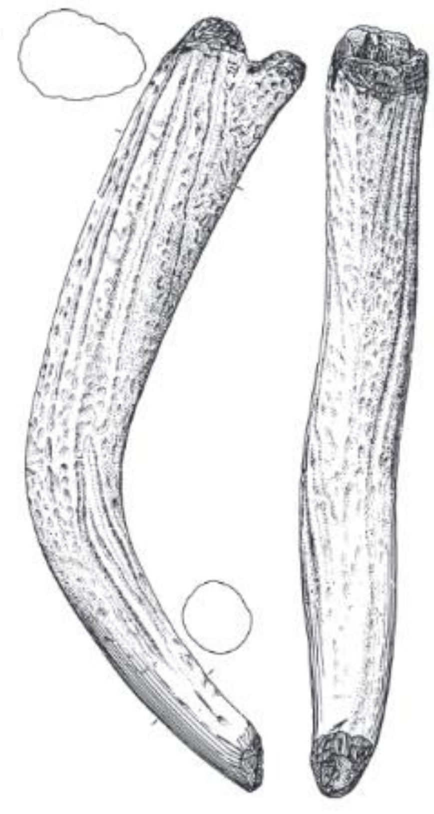


Figure 5 Antler tool from the North Sea (Andersen 2005)

7.2. Topographic potential for traces of early Stone Age activity

Large parts of Denmark were covered by a thick layer of ice during the Late Pleistocene. But ca. 20,000 years ago the ice began to retreat, partly because of melting due to increasing temperatures and partly because of glaciers calving icebergs into the sea. Enormous quantities of glacial meltwater were released into the world’s oceans throughout the Mesolithic period that ended about 6000 years ago. Studies have shown that global sea levels have risen 130m since the Late Glacial Maximum ca. 20,000 years ago (Fairbanks 1989; Lambeck et al. 2014). The Fugro boring program in the OWF area found peat layers that are evidence of sea levels previously being lower than today. However, sea level changes during the Stone Age are still not precisely described in the North Sea region. A central question for the geoarchaeological analysis of the Energy Island and windmill areas is therefore the archaeological potential of the deepest and least investigated areas of the project, which are furthest from the modern coast. Based on water depths at the proposed location of Energy Island (-27m or deeper), it is clear that any possible preserved Stone Age sites will date to the Late Palaeolithic or Early Mesolithic. The Late Palaeolithic dates to ca. 12800 – 9500 BCE, while the Mesolithic dates to ca. 9500-4000 BCE (see cultural developments in the Mesolithic, Fig. 6).

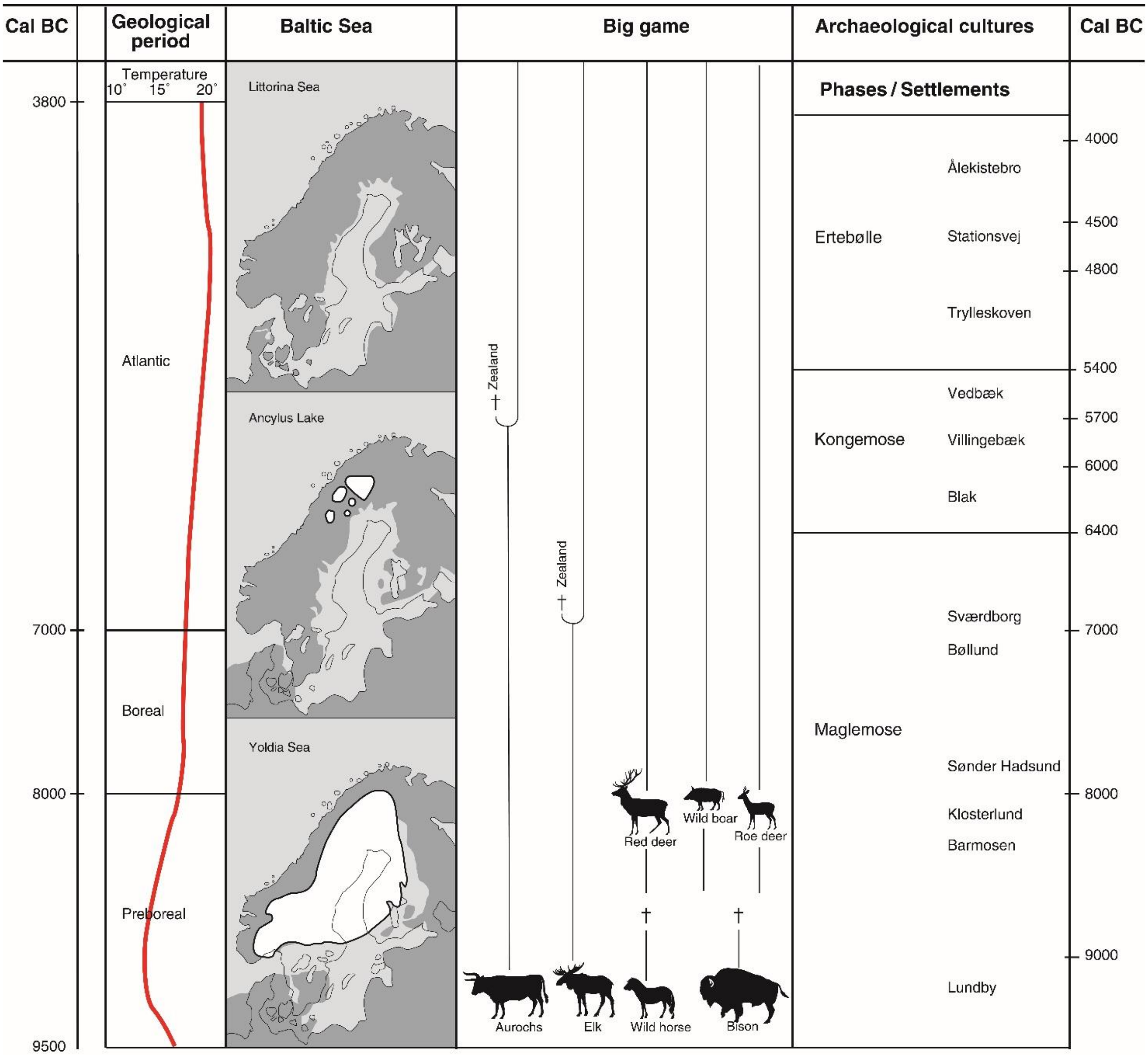


Figure 6 Schematic of cultural and natural developments in South Scandinavia in calibrated years BC. (Astrup 2018)

Many years of archaeological investigations have shown that Stone Age people did not randomly occupy landscapes. Rather, they chose their locations strategically based on a range of parameters in order to secure access to necessary resources, cultivate social networks, and maintain demographic viability. By reconstructing the now submerged landscapes as they appeared at various points in the past, it is possible to pinpoint areas that were better suited than others to obtain the necessary conditions for prehistoric lifestyles. Creating a detailed picture of the prehistoric landscape(s) is therefore vital to understanding where the upcoming construction work is at its highest risk of destroying potential archaeological localities. Evaluating an area's potential to have Stone Age settlements is typically based on topographic variables like the presence of lakes, streams, and coasts. However, in practice, different periods varied widely in their requirements for specific natural features and their accompanying resources. While the majority of the source material for our understanding of prehistoric hunter-gatherers in Denmark in the millennia prior to the Neolithic comes from coastal settlements, as of this writing it is unclear to what extent Late Palaeolithic and Early Mesolithic people also prioritized these areas.

In the area to be occupied by Energy Island, potential settlements (coastal as well as inland) are now on (or under) the sea floor – a location that is both difficult and expensive to survey. It is precisely here, however, that the last 30 years of underwater archaeology has shown the potential for making major scientific advances in the Danish inshore waterways. This is primarily due to two factors that can be characterized as "Preservation" and "Knowledge lacuna":

7.3. Preservation

Conditions of preservation on submerged settlements are renowned for being extremely good for organic materials such as wood and bones. This is the result of continuously rising sea levels that inundated coastal settlements. In the process, the archaeological layers and materials were enclosed in anoxic surroundings that have remained that way to the present day. Because of the special environment in these submerged cultural layers, oxygen was not present in sufficient amounts to allow the onset of decay, creating a sort of time capsule. Previous investigations of submerged settlements from the Kongemose and Ertebølle cultures have provided completely new insights into the types of wooden implements used in the Stone Age. This provides the example for the huge scientific potential that submerged and buried Stone Age sites in the North Sea could hold.

7.4. Knowledge lacunae

Submerged Stone Age landscapes on the sea floor represent one of the last uninvestigated areas in the Danish archaeological milieu. Because of this, they likely contain information that can fill some gaps in our knowledge that have remained unanswered by archaeological investigations since recognition of the various phases/periods of the Stone Age. It is still unknown, for example, the role of coasts in the Maglemose culture (9500-6400 BCE), as the subsistence economy of that period is almost exclusively known from archaeological remains found at inland sites far from them. To detect the earliest traces of coastal exploitation in Denmark, in recent years Moesgaard Museum has attempted to locate Maglemose culture sites near or at the archaic coastline that are now submerged in Aarhus Bay. Aarhus Bay is of special interest because it consists of sheltered waters where potential Maglemose culture settlements occur in water depths that are shallower than in more southern areas of Denmark. In 2017, 23 locations in the bay were tested and one produced dispersed flint flakes and blades at a depth of 6m. Based on this a small excavation was conducted two months later to determine if there could be the remains of a coastal settlement. This investigation showed that immediately below the seabed there was an in-situ deposit with worked flint (including diagnostic microliths) and organic materials that have been C14 dated to the latest part of the Maglemose culture (Astrup 2018). The find layer represents a coastal settlement and later investigations have recovered fish bones from the site that show the exploitation of marine species, demonstrating a coastal fishery already during the Maglemose period. Targeted diving investigations in archaic coastal areas are therefore a prerequisite for resolving important research questions such as:

- How widespread was coastal settlement in Late Palaeolithic and Maglemose cultures?
- How large a role did marine resources play in subsistence and what methods were used to collect them?
- Were coastal settlements occupied longer than those inland? Did the same people use both types of sites or were there some groups who occupied the coast while others remained inland?

The above points serve to illustrate that there is much we still do not know about life along the coasts in the Maglemose culture. Thus, it is a difficult task to decide where in the landscape people settled. However, this does not change the fact that it is absolutely crucial to have as detailed an understanding of the landscape as possible, since it formed the basis of life for the people who lived in the construction area. In light of this, the next section of the report aims to step-by-step recreate a detailed picture of the now submerged cultural landscape. The goal is to be able to evaluate which areas have the greatest potential for prehistoric settlements and whether they will today still contain preserved remains. In concrete terms this means constructing a model of past sea levels and using the geophysical data to identify relevant archaic terrain.

8. Modelling sea levels

1.1. Collection of data

It is vital to understand the development of the landscape in a given region to be able to identify the parts of a project area that have the greatest archaeological potential. One might be tempted to think that it is a simple task to reconstruct archaic coastlines in the North Sea region. However, this is not the case, and the most important reason is that the extent of glacial isostatic rebound throughout the area is not yet clear. Because of differences in the rate at which land has rebounded in the North Sea basin from when it was pressed down by the weight of glaciers, it is simply impossible to reconstruct archaic coastlines within a larger area based solely on isometric depth curves.

Additionally, from the area where construction work will occur there are so few dated samples that the relative sea level rise cannot be determined. It will therefore be vital to develop a shoreline displacement curve based on local data from the Energy Island area. In order to determine relative prehistoric sea levels, it is crucial to have access to well-dated material. We have compiled an overview of dated samples from the North Sea judged to be representative of the project area (Appendix 1). This involves samples that were either directly above or below the sea surface during the Late Palaeolithic and Mesolithic periods and can thus be used to bracket sea levels and coastlines at various points in the past. At some depth intervals there are few points that can be used to determine sea levels. To rectify this, an agreement was reached between Energinet and MAJ to date about 25 new samples to enable poorly covered intervals to be addressed with much greater precision going forward.

Boring samples

In the area where Energy Island will be, 105 CPTs were made, while an additional 171 were made in the surrounding OWF area (Figure 7, Figure 8). All Fugro's core logs were reviewed to identify samples from various depths for dating that are needed to produce a new shoreline displacement curve.

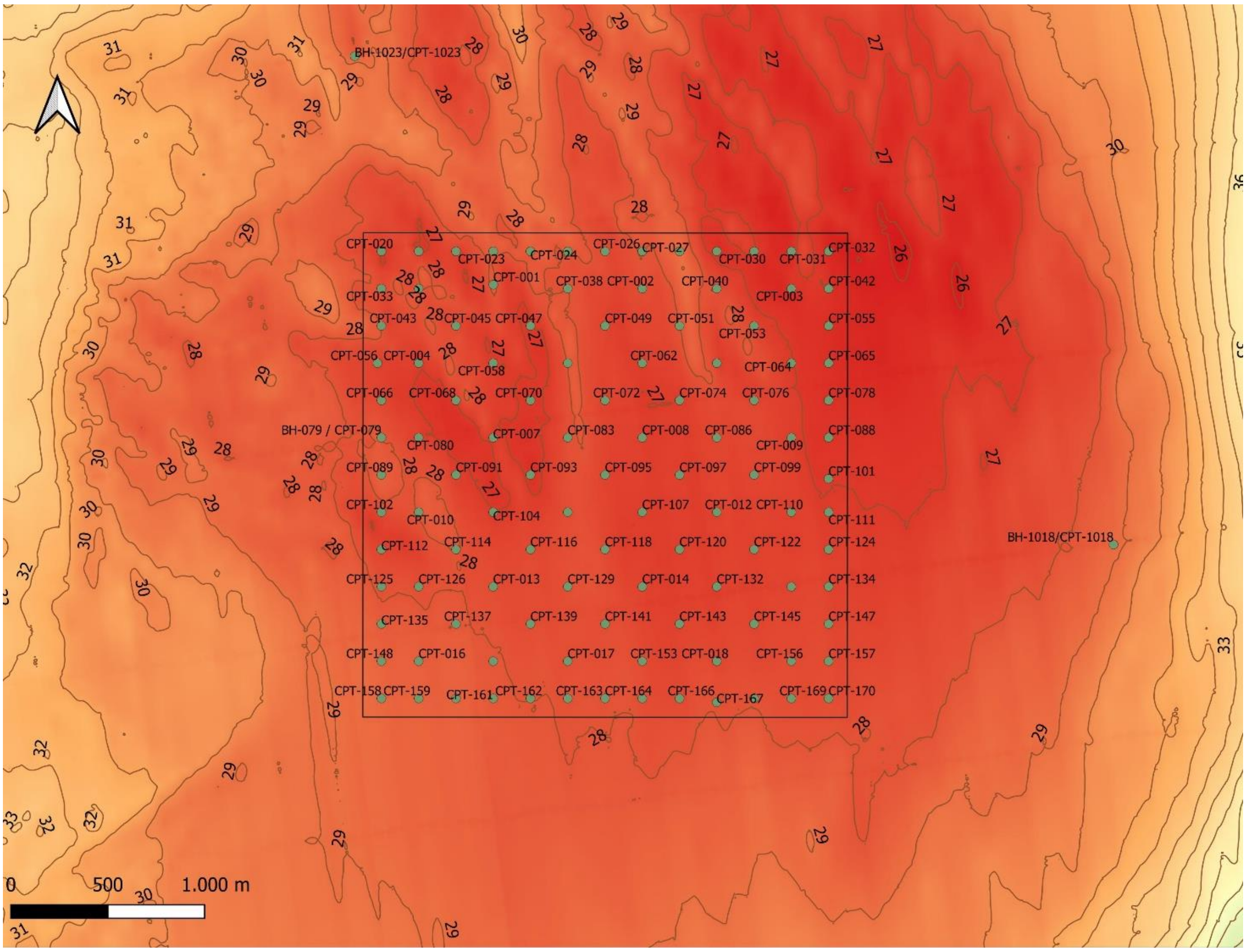


Figure 7 Map showing CPT locations in the Energy Island area in relation to current bathymetric conditions.

There are 7 borings (BH) from the island-area with detailed core logs. An additional 105 CPT-borings have simpler layer descriptions. In the descriptions of borings from the EI area there are no cores that have the remains of peat layers. It is therefore difficult to evaluate whether the layers recognized in the seismic profiles represent old land surfaces and lake basins. For most of the borings in this area, the upper 10-15m are sand and under this there are alternating bands of sand and clay.

Lacking peat from the island-area, three samples of marine shell from BH-079 were sent for dating. The shell samples were taken from -30.15, -30.65, and -33.10m masl and are overlain by 2.25, 2.75, and 5.2m of sand respectively. The remaining 22 dated samples come from cores that were taken in the surrounding windmill area (Figure 8, Table 2 and Appendix 1).

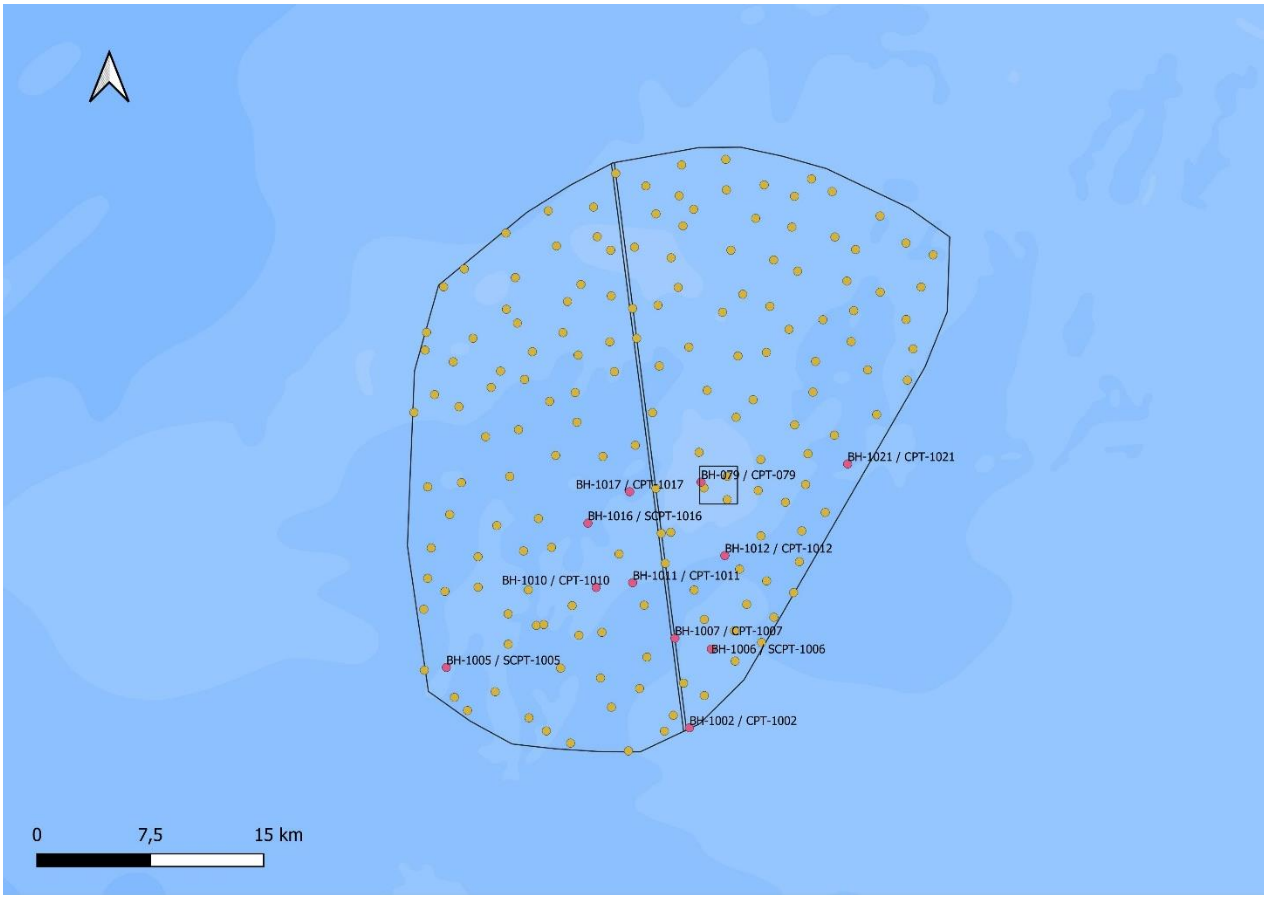


Figure 8 Cores (shown in pink) from which material was sent for C14 dating.

Selecting material for dating

MAJ requested 25 sediment samples from either marine or terrestrial layers based on Fugro's core logs. The samples were sieved at Moesgaard Museum with the goal of recovering material best suited for dating. From the marine samples, primarily marine molluscs were chosen for dating, while from the peat layers it was either peat or wood. All the shells were photographed before they were sent for rapid dating (Table 3). Marine geologist Ole Bennike from GEUS performed species identifications based on the photographs to determine whether the shells come from marine, brackish, or freshwater environments. Ole ascertained that there were exclusively marine molluscs, which suggests their findspot was below sea level at the time of deposition. It is often difficult to exclude if shells have been redeposited from where the animals originally lived/died and that pertains to the shells used in this study. Fragmented shells can indicate that layers are reworked/redeposited. On 2 September 2022, MAJ delivered 25 samples to the Aarhus AMS centre and the Museum received the results of these on October 7th.

1.2. Modelling sea levels – creating a shoreline displacement curve

A shoreline displacement curve shows relative sea levels at various points in time in relation to the current level. The curve that was made for this project is based on both existing dated samples (for example, those produced in connection with the Thor offshore windmill project) and others collected specifically for the Energy Island project and the surrounding OWF area. In order for samples to be included in the analysis they must meet the following criteria: 1) provide information about prehistoric sea levels, 2) were recovered in a secure context, (in situ), 3) vertical placement information is available, and 4) the sample is absolutely dated (e.g. with radiocarbon dating).

Table 2 shows samples from the Energy Island and OWF areas sent for dating in connection with the geoarchaeological analysis. Terrestrial/lacustrine samples are green and marine samples are blue. Grey samples are believed to come either from water-deposited layers along the contemporary coast or near a lakeshore. The table also shows what material was dated and its vertical location (masl). The last column indicates how much sediment overlays the dated sample.

Sample information	Layer	Dated material	ETRS 89 zone 32 N	ETRS 89 zone 32 E	Sample elevation (m)	Sediment cover (m)
P1 : BH-1012 : sample 04BagA	Sand	Shell	6258709	349662	-39.6	3
P2 : BH-1012 : sample 05BagB	Sand	Shell	6258709	349662	-40.9	4.3
P3 : BH-079 : sample 04BagB	Sand	Shell	6263564	348090	-30.15	2.25
P4 : BH-079 : sample 05BagB	Sand	Shell	6263564	348090	-30.65	2.75
P5 : BH-079 : sample 10BagB	Sand	Shell	6263564	348090	-33.1	5.2
P6 : BH-1002 : sample 53BagA	Peat	Peat	6247314	347315	-89.2	50.5
P7 : BH-1002 : sample 53BagA	Peat	Wood	6247314	347315	-89.2	50.5
P8 : BH-1005 : sample 07BagA	Peat	Wood	6251314	331240	-47.4	5.5
P9 : BH-1005 : sample 07BagA	Peat	Wood	6251314	331240	-47.4	5.5
P10 : BH-1005 : sample 54BagB	Peat	Wood	6251314	331240	-93.95	52.05
P11 : BH-1005 : sample 54BagB	Peat	Wood	6251314	331240	-93.95	52.05
P12 : BH-1005 : sample 55BagA	Peat	Wood	6251314	331240	-94.9	53
P13 : BH-1006 : sample 09BagA	Sand or peat	Organic mat.	6252531	348762	-49.6	8
P14 : BH-1007 : sample 30BagB	Peat	Wood	6253246	346355	-64.3	23.7
P15 : BH-1007 : sample 31BagA	Peat	Wood	6253246	346355	-65.1	24.5
P16 : BH-1010 : sample 08BagC	Peat	Peat	6256600	341141	-41.9	6.9
P17 : BH-1010 : sample 08BagC	Peat	Peat	6256600	341141	-41.9	6.9
P18 : BH-1011 : sample 03BagA	Sand	Wood	6256918	343560	-38.2	2
P19 : BH-1011 : sample 03BagA	Sand	Shell	6256918	343560	-38.2	2
P20 : BH-1016 : sample 69BagA	Peat	Wood	6260855	340604	-109.8	67.21
P21 : BH-1016 : sample 69BagA	Peat	Wood	6260855	340604	-109.8	67.21
P22 : BH-1017 : sample 17BagA	Sand	Shell	6262939	343364	-54.4	11
P23 : BH-1017 : sample 18BagA	Sand	Wood	6262939	343364	-54.9	11.5
P24 : BH-1017 : sample 18BagB	Sand	Wood	6262939	343364	-55.1	11.7
P25 : BH-1021 : sample 45BagC	Sand	Shell	6264770	357783	-85.8	44.3

Table 2 Samples sent for dating. Terrestrial samples: green, Marine samples: blue, Water-deposited shoreline/coastal samples: grey

 P1	 P2
 P3	 P4
 P5	 P19
 P22	 P25

Table 3 Shells that were sent for dating. All the shells were determined to come from animals that lived in marine surroundings by marine geologist Ole Bennike.

The shoreline displacement curve was created by entering the uncalibrated C14 dates and vertical placement information (masl) into an Excel spreadsheet, after which it was imported into the computer program OxCal V.4.4 and calibrated. The dates were modelled in OxCal after age and vertical location using the depth model function. Samples are calibrated and shown in the shoreline displacement curve with a 95.4% confidence interval. Previous dates that were done in Copenhagen on marine samples have a built-in correction for the marine reservoir effect so no additional correction was done for this study. The marine samples that were dated at the AMS laboratory in Aarhus and other laboratories are corrected with a reservoir effect of 400 years. All the dates are calibrated after the new IntCal 20 curve (Reimer et al. 2020) and plotted in the curve by comparing the vertical location versus age.

The shoreline displacement curve shows marine samples in blue (for example, marine shells), terrestrial samples in green, and grey is used for samples that come from sand layers that could come from the coast or a lakeshore. All the fixed points on the curve were assigned a number (R_Data) that can be referenced in Appendix 1 (column “id”) and Figure 9 so it is possible to see additional information about the individual samples that are dated.

The curve clearly shows that sea levels rose dramatically during the Holocene period. This indicates that the horizon and possible land surface found at around -40m masl (H10) can only have been dry land in the period from the last glaciation up until ca. 8500 BC. After this it was transgressed by rising sea levels and the presence of potential archaeological settlements from both the Kongemose (6400-5400 BC) and Ertebølle (5400-4000 BC) cultures can therefore be excluded.

It is not possible to determine sea levels more precisely than ± 2-3m because the samples’ vertical reference does not typically correlate precisely with that in the past. On top of that is the uncertainty associated with dating shells and peat, combined with the still long intervals where there are few dates to use for determining sea levels. Another issue that affects placement of the curve is the isostatic rebound that has changed the vertical position of the samples used in the shoreline displacement reconstructions. In general, lands to the NE of the island location have been lifted more than those to the SW. Thus it is problematic to include points from a wide geographic area. Because the degree of difference in rebound within the area is not known precisely, it is not corrected for in this curve.

Figure 9 shows the shoreline displacement curve where the dashed line gives the hypothesized sea level in the island area during the Holocene. The numbers refer to Appendix 1, where additional information is provided about the individual SLIPs.

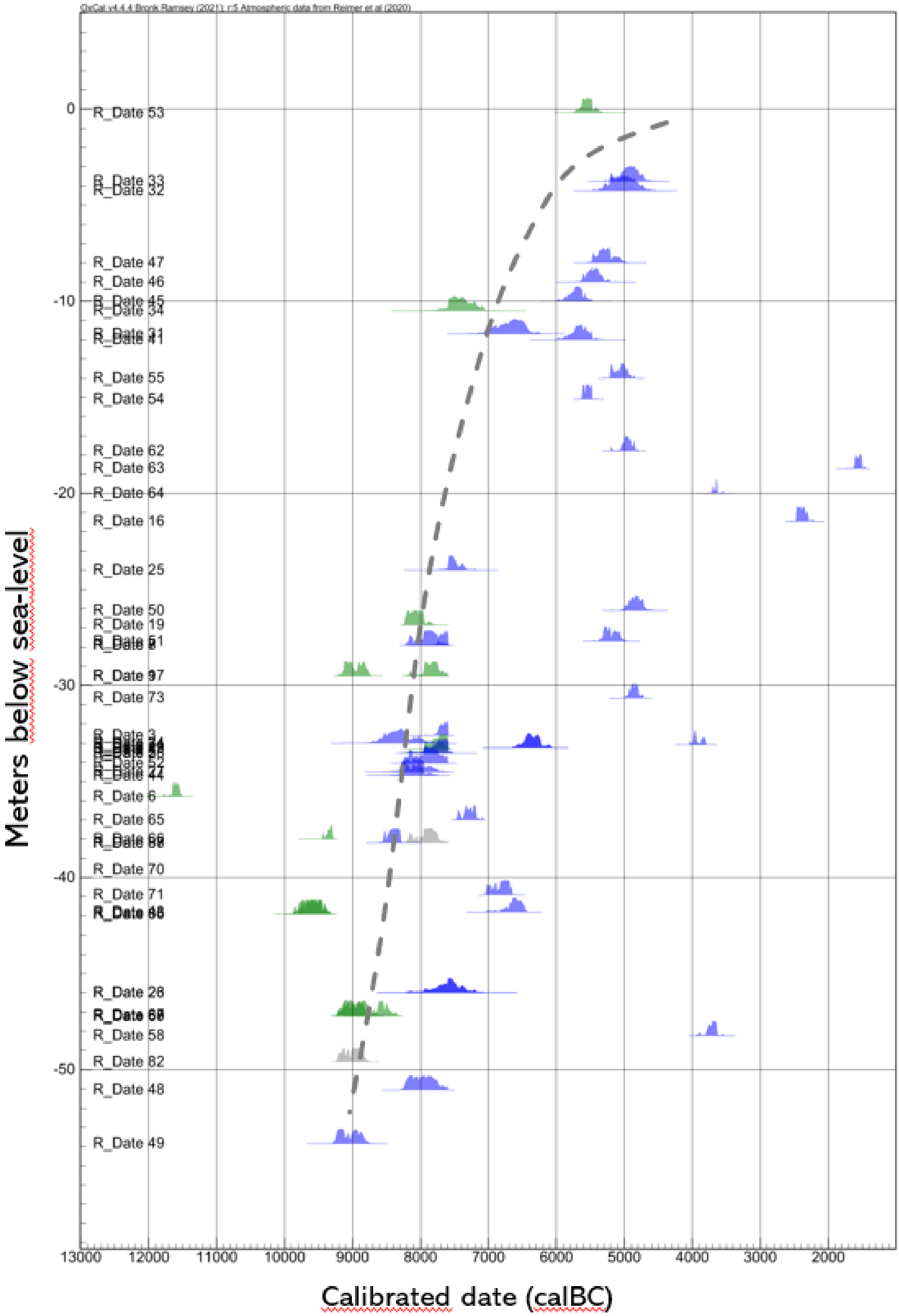


Figure 9 Shoreline displacement curve where the dashed line gives the hypothesized sea level in the island area during the Holocene. Peter Moe Astrup.

9. Sub-bottom seismic data and landscape correction

MAJ received a large dataset with seismic data and interpreted surfaces/horizons from Energinet. The museum applied the interpreted horizons (H10 and H20) that were provided in geotiff format to the geoarchaeological analysis. MMT identified a total of 13 seismic units that constitute the geologic model of the area. Figure 10 below shows the seismostratigraphic interpretation, displaying the mapped horizons and the interpreted seismic units. The horizons that bound the seismic units represent seismostratigraphic boundaries and mark the base of the deposits they define. As such, these boundaries have chronostratigraphic and kinetostratigraphic meaning, and should not be interpreted in lithostratigraphic terms. The bases and units are numbered sequentially based on their stratigraphic position, and have an alphanumeric naming convention (e.g., H10 corresponds to the base of seismic unit U10). The deepest and oldest seismic unit is referred to Base Seismic Unit (BSU). The top of the Base Seismic Unit is defined by a composite surface produced from the amalgamation of the deepest mapped horizons. The bottom of the Base Seismic Unit corresponds to the processing "last knee" that is an artificial, linear boundary near the terminus of the seismic record. The labelling scheme in Figure 10 was applied to all seismic examples in this report. The horizons generally mark the bottom of the unit they are named after.

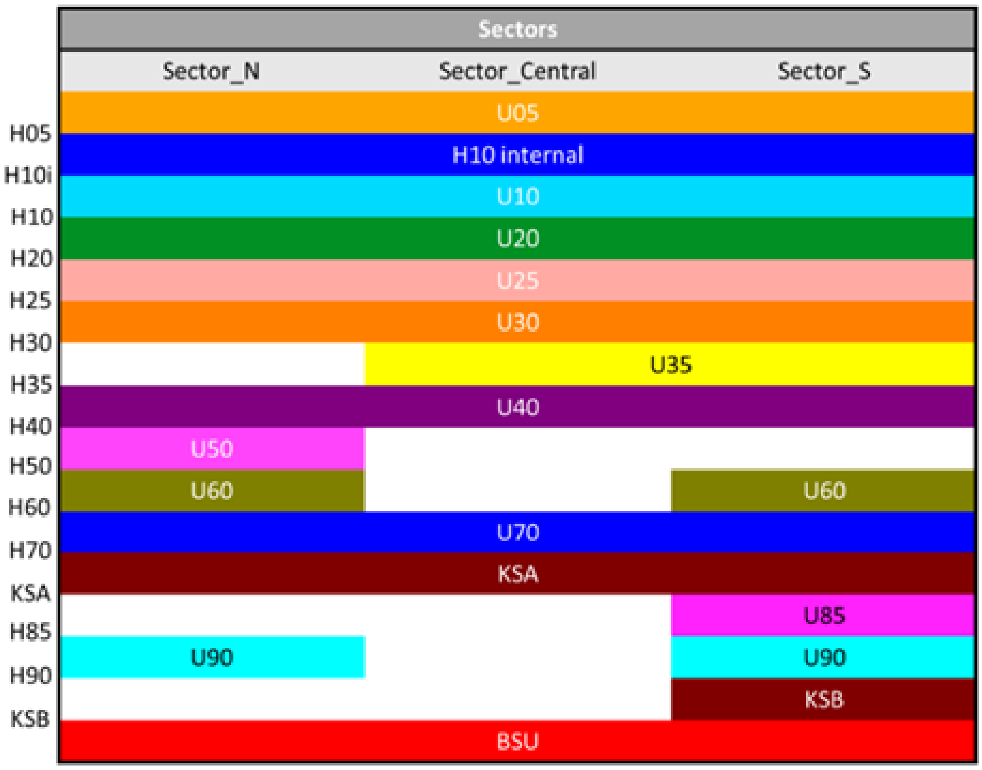


Figure 10 North-south profile with seismostratigraphic interpretation, displaying the mapped horizons and the interpreted seismic units. (MMT 2022 GEOPHYSICAL SURVEY REPORT – ENERGY ISLAND)

As highlighted by MMT (GEOPHYSICAL SURVEY REPORT – ENERGY ISLAND), it is not possible to arrive at precise dates for units/horizons. It can be said that H05 and H10 are assumed to date to the Holocene. Overall, MMT is of the opinion that units/horizons are either linked to glacial processes or those connected to changes in sea levels and shoreline displacement. Their report (p. 255) states, "Sediment deposition above H35 appears to be dominated by high frequency sea-level fluctuations, related to eustatic-isostatic and autogenic processes, away from any glacial influence. An overall transgressive sequence infilled the basins, starting with the deposition of U35 fluvial bedforms at the base, followed by the finer deposits of U30. As the sea level rose, flooding of the basins led to the deposition of the lower section of unit U25, likely within a transgressive estuary setting, no longer constrained by the basins' margins. The increase of small channel-incisions within the upper deposits of U25 suggests the occurrence of a regressive event/fluctuation (at least in relative terms). The deposits of U20 consist of infills of small basins and/or channels, which could be related to a restricted marine tidal deposition and partially to a subaerial fluvial infill. Above the ravinement surface of H10 (likely a wave cut) rests the last and most recent U10 deposits. This unit is made up of the recent transgressive deposits (possibly some high-stand) and includes the modern seabed marine sandy deposits"

U05 represents a Holocene sand layer at a water depth between -26.4 and -43.7 masl. It has a thickness of up to 3.9m and is only found on top of U10. U10 is slightly deeper, between -31.7 and -51.8 masl, with a thickness of up to 18.1m. H10 is interpreted as a transgression ravinement deposition that apparently consists mostly of sand with an admixture of silt and gravel. U10 has the appearance of a marine deposition created during the Holocene. U20 represents fill of old crevices and basins, found at depths of 32.6 – 92.5m under masl and with a thickness of up to 48.9m (Figure 11). It is assumed that U20 formed in marine conditions, but it is not stated in the geophysical report (GEOPHYSICAL SURVEY REPORT – ENERGY ISLAND) when it was formed.

When correcting for the changes (sediment transport, erosion/accumulation) that have occurred in the island area since the Stone Age it is vital to use the most suitable horizon. If there are, for example, traces of buried valleys/lakes/depressions in a horizon it is crucial to correct for them or else there is a risk of giving these areas a misleading influence on the results (and lead possible marine archaeological investigations to the wrong places). MMT considers U05 and U10 (horizons H05 and H10) to have been formed during the Holocene after the area was transgressed. Therefore, the surface of H10 seems to be a better reflection of the prehistoric landscape than the modern seabed. In the island area it was not possible to register any terrestrial land surfaces/horizons under H10, which means that it does not necessarily represent an inhabitable landscape if there are also marine deposits below that level.

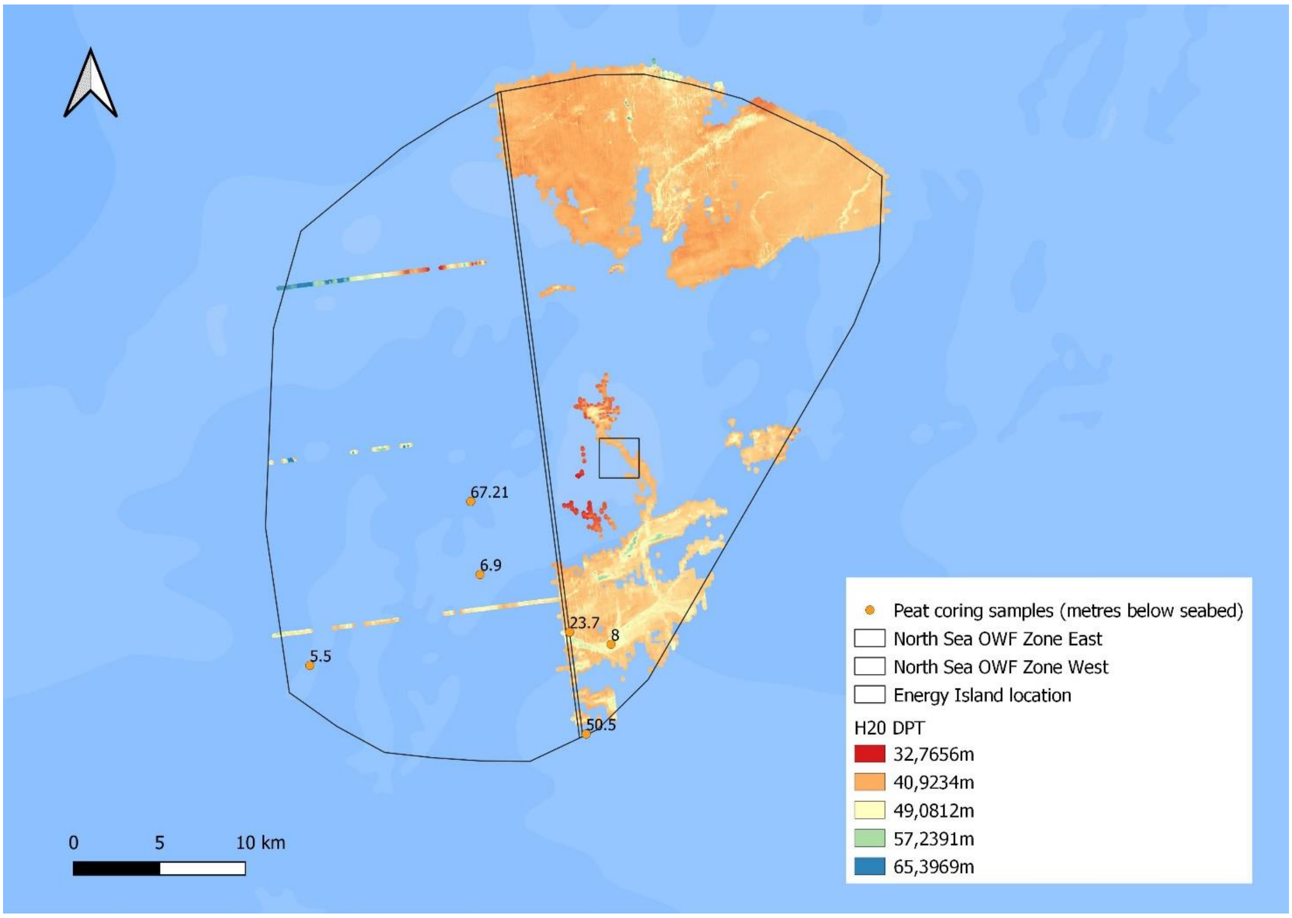


Figure 11 H20 along with documented peat layers. H20 shows buried valleys and other features in parts of the OWF area.

In this analysis we chose to use H10 to correct the current depth information. The reason for this is that MMT dates the horizon to the Holocene period.

There are clear differences between modern depths and H10 (Figure 12). The fact is that the shallowest depths are found today in the proposed island location while H10 shows that to the west a large area was originally 5-6m higher. This indicates that after H10 was formed a great quantity of sediment (min. 10-15m) was added to the island area. H10 in Figure 12 suggests that more material was accumulated in the highest surfaces west of the planned island location during the Holocene. However, the model does not show how much was possibly eroded away. The upper boundary of the material accumulated in the EI area (that is to say, the modern seabed) is higher than the upper boundary of the old H10 surface in the area (west of the island location) that was the highest during the Stone Age.

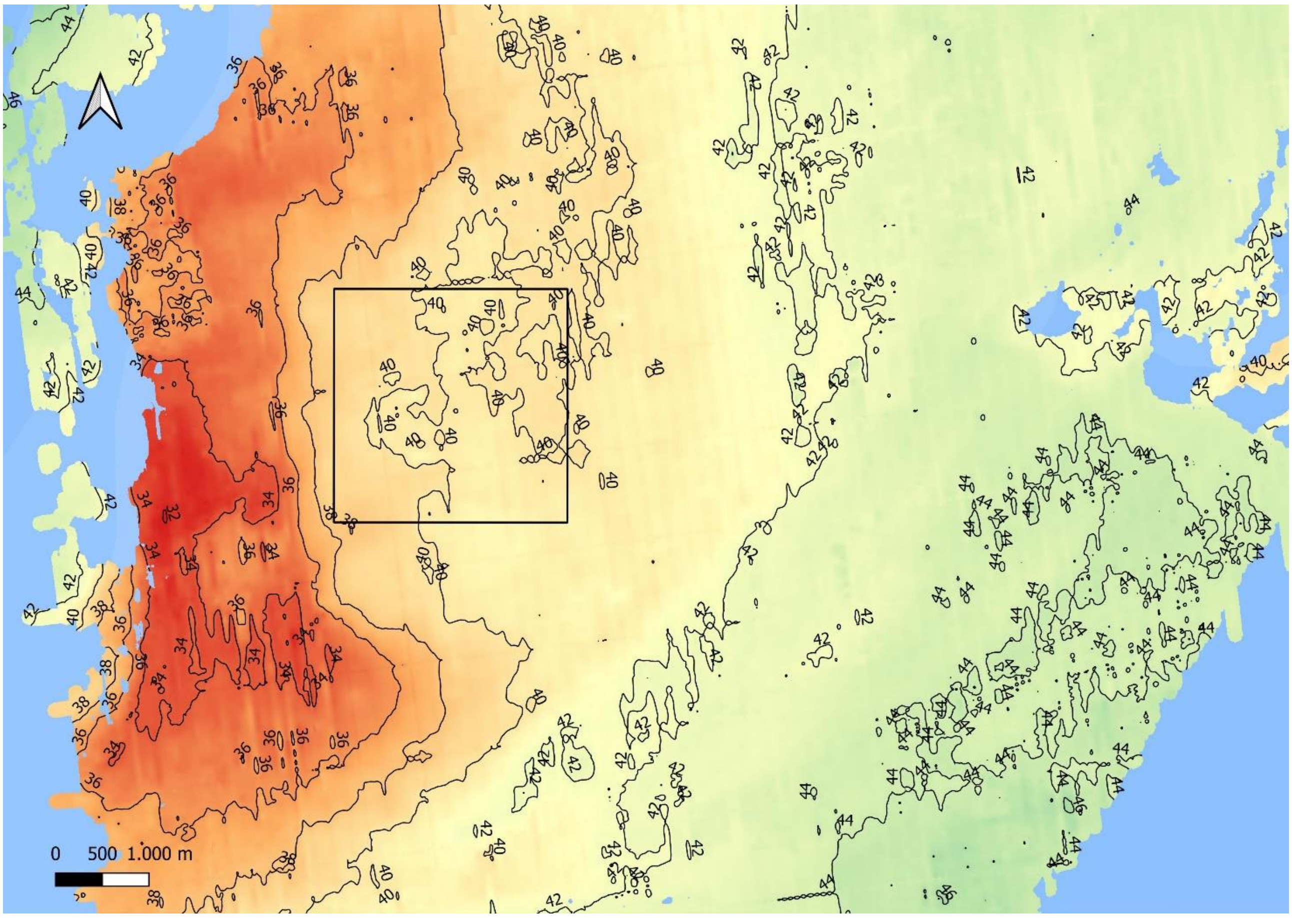


Figure 12 The location of the Energy Island area in relation to H10.

It can be assumed that the differences in levels were higher in the Stone Age than now because over time material from the highest levels would be deposited in the lower ones. The lowest/deepest areas recognized on the bathymetric chart (along with horizons) are especially interesting because they can be thought to represent lake basins that are filled with sediment. The material that is deposited over the archaic lake basins, peat layers, etc. both preserves them and makes them difficult to research. Higher areas on slopes are more exposed and subject to erosion but are also better suited to diver reconnaissance precisely because settlement traces are not buried under a thick layer of sediment.

Identification of the areas with the greatest Holocene layer formation shows both 1) where archaeological materials can have avoided erosion, 2) where it would be difficult to access layers with dives, and 3) where layers are too deep to be affected by construction work. Therefore, planning will often seek to target archaeological surveys in the areas best suited for settlement where past sedimentation allows such investigations without extreme difficulty in accessing the layers. The artificial island is proposed to be constructed in an area where between 10 to 15m of sediment accumulated during the Holocene (Figure 13). Figure 13 can therefore also be used to where archaeological materials can be expected to have been eroded away and/or buried under younger sediments.

The critical period experienced by a settlement/deposit regarding its future preservation is the time when the waves first begin to wash over it and the following centuries when they break over the area. Factors that can have a positive effect on the preservation of a site include: 1) a gentle slope on the seabed and coastline so wave action is minimized in the surf, 2) sheltered waters where waves cannot build over long distances,

3) deposition in peat or compact sediments that protect the material during transgressions. These considerations show that preservation or destruction of a given archaeological locality (whether inland or at the coast) depends on the local topography and environment at that location. Bore samples provide the opportunity to deduce where possible settlements will today be protected under later sediments or else eroded away.

Figure 13 shows the location of the EI area in relation to the thickness of U10. Based on the interpretation of the data, between 10 and 13m of sediment was deposited over most of the area since H10 was formed. This occurred as the marine transgression removed material from other areas.

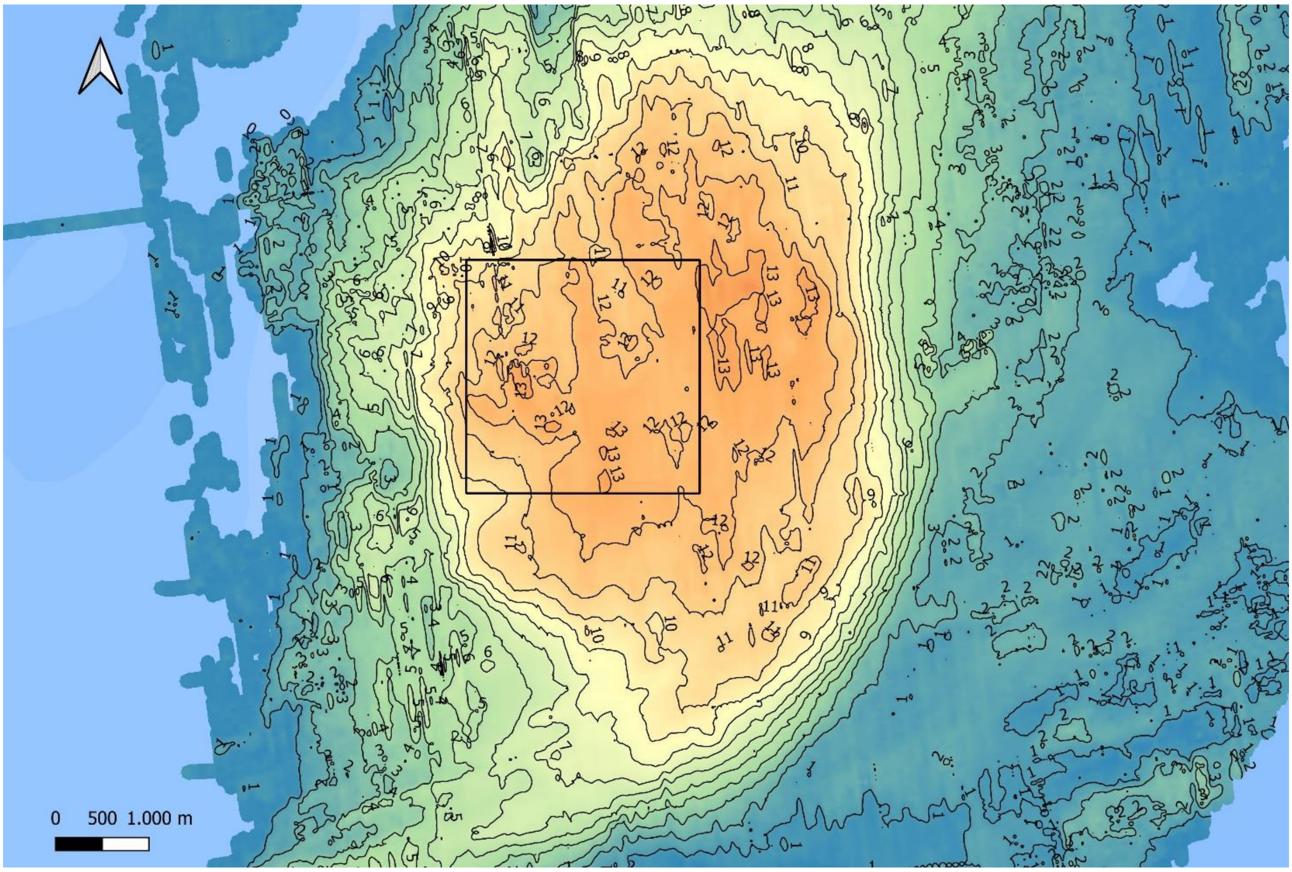


Figure 13 Location of the EI area in relation to the thickness of U10.

10. Conclusions and recommendations regarding the Stone Age potential in the project area

The geoarchaeological analyses show that there is little likelihood that possible survey efforts will lead to the discovery of archaeological material. We do not believe that there is sufficient evidence to suggest there are Stone Age settlements in the island area. We cannot exclude the possibility of very old settlements here but do not believe there is justification for attempting to detect them. This is primarily because:

In the 105 CPTs that were made in the island area, there are no sure indications of archaic land surfaces (for example, peat, lakes, bogs, etc.) Similarly, there is no guarantee that H10 represents a surface that was inhabitable when sea levels were lower than the present. Moreover, it is unclear to what extent the archaic landscapes are preserved or eroded away.

The sub-bottom seismology and borings show that in much of the area a 10-15m thick layer of marine sediments were deposited on top of H10. The layers over H10 are assumed to have been formed after the sea transgressed the area and are not believed to have significant archaeological potential. Moreover, in practice it would be very difficult to conduct marine archaeological investigations at a water depth of 40m and under 10-15m of sediment. The methods available for such an investigation would result in the removal of so much context information that any possible finds would lose so much of their scientific value that they could not justify the costs.

Normally in a geoarchaeological analysis the reconstructed landscape would be used with topographic models (e.g., the fishing site model) to designate areas where it is believed there is an especially high likelihood of human activities. However, we believe that the available geological data from the area cannot be used to find the most favourable topographical locations on the basis of model predictions. The reason being that potential settlements lie at water depths of 40m, which means that they would have occurred so far back in time (min 10.000 years) that it is not clear this model would apply. It is simply uncertain whether settlement occurred at the coasts in this timeframe. Another reason that the topographic model is judged to be an unsuitable tool to find settlements at Energy Island is that we still know too little about the area's original topography and environment. It is unknown whether the coastal zone resembled that of today with large, exposed beaches subjected to powerful surf and significant tidal effects (and with long stretches uninterrupted by bays or lagoons), or if it to a greater extent resembled the landscapes and environments found today in the inner Danish waters such as the Belts. A third possibility is that part of the region consisted of tidal mudflats like those now found in southwestern Denmark. Clearly, it is necessary to increase our knowledge of past landscapes and environments before it will be possible to use topographic models to suggest locations with the greatest archaeological potential.

The moraine plateau and outwash plains of southwestern Jutland contain (compared with the rest of Denmark) relatively sparse amounts of archaeological material that can be dated to the early Mesolithic period (9500-6400 BC). It is still unknown whether to expect the same distribution pattern (and density) of settlement in the North Sea area as in western Jutland or if there were more sites in proximity to the coasts. Possible Stone Age sites in the area would date to the Late Palaeolithic or Early Mesolithic, as it was inundated by rising sea levels ca. 9000-8500 BC. There are few sites known from these periods in the rest of Denmark to date and it therefore seems unlikely that a small sampling program will succeed in finding significant additional archaeological material (not least considering the methods that would have to be employed to recover such material). We determine therefore that, even in the most potentially interesting areas, there is very little reason to expect that a possible archaeological investigation will uncover settlement traces. Based on this we do not recommend Energinet or SLKS that any field investigations be conducted in order to locate Stone Age sites in the Energy Island area.

11. Submerged historical archaeological potential

11.1. SSS anomalies

SSS data was analysed by the MAJ maritime archaeologists Anders Jensen, Jan Hammer Larsen and Daniel Peter Dalicsek. The high and low frequency side scan sonar data as XTF-files with corrected navigation were reviewed in the software SonarWiz 7.

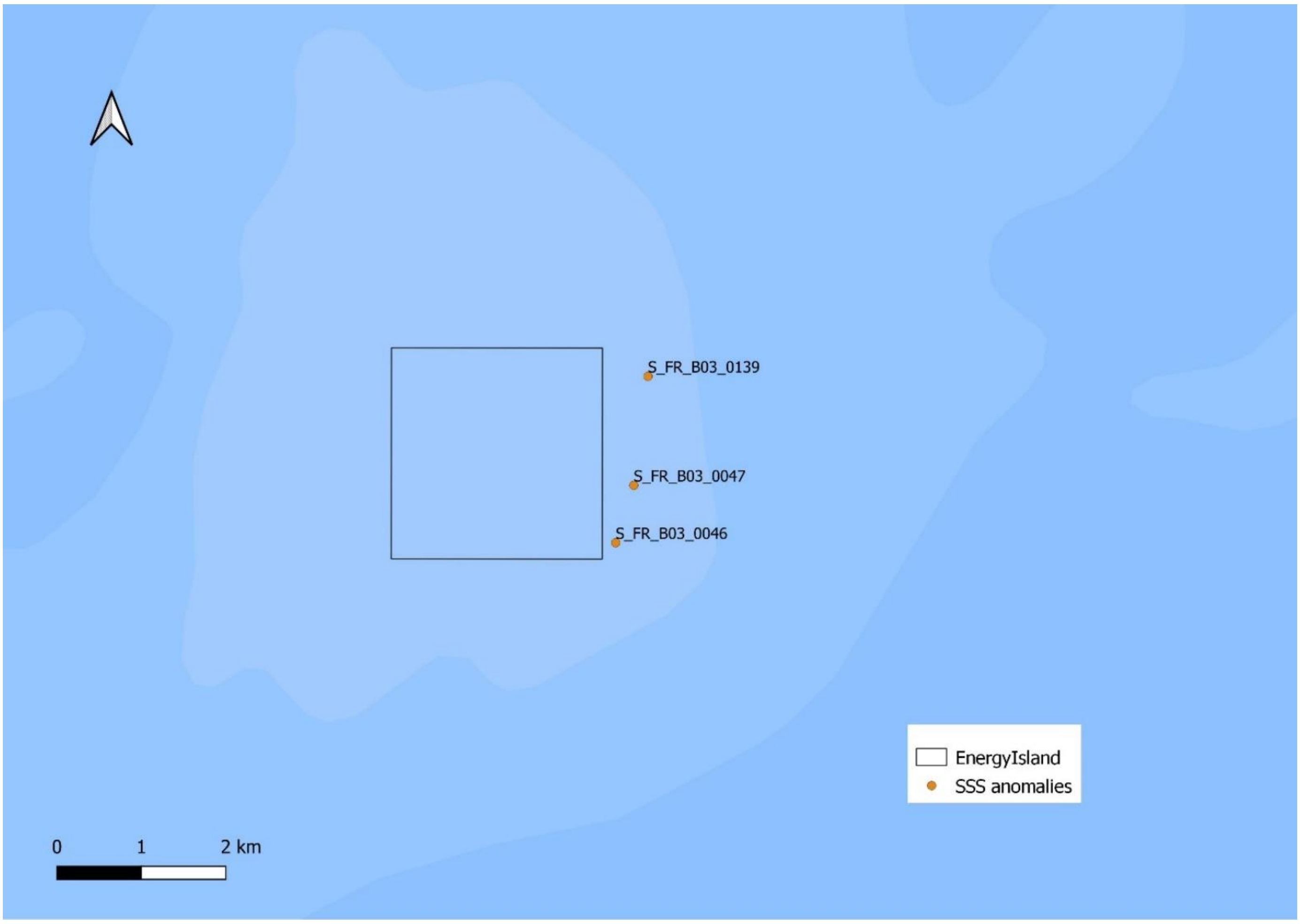


Figure 14 SSS anomalies

The dataset was reviewed and then compared to the anomaly list generated by MMT (103783-ENN-MMT-WPA-EI-MBES-SSS-Contact-List_Images). One anomaly (S_FR_WPA_BM03_0139) was identified that MMT did not identify. However, this anomaly lies outside of the EI site and in the OWF East area. This was an important part of the EI project as a sub-project of the whole Energy Island OWF project. It was indicative for the future works at OWF Zone East and West whether a review of the anomalies identified by Fugro and MMT is sufficient, and their analysis is reliable for the identification of maritime archaeology.

Focus for target identification was on:

• Anomalies with the character of boulders/stones

• Linear objects without a shadow

An assessment has also been made of the objects outside the above categories. We have identified three targets, which may contain objects of a potential anthropogenic nature. None of the three SSS anomalies had a MAG anomaly correlation. All three targets lie outside of the EI site, but could be impacted by the construction. The museum recommends that the following three SSS targets be inspected:

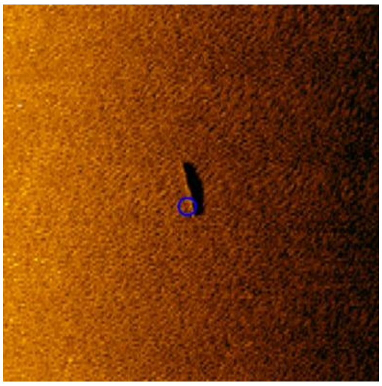
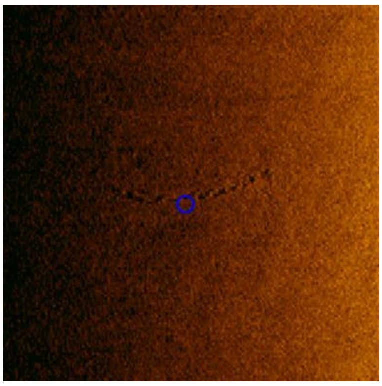
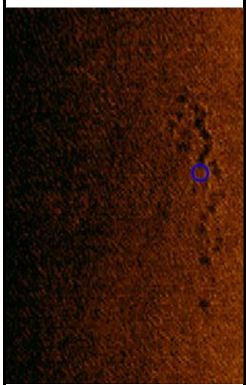
Target Image	Target Info	User Entered Info
	**S_FR_WPA_BM03_0046** • Sonar Time at Target: 01-07-2021 10:11:08 • Click Position 56.4815860925 6.5748290186 (WGS84) 0.0000000000 0.0000000000 (NAD27LL) 56.4815808411 6.5748208031 (LocalLL) (X) 350650.47 (Y) 6262316.14 (Projected Coordinates) • Map Projection: :ETRS89_UTM32N_20215 • Acoustic Source File: V:\2021\103783-Energinet_OWF_EI\2-Raw_Data\FR\SSS\BM3\MMT_783_ENN_FR_ROTV_SSS_WPA_BM3_OWF_E_ML_05600_0.646.jsf • Ping Number: 198109 • Range to target: 31.95 Meters • Fish Height: 7.48 Meters • Heading: 355.350 Degrees • Event Number: (-1) • Line Name: MMT_783_ENN_FR_ROTV_SSS_WPA_BM3_OWF_E_ML_05600_0.646 • Water Depth: 21.02 Meters	**Dimensions and attributes** • Target Width: 0.46 Meters • Target Height: 0.31 Meters • Target Length: 5.33 Meters • Target Shadow: 1.40 Meters • Mag Anomaly: • Avoidance Area: • Classification1: Debris • Classification2: CONF 1 • Area: • Block: • Description: Linear debris
	**S_FR_WPA_BM03_0047** • Sonar Time at Target: 08-06-2021 07:19:44 • Click Position 56.4877578305 6.5779154012 (WGS84) 0.0000000000 0.0000000000 (NAD27LL) 56.4877525792 6.5779071849 (LocalLL) (X) 350864.71 (Y) 6262996.15 (Projected Coordinates) • Map Projection: :ETRS89_UTM32N_20215 • Acoustic Source File: V:\2021\103783-Energinet_OWF_EI\2-Raw_Data\RE\SSS\BM3\MMT_783_ENN_RE_ROTV_SSS_WPA_BM3_OWF_E_2D_05880.470.jsf • Ping Number: 947940 • Range to target: 49.28 Meters • Fish Height: 9.05 Meters • Heading: 177.720 Degrees • Event Number: (-1) • Line Name: MMT_783_ENN_RE_ROTV_SSS_WPA_BM3_OWF_E_2D_05880.470 • Water Depth: 15.25 Meters	**Dimensions and attributes** • Target Width: 0.89 Meters • Target Height: 0.00 Meters • Target Length: 17.12 Meters • Target Shadow: 0.00 Meters • Mag Anomaly: • Avoidance Area: • Classification1: Debris • Classification2: CONF 1 • Area: • Block: • Description: Possible anchor chain.
	**S_FR_WPA_BM03_0139** • Sonar Time at Target: 29-05-2021 12:06:08 • Click Position 56.4993887797 6.5799005710 (WGS84) 0.0000000000 0.0000000000 (NAD27LL) 56.4993887797 6.5799005710 (LocalLL) (X) 351033.05 (Y) 6264286.55 (Projected Coordinates) • Map Projection: UTM84-32N • Acoustic Source File: C:\Users\anders.jensen\Desktop\Energi�en\Datapakke 07-04-22\XTF_HF\BM03\MMT_783_ENN_RE_ROTV_SSS_WPA_BM3_OWF_E_2D_06300.940_jsf-CH34.xtf • Ping Number: 1811782 • Range to target: 41.93 Meters • Fish Height: 8.52 Meters • Heading: 349.070 Degrees • Event Number: (-1) • Line Name: MMT_783_ENN_RE_ROTV_SSS_WPA_BM3_OWF_E_2D_06300.940_jsf-CH34 • Water Depth: 14.70 Meters	**Dimensions and attributes** • Target Width: 2.47 Meters • Target Height: 0.00 Meters • Target Length: 20.03 Meters • Target Shadow: 0.00 Meters • Mag Anomaly: • Avoidance Area: • Classification1: anchorchain • Classification2: CONF 1 • Area: • Block: • Description: Twisted pattern anomaly with shadows. Possible anchor chain or ballast stones.

Table 4 SSS targets selected for further investigation

11.2. MAG anomalies

The MAG anomalies were reviewed by the MAJ maritime archaeologists Anders Jensen, Jan Hammer Larsen and Daniel Peter Dalicsek. Targets with an anomaly value <50nT were excluded from the review.

62 of the magnetic anomalies identified for the UXO survey had a value of >50nT. None of these anomalies had an associated SSS target. 30 targets were marked by RPS as being below a non-defined threshold. 33 of the anomalies were designated possible UXO.

MAJ has reviewed the results of the EOD campaign described in report 1308 104087-ENN-MMT-SUR-REP-WPD-UXO and its appendices.

Target ID 0399 is deemed as an object with value for cultural heritage. The object is a stocked anchor of admiralty type, but wider than those of the standard Royal Navy anchors. It is without its stock. The estimated weight (according to MMT) is 120kg. MAJ recommends lifting of the object and to be given into the care of MAJ for further detailed documentation.

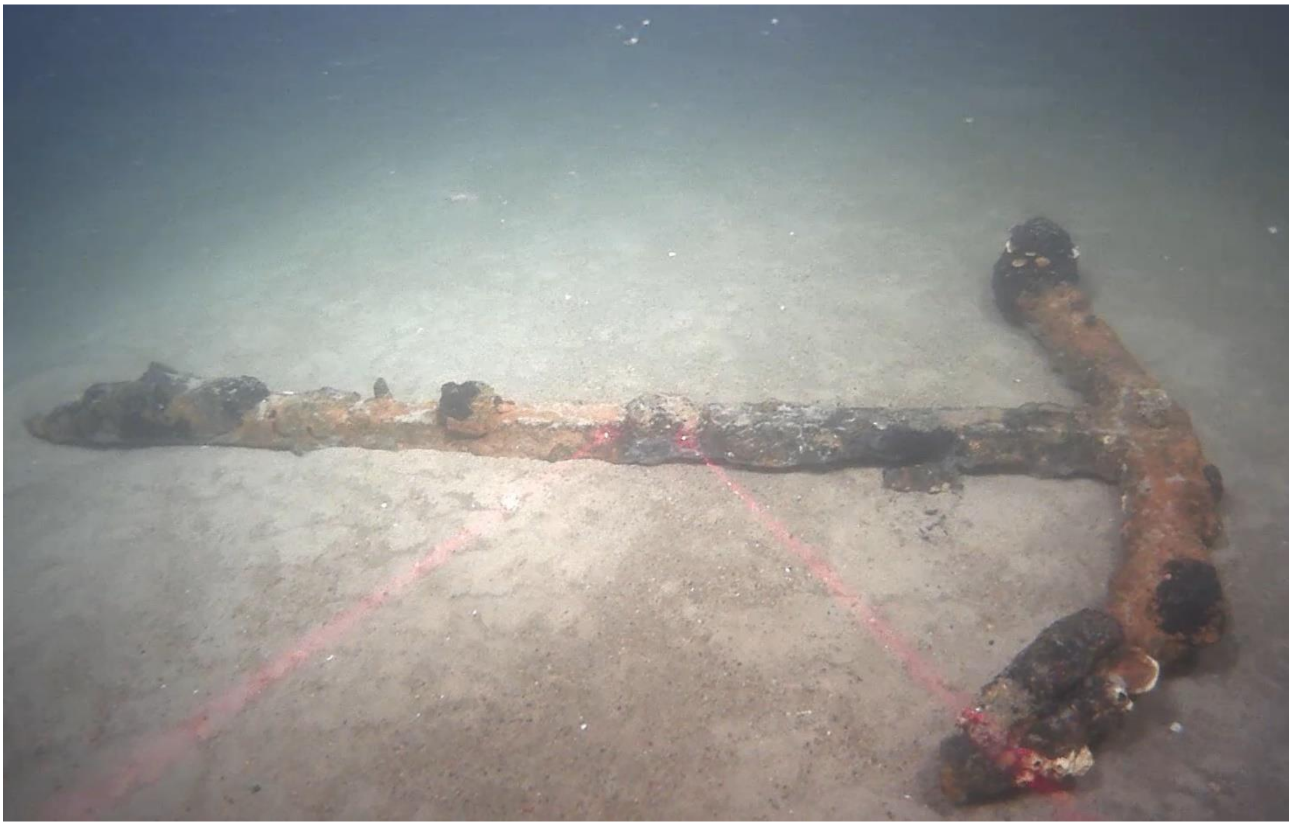


Figure 15 Target Id 0399 on the EOD campaigns ROV video, Source: Client

Target ID 0323 is a creeper, an anchor like grapple to recover lost fishing gear by dragging it across the seafloor. The creeper has chain attached to it and modern rope at the end of the chain. Although creepers were used in the 19th century, this one is judged to be more modern and not of archaeological character.

All other MAG targets investigated in the UXO survey and EOD campaign are deemed to be without archaeological value.

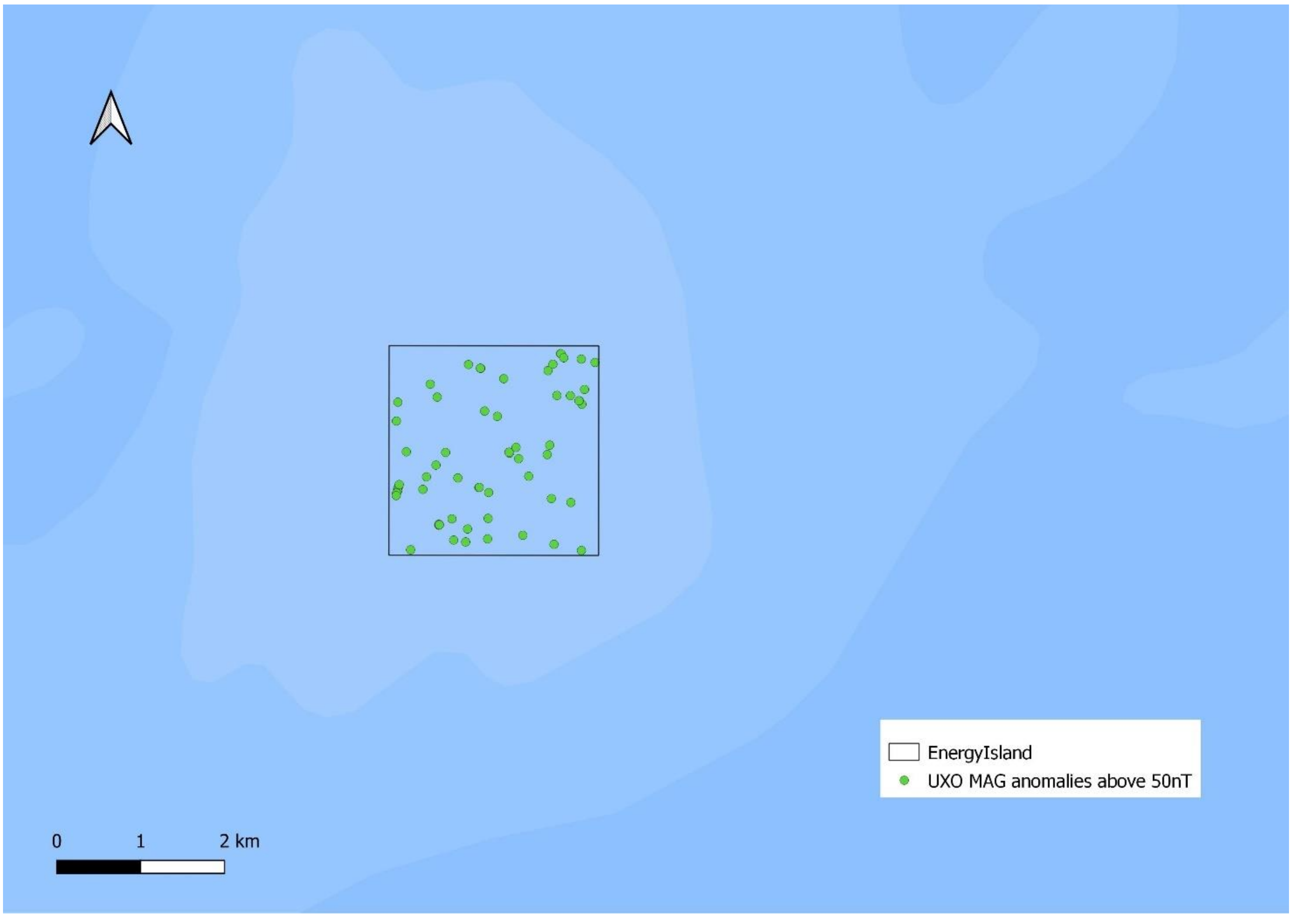


Figure 16 UXO anomalies

12. Conclusion on wrecks

The review and analyses of the geophysical survey has not shown any clear large-scale shipwrecks, shipwreck debris or wrecks of aircraft or submarines in the area.

Three SSS anomalies were identified as debris possibly associated with shipwrecks and of interest for submerged cultural heritage. These anomalies should be visually inspected (ROV dives, high resolution MBES). All three anomalies are outside of the EI site. If the anomaly sites are not inspected further, an exclusion zone of 200m radius is advised around the locations.

62 magnetic anomalies are above the threshold (50nT) MAJ considers relevant for objects of maritime archaeological interest. These anomalies were investigated in the EOD campaign and Target ID 0399 is judged to be of archaeological character and value.

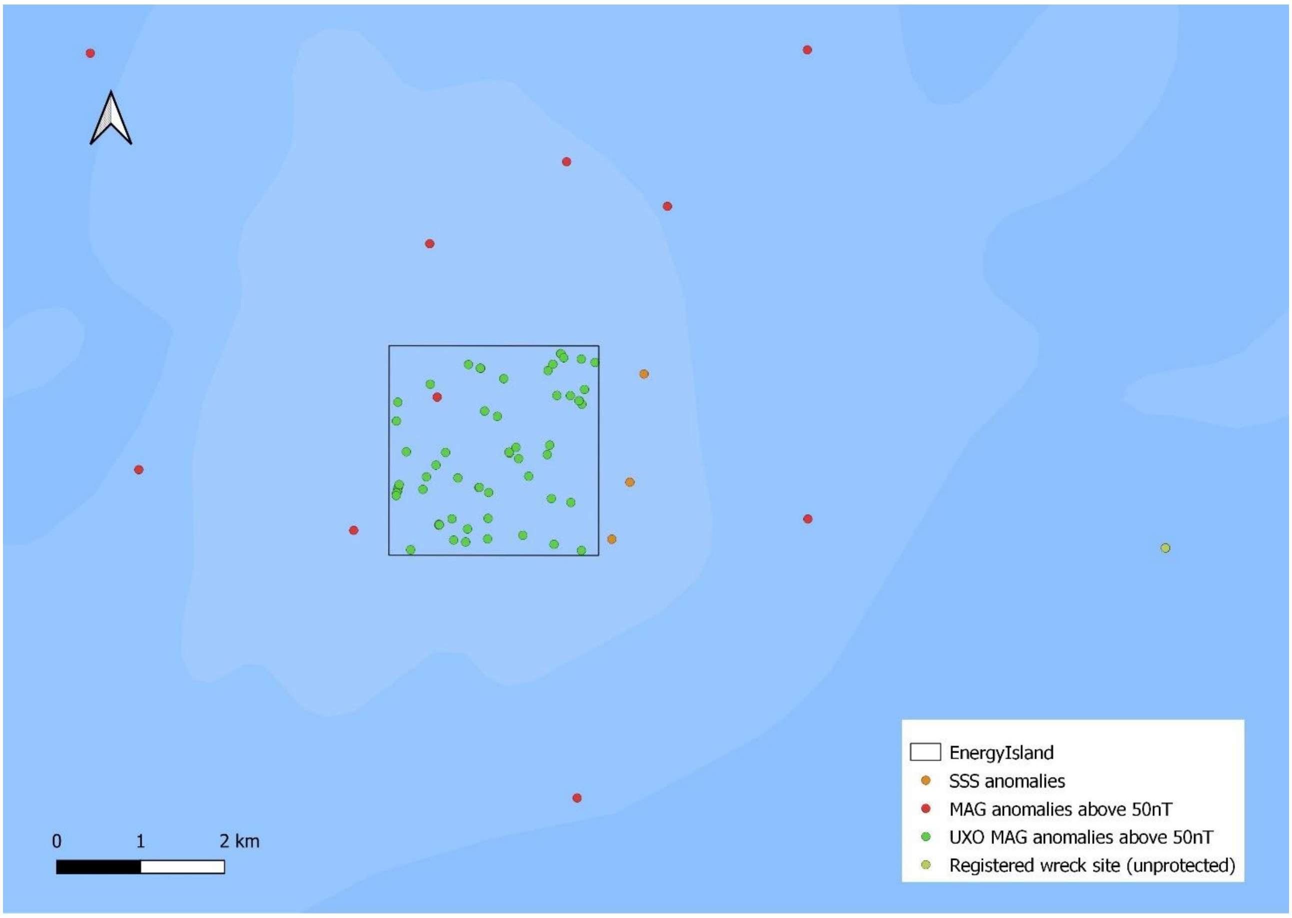


Figure 17 EI and surrounding points of interest

13. Target investigation

If avoidance is not possible or proves impractical, as is the case in EI area, the target should be investigated to identify whether it is of archaeological character. Target investigation is generally conducted by deploying divers or ROV's or a combination of both. Consideration needs to be given as to whether the target is located on the surface or buried and additionally to the visibility on site.

Work class ROV's are considered a safe and practical way to investigate targets as they can be equipped with cameras and survey equipment and with dredge pumps for excavation.

If ROV's are to be used, MAJ recommends the following equipment/requirements:

- Work Class ROV as a minimum
- Capable of operating within the following conditions:
    - significant wave height min 2.5 m
    - wind 12 m/s
    - 2 knots current, fully laden (i.e. all equipment operating)
- ROV HD camera system (2 per ROV)
- Inertial Nav System (INS)
- Doppler velocity log
- Digital Edge HD recording system (or equivalent)
- Adequate manipulators and grinders to conduct the required operations

- Depth sensor accurate to +/- 1 m
- Ability to carry out excursions at least 150 m from the vessel
- Obstacle avoidance sonars
- USBL system, IXSea Gaps or equivalent
- Dredge pump capable of efficiently excavating sediments given the seabed conditions
- Metal detector (e.g. innovatum/gradiometer (7pin) or TSS pipe tracker (2 m array minimum)) for target relocation

Optional:

- High Resolution Sub-Bottom Imager (e.g. Pangeo SBI)
- ARIS Sonar (or equivalent)

The configuration of the camera system should allow for variations in view, strobe orientation and focal length in order to maximise data quality with respect to the prevailing conditions. A method of determining scale for the field of view should be evident in the video frame. The video should be supplied with its own source of illumination, which will be no less than 100 W (equivalent) and suitable to provide colour-balanced scene illumination at depth. The video shall be digitally recorded on board the vessel with a means to review, replay, capture and extract data digitally immediately after acquisition.

Due to certain factors the use of divers can be advantageous. The divers would use hand-held locators (metal detectors) to relocate the target and diver operated air lifts to expose buried objects. However, if targets are buried deeply i.e. more than 1 m then it may be preferable to use remote operated excavation equipment due to the safety implications of diving near excavations and the risk of hole collapse.

If divers are to be used, MAJ recommends the following equipment to be deployed during the investigations as a minimum, but in accordance with the client´s operating procedures on underwater works:

- Divers must have archaeology familiarisation and search training/experience
- Surface Supplied Diving (as opposed to SCUBA). If SCUBA is proposed, justification for this method should be provided
- Diver to surface communications and live and recordable video link, via the diver’s helmet
- Diver held metal detectors capable of detecting to 2 m below seabed
- Digital Edge HD recording system (or equivalent)
- USBL system (IXSea Gaps or better)

A method of determining scale for the field of view should be evident in the video frame. The video should be supplied with its own source of illumination, which will be no less than 100 W (equivalent) and suitable to provide colour-balanced scene illumination at depth. The video shall be digitally recorded on board the vessel with a means to review, replay, capture and extract data digitally immediately after acquisition.

14. Conclusions

MAJ has reviewed the data provided by Energinet and completed a desk-based analysis of the geophysical survey. MAJ concludes that there is very little potential for Stone Age finds in the EI area and the chances of finding traces of Stone Age human activity do not warrant a Phase III survey excavation in the Energy Island area. MAJ could not identify large scale shipwrecks or shipwreck debris in the Energy Island area but has identified magnetic anomalies within the EI area boundary and SSS anomalies on the edge of the EI area for further investigation.

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17. Appendices

1. Coring data

Sample	Lab-number	Placename / core	Euref 89 zone 32 N (East)	Euref 89 zone 32 N (North)	Water depth	Sample elevation masl	Sediment	Dated sample	Species	Environmet	Uncalibrated 14C measurement bp	Reservoir correction	Reservoir corrected age bp	uncertainty (±)	Sediment cover above SLIP (m)	Id (Number in sea-level curve)	Calibrated age interval (BC)(2σ), start	Calibrated age interval (BC)(2σ), end	Smaple elevation used in sea-level curve
R1	AAR-31695	282-VC-R2-004	429513,50	6252964,50	-27	-31,50	Marine sediments	Shell	*Spisula species*	Marine	42654 ± 420	400	42254	420	4.0-5.0	1	43981	43216	-31,50
R2	AAR-31696	282-VC-R2-004	429513,50	6252964,50	-27	-32,70	Marine sediments	Shell	*Spisula soldia*	Marine	43350 ± 577	400	42950	577	5.0-5.55	2	44781	43636	-32,70
R3	AAR-31697	282-VC-OWF-B1-007	404742,50	6233577,20	-31	-32,60	Marine sediments	Shell	*Cerestoderma edula*	Marine	9060 ± 41	400	8660	41	1.0-2.25	3	7902	7731	-32,60
R4	AAR-31698	282-VC-OWF-B1-007	404742,50	6233577,20	-31	-33,31	PEAT	PLANT	Reeds? Phragmites stemps	Terrestrial	8687 ± 39	0	8687	39	2.25-2.37	4	7716	7610	-33,31
R5	AAR-31699	282-VC-OWF-B1-007	404742,50	6233577,20	-31	-33,50	PEAT	PLANT	Reeds?	Terrestrial	8752 ± 49	0	8752	49	2.37-2.68	5	7938	7683	-33,50
R6	AAR-31700	282-VC-OWF-B1-007	404742,50	6233577,20	-31	-35,79	PEAT	Wood	Tvig with bark	Terrestrial	11704 ± 44	0	11704	44	4.68-4.90	6	11608	11526	-35,79
R7	AAR-31701	282-VC-OWF-B2-005	416054,80	6243508,70	-26	-27,90		Wood	Woodfragment (waterworn)	Coastal	8664 ± 38	0	8664	38	1.40-2.40	7	7706	7600	-27,9
R8	AAR-31702	282-VC-OWF-B2-005	416054,80	6243508,70	-26	-27,90	Marine sediments	SHELL	*Cerestoderma edule*	Marine	9205 ± 48	400	8805	48	1.40-2.40	8	8164	7986	-27,90
R9	AAR-31703	282-VC-OWF-B2-005	416054,80	6243508,70	-26	-29,52	PEAT	WOOD	Wood fragment	Terrestrial	8776 ± 43	0	8776	43	3.40-3.64	9	7938	7750	-29,52
R10	AAR-31704	282-VC-OWF-B3-003	419910,50	6255663,59	-27	-30,58	Marine sediments	SHELL	Ubestemt marin	Marine	45983 ± 641 **)	400	45583	641	3.42-3.75	10	47790	46460	-30,58
R11	AAR-31705	282-VC-OWF-B4-010	425338,60	6233562,90	-25	-27,13	Marine sediments	SHELL	Ubestemt marin, *Tellina*	Marine	42385 ± 424	400	41961	424	2.04-2.22	11	43765	43006	-27,13
R12	AAR-31706	282-VC-OWF-B4-010	425338,60	6233562,90	-25	-27,57		WOOD	Woodfragment	?	47495 **)	0	0	0	2.22-2.93	12	out of range	out of range	-27,57
R13	AAR-31707	282-VC-OWF-B4-010	425338,60	6233562,90	-25	-27,57	Marine sediments	SHELL	Ubestemt art (waterworn)	Marine	43285 ± 502	400	42885	502	2.22-2.93	13	44630	43641	-27,57
R14	AAR-31708	282-VC-OWF-B4-010	425338,60	6233562,90	-25	-28,31	Marine sediments	SHELL	*Actica islantica*	Marine	45073 ± 544 **)	400	44673	544	2.93-3.70	14	46741	45320	-28,31
R15	AAR-31709	282-VC-R3-025	433415,60	6249849,00	-26	-27,64	PEAT	WOOD	Woodfragments	?	46280 **)	0	0	0	1.60-1.69	15	out of range	out of range	-27,64
R16	AAR-31710	282-VC-R5-065	438420,40	6235163,09	-20	-21,46	Marine sediments	SHELL	*Actica islantica*	Marine	4303 ± 32	400	3903	32	1.41-1.51	16	2541	2442	-21,46
R17	AAR-31711	282-VC-OWF-B1-004	410789,00	6244688,50	-29	-29,51	PEAT	WOOD	Wood, tvig with bark	Terrestrial	9558 ± 40	0	9558	40	0.40-0.62	17	9122	8814	-29,51
R18	AAR-31712	282-VC-R3-018	425756,60	6245074,50	-28,7	-29,89	Marine sediments	SHELL	*Cerestoderma edule*	Marine	43060 ± 415	400	42660	415	1.11-1.28	18	44326	43532	-29,89
R19	AAR-31713	282-VC-OWF-B1-ARC-004	405491,30	6238662,20	-25,9	-26,85	MUD/PEAT	WOOD	Wood fragment	Terrestrial	8887 ± 38	0	8887	38	0.90-1.00	19	8204	7974	-26,85
R20	AAR-31714	282-VC-R2-015A	441963,00	6256286,00	-16,5	-20,00	CLAY/SILT	WOOD	Wood fragment	?	out of range	0	0	0	3.35-3.66	20	out of range	out of range	-20,00
R21	AAR-31715	282-VC-R5-056A	428135,63	6237873,75	-26,4	-28,45	CLAY/SILT	SHELL	*Cerestoderma edula*	Marine	41259 ± 397	400	40859	397	2.00-2.10	21	42855	42060	-28,45
	AAR-1819	Jyske Rev, core 562003	406899,00	6305681,00	?	-33,25	Marine sediments	SHELL	*Tellina fabula*	Marine	7920 ± 110	400	7520	110	?	22	6462	6251	-33,25
	AAR-1818	Jutland Bank	390814,63	6319068,16	?	46,00	Marine sediments	SHELL	*Littorina littorea*	Marine	8930 ± 150	400	8530	150	?	23	8281	7841	46,00

Sample	Lab-number	Placename / core	Euref 89 zone 32 N (East)	Euref 89 zone 32 N (North)	Water depth	Sample elevation masl	Sediment	Dated sample	Species	Environmet	Uncalibrated 14C measurement bp	Reservoir correction	Reservoir corrected age bp	uncertainty (±)	Sediment cover above SLIP (m)	Id (Number in sea-level curve)	Calibrated age interval (BC)(2σ), start	Calibrated age interval (BC)(2σ), end	Smaple elevation used in sea-level curve
380	AAR-1828	Jyske rev. Agger II	388205,79	6325515,11	?	-33,00	Marine sediments	SHELL	?	Marine	9500 ± 140	400	9100	140	?	24	8561	8015	-33,00
381	AAR-1827	Jyske rev. Agger I	380441,63	6329025,36	?	-24,00	Marine sediments	SHELL	?	Marine	8870 ± 90	400	8470	90	?	25	7594	7459	-24,00
382	AAR-1818	Jyske rev. Agger II	390814,63	6319068,16	?	-46,00	Marine sediments	SHELL	*Littorina littorea*	Marine	8930 ± 150	400	8530	150	?	26	7754	7358	-46,00
383	AAR-1822	Jyske rev, Boring 562011	442651,06	6296145,57	?	-34,50	Marine sediment	SHELL	*Cardium edule*	Marine	9350 ± 100	400	8950	100	3,45	27	8756	8467	-34,50
384	AAR-1820	Jyske rev, Boring 562010	442651,06	6296145,57	?	-33,54	Marine sediment	SHELL	*Cardium edule*	Marine	9080 ± 90	400	8680	90	5,50	28	8448	8225	-33,54
385	AAR-1819	Jyske rev, Boring 562003	442651,06	6296145,57	?	-33,25	Marine sediment	SHELL	*Tellina fabula*	Marine	7920 ± 110	400	7520	110	2,43	29	7027	6660	-33,25
	AAR-1821	Jutland Bank, 562010-V	420286,82	6289188,13	?	?	Marine sediment	SHELL	*Nucula nitida*	Marine	9090 ± 90	400	8690	90	2,50	30	7908	7592	?
1056	K-6149	Strande I	448797,41	6270636,90	?	-11,70	Marine sediments	SHELL	?	Marine	7780 ± 155	0	7780	155	?	31	6908	6462	-11,70
1057	K-6148	Strande I	448797,41	6270636,90	?	-4,25	Marine sediments	SHELL	*Ostrea edulis*	Marine	6090 ± 140	0	6090	140	?	32	5214	4849	-4,25
1058	K-6147	Strande I	448797,41	6270636,90	?	-3,75	Marine sediments	SHELL	*Ostrea edulis*	Marine	6020 ± 100	0	6020	100	?	33	5056	4792	-3,75
1059	K-6150	Strande II, freshwater	448797,41	6270636,90	?	-10,50		Gytja	Gyttja	Lacustrine	8400 ± 144	0	8400	144	?	34	7588	7200	-10,50
695	AAR-2593	Nissum Bredning	460179,93	6282325,67	?	?	Marine sediments	FORAMS	*Ammonia beccari*	Marine	7065 ± 60	400	6665	60	2,15	35	5636	5539	?
696	AAR-2594	Nissum Bredning	460451,71	6278613,04	?	?	Marine sediments	FORAMS	*Ammonia beccari*	Marine	7160 ± 60	400	6760	60	1,95	36	5711	5631	?
697	AAR-2595	Nissum Bredning	460451,71	6278613,04	?	?	Marine sediments	FORAMS	*Ammonia beccari*	Marine	7230 ± 80	400	6830	80	2,55	37	5783	5640	?
698	AAR-2596	Nissum Bredning	463216,42	6279329,42	?	?	Marine sediments	FORAMS	*Ammonia beccari*	Marine	3280 ± 60	400	2880	60	1,85	38	1187	945	?
699	AAR-2597	Nissum Bredning	463216,42	6279329,49	?	?	Marine sediments	FORAMS	*Ammonia beccari*	Marine	3930 ± 65	400	3530	65	3,00	39	1942	1767	?
700	AAR-2598	Nissum Bredning	459037,32	6269907,08	?	?	Marine sediments	FORAMS	*Ammonia beccari*	Marine	6200 ± 75	400	5800	75	0,80	40	4726	4547	?
	K-4596	Dødemandsbjerg, corring	446277,58	6232216,86	?	-12,00	Marine sediment	SHELL	*Ostrea edulis*	Marine	6740 ± 130	0	6740	130	12,50	41	5760	5534	-12,00
	K-3421	Stauning Pynt	460212,17	6200474,87	?	?		PEAT	?	Terrestrial	6470 ± 100	0	6470	100	1,10	42	5512	5339	?
	AAR-3289	North sea, Jyske Rev	385479,61	6310262,37	?	-41,80	Marine sediments	SHELL	Div. species	Marine	8180 ± 80	400	7780	80	3,60	43	6686	6501	-41,80
	AAR-3296	Jyske Rev (Agger clay)	438316,49	6296310,92	?	-34,70	Marine sediments	SHELL	Div. species	Marine	9380 ± 90	400	8980	90	6,00	44	8286	7982	-34,70
	K-4502	Rønland, corring E 66 from -9,5 to -10,5	450522,75	6280142,58	?	-10,00	Marine sediments	SHELL	*Ostrea edulis*	Marine	6800 ± 105	0	6800	105	11,50	45	5809	5625	-10,00
	K-4503	Rønland, corring E 66 from -8,5 to -9,5,	450522,75	6280142,58	?	-9,00	Marine sediments	SHELL	*Ostrea edulis*	Marine	6500 ± 100	0	6500	100	10,50	46	5557	5374	-9,00
	K-4504	Rønland, corring E 66 from -7,5 to -8,5	450522,75	6280142,58	?	-8,00	Marine sediments	SHELL	*Ostrea edulis*	Marine	6320 ± 100	0	6320	100	9,50	47	5466	5217	-8,00
	AAR-3281	Jyske Rev	410315,70	6326534,19	?	-51,05	Marine sediments	SHELL	Div. species	Marine	9240 ± 80	400	8840	80	2,10	48	8199	7818	-51,05

Sample	Lab-number	Placename / core	Euref 89 zone 32 N (East)	Euref 89 zone 32 N (North)	Water depth	Sample elevation masl	Sediment	Dated sample	Species	Environmet	Uncalibrated 14C measurement bp	Reservoir correction	Reservoir corrected age bp	uncertainty (±)	Sediment cover above SLIP (m)	Id (Number in sea-level curve)	Calibrated age interval (BC)(2σ), start	Calibrated age interval (BC)(2σ), end	Smaple elevation used in sea-level curve
	AAR-3290	Jyske Rev	410315,70	6326534,19	?	-53,85	Marine sediments	SHELL	*Abra prismatica*	Marine	10050 ± 70	400	9650	70	4,95	49	9236	8854	-53,85
	AAR-3294	Jyske Rev (Agger clay)	390255,01	6301780,16	?	-26,10	Marine sediments	SHELL	*Corbula gibba*	Marine	6350 ± 70	400	5950	70	3,10	50	4932	4729	-26,10
	AAR-3295	Jyske Rev (Agger clay)	390255,01	6301780,16	?	-27,70	Marine sediments	SHELL	*Corbula gibba*	Marine	6650 ± 65	400	6250	65	4,70	51	5311	5079	-27,70
	AAR-3298	Jyske Rev (Agger clay)	438316,49	6296310,92	?	-34,05	Marine sediments	SHELL	*Mytilus edulis*	Marine	9190 ± 75	400	8790	75	5,35	52	8169	7716	-34,05
	K-4552	Dover Odde, cultural layer	466979,47	6285892,91	?	-0,20	Archaeological site	Cultural deposit	Hazelnut	Terrestrial	6610 ± 100	0	6610	100	?	53	5626	5481	-0,20
	AAR-7299	North sea, N of Horns Rev	441930,99	6215858,99	?	-15,10	Marine sediments	SHELL	*Scrobicularia plana*	Marine	7005 ± 47	400	6605	47	1,53	54	5613	5510	-15,10
	AAR-7297	North sea, N of Horns Rev	441930,99	6215858,99	?	-14,00	Marine sediments	SHELL	*Cerastoderma edule*	Marine	6517 ± 50	400	6117	50	0,54	55	5206	4960	-14,00
	AAR-1825	North sea, 578001-IX	336810,04	6238090,95		?	Marine sediments	SHELL	*Cyprina islandica*	Marine	7700 ± 70	400	7300	70	6,00	56	6226	6081	?
	AAR-1826	North sea, 578001-X	336810,04	6238090,95		?	Marine sediments	SHELL	*Macoma baltica*	Marine	9400 ± 100	400	9000	100	6,00	57	8299	7975	?
	AAR-3293	Lille Fisker Banke.	336810,04	6238090,95		-48,23	Marine sediments	SHELL	*Acanthocardia echinata*	Marine	5325 ± 55	400	4925	55	4,23	58	3762	3651	-48,23
	AAR-7183	Horns Rev	446472,20	6181894,88		?	Marine sediments	SHELL	*Spisula solida*	Marine	5670 ± 50	400	5270	50	?	59	4228	3996	?
	AAR-7184	North sea, N of Horns Rev	446472,20	6181894,88		?	Marine sediments	SHELL	*Spisula solida*	Marine	5695 ± 60	400	5295	60	?	60	4231	4045	?
	AAR-7185	North sea, N of Horns Rev	446472,20	6181894,88		?	Marine sediments	SHELL	*Spisula solida*	Marine	5520 ± 45	400	5120	45	?	61	3974	3809	?
	UBA-32860	B0203VC, VIKING LINK	443802,32	6181000,41	?	-17,80	Marine sediments	SHELL	*Scrobicularia*	Marine/brackish	6457±43	400	6057	43	1.6-1.8	62	6971	6853	-17,8
	UBA-32861	B0220VC, VIKING LINK	412834,39	6184743,08	?	-18,70	Marine sediments	SHELL	*Scrobicularia*	Marine/brackish	3687±30	400	3287	30	1.7-2.0	63	3557	3480	-18,7
	UBA-32862	B0226VC, VIKING LINK	408051,08	6185061,82	?	-19,89	Marine sediments	SHELL	*Scrobicularia*	Marine/brackish	5277±32	400	4877	32	1.6-3.0	64	3694	3652	-20
	Beta-479843	Beta-479843, Baltic Pipe	368159,00	6186111,95	?	-37,29	Marine sediments	SHELL	*Macoma baltica*	Marine/brackish	8660±30	400	8260	30	3.10-3.17	65	7354	7216	-37
	Beta-479081	Beta-479081, Baltic pipe	368159,00	6186111,95	?	-37,70	PEAT			Terrestrial	9900±30	0	9900	30	3.38-3.80	66	9370	9309	-38
	KIA-51169	DOG 2	321417,46	6248391,46	-42,1	-47,16	PEAT	BULK SAMPLE		Terrestrial	9547 ± 60	0	9547	60	5.06-5.07	67	9099	8818	-47,16
	KIA-51170	DOG 2	321417,46	6248391,46	-42,1	-47,20	PEAT	BULK SAMPLE		Terrestrial	9311 ± 51	0	9311	51	5.10-5.11	68	8630	8486	-47,2
	KIA-51171	DOG 2	321417,46	6248391,46	-42,1	-47,23	PEAT	BULK SAMPLE		Terrestrial	9595 ± 51	0	9595	51	5,13	69	9132	8871	-47,23
	AAR-35647	Energiø, Northsea P1 : BH-1012 : sample 04BagA : 03.00 Expected age:	349662	6258709		-39,6	Marine sand	Shell		Marine	2671 ± 30	400	2271	30	3	70			-39,6
	AAR-35648	Energiø, Northsea. P2 : BH-1012 : sample 05BagB :	349662	6258709		-40,9	Marine sand	Shell	*Cardium*	Marine	8320 ± 41	400	7920	41	4,3	71			-40,9

Sample	Lab-number	Placename / core	Euref 89 zone 32 N (East)	Euref 89 zone 32 N (North)	Water depth	Sample elevation masl	Sediment	Dated sample	Species	Environmet	Uncalibrated 14C measurement bp	Reservoir correction	Reservoir corrected age bp	uncertainty (±)	Sediment cover above SLIP (m)	Id (Number in sea-level curve)	Calibrated age interval (BC)(2σ), start	Calibrated age interval (BC)(2σ), end	Smaple elevation used in sea-level curve
		04.30 Expected age:																	
	AAR-35649	Energiø, Northsea. P3 : BH-079 : sample 04BagB : 02.25	348090	6263564		-30,15	Marine sand	Shell		Marine	36268 ± 769	400	35868	769	2,25	72			-30,15
	AAR-35650	Energiø, Northsea. P4 : BH-079 : sample 05BagB : 02.75	348090	6263564		-30,65	Marine sand	Shell		Marine	6372 ± 37	400	5972	37	2,75	73			-30,65
	AAR-35651	Energiø, Northsea. P5 : BH-079 : sample 10BagB : 05.20	348090	6263564		-33,1	Marine sand	Shell		Marine	5533 ± 38	400	5133	38	5,2	74			-33,1
	AAR-35652	Energiø, Northsea. P6 : BH-1002 : sample 53BagA : 50.50	347315	6247314		-89,2	Peat	Peat		Terrestrial	>47906	0	47906		50,5	75			-89,2
	AAR-35653	Energiø, Northsea. P7 : BH-1002 : sample 53BagA : 50.50	347315	6247314		-89,2	Peat	Wood		Terrestrial	>45847	0	45847		50,5	76			-89,2
	AAR-35654	Energiø, Northsea. P8 : BH-1005 : sample 07BagA : 05.50	331240	6251314		-47,4	Peat	Wood		Terrestrial	>45244	0	45244		5,5	77			-47,4
	AAR-35655	Energiø, Northsea. P9 : BH-1005 : sample 07BagA : 05.50	331240	6251314		-47,4	Peat	Wood		Terrestrial	>46893	0	46893		5,5	78			-47,4
	AAR-35656	Energiø, Northsea. P10 : BH-1005 : sample 54BagB : 52.05	331240	6251314		-93,95	Peat	Wood		Terrestrial	>45123	0	45123		52,05	79			-93,95
	AAR-35657	Energiø, Northsea.P11 : BH-1005 : sample 54BagB : 52.05	331240	6251314		-93,95	Peat	Wood		Terrestrial	>44060	0	44060		52,05	80			-93,95
	AAR-35658	Energiø, Northsea. P12 : BH-1005 : sample 55BagA : 53.00	331240	6251314		-94,9	Peat	Wood		Terrestrial	>42942	0	42942		53	81			-94,9
	AAR-35659	Energiø, Northsea. P13 : BH-1006 : sample 09BagA : 08.00	348762	6252531		-49,6	Sand or peat	Organic material		?	9608 ± 44	0	9608	44	8	82			-49,6
	AAR-35660	Energiø, Northsea. P14 : BH-1007 : sample 30BagB : 23.70	346355	6253246		-64,3	Peat	Wood		Terrestrial	>45124	0	45124		23,7	83			-64,3
	AAR-35661	Energiø, Northsea. P15 : BH-1007 : sample 30BagB : 24.50	346355	6253246		-65,1	Peat	Wood		Terrestrial	>49867	0	49867		24,5	84			-65,1
	AAR-35662	Energiø, Northsea. P16 : BH-1010 : sample 08BagC : 06.90	341141	6256600		-41,9	Peat	Peat		Terrestrial	10055 ± 49	0	10055	49	6,9	85			-41,9

Sample	Lab-number	Placename / core	Euref 89 zone 32 N (East)	Euref 89 zone 32 N (North)	Water depth	Sample elevation masl	Sediment	Dated sample	Species	Environmet	Uncalibrated 14C measurement bp	Reservoir correction	Reservoir corrected age bp	uncertainty (±)	Sediment cover above SLIP (m)	Id (Number in sea-level curve)	Calibrated age interval (BC)(2σ), start	Calibrated age interval (BC)(2σ), end	Smaple elevation used in sea-level curve
	AAR-35663	Energiø, Northsea. P17 : BH-1010 : sample 08BagC : 06.90	341141	6256600		-41,9	Peat	Peat		Terrestrial	10025 ± 43	0	10025	43	6,9	86			-41,9
	AAR-35664	Energiø, Northsea. P18 : BH-1011 : sample 03BagA : 02.00	343560	6256918		-38,2	SAND	Wood		Terrestrial	8807 ± 47	0	8807	47	2	87			-38,2
	AAR-35665	Energiø, Northsea. P19 : BH-1011 : sample 03BagA : 02.00	343560	6256918		-38,2	SAND	Shell		Marine	9592 ± 47	400	9192	47	2	88			-38,2
	AAR-35666	Energiø, Northsea. P20 : BH-1016 : sample 69BagA : 67.00	340604	6260855		-109,8	Peat	Wood		Terrestrial	>48336	0	48336		67	89			-109,8
	AAR-35667	Energiø, Northsea. P21 : BH-1016 : sample 69BagA : 67.00	340604	6260855		-109,8	Peat	Wood		Terrestrial	>45765	0	45765		67	90			-109,8
	AAR-35668	Energiø, Northsea. P22 : BH-1017 : sample 17BagA : 11.00	343364	6262939		-54,4	SAND	Shell		Marine	>48000	400	48000		11	91			-54,4
	AAR-35669	Energiø, Northsea. P23 : BH-1017 : sample 18BagA : 11.50	343364	6262939		-54,9	SAND	Wood		Terrestrial	>47708	0	47708		11,5	92			-54,9
	AAR-35670	Energiø, Northsea. P24 : BH-1017 : sample 18BagB : 11.70	343364	6262939		-55,1	SAND	Wood		Terrestrial	>51096	0	51096		11,7	93			-55,1
	AAR-35671	Energiø, Northsea. P25 : BH-1021 : sample 45BagC : 44.30	357783	6264770		-85,8	SAND	Shell		Marine	>45900	400	45900		44,3	94			-85,8