Aramis Pipeline

An archaeological assessment
Of geophysical survey results

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At the request of

TotalEnergies EP Nederland B.V.

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Aramis Pipeline – An archaeological assessment of geophysical survey results
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Table 1. Dutch archaeological periods

Period	Time in Years				
Post-medieval / Modern Times	1500	A.D.	-	Present	
Late medieval period	1050	A.D.	-	1500	A.D.
Early medieval period	450	A.D.	-	1050	A.D.
Roman Times	12	B.C.	-	450	A.D.
Iron Age	800	B.C.	-	12	B.C.
Bronze Age	2000	B.C.	-	800	B.C.
Neolithic (New Stone Age)	5300	B.C.	-	2000	B.C.
Mesolithic (Stone Age)	8800	B.C.	-	4900	B.C.
Paleolithic (Early Stone Age)	300.000	B.C.	-	8800	B.C.

Table 2. Administrative details

Location:	North Sea	
Province	Zuid-Holland	
Municipality	Rotterdam	
Toponym Dutch:	Aramis pipeline	
Chart:	1801-01, 1811-01	
Coordinates Geodetic datum: ETRS89 Projection: UTM31N	Geophysical survey area	
	Centre	E 564 944 - N 5 856 821
	Northwest	E 580 104 - N 5 953 697
	Northeast	E 542 599 - N 5 953 697
	Southwest	E 542 599 - N 5 759 945
	Southeast	E 580 104 - N 5 759 945
Depth (LAT):	4.8 to 39.6 meter, average 27.0 meter	
Area (km^2):	Survey area	243.25 km^2
Environment:	Tidal currents, salt water	
Area use:	Shipping, fishing, oil, and gas industry	
Area administrator:	Rijkswaterstaat Zee en Delta	
Competent authority	Rijkswaterstaat Zee en Delta	
Advising body	Cultural Heritage Agency of the Netherlands [redacted]	
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Samenvatting (Abstract in Dutch)

In opdracht van TotalEnergies Nederland B.V. heeft Periplus Archeomare een archeologische analyse uitgevoerd van de geofysische onderzoeksresultaten van het Aramis pijpleidingtracé.

Een grote hoeveelheid onderzoeksgegevens (*sidescan-sonar, magnetometer, multibeam echosounder* en *subbottom-profiler*) van een gebied met een totale oppervlakte van 243 km2 is geanalyseerd om een archeologische beoordeling uit te voeren.

Deze analyse van geofysische onderzoeksresultaten is de tweede stap in de AMZ-cyclus, na de bureaustudie. Het doel van deze analyse is het toetsen van de op de bureaustudie gebaseerde verwachting voor archeologische resten in het gebied. De verwachting omvat overblijfselen van scheepvaartgerelateerde resten (wrakken), vliegtuigen uit de Tweede Wereldoorlog en prehistorische nederzettingen.

Sidescan-sonar en multibeam-contacten

Binnen het onderzochte gebied is aan in totaal acht contacten een archeologische verwachting toegekend. In overeenstemming met de Nederlandse wet- en regelgeving mogen hier geen bodemverstoringen plaatsvinden. Indien er binnen een straal van 100 meter van een potentiële archeologische locatie activiteiten plaatsvinden, wordt in overleg met de Rijksdienst voor het Cultureel Erfgoed (RCE) van geval tot geval bekeken of de 100 meter gehandhaafd moet blijven.

Magnetische afwijkingen

In totaal zijn op 2748 locaties magnetische afwijkingen waargenomen. Op tien locaties zijn magnetische afwijkingen met een piek-tot-piekwaarde van meer dan 500 nT in kaart gebracht, die niet gerelateerd kunnen worden aan bekende objecten zoals pijpleidingen of kabels en die van potentieel archeologisch belang kunnen zijn. De objecten die deze afwijkingen veroorzaken, zijn niet zichtbaar op sidescan-sonar- of multibeam-beelden en worden daarom geacht in de zeebodem te zijn begraven. Deze objecten kunnen (naast archeologische objecten) onder meer puin, explosieven, verloren ankers, et cetera zijn. Zolang het karakter van deze objecten niet is vastgesteld, worden de objecten geacht van potentieel archeologisch belang te zijn. Negen van de tien contacten vallen binnen een straal van 100 meter van de voorgestelde route.

In overeenstemming met de Nederlandse wet- en regelgeving mogen geen bodemverstoringen plaatsvinden op deze locaties. Indien binnen een straal van 100 meter van een potentiële archeologische locatie activiteiten plaatsvinden, wordt in overleg met de Rijksdienst voor het Cultureel Erfgoed (RCE) van geval tot geval bekeken of de 100 meter gehandhaafd moet blijven. Alle locaties van potentieel archeologisch belang binnen een straal van 100 meter van de voorgestelde route zijn weergegeven in figuur 1.

Prehistorische resten

De fysieke kwaliteit, dat wil zeggen de integriteit en het behoud van prehistorische resten, is sterk afhankelijk van de mate waarin prehistorische landschappen en archeologische niveaus daarin zijn aangetast door erosie. De seismische gegevens geven aan dat een deel van het Pleistoceen-landschap is geërodeerd tijdens de mariene transgressie in het vroege Holoceen, waardoor de integriteit van mogelijke prehistorische nederzettingen is aangetast. Lokaal kunnen de geologische eenheden die zijn gedefinieerd

als potentiële lagen met prehistorische overblijfselen intact zijn gebleven, vooral in gebieden waar veen is gevonden. De interpretatie van lithostratigrafische eenheden en het karakter van de laaggrenzen (erosief versus niet-erosief) uit de seismische gegevens is gebaseerd op de beschikbare geologische gegevens en het oordeel van deskundigen. De seismische interpretatie moet worden geverifieerd door middel van vibrocore-bemonstering. De werkelijke geologische sequenties die in het gebied aanwezig zijn en de integriteit van de laaggrenzen zullen worden geverifieerd, wat een instrument zal bieden voor verdere analyse van de prehistorische landschappen en het specificeren en testen van het archeologische potentieel.

Advies prehistorie

Periplus Archeomare beveelt aan verder archeologisch onderzoek uit te voeren dat zich richt op het ontstaan en de integriteit van paleo-landschappen langs de Aramis-routetrajecten voor algemene archeologische onderzoeksdoeleinden. Dit onderzoek omvat een inventarisatie van veldonderzoek door middel van vibrocore-bemonstering conform de Nederlandse Kwaliteitsnorm voor Archeologie (KNA Waterbodems 4.1). Er wordt een geotechnische campagne uitgevoerd om een geologisch model te genereren van de ondergrond van de pijpleidingcorridor en om de fysische eigenschappen van de aanwezige sedimentlagen te bepalen. Wij adviseren om een aantal vibrocore-locaties aan te wijzen waar sedimentmonsters worden verzameld die gebruikt kunnen worden voor geo-archeologisch onderzoek.

De intacte monsters moeten door een (senior) prospector worden onderzocht en beschreven volgens de Standaard Boorbeschrijvingsmethode (SBB). Monsters worden geselecteerd en gestabiliseerd om te worden geanalyseerd door specialisten op het gebied van OSL- en radiokoolstofdatering, sedimentpetrografie, palynologie, micropaleontologie (foraminiferen, ostracoden, diatomeeën, et cetera), macroresten van planten en dieren en weekdieren om inzicht te krijgen in de ontwikkeling van landschappen in de loop van de tijd en de mate waarin deze paleolandschappen bewaard zijn gebleven.

Conform de Nederlandse Kwaliteitsnorm voor Archeologie (KNA Waterbodems 4.1) moet er een Programma van Eisen (PvE) en/of Plan van Aanpak (PvA) worden opgesteld. Dit PvE/PvA omvat de doelstelling, de onderzoeksstrategie en -methodiek, de kaders en de praktische uitvoering van het onderzoek, zodat het proces soepel verloopt en meervoudig gebruik van de op uniforme wijze verkregen data wordt bereikt. Geadviseerd wordt om deze PvE/PvA ter goedkeuring voor te leggen aan het Bevoegd Gezag en de RCE. Na afronding van het inventariserend veldonderzoek kunnen tijdens de aanleg van de pijpleiding gegevens worden verzameld die – vanuit archeologisch oogpunt – op gedetailleerd niveau waardevolle informatie opleveren. Het kan zeer nuttig zijn om deze informatie vanuit archeologisch oogpunt verder te onderzoeken. Het verdient aanbeveling om, nadat de plannen zijn uitgewerkt, in overleg met de RCE de mogelijkheden hiervoor te onderzoeken.

Tijdens de installatie van de leiding kunnen archeologische voorwerpen worden ontdekt die volledig zijn begraven of tijdens het geofysisch onderzoek niet als archeologisch object zijn herkend. Wij adviseren passieve archeologische begeleiding op basis van een goedgekeurd Programma van Eisen. Passieve archeologische begeleiding houdt in dat een archeoloog tijdens de uitvoering van de werkzaamheden niet aanwezig is, maar altijd op afroep beschikbaar is. Het opvolgen van deze aanbeveling voorkomt vertragingen tijdens de werkzaamheden wanneer er onverwacht archeologische resten worden aangetroffen. Op grond van de Erfgoedwet is het verplicht om deze bevindingen te melden aan de toezichthouder (Minister van OCW). Deze melding moet ook worden opgenomen in het bestek van het werk.

Summary

TotalEnergies Nederland B.V. has contracted Periplus Archeomare B.V. to conduct an archaeological assessment of geophysical survey results of the Aramis pipeline route survey.

A large quantity of survey data (*side scan sonar, magnetometer, multibeam echosounder* and *subbottom profiling*) covering a total area of 243 km^2 have been analyzed to conduct an archaeological assessment.

The current analysis of geophysical survey results is the second step in the AMZ-cycle, following the desk study. The purpose of this assessment is to test the desk study-based expectancy for archaeological remains in the area. The expectancy covers remains of shipping related objects (wrecks), airplanes from World War II and prehistoric settlements.

Side scan sonar and multibeam contacts

Within the surveyed area, an archaeological expectation was assigned to a total of 8 contacts. In accordance with Dutch Law and Legislation no seabed disturbances should be carried out within 100 meters of each of the marked locations. If any activities will take place within 100 meters of a potential archaeological location, it will be examined on a case-by-case basis whether the 100 meters should be maintained in consultation with the Cultural Heritage Agency of the Netherlands (RCE).

Feature	NCN	Easting	Northing	Route section	Distance
BK_FSEA_SSS_0022	-	551288	5924521	D	**+50**
BK_FSEA_SSS_0179	-	555839	5929168	D	-240
BJ_FD_SSS_0015	-	548443	5894128	F	+230
BB_FS_SSS_0683	219	570384	5762003	East	-540
BH_FSEA_SSS_0104	531	559172	5935317	C	**+25**
BK_FSEA_SSS_0163	967	550165	5921956	D	**-56**
BN_FD_SSS_0025	945	576689	5920367	E Neptune	+220
BB_FS_SSS_0433	-	570711	5761481	East	-210

Three of the eight contacts fall within 100 meters of the proposed route.

Magnetic anomalies

A total of 2748 magnetic anomalies have been observed. At 10 locations magnetic anomalies with a peak-to peak value over 500 nT have been mapped which cannot be related to known objects like pipelines or cables and may be of potential archaeological interest. The objects that cause these anomalies are not visible on side scan sonar or multibeam images and are therefore considered to be buried in the seabed. These objects could, apart from archaeological objects, include debris, UXO, lost anchors, et cetera. As long as the character of these objects has not been determined, the objects are considered to be of potential archaeological interest.

Target	E	N	nT	Section	Distance
BAB_FS_UXO_0010	570711	5761625	808	East	-210
BAB_FS_UXO_0599	570931	5761671	514	East	**+5**
BAB_FS_UXO_0603	570932	5761987	2312	East	**+8**
BAB_FS_UXO_0605	570933	5761957	1158	East	**+8**
BAB_FS_UXO_0618	570936	5761510	729	East	**+11**
BAB_FS_UXO_0657	570948	5761543	1348	East	**+22**
BC_FD_MAG_0121	571170	5763666	666	East	**+4**
BH_FSEA_MAG_0044	559169	5935057	578	C	**-2**
BJ_FD_MAG_0050	563642	5875159	2089	F	**-59**
BP_FD_MAG_0016	559490	5931390	591	B	**-60**

Table 3. Magnetic anomalies over 500 nT with an archaeological expectation.

Nine of the ten contacts fall within 100 meters of the proposed route.

In accordance with Dutch Law and Legislation no seabed disturbances should be carried out within 100 meters of each of the marked locations. If any activities will take place within 100 meters of a potential archaeological location, it will be examined on a case-by-case basis whether the 100 meters should be maintained in consultation with the Cultural Heritage Agency of the Netherlands (RCE). All locations of potential archaeological interest within 100 meters of the proposed route are shown in the next figure.

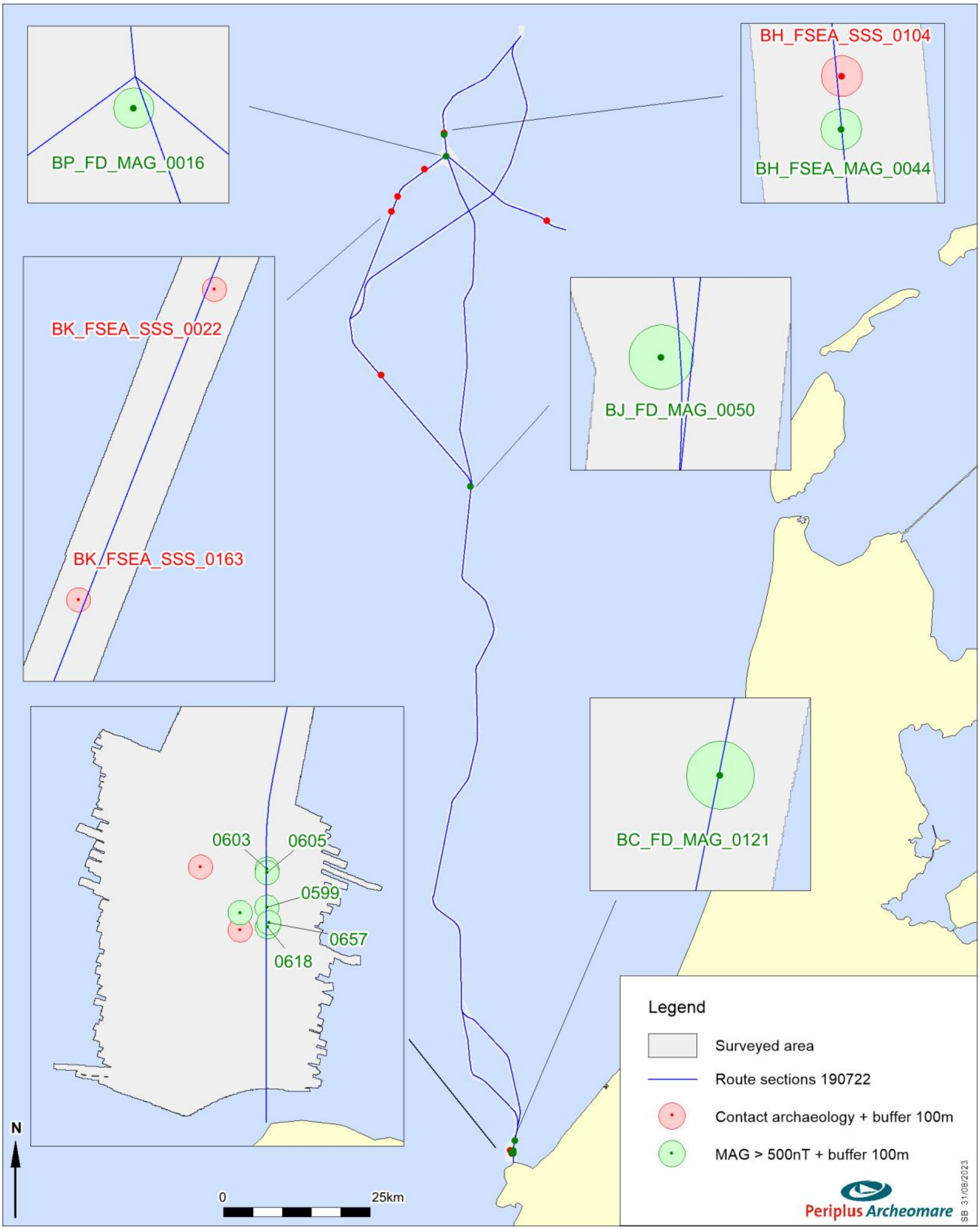

Figure 1. Overview of the potential archaeological targets within 100 meters of the proposed route

Prehistoric remains
Areas of potential archaeological interest listed below.

Depositional environment Areas of potential archaeological interest	**Lithostratigraphic Unit**	**Time of deposition**	**Archaeological period**
Peat-covered aeolian and small scale fluvial deposits	Boxtel Formation	*Late Glacial* and Early *Holocene*	Late Paleolithic and Early Mesolithic
Catchment of the Rhine	Kreftenheye Formation	Pleniglacial	Middle Paleolithic
Shores of lakes and lagoons	Brown Bank Member	Early *Weichselian*	Middle Paleolithic to Early Mesolithic

The physical quality, that is, the integrity and preservation of prehistoric remains is highly dependent on the extent to which prehistoric landscapes and archaeological levels herein have been affected by erosion. The seismic data indicate that part of the *Pleistocene* landscape has eroded during the Early *Holocene* marine ingression, thus affecting the integrity of possible prehistoric settlements. Locally the geological units defined as potential containers of prehistoric remains may have been preserved intact, especially in areas where peat has been found. The interpretation of lithostratigraphic units and the character of the layer boundaries (erosive versus non-erosive) from the seismic data is based on the geological data available and expert judgement. The seismic interpretation shall be ground-truthed by vibrocore sampling. The actual geological sequences present in the area and the integrity of layer boundaries will be verified, thus offering a tool for further analysis of the prehistoric landscapes and specify and test the archaeological potential.

Recommendation

Prehistory
Periplus Archeomare recommends conducting further archaeological research that focuses on the genesis and integrity of paleo-landscapes along the Aramis route trajectories for general archaeological research purposes. This research comprises an inventory of field research by means vibrocore sampling in accordance with the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1). A geotechnical campaign is carried out to generate a geological model of the subsurface of the pipeline corridor and to determine the physical properties of the sediment layers present. We recommend designating a number of vibrocore locations where sediment samples are collected that can be used for geo-archaeological research.

The intact samples must be examined by a (senior) prospector and described in accordance with the *Standaard Boorbeschrijvingsmethode* (SBB). Samples are selected and stabilized to be analyzed by specialists in the field of OSL and radiocarbon age dating, sediment petrography, palynology, micropaleontology (foraminifera, ostracods, diatoms, et cetera), macro-remains of plants and animals and molluscs to gain insight into the development of landscapes over time and the extent to which these paleolandscapes have been preserved.

In accordance with the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1), a Program of Requirements (PvE) and / or Plan of Action (PvA) must be drawn up. The PvE/PvA includes the objective, the research strategy and methodology, the frameworks and the practical implementation of the research, so that the process runs smoothly, and multiple use of the data acquired in a uniform manner is achieved. It is advised to submit this PvE / PvA for approval to the Competent Authorities and the RCE. After completion of the inventory field research, during the construction of the pipeline, data can be collected that - from an archaeological point of view - provides valuable information at a detailed level. It can be very useful to investigate this information further from an archaeological point of view. It is advised to investigate the possibilities for this in consultation with the RCE, once the plans have been worked out.

During the installation of the pipeline, archaeological objects may be discovered which were completely buried or not recognized as an archaeological object during the geophysical survey. We recommend passive archaeological supervision based on an approved Program of Requirements. Passive archaeological supervision means that an archaeologist is not present during the execution of the work but always available on call. Following this recommendation would prevent delays during the work when unexpectedly archaeological remains are found. In accordance with the Erfgoedwet, it is required to report those findings to the enforcing authority (Minister of OCW). This notification must also be included in the Scope of Work.

1 Introduction

TotalEnergies Nederland B.V. has contracted Periplus Archeomare B.V. to conduct an archaeological assessment of geophysical survey results of the Aramis pipeline route survey.

The area of investigation (243 km^2) is located in the North Sea, and runs from Maasvlakte II to offshore block L4 over a distance of 192 km.

Figure 2. Location map of the area of investigation

1.1 Background

TotalEnergies plans to build a new pipeline from Maasvlakte 2 to offshore blocks L4/K6 as part of the Carbon Capture and Storage (CCS) project Aramis. The CCS system will consist of an onshore pipeline, the compressor station, an offshore pipeline and the storage of CO_2 in the deep subsoil of the North Sea (figure 3). The capture of CO_2 from the harbour's industries and the use of CO_2 of the storage of it underground is one of the measures to achieve the climate objectives. The area to be surveyed encompasses:

(1) the shore approach/Landfall pipeline routing for HDD and dredging part at Maasvlakte
(2) the offshore rigid pipeline routing from Maasvlakte to blocks L4/K6
(3) the offshore distribution hub[1].

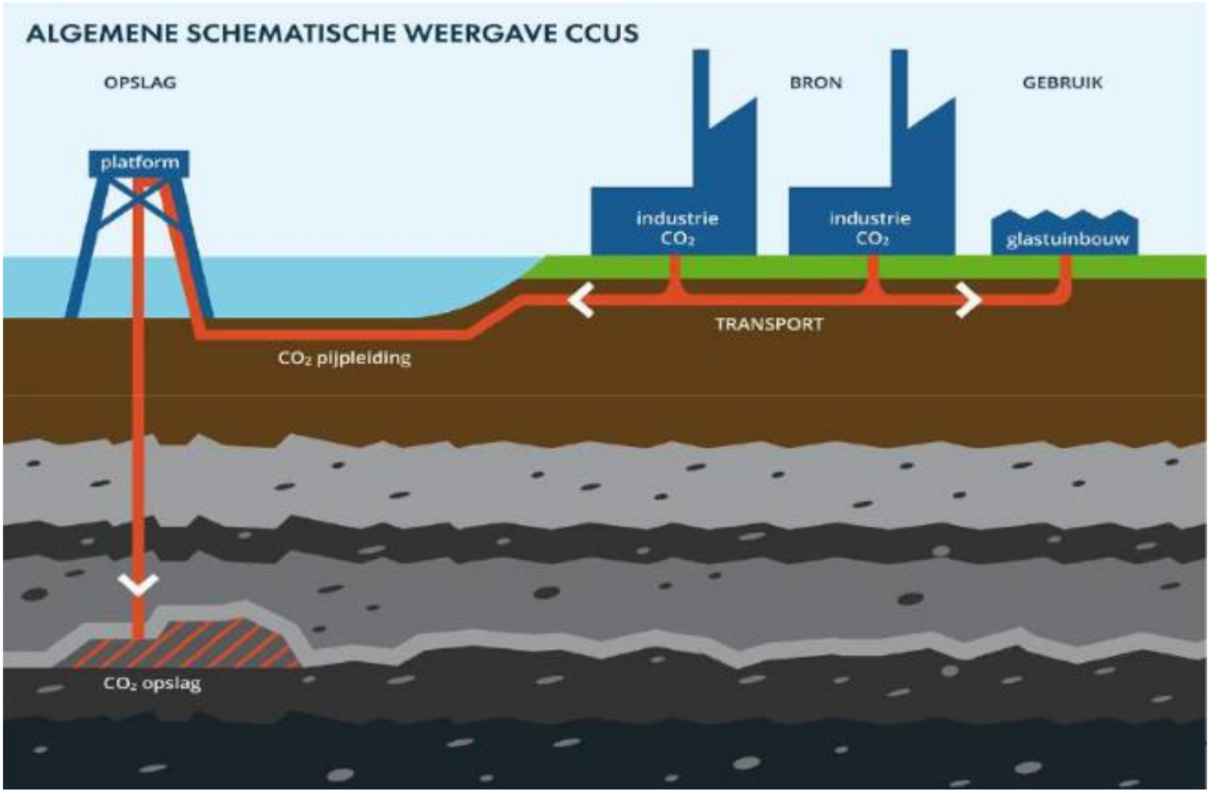

Figure 3: Schematic representation of the transport and storage system.

Offshore, the proposed 32 inch pipeline will be trenched into the seabed to a maximum depth of one meter[2].

In the Erfgoedwet[3] the protection of the archaeological heritage is embedded. Planned activities, such as the installation of a pipeline in the North Sea, may affect the archaeological values if present. If the remains are in jeopardy, there is a statutory obligation to conduct archaeological research. In line with this obligation an archaeological desk study has been carried out.

[1] Porthos project
[2] Concept Notitie Reikwijdte en Detailniveau Aramis CO2-transportinfrastructuur
[3] De Erfgoedwet became effective on the 1st of July 2016.

An archaeological desk study is the first step in the so-called *AMZ* cycle (Archeologische Monumenten Zorg). The *AMZ* cycle includes a description of procedures for subsequent phases of archaeological research to be performed in order to ensure the protection of archaeological heritage in the Netherlands.

The second phase of the *AMZ* cycle is an inventory archaeological field study. As a rule, this field study comprises a geophysical survey of the seabed. The survey executed by Fugro was not primarily set to provide data to be used in the course of archaeological research. However, a scan of the survey data acquired, prove these data to be fit for an archaeological assessment.

The separate phases of the AMZ-cycle are embedded in the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1). This standard dictates a mandatory workflow for archaeologists. A detailed description of the different phases of archaeological research is included in appendix 4.

1.2 Results desk study

In January 2022 an archaeological desk study has resulted in specific information on the archaeological remains which are to be expected within the entire area of interest of the Aramis pipeline[4]. The results of the desk study will be discussed below.

The area of interest has high expectations for the presence of (remains of) ship wrecks and WWII plane wrecks. Intact prehistoric landscapes and related *in situ* remains of Palaeolithic and Early Mesolithic camp sites and inhumations are expected to have been preserved in places.

The proposed pipeline routes have not been investigated by detailed geophysical surveys yet. These areas may contain more undiscovered shipwrecks or remains of shipwrecks than are currently known.

At this stage little is known about the integrity of the *Pleistocene* landscape. By means of subbottom profiling the occurrence geological units (both horizontal as vertical) and archaeological levels herein can be mapped. The character of layer boundaries (erosive or non-erosive) can be interpreted. It is unlikely however that archaeological remains of Paleolithic and Mesolithic camp sites can be identified with sufficient certainty (based on the geophysical and geotechnical surveys) to impose restrictions on pipeline development. At this stage focus should therefore not be put on tracing prehistoric camp sites but on a pragmatic employment of geophysical techniques in order to obtain a better insight in (the integrity of) the *Pleistocene* landscape. The insights gained shall be used to a) refine the archaeological expectancy model and b) allocate areas with a high expectancy for *in situ* prehistoric remains.

In accordance with the AMZ cycle it is advised to conduct a field investigation (in Dutch '*Inventariserend veldonderzoek opwaterfase*') in order to test the archaeological predictive model and further specify the type, vertical and lateral extent, age, integrity and preservation of shipwrecks, prehistoric landscapes and potential archaeological levels.

[4] Van den Brenk en van lil, 2022

Archaeological Expectancy	Method		Goal	Remarks
Ship and aircraft wrecks	Geophysical	Side Scan Sonar	detect and map wreck sites	wrecks exposed at, or protruding from the seabed
		Multibeam	characterize wreck sites morphologically; detect (partially) buried wrecks by the occurrence of scours	in addition to side scan sonar
		Sub-bottom Profiler	detect buried objects including possible shipwrecks and remains of aircraft	nature of the buried object cannot be determined directly
		Magnetometer		
Prehistoric settlements (camp sites)		Sub-bottom Profiler	map the Pleistocene landscape; specify expectancy	supported by, and validated with drill data
	Geotechnical	Geological Sampling	determine lithostratigraphy, soil layer boundaries (erosive or gradual) and characteristics of soil formation and maturation; specify expectancy	designation of borehole and/or vibrocore locations for geo-archaeological research based on SBP data
		Cone Penetration Test	determine lithostratigraphy	correlate with drilling data

In general, similar investigations carried out in the past consist of a geophysical survey with *side scan sonar*, *magnetometer* and *subbottom profiler* and a geotechnical survey. The resulting data should be assessed after the general processing, interpretation and reporting has been performed by the survey contractor.

The archaeological assessment of the data shall be conducted by a geophysical specialist (KNA prospector Waterbodems). The data quality from the surveys needs to match the demands for this archaeological assessment. To ensure compatibility between the site investigation and the required quality for this assessment it is recommended to define a Program of Requirements (In Dutch: 'Programma van Eisen') in accordance with the 'KNA' (the Dutch quality standards for archaeological research), to be authorized by the competent authority.

1.3 Objective

The purpose of the archaeological assessment is to test the desk study-based expectancy for archaeological remains in the area. The expectancy covers remains of shipping related objects (wrecks), airplanes from World War II and prehistoric settlements.

The goals set for this assessment are:

- To determine the historical or archaeological value of contacts found in the geophysical survey;
- To validate the locations of known wrecks;
- Assess the prehistoric landscape based on seismic data.

1.4 Research questions

For the inventory archaeological field study, the following research questions have been defined in the Program of Requirements[5].

Primary Question : Are any archaeological remains present within the Area of Interest and to what extent are these remains traceable?

With respect to side scan sonar, magnetometer and multibeam survey:

- Are there any phenomena visible on the seabed?

If so:

- What is the description of these phenomena?
- Do these phenomena have a man-made or natural origin?

If these phenomena can be designated to be man-made:

- What classification can be attached?

If these phenomena can be classified as archaeological:

- Is it possible to interpret the nature of the archaeological objects?

If these phenomena can be identified as natural:

- What is the nature of these natural phenomena?
- Based on the acoustic image is it possible to designate zones of high, middle or low marine activity on the seabed?

If so:

- How can these zones be interpreted?

General:

- What is the relation between the observed objects and the topography of the seabed? Based on this relationship can risk-prone areas be marked selectively?
- If no acoustic phenomena can be observed, are there any clues that this is a consequence of either natural erosion, sedimentation or human interference?

With respect to the seismic data:

- What is the depth of the top of the Pleistocene and Holocene landscape(s) relative to a) LAT and b) the present seabed?
- What lithostratigraphic units can be distinguished along the pipeline routes?

The answer to this question shall include information on:

- the classification,
- the occurrence (lateral extent and depth),
- the lithologic and stratigraphic characteristics,
- the age and depositional environment,
- the character of the layer boundaries (gradual or instantaneous |erosive) of these units.

- Are channel-like features observed?

If so:

- What are the characteristics of the channel-like features in terms of spacial distribution (width, depth, shape, extent), channel infill composition, stratigraphic position and age.

- Are occurrences of peat and/or organic clay observed?

[5] Van den Brenk and van Lil, 2022.

If so:

- What is the spacial distribution (depth, extent) stratigraphic position and age of these deposits.
- Are intact prehistoric landscapes affected by the installation of the pipeline based on their vertical position related to the seabed?
- Are there any indications observed on the seismic profiles for the presence of buried (man-made) objects?

If so:

- Based on the presence of buried objects and their correlation with side scan sonar, magnetometer en multibeam data can something be said about the nature of these buried objects?

2 Methodology

2.1 Introduction

As part of the installation of the pipeline, a geophysical and geotechnical survey has been carried out by Fugro. The aim of the survey was to contribute to the bathymetrical, morphological, and geological understanding of area of interest, as defined in the scope of work. The results have been compiled in a survey report[6].

This geophysical survey provides the information needed for the planning and preparation of the geotechnical survey. The outcome of the geotechnical survey will be combined with the seismic data to create an Integrated Ground Model (IGM).

The following methods have been deployed:
- Side scan sonar (SSS)
- magnetometer (MAG)
- multibeam echo sounder (MBES)
- sub-bottom profiler (SBP)
- ultra-high resolution seismic (UHR)

The results of the survey and geotechnical activities have been recorded in reports, listings, drawings, and images. Prior to the execution of the archaeological assessment the quality and completeness of the delivered survey data have been judged. It is concluded that the data is of high quality and that the data are fit for the purpose of this archaeological assessment.

SSS	- event listings containing all contacts observed. - Geotiffs mosaics of all contacts listed
MAG	- event listings containing all anomalies observed
MBES	- validated *multibeam* XYZ point cloud dataset (grid 25x25cm)
SBP/UHR	- representative subbottom profiles
Report	- survey reports

Table 4. Data used for archaeological assessment.

[6] Fugro report F192961_REP_007 01, rev 00, 23 September 2022.

2.2 Geophysical survey

The geophysical survey was carried out by Fugro between July 2022 and April 2023. For the execution of the survey the vessels '*MV Fugro Discovery*', '*MV Fugro Seeker*', and the '*Fugro Searcher*' were employed. An overview of the survey campaign and the employed methods is presented in the table below.

Region	Survey Type	Vessel	Survey		Survey Methods
			Start	End	
Offshore	Geophysical	MV Fugro Discovery	11-11-2022	12-12-2022	Multibeam (MBES), Sub Bottom Profiler (SBP), Side Scan Sonar (SSS), Two-dimensional Ultra-heigh Resolution (2DUHR), and Magnetometer
Nearshore	Geophysical	MV Fugro Seeker	11-07-2022	22-09-2022	Multibeam (MBES), Sub Bottom Profiler (SBP), Side Scan Sonar (SSS), and Two-dimensional Ultra-heigh Resolution (2DUHR)
Offshore	Geophysical	MV Fugro Searcher	09-10-2022	23-01-2023	Multibeam (MBES), Sub Bottom Profiler (SBP), Side Scan Sonar (SSS), and Two-dimensional Ultra-heigh Resolution (2DUHR), and a Sparker
Offshore & Nearshore	Geotechnical	MV Normand Mermaid	11-11-2022	24-01-2023	CPT and Vibrocore
Offshore & Nearshore	Geotechnical	MV Kommandor Orca	02-12-2022	12-12-2022	CPT and Vibrocore

Table 5. Overview of the survey campaigns and the employed survey methods (source: Fugro report F197217-REP-001 | 01 | 18 April 2023).

77 geotechnical locations were investigated during the geotechnical surveys. All locations comprise of Vibrocore (VC) and Cone Penetration Test (CPT).

Details about the geophysical and geotechnical surveys can be found in the integrated Geophysical and Geotechnical reports in Appendix 3

2.3 Known objects.

Fugro has summarized the *side scan sonar* contacts and *magnetometer* anomalies encountered within the survey area in detailed event listings. From different databases the occurrence of a number of objects within the area is known, as described in the desk study[7]. The contacts included in the survey event listings are compared with the database objects in the area. For this comparison four different datasets are used:

- The Hydrographic Service database (hereafter referred to as NLhono database);
- The Rijkswaterstaat SonarReg database (hereafter referred to SR database);
- The Dutch Cultural Heritage Agency database ARCHIS;
- The Dutch Nationaal Contact Nummer database (hereafter referred to as NCN);
- The NCN database contains all basic information (E, N, and description) of the Nlhono, SR and Archis databases. More detailed information is gathered through the other datasets.

[7] Van den Brenk en van lil, 2022

The National Contact Number (NCN)

The NCN database combines the data from three governmental databases:

- The Dutch Continental Shelf and Westerschelde wrecks register from the Hydrographic Service of the Royal Netherlands Navy;
- The SonarReg object database of Rijkswaterstaat;
- The ARCHIS database (the official archaeological database of the Ministry of Cultural Heritage)

The permission for the use of the NCN database for the analysis was granted by the owner (Rijkswaterstaat Zee en Delta).

In addition to shipwrecks, information on contacts referred to as ‘foul’ or ‘obstruction’ are included. From these objects the origin is not always known, but information on the location, dimensions and other valuable information is listed. Besides the databases other sources containing information on wrecks and historic finds are consulted for comparison with the survey results.

All known data is combined and plotted in GIS. In this way an overview is made of the areas in which archaeological remains are present or to be expected. The known contacts are a reference framework for the assessment of data recorded during the route survey.

2.4 Archaeological assessment of survey data

The geophysical and hydrographic survey techniques employed include *side scan sonar* (SSS), *magnetometer* (MAG), *multibeam* (MBES), subbottom profiling (SBP) and ultra-high resolution multi-channel seismic (UHRS). The natures of those methods differ, with coherent strengths and weaknesses.

Table 6 provides a summary of the objective(s) the methods employed and the nature of those methods in terms of seabed penetration and coverage. Data are cross correlated because the methods are complementary. E.g., *multibeam* data can aid in the interpretation of a *side scan sonar* contact by providing information on its height with respect to the surrounding seabed, the occurrence of scouring next to the contact, and the accuracy and precision of the object. CPT's, borehole and vibrocore data will aid in the determination of geological units from seismic strata.

Method	**Objective**	**Seabed**		**Accuracy and Precision**	**Cross Correlation**
		Penetration	**Coverage**		
SSS	Identification of outcropping objects; seabed classification	No	Full	High	MBES / MAG
MBES	Charting of seabed morphology; identification of scours	No	Full	Very high	SSS
MAG	Identification of magnetic anomalies induced by ferromagnetic objects	Yes*1	Full*2	Accuracy = high Precision = poor*3	SSS
SBP/UHRS	Identification of seismic strata and buried objects such as pipelines, cables and boulders	Yes	No Profile data beneath sailed line	High	BH/VC/CPT*4 MAG
BH/VC	Determination physical properties of sediments and lithostratigraphy	Yes VC appr. 5 m bsb BH 60 to 80 m bsb	No Point location	High	CPT/ SBP/UHRS
CPT	Determination of physical properties of sediments and lithostratigraphy	Yes Up to 50 to 80 m bsb	No Point location	High	BH/VC/ SBP/UHRS

Table 6. Characteristics of geophysical and geotechnical methods employed.

NOTE:
*1 detection dependent on size of the ferromagnetic object, depth of burial, height of *magnetometer* above the seabed and distance cross course.
*2 distant and/or deeply buried objects can be missed.
*3 accuracy: perpendicular to ship heading = ½ * spacing of sailed lines; parallel to ship heading = approximately 1 m.
*4 interpretation of geology through correlation of seismic data with BH/VC/CPT-data.

With *side scan sonar* all objects and structures on the seabed can be made visible. Seabed sediment of different composition can be distinguished by their characteristic reflection. *Multibeam* images reveal the morphology of the seabed. Large objects and scouring can be mapped. Smaller objects, like thin cables, or flat objects lying on the seabed often are impossible to identify in *multibeam* images.

The strength of *side scan sonar* resides in the ability to visualize differences in reflectivity of seabed sediments and exposed objects. Variations in seabed composition cannot be observed in *multibeam* data, unless those variations are accompanied by morphological changes. This also applies for objects which are barely elevated above the seabed. Another strength of *side scan sonar* is the full coverage which is accomplished with a limited number of survey lines. A limitation of *side scan sonar* buried objects cannot be found with this technique.

The strength of *multibeam* lies in the high accuracy and high precision images of the seabed morphology the technique provides. Sand waves and current ripples can clearly be observed in *side scan sonar* data, but the height of those sedimentary structures can far better be established by means of *multibeam*. However, buried objects generally cannot not be traced with *multibeam*, scours caused by shallowly buried objects can lead to the identification of buried objects.

In this study *side scan sonar* and *multibeam* data were combined in the identification of objects which are of potential archaeological interest. The listing of potential archaeological objects is considered to be complete as far as it concerns exposed objects, although the presence of buried non-ferro-magnetic archaeological objects or objects which erroneously have been labelled as non-archaeological, can never be fully excluded.

Magnetometer contacts are identified by the presence of ferro-metallic objects which induce an anomaly in the earth magnetic field. These objects can be buried or lying on the seabed. Unlike *side scan sonar* and *multibeam* the contacts are tagged at the sailed survey line. The actual object can be located at both sides of the survey line. Given the 70-meter spacing of the run lines the precision perpendicular to the line is in the order of 35 meter. The precision parallel to the run line is in the order of one meter.

The strength of a *magnetometer* lies in its ability to trace buried objects, if those objects are ferro-magnetic. The technique provides a strong tool in mapping continuous linear structures like buried cables and pipelines. Also, an indication of the presence and distribution of isolated ferro-magnetic objects in an area of investigation is obtained.

An important limitation of the *magnetometer* is the poor accuracy and precision of the positions, size and weight of the objects found. An object must be boxed in by sailing additional lines with a *magnetometer* to pinpoint the location of the object. The measured amplitude of a magnetic anomaly is determined by different parameters, such as the size of the object, the depth of burial, the height of the *magnetometer* above the seabed and the distance cross course. Because the measured anomaly is influenced by multiple unknown parameters it is a priori not possible to deduce the size | iron content of the object from the measured anomaly. Magnetic anomalies are in many cases induced by buried objects. From the character of the magnetic anomaly (monopole or dipole) it is not possible to identify the nature of this buried object.

The listing of *magnetometer* anomalies is expected to be complete as far as it concerns large ferro-magnetic objects. As the line spacing employed is 100 meters it cannot be excluded that especially small distant buried objects have been missed.

Fugro processed their survey data and produced detailed event listings of the *side scan sonar* and *magnetometer* contacts encountered within the survey areas. Like the known objects the locations of the contacts are plotted in a GIS.

In the course of this archaeological assessment a selection was made based on the dimensions of the reported contacts. All contacts have been assessed, and the fraction of contacts larger than or equal to four (4) meters is investigated in more detail, because these objects are considered to be more likely to be related to wreck sites than the smaller contacts. This choice is based on best professional judgment and not prescribed by legislation or the KNA. The purpose of this analysis is to identify contacts that could reflect potential archaeological sites.

This is done by analyses of:

- *Side scan sonar* images included in the survey reports;
- raw *side scan sonar* data (XTF-files);
- raw *multibeam*-data (xyz-files);
- values of magnetic anomalies reported in the survey reports;
- comparison of *side scan sonar* and *magnetometer* contacts;

Apart from the survey data studied the geological constellation and seabed morphology of the area are considered as outcrops of geological strata and sedimentary structures can lead to (apparent) anomalies in the *side scan sonar* record.

The *side scan sonar* images are scanned to define potential archaeological sites. A selection of contacts was made of contacts to be studied in detail. The interpretation and selection of *side scan sonar* contacts is based on best professional judgment. If desired or needed the exact nature of the contacts observed can be established with certainty through the execution of additional research by means of a ROV or divers in a following phase.

Fugro has acquired and processed shallow seismic data using a sub-bottom profiler (SBP) and an ultra-high resolution multi-channel sparker (UHR). The processing involved an analysis of seismic profiles which had a line spacing of 70 m for both the main lines and the cross lines. Observed seismic strata have been digitized and – based on known geological data from the area – lithostratigraphic units have been identified. The base of each lithostratigraphic unit has been interpolated into a grid. The results have been summarized and reported. In addition to the identification and occurrence of lithostratigraphic units, seismic anomalies which are expected to reflect potential hazardous phenomena have been identified.

2.5 Data Analysis

The first step in the data analysis is to cross-reference known objects within the surveyed area with the survey data. For the comparison the results of the desk study and the survey datasets were used. All the known objects were projected in a GIS together with the survey data.

For cross-reference it was assumed that all present possible contacts and anomalies have been reported and described by the survey contractor. The raw data was used only to verify the description of found objects and anomalies as reported.

The positions of the interpreted contacts from the different surveys were compared with the positions of the known objects collected from the databases. Besides that, all the positions of both the survey contacts and the known objects were plotted on the high resolution *multibeam* grid to visualize the morphological influence of the presence of these objects. This assisted in the determination of possible archaeological value of the present remains. If an object had a potential archaeological value, the description of the object was finalized.

Besides the objects detected from the *side scan sonar* survey also the *magnetometer* contacts were plotted on the high resolution *multibeam* grid. For the *magnetometer* contacts that corresponded with the *side scan sonar* contacts within 50 meters of each other, these contacts were related. When in the vicinity of a magnetic anomaly no visible object was found the size of the anomaly defines whether the buried object causing the magnetic anomaly is of potential archaeological interest. If the magnetic anomaly of a contact is more than 500 nT (nano-Tesla) then it is stated that the contact could possibly be of archaeological value[8]. All the *magnetometer* contacts above 500 nT but within 25 meters of the existing cable and pipeline routes are exempt for further investigation. It must be stressed that within this assessment no distinction can be made between anomalies related to possible archaeological objects or anomalies related to (for example) unexploded ordinance (UXO's).

An archaeological assessment has been undertaken for all visible contacts. This interpretation is based on the best 'professional judgment'.

The interpreted seismic data have been assessed to test the archaeological expectation with respect to remains of prehistoric settlements in the area. The archaeological desk study has resulted in the identification of lithostratigraphic units which could contain archaeological levels. The grids produced by Fugro have been used to get an insight in both the lateral and vertical distribution of the lithostratigraphic units and the expected archaeological levels herein. Thus, testing the desk study based archaeological expectation. An important factor included in the assessment is the integrity of layer boundaries, because erosion by natural processes poses a significant threat to archaeological levels. Based on the assessment, zones along the pipeline route which are expected to contain archaeological remains are mapped and presented. The results are reviewed in the context of the activities planned to predict possible influence on the potential archaeological remains.

The analysis was executed in June 2023 by R.W. Cassée (KNA Archaeologist Ma specialism Waterbodems), R. van Lil and S. van den Brenk (both KNA senior prospector). The investigation is carried out according to specifications set up within the Dutch Quality Standard for Archaeology (*KNA Waterbodems 4.1; protocol 4103*).

[8] The designated value of 50 nT to discriminate between anomalies that are induced by objects of possible archaeological value (>50nT) and that are not (<50 nT) is arbitrary. Given the employed lines spacing of 70 m, an anomaly that solely is observed on one survey line could be located within 35 m on either side of this survey line. It is estimated that an iron mass of 1000 kg located at 10 m from the magnetometer will result in a 50 nT magnetic anomaly. On the other hand, an iron mass of 1 kg located within 3 m of the magnetometer will also result in a 50 nT anomaly, albeit that the anomaly with will be less. It is estimated that an iron mass of 100 kg that is located at 30 m from the magnetometer will result in an anomaly of less than 2 nT. This value is often below the limit of detection. If those small values were to be labelled as anomalies caused by objects of possible archaeological interest all magnetic anomalies found in the survey area were to be labelled as such. Therefore, the arbitrary value of 50 nT is chosen, given the current line spacing. If a closer line spacing is used a larger value shall be considered.

2.6 Used Sources

The following sources were used for the analysis:

- Survey data Fugro, original survey data and reported interpretations;
- Archaeological desk study Periplus (19A029-01);
- ARCHIS database Cultural Heritage Agency;
- Archeomare Database;
- Nlhono database Hydrographic Service of the Royal Netherlands Navy;
- Wrecksite.eu;
- Database, Nationaal Contact Nummer (NCN).

For a complete list of used sources and literature see the reference list at page 67.

Italic written words are explained in the glossary at page 65.

3 Results

3.1 Seabed bathymetry and morphology

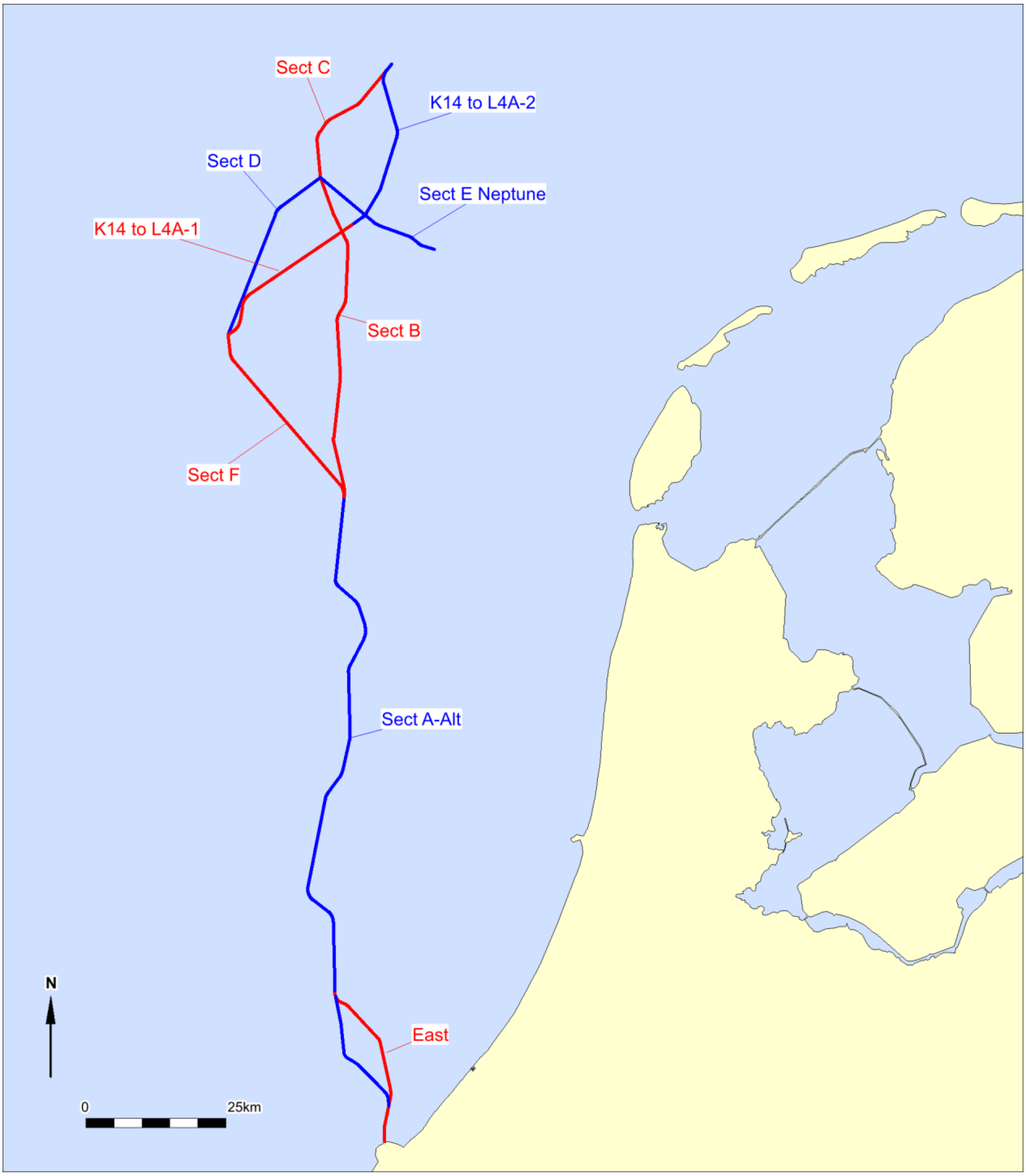

Figure 4. Sections bathymetric profiles based on the multibeam recordings (source data: Fugro 2022)

Based on the 2022 survey data the water depth within the survey corridor varies from 4.8 to 39.6 m, with an average depth of 27.0 m LAT. Bathymetric profiles along the different sections are presented in the next figure.

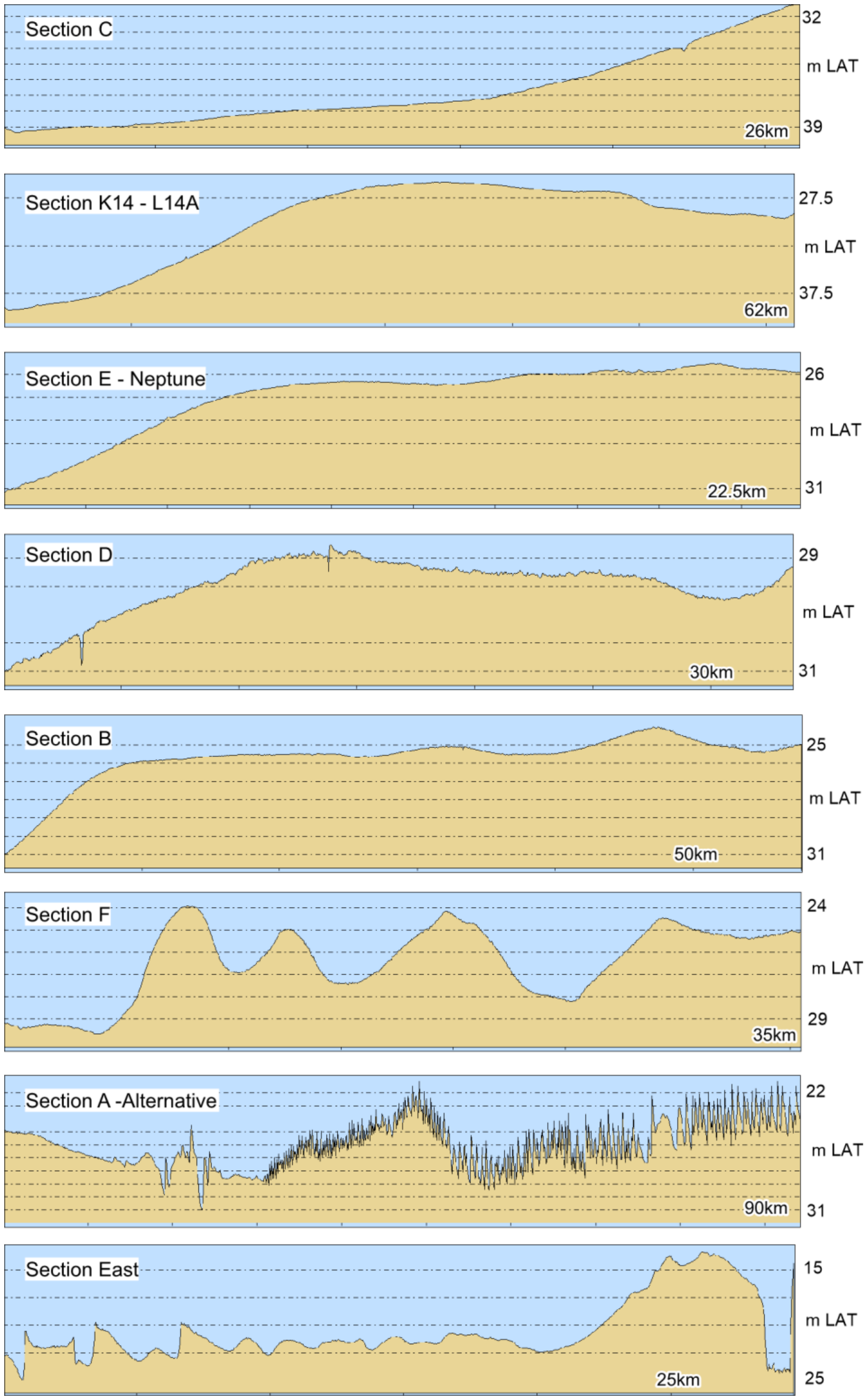

Figure 5. The seabed profiles along the different sections from north to south.

Seabed morphology

The seabed along the route is characterized by a complex pattern of bedforms of various orders. Those bedforms include very large ridges (hereafter sand banks), sand dunes, mega ripples and small ripples. The sand banks are some 2 to 2.5 km wide and stretch more or less north - south. The sand banks are separated by low-lying areas. The difference in height between the troughs and crests of the sand banks is up to 7.5 m. The wavelength of the sand dunes varies, the height of the ranges from 1 m to 3 m. Superimposed on the major sand dunes and sand banks lie mega ripples with an average wavelength of 20 m. The height of the mega ripples ranges from 0.2 m to 0.4 m. The mega ripple crests stretch west northwest - east.

Migration rate

The mobility of the seabed sediments imparts major implications to the prospection of archaeological remains in the area. Wreck remains can be covered by a layer of sandy seabed sediments, as a result the remains are not exposed to the seabed and cannot be traced with *side scan sonar.* Remains can become exposed at a later stage due to the ongoing migration of the sand dunes.

Each of the morphological features in the area has its typical migration rate. The position of the north-south oriented sand banks is fairly stable. Van der Meulen et al. (2004) reported a migration rate for sand dunes of over 20 m/year near the island of Texel, with typical migration rates decreasing southwards to a stationary (0 – 3 m/year) field near the entrance of the Rotterdam Harbour[9]. Deltares studied the migration rate of sand dunes in the Prinses Amalia WFZ and concluded that the dunes in this area migrate some 4 m/year[10].

To assess the migration rate of sand dunes in the IJmuiden Ver wind farm zone a comparison of *multibeam* data acquired 30 days apart was made. Within this short period of time a sand dune had migrated two meters and the shape of the sand dune had altered[11].

[9] Meulen, M.J. van der, et al. 2004.

[10] Fugro survey report P904162, Volume 3.

[11] Van Lil et al. 2023

3.2 Known objects: As Found positions versus database positions.

In the archaeological desk study report a total of 316 archaeological records, 458 shipwrecks, and 3494 other known objects have been reported.

However, the survey area (243 km^2) is considerably smaller than the area which had been defined as area of investigation for the archaeological desk study (11.355 km^2). Additionally, since the finalization of the archaeological desk study, new objects have been added to the NCN-database. The known objects which, according to their database positions are located within the survey area are listed in the table below.

Type	amount
Anchor with chain	2
Seabed distortion	9
Cable or chain	27
Unidentified object	124
Boulder	1
Wreck and wreck remains	8
Total	**171**

Table 7. Known objects within the surveyed area.

The SSS and MBES contacts and the MAG anomalies encountered during this survey have been stored in event listings. The positions of the contacts and anomalies in these listings are compared with the theoretical positions of objects in the NCN database. To conduct this comparison all SSS contacts and MAG anomalies found within a range of 25 meters around the database locations are selected.

The outcome of this comparison can be:

- The As Found position of a shipwreck is in agreement with the database position of a known wreck;
- The As Found position of a contact is in agreement with the position of a contact listed in the database, but the interpretations do not match;
- The As Found position of a shipwreck is not in agreement with the database position of a known wreck;
- A wreck listed in the database has not been found;
- A new wreck has been found.

Known NCN objects found

A total of 37 out of 171 known NCN objects were found during the survey.

NCN	Contact type	E	N	Survey_ID
219	Wreck remains	570384	5762003	BB_FS_SSS_0683
531	Wreck	559172	5935317	BH_FSEA_SSS_0104
967	Wreck remains	550165	5921956	BK_FSEA_SSS_0163
4543	Unidentified object	571058	5762056	BB_FS_MAG_0458
4547	Unidentified object	570585	5761590	BB_FS_SSS_0483
4559	Unidentified object	570645	5763097	BC_FD_MAG_0089
4623	Unidentified object	571139	5761040	BB_FS_MAG_0080
8099	Unidentified object	570782	5761179	BB_FS_MAG_0083
8104	Cable / Chain	570716	5761482	BB_FS_SSS_0433

NCN	Contact type	E	N	Survey_ID
8111	Unidentified object	569849	5761781	BB_FS_MAG_0129
8120	Unidentified object	570177	5761705	BB_FS_MAG_0164
8121	Cable / Chain	570729	5761506	BAB_FS_UXO_0074
13434	Unidentified object	571042	5761479	BB_FS_SSS_0431
13881	Unidentified object	570170	5761683	BB_FS_MAG_0139
13882	Unidentified object	570722	5761528	BAB_FS_UXO_0033
17443	Cable / Chain	570751	5760384	BB_FS_SSS_0019
17446	Unidentified object	569970	5761679	BB_FS_SSS_0513
17852	Unidentified object	570668	5761516	BB_FS_MAG_0147
17863	Unidentified object	570285	5761300	BB_FS_SSS_0307
17866	Unidentified object	570283	5761184	BB_FS_SSS_0241
17870	Seabed distortion	569820	5761550	BB_FS_SSS_0465
17873	Cable / Chain	570079	5761633	BB_FS_MAG_0106
17883	Unidentified object	571009	5761365	BB_FS_SSS_0355
19203	Unidentified object	570846	5761183	BB_FS_MAG_0089
19214	Unidentified object	570608	5761553	BB_FS_SSS_0464
19222	Unidentified object	571021	5761490	BB_FS_SSS_0439
19585	Unidentified object	562818	5899439	BF_FD_SSS_0019
20270	Unidentified object	571246	5761234	BB_FS_MAG_0141
20279	Seabed distortion	570157	5761591	BB_FS_SSS_0481
20280	Unidentified object	570772	5761331	BB_FS_SSS_0328
20282	Unidentified object	570154	5761363	BB_FS_SSS_0374
20283	Seabed distortion	570757	5760383	BB_FS_SSS_0019
20288	Unidentified object	571165	5761318	BB_FS_MAG_0143
29706	Unidentified object	569875	5762289	BB_FS_SSS_0835
33006	Unidentified object	563254	5896797	BF_FD_SSS_0026
33416	Unidentified object	558944	5814439	BD_FD_SSS_0218
33993	Cable / Chain	570971	5761365	BB_FS_SSS_0363

Table 8. As Found NCN objects

Known wrecks found and not found

NCN	E	N	Description	Arch value	Survey_ID
219	570384	5762003	Fishing vessel reported lost in 1945	Unknown	BB_FS_SSS_0683
531	559172	5935317	Wreck reported in 2011. 24x11x2.5m	Unknown	BH_FSEA_SSS_0104
967	550165	5921956	HMS Ivanhoe, sunk 01-09-1940 (ARCHIS ID 4030384100)	Yes	BK_FSEA_SSS_0163
1133	564181	5917118	Wreck reported in 1941, not found during several surveys	No	(not found)
1822	571084	5760899	Sailing vessel Lindis Farne, sunk 03-01-1908. Wreck cleared away according to Hydrographic service	No	(not found)
1902	569952	5777662	Wreck reported in 1945, not found during several surveys	No	(not found)

NCN	E	N	Description	Arch value	Survey_ID
2113	566176	5846859	Steam ship Nipponia, sunk 13-10-1908. Wreck cleared away to a depth of 17 m in 1909. Remains not found during several surveys	No	(not found)
32851	570262	5762370	Motorvessel Clearwater, sunk 29-08-1968. Wreck raised in 1968 according to Hydrographic service	No	(not found)

Table 9. Known shipwrecks found and not found

The five shipwrecks that have not been found during the survey are probably in a different location or completely salvaged in the past, because they were also not found during previous surveys. If they were covered in the seabed, this would have resulted in magnetic anomalies at the locations.

Examples of the shipwrecks that have been found are presented below.

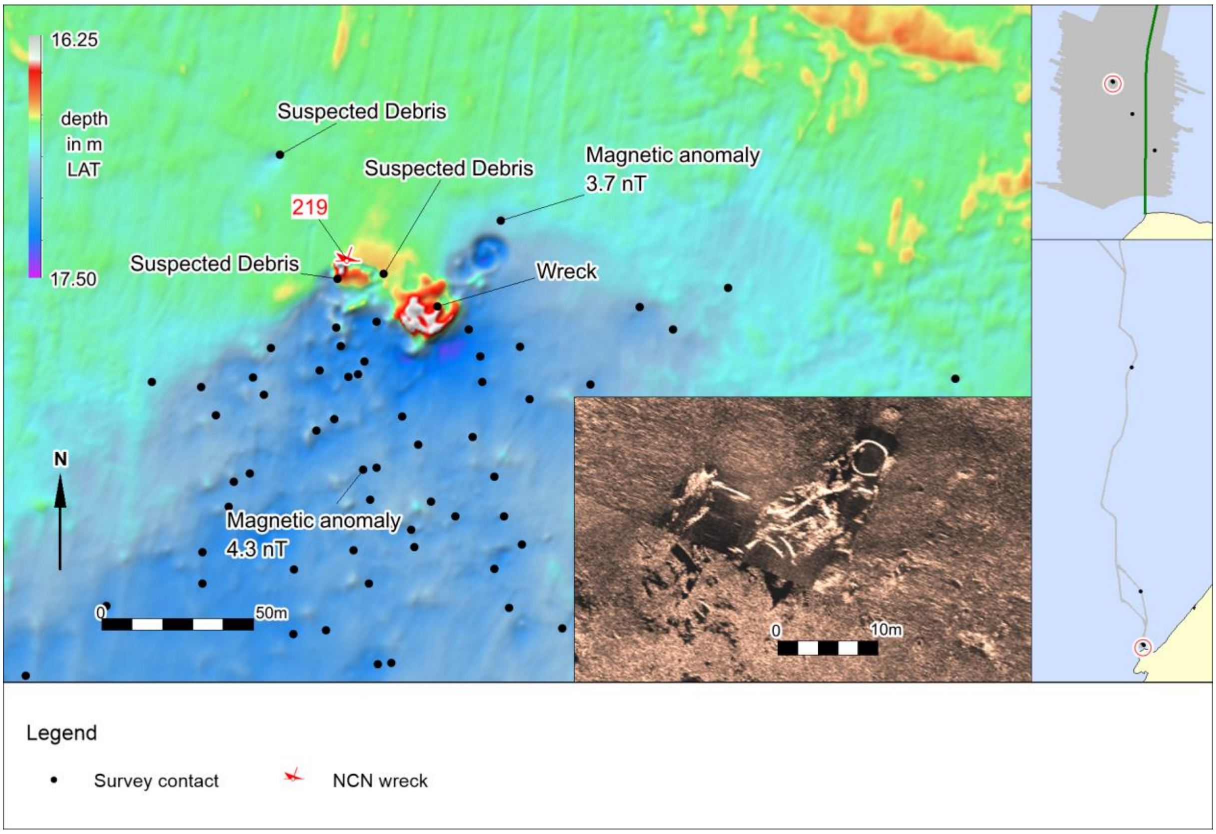

Figure 6. Multibeam image of NCN 219

NCN 219 represents the location of a fishing vessel reported lost in 1945. Both side scan sonar en multibeam images show an area of 22 x 20m scattered with debris at a depth of 17m LAT. Relatively small magnetic anomalies are observed in the surroundings of the area. The location is situated 544 meter west of the proposed route section C-East. The possible wreck remains have not been identified yet, so the archaeological value is not known. It is advised to avoid this location including a buffer zone of 100 meters during pipeline construction.

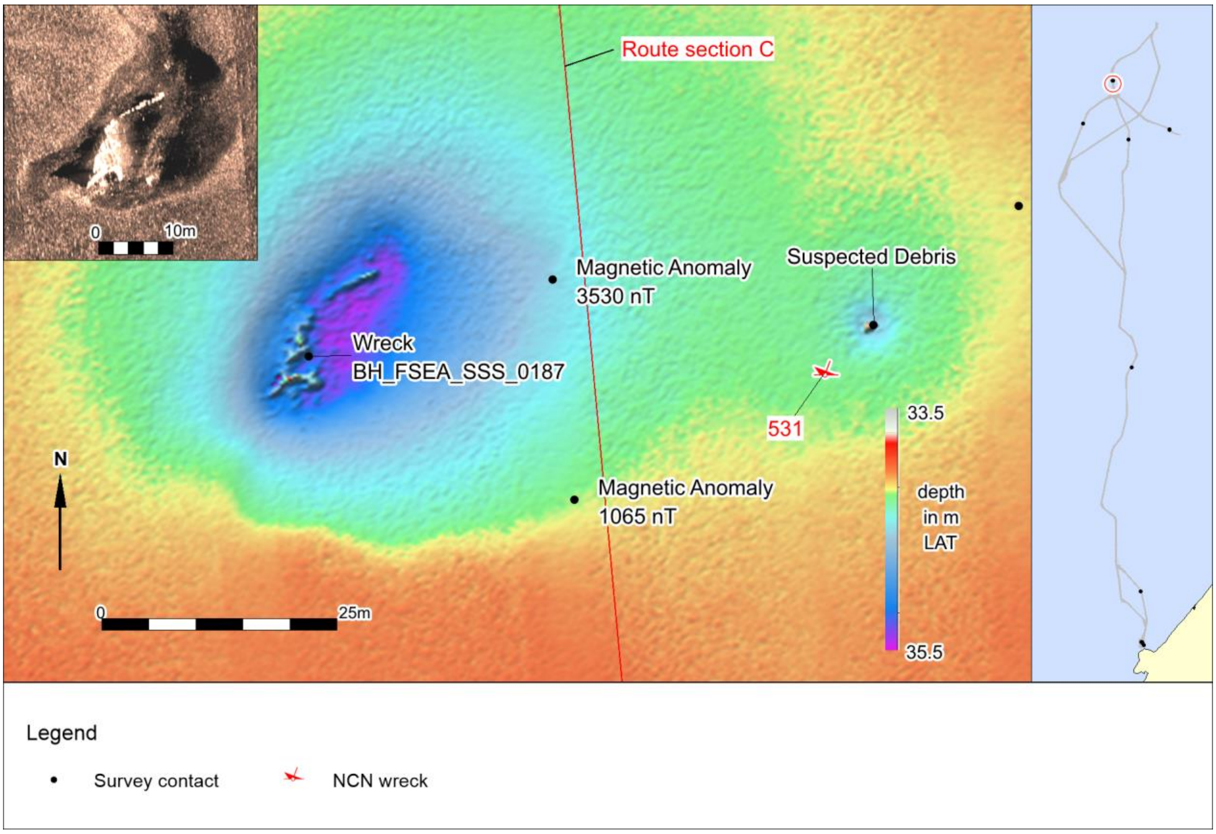

Figure 7. Sonar and multibeam image of NCN 531

NCN 531 is an unidentified wreck reported by the Hydrographic Office in 2011. Both side scan sonar en multibeam images show an area of 63 x 18m at the theoretical location of NCN 531 with a large structure in the west and a smaller object in the east at a depth of 34m LAT. Both locations lie within 30 meters of the proposed route (Section C) In between, very large magnetic anomalies are observed suggesting buried remains. The possible wreck remains have not been identified yet, so the archaeological value is not known. It is advised to avoid this location including a buffer zone of 100 meters during pipeline construction.

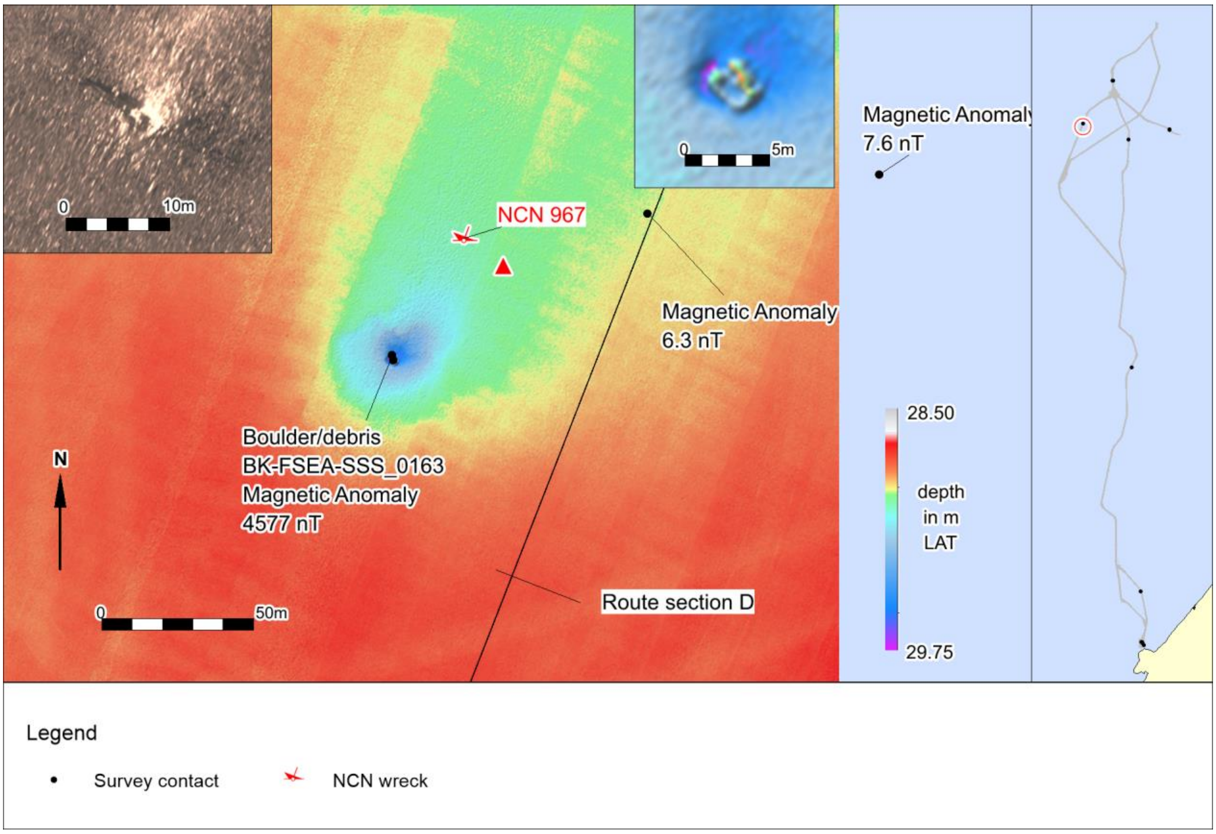

Figure 8. Sonar and multibeam image of NCN 967

Contact BK-FSEA-SSS-0163 is a square object of 2.9 x 2.6 m at a depth of 29m LAT surrounded by scouring. At the location, a very large magnetic anomaly of 4577 nT was observed. Smaller anomalies lie to the east of the object and may present buried wreck remains. The object is located within 50 meters of the theoretical position of NCN 967. This represents the wreck of the HMS *Ivanhoe*, a British destroyer built for the Royal Navy in the mid-1930's. Together with sistership HMS *Esk* it hit a mine on August 31, 1940 and sunk. The location of the wreck of the HMS ESk is confirmed and lies 2900m to the east.

The location is situated 63 meter west of the proposed route section D. If these are the remains of the HMS Ivanhoe, it is considered to be of archaeological value. It is advised to avoid this location including a buffer zone of 100 meters during pipeline construction.

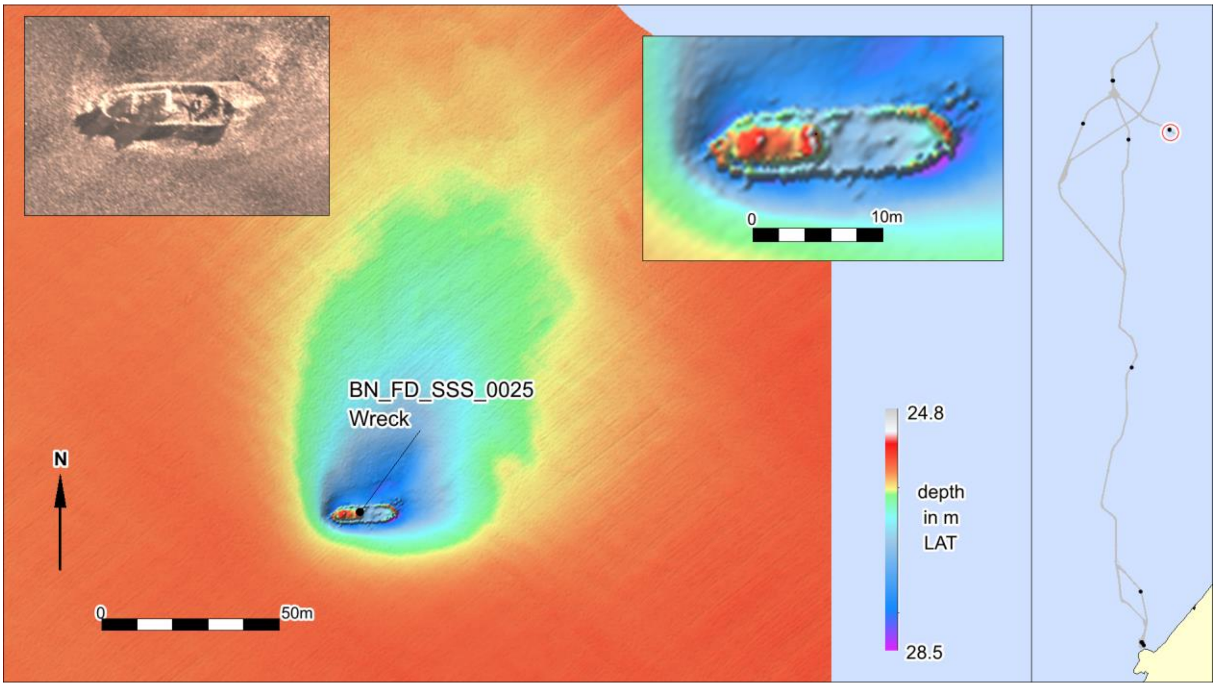

Figure 9. Sonar and multibeam image of contact BN_FD_SSS_0025

Contact BN-FD-SSS-0025 is an unidentified wreck. Both side scan sonar en multibeam images show a clear shipwreck with dimensions of 19.7 x 5.1 x 1.0 m at a depth of 25 m LAT. The location lies 220 m northeast of proposed pipeline section E.

The wreck has the characteristics of a fishing trawler. This might be a known wreck (NCN 945) which theoretical location is situated 200 meters to the north, just outside of the surveyed area. NCN 945 represents the fishing trawler *Stormvogel* (IJM 9) sunk at 7-04-1981 and has no archaeological value.

3.3 Side scan sonar

Fugro has identified 3806 *side scan sonar* contacts within the surveyed corridor. The classification of the contacts is listed below.

Classification	Amount
Boulder	3010
Debris	159
Depression Pockmark	5
Fishing Gear	7
Mattress	2
Pipeline	4
Seabed Mound	98
Suspected Debris	517
Wreck	4
Total	**3806**

Table 10. Side scan sonar contacts identified by Fugro

The objects classified as '*Boulder*' are found throughout the whole surveyed area. These probably also include clay boulders, because known stone boulders in the North Sea only occur north of the city of Den Helder.

All contacts which match known objects have been discussed in the previous paragraph. The remaining *side scan sonar* contacts and images have been scanned and checked for the presence of potential archaeological contacts. This is done by analyses of:

- *Side scan sonar* geotiffs;
- *Multibeam* grids;
- Comparison of *side scan sonar* and *magnetometer* contacts.

Apart from the survey data studied, the geological constellation and seabed morphology of the area are taken into account, as outcrops of geological strata and sedimentary structures can lead to (apparent) anomalies in the *side scan sonar* record.

All side scan sonar contacts greater than four meters in any dimension, 117 in total, have been examined in detail, because these objects are considered to be more likely to be related to wreck sites than the smaller contacts. The purpose of this analysis is to identify contacts that could reflect potential archaeological sites.

A summary of the outcome of the detailed inspection of selected contacts larger than four meters is presented in the table below. It should be noted that the seven contacts that are classified as '*wreck*' refer to four different wrecks, which are already discussed in the previous paragraph. Appendix 3 contains a complete listing of the results of this assessment.

Category	Amount
Anchor	1
Buoy anchor	1
Cable/chain	10
Matress	3
Natural ridge	1
Pipeline	4
Seabed disturbance	11
Shell bed	1
Shipwreck	7
Spudcan depression	4
Unidentified object	74
Total	**117**

Table 11. Results of the assessment of selected side scan sonar contacts

At total of seven side scan sonar contacts larger than four meters are attributed to four different wreck sites (which have been discussed in section 3.2) and three possible new wreck sites. Additionally, one side scan sonar contact is attributed to a large anchor. The summary of the side scan sonar records with potential archaeological interest is listed below.

Feature	Easting	Northing	Fugro	L	W	H	Z	Interpretation PPA
BK_FSEA_SSS_0022	551288	5924521	Boulder	5.6	2.9	5.2	-29.8	Buried remains with magnetic anomalies - wreck remains
BK_FSEA_SSS_0179	555839	5929168	Boulder	6.7	5.7	1.0	-30.3	Large anchor shaft 3.2m arms 2.1m with scouring
BJ_FD_SSS_0015	548443	5894128	Debris	5.6	1.8	0.0	-26.4	Elongated object 5.6m - wreck remains
BB_FS_SSS_0433	570711	5761481	Wreck	4.3	2.4	0.3	-18.9	Oval contact, possibly wreck remains

Table 12. Listing of side scan sonar records with potential archaeological interest.

The results with examples of the four objects are discussed below.

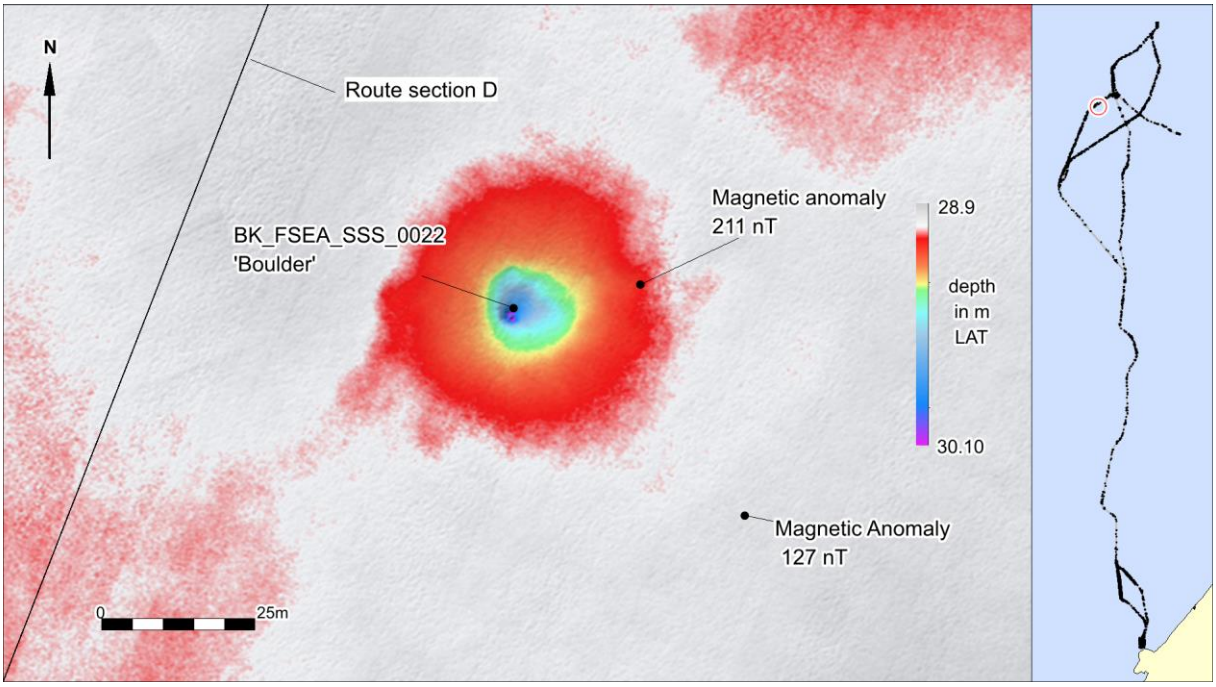

Figure 10. Multibeam image of survey contact BK-FSEA-SSS-022

Contact BK-FSEA-SSS-0022 was interpreted by Fugro as a '*boulder*'. The multibeam image shows an object surrounded by a round scour depression with a diameter of 30 meters and a relative depth of one meter.

Two large magnetic anomalies have been observed to the east of the contact. These might represent a buried structure; possibly unidentified wreck remains. The location lies 55 meters east of route section D.

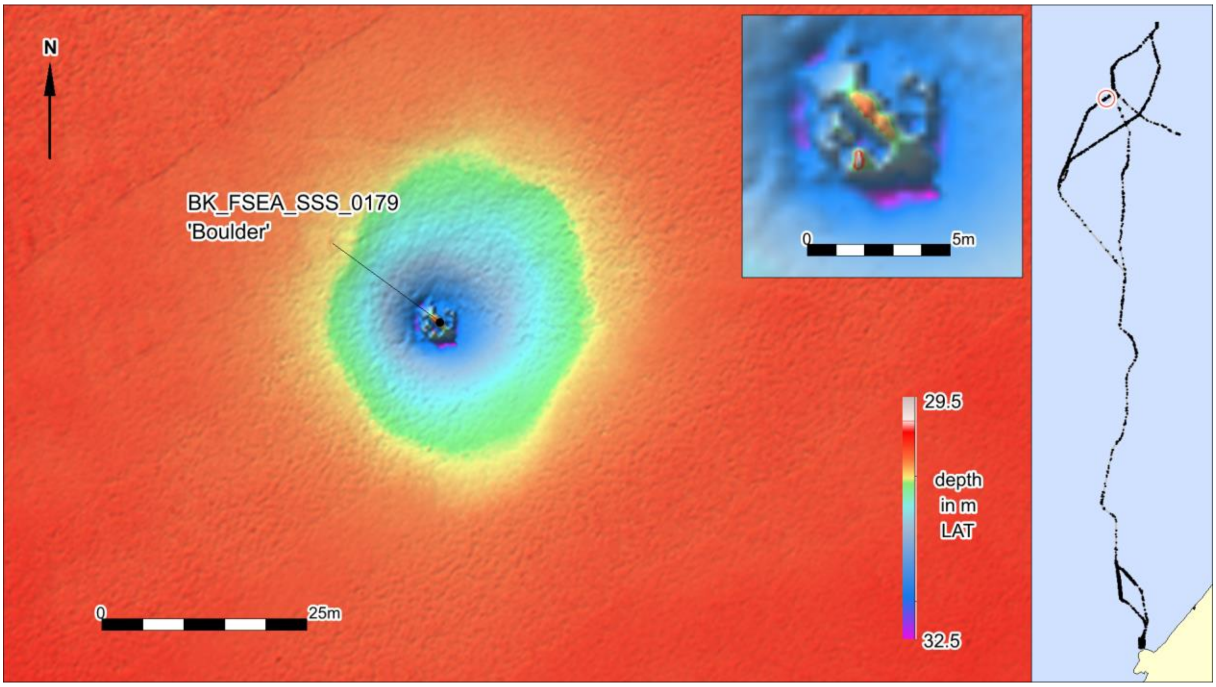

Figure 11. Multibeam image of survey contact BK-FSEA-SSS-0179

Contact BK-FSEA-SSS-0179 was interpreted by Fugro as a '*boulder*'. The multibeam image shows a triangular object surrounded by a round scour depression with a diameter of 20 meters and a relative depth of 1.5 meter. In more detail, the object resembles an anchor with a shaft length of 3.2 meters and arms of 2.1 meters. This might be an historical Admiralty Pattern anchor, or simply "Admiralty", commonly used in the 17th and 18th century. The location lies 240 meters west of route section D.

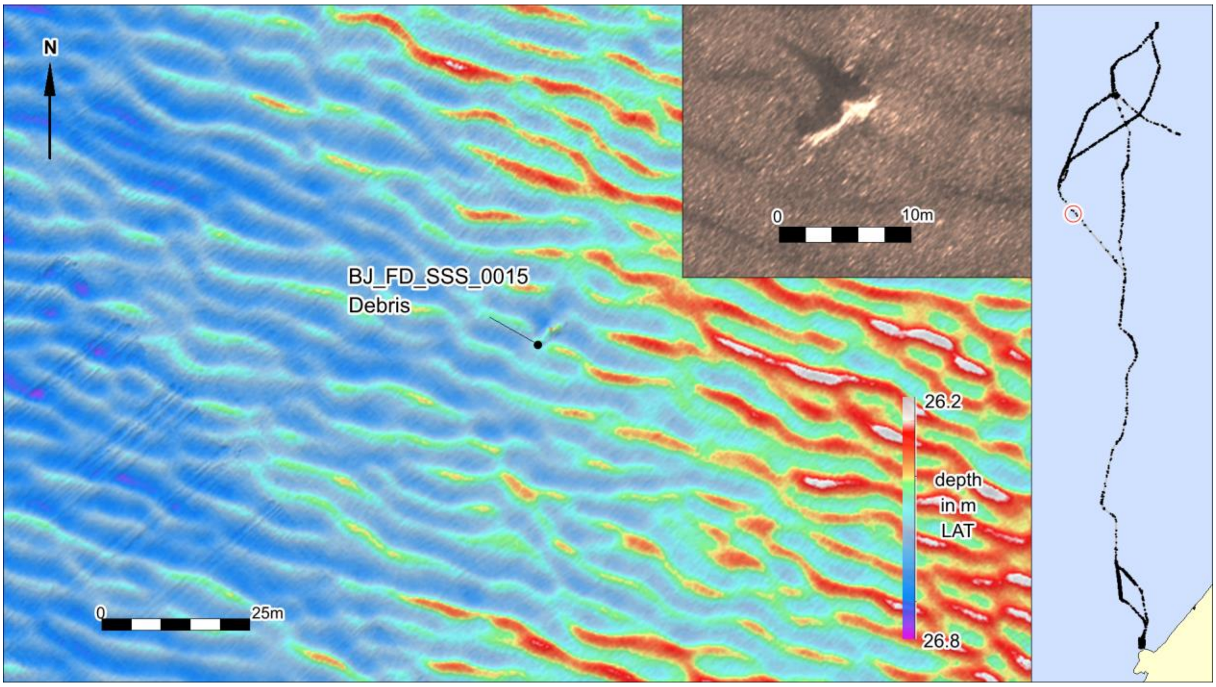

Figure 12. Sonar and multibeam image of survey contact BJ-FD-SSS-015

Contact BJ-FD-SSS-0015 was interpreted by Fugro as a '*debris*'. Both multibeam and side scan sonar images show an elongated irregular object of 5.6 x 1.5 x 1.0 meters perpendicular to the surrounding sand ripples. No magnetic anomalies have been observed in the surrounding area. The object might be the remains of a wreck. The location lies 232 meters east of route section F.

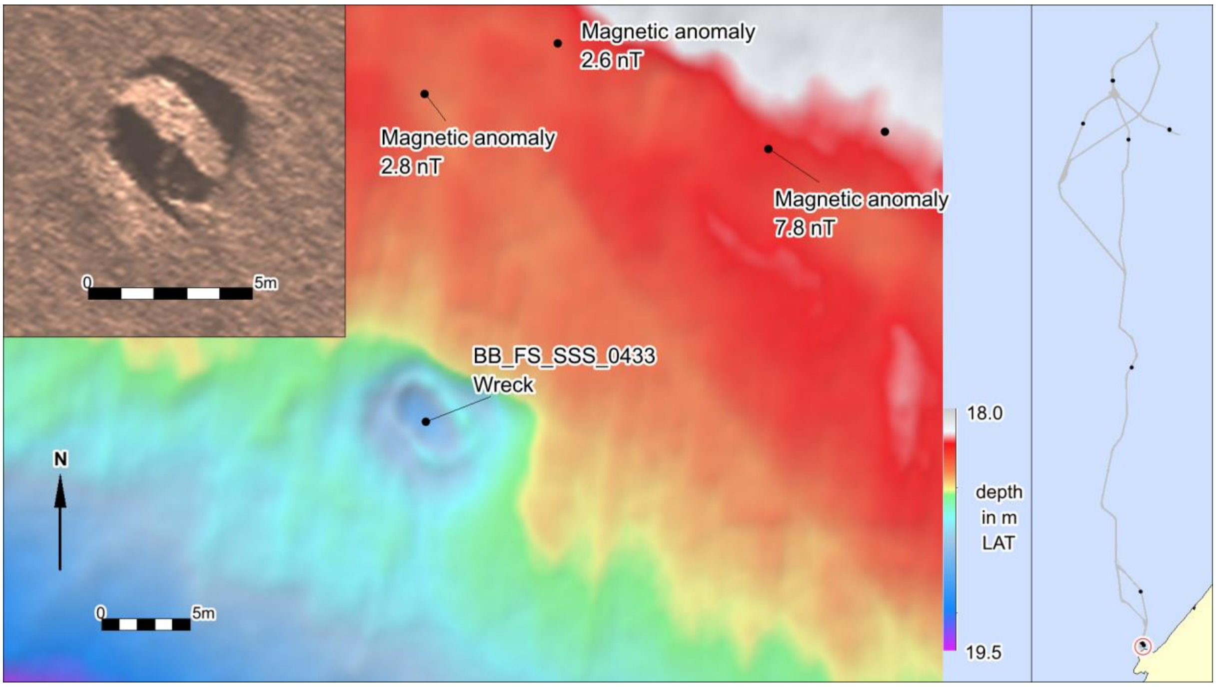

Figure 13. Multibeam image of survey contact BB-FS-SSS-0433

Contact BB-FS-SSS-0433 was interpreted by Fugro as a ‘wreck’. Both multibeam and side scan sonar images show an oval object of 4.3 x 2.4 x 0.3 meters surrounded by (relatively small) magnetic anomalies. The object might be the remains of a wreck. The location lies 216 meters west of route section West.

Summary of side scan sonar / multibeam contacts

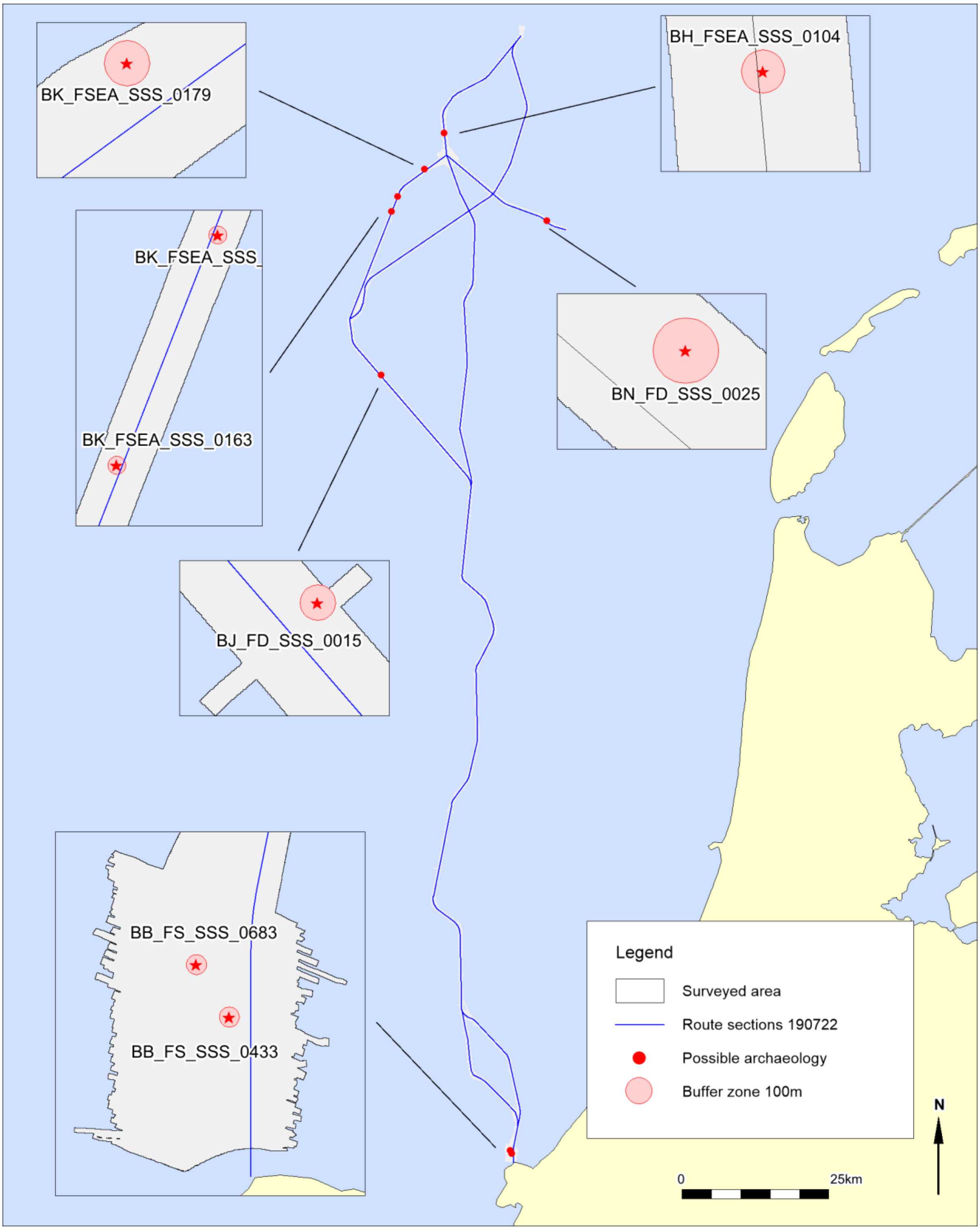

Figure 14. Overview of all side scan sonar / multibeam contacts with an archaeological expectation

3.4 Multibeam

Apart from the *multibeam* images discussed in the previous sections no *multibeam*-features have been observed outside the side scan sonar contacts which are interpreted to reflect the presence of archaeological objects or structures.

3.5 Magnetometer

A total of 2748 magnetic anomalies have been observed within the area of investigation. An overview is given in the next figure.

Figure 15. Spatial distribution of all magnetic anomalies

A number of these anomalies can be related to infrastructure (cables and pipelines), but the majority have an unknown origin. Although the nature of these objects is not known it is possible that the anomalies represent archaeological remains buried in the seabed, and therefore have to be taken into account within this assessment. The average line spacing for the magnetometer was 20 to 40 meters. A minimum value of 500 nT has been used to classify the objects as potentially archaeological targets.

Note on magnetic anomalies and value of 500 nT.
A magnetic anomaly is a local deviation from the natural magnetic field, expressed in nanoTesla. The measured value depends on the mass of the iron contained by an object, but also largely on the distance between magnetometer and the object. With a relatively large line spacing (>= 100m) chances are, that objects are missed or have an apparent lower reading on the magnetometer.

For example: a mass of 1000 kg iron results in a value of 50 nT at 12 meters, and 500 nt at 5 meters. The term 'large anomaly' is therefore subjective and depends mainly on the line spacing of the magnetometer survey.

For archaeological assessments, as a rule of thumb, the following minimum values for unidentified deviations are therefore considered to be of archeological interest:
Line spacing ~100 meters: 50 nT
Line spacing ~50 meters: 500 nT

According to Fugro, 212 anomalies with an unknown origin are larger than 500 nT. After re-examination, 202 anomalies can be associated with known present objects like pipelines and wellheads.

Association	**Amount**
Cable	1
Pipeline	194
Wellhead	2
Known NCN	5
Unknown	10
Total	**212**

Table 13. Magnetic anomalies over 500 nT

The remainder, a total of 10 magnetic anomalies, cannot be related to known pipelines and cables, or visible objects at the seabed surface. These anomalies are induced by unknown ferrous objects buried in the seabed, covered by sediments. These objects could consist of pieces of cable, chain, debris, lost anchors, UXO, iron parts of shipwrecks, et cetera. The 10 objects which induced anomalies of more than 500 nT are considered to be of potential archaeological interest, until proven differently.

An overview is presented in the figure below.

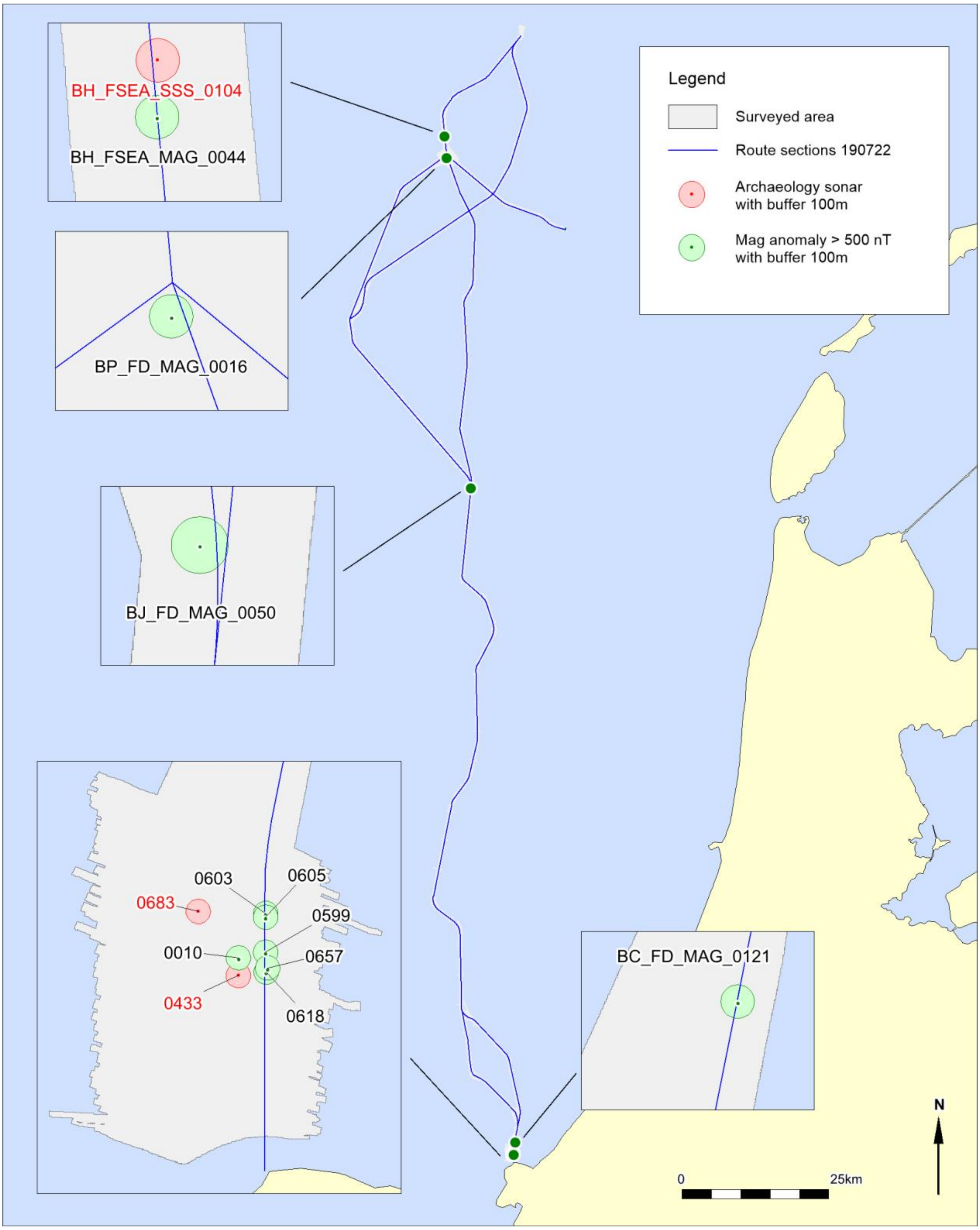

Figure 16. Magnetic anomalies larger than 500nT not related to known objects, infrastructure or objects found with side scan sonar.

3.6 Subbottom data

Desk study results

The archaeological desk study has indicated that the combined thickness of the *Holocene* sequence is expected to range from 0 to 30 meters in the area.

The variations in thickness are due to:

- lateral variations in water depth, mobility of the seabed, sediment supply and sedimentation rate from the onset of the Early Holocene till present day.
  general trend:
  a) near coastal shallow waters with high mobility of seabed in the southern part: high thickness of Holocene cover;
  b) distal parts of trajectories with deep waters and low mobility of seabed: thin Holocene cover;

- the morphology of the seabed
  a) in part of the trajectory sand ridges and sand waves occur (Pleistocene deep-seated), which alternate with:
  b) low-lying areas in between those ridges and sand waves (Pleistocene more roximate to seabed surface);

- the original morphology Pleistocene landscape which was present prior to the Holocene marine ingression in the area;

- the various extent to which the Pleistocene landscape has eroded during the Holocene marine ingression.

The *Holocene* units include the surface sediments of the Bligh Bank Member (south) and Terschellingerbank Member| Southern Bight Formation and the Urania Formation (north). Those units locally cover deposits of the Wormer Member | Velsen Bed | Naaldwijk Formation and/or the Basal Peat Bed | Nieuwkoop Formation.

Just north of the Maasgeul a more than one-meter-thick bed of stiff Early to Mid-Holocene river clay is present. This clay is part of the Echteld Formation and wedges out to the north. Stratigraphically this clay of the Echteld Formation is positioned in between the Basal Peat Bed and lagoonal and marine deposits of the Wormer Member | Naaldwijk formation. Further, in the Maasgeul area Early Holocene overbank deposits of the Rhine can be present. These stiff ripened clays and silts are classified as the Wijchen Bed | Kreftenheye Formation. On top of the Wijchen Member locally Early Holocene wind-blown deposits (river dunes) of the Delwijnen Member can be present. The flanks of these river dunes are covered by the Basal Peat bed and Echteld Formation.

The *Holocene* deposits cover *Pleistocene* units of:

- the Eem Formation (Eemian marine)
- the Brown Bank Member | Eem Formation (Early Weichselian lagoonal and shallow marine)
- the Kreftenheye Formation (Pleniglacial river), and
- the Boxtel Formation (Late Glacial terrestrial - stream deposits and aeolian).

To illustrate the variations in the subsurface geology we present in figure 17 the Top Pleistocene Map by TNO | Laban from 2004 and the Geological Map of the Netherlands produced by Geological Survey of The Netherlands in 2021. This image provides a reference framework for the interpretation of the subbottom profiler data.

In the left panel of figure 17 the 2004 Top Pleistocene map is displayed. This map shows the Pleistocene units that subcrop below a cover of Holocene deposits. Those Holocene deposits include the mobile sands of the Bligh Bank Member | Southern Bight Formation and towards the north the Terschellingerbank Member | Southern Bight Formation and Urania Formation which are exposed at the seabed over the full extent of the route. Locally these recent deposits cover Early Holocene deposits of the Basal Peat Bed | Naaldwijk Formation and Wormer Member | Naaldwijk Formation.

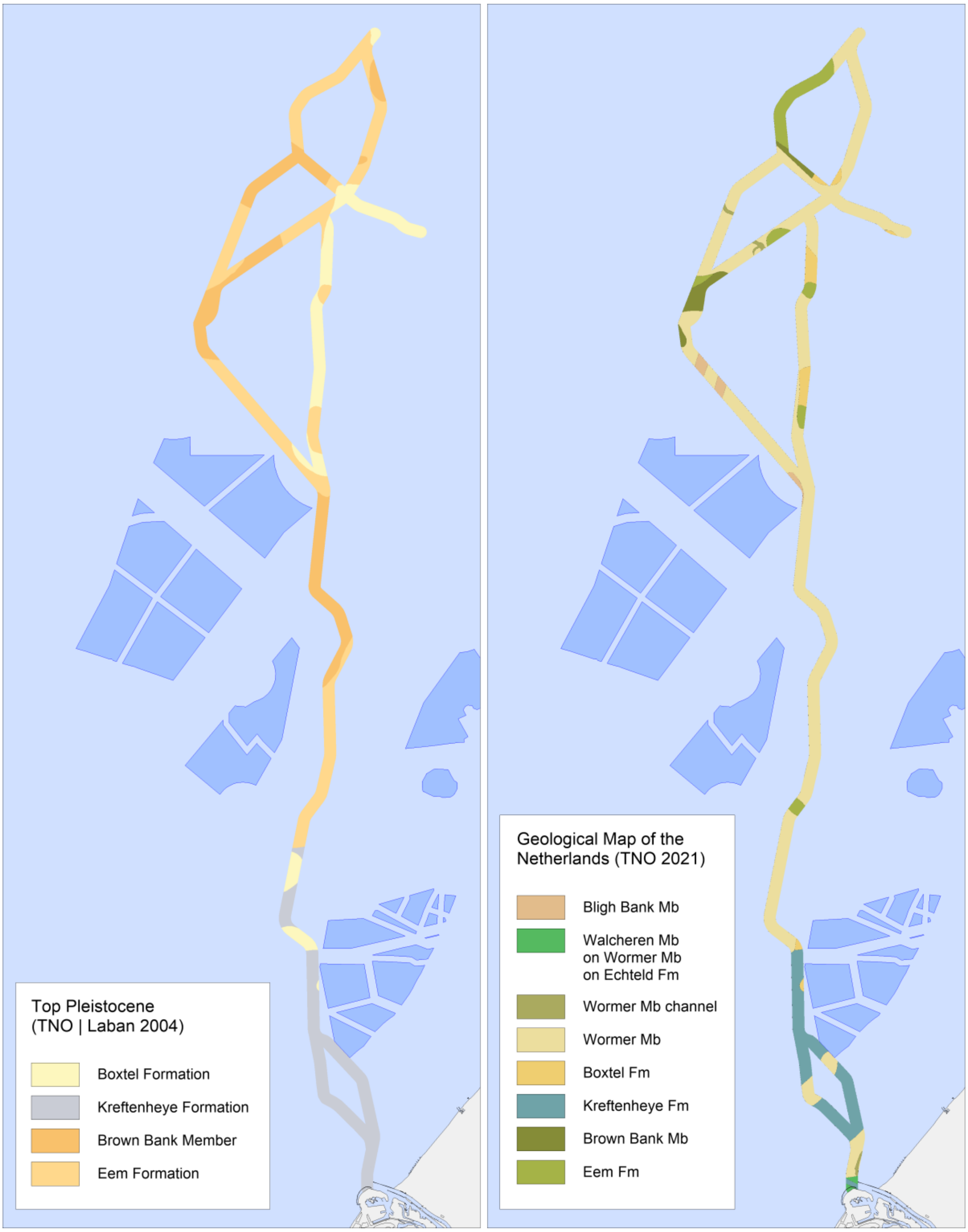

Figure 17. Subcropping Pleistocene units within 2000-meter corridor along the optional Aramis routes according to the 2004 Top Pleistocene Map and 2021 Geological map of the Netherlands; wind farm sites displayed to provide some spatial context.

As described above, in the Maasmond area Early to Middle Holocene fluvial clays of the Echteld Formation are present. Also, local occurrences of Early Holocene river dunes of the Delwijnen Member | Boxtel Formation and repined overbank clays of the Wijchen Member | Kreftenheye Formation could be encountered.

The Geological Map of the Netherlands is shown in the right panel of figure 17. This image shows the units that are subcropping below the Southern Bight Formation and Urania Formation. Contrary to TNO | Labans' map those subcropping deposits also include Holocene units.

In the online explanatory document that comes along with the Geological map the following is stated: '*Coversand (BX4: Boxtel Fm, Wierden Mb) and loess (BX5: Boxtel Fm, Schimmert Mb) are only shown if more than 2 m thick. The ubiquitous layer of actively transported open-marine sand (SB2: Bligh Bank Mb) is only shown if it is more than 7 m thick. Anthropogenic deposits are not shown on the map.*'

Occurrences of the Boxtel Formation are very often less than 2 meter thick. It should therefore be borne in mind that in areas where other units such as the Brown Bank Member are mapped the Boxtel Formation can still be present as a thin bed topping this unit.

Another important note is that recent research in the IJmuiden Ver Wind Farm Zone and personal communication with Cees Laban indicates that offshore deposits that in the past - based on seismic data - were classified as the Wormer Member[12] also include small-scale fluvial and aeolian deposits of the Late Glacial Boxtel Formation. The Boxtel Formation is often found offshore in stream valleys. Stream valleys were low-lying parts of the paleo-landscape. Because of this relative low-lying position and the presence of firm beds of the Early Holocene Basal Peat Bed and clayey Velsen Bed the Boxtel Formation was better protected against erosion in the stream valleys than in the surrounding landscape.[13]

[12] In the 20th Century the units that currently are classified as the Wormer Member and Basal peat Bed were mapped as the 'Elbow Formation'.

[13] Pers. Comm. F. Busschers 2023.

Assessment of seismic data

Table 14 shows the shallow seismic units which have been identified by Fugro along the Aramis route trajectories. The table contains an interpretation of the lithostratigraphic units that according to Fugro could be part of the identified seismic units.

Dataset	Unit	Horizon Top	Horizon Base	Seismic Signature and Character of the Base	Distribution	Lithology[1]	Geological Formation / *Member*	Depositional Environment
SBP	DS	H00	H_DS	Semi-transparent and chaotic. The basal reflector marks the change from chaotic to acoustically transparent or structured seismic facies.	Present in nearshore part only (Maaskanaal)	Clayey sand to sandy clay	-	-
	A	H00	H10	Acoustically transparent to chaotic, with locally high amplitude reflections. Base is marked by a medium to high amplitude, flat reflector.	Present across the entire route	Sand	Southern Bight	Marine
SBP, 2D-UHRS	B	H00, DS, H10	H15	Various; semi-transparent and structureless to locally bedded with low to medium amplitude parallel reflectors; locally, internal channels with high amplitude parallel reflectors observed; locally internal erosion surfaces observed. The base is locally channelised and the infill of these channels has typically chaotic or structured (layered) character with high amplitude reflections. The basal reflector has a medium to high amplitude; irregular to undulating. High amplitude (negative on the 2D-UHRS) reflectors may indicate layers/pockets of peat / organic clay frequently present in this unit.	Present basically across the entire route; locally absent in the southern part of the route	Sand, clay, locally laminated sand and clay, locally thin beds or laminae of peat	Naaldwijk Boxtel Kreftenheye	Coastal to tidal-flat, locally lagoonal; locally periglacial to fluvial
2D-UHRS	C	H15	H20	Mostly structured (layered) with low to medium-amplitude parallel reflectors. Locally, in the upper part of the unit, structureless, semi-transparent interval locally semi-transparent, structureless. In the north-eastern part of the route, the unit is characterised by overall semi-transparent seismic facies with local high amplitude negative reflectors of various extent. The high amplitude reflectors may indicate layers of pockets of peat and/or organic clay. Base forms a sub-horizontal erosional surface, locally forming broad channels/depressions.	Present in the central and large portion of the northern part of the route	Laminated sand and clay, locally sand, locally thin beds or laminae of peat	*Brown Bank*	Lagoonal, estuarine, tidal flat
	D	H15, H20	H25	Acoustically transparent to semi-transparent, structureless. Locally, layered intervals, internal erosion surfaces marked by strong undulating or inclined reflectors. Internal channelling features are locally present. The infill of these channels is various from chaotic to structured (layered). Base forms a sub-horizontal erosional surface, locally forming channels.	Present almost across the entire route, except small area in the centre and in the most southern part of the route	Sand	Eem Kreftenheye (nearshore)	Marine
	E	H25	H30	Acoustically transparent to semi-transparent, structureless; locally chaotic. Base forms a sub-horizontal erosional surface, locally forming channels.	Present in the northern part of the route	Sand	Egmond Ground	Marine
	F	H25, H30	H35	Semi-transparent infill with occasional amplitude anomalies. locally discontinuous, wavy and steeply inclined medium-amplitude reflectors. Internal channels near the top. The basal reflector forms U-shaped channel / valley.	Present locally in the northern and central part of the route	Sand with clay interbeds	Peelo	Fluvio-glacial, glacio-lacustrine (subglacial valley infill)
	G	H20, H25, H30, H35	H40 (internal) BPD	Chaotic to acoustically semi-transparent, locally discontinuous, inclined medium-amplitude reflectors. Locally, internal erosion surfaces and internal channels / channelling features. Horizon H40 marks internal erosion surface, at which locally high amplitude negative reflectors are present, indicating a thin bed or laminae of peat /organic clay.	Present across the entire route	Sand with local clay interbeds	Yarmouth Roads	Fluvio-deltaic to marine

Notes:
DS = disturbed sediments
Hyphen = not applicable
BPD = below penetration depth of seismic reflection data
1) predominant soil type; more detailed information will be provided in the Integrated Report (F197217-REP-007), which will include data of the geotechnical investigation

Table 14. Overview of seismostratigraphic units (source: Fugro survey report F197217-REP-001)

The result of the assessment of the prehistoric landscapes from the subbottom profiler and UHRS data is described below. A geological x-section from south to north along the sections nearshore east, A, B, and C is included as Appendix 3 in this report. Focus is put on the upper 5 meters below the seabed plane that marks the base of the mobile seabed sediments, because the As Planned pipeline installation foresees a burial depth of 1 m below the seabed after a pre-sweep of sand waves have been carried out. This does not mean that geological units that occur at greater depths are fully disregarded. Phenomena of interest for the evolution of prehistoric landscapes are looked into.

Section Nearshore East

This x-section covers:

- the landfall of the pipeline at the Maasvlakte 2,
- the pipeline crossing of the Maasgeul,
- the shallow parts of the seabed with depths less than 15 meters north of the Maasgeul between KP 1.5 and KP 8.5 in a section that can be described as a bulge, and
- the trajectory between KP8.5 and KP 30.6 with depths varying from 20 to 30 meters.

Both on the southern and northern edge of the Maasgeul Pleistocene en Holocene units are exposed at the intersection of these layers and beds with the Maasgeul. North of the Maasgeul the top of Unit B likely consists of Mid-Holocene fresh-water fluvial tidal deposits of firm to stiff clay with plant remains. This bed of clay is part of the Echteld Formation.

To illustrate the different sediment beds and lithostratigraphic units that are contained in Unit B in the Maasgeul area we projected the lithological column of DINO borehole B37A0952 onto the x-section of the Nearshore East section. The borehole lies 46 m west of the route trajectory. No lithostratigraphic interpretation is given in DINO.

We interpret the sequence from bottom to top as:

- medium coarse sand of the Kreftenheye Formation,
- peat and organic clay of the Basal Peat Bed,
- very coarse sand with clay bed of Wormer Member (?),
- clay of the Echteld Formation.

Between KP 1.5 and KP 6.5 the Echteld Formation is covered by tidal deposits of the Wormer Member and the Walcheren Member | Naaldwijk Formation, and mobile sands of the Bligh Bank Member | Southern Bight Formation (Unit A). Within this KP 1.5 to KP 6.5 section the Echteld Formation wedges out towards the north.

Further north, around KP 5.0 foresets are observed in the upper part of Unit B (see figure 18 below). We interpret the upper part of Unit B as estuarine deposits of the Naaldwijk Formation. At the base Fugro mapped acoustic blanking. It is not known if the blanking is related to occurrences of peat in the subsurface.

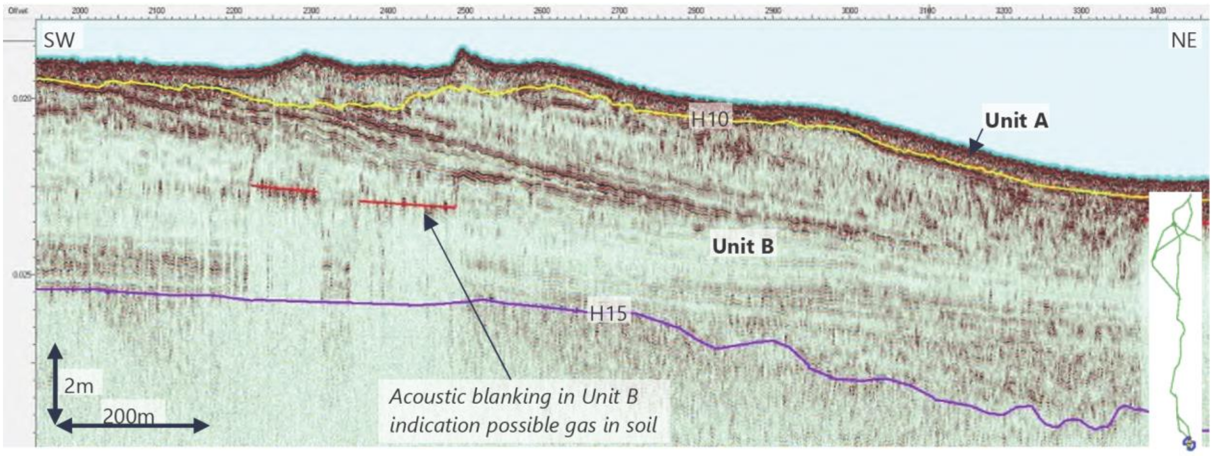

Figure 0.12: SBP data example of acoustic blanking in Unit B. (Line SBP_TA3C2020P1)

Figure 18. Wormer Member | Naaldwijk Formation in the upper part of Unit B around KP 5.0 of the Section Nearshore East

The section between KP 8.5 and the end of Section Nearshore East at KP 30.5 shows a gradual thickening of Unit A. The thickness of Unit B varies from 1 to 4 meters. Possibly Unit B represents tidal deposits of the Wormer Member. However, this is not certain. As can be seen in figure 19 Unit B has a (semi)transparent character, while the underlying Unit C has a more homogenous character with occasional anomalies. It might be possible that both Unit B and Unit C consist of Pleistocene deposits of the river Rhine that are classified as the Kreftenheye Formation, with H15 being an internal reflector.

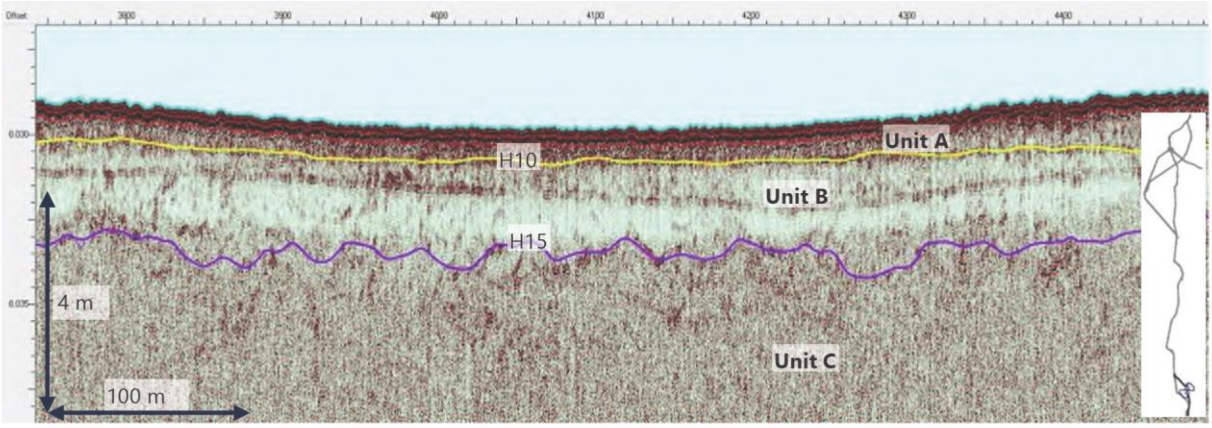

Figure 0.9: SBP data example of route section Export Route East MT. (Line SBP_TA3C2016P2)

Figure 19. River sands of the Kreftenheye Formation (Unit C). The interpretation of Unit B is uncertain. Unit B could also consist of the Kreftenheye Formation with H15 as an internal reflector or Unit B consists of Holocene tidal deposits of the Wormer Member.

Section A

In this section the seabed morphology is characterized by up sand dunes with elevations up to 5 meter relative to the surrounding seabed. The sand dune crests lie on average some 500 meters apart. The sands from which the dunes are built are classified as the Southern Bight Formation | Bligh Bank Member. The base of the Unit A (reflector H10) likely coincides with the base of the Bligh Bank Member. However, in places where the Bligh Bank Member covers sandy deposits of the Wormer Member, the layer boundary between those two lithostratigraphic units might not show as a reflector in the subbottom profile. Where a classic Early Holocene bottom to top sequence of the Nieuwkoop Formation | Basal Peat Bed, organic clay of the Naaldwijk Formation | Velsen Bed and coarsening upward fine sand of the Naaldwijk Formation | Wormer Member has been preserved intact, the transition from the generally thin layers of the Basal Peat Bed and Velsen Bed to underlying Pleistocene sands will show as a distinct reflector in the subbottom profile. Therefore, it is possible that Unit A also includes those Early Holocene organic and argillaceous deposits. Intermittent occurrences of peat and/or organic clay have been mapped at the transition from Unit A to Unit B. We interpret these occurrences of peat and organic clay as the Basal Peat Bed and Velsen Bed. An example is shown in figure 20.

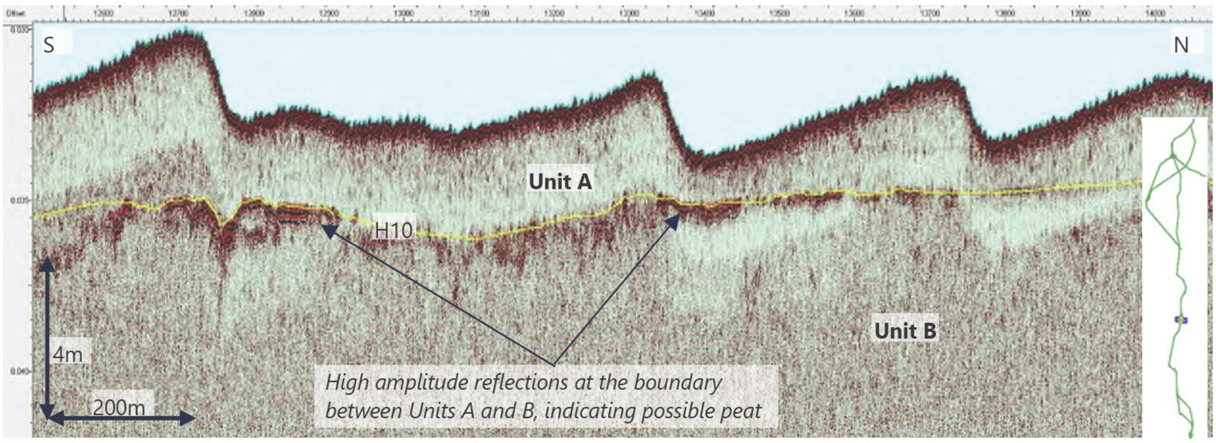

Figure 0.11: SBP data example of anomalies indicating possible peat in Unit B. (Line SBP_TA3E2134P1)

Figure 20. Possible peat the transition from Unit B to Unit A

As can be seen in x-section A in Appendix X, peat also occurs as beds covering the layered infills of channel features. Because of the stratigraphic position of the channels relative to the Basal Peat Bed we conclude that the channels are older than the Basal Peat Bed.[14] Because the channels incised the surrounding sediments that are part of the seismic Unit B, we also conclude that the channel infills are younger than the surrounding sediments. This age difference can be large or small. We interpret the channel features as Late Glacial (?) stream valleys that are infilled with fine sandy or loamy fluvial deposits of the Boxtel Formation | Singraven Member with possible intercalations or topping of fine well-sorted aeolian sand (cover sand) of the Boxtel Formation | Wierden Member. An example of a channel feature that incised Unit B is shown in figure 21. The seismic facies of Unit B in this part of the pipeline route trajectory is described as transparent and semi-transparent with rare high amplitude reflectors. This seismic facies points, together with the known geological constellation of the area, at the presence of fluvial deposits of the Kreftenheye Formation. These fluvial deposits consist of poorly sorted Early Pleniglacial river sands of the Rhine.

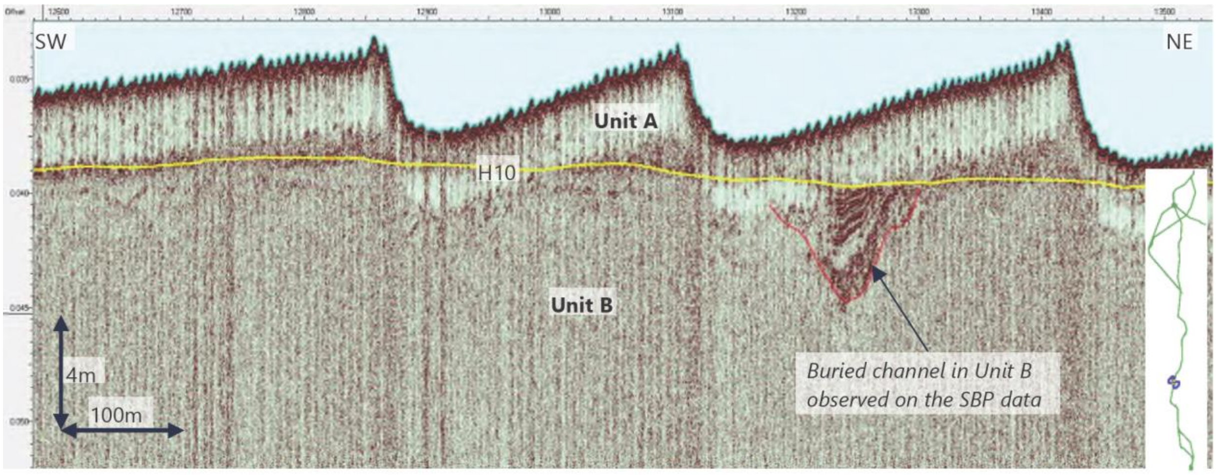

Figure 0.10: SBP data example of buried channels in Unit B. (Line SBP_TA3D2118P1)

Figure 21. Channel-like feature in top of Unit B (source: Fugro survey report F197217-REP-001)

At KP 63.2 a change in seabed morphology is observed. South of this point sand waves are present; north of this point the seabed is generally flat with few ridges. These ridges are elevated some 2.8 meters relative to the surrounding seabed. The fading sand dunes coincide with the appearance of high-amplitude parallel reflectors and high negative amplitude anomalies at relatively shallow depths in the seismic profile. For instance, at KP 67.9 the top of this sequence lies at approximately 1.3 m below the seabed. This coherent layered seismic facies is mapped as Unit C. We interpret Unit C as Early Weichselian layers and laminae of (organic) clay, silt, fine sand, and detritus of the Eem Formation | Brown Bank Member. The fine clastic layered sediments have been deposited in a brackish water lagoonal and shallow marine environment.

Between KP 67.5 and KP 81.0 the top of Unit C, the presumed Brown Bank Member, is found proximate to the seabed surface, and the overlying Unit B is very thin. According to the Geological Map of the Netherlands (2021) partly reworked Early Holocene tidal deposits of the Wormer Member | Naaldwijk Formation are present below the mobile deposits of the Bligh Bank Member. However, if a bed of peat and/or organic clay that was mapped by Fugro around KP 79.4 at the interface between Unit A and Unit B indeed is there, this bed of peat and/or organic clay likely comprise the Basal Peat Bed and/or Velsen Bed. This implies that - at this location - the deposits of Unit B cannot be part of the Wormer Member but shall

[14] In other words: the channel infill is covered by a layer of peat.

be classified as Late Glacial deposits of the Boxtel Formation or a veneer of Early Pleniglacial river deposits of the Kreftenheye Formation.

Between KP 80.7 and KP 87.3 the base of Unit B has a basin-like shape and reaches a thickness of 5 meters. The lithostratigraphic interpretation is uncertain. In this interval Unit C, that is the Brown Bank Member | Eem Formation, has eroded during the deposition of the sediments that are now contained in Unit B. Possibly, sedimentation took place during the Early Pleniglacial, when the catchment area of the Rhine reached far into North Sea area. At KP 87.3 a peat bed has been identified in the upper section of Unit B that probably is part of the Basal Peat Bed.

Between KP 80.7 and the end of section A around KP 94.0 the seabed surface is flat with minor decimeter high current ripples. Unit A has a very consistent thickness of 2.8 meters. If the pipeline is installed at 1 meter below the seabed, the seabed disturbance will be limited to the Holocene top layer. The underlying Pleistocene landscapes will not be affected.

Section B

Between KP 0.0 and KP 12.5 Unit A is 2.5 meters thick. The seabed morphology and thickness of Unit A form a continuation of what is observed in Section A.

Between KP 0.0 and KP 45.0 Unit B is present throughout. The thickness of Unit B varies from a few decimeters to nearly 3 meters. Between KP 30.0 and KP45.0 Unit A is thinner than in other parts of Section B. The interpretation of Unit B is not straightforward. According to the TNO | Laban 2004 Top Pleistocene map the Boxtel Formation occurs as subcropping unit in major part of Section B. On the 2021 Geological Map of the Netherlands the Wormer Member | Naaldwijk Formation is mapped as subcropping unit below the Bligh Bank Member. From KP 45.0 northward Unit B thickens to 8 meters around KP 50.0. Along with Unit B, Unit A also thickens to some 2.5 meters.

Fugro has mapped occurrences of peat at the top of Unit B, (around KP 42.2), as intraformational beds within Unit B (between KP 44.0 and 48.0), and at the base of Unit B (between KP 51.0 and 58.0). The peat that was identified at the base of Unit B lies around -37 m LAT. The seismostratigraphic position of this peat bed (base of Unit B) is different from the stratigraphic position of the peat in Section A (top of Unit B). The interpretation is therefore not straightforward. Possibly the peat bed is again the Basal Peat Bed, but now covered by a thick sequence of tidal deposits of the Wormer Member. Another, possibly more likely option, is that the peat bed was deposited during an interstadial period of the latest ice age, the Weichselian. The peat could be part of the Boxtel Formation or the Early Weichselian Woudenberg Formation.

Section C

The general trend in Section C is an overall deepening of the seabed surface from 31 meters in the south (KP 0.0) to 39 meters in the northern part of this section (KP 26.2). The combined thickness of Unit A and Unit B is less than 2 meters between KP 12.8 and the end of Section C.

Intermittent peat is found at the base of Unit B. As mentioned above the timing of deposition and the lithostratigraphic unit where these peat layers are part of is uncertain. The base of Unit B (= top of Unit C) is a straight plane that very gently dips from -39 m LAT at KP 0.0 to -41 m LAT at KP 26.2.

Distinct channel features have been mapped at the base of Unit B. The incision depth of these channels ranges from 2 to 4 meters. The intermittent peat beds at the base of Unit B cover the channel infills. The development of the channels and the later deposition of peat represent different phases in the development of the landscape. These phases could either be separated by a time hiatus or have followed shortly after each other.

Figure 22 shows a subbottom data example of section C including a channel feature and intermittent occurrences of peat at the base of the well-bedded sequence of Unit B (source: Fugro survey report F197217-REP-001). Clearly visible is the thinning of Unit B from south (left side of the image) to north (right side of the image. Figure 23 shows a subbottom data example of section K14-L4A in which channel features are visible that are also encountered in section C.

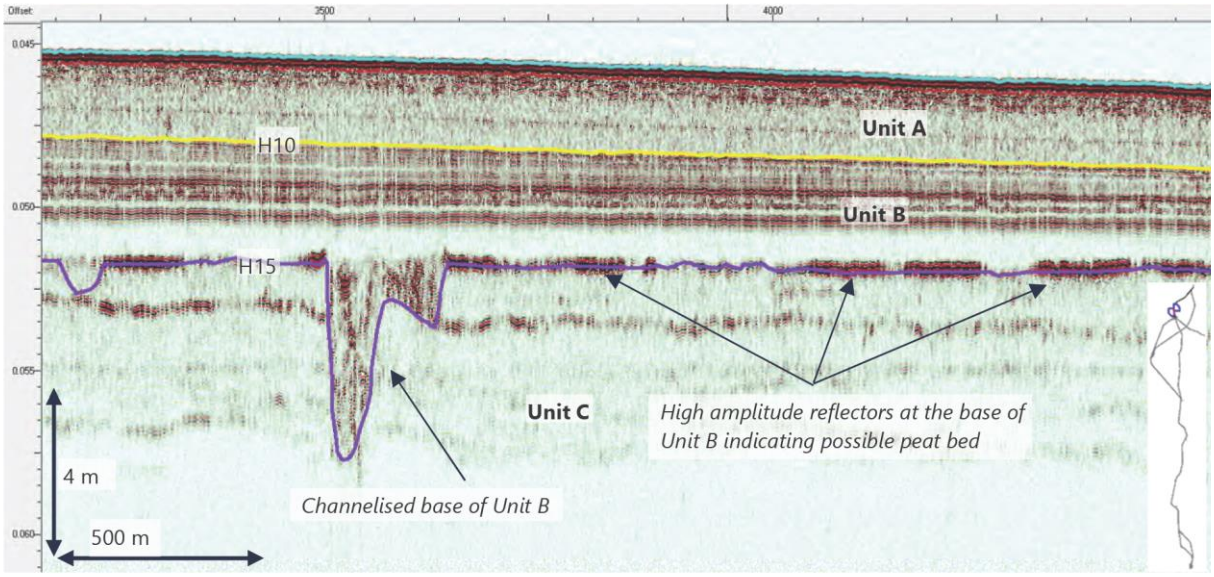

Figure 0.8: SBP data example of route section C. (Line SBP_TA3H23321P1_1)

Figure 22. Channel feature and intermittent occurrences of peat at the base of the parallel bedded sequence of Unit B (source: Fugro survey report F197217-REP-001)

The upper part of Unit C has a (semi)transparent character with a faint plan-parallel sub-horizontal bedding. Although the deposits within Unit C appear to be bedded, this bedding does not show as clear reflectors in the subbottom profile. The top of Unit C probably consists of sandy deposits with little difference and/or gradual changes in grain-size and composition. We interpret the top of Unit C as Eemian marine deposits of the Eem Formation.

The channels that incised Unit C have been infilled with sediments that, at least in figure 23, have not resulted in clear reflectors in the subbottom profile. Probably the absence of clear reflectors is due to limited variation in the lithological composition of the channel infills, which could point to an infill with predominantly (fine) sandy sediments.

The channel infills are truncated by discrete sub-horizontal plan-parallel reflectors at the base of Unit B. These clear reflectors relate to alternating beds with different acoustic impedances. Likely, these differences in acoustic impedance are caused by lithological variations such as alternating beds of fine sand, silt, clay, and peat.

If Unit B consists of Early Holocene tidal deposits of the Wormer Member | Naaldwijk Formation, the peat bed at the base is of Unit B is the Early Holocene Basal Peat Bed. The layered to laminated character of Unit B would fit an Early Holocene tidal setting. The truncated channel features could then represent Late Glacial stream valleys that are infilled with fine sandy or loamy sediment. However, it should be noted that the plan-parallel alternations of fine sand, silt, clay, and detritus also are characteristic of the Early Weichselian Brown Bank Member | Eem Formation. The option that Unit B represents the Brown Bank Member can therefore not be excluded.

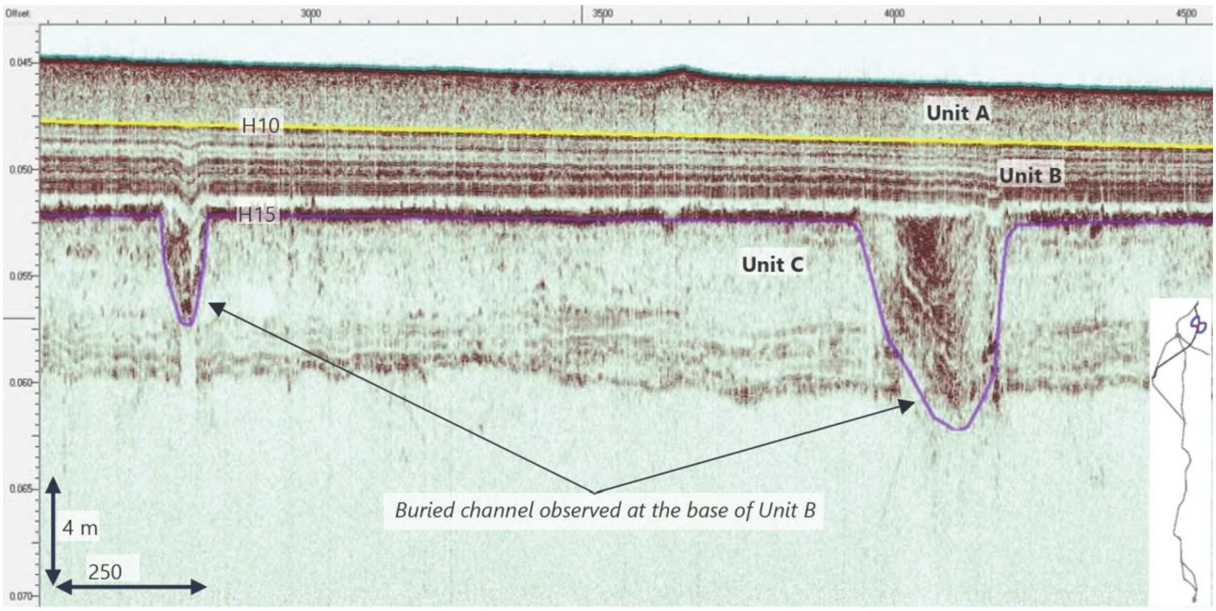

Figure 13.7: SBP data example of route section K14-L4A. (Line SBP_TA3M2321P1_1)

Figure 23. Channel features that are truncated by parallel beds of Unit B (source: Fugro survey report F197217-REP-001)

4 Synthesis

For this investigation different research questions are defined in the Program of Requirements[15]. Based on the results of de data analysis the research questions are answered.

Primary Question : Are any archaeological remains present within the Area of Interest and to what extent are these remains traceable?

Yes. At 19 locations objects have been found with a possible archaeological value. Eight of these objects are related to visible contacts at the seabed and may represent shipwreck remains. At 10 locations magnetic anomalies with a peak-to peak value over 500 nT have been mapped which cannot be related to known objects like pipelines or cables and may be of potential archaeological interest. The objects that cause these anomalies are not visible on side scan sonar or multibeam images and are therefore considered to be buried in the seabed. These objects could, apart from archaeological objects, include debris, UXO, lost anchors, et cetera. As long as the character of these objects has not been determined, the objects are considered to be of potential archaeological interest.

With respect to side scan sonar, magnetometer and multibeam survey:
Are there any phenomena visible on the seabed?
Yes. With side scan sonar and multibeam a total of 3806 contacts have been mapped. With magnetometer, a total of 2748 magnetic anomalies have been observed within the area of investigation.

If so: What is the description of these phenomena?
Fugro has identified 3806 *side scan sonar* contacts within the surveyed corridor. The classification of the contacts is listed below.

Classification	**Amount**
Boulder	3010
Debris	159
Depression Pockmark	5
Fishing Gear	7
Mattress	2
Pipeline	4
Seabed Mound	98
Suspected Debris	517
Wreck	4
Total	**3806**

Do these phenomena have a man-made or natural origin?
The majority of the contacts have been classified as man-made.

If these phenomena can be designated to be man-made: What classification can be attached?
See the table above.

[15] Van Lil and van den Brenk, 2022

If these phenomena can be classified as archaeological: Is it possible to interpret the nature of the archaeological objects?
Eight of these objects are related to visible contacts at the seabed and may represent shipwreck remains. At 10 locations magnetic anomalies with a peak-to peak value over 500 nT have been mapped which cannot be related to known objects like pipelines or cables and may be of potential archaeological interest. The objects that cause these anomalies are not visible on side scan sonar or multibeam images and are therefore considered to be buried in the seabed. These objects could, apart from archaeological objects, include debris, UXO, lost anchors, et cetera. As long as the character of these objects has not been determined, the objects are considered to be of potential archaeological interest.

If these phenomena can be identified as natural: What is the nature of these natural phenomena?
Over 3000 contacts are classified as 'boulder'. These probably also include clay boulders, because known stone boulders in the North Sea only occur north of the city of Den Helder.

Based on the acoustic image is it possible to designate zones of high, middle or low marine activity on the seabed?
Along the route sand waves have been mapped which are known to migrate a few meters per year northwards. Sand ripples originated by tidal currents are present along the entire route.

General:
What is the relation between the observed objects and the topography of the seabed? Based on this relationship can risk-prone areas be marked selectively?
Larger objects like the shipwrecks show scouring but are largely embedded in the seabed sediments. This appears to be the case throughout the area. Therefore, it is not possible to mark risk-prone areas selectively.

If no acoustic phenomena can be observed, are there any clues that this is a consequence of either natural erosion, sedimentation or human interference?
This question is given the results of the investigation not applicable.

With respect to the seismic data: What is the depth of the top of the Pleistocene and Holocene landscape(s) relative to a) LAT and b) the present seabed?
The depth of the Pleistocene landscapes relative to both LAT and the present seabed could not always be determined, because the boundaries of the identified seismic units do not always coincide with those of the lithostratigraphic units. The lithostratigraphic sequences along the routes cannot always be deduced from the seismic data. The presence of peat found by Fugro does help in determining the top of the Pleistocene. The Basal Peat Bed is a bed of peat that has been deposited throughout the North Sea area when groundwater levels rose in response to the rising of the sea level from the beginning of the Holocene to present. The timing of the deposition of the Basal Peat Bed differs with the elevation of the landscape at the moment of inundation.

We produced a south to north x-section utilizing the seismic data delivered by Fugro to provide a context of the geological constellation in the area. The x-section includes the sections Nearshore East, A, B and C. The findings for these sections are also applicable for the other route options.

Section Nearshore East

In the nearshore section, no occurrences of peat were reported. Based on the known geological constellation in this part of the route trajectory we expect the top of the Pleistocene landscape to be buried by tidal deposits of the Naaldwijk Formation, at multiple meters below the seabed. An exception is the Maasgeul where the top of the Pleistocene sequence is expected to intersect with edge of the Maasgeul at or below -20 m LAT.

Section A

In section A occasional peat has been mapped at the base of Unit A | top of Unit B. We interpret these beds of peat as the Basal Peat Bed that covers Pleistocene deposits that are contained in Unit B. The Basal Peat Bed has an intermittent character. The reason for this can be two-fold: 1) peat has never been deposited, and 2) peat has initially been deposited, but has eroded at a later stage. Yet, in between the peat occurrences we expect the top of the Pleistocene landscape in Section A to be located at the same stratigraphic level, that is the top of the seismic Unit B (= H10), albeit that the change that the top of these deposits has eroded is significantly larger than in areas where peat has been found. Along with the occurrence of peat, the top of the Pleistocene sequence has been found at 25 to 30 meters relative to LAT in Section A. The depth of the Pleistocene sequence relative to the seabed varies with the thickness of Unit A. This means that in between sand waves the top of the Pleistocene can be close to being exposed at the seabed or solely covered by a veneer of sand. At the locations of sand wave crests the top of the Pleistocene can be located up to 7 meters below the seabed.

Section B

Given the seismic character of Unit C, including clear subhorizontal subparallel reflectors we interpret Unit C as the Eem Formation, including the Brown Bank Member. The interpretation of Unit B is uncertain. Unit B can include Late Glacial terrestrial deposits of the Boxtel Formation, Early Holocene deposits of the Naaldwijk Formation and even also shallow marine deposits of the Eem Formation and Brown Bank Member. Beds of peat or organic clay are also identified in Section B. The amount and continuity of the peat increases from south to north. Most peat occurs at a different stratigraphic level than in Section A. In Section B peat is often found at the base of the seismic Unit B. This peat could either be the Basal Peat Bed or peat from a deeper stratigraphic level such as the Boxtel Formation or Woudenberg Formation. If the Pleistocene landscape coincides with the base of Unit A, the top of the Pleistocene lies -26.5 m to -34 m LAT and 1 to 3 meters below the seabed. If the Pleistocene landscape coincides with the base of Unit B, the top of the Pleistocene lies -28 m to -40 m LAT and 2.5 to 11 meters below the seabed. Ground truthing is necessary to make a better judgement.

Section C

The very flat seabed in Section C deepens to the north from -32 m LAT to -39 m LAT. Towards the north the combined thickness of Unit A and Unit B decreases to less than 2 meters. The base of Unit B gently dips towards the north from -39 m LAT in the south to -41 m LAT in the north. Intermittent peat is found in many locations at the base of Unit B. Discrete channel features have been mapped that incise Unit C. The peat beds cover these channel features. If the Pleistocene landscape coincides with the base of Unit A, the top of the Pleistocene lies -34 m to -40 m LAT and 0.7 to 3 meters below the seabed. If the Pleistocene landscape coincides with the base of Unit B, the top of the Pleistocene lies -39 m to -41 m LAT and 1.3 to 7.5 meters below the seabed. Ground truthing is necessary to make a better judgement.

What lithostratigraphic units can be distinguished along the pipeline routes?
It is not possible to distinguish lithostratigraphic units based on the seismic data alone. The dominant lithostratigraphic units that are expected to be present are listed in the table below.

Classification	**Occurrence Section**	**Lithology**	**Age**	**Environment**	**Layer boundary**
Naaldwijk Fm	Nearshore	sand and clay	holocene	tidal, estuarine	erosive
Basal Peat Bed Nieuwkoop Fm	Nearshore A, B and C	peat	holocene	Marsh, swamp	conformable
Boxtel Fm	Nearshore A, B and C	Homogeneous fine sand loam, peat, clay	Late Glacial	polar desert, small stream	erosive
Kreftenheye Fm	Nearshore A, poss. B	poorly sorted sand	Pleniglacial	braided river	erosive
Brown Bank Mb	A, B and C	layered and laminated fine sand, silt, clay, and detritus	Early Weichselian	lagoon, lake	conformable
Eem Fm	A, B and C	sand and clay	Eemian	marine	erosive

Table 15. Lithostratigraphic units along the pipeline routes

Have channel-like features been observed?
Yes.

If so: What are the characteristics of the channel-like features in terms of spatial distribution (width, depth, shape, extent), channel infill composition, stratigraphic position and age.
Channel features are observed at two seismostratigraphic levels:

1- As incisions into the top of Unit B
2- As incisions into the top of Unit C

The depth of incision is limited to a few meters or less. At both stratigraphic levels the channel features are covered by peat. From this we conclude that the channel infills are older than the peat depositions. We interpret the channels that incised the top of Unit B as Late Glacial stream valleys that are filled-in with fine sand or loam and later covered by Early Holocene peat of the Basal Peat Bed.

The channel features that incised Unit C could also be Late Glacial with a cover of the Basal Peat Bed, but the interpretation of the peat at this stratigraphic level is uncertain (possible Boxtel Fm or Woudenberg Fm?).

Are occurrences of peat and/or organic clay observed?
Yes.

If so: What is the spatial distribution (depth, extent) stratigraphic position and age of these deposits.
Please refer to the answers to the previous questions.

The Basal Peat Bed is expected to occur at the base of Unit A in Section A. The peat beds that are found at the base of Unit B could be the Basal Peat Bed, but older peat from the Boxtel Formation or Woudenberg Formation cannot be excluded.

Are intact prehistoric landscapes affected by the installation of the pipeline based on their vertical position related to the seabed?
Yes, even if the trenching depth is limited to one meter below the seabed intact prehistoric landscapes could be affected by the installation of the pipeline. Risk-prone areas are sections where peat beds occur proximate to the seabed surface. Those areas have been identified in Section A in where peat occurs in low-lying areas in between sand dunes and in the northern parts where peat occurrences a wide-spread and the combined thickness of Unit A and Unit B is less than two meters.

Are there any indications observed on the seismic profiles for the presence of buried (man-made) objects?
No.

If so: Based on the presence of buried objects and its correlation with side scan sonar, magnetometer en multibeam data can something be said about the nature of these buried objects?
This question is not applicable.

.

5 Summary and recommendations

A large quantity of survey data (*side scan sonar, magnetometer, multibeam echosounder* and *subbottom profiling*) covering a total area of 243 km^2 have been analyzed to conduct an archaeological assessment.

The current analysis of geophysical survey results is the second and step in the AMZ-cycle, following the desk study. The purpose of this assessment is to test the desk study-based expectancy for archaeological remains in the area. The expectancy covers remains of shipping related objects (wrecks), airplanes from World War II and prehistoric settlements.

Side scan sonar and multibeam contacts

Within the surveyed area, an archaeological expectation was assigned to a total of 8 contacts. In accordance with Dutch Law and Legislation no seabed disturbances should be carried out within 100 meters of each of the marked locations. If any activities will take place within 100 meters of a potential archaeological location, it will be examined on a case-by-case basis whether the 100 meters should be maintained in consultation with the Cultural Heritage Agency of the Netherlands (RCE).

Feature	NCN	Easting	Northing	Route section	Distance
BK_FSEA_SSS_0022	-	551288	5924521	D	**+50**
BK_FSEA_SSS_0179	-	555839	5929168	D	-240
BJ_FD_SSS_0015	-	548443	5894128	F	+230
BB_FS_SSS_0683	219	570384	5762003	East	-540
BH_FSEA_SSS_0104	531	559172	5935317	C	**+25**
BK_FSEA_SSS_0163	967	550165	5921956	D	**-56**
BN_FD_SSS_0025	945	576689	5920367	E Neptune	+220
BB_FS_SSS_0433	-	570711	5761481	East	-210

Table 16. Objects with an archaeological expectation.

Three of the eight contacts fall within 100 meters of the proposed route.

Magnetic anomalies

A total of 2748 magnetic anomalies have been observed. At 10 locations magnetic anomalies with a peak-to peak value over 500 nT have been mapped which cannot be related to known objects like pipelines or cables and may be of potential archaeological interest. The objects that cause these anomalies are not visible on side scan sonar or multibeam images and are therefore considered to be buried in the seabed. These objects could, apart from archaeological objects, include debris, UXO, lost anchors, et cetera. As long as the character of these objects has not been determined, the objects are considered to be of potential archaeological interest.

Target	E	N	nT	Section	Distance
BAB_FS_UXO_0010	570711	5761625	808	East	-210
BAB_FS_UXO_0599	570931	5761671	514	East	**+5**
BAB_FS_UXO_0603	570932	5761987	2312	East	**+8**
BAB_FS_UXO_0605	570933	5761957	1158	East	**+8**
BAB_FS_UXO_0618	570936	5761510	729	East	**+11**
BAB_FS_UXO_0657	570948	5761543	1348	East	**+22**
BC_FD_MAG_0121	571170	5763666	666	East	**+4**
BH_FSEA_MAG_0044	559169	5935057	578	C	**-2**
BJ_FD_MAG_0050	563642	5875159	2089	F	**-59**
BP_FD_MAG_0016	559490	5931390	591	B	**-60**

Table 17. Magnetic anomalies over 500 nT with an archaeological expectation.

Nine of the eleven contacts fall within 100 meters of the proposed route.

In accordance with Dutch Law and Legislation no seabed disturbances should be carried out within 100 meters of each of the marked locations. If any activities will take place within 100 meters of a potential archaeological location, it will be examined on a case-by-case basis whether the 100 meters should be maintained in consultation with the Cultural Heritage Agency of the Netherlands (RCE). All locations of potential archaeological interest within 100 meters of the proposed route are shown in the next figure.

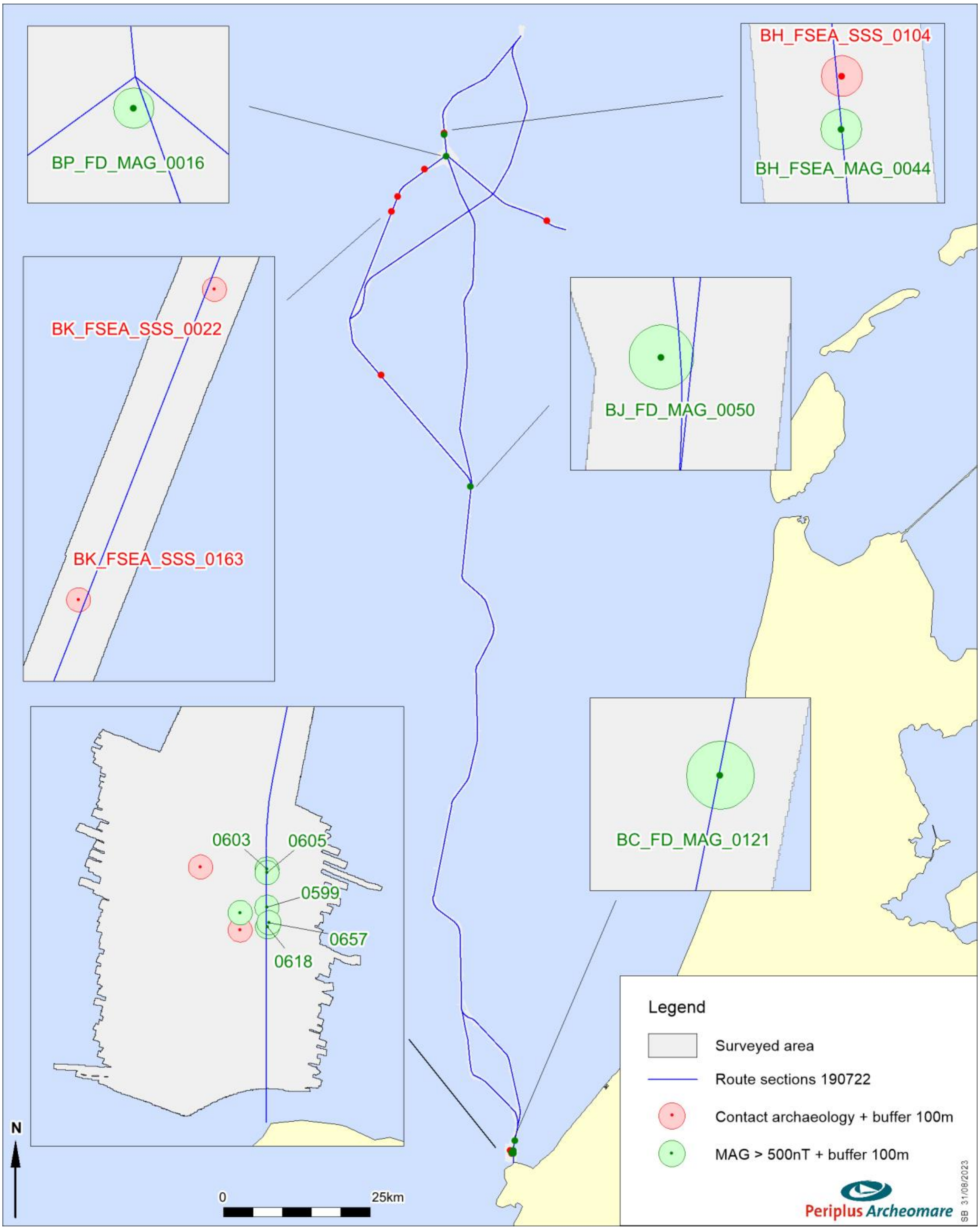

Figure 24. Overview of the potential archaeological targets within 100 meters of the proposed route

Prehistoric remains
Areas of potential archaeological interest listed below.

Depositional environment Areas of potential archaeological interest	Lithostratigraphic Unit	Time of deposition	Archaeological period
Peat-covered aeolian and small scale fluvial deposits	Boxtel Formation	*Late Glacial* and Early *Holocene*	Late Paleolithic and Early Mesolithic
Catchment of the Rhine	Kreftenheye Formation	Pleniglacial	Middle Paleolithic
Shores of lakes and lagoons	Brown Bank Member	Early *Weichselian*	Middle Paleolithic to Early Mesolithic

Table 18. Areas of potential archaeological interest

The physical quality, that is, the integrity and preservation of prehistoric remains is highly dependent on the extent to which prehistoric landscapes and archaeological levels herein have been affected by erosion. The seismic data indicate that part of the *Pleistocene* landscape has eroded during the Early *Holocene* marine ingression, thus affecting the integrity of possible prehistoric settlements. Locally the geological units defined as potential containers of prehistoric remains may have been preserved intact, especially in areas where peat has been found. The interpretation of lithostratigraphic units and the character of the layer boundaries (erosive versus non-erosive) from the seismic data is based on the geological data available and expert judgement. The seismic interpretation shall be ground-truthed by vibrocore sampling. The actual geological sequences present in the area and the integrity of layer boundaries will be verified, thus offering a tool for further analysis of the prehistoric landscapes and specify and test the archaeological potential.

Recommendation

Prehistory
Periplus Archeomare recommends conducting further archaeological research that focuses on the genesis and integrity of paleo-landscapes along the Aramis route trajectories for general archaeological research purposes. This research comprises an inventory of field research by means vibrocore sampling in accordance with the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1). A geotechnical campaign is carried out to generate a geological model of the subsurface of the pipeline corridor and to determine the physical properties of the sediment layers present. We recommend designating a number of vibrocore locations where sediment samples are collected that can be used for geo-archaeological research.

The intact samples must be examined by a (senior) prospector and described in accordance with the *Standaard Boorbeschrijvingsmethode* (SBB). Samples are selected and stabilized to be analyzed by specialists in the field of OSL and radiocarbon age dating, sediment petrography, palynology, micropaleontology (foraminifera, ostracods, diatoms, et cetera), macro-remains of plants and animals and molluscs to gain insight into the development of landscapes over time and the extent to which these paleolandscapes have been preserved.

In accordance with the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1), a Program of Requirements (PvE) and / or Plan of Action (PvA) must be drawn up. The PvE/PvA includes the objective, the research strategy and methodology, the frameworks and the practical implementation of the research, so that the process runs smoothly, and multiple use of the data acquired in a uniform manner is achieved. It is advised to submit this PvE / PvA for approval to the Competent Authorities and the RCE. After completion of the inventory field research, during the construction of the pipeline, data can be collected that - from an archaeological point of view - provide valuable information at a detailed level. It can be very useful to investigate this information further from an archaeological point of view. It is advised to investigate the possibilities for this in consultation with the RCE, once the plans have been worked out.

During the installation of the pipeline, archaeological objects may be discovered which were completely buried or not recognized as an archaeological object during the geophysical survey. We recommend passive archaeological supervision based on an approved Program of Requirements. Passive archaeological supervision means that an archaeologist is not present during the execution of the work but always available on call. Following this recommendation would prevent delays during the work when unexpectedly archaeological remains are found. In accordance with the Erfgoedwet, it is required to report those findings to the enforcing authority (Minister of OCW). This notification must also be included in the scope of work.

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Glossary and abbreviations

Terminology	Description
AMZ	Archeologische Monumenten Zorg, a description of procedures to ensure the protection of National archaeological Cultural Heritage
Allerød	Warm period (*interstadial*) within the *Late Glacial*, 13,900 to 12,900 cal years BP
Bioturbation	Disturbance of sediment layers by burrowing animals
Bølling	Warm period (*interstadial*) within the *Late Glacial*, 14,700 to 14,000 cal years BP
CPT	Cone penetration test
Cryoturbation	Disturbance of sediment layers due to freezing and thawing
Diffraction Hyperbola	Isolated point reflectors induced by e.g. boulders or pipelines show as hyperbola in a seismic profile, because the reflections of these objects are not only registered during the crossing of the object (top of hyperbola), but also before and after the crossing (arms of hyperbola)
Eemian	Warm period (*interglacial*) between *Saalian* and *Weichselian* from 130,000 to 115,000 years ago
Erratic	An (glacial) erratic is a piece of rock that differs from the size and type of rock native to the area in which it rests. These rocks are carried by glacial ice, often over distances of hundreds of kilometres. Erratics can range in size from pebbles to large boulders.
Ferrous	Material, which is magnetic or can be magnetized, and well-known types are iron and nickel
Glacial	Ice-age
Holocene	Youngest geological epoch (from the last Ice Age, around 10,000 BC. to the present)
In situ	At the original location in the original condition
Interglacial	Warm period in between two ice-ages
Interstadial	Warm period within an ice-age
Late Glacial	Last part of the Weichselian, 15,000 to 12,000 years ago
ka	Kiloanus or kiloyear, a period of 1,000 years
Magnetometer	Methodology to measure deviations from the earth's magnetic field (caused by the presence of ferro-magnetic = ferrous objects)
Multibeam	Acoustic instrument that uses different bundles or beams to measure the depth in order to create a detailed topographic model
Odderade	Warm period (*interstadial*) within the Early *Weichselian*, 85,000 to 75,000 years ago
Pleistocene	Geological era that began about 2 million years ago. The era of the ice ages but also moderately warm periods. The *Pleistocene* ends with the beginning of the *Holocene*
Pleniglacial	Coldest part of the *Weichselian*, 75,000 ka to 15,000 years ago
PvE	Program of Requirements (Dutch: Programma van Eisen)
RCE	Ministry of Cultural Heritage (Dutch: Rijksdienst voor het Cultureel Erfgoed)
ROV	Remotely Operated Vehicle
Saalian	Second last Ice age (glacial), 240,000 to 130,000 years ago
Sandr	Fan shaped outwash plain in front of a glacier

Terminology	Description
Side scan sonar	Acoustic instrument that registers the amplitude of reflections of the seabed. The resulting images are similar to a black / white photograph. The technique is used to detect objects and to classify the morphology and type of soil
Current ripples	Asymmetrical wave pattern at the seabed caused by currents. The steep sides of the ripples are always on the downstream side
Subbottom profiler	Acoustic system used to create seismic profiles of the subsurface
Trenching	Construction of a trench for the purpose of burying a cable or pipeline
Vibrocore	Vibrocore bore is a special drilling technique where a core tube is driven by means of vibration energy in the seabed. In addition, the core tube is provided with a piston so that the bottom material in the core tube remains in place
Weichselian	Last Ice Age (glacial) from 115,000 to 12,000 years ago

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Atlases and Maps

- GeoTOP-model Laag van Wijchen en Hollandveen Laagpakket
- Globale Archeologische Kaart van het Continentale Plat
- Noordzee atlas
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Sources from the Internet

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- Olie en Gasportaal (www.nlog.nl)
- Stichting Aircraft recovery Group 40-45 (http://www.arg1940-1945.nl)
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Various sources

- Archis III, archeologische database Rijksdienst voor het Cultureel Erfgoed
- KNA Waterbodems 4.1
- Nationaal Contactnummer Nederland (NCN)
- SonarReg92, objectendatabase Rijkswaterstaat Noordzee en Delta

Appendix 1. Listing of selected side scan sonar contacts

The table below contains a selection of 117 *side scan sonar* contacts with a possible archaeological expectation, based on the comparison with known objects (NCN), their size (larger than four meters) and characteristics.

After reviewing, an archaeological expectation has been assigned to 9 contacts marked with a light green colour, presented in the table below.

Feature_name	Easting	Northing	Feature description Fugro	L	W	H	Z	Description PPA
BH_FSEA_SSS_0036	572394	5953350	Mattress	18.7	2.3	0.0	-32.8	Mattress
BH_FSEA_SSS_0003	572516	5953431	Depression Pockmark	7.7	6.6	0.0	-39.6	Spudcan depression
BH_FSEA_SSS_0007	572470	5953396	Depression Pockmark	8.2	6.2	0.0	-39.6	Spudcan depression
BH_FSEA_SSS_0004	572548	5953407	Depression Pockmark	6.1	5.9	0.0	-39.5	Spudcan depression
BH_FSEA_SSS_0005	572529	5953379	Depression Pockmark	7.0	6.1	0.0	-39.5	Spudcan depression
BH_FSEA_SSS_0016	572402	5952674	Depression Pockmark	4.3	4.1	0.0	-39.4	oval contact
BH_FSEA_SSS_0001	572373	5953287	Mattress	16.0	0.8	0.1	-39.3	mattress
BM_FSEA_SSS_0354	571321	5945854	Suspected Debris	4.4	0.3	0.0	-38.1	Elongated contact
BM_FSEA_SSS_0042	572235	5942929	Suspected Debris	4.3	0.9	0.2	-36.8	Oval contact, clustered with other oval contacts
BH_FSEA_SSS_0245	558780	5937355	Suspected Debris	12.7	3.1	0.0	-35.1	irregular contact, possibly a seabed disturbance
BM_FSEA_SSS_0030	573164	5939530	Seabed Mound	5.6	1.5	0.0	-34.7	Elongated thin contact, possible cable or chain
BH_FSEA_SSS_0117	558891	5936096	Suspected Debris	4.0	1.3	0.4	-34.2	Irregular contact in depression.
BM_FSEA_SSS_0078	572899	5938204	Suspected Debris	11.5	7.2	0.0	-33.8	Matrasses Pipeline Total L7-A to L7-P
BH_FSEA_SSS_0107	559378	5933267	Suspected Debris	4.3	0.3	0.4	-32.3	Elongated straight contact
BP_FD_SSS_0003	560054	5931344	Debris	5.7	1.0	0.0	-31	Seabed disturbance
BP_FD_SSS_0010	559575	5930614	Debris	7.5	3.2	0.0	-30.6	no contact visible
BK_FSEA_SSS_0290	543796	5905721	Boulder	4.3	4.7	0.0	-29.6	Seabed disturbance
BK_FSEA_SSS_0108	551298	5924649	Boulder	28.8	1.2	0.2	-29.4	buoy anchor with cable
BK_FSEA_SSS_0174	544378	5904424	Boulder	4.3	2.4	0.0	-29.4	elongated contact
BK_FSEA_SSS_0154	546697	5913055	Boulder	9.8	0.6	0.2	-29.3	Patch of shells
BK_FSEA_SSS_0044	547294	5914807	Boulder	4.5	2.2	0.0	-29.2	Nothing Visible on SSS and MBES
BK_FSEA_SSS_0120	547879	5915829	Boulder	6.8	0.8	0.0	-29.2	Nothing Visible on SSS and MBES
BK_FSEA_SSS_0196	545707	5909928	Boulder	4.3	3.1	0.0	-29.2	oval contact
BK_FSEA_SSS_0260	545890	5910411	Boulder	4.2	1.1	0.0	-29.2	oval contact
BK_FSEA_SSS_0274	547617	5914888	Boulder	5.2	5.6	0.0	-29.2	oval contact

Feature_name	Easting	Northing	Feature description Fugro	L	W	H	Z	Description PPA
BK_FSEA_SSS_0075	549384	5919899	Boulder	6.0	3.3	0.0	-29.1	Elongated straight contact
BK_FSEA_SSS_0175	545656	5908303	Boulder	4.3	1.0	0.1	-29.1	oval contact
BM_FSEA_SSS_0086	570587	5931442	Suspected Debris	4.0	0.5	0.0	-29.1	Seabed disturbance
BE_FD_SSS_0003	561690	5822980	Suspected Debris	5.7	2.7	0.1	-28.9	oval contact
BN_FD_SSS_0039	562547	5929173	Debris	4.1	1.0	0.0	-28.9	no contact visible
BE_FD_SSS_0002	560603	5821138	Suspected Debris	8.3	4.3	0.4	-28.8	oval contact in depression
BM_FSEA_SSS_0292	546644	5910321	Suspected Debris	7.8	0.2	0.1	-28.8	Elongated contact
BK_FSEA_SSS_0286	542892	5903521	Boulder	9.8	0.5	0.0	-28.7	thin straight contact, possibly depression
BM_FSEA_SSS_0377	547318	5911315	Suspected Debris	6.4	0.3	0.0	-28.7	Elongated contact, cable or chain
BM_FSEA_SSS_0098	570182	5930164	Suspected Debris	4.6	0.6	0.0	-28.3	Elongated contact
BG_FD_SSS_0014	561067	5926853	Pipeline	25.1	0.8	0.1	-28.2	Pipeline
BG_FD_SSS_0021	561279	5926721	Pipeline	53.6	0.5	0.0	-28.1	Pipeline
BG_FD_SSS_0010	561476	5926599	Pipeline	87.8	0.6	0.0	-27.8	Pipeline
BG_FD_SSS_0017	561489	5926592	Pipeline	53.9	0.5	0.3	-27.6	Pipeline
BG_FD_SSS_0009	561534	5926360	Suspected Debris	5.7	3.4	0.0	-27.3	Nothing Visible on SSS and MBES
BN_FD_SSS_0025	576689	5920367	Wreck	17.5	5.2	1.5	-27	See NCN 945 / Contact bn_fd_sss_0025
BE_FD_SSS_0035	562830	5824316	Suspected Debris	24.6	1.0	0.0	-26.9	Elongated contact, possibly cable or chain
BJ_FD_SSS_0004	545175	5897731	Debris	4.5	2.3	0.0	-26.9	Nothing Visible on SSS and MBES
BE_FD_SSS_0015	561724	5823492	Suspected Debris	15.9	0.7	0.0	-26.8	Elongated contact, possibly cable or chain
BE_FD_SSS_0031	564689	5840888	Suspected Debris	6.0	1.1	0.0	-26.8	Elongated contact, possibly cable or chain
BM_FSEA_SSS_0082	567876	5925957	Suspected Debris	4.0	0.4	0.0	-26.6	Elongated contact
BG_FD_SSS_0020	562256	5924505	Suspected Debris	13.2	0.4	0.0	-26.4	Long Small Bended Contact, Nothing on Mbes, Possible Rope or Chain
BN_FD_SSS_0010	566548	5925589	Debris	5.7	3.1	0.0	-26.4	no contact visible
BM_FSEA_SSS_0014	566988	5924284	Suspected Debris	4.6	0.4	0.1	-26.3	no contact visible
BF_FD_SSS_0026	563257	5896796	Seabed Mound	6.6	3.2	0.7	-26.2	oval contact, possibly a stone
BM_FSEA_SSS_0130	559140	5919286	Suspected Debris	4.9	0.4	0.0	-26.2	cable/chain
BM_FSEA_SSS_0283	566066	5924076	Suspected Debris	4.3	0.7	0.0	-26.2	Elongated contact
BM_FSEA_SSS_0279	565452	5923640	Suspected Debris	10.1	0.8	0.0	-26.1	Elongated contact

Feature_name	Easting	Northing	Feature description Fugro	L	W	H	Z	Description PPA
BN_FD_SSS_0017	571919	5922297	Debris	4.1	0.8	0.0	-26.1	elongated curved contact
BM_FSEA_SSS_0263	560640	5920327	Suspected Debris	5.7	0.6	0.0	-26	Elongated contact
BM_FSEA_SSS_0277	561266	5920672	Suspected Debris	4.7	0.8	0.0	-26	Elongated contact
BM_FSEA_SSS_0333	561394	5920909	Suspected Debris	5.3	0.7	0.0	-26	Elongated contact
BM_FSEA_SSS_0367	564897	5923160	Suspected Debris	4.9	0.6	0.0	-26	Elongated contact
BG_FD_SSS_0023	563609	5921710	Debris	5.7	0.5	0.0	-25.9	Cluster of small oval contacts
BM_FSEA_SSS_0221	562349	5921382	Suspected Debris	4.2	0.4	0.0	-25.9	Elongated contact
BM_FSEA_SSS_0256	562509	5921591	Suspected Debris	6.1	0.4	0.0	-25.9	Elongated contact
BM_FSEA_SSS_0273	562187	5921340	Suspected Debris	5.7	0.7	0.0	-25.9	Elongated contact
BM_FSEA_SSS_0317	563598	5922366	Suspected Debris	8.0	0.9	0.0	-25.9	Elongated contact
BN_FD_SSS_0034	574301	5921805	Debris	6.7	2.5	0.0	-25.9	Seabed disturbance
BF_FD_SSS_0002	562271	5906303	Seabed Mound	6.5	4.0	0.2	-25.8	oval contact
BF_FD_SSS_0004	562337	5906463	Debris	4.8	1.4	0.1	-25.8	oval contact
BF_FD_SSS_0005	562372	5906435	Seabed Mound	4.1	1.3	0.1	-25.8	oval contact
BF_FD_SSS_0009	562478	5906537	Seabed Mound	5.1	1.0	0.0	-25.8	oval contact
BE_FD_SSS_0033	564696	5841065	Suspected Debris	6.7	0.4	0.0	-25.7	Elongated contact, possibly cable or chain
BF_FD_SSS_0007	562431	5905891	Seabed Mound	11.9	3.3	0.3	-25.7	Elongated triangular contact, with a grinding channel
BF_FD_SSS_0008	562436	5905902	Seabed Mound	6.8	3.0	0.2	-25.7	oval contact, with a depression
BF_FD_SSS_0015	562631	5906896	Seabed Mound	4.3	2.2	0.1	-25.7	Oval contact in a cluster of smaller oval contacts
BF_FD_SSS_0021	562712	5906802	Seabed Mound	5.6	1.4	0.1	-25.7	oval contact
BF_FD_SSS_0027	563122	5908014	Suspected Debris	13.3	2.4	0.2	-25.7	Elongated contact
BG_FD_SSS_0008	564555	5919314	Suspected Debris	5.3	0.5	0.0	-25.7	Elongated contact
BF_FD_SSS_0006	562395	5905025	Debris	4.7	1.2	0.2	-25.6	Two oval contacts, possibly stones
BF_FD_SSS_0013	562585	5906295	Seabed Mound	12.9	2.5	0.1	-25.6	Elongated, curved contact, possibly a depression
BF_FD_SSS_0023	562758	5906789	Seabed Mound	6.3	1.5	0.0	-25.6	Nothing Visible on SSS and MBES
BG_FD_SSS_0030	564078	5914876	Debris	16.5	5.2	0.0	-25.6	Nothing Visible on SSS and MBES

Feature_name	Easting	Northing	Feature description Fugro	L	W	H	Z	Description PPA
BF_FD_SSS_0030	563476	5908191	Seabed Mound	13.6	2.8	0.1	-25.5	Elongated contact
BF_FD_SSS_0032	563600	5908415	Seabed Mound	5.3	1.9	0.1	-25.5	Oval contact in a cluster of smaller oval contacts
BF_FD_SSS_0034	563664	5908420	Seabed Mound	4.0	2.6	0.0	-25.5	Oval contact in a cluster of smaller oval contacts
BF_FD_SSS_0035	563664	5908843	Seabed Mound	7.9	1.2	0.1	-25.5	Elongated contact
BF_FD_SSS_0038	563778	5908537	Seabed Mound	12.4	3.1	0.1	-25.5	Elongated, curved contact, possibly a depression
BF_FD_SSS_0041	563849	5908905	Seabed Mound	11.2	3.1	0.1	-25.5	Elongated contact in a cluster of smaller oval contacts
BF_FD_SSS_0042	563897	5908744	Seabed Mound	8.3	2.8	0.1	-25.5	Elongated contact
BF_FD_SSS_0049	564270	5910802	Seabed Mound	4.2	0.8	0.0	-25.5	no contact visible
BG_FD_SSS_0004	564261	5911517	Debris	8.2	1.4	0.0	-25.5	Nothing Visible on SSS and MBES
BJ_FD_SSS_0010	553035	5888675	Debris	4.3	0.7	0.0	-25.4	elongated curved contact
BF_FD_SSS_0025	562976	5899476	Fishing Gear	84.9	0.6	0.0	-25.3	Elongated contact, cable or chain
BJ_FD_SSS_0008	549409	5892980	Debris	4.0	1.6	0.0	-25	oval contact in depression
BE_FD_SSS_0026	564436	5829719	Suspected Debris	5.0	0.6	0.0	-24.2	Seabed disturbance
BB_FS_SSS_0147	569907	5761041	Suspected Debris	6.5	0.9	0.4	-24	Seabed disturbance
BE_FD_SSS_0009	564748	5833956	Suspected Debris	4.2	2.0	0.1	-23.9	oval contact lying on a sand wave
BE_FD_SSS_0028	564355	5830266	Suspected Debris	4.5	3.2	0.0	-23.9	Oval contact, possibly stone
BD_FD_SSS_0642	563132	5781065	Debris	5.1	0.8	0.1	-23.7	Nothing Visible on SSS and MBES
BB_FS_SSS_0481	570154	5761583	Suspected Debris	6.0	2.2	0.1	-23.2	Nothing Visible on SSS and MBES
BE_FD_SSS_0020	563657	5826463	Suspected Debris	11.0	2.7	0.0	-23.2	Seabed disturbance
BD_FD_SSS_0224	557171	5805022	Debris	4.1	1.0	0.0	-23.1	No contact on the SSS, in the Mbes an elongated contact parallel to the sand golf
BB_FS_SSS_0419	570165	5761433	Suspected Debris	8.9	0.6	0.4	-22.6	Elongated straighht contact, partially cut off by the mosaic
BE_FD_SSS_0008	564243	5829215	Suspected Debris	5.9	1.1	0.3	-20.7	No contact on the SSS, in the Mbes an elongated contact parallel to the sand golf
BB_FS_SSS_0433	570711	5761481	Wreck	4.3	2.4	0.3	-18.9	oval contact

Feature_name	Easting	Northing	Feature description Fugro	L	W	H	Z	Description PPA
BB_FS_SSS_0444	570947	5761501	Suspected Debris	4.4	0.5	0.1	-18.4	Natural Ridge
BB_FS_SSS_0025	570853	5760453	Suspected Debris	7.9	1.1	0.2	-18.1	Seabed disturbance
BB_FS_SSS_0705	569990	5762046	Suspected Debris	7.3	0.9	0.2	-17	Elongated contact, possibly cable or chain
BB_FS_SSS_0835	569874	5762289	Suspected Debris	4.1	1.2	0.3	-17	irregularly formed contact
BB_FS_SSS_0937	569719	5762832	Suspected Debris	7.2	0.6	0.2	-16.4	oval contacts, possibly stones
BB_FS_SSS_0019	570760	5760382	Suspected Debris	4.9	1.2	0.5	-14.9	NCN 20283, Seabed disturvance
BA_FS_SSS_0035	570150	5760234	Suspected Debris	4.8	0.5	0.3	-11.5	Elongated contact
BB_FS_SSS_0620	570364	5761961	Suspected Debris	4.1	0.4	0.3	-17	See Wreck NCN 219
BB_FS_SSS_0678	570397	5761996	Wreck	31.9	20.5	1.6	-17	See Wreck NCN 219
BB_FS_SSS_0684	570389	5762001	Suspected Debris	4.3	0.6	0.4	-17	See Wreck NCN 219
BH_FSEA_SSS_0187	559117	5935318	Wreck	17.1	3.9	1.7	-34	See Wreck NCN 531
BJ_FD_SSS_0015	548443	5894128	Debris	5.6	1.8	0.0	-26.4	Elongated object 5.6 perpendicular to sand waves
BK_FSEA_SSS_0022	551288	5924521	Boulder	5.6	2.9	5.2	-29.8	Buried Remains with Magnetic Anomalies
BK_FSEA_SSS_0163	550142	5921916	Boulder	0.0	2.5	2.5	-29	See NCN 967
BK_FSEA_SSS_0179	555839	5929168	Boulder	6.7	5.7	1.0	-30.3	Large Anchor Shaft 3.2 M Arms 2.1m With Scouring

Appendix 2. Phases of maritime archaeological research

The Dutch Quality Standard for Archaeology (KNA Waterbodems, version 4.1) describes all procedures and requirements for the archaeological research process. Below a brief description of the steps involved:

1. **Desk study**
   The purpose of a desk study is to collect and report all available historical data, geological information, and information about disturbances in the past. The result is an archaeological expectation map or model.
   The desk study may be expanded with an analysis of sonar and multibeam data, if available.

   IF the outcome of the desk study shows that there is a risk of occurrence of archaeology, then the next phase must be carried out:

2. **Exploratory field research (opwaterfase)**

   a. Geophysical survey
   In order to test the archaeological expectation, a geophysical survey is carried out. The type of survey depends on the type of expected objects, local geology and expected depth of the objects below the seafloor. In practice, the research usually consists of a side scan sonar survey, if necessary, supplemented with multibeam echo sounder recordings, subbottom profiling and magnetometer measurements. The requirements of the survey are based on the desk study and should be included in a program of requirements which must be approved by the competent authorities.

   IF potential archaeological objects are found, then the next phase (**3**) must be carried out.

   b. Geotechnical survey
   In order to reconstruct prehistoric landscapes and refine and test the archaeological expectation related to those landscapes a geotechnical survey can be carried out. A geotechnical survey comprises penetration tests (CPT's) and/or bottom sampling (*vibrocore*, Acqualock, Begemann, grab sampling, etcetera). The sample strategy and sample locations are based on the geological constellation of the area and interpreted subbottom profiling data. The requirements of the survey shall be listed in a program of requirements which must be approved by the competent authorities.

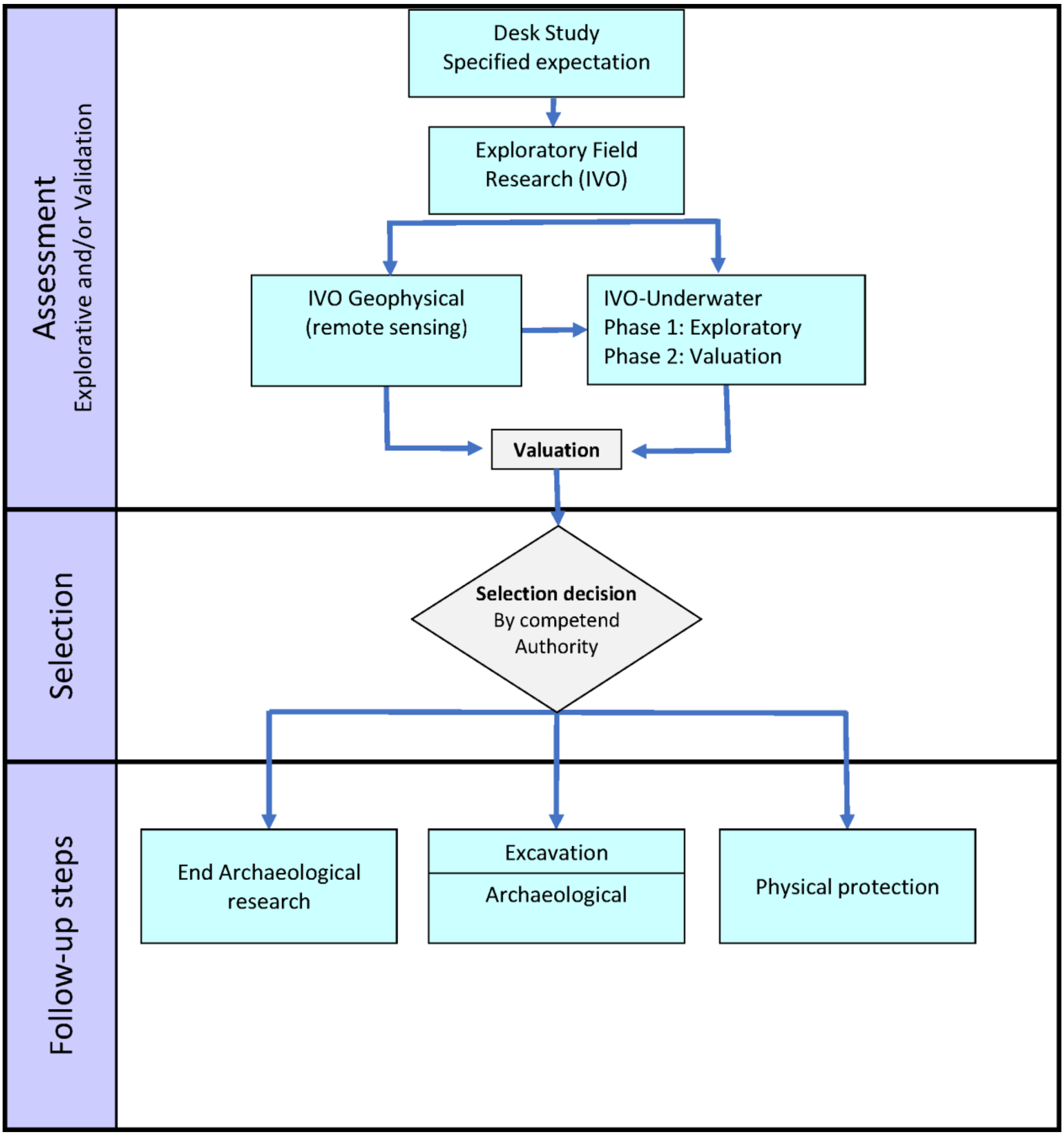
3. **Exploratory field research (onderwaterfase verkennend)**
   The suspected sites are investigated by specialized divers in order to identify the objects. The requirements of the underwater research are included in a program of requirements which must be approved by the competent authorities.

   IF as site is identified as an archaeological object or structure then the next phase must be carried out:

4. **Appreciative field research (onderwaterfase waarderend)**
   The archaeological remains at the site are thoroughly investigated and mapped by a specialized archaeological diving team and samples are collected for additional research. Then a decision will be made whether the archaeological remains are worth preserving. If the latter is the case, then there are two possibilities: either the remains can be preserved in situ (adjustment of plans), or the next phase will be conducted:

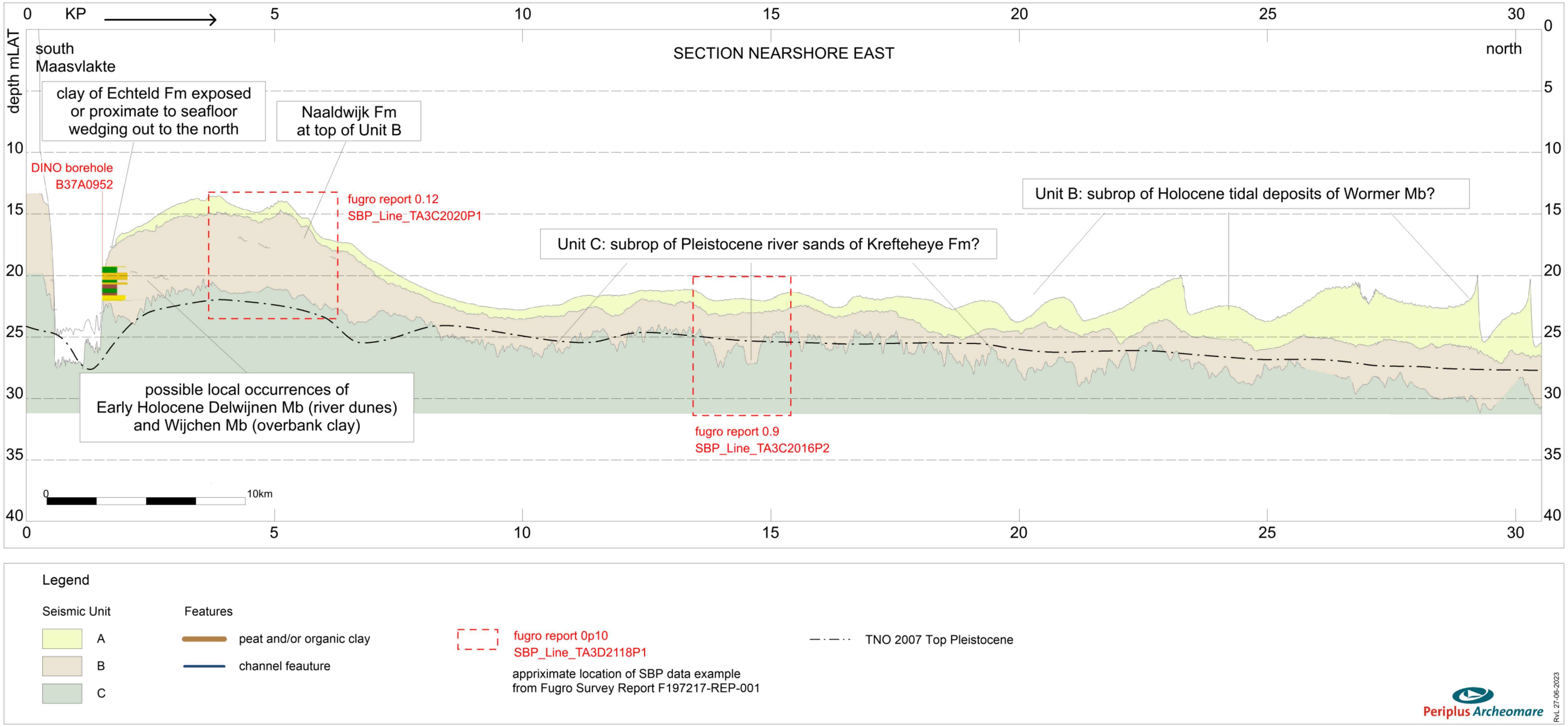
5. **Archaeological excavation**
The archaeological remains are excavated under supervision of a senior maritime archaeologist. All remains need to be documented, registered, and conserved. The requirements of the underwater research are included in a program of requirements which must be approved by the competent authorities.

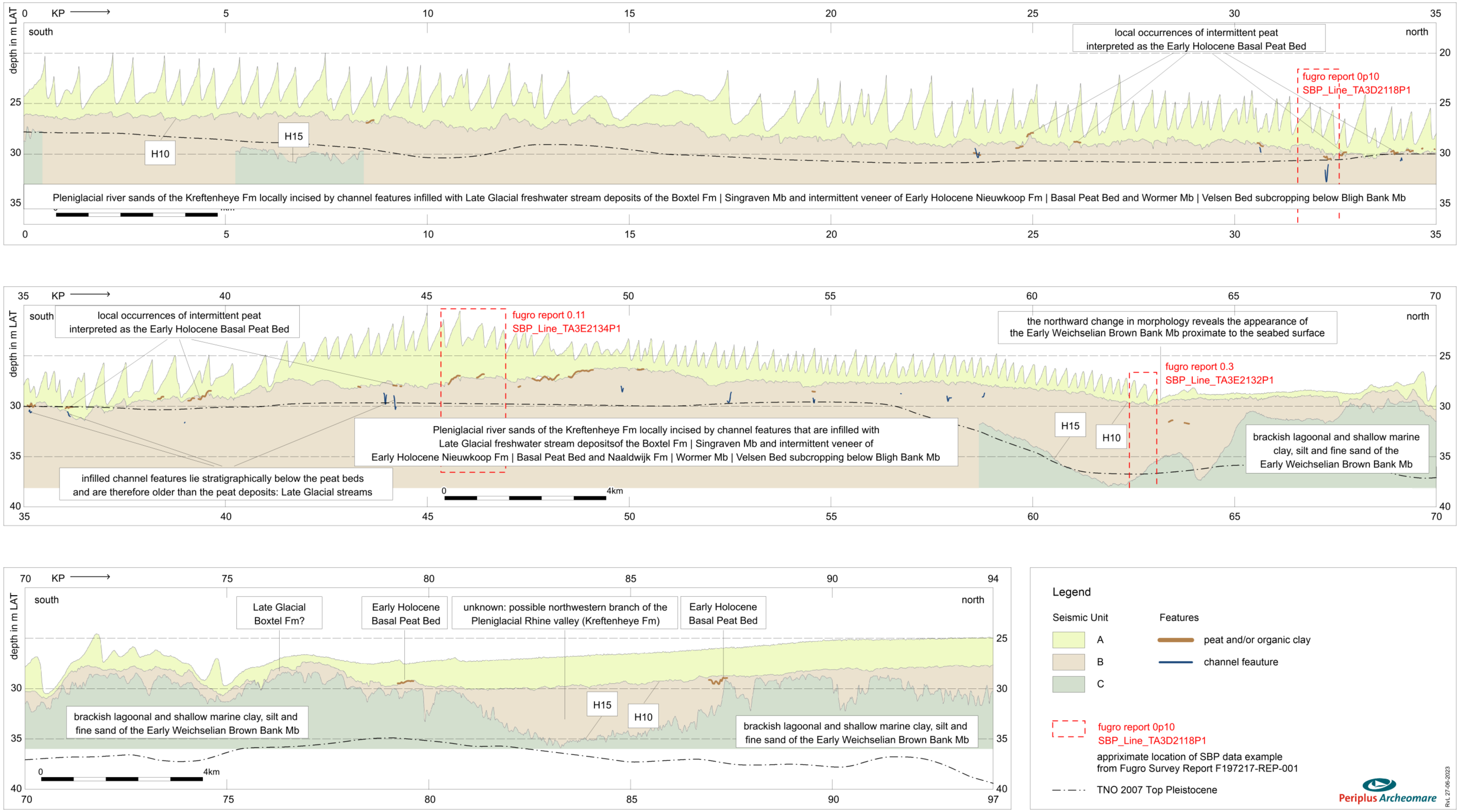
The phases described above contain a number of decision points that are dependent on the detected archaeological objects. The figure below shows these moments schematically.

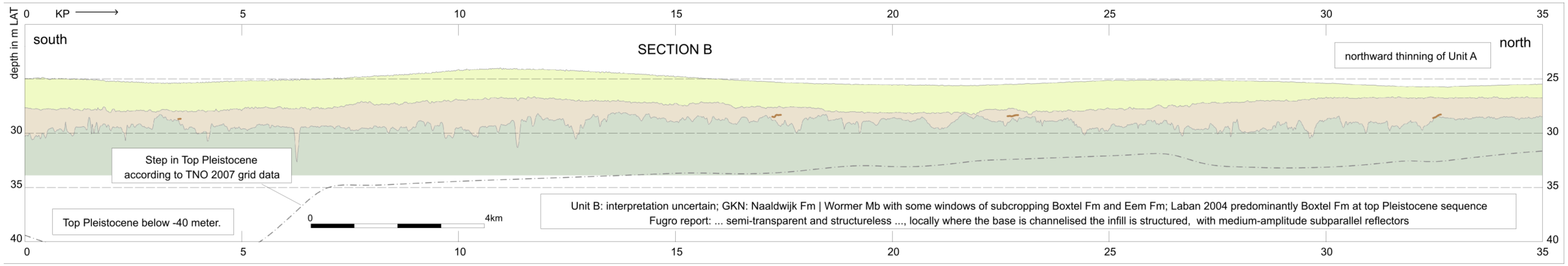


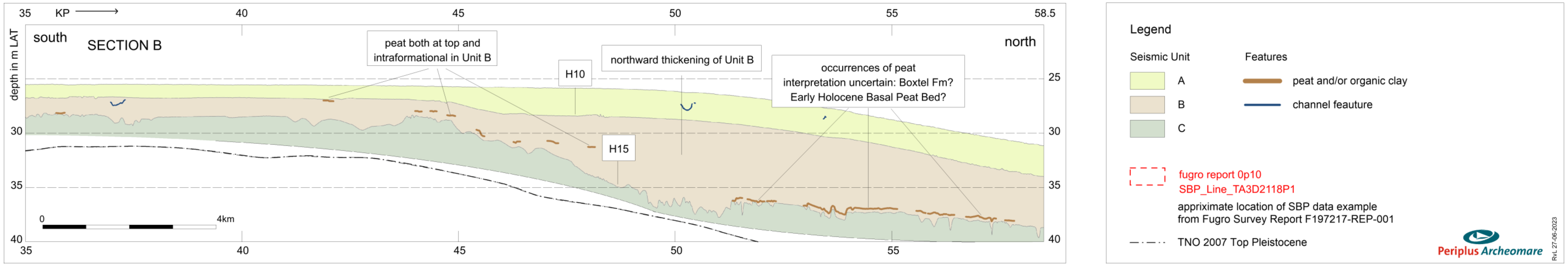
Appendix 3. X-sections

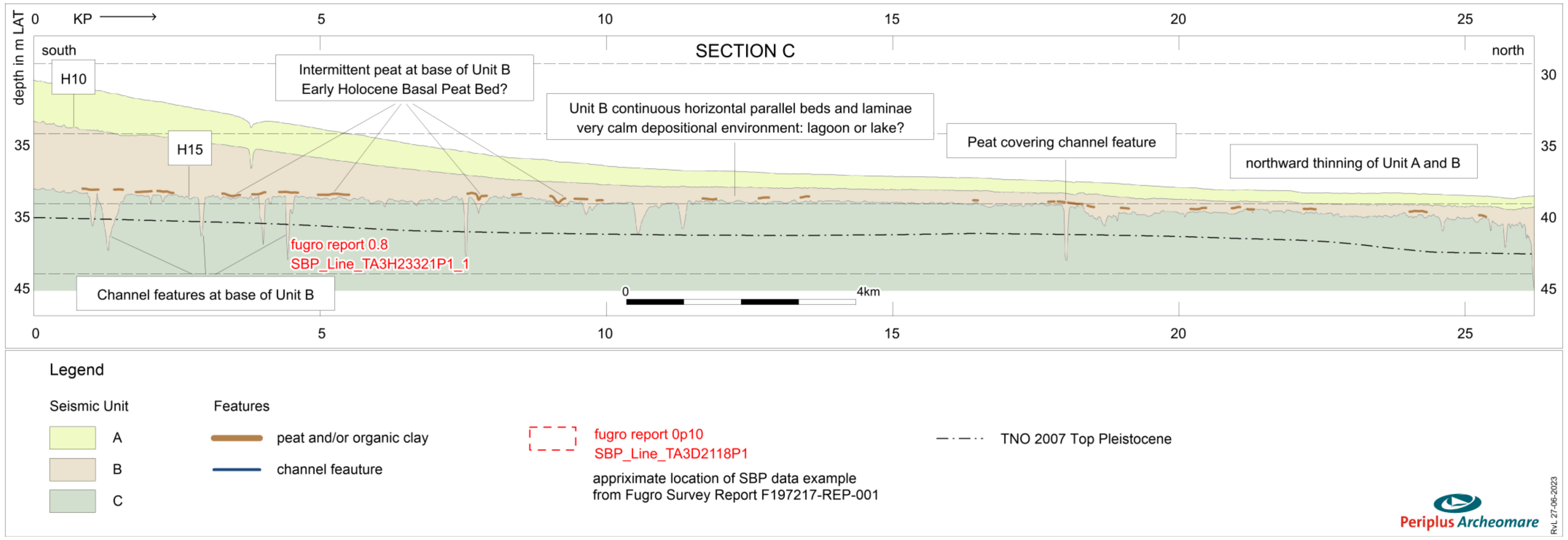
Section Nearshore East, A, B and C


0 KP
5
10
15
20
25
30
depth mLAT
south
Maasvlakte
SECTION NEARSHORE EAST
north
clay of Echteld Fm exposed or proximate to seafloor wedging out to the north
Naaldwijk Fm at top of Unit B
DINO borehole B37A0952
fugro report 0.12
SBP_Line_TA3C2020P1
Unit B: subrop of Holocene tidal deposits of Wormer Mb?
Unit C: subrop of Pleistocene river sands of Krefteheye Fm?
possible local occurrences of Early Holocene Delwijnen Mb (river dunes) and Wijchen Mb (overbank clay)
fugro report 0.9
SBP_Line_TA3C2016P2
10km
Legend
Seismic Unit
A
B
C
Features
peat and/or organic clay
channel feauture
fugro report 0p10
SBP_Line_TA3D2118P1
appriximate location of SBP data example from Fugro Survey Report F197217-REP-001
TNO 2007 Top Pleistocene
Periplus Archeomare
RvL 27-06-2023


KP
south
north
depth in m LAT
local occurrences of intermittent peat interpreted as the Early Holocene Basal Peat Bed
fugro report 0p10
SBP_Line_TA3D2118P1
H10
H15
Pleniglacial river sands of the Kreftenheye Fm locally incised by channel features infilled with Late Glacial freshwater stream deposits of the Boxtel Fm | Singraven Mb and intermittent veneer of Early Holocene Nieuwkoop Fm | Basal Peat Bed and Wormer Mb | Velsen Bed subcropping below Bligh Bank Mb
fugro report 0.11
SBP_Line_TA3E2134P1
the northward change in morphology reveals the appearance of the Early Weichselian Brown Bank Mb proximate to the seabed surface
fugro report 0.3
SBP_Line_TA3E2132P1
Pleniglacial river sands of the Kreftenheye Fm locally incised by channel features that are infilled with Late Glacial freshwater stream depositsof the Boxtel Fm | Singraven Mb and intermittent veneer of Early Holocene Nieuwkoop Fm | Basal Peat Bed and Naaldwijk Fm | Wormer Mb | Velsen Bed subcropping below Bligh Bank Mb
brackish lagoonal and shallow marine clay, silt and fine sand of the Early Weichselian Brown Bank Mb
infilled channel features lie stratigraphically below the peat beds and are therefore older than the peat deposits: Late Glacial streams
0
4km
Late Glacial Boxtel Fm?
Early Holocene Basal Peat Bed
unknown: possible northwestern branch of the Pleniglacial Rhine valley (Kreftenheye Fm)
Early Holocene Basal Peat Bed
brackish lagoonal and shallow marine clay, silt and fine sand of the Early Weichselian Brown Bank Mb
brackish lagoonal and shallow marine clay, silt and fine sand of the Early Weichselian Brown Bank Mb
Legend
Seismic Unit
A
B
C
Features
peat and/or organic clay
channel feauture
fugro report 0p10
SBP_Line_TA3D2118P1
appriximate location of SBP data example from Fugro Survey Report F197217-REP-001
TNO 2007 Top Pleistocene
Periplus Archeomare
Rvl. 27-06-2023


depth in m LAT
KP
0
5
10
15
20
25
30
35
south
SECTION B
north
northward thinning of Unit A
Step in Top Pleistocene
according to TNO 2007 grid data
Top Pleistocene below -40 meter.
0
4km
Unit B: interpretation uncertain; GKN: Naaldwijk Fm | Wormer Mb with some windows of subcropping Boxtel Fm and Eem Fm; Laban 2004 predominantly Boxtel Fm at top Pleistocene sequence
Fugro report: ... semi-transparent and structureless ..., locally where the base is channelised the infill is structured, with medium-amplitude subparallel reflectors
25
30
35
40


depth in m LAT
KP
35
40
45
50
55
58.5
south
SECTION B
north
peat both at top and
intraformational in Unit B
H10
northward thickening of Unit B
occurrences of peat
interpretation uncertain: Boxtel Fm?
Early Holocene Basal Peat Bed?
H15
0
4km
25
30
35
40
Legend
Seismic Unit
Features
A
B
C
peat and/or organic clay
channel feauture
fugro report 0p10
SBP_Line_TA3D2118P1
apprixmate location of SBP data example
from Fugro Survey Report F197217-REP-001
TNO 2007 Top Pleistocene
Periplus Archeomare
Rvl. 27-06-2023


depth in m LAT
KP
0
5
10
15
20
25
south
SECTION C
north
H10
Intermittent peat at base of Unit B
Early Holocene Basal Peat Bed?
Unit B continuous horizontal parallel beds and laminae
very calm depositional environment: lagoon or lake?
H15
Peat covering channel feature
northward thinning of Unit A and B
fugro report 0.8
SBP_Line_TA3H23321P1_1
Channel features at base of Unit B
0
4km
30
35
40
45
Legend
Seismic Unit
Features
A
B
C
peat and/or organic clay
channel feauture
fugro report 0p10
SBP_Line_TA3D2118P1
apprixmate location of SBP data example
from Fugro Survey Report F197217-REP-001
TNO 2007 Top Pleistocene
Periplus Archeomare
Rvl. 27-06-2023

Appendix 4. Integrated Geophysical and Geotechnical reports

F197217-REP-001_(01) Geophysical Results Report.pdf

By Fugro