Porthos Pipeline

An archaeological assessment
of the
Geophysical survey results

Periplus Archeomare rapport 20A029-01

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Porthos Pipeline: An archaeological assessment of the geophysical survey results

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Content

Samenvatting (Dutch) **5**

Summary **6**

1. Introduction **8**

1.1. Background 8

1.2. Results desk study 10

1.3. Objective 13

1.4. Research questions 13

2. Methodology **15**

2.1. Introduction 15

2.2. Objective 15

2.3. Survey equipment 15

2.4. Known objects 16

2.5. Archaeological assessment of survey data 17

2.6. Data Analysis 18

2.7. Used Sources 19

3. Results **20**

3.1. Seabed bathymetry and morphology 20

3.2. Known objects: As Found positions correlated with database positions 20

3.3. Side scan sonar 24

3.4. *Multibeam* 27

3.5. *Magnetometer* 28

3.6. Subbottom data 30

4. Synthesis **35**

5. Conclusion and Advice **40**

List of figures **42**

List of tables **43**

Glossary and abbreviations **44**

References **45**

Appendix 1. Archaeological and geological time table **47**

Appendix 2. AMZ Cycle (Dutch) **48**

Appendix 3. Locations of potential archaeological interest **49**

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.
Palaeolithic (Early Stone Age)	300.000	B.C.	-	8800	B.C.

Province	Zuid-Holland	
Municipality:	Rotterdam	
Location:	Maasvlakte 2, Noord sea	
Enforcing authority:	Rijkswaterstaat Zee en Delta	
Depth of seafloor (in mLAT)	Maximum Average Minimum	-2.78 m -19.81 m -35.31 m
Environment	Tidal currents, saltwater	
Current Use	Shipping lane	
Toponym	Porthos Pipeline	
Charts:	37A, 30C en 1801	
Coordinates (UTM31N ED50)	West	E 563228
	Oost	E 572185
	Noord	N 5776741
	Zuid	N 5760009
Surface Area	42 km^2	
Enforcing authority:	Rijkswaterstaat Zee en Delta Gemeente Rotterdam	
Enforcing authority contact:	mr. R. Duijts	
Enforcing authority advisory body:	Rijksdienst voor het Cultureel Erfgoed	
Enforcing authority advisor:	Mrs. M. Snoek, mr. B.I. Smit & mr. J. Opdebeeck	
ARCHIS-research report (CIS-code):	4901701100	
Periplus project reference:	20A029-01	
Period of execution:	October 2020	
Archive:	Periplus Archeomare BV, Amsterdam	

Table 2. Administrative details of the research area

Samenvatting (Dutch)

Follows in the Final report.

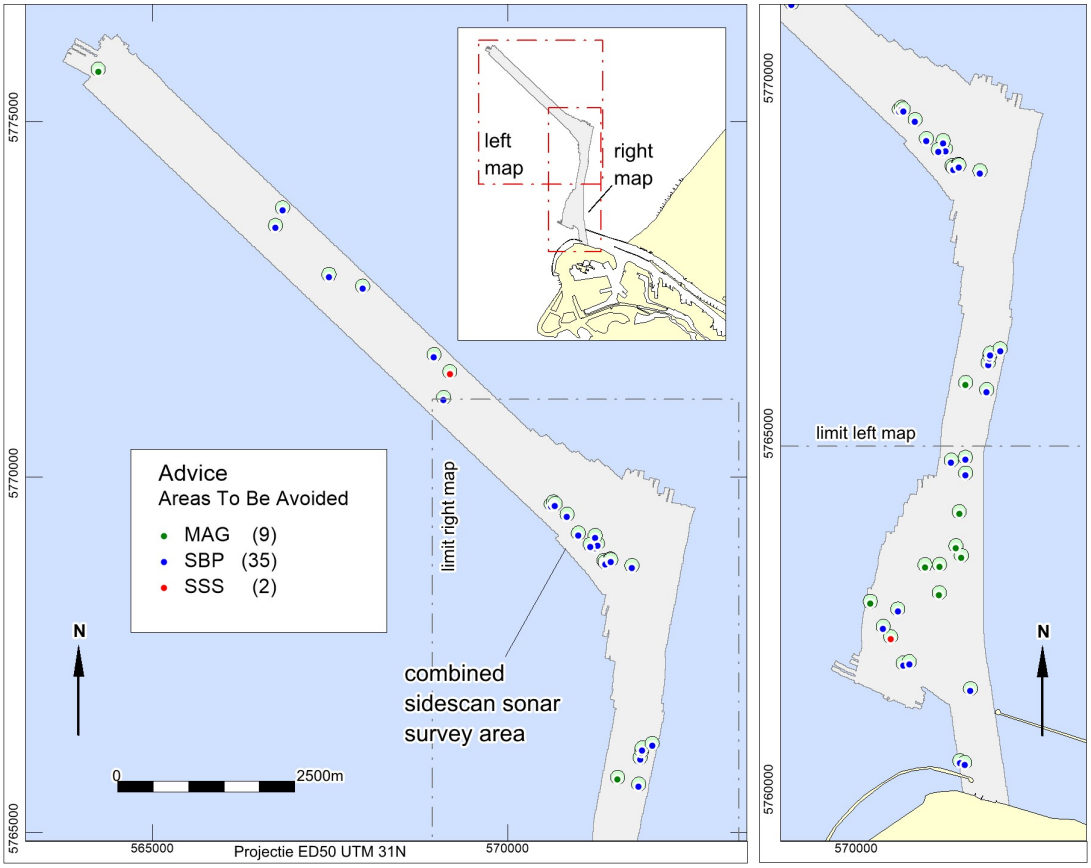
Summary

Porthos Development C.V. has contracted Periplus Archeomare B.V. to conduct an archaeological assessment of geophysical route survey data in the context of the proposed installation of the Porthos Pipeline. Prior to this assessment an archaeological desk study was carried out in June 2020.

The archaeological assessment has resulted in the identification of 18 sites of potential archaeological interest:

- Sidescan sonar (2)
- *Multibeam* (0)
- *Magnetometer* (9)
- *Subbottom profiler* and *Multibeam* (7)

The objects found exposed at the seabed comprise an unidentified shipwreck (NCN 219) and newly found remains of possible wreck (POR_SSS_0056). Apart from the two (possible) shipwrecks, 9 magnetic anomalies with peak-to-peak values over 500 nT have found. Further a total of 7 buried objects have been identified through the observation of reflection hyperbola in the seismic records which also coincide with a significant magnetic anomaly. These sidescan sonar contacts, magnetic anomalies and *Subbottom profiler* contacts could not be correlated with infrastructure related to the production or transport of hydrocarbons, objects known from database sources.



The 2 exposed (possible) wreck sites and 16 buried objects are considered to be of possible archaeological value until proven differently. It is advised to avoid these locations and abstain from trenching operations and other seabed disturbing activities within a 100 m buffer zone around these locations. It should be stressed that the origin of the magnetic anomalies is unknown. Apart from archaeological remains any type of man-made objects can be encountered including unexploded ammunition, anchors, pieces of chains and cables, debris, etcetera.

The buffer zone of 100 meters is a standard that applies to the protection of cultural heritage, this distance may be reduced if it can be substantiated that the applied disturbance has no effect on the archaeological object. For example, when no anchoring is used during cable lay operations the buffer zone can be decreased. Reduction of the distance has to be approved by Rijkswaterstaat (RWS). Rijkswaterstaat is the competent authority, acting on behalf of the Ministry of Economic Affairs. The Cultural Heritage Agency of the Netherlands (RCE) acts as an advisor to Rijkswaterstaat.

If it is not feasible to avoid the reported wreck sites, *Magnetometer* and *Subbottom profiler* locations, additional research is required in order to determine the actual archaeological value of the reported locations. If this indicates that the object has no archaeological value, the location can be omitted.

Disturbance of undisturbed Late Weichselian and Early *Holocene* levels, and possible in situ prehistoric remains contained herein, cannot be prevented. It is therefore advised to conduct geo-archaeological research on vibrocore samples. Prospection for archaeological remains is not the primary focus of this research. The purpose of the vibrocore analysis is to obtain additional information on the integrity of archaeological levels and the development of the prehistoric landscapes including both terrestrial and aquatic environments.

It is important for the analysis of vibrocores for geo-archaeological purposes that these cores are intact. Samples that have been used for strength tests and grain size determination are generally not suitable for archaeological research, because they are no longer intact. It is therefore important to coordinate the use of the samples. One possibility could be that the cores are examined by a certified KNA (Dutch Quality Standard for Archaeological Research) prospector aquatic soils prior to use for determining physical parameters (strength / grain size). The prospector can also make a selection of samples for specialist research, for example C14 analyzes or research of pollen, animal and vegetable macro residues, molluscs, diatoms, et cetera. The requirements and preconditions set for the archaeological research of vibrocores must be recorded in a Program of Requirements (PoR) or a Plan of Action (PoA).

1. Introduction

Porthos Development C.V. has contracted Periplus Archeomare B.V. to conduct an archaeological assessment of geophysical route survey data in the context of the proposed installation of the Porthos Pipeline. Prior to this assessment an archaeological desk study was carried out by Periplus in June 2020.[1]

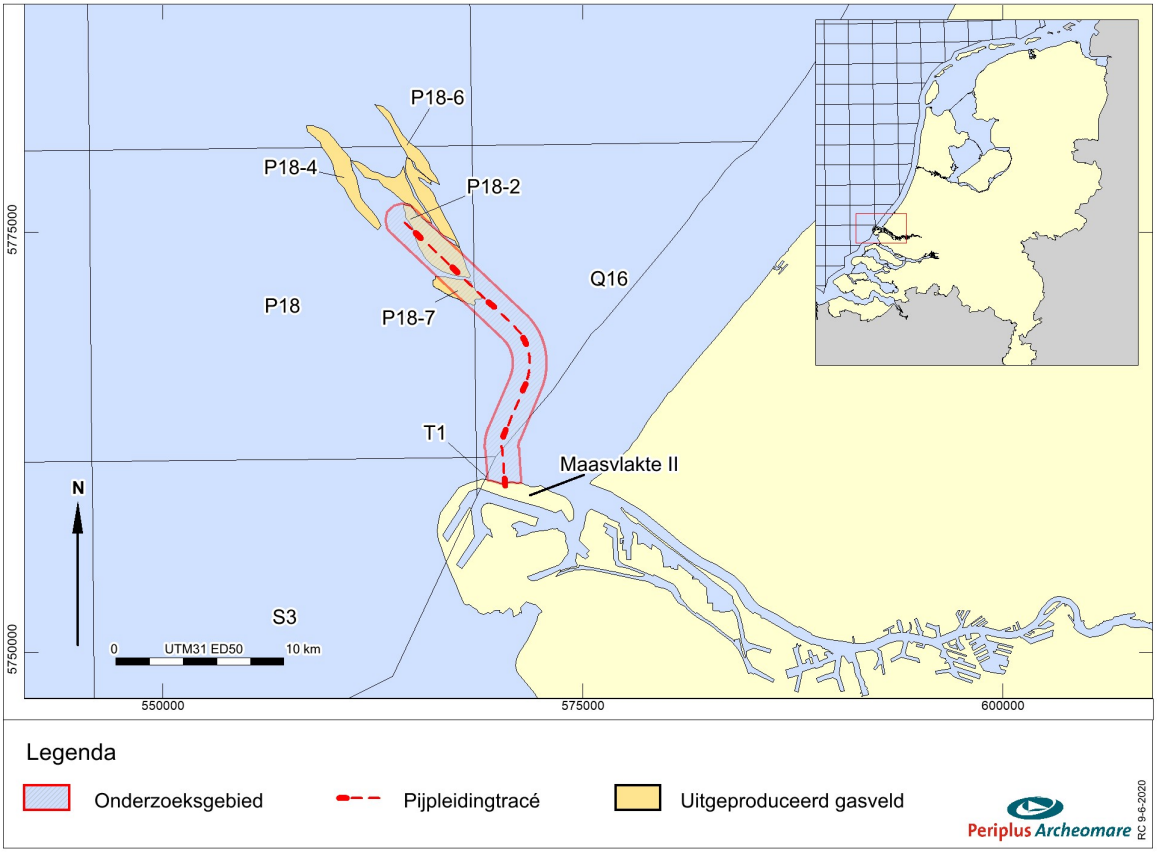


Figure 1: Location of the research area.

1.1. Background

The Port of Rotterdam and its partners the Gasunie and EBN intend to realise the construction of a CO_2 transport pipeline from the Port of Rotterdam to the P18 fields in the North Sea, where the CO_2 will be stored. The intended pipeline route will be laid entrenched in the bottom of the North Sea to the exhausted gas fields in the North Sea. The CO_2 infrastructure will be 21 km long. The transport and storage system consists of an onshore pipeline, the compressor station, an offshore pipeline and the storage of CO_2 in the deep subsoil of the North Sea. The capture of CO_2 from the harbour's industries and the use of CO_2 or the storage of it underground (Carbon Capture Usage and Storage, CCUS for short) is one of the measures to achieve the climate objectives.

[1] Van Lil 2020.

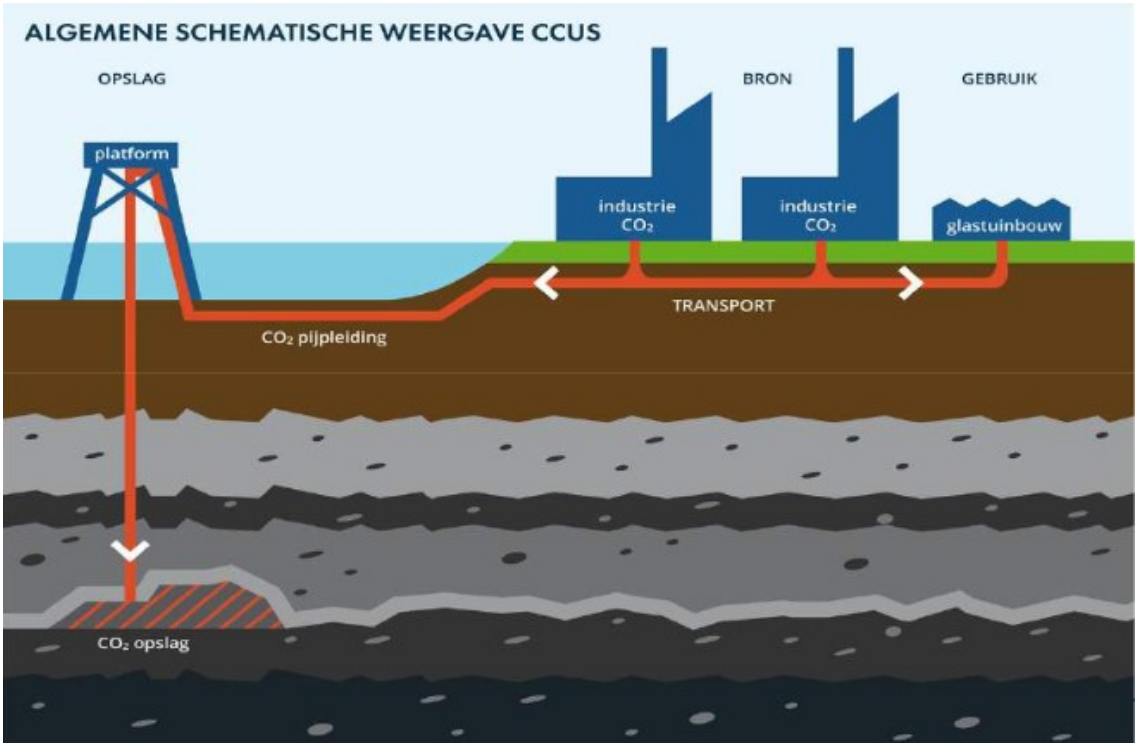


Figure 2: Schematic representation of the transport and storage system.

The protection of the archaeological and historical heritage is anchored in the Dutch Heritage Act (July 2016).[2] The installation of platforms, wells and coherent infrastructure might affect archaeological remains, if present. As the planned activities might jeopardize archaeological remains, Economic Affairs considers a research effort is needed to assess the archaeological potential of the area.

The so-called AMZ cycle (Dutch: Archeologische Monumenten Zorg cyclus) consists of a series of procedures for the subsequent phases of archaeological research to be performed in order to ensure the protection of archaeological heritage in the Netherlands. 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 2.

The first step in the AMZ-cycle is an archaeological desk study. In 2020 a desk study has been performed. [3] The first study covers a wide area of the A- and B-blocks; the second study zooms in at the then planned appraisal well sites A15-05 and B10-04 (refer to figure 1).

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.

[2] Dutch: Erfgoedwet.
[3] Van Lil 2020.

1.2. Results desk study

The archaeological desk study performed in June 2020 has resulted in specific information on the archaeological remains that are to be expected in the area. The desk investigation has shown that ship and aircraft wrecks and in situ remains are to be expected within the research area.

Prehistory

The subsoil of the planned route of the Porthos pipeline may contain intact prehistoric landscapes and archaeological remains from the Palaeolithic and Mesolithic related to these landscapes. The archaeological expectation concerns remains of camp sites, burial remains and lost or dumped hunting attributes from the early Prehistory. Remains from these periods are expected within a succession of early *Holocene* sediments, which have been deposited in widely varying environments (river dunes, flood clays, peat, freshwater tidal deposits, brackish-estuarine deposits). The river dunes were preferred locations of Mesolithic camping sites. The Mesolithic remains found on a river dune in the Yangtze harbour at 20 meters below NAP show that these dunes are actually for habitation. The correlation between the archaeological levels and lithostratigraphic units are summarized in the table below.

Formation	Member Bed	Age	Remarks	Archaeological expectation	Period
Southern Bight	Bligh Bank	*Holocene*	marine sand mobile layer	I, IV	ME – NT
Naaldwijk	Wormer	From 6000 BC	brackish/salt tidal deposits	I, II, IV	LMESO
Echteld	Terbregge	7250 - 6000 BC	fresh/brackish fluvio-tidal clay	I, II en IV, possibly III	MMESO
Nieuwkoop	Basal Peat	7250 - 6500 BC	coastal peat	II en IV, possibly III	MMESO
Kreftenheye	Wychen – 1	8000 BC	overbank deposits	II en III	EMESO
Boxtel	Delwijnen	9000 BC	river dunes	III	MESO
	Wierden	Weichselian - Early *Holocene*	aeolian	III	LPALEO - EMESO
	Singraven		stream deposits	II, III (stream valley) and IV	LPALEO – EMESO
Kreftenheye	Wychen – 2	9500 v. Chr	overbank deposits	II en III	LPALEO – EMESO
	-	Weichselian	channel deposits	II en IV	MPALEO – EMESO
Eem	Brown Bank	Eemian - Early Weichselian	lagoonal and lacustrine clays	II en III (shores)	MPALEO
	-	Eemian	marine deposits	IV	MPALEO

Table 3. Archaeological expectation related to the lithostratigraphy.

Archaeological expectation	
I	Shipwrecks and shipping-related objects; plane wrecks
II	Lost or dumped objects, incl. flints and bones, hunting equipment, fishing wears, fish traps, log boats
III	Settlements and burial remains
IV	Reworked artefacts

Table 4. Explanation of the archaeological expectation.

Table 3 shows that remains of prehistoric settlements (III) in river dunes of the Delwijnen Member, aeolian sands from the Wierden Member and stream deposits from the Singraven Member are expected. The locations where intact river dunes, fluvial sand ridges and heads, or edges of stream valleys occur within the pipeline route is not known.

Lost and dumped objects and / or washed-up artifacts may occur in the Maasmond area, they are related to the underwater clays of the Echteld Formation and the Wormer Member. To the north of the Maasgeul, these deposits are locally exposed on the seabed. Therefore, the Echteld Formation and the Wormer Member may also contain shipwrecks.

The presence of camp sites (III) is marked by flint and bone artifacts, bone remains, charcoal and / or burnt seeds and nuts (hazelnut shells). The size of the camping sites can vary from small (one-off briefly used hunting camps) to large (repeated intensive use and seasonal occupation).

It is unknown to what extent the early *Holocene* landscape along the pipeline route has been affected by erosion. Given the very rapid "drowning" of the *Pleistocene* landscape in the Early *Holocene* and the covering of archaeological levels by peat and clay, prehistoric remains may be (very) well preserved. This expectation applies to both organic and inorganic residues. If the archaeological levels have not been affected by human activity or natural processes, prehistoric remains of very high physical quality can be expected. This contrasts with the early Mesolithic sites found in the high-lying sandy areas of the Netherlands. At these sites, the find layer is often included in the furrow and the ground tracks are located directly below the furrow and above the groundwater table. The physical quality of these sites has always been affected to a greater or lesser extent.

Another point where the expected settlements along the pipeline route distinguish themselves from the known sites on the mainland is their low location in the North Sea area. Little is known about the early *Holocene* inhabitants of the North Sea region, their settlements, and the way in which they maintained themselves in the rapidly changing landscape. The information value of the expected settlements in the area is therefore high. This is also stated in the National Research Agenda for Early Prehistory: Locations and any surrounding phenomena that are located in paleo-scenic contexts that have not yet or have hardly been studied, by definition have a large information value.[4]

Shipwrecks

Nine shipwrecks are known within the research area. Few details are known of most of these wrecks; the origin and age have not yet been determined. These wrecks can therefore be of archaeological value. Undiscovered wrecks may also occur within the research area, which are covered by migrating sand waves. An overview of the known shipwrecks is shown in the table and image below.

NCN	Description	RWS	DHY	Easting	Norhting	R95
219	This was RWS_nr 1930	3148	1930	570385	5761989	5
222	*This was RWS_nr 1948*	75	1948	569387	5762626	5
230	No description in database	1920	1969	570700	5765129	5
234	No description in database	40	0	564161	5775605	100
366	No description in database	161	2951	563234	5775714	0.1
1822	The wreck has been salvaged	0	1928	571084	5760899	1000

[4] Nationale Onderzoeksagenda, hoofdstuk 11: De Vroege Prehistorie.

NCN	Description	RWS	DHY	Easting	Norhting	R95
1900	1899 wreckage reported. Due to the presence of platform P18-A, no further investigation has been carried out on this wreck.	0	2047	564648	5776200	1000
761	Nothing known, only mapped			570898	5764752	1500
831	Wreck of the 'Stubbenkammer', sunk in 1967.			570448	5762891	30
834	Wreck of the 'Clearwater', sunk in 1968, lifted on 5 September 1968 by van v.d. branch recovery company and transported to Maassluis.			569664	5761706	30

Table 5. Known shipwrecks within the research area of the desk study.

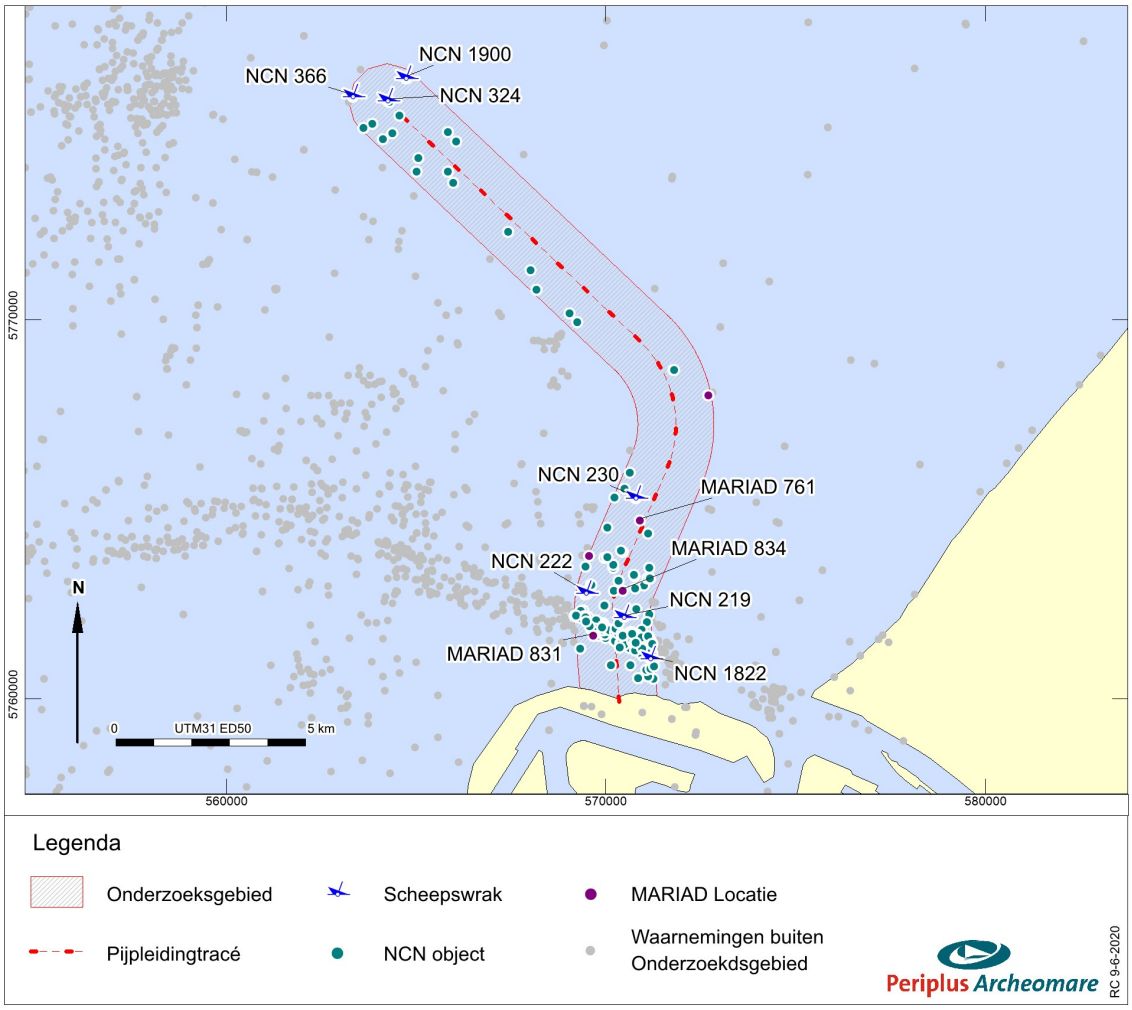


Figure 3. Known shipwrecks within the research area of the desk study.

Plane wrecks: In total, more than 5000 aircraft crashed in the Netherlands during the war years. Various sources are unclear about the number of aircraft that are still missing in the North Sea area. In any case, it concerns hundreds. Several reports of aircraft wrecks are known in the vicinity of the research area. It is conceivable that there are several undiscovered remains in the area.

1.3. Objective

The purpose of the archaeological assessment is to test the desk study-based expectancy for archaeological remains in the area. Included in this likelihood are remains of shipping related objects (shipwrecks), aircraft from World War II and prehistoric remnants related to the drowned *Pleistocene* landscape.

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;
- To assess the prehistoric landscape based on the seismic data.

1.4. Research questions

For the inventory archaeological field study, the following research questions have been defined.

With respect to Side Scan Sonar 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 attach an interpretation to the nature of the archaeological objects and to prioritize importance?

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 caused by either natural erosion, sedimentation or human interference?

With respect to *Magnetometer* survey:

- Have magnetic anomalies been identified in the survey area?

If so:

- What is the location and size (peak-to-peak residual total field value) of those anomalies?
- Are the anomalies induced by known infrastructure?

- Can the anomalies be correlated with objects known from database sources or newly found side scan sonar and/or *Multibeam* contacts?

With respect to *Subbottom profiler* survey:

- At what depth below the seabed has the *Pleistocene* landscape been found?
- What sub-cropping *Pleistocene* unit(s) have been found below the cover of *Holocene* deposits?
- What is the depositional environment of these *Pleistocene* units?
- Is the top of the *Pleistocene* landscape intact?
- What *Holocene* unit(s) are found?
- Do the seismic data show indications for the presence of peat or organic clay at the base of the *Holocene* sequence?
- Can zones be identified where remains of prehistoric settlements are to be expected?

If so:

- Could these expected settlement remains be affected by the planned activities?
- 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 its correlation with side scan sonar, *Magnetometer* and *Multibeam* data can something be said about the nature of these buried objects?
- Are there any mitigating measures necessary to avoid disturbance of possible archaeological remains?

2. Methodology

2.1. Introduction

DEEP BV has carried out a geophysical survey as part of the planned activities for the intended Porthos pipeline. This survey consists of two mobilization periods. The first mobilization was carried out in August of 2019. The second mobilization was conducted from June 21 to June 31, 2020.

Prior to the DEEP survey, Fugro performed a geophysical survey in the context of the ROAD project in August 2010. The Fugro data have been included in this assessment.

2.2. Objective

The purpose of the archaeological assessment is to test the desk study-based expectancy for archaeological remains in the area. Included in this likelihood are remains of shipping related objects (shipwrecks), aircraft from World War II and prehistoric remnants related to the drowned *Pleistocene* landscape.

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;
- To assess the prehistoric landscape based on the seismic data.

2.3. Survey equipment

2019 | 2020 DEEP surveys

The surveys were conducted by the MV Seapal, using *Multibeam Echo Sounder* (MBES), side scan sonar (SSS), *Magnetometer* (MAG) and sub-bottom profiler (SBP).

During the survey operations the following techniques were used:

- *Multibeam* echosounder to accurately map the bathymetry covering a 300–500 metre corridor along the preferred pipeline route. Besides measuring the water depth, *Multibeam* data was used to detect objects on the seabed.
- Sidescan sonar was used for the detection of objects on the seabed, and for seabed and features. Scanning range was set to 75 m per channel and line spacing was 40 m. Lines were sailed with sufficient overlap to cover the sonar nadir and achieve a full 300% coverage.
- A *Magnetometer* was deployed for the detection of (large) ferromagnetic objects, and for determining the position of buried pipelines. Survey lines were sailed every 40 metres along the pipeline route. A realistic towfish height (*Magnetometer* piggy backed on sidescan sonar) of 5m above seabed results in a ferro mass detection of approximately 700kg.
- A parametric sub-bottom profiler was used for the mapping of shallow geological layers and for the detection of buried objects, amongst which existing pipelines. Survey lines were sailed every 40 metres along the pipeline route and every 750 m across the preferred route.
- A sparker seismic reflection system was used for the mapping of shallow geological layers near the shipping lane. Survey lines were sailed every 40 metres along the pipeline route and every 750 m across the preferred route.

2010 FUGRO survey

The surveys were conducted by the MV Aurelia, using *Multibeam Echo Sounder* (MBES), side scan sonar (SSS), *Magnetometer* (MAG) and sub-bottom profiler (SBP). The operational settings are listed below.

- *Multibeam Echo Sounder*
  - *Multibeam Echo Sounder* Reson SeaBat 8125
  - Frequency 455 kHz
  - Swath coverage 120º
  - Number of beams 240
  - Heave compensation Seatex MRU
  - Transducer depth (z) 4.51 m

- Side scan sonar
  - Side scan sonar EdgeTech 4200
  - Range 75 m or 100 m
  - Frequency 300 kHz or 600 kHz
  - Cable out 30 m / 100 m (depending on water depth and ship's speed)

- Sub-bottom profiler
  - Pipeliner : Oretech 3010P, Fish model 3040P, ULTRA 120 recorder
  - Range : 40 msec
  - Frequency : 3.5 kHz / 5.0 kHz / 7.0 kHz / 10 kHz
  - Cable out : 8 m
  - Power : 75% of 5 kW
  - Firing rate : 40 to 80 msec
  - Paper speed : 120 lpi

- *Magnetometer*
  A Marine Magnetics SeaSPY *Magnetometer* was use to identify any ferromagnetic object along the centre line of the proposed route. The *Magnetometer* was interfaced via the side scan sonar towfish and towed as close to seabed as safely possible (usually 3 m to 6 m above seabed). The *Magnetometer* data was logged to the Starfix processing suite, processed and interpreted to identify any anomalies in the background magnetic field.

2.4. Known objects

FUGRO and DEEP have summarized the side scan sonar contacts, magnetometric anomalies and *Subbottom profiler* hyperbola encountered within the survey area in detailed event listings. From different databases the occurrence of objects within the area is known. The contacts included in the survey event listings are compared with the database objects in the area. For this comparison the database of National Contact Number (NCN) is used.

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 Sea and Delta)

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.

All known data is combined and plotted in a 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.

2.5. Archaeological assessment of survey data

The geophysical and hydrographic survey techniques employed include side scan sonar (SSS), *Magnetometer* (MAG), *Multibeam* (MBES) and subbottom profiling (SBP). With side scan sonar all objects and structures larger than 0.5 meter in any dimension on the seabed can be made visible. Seabed sediments of different composition can be distinguished by their characteristic reflection and were validated by core samples. *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.

Magnetometer contacts are identified by the presence of ferro-metallic objects which induce an anomaly in the earth magnetic field. These objects comprise both buried objects and objects which are exposed at the seabed. Unlike side scan sonar and *Multibeam* contacts are tagged at the sailed survey line. The actual object can be located at both sides of the survey line. Given the 40 meter (DEEP) en 60 meter (FUGRO) spacing of the run lines the accuracy perpendicular to the line is in the order of 20 meter (DEEP) and 30 meter (FUGRO). The survey companies processed their survey data and produced detailed event listings of the side scan sonar contacts and magnetic anomalies encountered within the surveyed areas. Both the location of the known objects as well as the locations of the contacts are plotted in a GIS.

In the course of this archaeological assessment a selection is 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 meter is analysed in more detail, because these objects are considered to be more likely to be related to wreck sites than the smaller contacts. This approach is based on best professional judgment and not prescribed by legislation or the KNA. 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;
- Side scan sonar geotiffs (0.15m resolution);
- *Multibeam* geotiffs (0.30m resolution);
- 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 taken into account 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 in order 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). The processing involved an analysis of a seismic profile along the centre line of the proposed umbilical route. Observed seismic reflectors have been digitized and - based on known geological data from the area - lithostratigraphic units have been identified. The results have been summarized in a survey report including two site maps for the proposed A15 platform location and the existing A12-CPP platform site and three overlapping alignment charts for the proposed umbilical route from A15 to A12-CPP. In addition to the identification and occurrence of lithostratigraphic units, seismic anomalies - which are expected to reflect existing pipelines and potential hazardous phenomena - have been identified.

2.6. 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 known objects were projected in a GIS together with the survey data.

For the cross-reference we have assumed that all present possible contacts and anomalies have been reported and described by the survey contractor. The raw data is only used, if available, 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. *Magnetometer* contacts which were found within 25 meters of a side scan sonar contact were considered to be potentially related to this sonar contact. The correlation between the magnetic anomaly and side scan sonar contact was then assessed. When at the

position of the *Magnetometer* anomaly no visible object was recognized the size of the anomaly was leading.

Given the employed line spacings of 40 and 60 meter a magnetic anomaly of more than 500 nT (nano-Tesla) is considered to reflect the potential presence of an object of archaeological interest. All the *Magnetometer* contacts above 500 nT but within 100 meters of the existing cable and pipeline routes are exempt for further investigation. It has to 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 best 'professional judgment'.

The interpreted seismic data have been assessed to investigate 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 seismic grids and profiles produced by DEEP and FUGRO have been used to get an insight 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 sections of the proposed umbilical route which are expected to contain archaeological remains are mapped and results are put in the context of the activities planned in order to predict of the activities might damage potential archaeological remains.

The analysis was executed in September - October 2020 by R. van Lil (Senior KNA prospector) and R.W. Cassée (maritime archaeologist). The investigation is carried out according to specifications set up within the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1; protocol 4103).

2.7. Used Sources

The following sources were used for the analysis:

- Survey data Fugro 2010 (ROAD project), original survey data and reported interpretations; [5]
- Survey data DEEP 2019|2020, original survey data and reported interpretations;
- Archaeological desk study Periplus Archeomare (20A019-01);
- ARCHIS database Cultural Heritage Agency;
- Archeomare Database;
- NLhono database Hydrographic Service of the Royal Netherlands Navy;
  Wrecksite.eu;
- Database, Nationaal Contact Nummer (NCN, Rijkswaterstaat Zee en Delta).

For a complete list of used sources and literature see the reference list at page 45.

Italic written words are explained in the glossary at page 44.

[5] Chisholm 2010.

3. Results

3.1. Seabed bathymetry and morphology

The seabed height in the DEEP 2019|2020 survey area varies from -12.5 to -35.1 mLAT. De modus value is -21.8 mLAT.

Seabed characteristic

The seabed morphology along the pipeline route is characterized by an elevated plateau-like section up to 6 kilometres north of the Maasgeul. The seabed is found here at depths less than 20 m LAT with two tops at -13.8 m LAT. The seabed lacks clear sedimentary structures and the surface is uneven with pocks. The occurrence of this plateau-like area is probably related to the occurrence of continuous clay deposits of the Wychen Member|Kreftenheye Formation and Terbregge Member|Echteld Formation.

Towards the Q16-FA-1 well site depth increases and the seabed surrounding the site is even and flat with a large with numerous trawler marks. The pipeline section from Q16-FA-1 to P15-A shows westward an increasing amount of mega sand ripples with crests running northwest-southeast, parallel to the pipeline route. The crests are 0.30 m high and occur at a spacing of 10 m.

3.2. Known objects: As Found positions correlated with database positions

A total of 155 contacts including 7 wreck sites are known from the NCN database within the boundaries of the area of investigation defined for the archaeological desk study. Another 3 wrecks are known from the MARIAD database which are not registered in the NCN database, bringing the total to 158 objects.

The total area surveyed by FUGRO in 2010 en DEEP in 2019 and 2020 is much smaller than the area of investigation of the desk study. Within the combined survey area a total of 73 contacts including 2 wreck sites are known from the NCN database. One (1) wreck is known from the MARIAD database which is not registered in the NCN database, totalling to 74 objects found.

An overview of these objects is given in the table below.

Type of contacts	Archaeological Desk Study Area of Investigation	Combined FUGRO | DEEP Survey Area
Wellsite	5	5
Seabed disturbances	10	5
Cables or chains	12	5
Man-made objects	1	-
Unknown	119	55
Boulders	1	1
Shipwrecks	10	3
Total	**158**	**74**

Table 6. Overview of known objects and contacts in the research area.

The SSS contacts and 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. In order to conduct this comparison all SSS contacts and MAG anomalies found within a range of accuracy 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.

An overview of the As Found- versus Not Found known objects is presented in the next figure.

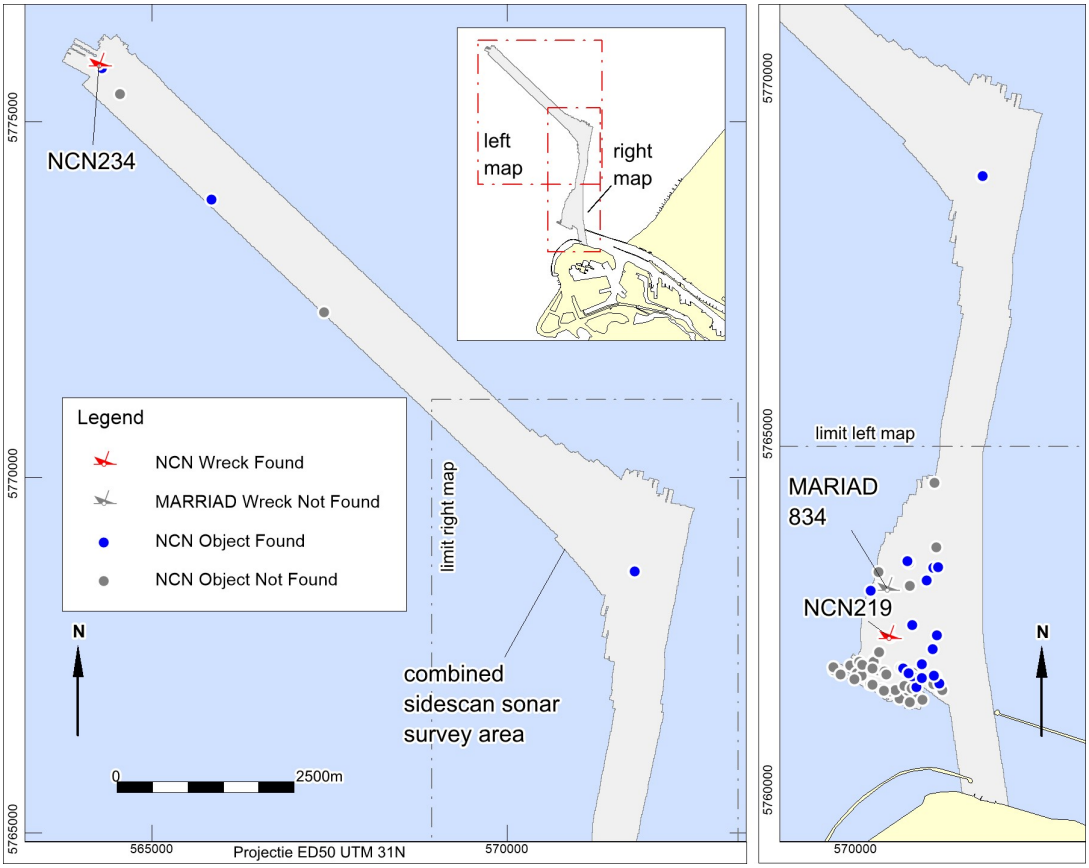


Figure 4. NCN|MARIAD contacts: Found versus Not Found.

NCN | MARIAD contacts Found in Sidescan sonar data

A total of 40 sidescan sonar contacts identified in the DEEP and FUGRO survey data have been found in the vicinity of 21 contacts known from the NCN database.

14 contacts comprise existing infrastructure related to the current and past production of hydrocarbons. The locations of two of these 14 contacts correspond with NCN-contact 234 which is registered in the NCN database as a 'wreck'. In fact this supposed wreck is most likely an isolated rockdump, which is part of the P18-A infrastructure as indicated by DEEP, Fugro and Periplus Archeomare.

One (1) contact has been found at the wreck site of NCN-contact 219 (see figure 5). NCN 219 comprises a wreck of which little is known other than its location (see Table 7). The sidescan sonar image indicates that major part of the wreck is embedded in the clayey seabed. On the surrounding seabed scattered small contacts are visible which could comprise small debris related to the wreck site.

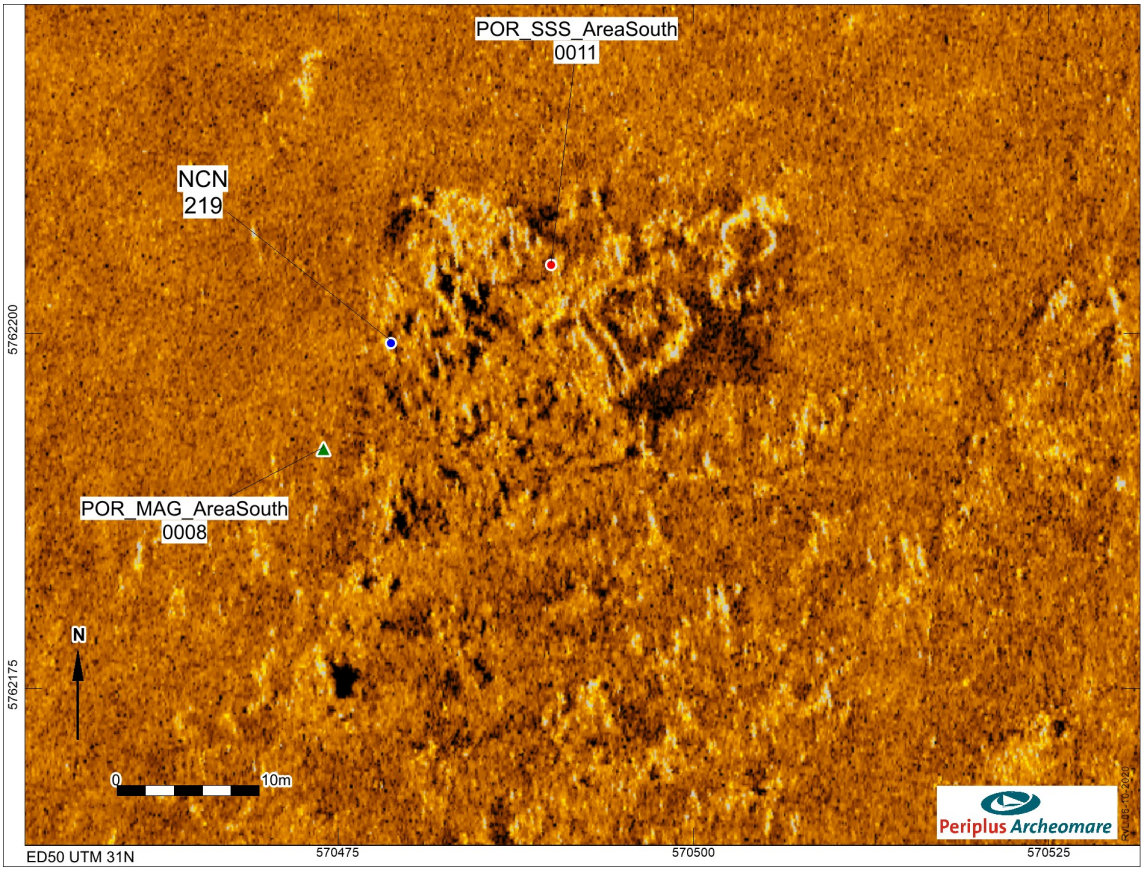


Figure 5. Unknown wreck (DEEP contact POR_SSS_AreaSouth_0011) as found on the location of NCN 219

DEEP	NCN	RWS	DHY	ETRS89		ED50		R95	Source
				Easting	Northing	Easting	Northing		
-	219	3148	1930	570385	5761989	570477	5762199	5	NCN
POR_SSS AreaSouth_0011	-	-	-	570398	5761995	570490	5762205	-	DEEP 2020 survey

Table 7. Contacts known from the NCN database which have been found with sidescan sonar

The remainder of sonar contacts have been interpreted as small non-archaeological objects (18), seabed disturbances (3) and man-made objects like possible buoy anchors (2), cables or chains (2). The assessed known contacts which have been found with sidescan sonar are listed in table 8 below.

Periplus Archeomare Assessment	Number
Cable or chain	2
Man-made object; possible bouy anchor	2
P18-02 Wellhead	1
P18-A Infrastructure; Ground Base Structure, mattresses, rockdumps	10
Q16-FA-1 Infrastructure; Subsea Completion, 8/2-Inch Gas/Methanol pipeline approach on SSC	3
Seabed disturbance (clay)	3

Periplus Archeomare Assessment	Number
Small object; non-archaeological	18
Wreck site NCN 219	1
Total	**40**

Table 8. Contacts known from the NCN database which have been found with sidescan sonar

NCN | MARIAD contacts Found - *Magnetometer*

A total of 15 magnetic anomalies identified in the DEEP and FUGRO survey data have been found in the vicinity of, and are likely induced by 13 objects known from the NCN database.

12 of the 15 magnetic anomalies correlate with objects which are found exposed at the seabed with sidescan sonar. The character of the sidescan sonar contacts to which the 12 anomalies are related have been discussed above.

3 of the 15 magnetic anomalies have not been found exposed at the seabed with sidescan sonar during the 2010, 2019 and 2020 surveys. The 3 magnetic anomalies do seem to relate to two known NCN-contacts.

2 of the 3 isolated magnetic anomalies are found proximate to NCN 3523. The visible part of this NCN-contact is 1.6 x 1.1 x 0.1 m. In itself it seems unlikely that this small contact represents an object of archaeological value. The two anomalies, however, have peak-to-peak values of 30 nT | 649 nT at distances of 24 m | 11m from NCN 3523. These large values can be induced by a small object containing a large portion of iron. Another option is that major part of the object or structure registered as NCN 3523 is buried beneath the seabed surface. In that case this object could be of archaeological value.

	SSS	SSS and MAG	MAG	Total
Number of NCN contacts Found	10	10	2	22
Number of contacts and anomalies identified in the 2020 | 2019 | 2020 survey data at the locations of the NCN contacts	17	23 and 12	3	55

Table 9. Contacts known from the NCN database which have been found with sidescan sonar and Magnetometer

3 of the 15 magnetic anomalies have not been found with sidescan sonar surveys during the 2010, 2019 and 2020 surveys, but do correlate with 2 NCN contacts. Two of these 3 magnetic anomalies are related to NCN 3523, an unknown object (L=1.6 m; W=1.1 m; H=0.1 m). This object in itself does not appear to be of archaeological interest. It can, however, not be excluded that part of the object or structure is buried beneath the seabed.

NCN | MARIAD contacts Not Found

Within the surveyed area 74 contacts are known from database sources. 52 of those known contacts have not been found.

Within the boundaries of the FUGRO|DEEP combined survey area 3 wreck sites are known from database sources:

- NCN 2
- MARIAD 1

One (1) the NCN wreck sites (NCN 219) have been found during the DEEP 2020 survey (see text above). One (1) the NCN wreck sites (NCN 234) most likely is not a wreck, but an isolated rock dump at the P15-A well site (see text above).

The remaining wrecks known from MARIAD (nr 834) database has not been found. This wreck, called the 'Clearwater', sank in 1968, and has been salvaged on September 5, 1968 and transported to Maassluis. Remnants of this wreck could have been left behind, but neither the sidescan sonar nor the *Magnetometer* data show any indications that this in fact is the case.

3.3. Side scan sonar

FUGRO and DEEP have identified a total of 332 side scan sonar contacts in the survey data acquired in 2010, 2019 and 2020. An overview of the sidescan sonar contacts found is shown in figure 6 below.

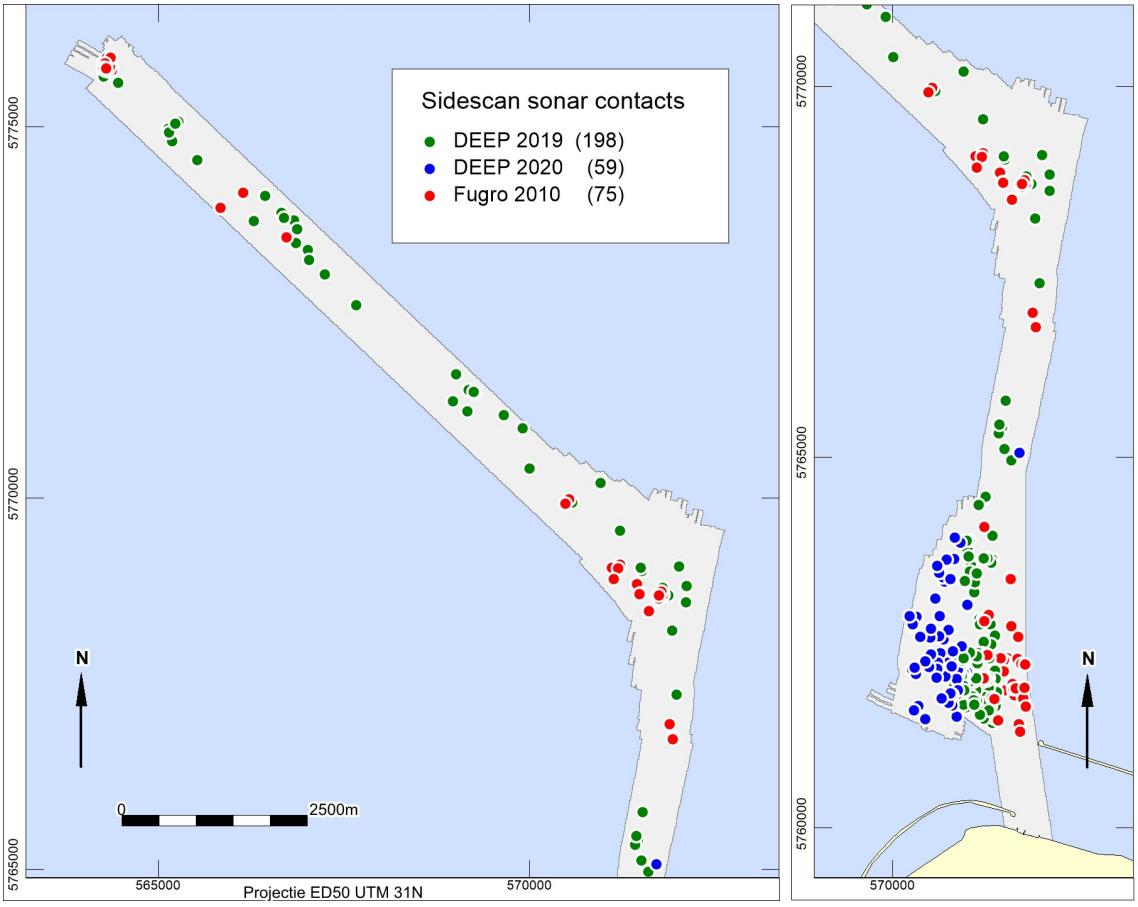


Figure 6. Combined results of sidescan sonar surveys performed by FUGRO and DEEP

The classification of the contacts is listed below.

The 40 contacts which match the known NCN-objects have been discussed in the previous section. The other 292 side scan sonar contacts and images also have been scanned and checked for the presence of potential archaeological contacts. This is done by analyses of:

- Side scan sonar images as delivered;

- 1m *Multibeam* grid data (xyz-file);
- 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.

A summary of the outcome of the detailed inspection of selected contacts is presented in the table below:

Category	Interpretation		Number Found	
Hydrocarbon related	Pipeline exposure	16/3-Inch Active Gas/Methanol Pipeline Piggyback From P18-A To P15-D	1	**63**
		26-Inch Active Gas Pipeline from P15-D to Maasvlakte	11	
		8/2-Inch Gas/Methanol Pipeline Piggyback From P18-A To Q16-FA-1	5	
		unknown pipeline	1	
	P18-02 Wellhead		1	
	P18-A Infrastructure: Active 8/3-Inch Gas/Methanol Pipeline From P18-A To Q16-FA-1, GBS, rockdumps, mattresses on pipeline sections and spoolpieces, wet stored mattresses, spudcan depressions		27	
	Piece of pipe		1	
	Q16-05 Isolated rock dump		4	
	Q16-05 Wellhead		1	
	Q16-FA-1 Infrastructure: Active 8/2-Inch Gas/Methanol Pipeline, spoolpieces, SSC, jackup rig footprints		11	
Natural phenomena	Seabed disturbance (clay)		46	**58**
	Sediment mound		6	
	Clay boulder		2	
	Shell bed		4	
Man-made Non-archaeological recognizable	Anchor		6	**24**
	Anchor mark		1	
	Anchor with chain		2	
	Buoy anchor with chain		2	
	Cable or chain		7	
	Cluster of unknown objects		3	
	Coiled fishing net		3	
Man-made Non-archaeological Non recognizable	Unknown linear object		23	**185**
	Unknown object		162	
Possible Archaeological	Possible wreck remains		1	**2**
	Wreck site NCN 219		1	
	Total		**332**	**332**

Table 10. Assessed sidescan sonar contacts within the combined FUGRO|DEEP survey area

The listing of 332 sidescan sonar contacts includes 63 phenomena reflecting the production and transport of hydrocarbons such as the Q16-FA-1 Subsea Completion, the P18-A Ground Base Structure, pipeline protecting items like mattresses and rockdumps, pipeline exposures, et cetera.

The clayey seabed (= outcrop of greyish/brackish water clay of the Terbregge Member|Echteld Formation) directly north of the Maasgeul often displays a pocked surface which can result in acoustic phenomena in the sidescan sonar data which resemble objects at the seabed, but in fact solely reflect seabed disturbances. A total of 58 'natural' phenomena have been observed, like shell beds (4), sediment mounds (6) seabed disturbances (46) and clay boulders (2).

24 recognizable man-made objects found include lost or dumped objects, like anchors (11), chains and cables (7) and fishing gear (3).

A large number of contacts (185) has been labelled as 'Unknown (linear) object'. Those contacts generally comprise small contacts from which the character not conclusively could be identified from the sonar images.

Out of the 332 assessed sidescan data 2 are considered to be of potential archaeological interest. The first is the unidentified wreck site (POR_SSS_AreaSouth_0011) which is contained in the NCN database as NCN-contact 219 (see figure 5).

The second contact (POR_SSS_0056) comprises a concentration of criss-cross linear reflectors. In the surrounding seabed scattered linear reflectors alike are visible. The phenomena observed in the sidescan sonar image at this location could represent wreck remains. The actual objects present at this location can only be determined by an ROV survey or divers.

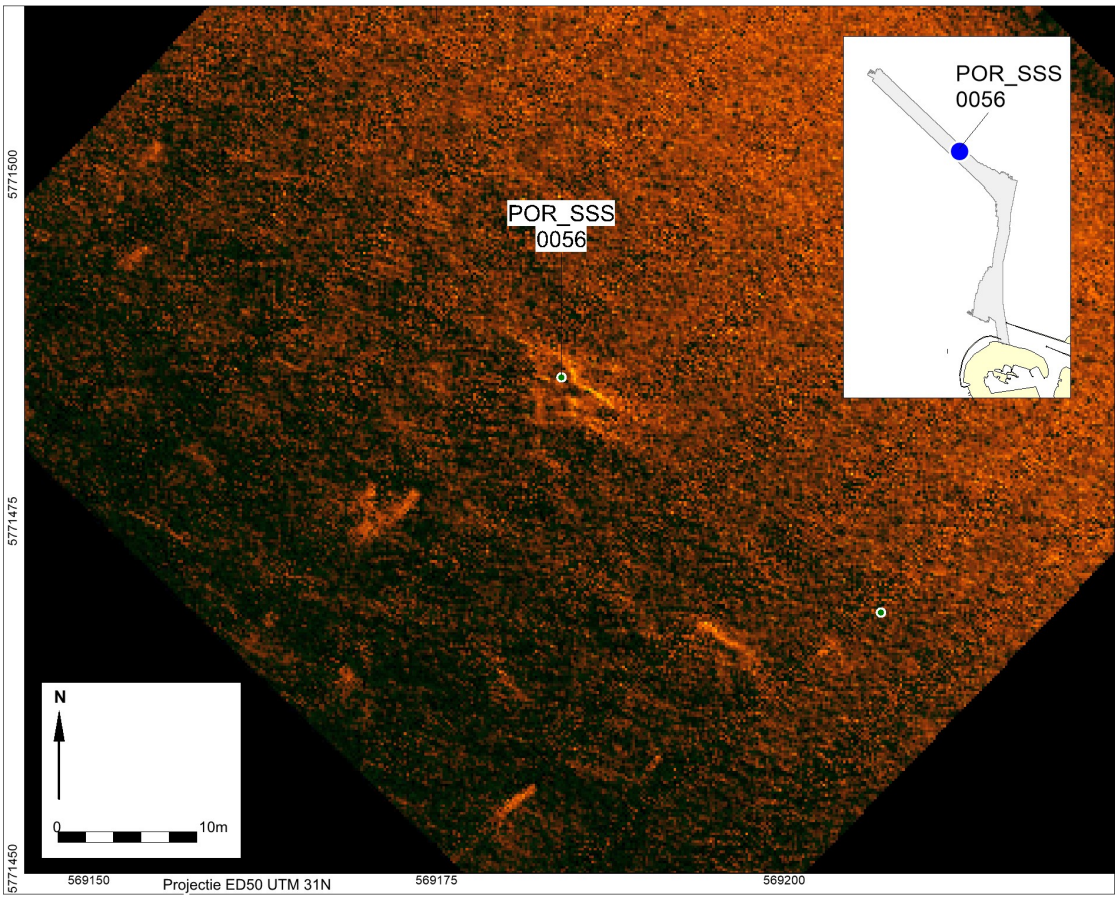


Figure 7: Contact POR_SSS_0056 - site of potential archaeological interest

3.4. *Multibeam*

The DEEP surveys have resulted in the identification of 84 *Multibeam* contacts. Fugro has not reported any *Multibeam* contacts. All side scan sonar contacts have been correlated with the *Multibeam* contacts.

22 *Multibeam* contacts do not correlate with the side scan sonar contacts. Three of those contacts comprise two pipelines and a rockdump near the P18-A platform location. Another *Multibeam* contact is a dump within the 'loswal' area. Further what appears to be a long piece of flexible pipeline is found and 17 seabed disturbances / small objects in the southern part of the area.

None of the *Multibeam* contacts have been interpreted as objects or structures of potential archaeological interest.

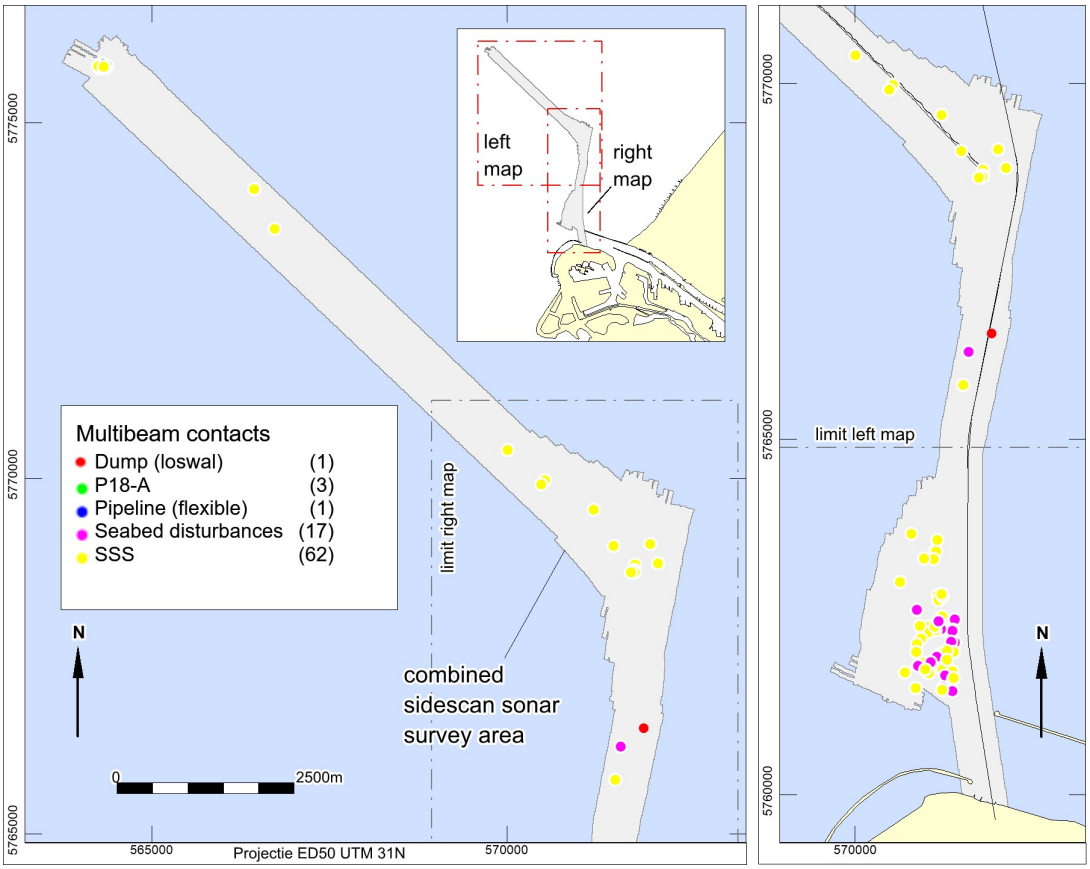


Figure 8. Results of Multibeam surveys performed by DEEP

3.5. *Magnetometer*

Besides the two objects of potential archaeological interest found with sidescan sonar, there are large magnetic anomalies which can not be related to sidescan sonar or *Multibeam* data. 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.

A total of 1240 magnetic anomalies have been identified in the *Magnetometer* data collected during the FUGRO 2010 and DEEP 2019|2020 surveys. 255 of these anomalies can be linked to known and inferred pipelines (143), (possible) cables (24), two wellheads (5), known NCN contacts (14), sidescan sonar contacts identified during the surveys (66) and *Multibeam* contacts (3). A classification is of these anomalies is listed in the table below.

Classification		**Number**	**Total**
Magnetic anomalies related to infrastructure and objects known from database sources and found during the FUGRO 2010 and DEEP 2019|2020 surveys	Pipelines	143	255
	(Possible) Cables	24	
	Wellheads	5	
	Known NCN contacts	14	
	SSS contacts	66	
	MBES contacts	3	
Magnetic anomalies induced by unknown ferrous objects			985
Total			**1240**

Table 11. Classification of the magnetic anomalies

The known shipwreck (NCN 219; sonar contact POR_SSS_AreaSouth_0011) has induced a 1397 nT magnetic anomaly (POR_MAG_AreaSouth_0008). At the location POR_SSS_0056 the sidescan sonar image displays a cluster of linear objects and scattered linear objects, which could reflect a site of potential archaeological interest (wrecksite?). However at this site no magnetic anomalies have been measured.

7 of the 1240 magnetic anomalies correlate with buried objects which cause reflection hyperbola in the analysed *Subbottom profiler* records.

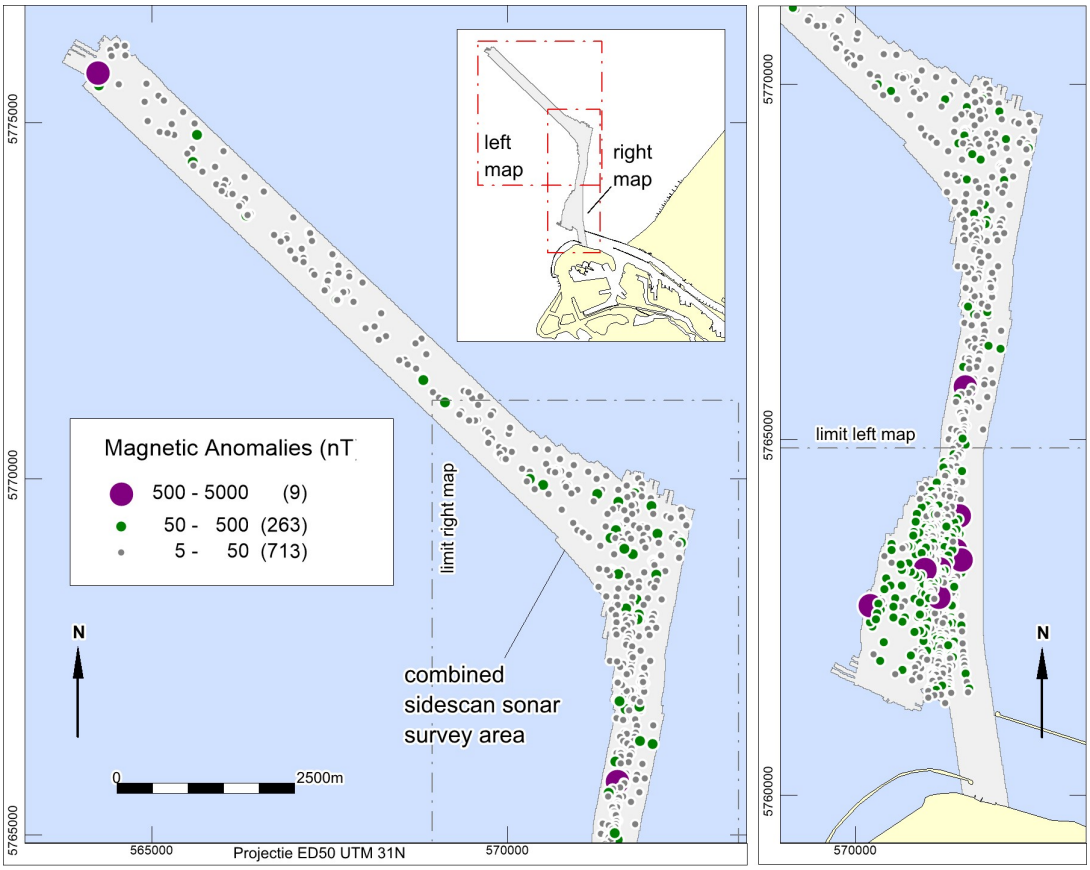


Figure 9. Magnetic anomaly classified on the measured peak-to-peak values (infrastructure related anomalies are not shown)

985 anomalies cannot be related to known pipelines and cables, or visible objects at the seabed surface. These are related to unknown ferrous objects which have been covered by sediments. 9 of these anomalies have peak to peak amplitude of 500 nT. The character of the iron-bearing objects which induce these anomalies cannot be determined from the current data. The anomalies could be caused by pieces of cable, anchors, UXO's, et cetera. Because the character of these iron-bearing objects cannot be determined, the objects present also include objects of potential archaeological interest. The positions are listed in the following table:

MAG_ID	ED50 E	ED50 N	Peak-To_Peak	Remark
POR_MAG_0554	571546	5765779	1974	
POR_MAG_0672	571454	5763964	849	
POR_MAG_0748	571408	5763485	517	
POR_MAG_0793	571178	5763221	649	NCN 3523 unknown object L=1.6 m; W=1.1 m; H=0.1 m E 571075 N 5763010
POR_MAG_0868	571174	5762823	506	
POR_MAG_AreaSouth_0014	570974	5763218	660	
POR_MAG_AreaSouth_0030	570204	5762702	938	
MA01	564237	5775739	1110	
MA21	571485	5763347	563	SBP - SB49 DOB=0.2 m

Table 12. Unknown ferro-magnetic objects of potential archaeological interest

3.6. Subbottom data

Buried objects like pipelines, boulders and debris can be found in *Subbottom profiler* data, due to the anomalous reflective characteristics with respect to the surrounding sediments. The objects can be traced through the identification of so-called reflection hyperbola in the seismic image. An example is shown in figure 10 below.

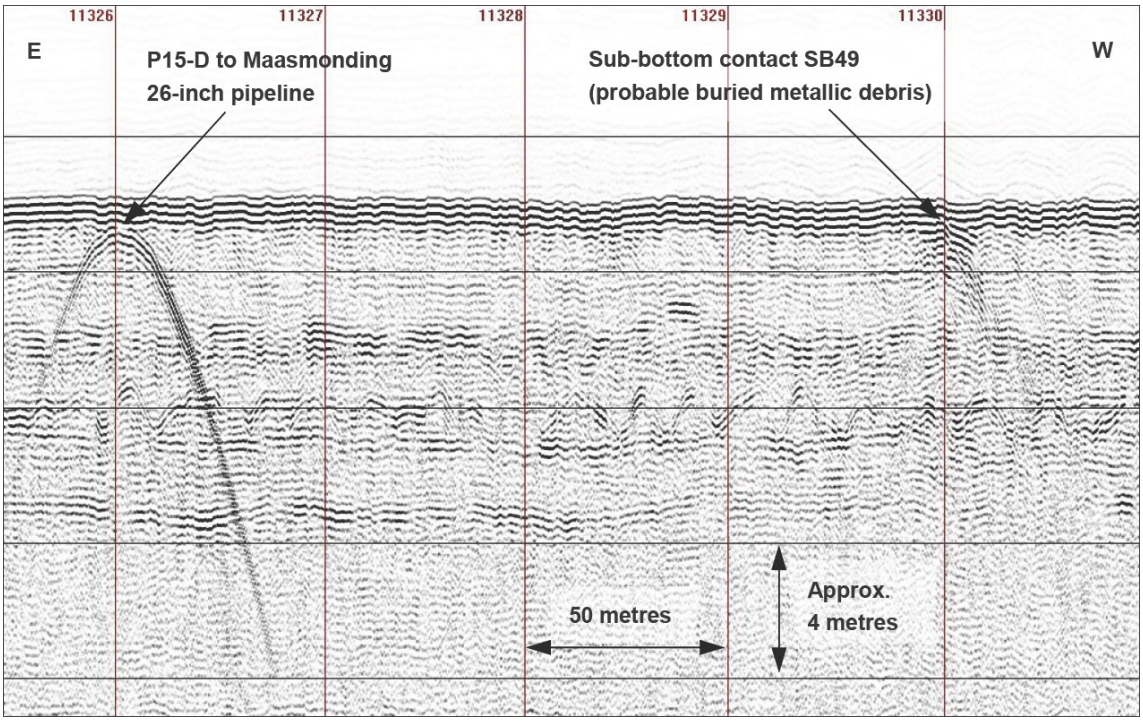


Figure 10. Reflection hyperbola observed in the Fugro 2010 SBP data reflecting the presence of a pipeline and an unknown iron-bearing object

The combined surveys resulted in the identification of 107 reflection hyperbola in the *Subbottom profiler* data. 72 objects can be correlated to existing infrastructure like pipelines (62) and mattresses (2). One (1) hyperbola is caused by the unidentified wreck of potential archaeological value (NCN 219). Another 7 hyperbola coincide with a magnetic anomaly. The latter means that these 7 magnetic anomalies are induced by an object that is located straight under the transducer and not somewhere in between the sailed lines.

The remaining 35 hyperbola are likely to be caused by unknown buried objects. The character of these buried objects cannot be determined from the *Subbottom profiler* data.

Classification		**Number**	**Total**
Subbottom profiler contacts related to infrastructure and objects known from database sources and found during the FUGRO 2010 and DEEP 2019|2020 surveys	Pipelines	62	72
	Mattresses	2	
	Known NCN contacts (NCN 219)	1	
	Magnetic anomalies	7	
Unidentified buried objects found with SBP			35
Total			**107**

Table 13. Classification of Subbottom profiler contacts

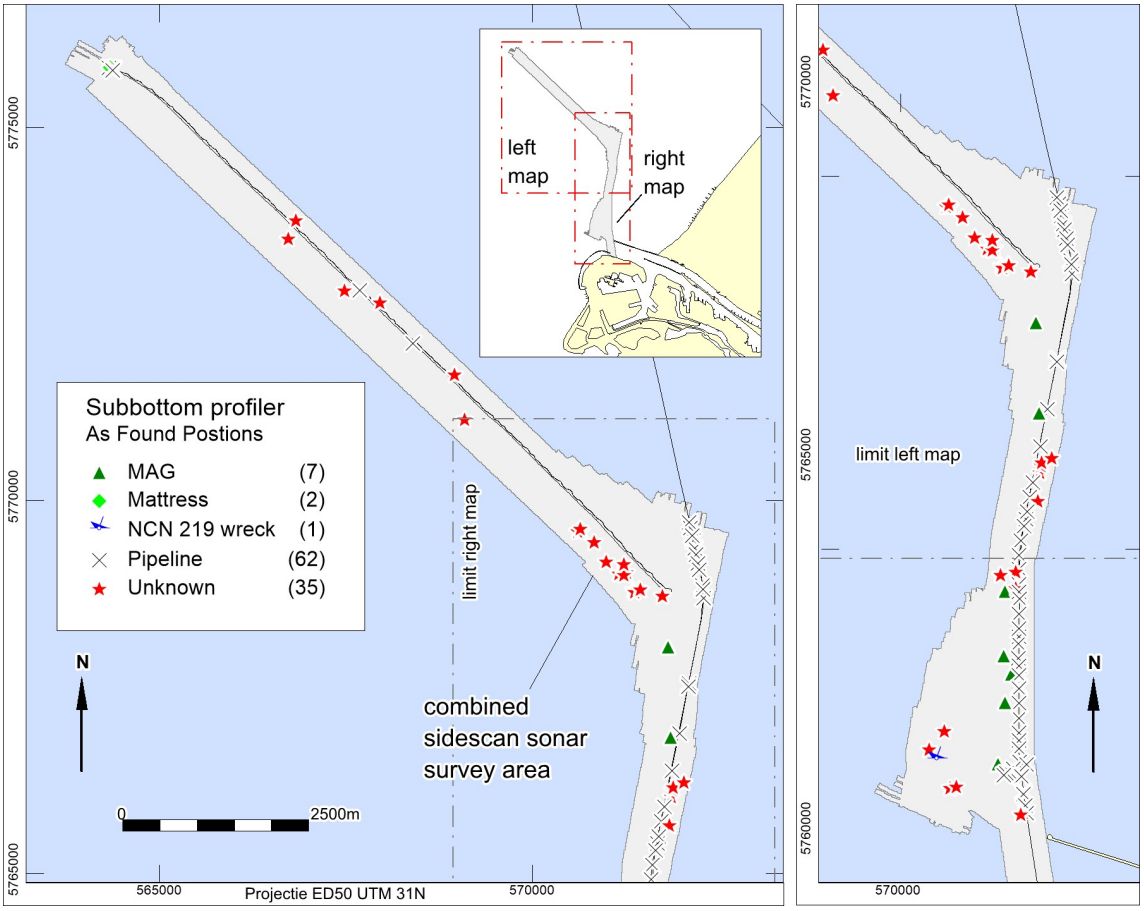


Figure 11. Correlation of Subbottom profiler contacts with known infrastructure, contacts from the NCN database and the positions of magnetic anomalies

The 35 subbotom profiler contacts could, apart from isolated buried man-made objects, also be caused by geological features. Therefore the 7 *Subbottom profiler* which coincide with magnetic anomalies are considered to be of potential archaeological interest, because at those locations the occurrence of a unknown buried man-made object or structure of significant extent has been proven.

The positions of these potential archaeological anomalies are listed below:

ID	Easting	Northing
POR_SBP_0017	571405	5764458
POR_SBP_0018	571381	5763597
POR_SBP_0019	571309	5762146
POR_SBP_0020	571397	5762967
SB22	571818	5768062
SB25	571855	5766848
SB49	571485	5763347

Table 14. Positions of potential archaeological features in subbottom profiler data

Prehistoric landscape

Based on the archaeological desk study the top of the subcropping *Pleistocene* sequence is expected to consist primarily of Weichselian fluvial deposits of the Kreftenheye Formation, locally overlain by terrestrial deposits of the Boxtel Formation. Especially in areas where those units have been covered by Early *Holocene* peat (Basal Peat Bed) well-preserved in situ prehistoric remains of high integrity are to be expected. Directly north of the Maasgeul the Porthos pipeline trajectory crosses an area where Early *Holocene* fresh to brackisch water clays of the Terbregge Member|Echteld Formation cover the *Pleistocene* landscape and local occrrences of the Basal Peat Bed. Those clays deposits outcrop at the north edge of the Maasgeul.

An overview of the expected lithostratigraphy is shown in table 3.

The expected remains include Late Palaeolithic and Mesolithic camp sites, burials, lost or dumped objects such as flint and bone artefacts, hunting gear and canoes. Prehistoric camp sites in the context of sandy deposits of the Boxtel Formation are characterized by the scattered occurrence of flint artefacts and debris resulting from the production of flint tools accompanied by burnt seeds (hazel nuts), charcoal and bone. The camp sites are generally small with few remains, though larger sites with a medium to high density of flint artefacts can occur in case a site has been used repeatedly and/or for a prolonged period of time.

Figure 12 shows an example from the seismic data gathered by DEEP in 2020. Unfortunately the location of this example is not clear. DEEP distinguishes between the northern part and the southern part of the route. In the northern part a weak discontinuous reflector was observed at two to three meters below the seabed separating what was interpreted to be homogeneous sediments. Most likely the discontinuous reflector separates the mobile sand layer of the Bligh Bank Member from the underlying *Pleistocene* fluvial sands of the Kreftenheye Formation.

In the southern part, where the section displayed in figure 12 probably has been recorded, two horizons are distinguished, H2 and H3.

H2 is a reflector found at the base of acoustic transparent top layer, which possibly constitutes the Wormer Member|Naaldwijk Formation and/or Bligh Bank Member|Southern Bight Formation. H2 forms the top of a parallel bedded layer which consists of Early *Holocene* fresh to brackisch water clays of the Terbregge Member|Echteld Formation. The top of the Terbregge Member outcrops north of the Maasgeul and gently dips towards the north.

According to DEEP a layer of peat occurs at the base of the clays of the Terbregge Member. This is the Basal Peat Bed | Nieuwkoop Formation which covers the Kreftenheye Formation. The transition between the Basal Peat Bed and the Kreftenheye Formation has been digitized as the continuous reflector H3. The Basal Peat Bed is found at 8 m below the seabed some 2000 m north of the shipping lane and outcrops at the northern edge of the channel. Vibrocore logs indicate that the top of the Kreftenheye Formation consist of a claybed of variable thickness which separately is classified as the Wychen Member at the top of Kreftenheye Formtion.[6] The seismic profile shows strongly undulating internal reflectors below the H3 reflector. These layers comprise sandy and possibly gravelly bedding deposits of the Rhine|Meuse system

[6] In the Yangtze Harbor area two separate clay beds of the Wychen Member are distinghuished (KRWY-1 and KRWY-2).

with clear channels. Locally river dunes can occur between the Kreftenheye Formation and the Basal Peat Bed. Those river dunes are classified as the Delwijnen Member|Boxtel Formation. The resolution of figure 12 is too poor to allow for a good classification, the two arrow pointing at the H3 Layer could point at the flanks of an elevated dune-like phenomenon.

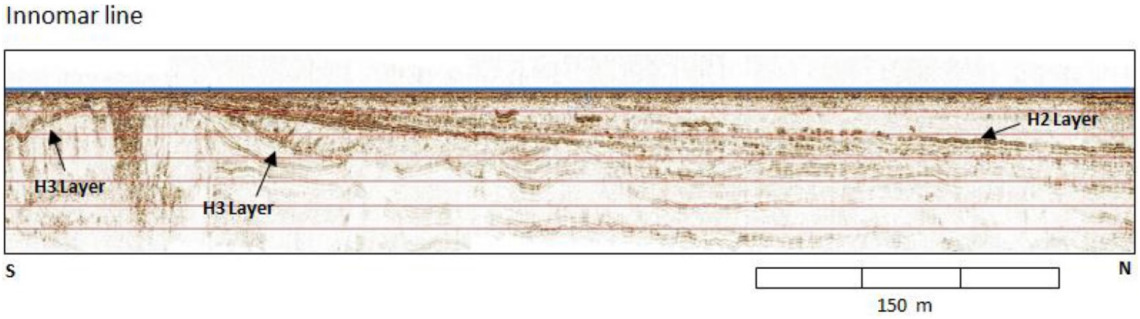


Figure 12. Innomar parametric Echo Sounder example (source: DEEP survey report P3711_SURV_REP_R00, 2020)

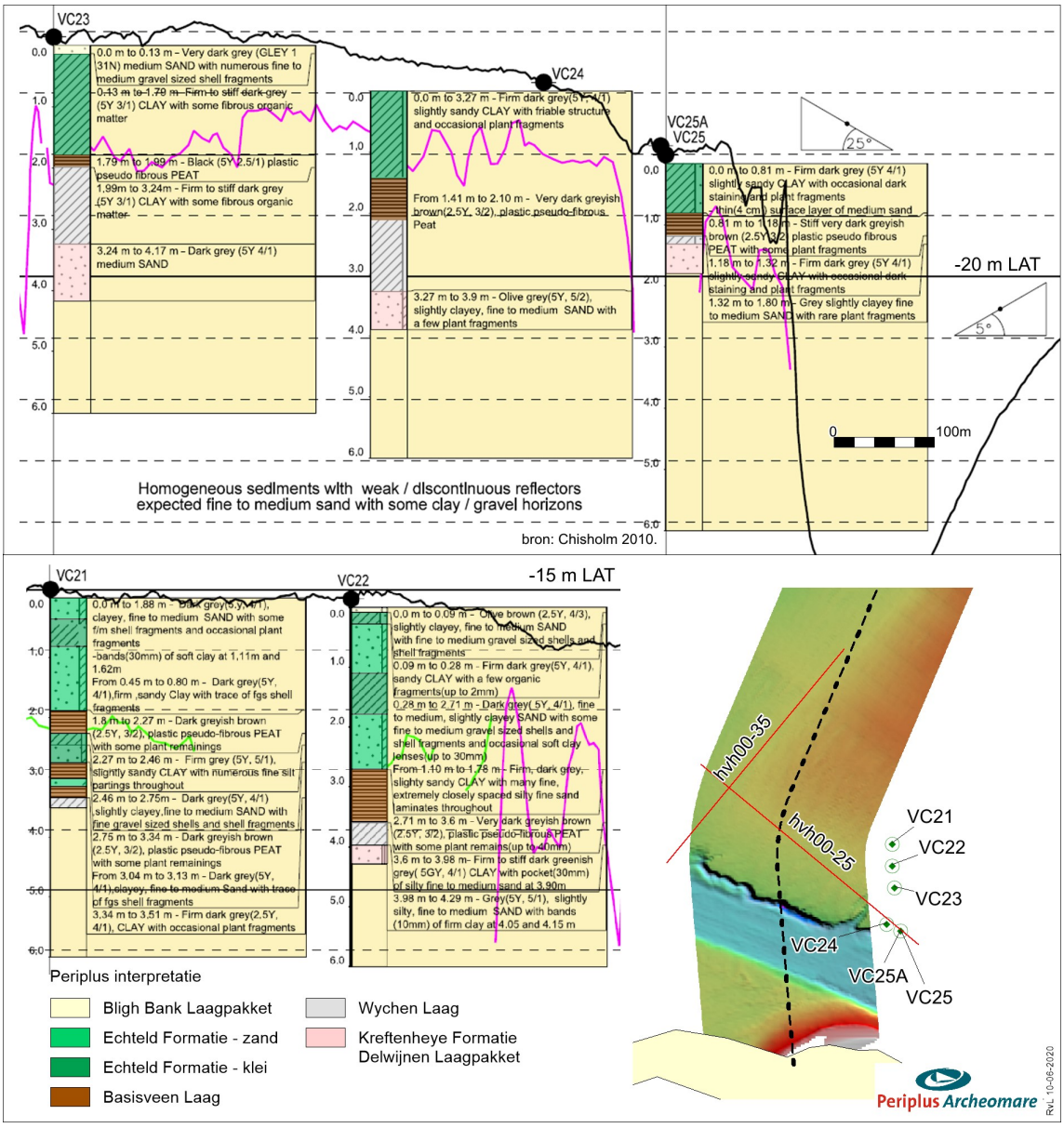


Figure 13. Vibrocore profile Fugro survey - Alignment Charts (source: Chisholm 2010)

Based on the expected (local) occurrence of an intact prehistoric landscape underneath the Basal Peat Bed intact prehistoric remains can occur within the pipeline trajectory.

4. Synthesis

Based on the results of this assessment the research questions are answered below.

With respect to Side Scan Sonar and *Multibeam* survey:

- *Are there any phenomena visible on the seabed?*

Yes, the surveys have resulted in the identification of 332 sidescan sonar contacts and 84 *Multibeam* contacts. Out of these 332|84 contacts, 62 have been found on both sidescan sonar and *Multibeam*; 22 solely with *Multibeam*.

If so:

- *What is the description of these phenomena?*

The classification of the phenomena found in the sidescan sonar data is listed in the table below.

Category	Interpretation		Number Found	
Hydrocarbon related	Pipeline exposure	16/3-Inch Active Gas/Methanol Pipeline Piggyback From P18-A To P15-D	1	**63**
		26-Inch Active Gas Pipeline from P15-D to Maasvlakte	11	
		8/2-Inch Gas/Methanol Pipeline Piggyback From P18-A To Q16-FA-1	5	
		unknown pipeline	1	
	P18-02 Wellhead		1	
	P18-A Infrastructure: Active 8/3-Inch Gas/Methanol Pipeline From P18-A To Q16-FA-1, GBS, rockdumps, mattresses on pipeline sections and spoolpieces, wet stored mattresses, spudcan depressions		27	
	Piece of pipe		1	
	Q16-05 Isolated rock dump		4	
	Q16-05 Wellhead		1	
	Q16-FA-1 Infrastructure: Active 8/2-Inch Gas/Methanol Pipeline, spoolpieces, SSC, jackup rig footprints		11	
Natural phenomena	Seabed disturbance (clay)		46	**58**
	Sediment mound		6	
	Clay boulder		2	
	Shell bed		4	
Man-made Non-archaeological recognizable	Anchor		6	**24**
	Anchor mark		1	
	Anchor with chain		2	
	Buoy anchor with chain		2	
	Cable or chain		7	
	Cluster of unknown objects		3	
	Coiled fishing net		3	
Man-made Non-archaeological Non recognizable	Unknown linear object		23	**185**
	Unknown object		162	
Possible Archaeological	Possible wreck remains		1	**2**
	Wreck site NCN 219		1	
	Total		**332**	**332**

Table 15 Listing of interpreted sidescan sonar contacts

The 22 *Multibeam* contacts that not correlate with sidescan sonar contacts comprise pipelines (2), a rockdump (1) near the P18-A platform location, a dump (1) within the 'Loswal' area, a large piece of flexible pipeline (1) and seabed disturbances / unknown objects (17) in the southern part of the area.

- *Do these phenomena have a man-made or natural origin?*

These phenomena are both man-made and natural of origin. The origin of the unidentified found sidescan sonar (188) and *Multibeam* (17) is uncertain. We consider it however likely that the majority are small man-made objects which are lost or dumped. Near the northern Maasgeul edge small contacts could also comprise lumps of clay or peat which outcrops in this part of the pipeline trajectory.

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

- *What classification can be attached?*

The identified man-made objects consists of infrastructure (66) related to the production and transport of hydrocarbons, such as a ground base structure, a subsea completion, pipeline bundels, spoolpieces, mattresses and rockdumps. The other identified man-made objects (23) include two wreck (2) and lost or dumped items of debris, including anchors, chains, cables and fishing gear.

The two (possible) wreck sites are classified as archaeological, until proven differently; the remainder of man-made objects is classified as non-archaeological. The unidentified objects are due to their size and appearance not classified as archaeological. It is not possible to judge if the small unknown objects are UXO.

If these phenomena can be classified as archaeological:

- *Is it possible to attach an interpretation to the nature of the archaeological objects and to prioritize importance?*

The two sites of potential archaeological value comprise a wreck site which is known from database sources (NCN 219) and a newly found site which has been interpreted as a possible wreck sites. The archaeological has neither been established for the NCN 219 wreck nor for the newly found (possible) wreck (POR_SSS_0056).

If these phenomena can be identified as natural:

- *What is the nature of these natural phenomena?*

The natural phenomena consist of sediment mounds, shell beds, clay and peat boulders (especially directly north of the Maasgeul edge).

- *Based on the acoustic image is it possible to designate zones of high, middle or low marine activity on the seabed?*

No , the seabed surface is characterized gradual changes in depth with sedimentary structures like sand ripples or dunes occurring in the last 2.5 km of the trajectory towards the P18-A platform. A large number of trawling scars is also encountered.

If so:

- *How can these zones be interpreted?*

This question is not applicable.

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?*

Objects are found embedded in the surrounding sediment, often with a shallow spherical scour around them. Based on the relationship with the topography it is not possible to designate risk-prone area.

- *If no acoustic phenomena can be observed, are there any clues that this is caused by either natural erosion, sedimentation or human interference?*

This question is not applicable.

With respect to *Magnetometer* survey:

- *Have magnetic anomalies been identified in the survey area?*

Yes, a total of 1240 magnetic anomalies have been identified in the *Magnetometer* data acquired during the FUGRO and DEEP surveys.

If so:

- *What is the location and size (peak-to-peak residual total field value) of those anomalies?*

The majority of magnetic anomalies is found in the southern part of the pipeline route. Peak-to-peak values vary from 3 to 3048 nT.

- *Are the anomalies induced by known infrastructure?*

Yes, 172 magnetic anomalies are related to pipelines (143), two wellheads (5) and (possible) cables (24).

- *Can the anomalies be correlated with objects known from database sources or newly found side scan sonar and/or Multibeam contacts?*

Yes, 83 anomalies can be related to sidescan sonar (66) and *Multibeam* (3) contacts.

With respect to *Subbottom profiler* survey:

- *At what depth below the seabed has the Pleistocene landscape been found?*

The top of the *Pleistocene* landscape intersects and outcrops the northern Maasgeul channel edge around -19 m LAT. Towards the north, with decreasing water depths, the top is found at depths increasing to 8 m below the seabed. At 6.5 kilometers north the Maasgeul edge, the water depth increases to more than 20 m, and the top of the *Pleistocene* is found at depth of 2.5 to 3 m below the seabed in the remainder of the pipeline route. The transition from *Pleistocene* to *Holocene* is marked by a weak discontinuous reflector due the small change in lithology (and therefore acoustic impedence) between the *Pleistocene* and *Holocene* deposits.

- *What sub-cropping Pleistocene unit(s) have been found below the cover of Holocene deposits?*

The sub-cropping *Pleistocene* unit consists of the Kreftenheye Formation. The top of the Kreftenhye Formation consist of a layer of stiff grey clay and loam of the Wychen Member in the pipeline section north of the Maasgeul edge. In the northern part of the pipeline route, where the waterdepth exeeds 20 m, the Wychen Member is lacking and the Kreftenheye Fomration consists of sand. Local channel insission could have been filled with more clayey material. Local sands of the the Delwijnen Member | Boxtel Member can occur. This unit has not been identified with certainty.

- *What is the depositional environment of these Pleistocene units?*

The Wychen Member consists of Late Weichselian to Early *Holocene* overbank deposits. The sandy deposits with small channel infills are river bedding deposits. The Delwijnen Member consists of Early *Holocene* aeolian dune sand.

- *Is the top of the Pleistocene landscape intact?*

The top of the *Pleistocene* landscape is expected to be locally intact in the first 3.5 km north of the Maasgeul edge. Especially in places where the Basal Peat Bed occurs the change of an intact *Pleistocene* surface is large. In the more proximate parts of the pipeline route intact *Pleistocene* deposits are found where pre-*Holocene* channel infills occur. Those channel infills can contain fossils of (large) mammals like the mammoth.

- *What Holocene unit(s) are found?*

The *Holocene* units found include - from bottom to top - peat of the Basal Peat Bed | Nieuwkoop Formation, fresh to brackish water clay of the Terbregge Member | Echteld Formation, tidal deposits of the Wormer Member | Naaldwijk Fromation and sand of the Bligh Bank Member | Southern Bight Formation.

- *Do the seismic data show indications for the presence of peat or organic clay at the base of the Holocene sequence?*

Yes, DEEP found reflectors in the seismic which are indicative of the occurrence of peat at the base of the *Holocene* sequence. The peat occurrences have ot been mapped as a separate unit.

- *Can zones be identified where remains of prehistoric settlements are to be expected?*

No, special interest should be paid to the occurrence of river dunes of the Delwijnen Member. This unit has not been mapped separately.

If so:

- *Could these expected settlement remains be affected by the planned activities?*

The occurrence of settlement remains is related to the occurrences of intact *Pleistocene* and *Holocene* units like the river dunes of the Delwijnen Member. The Delwijnen Member has not been mapped as a separate unit.

- *Are there any indications observed on the seismic profiles for the presence of buried (man-made) objects?*

Yes, in the seismic profiles 107 hyperbola have been identified. These hyperbola indicate that a buried object is present at the location of the hyperbole.

If so:

- *Based on the presence of buried objects and its correlation with side scan sonar, Magnetometer and Multibeam data can something be said about the nature of these buried objects?*

The correlation of the hyperbola with known objects and infrastructure and the results of the sidescan sonar, *Magnetometer* and *Multibeam* analysis is shown in the table below. 35 subbotom profiler contacts could not be matched with known objects and infrastructure or newly found objects. The character of these objects or structures remains unresolved to date. It should be noted that apart from isolated man-

made objects hyperbola can also be induced by geological features. Therefore the 7 *Subbottom profiler* which coincide with magnetic anomalies are considered to be of potential archaeological interest, because at those locations the occurrence of an unknown buried man-made object or structure of significant extent has been proven.

Classification		**Number**	**Total**
Subbottom profiler contacts related to infrastructure and objects known from database sources and found during the FUGRO 2010 and DEEP 2019|2020 surveys	Pipelines	62	72
	Mattresses	2	
	Known NCN contacts (NCN 219)	1	
	Magnetic anomalies	7	
Unidentified buried objects found with SBP			35
Total			**107**

Table 16. Correlation of Subbottom profiler contacts with known objects/infrastructure and survey results

- Are there any mitigating measures necessary to avoid disturbance of possible archaeological remains?

Yes, it is advised not to trench the pipeline within 100m from the centre locations objects which are considered to be of potential archaeological interest. The expected remains primarily consist of ancient ship wrecks and remains of World War II aircraft. Disturbance of in situ prehistoric remains contained in undisturbed Late Weichselian and Early *Holocene* levels cannot be prevented. It is therefore advised to conduct geo-archaeological research on vibrocore samples to obtain additional information on the integrity of archaeological levels and the development of the prehistoric landscapes including both terrestrial and aquatic environments.

5. Conclusion and Advice

A large quantity of geophysical data was recorded within the routes surveyed by FUGRO (2010), and DEEP (2019 and 2020). For this study the sidescan sonar contacts (332), magnetic anomalies (1240), *Multibeam* contacts (84) and *Subbottom profiler* contacts (107) have been archaeologically assessed and correlated with known infrastructure and objects. This assessment of geophysical survey results is the second step in the process of archaeological research (AMZ-cycle), following the desk study.[7]

The assessment has resulted in the designation of 18 locations as sites of potential archaeological value. A list of the positions of these locations is presented in Appendix 3.

The sidescan sonar contacts, magnetic anomalies and *Subbottom profiler* contacts found at these sites could not be correlated with infrastructure related to the production/transport of hydrocarbons or to objects known from database sources.

At 2 of the 18 sites objects have been found exposed at the seabed. These objects comprise an unidentified shipwreck (NCN 219) and newly found remains of a possible wreck (POR_SSS_0056).

At the other 16 of the 18 sites iron-bearing objects have been found buried beneath the seabed:

- 9 of these buried objects have induced magnetic anomalies with peak-to-peak values over 500 nT;
- 7 of these buried objects have been identified through the observation of reflection hyperbola in the seismic records and coincide with a magnetic anomaly.

The 2 exposed (possible) wreck sites and 16 buried objects/structures are considered to be of archaeological value until proven differently. It is advised to avoid these locations and abstain from trenching operations and other seabed disturbing activities within a 100 m buffer zone around these locations. It should be stressed that the origin of the magnetic anomalies is unknown. Apart from archaeological remains any type of man-made objects can be encountered including unexploded ammunition, anchors, pieces of chains and cables, debris, etcetera.

The buffer zone of 100 meters is a standard[8] that applies to the protection of cultural heritage, this distance may be reduced if it can be substantiated that the applied disturbance has no effect on the archaeological object. For example, when no anchoring is used during cable lay operations the buffer zone can be decreased. Reduction of the distance have to be approved by Rijkswaterstaat (RWS). Rijkswaterstaat is the enforcing authority, acting on behalf of the Ministry of Economic Affairs. The Cultural Heritage Agency of the Netherlands (RCE) acts as an advisor to Rijkswaterstaat.

If it is not feasible to avoid the reported wreck sites, *Magnetometer* and *Subbottom profiler* locations, additional research is required in order to determine the actual archaeological value of the reported locations. If this indicates that the object has no archaeological value, the location can be omitted.

[7] Van Lil 2020.

[8] In accordance with the 'Beleidsregels ontgrondingen in Rijkswateren'; https://wetten.overheid.nl/BWBR0028498/2010-10-01.

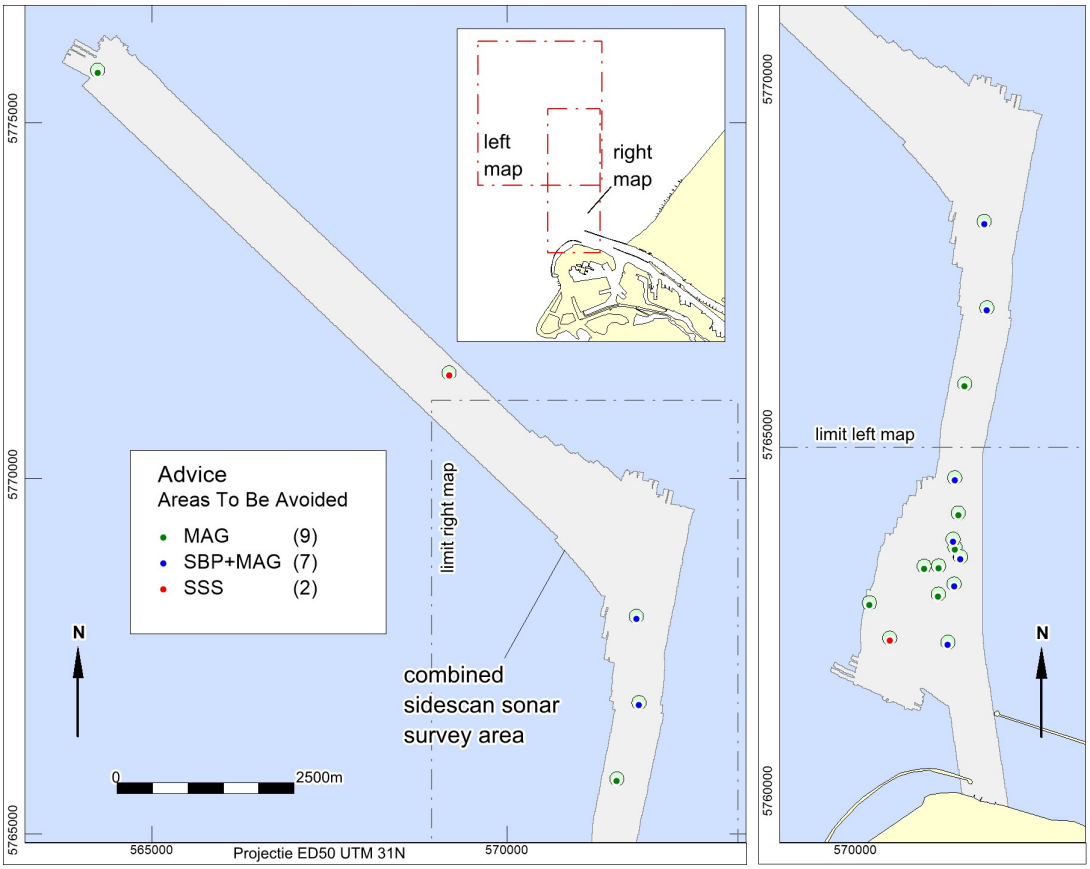


Figure 14. Advice

Disturbance of undisturbed Late Weichselian and Early *Holocene* levels, and possible in situ prehistoric remains contained herein, cannot be prevented. It is therefore advised to conduct geo-archaeological research on vibrocore samples. Prospection for archaeological remains is not the primary focus of this research. The purpose of the vibrocore analysis is to obtain additional information on the integrity of archaeological levels and the development of the prehistoric landscapes including both terrestrial and aquatic environments.

It is important for the analysis of vibrocores for geo-archaeological purposes that these cores are intact. Samples that have been used for strength tests and grain size determination are generally not suitable for archaeological research, because they are no longer intact. It is therefore important to coordinate the use of the samples. One possibility could be that the cores are examined by a certified KNA (Dutch Quality Standard for Archaeological Research) prospector aquatic soils prior to use for determining physical parameters (strength / grain size). The prospector can also make a selection of samples for specialist research, for example C14 analyzes or research of pollen, animal and vegetable macro residues, molluscs, diatoms, et cetera. The requirements and preconditions set for the archaeological research of vibrocores must be recorded in a Program of Requirements (PoR) or a Plan of Action (PoA).

List of figures

Figure 1: Location of the research area. 8
Figure 2: Schematic representation of the transport and storage system. 9
Figure 3. Known shipwrecks within the research area of the desk study. 12
Figure 4. NCN|MARIAD contacts: Found versus Not Found. 21
Figure 5. Unknown wreck (DEEP contact POR_SSS_AreaSouth_0011) as found on the location of NCN 219 22
Figure 6. Combined results of sidescan sonar surveys performed by FUGRO and DEEP 24
Figure 7: Contact POR_SSS_0056 - site of potential archaeological interest 26
Figure 8. Results of Multibeam surveys performed by DEEP 27
Figure 9. Magnetic anomaly classified on the measured peak-to-peak values (infrastructure related anomalies are not shown) 29
Figure 10. Reflection hyperbola observed in the Fugro 2010 SBP data reflecting the presence of a pipeline and an unknown iron-bearing object 30
Figure 11. Correlation of Subbottom profiler contacts with known infrastructure, contacts from the NCN database and the positions of magnetic anomalies 31
Figure 12. Innomar parametric Echo Sounder example (source: DEEP survey report P3711_SURV_REP_R00, 2020) 33
Figure 13. Vibrocore profile Fugro survey - Alignment Charts (source: Chisholm 2010) 34
Figure 14. Advice 41

List of tables

Table 1. Dutch archaeological periods 4
Table 2. Administrative details of the research area 4
Table 3. Archaeological expectation related to the lithostratigraphy. 10
Table 4. Explanation of the archaeological expectation. 10
Table 5. Known shipwrecks within the research area of the desk study. 12
Table 6. Overview of known objects and contacts in the research area. 20
Table 7. Contacts known from the NCN database which have been found with sidescan sonar 22
Table 8. Contacts known from the NCN database which have been found with sidescan sonar 23
Table 9. Contacts known from the NCN database which have been found with sidescan sonar and Magnetometer 23
Table 10. Assessed sidescan sonar contacts within the combined FUGRO|DEEP survey area 25
Table 11. Classification of the magnetic anomalies 28
Table 12. Unknown ferro-magnetic objects of potential archaeological interest 29
Table 13. Classification of Subbottom profiler contacts 30
Table 14. Positions of potential archaeological features in subbottom profiler data 31
Table 15 Listing of interpreted sidescan sonar contacts 35
Table 16. Correlation of Subbottom profiler contacts with known objects/infrastructure and survey results 39

Glossary and abbreviations

Terminology	Description
AMZ	Archeologische Monumenten Zorg, a description of procedures to ensure the protection of National archaeological Cultural Heritage
CPT	Cone penetration test
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
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
KNA	Kwaliteitsnorm Nederlandse Archeologie
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
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*
PvE	Program of Requirements (Dutch: Programma van Eisen)
RCE	Ministry of Cultural Heritage (Dutch: Rijksdienst voor het Cultureel Erfgoed)
ROV	Remotely Operated Vehicle
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.

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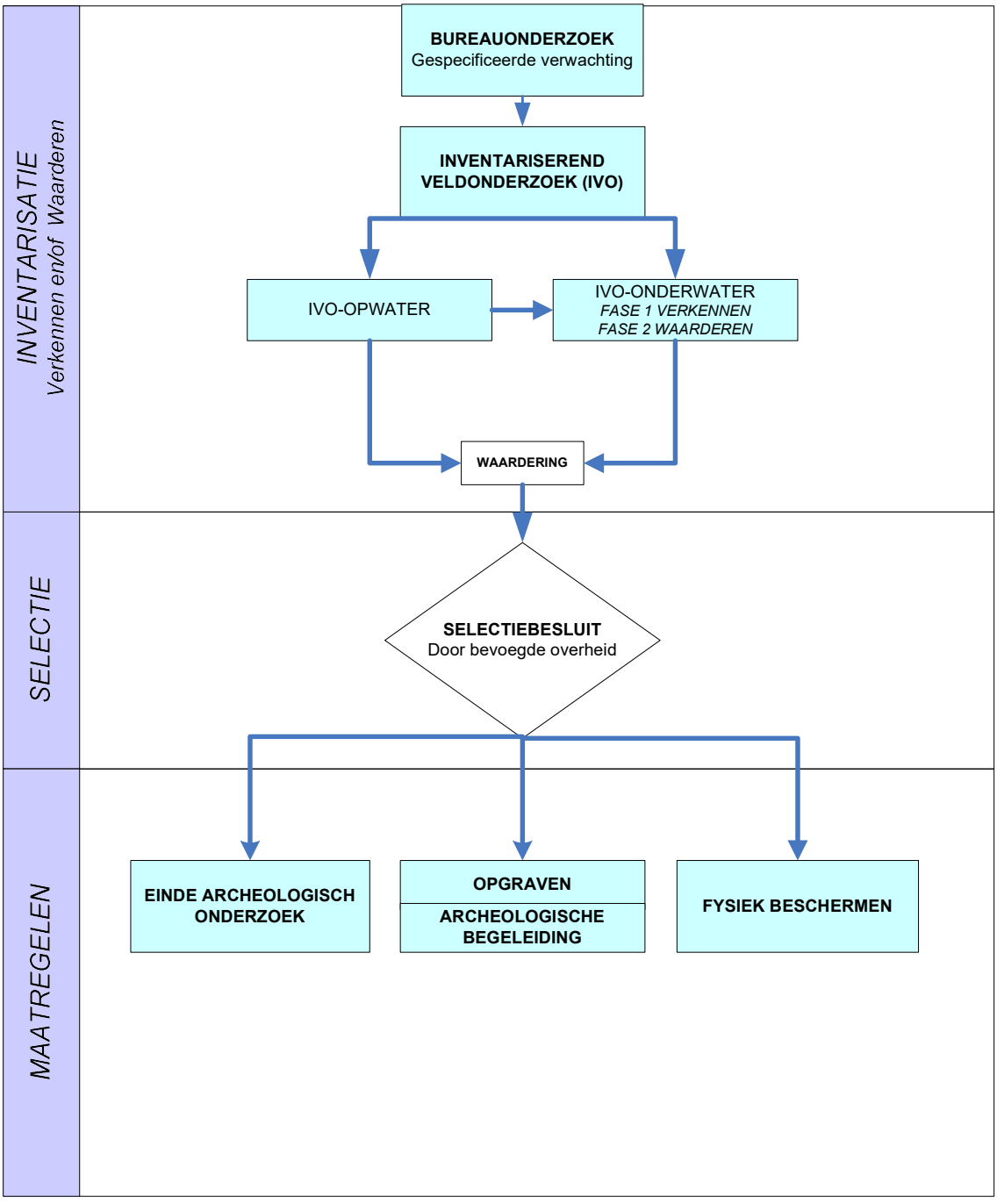
- SonarReg92, objectendatabase Rijkswaterstaat Noordzee en Delta

Appendix 1. Archaeological and geological time table

CHRONOSTRATIGRAFIE			TIJD	ARCHEOLOGISCHE PERIODE				DATERING
SERIE	ETAGE - CHRONOZONE			TIJDPERK				
Holoceen	**Laat Subatlanticum**		**1150 n. Chr**	Nieuwe tijd		C		1850
						B		1650
						A		1500
	Vroeg Subatlanticum			Middeleeuwen	Laat	B		1250
						A		1050
					Vroeg	D		900
						C		725
						B		525
			0			A		450
				Romeinse tijd		Laat		270
						Midden		70 n. Chr.
			450 v. Chr			Vroeg		15 v. Chr.
	Subboreaal			Prehistorie	Metaaltijden	IJzertijd	Laat	250
							Midden	500
							Vroeg	800
						Bronstijd	Laat	1100
							Midden	1800
			3700				Vroeg	2000
	Atlanticum				Steentijd	Neolithicum	Laat	2850
							Midden	4200
			7300				Vroeg	4900/5300
	Boreaal		8700			Mesolithicum	Laat	6450
							Midden	8640
	Preboreaal		9700				Vroeg	9700
Pleistoceen	Weichselien	Laat Glaciaal	Jonge Dryas			Paleolithicum	Laat	B	12.500
			Allerød						
			Oude Dryas						
			Bølling						
		Pleniglaciaal L					Jong		16.000
			Late Glacial Max						
								A	35.000
			Denekamp						
		Pleniglaciaal M					Midden		250.000
			Hengelo						
		Pleniglaciaal V							
			Moershoofd						
							Oud		
		Vroeg Glaciaal	Odderade						
			Brørup						
			Amersfoort						
			114.000						
	Eemien		126.000						
	Saalien		236.000						
	Oostermeer		241.000						
	onbenoemd		322.000						
	Belvédère		336.000						
	onbenoemd		384.000						
	Holsteinien		416.000						
	Elsterien		463.000						

Appendix 2. AMZ Cycle (Dutch)



Appendix 3. Locations of potential archaeological interest

Centre locations of the sites of potential archaeological interest.
The designated Area To Be Avoided is the centre location + a buffer zone of 100m around these locations.

ID	Easting	Northing
POR_SSS_0056	569184	5771486
POR_SSS_AreaSouth_0011	570490	5762205
POR_MAG_0554	571546	5765779
POR_MAG_0672	571454	5763964
POR_MAG_0748	571408	5763485
POR_MAG_0793	571178	5763221
POR_MAG_0868	571174	5762823
POR_MAG_AreaSouth_0014	570974	5763218
POR_MAG_AreaSouth_0030	570204	5762702
MA01	564237	5775739
MA21	571485	5763347
POR_SBP_0017	571405	5764458
POR_SBP_0018	571381	5763597
POR_SBP_0019	571309	5762146
POR_SBP_0020	571397	5762967
SB22	571818	5768062
SB25	571855	5766848
SB49	571485	5763347
UTM31N ED50		