Hollandse Kust (zuid) Wind Farm Zone
Sites I&II – Geophysical Site Investigation

Webinar, 13 December 2016, J. Chisholm (Fugro)

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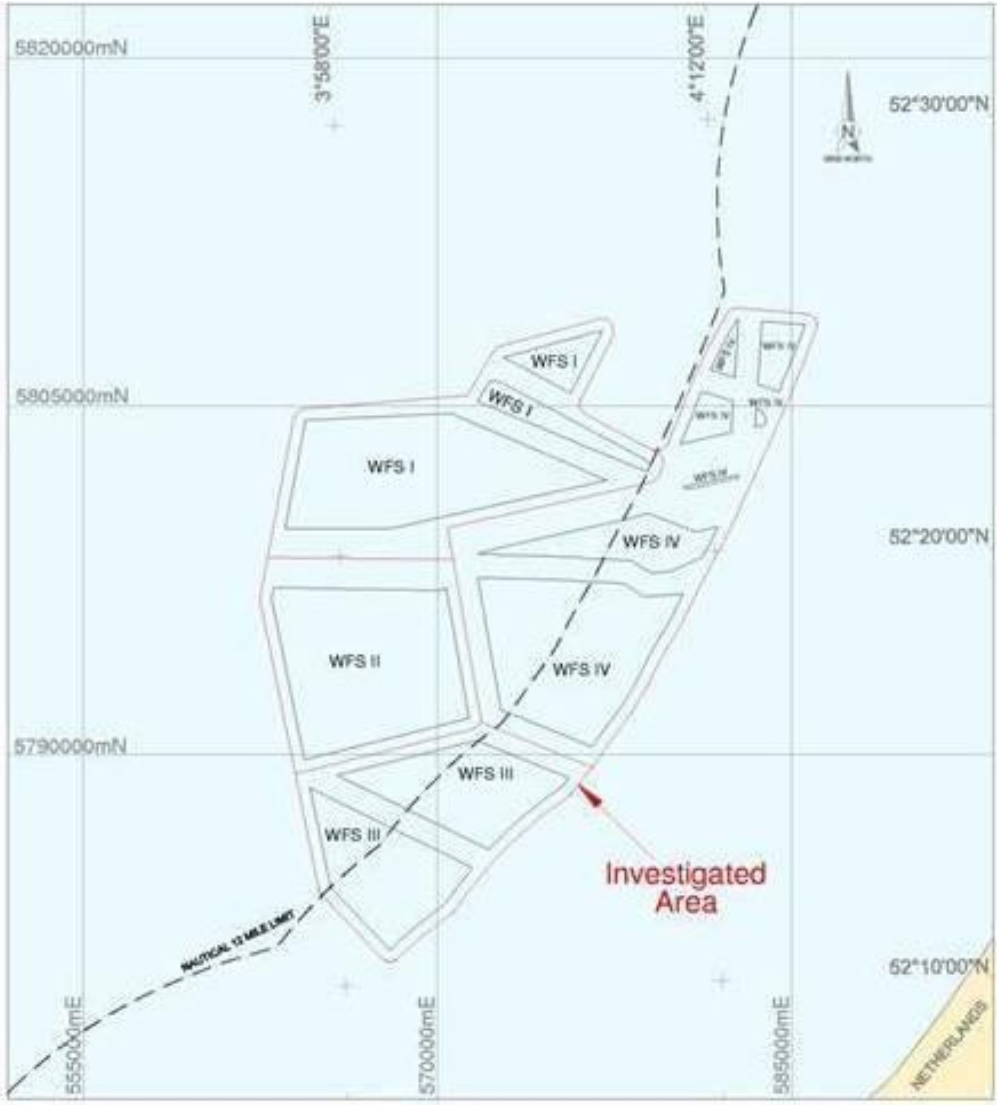
Introduction - Purpose of Geophysical Site Investigation

Purpose of the Geophysical Site Investigation:

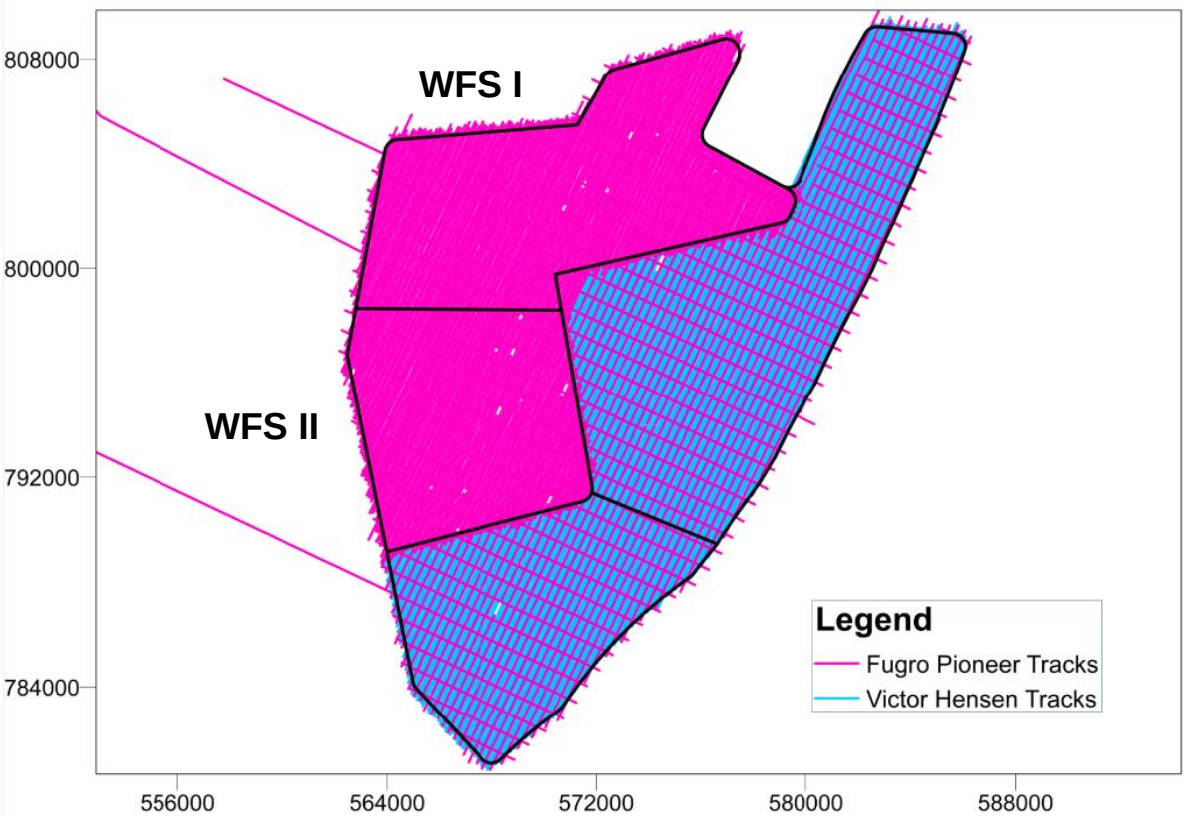
- To gather data to assist in the design of offshore foundations/ structures and cable burial for the wind farm development
- To obtain accurate **bathymetry** of the development areas
- To provide information on the presence of all **seabed features** including natural features and any man-made objects such as existing cables, pipelines, wrecks, debris and/or UXO items
- To provide detailed **geological interpretation** showing facies variations and structural feature changes
- To locate any **structural complexities** or **geohazards** within the shallow geological succession such as faulting, accumulations of shallow gas, buried channels, etc.
- To provide **input** into the specification and scope for a geotechnical sampling and testing programme

Introduction – Key Parameters



- Survey dates: 7 March to 18 April 2016
- Geographical and projection coordinates are based on ETRS89
- Projection coordinates in Universal Transverse Mercator (UTM) grid, Zone 31, Northern Hemisphere
- Vertical datum is Lowest Astronomical Tide (LAT)

Introduction – Equipment and Line Plan



MBES: Kongsberg EM2040 dual-head

SSS: EdgeTech 4200-FS (100/600 kHz)

MAG: G-882 Marine magnetometer

SBP: Massa TR-1075 pinger 4x4+2 array (hull-mounted)

MCS: GSO 540-tip dual-frequency sparker with Geometrics GeoEel 48 channel streamer (half-fold recording)

SCS: GSO 100-tip parker with Geo-Resources Geo-Sense mini-streamer

Fugro Pioneer combined **Geophysical** (SSS, SBP, MBES and MAG) and **Seismic** (UHR) Scopes in a single pass acquisition campaign.

Data Quality and Resolution

- ✓ ***MBES*:** The theoretical footprint ranges from 0.1 m to 0.5 m. A bin cell size of 0.5 m was used for the creation of the final DTM. Targets smaller than 0.5 m may not be identified in the final DTM.

- ✓ The Danish Technical University (DTU13) model was used for vertical (tide) reduction. The vertical accuracy was generally observed to be within 0.15 m.

- ✓ ***SBP*:** The useful acoustic penetration was generally limited due to local geological constraints to about 10 ms (approximately 8 m) below seabed. The vertical resolution is estimated as 0.1 m.

- ✓ ***SSS*:** Lateral resolution of approximately 0.2 m.

- ✓ ***SCS:*** The vertical resolution is estimated at 0.46 m.

- ✓ ***MCS*:** The vertical resolution is estimated at 0.5 m in the shallower part (average Vp of ~1600 m/s) to 0.9 m in the deeper part (Vp of ~1800 m/s).

Overview of Available Information

Geophysical Raw Data

- Multibeam (.all, .xyz , .svp)
- Sidescan Sonar (.xtf)
- Magnetometer (.csf)
- Sub-bottom Profiler (.segY)
- UHR (.segD)
- Tidal data (.csv)

Geophysical Processed Data

- Multibeam (.xyz, .xyb, GeoTiff)
- Sidescan Sonar (.GeoTiff)
- Magnetometer (Oasis Montaj project)
- Sub-bottom Profiler (Kingdom project)
- UHR (Kingdom project, SegY – Migrated sections Time and Depth, Near Trace)
- GIS geodatabase

Reports (.doc & .pdf)

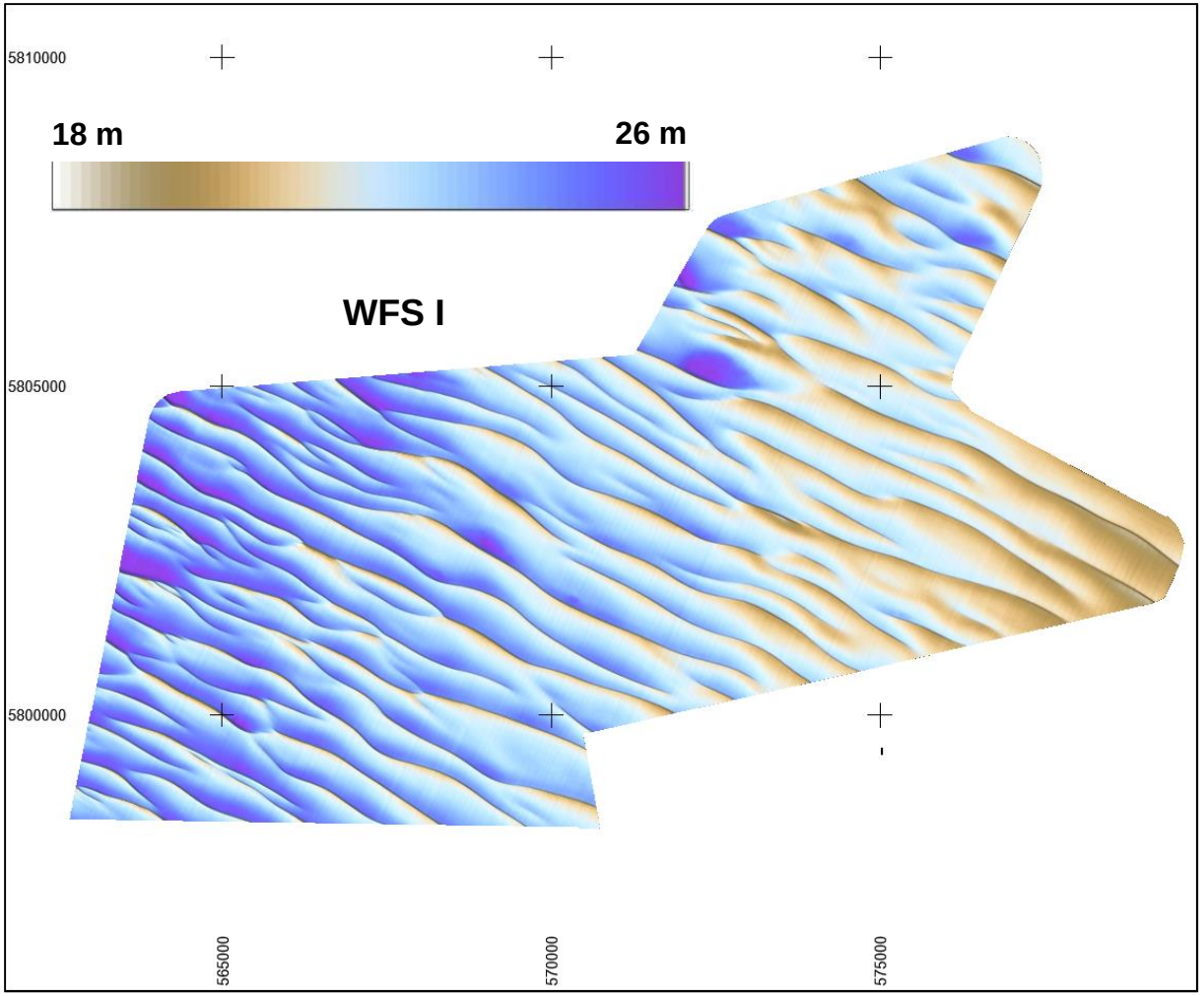
- R1 - Wind Farm Site I
- R2 - Wind Farm Site II
- R5 - Operations & Calibrations

Charts (.dwg & .pdf)

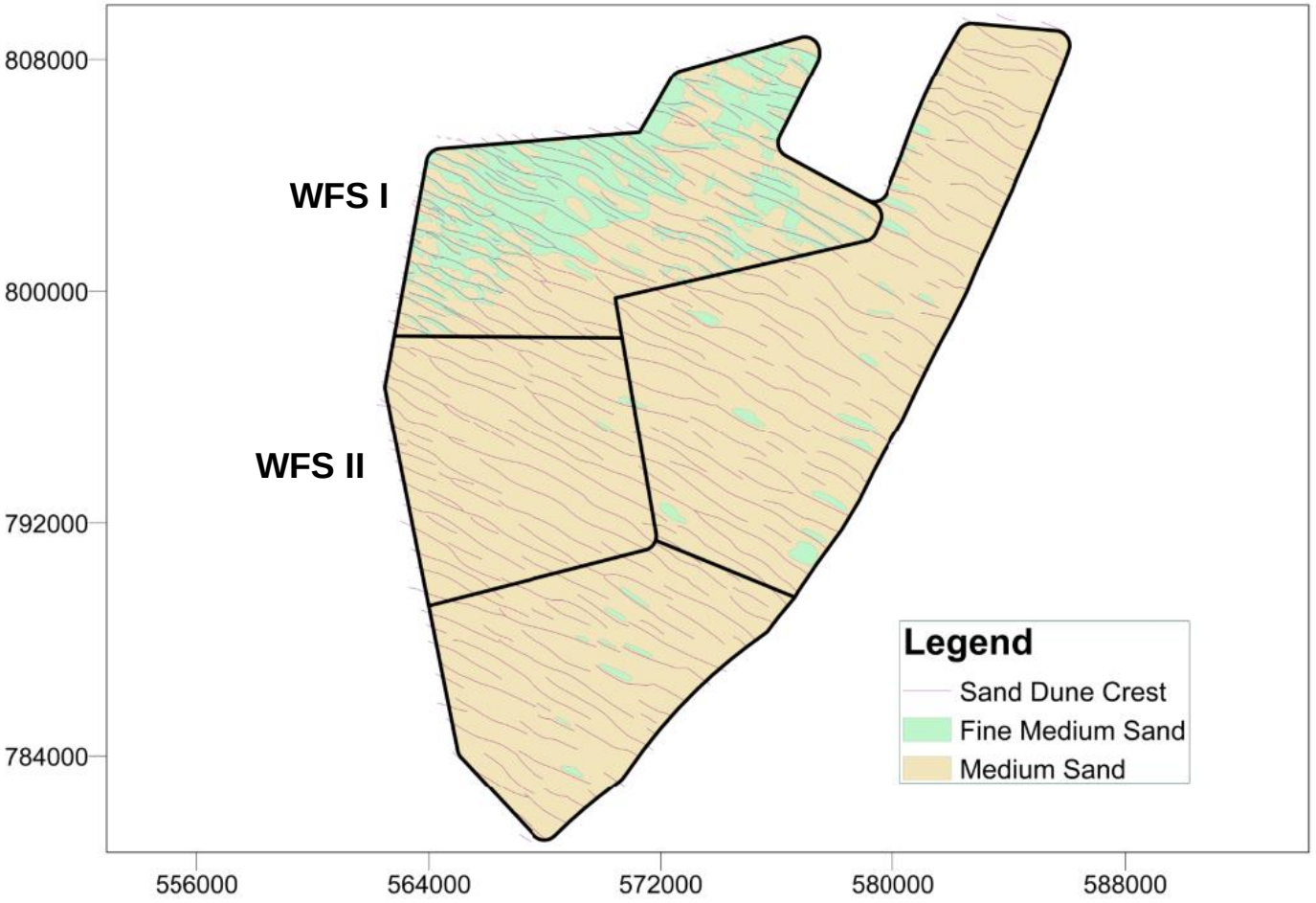
- Track charts
- Bathymetry charts
- Seabed and sediment classification chart
- Contact chart
- Geological chart and profiles
- Geohazard chart

Seafloor Conditions - Bathymetry

- The bathymetry of the entire Hollandse Kust (zuid) WFZ shows a dynamic morphology characterised by a complex pattern of bedforms (very large dunes), with superimposed medium dunes
- Very large dunes have NW to SE trending crests with heights ranging from 2 to 6 m
- Maximum gradients of up to 20 degrees on the lee sides of the very large dunes
- WFS I: 18 m LAT - 28 m LAT
- WFS II: 18 m LAT - 27 m LAT



Seafloor Conditions - Sediments



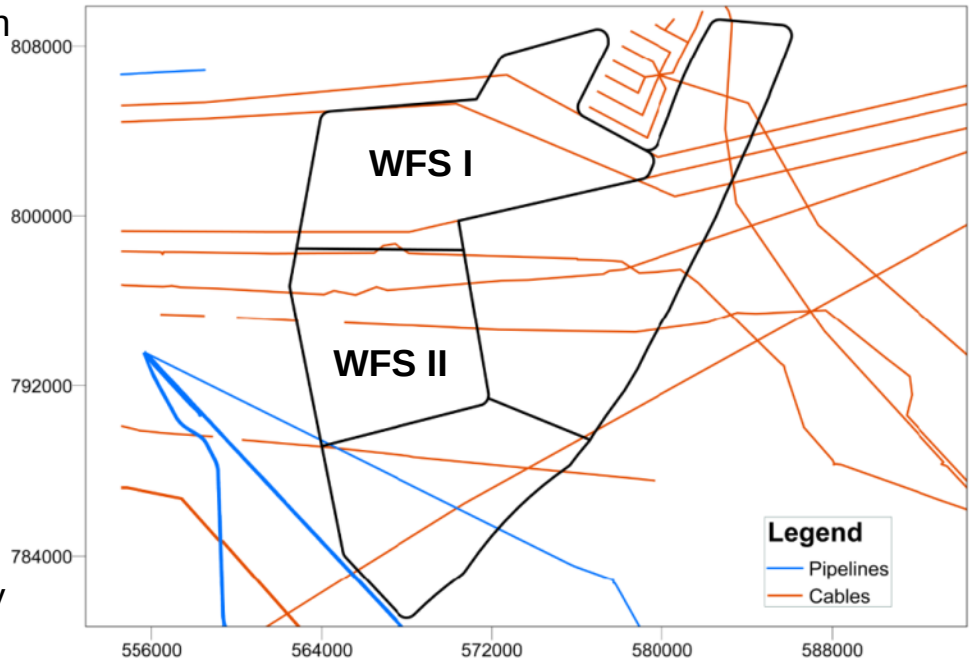
Bedforms across WFS I and WFS II are classified (throughout) as very large dunes with superimposed medium dunes.

Sediments across WFS I and WFS II are classified as fine to medium SAND and medium SAND.

Seafloor Conditions - Infrastructure

The WFS I area is crossed by four (4) cables an no (0) pipelines.

Cable	MAG	SSS	MBES	Remarks
Concerto 1 Segment 1 North	YES	NO	NO	Observed by magnetometer data to be 14 m offset with respect to the provided database position
Circe 1 North	YES	NO	NO	Observed by magnetometer data to be up to 18 m offset with respect to the provided database position
Ulysses 2	YES	NO	NO	Observed by magnetometer data to be up to 12 m offset with respect to the provided database position
TAT14 Segment I	YES	NO	NO	Observed by magnetometer data to be up to 47 m offset with respect to the provided database position
Unknown	YES	NO	NO	Potential unknown cable (or pipeline)



The WFS II area is crossed by one (1) pipeline and three (3) cables (one cable not identified by this survey).

	MAG	SSS	MBES	Remarks
Cables				
TAT 14 Seg I	YES	NO	NO	Observed by magnetometer data to be up to 10 m offset with respect to the provided database position.
Hermes 1	NO	NO	NO	Not observed
UK – NL 6 (abandoned)	YES	NO	NO	Observed by magnetometer data to be up to 190 m offset with respect to the provided database position.
Pipelines				
ENGIE Q13a-A to P15-C 8 inch pipeline	YES	NO	NO	Observed by magnetometer data in the same location as the provided database position.

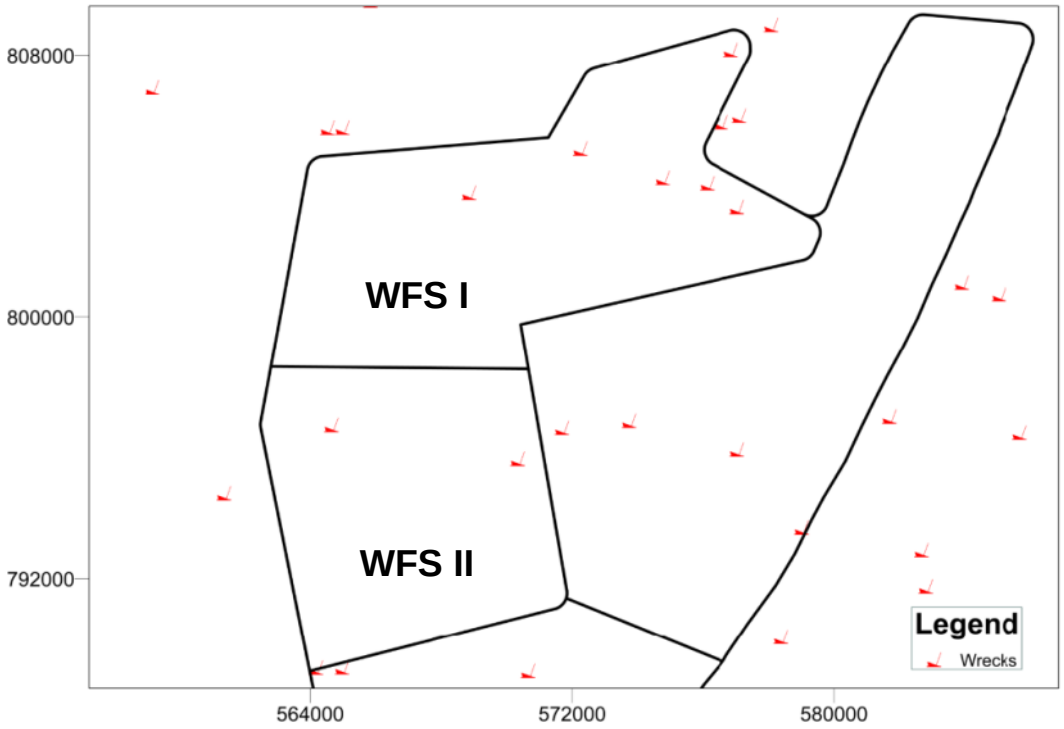
Seafloor Conditions – Contacts and Wrecks

132 SSS contacts and 546 magnetometer contacts were detected in WFS I.

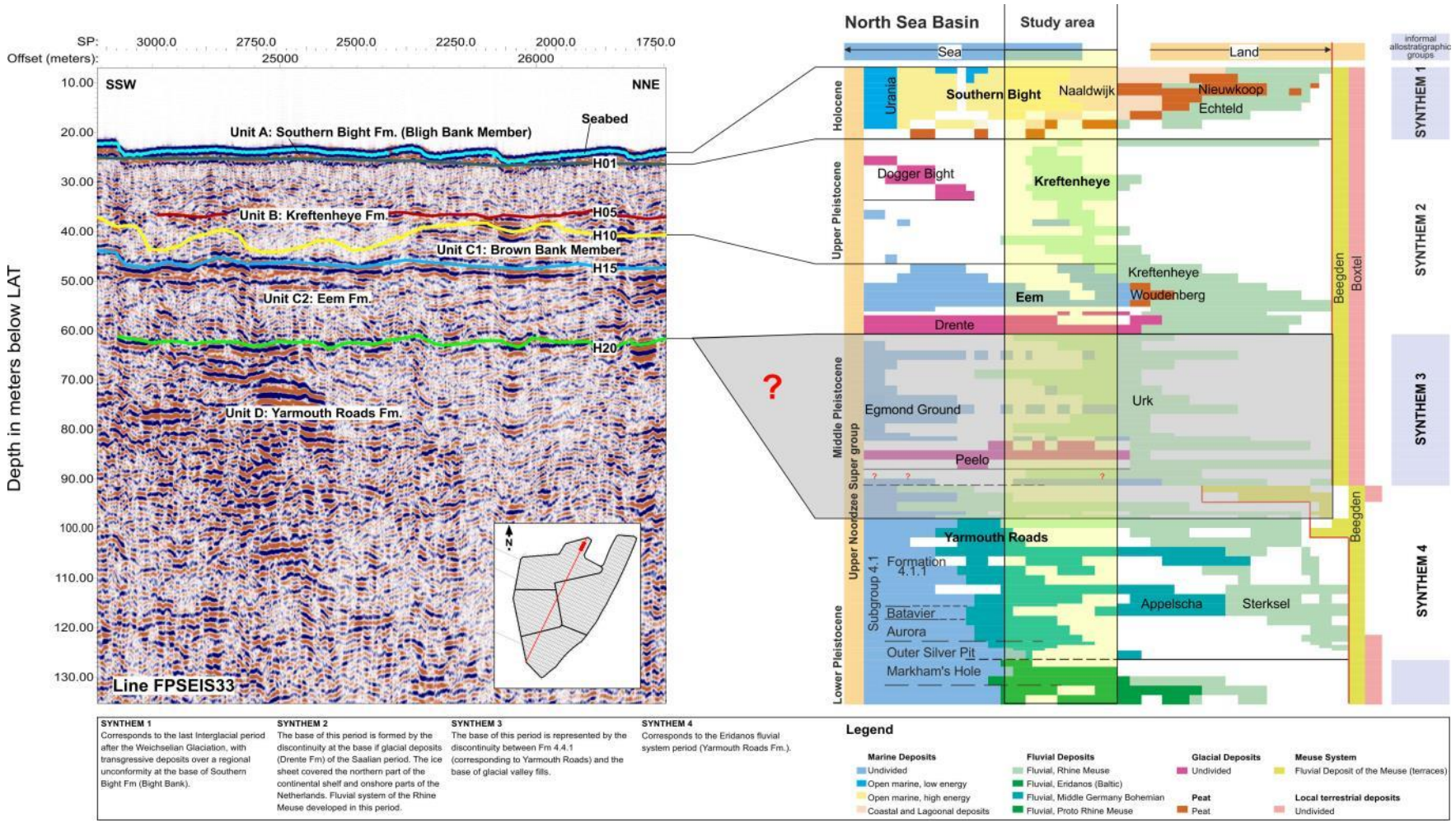
101 SSS contacts and 403 magnetometer contacts were detected in WFS II.

None (0) of the six (6) wrecks listed in the supplied database for WFS I was observed on any of the sensors.

None (0) of the three (3) wrecks listed in the supplied database for WFS II was observed on any of the sensors.



Shallow Geology - Stratigraphic Correlation



The limit of interpretation was 100 m bsb.

Shallow Geology - Geological Units

Seismic Units	Reflectors		Base of Unit min/max depth in m bLAT [1]	Base of Unit min/max depth in m below seabed [1]	Geometry of the base of the Unit	Unit seismic signature	Amplitude distribution within the Unit	Continuity of internal reflectors	Indicative lithology [2]	Depositional environment	Formation	Age
	Top	Base										
A	Seabed	H01	22.9 / 30.4	1.4 / 7.8	Erosional surface	Discontinuous internal reflectors	Variable from low to medium	Low	Coarse SAND, with shells and shell fragments, rare SILT and CLAY laminae and rare GRAVEL	Marine	Southern Bight	Holocene
B	H01	H10	30 / 54	9 / 28	Erosional surface	Discontinuous internal reflectors	Variable from low to medium	Low	Medium to coarse SAND with shells, wood fragments and hard CLAY pebbles	Fluvial environment	Kreftenheye	Upper Pleistocene
C1	H10	H15	39 / 50	16 / 27	Uneven surface	Discontinuous internal reflectors	Medium to moderately high	Medium to low	CLAY, SILT and SAND with presence of peat	Shallow marine	Brown Bank member – Eem	Upper Pleistocene
C2	H15	H20	54 / 75	32 / 50	Erosional surface	Highly discontinuous	Variable from low to medium	Low	Fine to medium coarse SAND, with shells and minor GRAVEL and CLAY		Eem	Upper Pleistocene
D	H20	Unknown	Unknown	Unknown	Not visible	Highly discontinuous	Low	Low	Medium-fine SAND, with CLAY lamination and local intercalation of peat	Fluvial environment	Yarmouth Roads	Lower to Middle Pleistocene

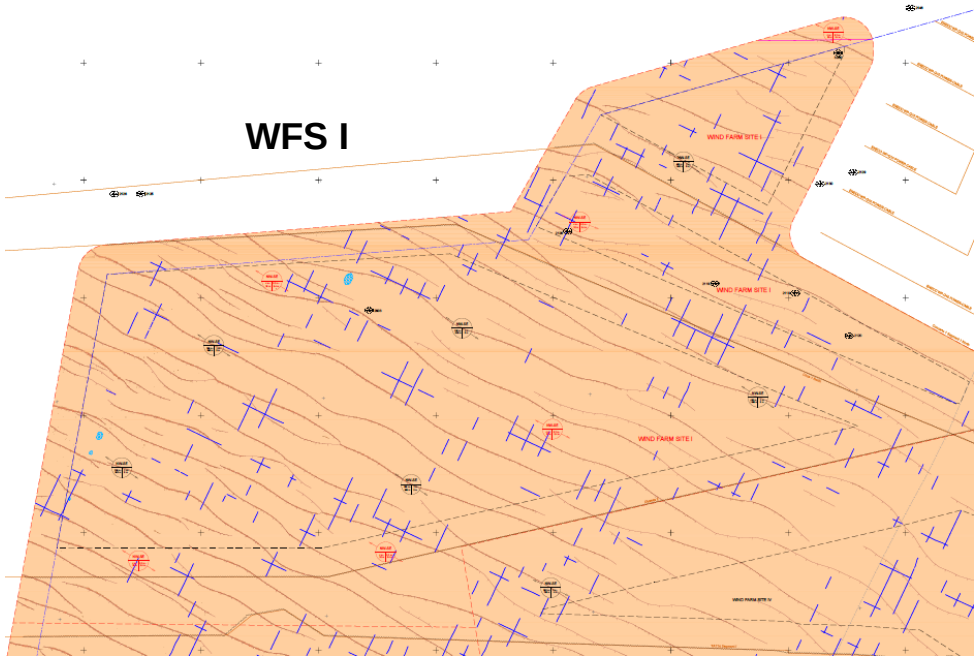
The Quaternary geology has been sub-divided into four (4) seismic units (Units A to D):

- Unit A: Bligh Bank member (Southern Bight Fm.)
- Unit B: Kreftenheye Fm.
- Unit C: Brown Bank Member (Eem Fm.)
- Unit D: Yarmouth Roads Fm.

Sub-unit C1 was not identified in WFS II.

Installation Constraints – WFS I Overview

	WFS I
Seabed hazards – Sand Dunes	★
Seabed hazards – Wrecks	✖
Palaeochannel infill	★
Surficial Faults	✖
Peat layer/Biogenic gas charged sediment	✖
Hard/GRAVEL layers	★

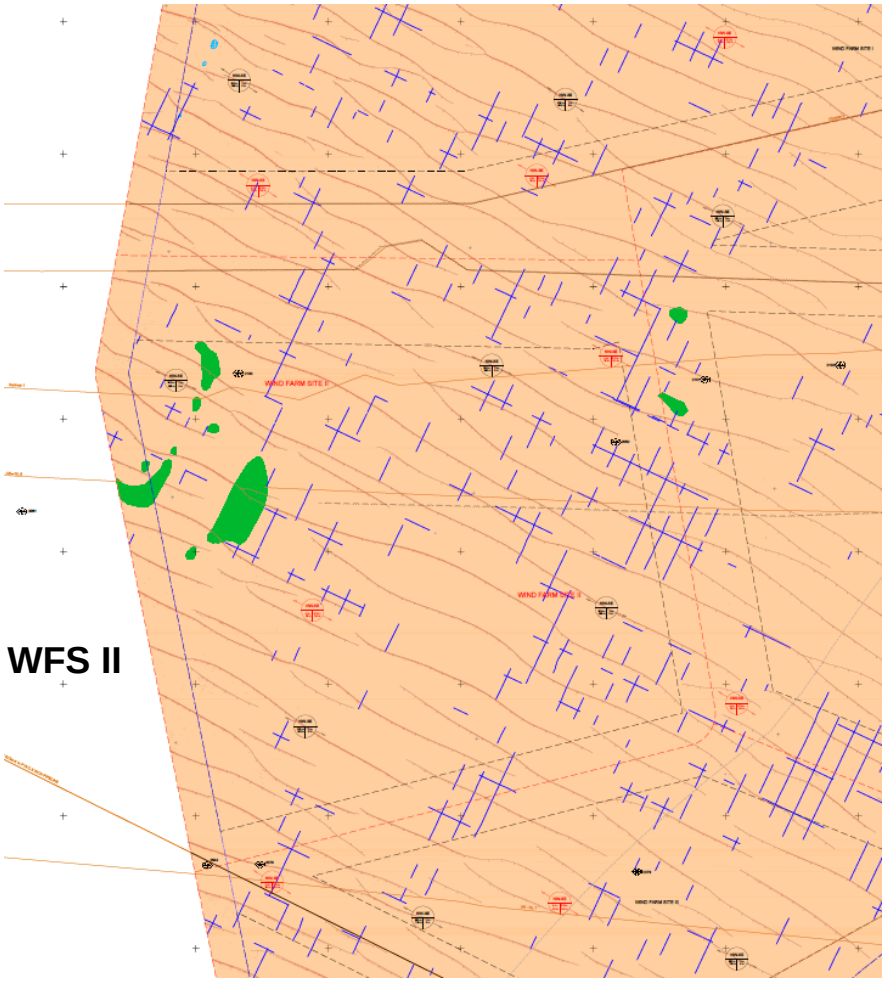


Geohazard mapping for WFS I shows:

- Sand dune crests (brown lines)
- Palaeochannel locations (blue lines)
- Hard/GRAVEL layers (blue areas)

Installation Constraints – WFS II Overview

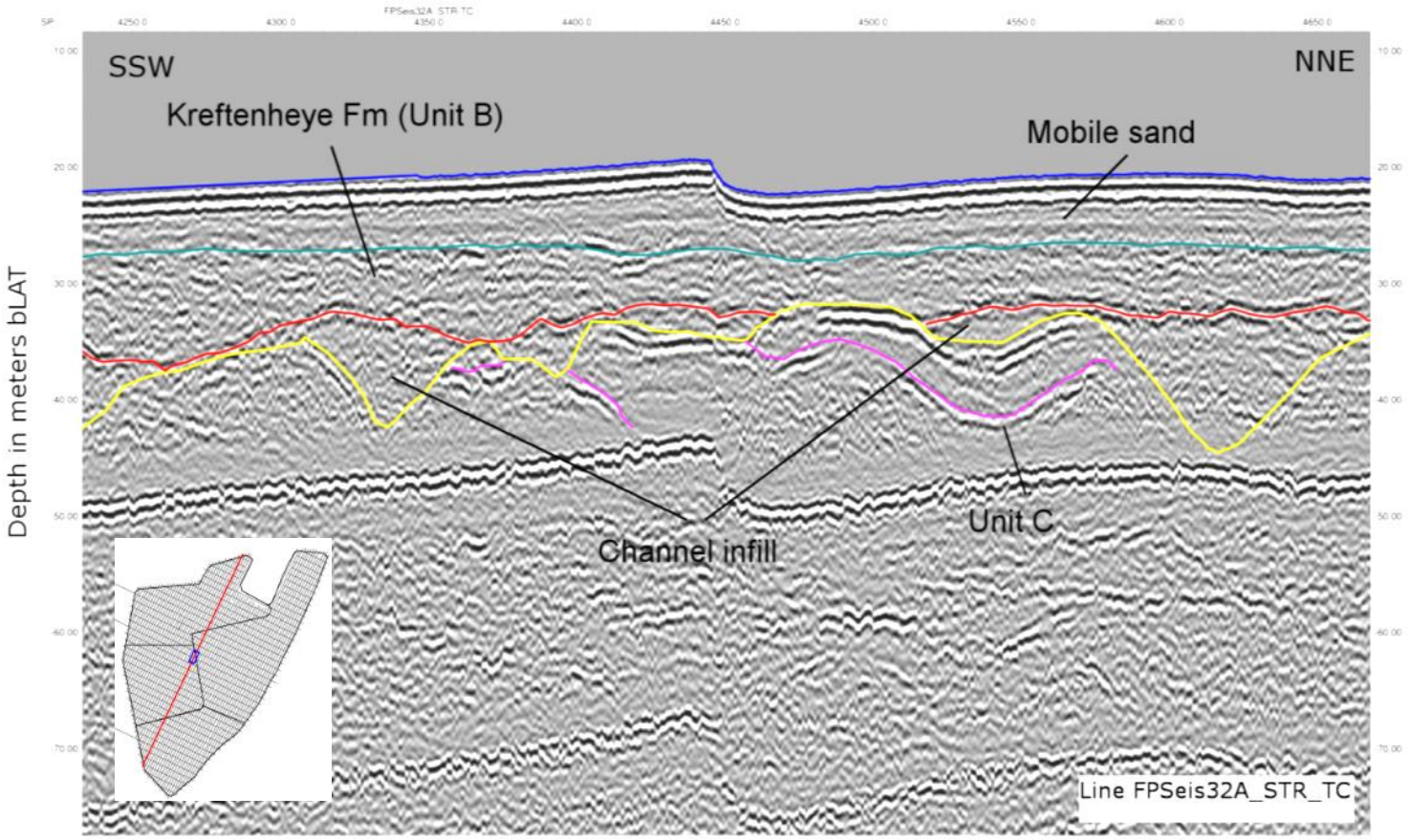
	WFS II
Seabed hazards – Sand Dunes	★
Seabed hazards – Wrecks	✖
Palaeochannel infill	★
Surficial Faults	✖
Peat layer/Biogenic gas charged sediment	★
Hard/GRAVEL layers	✖



Geohazard mapping for WFS II shows:

- Sand dune crests (brown lines)
- Palaeochannel locations (blue lines)
- Peat/possible shallow gas (green areas)

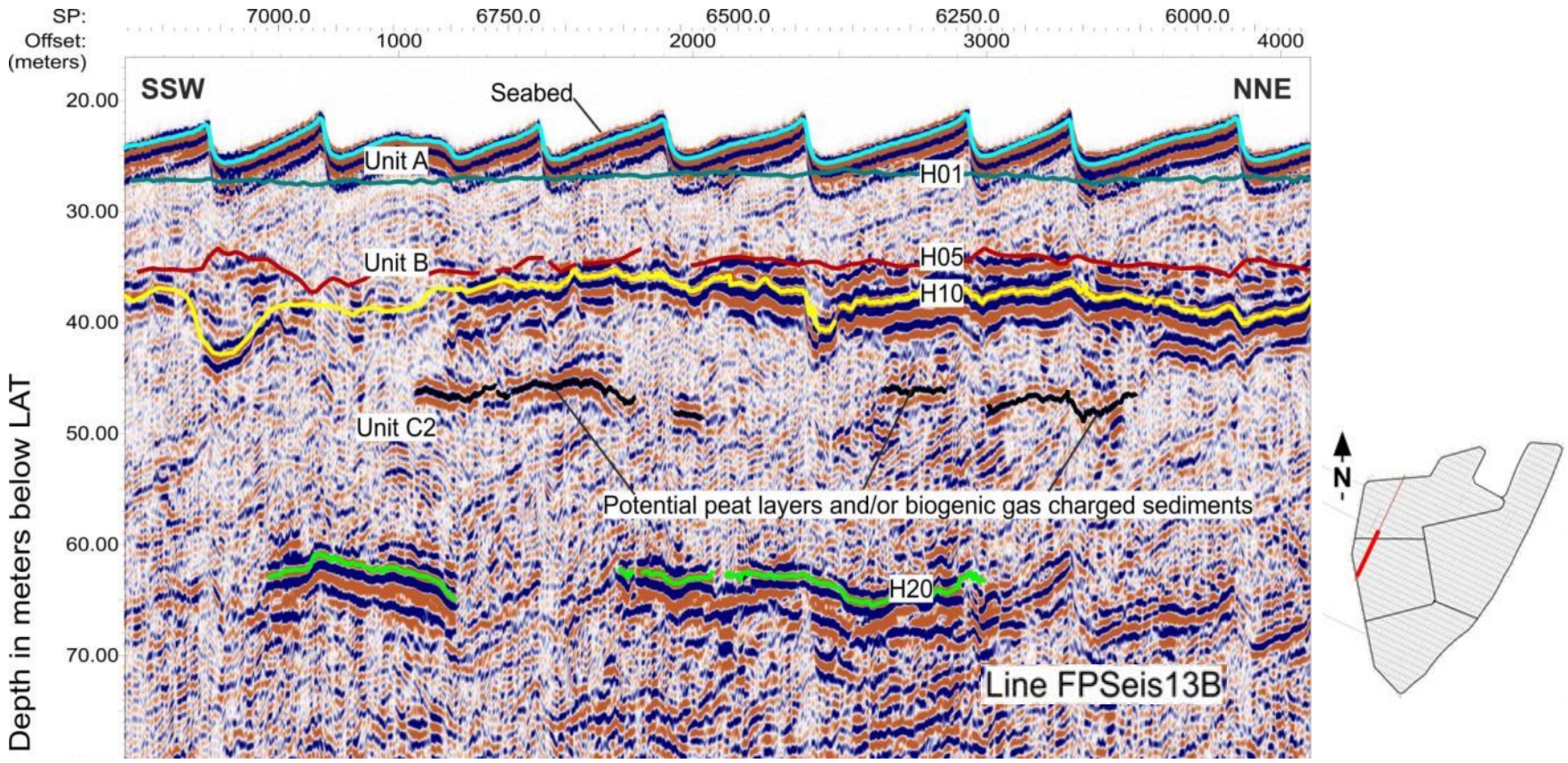
Installation Constraints – Palaeochannels (Buried Channels)



Single channel sparker line through WFS I and WFS II showing buried channels within Unit B.

Palaeochannel infills are heterogeneous and can pose an engineering hazard due to lateral changes in mechanical resistance.
The nature of the channels across WFS I and WFS II is highly variable, and discontinuous.

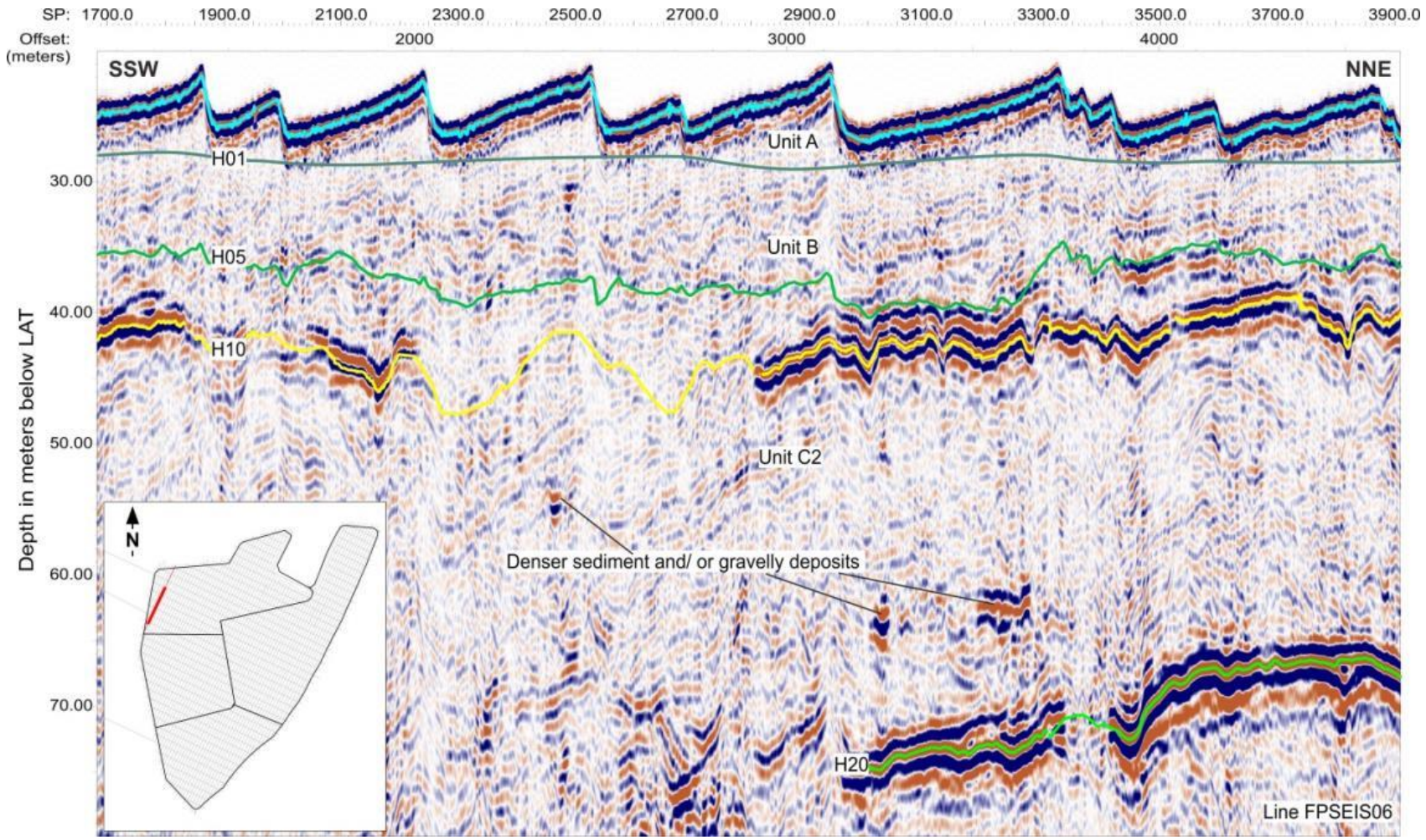
Installation Constraints – Shallow Gas or Peat



Shallow gas anomalies and peat usually show high amplitude, reverse polarity (consistent with gas) and acoustic blanking of the deeper layers.

Acoustic anomalies showing these characteristics were recognised within Unit C.

Installation Constraints – Hard/Gravel Layers

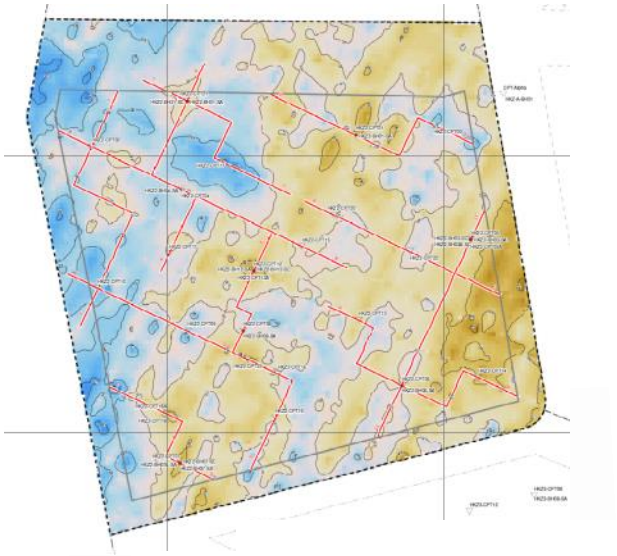


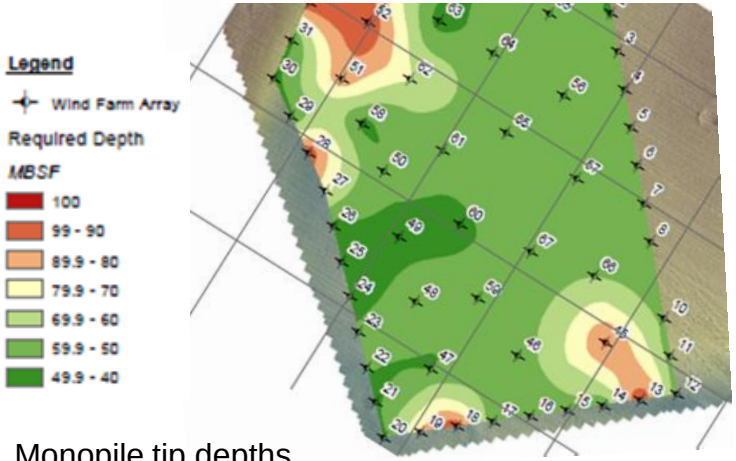
Reflectors with positive high amplitudes interpreted as patches of hard layers/GRAVEL layers were identified in the north-west of WFS I within Unit C.

Limitations of the Geophysical Data

- Some seafloor targets (>0.2 m) may not have been identified.
- Limited sub-bottom profiler (SBP) penetration (due to lithology) and ability to resolve geological horizons.
- Horizons, including buried channel boundaries, could not be traced continuously across the wind farm sites.
- Shallow geological features smaller than the line spacing (300 m / 750 m) may not have been detected.
- The UHR data were not suitable for detailed fault mapping. The presence of faults and fractures cannot be ruled out.
- Small anomalies which could indicate shallow gas or peat layers may not have been identified below the first seabed multiple.
- The interpretation of shallow gas is only indicative, and needs to be calibrated with the results of the geotechnical campaign.

GIS Ground Model





Monopile tip depths

- The geophysical site investigation data have been used to develop a geological ground model in combination with the geotechnical investigation
- The ground model builds on the results of the two surveys
- The current GIS ground model can be extended with:
  - Monopile sizing and mapping for any location using scripted design profile selection and design analyses
  - Jack-up penetration and punch through probability mapping for entire wind farm
  - Mapping of local and regional scour potential
  - Strategic visualisation of any supplementary site investigation data still to be acquired
  - And more…

THANK YOU