THOR OFFSHORE WIND FARM

Program for seabed investigations

2019-05-13 Workshop on site investigations

PROGRAM FOR SEABED INVESTIGATIONS (100%)

Introduction

Purpose of presentation

- **Overview**: Planned activities.
- Encourage to provide **feedback**.
- Keep in mind: **Program changes likely**.

Content of presentation

1. OWF geophysical site survey
2. OWF prelim. geotechnical investigations
3. OWF 3D geological model
4. Export cable route survey
5. Desk study, Marine archaeological assessment
6. Desk study, UXO risk management
7. Time Schedule

PROGRAM FOR SEABED INVESTIGATIONS

Introduction

Content of presentation

1. OWF geophysical site survey
2. OWF prelim. geotechnical investigations
3. OWF 3D geological model

PROGRAM FOR SEABED INVESTIGATIONS

Guideline for planning and performance of OWF site investigations

Minimum requirements as described from German BSH

Content of presentation

1. OWF geophysical site survey
2. OWF prelim. geotechnical investigations
3. OWF 3D geological model

PROGRAM FOR SEABED INVESTIGATIONS

Stage 1 to 4 part of development phase before contract award

2019 - 2021

2022 -

Phase	Stage	Geological survey	Geotechnical survey	Report[1]
Development	1	Desk Study		Preliminary geological report, "Geologischer Vorbericht" (content reflects the geological report)
	2	Geophysical investigations		
	3		Preliminary geotechnical investigation	Preliminary geotechnical site survey report, "Baugrundvoruntersuchungsbericht" Soil and foundation expertise report (Development phase), „Baugrund- und Gründungsgutachten (Entwicklungsphase)"
	4	Geophysical postinterpretation including the results of geotechnical survey		Geological report, "Geologischer Bericht" (Findings from 1 to 4)
Construction	5		Main geotechnical investigation	Main geotechnical site survey report, „Baugrundhauptuntersuchungsbericht" Soil and foundation expertise report (Construction phase), "Baugrund- und Gründungsgutachten (Konstruktionsphase)"

CONTENT OF PRESENTATION

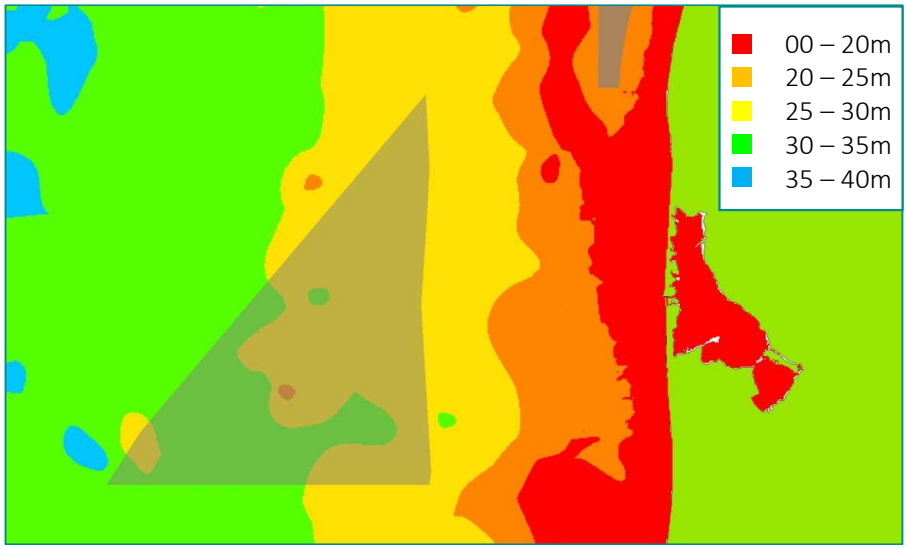
Program for seabed investigations

1. OWF geophysical site survey
2. OWF preliminary geotechnical investigations
3. OWF 3D geological model
4. Export cable route survey
5. Desk study, Marine archaeological assessment
6. Desk study, UXO risk management
7. Time Schedule

1. OWF GEOPHYSICAL SITE SURVEY

Area of investigation - OWF

Water Depth (m)



© DMA, 2012, 100m DTM

Seabed surface geology

© GEUS, 2015

1. OWF GEOPHYSICAL SITE SURVEY

Survey objectives determined in DEA instruction to Energinet:

Establish information to …

1. Delimit project area
2. Investigate potential location of turbines, cables and platforms
3. Plan and assess the feasibility of installation activities such as e.g. jack-up vessels, anchoring, foundation works, cable lay and protection.
4. Support environmental assessments and planning.
5. Perform preliminary assessments of marine archaeological and of UXO risk.
6. Planning of preliminary geotechnical investigations.

1. OWF GEOPHYSICAL SITE SURVEY (100%)

Scope

Target of mapping	Products	Methodology
Water Depth	DTM overview DTM detailed Contour curves	High-resolution bathymetric mapping
Seabed Surface	Maps, Surface geology Maps, Surface morphology Maps, Man-made objects (Maps, *Benthic habitats ?*)	Acoustic surface mapping Ferromagnetic reconnaissance Ground truthing
Seabed Geology	Maps, Soil unit interfaces, m below CD Maps, Soil unit interfaces, m BSB Maps, Soil unit interfaces, thickness	High-resolution seismic system Medium-resolution seismic system

1. OWF GEOPHYSICAL SITE SURVEY

Scope

Target of mapping	Products	Methodology
Water Depth		
Seabed Surface		
Seabed Geology		

1. OWF GEOPHYSICAL SITE SURVEY

Selected product quality parameters

Multibeam Echosounding	Full coverage, At least IHO special order DTM w 0.25m spatial resolution Re-survey after ca. 1 year
Side Scan Sonar	Dual-Frequency 200% coverage Detect all objects > 0.5m
High-resolution Seismic profiling	Penetration to 10m bsb Line spacing ca. 100m Single channel receiver system
Medium-resolution Seismic profiling	Penetration to 60m bsb Line spacing ca. 500m Multi channel receiver system

Magnetometer	Reconnaissance, all survey lines Line spacing ca. 100m
Grab sampling	For seabed surface interpretation +100 samples Geological classification Particle size and organic content
Horisontal positioning uncertainty	< 0.5m for vessels < 2.5m for towed equipment

1. OWF GEOPHYSICAL SITE SURVEY

Products

Report	Geophysical Site Survey Report 2019 Hydrographical Report 2020
Drawings	Charts – bathymetry Charts – seabed surface (geology, morphology, man-made objects) Charts – soil units (interface elevations and depth bsb, isopach) A number of representative cross sections
Digital products	Survey data, raw and processed data formats GIS deliverables, Interpreted data

1. OWF GEOPHYSICAL SITE SURVEY

Deviations?

- No deviations
- Quality control elements
  - Offshore Client representatives during mobilization and acquisition
  - Deliverables verified by qualified geoscientists
  - Supplier contracts with terms for deliverables

CONTENT OF PRESENTATION

Program for seabed investigations

1. OWF geophysical site survey
2. **OWF preliminary geotechnical investigations**
3. OWF 3D geological model
4. Export cable route survey
5. Desk study, Marine archaeological assessment
6. Desk study, UXO risk management
7. Time Schedule

2. OWF PRELIM. GEOTECHNICAL INVESTIGATIONS

Main objectives - in general

Gather geotechnical data as basis for

1. Evaluation of different methods for foundation and installation as well as
2. Preliminary design of wind turbines
3. Preliminary design of offshore platforms

2. OWF PRELIM. GEOTECHNICAL INVESTIGATIONS

Main objectives – the results must be used to

1. Verify the **geological units** found during the geophysical survey
2. Characterise these geological units in **geotechnical terms**, and obtain geotechnical data for the soils and layers
3. Correlate with **interpreted geophysical results** for detailed delineation of sediment types and layers
4. Verify **soil risks** such as geophysical found/indicated possible accumulations of shallow gas, buried channels, soft sediments, etc.
5. Assessment of possibilities to **jack up** on the seabed when installing the foundations
6. Assessment of **transport of sediments** around the foundations after installation
7. Update the preliminary **3D geological model** based upon the geophysical survey results

2. OWF PRELIM. GEOTECHNICAL INVESTIGATIONS

Marine works → Scope

- Investigation target depths, 50m to 70m below seabed
- Geotechnical boreholes with soil sampling
- Cone Penetration Test (CPT)
  - Continuous from seabed
  - Down-the-hole
  - Blind-drilled boreholes

INPUT REQUESTED

- Comments on methods?

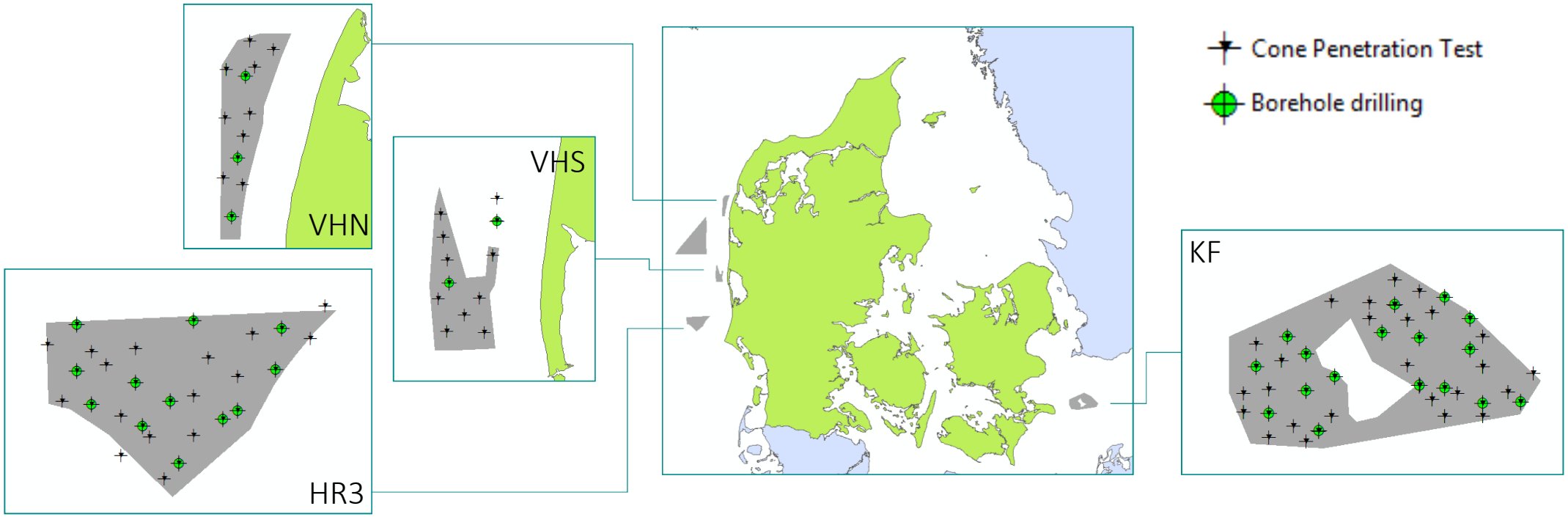
2. OWF PRELIM. GEOTECHNICAL INVESTIGATIONS

Marine works → Scope

- **Question 1**: How many boreholes and CPTs?
- **Question 2**: Where should the investigations be located?

2. OWF PRELIM. GEOTECHNICAL INVESTIGATIONS

Previous projects: Experiences with scope in development phase



2. OWF PRELIM. GEOTECHNICAL INVESTIGATIONS

Previous projects: Experiences with scope in development phase

Site	KM2	BH	CPT	KM2 pr BH	KM2 pr CPT
HR3	ca. 145	12	28	12,1	5,2
KF	ca. 170	17	42	10,0	4,0
VHS	ca. 50	2	12	25,0	4,2
VHN	ca. 60	3	12	20,0	5,0

2. OWF PRELIM. GEOTECHNICAL INVESTIGATIONS

Previous projects: Experiences with scope in development phase

Site	KM2	BH	CPT	KM2 pr BH	KM2 pr CPT
HR3	ca. 145	12	28	12,1	5,2
KF	ca. 170	17	42	10,0	4,0
VHS	ca. 50	2	12	25,0	4,2
VHN	ca. 60	3	12	20,0	5,0
Thor Scenario 1	ca. 440	44	110	10	4
Thor Scenario 2	ca. 440	18	73	25	6

2. OWF PRELIM. GEOTECHNICAL INVESTIGATIONS

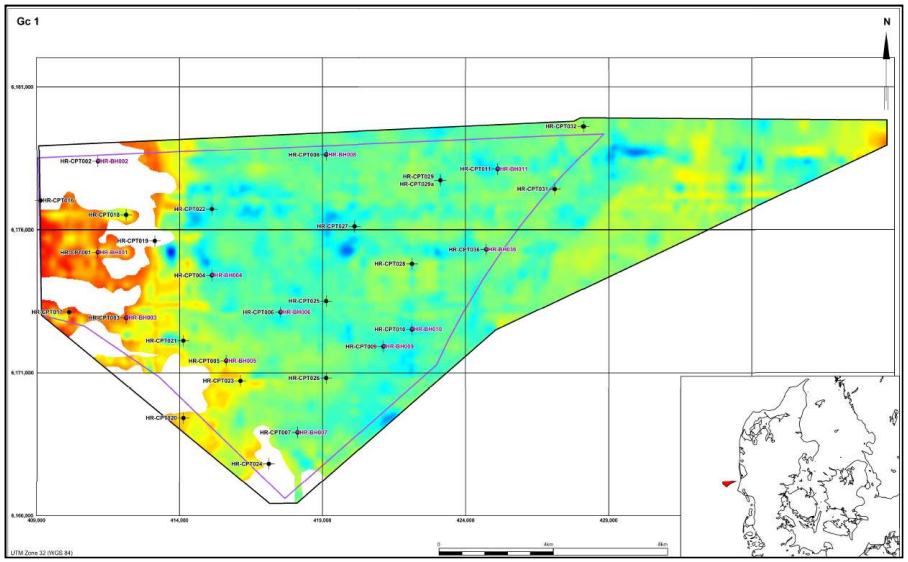
Previous projects: Experiences with scope in development phase

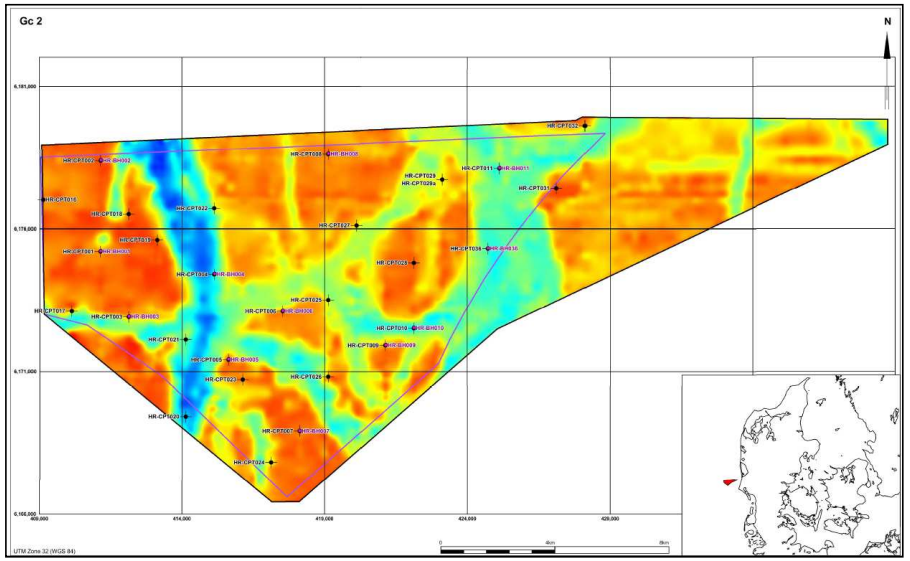
Site	KM2	BH	CPT	KM2 pr BH	KM2 pr CPT
HR3	ca. 145	12	28	12,1	5,2
KF	ca. 170	17	42	10,0	4,0
VHS	ca. 50	2	12	25,0	4,2
VHN	ca. 60	3	12	20,0	5,0
Thor Scenario 1	ca. 440	44	110	10	4
Thor Scenario 2	ca. 440	18	73	25	6
Thor Plan	ca. 440	**10 – 15**	**50 - 70**	-	-

2. OWF PRELIM. GEOTECHNICAL INVESTIGATIONS

Expectations to variance in seabed geology …

Example from HR3





- Base of Mw sand (Weichsel / Saale)
- Base of Till and Mw deposits (Saale / Elster)

2. OWF PRELIM. GEOTECHNICAL INVESTIGATIONS

Marine works → Scope

- **Question 1**: How many boreholes and CPTs?
  - Planned no. of BH 10 - 15
  - Planned no. of CPT 50 - 70

- **Question 2**: Where should the investigations be located?
  - Guided by interpretation of geophysical survey

INPUT REQUESTED

- Comments?

2. OWF PRELIM. GEOTECHNICAL INVESTIGATIONS

Methods and Scope → Laboratory testing

- Geotechnical classification tests

- No advanced soil testing
  - Chemical tests
  - Thermal resistivity
  - Triaxial tests
  - Cyclic tests

INPUT REQUESTED

- Approach to laboratory tests?

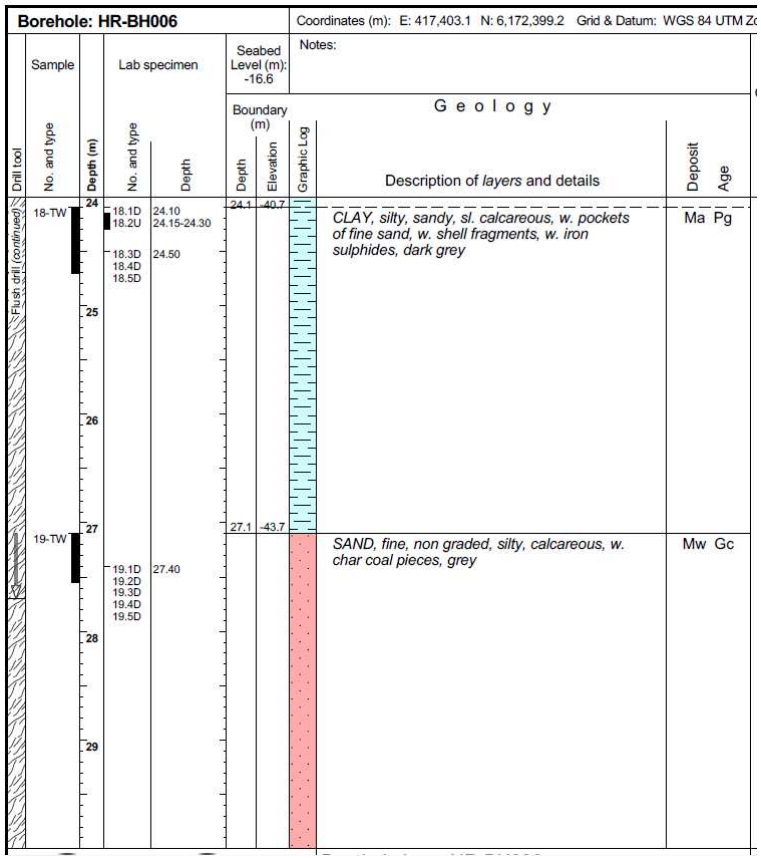
→

- Geological description and classification
- Water content
- Saturated moisture content
- Bulk density
- Grain size distribution
- Atterberg limits
- Particle density
- Density index of granular soils (emin/emax)
- Loss on ignition (organic content)
- Degree of Roundness of Sand

2. OWF PRELIM. GEOTECHNICAL INVESTIGATIONS

Products

Report	Geotechnical report
Drawings	Charts with geographical locations CPT profiles, measured and interpreted Integrated borehole profiles
Digital products	GIS layers with scope Geotechnical data as AGS data file



2. OWF PRELIM. GEOTECHNICAL INVESTIGATIONS

Deviations?

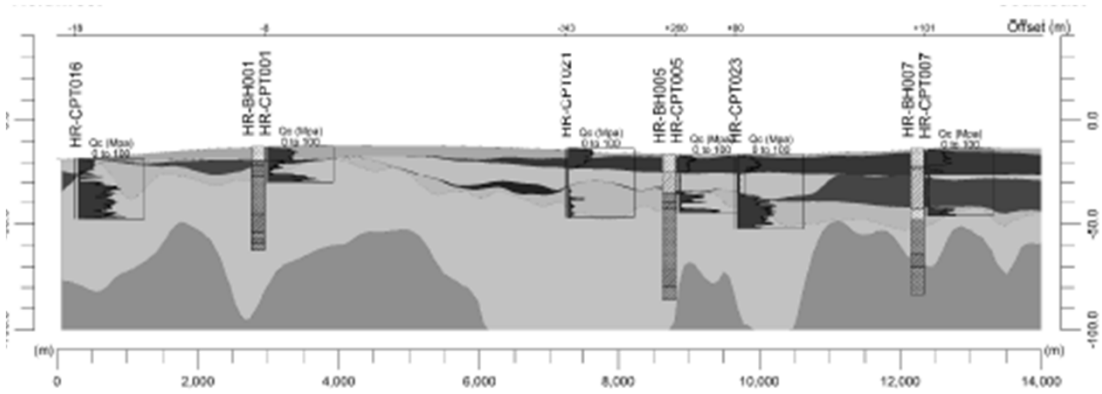
- Yes – there are deviations:
  - Foundation locations not yet determined
  - Organizational differences

- Quality control elements
  - Offshore Client representatives during mobilization and investigation
  - Deliverables verified by qualified geotechnical engineer
  - Supplier contracts with terms for deliverables

CONTENT OF PRESENTATION

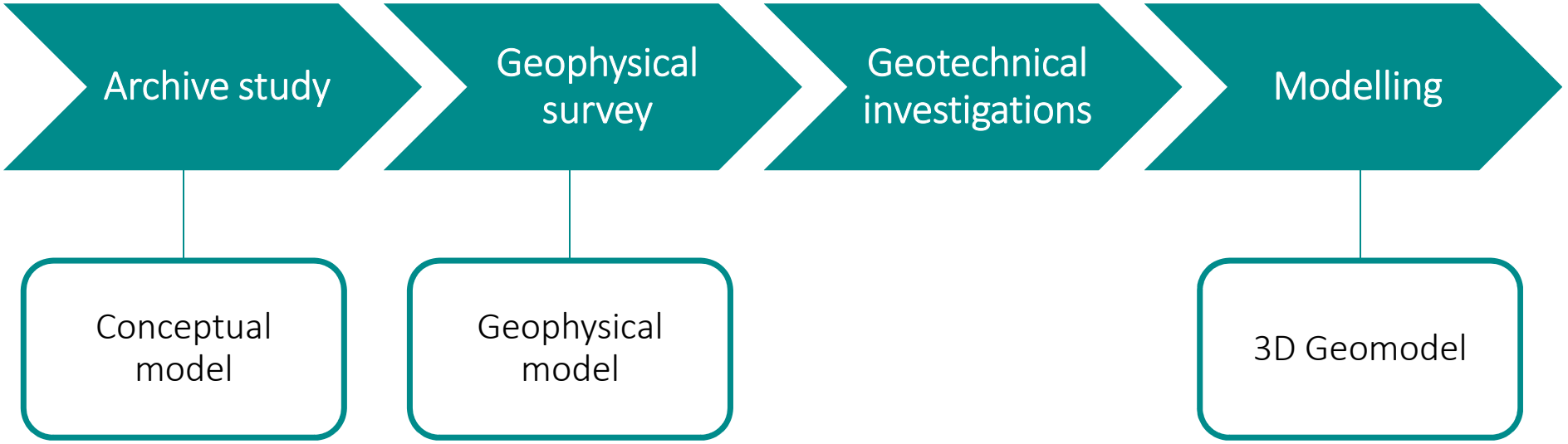
Program for seabed investigations

1. OWF geophysical site survey
2. OWF preliminary geotechnical investigations
3. **OWF 3D geological model**
4. Export cable route survey
5. Desk study, Marine archaeological assessment
6. Desk study, UXO risk management
7. Time Schedule



3. OWF 3D GEOLOGICAL MODEL

Proces



3. OWF 3D GEOLOGICAL MODEL

Scope

Use in-situ information from geotechnical investigations to

- Confirm or revise geophysical model layer interfaces
- Confirm or revise soil units (lithology description, age and depositional environment)
- Characterise geotechnical properties of soil units – typical parameters

3. OWF 3D GEOLOGICAL MODEL

Products

Report	Modeling report: Methodology and results
Drawings	Soil unit charts of layer interface (elevation maps and depth bsb maps) Soil unit charts of layer thickness A number of representative cross sections
Digital products	3D geomodel in native software format Soil unit interfaces as GIS deliverables

CONTENT OF PRESENTATION

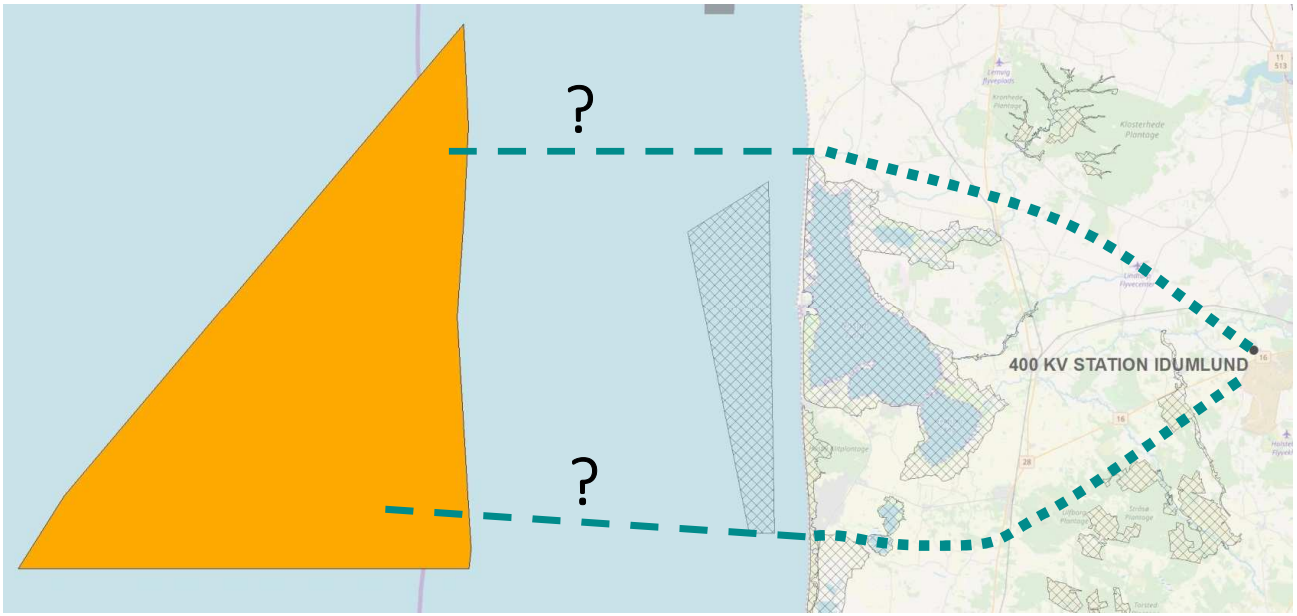
Program for seabed investigations

1. OWF geophysical site survey
2. OWF preliminary geotechnical investigations
3. OWF 3D geological model
4. **Export cable route survey**
5. Desk study, Marine archaeological assessment
6. Desk study, UXO risk management
7. Time Schedule

4. EXPORT CABLE ROUTE SURVEY

Export cables – onshore routes

- Grid connection: Idumlund 400 kV station
- Two alternative routes. Development ongoing
- Installed by Energinet
- Nissum Fjord
- Protected areas
- Recreational villages



4. EXPORT CABLE ROUTE SURVEY

Export cables – offshore routes

High risk constraints:

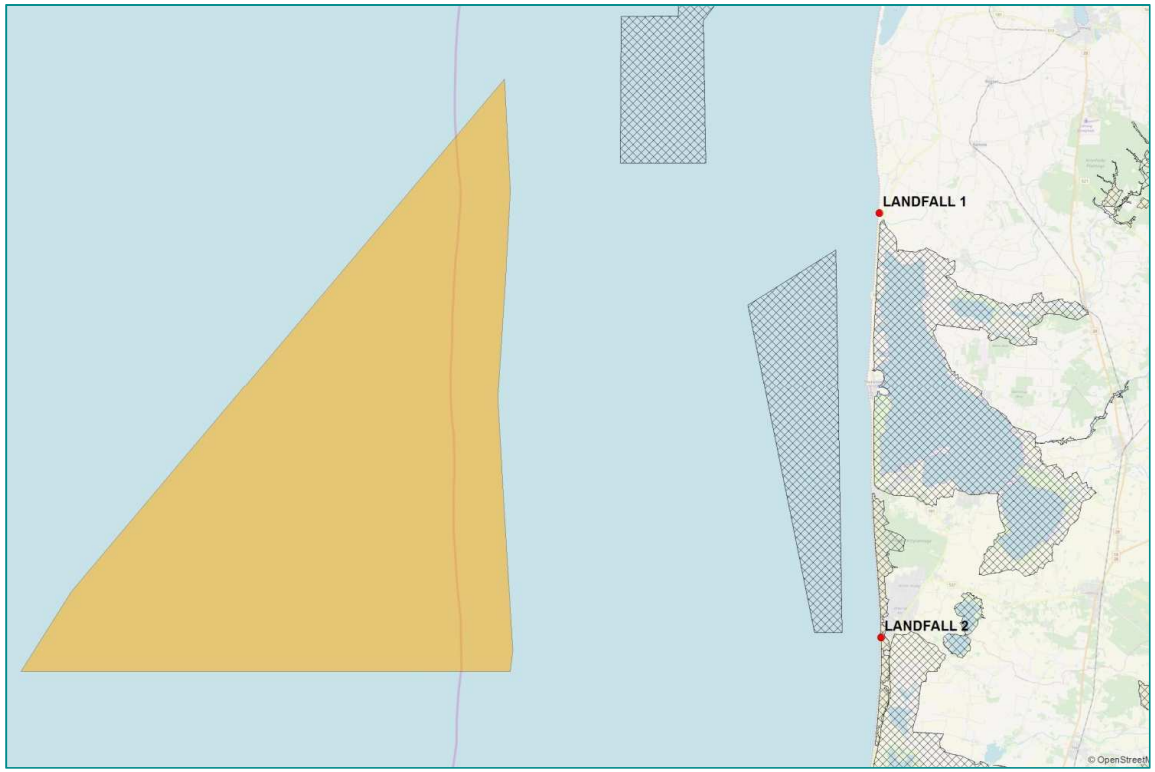
1. Nature protected areas
2. Raw material areas

AVOID

Medium risk constraints:

3. Archaeology / UXO
4. Seabed surface

SURVEY



4. EXPORT CABLE ROUTE SURVEY

Export cables – offshore routes

High risk constraints:

1. Nature protected areas
2. Raw material areas

AVOID

Medium risk constraints:

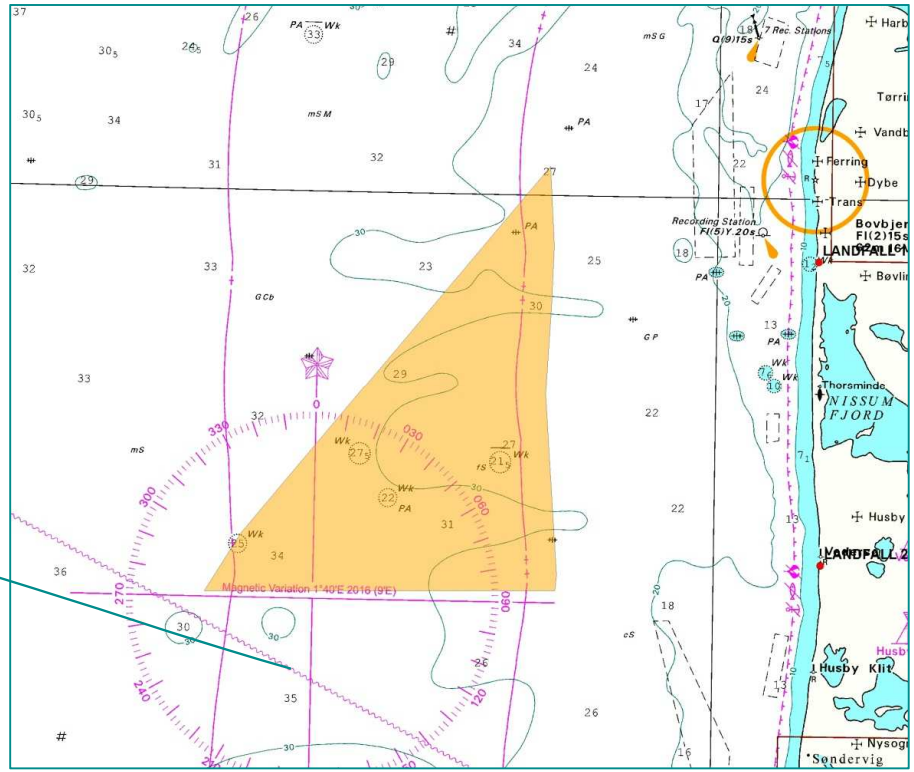
3. Archaeology / UXO
4. Seabed surface

SURVEY

Low risk constraints:

5. Infrastructure
6. Vessel traffic
7. Military use
8. Water Depth

DESK STUDY



4. EXPORT CABLE ROUTE SURVEY

Export cables – offshore routes

AIS © DMA, 2016

<u>High risk constraints:</u>

1. Nature protected areas
2. Raw material areas

AVOID

<u>Medium risk constraints:</u>

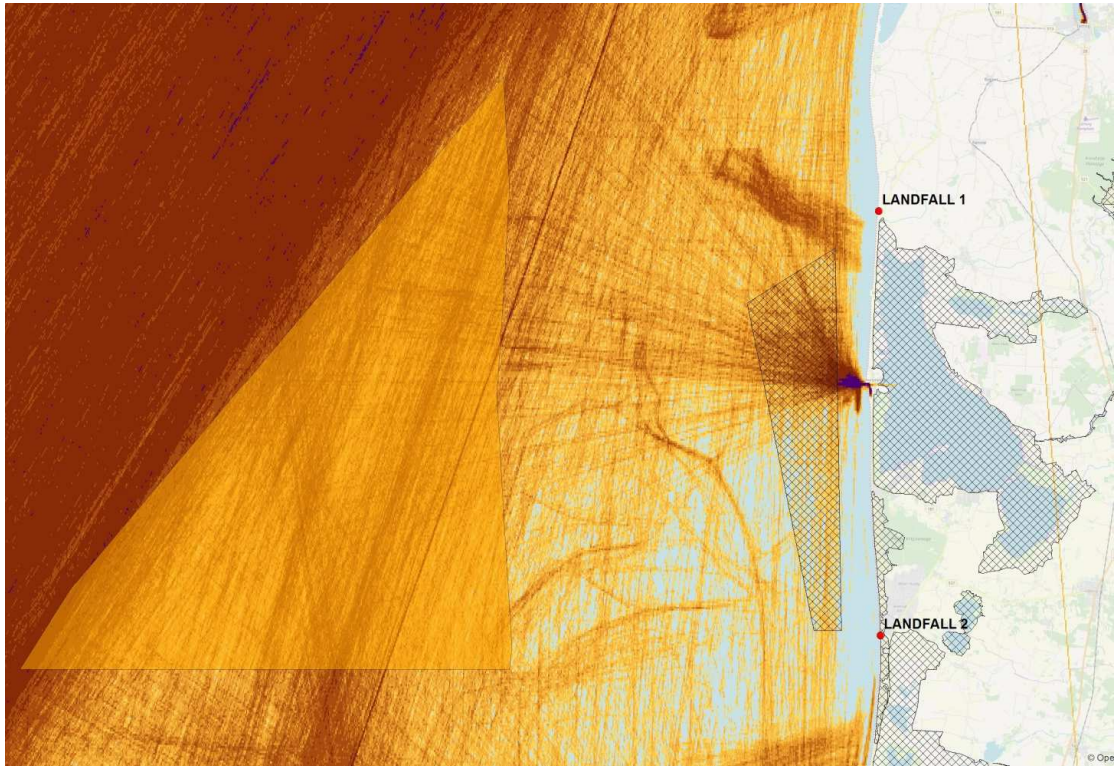
3. Archaeology / UXO
4. Seabed surface

SURVEY

<u>Low risk constraints:</u>

5. Infrastructure
6. **Vessel traffic**
7. Military use
8. Water Depth

DESK STUDY



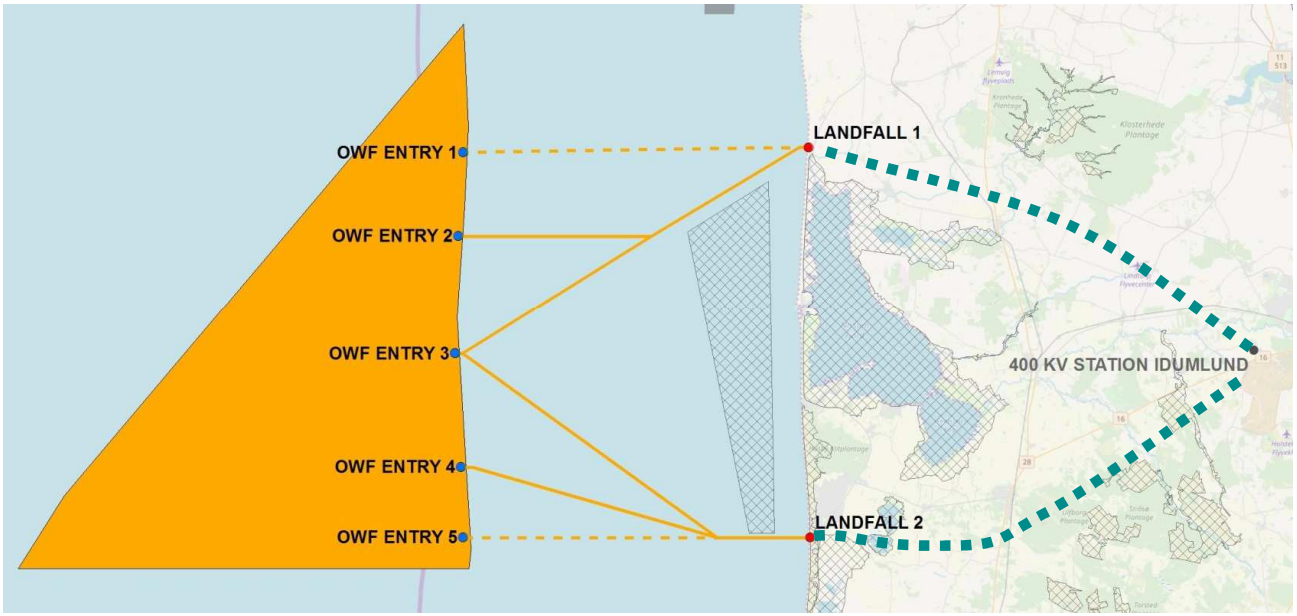
4. EXPORT CABLE ROUTE SURVEY

Export cables – offshore routes

- Two landfall alternatives
- Multiple options for offshore connection – reduce cable route distance.
- Width of survey corridor: 500m to 1000m

INPUT REQUESTED

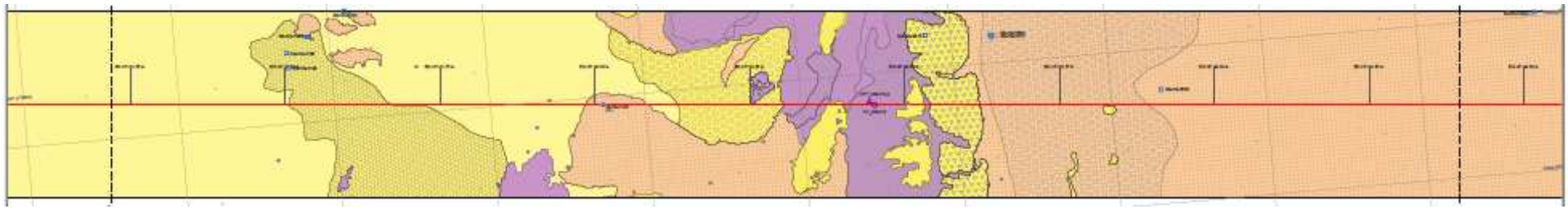
- OWF Entry 1 and 5: Relevant?
- One or two offshore platforms?
- Width of survey corridor?



4. EXPORT CABLE ROUTE SURVEY

Main objectives with survey is to establish information to support …

1. Environmental studies
2. Archaeological assessments
3. Detailed route planning
4. Engineering of cable burial and protection
5. Tender for cable and installation



4. EXPORT CABLE ROUTE SURVEY

Survey spread and Scope

Survey spread overview:

- Multi-Beam Echo-Sounding
- Side Scan Sonar
- Magnetometer
- Seismic profiling
- Grab sampling
- Core sampling to 6m bsb
- CPT tests to 6m bsb

Scope elements

- 2019:
  - Geophysical survey – offshore
  - Geophysical survey – near shore
  - Geotechnical investigations
- 2020
  - Hydrographical survey (option)

4. EXPORT CABLE ROUTE SURVEY

Products

Report	Cable Route Survey Report 2019 Hydrographical Report 2020
Alignment charts	Bathymetry Seabed surface (geology, morphology, man-made objects) Seabed sub-surface geology Geotechnical profiles
Digital products	Survey data, raw and processed data formats GIS deliverables, Interpreted data

CONTENT OF PRESENTATION

Program for seabed investigations

1. OWF geophysical site survey
2. OWF preliminary geotechnical investigations
3. OWF 3D geological model
4. Export cable route survey
5. **Desk study, Marine archaeological assessment**
6. **Desk study, UXO risk management**
7. Time Schedule

5. MARINE ARCHAEOLOGICAL ASSESSMENT

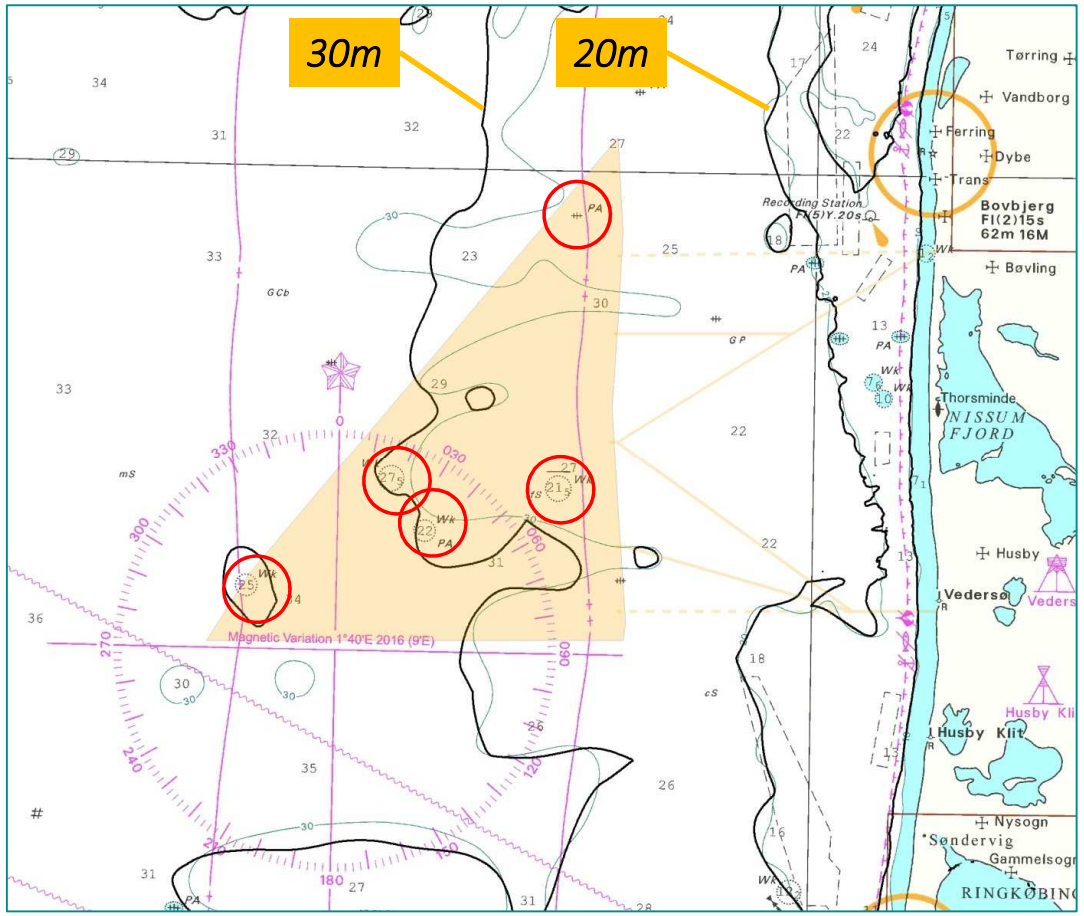
Background

Stone age

- 11 000 to 6 000 y BP: Transgression from WD ca. 30m to present day shoreline.
- Potential for heritage.

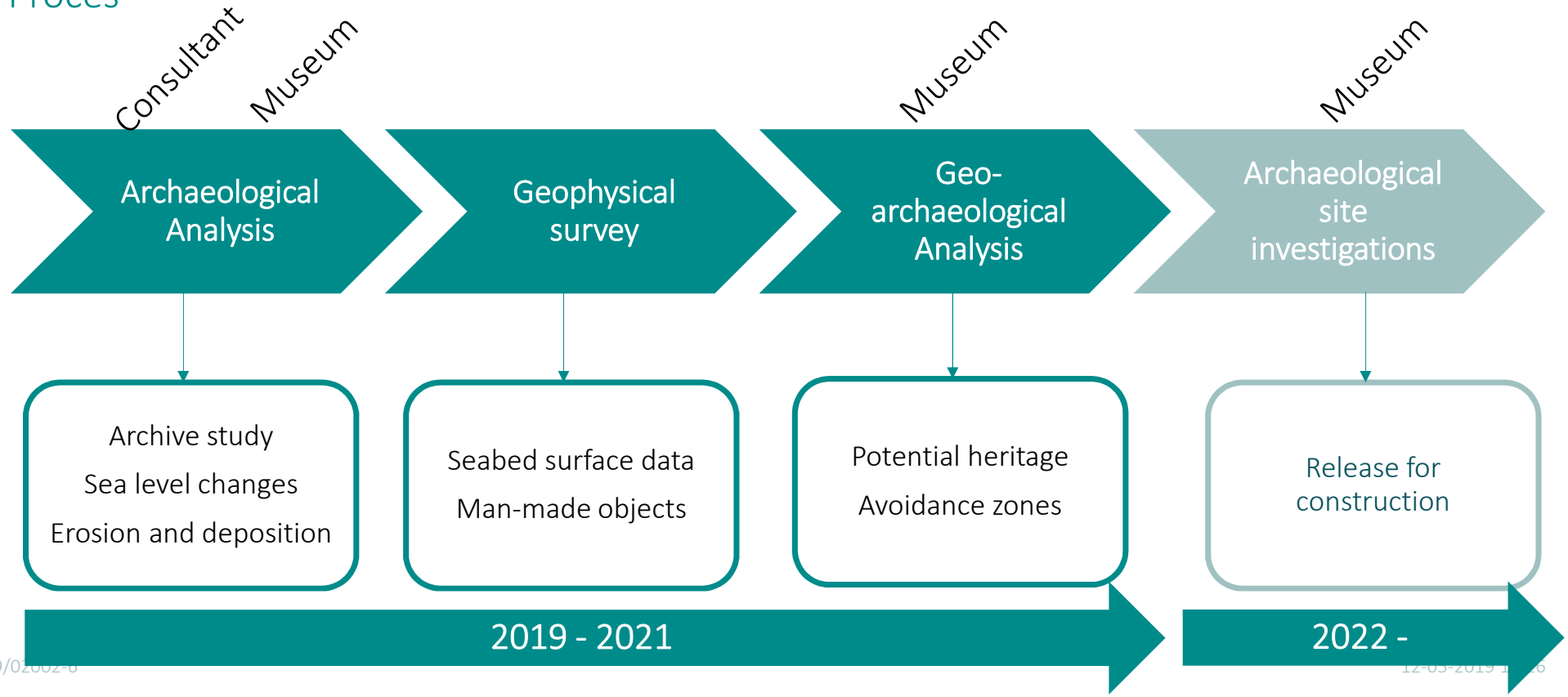
Wrecks

- Multiple chartered wreck sites



5. MARINE ARCHAEOLOGICAL ASSESSMENT

Proces



5. MARINE ARCHAEOLOGICAL ASSESSMENT

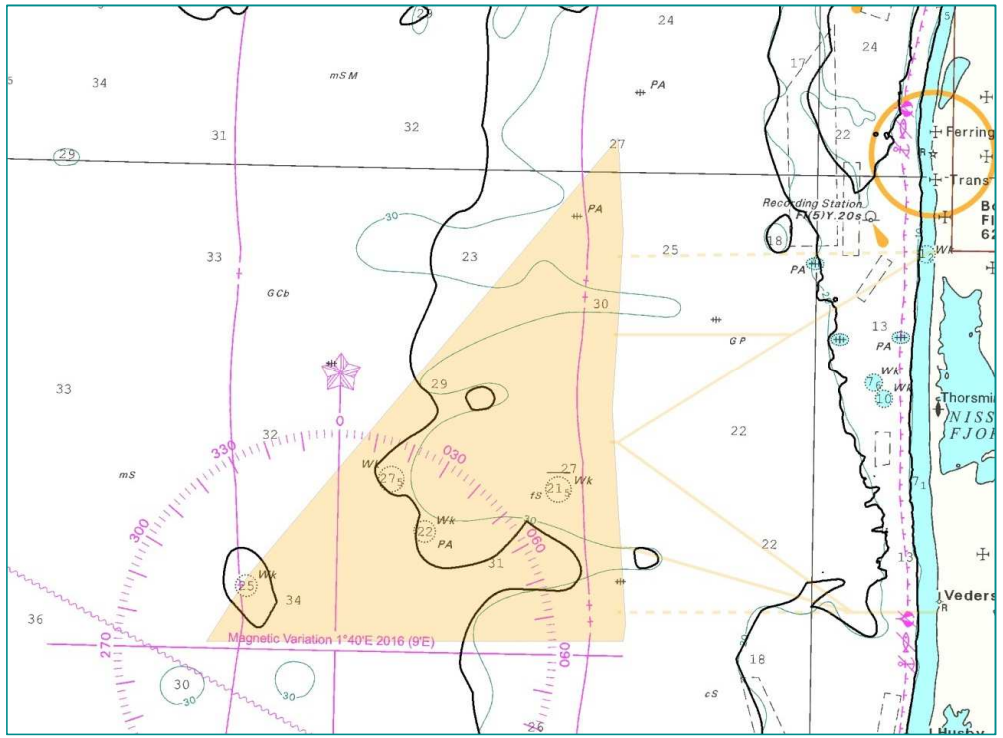
Products

Report	Archaeological Analysis: Pre-survey desk study Geo-archaeological Analysis: Survey data analysis, avoidance zones
Digital products	GIS deliverables, Interpreted data

6. UXO RISK MANAGEMENT

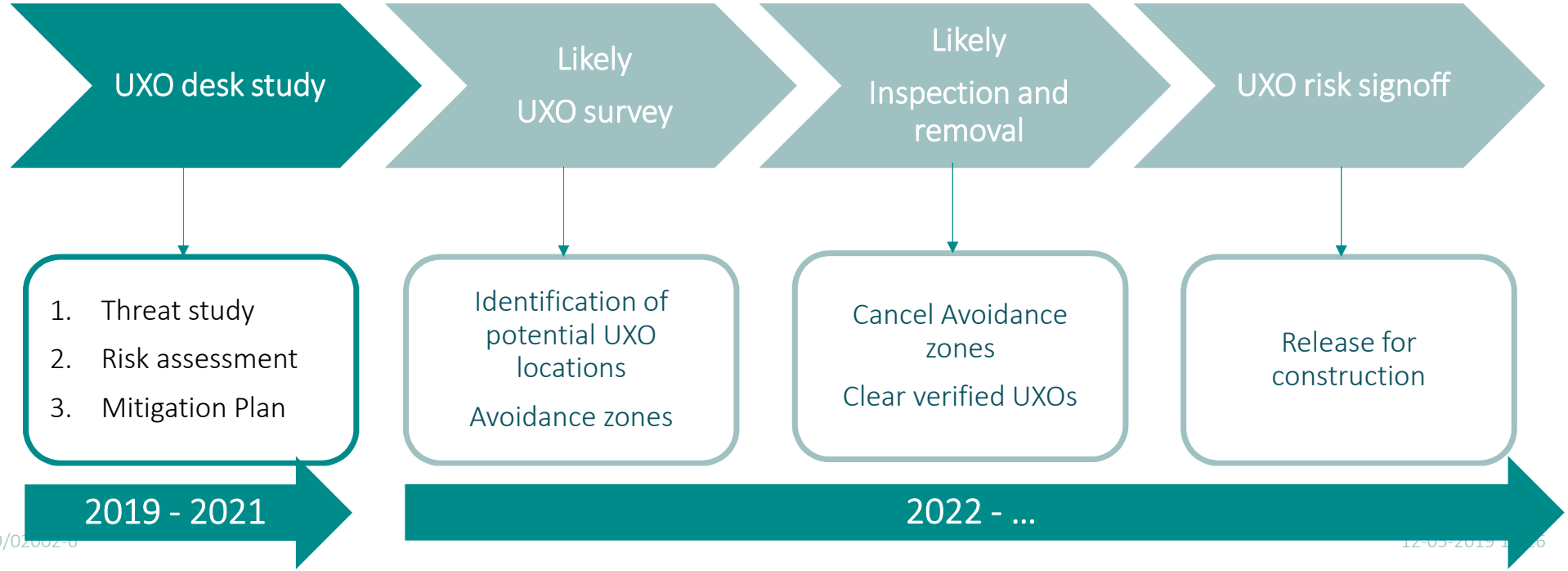
Background

- UXOs from WWI and WWII very likely.
- Ground mines, Anchor mines, Air-delivered bombs, Military wrecks,…
- Risk that items may be burried in seabed.
- Charted minefield within 1 nm of coast.



6. UXO RISK MANAGEMENT

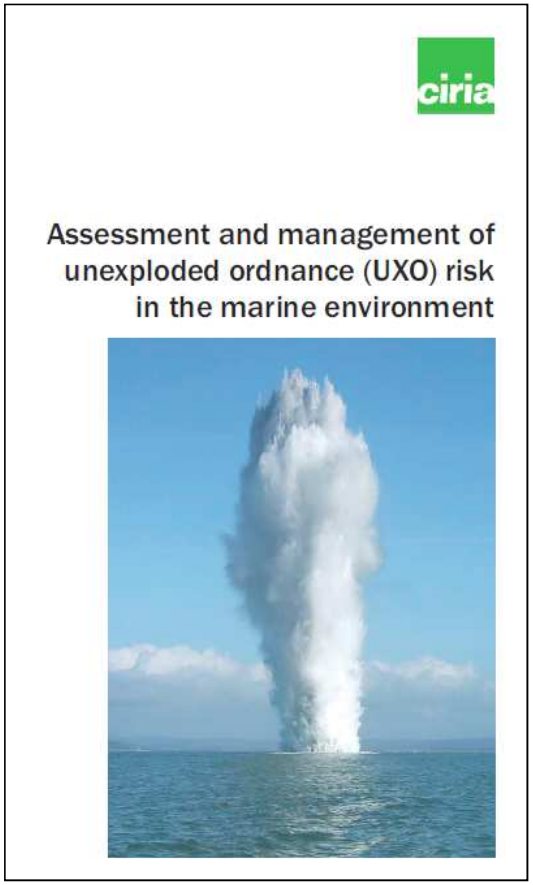
Proces



6. UXO RISK MANAGEMENT

Products

Report	Threat study	• Geographical zonation of UXO risk – if possible • Characterize UXOs (type, dimensions, NEQ, origin,…) • Describe if UXOs may be buried in seabed
	Risk assessment	• Assess expected project activities with seabed interaction
	Mitigation Plan	• Minimum requirements for UXO survey • Any passive mitigation measures



CONTENT OF PRESENTATION

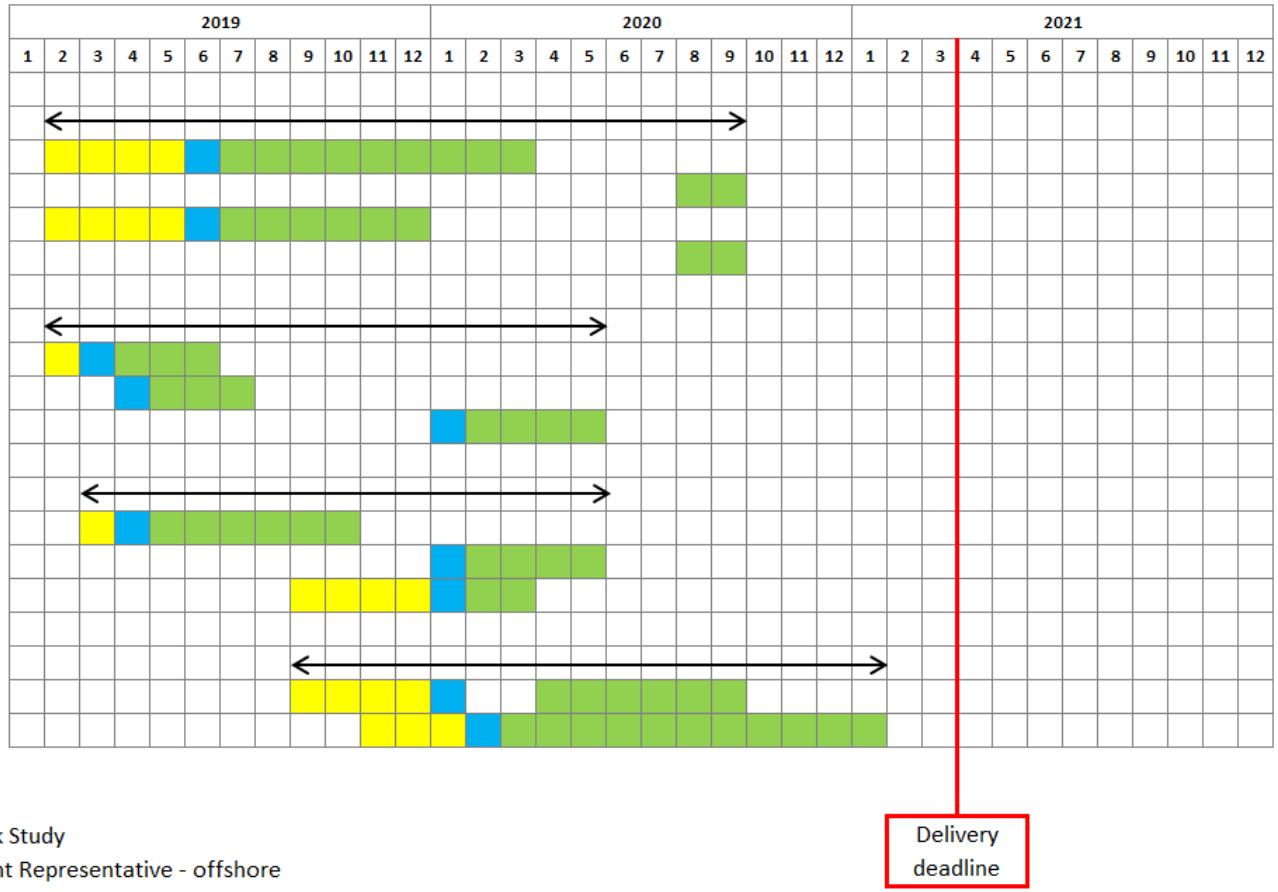
Program for seabed investigations

1. OWF geophysical site survey
2. OWF preliminary geotechnical investigations
3. OWF 3D geological model
4. Export cable route survey
5. Desk study, Marine archaeological assessment
6. Desk study, UXO risk management
7. Time Schedule

8. TIME SCHEDULE

Plan pr. 2019-02-27

Line	Main acitivity	DS	CR
10	**Geophysical survey**		
11	Offshore wind farm site		X
12	Offshore wind farm site - 2nd bathy survey		
13	Cable routes		X
14	Cable routes - 2nd bathy survey		
20	**Marine archaeology**		
21	#1: Geology and sea level	X	
22	#2: Pre-survey site assessment	X	
23	#3: Post-survey site assessment	X	
30	**UXO activities**		
31	#1: Threat and risk assessment	X	
32	#2: Threat and risk assessment - post survey data	X	
33	#3: UXO survey for prelim. geotechn. inv.		X
40	**Geotechnical investigations**		
41	Preliminary investigations, boreholes and CPTs		X
42	3D geological model	X	



Procurement
Contract
Delivery

DS Desk Study
CR Client Representative - offshore

END OF PRESENTATION – QUESTIONS ?

Any comments or feedback appreciated. But in particular …

Subject	Input requested regarding
Prelim. geotechnical investigations	• Methods (combined boreholes + CPTs) • Scope (quantities, locations) • Approach to lab tests
Cable Route Survey	• Multiple export cable route alternatives • Width of survey corridor • One or two offshore platforms?
Anything else …	