

SCOPE OF SERVICES

Project	Energy islands						
Assignment	Geophysical survey for offshore wind farms and energy island						
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1. Introduction

1.1 Political background

Following a decision in the Danish Parliament June 2020 Denmark is on the path to establish offshore energy infrastructure in the Danish North Sea and in the Danish Baltic Sea to connect respectively 3 GW and 2 GW offshore wind energy to the Danish mainland and to neighbouring countries via offshore energy hubs.

Figure 1-1 illustrate the regional locations of the project.



Figure 1-1. Project locations for the North Sea and the Baltic Sea.

1.2 The project

The offshore part of the project include the following main parts:

North Sea:

- 1 offshore wind farm area, of 3 GW.
- 1 energy island (caisson structure) to host substation functionality and potentially PtX and maintenance facilities.
- Subsea cables from energy island to offshore wind farms.
- Subsea cables from energy island to Denmark (Jutland).
- Subsea cables from energy island to a neighbouring country.

Baltic Sea:

- 2 offshore wind farms, each of 1 GW.
- Subsea cables from energy island (Bornholm) to offshore wind farms.
- Subsea cables from energy island (Bornholm) to Denmark (Jutland).
- Subsea cables from energy island (Bornholm) to a neighbouring country.

The project site parts are illustrated in Figure 1-2 and Figure 1-3 below.

Preliminary feasibility studies indicate that the energy island in the North Sea will require a construction site area in the order of 500m x 500m.



Figure 1-2. Conceptual illustration of the project site parts in the North Sea.



Figure 1-3. Conceptual illustration of the project site parts in the Baltic Sea.

1.3 Site investigations

Following the political decision the Danish Energy Agency has instructed the Client to initiate site investigations, environmental and metocean studies for the abovementioned main project elements.

On the basis of the instruction from the Danish Energy Agency the Client requests the Consultant to commence geophysical survey activities in 2021. The overall project has been split into 3 individual parts, each handled by individual contractors, where this document deals with the work packages for the geophysical site survey for offshore wind farm (OWF) zone east, and the energy island locations (Table 1-1).

Surveys for the subsea cables are not included in the present scope of services.

Table 1-1. Overview of project parts included in the scope of services, the associated work packages (see section 2.2) and contract lot.

Part	Site	Region	Work package	Contract Lot
1	OWF – zone east	North Sea	A, B	1
6	Energy island – location 1	North Sea	A, C, D	1
Option:				
7	Energy island – location 2	North Sea	A, C, D	1

2. Scope or Services

To support the development of the project the Consultant must provide a geophysical surveys covering the area of investigation described in Chapter 5.

2.1 Purpose of assignment

The results of the survey should be able to be used as basis for

- Initial marine archaeological site assessment.
- Planning of environmental investigations.
- Planning of initial geotechnical investigations.
- Decision of foundation concept and preliminary foundation design.
- Assessment of subsea inter-array cable burial design.
- Assessment of installation conditions for foundations and subsea cables.
- Site information enclosed the tender for the offshore wind farm concession.

In particular for the energy island in the North Sea is further required that the survey should be able to be used as basis for

- Mitigation of the UXO risk

2.2 Scope of assignment

To accommodate the abovementioned purposes the assignment includes the following work packages:

- **Work Package A – Geophysical site survey**
A geophysical site survey including 2D UHR seismic survey is performed with commencement in 2021 and completion as soon as possible. The survey has full coverage in the area of investigation. The survey must map the bathymetry, the static and dynamic elements of the seabed surface and the sub-surface geological soil layers to at least 100m below seabed.
- **Work Package B – Magnetometry box survey**
A high-resolution magnetometry box survey is performed at rectangular areas subject to future geotechnical drilling work following the geophysical survey. In addition to magnetometry the scope also include high-resolution acoustic survey (multibeam echo-sounding and dual frequency side scan sonar). The work package is delivered after completion of the marine survey activities of Work Package A. Work Package B doesn't include the actual geotechnical investigations.
- **Work Package C – Deep 2D seismic survey**
To mitigate the potential risk of settlements underneath the future location of the artificial energy island a deep 2D survey for seismic inversion analysis is performed.
- **Work Package D – UXO survey and inspection**
To mitigate the UXO risk in the area planned for the North Sea energy island, a high-resolution UXO survey including magnetometry, side scan sonar and multibeam echosounder is performed.

All work packages includes, that the data acquired from the offshore investigations shall be processed, interpreted and supplied as a number of reports, charts and a set of digital deliverables.

Water depth ranges and aerial coverage for the various sites are shown in the Table 2-1. The geography of the area of investigations is described in chapter 5.

This document - including enclosures - describe the requirements for the scope of services.

Table 2-1. Project sites and approximative spatial coverage.

Part	Site	Region	Area	Water depth	Work packages
1	OWF – zone east	North Sea	526 ± 50 km ²	25 – 50 m	A, B
6	Energy island – location 1	North Sea	6.25 km ²	25 – 35 m	A, C, D
Option 1:					
7	Energy island – location 2	North Sea	6.25 km ²	25 – 25 m	A, C, D

3. Time Schedule

3.1 Requirements to time schedule

The Client requests that the services are performed with respect to the following schedule:

3.1.1 WPA – Geophysical site survey

1. Marine survey activities are commenced no later than **May 2021**.
2. All marine survey activities are completed no later than **December 2021**.
3. Complete delivery package, revised issue, is provided no later than **2022-05-01**.
4. The Consultant must allow for the following amount of time for the Client to review and comment the draft work package deliverables: **4 weeks**.

3.1.2 WP B – Magnetometry box survey

5. To allow for the subsequent geotechnical activities, all marine survey activities are completed no later than **April 2022**
6. Complete delivery package, revised issue, is provided no later **than 2022-06-01**.
 - a. The Consultant must allow for the following amount of time for the Client to review and comment the draft work package deliverables: **2 weeks**.

3.1.3 WP C – Deep 2D seismic survey

7. All marine survey activities are completed no later than **November 2022**.
8. Complete delivery package, revised issue, is provided no later **than 2023-05-31**.
9. The Consultant must allow for the following amount of time for the Client to review and comment the draft work package deliverables: **4 weeks**.

3.1.4 WP D – UXO survey and inspection

10. All marine survey activities are completed no later than **September 2022**.
11. Complete delivery package, revised issue, is provided no later **than 2022-12-16**.
12. The Consultant must allow for the following amount of time for the Client to review and comment the draft work package deliverables: **4 weeks**.

3.2 Contract milestones

As part of the Consultants tender response, the Consultant supplied milestone dates for the performance of the Scope of Services based on the template displayed in Figure 3-1.

Together with the Consultants detailed time schedule (Gantt style) the provided milestone dates constitutes the contracted time schedule. It appear from *Table 3-1*, that some selected milestones are subject to liquidated damages (LD) as described in the Service Agreement.

Table 3-1. Overview of contract milestones subject to liquidated damages.

Table 5-1: Overview of contract milestones subject to liquidated damages.				
Milestone	WP	Event	Project Part	Contract Lot
M 101	(all)	Premob deliverables provided	1	1
M 105	A	Report provided, draft issue		
M 109	B	Report provided, draft issue		
M 601	(all)	Premob deliverables provided	6	1
M 609	B	Report provided, draft issue		
M 613	C	Report provided, draft issue		
M 617	D	Report provided, draft issue		
Option 1:				
M 701	(all)	Premob deliverables provided	7	1
M 709	B	Report provided, draft issue		
M 713	C	Report provided, draft issue		
M 717	D	Report provided, draft issue		

Item	Event	Note	Due date	LD	Milestone
1	Commencement of contract		2021-05-03		
2	Project execution and QHSE plans provided				
3	Kick-off meeting				
4	Premob deliverables provided	3, 4		YES	101
5	Work Package A - Geophysical site survey				
6	Marine operations commenced	1			102
7	Marine operations commenced, 2D UHRS	1			103
8	All marine operations completed				104
9	Report provided, draft issue	2		YES	105
10	Report, Client review		(4 weeks)		
11	Report provided, revised issue	2			106
12	Work Package B - Magnetometry box survey				
13	Marine operations commenced	1			107
14	All marine operations completed				108
15	Report provided, draft issue	2, 3		YES	109
16	Report, Client review		(2 weeks)		
17	Report provided, revised issue	2			110
Note 1	Event has occurred at first day with working time recorded as OPERATIONAL TIME.				
Note 2	Event has occurred when report, including all charts and all digital deliverables have arrived at the Clients' office in Fredericia, Denmark.				
Note 3	Milestones marked with "YES" in the table column "LD" are subject to potential delay damages acc. to contract.				
Note 4	Premobilization deliverables must be provided within 20 calendar days of contract signature. Premobilization deliverables include evidence for meeting the insurance requirements and the performance guarantee. See the Consultancy Agreement for detailed requirements.				

Figure 3-1. Template for contract milestones that must be completed by Consultant as part of his proposal. The milestones regarding provision of the draft reports are subject to liquidated damages (LD) as described in the Service Agreement. The template apply for project part 1. For project parts 6 and 7 similar templates apply.

4. Requirements

For the areas of investigation described in section 5 the Consultant must provide data acquisition, seabed sampling and testing, laboratory analyses, data processing, data interpretation and reporting that satisfies the requirements described in section 4.

Work packages A and B apply for all project part 1 (OWF – area east).

Work packages B, C and D apply for project parts number 6 and 7 (Energy island, North Sea). See **Error! Reference source not found.** above. See details regarding the area of investigation for work package C and D in chapter 5.

4.1 Functional Requirements

4.1.1 Work Package A– Geophysical site surveys

The Consultant must carry out a detailed mapping of the seabed surface to provide:

- Accurate bathymetric data and charts in the surveyed area.
- The morphology and natural features of the seabed surface such e.g. as mega-ripples, sand-waves, boulders, outcropping geology, seaweed and reefs.
- Possible man-made features such as wrecks, debris, fishing gear, trawl marks, anchor scars, objects of potential archaeological interests.
- Identification of features of potential conservation interest including but not limited to; sandbanks, gravel reef, cobble reef, rocky reef and biogenic reef structures.

The Consultant must carry out mapping of the upper part of the subsurface in a sufficient level of detail to:

- Map all major geological layers and structures to at least 100m below seabed.
- Locate structural complexities or geohazards within the shallow geological succession such as faulting, accumulations of shallow gas, buried channels, soft sediments, etc.

4.1.2 Work Package B – Magnetometry box survey

Within the areas of investigation for this work package (see section 5) the Consultant must carry out a detailed mapping of the seabed surface to:

- Identify and locate any man-made or natural objects on the seabed larger than 0.5 m.
- Identify and locate any buried objects with a ferrous mass larger than 50 kg that are buried up to 2 m below the seabed surface.
- Supplement existing survey data to provide a complete data set for target interpretation in the surveyed area.
- Chart any findings and observations relevant to the geotechnical contractor (e.g. boulders, wrecks and other Man-Made-Objects), in an appropriate chart format suggested by the Consultant.

4.1.3 Work Package C – Deep 2D seismic survey

The Consultant must carry out a high-resolution mapping of the subsurface geology to at least the top of chalk surface (1200-1600m below seabed) to identify and map:

- Detailed seismic stratigraphic interpretation of the sedimentary succession from the seabed to the top of chalk surface.
- Prepare the data for a detailed seismic inversion analysis.

4.1.4 Work Package D – UXO survey and inspection

The Consultant must carry out detailed UXO detection and geophysical seafloor mapping followed by inspection and removal of UXOs.

No UXO threat study is available.

The UXO Survey shall:

- Detect and map items that are on the seabed surface, partly buried or with a 2m burial depth (measured from the seabed surface to the top of the item) with the following minimum characteristics:
 - 0.5m along the shortest dimension.
 - 50kg ferrous mass.
- Provide accurate positioning of objects causing anomalous responses.
- Provide a high resolution bathymetrical model of the seabed surface.

The UXO Inspection shall

- Provide inspection of targets if pUXO objects are found. The inspection include targets from both exposed and buried objects.

The Client will together with the Client's UXO Consultant provide the list of pUXO that shall be subject to inspection.

The UXO Removal shall:

- Provide a setup, including vessels, equipment and personnel, that the Danish Navy EOD team can use as a platform to launch their own small vessel from, when they perform the detonation.
- Ensure that the offered setup including vessels, equipment and methodology complies with Danish regulations.

The Client will together with the Clients UXO Consultant provide the list of UXO that will be subject to removal.

4.2 Technical Requirements

To meet the functional requirements the following technical requirements described in this section shall apply.

Detailed technical requirements applying for the scope of services are described in Enclosure 1.

4.2.1 Work Package A – Geophysical survey

The Geophysical survey includes the following:

- **Multi-Beam Echo-Sounding** including **backscatter** for bathymetric mapping, complete coverage within the area of investigation.
- **Side Scan Sonar** (dual frequency) for mapping of the seabed surface. The coverage must have overlap to cover nadir of adjacent survey lines.
- **Magnetometer** for screening of ferrous objects and crossing cables and pipelines.
- **Grab sampling** to support the interpretation of the seabed surface geology.
- **Seismic investigations** using multiple systems
 - Single-channel, high-resolution sub-bottom profiler for mapping of shallow soils in entire area of investigation.
 - 2D Ultra High Resolution Seismic (2D UHRS) system for mapping of soil units to at least 100m below seabed in the entire area of investigation.

4.2.2 Work Package B – Magnetometry box survey

The magnetometry box survey include the following:

- An appropriate **multi magnetometer / gradiometer** setup, proposed by the Consultant, that can identify ferrous objects placed on the seabed, partly buried and shallow buried within a given accuracy.
- **High-resolution multibeam echo-sounding** and dual frequency **Side Scan Sonar**, complete coverage within the area of investigation.
- Conduct an equipment verification test over a known object as part of the Consultants offshore mobilization.

Important note:

The Client recognizes that the acoustic spread (MBES and SSS) will cover seabed that already during Work Package A has been surveyed with these methods. The purpose of Work Package B is to achieve a more detailed object resolution on and below the seabed surface. Therefore MBES and SSS acquisition are required again for Work Package B. Detailed requirements are specified in Enclosure 1.

4.2.3 Work Package C – Deep 2D seismic survey

The deep 2D seismic survey consist of a **multi-channel / multi-source seismic system** able to map the entire sub-surface succession, from the seabed down to the top chalk surface underneath the location for the future artificial energy island. The top chalk surface is located at a depth between 1200-1600m in the area.

The acquired data will be the base for a seismic inversion analysis to determine the rock properties and elastic parameters of the sedimentary succession down to the top chalk surface.

Receiver arrays (both ends) and seismic sources must be positioned with GNSS antennas to determine their accurate location during acquisition.

Important note:

The survey grid is already covered with relatively new bathymetrical data from preceding survey activities during this overall project. These data will be made available for the Consultant.

4.2.4 Work Package D – UXO survey and inspection

To meet the functional requirements the following technical requirements shall apply for the Scope of Services:

The marine UXO Survey shall include the following:

- High resolution **magnetometer** survey to map anomalies from ferrous items that are as described in section 4.1.4.
- **Multi Beam Echo Sounding** for bathymetric mapping with complete coverage.
- Dual Frequency **Side Scan Sonar** for mapping of the seabed surface. The coverage must have overlap to cover nadir of adjacent survey lines.
- Apply high precision subsea navigation methods such as e.g. USBL to determine the position of subsea sensors.
- Apply accurate GNSS methods to determine the best possible position of the vessels.

The UXO Inspection can be performed by ROV or other suitable method. The inspection task must be able to uncover objects as described in section 4.1.4.

Removal activities shall be conducted from a suitable vessel that are:

- Able to accommodate Danish Navy EOD personnel, deck space for containers and crane for launch and recovery of RIB (Rigid Inflatable Boat) as well as deck space for equipment related to removal/detonation of UXO. Number of personnel and deck space required will increase when operation in water depths >30m.

4.3 Reporting and Data delivery

The Consultant shall process and interpret all data acquired during surveying as well as carry out all necessary reporting according to the requirements specified in the documents

- Enclosure 1 - Technical Specifications and
- Enclosure 2 - Standards of Deliverables.

4.4 UXO risk mitigation

Some parts of the area of investigation are likely to be located in areas with elevated probability for encountering UXO objects. The Client has not yet conducted a UXO desk study.

Therefore the Consultant shall include in his Project and QHSE plan a procedure to mitigate this risk related to direct seabed interactions.

The Client accepts that this risk can be minimized within the principles of ALARP if seabed interactions are localized within 5 m of geophysical survey lines free of any anomalies.

4.5 HSE requirements

To manage the Health, the Safety and the Environmental under the assignment a number of requirements attached as Enclosure 3 must apply for Consultants provision of the services.

4.6 Quality requirements

To manage the Quality under the assignment a number of requirements attached as Enclosure 4 must apply for Consultants provision of the services.

5. Areas of investigation

The coordinates for the area of investigations subject to this assignment are provided by the Danish Energy Agency as part of their instruction to Energinet.

Coordinate lists and ESRI shape files for the area of investigation (OWF – area east) are prepared for the project.

The coordinates are found in Annex 1 and the ESRI shape files are enclosed the Scope of Services.

Regional location of the OWF – zone east area (project part 1 – with red outline) is displayed in Figure 5-1 along with the location of OWF – zone west (project part 2). The areas of investigations for part 1 and part 2 in the North Sea share an overlap of 200m. Both energy island locations will be within OWF – area east.

Table 5-1. Overview of project parts.

Part	Site	Region	Area Km ²	Work packages
1	OWF – zone east	North Sea	526 ± 50	A, B
6	Energy island – location 1	North Sea	6.25	A, C, D
Option 1:				
7	Energy island – location 2	North Sea	6.25	A, C, D



Figure 5-1. Regional overview of area of investigation for part 1 (OWF – zone east) highlighted in red and neighboring part 2 (OWF -zone west).

Further details regarding the area of investigation for project part 6 (and the option for project part 7), energy island, North Sea, are shown in Table 5-2 and Figure 5-2:

- For WP A and B, the area of investigation was determined in March 2021.
- For WP C and D, the area of investigation is determined on the basis of the results from WP A.

Table 5-2. Project sites, approximative spatial coverage and work packages.

Part	Site	Area of investigation	Basis	WP
1	Offshore wind farm – zone east	526 km ²	Final	A, B
6	Energy island – location 1	20 km ²	Estimated – not final	A, B
6	Energy island – location 1	6.25 km ²	Estimated – not final	C, D
Option 1:				
7	Energy island – location 2	15 km ²	Estimated – not final	A, B
7	Energy island – location 2	6.25 km ²	Estimated – not final	C, D

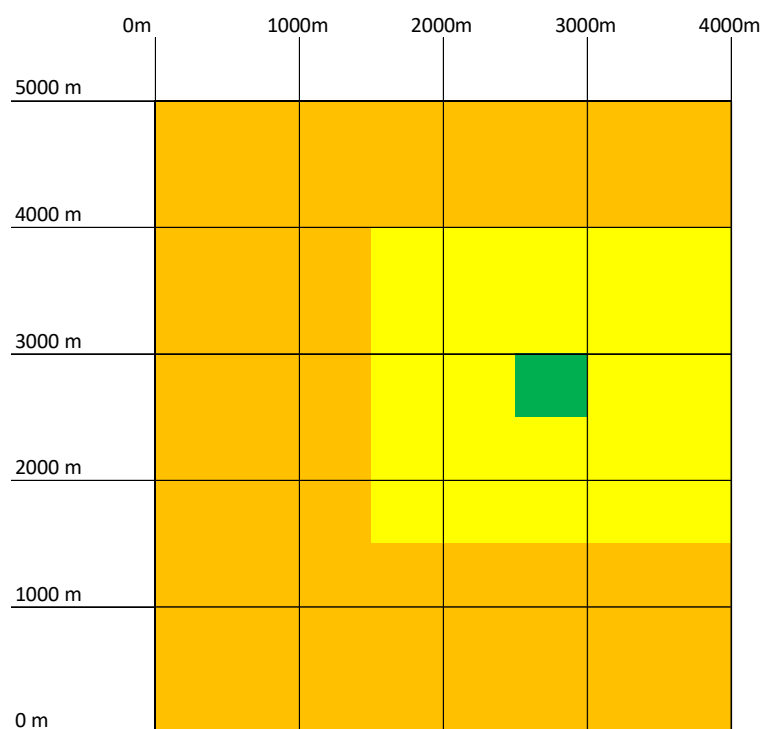


Figure 5-2. Concept for defining area of investigation for project part 6 energy island (and optional project part 7), North Sea: **GREEN AREA**: Anticipated footprint of construction site 500m x 500m. **ORANGE AREA**: Area of investigation for work packages A and B 4000m x 5000 (for option 1 the WP A+B area is assumed to be 15km²). **YELLOW AREA**: Area of investigation for work packages C and D (2500m x 2500m).

5.1 Admiralty charts

Figure 5-3 shows the area of investigation together with admiralty chart.

In the North Sea several utilities and wreck sites are seen to intersect the general project development area.

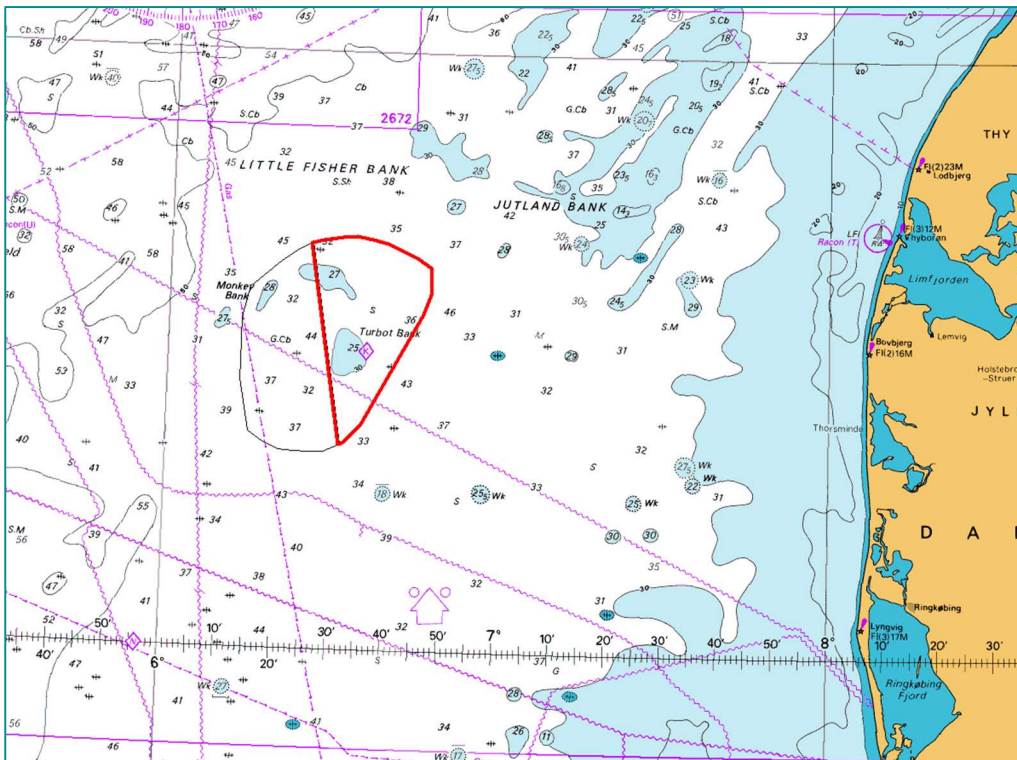


Figure 5-3. Chart 28 Central North Sea. The red outline shows the general project development area for OWF – zone east. The adjacent OWF – zone west is highlighted with the black polygon.

5.2 Water depths

The Clients expectations of the water depths in the area of investigation are seen in Table 5-3 and Figure 5-4. The bathymetrical DTM information in the figure is based on regional models of ca. 100m spatial resolution (Emodnet 2018 MSL). From the figures the following expectations to the minimum/maximum water depths may be assumed:

Table 5-3 Expected water depths within the area of investigation.

Part	Site	Water depth ranges
1	OWF – zone east	25m to 50m
6	Energy island – location 1	25m to 35m
7	Energy island – location 2	25m to 35m

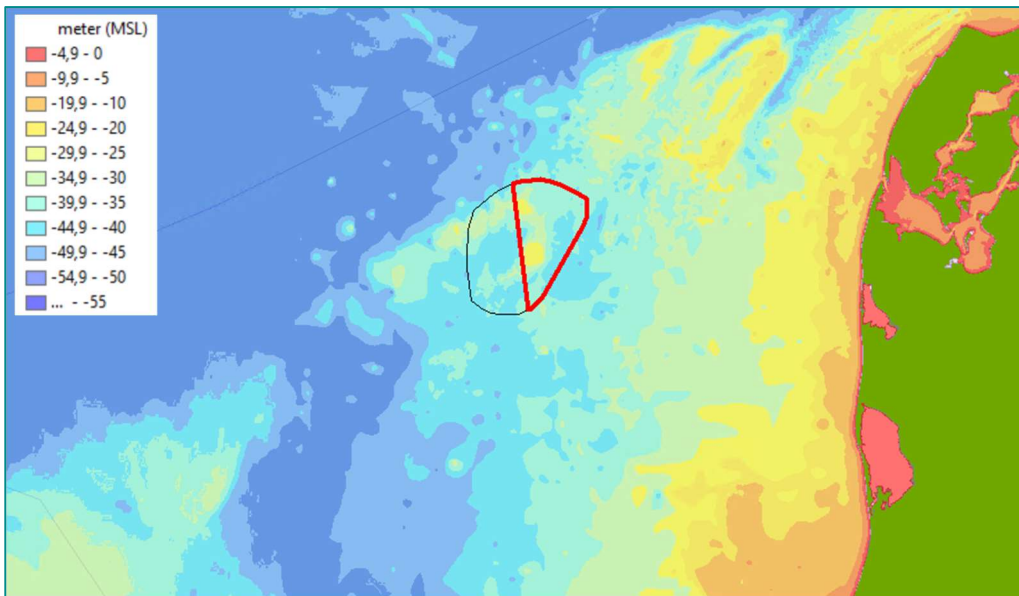


Figure 5-4. Water depths (Emodnet 2018 MSL). The red outline shows the general project development area for OWF – zone east. The adjacent OWF – zone west is highlighted with the black polygon.

5.3 Geology

Figure 5- show the surface geology in the area of investigation based on models from GEUS (Danish Geological Survey) 2015.

The Client is in the process of establishing geological baseline desktop studies intended for supporting the interpretation of the geophysical and seismological investigations. The studies will be made available for the Consultant.

For the general project development area in the North Sea, the seabed surface sediments are primarily consisting of coarse, mobile sediments (gravel and sand). These sediments are considered to be of marine and postglacial origin. Some areas include glacial till / diamicton outcropping or with shallow burial below the postglacial coarse sediments.

The northern margins of the general project development area are likely to coincide with the maximum glacial advance of the Weichsel ice age.

Buried paleo-valleys and deformed sediments are likely to be found within the quaternary succession in the area.

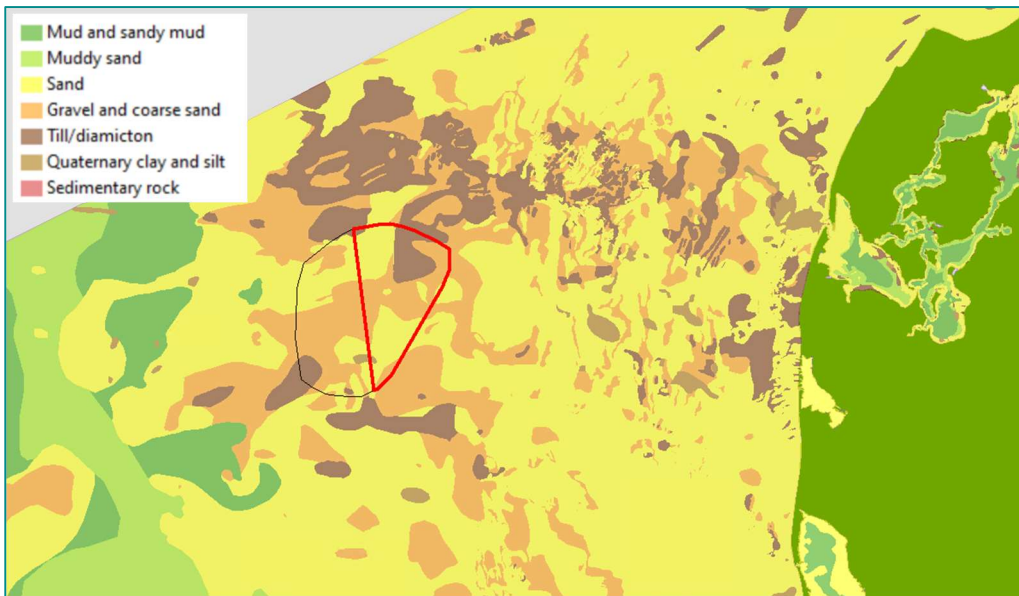
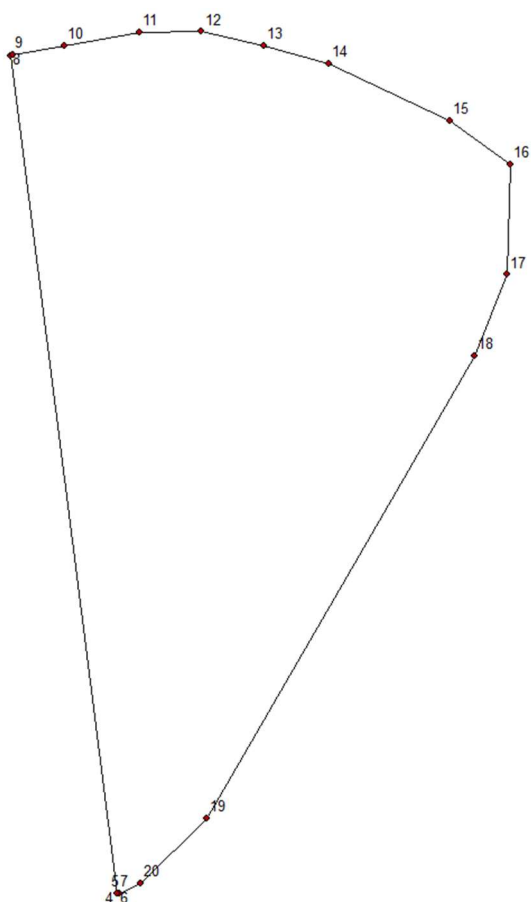


Figure 5-5. Geology, seabed surface (GEUS 2015). The red outline shows the general project development area for OWF – zone east. The adjacent OWF – zone west is highlighted with the black polygon.

Annex 1 – Part 1 - North Sea – OWF zone east

POINTID	EASTING [meter]	NORTHING [meter]	LATITUDE [DD mm.mmm]	LONGITUDE [DD mm.mmm]
1	347 030	6 247 129	6° 31,498' E	56° 20,646' N
2	346 938	6 247 085	6° 31,410' E	56° 20,621' N
3	346 938	6 247 085	6° 31,410' E	56° 20,621' N
4	346 934	6 247 093	6° 31,406' E	56° 20,625' N
5	346 932	6 247 102	6° 31,403' E	56° 20,630' N
6	346 930	6 247 111	6° 31,401' E	56° 20,634' N
7	346 929	6 247 116	6° 31,400' E	56° 20,637' N
8	342 154	6 284 636	6° 25,404' E	56° 40,748' N
9	342 250	6 284 687	6° 25,497' E	56° 40,777' N
10	344 547	6 285 095	6° 27,729' E	56° 41,043' N
11	347 929	6 285 695	6° 31,017' E	56° 41,433' N
12	350 709	6 285 722	6° 33,736' E	56° 41,501' N
13	353 508	6 285 119	6° 36,497' E	56° 41,230' N
14	356 385	6 284 305	6° 39,339' E	56° 40,845' N
15	361 807	6 281 725	6° 44,729' E	56° 39,553' N
16	364 533	6 279 789	6° 47,455' E	56° 38,558' N
17	364 373	6 274 835	6° 47,455' E	56° 35,887' N
18	362 907	6 271 194	6° 46,139' E	56° 33,900' N
19	350 927	6 250 491	6° 35,163' E	56° 22,532' N
20	347 985	6 247 579	6° 32,409' E	56° 20,907' N



TECHNICAL REQUIREMENTS

Project	Energy islands						
Assignment	Geophysical survey for offshore wind farms and energy island						
Document Title	Scope of Services – Enclosure 1 – Technical Requirements						
Document No.	20/08794-3						
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3	For tender	JCO	2021-02-18	MZA	2021-02-18	MZA	2021-02-18
4	For rev tender	XMBHA	2021-03-12	JCO	2021-03-12	MZA	2021-03-12
5	For updated WPC scope	XMBHA	2022-11-09	XLSSR	2022-11-09		

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1. Introduction

In the document "Scope of Services" the objectives and the general outcome of the survey activities are described.

This specification, when read in conjunction with the Agreement, referenced standards, specifications and other listed documentation, defines the minimum technical, functional and procedural requirements for the Services associated with the project.

The Consultant shall take responsibility to ensure all survey operations are conducted safely and with full regard to national, international and area specific environmental considerations.

1.1 Constraints

The Client's approval of the Consultant's time schedule, organisation plan, list of subcontractors, list of equipment, etc., shall not relieve the Consultant of any responsibility for the performance of his obligations.

The Consultant shall perform the Services in accordance with best professional standards and practice within the industry plus in accordance with equipment and software manufacturer's recommendations and descriptions.

The presence of and the inspection and supervision by the Client at the worksite as well as any approval, consent, comments and the like given to the Consultant by or on behalf of the Client shall not relieve the Consultant from his obligations and responsibilities.

All data and reports that are a result of the Services are confidential and cannot be distributed to third parties without written permission from the Client.

2. Geodetic Reference system

The survey data is acquired, processed, reported, and charted with respect to the following geodetic requirements:

North Sea:

- Datum: ETRS89
- Projection: UTM 32N
- Vertical reference: Mean Sea Level (MSL)
Use model DTU18MSL

Baltic Sea:

- Datum: ETRS89
- Projection: UTM 33N
- Vertical reference: Mean Sea Level (MSL)
Use model DTU18MSL

All vertical information are provided as *depths* relative to MSL such that water depths are positive *downwards*.

3. Work packages and quantities

A number of Work Packages are defined to organize the different requirements in the Scope of Services:

- Work Package A – Geophysical survey
- Work Package B – Magnetometry box survey
- Work Package C – Deep 2D seismic survey
- Work Package D – UXO survey and inspection

This section describes the Work Packages that are necessary to complete the Scope of Services for the areas of investigations.

The requirements for the work packages have been organized in individual chapters in this document to reflect that the work packages have different purposes and different quality parameters:

- Chapter 8. Equipment and Methods – WP A – Geophysical site survey
- Chapter 9. Equipment and methods – WP B – Magnetometry box survey
- Chapter 10. Equipment and methods – WP C – Deep 2D seismic survey

Chapter 0. All survey lines will be acquired with a dual seismic setup focussing on the shallow and deep sections respectively.

The shallow section

The system could be using a triple sparker source or similar for detailed seismic inversion of the stratigraphic succession of at least the uppermost 250 m below the seabed. Especially, the system shall be designed, operated and data processed for seabed multiple suppression and being suitably for pre-stack inversion.

The system(s) shall be towed after the vessel(s) and shall as a minimum have the following general specifications:

- Fundamental frequency between 150 and 1500 kHz.
- Vertical resolution better than 1 m.
- Penetration to at least 250 m below seabed.
- Fire rate each 6.25 m.
- Source energy around 18 000 J.
- A suitable multi-channel and multi-element hydrophone streamer (e.g. 48 channels @ 3.125m) with depth control plus depth measurement for continuously monitoring and recording of streamer depth.

The deep section

The system could be using a dual air gun source or similar for detailed seismic inversion of the stratigraphic succession down to at least the top of the chalk. Desk studies suggest that the top of the chalk is located at 1200m to 1600m below seabed.

Especially, the system shall be designed, operated and data processed for seabed multiple suppression and being suitable for pre-stack inversion.

The system(s) shall be towed after the vessel(s) and shall as a minimum have the following general specifications:

- Fundamental frequency between 20 and 170 Hz.
- Vertical resolution better than 4 m.
- Penetration down to at least the Top Chalk surface (1200-1600m).
- Fire rate every 6.25 m
- Source energy around 120 cui.
- A suitable multi-channel and multi-element hydrophone streamer (e.g. 192 channels @ 6.25 m) with depth control plus depth measurement for continuously monitoring and recording of streamer depth.
- Equipment and methods – WP D – UXO survey and inspection

3.1 Work Package A – Geophysical site survey

Within the area of investigation, the following requirements must be fulfilled by the survey:

- Multi-beam Echo-sounding survey with full bathymetric coverage. The data quality must accommodate the preparation of digital elevation models (DTMs) of the bathymetry with 25cm spatial resolution.
- Dual frequency side scan sonar with > 200% coverage to ensure overlap with nadir of adjacent survey lines. Detection of all objects > 0.5m.
- Single magnetometer or gradiometer towed after vessel, all survey lines.
- Sub-bottom profiling with two high resolution seismic systems:
 - One high resolution and relative high frequency single channel system, all survey lines.
 - 2D UHRS: One deep penetration and relative medium frequency multi-channel system with survey line spacing of maximum 250m and cross-lines every 1000m.
- Horizontal positioning uncertainty < 0.5m for vessels.
- Horizontal positioning uncertainty < 2.0m for towed equipment.
- Grab samples to support interpretation of bathymetric and side scan sonar data. Quantities as listed in Table 3-1.

Furthermore, Work Package A include processing and interpretation of the acquired data as described in section 12 and section 13 and specified in the document “Scope of services – Enclosure 2 – Standards of deliverables”.

Table 3-1. Scope for grab sampling. Planning basis for individual project parts based on sampling density of 1 grab sample pr. 3 km².

Part	Site	Area	No of grab samples
1	OWF – zone east	526km ²	150
2	OWF – zone west	533km ²	150
3	NA		
4	Bornholm I	255km ²	85
5	Bornholm II	298km ²	100
6	Energy island – location 1	20km ²	10
Option 1:			
7	Energy island – location 2	15km ²	10

3.2 Work Package B – Magnetometry box survey

For a number of discrete, rectangular subareas within area of investigations a high-resolution magnetometry survey must be performed.

The subareas span either 200m x 150m or 150m x 100m.

The quantities for Work Package B are listed in Table 3-2 but may vary plus/minus 25%.

Table 3-2. Scope for WP B magnetometry box survey for individual project parts.

Part	Site	No of locations 200m x 150m	No of locations 150m x 100m
1	OWF – zone east	20	50
2	OWF – zone west	20	50
3	NA		
4	Bornholm I	12	40
5	Bornholm II	12	40
6	Energy island – location 1	9	20
Option 1:			
7	Energy island – location 2	9	20

The locations of the subareas (boxes) are proposed by the Consultant (see section 4.3).

The high resolution magnetometry data must be combined with multibeam echo-sounding and side scan sonar data to identify anomalies caused by surficial or buried sources that potentially could be UXOs.

3.3 Work Package C – Deep 2D seismic survey

To mitigate the potential risk of settlements underneath the future location of the artificial energy island a 2D seismic survey with a penetration depth down to the Top Chalk surface (1200-1600m below the seafloor) is performed. The acquired seismic data will be used for a seismic inversion analysis to determine the elastic parameters of the sedimentary succession between the seabed and the Top Chalk surface.

3.4 Work Package D – UXO survey and inspection

The work package includes the following main activities:

- High-resolution geophysical survey
- Inspection of selected targets and removal of confirmed UXOs.

3.4.1 High-resolution geophysical survey

The objective of the UXO survey is to provide a full assessment of any anomalies, caused by objects on the seabed surface or buried. Anomalies shall be identified via the geophysical datasets MBES, SSS and MAG that include:

- High resolution Seabed Bathymetry (MBES)
- High resolution Seabed Imagery (SSS)
- High resolution magnetometry (MAG)

It is of high importance that the geophysical anomalies are identified with the best possible horizontal accuracy, to benefit the next phase.

The quantities for this work package is determined by the area of investigation (see document “Scope of services”).

3.4.2 Inspection of selected targets and removal of confirmed UXOs

After completion of the UXO survey, the Consultant is required to deliver a target assessment and target list for the Clients UXO consultant, based on the interpretation of the geophysical anomalies from the UXO survey. Further requirements are specified in the document “Scope of services – Enclosure 2”.

The quantities for this work package is determined by the number of targets for inspection and removal. See quantities pre-printed in the price list.

3.5 All work packages: Reporting and data delivery

All work packages include preparation of reports and charts as described in section 14 and specified in detail in the document “Scope of Services – Enclosure 2 – Standards of Deliverables”.

4. Planning

As an integrated part of the Scope of Services the Consultant must carry out planning related to the Scope of Services. The planning work must include:

- Work Package A to D: Preparation of survey line plans.
- Work Package A: Planning of grab sampling locations.
- Work Package B: Planning of geotechnical program with boreholes and CPTs for subsequent 3rd party contractor.

4.1 Preparation of survey line plans

Before commencement of the marine activities the Consultant must prepare a survey line plan that meets the technical requirements for Work Package A to D.

The survey line plans must accommodate that the quality requirements described in section 8 are met.

On a continuous basis and during the survey the Consultant must monitor the quality of the acquired data and assess if the requirements are met. If the requirements are not met the Consultant must plan infill lines and progress with supplementary survey activities.

It is the responsibility of the Consultant to prepare survey lines plans including infill that consider the environmental and metocean conditions in the areas of investigation.

Additional survey lines may be instructed by the Client Representative and agreed as variation orders to the Agreement.

4.2 Planning of grab sampling

For Work Package A the Consultant must prepare a program for grab sampling on basis of a preliminary interpretation of the geophysical data.

The program for grab sampling will primarily be related to selecting the geographical locations for sampling. The locations shall be selected such that seabed surface units of variable sonar reflectivity are sampled.

The program must be reviewed and approved by the offshore Client Representative.

4.3 Planning of geotechnical boreholes and CPTs

In 2022 the Client plans to let a third party supplier perform preliminary geotechnical investigations with boreholes and seabed CPTs at the wind farm site.

To mitigate the risk towards drilling platforms and seabed units from UXOs, wrecks, debris and large boulders the scope of Work Package B is required.

The Consultant propose a program for geotechnical boreholes and CPTs for the quantities stated in Table 3-2 plus 25%.

The proposal is developed on basis of a preliminary interpretation of the 2D UHRS results. The response format consists of a table with location coordinates and a short memo that summarizes the selection principles and considerations.

5. Permissions and consenting processes

The following permits and consenting processes are required ahead of the marine activities:

1. Danish Energy Agency, Permission for site investigations
2. Danish Geodata Agency, Permission for survey
3. Danish Maritime Agency, Risk Assessment of traffic safety
4. Danish Maritime Agency, Notice to Mariners

The Client is responsible for acquiring #1 and #2 and part one of #3.

The Client has defined 2021-04-07 as deadline for completing #1 to #3.

The Consultant is responsible for completion of part two of #3 and submission of #4.

6. Vessels

6.1 General requirements

Based on the Consultant's experience and detailed operational knowledge, it's the responsibility of the Consultant to select the proper number of vessels necessary for performing the Scope of Services.

It is required that vessels for Work Package A and Work Package B and have full processing and interpretation capabilities on-board.

Based on the Consultants experience and availability of appropriate vessels, it's the responsibility of the Consultant to propose and carry out most favourable mode of operations.

The vessels shall have been built for survey activities or suitably converted to undertake the specified work in the designated geographic area.

The vessels shall be able to operate under the meteorological and oceanographic conditions within the limitations stated by the Consultant in his tender.

The vessel(s) shall be equipped with adequate communication equipment for telephone communication plus continuously high-speed internet connections with a speed of at least 1 Mbit/s for digital data distribution.

The vessels shall be proven to be acoustically quiet to enable good quality acoustic data to be acquired. The acoustic noise signature shall be acceptable outside the acoustic frequency range of the survey equipment to be deployed from the vessels.

Vessel deck areas used for survey operations shall have good lighting and be free of trip hazards. All areas of the vessel used for the survey equipment deployment/recovery shall be either visible from the bridge, or good quality closed-circuit video of such areas shall be provided on the bridge at all times of such operations.

6.2 AIS

The vessels shall be equipped with AIS. The AIS transponder on board the vessels shall automatically, and with the required accuracy and update rate, provide other vessels and authorities with relevant information about the vessels and their navigation.

6.3 Offshore Client Representative

The Client will employ a Client Representative to provide offshore presence during the mobilisation and operation at any vessel offered by the Consultant.

The specific roles and responsibilities of the offshore Client Representatives will be addressed at the project kick-off meeting.

On the offshore vessels, operated at 24 hours basis, the Consultant must allow for two (2) Client Representatives. If vessels are operated at 12 hours basis, the Consultant must allow for one (1) Client Representative.

As a minimum the Client Representative cabin shall be a single cabin and fitted with telephone, at least 1 Mbit/s internet connections and adequate offline facilities for evaluation of the results.

6.4 Marine Mammal Observer and Passive Acoustic Monitoring system

It is required to provide Marine Mammal Observer (MMO) and PAM (Passive Acoustic Monitoring) for work packages A and C.

The detailed requirements will be defined by the Danish Energy Agency as part of the survey permit.

7. Personnel and crew

The manning of the survey team is the responsibility of the Consultant. The Consultant must provide sufficient competent supervisory, technical and other personnel to properly perform the service.

The Consultant may not replace key personnel without written approval from the Client. All marine personnel should be qualified in accordance with the requirements of the flag of registration.

The master and other principal vessel officers must be fluent in written and spoken English. All personnel sailing on the vessels are expected to be medically fit and the Consultant is required to ensure that regular medical examinations are undertaken.

The Party Chief shall be the Consultant's nominated offshore Survey Representative and shall liaise directly with the offshore Client Representative.

8. Equipment and Methods – WP A – Geophysical site survey

The Consultant's equipment, materials, supplies and tools shall be of first-class quality and shall be in good and safe operational condition, approved for use in the survey area. The Consultant shall maintain and repair all equipment and tools and maintain adequate stock levels and spare parts and spare equipment in order to ensure timely operations.

All equipment shall be installed and operated in such a way no interferences or disturbances between the various equipment units or the vessel and the equipment units occur.

All equipment and instruments must be able to operate under the meteorological and oceanographic limitations stated by the Consultant in his tender.

As a minimum but not limited to, the vessels shall be equipped with the equipment specified below.

8.1 Vessel Positioning System

The positioning of the vessels shall be determined with a highly accurately Global Navigation and Satellite System (GNSS) positioning system(s). Positioning shall be carried out such that coordinates are derived with sufficient accuracy to meet the objectives and needs of the project as specified in section 3.

As part of the mobilisation and acceptance test in the port(s) of mobilisation, the GNSS antennas position determined by the GNSS-system(s) shall be compared with the GNSS antennas position determined by land survey methods.

At least two independent vessel positioning systems need to be available. Furthermore the vessel(s) shall be equipped with motion sensor and gyro.

The vessel gyro shall meet the following specifications:

- Dynamic heading accuracy of $\pm 0.2^\circ$ or better
- Static heading accuracy of $\pm 0.05^\circ$ or better

The horizontal and vertical uncertainty of the vessel position shall be less than 0.5m.

8.2 Towed Equipment Positioning System(s)

All towed equipment shall be positioned relative to the vessel by highly accurately positioning systems, e.g., Ultra-Short Baseline (USBL) systems, with a horizontal uncertainty less than 2m.

The relative positions of all the towed equipment in relation to the vessel shall be interfaced to the positioning computer to provide orientations and distances for computation of offset positions from the GNSS antenna(s) as well as absolute positions. Mini-beacons must be provided to support the positioning of towed equipment.

The relative as well as the absolute positions of the towed equipment shall be stored in the positioning database.

The tow cable winch shall be remotely controlled from the geophysical survey instrument room and fitted with a remote alarm.

Layback of the towed equipment shall be measured by a calibrated meter on the deployment pulley and by USBL. Alterations to the tow cable length during surveying shall automatically be recorded in the acquisition system.

8.3 Bathymetric System(s)

The bathymetric data shall be acquired with a multi-beam echo-sounding (MBES) system and provide a spatial density that at least has 16 depth soundings pr. square meter.

The acquired set of soundings are feasible for manufacturing digital elevation models (DTMs) of the bathymetry with 25cm spatial resolution such that the grid standard deviation (95% confidence interval) is less than 0.2m.

The data shall be acquired in *equal distance* mode.

The MBES system shall record backscatter images.

The bathymetric system shall be supplied with ability to compensate for motion such as Pitch, Roll, Yaw and Heave.

8.4 Sound Velocity Profiler

The speed of sound in water shall be measured in the survey area at intervals not exceeding 6 hours.

The measurement shall be made using calibrated sound velocity profiler. Measurements shall be taken at suitable intervals from the sea surface to the seabed.

A second set of readings shall be taken from the seabed to the sea surface and the speed of sound computed from the measured values.

It's the responsibility of the Consultant to ensure the required vertical as well as horizontal resolutions are achieved and maintained during all periods of surveying. If so needed, the Consultant must apply and operate a moving sound velocity profiler system, which allows continuous monitoring of the entire water column. If also so needed to be able to achieve the required resolutions, acoustic ray bending algorithms shall be applied for depth and position calculations.

8.5 Dual Frequency Side Scan Sonar System(s)

A dual channel side scan sonar system shall be provided. The Consultant shall propose an instrument with operating HF and LF frequencies that will optimize the performance with respect to coverage and resolution in relation to the objectives of this survey.

Objects larger than 0.5m along the shortest axis must be resolved in the sonar images.

The applied operational range of the side scan sonar system shall be selected to ensure as high resolution as possible plus to ensure side scan sonar overlap to cover nadir regions of adjacent survey lines (i.e. coverage > 200%).

The Client anticipates that the side scan sonar system shall be installed and operated in a terrain following mode at a fixed height above seabed at 8-12% of the operational range. The Consultant may propose other configurations if this is a benefit for the survey.

The towing system shall be designed and operated to ensure the side scan sonar system is adequately decoupled from vessel's heave, pitching and rolling motion.

The survey speed at which side scan sonar surveys are undertaken shall normally be maintained at 4.0 knots ($\pm 10\%$).

8.6 Seismic profiling

Two high resolution seismic systems must be provided:

- One relative high-frequency single channel system for mapping the geology to 10m below seabed.
- One relative medium frequency multi-channel system for mapping the geology to 100m below seabed.

8.6.1 Relative high-frequency single channel system

The sub-bottom system shall be able to in details to map at least the uppermost 10m of seabed sediments and sedimentary bedrock in a variety of geological conditions.

One high-frequency single-channel sub-bottom profiler system must be provided (e.g. Innomar SES-2000 or similar) to map shallow geology including layer interfaces to 10m below seabed with a vertical resolution better than 0.3m.

To achieve this to Consultant must provide a system that is optimized for the above-mentioned objective regarding:

- Altitude of towfish with seismic system
- Ping rate
- Signal frequency

8.6.2 2D UHRS: Relative medium frequency multi-channel seismic system

The system could be using e.g. GeoSparcker 200, or similar for detailed geological mapping of at least the uppermost 100 m of the seabed sediments. Especially, the system shall be designed, operated and data processed for seabed multiple suppression and relative deep penetration. The system(s) shall be towed after the vessel(s) and shall as a minimum have the following general specifications:

- Fundamental frequency between 1 and 3 kHz.
- Vertical resolution better than 0.3m.
- Penetration to at least 100m below seabed.
- Fire rate ≥ 2 pulses/second.
- Variable energy levels between 100 and 1000 Joules.
- A suitable multi-channel and multi-element hydrophone streamer (e.g. 48 channels @ 3.125m) with depth control plus depth measurement for continuously monitoring and recording of streamer depth.

8.7 Magnetometer

A marine magnetometer (e.g. Geometrics G-882 or similar) must be towed behind the vessel.

The magnetometer must be towed in a distance from the vessel such that the instruments are free of the vessel magnetic noise.

The seabed altitude of the magnetometer must be recorded with an altimeter.

The following requirements shall apply for the magnetometer:

- Magnetometer seabed altitude: ≤ 5 m
- Magnetometer measurement sensitivity: 0.01 nT
- Magnetometer sampling frequency: 1 – 20 Hz (selectable)
- Noise level ≤ 2 nT.
- All measurements must be recorded digitally.

8.8 Grab sampling

An appropriate numbers of Ground Truth Sampling, e.g. grab samples or similar, must be carried out to be able to, in conjunction with the results from the side scan sonar and bathymetric system(s) to characterize the seabed according to industry standard.

The locations for grab sampling must be selected together with the Client's Representative on basis of a preliminary interpretation of the swathe bathymetric and side scan sonar results.

The Grab Sampling shall be carried out not more than 5m from the designated position. The accuracy of the positioning of the Ground Truth Sampling shall be better than 2m.

If less than 5 kg of geological sample material is obtained, the Client Representative may instruct up to two (2) additional attempts on each site, without any extra costs.

Samples shall be preserved. After a preliminary visual geological description of the soil, the samples shall be carefully sealed and stored on the vessel for potential later transportation to an onshore laboratory for potential further testing.

All grab samples must be subject to a geological characterization according to

- A guide to engineering geological soil description. G. Larsen et. al. DGF-Bulletin 1. Danish Geotechnical Society.

Among other things this requirement means that samples must be described regarding:

- Lithology
- Depositional environment
- Geological age

A selected number of grab samples must be subject to the following geotechnical classification tests:

- Particle size, Sieve analysis
- Particle size, Hydrometer analysis
- Organic content, Loss on ignition

9. Equipment and methods – WP B – Magnetometry box survey

The Consultant's equipment, materials, supplies and tools shall be of first-class quality and shall be in good and safe operational condition, approved for use in the survey area. The Consultant shall maintain and repair all equipment and tools and maintain adequate stock levels and spare parts and spare equipment in order to ensure timely operations.

All equipment shall be installed and operated in such a way no interferences or disturbances between the various equipment units or the vessel and the equipment units occur.

All equipment and instruments must be able to operate under the meteorological and oceanographic limitations stated by the Consultant in his tender.

As a minimum but not limited to, the vessels shall be equipped with the equipment specified below.

The geophysical vessel shall, be equipped with the equipment specified in this chapter.

9.1 Vessel Positioning System

Section 8.1 apply.

9.2 Towed Equipment Positioning System

Section 8.2 apply.

9.3 Bathymetric System(s)

The provided bathymetry system(s) shall be suitable for the water depths (20 – 50 m) and conditions likely to be encountered in the survey areas (e.g. weather, wave height and currents).

The swathe bathymetry system shall be supplied with the following general specifications:

- Frequency: ≥ 300 kHz
- Soundings: Equidistant
- Number of soundings per ping: ≥ 250
- Ping rate: ≥ 30 Hz
- Depth resolution: ≤ 1 cm
- SV measurements on transducer: Yes
- Roll, pitch and yaw stabilised: Yes
- Backscatter recording: Yes

In addition to these quality parameters the bathymetric soundings must be acquired to facilitate a DTM with a spatial resolution of 20cm.

9.4 Sound Velocity Profiler

Section 8.4

9.5 Side Scan Sonar System

A dual channel side scan sonar system shall be provided with the following general specifications:

- Operation frequency: 400/900 kHz or comparable
- Horizontal beam width: ≤ 0.3 degree
- Operational range (meters/side): ≤ 50 m
- Resolution across track: ≤ 5 cm
- Chirp technology: Yes
- Multi-pulse technology: Yes

The applied operational range of the side scan sonar system shall be selected to ensure as high resolution as possible plus to ensure coverage $>200\%$ of side scan sonar to cover nadir of adjacent survey lines.

The Consultant is requested to submit a note in the tender on how to handle this, in order to provide high quality data.

The towing system shall be designed and operated to ensure the side scan sonar system is adequately decoupled from any vessel heave, pitching and rolling motion. The tow cable winch shall be remotely controlled from the geophysical survey instrument room.

Layback of the side scan sonar system shall be measured by a calibrated meter on the deployment pulley. Alterations to the tow cable length during surveying shall automatically be recorded in the acquisition system.

9.6 Magnetometer / Gradiometer

The magnetometry survey shall satisfy the following requirements:

- Utilize total field magnetometer sensors.
- Utilize total field magnetometer sensors capable of recording variations in the magnetic field strength with sensitivity up to 0.02 nT/m.
- Record data digitally at a sample rate ≥ 10 Hz.
- Sensor height above seabed: Maximum 2.5 m
- Involve magnetometers equipped with altimeters and depths sensors.
- Provide 100% coverage in the areas of operation.
- Noise level ≤ 2 nT.

The magnetometers shall be with an operating range of $20,000$ to $100,000$ nanotesla (nT), and a counter sensitivity of less than 0.004 nT/ PHz rms. The magnetometers should have a heading accuracy of less than 1 nT over the entire 360° spin and tumble and an absolute accuracy of less than 3 nT throughout range. They should be suitable for use in the full range of water depth expected at the site.

Each magnetometer (or its fixed frame to which it is attached) shall be fitted with depth sensors and altimeters. Any proposal or method statement omitting depth and height sensors may be considered invalid. The maximum roll angle that the magnetometer/gradiometer can operate under and still have an error limit that is below the gradient required from the EVT needs to be accounted for as a cut-off factor for data quality.

Magnetometers are generally factory calibrated and cannot be altered. In port and at sea testing of the magnetometers shall be carried out prior to the commencement of the work and shall be witnessed and signed off by the Client's onsite representative.

At least two (2) spare magnetometers and altimeters should be available on each vessel.

9.7 Mobilisation

For each survey spread, all systems shall be tested and calibrated during mobilisation in port, upon arrival on site prior to commencing operations, whenever a system is replaced and at any time requested by Client if there is doubt as to its proper performance.

The purpose of the calibrations is to test that all data acquisition sensors and navigational equipment performs as specified by the manufacturer's instructions and the accuracies required under this contract.

The calibration shall at least include:

- Tests of the installation (if required) of all navigation and positioning systems to an in-port state of readiness of the required spreads.
- In-port tests and calibrations of positioning, navigation, geophysical and all other systems.
- Transit to site and on-site pre-operations tests and calibrations of the positioning, navigation, geophysical and any other systems as necessary.

The vessel is calibrated when all equipment are tested and the calibration reports have been signed.

9.7.1 Equipment Verification Test Brief

Prior to undertaking the UXO-specified geophysical survey, in accordance with best practice (see CIRIA C754), an EVT must be undertaken by the Consultant.

This phase does not cover the mobilisation and calibration of the survey equipment array, these activities are generally part of the vessel's mobilisation activities, but tests the functionality of all systems within the array as they will be used within the survey working together.

No potential UXO interpretive parameters or discriminatory data shall be derived from the test.

The Consultant shall qualify the equipment in the manner described in this document. Substitutions or alterations to the plan may need to be considered if, for example, the Consultant can demonstrate suitable tests that fulfil the verification objectives. Such changes or exceptions to this specification shall be clearly described and presented to the Client.

The Consultant should undertake an EVT using a known test piece (specified as a discrete item with a known response) which will aim to achieve the following:

- Document the capabilities and limitations of each geophysical detection instrument selected for UXO risk mitigation.

- Confirm the achievable probability of detection and confidence levels for a known item.
- Observe each geophysical detection instrument operating in the Consultant's configuration, using the Consultant's personnel and methodologies.
- Evaluate the Consultant's data collection, data transfer quality, and data QC method(s).
- Evaluate the Consultant's method(s) of data analysis and evaluation.
- Document system reliability.
- Illustrate how predictive models compare to a known item.

9.7.2 Selection of Test Item

The selection of the test item makes up the first stage of the EVT process. The item should not necessarily aim to replicate a specific item of UXO but provide a repeatable and meaningful test for the survey array to ensure all sensors and positional systems are functioning as designed.

For this, typically a tubular section of rolled steel with appropriate lifting eyes is sufficient although alternative items would be considered.

9.7.3 Equipment Verification Test Methodology

The EVT should aim to replicate survey activity contracted by the Client, therefore all sensors which are to be run in the full survey should be utilized and recorded. The test should take place close to or on the Site of the Project to ensure conditions during the test are as representative of the full survey as possible. The EVT methodology should be included in the Consultant's PEP.

The following shall at least be covered:

- Launch and recovery of the test item;
- Location recognizance to locate a magnetically "clean" and relatively featureless area of seabed for the EVT;
- Location of test;
 - N/S, S/N, E/W, W/E running of survey array over the item;
- Data outputs;
 - MBES; gridded GeoTiff;
 - SSS; mosaic GeoTiff, targets picked and measured;
 - MAG; all 4 runs independently gridded residual grid GeoTiff, targets picked and measured, Oasis Montaj project of EVT data and grids.

10. Equipment and methods – WP C – Deep 2D seismic survey

10.1 Vessel Positioning System

Section 8.1 apply.

10.2 Towed Equipment Positioning System(s)

All towed equipment is positioned in real-time using a network of dual-DGPS antennas located with the seismic sources, and at front and tail buoys for each individual streamer.

The position of each channel, for each shot, will be calculated based on the active positioning system.

Positioning data will be stored in a raw file, in the SEG-Y header and a P1/90 format navigation file will be generated for each swath.

The relative as well as the absolute positions of the towed equipment shall be stored in the positioning database.

The tow cable winch shall be remotely controlled from the geophysical survey instrument room and fitted with a remote alarm.

Layback of the towed equipment shall be measured by a calibrated meter on the deployment pulley and by USBL. Alterations to the tow cable length during surveying shall automatically be recorded in the acquisition system.

10.3 Bathymetric System(s)

No requirements.

10.4 2D dual seismic setup: Relative medium and high frequency multi-channel seismic system

All survey lines will be acquired with a dual seismic setup focussing on the shallow and deep sections respectively.

The shallow section

The system could be using a triple sparker source or similar for detailed seismic inversion of the stratigraphic succession of at least the uppermost 250 m below the seabed. Especially, the system shall be designed, operated and data processed for seabed multiple suppression and being suitably for pre-stack inversion.

The system(s) shall be towed after the vessel(s) and shall as a minimum have the following general specifications:

- Fundamental frequency between 150 and 1500 kHz.
- Vertical resolution better than 1 m.
- Penetration to at least 250 m below seabed.
- Fire rate each 6.25 m.
- Source energy around 18 000 J.
- A suitable multi-channel and multi-element hydrophone streamer (e.g. 48 channels @ 3.125m) with depth control plus depth measurement for continuously monitoring and recording of streamer depth.

The deep section

The system could be using a dual air gun source or similar for detailed seismic inversion of the stratigraphic succession down to at least the top of the chalk. Desk studies suggest that the top of the chalk is located at 1200m to 1600m below seabed.

Especially, the system shall be designed, operated and data processed for seabed multiple suppression and being suitable for pre-stack inversion.

The system(s) shall be towed after the vessel(s) and shall as a minimum have the following general specifications:

- Fundamental frequency between 20 and 170 Hz.
- Vertical resolution better than 4 m.
- Penetration down to at least the Top Chalk surface (1200-1600m).
- Fire rate every 6.25 m
- Source energy around 120 cui.
- A suitable multi-channel and multi-element hydrophone streamer (e.g. 192 channels @ 6.25 m) with depth control plus depth measurement for continuously monitoring and recording of streamer depth.

11. Equipment and methods – WP D – UXO survey and inspection

This section specify requirements to equipment and methods for UXO survey, inspection and removal.

11.1 High-resolution geophysical survey

The UXO survey include the following elements main elements in the sensor spread:

- High resolution Seabed Bathymetry (MBES)
- High resolution Seabed Imagery (SSS)
- High resolution magnetometry (MAG)

The magnetometry acquisition is assumed to be performed using an ROTV connected with multiple magnetometers.

See chapter 9 regarding requirements to equipment and methods applicable for

- Vessel positioning system
- Towed equipment positioning system
- Bathymetric system(s)
- Sound velocity profiler
- Side scan sonar system
- Magnetometer / Gradiometer
- Mobilisation

11.2 Inspection and removal

The following are not given as fully comprehensive specifications and as such Consultant shall provide complete details and specifications within its proposal and method statement as to how the following requirements will be met and exceeded. The maximum sea state for safe

vessel working and data acquisition should be stated for both the ROV and divers (or other identification methods proposed).

When working in areas of adverse environmental conditions such as high currents, the Provider shall propose methods to increase dive time windows wherever possible.

ROV

For the inspections the Consultant shall use a work-class ROV to locate pUXOs stipulated for positive identification as a result of the geophysical survey.

The ROV shall be equipped with:

- A system to accurately locate the pUXO such as e.g. TSS440.
- Lighting, video and stills photographic equipment (colour and black & white cameras).
- Ultra-high frequency (e.g. Blueview or equivalent) sonar, complete with a 3-dimensional sonar visualisation system.
- Altitude and depth measurement system.
- Excavation system for exposing of targets, such as a non-magnetic airlift system.
- Manipulators to relocate and investigate objects.
- USBL Underwater positioning.
- Underwater INS (Inertial Navigation System) and Gyrocompass, to enhance subsea positioning.
- Online 4-channel Digital Recording System for recording Navigation, Magnetometer data, Video & Sonar including an overly system to add survey-data to the recording.

The ROV shall be

- Feasible for operating with the subsea conditions that must be expected in the areas of investigation, such as sea current, rugged seabed and water depths.
- Able to provide a stable platform for the measuring equipment. The performance shall be sufficiently documented by the Consultant.

12. Data Processing

The Consultant shall process all data acquired during the survey operations.

The data processing shall improve the subsequent interpretation and ensure the highest possible quality and resolution of the digital deliverables.

Requirements to data formats and specific deliverables are described in the document “Scope of services – Enclosure 2 – Standards of Deliverables”.

In particular for Work Package A and C that include processing of 2D UHRS data respectively, the Consultant propose a sequence of processing steps for the Client’s approval.

According to the Agreement the Consultant is obligated to amend any non-conformances of the provided services.

Therefore the Consultant shall include safe storage of all digital hydrographical, geophysical, grab samples and other data that has been acquired as a part of the project.

13. Data Interpretation

To meet the objectives of the Services plus the requirements for charting, reporting and digital deliverables, the Consultant shall interpret all the acquired and processed data to meet the highest possible quality.

The Consultant must carry out a number of integrated interpretations using both the geophysical and grab sample data.

13.1 WP A – Geophysical site survey

13.1.1 Geophysical anomalies

When processing of the geophysical data is completed then the data must be analysed to identify anomalies in Multi-beam Echo-sounding, Side Scan Sonar, Sub-Bottom Profiling and Magnetometer.

After the identification of the anomalies they have to be analysed and interpreted e.g. as man-made-objects or as natural seabed features.

Detailed requirements for the deliverables from the interpretations are listed in the document “Scope of Services – Enclosure 2 – Standards of Deliverables”.

13.1.2 Integrated seabed surface interpretation

An integrated data analysis of the geophysical and the grab sample data must be carried out to identify and interpret the following seabed surface themes:

1. **Seabed Surface Features** including morphological units such as dynamic seabed, biology, scars from man-made activities, gas escape features, slopes, scour patterns, erosion and deposition features and boulders.
The Consultant must propose criteria for interpretation of survey data as individual boulders or areal boulder zones. The Client anticipates that “large” boulders are always individually picked in data.
2. **Seabed Surface Geology** including lithological zones, zones of different boulder coverage, outcropping till and others. The Client requests consistency between the geophysical data and the grab sample investigations in the results of the interpretation of the Seabed Surface Geology.
3. **Debris and Man-Made-Objects** including wrecks, potential UXO objects, fishing gear and others.

The integrated interpretation of the abovementioned items #1, #2 and #3 must be done such that full class coverage is obtained within the area of investigation.

Detailed requirements for the deliverables from the interpretations are listed the document “Scope of Services – Enclosure 2 – Standards of Deliverables”.

13.1.3 Geology

Seismic data acquired with the single-channel and multi-channel systems (2D UHRS) must be interpreted for all survey lines.

The seismic lines must be interpreted to be used for assessment of:

- Morphological features below the seabed, e.g. stone and bubble reefs.
- Depth, thickness and distribution of geological layers.
- Geological hazardous features below seabed, e.g. soft seabed, shallow gas, pock-marks, boulders and peat.

The description of the seismic units shall use the nomenclature for soil unit descriptions defined by the reference:

- A guide to engineering geological soil description. G. Larsen et. al. DGF-Bulletin 1. Danish Geotechnical Society.

The seismic data shall be interpreted to achieve consistency with the ground-truthing information from available archive geotechnical information and the surface geophysical results.

Adjacent survey lines must be compared and seismic reflectors must be correlated and joined to form a set of interpretation points, such that layer surface grids and isochore grids can be derived coherently for the area of investigation.

Detailed requirements for the deliverables from the interpretations are listed the document "Scope of Services – Enclosure 2 – Standards of Deliverables".

13.2 WP B – Magnetometry box survey

13.2.1 Interpretation of Objects and Lineaments

The acquired geophysical data – including bathymetrical data, Side Scan Sonar and magnetic data – shall by the Consultant be analysed to identify point- and linear-shaped anomalies.

The object and lineament interpretation must identify any targets on the seabed or objects that are partly or completely buried at shallow depths.

The object and lineament interpretation must identify any seabed features such as pipelines, cables, wrecks, debris, boulders, archaeological features, lost fishing gear, waste, UXO or reefs.

The interpretation must include:

- Analysis of magnetic data for object identification.
- Analysis of swathe bathymetric depth as well as side scan sonar data for object and lineament identification
- Combined analysis of magnetic data with swathe bathymetric depth as well as side scan sonar data for object and lineament validation.

13.3 WP C – Deep 2D seismic survey

A full seismic stratigraphic interpretation of all major geological interfaces from the seabed down to the top of chalk is required on the acquired dataset. The IDA-1 wildcat well to the west of the 3GW OWF area will be the reference point for the later seismic inversion analysis.

13.4 WP D – UXO survey and inspection

To the extent that the acquired ROV data allows, the acquired inspection data is interpreted based on information provided by the Client.

13.4.1 Interpretation of Objects and Lineaments

See section 13.2.1.

14. Reporting requirements

During the various stages of the assignment the Consultant has to deliver a number of plans, reports and digital deliverables.

Table 14-1 provides a schematic and staged overview of the outputs that must be provided as an integrated part of performing the Scope of Services for each individual work package.

Section 14 gives in conjunction with the document “Scope of Services – Enclosure 2 – Standards of Deliverables” a description of the requirements that apply to the deliverables.

Furthermore - in order for the Client to complete his part of the application for permissions the Consultant must upon request and without delay provide the Client with any supplementary relevant master data or metadata relating the vessels, instruments, crew or other parameters related to the survey.

For the provision of the Draft deliverables indicated in Table 14-1 the Client will use the time indicated in the document Scope of Services, section 3 for Client review. Hereafter, the Consultant will finalize revised deliverables based on the Client’s comments and feedback.

Table 14-1. Schematic overview of the various deliverables that must be provided during the Agreement.

Event	Deliverable	Work Package				Section
		A	B	C	D	
Agreement	Project Execution Plan	X	X	X	X	14.1
	HSE Management Plan	X	X	X	X	14.1
	Quality Management Plan	X	X	X	X	14.1
Kick-off meeting						
Mobilization start	Acceptance Test Report	X	X	X	X	14.2
Mobilization end						
Survey operations	Daily Progress Reports	X	X	X	X	14.3
	Weekly Management Reports	X	X	X	X	14.4
	Monthly HSE Reports	X	X	X	X	14.5
De-Mobilization end	Operations Report	X	X	X	X	14.6
Provision of <u>Draft</u> deliverables	Geophysical site survey report	X				14.7
	Magnetometry box survey Report		X			14.8
	3D UHR seismic survey report			X		14.9
	UXO survey report				X	14.10
	UXO inspection report				X	14.10
Provision of <u>Revised</u> deliverables	Do.	X	X	X	X	Do.

14.1 Project Execution and QHSE management plan's

As a part of his project mobilization prior to marine activities the Consultant must prepare and forward three plans to the Client:

- A plan for Project execution
- A plan for HSE management
- A plan for Quality management

The Consultant shall forward the plans to the Client in due time for the Client to review before the kick-off meeting.

The Project Execution Plan shall at least include the following parts:

1. Program planning.
 - a. A high-level description of main activities and their order of performance.
 - b. Technical method statement regarding marine operations (e.g. LARS activities).
 - c. Description of survey line plan and how the plan accommodates that the quality requirements described in sections 8 to 10 are met. The survey line plan must be provided in an ESRI digital format.
 - d. Description of how to plan the scope for grab sampling.
2. Plan for technical quality assurance and quality control.
 - a. Plan for nomenclature and denomination of survey lines, tracks, locations and grabs.
 - b. Plan for nomenclature and denomination of digital deliverables.
3. Plan for the execution of the acceptance tests including pass criteria
 - a. Template for the acceptance test reports for instruments applied for the execution of the Services.

The HSE management plan shall fulfil the requirements specified in the document:

- Scope of Services - Enclosure 3 - HSE requirements

The Quality management plan meets the requirements in the document:

- Scope of Services - Enclosure 4 - Quality requirements

Based on the Client's comments the Consultant shall forward a final Project Execution Plan to the Client for approval.

No quality related services must be commenced prior to the approval of the Project Execution Plan by the Client. This means that the plan needs to be approved prior to commencing off-shore activities.

14.2 Acceptance Test Reports

The vessels are mobilized when all equipment are tested and calibrated and the data acquisition can begin.

As part of the mobilization of the vessels, the final testing and calibrating shall be witnessed by the Client Representative and reported by the Consultant in an Acceptance Test Report for each vessel to be applied for execution of the services.

The Client Representative and the Consultant's party chief shall by signing the Acceptance Test Report agree that the vessels are mobilized and ready for survey.

In particular for Work Package B – Magnetometry box survey, the Acceptance Test Report include also the results of the Equipment Verification Test.

14.3 Daily Progress Reports

Daily Progress Reports for a vessel shall be prepared and submitted from start of mobilization and uninterrupted until end of demobilization.

The Daily Progress Reports must include information regarding:

- Survey status: Completed quantities (current day and cumulated) and remaining quantities.
- Time break down: Mobilization, Operation, Standby, Transit, etc. (current day and cumulated).
- Weather observations (sea state, wind and visibility).
- Weather forecast – next 24 hours.
- Instrumental deviations from normal operation (break downs, calibration issues, etc.).
- QHSE incidents.

The Daily Progress Report must be submitted to the Client before 09.00 am the following day.

The final format of the Daily Progress Report should be addressed at the project kick-off meeting and agreed with the Client.

14.4 Weekly Management Reports

From commencement to completion of the Agreement, Weekly Management Reports (WMR) shall be prepared and submitted by the Consultants contract manager.

The purpose of the report is to inform managers, directors and non-technical stakeholders about the performance and progress. The Client assumes that the WMR's are prepared based on the business data available in the already provided Daily Progress Reports.

The weekly management reports shall cover the previous week's services plus the actual status of the project as on Sunday at 24:00 hrs. UTC.

The WMR is using a short (maximum two pages) and fixed format covering the following information:

Progress table displaying:

- Survey quantities (e.g. line-km, grab samples, box surveys, inspections,...), planned
- Survey quantities, completed last week
- Survey quantities, completed in total
- Survey quantities, remaining

Time-break-down table displaying information about the time categories

- Operations
- Transit
- Down-time, weather
- Down-time, other
- Port call
- ...

For each time category the following figures are provided:

- Planned time
- Time completed last week
- Time completed in total
- Time expected remaining

A table with status on selected milestones

- All marine activities completed
- Report provided, revised issue

For each milestone the following figures are provided:

- Milestone date agreed, time of contract
- Milestone date agreed, revised agreement
- Consultants forecast of date for completion

The Weekly Management Reports are issued every Monday before EOB.

14.5 Monthly HSE reports

On a monthly basis the Consultant is required to submit work hour statistics to the Client. The requirements to the HSE report is described in the document "Scope of Services - Enclosure 3 - HSE requirements", section 1.22.

The specific format of delivery is discussed and agreed at the project kick-off meeting.

14.6 Operations Report

The Consultant must submit an Operations Report that documents vessels, instruments and equipment, methods and procedures, etc.

The Operations Report must cover the operations of all on- and offshore resources. The Acceptance tests reports must be attached the Operational Report.

Requirements to the Operations Report are described in the document "Scope of Services – Enclosure 2 – Standards of Deliverables".

14.7 Geophysical site survey report

The Consultant must submit a Geophysical site survey report by the time indicated in the contracted time schedule.

In general, the Geophysical site survey report inclusive charts and digital deliverables shall present the results and findings of the survey.

The Geophysical site survey report shall be interpretative and provide a detailed assessment of the seabed and sub-seabed conditions by correlating the results gained from the various instruments during the survey activities.

The preparation of the Geophysical site survey report must follow the requirements described in the document "Scope of Services – Enclosure 2 – Standards of Deliverables".

Throughout the preparation of the Geophysical site survey report, the charts and the digital data deliverables, the Consultants Reporting Manager shall maintain a regular dialogue with the Client.

14.8 Magnetometry box survey report

The Consultant must submit a draft Magnetometry box survey Report incl. digital deliverables. In general, the Magnetometry box survey Report incl. digital deliverables shall address all the objectives of the Services.

The Magnetometry box survey Report incl. digital deliverables must follow the requirements described in "Scope of Services – Enclosure 2 – Standards of Deliverables".

The report shall be interpretative and provide a detailed assessment of the seabed by correlating the results gained from the various instruments during the survey activities.

Throughout the preparation of the report and the digital deliverables, the Consultants reporting manager shall maintain a regular dialogue with the Client. The Consultant shall immediately inform the Client of any potential difficulties/areas of concern for the project. Interim results shall be released during the reporting phase if requested by the Client.

14.9 Deep 2D seismic survey report

The Consultant submits a deep 2D seismic survey report by the time indicated in the contracted time schedule.

In general, the deep 2D seismic survey report inclusive charts and digital deliverables shall present the results and findings of the survey.

The report shall be interpretative and provide a detailed assessment of the seabed and sub-seabed conditions by correlating the results gained from the various instruments during the survey activities.

The preparation of the report must follow the requirements described in the document “Scope of Services – Enclosure 2 – Standards of Deliverables”.

14.10 UXO survey and inspection report

The Consultant must submit two independent reports by the time indicated in the contracted time schedule:

- UXO survey report and
- UXO inspection and removal report

In general, the reports, inclusive charts and digital deliverables, shall present the results and findings of the survey.

The reports shall be interpretative and provide a detailed assessment of the seabed and sub-seabed conditions by correlating the results gained from the various instruments during the survey activities.

The preparation of the reports must follow the requirements described in the document “UXO Survey and Inspection - Scope of Services - Annex 2 - Standards of Deliverables”.

14.11 Digital deliverables

Together with the reports a number of digital deliverables must be supplied. Digital deliverables include the measured data from the various geophysical and hydrographical sensors as well as GIS deliverables.

The digital deliverables must be provided for all work packages.

The format and specifications of these deliverables must follow the requirements described in the document “Scope of Services – Enclosure 2 – Standards of Deliverable”.

15. Meetings

The meeting activities described in this chapter cover all work packages.

There must be an individual kick-off meeting for each specific work package.

When convenient, the weekly and monthly management meetings may process work and activities from multiple work packages.

15.1 Kick-off meeting

The Consultant must facilitate a project kick-off meeting at his own premises where at least the following topics will be a part of the agenda:

- Mobilization and acceptance test criteria
- Project execution plan and Daily Progress Reports
- Principles for planning and adjusting the program of work
- Project Deliverables
- Time Schedule
- Organisation, roles and responsibilities
- QHSE
- Commercial matters
- Contractual matters

The project kick-off meeting shall be scheduled prior to the mobilization of the marine resources.

15.2 Weekly Management Meetings

From commencement of the services and uninterrupted until the completion of the services, every Tuesday morning and based on the previous days weekly management and technical reporting, management web-meetings between the Consultants and the Client's project management incl. reporting manager shall be held.

The Consultant shall facilitate the web-meetings.

The Consultant shall minute the meetings and not later than 24 hours after ending of the meeting, the minutes shall be distributed as on the project kick-off meeting.

15.3 Monthly Status Meeting

The Consultant participates in monthly status meetings that will be hosted every second month by the Client in Frederica, Denmark and every second month by the Consultant.

The purpose of the Status Meeting is to address the status and progress, the data quality, the deliverables as well as the commercial and contractual status of the Agreement. Furthermore relevant technical key topics may be addressed depending on current project phase.

The Consultant shall at least be represented by two persons of whom the Consultants project manager is one of them.

Unless otherwise agreed the Monthly Status meetings shall be held until the agreed deliverables have been accepted by the client.

STANDARDS OF DELIVERABLES

Project	Energy islands						
Assignment	Geophysical survey for offshore wind farms and energy island						
Document Title	Scope of Services - Enclosure - 2 - Standards of Deliverables						
Document No.	20/08794-4						
Audience	Tenderers						
Version	Document status	Prepared by		Reviewed by		Approved by	
		Name	Date	Name	Date	Name	Date
1	Template	JCO	2021-01-20				
2	For tender	JCO	2021-01-27	NHW	2021-01-28	JRA	2021-01-28
3	For updated WPC scope	XMBHA	2022-11-08	XLSSR	2022-11-09		

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1. Introduction

This document specifies a set of requirements that must apply for the deliverables supplied to the Client by Consultants.

The concept of "minimum requirements" is used to express a set of general requests for the deliverables supplied to the Client. This concept does not relieve any Consultant from producing deliverables that meet the general industry standard.

The Consultant can only deviate from these specifications upon agreement with the Client.

All reports including all attached charts, profiles, enclosures and annexes must be provided in English language and as standard PDF files.

The Scope of Service does not require that any deliverable is provided as printed paper reports.

2. Operations Report

The Operations Report must in general describe how the survey was completed. As such the Operations report must at least include the following:

- a. Executive summary.
- b. Description of any QHSE events
- c. Project introduction and background.
- d. Description of the applied vertical and horizontal reference systems.
- e. Description of all applied vessels.
- f. Detailed description of all instruments and measurement equipment.
- g. Documentation of the calibration and system tests (enclose Acceptance Test Reports).
- h. Definition of area of investigation.
- i. Description of planned offshore scope such as survey line plans and seabed test locations.
- j. Description of completed offshore scope including cumulative quantities.
- k. Documentation of the spatial accuracies achieved for the different systems including multi-beam echo-sounding system and subsea positioning systems.
- l. Description of data processing and interpretation methods.
- m. Description of norms and standards applied for the various work packages.
- n. Description of the cumulative time breakdown from the start of the mobilization to the end of the demobilization.

An Operations Report is providing for each individual work package.

3. Geophysical site survey report

The report must present the results of the survey, the achieved data quality and the interpreted data products.

The report must at least include the following:

- a. Executive Summary.
- b. Project introduction and background.
- c. Description of area of investigation.
- d. Description of the applied vertical and horizontal reference systems.
- e. Summary of the vessels and instrumental spread.
- f. Assessment of the achieved data quality.
- g. Presentation of survey results for the seabed surface:
 - a. Bathymetry
 - b. Seabed surface classification, geology
 - c. Seabed surface classification, morphology
 - d. Seabed surface classification, man-made features.
 - e. Seabed surface classification, substrate type (see Annex 2)
- h. Presentation of survey results for the subseabed geology including:
 - a. A summary of the regional geological history based on desk study.
 - b. A presentation of the identified seismic reflectors including statistics on reflector depth below seabed and reflector elevation relative to applied vertical datum.
 - c. An interpretation of the soil units associated with the identified reflectors. The interpretation include expectations to sedimentology, depositional environment as wells as age of sediment deposition. Nomenclature and conventions according to /1/.
- i. Summary of archaeological findings and anomalies with archaeological potential.
- j. Overview of the digital deliverables.

3.1 Charts, Drawings and Enclosures

The Geophysical Report must as a minimum be enclosed the following charts:

- a. Overview chart showing coastlines, EEZ, large scale bathymetric features and area of investigations.
- b. Chart showing actual performed survey lines and seabed sampling positions.
- c. Bathymetry chart with contour lines and presented as colour shaded relief maps.
- d. Backscatter mosaic image chart.
- e. Seabed surface classification chart, geology
- f. Seabed surface classification chart, morphology.
- g. Seabed surface classification chart, substrate type (see Annex 2).
- h. Seabed objects, identified objects and lineaments (swathe bathymetric and side scan sonar objects, lineaments, magnetic objects, etc.).
 - a. Chart
 - b. Catalogue with at least
 - i. ID and coordinates.
 - ii. Dimensions: Height, Lengths and Width.
 - iii. Bathymetrical and side scan sonar imagery.

- iv. Object interpretation.
- v. Object interpretation certainty.
- i. Seabed features chart, with all identified seabed features including, morphological, archaeological, seabed obstructions and infrastructure.
- j. Sub-seabed geology, charts with depth below seabed of identified horizons.
- k. Sub-seabed geology, charts with elevation of identified horizons.
- l. Sub-seabed geology, cross-section, profiles.
 - a. The Consultant must propose for Client approval a selected number of seismic lines for profile drawing.
 - b. The proposed lines must be selected such that all soil units and most prominent geological structures are displayed.
 - c. All survey lines surveyed with multi-channel seismic system must be potentially selected for profile drawing. The Client anticipates that a maximum of 25% of the lines surveyed with multi-channel seismic system are requested for drawings.

For all maps the Consultant shall propose for Client approval the formats of the maps. This should at least include content, symbology, paper size, map scale and layout.

4. Magnetometry box survey report

The report presents the results of the activities and include at least the following:

- a. Executive Summary.
- b. Project introduction and background.
- c. Summary of the vessels and technical setup.
- d. Applied geodetic system including both location and vertical elevation.
- e. Summary of spatial accuracies for the localisation of the vessels, subsea equipment and geophysical anomalies.
- f. Presentation of the bathymetry: Description of the bathymetry including slopes, dynamic seabed (sand waves / mega ripples / ripples), crests and other morphological features.
- g. Presentation of identified geophysical anomalies from; bathymetrical data, side scan sonar data and magnetometry.
- h. Presentation of targets selected for UXO Consultant evaluation.
- i. An overview of the associated digital deliverables.

4.1 Charts and drawings

The report is enclosed the following charts:

- a. Overview map showing coastlines, EEZs, general indication of the area of operations.
- b. Alignment charts presenting the detailed results from the UXO survey including
 - a. Shaded relief imagery of the bathymetry including depth contour lines including bathymetrical anomalies and targets.
 - b. Imagery of the side sonar mosaics including sonar anomalies and targets.
 - c. Imagery of the magnetometry including magnetic anomalies and targets.
 - d. Vessel tracks and magnetometry instrument tracks and outline of UXO Box area.
- c. Target catalogue presenting for each target
 - a. Anomaly ID, coordinates, geophysical method, water depth (MSL)
 - b. All relevant geophysical attributes.
 - c. Imagery panels with bathymetry, side scan sonar mosaic and magnetometry.
- d. Magnetic linear anomaly catalogue presenting for each linear anomaly
 - a. Anomaly ID, coordinates, geophysical method, water depth (MSL)
 - b. All relevant geophysical attributes.
 - c. Imagery panels with bathymetry, side scan sonar mosaic and magnetometry.

The format and data content of the charts shall be agreed with the Client based on proposed layouts prepared by the Consultant.

5. Deep 2D seismic survey report

The Deep 2D Seismic Survey report presents the results of the survey, the achieved data quality, and the interpreted data products.

The report must at least include the following:

- a. Executive Summary.
- b. Project introduction and background.
- c. Description of area of investigation.
- d. Applied geodetic system including both location and vertical elevation.
- e. Summary of the vessels and instrumental spread.
- f. Assessment of the achieved data quality.
- g. Presentation of survey results for the sub-seabed geology including:
 - a. A summary of the regional geological history based on desk study.
 - b. A presentation of the identified seismic reflectors including statistics on reflector depth below seabed and reflector elevation relative to applied vertical datum.
 - c. An interpretation of the soil units associated with the identified reflectors. The interpretation include expectations to sedimentology, depositional environment as wells as age of sediment deposition. Nomenclature and conventions according to /1/.
- h. Overview of the digital deliverables.

5.1 Charts, Drawings and Enclosures

The Geophysical Report must as a minimum be enclosed the following charts:

- a. Overview chart showing coastlines, EEZ, large scale bathymetric features and area of investigations.
- b. Chart showing actual performed survey lines.
- c. All survey lines surveyed with multi-channel seismic system must presented as profiles in drawing:

The Consultant may propose charts and drawings that are most suitable for the report and communication with stakeholders.

For all profiles and maps the Consultant shall propose for Client approval the formats of the profiles and maps. This should at least include content, symbology, paper size, map and profile scale, and layout.

6. UXO survey report

The UXO Survey Report must present the results of the activities and must at least include the following:

- a. Executive Summary.
- b. Project introduction and background.
- c. Summary of the vessels and technical setup.
- d. Summary of spatial accuracies for the localisation of the vessels, subsea equipment and geophysical anomalies.
- e. Presentation of the bathymetry: Description of the bathymetry including slopes, dynamic seabed (sand waves / mega ripples / ripples), crests and other morphological features.
- f. Presentation of identified geophysical anomalies from; bathymetrical data, side scan sonar data and magnetometer data.
- g. Presentation of targets selected for UXO Consultant evaluation.
- h. An overview of the associated digital deliverables.

6.1 Charts and drawings

The UXO Survey Report must as a minimum be enclosed the following charts:

- a. Overview map showing coastlines, EEZs, general indication of the area of operations.
- b. Charts presenting the detailed results from the UXO survey including
 - a. Shaded relief imagery of the bathymetry including depth contour lines including bathymetrical anomalies and targets.
 - b. Imagery of the side sonar mosaics including sonar anomalies and targets.
 - c. Imagery of the magnetometry including magnetic anomalies and targets.
 - d. Morphological classification of the seabed surface.
 - e. Vessel tracks and magnetometry instrument tracks and.
- c. Target catalogue presenting for each target
 - a. Anomaly ID, coordinates, geophysical method, water depth.
 - b. All relevant geophysical attributes.
 - c. Imagery panels with bathymetry, side scan sonar mosaic and magnetometry.
- d. Magnetic linear anomaly catalogue presenting for each linear anomaly
 - a. Anomaly ID, coordinates, geophysical method, water depth.
 - b. All relevant geophysical attributes.
 - c. Imagery panels with bathymetry, side scan sonar mosaic and magnetometry.

The format and data content of the charts shall be agreed with the Employer based on proposed layouts prepared by the Provider.

7. UXO inspection report

If UXO identification for one or more work packages is necessary based on the findings of the surveys, separate inspection result reports must be submitted. The report shall contain:

- a. Executive Summary.
- b. Project introduction and background.
- c. Summary of the vessels and technical setup.
- d. For each target:
 - a. A description of the position and type of targets.
 - b. A description of inspection activities performed including visual imaging and possible actions to uncover the target.
- e. Pictures of each target if available.

7.1 Charts and drawings

The UXO Survey Report must as a minimum be enclosed the following charts:

1. Overview map showing coastlines, EEZs, the pipeline route with KP markings, general indication of the area of operations.
2. Target catalogue presenting for each target
 - a. Anomaly ID, coordinates, geophysical method, water depth.
 - b. All relevant geophysical attributes.
 - c. Imagery panels with bathymetry, side scan sonar mosaic and magnetometry.
 - d. Imagery panels with visual images from the ROV inspection.

Individual UXO Inspection Reports must be provided for Area A and Area B respectively. The UXO Inspection Reports must cover both WP1 and WP2.

8. Digital deliverables – Work Package A

8.1 General structure

This section describes the digital deliverables that must be provided as a part of the delivery.

The digital deliverables are specified below as a numbered list such that each deliverable has a unique ID. This ID must be used in referencing the specific deliverable during the project execution.

The package of digital deliverables must be provided with a suitable spreadsheet that lists the individual deliverables including the following information:

- Unique deliverable ID number
- Deliverable name
- Deliverable type
- Revision number
- Date of issue
- Data file format

The digital deliverables are provided on external hard drives in two (2) copies.

8.2 GIS deliverables

A number of the digital deliverables must be delivered for ESRI ArcGIS using the Clients template as described in Annex 1. The template is referred to as a *Template Survey Geodatabase* or as TSG.

In the list below describing the requirements for the digital deliverables references will be made to specific data objects in the TSG.

Multiple deliverables are required to be loaded to the same TSG data object. For instance it is required that vessel tracks and instrument-specific tracks are stored in the same object (TRACKS_LIN). To distinguish between the different input data, the attributes must be configured to reflect the different sources.

For the geophysical survey data (MBES, SSS, MAG and SBP) targets are required at two levels:

- As anomalies (the ANOMALY data objects).
- As interpreted targets (the MMO and the SEABED_FEATURE data objects).

In this context *anomalies* should not be interpreted – these are considered as data markers only. Interpretation of *targets* should be performed taking all swathe data into consideration. The data objects MMO and SEABED_FEATURES include attributes to store interpretation, certainty and anomaly reference.

The Consultant may propose changes to the TSG code lists (ESRI *Domains*).

8.3 Bathymetric data

The results of the bathymetric survey must be delivered as processed and despiked data with the following deliverables:

1. Un-gridded soundings, (X,Y,Z) values in ASCII format.
2. Gridded soundings, 0.25m resolution, (X,Y,Z) values in ASCII format.
3. Gridded soundings, 0.25m resolution, GeoTIFF grid format.
4. Gridded soundings, 1.00m resolution, (X,Y,Z) values in ASCII format.
5. Gridded soundings, 1.00m resolution, GeoTIFF grid format.
6. Gridded soundings, 5.00m resolution, (X,Y,Z) values in ASCII format.
7. Gridded soundings, 5.00m resolution, GeoTIFF grid format.
8. Bathymetric contour curves with 50cm interval, as TSG object CONTOURS_LIN
9. Vessel tracks, as TSG object TRACKS_LIN, indicate equipment carrier and equipment type in attributes.
10. Bathymetry - TVU 1.00 m resolution, (X,Y, TVU) values in ASCII format
11. Bathymetry - TVU 1.00 m resolution, GeoTIFF grid format
12. Bathymetry - THU 1.00 m resolution (X,Y,THU) values in ASCII format
13. Bathymetry - THU 1.00 m resolution, GeoTIFF grid format
14. Bathymetry – Backscatter, GeoTIFF 32bit (amplitude populated channels).
15. Sound velocity profiles (SVP) in native format
16. MBES Anomaly target list, as TSG object MBES_ANOMALY_PTS, anomaly characteristics provided in attributes.

The GeoTIFF grid format must satisfy the following requirements:

- GeoTIFF Grids are stored in a ESRI file geodatabase.
- *Spatial Reference* has been configured.
- *Calculate Statistics* has been performed.
- *Build Pyramids* has been performed.

Deliverable item 1 (ungridded soundings) is delivered as data files corresponding to the data acquisition along the vessel tracks. The filenames reflect the vessel track ID's are corresponding one-to-one with contents of deliverable 9.

8.4 Side scan sonar data

The results of the SSS data must be supplied as:

17. Side scan sonar data as XTF-files with corrected navigation, High frequency.
18. Side scan sonar data as XTF-files with corrected navigation, Low frequency.
19. Navigation files, CSV-format.
20. SSS instrument tracks, as TSG object TRACKS_LIN, indicate equipment carrier and equipment type in attributes.
21. SSS Anomaly target list, as TSG object SSS_ANOMALY_PTS, anomaly characteristics provided in attributes.
22. SonarWiz 7 project including the bottomtracked and suitably processed .XTF files and SSS and Magnetometer targets

8.5 Magnetometer data

The results of the MAG data must be supplied as:

23. MAG measurements, CSV-format, with the following data columns
 - a. Date (YYYY-MM-DD)

- b. Time (HH:MM:SS)
 - c. Location ID (Unique location ID number)
 - d. Magnetometer line ID (Unique line number)
 - e. Survey line Heading
 - f. Total field (Raw magnetic measurement, nT)
 - g. Residual field (Residual magnetic field, nT)
 - h. Easting1, Northing1 (Measured coordinates, meters)
 - i. Easting2, Northing2 (Processed coordinates, meters, filtered coordinates and reduced for obvious noise)
 - j. Lay-back (Instrument lay-back distance, meters)
 - k. Altitude (Instrument altitude above seabed, meters)
24. MAG instrument tracks, as TSG object TRACKS_LIN, indicate equipment carrier and equipment type in attributes.
25. MAG Anomaly target list, as TSG object MAG_ANOMALY_PTS, anomaly characteristics provided in attributes.

The magnetic residual field (item 23.g above) is the result of a process where the measured Total magnetic field (item 23.f above) is subtracted medium- and long-wavelength signals caused by the geomagnetic field, ionospheric and sources and regional geological sources.

The magnetic Residual field must be processed to reflect any ferrous or magnetic objects on the seabed or with shallow burial within the seabed e.g. wrecks, debris subsea cables and pipelines or other Man-Made ferrous objects.

8.6 Sub-bottom profiling data and 2D UHRS data

The results of the seismic data acquisition must be supplied as:

- 26. Processed SBP and UHRS recordings, SEG Y format. Processing include at least that
 - a. SEG Y headers are configured with geometry
 - b. Traces are corrected for motion
 - c. Traces are aligned with datum
- 27. Processed SBP and UHRS recordings, as image-files (Tiff or PNG)
- 28. SBP and UHRS instrument tracks, as TSG object TRACKS_LIN, indicate equipment carrier and equipment type in attributes.
- 29. SBP and UHRS Anomaly target list, as TSG object SBP_ANOMALY_PTS, anomaly characteristics provided in attributes.
- 30. Interpretation of the processed seismic data. These data include interpretation points for digitized horizons identified in the seismic recordings. The data must be delivered as a point list file in CSV-format with the following data columns:

a. PointID	Unique identification number
b. Survey line ID	Unique survey line identification
c. SEG Y_Name	Filename of SEG Y file
d. KP	Km point or shotpoint ID
e. Easting, Northing	Coordinates, meters
f. TWT	Two-way-time, millisec
g. Elevation	Elevation, LAT, meters
h. Depth BSB	Depth Below Seabed, meters, based on constant velocity
i. Type	The interpretation points must be assigned a

"type value" to identify the observed layer boundaries, etc.

31. Generated **elevation grids** relative to vertical datum for each interpreted horizon in 5 m resolution as
 - a. GeoTIFF grid
 - b. An (X,Y,Z) values in ASCII format (Z as the horizon elevation in meter)
32. Generated **depth below seabed** (BSB) grids for each interpreted horizon in 5 m resolution as
 - a. GeoTIFF grid
 - b. An (X,Y,Z) values in ASCII format (Z as the horizon depth BSB in meter)
33. Generated **Isochore** (layer thickness) grids for each interpreted soil unit in 5 m resolution as
 - a. GeoTIFF grid
 - b. An (X,Y,Z) values in ASCII format (Z as the layer thickness in meter)
34. **Kingdom project** including SBP and UHRS data, both as TWT and as DEPTH conversion.

The GeoTIFF grid format must satisfy the following requirements:

- GeoTIFF Grids are stored in a ESRI file geodatabase.
- *Spatial Reference* has been configured.
- *Calculate Statistics* has been performed.
- *Build Pyramids* has been performed.

8.7 Grab sampling

The results of the ground truth sample data must be delivered as:

35. Grab sample positions, as TSG object GEOTECHNIC_PTS, indicate sampling characteristics in attributes.
36. Grab sample classification, MS-Excel spread sheet with the following data columns:
 - a. Unique sampling ID
 - b. Geological description of the recovered sample,
 - i. Lithology
 - ii. Depositional environment
 - iii. Depositional age
37. Grab sample laboratory analysis, overview table and result tables, MS-Excel spread sheet.

8.8 Integrated seabed surface interpretation

The acquired data must be used for an integrated interpretation of the following themes related to the seabed:

- Seabed Surface Geology.
- Seabed Surface Features.

- Seabed Substrate type
- Debris and Man-Made Objects.

The Client assumes that the most feasible solution for interpretation of

- **boulders** on the seabed is performed using automatic boulder interpretation methods.
- **seabed surface** geology, features and substrate type is performed with backscatter images.

The results of the interpretation must be provided as:

38. Seabed Surface Geology, as TSG object SEABED_GEOLOGY_POL, indicate surface geological unit in attributes.
39. Seabed Surface Features, as TSG object SEABED_SURFACE_PTS, indicate surface forms in attributes.
40. Seabed Surface Features, as TSG object SEABED_SURFACE_LIN, indicate surface forms in attributes.
41. Seabed Surface Features, as TSG object SEABED_SURFACE_POL, indicate surface forms in attributes.
42. Seabed Substrate type, as TSG object SEABED_SUBSTRATE_POL, indicate substrate type in attributes.

The polygon deliverables 38 and 41 must have full coverage within the survey area.

43. Man-Made-Objects, as TSG object MMO_PTS, indicate MMO type in attributes.
44. Man-Made-Objects, as TSG object MMO_POL, indicate MMO type in attributes.
45. Man-Made-Objects, as TSG object MMO_LIN, indicate MMO type in attributes.

9. Digital deliverables – Work Package B

9.1 General structure

Section 8.1 apply.

9.2 GIS deliverables

Section 8.2 apply.

9.3 Bathymetric data

The results of the bathymetric survey must be delivered as processed and despiked data with the following deliverables:

1. Un-gridded soundings, (X,Y,Z) values in ASCII format.
2. Gridded soundings, 0.20m resolution, (X,Y,Z) values in ASCII format.
3. Gridded soundings, 0.20m resolution, GeoTIFF grid format.
4. Gridded soundings, 1.00m resolution, (X,Y,Z) values in ASCII format.
5. Gridded soundings, 1.00m resolution, GeoTIFF grid format.
6. Bathymetric contour curves with 50cm interval, as TSG object CONTOURS_LIN
7. Vessel tracks, as TSG object TRACKS_LIN, indicate equipment carrier and equipment type in attributes.
8. MBES anomalies, as the TSG object MBES_ANOMALY_PTS with at least the following attributes:
 - a. Unique MBES target ID
 - b. MBES survey line ID
 - c. Target dimensions, Length / Height / Width (meters)
 - d. Target interpretation

The GeoTIFF grid format must satisfy the following requirements:

- GeoTIFF Grids are stored in a ESRI file geodatabase.
- *Spatial Reference* has been configured.
- *Calculate Statistics* has been performed.
- *Build Pyramids* has been performed.

Deliverable item 1 (ungridded soundings) is delivered as data files corresponding to the data acquisition along the vessel tracks. The filenames reflect the vessel track ID's are corresponding one-to-one with contents of deliverable 9.

9.4 Side scan sonar data

Section 8.4 apply.

9.5 Magnetometer data

The results of the MAG data must be supplied as:

9. MAG measurements, CSV-format, with at least the following data columns
 - a. Date (YYYY-MM-DD)
 - b. Time (HH:MM:SS)
 - c. Location ID (Unique location ID number)

- d. Magnetometer line ID (Unique line number)
 - e. Survey line Heading
 - f. Total magnetic field, measured values, raw magnetic measurements (nT)
 - g. Total magnetic field, processed values, filtered and reduced for obvious noise sources (nT)
 - h. Residual field magnetic field (nT)
 - i. Easting1, Northing1 (Measured coordinates, meters)
 - j. Easting2, Northing2 (Processed coordinates, meters, filtered coordinates and reduced for obvious noise)
 - k. Lay-back (Instrument lay-back distance, meters)
 - l. Altitude (Instrument altitude above seabed, meters)
10. MAG instrument tracks, as TSG object TRACKS_LIN, indicate equipment carrier, line name and equipment type in attributes.
11. MAG anomalies, as TSG object MAG_ANOMALY_PTS, anomaly characteristics provided in attributes:
- a. Unique MAG target ID
 - b. Magnetometer line ID
 - c. Residual anomaly magnetometer value, Peak-to-Peak, nT
 - d. Target interpretation
12. Gridded magnetic data as a relevant file (.grd /.tif /.flt)
13. Oasis Montaj Project including the following:
- a. Databases with magnetometer measurements
 - b. Databases with target lists
 - c. Grids with total magnetic field, (0.5m cell size)
 - d. Grids with residual magnetic field, (0.5m cell size)
 - e. Grids with sensor altitude, (0.5m cell size)

The Magnetic Residual Field is the result of a process where the measured Total magnetic field is subtracted medium- and long-wavelength signals caused by the geomagnetic field, ionospheric and regional geological sources.

The Magnetic Residual Field must be processed to reflect any ferrous or magnetic objects on the seabed or with shallow burial within the seabed such as wrecks, debris, UXO's anchor chains, subsea cables and pipelines or other Man-Made ferrous objects.

9.6 Interpreted data – Targets

A number of the geophysical anomalies – bathymetry, side scan sonar and magnetometer – are selected as targets for further assessment of the Client (see Section 2 for details).

The acquired data must be used for an interpretation of the Seabed Surface Features. The results of the interpretation must be provided as:

14. Man-Made-Objects, as TSG object MMO_PTS with the following characteristics included in the attributes:
- a. Record unique Target ID.
 - b. Record "TARGET" in the MMO_TYPE attributes

- c. Record geophysical type (bathymetry, side scan sonar and magnetometer).
- d. Record geophysical anomaly ID.
- e. Record target dimensions in meters, Length / Height / Width.
- f. Record standardized description / interpretation.
- g. If target from MAG data: Record Peak-to-Peak amplitude (nT).
- h. If target from MAG data: Record instrument altitude in meters.

9.7 Interpreted data – Magnetic linear anomalies

The acquired magnetic data must be used for an interpretation of linear magnetic anomalies that may have been caused by ferrous debris (anchor chains) or buried utilities such as pipelines, power cables or communication cables.

The results of the interpretation must be provided as:

15. Man-Made-Objects, as TSG object MMO_LIN, indicate interpreted source in the MMO-TYPE attribute.

10. Digital deliverables – Work Package C

The results of the seismic data acquisition must be supplied as:

10.1 General structure

Not applicable

10.2 Deep 2D seismic data

The results of the seismic data acquisition must be supplied as:

1. Processed UHRS recordings, SEGY format. Processing includes at least that:
 - a. SEGY headers are configured with geometry
 - b. Traces are corrected for motion
 - c. Traces are aligned with datum
2. 2D seismic instrument tracks, as TSG object TRACKS_LIN, indicate equipment carrier and equipment type in attributes.
3. SBP and UHRS Anomaly target list, as TSG object SBP_ANOMALY_PTS, anomaly characteristics provided in attributes.
4. Interpretation of the processed seismic data. These data include interpretation points for digitized horizons identified in the seismic recordings. The data must be delivered as a point list file in CSV-format with the following data columns:

a. PointID	Unique identification number
b. Survey line ID	Unique survey line identification
c. SEGY_Name	Filename of SEGY file
d. KP	Km point or shotpoint ID
e. Easting, Northing	Coordinates, meters
f. TWT	Two-way-time, millisec
g. Elevation	Elevation, LAT, meters
h. Depth BSB	Depth Below Seabed, meters, based on constant velocity
i. Type	The interpretation points must be assigned a "type value" to identify the observed layer boundaries, etc.
5. Generated **elevation grids** relative to vertical datum for each interpreted horizon in 5m resolution as:
 - a. GeoTIFF grid
 - b. An (X,Y,Z) values in ASCII format (Z as the horizon elevation in meter)
6. Generated **depth below seabed** (BSB) grids for each interpreted horizon in 5 m resolution as:
 - a. GeoTIFF grid
 - b. An (X,Y,Z) values in ASCII format (Z as the horizon depth BSB in meter)

7. Generated **Isochore** (layer thickness) grids for each interpreted soil unit in 5 m resolution as:
 - a. GeoTIFF grid
 - b. An (X,Y,Z) values in ASCII format (Z as the layer thickness in meter)
8. **Kingdom project** including SBP and UHRS data, both as TWT and as DEPTH conversion.

The GeoTIFF grid format must satisfy the following requirements:

- GeoTIFF Grids are stored in a ESRI file geodatabase.
 - *Spatial Reference* has been configured.
 - *Calculate Statistics* has been performed.
 - *Build Pyramids* has been performed.
9. **Updated Kingdom** with 2D seismic interpretation integrated with borehole data including SBP, 2D seismic data, both as TWT and as DEPTH converted version.
 10. 2D deep seismic instrument tracks, as TSG object TRACKS_LIN, indicate equipment carrier and equipment type in attributes.

The Consultant may supplement the delivery list to complete the provision of the 2D deep seismic survey results.

10.3 SolidGround: Standard of deliverables Work Package C

1. Seismic inversion report

The report must at least include the following:

** Reference to WP from SolidGround*

- a. Executive Summary.
- b. Project introduction and background.
- c. Description of area of investigation.
- d. Assessment of the achieved data quality.
- e. Presentation of survey results for – Integration, interpretation and modelling (WPD*):
 - i. 2D seismic interpretation integrated with borehole data
 - ii. Build 3D model of seismic interpretation (digital deliverable?)
 - iii. Convert interpretation from time to depth
 - iv. Build 3D geostatistical models of elastic and relevant geotechnical properties
- f. Presentation of survey results for - Seismic inversion for physical elastic parameters (WPE*):
 - i. Seismic inversion for physical elastic properties:
 1. Bulk modulus, shear modulus and density
 - ii. Wavelet estimation
 - iii. Inversion parameter testing
 - iv. QC of inversion products at selected geotechnical locations and section.

2. Charts, Drawings and Enclosures

The Geophysical Report must as a minimum be enclosed the following charts:

The Consultant may propose charts and drawings that are most suitable for the report and communication with stakeholders.

For all profiles and maps the Consultant shall propose for Client approval the formats of the profiles and maps. This should at least include content, symbology, map and profile scale, and layout.

3. Overview of the digital deliverables.

(Digital deliverables that will be provided from SolidGround to Energinet)

- a. 3D model of seismic interpretation provided to Energinet in Kingdom.
- b. Spreadsheet containing deformation parameters.

11. Digital deliverables – Work Package D

11.1 General structure

Section 8.1 applies.

11.2 GIS deliverables

Section 8.2 apply.

11.3 Bathymetric data

Section 9.3 applies.

11.4 Side scan sonar data

Section 8.4 applies.

11.5 Magnetometer data

Section 9.5 applies.

11.6 Interpreted data

Section 9.6 and section 9.7 apply.

11.7 UXO Inspection and removal

During the UXO inspection and removal phase a number of *potential UXOs* are investigated and possibly removed. Removal can occur both in the event that the pUXO is verified as a real UXO and in the event that the pUXO is classified as debris.

The following digital deliverables must be provided:

- a. For the identification phase it is required that all investigations by ROV or other equipment are delivered and must include video recordings of all data recorded. Any video recordings must be delivered as standard video files (e.g. Mp4) or otherwise agreed.
- b. A revised TSG including a revised issue of the TSG object MMO_PTS where the attribute MMO_TYPE is reconfigured depending on the conclusion of the inspection.

12. References

- /1/ A guide to engineering geological soil description. G. Larsen et. al. DGF-Bulletin 1.
Danish Geotechnical Society.

Annex 1 – Requirements to TSG

Annex 2 – Substrate type classification

The substrate type map is divided into the following substrate types, cf. the Danish Råstof-bekendtgørelsen (BEK no. 1680 of 17/12/2018, Phase IB):

Substrate type 1 - Sand, silt and mud: Areas consisting of fine-grained soft bottom or solid sand bottom (possibly with dynamic bottom shapes (sand ripples etc.)) with varying amounts of shells and gravel. Sand is defined as grain sizes in the range of 0.06-2.0 mm.

Typically, substrate type 1 is subdivided into substrate type 1a (silty, soft bottom), 1b (solid sandy bottom) and 1c (clay bottom), which is not stated in the “Råstofbekendtgørelsen”. It is a standard substrate type subdivision used in a wide range of marine raw material investigations, Natura 2000 projects etc. The subdivision is approved by MST (MST = Danish Environmental Protection Agency).

Substrate type 2 - Sand, gravel and pebbles: Areas consisting of a mixture of coarse sand and gravel with a grain size of approx. 2-20 mm and pebbles with sizes of approx. 2-10 cm. The substrate type also contains some larger stones from approx. 10 cm and larger, covering from 1-10% of the seabed.

Substrate type 2 can be subdivided into substrate types 2a and 2b, respectively. According to the “Råstofbekendtgørelse”, these two types constitute the same substrate type, but on the basis of their different characteristics a division can be made. Substrate type 2a consists mainly of coarse sand, gravel and pebbles. This type of substrate typically consists of only a few larger stones over 10 cm. Substrate type 2b consists of 1-10% larger stones typically on a coarse sandy bottom.

Substrate type 3 - Sand, gravel and pebbles, and larger stones: Areas consisting of mixed substrates with sand, gravel and pebbles with a varying amount of larger stones from approx. 10 cm covering 10-25% of the seabed. The substrate type differs from substrate type 2 by containing a greater number of stones from ca. 10 cm and upwards. The stones are usually scattered, and only in one layer.

Substrate Type 4 - stony areas and stone reefs with 25-100% of larger stones: Areas dominated by stones from approx. 10 cm and up - from dense irrigation to actual stone reefs with or without cavities. There may also be varying amounts of sand, gravel and pebbles, as well as biogenic reefs or limestone reefs in this substrate type. The stones can be in one layer, or form actual stone reefs, which rise above the surrounding bottom with several layers (cavity forming).

Table 1. Substrate classes.

Class	Description of substrate class
1a	Sand, silty, soft bottom
1b	Sand, solid sandy bottom
1c	Clay bottom
2a	Sand, gravel and pebbles – few larger stones
2b	Sand, gravel and pebbles – seabed cover of larger stones 1% to 10%
3	Sand, gravel and pebbles – seabed cover of larger stones 10% to 25%
4	Stony areas and stone reefs - seabed cover of larger stones 25% to 100%