Date 29th October 2021

Status Final

Geophysical Survey IJmuiden Ver Site V-VI

Annex 6 - Section IV

Scope of Work

IJmuiden Ver Wind Farm Zone

Colophon

Project name	Geophysical Survey IJmuiden Ver Site V-VI
Project number	WOZ2210265
Version	Final
File name	IJ56_20211029_RVO_GP_Annex 6_Section IV_Scope of Work_F
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1 Introduction

1.1 Scope of this document

This document and its appendices detail the scope of the WORK as part of the CONTRACT that CLIENT has awarded to CONTRACTOR for carrying out geophysical investigations at IJmuiden Ver Wind Farm Sites V and VI (IJ56). IJ56 is located within the IJmuiden Ver Wind Farm zone (IJVWFZ).

1.2 Background

The Ministry of Economic Affairs and Climate Policy is responsible for the legislative framework for the development of offshore wind farms in the Netherlands. Within this framework (a) (concession) tender(s) for permit for construction and operation of (a) wind farm(s) will be organized under the current regulation. As part of the tender documentation, the participants will receive an information package in which detailed information on the offshore site is included. Detailed information on the soil conditions at the site will be part of this information package.

Information on the soil conditions at the site is to be developed through a sequence of commissions for geological, geophysical, geotechnical and morphodynamical studies. Information will be presented as factual data, integrated and interpreted data (a Ground Model) and will be comprehensively reported.

The Ground Model is to be of sufficient precision to allow participants to make initial plans and costings for foundation design and cable installation.

This assignment is concerned with the geophysical investigation component, contributing to the information package to be provided to participants.

1.3 Site description

The IJ56 sites are an extension to the four sites (IJmuiden Ver sites I-IV) that have been investigated for the offshore wind development of the Netherlands. The sites IJ56 will be added to the sites determined in the roadmap 2030 as presented in Figure 1. With the extension of the IJVWFZ will consist of 6 sites with a total capacity of 6000 MW.

The IJVWFZ is indicated in Figure 1, taken from Annex 6 section VII of the Tender information pack, Starting Points and Assumptions, and Figure 2 illustrating the Investigation Area (IA) area specific to the Geophysical Survey of IJ56.

The Geological Desk Study to be provided by RVO for the IJVWFZ provides information on the expected stratigraphic units, geological structures and possible influence on the design and the construction of offshore wind farms in the IA.

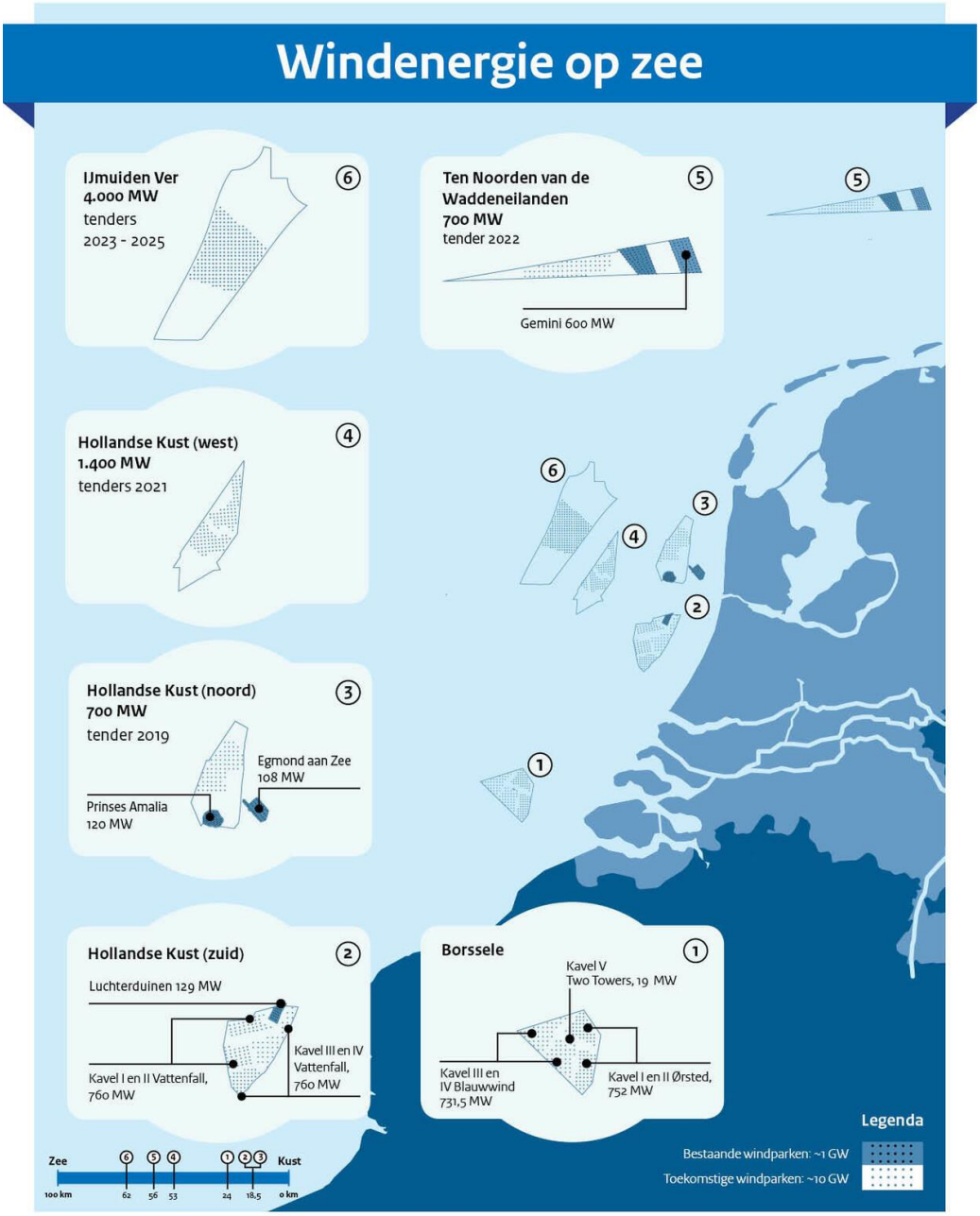

Figure 1. Designated Wind Farm Zones in the Netherlands

The IJVWFZ will be tendered in 3 stages in 2024 (I-II) ,2025 (III-IV) and 2026 (V-VI).

1.4 Investigation Area

It is the intention to obtain a single set of geophysical data, reports and drawings for an IA. The IA covers the area to be occupied by the Wind Farm Sites (WFS), including an additional buffer zone (500 m) around the WFS. The IA is shown in Figure 2, and its vertices are provided in Table 1.

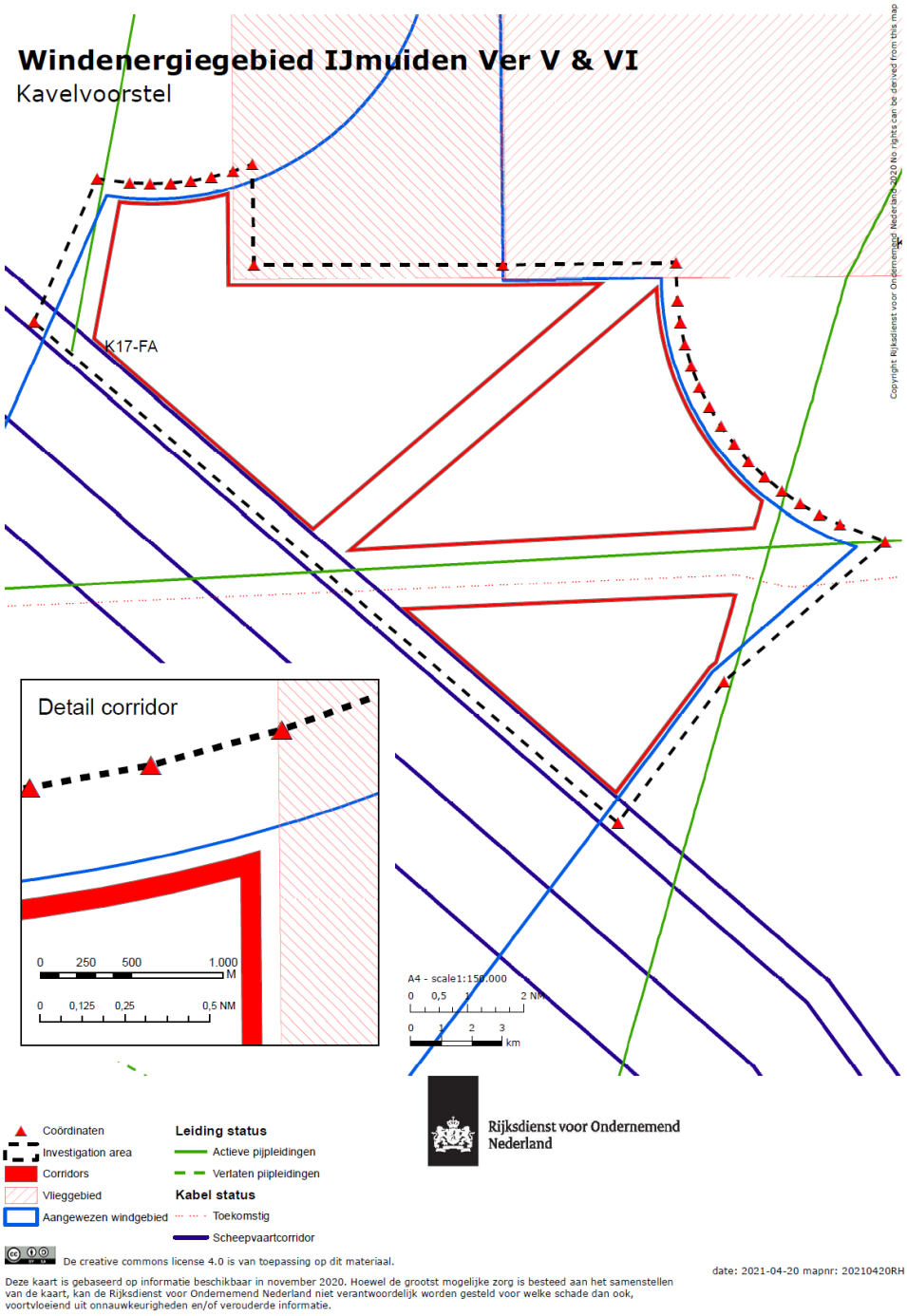

Figure 2. IA to be surveyed during the 2022 geophysical campaign at the IJVWFZ

The IA is divided in 2 sections

1) 2D survey area

This area will consist of the entire area within the Wind Farm sites 5 and 6 including the 500m zone outside the WFS boundary. Vertices are provided in Table 1. The IA overlaps the military zone to the N by 500m.

The coordinate points defining the IA are provided in Table 1 in this document. Note that Table 1 represents the IA to be surveyed to specification by the geophysical survey and includes a buffer around the Wind Farm Sites.

Table 1. Coordinates of the vertices of the outer boundary of the Investigation Area for the Geophysical Survey for the IJ56

IJVWFS coordinates of geophysical survey area		
Point No.	**Easting**	**Northing**
IAGP_10	553919,7	5863901,5
IAGP_11	534765,4	5880348,7
IAGP_12	536839,2	5885050,7
IAGP_13	537896,9	5884917,6
IAGP_14	538570,3	5884884,8
IAGP_15	539243,9	5884904,5
IAGP_16	539914,4	5884976,7
IAGP_17	540576,6	5885099,2
IAGP_18	541294,5	5885293,7
IAGP_19	541934,2	5885520,3
IAGP_20	541978,6	5882216,6
IAGP_21	550141,7	5882216,6
IAGP_22	555819,4	5882292,6
IAGP_23	555869,2	5881052,2
IAGP_24	555960,3	5880324,1
IAGP_25	556111,4	5879605,9
IAGP_26	556322,1	5878903,6
IAGP_27	556591,9	5878221,3
IAGP_28	556917,2	5877562,9
IAGP_29	557295,2	5876934,2
IAGP_30	557725,1	5876340,1
IAGP_31	558203,6	5875783,7
IAGP_32	558726,6	5875269,3
IAGP_33	559291,1	5874801,2
IAGP_34	559893,3	5874382,0

IAGP_35	560528,7	5874014,0
IAGP_36	561191,6	5873699,7
IAGP_37	562685,9	5873141,9
Coordinate system: ETRS_1989_UTM_Zone_31N		
WKID: 25831 Authority: EPSG		

2) 3D Survey area

This area consist of a 110 m wide corridor located inboard of each of the WFS boundaries, inset by 100m from the edge of wind farm sites.

The location of 3D corridor is represented in the .mpk file associated with this ITT, reproduced in red on figure 2.

1.4.1 *Coordinate reference system and datum, and project coordinates*

The project coordinate reference system, horizontal datum and vertical datum are defined in Annex 6 - section VII: Starting Points and Assumptions. The coordinate points defining the IA are provided in Table 1 in this document. Note that Table 1 represents the IA to be surveyed to specification by the geophysical survey and includes a buffer around the Wind Farm Sites.

Vertical datums for this project are Lowest Astronomical Tide (LAT) (primary, default) and mean Sea Level (MSL) (secondary). More detail is provided in section 2.3.4.

1.5 Aims of the geophysical survey

The aim of the geophysical soil investigation is to contribute to the bathymetrical, morphological and geological understanding of IJ56. The investigation is required to obtain seabed and sub-seabed information on this location. The information is required to be suitable for the planning and preparation of geotechnical investigations, and suitable for integration into a ground model of sufficient quality to progress the design and installation requirements for offshore wind farms, including, but not limited to, foundations and cables.

The investigation is expected to provide:

- An accurate bathymetric dataset
- Information describing all seabed features of significance to the construction of wind farm facilities including but not limited to:
  - Sea floor materials, their variation and morphology
  - any natural features such as boulders, scour hollows, pock-marks;
  - any non-natural features such as wrecks and debris (both known and previously unmapped), pipelines, cables and infrastructure;
- Soil and water samples for a T0 (baseline) ecological campaign to serve as a reference for changes in species composition of (mainly) soft substrate fauna that occur after the installation of a wind farm.
- Sub-Seabed datasets of sufficient quality to support construction of a ground model to at least 100 m below seabed, with resolution and signal-to-noise ratio optimised for production of an Integrated Ground Model
- A Preliminary Ground Model (PGM) of the site, including as a minimum;
  - Estimated elevation and depth below seabed of the base of mobile sediments if detectable.

  - Estimated elevation and depth below seabed for a set of interfaces between principal geological formations or other horizons of interest;
  - The locations of structural features or geohazards within the shallow geological succession including but not limited to faulting, accumulations of shallow gas, peat, buried/infilled channels, structures associated with sub-glacial processes or glaciotectonism;
  - Correlation with existing geophysical and geotechnical interpretation at IJV I-IV and elsewhere as available.
- The current position of existing (in service & out of service) cables and pipelines.
- A comprehensive interpretative report on the survey results obtained, describing the PGM; and
- A preliminary zonation of the site for input into the specification and scope for a geotechnical sampling and testing programme to follow the completion of the geophysical survey.

The output of the investigation shall be delivered in formats defined in this scope of work including digital data, Seismic Workstation and Geographic Information System project filesystems, chart data and reports.

The Geophysical Survey follows and receives information from the Geological, Archaeological and UXO Desk Studies, and it is expected to precede and supply information to a geotechnical investigation, an Integrated Ground Model (IGM, integrating the results of Geological, Geophysical and Geotechnical investigations) and a morphodynamical investigation.

It is expected that the IGM (to be developed under a separate, later commission following geotechnical data acquisition) will be a revision and significant enhancement of the PGM. It is expected to include refinement to data processing of sub-seabed data, ground-truth calibration of geophysically estimated depths, rationalisation of geotechnical and geophysical observations, refinement of the preliminary litho-stratigraphic model to include geotechnically relevant structures and the development of a 3D distribution of geotechnical parameters.

1.6 Execution of the investigation

CONTRACTOR shall take into account that arrangements on the survey plans (timing and location at the site where the survey is carried out) shall be made with other contractors working at the site and/or third parties using the space if required.

CONTRACTOR shall take into account arrangements for permits to use the survey equipment within the investigation area and shall adhere to requirements of environmental and other permits acquired by RVO.

CONTRACTOR shall interface with Ministry of Defence with regards to working in and closely to a site of the Royal Netherlands Navy including possible disturbance of data acquisition. CLIENT notified the Ministry of Defence during the tender process that survey works in the vicinity of the Defence are planned in Q2-Q3 2022.

1.7 Co-creation

The CLIENT wishes to work with and encourages the concept of co-creation in the project. This means that new working forms between CONTRACTOR and CLIENT will be explored. In this context, the following co-creation opportunities are foreseen:

- Work together as a team between RVO, RVO experts and CONTRACTOR to come to the optimum result for all parties involved;
- Development of the Preliminary Ground Model;

- Dissemination activities such as webinar and answering questions from the market;
- Development of use of 3D site surveys for offshore wind farm planning; and
- Reduction of environmental impact for survey operations.

1.8 Timing of the investigations

The data acquisition for the geophysical survey shall be carried out in Q1-Q3 2022.

1.9 Available information

1.9.1 *WFZ specific information*

CLIENT has carried out desk studies on the entire IJVWFZ including IJ56. The following desk studies are available on https://offshorewind.rvo.nl;

- Geological desk study;
- Archaeological desk study;
- UXO desk study.

Additional to above a geophysical survey within the IJVWFZ is completed for sites I-IV. Results from this survey are available at https://offshorewind.rvo.nl/.

1.9.2 *Other information*

Further, for information, the results of the geophysical and geotechnical surveys carried out for Borssele, HKZ, HKN, HKW, TNW WFZ are available at https://offshorewind.rvo.nl/. It should be noted that this scope of work deviates from those of previous investigations *and may introduce additional requirements.*

2 Scope of Work

2.1 General scope of work

2.1.1 *Activities*

The activities which are to be carried out to obtain the information detailed in section 1.5 are the following:

- **Preparation**:
  - all preparatory works required for the geophysical survey, including preparation of all plans that need to be provided (and approved) before the works can start.
  - Permit to perform survey works with the proposed equipment within the IA.
- **Data Acquisition and processing**:
  - High resolution bathymetric and backscatter survey
  - High resolution side scan sonar survey
  - Magnetometer survey
  - Shallow Penetration Sub-Bottom Profiler (SBP) survey
  - 2D Multi-Channel Ultra High-Resolution Seismic (2D-UHRS) profiling survey
  - 3D Multi-Channel Ultra High-Resolution Seismic (3D-UHRS) profiling survey
  - Seabed Sampling (ecological, box corer)
  - Seabed Sampling (geoscience, box corer or grab sampler)
  - Water sampling
  - Vibrocore Sampling
- **Data Interpretation:**
  - Produce derived products including interpretation
  - Integrate the survey elements into a Preliminary Ground Model
- **Quality Assurance and Quality Checking**
  - Apply a coherent Quality Management Plan throughout the work
- **Reporting:**
  - Create final data package with QA and metadata elements
  - present the results in clear reports and drawings.
  - Provide zonation and extents of sub-seabed geological units as guidance for design of a geotechnical investigation campaign
  - Provide input for a morphodynamical study.
  - Provide input for an archaeological study.
- **Delivery**
  - Products of the survey are to be delivered as a coherent and integrated data package with clear documentation.

This scope of work is designed to provide a minimum acceptable specification and contains important requirements throughout the document. Key requirements for survey layout are provided in sections 1.4 and 2.2.2, and for resolution of positioning and individual measurements in section 2.3.

The description of the survey aims, together with the GDS, should inform the CONTRACTOR in preparing their proposal which should clearly describe their suggested specification suitable to achieve the survey aims.

It should be recognised that the results of the survey are to be integrated with other products and made available to multiple parties as part of the information package associated with the tender process described in section 1.2. The deliverable products of the survey must allow third parties receiving the data package to evaluate,

reprocess, reinterpret or otherwise rework the data to fit the needs of their processes. To this end, it is emphasised that raw data, positioning information, reporting and metadata are important elements of the deliverable package.

2.1.2 *Deliverables*

The survey data together represent a significant array of elements which are required to be arranged in a coherent format. The specifications of raw, processed, and interpreted deliverables from individual survey elements are described within their respective sections.

Three integrated deliverables are required: a GIS project (*ESRI ArcGIS is preferred)* containing *all* processed and integrated elements that may be represented in GIS; a single seismic workstation project (*IHS Kingdom is preferred*) containing *all* the subsurface data elements, and an integrated interpretative report describing the PGM.

The contents of these integrated deliverables are to be supplemented by raw data suitable to allow reprocessing, intermediate processed data as specified for each data element, final data, interpreted data, metadata and reporting.

2.2 Preparation

2.2.1 *Scrutiny of available information*

CONTRACTOR shall scrutinise the information that has been made available by CLIENT as specified in 1.9. Information that is relevant for carrying out the WORK shall be considered while preparing the WORK.

2.2.2 *Design Requirements of the Survey Layout and Configuration*

It is anticipated that the acquisition of geophysical, hydrographic and environmental datasets may involve one or more passes across the IA. The CONTRACTOR shall select their optimum survey layout and acquisition configuration (*e.g.* single or multiple passes, single- or multi-vessel solution) to achieve the survey objectives and data quality requirements.

CONTRACTOR is required to determine an effective logistical solution with regards to the requirements of each measurement type within the IA boundary as indicated in section 1.4.

The following criteria represent layout requirements for the proposal*,* covering the entire IA:

- Multi-Beam Echo Sounder (MBES) bathymetry, Side-Scan Sonar (SSS), magnetometry (MAG), shallow penetration, high resolution Sub Bottom Profiler (SBP[1]) and 2D Multi-Channel Ultra High Resolution Seismic (2D-UHRS) are to be acquired with parallel primary lines at not greater than 70 m line spacing.
- The primary line orientation for 2D data shall be oriented at CONTRACTOR's discretion taking into account technical and quality considerations for all sensors, survey efficiency, representative tidal current speed and direction, and interfaces at the survey boundaries.
- Secondary lines (tie or cross lines) are to be within 10° of the orthogonal to the primary lines.
- Secondary lines are to be acquired at a maximum spacing of 420 m for the MBES, SSS, MAG, SBP and 2D-UHRS surveys

[1] Sub Bottom Profiler (SBP) refers in this document to systems with shallow penetration i.e. Pinger, Chirp or parametric or equivalent systems

- The maximum separation of the 2D-UHRS near-channel mid-point track and the SBP track on all lines is anticipated to be 15 m.
- Minimum length of any line or line segment shall be 500 m.
- Every line or line segment shall have at least two intersections, with intersections within 420 m of each line end
- At least 30 box-corer seabed sediment samples are to be acquired, to adequately characterise the ecology of the seafloor. These must be conserved for onshore analysis.
- At least 25 Vibrocore samples are to be acquired, to adequately sample the geological and morphological variation of the seabed.
- At least 30 water samples are to be acquired with a water sampler (e.g. Niskin Bottle, minimum 1 liter volume), filtered and stored frozen at or below -15C° for onshore eDNA analysis.
- At least 12 sediment grab samples (Box corer, Van Veen grab or similar) for seabed soil classification independent of the ecological samples.
- At least 300 km are to be surveyed outside of IJ56 with regards to nearby (within 90 km from IJ56) investigation areas with MBES, SBP and 2D-UHRS systems active. The exact locations of the link lines are to be determined after contract award.
- Two line segments totalling a maximum of 20km are to be re-occupied up to three times over the survey duration to record bathymetry data, providing information on seabed mobility analysis

The following criteria represent layout requirements for the *3D-UHRS Proposal,* covering a subset of the IA.

- 3D Multi-Channel Ultra High Resolution Seismic (3D-UHRS) data are to be acquired within a set of corridors supplied in table 2, nominally 110m wide, parallel to, and inboard of, the boundary of the IJ56 WFS. 3D-UHRS data are to be acquired on sub-parallel sail lines to deliver a minimum of 12-folddata with a bin size of ≤1.0m (inline) and ≤2.0m (cross line). For the avoidance of doubt, a 30m halo of data is included in the 110m corridor boundary, this is to be acquired to provide a target 50m wide central corridor of fully migrated data to ~60m depth.

Up to three (3) vessel(s) may be used by the CONTRACTOR to acquire the required datasets (MBES/SSS/MAG/SBP/2D-UHRS/3D-UHRS/sampling). Acceptable solutions include but are not limited to the use of the following configurations:

- One- or multiple-vessel solution each with a single pass to cover the MBES/SSS/MAG/SBP/2D-,3D-UHRS/sampling surveys concurrently.
- One- or multiple-vessel solution with multiple passes to cover the MBES/SSS/MAG/SBP/2D-,3D-UHRS/sampling surveys consecutively.

It is preferred that primary MBES/SSS/MAG/SBP data are collected from the same vessel.

It is required that MBES data are acquired, processed and delivered with both the 2D-UHRS and 3D-UHRS survey to support source and receiver height compensation in UHRS (re)processing.

Two pass or two vessel operations must deliver the results as a single, coherent body of data. All data must be referenced to a common vertical datum. Final time-domain seismic data must be corrected to a time-pseudo-datum corresponding to the vertical datum(s), all non-dipping waterbottom reflections must tie within ≤0.2 ms. Vessel specification sheets including instrumentation, settings and appropriate procedures are required to be produced, maintained and followed where multiple vessels and/or multiple personnel rosters contribute to the same measurement type.

Equipment interference must be minimised in all cases, shall be proactively monitored and reported, and shall not impact the data quality. The mitigation measures for potential sources of interference should be described in the proposal.

2.2.3 *Permits and notifications*

CONTRACTOR shall obtain and manage all necessary permissions other than the environmental exemption (underwater noise), and/or notifications, to perform the survey (including all permissions and fees necessary for access and safety arrangements to harbours and offshore positions). CLIENT shall arrange for environmental permit, on the basis of the documentation provided by the tenderers, and CONTRACTOR shall work within the requirements of this permit throughout survey activity.

Operation of an Acoustic Deterrent Device (ADD) "Pinger" during all offshore works is mandatory to CONTRACTOR. Specifications of the active sources for sub-bottom profiler devices (all sources for SBP, 2D- and 3D UHRS) shall not vary during the project from those supplied to the CLIENT for application of the ecological exemption (underwater noise). Furthermore, a soft start procedure for the sub bottom profiler devices should be in place before the start of the survey works.

CONTRACTOR shall agree with the Ministry of Defence with respect to SIMOPS and permission for CONTRACTOR to work within / on the edge of the Defence Area located directly next to the IJ56 IA. The IA overlaps the Defence Area.

The shipping lane (Scheepvaartcorridor on figure 2) will not be in force according to Rijkswaterstaat at the time of survey yet.

2.2.4 *UXO assessment and measures*

The general risk regarding the presence of UXO (unexploded ordnance) has been assessed and reported by REASeuro. Their report is to be found here: https://offshorewind.rvo.nl/obstructionsIJmuiden

CONTRACTOR shall carry out an independent UXO risk assessment for the proposed seabed sampling and vibrocore locations (that will be located on the magnetometer lines or crosslines) and undertake any required additional measures in order to reduce the risk to as low as reasonably practical (ALARP). The approach shall be described in the Project Implementation Plan.

2.2.5 *Project Plans*

CONTRACTOR shall prepare all required project plans as required by the CONTRACT. These documents (the Project Documentation) shall include planning for the execution of operations, quality management and safety management. The organisation of these elements shall be according to the CONTRACTOR's normal working practice but the planning material must include (but not be limited to) the following for every data type to be acquired:

- Project implementation plan including method statements and safe systems of work
- Quality monitors
- Mobilisation, equipment verification, parameter optimisation
- Spares inventory management

And for the general project management:

- Safety management and emergency response
- Quality management throughout the project

- Plans to interface between CONTRACTOR's offshore team, CONTRACTOR's onshore management, CLIENT's offshore representative and CLIENT's onshore team
- Interface between the project and any third parties requiring it

CONTRACTOR shall only commence the WORK when all project plans have been reviewed by CLIENT and all comments made by the CLIENT are resolved and approved.

The preparation of Project Documentation is expected to include an onshore based Technical Kick-Off Meeting (TKOM) and Hazard Identification and Risk Assessment (HIRA, refer to Annex 6 - section V HSE Requirements) as physical meetings prior to a Vessel Kick-Off Meeting (VKOM) to be held as mobilisation starts.

Offshore equipment verification and parameter testing shall be required input for finalised production procedures, to be completed after the offshore testing phase.

2.3 Data acquisition

2.3.1 *Mobilisation and demobilisation*

Mobilisation of the vessel(s) to the site will be considered completed when all necessary survey and Project Documentation, equipment, critical spares and personnel are accepted as operational to the specification agreed by the CLIENT and approved by the CLIENT. Verification of performance shall be made according to an agreed plan with all required testing and calibration of vessel and equipment (defined during TKOM) documented and signed off (this is regarded as part of the mobilisation).

Where the final configuration of any survey equipment is not pre-defined in plans, (*e.g. where on-site configuration or optimisation is required)* ALL deployed options and spares are to be verified as operational during the mobilisation phase.

The harbour to be used for mobilisation of survey vessel(s), equipment and personnel is chosen by the CONTRACTOR with approval of the CLIENT.

Demobilisation of the vessel will be authorised when all the data required have been acquired and have passed field QAQC criteria to the satisfaction of the CLIENTS offshore representative.

2.3.1.1 Lost Equipment

CONTRACTOR shall be responsible at his own cost for the marking the location and recovery of equipment dropped or lost during the execution of the project. CONTRACTOR shall mark the positions of equipment on or below the seabed with marker buoys if necessary and recover the equipment at the earliest possible opportunity. All equipment shall be removed to a reference level which is the trough of mobile sand waves in the area.

2.3.2 *Testing*

Following mobilisation, a testing phase shall be implemented to establish the appropriate configuration and parameterisation of data acquisition equipment and finalisation of the survey QA parameters. Where data processing operations are critical to either in-field QA/QC or evaluation of the suitability of the data acquisition configuration, design and parameterisation of these operations shall be part of the testing phase. A testing programme shall be agreed as part of the planning phase, and should include the collection of data properly representative of the range of ground conditions at the site. Provision shall be made for tests to be evaluated by both OCR and onshore client personnel. One CLIENT representative may be deployed offshore on each vessel during testing to facilitate optimisation and approval – suitable

accommodation and messing shall be provided. If a port call is required to allow disembarkation of the CR, this shall be arranged to coincide with a planned port call at no charge, or a rate for a port call with no other purpose for CONTRACTOR specified in the proposal.

Acceptance by CLIENT of data acquisition configuration is expected to take place as soon as possible after mobilisation and testing. Production data acquired prior to acceptance of the data acquisition configuration is acquired at the CONTRACTOR'S risk, shall be subject to rigorous QC and may be rejected by the CLIENT offshore representative with no opportunity for CONTRACTOR to claim for compensation.

A draft mobilisation, calibration and testing report is to be provided within two calendar weeks of acceptance of the data acquisition configuration. This report is to be included as an appendix to the Operations Report.

2.3.3 *Positioning*

Navigational accuracy, tidal height accuracy, frequency and method of navigation checks and positioning specifications shall be stated in project documentation. Navigation checks and positioning calibrations shall be completed prior to leaving harbour at mobilisation. The combined precision and accuracy of the navigational positioning capability and post-processing methods must be sufficient to allow horizontal positions of moving survey hardware to be determined to within ±1 m, with height values within ±0.1 m. Static measurements shall have DGPS positioning to ±0.1m in all 3 dimensions. Equipment must be positioned using DGPS (or better) for surface and DGPS (or better) and USBL for subsurface gear.

USBL system accuracy: ≤0.5 % of Slant Range

Accurate positioning is essential. Coverage requirements dictate the course of MBES and SSS data acquisition, while pre-plot line-plans are the primary target for positioning of MAG, SBP and UHRS data acquisition. Where seismic data are intended to be co-located an achievable positioning tolerance is to be agreed with the CLIENT, prior to the acquisition of production data. Co-location is defined as a common track of the reflection point at the seabed (near channel reflection point for UHRS).

For seabed sampling or vibrocore location, a CTD probe profile or equivalent CLIENT approved methods is established to determine at least the water depth and the water temperature at seafloor.

The exact position of the measurements must be recorded with an acoustic tracking system such as a USBL, giving the position of the equipment underwater relative to the vessel surface position.

The acoustic underwater positioning system must be used to provide X, Y and Z offset to all seabed deployed systems. The offset to each sensor is used in real time to provide an absolute position coordinate and logged together with all raw data relative to a common DGPS time base.

The CONTRACTOR must calibrate the system(s) in the work area or at similar water depth and demonstrate the validity of the calibration procedures prior to initiating survey work.

All measurements should be positioned within a 5 m radius of the target coordinates. If re-positioning is required, the seabed frame should be positioned as close to the target coordinates as possible. If an obstruction is encountered on the seabed or the seabed slope exceeds 5-10 degrees (depending on availability of a levelling system),

the seabed investigation shall be re-positioned to avoid the obstruction or excess slope whilst keeping the CPT location as close to the target co-ordinates as possible.

Repositioning is to be confirmed and approved by the CLIENT OFFSHORE REPRESENTATIVE.

2.3.4 *High Resolution Bathymetric Survey*

The objective of the High-Resolution Bathymetry (HRB) Survey is to contribute to the model of the seabed including:

- seabed elevations / depths relative to LAT and MSL;
- identification and mapping of static and potentially mobile bedforms;
- identification and mapping of potential hazards to the development of offshore wind farm infrastructure at the site;
- identification and mapping of natural and anthropogenic seabed features and objects;
- classification and mapping of sea-bed sediments.

Required elements

The HRB Survey must include:

- Survey wide bathymetric measurement
- Tie lines to IJV I-IV
- Repeat measurements on up to two transects, up to additional three passes
- Sound velocity measurement (real time at receiver and min. 2 daily vertical profiling)
- Backscatter strength measurement for input to AGDS analysis

Specifications

Acquisition of high-resolution bathymetric data using a Multi-Beam Echo Sounder (MBES) with at least 100% coverage of the IA.

Data will be acquired to exceed IHO Standard S-44 Edition 6[2] Special Order standard according to specifications issued by the International Hydrographic Association (IHO). The system shall be capable of providing a minimum of 9 soundings per 0.5x0.5 m cell when deployed on-site. The CONTRACTOR shall define the technology and line spacing employed to meet these requirements based on existing water depth information. Compliance with IHO Standard S-44 Edition 6 Special Order uncertainty thresholds must be demonstrated in the Field report.

Matrix Code: Ba9, Bc10, Bd8, Be6, Bg9, Bh9 + 9 Pings/0.5x0.5m.

MBES data must be recorded with optimised (preferred are consistent) settings for backscatter and bathymetrical analyses of the seafloor. Guidance on best practice and optimised settings for backscatter surveys can be found in the GEOHAB backscatter report[3].

The bathymetry data forms a baseline for the anticipated morphodynamical study. To support this work, repeat occupation of up to two suitable line segments with a maximum total line length of 20 km is required, at the beginning and end of the geophysical survey period and up to two additional passes, one to be saved for acquisition immediately following any significant storm event. The location of the line segments is to be confirmed at the TKOM.

[2] https://iho.int/uploads/user/pubs/Drafts/S-44_Edition_6.0.0-Final.pdf

[3] Lurton, X.; Lamarche, G. (Eds) (2015) Backscatter measurements by seafloor-mapping sonars. Guidelines and Recommendations. 200p. http://geohab.org/wp-content/uploads/2014/05/BSWGREPORT-MAY2015.pdf

Guidance

The system should incorporate a sound velocity probe to monitor the speed of sound in water in real time at the receiver to provide a constant comparison against a vertical Sound Velocity Profile (SVP) through the entire water column. The sound velocity probe incorporated into the MBES system should have an accuracy of better than ±0.15 m/s.

Vertical SVPs to measure the speed of sound in water should be obtained in the survey area at regular intervals. It is recommended that SVPs are obtained at the start and end of each day, and initially at low and high tides. SVP acquisition intervals may be increased with the agreement of the CLIENT's OFFSHORE REPRESENTATIVE. Measurements should be made using a calibrated velocimeter or calculated using temperature and salinity measurements, to create a static vertical SVP. Measurements should be taken continuously between the sea surface and the seabed in a vertical profile.

Reported water depths from MBES must be sound velocity corrected and reduced to LAT by applying the latest LAT model for the Dutch North Sea (NLLAT18[4]). Bathymetry relative to MSL shall be derived *from* the LAT referenced data, for MSL reduction the latest DTU21[5] Mean Sea Level model shall be used. The methods for reduction shall be comprehensively explained in detail in the project plan and the final report.

Backscatter/snippets data from seabed returns should be logged and processed for use in seabed characterisation using an AGDS together with side-scan sonar and sample data as appropriate. AGDS analysis should be carried out by an experienced AGDS analyst who is demonstrably familiar with the specific AGDS used. The methods for AGDS shall be comprehensively described in detail in the project plan and the final report.

The geological desk study suggests that little pre-existing seabed and shallow borehole data usable for AGDS calibration are available. Seabed sample acquisition and Vibrocore sampling is required during this survey campaign (section 2.3.7). If possible, relative correlation with the IJV I-IV data should be made.

Data Processing

Data shall be reduced to datum, then gridded to produce a raster Digital Terrain Model (DTM) of the seabed at 0.5 x 0.5 m resolution or better. Grids at 1.0 x 1.0 m and 0.5 x 0.5 m are required.

The reduction method and vertical and horizontal datums used must be compliant with Section 2.3.4, 2.3.5 and IHO standards and guidance (IHO, 2005[6]; IHO, 2020[7]). Details of the vertical reduction process (MSL and LAT)must be included in the Operations Report and demonstrated to meet or exceed the requirements of the specified standards and guidelines, using appropriate illustrations.

Full QA/QC must be carried out in order to generate statistical proof that the survey meets the requirements. A statistical description of Total Horizontal Uncertainty (THU) and Total Vertical Uncertainty (TVU) must be generated with the resulting values being demonstrated to meet or exceed the 'Special Order' minimum requirements described in the IHO Standard S-44 Edition 6. A quantitative assessment of the feature

[4] https://english.defensie.nl/downloads/applications/2020/06/12/nllat2018

[5] https://ftp.space.dtu.dk/pub/DTU21/ Please note that DTU is in the TOPEX and mean tide system for use with satellites. DTU21 needs to be updated to ETRS89 ellipsoid and Tide Free system for consistency.

[6] IHO. 2005. Manual on Hydrography (C-13). International Hydrographic Bureau, Monaco, 1st ed. (corrections to February 2011), 36 pp.

[7] IHO. 2020. IHO Standards for hydrographic surveys (S-44). IHO Publications No. 44. International Hydrographic Bureau, Monaco, 6th ed., 49 pp

detection thresholds for the survey must also be included and demonstrated to meet or exceed the Special Order minimum requirements.

Interpretation

MBES Contact picking should be carried out based on gridded data or point cloud data to support the interpretation of SSS Contacts.

MBES Contacts must be identified and should be listed separately in a spreadsheet, along with a description of the Contact length, width and depth/height where appropriate.

Contacts must be classified *at minimum* into the following categories:

- Wreck-associated, correlated to local wreck registers, if available, and associated magnetometer/SSS Contacts;
- Debris-associated, correlated to associated magnetometer/SSS Contacts;
- Possible pipeline (with appropriate ID to indicate where multiple Contacts are thought to be associated with the same pipeline);
- Possible cable (with appropriate ID to indicate where multiple Contacts are thought to be associated with the same cable);
- Mound;
- Depression.

Deliverables

The following deliverables including their metadata are required at minimum:

Table 2: MBES deliverables

Item ID	Measurement	Module R = Raw P = Processing I = Interpretation	Description	Resolution	Format	Load into GIS-database
1	MBES	R	MBES output files	n/a	Ascii+prj	N
2		P	Despiked, cleaned, positioning corrected soundings as x,y,z, per line, full density		Ascii+prj	N
3			Despiked, cleaned, positioning corrected MBES backscatter data as x,y,z, per line, full density		Ascii+prj	N
4			Subset of 2 for repeat lines		Ascii+prj	N
5			Subset of 3 for repeat lines		Ascii+prj	N
6			Speed of sound in seawater vertical dip data profiles	n/a	.xlsx, Ascii+prj	N
7			MBES tracks (navigation) data, Survey line ID and fix point index	n/a	.gdb, Ascii+prj	Y
8			Gridded bathymetry, relative to LAT	0.5 m	Ascii+prj	N
9			Gridded bathymetry, relative to MSL	0.5 m	Ascii+prj	N
10			Gridded bathymetry, relative to LAT	0.5 m	Geotiff	Y
11			Gridded bathymetry, relative to MSL	0.5 m	Geotiff	Y
12			Gridded bathymetry, relative to LAT	1.0 m	Ascii+prj	N
13			Gridded bathymetry, relative to MSL	1.0 m	Ascii+prj	N
14			Gridded bathymetry, relative to LAT	1.0 m	Geotiff	Y
15			Gridded bathymetry, relative to MSL	1.0 m	Geotiff	Y
16			Height adjusted gridded bathymetry relative to LAT	1.0 m	.gdb	Y
17			Tile map index [polygon]	n/a	.gdb	Y
18			Total Vertical Uncertainty (TVU) gridded XYZ	0.5 m	Ascii+prj	N

19			Total Horizontal Uncertainty (THU) gridded XYZ	0.5 m	Ascii+prj	N
20			Total Vertical Uncertainty (TVU) raster	0.5 m	Geotiff	Y
21			Total Horizontal Uncertainty (THU) raster	0.5 m	Geotiff	Y
22			Bathymetric contours, typically 1 m interval.	n/a	.gdb	Y
23			Backscatter data, gridded xyz	1.0 m	Ascii+prj	N
24			Backscatter data, geo-referenced raster	1.0 m	Geotiff	Y
45			Bathymetry slope in degrees, xyz	0.5 m	Ascii+prj	N
26			Bathymetry slope in degrees Georeferenced raster	0.5 m	Geotiff	Y
27			time-stamp indexed text file of tidal correction	1 minute	.txt	N
28		**I**	MBES Contact list	n/a	.xlsx	N
29			MBES Contact list [pnt]	n/a	.gdb	Y

Notes on MBES deliverables

Raw:

- Raw output files from the MBES instrument are required.

Processed:

- MBES backscatter data, in a standard format to be agreed.
- MBES trackplot (fix point and line).
- The bathymetry at a resolution of 0.5 x 0.5 m or better reduced to datums and produced by gridding the swath bathymetry data to a regular grid, as a single or tiled set of xyz text files (*.xyz/*.pts) without overlaps together with projection information saved in a .prj file; ***and*** a single or tiled raster/grid without overlaps.
- Bathymetry contours at an appropriate interval for the topographic complexity, the grid vertical accuracy/precision and the depth range (typically 1 m).
- MBES backscatter image at an appropriate resolution, produced by gridding the swath bathymetry backscatter data to a regular grid, as: a single or tiled set of xyz text files (*.xyz/*.pts) without overlaps together with projection information saved in a .prj file; ***and*** a single or tiled raster/grid without overlaps.
- Bathymetry Total Vertical Uncertainty (TVU) and Total Horizontal Uncertainty (THU) grids at an appropriate resolution, as: a single or tiled set of xyz text files (*.xyz/*.pts) without overlaps together with projection information saved in a .prj file; ***and*** a single or tiled raster/grid without overlaps.
- Height adjusted bathymetry grid to remove survey artefacts of overlapping and crossing survey lines. This grid shall **NOT** be used for any depth related analyses but for **surface analyses only**.
- The bathymetry slope in degrees calculated from the height adjusted bathymetry grid as a single or tiled set of xyz text files (*.xyz/*.pts) without overlaps together with projection information saved in a .prj file; ***and*** a single or tiled raster/grid without overlaps.
- A time-stamp indexed text file of the tidal correction.
- Interpreted:
- Multi Beam Echo Sounder data series should have a Contact table and associated point, line and polygon spatial data files with columns for:
    - unique ID;
    - Contact classification (wreck, boulder, debris, *etc.*);
    - X co-ordinate (centre);
    - Y co-ordinate (centre);
    - dimension(s);
    - short description;
    - where relevant, associated wreck number or cable/pipeline ID

and columns as appropriate to relate the Unique Contact ID where multiple sensors have apparently detected the same feature.

- All raster deliverables for single-variable data should be supplied as single-band files with actual cell values (e.g. elevation, intensity). If provided in a non-ESRI GIS format (*e.g.* CAD, microstation), all processed deliverables listed above must be provided additionally in the project GIS archive.

2.3.5 *High resolution side scan sonar survey*

The objective of the Side Scan Sonar (SSS) Survey is to contribute to the model of the seabed including:

- identification and mapping of potentially mobile bedforms;
- identification and mapping of potential hazards or influences to the development of offshore wind farm infrastructure at the site;
- identification and mapping of natural and anthropogenic seabed features and objects;
- classification and mapping of seabed sediments.

The Side Scan Sonar survey should be run simultaneously with MBES acquisition.

Required elements

The SSS Survey must include:

- survey-wide continuous (≥200%) Side Scan Sonar measurement
- mosaic produced at no greater than 0.5 x 0.5 m grid pitch

Required Specifications

The SSS survey should be carried out using simultaneous multiple channel, multiple frequency side scan sonar with at least two frequencies of ≥100 kHz and ≥600 kHz.

The line spacing should be defined to ensure that the SSS survey shall provide at least 200% coverage of the IA with frequency sufficient to resolve all objects of 0.5 x 0.5 x 0.5 m or larger, including sufficient overlap to obtain data at the nadir (the area between port and starboard scans, beneath the SSS instrument).

Instrument gain should be managed to allow SSS data to contribute optimally to the seabed classification operations.

Evaluation of proposals will be made with reference to the following method preferences:

The side-scan sonar tow fish should be towed at the optimum altitude for the water depth encountered. The towing altitude is normally expected to be between 8% and 15% of the selected sonar range. The slant range used should be set to yield >100% coverage of the survey area with ≥600 kHz data and with line spacings set to provide enough lateral overlap that the nadir of each line is covered by the range of at least one adjacent line. No blank nadir is to appear in the mosaic. Proposals that exploit instrumentation which eliminates a nadir gap without requiring overlap, while maintaining or improving object detection performance, are encouraged.

Scale ranges, depth of tow and tow speed should be determined on site to attain optimum resolution and area coverage.

Guidance

Interference in the SSS data from other equipment (*e.g*. seismic or magnetometer altimeter) should be minimised and should not impact on the SSS data quality and

interpretability. Seabed features should be correlated with seabed samples and any other visual observations where provided by the CLIENT.

Proposals involving innovative SSS instrumentation, which meet the baseline specification, are encouraged.

Data Processing

Data shall be corrected for slant range, towfish skew, absorption of sound by seawater, geometric spreading and ship speed to produce the SSS mosaic. The bathymetry elevation data should be used for topographic corrections such that the corrections are carried out based on 3D positioning. The data should be mosaicked to 0.5 x 0.5 m or better and the nadir gap should not appear in the final mosaic.

Interpretation

SSS Contact picking must be carried out. SSS contacts should be picked on scan plots and referenced to accurately positioned MBES features where possible. The inspection should target the features *at minimum*:

1. Wrecks;
2. Both linear and point debris ≥ 0.5 m;
3. Locations of Boulders ≥ 0.5 m, or perimeters of boulder fields where number density is > 20 per 100x100 m area.
4. Boulders or other seabed objects ≥ 1.0 m with measured length, width and height
5. Pock-marks/depressions
6. Gas plumes;
7. Cables;
8. Pipelines; and
9. Trawl scars and regions of trawl scars

Where a class of Contact feature is not detected within the IA, reporting of the search for and conclusions of the absence of such features is required.

The thresholds indicated are nominal, and a higher threshold and/or mapping of discrete areas of anomalously high Contact density may be appropriate if feature densities are high, subject to approval by the CLIENT. Proposed identification thresholds should be indicated within the CONTRACTOR's Project Documentation for approval by the CLIENT.

Deliverables

The following deliverables and their metadata are required at minimum:

Table 3: SSS deliverables

Item ID	Measurement	Module R = Raw P = Processing I = Interpretation	Description	Resolution	Format	Load into GIS-database
30	**SSS**	**R**	Raw XTF, nav corrected - High Frequency	n/a	.xtf	N
31			Raw XTF, nav corrected - Low Frequency	n/a	.xtf	N
32		**P**	SSS tracks (navigation - xyz) data, Survey line ID included as attribute	n/a	.gdb	Y
33			SSS tracks (navigation - xyz) data, fix point included as attribute	n/a	.gdb	Y
34			High frequency processed sidescan data, geo-referenced Mosaic tiles	0.5 m	Geotiff	Y
35			Low frequency processed sidescan data, geo-	0.5 m	Geotiff	Y

Table 3: SSS deliverables						
Item ID	**Measurement**	**Module R = Raw P = Processing I = Interpretation**	**Description**	**Resolution**	**Format**	**Load into GIS-database**
			referenced Mosaic tiles			
36			Tile index	n/a	.gdb	Y
37			SSS Contact list	n/a	.xlsx	N
38			SSS Contact list [pnt]	n/a	.gdb	Y
39			SSS Contact list [lin]	n/a	.gdb	Y
40			SSS linear features (scars, sandwave crests etc) [lin]	n/a	.gdb	Y
41		**I**	SSS area features (boulder fields, bedform classification, trawl scars etc) [pgn]	n/a	.gdb	Y
42			Sidescan sonar contact report containing information and images	n/a	.docx	N
43			Sidescan sonar contact report containing information and images	n/a	.pdf	N
44			Sidescan sonar contact images	0.5 m	.gdb	Y

Notes on Sidescan Sonar deliverables

Raw:

- Side-Scan Sonar data in the form of raw, un-mosaiced data files (*e.g.* *.xtf files)

Processed:

- SSS trackplot (fix point and line).
- Single or tiled Side-Scan Sonar mosaic at 0.5 m cell size without overlaps in raster format (*e.g.* *.tif).

Interpreted:

- Side-Scan Sonar data series should have a Contact table and associated point, line and polygon spatial data files with columns for:
    - unique ID;
    - Contact classification (wreck, boulder, debris, *etc.*);
    - X co-ordinate (centre);
    - Y co-ordinate (centre);
    - dimensions for object with dimension >1m;
    - short description;
    - where relevant, associated wreck number or cable/pipeline ID;

  and columns as appropriate to relate the Unique Contact ID where multiple sensors have apparently detected the same feature.
- Comprehensive Side Scan Sonar contact report containing information and waterfall images for all identified SSS Contacts in Microsoft Word and Adobe pdf formats.

2.3.6 *Ecological Sampling– box corer*

The objective of the box corer sampling campaign is to collect data to define an ecological T0 (baseline) situation to support an ongoing ecological study.

Locations of the ecological sampling shall be within 10m radius of the seabed sampling locations where coincident samples are specified.

At least 30 box corer samples shall be collected to provide sample material for ecological analyses. Additional samples acquired shall be priced at a rate equal or less than the rate provided in Annex 4.

No ecological laboratory analyses are requested in this tender. Delivery of samples, under suitable conditions to conserve sample integrity, to a recipient within the Netherlands shall be included in the costs of proposal.

The samples shall be distributed to adequately sample the anticipated distribution of seabed sediments and seabed morphology indicated by the geological desk study. A sample location plan shall be proposed by CONTRACTOR and agreed by CLIENT.

Required Elements

The ecological sampling survey must include:

- 30 box corer sediment samples from sites > 1 km apart;
- USBL positioning of box corer;
- Preliminary field analysis;
- Photographic documentation;
- 30 push cores, 100mm diameter, full depth of the box core sample;
- Preparation and sieving of sample at 1mm mesh size;
- Sample conservation, storage and delivery to onshore analysis facility.

Specification

A field evaluation is required to be reported on a field log in an appropriate format for use in geological, chemical and biological investigations.

The box corer shall be designed to extract core with a minimum upper surface area of 0.078m^2, and cores are required to have at least 15cm recovery and if requested by CLIENT REPRESENTATIVE, CONTRACTOR shall undertake a maximum of one (1) re-test per location at no cost to CLIENT. If the re-test recovers less than 15cm it shall be retained for analysis and documented as a low-recovery sample. Samples are to be conserved and stored for onshore analysis using appropriate protocols to be proposed by CONTRACTOR and approved by CLIENT.

Guidance

The preferred sampling equipment is a Reineck box corer. Similar box corer devices with a sample upper-surface-area of ≥0.078m^2 can be proposed by CONTRACTOR and must be approved by CLIENT.

Operation of the box corer must follow the Mapping European Seabed Habitats (MESH) guidelines for operating a box corer[8].

Excess water on the sample within the box corer needs to be carefully removed with a hose before further samples can be taken. Sample logging shall be performed immediately after a sample has been retrieved, by a qualified CONTRACTOR's geologist, and photographed. Each recovered sample shall be photographed with quality, focus, colour and resolution adequate to resolve millimetre scale features.

Prior to sieving the sample to extract ecological sample material, an appropriate push core liner with a diameter of 100mm must sample the box corer sample to its full depth for grain size analyses. Documentation of grain size sub-sampling must include the geographic position, water depth relative to LAT, time and date, sample identification number.

[8] Hopkins, A. (2007). Recommended Operating Guidelines (ROG) for box coring. MESH Guidance document https://webarchive.nationalarchives.gov.uk/ukgwa/20101014084857/http:/www.searchmesh.net/PDF/GMHM3_Box_Coring_ROG.pdf

All onshore laboratory testing of the push cores shall be carried out at an approved geotechnical laboratory. Grain size distribution analyses shall follow EN ISO 17892-4. All soil testing shall be carried out, where applicable, respectively to Eurocode EN 1997-2, ISO 19901-8, or CLIENT approved equivalent.

Preparation of the ecological sample shall be documented and follow proper biological sampling practice. CONTRACTOR shall propose a suitable, systematic protocol. The following steps indicate the general method anticipated:

1. After retrieval of the box core, the immediately visible biology (Hydrozoa (hydropolises), Anthozoa (anemones) and Nudibranchia (nudibranchs), abbreviated HAN,) shall be removed from the residue and placed in the sample container.
2. The remaining box corer sample must be sieved (1mm mesh size) to separate (most) sediments from the ecological sample in the sieve, which is transferred to the sample container.
3. The ecological sample is fixed with 4-6% formaldehyde on seawater, buffered with an excess of borax. The ecological sample is sealed, labelled with a specific location code and stored at temperature similar to that at the seabed.

Documentation of ecological sample must include the geographic position, water depth in LAT, time and date, sample identification number.

Deliverables

The following deliverables and their metadata are required at minimum:

Table 4: Ecological Sampling – Box Corer Sampling deliverables

Item ID	Measurement	Module S = samples A = Analyses	Description	Resolution	Format	Load into GIS-database
45	**Sampling**	**S**	Conserved Sample material	n/a	n/a	N
46		**S**	Sample Photographs	n/a	.jpg	N
47		**S**	Technical Note including Sampling protocol	n/a	n/a	N
48		**S**	Sample location with Sample protocol information	n/a	.gbd	Y

2.3.7 *Ecological Sampling – Water sampling*

The objective of the water sampling campaign is to collect data for environmental DNA analyses to allow for defining a T0 (baseline) situation for long term environmental site studies.

Required Elements

- 30 water samples (one at each box corer sample site, minimum 1 liter)
- Sample conservation and frozen storage at or below -15°C
- USBL positioning of sample location

Specification

A field evaluation is required to be reported on a field log in an appropriate format for use in chemical and biological investigations.

Water sampling device shall be a sterile Niskin Water Sampler with a sampling volume of min. 1 Liter. Similar sampling devices can be proposed by CONTRACTOR and must be approved by CLIENT.

Guidance

Water samples shall be taken together with box corers or sequentially at the same geographic location. The sterile Niskin Bottle shall be closed at 2-5m altitude above the seafloor.

Water depth in LAT, altitude, location, date and time must be documented for each sample as a minimum.

A water sample of at least 1 liter must be filtered through a sterile specially designed funnel filters with 1µm mesh size. The filter must then be fixed using molecular-grade ethanol and freezer (< -15°C) and covered against the influence of light. Interruption of cold chain during sample transport, storage and handling must be avoided.

Special emphasis lies on contamination avoidance. CONTRACTOR shall propose appropriate work flows to minimize sample contamination.

Deliverables

The following deliverables and their metadata are required at minimum:

Table 5: Ecological Sampling – Water Sampling deliverables

Item ID	Measurement	Module S = samples	Description	Resolution	Format	Load into GIS-database
49	**Sampling**	**S**	Conserved Sample material	n/a	n/a	N
50		**S**	Technical note including Sampling protocol	n/a	n/a	N
51		**S**	Sample locations with sample protocol information	n/a	.gdb	Y

2.3.8 *Seabed Sampling*

The objective of the seabed sediments sampling campaign is to collect grain size data to calibrate AGDS interpretation, and to inform the seabed mobility.

A field evaluation is required to be reported on a field log in an appropriate format for use in geological, chemical and biological investigations.

Samples are to be conserved and stored for onshore analysis using appropriate protocols to be proposed by CONTRACTOR and approved by CLIENT.

Required Elements

- Twelve (12) seabed sediment samples
- Preliminary field analysis
- Sample conservation and storage
- Onshore analysis of sediment composition and grain size distribution
- USBL positioning

Specification

Twelve (12) seabed sediment samples shall be collected to provide ground-truth for the seabed classification data. Additional samples acquired shall be priced at a rate equal or less than the rate provided in Annex 4.

The samples shall be distributed to adequately sample the anticipated distribution of seabed sediments and seabed morphology indicated by the geological desk study. A sample location plan shall be proposed by CONTRACTOR and agreed by CLIENT.

Locations of the seabed sampling shall be within 10m radius of the ecological sampling locations where coincident samples are specified.

Guidance

Recovery of Samples and offshore sample handling Sampling equipment should be a box corer, van Veen grab or similar grab sampling device for sampling only the surface layer (if a box corer is used, the upper surface should be extracted). Sample logging immediately after a sample has been retrieved by a qualified CONTRACTOR's geologist, and photographed. The soil description shall follow EN ISO 14688.

Each recovered sample shall be photographed with quality, focus, colour and resolution adequate to resolve millimetre scale features. Sub-samples are to be labeled in an adequate manner and stored for onshore laboratory testing. Documentation of sampling must include the geographic position, water depth in LAT, time and date, sample identification number.

Laboratory testing

All onshore laboratory testing shall be carried out at an approved geotechnical laboratory. Grain size distribution analyses shall follow EN ISO 17892-4. All soil testing shall be carried out, where applicable, respectively to Eurocode EN 1997-2, ISO 19901-8, or CLIENT approved equivalent.

All test data shall be presented in ASCII format for easy manipulation, data transfer, and integration. The CONTRACTOR is to ship all recovered samples and cores to the onshore laboratory, and after testing transfer to storage facilities to be agreed with CLIENT.

The following deliverables and their metadata are required at minimum:

Table 6: Seabed Sampling deliverables

Item ID	Measurement	Module S = samples A = Analyses	Description	Resolution	Format	Load into GIS-database
52	**Sampling**	**S**	Conserved Sample material	n/a	n/a	N
53		**A**	Sample Photographs	n/a	.jpg	N
54			Sample locations with test results	n/a	.gdb	Y

55			Field Report	n/a	.pdf	N
56			Laboratory test results	n/a	ascii	N
57			Laboratory test report	n/a	.pdf	N

Description of the requirements for reporting and charting is provided in section 2.6

2.3.9 *Vibrocore Sampling*

The objective of vibrocore sampling during the geophysical campaign is to provide ground truth for seabed classification, and to enable a detailed assessment ofsoils, within bedforms and static areas, to support the morphodynamical study to be performed under a separate contract.
25 Vibrocore sediment samples shall be collected. Additional samples acquired shall be priced at a rate equal or less than the rate provided in Annex 4.

Required Elements

The Vibrocore sampling survey must include:

- 25 vibrocore samples from sites
- USBL supported positioning within a 2m radius of the selected site
- Preliminary field analysis
- Sample conservation and storage
- At least 3 meter and maximum 6 meter penetration depth
- Inner diameter should be 100 mm *
- The filled core liner is to be cut in to one meter long segments, described and tested at top/bottom, capped, sealed, labelled, preserved and stored for on shore testing.
- Field tests at the base of each core liner segment shall contain the following:
  - Natural water (moisture) content
  - Bulk density
  - Index strength tests in cohesive soils (torvane and pocket penetrometer)

* smaller diameters (e.g. 86 mm) are permitted if the CONTRACTOR ensures an equivalent quality of the recovered material when compared to the 100 mm system.

Specification

A field evaluation is required to be reported on a field log in an appropriate format for use in geological, chemical and biological investigations.

A minimum of three (3) m recovery is required per location and if requested by CLIENT REPRESENTATIVE, CONTRACTOR shall undertake a maximum of one (1) re-test per location at no cost to CLIENT.

Samples are to be conserved and stored for onshore analysis using appropriate protocols to be proposed by CONTRACTOR and approved by CLIENT.

Guidance

Sample acquisition

Up to three (3) sand waves may be identified as representative in consultation with CLIENT. Per selected sand wave, a group of 5 measurements will be performed (one on the crest, one on the trough and three on the side slopes). These 5 measurements will be aligned perpendicular to the sand wave crest and be performed with a spacing of the order of 75m. The vibrocore equipment shall be designed to achieve a maximum penetration depth of 6 m.

At least 10 additional VCs will be required to sample the shallow geology independent of bedform studies.

Sample locations shall be mutually agreed between CONTRACTOR and CLIENT informed by pre-existing and newly acquired geophysical results.

The CONTRACTOR is to ship all recovered samples and cores to the onshore laboratory, and after testing package appropriately for conservation and transfer to storage facilities to be agreed with CLIENT.

Laboratory testing

All onshore laboratory testing shall be carried out at an approved geotechnical laboratory. Grain size distribution analyses shall follow EN ISO 17892-4. All soil testing shall be carried out, where applicable, respectively to Eurocode EN 1997-2, ISO 19901-8, or CLIENT approved equivalent as and where applicable.

All test data shall be presented in ASCII format for easy manipulation, data transfer, and integration.

CONTRACTOR shall be required to demonstrate a system to prove that every sample is photographed during analysis onshore to a standard to be accepted by CLIENT and recorded on to hard storage media. Examples shall be provided to nominated CLIENT expert CLIENT for approval prior to photography commencing.

As a general guideline, the following types of tests will normally be required for the different material types expected. The testing programme shall be proposed by CONTRACTOR and approved by CLIENT.

Granular Soil

- Natural water (moisture) content
- Bulk density
- Particle density
- Carbonate tests
- Particle size analysis (sieve)
- Particle size analysis (using sieve and pipette method for fines fraction)
- Organic tests (dichromate)
- Organic tests (loss on ignition)
- Total Carbon (dry air combustion)
- Determination of thermal conductivity and specific heat capacity (needle probes)
- Determination of thermal conductivity and specific heat capacity (hot disc method)
- Electrical resistivity
- Pore water salinity
- Shear Box tests
- Microscopic photography

Cohesive Soil

- Natural water (moisture) content
- Bulk density
- Particle density
- Particle size analysis (using pipette method for fines and if applicable sieve)
- Atterberg limits (plastic and liquid limits, fall cone test)
- Organic tests (dichromate)
- Organic content (loss on ignition)
- Total carbon content (dry air combustion)
- Unconsolidated undrained (UU) triaxial compression tests on undisturbed and remoulded samples
- Determination of permeability and porosity
- Determination of thermal conductivity and specific heat capacity (needle probes) (on undisturbed and remoulded samples)
- Electrical resistivity

- Pore water salinity
- Microscopic photography

Deliverables

The following deliverables and their metadata are required at minimum:

Table 7: Seabed Sampling deliverables

Item ID	Measurement	Module S = samples A = Analyses	Description	Resolution	Format	Load into GIS-database
58	**Sampling**	**S**	Conserved Sample material	n/a	n/a	N
59		**A**	Sample Photographs	n/a	.jpg	N
60			Core logging	n/a	.pdf	N
61			Sample locations	n/a	.gdb	Y
62			Field Report	n/a	.pdf	N
63			Laboratory Test Results	n/a	ascii	N
64			Laboratory test report	n/a	.pdf	N

Description of the requirements for reporting and charting is provided in section 2.6

2.3.10 *Magnetometry survey*

The objective of the Magnetometry (MAG) Survey is to contribute to the model of the seabed including:

- identification and mapping of natural and anthropogenic seabed features and objects;

The primary purpose of this survey will be the identification/confirmation of the positions of all pipelines and possibly electrical and communications cables. It is acknowledged that a magnetometer survey along widely spaced lines will not be suitable for a comprehensive UXO survey. However sampling, coring and later geotechnical investigations may use the magnetometry data for UXO clearance in restricted area proximal to the sensor track. Therefore signal to noise performance, sensitivity and flight height should be maintained at levels described below.

The magnetometer shall be deployed in the same survey pass as the MBES and SSS surveying.

Required elements

The MAG survey must include:

- Total Magnetic Intensity (TMI) at measurement altitude
- Calibrated, continuous magnetometer position and altitude

Required Specification

The magnetometer survey line spacing should be equal to or smaller than the line spacing for the SSS and SBP survey.

Nominal altitude (h) of Magnetometer from seabed: 4 m ≥ h

Magnetometer sensitivity: 0.01 nT/√Hz or better

Magnetometer sample rate: 10 Hz or greater

The magnetometer survey line spacing should as a minimum be equal to the line spacing for the SSS survey with minimal track offset from these measurements.

The magnetometer shall be deployed in the same survey pass as the MBES and SSS surveying.

Guidance

The magnetometer should be deployed at sufficient distance from the survey vessel to minimize magnetic interference from the vessel. This distance is normally expected to be at least three times the length of the vessel. Where the magnetometer is piggy-backed to other equipment such as a Side-Scan Sonar towfish, a tow distance sufficient to prevent interference from the towfish and other instruments (*e.g.* seismic) should be ensured. The mounting of any position-tracking equipment (ultra short base line (USBL)) on magnetometer tow cables must also be such that interference is minimized. Deck cabling should be arranged to minimize noise.

The magnetometer should be towed as close to seabed as practicable during surveying to optimise sensitivity to small deviations in the Earth's magnetic fields such as those produced by thin submarine communications cables. CLIENT requires a target altitude of no greater than 4m above seabed. Exceptions will be allowed in areas where the presence of bedforms may create risk of damage to the equipment, in which case the increased tow height should be approved by the CLIENT or CLIENT offshore representative. In all cases it is recommended that the distance between the magnetometer sensor and the seabed should not exceed 7 m

Data Processing

During processing, the CONTRACTOR is to edit the TMI data to remove obvious noise spikes and to de-trend the raw data to extract residual magnetic anomalies. The de-trending and reduction to residual magnetic anomaly procedures must be described in detail in the Final report. Positioning using USBL systems is preferred.

Magnetic signal with large scale spatial coherency may be indicative of geology, and CLIENT may request processing to recover such data in addition to the target picking data.

Residual magnetic anomaly data must not be interpolated between adjacent lines and residual magnetic anomaly data must under no circumstances be gridded; generation of an Analytic Signal Chart series is not required. Should it be required to plot the residual magnetometer data in plan-view in addition to plotting of the Contacts, ribbon plots should be used.

Interpretation

Magnetometry Contact picking must be carried out based on magnetic residual profile data. Ribbon plots may be useful for co-location of contacts with SSS and MBES Contacts.

Magnetometry Contacts must be identified and listed separately in a spreadsheet, along with a description of the anomaly type (positive/negative monopole, dipole). The recommended picking threshold is a peak-to-trough amplitude of ≥5 nT. A higher threshold may be appropriate if noise levels are high, subject to approval by the CLIENT.

Contacts must be classified *at minimum* into the following categories:

- Wreck-associated, correlated to local wreck registers, if available, and associated bathymetry/SSS Contacts;
- Debris-associated, correlated to associated bathymetry/SSS Contacts;
- Possible pipeline (with appropriate ID to indicate where multiple Contacts are thought to be associated with the same pipeline);
- Possible cable (with appropriate ID to indicate where multiple Contacts are thought to be associated with the same cable);
- Possible UXO;
- Undesignated.

Checks must be carried out on the magnetometry data to identify those magnetometry Contacts that are probably related to wrecks that are visible in the SSS/MBES data, and to identify additionally any magnetometry Contacts that may be indicative of buried wrecks (or potentially UXO). If possible UXO Contacts are identified, these must be indicated in the Contact table.

Deliverables

The following deliverables and their metadata are required at minimum:

Table 8: Magnetometry deliverables

Item ID	Measurement	Module R = Raw P = Processing I = Interpretation	Description	Resolution	Format	Load into GIS-database
65	**MAG**	**R**	Raw magnetometry	n/a	Ascii+prj	N
66		**P**	Cleaned de-spiked MAG data after applicaton of positioning QC and (USBL derived) layback correction	n/a	Ascii+prj	N
67			MAG tracks (navigation) data including altitude, Survey line ID included as attribute [lin]	n/a	.gdb	Y
68			MAG tracks (navigation) data, fix point included as attribute [pnt]	n/a	.gdb	Y
69			Processed MAG data: Residual anomaly of TMI	n/a	Ascii+prj	Y
70			Residual mag anomaly ribbon plot	1.0 m	Geotiff	Y
71		**I**	MAG anomaly list	n/a	.xlsx	N
72			MAG anomaly list [ptn]	n/a	.gdb	Y

Notes on magnetometry deliverables
Raw:

- Raw magnetometry is required

Processed:

- Cleaned, de-spiked magnetometer data as text (x,y,z) files per line/file, after application of positioning QC and layback
- Magnetometer trackplot and altitude (fix point and line)

- Cleaned, de-spiked TMI residual data as text (x,y,z) files per line/file, including layback, detrended to residual anomaly

Interpreted:

- The Magnetometry data series should have a Contact table and associated point, line and polygon spatial data files with columns for:
    - unique ID;
    - Contact classification (wreck, boulder, debris, *etc.*);
    - X co-ordinate (centre);
    - Y co-ordinate (centre);
    - dimension(s);
    - short description;
    - where relevant, associated wreck number or cable/pipeline ID;
    - approximate total peak-to-trough magnitude;
    - approximate in-line anomaly width;
    - anomaly shape, *e.g.* negative monopole, positive monopole or dipole

  and columns as appropriate to relate the Unique Contact ID where multiple sensors have apparently detected the same feature.

- All raster deliverables for single-variable data should be supplied as single-band files with actual cell values (e.g. elevation, intensity). If provided in a non-ESRI GIS format (*e.g.* CAD, microstation), all processed deliverables listed above except the cleaned, de-spiked magnetometer data must be provided additionally in the project GIS archive.

2.3.11 *Sub-Seabed seismic investigations - general*

The objective of the 2D- and 3D- High-Resolution Seismic (2D- and 3D-UHRS) and Sub Bottom Profiling (SBP) Surveys is to contribute to the model of the seabed including:

- identification and mapping of static and potentially mobile bedforms such as megaripples and sand waves, including the thickness of potentially mobile sediments;
- identification and mapping of potential hazards or influences on the development of offshore wind farm infrastructure at the site *e.g.* faults, seabed or buried channels, shallow gas, peat, *etc.*;
- identification and mapping of significant stratigraphic and lithological horizons that characterise the site, the key geological units defined by the Geological Desk study and any other relevant literature or data;
- identification and mapping of subsurface structures that may represent changes in material properties relevant to the design, emplacement and operation of Offshore Wind Farm infrastructure.

2.3.12 *Ultra High Resolution Seismic and Sub Bottom Profiling survey – 2D*

The SBP survey is required for sufficiently detailed imaging of the Holocene formations including the base of the mobile sediments. The primary purpose of the SBP survey is to provide information about the top 5 m as this depth range is important for cable design and installation.

A 2D- UHRS data set will be acquired over the entire depth range of interest within the IA, to enable the detection, interpretation and mapping of all significant subsurface horizons including formation interfaces, buried channel features and other relevant indicators of geohazards

The seismic image and interpreted preliminary velocity field are required. The depth range of interest is from seabed to a depth not less than 100 m below seabed for the 2D-UHRS survey.

Required elements

- Single-channel, shallow penetration seismic surveying with a Sub-Bottom Profiler system (SBP), *i.e.* Pinger, Chirp, parametric or other system with equivalent performance. Sound Exposure Level single strike (SELss) specifications are required in the tender in order to support CLIENT's application for an environmental exemption (underwater noise).

- For 2d UHRS: Multi-Channel Ultra High-Resolution Seismic (UHRS) surveying with a *high bandwidth* Sparker system suitable for the resolution and penetration specifications. Sound Exposure Level single strike (SELss) specifications are required in the tender in order to support CLIENT's application for an environmental exemption (underwater noise).

Required Specification

Data acquisition should be designed to optimise vertical and horizontal resolution (defined here as ¼ dominant wavelength), the signal-to-noise ratio and the recovery of coherent signal throughout the depth range of interest.

Near surface resolution within 5 m of seabed:	Inline trace spacing <1 m
	Vertical resolution: 0.2 m
	Nominal penetration: ≥3 m
Resolution to 40 m below sea bed:	Inline trace spacing ≤ 1.57 m
	Vertical resolution ≤ 0.5 m
	Nominal penetration: ≥40 m
Resolution from 40 m below sea bed to >100 m below sea bed:	Inline (stack) trace spacing ≤ 1.57 m
	Vertical resolution ≤ 1.5 m
	Nominal penetration: ≥100 m

Note that the specification is *outcome focussed* and required that the *delivered* (*i.e.* processed) data meet the resolution and signal penetration criteria.

The CMP fold of 2D-UHRS data is to be ≥ 24 real traces (without interpolation) and the maximum offset is to be not less than 90 m and not greater than 150 m.

Positioning of all components of the seismic instrumentation is to be accurately monitored using GPS antennae at key points, and supplemental positioning processes where applicable to improve accuracy. Depth control of seismic source and streamer is to be maintained within defined tolerances and described in method statements within the project documentation. All sub-seabed data are to be acquired on co-located lines with minimised offset between reflection point tracks. A track separation (between SBP and 2D-UHRS) threshold shall be set during the testing phase but shall not be greater than 15 m.

All systems generating acoustic signal must conform to the sound pressure specifications described in the environmental permit. Acoustic deterrent systems and

procedures are to be implemented and shall be described in the project documentation.

Guidance

A line-plan must be submitted with the CONTRACTOR's proposal as a properly referenced shapefile with description of line spacings, bearings of the primary and secondary line directions.

Vessel(s) or other platforms selected for data acquisition must be established as *low noise* relative to the type of seismic data acquisition proposed, with particular reference to the seismic source power and spectral characteristics in the context of the sea-bed conditions of the IA. Demonstration via representative data should be provided.

SBP must be hull- or pole-mounted and provide effective heave and attitude compensation. Parametric systems are preferred if CONTRACTOR can demonstrate track record of their successful use. Sufficient data processing is required to enable effective identification of the base of mobile sediments at the required resolution. Minimisation of ringing in the data is to be demonstrated during testing, and mitigation measures described in the proposal.

SBP and UHRS systems, if operated concurrently, must be arranged to minimise interference while optimising the horizontal resolution of each.

The UHRS equipment should include a streamer with group spacing of preferably 2 m or less and no more than 3.125 m to provide high horizontal resolution; an active streamer length of between 90 m and 150 m is preferred. Shot interval should be defined to deliver the required CMP fold and interval. A consistent, broad band seismic pulse is required and QA metrics demonstrating this should be provided.

It is required that seismic sources and hydrophone cables are deployed by personnel demonstrably experienced in their configuration, parameterisation and optimisation. Team composition and their track record will be part of the evaluation of bids.

Slant-cable or hybrid-cable proposals are acceptable if the vessel operations and data processing teams are demonstrated to have had prior successful experience of the systems proposed. Any required data processing and QA schemes must be described and demonstrated to be established in production work.

Data Processing

SBP and UHRS data require data processing to be applied to optimise quality and resolution. Full reporting is required for each type of data collected. Data processing will be monitored for quality, and CLIENT may require opportunity to inspect data, provide input and request modification at any point prior to delivery. Data processing of UHRS data should be comprehensively tested, reported and signed off by CLIENT on up to 7 lines prior to production processing.

UHRS data may have 'brute stacks' generated for use in the QA operations on-board. Brute Stacks should contain the minimum processing required to evaluate the quality of the recorded data. A suggested 'Brute stack' processing sequence should be provided in the proposal. Brute stacks form one element of the deliverables set.

The data are to be located using accurate source and receiver positions. Layback correction should be carried out such that each stacked trace has its own unique co-ordinate pair associated with its common mid-point (CMP). A description of the layback correction procedure must be included in the Field Report.

Full navigation editing must be carried out to ensure that erroneous, zero and duplicate co-ordinates have been removed and new values interpolated. Trace numbering must be sequential in increments of 1, with no duplicates. Navigation data

must be included in header bytes 73-80 and 81-88 for pre-stack shot and receiver locations, and 181-188 for stacked CMP data.

2D-UHRS stack and SBP trace headers should conform to SEG Y Rev1 (2002)[9] in structure and should contain the appropriate information, including survey metadata in the text header.Time correction for the source and receiver elevation to a single datum is required such that the SBP, 2D- and 3D-UHRS data have their seabed signal aligned in the processed final deliverables. Datum corrections should be written to pre-stack header words for deliverables but *not* applied to the data.

Some, or all operations of the final, production processing sequence for SBP and UHRS data may be applied onboard or ashore (the preferred option). In either case the details of all processing undertaken must be explained and discussed in the Final Report. At minimum, the processing operations applied to each dataset must be described and parameter tests presented. An outline prediction of the UHRS 'Final stack' processing sequence should be provided in the proposal, with options presented as appropriate. The Final stack processing sequence should include at minimum:

- Positioning and Geometry assignment
- Denoise
- Signal conditioning (e.g. deconvolution, deghosting)
- Amplitude correction
- Stacking Velocity analysis at ≤ 1000 m interval
- Demultiple
- NMO correction, mute and stack
- Migration (pre or post stack)

The actual processing sequence is expected to be more complex than the list provided and may not be in the same order.

Interpreted seismic velocity is required to be delivered with appropriate QA metrics. Stacking velocity interpretation is required throughout the depth range of interest. Conversion to a coherent interval velocity model is required. Consideration must be made of the requirement for consistent velocity interpretation, within the bounds of the 2D approximation, at line intersections. Velocities are to be supplied as ASCII and SEGY data.

The method by which depth values have been obtained from the seismic time picks, and the velocity used for converting seismic interpretation (SBP and UHRS) to depth must be described and provided as SEG-Y if appropriate.

Interpretation

The sub-seabed investigations are to be interpreted using a seismic workstation package. Both SBP and 2D-UHRS data are to be loaded to the same workstation project in the time domain. 2D- and 3D-UHRS final interpretation is to be provided in the workstation project in the depth domain, converted using a preliminary velocity field to be defined during the project and approved by CLIENT. Interpretation of SBP and UHRS data together is encouraged. It is required that a single set of horizons is provided with no duplication between SBP and UHRS.

The definition of stratigraphic horizons to be interpreted shall be finalised by agreement between CLIENT and CONTRACTOR during the course of the project; up to four site-wide-equivalent sub-seabed horizons plus interpretation of buried channel-like features should be anticipated. Interpretation of indication of geohazards relevant to windfarm planning shall be provided.

The integrated interpretation of SBP and UHRS data is discussed in section 2.4.

[9] May be downloaded from http://www.seg.org/resources/publications/misc/technical-standards.

2D Multi-Channel Ultra High Resolution Seismic survey deliverables

The following deliverables and their metadata are required at minimum:

Table 9: Multi-Channel Ultra High-Resolution Seismic deliverables						
Item ID	**Measurement**	**Module R = Raw P = Processing I = Interpretation**	**Description**	**Resolution**	**Format**	**Load into GIS-database**
73	**UHRS Seismic**	**R**	Raw navigation merged shots *	n/a	SEG-D	N
74			Multichannel tracks (navigation) data, Survey line ID included as attribute [lin]	n/a	.gdb	Y
75			Multichannel tracks (navigation) data, fix point included as attribute [ptn]	n/a	.gdb	Y
76			EOL QC document (For every line, provided every 24h)	n/a	.pdf	N
77		**P**	QC log sheet (provided every 24h and final version at EOJ)	n/a	.xlsx	N
78			Brute stack *	n/a	SEG-Y	N
79			Demultiple CMP gathers	n/a	SEG-D or SEG-Y	N
80			Demultiple stack (time domain)	n/a	SEG-Y	N
81						
82			Final stack (with post migration processing) (time domain)	n/a	SEG-Y	N
83			Interval velocity vs. time	n/a	SEG-Y	N
84			RMS stacking velocity file	n/a	ascii	N

Notes on multi-channel seismic deliverables:

Raw:

- Multi-channel raw seismic data with geometry and correct navigation applied (shot gathers) in SEG-Y or SEG-D format.

Processed:

- Trackplot for the multi-channel survey, based on stacked traces (point and line).
- Multi-channel processed seismic CDP gather data, without NMO application and with correct geometry and navigation and processing up to multiple attenuation applied, in SEG-Y or SEG-D format. In the time domain, to facilitate reprocessing and/or supplemental velocity analysis.
- Multi-channel processed stacked seismic data with correct navigation and tidal correction applied in SEG-Y format, before and after migration and after final scaling and filtering, in the time domain.

Sub-Bottom Profiler deliverables

The following deliverables and their metadata are required at minimum:

Table 10: Sub-Bottom Profiler deliverables						
Item ID	**Measurement**	**Module R = Raw P = Processing I = Interpretation**	**Description**	**Resolution**	**Format**	**Load into GIS-database**
85	**SBP**	**R**	Raw data SBP with navigation applied	n/a	SEG-Y	N
86		**P**	SBP tracks (navigation) data, Survey line ID as attribute [lin]	n/a	.gdb	Y
87			SBP tracks (navigation) data, fix point included as attribute [ptn]	n/a	.gdb	Y
88			Processed SBP data with navigation applied	n/a	SEG-Y	N

Notes on Sub-Bottom Profiler deliverables:

Raw:

- Raw SBP data with correct navigation applied in SEG-Y format (if applicable, heave information shall be provided separately and not applied to the raw data).

Processed:

- Trackplots for the SBP seismic survey.
- Processed SBP data where post-processing is required to deliver interpretable data at the resolution specified: interference is to be attenuated, and processes to achieve a compact wavelet with minimal ringing are to be applied

Interpretation

Interpretation of SBP data is to be implemented co-operatively with the 2D-UHRS such that a single, coherent set of horizons is delivered with the same vertical (depth and time-equivalent) datum. It is expected that SBP data are interpreted where their penetration is sufficient to exploit a resolution advantage over the 2D-UHRS data.

Sub-seabed interpretation deliverables are described in section 2.4.6

All raster deliverables for single-variable data should be supplied as encoded single-band files with actual cell values (*e.g.* elevation, intensity), *not* as multi-band RGB images. If provided in a non-ESRI GIS format (*e.g.* CAD, microstation), all processed deliverables listed above must be provided additionally in the project GIS archive.

2.3.13 *3D Ultra High Resolution Seismic Survey*

The 3D-UHRS area is required for the high potential area for the location of offshore wind turbines at the perimeter of the installable areas. To be able to provide more detailed information in these areas a 3D-UHRS survey will be performed to enable the detection, interpretation and mapping of all significant subsurface horizons including formation interfaces, buried channel features and other relevant indicators of geohazards in high detail.

The seismic image and interpreted preliminary velocity field are required. The depth range of interest is from seabed to not less than 60m below seabed for 3D-UHRS survey.

Required Elements

- 1500 sail-line km of survey data to be acquired providing at minimum complete coverage of the perimeter corridor defined in Table 1, at full target fold, plus additional area(s) to be defined. Maximum bin sizes are defined below.
- 3D-Multi-Channel Ultra High-Resolution Seismic (UHRS) surveying with a *high bandwidth* Sparker system(s), suitable for the resolution and penetration specifications for 3d imaging. Sound Exposure Level single strike (SELss) specifications are required in the tender in order to support CLIENT's application for an environmental exemption (underwater noise).
- A multi-streamer hydrophone array and logging systems
- GPS positioning on source(s), and head and tail buoys of hydrophone cables
- The CMP fold of 3D-UHRS data is to be ≥ 12 traces
- The maximum offset is to be not less than 30 m and not greater than 90 m.
- 3D processing including deghosting, sufficient to deliver preliminary interpretation, including 3D migration, is required.

The configuration of sources, receiver cables and line spacing required to achieve the bin distribution and fold targets is not unique. For configurations that meet the minimum bin-size and fold requirements, evaluation of proposals will consider bin size (smaller and square is preferred, to a minimum of 0.5 x 0.5m) and the number of line km required to complete the perimeter (fewer preferred, with the balance to 1500 km to be assigned to additional area(s)).

Curved sections of the corridor are to be surveyed with bin sizes and fold specifications as with the straight line segments. They may be surveyed using linear segments as long as full coverage of the curved corridor is maintained (recognising that this may require additional width).

Delivery of the 3D data in a single data volume or multiple linear sections is to be decided. Neither option shall incur additional cost.

Required Specification

Data acquisition should be designed to optimise vertical and horizontal resolution (defined here as ¼ dominant wavelength), the signal-to-noise ratio and the recovery of coherent signal throughout the depth range of interest.

Resolution to 40 m below sea bed:	Inline bin spacing ≤ 1.0 m Xline bin spacing ≤ 2.0 m
	Vertical resolution ≤ 0.5 m
	Nominal penetration: ≥40 m
Resolution from 40 m below sea bed to >60 m below sea bed:	Inline bin spacing ≤ 1.0 m Xline bin spacing ≤ 2.0 m
	Vertical resolution ≤ 1.5 m
	Nominal penetration: ≥100 m

Note that the specification is *outcome focussed* and required that the *delivered* (*i.e.* processed) data meet the resolution and signal penetration criteria.

The CMP fold of 3D-UHRS data is to be ≥ 12 traces and the maximum offset is to be not less than 30 m and not greater than 90 m.

Bin sizes specified are *maximum values* – smaller bin sizes, maintaining the minimum fold of coverage, are considered additional value if acquired within the maximum sail-line km specified

Specification of acceptable fold shall be finalised on the basis of a maximum number of adjacent bins failing a minimum fold criterion (a gap) corresponding to a maximum acceptable size, with limitation on the number of smaller gaps per corridor km. A working criterion for application only to the proposal shall be:

- Maximum dimension of low fold zone (gap) ≤20m.
- Total number of 'gaps' between 10m and 20m dimension per corridor-km shall be limited to 3
- Total number of gaps between 2 m and 10 m dimension per corridor-km shall be limited to 10.

Initial tolerances shall be agreed at TKOM and finalised after offshore testing in conditions representative of the site.

A diagram of the proposed source and cable specification to illustrate the binning strategy is required in the proposal.

All systems generating acoustic signal must conform to the sound pressure specifications described in the environmental permit. Acoustic deterrent systems and procedures are to be implemented and shall be described in the project documentation.

Guidance

A line-plan must be submitted with the CONTRACTOR's proposal as a properly referenced shapefile with description of line spacings, bearings of the primary and secondary line directions.

Diagrams illustrating the source and receiver configuration leading to the desired bin size and fold is required in the project documentation.

Vessel(s) or other platforms selected for data acquisition must be established as *low noise* relative to the type of seismic data acquisition proposed, with particular reference to the seismic source power and spectral characteristics in the context of the sea-bed conditions of the IA. Demonstration via representative data should be provided.

The UHRS equipment should include a streamer with group spacing of preferably 2 m or less and no more than 3.125 m to provide the required horizontal resolution; an active streamer length of between 30 m and 90 m is preferred. Shot interval should be defined to deliver the required CMP fold and bin size. A consistent, broad band seismic pulse is required and QA metrics demonstrating this should be provided.

It is required that seismic sources and hydrophone cables are deployed by personnel demonstrably experienced in their configuration, parameterisation and optimisation. Team composition and their track record will be part of the evaluation of bids.

Slant-cable or hybrid-cable proposals are acceptable if the vessel operations and data processing teams are demonstrated to have had prior successful experience of the systems proposed. Positioning and depth control must be monitored and documented. Any required data processing and QA schemes enabling the use of slant cables must be described and demonstrated to be established in production work.

Data Processing

3D-UHRS data require extensive data processing to be applied to optimise quality and resolution. It is anticipated that a significant proportion of processing will be performed onshore, with offshore processing focussed on data acquisition QA. Full reporting is required including operations and processing reports.

Offshore and onshore data processing will be monitored for quality, and CLIENT may require opportunity to inspect data, provide input and request modification at any point prior to delivery. Offshore QA data processing of 3D-UHRS data should be comprehensively tested, reported and signed off by CLIENT on up to 3 sail-lines prior to production processing.

3D-UHRS data should have 'brute stacks' for a single inline generated for use in the QA operations on-board. Brute Stacks should contain the minimum processing required to evaluate the quality and penetration of the recorded data. A suggested 'Brute stack' processing sequence should be provided in the proposal. Brute stacks form one element of the deliverables set.

The data are to be located using accurate source and receiver positions. Geometry assignment should be carried out such that each stacked trace has its own unique co-ordinate pair associated with its common mid-point (CMP). A description of the geometry assignment procedure must be included in Operations and Processing Reports. Raw shots with assigned geometry included in headers are a deliverable.

Full navigation editing must be carried out to ensure that erroneous, zero and duplicate co-ordinates have been removed and new values interpolated. Trace numbering must be sequential in increments of 1, with no duplicates. Navigation data must be included in header bytes 73-80 and 81-88 for pre-stack shot and receiver locations, and 181-188 for stacked CMP data.

3D-UHRS stack trace headers should conform to SEG Y Rev1 (2002)[10] in structure and should contain the appropriate information, including survey metadata in the text header.

[10] May be downloaded from http://www.seg.org/resources/publications/misc/technical-standards.

Time correction for the source and receiver elevation to a single datum is required such that the SBS, 2D- and 3D-UHRS data have their seabed signal aligned in the seismic workstation project. Non-dipping seabed reflections should tie to ≤0.2 ms.

Some, or all operations of the final, production processing sequence 3D-UHRS data may be applied onboard or ashore (the preferred option). In either case the details of all processing undertaken must be explained and discussed in the Processing Report. At minimum, the processing operations applied to each dataset must be described and parameter tests presented. An outline prediction of the UHRS 'Final stack' processing sequence should be provided in the proposal, with options presented as appropriate. The Final stack processing sequence should include at minimum:

- Positioning and Geometry assignment
- Denoise
- Signal conditioning (e.g. deconvolution, deghosting)
- Amplitude correction
- Stacking Velocity analysis at < 1000 m interval
- Demultiple
- NMO correction, mute and stack
- Migration (post stack)

The actual processing sequence may be more complex than the list provided and may not be in the same order.

Interpreted seismic velocity is required to be delivered with appropriate QA metrics. Stacking velocity interpretation is required throughout the depth range of interest, and should be coherent with the horizons picked on 2D-UHRS data Conversion to an interval velocity model is required. Velocities are to be supplied as ASCII and SEGY data.

Interpretation

Interpretation of 3D-UHRS data is not required beyond that implicit in velocity analysis.

3D Multi-Channel Ultra High Resolution Seismic survey deliverables

The following deliverables and their metadata are required at minimum:

Table 11: 3D Multi-Channel Ultra High-Resolution Seismic deliverables

Item ID	Measurement	Module R = Raw P = Processing I = Interpretation	Description	Resolution	Format	Load into GIS-database
89	**UHRS Seismic**	**R**	Raw navigation merged shots *	n/a	SEG-Y or SEG-D	N
90			Multichannel sail line tracks (navigation) data, Survey line ID included as attribute [lin]	n/a	.gdb	Y
91			Multichannel sail line (navigation) data, fix point included as attribute [ptn]	n/a	.gdb	Y
92			EOL QC document (For every line provided every 24h)	n/a	.pdf	N
93		**P**	QC log sheet (provided every 24h and final version at EOJ)	n/a	.xlsx	N
94			Brute stack *	n/a	SEG-Y	N
95			Demultiple CMP gathers	n/a	SEG-Y or SEG-	N

Table 11: 3D Multi-Channel Ultra High-Resolution Seismic deliverables						
Item ID	**Measurement**	**Module R = Raw P = Processing I = Interpretation**	**Description**	**Resolution**	**Format**	**Load into GIS-database**
					D	
96			Demultiple stack (time domain)	n/a	SEG-Y	N
97			Final Bin fold plot	Bin size	raster	Y
98			Final stack (with post migration processing) (time domain)	n/a	SEG-Y	N
99			Interval velocity vs time	n/a	SEG-Y	N
100			RMS stacking velocity file	n/a	ascii	N

Notes on 3D multi-channel UHRS deliverables:

Raw:

- Multi-channel raw seismic data with geometry and correct navigation applied (shot gathers) in SEG-Y or SEG-D format.

Processed:

- Trackplot for sail lines of the 3D UHRS survey (point and line);
- Raw, nav merged shot gathers and a full set of CMP gathers after multiple attenuation is applied (without NMO correction) are required to facilitate reprocessing;
- Stacked, migrated seismic data with correct navigation and tidal correction applied in SEG-Y format; including the entire corridor specified in table 1.
- Interval velocity vs TWTT at all CDP locations in the corridor as SEGY; and
- Stacking velocity vs TWTT pairs at analysis locations.

2.4 Integrated Interpretation

Seabed and sub-seabed data acquired during the geophysical campaign are to be interpreted in order to form a coherent PGM. The purpose of this PGM is to deliver the set of products associated with the seabed itself (integrated interpretation of SSS, MBES, MAG and SBP and their derived data) and to informthe design of the anticipated Geotechnical Investigation. It is expected to be updated, incorporating the output of the Geotechnical Investigation to form an Integrated Ground Model (IGM) which is expected to develop the subsurface geological model extensively. The construction of the IGM is outside the scope of the Geophysical (and Geotechnical) Investigations.

The integration operations required of the PGM are principally the aggregation of the seabed data (MBES, SSS, MAG, (SBP)) to deliver a set of interpreted datasets, the aggregation of the sub-seabed data (UHRS, SBP) to deliver a sub-seabed workstation project, the integration of all suitable data elements into a GIS project, and the final reporting. 3D-UHRS data are required to be compatible and referenced to the same vertical datum, but integration of the 3D-UHRS data into the PGM is not required.

CLIENT expects to be closely involved with work during the interpretation of individual survey elements and the integration stage. A workshop to finalise the interpretation shall be held prior to the assembly of the draft reporting.

2.4.1 *Seabed data integration*

Overview

Contact picking must be carried out on SSS, magnetometry and MBES datasets. Targets should be reported as points, polygons and polylines. Linear Contacts of lengths on the order of the line-spacing or greater must be provided as polylines, not points.

Contacts shall be assigned a unique number and a table relating this to the identifiers of events on the individual sensor datasets is required.

Where a linear Contact is identified based on a number of point Contacts from one or more of the MBES, SSS and magnetometry data, both the point and linear Contacts must be retained in the deliverables. Linear Contacts that are associated with known cables/pipelines must be mapped and included in the deliverables. The CONTRACTOR shall investigate before commencement of the survey if further in-service and out-of-service cables and pipelines can be found in the area, based on their own information and on the Geological Desk Study and associated GIS archive.

An overview of active cables and pipelines known to CLIENT is included in Annex 6 - section VII (the provided GIS-file). CONTRACTOR shall investigate before commencement of the survey if further in-service and out-of-service cables and pipelines can be found in the area, based on own information.

Seabed material classification

Seabed classification shall be carried out based primarily on MBES backscatter/snippets (AGDS) and SSS data together with the seabed samples. A single seabed material map shall be produced.

Bedform classification

Bedform zonation, carried out according to a recognised, documented classification scheme, is required. It is suggested that nomenclature follows that used in the morphodynamical studies of other WFZ data packages of the Hollandse Kust series. The quantitative basis for the classification scheme selected must be described in the report and a table of parameters (bedform length, width, height and shape) for each selected class must be provided. At minimum, the following features shall be mapped:

- Megaripples
- Sandwaves
- Large sandwaves.
- Linear Tidal Sand Ridges.
- Anthropogenic features (*e.g.* dredging areas).

Where bedforms of different classes are co-located, this shall be indicated through the use of separate, overlapping class polygons (*i.e.* in an area where small dunes are superimposed on large dunes, the polygons for these two classes shall overlap).

The seabed slope (degrees) shall be calculated on levelled DTM, classified, and mapped.

The position of the crests of Sandwaves and Large Sandwaves shall be mapped.

2.4.2 *Outputs - Seabed*

The result of the MBES, MAG, SSS and sampling survey shall be:

- Seabed features as GIS layers and on one or more A0 charts at an appropriate scale showing both SSS Magnetic Contacts and MBES Contacts superimposed on the SSS mosaic. All pipelines/cables, both previously known and unknown, must be mapped both as linear and associated point Contacts.

- Seabed features as GIS layers and on one or more A0 charts at an appropriate scale showing both SSS and Magnetic Contacts (and MBES Contacts, if picked) superimposed on a ribbon plot of the processed magnetometer data. All pipelines/cables, both previously known and unknown, must be mapped both as linear and associated point Contacts.
- In addition to a full Contact list (within the report or as an appendix), the report must contain a summary table indicating the number of magnetometry Contacts of each classification.
- In addition to a full Contact list (within the report or as an appendix), the report must contain a summary table indicating the number of SSS Contacts of each classification.
- The report must contain a table of the wrecks identified through all methods. If any known wreck is not identified then the possible reasons for this must be discussed.
- If an object is located offset from the location recorded in the relevant database, both the recorded and as-found locations and dimensions must be indicated on charts and Contact tables.
- The report must contain a table of cables and pipelines identified through all methods. The report must contain an evaluation comparing the expected and actual location for cables and pipelines in the IA. The evaluation should include a map and a discussion in the text. If identity/location of (part of) cables and pipelines cannot be confirmed the reason for this shall be clearly specified.

2.4.3 *Seabed data - Integrated Interpretive deliverables*

The following interpretative deliverables and their metadata are required at minimum:

Table 12: Seabed (MBES, SSS, MAG) Integrated Interpretative deliverables

Item ID	Measurement	Module I = Interpretation	Description	Resolution	Format	Load into GIS-database
101	**Integrated MBES SSS MAG**	**I**	Correlated Contact list for all sensors	n/a	.xlsx	N
102			Correlated Contact file for all sensors [pnt]	n/a	.gdb	Y
103			Isolated boulder table containing co-ordinates and size estimate	n/a	.xlsx	N
104			Isolated boulder file containing co-ordinates and size estimate	n/a	.gdb	Y
105			Bedform classification (polygon)	n/a	.gdb	Y
106			Linear features (scars, sandwave crests etc) [lin]	n/a	.gdb	Y
107			Area features (trawl scars, debris fields, boulder fields etc) [pgn]	n/a	.gdb	Y
108			Sediment classification raster	TBC	Geotiff	Y
109			Sediment classification [pgn]	n/a	.gdb	Y
110			Sediment classification	n/a	CAD [dxf]	N
111			Cable/pipeline table containing vertex co-ordinates	n/a	.xlsx	N
112			Cable/pipeline table containing vertex co-ordinates [lin]	n/a	.gdb	Y

Notes on integrated interpretative deliverables:

- Boulder fields should describe the extent of the feature and be classified with suitable array of boulder frequency values.
- Sediment distribution/seabed classification, depending on the classification method used to be provided as: either a single or tiled set of xyz text files (*.xyz/*.pts) without overlaps and a single or tiled raster/grid without overlaps; ***or*** a digital vector file/drawing (ArcGIS, AutoCAD or Microstation format or similar).
- Separate table containing all vertex co-ordinates for each identified cable/pipeline, indexed by cable/pipeline ID.

2.4.4 *Sub-seabed data integration*

Subsurface data are to be interpreted using a workstation package at least capable of representation of all subsurface data elements in a common system. It must be capable of picking interfaces in the time and depth domain and rationalising those picks between the data elements and at line intersections to ensure consistency. The Kingdom application from IHS Markit is preferred, software version to be agreed at TKOM.

The interpretational framework shall be initiated using a subset of not less than 5 lines to be selected prior to survey data acquisition; these lines shall be acquired, processed and interpreted first, in close collaboration with CLIENT and the framework and strategy agreed with CLIENT prior to further interpretation. All 2D-UHRS and SBP data are to be interpreted.

The interpretation must include consistency/line-tie checks between the SBP, 2D-UHRS and 3DUHRS datasets within the same interpretation environment, and these checks must be described in the interpretative report.

Formation boundaries as required must be gridded and contoured. A single grid should be provided for each interface. The gridding methods and parameters used to generate interface grids from the original pick files must be described in full. A quantitative discussion of the elevation uncertainty of all delivered interfaces must be included in the report.

Geohazard interpretations may be gridded or presented as pick plots depending on their extent and continuity. The spatial extent of interfaces and geohazards is to be mapped and delivered within both seismic workstation and GIS deliverables.

If a significant portion of the subsurface is characterised by intense faulting, the characterisation of the faulting pattern (aggregated fault-throw and fault density) can replace the picking of each individual fault.

2.4.5 *Outputs – sub-seabed*

The output of the subsurface interpretation shall be:

- Seismic workstation project incorporating 2D UHRS and SBP data, horizon picks, grids, culture and other information used in interpretation.
- Geological cross-sections identifying all significant features and horizons (superimposed on the processed seismic data) for a representative subset of lines from each dataset on one or more A0 charts at an appropriate scale.
- Gridded elevation surface and contours (isolines) for each interface showing depth to base of formation/formation member/unit) below datum (LAT), electronically as ascii data and ArcGIS geodatabase elements.
- Gridded depth below seabed and depth below seabed contours of each formation/formation member/unit) electronically as ascii data and ArcGIS geodatabase elements.
- Mapped extents for each formation/formation member/unit) and laterally extensive geohazard (*e.g*. shallow gas, peat, buried channel or boulder-field), electronically as ascii data and ArcGIS geodatabase elements and as one or more A0 charts at an appropriate scale.
- Preliminary zonation of the site into zones of common geological sequence as ESRI shapefile, for input to geotechnical campaign planning.

2.4.6 *Sub-Seabed data - Integrated Interpretive deliverables*

The following interpretative deliverables are required at minimum:

Table 13: Sub-Seabed integrated interpretative deliverables

Item ID	Measurement	Module I = Interpretation D = Database	Description	Resolution	Format	Load into GIS-database
113	**Integrated SBP UHRS**	**I**	Pick files for each interpreted stratigraphic or other horizon or interface, XYZ and XYT	n/a	Ascii+prj	N
114			Gridded elevation surface for each horizon or interface, reduced to LAT and MSL datums, XYZ	tbc	Ascii+prj	N
115			Gridded elevation surface for each horizon or interface, reduced to LAT and MSL datums, raster	tbc	Geotiff	Y

Table 13: Sub-Seabed integrated interpretative deliverables						
Item ID	**Measurement**	**Module I = Interpretation D = Database**	**Description**	**Resolution**	**Format**	**Load into GIS-database**
116			Gridded elevation surface for each horizon or interface, below seabed, XYZ	tbc	Ascii+prj	N
117			Gridded elevation surface for each horizon or interface, below seabed, raster	tbc	Geotiff	Y
118			Elevation Contours for all horizon or interface, reduced to LAT and MSL datums [line]	tbc	.shp, .gdb	Y
119			Elevation Contours for all horizon or interface, below seabed [line]	tbc	.shp, .gdb	Y
120			Extent polygons for sub-seabed geology [polygon]	n/a	.shp .gdb	Y
121			Sub-bottom Contacts that present a geohazard [point]	n/a	.shp .gdb	Y
122			Sub-bottom Contacts that present a geohazard	n/a	.xlsx	N
123			Laterally extensive geohazard (such as shallow gas or peat) [line, polygon]	n/a	.shp .gdb	Y
124			Faults [line]	n/a	.shp .gdb	Y
125			Area of faulting [polygon]	n/a	.shp .gdb	Y
126			Preliminary zonation	n/a	.shp, .gdb	Y
127		**D**	Kingdom Seismic Direct project including all SBP and 2D-UHRS data in TWTT. Interpretation to be supplied in TWTT and depth.	n/a	.tks	N

Notes on sub-seabed integrated interpretation deliverables:

- Text (or csv) pick files for each interpreted horizon (including seabed and interfaces/features that were of too small extent or too sparse to be gridded) to be provided in an exchangeable format with at minimum fields for XY coordinates, survey line name, shot point/trace number, two way time and elevation relative to LAT and MSL
- Elevation surfaces for all interpreted horizons at an appropriate resolution (~0.25-1 x line spacing, to be agreed with CLIENT), reduced to datum and produced by gridding the pick data to a regular grid, as an xyz text file (*.xyz/*.pts) ***and*** a raster/grid. Products to be delivered relative to both LAT and MSL datums.
- Elevation contours relative to LAT and MSL for all interpreted horizons at an appropriate interval.
- Depth below seabed information for all interpreted horizons at the same resolution as the elevation grids, as an xyz text file (*.xyz/*.pts) ***and*** a raster/grid.
- Depth below seabed contours at an appropriate interval.
- Sub-surface point geohazard (such as diffraction apices that may indicate the presence of boulders) table(s) and associated point spatial data with columns for X and Y co-ordinates at minimum and depth where appropriate.

- Formation/formation member/unit and laterally extensive geohazard (such as shallow gas or peat) extents as polygons in ArcGIS, AutoCAD or Microstation format or similar. Extent polygons should:
    - include and clearly indicate areas where the unit/feature is thought to be present but the base/top cannot be interpreted; and
    - exclude areas where the unit/feature is absent.
- Faulting as linear features (individual faults) and/or polygons (areas of faulting).

All raster deliverables for single-variable data should be supplied as single-band files with actual cell values (*e.g.* elevation, intensity), not as multi-band RGB images. If provided in a non-ESRI GIS format (*e.g.* CAD, microstation), all processed deliverables listed above must be provided additionally in the project GIS archive.

2.4.7 *Geographic Information Systems*

A project Geographic Information System (GIS) archive is to be delivered in a single GIS deliverables folder with metadata in accordance with requirements as specified in Annex 6-Section VII Annex A. Accompanying map document(s) (*.mxd), containing data as specified throughout this Scope of Work should be provided.

Data should ideally be provided in a geodatabase file, but shapefile data would be acceptable with appropriate handling of 'null' values.

The GIS data must be consistent with all other data deliverables (*e.g.* Contact feature classes in the GIS archive must contain the same attribute columns and values as in the Excel/text file Contact tables and report appendices, Kingdom-generated elevation grids and GIS elevation rasters should match, *etc.*).

Further specifications for GIS can be found in the RVO starting points and assumption document (Annex 6 - Section VII).

The GIS data archive must include *at minimum*:

Table 14: GIS deliverables

Item ID	Measurement	Module M = Map D = Database Meta = Metadata	Description	Resolution	Format	Load into GIS-database
128	**all**	**M**	Master Map document	n/a	.mxd	Y
129	**all**	**D**	ArcGIS geodatabase	n/a	.gdb	Y
130	**Survey**	**D**	Project area, wind farm and survey boundaries (polygons).	n/a	.gdb: polygon	Y
131	**Tracks**	**D**	Vessel trackplot(s) and fix points.	n/a	.gdb: line, point	Y
132	**Tracks**	**D**	Sensor trackplots and fix points	n/a	.gdb: line, point	Y
133	**Seabed**	**D**	Bathymetry grid and contours.	Full	.gdb: raster, line	Y
134	**Seabed**	**D**	TVU and TVH uncertainty grids.	Full	.gdb: raster	Y
135	**Seabed**	**D**	MBES backscatter grids.	Full	.gdb: raster	Y
136	**Seabed**	**D**	SSS mosaic	Full	.gdb: raster	Y
137	**Contacts**	**D**	MBES, SSS and MAG Contacts	n/a	.gdb: point, line, polygon	Y
138	**Contacts**	**D**	Boulders and Boulder fields	n/a	.gdb: point, polygon	
139	**Geology**	**D**	Elevation grids and contours for all interpreted interfaces	Full	.gdb: raster	Y
140	**Geology**	**D**	depth below seabed grids and contours for all interpreted interfaces	Full	.gdb: raster	Y
141	**Geology**	**D**	Polygon extents for each identified geological unit, Formation and feature	n/a	.gdb: polygon	Y
142	**Geohazards**	**D**	Point and polyline geohazards	n/a	.gdb: point, line	Y
143	**Geology**	**D**	Seabed sediment sample locations	n/a	.gdb: point	Y
144	**Geology**	**D**	Seabed sediment classification.	n/a	.gdb: polygon	Y
145	**Seabed**	**D**	Bedform classification.	n/a	.gdb: polygon	Y
146	**Seabed**	**D**	Geotiffs of waterfall images for all reported side scan sonar contacts.	n/a	.gdb: raster	Y
147	**all**	**Meta**	Metadata to specification provided in Annex A06 s VII A	n/a	.gdb	Y

Notes on GIS deliverables:

- Sensor trackplots and fix points (transmitter/receiver midpoint where transmitter and receiver are not co-located; CDP-based for the UHRS trackplots).
- MBES, SSS and magnetometer Contacts (point, linear and polygon Contacts to be symbolised appropriately; *e.g.* significant linear Contacts should be recorded

as line features and not points), including as-found cables, pipelines, wrecks *etc.*

- MBES and SSS Contacts may be combined into a single Feature Class/shapefile but magnetometer Contacts must be kept separate.
- Elevation and depth below seabed grids and contours for all interpreted interfaces (including gridded geohazards, *e.g.* top shallow gas). Grid and contour coverage must be consistent with the associated extent polygons.
- Polygon extents for each identified geological unit and Formation and all spatially-extensive geohazards (gas, significant channels, areas of faulting *etc.*). Areas where an interface or geohazard is thought to be present but is not interpretable must be differentiated from areas where it is thought to be absent.
- Point and polyline geohazards (suspected boulders, isolated peat occurrences of too small an extent to be gridded, *etc.*).
- The master map (*.mxd document) should include a layout containing at minimum a map window (with appropriate graticule), scale bar and legend. All data should be symbolised using similar schemes as per the report charts for ease of cross-referencing.
- Layers should be grouped into meaningful categories (background mapping, geohazards, seabed features, *etc.*) and layer and group names should be used that can be easily cross-referenced to the report text and charts (rather than simply using the feature class/grid names.

2.5 Quality Assurance and Quality Control

Annex 6 - section VI Quality Requirements and Administrative Instructions contains a brief description of the operational quality management requirements to be implemented during the survey work. A Quality Management Plan (QMP) is required, this section describes specific operational QA requirements in support of those described in Annex 6 - section VI section 1.2.5.

During data acquisition, MBES, SSS, MAG and sub-bottom (SBP and 2D/3D UHRS) datasets shall be monitored continuously to ensure both coverage and quality (including resolution) are maintained. The survey *speed over ground* shall be no more than 5 knots, vessel speed will be subject to weather and current conditions encountered and may impact on data quality (particularly for the 2D/3D UHRS data) so shall be monitored. Throughout the offshore survey activity, data quality checks shall be carried out on board by a qualified geophysicist including comparison of data collected on adjacent and perpendicular survey lines to ensure continuity. Any omissions, inconsistencies or other issues that may impair the quality, quantity or interpretation of the final data shall be immediately discussed with the CLIENT offshore representative and suitable actions agreed to rectify any dataset deficiencies.

Suitable field data processing shall be undertaken on board by suitably qualified and experienced personnel to identify any anomalous or specific field data of interest, so that further investigation can be made while the offshore work is ongoing as appropriate. Any specific data processing operations required as a result of the data acquisition configuration shall be associated with a QA operation onboard to assure that collected data are acceptable. The CONTRACTOR shall implement and perform suitable quality control procedures to ensure that data of appropriate quality are being collected. The CONTRACTOR shall ensure that the CLIENT offshore representative is sufficiently aware of any obligatory data processing operations that the CLIENT offshore representative can effectively perform QA role.

All offshore data processing is to be considered preliminary and subject to rework should it be found deficient. The onboard QA activities are specifically defined to assure that data acquired are fit-for-purpose. Any attempt at on-board *final* processing is to be secondary to the task of quality management of the acquired data.

Navigational accuracy, tidal height accuracy, frequency and method of navigation checks and positioning specifications shall be stated. Navigation checks shall be completed prior to leaving harbour. The procedures to be followed in event of navigational non-compliance shall be logged and the CLIENT offshore representative advised at the Worksite.

Accurate positioning is essential, and in the discussion of interpreted Contact locations, interface depths *etc*. in reports and other documentation the chain of positioning errors (Contact to instrument package to vessel to GPS network) must be considered in order to provide quantified uncertainty values. The derivation of these uncertainty values must be explicitly described.

During UHRS acquisition, daily data quality assessment shall be performed by generation of stacks with the minimum feasible data processing operations to enable evaluation of quality. The shot quality shall be continuously monitored. The QMP must include, prior to the start of production data acquisition, a set of criteria for acceptable quality. For example a shot may be deemed 'bad' if navigation is lost, feathering angle threshold is exceeded, streamer balancing is compromised, signal-to-noise ratio is compromised, source signature is poor/not constant, shot point distance is not constant and at required intervals or shots are missing/misfired, *etc*.

End-of-line quality assessment shall comprise of an end-of-line report summarising such pertinent QA monitors for all datasets being acquired. The content of the EOL QA

shall be suggested within the CONTRACTOR's proposal and finalised before production data acquisition begins.

The following must be agreed with the CLIENT before UHRS surveying commences:

- A Quality Assurance monitoring programme for the data acquisition.
- Acceptance criteria for completion of acquisition for a seismic line.

2.5.1 *Offshore Representation*

The CLIENT may require up to two (2) CLIENT offshore representative per vessel to witness the offshore phase of the surveys.

The CONTRACTOR is to be responsible for providing safety induction training for the CLIENT offshore representative who are to work on or visit any vessel in connection with the execution of the work.

The CONTRACTOR shall provide adequate facilities for the CLIENT offshore representative on any vessels to include a private cabin, office space, PC of sufficient power and with applications loaded suitable for QA operations, communication systems including satellite phone and appropriate internet connection and messing facilities. The CLIENT cabin needs to have an internet connection with a minimum speed of 512 kbits/sec upload / download.

CONTRACTOR shall provide Personal Protective Equipment (PPE), life jackets and any special offshore PPE for the CLIENT offshore representative for the duration of the project.

2.6 Reporting

The reporting requirements for the geophysical survey work are as follows:

2.6.1 *Daily & Weekly reporting*

The CONTRACTOR is to submit daily reports throughout the period of the fieldwork, providing full details of previous 24 hours' work and results. Further CONTRACTOR shall issue a weekly report providing insight in the progress of the WORK on a weekly basis. The minimum content of the daily and weekly reports is specified in Annex 6 - section VI of this CONTRACT.

The CONTRACTOR may be requested by the CLIENT to provide Data Quality Reports ("DQR") when appropriate. The DQR will not have to be provided on a daily basis but the CONTRACTOR must be prepared to compile and provide these reports under the supervision of the CLIENT offshore representative. Content of standardised elements of DQRs is to be established at the TKOM.

Upon request from the CLIENT, the CONTRACTOR shall provide a portion of raw or processed data by email or web transfer for the purpose of monitoring Quality Control. The CONTRACTOR shall provide the CLIENT such data within 24 hours of the request.

2.6.2 *Field report - Geophysics*

A Field Report shall be made available for the IA within three (3) weeks of completion of the fieldwork. The Field Report shall contain daily logs and summaries of the work completed, together with any preliminary results that can be provided.

The Field Report should include as a minimum:

- A statement of the purpose of the investigation and Scope of Work;
- A description of the work carried out, including:
    - Project personnel (GDPR compliant); vessels; equipment list;
    - Vessel Offset Diagrams for each vessel and, if instrument configurations were changed in the field, each instrument configuration;
    - Mobilisation, Testing and Calibration operations
    - Exact positions of all survey data and details of survey positioning control (positioning calibrations, geodetic data, *etc.*), with accompanying calibration records; field procedures, including methodology,
    - Acquisition methodology for each dataset.
    - Quality Control procedures and reference to specifications and standards adopted and any deviations from them for each survey type;
    - End-of-line reports.
    - Environmental observations;
    - Health & Safety records, Incident reports and safety meeting minutes.
    - Copies of daily reports,
    - Relevant signed calibration sheets

The CONTRACTOR shall provide a Draft Field Report, through ftp site or other electronic means, which shall be made final after processing of comments and approval by the CLIENT.

Table 11: Reporting and Chart deliverables						
Item ID	**Measurement**	**Module R = Reports C = Charts**	**Description**	**Resolution**	**Format**	**Load into GIS-database**
148	**Report and Charts**	**R**	Mobilisation and Testing Report	n/a	.pdf	N
149			Field (operations) Report	n/a	.pdf	N
150			Seismic Processing Reports, (2D and 3D) - as appendix to Operations Report	n/a	.pdf	N
-			Seabed Sampling Field and Laboratory reports – as appendix to Operations Report	n/a	.pdf	N
-			Ecological Sampling Field Reports	n/a	.pdf	N
151			Interpretation Report	n/a	.pdf	N
152		**C**	Bathymetry overview chart	n/a	.pdf	N
153			Seabed features overview chart	n/a	.pdf	N
154			Seabed sediment classification chart (incl. sample locs)	n/a	.pdf	N
155			Seabed contacts overview chart	n/a	.pdf	N
156			Geohazards overview chart	n/a	.pdf	N
157			Geological Cross Sections	n/a	.pdf	N
158			Geological unit elevations and extents	n/a	.pdf	N
159			Preliminary Zonation chart	n/a	.pdf	N

2.6.3 *Final report - Geophysics*

A Final Report shall be made available, incorporating interpretational reporting, for the IA within ten (10) weeks following completion of the fieldwork. This Final Report shall include:

- A statement of the purpose of the investigation;
- A description of the work carried out, including methodology used for the processing of each dataset and the positioning data plus reference to specification and standards adopted and any deviations from them;
- Exact locations of all survey lines;
- Geophysical and geological data interpretation and conclusions drawn. This includes all results deliverables specified in Section 2.3, 2.4 and 2.4;
- Electronic copies of all raw and processed data from the survey;
- Charts at an appropriate scale on A0 of all outputs defined by CLIENT as required.

All reports and data deliverables shall be accompanied by metadata that are compliant with RVO's metadata requirements specified in Annex A06-Section VII Annex A.

The CONTRACTOR shall provide a Draft Final Report, which shall be made final after processing of comments and approval by the CLIENT.

It is anticipated that a physical meeting should be arranged after delivery of draft report and data, to facilitate the review and implementation of any corrections and changes required.

Deliverables

A complete data archive as defined in the preceding sections must be provided with each and all draft and final interpretative reports.

The following reporting and charting deliverables are required at minimum:

Notes on reporting and charting:

A table of file names against line names for all MBES, SSS, MAG and seismic data files as plain text file or spreadsheet is required. For lines associated with multiple line-part data files, each data file should have its own entry in the index table. The table should also contain the following information against each line name entry:

- Acquisition vessel;
- Acquisition date;
- Source type and ID;
- Receiver type and ID;
- Start and End fix points;
- Name of the relevant Vessel Offset Diagram;
- Indication of whether the file is a production file or has not been processed;

All raster deliverables for single-variable data should be supplied as single-band files with actual cell values (e.g. elevation, intensity), not as multi-band RGB images, with the exception of the SSS mosaic. If provided in a non-ESRI GIS format (*e.g.* CAD, microstation), all processed deliverables listed that can be included in a GIS archive must be provided additionally in the project GIS archive.

2.6.4 *Field report Lot 1 Seabed Sampling (Seabed Sampling and Vibrocores)*

The field results obtained from seabed sampling (sampling, vibrocoring and offshore laboratory testing) shall be presented as the first version of the "Seabed Sampling Report", within three (3) weeks of the completion of the fieldwork (Section 2.9.2).

The CONTRACTOR shall be required to submit a reporting template for the "Seabed Sampling Report" within one week after the Start of the offshore works.

Version 1 (Field Report) of the "Seabed Sampling Report" shall include, but is not limited to:

- A statement of the purpose of the investigation;
- A description of the Work carried out, including reference to specification and standards adopted and any deviations from them;
- Exact locations of all samples and vibrocores (coordinates shall be with respect to ETRS89 datum, given in degrees and decimal minutes format as well as in eastings and northings using a ETRS89 UTM Zone 31N projection). The coordinates should also be provided in electronic format (xlsx);
- Drawings (GIS format or similar as well as PDF) showing the locations of all samples and vibrocores undertaken;
- Any and all calibration certificates;
- Preliminary (field) vibrocore logs;
- Preliminary (field) sample records;
- Obstruction list (lost equipment on and below seabed) incl. coordinates and depth.

The CONTRACTOR shall provide one (1) electronic copy of this report.

2.6.5 *Final Report Lot 1 Seabed Sampling (Seabed Sampling and Vibrocores)*

The CONTRACTOR shall submit a complete draft (first version) of the "Seabed Sampling Report" no later than no later than ten (10) weeks following the completion of fieldwork (Section 2.9.2).

This report should include the following (as appropriate):

- A statement of the purpose of the investigation;
- A description of the work carried out, including reference to specification and standards adopted and any deviations from them;

- Exact locations of all vibrocores and seabed samples, co-ordinates, water depths as defined in Section 1.6 and 2.4.2. The coordinates should also be provided in electronic format (xlsx);
- Drawings (GIS or similar as well as PDF) showing the locations of the vibrocores undertaken;
- Final (approved) vibrocore logs;
- Final (approved) sample records;
- Final (approved) detailed laboratory test results;
- Summary of Laboratory Test Results;
- Colour photographs of samples/cores both whole and split;
- Lab test data in AGS format and ASCII format.

Maps (in GIS and PDF) will not show any specific Wind Farm Sites but will only show the outer boundary of the Wind Farm Zone and the Investigation Areas.

The CONTRACTOR shall provide digital draft reports, which shall be made final after processing of comments and approval by the CLIENT. The draft reports shall contain all information to allow a comprehensive review to be performed by CLIENT.

CONTRACTOR shall provide one (1) electronic copy of the FINAL REPORT and data.

2.7 Delivery

Draft and Final deliveries should contain all reports, data and charts. Partial or interim deliveries are not encouraged. All Deliverables MUST be subject to rigorous QC by the CONTACTOR to ensure completeness and correctness of all components.

The Draft (1st and 2nd version) and Final Reports must each be accompanied by a complete set of data deliverables as defined in Section 0, including the project GIS archive. Data shall be provided via multiple portable hard drives (5) for all 3 reports, electronic delivery may be accepted with prior agreement of CLIENT, though agreement to delivery in this way is not guaranteed.

CONTRACTOR shall present the Final Reports in two webinars to be organised by CLIENT.