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Soil Investigations Wind Farm Sites

Annex 6 - Section V

Scope of Work

Integrated Ground Model and Geotechnical Interpretation Report

IJmuiden Ver Wind Farm Zone Sites V & VI

Colophon

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REFERENCES

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- ASTM D 5311-13 Standard Test Method for Load Controlled Cyclic Triaxial Strength of Soil, ASTM International, 2013
- ASTM D7400-19 Standard Test Methods for Downhole Seismic Testing, ASTM International, 2019
- BS 1377 Soils for civil engineering purposes Part 1 to 9. British Standard, 1990 to 2021 depending on the section (latest version of each part to be considered).
- BS 5930 Code of practice for ground investigation, British Standard, 2020
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- DNVGL-RP-0416 Recommended Practice Corrosion protection for wind turbines. DNV GL, 2016.
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- EN ISO 9001:2015 Quality management systems — Requirements. International Organization for Standardization (ISO), 2015.
- EN ISO 14688-1:2017 Geotechnical investigation and testing — Identification and classification of soil — Part 1: Identification and description. International Organization for Standardization (ISO), 2017.
- EN ISO 14688-2:2017 Geotechnical investigation and testing — Identification and classification of soil — Part 2: Principles for a classification. International Organization for Standardization (ISO), 2017.
- EN ISO 19901-2:2017 Petroleum and natural gas industries: specific requirements for offshore structures – Part 2: Seismic design procedures and criteria. International Organization for Standardization (ISO), 2017.
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- EN ISO 19901-8:2014 Petroleum and natural gas industries — Specific requirements for offshore structures — Part 8: Marine soil

	investigations. International Organization for Standardization (ISO), 2014.
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EN ISO 22476-1:2012	Geotechnical investigation and testing — Field testing — Part 1: Electrical cone and piezocone penetration test. International Organization for Standardization (ISO), 2012.
EN 1997-1:2004	Eurocode 7 – Geotechnical design – Part 1: General rules. European Committee for Standardisation (CEN), 2004.
EN 1997-2:2007	Eurocode 7 – Geotechnical design – Part 2: Ground investigation and testing. European Committee for Standardisation (CEN), 2007.
EN 1998-1:2004	Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, Seismic actions and rules for buildings. European Committee for Standardisation (CEN), 2004.
ISO/IEC80000	Quantities and Units – Part 1: General. Organization for Standardization (ISO), 2009.
ISSMGE	International Reference Test Procedure for the Cone Penetration Test (CPT) and the Cone Penetration Test with pore pressure (CPTU). International Society of Soil Mechanics and Geotechnical Engineering, 2001.

LIST OF ABBREVIATIONS

CMP	Common Mid Point
CPT	Cone Penetration Test
f_s	sleeve friction
G_{max}	small strain shear modulus
GGM	Geological Ground Model
GIS	Geographic Information System
GP	Geophysical Contractor
GT	Geotechnical Contractor
GIR	Geotechnical Interpretation Report
HKW	Hollandse Kust West
IGM	Integrated Ground Model
IA	Investigation Area
LTAF	Laboratory Test Assignment Form
LAT	Lowest Astronomical Tide
MW	Mega Watt
MIC	Microbially Induced Corrosion
MC UHRS	Multi Channel Ultra High Resolution Seismic
PSD	Particle Size Distribution
PCPT	Piezo Cone Penetration Test
PGM	Preliminary Ground Model
PEP	Project Execution Plan
PQP	Project Quality Plan
QA	Quality Assurance
QC	Quality Control
QI	Quantitative Interpretation
q_t	corrected cone resistance
SCPT	Seismic Cone Penetration Test
SBP	Sub Bottom Profiler
TCPT	Temperature Cone Penetration Test
TNW	Ten noorden van de Waddeneilanden
UHRS	Ultra High Resolution Seismic
u_2	pore pressure
VC	Vibrocore
WFZ	Windfarm Zone
WPM	Work Progress Meeting

1 Introduction & Background

1.1 Scope of this Document

This document details the scope of the WORK as part of the CONTRACT that CONTRACTING AUTHORITY has awarded to the INTEGRATED GROUND MODEL (IGM) and GEOTECHNICAL INTERPRETATION REPORT (GIR) CONTRACTOR for carrying out the integration of all acquired geophysical and geotechnical data sets across the IJmuiden Ver Wind Farm Sites V and VI (IJVWFS V-VI). IJVWFS V-VI are 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 subsidy for construction and operation of (a) wind farm(s) will be organized under the Offshore Wind Energy Act. 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 provided by the geophysical survey through a sequence of commissions for geological, geophysical, geotechnical and morphodynamical studies. Information will be presented as factual data, integrated and interpreted data (a Preliminary Ground Model) and will be comprehensively reported. In combination with further site and laboratory data from a geotechnical survey, an Integrated Ground Model (IGM) and a Geotechnical Interpretation Report (GIR) will be created. The IGM will be of sufficient precision to allow participants to make initial plans and costings for foundation design and cable installation. A comprehensive report will be added for the IGM. In general, the CONTRACTING AUTHORITY is ultimately seeking an Integrated Ground Model that incorporates industry Best Practice and represents the current State-of-the-Art.

This assignment is concerned with the Integrated Ground Model (IGM) and the Geotechnical Interpretation Report (GIR) component, contributing to the information package to be provided to participants.

After Borssele, Hollandse Kust Zuid, Noord and West) and Ten noorden van de Waddeneilanden this is the extension to the sixth WFZ (IJmuiden Ver I-IV) for which site investigations are executed and ground models are developed within the Netherlands Offshore Wind Energy Roadmap 2030.

1.3 Site Description

The locations of the Dutch Offshore Windfarm Zones are summarized in Figure 1. The IJVWFS V-VI are further extensions to the IJmuiden Ver sites I-IV. They are located north of the shaded area of the IJVWFZ (Figure 1) and cover approximately 283 km². The total capacity of IJVWFZ will be, including this extension, 6000 MW.

The current schedule indicates that IJVWFZ will be tendered in three stages in 2024 (I-II), 2025 (III-IV) and beyond (V-VI). The site investigation campaigns as well as result deliveries for the IJmuiden Ver Wind Farm sites I-IV will be completed during the here assigned project schedule.

Water depths range between 16.8 and 46.9 m (LAT). The seabed is typical for areas with high tidal energy with sand ridges and sand waves (cited from Geological Desk Study for IJVWFZ, see section 1.5).

The IJmuiden Ver sites I-VI are located approximately 18 km to the west of the *Hollandse Kust West* (HKW) WFZ. The ground conditions of the upper 100 m subsurface at this region are interpreted to be, at least in part, comparable to HKW, containing Holocene and Pleistocene sediments with depositions characterised by the Doggerland inundation. Hence, fluvial, fluvio-deltaic, deltaic, tidal flat, and marine deposition environments are expected as well as channel infills, especially within the Pleistocene succession and the Holocene transgression sediments in the northern part of the Investigation Area (IA).

The Geological Desk Study, available from offshorewind.rvo.nl, delivers initial information on the expected stratigraphic units, geological structures, and possible influence on the design as well as the construction of offshore wind farms in the IA. Appropriate information from the IJVVWFZ I-IV and the HKW site will be made available to the CONTRACTOR as initial information to assess the interpretation and integration potential (see section 1.5).

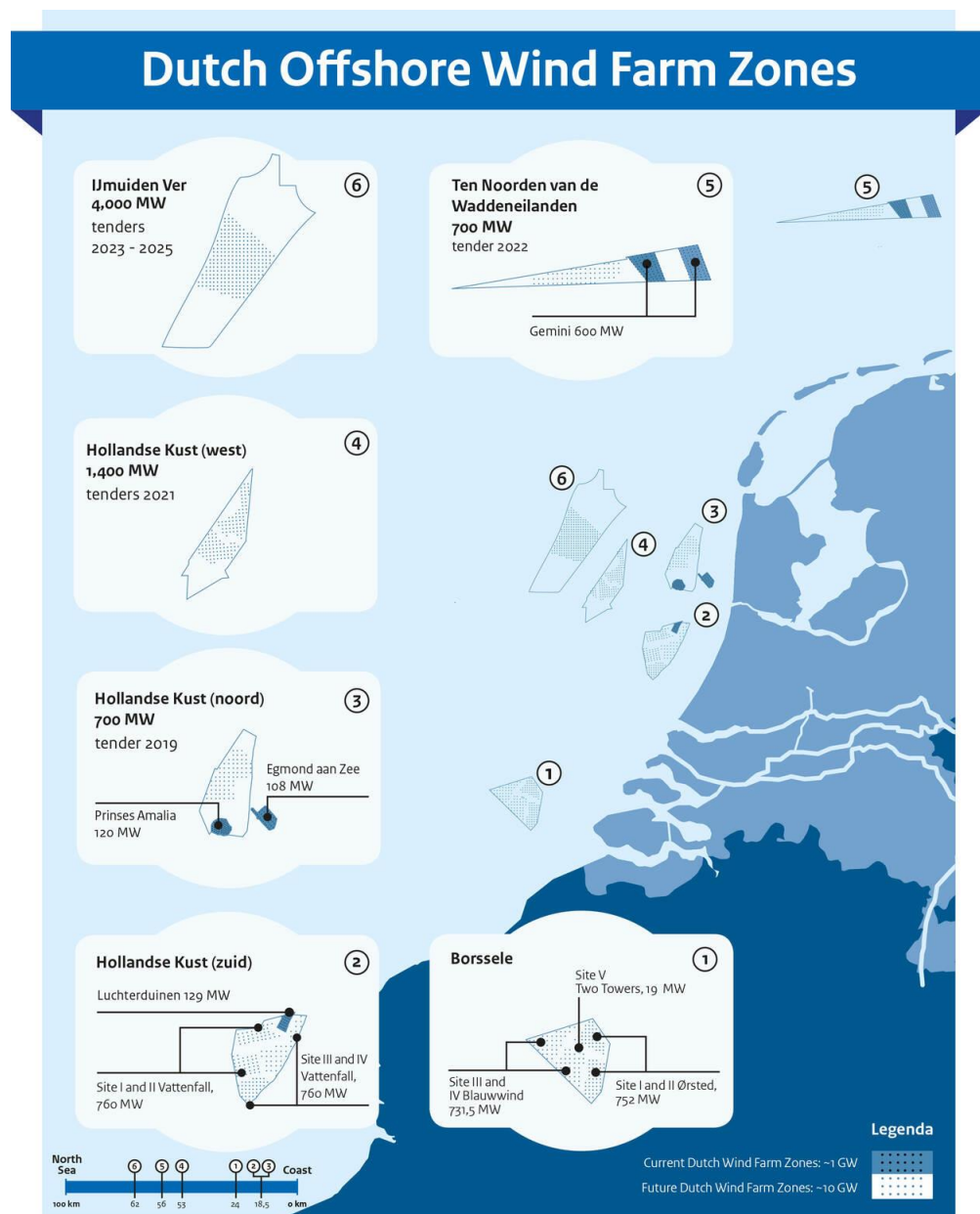


Figure 1: Designated Offshore Wind Farm Zones in the Netherlands

1.4 Investigation Area

The CONTRACTOR will be working from a set of geotechnical and geophysical data for the IJWFS V-VI.

The Integrated Ground Model IA is identical to the Geophysical IA, which covers the IJWFS V-VI zone plus a *0.5 km wide buffer zone around the WFZ* as illustrated with Figure 2. The striped, red area north of the IJWFS V-VI marks a military zone. The northern buffer zone overlaps the military zone by 500 m. In red (Figure 2 and insert), a detail corridor is drawn where a 3D Multi-Channel Ultra High-Resolution Seismic (3D-UHRS) investigation will be performed. In the other parts of the entire area, 2D Multi-Channel Ultra High-Resolution Seismic (2D-UHRS) data will be collected with a track line spacing of at nominally 70 meters. Moreover, the geophysical survey will provide a detailed dataset including bathymetry and backscatter survey, side-scan sonar, magnetometry, seabed and vibrocore and seabed sediment sampling for the entire area. The maximum depth of interest is set to 100 m below seafloor for the Geophysical Survey. The 2D UHRS data will cover approximately 272 km² with an estimated total of 4750 line km within the IJWFS V-VI and 1500 line km of 3D UHRS data. Furthermore, a total of 300 line km of 2D UHR data will be acquired within 90 km of the IJWFS V-VI area. This additional 2D UHR data will cover future tie-in lines. For further information on the scope of the Geophysical Survey, see section 2.2.2.

The Geotechnical IA will cover the entire IJWFS V-VI but is planned to be *exclusive* of the above-mentioned buffer zone. The depth of interest for the Geotechnical Survey will cover the seafloor to approximately 100 m depth. Hence, the validity range for the IGM must cover the same depth.

The boundary coordinates of the site for which the Integrated Ground Model needs to be developed, are provided in Table 1, section 1.4.1, repeated from Annex 5: Starting Points and Assumptions. These co-ordinates are identical to the extent of the Geophysical survey.

The investigation area specifically excludes any potential export cable routes.

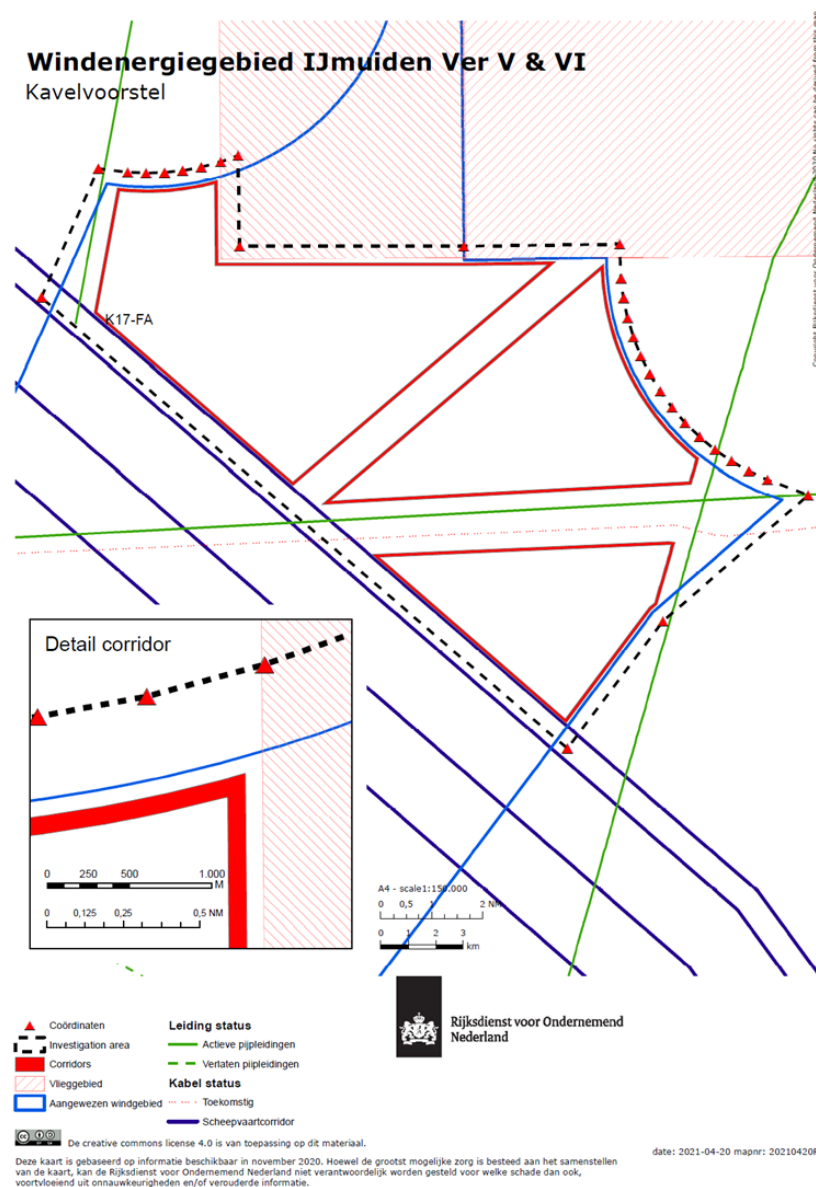


Figure 2: Geophysical Survey Investigation Area and Integrated Ground Model Area for IJmuiden Ver Wind Farm Sites V-VI.

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 5: Starting Points and Assumptions.

The vertical datum for this project is Lowest Astronomical Tide (LAT).

The Integrated Ground Model shall be compiled with the vertical datum LAT.

Table 1 summarizes the boundary coordinates for the assigned IA.

Table 1. Coordinates of the vertices of the outer boundary of the Investigation Area for the Geophysical Survey and the Integrated Ground Model for IJWFS V-VI (including buffer zone).

IJWFS V-VI Coordinates of Geophysical Survey Area and Integrated Ground Model		
Point No.	Easting (m)	Northing (m)
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		

1.5 Additional Information

In addition to the available results from the geophysical survey, the following studies will be provided by CONTRACTING AUTHORITY separately to the CONTRACTOR before start of the works¹:

- Geological desk study, via
[https://offshorewind.rvo.nl/cms/view/2dd28a50-5344-47a6-b3ff-7d0e36911159/soil-ijmuiden-ver](https://offshorewind.rvo.nl/cms/view/2dd28a50-5344-47a6-b3ff-7d0e36911159/soil-ijmuiden-ver;);
- UXO desk study, via
<https://offshorewind.rvo.nl/cms/view/10a7d488-abd1-43c2-8d99-3132b2070881/obstructions-ijmuiden-ver>;
- Base map (MPK) containing information on location, via
<https://offshorewind.rvo.nl/cms/view/796048cf-12cb-4e90-8124-ae4eb73c1c49/general-information-tnw>;
- Archaeological desk study, via
<https://offshorewind.rvo.nl/cms/view/10a7d488-abd1-43c2-8d99-3132b2070881/obstructions-ijmuiden-ver>.

Furthermore, the results of the geophysical and geotechnical surveys carried out for Borssele, HKZ, HKW, HKN and TNW WFZ and the geophysical survey results from IJV I-IV are available at <http://offshorewind.rvo.nl/>. It should be noted that the scope of work for the previous surveys instructed by the CONTRACTING AUTHORITY may deviate from the current scope of work.

Further results from the geotechnical survey as well as the IGM contents of the ongoing investigations for the IJWFS V-VI will be made available by the CONTRACTING AUTHORITY as soon as possible and is expected to be considered during the WORK of the CONTRACTOR.

¹ All studies, excluding the Geophysical Survey Reports, are available within this Tender package

2 Scope of Work

2.1 Introduction

The scope of work provides a detailed and straightforward guideline for the project milestones, input parameters, activities and required deliverables for the IGM and GIR CONTRACTOR. The workflow is binding, further options and flexibilities are explicitly assigned. A summary table for the deliverables of every workflow step is presented in section 2.2.20.

2.2 Workflow and deliverables

2.2.1 Project Execution Plan

Milestone: Proposal Project Execution Plan (PEP) outlining CONTRACTOR's understanding of the WORK, clear and concise outline of methodologies for the various activities associated with the WORK, identification of risks and mitigation measures, and schedule.

The CONTRACTOR is requested to provide with Tender a Project Execution Plan (PEP) in which the fundamental approach and methodologies are set out and explained. Upon award of the WORK, the CONTRACTOR is required to provide the PEP which represents the roadmap for the duration of the CONTRACT. Key items such as the reprocessing of the geophysical data, methodology for preparation of the GIR and IGM deliverables are expected to be captured in the PEP.

During the project and depending on the achievement of specific milestones, periodic updates to the PEP are expected under a management of change protocol, with the document being as accurate, detailed and specific as is possible and reasonable at all times. The schedule for the delivery of PEP updates will be determined by the CONTRACTING AUTHORITY during the project phase (exemplary milestones for updates are indicated below). Requirements of the various deliverables are discussed in the following sections. The feasibility phase and general strategy planning are to be outlined by the CONTRACTOR and, finally, approved by the CONTRACTING AUTHORITY prior to the geotechnical site investigation planning (see 2.2.5). The project specific Project Execution Plan (PEP) is to be delivered as early as possible after project kick off.

Input:

- Relevant geophysical and geotechnical as well as IGM/GIR investigations of other Dutch wind farm zones, especially HKW, TNW WFZ and IJWWFZ I-IV, see section 1.5
- Geological Desk study IJWWFZ, see section 1.5
- Input for PEP update after milestone 2.2.2 is completed:
 - Complete PGM
 - Raw and interpreted sub-seabed data from geophysical survey (2D/3D MC UHRS) as well as preliminary velocity model and seismic processing methods of the GP
 - Seabed assessment
 - Shallow seabed and zonation classification
- Input for PEP update along with milestone 2.2.7
 - Activities of the CONTRACTOR performed up to this project state
 - Incoming data and information of the geotechnical field campaign
- Input for PEP update along with milestone 2.2.14
 - All activities by the CONTRACTOR up to this stage and explicitly the full reprocessing procedure of the geophysical data to compile a Geological Ground Model which meets the requirements for the IGM,

as well as the review and (pre-)analysis of the geotechnical field and laboratory data

Activities:

The CONTRACTOR is required to address the following items in the PEP as well as PEP updates:

- Strategy for reprocessing sub-seabed MC UHRS data, especially outlining methods used to establish further velocity models and refinement procedures resulting in a refinement of the geophysical dataset to meet the requirements of the Geological Ground Model and the IGM, see 2.2.2, 2.2.3, 2.2.7, 2.2.14, and 2.2.17
- A detailed section of the above strategy plan describing explicitly aspects of advanced reprocessing and refinement methods of MC UHRS data with focus on the correlation and spatial assignment of geotechnical parameters based on seismic signal interpretations
- A strategy description for the enhancement of the Geological Ground Model, outlining potential sub-unit/lens/horizon definitions additional to the principal geological interfaces of the PGM, see 2.2.2, including a litho-genetic conceptual design and regarding requirements as outlined in 2.2.14
- A proposed array of geotechnical parameters to be assessed and presented (measured and derived) suitable for the design and installation of (mono)piles and inter array cables, including a methodology to define characteristic values for each parameter, if relevant
- A detailed description of the interpretive framework for assessing and presenting results from drained and undrained cyclic strength tests
- A strategy plan to compile the GIR, which includes statements for confirming, adding or constraining with plausible reasons the derivation of geotechnical parameters as defined by the CONTRACTOR, see above
- A detailed description of methods to distinguish horizons and soil bodies of similar geotechnical behaviour in the context of a wind farm development including cable installation regarding contents of the expected GIR analysis
- A detailed description of a proposal for a zonation processing of the investigation area (IA) into Geotechnical Provinces, providing information about similarities of geotechnical soil behaviour downhole the entire sequence of investigation depth or an appointed depth range in context to wind farm and cable installation/foundation purposes
- A detailed description of predicted CPT derivation for a minimum of parameters as defined explicitly in section 2.2.15, e.g. plan for the use of machine learning or advanced geostatistical methods designed for this purpose, including sensitivity analyses for evaluation of different methods, optimisation and validation of approach
- A detailed statement of expected constraints and uncertainties of the IGM product due to inherent (natural) variability in ground properties (which as well includes capturing the autocorrelation) and soil property uncertainties (data scatter e.g. due to measurement error and systematic uncertainty due to transformation, modelling and other biases)
- Proposal for the level-of-detail of the IGM
- Innovative proposals for the technical representation of 3D high-resolution multi-attribute models in hundreds-of-square-kilometer scales as a key content of the IGM (e.g. parameter-on-demand-solutions, dynamic resolution fitting techniques to end-user filter or view options), see 2.2.17
- Assessment of risk and mitigation measures for the geotechnical site investigations and project execution, see also 2.2.2 and 2.2.5. Note, that the CONTRACTING AUTHORITY is to be contacted and informed *immediately* if (further) risks for the geotechnical site investigation as well as the project execution has been detected by the CONTRACTOR. The CONTRACTOR is

requested to provide mitigation measures updates as soon as possible. This must not be bound to the schedule of PEP updates or milestone deliveries

- The preparation of a time schedule of the CONTRACTOR for the execution of project activities
- Overview of deliverables and deliverables format required under the contract.
- A Project Quality Plan (PQP) in accordance with EN ISO 9001:2015, Incorporating elements included below in 'Quality Assurance interface' sections which describe minimum interaction with CONTRACTING AUTHORITY

Quality Assurance interface:

Project documentation shall be reviewed and approved by the CONTRACTING AUTHORITY using a document response form, review and approval process.

Deliverables:

Deliverables are to be provided by the CONTRACTOR as early as possible after project kick off and as follows:

- The PEP is to be delivered as text with comprehensive descriptions of the above assigned issues, including:
 - Method statements
 - Quality Assurance processes, metrics and deliverables
 - Pre-feasibility studies or scientific publications to methodologies
 - Process flow charts
 - GANTT charts as required
- One meeting to discuss the contents of the PEP with the CONTRACTING AUTHORITY and to initiate further workflow steps.

2.2.2 *Review Geophysical Site Investigation*

Milestone: Geophysical site investigation. Preliminary Ground Model (PGM). Seabed sampling report.

The CONTRACTING AUTHORITY has appointed a geophysical contractor (GP) to carry out a geophysical survey. The geophysical survey will include a comprehensive geophysical data acquisition campaign with associated seabed sampling techniques at selected sites. The execution of the investigations is planned for Q1-Q3 2022. The CONTRACTOR shall be invited to provide input during the geophysical campaign to assure awareness of the nature of the geophysical data and compatibility of processes prior to their finalization. The CONTRACTING AUTHORITY, through its appointment of the GP, will remain responsible for the execution of the geophysical site investigation.

Input:

The results of the geophysical campaign will include the following items:

- High resolution bathymetric and backscatter survey
- Side scan sonar survey
- Magnetometer survey
- Shallow Penetration Sub-Bottom Profiler (SBP) survey
- 2D- (covering 272 km² and approximately 4750 line km) and 3D-multichannel-UHRS (1500 line km) seismic profiling survey within the IJWFS V-VI area as outlined in section 1.4 and Figure 2
- 2D UHRS seismic profiling survey (300 line km) at future tie lines.
- At least 30 seabed (box core) sampling (ecological, not to include in IGM)
- At least 30 water sampling (ecological, not to include in IGM)
- At least 25 vibrocore sampling with penetration depths between 3 m to 6 m
- At least 12 seabed (grab) sampling locations for geotechnical purposes
- A Preliminary Ground Model (PGM) including:
 - estimated base depth of mobile sediments,
 - estimated depth of a set of principal interfaces of geological formations or other horizons of interest,

- preliminary velocity field from seismic data processing,
- locations of structural features (faulting, shallow gas, peat, channel infills, sub-glacial and glaciotectionic structures),
- correlation to the other geophysical and geotechnical interpretations available in this region, especially from IJWWFZ sites I-IV
- a comprehensive report with geohazard risk assessment.
- Zonation of sub-seabed geological units and seabed classification

Beside the interpreted data package of the PGM, all raw datasets and intermediate data will be made available to evaluate, reprocess, reinterpret, and rework. Beside raw data formats (e.g., SGY, ASCII, xyz etc.), the deliverables will include GIS files and a single seismic workstation project (IHS Kingdom).

Activities:

The CONTRACTOR is expected to perform following tasks, scheduled for Q2-Q4 2022:

- Review of all data (raw, intermediate, and interpreted) and statistics from the geophysical site investigation
- Review of vibrocore and seabed samples obtained during the geophysical campaign as well as performed field and laboratory tests on samples. Note that the recovered ecological samples will not form part of the ground model. Review of all site investigation documentations and reports
- Review of the PGM project contents and the accompanying report provided by the GP contractor
- Assessment and presentation of requirements and potential methods for reprocessing of the 2D/3D-MC UHRS data (ongoing, see sections 2.2.3, 2.2.7, 2.2.9, 2.2.14 and 2.2.17) to support GIR processing, the IGM, and quantitative interpretation (QI). It is anticipated that the following aspects of seismic data processing may require rework:
 - General imaging, demultiple and signal quality
 - Improvement in image fidelity
 - Stacking Velocity Analysis
 - Improvement in image fidelity
 - Imaging velocity as a ground model asset
 - Amplitude and spectral consistency
 - Ensure dataset is compatible with anticipated QI processes

Deliverables:

The CONTRACTOR is expected to deliver following services, scheduled for late Q3 to early Q4 2022:

- Technical Note including short independent statements to the above assigned review activities including data quality assessment, uncertainty evaluation (structural and parametrical), geological complexity, prominent geological features (e.g. channel infills, glaciotectionic features, remarkable peat horizons) and degree of correlation to nearby wind farm investigations (IJWWFZ).
- Technical Note for the geophysical data acquired at the tie-in lines, including short independent statements to the above assigned review activities including data quality assessment, uncertainty evaluation (structural and parametrical), geological complexity, prominent geological features (e.g. channel infills, glaciotectionic features, remarkable peat horizons) and degree of correlation to nearby wind farm investigations (IJWWFZ).
- One meeting with the CONTRACTING AUTHORITY to discuss results and deliverables.

2.2.3 *Implement Initial Reprocessing of Geophysical Sub-Seabed data*

Milestone: Refinement of geophysical datasets to optimise data fidelity in preparation for detailed and quantitative interpretation

Sub-seabed geophysical data (2D-, 3D-MC UHRS data and SBP) are anticipated to require some re-processing per the outcome of section 2.2.2. Based on the quality of the data set and the proposed reprocessing methodology outlined in the PEP, CONTRACTING AUTHORITY will assess the need and extent of the reprocessing efforts. Components of this workflow which are independent of the interpretative geological model may be initiated as soon as necessary. These may include, but are not limited to, static shifts, denoise, wavelet shaping, demultiplex. Interpretative reprocessing, in particular velocity modelling and processes which are dependent on seismic stacking velocity analysis (migration, stack and post-stack processing) are included in section 2.2.9.

Inputs:

- 2D-MC UHRS, 3D-MC UHRS, SBP, see 2.2.2
- PGM, see 2.2.2

Activities:

- Evaluation, parameterisation and application of data within the IJWFS V-VI area, processing using interpretation-independent operations.

Quality Assurance interface:

- Interactive dialogue with CONTRACTING AUTHORITY
- Parameter testing notes and displays for all significant processing operations
- Velocity modelling QC e.g. residual moveout and/or stack power displays

Deliverables:

- Reprocessed pre-stack seismic data for input to velocity analysis and QC as required
- Reprocessed stacked seismic data as SEG-Y with fully populated header
- A weekly processing status update with respect to the plan, detailing the testing integration, processing workflow of the ongoing reprocessing of MC UHRS data from the GP and QA/QC processes used during the reprocessing.
- Technical note documenting results.

2.2.4 *Laboratory Testing Strategy*

Milestone: Document outlining laboratory testing strategy

CONTRACTING AUTHORITY will appoint the execution of the laboratory testing to one or multiple geotechnical contractors (GT). The laboratory testing will include standard and advanced (dynamic/cyclic) soil testing. Factual parameters reported by the GT will include, but are not limited to, the following:

- Description and index classification
- Strength parameters
- Deformation properties
- Cyclic and dynamic behaviour
- Permeability
- Vertical *in situ* stress conditions
- Chemical parameters
- Microbiological conditions
- Thermal parameters

An important objective of the GIR and IGM is to provide developers of offshore wind farms with a wide range of geotechnical parameters that enable cost-efficient FEED design, not restricting the developers to certain design philosophies. Therefore, the CONTRACTOR is requested to develop a geotechnical laboratory testing strategy to

obtain relevant geotechnical, chemical and thermal parameters for a wide range of design applications and installation methods for offshore wind foundations and infield cables. Note that the CONTRACTING AUTHORITY requests from the GT that both undrained and drained cyclic strength testing is carried out. Test specifications shall be provided by the CONTRACTOR. The results are to be interpreted by the CONTRACTOR.

The CONTRACTOR shall provide a comprehensive laboratory test strategy that outlines the type of tests, applicable and test frequency for various soil types. The strategy document should provide guidance to the GT when preparing the laboratory test assignment form (LTAF) sheets for the standard and advanced testing (section 2.2.8, 2.2.10).

More details on the geotechnical parameters and the requirements of the requested GIR are given in sections 2.2.12, 2.2.13, and 2.2.16.

The CONTRACTING AUTHORITY is responsible for reviewing and approving of the laboratory test strategy.

Input:

- Content of activities of 2.2.1, PEP document
- Content of activities of 2.2.2 and 2.2.3
- Information of geotechnical site investigation of nearby WFZ, especially IJWWFZ, see section 1.5

Activities:

- Definition of a geotechnical soil testing strategy, outlining the type, reference method and quantity of laboratory tests with respect to geological layers, seismic facies or important horizons, mapped channels, etc. as required by the CONTRACTOR to optimize the IGM and GIR as well as to provide early notification of need for early classification testing (e.g. sieving and/or min-max density testing) for example for batching of sand samples prior to the execution of the laboratory tests in the programme. Proposal for appropriate methodology for assessing sample quality for specific undisturbed tests (e.g., as per table 6 of ISO 19901-8:2014).

Quality Assurance interface:

The CONTRACTING AUTHORITY is responsible for reviewing and approving of the laboratory test strategy through a document review process.

Deliverables:

A technical note including:

- Methodology statements, clear tables, workflow, process map, specifying the types of laboratory tests to be undertaken on Lot 1 samples (for example, but not limited to, classification tests, thermal conductivity and heat capacity)
- Methodology statements, clear tables, workflow, process map for reviewing the laboratory test schedules as they are issued during the fieldwork and text, including forward guidance for selecting samples for samples obtained during the Lot 2 (borehole) investigation (i.e., particle size analysis, classification, strength, consolidation, electrical/thermal conductivity, and chemical tests), together with the Age Dating testing/analysis and Microbially Induced Corrosion (MIC) testing/analysis
- Methodology statement and description of processes for the advanced testing program. This may include batching requirements of course grained samples, strength reference testing and cyclic/dynamic strength testing. It must include a clear stipulation of the test conditions with regard to stress state (e.g. isotropic or anisotropic) and drainage conditions (drained or undrained).
- Statement to preferred data formats for digital data deliveries of the GT contractor

- Interaction diagrams that will be produced to present the interpretation of the cyclic laboratory test results.

Note that based on the CONTRACTOR's laboratory strategy the GT will propose testing schedules, referred to as LTAF, at each geotechnical location. The LTAF review and subsequent specification of test pressures is a responsibility for the CONTRACTOR which is further specified in sections 2.2.8 and 2.2.10 for the standard borehole testing programme and advanced/cyclic testing program, respectively.

2.2.5

Geotechnical Location Plans

Milestone: Planning of geotechnical site investigation.

The CONTRACTING AUTHORITY will appoint one or multiple GT for the execution of a site investigation, laboratory testing and associated factual reporting. The fieldworks are scheduled for Q1-Q3 2023. The site investigation comprises two Lots, which will be executed sequentially:

- Lot 1: seabed phase, comprising seabed *in situ* PCPTs and shallow sampling techniques
- Lot 2: downhole phase, comprising of boreholes with *in situ* PCPT testing (including SCPT in selected boreholes), sampling, or a combination of both. Microbially Induced Corrosion (MIC) and Geological Age Dating tests (anticipated in the order of 200 samples) will be also part of the geotechnical survey. Geophysical downhole logging techniques may also be carried out as part of the Lot 2 investigations.

It is currently anticipated that for Lot 1 approximately between 100 to 140 seabed PCPT tests will be carried out. It is estimated that 20 to 30 of these will be including seismic measurements (SCPT) and 30 to 40 with temperature measurements (TCPT). It is estimated that between 50 to 100 vibrocores will be carried out. The *in situ* testing will include standard piezocone tests, measurements of shear wave velocities using seismic cones and pore pressure dissipation testing.

For Lot 2, it is currently anticipated that in the order of 50 to 60 sampling boreholes will be drilled. The sampling and testing strategy of the boreholes is yet to be defined and may be a combination of *in situ* PCPTs and sampling techniques down to maximum depths of approximately 100 m beneath seafloor. It is a requirement that a number of boreholes will be logged using downhole geophysical logging techniques and seismic CPTs. The CONTRACTOR is to advise on the quantity and locations of these tests.

The CONTRACTING AUTHORITY will be responsible for the development of a Scope of Work and Technical Specifications for the site investigation and laboratory testing for both lots. The CONTRACTOR shall assist the CONTRACTING AUTHORITY by providing input to optimize the compiling of the IGM and GIR. This is currently scheduled for Q4 2022 - Q1 2023.

The CONTRACTING AUTHORITY is responsible for approving the final site investigation plans.

Input:

- Content of activities of 2.2.1, PEP document
- Content of activities of 2.2.2 and 2.2.3
- Information of geotechnical site investigation of nearby WFZ, especially IJWWFZ, see section 1.5
- Execution guideline as provided by the CONTRACTING AUTHORITY and broadly outlined above.

Activities:

The CONTRACTOR is responsible for developing the following items:

- A proposal location plan, for review by the CONTRACTING AUTHORITY, for the Lot 1 seabed geotechnical investigation that includes seabed CPTs (PCPT, SCPT, TCPT, dissipation tests) and seabed sampling techniques (vibrocore, seabed grab samples). The CONTRACTOR shall take into account the geological layers, seismic facies or important horizons, mapped channels, etc. as interpreted from the geophysical data and other sources of information.
- A proposal location plan, for review by the CONTRACTING AUTHORITY, for the downhole geotechnical investigation as part of a detailed program for the execution of boreholes (downhole PCPT, SCPT, pore pressure dissipation tests, sampling intervals / sampling and downhole geophysical logging) targeting relevant geological layers, seismic facies and/or important horizons, mapped channels, etc.
- Definition of sampling locations and depths for geological age dating (Geochronological analysis) and Microbially Induced Corrosion (MIC) testing
- Prepare *prognosis sheets* for each geotechnical investigation location illustrating expected conditions (geological and hazard) at seabed and below
- Risk and mitigation assessment for location plans along with the geohazard evaluation of the GP and as assessed by the CONTRACTOR in 2.2.2 and 2.2.3 as well as feasibility assessment in consultation to the GT

Quality Assurance interface:

- Interactive dialogue with CONTRACTING AUTHORITY during activities.
- The CONTRACTING AUTHORITY is responsible for review and approval of the documents forming the Geotechnical Investigation Plan through document review process. A final decision for formats of digital geotechnical data deliveries will be performed in 2.2.11.

Deliverables:

The CONTRACTOR shall provide the following services in Q4 2022:

- Participation two meetings with the CONTRACTING AUTHORITY during the preparation phase of the Scope of Work for the GT
- Further consultation availability as needed from the CONTRACTING AUTHORITY to optimize the Scope of Work of the GT.

The CONTRACTOR is expected to provide the following services in late Q4 2022/early Q1 2023:

- Location plan for Lot 1 as Text, GIS map and AutoCAD file
- One meeting to finalize field work scheduling, risk and mitigation aspects with GT and CONTRACTING AUTHORITY
- Prognosis sheets for each Lot 1 geotechnical investigation location illustrating expected conditions (geological and hazard) at seabed and below.

The CONTRACTOR is expected to provide following items in late Q1/early Q2 2023:

- Location plan for Lot 2 as Text, GIS map and AutoCAD file
- One meeting to finalize field work scheduling, risk and mitigation aspects with GT and CONTRACTING AUTHORITY
- Prognosis sheets for each Lot 2 geotechnical investigation location illustrating expected conditions (geological and hazard) at seabed and below.

2.2.6 *Review of CPT and borehole data (ongoing throughout GT field campaign)*

Milestone: Geotechnical field work. Immediate review of results from field investigation, provide feedback and modifications if required (ongoing).

The review of the ongoing field data acquisition by the GT and documentation shall start immediately after commencement of field work. The acquisition of Lot 1 is scheduled for Q1-Q2 2023 and Lot 2 for Q2-Q3 2023. The CONTRACTOR is expected to be available to provide input to potential modifications to the prognosis sheets

within the context of providing support to the ongoing site investigation in dialogue with CONTRACTING AUTHORITY.

Input:

- Deliverables as assigned in 2.2.4, 2.2.5 and approved execution plan of the geotechnical survey as decided by the CONTRACTING AUTHORITY
- All immediate deliverable digital data from the ongoing geotechnical site investigation
- Vessel and equipment information, offshore progress information.

Activities:

The review shall include following aspects explicitly:

- Review and familiarisation of the Scope of Work for the GT
- Confirmation that the requirements for the IGM and GIR creation can be fulfilled
- Proposal for any actions to be made if any concerns exist
- Accompanying assessment of incoming field data in combination with the PGM (see section 2.2.2) and ongoing reprocessing procedure of the MC UHRS data from the GP.

Deliverables:

The CONTRACTOR is expected to provide following services:

- Documentation of review process
- Weekly online meeting or call with CONTRACTING AUTHORITY to clarify progresses and identify needed actions with senior personnel

2.2.7 *Integration of borehole and CPT data into the Ground Model*

Milestone: Integration of geotechnical field data. Correlation of the geotechnical data, available at that time, and the sub-seabed geophysical data for the Geological Ground Model.

The full integration of the geotechnical field work data into the geophysical ground model is scheduled for Q4 2023 and shall finally be used for the refinement and enhancement of the Geological Ground Model for which requirements are outlined in section 2.2.14.

It is expected that of the order of 17 no. geotechnical/geological units may be required to characterise the site (indicative of the number of units in use at the adjacent wind farm sites) though this is not to be considered a fixed number. Not all units are expected to be present site-wide.

Input: All results, plans and information from sections 2.2.1 through to 2.2.6.

Activities:

The CONTRACTOR is expected to perform following work:

- Preparation of geotechnical field data and integration into a single seismic workstation project (IHS Kingdom)
- Inclusion of geotechnical parameters into the geotechnical data integration, if available
- Initial correlation of geotechnical and geophysical data to deliver time-depth pairs representing each geotechnically relevant layer interface
- Refinement of seismic velocity models local to each geotechnical investigation locations proposed and approved from the CONTRACTING AUTHORITY with the PEP (2.2.1).
- Refine, amend or reinterpret geological principal interfaces,

- Detect and locally interpret as appropriate: sub-layers, lenses and design-sensitive horizons (peat, channel infills, glaciotectionic features) as well as further geohazard potentials
- Assessment of the potential benefit and methods of further reprocessing of the GP as proposed and approved from the CONTRACTING AUTHORITY with the PEP (2.2.1) to enhance the estimation of geotechnical parameters out of the seismic signal data (requirements on this are given in section 2.2.15 and 2.2.17).

Quality Assurance interface:

- Prepare cross-sections drawings showing integrated geophysical reflectors and geotechnical stratification as ongoing deliveries following delivery of geotechnical results
- Bi-weekly update with CONTRACTING AUTHORITY.

Deliverables:

The CONTRACTOR is expected to provide following services:

- Conditioned geotechnical data as LAS files or similar for input to IHS Kingdom workstation project.
- Correlation drawings illustrating the geophysical and geotechnical data correlation corresponding to initial unitisation of the soil/rock columns. The correlation drawings in combination with CONTRACTOR's laboratory strategy will serve as input for the GT to assign laboratory tests at each location
- Time-depth pairs, inferred interval velocity and seismic imaging velocity profile at each geotechnical investigation location in a format suitable for input to IHS Kingdom seismic workstation, to be agreed with CONTRACTING AUTHORITY.

2.2.8 *Laboratory Test Assignment Form (LTAF) and Specification of Test Parameters*

Milestone: Review of LTAFs after fieldwork completion of each geotechnical test location.

Upon completion of a geotechnical sampling location the CONTRACTING AUTHORITY, through input from the GT, will propose LTAFs for each location. The LTAF will be prepared by the GT based on CONTRACTOR's laboratory strategy and location correlation sheets. A review of the LTAF will be requested by the CONTRACTOR. Once the LTAF is reviewed and approved, the GT can commence testing activities. For some tests, additional information for each sample interval will be required. This information (e.g. consolidation pressures, rates of shearing, density) will be requested from the CONTRACTOR ensuring that the appropriate test conditions will be specified in the context of the GIR and IGM.

Input:

- Contents of 2.2.2 and 2.2.3
- Deliverables 2.2.4, and 2.2.6
- Provisional LTAF from the GT.
- Test pressure sheet template

Activities:

Accompanying to the ongoing review activities as described in section 2.2.6, the standard laboratory test progress shall be accompanied and reviewed by the CONTRACTOR, and advised, if needed. The standard laboratory test program is scheduled for Q3 2023. The activities of the CONTRACTOR shall include following aspects explicitly:

- Reviewing the provisional LTAF prepared by the GT for early standard testing which could serve as input for the specification of e.g. sample densities for

reconstructed samples or the building of sample batches (e.g. minimum / maximum density, and particle size analysis)

- Reviewing the provisional LTAF prepared by the GT for the standard testing (e.g. classification, strength, consolidation, thermal conductivity, chemical and dynamic tests)
- Assigning test specifications; after definition and approval of the LTAF the GT will provide for each test an overview of required test details. Such details may include, but not limited to, test consolidation pressures, shear rates and definition of failure criteria.

Quality Assurance interface:

Approval of output by CONTRACTING AUTHORITY.

Deliverables:

The CONTRACTOR is expected to provide following services:

- Review / confirmation of LTAF sheet per geotechnical location within 48hrs of receipt (except weekends)
- Completion of specification of test parameters (Word or Excel sheets) as and when required
- Contact as required (online meeting, email, call), typically weekly, with GT and CONTRACTING AUTHORITY to clarify progress and identify actions with senior personnel. Can be combined with meetings of 2.2.6, if this is beneficial for all parties (CONTRACTOR, GT and CONTRACTING AUTHORITY)

2.2.9

Geological Ground Model

Milestone: Interim version of the Geological Ground Model as geometrical basis for the IGM.

It is expected that of the order of 17 no. geotechnical/geological units may be required to characterise the site (indicative of the number of units in use at the adjacent wind farm sites) though this is not to be considered a fixed number. Not all units are expected to be present site-wide.

The Interim version is expected to be finished by the CONTRACTOR in early Q1 2024.

Input: The work performed in 2.2.7 using 2.2.2 through to 2.2.7.

Activities:

The CONTRACTOR is expected to perform following activities until early Q1 2024.

- Completion of site-wide update of stacking velocity analyses incorporating updates indicated by ground-investigation-local updates in 2.2.7
- Test, parameterise and apply further interpretation-independent processing as appropriate following evaluation in 2.2.7
- Test, parameterise and apply re-migration / stack and post-stack processing as appropriate following evaluation in 2.2.7.
- Specification, parameterisation and production of seismic attribute set for input to CPT prediction methods
- Site-wide propagation of local interpretation updates performed in 2.2.7. Site-wide interpretation of all identified further geohazard and intra-formational interfaces
- Confirmation or revision of the litho-genetic conceptual design as proposed in PEP (2.2.1)
- Correlation of further (litho-)stratigraphical sequences to other nearby WFZ (especially IJWWFZ)
- Correlation (or revision) and integration of Age Dating results to confirm the geochronological order, if already available.

Quality Assurance interface:

- Interactive dialogue with CONTRACTING AUTHORITY during activities
- Velocity model QA as *e.g.* semblance, residual moveout, stack power displays to be agreed with CONTRACTING AUTHORITY at no greater than 250 m intervals.
- Parameter test panels and notes for all significant data processing operations to be agreed with CONTRACTING AUTHORITY.

Deliverables:

The CONTRACTOR shall provide following services until early Q1 2024:

- Seismic Processing Update Technical Note including description of testing, decisions, parameters and final processing sequence applied
- Reprocessed multi-channel seismic data as SEGY with fully populated header
- Seismic Attribute datasets as SEGY with fully populated header
- Stacking and Interval velocity as SEGY trace data at every seismic trace location
- At least one workshop with the CONTRACTING AUTHORITY presenting the Interim version of the Geological Ground Model.

2.2.10 *Advanced Laboratory Test Assignment Form and Specification of Test Parameters*

Milestone: Advanced Laboratory Test Assignment Form (advanced LTAF) and Test Pressure Sheets.

Following the standard laboratory phase, relevant geotechnical data is available to specify advanced tests. The CONTRACTOR may choose to establish large batches from samples that display similar characteristics and geological context. The CONTRACTOR is to outline this in the laboratory test strategy document discussed previously. After establishing the batches, a second phase of laboratory testing will commence with tests as defined in the laboratory test strategy.

The geotechnical contractor provides the advanced LTAF for review by the CONTRACTOR. Following the approval, the CONTRACTOR is requested to fill out the test specification sheet provided by the geotechnical contractor ensuring that the appropriate test conditions will be specified by the CONTRACTOR in the context of the GIR and IGM. The advanced laboratory test programme shall include cyclic tests accompanied by associated static and classification tests and may also include dynamic testing.

Input:

- Advanced LTAF
- Test specification sheet template
- Laboratory testing strategy (section 2.2.4)

Activities:

- Identification of suitable samples for batching (based on available classification test results), as has been required for the advanced testing programme on previous CONTRACTING AUTHORITY projects, including the likely need for batching of cohesionless samples from the same soil unit. The data required to select the individual cohesionless samples for batching should be stated *i.e.*, CPT data, borehole logs, sample descriptions, offshore lab test data, and relevant onshore PSD analyses. It is anticipated that five or six batches may need to be defined to provide a basis for the advanced testing programme.
- Review of the advanced LTAF for the advanced testing (*i.e.*, dynamic, and cyclic tests including any associated static and classification tests)
- Definition of test parameters associated with the advanced laboratory testing. During the test execution, several updates of the test pressure sheets are required due to the interdependency of subsequent cyclic tests

- Specifying any specialist testing required to further refine the Integrated Ground Model and Geotechnical Interpretation Report
- The CONTRACTOR should consider that a workshop / kick off meeting will be organised prior to the advanced laboratory testing.

Quality Assurance interface:

Approval of output by CONTRACTING AUTHORITY.

Deliverables:

- Review/confirmation of the advanced LTAF sheets per geotechnical location within 48hrs of receipt (except weekend)
- Completion of specification of test parameters (Word or Excel sheets).

2.2.11 *Review of Pilot Digital Data Deliverables*

Milestone: the GT will be requested to provide a pilot data base which will include an example output file of each of the digital deliverables. This data may include, but not limited to:

- AGS 4.0 (or higher) format
- ASCII
- Excel or csv
- LAS files.

The objective of this deliverable prior to delivery of the factual test results is to agree on the format of the data output as to be applied in a consistent manner throughout the project, see also 2.2.5. This also applies to any interim deliveries of laboratory data prior to provision of the final report.

Input:

- Laboratory test output files, data base files and output data from *in situ* test results

Activities:

- Review and agree on digital delivery formats

Quality Assurance interface:

- CONTRACTOR and CONTRACTING AUTHORITY shall use the pilot data base to set up their workflows, to confirm compatibility.

Deliverables:

- Review comments documented in Document Review Form (DRF).
- Written confirmation of acceptance of format.

2.2.12 *Review of Factual Reports GT and Digital Data*

Milestone: Delivery of Factual Reports and digital data by the GT.

The delivery schedule for the GT is scheduled as follows:

- Lot 1 seabed *in situ* testing report: Q2 2023
- Lot 1 seabed sampling report: Q2 2023.
- Lot 2 downhole testing and sampling report: Q1 2024.
- Lot 2 advanced laboratory testing report: Q2/Q3 2024.

Note that GT may be requested to provide interim deliveries of digital laboratory data (for example monthly deliveries) in the agreed data format, enabling the CONTRACTOR to commence interpretations of the data.

Input:

- Factual reports Lot 1 (seabed phase).
- Factual Reports and digital laboratory data associated with the Lot 2 (borehole) campaign for which input is provided by CONTRACTOR in section 2.2.5 and 2.2.8
- Factual Reports and digital laboratory data associated with the advanced laboratory testing for which input is provided by CONTRACTOR in section 2.2.10
- Final MIC and Age Dating factual reports provided by the GT.
- Contents and plan as provided in sections 2.2.1 through to 2.2.6.

Activities:

The CONTRACTING AUTHORITY provides the CONTRACTOR an opportunity to inspect the factual data report, digital data and data format and confirm initial acceptability of the data set. The CONTRACTING AUTHORITY will collate any review comments and communicate these to the geotechnical contractor. The CONTRACTING AUTHORITY reserves the right to approve or reject the reports.

Quality Assurance interface:

The CONTRACTING AUTHORITY shall review and moderate output.

Deliverables:

- Review comments captured in DRF
- If required, an online meeting with the GT and the CONTRACTING AUTHORITY to clarify comments.

2.2.13 *Geotechnical Interpretation of Standard Laboratory Test Results*

Milestone: Geotechnical Interpretation of standard laboratory test results as provided by the GT.

The interpretation of the standard lab test programme must be performed before or at least in early stages of the advanced lab test programme as assigned in section 2.2.10 and already planned in section 2.2.8.

Input: sections 2.2.5 and 2.2.11.

Activities:

The CONTRACTOR is expected to develop following items:

- Review and interpretation of relevant test types in support of the execution of the advanced laboratory testing.
- As part of the GIR establishing a geotechnical Soil Type (Soil Unit) classification for representing similar geotechnical behaviour optimized to parameters important for wind farm and cable installation/foundation services and in a meaningful context to the Geological Ground Model with its contents such as geological layer properties, grading sequences, litho-genetic conceptual design.
- Overview tables showing the results of the laboratory tests undertaken during the geotechnical site investigations, with the following summarised for each Soil Type:
 - total quantity of sample material recovered,
 - total quantity of test results undertaken per test type,
 - minimum, maximum and mean values of selected laboratory tests results
- Statistical description (e.g., low, best and high estimates) of the geotechnical parameters for each engineering Soil Type, as derived from laboratory and *in situ* tests. The statistical analysis must include the assessment and quantification of the associated uncertainties (e.g. testing biases, transformation models, spatial variability within the unit). The derived values of the geotechnical parameters shall include the parameters as proposed and

approved with the PEP document and updates for the basic soil types (i.e. cohesive, non-cohesive, transitional soils).

- Provision of table of contents of the GIR.

Deliverables:

The CONTRACTOR is expected to deliver following services in early Q2 2024:

- Overview tables as Excel sheets with short descriptions about performed work as text
- Draft GIR report with informative charts and diagrams for presenting principal statistics for each Soil Type.

2.2.14 *Final Geological Ground Model*

Milestone: Final version of the Geological Ground Model

The final Geological Ground Model shall be explicitly correlated with the Geotechnical Interpretation Report such that all geotechnical unit boundaries are represented within the structural model defined by the geophysics. The Soil Units shall represent bodies of common geotechnical behaviour in terms of wind farm and cable foundation/installation designs. The implementation of these Soil Unit bodies into the 3D model must be easy traceable with contents of the GIR. Time-depth pairs are to be updated as required, and nomenclature is to be common between the geological and geotechnical unitisation.

Input:

- Section 2.2.9 using information from sections 2.2.1 through to 2.2.7.
- factual reports of the GT,
- final MIC and Age Dating results.

Activities:

The CONTRACTOR is expected to finalize the Geological Ground Model by validating the Interim version of the enhanced and refined Geological Ground Model with the final input data, confirming or revising the litho-genetic conceptual design as well as the geochronological order resulting from age dating results. The CONTRACTOR is expected to cooperate with the GT who is responsible for the age dating procedure, to build a coherent chronostratigraphic and seismostratigraphic model.

Addition or modification of unit interfaces following Geotechnical Interpretation Reporting.

Quality Assurance interface:

Bi-weekly update meetings and up to two workshops with CONTRACTING AUTHORITY.

Deliverables:

The CONTRACTOR is expected to deliver following items and services with a schedule, which is estimated to be around late Q2 2024:

- Updated velocity sections (as SEG Y with populated headers) and updated time domain and depth converted seismic and/or surfaces, as may be required, in the same format as GP deliverables including:
 - Survey information with acquisition set-up, trace sampling and relevant navigational information (projection information etc.)
 - Processing workflow
 - Byte locations of CMP, SP, X Y data
- 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) in an exchangeable format with at minimum columns for XY coordinates, survey line name, shot point/trace number, time and elevation

- Elevation surfaces for all interpreted horizons at an appropriate resolution (~0.25-1 x line spacing, to be agreed with CONTRACTING AUTHORITY and discussed in level-of-detail agreements, see also section 2.2.3 and 2.2.9), 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
- Thickness (isochore) 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 information for all interpreted horizons at the same resolution as the elevation grids, as an xyz text file (*.xyz/*.pts) and a raster/grid
- Horizon depth uncertainty information, spatially variable or constant per interface as appropriate (to be agreed with CONTRACTING AUTHORITY)
- A single seismic workstation project (IHS Kingdom) including:
 - Soil profiles for every CPT and borehole location
 - Re-interpretation or additional interpretation of seismic data (as required) supplied as interpretive picks on seismic cross-sections or as spatial point/line components and as gridded as well as contoured surfaces
 - Re-interpreted interfaces as result of a composed analysis of multiple seismic datasets (e.g., MUHR and Innomar) as single interface grids including clear metadata information about the data sources, geotechnical correlation, and a short summary about the processing, constraints, and analysis
 - Geohazard and intra-formational interfaces as gridded interfaces or pick plots depending on their extent and continuity (e.g. Thalweg or peat layer, boulders etc.)
 - The spatial extent of interfaces and geohazards is to be mapped as a full set of horizons and rasters
 - Clear metadata information for all included workstation items
- Update of the GIS project, already established by the GP in 2.2.1, including:
 - Location of all seabed samples (geophysical campaign and geotechnical campaign), boreholes, seabed CPTs and vibrocores (geophysical and geotechnical campaigns) as point shape files
 - Contour maps at an appropriate interval, elevation rasters and extent polygons for all principal geological layer interfaces
 - Contour maps at an appropriate interval, elevation rasters and extent polygons for all sub-layer, striking sequences or lens interfaces
 - Extent polygons, elevation rasters and contour maps at an appropriate interval showing spatial (lateral and vertical) presence of extended geohazard features dependent on their spatial continuity
 - Sub-surface point geohazard (such as diffraction apices that may indicate the presence of boulders) table(s) and associated point shapes with columns for X and Y co-ordinates at minimum and depth where appropriate
 - Extent polygons of geological features including channels, escarpments and potential glaciotectionic features.
 - Faulting as linear features (individual faults) and/or polygons (areas of faulting)
 - Metadata for all GIS project deliverables compliant with Dutch standard metadata (ISO 19115 V1.3.1)
- A comprehensive report in digital format (e.g. .pdf), five (5) copies on flash drive, HDD drive or on a CONTRACTING AUTHORITY approved equivalent, documenting and describing all aspects of the Geological Ground Model including:
 - Summary of the data processing for the integration of the geotechnical field data (also probably particle size analysis) into the geophysical model

- Summary of reprocessing methods used to reinterpret the sub-seabed data
- Complete description of the geological layers and sub-layers in their stratigraphical context and their seismic facies properties as defined in the final Geological Ground Model
- Correlation drawings illustrating the geophysical and geotechnical data correlation corresponding to final unitisation of the soil/rock columns
- Inferred P-wave velocity (or velocity field if data support variability) for each soil unit from time-depth pairs
- Quantification and description of the global spatial lithological variability of the subsurface within the entire IA and additionally for each individual defined geological unit, e.g. as variography over particle sizes, as well as description of striking grading sequences (fining up, coarsening up) observed and identified in geotechnical investigations.
- (Appendix) At least 6 primary-line sections through geotechnical location (superimposed), time/depth corrected, and additionally in time-space, with picked horizons and fully annotated
- (Appendix) At least 3 cross-sections through geotechnical location (superimposed), time/depth corrected and additionally in time-space, and fully annotated
- (Appendix) Charts illustrating the top of each Geological surface identified and as assigned above. Scale to be approved by CONTRACTING AUTHORITY
- (Appendix) Charts illustrating the vertical thickness of each of the Geological Unit. Scale to be approved by CONTRACTING AUTHORITY
- (Appendix) Charts illustrating the geohazards as assigned above. Scale to be approved by CONTRACTING AUTHORITY
- (Appendix) Charts illustrating the extent of geotechnically important geological features including but not limited to channels, escarpments and potential glaciotectonics or other geobodies. Scale to be approved by CONTRACTING AUTHORITY
- (Appendix) Charts illustrating the subcrop geology below mobile seabed sediment, with mobile sediment thickness as contours superposed. Scale to be approved by CONTRACTING AUTHORITY

2.2.15 *Prediction of CPT and correlated measurements at seismic trace locations*

Milestone: The production of estimated CPT measurements at seismic trace locations for 2D- and 3D-MC UHRS datasets.

Inputs:

- Measured geotechnical data
- Derived, calculated or correlated geotechnical data
- Seismic amplitude, seismically derived velocity and other attribute data
- Seismic interpretation data

Activity:

At least two sets of predictions shall be generated:

- One set of linear parameter profiles representing best fit linear approximations within each soil unit, to be vertically and laterally variable as appropriate.
- One set of continuously variable (vertically and laterally) parameter profiles derived as a function of one or more input datasets derived from the seismic datasets. These may be produced by correlation with seismic and attribute traces by using machine learning or advanced (geo)statistical simulations or algorithms designated for this purpose, with at least four estimated parameters.

Multiple estimation methods are to be evaluated and estimation optimised for each of the above two datasets.

IGM CONTRACTOR shall provide a set of appropriate quality metrics indicative of the relative confidence in predicted values at appropriate spatial and depth intervals.

Quality Assurance interface:

- Interactive dialogue with CONTRACTING AUTHORITY during course of activity
- Leave-one-out comparisons of predicted vs measured Parameters at each Geotechnical investigation location.
- Geostatistical comparison of variability of measured vs predicted results
- Confidence and/or quality metrics to be defined by the CONTRACTOR
- Documentation to be reviewed using DRF process

Deliverables:

- All input parameters including attributes calculated from seismic traces if not specified in other work packages.
- Output predicted parameters for each prediction set as SGY at all input seismic trace locations, including but not limited to:
 - q_{tr} , corrected cone resistance,
 - f_s , sleeve friction,
 - u_2 , pore pressure,
 - G_{max} , small strain shear modulus.
- Output parameters at Geotechnical locations as AGS 4.0 including but not limited to:
 - q_{tr} , corrected cone resistance,
 - f_s , sleeve friction,
 - u_2 , pore pressure
 - G_{max} , small strain shear modulus.
- Reporting of method selection, evaluation and optimisation including documentation of all tested estimation methods and optimisation criteria.
- Reporting of structural and parametric uncertainty in predicted CPT and correlated parameters.
- Various workshops required to discuss progress and preliminary findings.

2.2.16 *Geotechnical Interpretation Report (GIR)*

Milestone: Realization of the Geotechnical Interpretation Report (GIR).

Input: Contents and deliverables of described in sections 2.2.5, 2.2.6, 2.2.10, 2.2.11, and in particular sections 2.2.12, 2.2.13 and 2.2.15.

The CONTRACTOR shall develop the contents of the GIR concurrently, precisely in an iterative supporting way, to the IGM compilation, so that the contents and the results of the GIR and the IGM are fully coherent and complementary. This is explicitly relevant for the Soil Unit definition (statistically, spatially), the zonation with Geotechnical Provinces and the prediction of CPT parameters, as part of both, the GIR and IGM, interpretations and usage. The GIR is expected to provide geotechnical characterisation of all identified GGM units, whereas the IGM is expected to provide the spatial distribution of those units within the windfarm zones.

Activities:

The completion of the GIR and IGM is scheduled for Q2 2024 to early Q3 2024.

The CONTRACTOR is expected to perform the following tasks in accordance to the delivered and approved PEP by the CONTRACTING AUTHORITY (see section 2.2.2):

- Derivation of design parameters for the identified geological units for the purpose of providing ranges to allow the preliminary design and installation assessment of monopiles, jacket piles and alternative foundations (e.g. suction caissons) under static and cyclic loading conditions.

- The characteristic values of geotechnical parameters shall be selected in the sense required by EN 1997-1 or assessed according to the approach outlined in DNV-RP-C207 (2019) and DNV-RP-C212 (2017).
- The characteristic values of geotechnical parameters should be derived for, or be appropriate for use in, a range of state-of-the-art calculation models used for the design of monopiles and jacket piles, including installation analyses. Examples of calculation models that could be considered include, but not limited to:
 - ISO (2016) CPT-based methods for axial resistance of jacket piles in frictional soils;
 - ISO (2016) Main Text method for axial resistance of jacket piles in cohesive soils;
 - Advanced numerical models *e.g.* PISA numerical-based method for the lateral resistance of monopiles;
 - PISA rule-based method for lateral resistance of monopiles;
 - ISO (2016) p-y method for lateral resistance of jacket piles;
 - Alm and Hamre (2001) SRD Method for pile drivability analysis of jacket piles
 - Finite element analysis using advanced constitutive models
 - Cyclic degradation models
 - ISO 2394 – Annex D
- Commentary on the methodology for selecting characteristic values of geotechnical parameters accounting for the variance in the general ranges in derived values of geotechnical parameters incl. upper and lower bound values.
- A seismic (earthquake) hazard assessment:
 - Probabilistic and determinist assessment of the seismic hazard
 - Assessment of soil liquefaction potential
 - Assessment of the design parameters as per ISO 19901-2:2017 and EN 1998-1:2004 Eurocode 8
 - Seismic zone classification according to ISO 19901-2:2017.
- Recommendations for microbiologically influenced corrosion (MIC) of steel piles that can be used as input into durability limit states for pile design (ISO, 2008; ISO, 2015; CEN, 2003b; DNV GL, 2016), based on a review of applicable codes of practice, information available in the public domain, an assessment of the general site setting, and the site-specific MIC test results/analysis carried out as part of the Geotechnical Site Investigation.

A statistical evaluation of the Derived Values of the geotechnical parameters shall be undertaken (accounting for and quantifying of all uncertainties, *e.g.*, testing biases, transformation models, sampling locations, etc.) and engineering judgement shall be applied and documented. Any inconsistencies in the Derived Values, particularly between different test types, should be highlighted and discussed, so that the reader fully understands why some data sets may be weighted higher than others, for example.

The ranges in characteristic values of geotechnical parameters shall take into account the spatial soil variability and the general requirements of the various design approaches and methods currently being used in the offshore wind energy industry for piled foundations.

In addition, the selection of characteristic values of geotechnical parameters shall be based on EN 1997-1 guidance, which includes taking into account the following:

- Geological and other background information, such as data from previous or neighbouring projects
- The variability of the measured properties and other relevant information *e.g.* from existing knowledge, site investigation and laboratory testing
- the extent of the field and laboratory investigation
- the type and number of samples

- the extent of the zone of ground governing the behaviour of the geotechnical structure at the limit state being considered
- the ability of the geotechnical structure to transfer loads from weak to strong zones in the ground

Deliverables:

The CONTRACTOR is expected to provide five (5) electronic copies of digital data of the Geotechnical Interpretation Report on flash drive, HDD drive or on a CONTRACTING AUTHORITY approved equivalent. The GIR document shall include in accordance with ISO 19901-8, EC-7 or similar:

- A full description and interpretation of relevant geotechnical parameters suitable for the design and installation of (mono)pile foundations and cable design and installation as outlined in detail above
- Any structural and parametric uncertainty evaluations for the interpreted and concluded contents of the GIR
- Informative and easy-readable charts to present the recommended parameter ranges together with the relevant laboratory data.
- Informative summary tables for a quick review, work with contents and extraction of parameters.

The delivery is scheduled at the latest to the second half of Q3 2024.

2.2.17 Integrated Ground Model (IGM)

Milestone: Realization of the Integrated Ground Model (IGM).

Input: All contents and deliverables of sections 2.2.1 through to 2.2.15.

The CONTRACTOR shall develop the contents of the IGM concurrently, precisely in an iterative supporting way, to the GIR compilation, such that the contents and the results of the GIR, GGM and the IGM are fully coherent and complementary. This is explicitly relevant for the Soil Unit definition (statistically, spatially), the zonation with Geotechnical Provinces and prediction of CPT parameters, as part of both, the GIR and IGM, interpretations and usage. The IGM is expected to provide the spatial distribution of the units identified in the GGM and geotechnically characterised in the GIR.

Activities:

The CONTRACTOR is expected to perform following work:

- The zonation of the entire IJWFS V-VI area into Geotechnical Provinces for depth intervals as proposed and approved with the PEP (2.2.1). The Geotechnical Provinces must be coherent and easy traceable with contents of the GIR and show a similarity of entire downhole geotechnical behaviour within each Province optimized to wind farm and cable foundation/installation purposes
- An update of the reprocessed MC UHRS data of 2.2.14 (Geological Ground Model) with focus on the correlation between processed seismic signals and geotechnical measurements resulting in IGM geometries (especially downhole *in situ* CPT data) and as proposed and approved with the PEP (2.2.1)) by the CONTRACTING AUTHORITY
- Based on the work above, spatial value allocation of all geotechnical parameters and characteristic values corresponding to the presence and lateral/vertical extent of each Soil Units as established in 2.2.14/2.2.16 and in coherence to the litho-genetic design established with the Geological Ground Model, as proposed and approved with the PEP (2.2.1) by the CONTRACTING AUTHORITY.
- Based on the work above, the inclusion of interpolated, predicted CPT data at an appropriate resolution dependent on the appointed IGM level-of-detail (e.g.

20m x 20m x 10cm voxel size) or (in approval with the CONTRACTING AUTHORITY) technical innovates for dynamic 3D multi-attribute model deliveries. One set of linear approximations of CPT and derived parameter measurements is to be derived within the soil-unit volumes, using the linear estimations developed in 2.2.15. One additional set of approximations of CPT and derived parameter measurements is to be produced derived from the continuously variable (vertically and laterally) parameter profiles developed in 2.2.15. Evaluation and description of the structural and parametric uncertainty of the geotechnical property distribution for each set of estimations.

Deliverables:

The CONTRACTOR is expected to deliver following items and services, scheduled at latest to early Q4 2024:

- The addition to the single seismic workstation project (IHS Kingdom), Geological Ground Model) including:
 - Interpolated soil profiles / cross-sections showing Soil Type (Soil Unit) with at least primary fraction, density, consistency tracing every CPT and borehole location and, if possible, cross sections for arbitrary coordinates within the wind farm zone
 - Cross-sections with CPTs must show at least cone resistance, pore pressure ratio and friction ratio versus depth profiles for all seabed and down-hole PCPTs
 - Profiles in cross-section showing downhole particle size analysis as grading sequences (same format as CPT curve integration) in context to Soil Unit definition, CPTs and seismic signals.
 - A 3D volume as a grid (voxel) or SGY containing predicted CPT parameters including at least the above assigned parameters (see *Activities*) in the appointed resolution with confidence intervals and feature importance values (if available) as approved with the PEP (2.2.1).
 - Parameter-on-Demand solutions or user-optimized dynamic resolution fitting techniques may be proposed but CONTRACTOR must commit to deliver static (voxel, 3D grid or SEG Y as above) data at no extra cost upon request of CONTRACTING AUTHORITY, see also 2.2.1.
 - Implementation of additional parameters (e.g. estimated friction ratio or correlated geotechnical parameter(s) in the 3D volume / format described above.
 - Structural and/or parametric uncertainty data, including characteristic values per agreed geotechnical / design standard as appropriate
 - The spatial extent as polygons of assigned Geotechnical Provinces as established in above-described activities
 - Clear metadata information for all included workstation items
- GGM GIS project including at minimum but not limited to:
 - All Geological Ground Model GIS content
 - All raster deliverables
 - All vector deliverables
 - Content of the Geophysical and Geotechnical survey deliverables unchanged in the IGM activity
 - Elevation (top/base) contour maps at an appropriate interval and extent polygons for all Soil Unit bodies with the IA
 - Thickness (vertical) contour maps at an appropriate interval and extent polygons for all Soil Unit bodies with the IA
 - All measured and calculated geotechnical parameters that can be represented as spatial data per soil unit.

- 3D GIS representation of the 3D volume described above Metadata for all GIS project deliverables compliant with Dutch standard metadata (ISO 19115 V1.3.1)
- Provision of all essential and design relevant contents of the IGM in at least one non-proprietary file format using binary or ASCII open-source file formats, such as ASCII 2D/3D grids, ASCII tables, Simple File Format, SGY or file formats usable in open-source software packages (e.g. ESRI shapes)
- Provision for a free-of-charge 3D data visualization tool that can be viewed and manipulated without specialist software or uses a 'viewer' component showing at least the Geological Ground Model and geotechnical Soil Unit bodies (as voxel) as well as the mapped Geotechnical Provinces. This shall be accompanied with a user's guide that provides a few examples and basic features of the visualisation tool for end users that may not be experienced with the software. The creation of the open accessible 3D data package shall be accompanied with QA and Dutch standard metadata (ISO 19115 V2.0.0) elements
- A provision of a free-of-charge extension/ implementation to the above-mentioned software or an extra tool, CONTRACTOR to derive geotechnical parameter vertical profiles as tables with confidence intervals/uncertainty information at arbitrary locations of the entire IJWFS V-VI area

2.2.18 *Integrated Ground Model Report*

Milestone: Realization of the report as accompanying document to the digital IGM package.

Input: sections 2.2.2 through to 2.2.17.

The CONTRACTOR is expected to deliver a report to document all performed work to create the IGM in a comprehensive, informative way. The report shall be delivered along with the digital IGM package in Q4 2024.

Activities:

The CONTRACTOR is expected to prepare a document with following content along with the final IGM in early Q4 2024:

- Full description of the geophysical integration and (re-)interpretation with explicitly mentioning these aspects:
 - Full description of the gridding methods and parameters used to generate interface grids from the original pick files. Short basic gridding information as content of a side label for each chart, presented in the appendices.
 - Description of how a final cumulative gridded interface of a multiple seismic data interpretation was derived from the picks of each seismic dataset. A quantitative discussion of the elevation uncertainty of all interfaces must be included.
 - Comprehensive representation of the explicit correlation of geotechnical parameters and seismic intersections to illustrate the unitisation of both.
- Full description of the geotechnical data integration and the used interpolation, regionalization, or mapping methodologies for all IGM contents.
- Full description of used algorithms for the attribution of geotechnical target parameters with characteristic values to the geophysical model, if not covered by above mentioned topics.
- As addition to the delivered quantification of the spatial lithological variability for the entire area and for each individual geological unit (2.2.14), the spatial variability of geotechnical relevant parameters is to be added in the same manner, e.g. per variography, as global assessment (entire area) and for each individual Soil Type. Full description of compiling methods of predicted CPTs including but not limited to:

- Derivation/estimation method for each of the estimated parameters as provided in 2.2.15 and 2.2.16
- Addition of performed sensitivity analysis for use or choice of different methodologies as well as for parametrical uncertainty assessment.
- Information about dependencies of the variability and spatial variability of input parameters, as well as distance of seismic signals to geotechnical measurements, to the confidence values, performance (e.g. convergence, cross-validation) and feature importance values of the chosen machine learning method, if used.
- If geostatistical methods will be used to predict CPT parameters, then full (cross-)variography of all input parameters must be added (Soil Unit wise, dependent on methodology) as well as cross-validations for all final estimation runs
- Documentation and discussion of the derivation and distribution of engineering characteristic values for each unit in relation to aleatoric and epistemic uncertainty of the natural materials and the measurement and estimation systems. Documentation and discussion of the derivation and distribution of structural uncertainty (elevations, thicknesses, depths) for each unit. Combination of parametric and structural uncertainty to be discussed.
- Statements to the data validity in context to the geological complexity and the investigation resolution.
- Statements to Age Dating Analysis incorporated into the IGM and descriptive comparison to Age Dating results in nearby WFZs.
- Identification of areas within the IJWFS V-VI IA that can be qualified in terms of suitability and quantified in terms of reduced or elevated development and installation costs inclusive explanation of appropriate measure for mitigation. This shall be illustrated for ease of reference.
- Identification and definition of the likelihood of the suitability of or possible constraints across the IJWFS V-VI regarding:
 - transfer of forces from wind turbine & substation foundation to seabed
 - microbially induced corrosion (MIC),
 - piling of foundations e.g. presence of boulders, rocks or other hard substrate,
 - the use of jack-ups,
 - the use of gravity base foundations,
 - the use of foundations based on suction piles or suction buckets,
 - the use of novel or composite foundations,
 - the installation of cables.

Deliverables:

The CONTRACTOR is expected to deliver a comprehensive report with informative graphs, charts and tables with required content as outlined above. The report shall be provided in digital format (e.g. .pdf), five (5) copies on flash drive, HDD drive or on a CONTRACTING AUTHORITY approved equivalent, Moreover, the appendices shall include:

- The mapped top of each major Soil Unit surface identified
- The mapped vertical thickness of each of the major Soil Unit (isopach maps)
- Graphical scheme/diagram of open accessible 3D IGM content to illustrate the implemented contents of the IGM with their context dependencies and derivable information (parameters) for usage as end-user product

Charts are to be provided in PDF and with the same layout as implemented within the GIS project as assigned in section in 2.2.17.

2.2.19 *Final Delivery IGM and GIR*

Milestone: Delivery of the reviewed and revised version of the IGM and the GIR, ready for publishing.

Input: sections 2.2.16 to 2.2.18.

Activities:

In general, the CONTRACTOR must ensure there is version control across all presented data formats (charts, GIS, 3D visualisation, and digital data files) with no variation in processing or presentation across the digital deliverables of the IGM and GIR. All relevant shapefiles of the GIS project are to be loaded into each digital deliverable as far as is possible or practical.

The CONTRACTOR must ensure that the terminology used in the geophysical report is transferred without alteration into both the IGM Report and the Geotechnical Interpretation Report, including that of geological formation naming and unitisation. Should the terminology be altered or added to, the CONTRACTOR will provide, at minimum, a correlation table and written justification of any alteration to be included in the reports.

Moreover, the CONTRACTOR is requested to provide a 2-5-page summary including the aims, objectives and approach and the main results to be published in the Project and Site Description. (Examples available from <https://offshorewind.rvo.nl/generalnh>). The summary for the Project and Site Description shall be provided in Word format.

Quality Assurance interface:

CONTRACTOR is required to specify a data transfer protocol to enable the safe and secure transfer of digital data.

Deliverables:

The deliverables comprise all deliverables requested with sections 2.2.16 to 2.2.18 in a reviewed and revised version, which is verified and prepared for publication. The final version of IGM and GIR content is scheduled to late Q4 2024.

Validation tool (e.g. checksum or file hash listing) with brief instruction guide to qualify successful transfer of digital data, suitable for both CONTRACTING AUTHORITY and third party use.

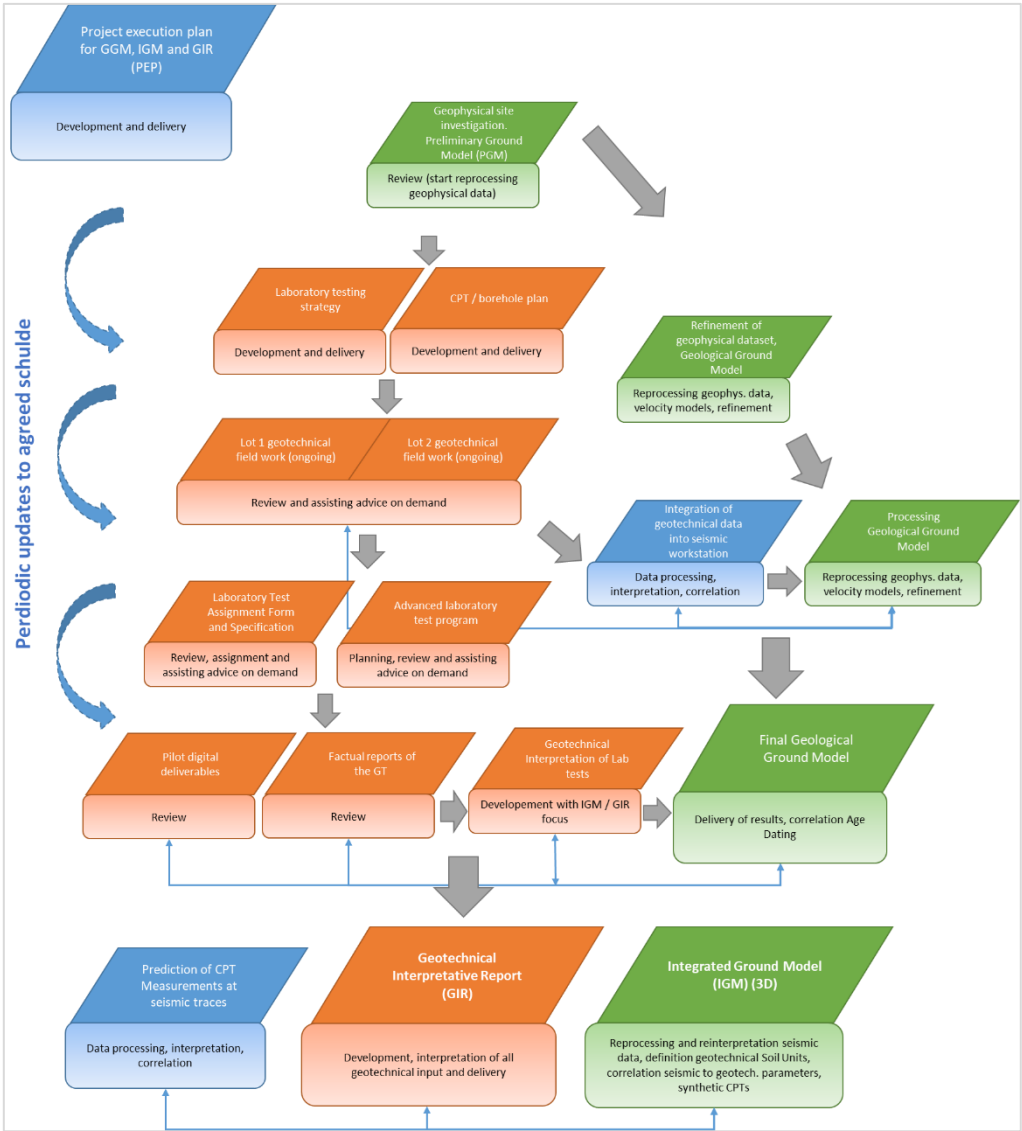
The CONTRACTOR is expected to provide following additional services:

- Project and Site Description
- Attendance to at least four workshops and/or online meetings with the CONTRACTING AUTHORITY discussing results and reviews for the IGM and GIR.

2.2.20 *Summary diagram of workflow and table of deliverables*

Following below, a diagram is presented summarizing the key milestones of the workflow and associated activities of the CONTRACTOR. Orange colours indicate geotechnically focussed work, green colour geophysical focussed work and in blue both. Blue connection arrows indicate a repetitive or iterative coordination and correlation of data, interpretation, and processing. The size of the bold arrows indicates the dependency of completed tasks in relation to the specific stages of the work.

Diagram 1: Workflow chart (orange = geotechnically focussed, green = geophysical focussed, blue = both, connecting arrows = co-creation and iterative in-and outputs, bold arrows = impact weight on following work).



A summary table is presented below for the milestones and associated deliverables as scheduled in the workflow to be performed by the CONTRACTOR.

Table 3: Summary table for each milestone as assigned in the workflow.

Section	Estimated Schedule		Milestone	Deliverables from CONTRACTOR		
	Year	Quarter		Input and/or review required	Digital output	Reports
2.2.1	2022-2024	Q2 2022 Q2 2024	Proposal for reprocessing geophysical data from the GP. Initial work strategy plan for GGM, GIR and IGM, definition of deliverables -> PEP.	Y	N	Y
2.2.2	2022	Q2-Q4	Geophysical site investigation. Preliminary Ground Model (PGM). Seabed sampling report. Technical notes on the PGM for the IJWFS V-VI and Tie-In lines.	Y	N	Y
2.2.3	2022	Q4	Refinement of geophysical datasets to optimise data fidelity in preparation for detailed and quantitative interpretation	Y	N	N
2.2.4	2022	Q4	Document outlining laboratory testing strategy	Y	N	Y
2.2.5	2022	Q4	Planning of geotechnical site investigation, location plans	Y	Y	Y
2.2.6	2023	Q1-Q3	Geotechnical field work. Immediate review of results from field investigation (ongoing).	Y	N	N
2.2.7	2023	Q4	Integration of geotechnical field data. Correlation of the geotechnical data and the sub-seabed geophysical data for the Geological Ground Model	Y	N	Y
2.2.8	2023	Q4	Review of LTAFs after fieldwork completion of each geotechnical test location	Y	N	Y
2.2.9	2024	Q1	Interim version of the enhanced Geological Ground Model as geometrical basis for the IGM	N	N	N
2.2.10	2024	Q2	Advanced LTAFs and Test Pressure Sheets.	Y	N	Y
2.2.11	2024	Q2	Review of Pilot Digital Data Deliverables	Y	N	N
2.2.12	2023-2024	Lot1 Q2 2023, Lot2 Q1/Q3 2024	Delivery of Factual Reports and digital data by the geotechnical contractor	Y	N	N
2.2.13	2024	Q2	Geotechnical Interpretation of standard laboratory test results as provided by the GT	Y	N	Y

Section	Estimated Schedule		Milestone	Deliverables from CONTRACTOR		
	Year	Quarter		Input and/or review required	Digital output	Reports
2.2.14	2024	Q2	Final version of the Geological Ground Model	N	Y	Y
2.2.15	2024	Q2-Q3	The production of predicted CPT measurements at seismic trace locations for 2D- and 3D-MC UHRS datasets	Y	N	N
2.2.16	2024	Q2-Q4	Realization of the Geotechnical Interpretation Report (GIR)	N	N	Y
2.2.17	2024	Q2-Q4	Realization of the Integrated Ground Model (IGM)	N	Y	Y
2.2.18	2024	Q3-Q4	Realization of the report as accompanying document to the digital IGM package	N	Y	Y
2.2.19	2024	Q3-Q4	Delivery of the reviewed and revised version of the IGM and the GIR, ready for publishing	Y	Y	Y

2.3 Additional Activities

2.3.1 Progress and Regular Interface Meeting

The CONTRACTOR shall be available to provide regular updates during Work Progress Meetings (WPM) with the CONTRACTING AUTHORITY. It is estimated that meetings will be scheduled on a bi-weekly basis for 1.5hrs. The CONTRACTOR shall attend these meetings with the designated project manager and relevant technical specialists. Occasionally multiple technical specialists may be required to attend to discuss specific topics of the WORK. The CONTRACTING AUTHORITY will prepare a meeting agenda, track actions in an action list and document meeting notes. CONTRACTOR will be required to provide a weekly report at least 24hrs prior to the WPM. The weekly report shall contain up to date information on the progress of the WORK, risks and opportunities, forecasted delivery dates and potential changes to scope as required.

During the execution of the WORK multiple interfaces are recognised. The main interfaces are with the GP and the GT. The CONTRACTING AUTHORITY requests the CONTRACTOR to participate in Joint Progress Meetings to discuss relevant interfaces and interdependencies of the WORK and to promote collaboration between parties. The CONTRACTOR shall attend these meetings with the designated project manager and relevant technical specialists. Joint Progress Meetings will be scheduled on 4-weekly basis for the duration of the contract (1.5hrs per meeting).

2.3.2 Workshops/Meetings to discuss outside of WPM

Besides the regular meetings outlined in section 2.3.1, the CONTRACTOR is required to attend various meetings and workshops. The workshops and meetings will be required at various stage throughout the contract period and will be utilised to, for example, discuss the results and output of various deliverables, alignment with interfaces or to discuss issues that may arise during the execution of the work. In some instances, preparation in the form of a presentation may be requested by the CONTRACTING AUTHORITY. For this Tender, CONTRACTOR is to consider the following in the proposal:

- Expert/specialist meetings, 2hrs each, estimated total of 30 meetings
- Workshops, 4hrs each, estimated total of 12 workshops

2.3.3 Webinars

The CONTRACTOR is requested to present the GIR and IGM results to the market through participation of at least two webinars. For this, the CONTRACTOR shall provide:

- Preparation of presentations including Powerpoint slides and script.
- Attendance and presentation of webinars at RVO location in Utrecht or by virtual attendance by at least two senior experts
- Provision of suitable number and qualified personnel to staff back office during and after webinars to respond to questions from the audience.

2.3.4 Answering Additional Questions

It is anticipated that additional questions (from the market or CONTRACTING AUTHORITY) regarding this Integrated Ground Model and Geotechnical Interpretation Report will be received after delivery of the study results. The CONTRACTOR is requested to support the CONTRACTING AUTHORITY in answering these questions.

The CONTRACTOR shall include cost-reimbursable rates in Annex 6-Section IV (Remuneration) for optional works related to answering questions.

2.4 HSE and COVID-19

CONTRACTOR shall provide adequate cover and team redundancy in order to adequately manage the impact from COVID-19 situation, including possible future outbreaks. The provisions shall include the option of remote/office working and facilities for conducting remote meetings including adequate internet and server connectivity and speed.

The backup team members shall be as a minimum equally qualified and experienced as the primary team.

3 SCHEDULE OF KEY DATES

The SCHEDULE OF KEY DATES is presented in Annex 4.