Date 30 May 2023

Status Final

Integrated Ground Models Hollandse Kust (west) VIII and Nederwiek (noord) Investigation Areas

Annex 6 - Section V

Scope of Work

Colophon

Project name	Integrated Ground Models Hollandse Kust (west) VIII and Nederwiek (noord) Investigation Areas
Project number	WOZ2230089/202304107(HKWVIII) & WOZ2230090 /202304106(NWN)
Version	Final
File name	NWN_HKWVIII_GM_Annex_6_V_Scope_of_Work_F.docx
Project Manager	J.M. Dekker
Annex(es)	
Author(s)	K. Blacker, N. Dyer, M. Falco
Reviewed	M. Faber, Ir F.C.W. van Erp, J.M. Dekker, G. van der Meulen
Approved	P. Lebbink

Contents

REFERENCES

ASTM D 6528-17	Standard Test Method for Consolidated Undrained Direct Simple Shear Testing of Fine Grain Soils, ASTM International, 2017
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
CEN, 2003b. EN 12501-2	Protection of metallic materials against corrosion – corrosion likelihood in soil – Part 2: Low alloyed and non-alloyed ferrous materials, Brussels.
DNVGL-RP-0416	Recommended Practice Corrosion protection for wind turbines. DNV GL, 2016, amended 2021-10.
DNV-RP-C207	Statistical representation of soil data, DNV, 2021
DNV-RP-C212	Offshore soil mechanics and geotechnical engineering, DNV, 2021.
EN ISO 2394:2015	General principles on reliability for structures, Annex D: Reliability of Geotechnical Structures, International Organization for Standardization (ISO), 2015.
EN ISO 13823:2008	International Organization for Standardization, 2008. General principles on the design of structures for durability. Geneva: ISO.
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.
EN ISO 19901-4: 2016	Petroleum and natural gas industries: specific requirements for offshore structures – Part 4 Geotechnical and foundation design considerations
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.

EN ISO 19901-10:2021 Petroleum and natural gas industries — Specific requirements for offshore structures — Part 10: Marine geophysical investigations. International Organization for Standardization (ISO), 2021.

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

BSF	Below seafloor
CMP	Common Mid Point
CPT	Cone Penetration Test
DMR	Downhole Magnetic Resonance
DRF	Document Response Form
DT	Dissipation Test
DTS	Desktop Study
ETRS	European Terrestrial Reference System
f_s	sleeve friction
G_{max}	small strain shear modulus
GGM	Geological Ground Model
GIR	Geotechnical Interpretation Report
GIS	Geographic Information System
GM	Ground Model Contractor
GP	Geophysical Contractor
GT	Geotechnical Contractor
GW	Giga Watt
HKN	Hollandse Kust Noord
HKWWFS	Hollande Kust (west) Wind Farm Site
HKWWFZ	Hollandse Kust (west) Wind Farm Zone
HKWVIII	Hollandse Kust (west) VIII
HKWVIII IA	Hollandse Kust (west) VIII Investigation Area
HKZ	Hollandse Kust Zuid
IA	Investigation Area
IGM	Integrated Ground Model
IJVWFZ	IJmuiden Ver Wind Farm Zone
LDGM	Legacy Data Ground Model
LTAF	Laboratory Test Assignment Form
LTS	Laboratory Testing Strategy
LAT	Lowest Astronomical Tide
Mag	Magnetometer
MBES	Multibeam Echosounder
MW	Mega Watt
MIC	Microbially Induced Corrosion
MC UHRS	Multi-Channel Ultra High Resolution Seismic
NWWFZ	Nederwiek Wind Farm Zone
NWN	Nederwiek Wind (noord)
NWN IA	Nederwiek Wind (noord) Investigation Area
PSD	Particle Size Distribution

PCPT	Piezo Cone Penetration Test
PGM	Preliminary Ground Model
P-S Logging	Compressional (P-wave) and Shear (S-wave) acoustic logging
PD	Project Documentation, as an overarching term for documents including for example, but not limited to: project execution plan, quality plan, health and safety plan, risk assessments and project schedules.
PQP	Project Quality Plan
QA	Quality Assurance
QC	Quality Control
QI	Quantitative Interpretation
q_t	corrected cone tip resistance
SBP	Sub Bottom Profiler
SCPT	Seismic Cone Penetration Test
SC UHRS	Single-Channel Ultra High Resolution
SGR	Spectral Gamma Ray (Natural Gamma)
SSS	Side Scan Sonar
TCPT	Temperature Cone Penetration Test
TNW	Ten noorden van de Waddeneilanden
UHRS	Ultra High Resolution Seismic
UTM	Universal Transverse Mercator
u_2	pore pressure
UXO	Unexploded Ordnance
VC	Vibrocore
WFZ	Wind Farm 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 Nederwiek (noord) Investigation Area (NWN IA) and Hollandse Kust (west) VIII Investigation Area (HKWVIII IA). The NWN IA is located within the Nederwiek Wind Farm Zone (NWWFZ), and the HKWVIII investigation area (HKWVIII IA) is located within the Hollandse Kust (west) Wind Farm Zone (HKWWFZ).

This scope of work comprises two lots as will be explained in the following sections. Tenderer may choose to tender for one or both lots.

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 sites will be part of this information package.

Information on the soil conditions at the sites is provided 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, Integrated Ground Models (IGM) and Geotechnical Interpretation Reports (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. Comprehensive reports will be created for the IGMs. In general, the CONTRACTING AUTHORITY is ultimately seeking Integrated Ground Models that incorporates industry best practice and represents the current state-of-the-art.

This assignment is concerned with the Geological Ground Model (GGM), Integrated Ground Model (IGM) and the Geotechnical Interpretation Report (GIR) components, contributing to the information package to be provided to participants in the tender(s).

The locations of the Dutch Offshore Windfarm Zones are summarized in Figure 1.

The HKWWFZ is located southwest of the IJVWFZ (Figure 1) and includes individual areas HKWVI, HKWVII and HKWVIII. HKWVIII covers approximately 80 km^2. The total capacity of HKWVIII is anticipated to be 700 MW.

The NWWFZ is located northwest of the IJVWFZ (Figure 1). The NWWFZ includes Nederwiek (zuid) and Nederwiek (noord) sites. The NWN IA covers approximately 673 km^2. The total capacity of entire NWWFZ will be 6000 MW, that of Nederwiek (noord) site alone 4000 MW. After Borssele, Hollandse Kust (zuid, noord and west) and Ten noorden van de Waddeneilanden and IJmuiden Ver the NWWFZ is the seventh WFZ for which site investigations are executed and ground models are developed within the Netherlands Offshore Wind Energy Roadmap 2030.

This tender comprises two lots:

1. Lot 1; Development of an Integrated Ground Model for HKWVIII
2. Lot 2; Development of an Integrated Ground Model for NWN

Lot 1: HKWVIII IA

The Lot 1 area consists of HKWVIII IA, located in the southern tip of HKWWFZ and represents an anticipated installed capacity of 700 MW.

Site investigations were executed in 2019. These investigations included geophysical surveys targeting the entire HKWWFZ and geotechnical investigations targeting the specific site of HKWVI and HKWVII. A geotechnical campaign at HKWVIII is planned to be performed between Q3 / 2023 and Q4 / 2023. For key dates when this data is anticipated to be available to the GM contractor, please refer to Annex 4a of the Tender documents.

No additional geophysical survey work for the purpose of informing the ground model is scheduled or anticipated for HKWVIII.

The current schedule indicates that the HKWVIII Wind Farm Site permit will be tendered in Q2 2026.

Water depths at HKWWFZ range between 18.6 and 35.5 m (LAT). A geological desk study, geophysical interpretation and geotechnical data for the HKW sites VI and VII are available as a preliminary knowledgebase for HKWWFZ to form the basis of the Ground model at HKWVIII.

Lot 2: NWN IA

The Lot 2 IA comprises two development sites, each with an anticipated installed capacity of 2 GW. The total NWWFZ will have an installed capacity of 6 GW.

The current schedule indicates that the NWN permits will be tendered in Q2 2026. The site investigation campaigns are scheduled for 2023 (geophysical and geotechnical).

Water depths at NWWFZ range between 24.5 and 34.0 m (LAT). A geological desk top study is available for the NWWFZ (noord and zuid) to form the basis of the Ground Model.

Figure 1: Designated Offshore Wind Farm Zones in the Netherlands. HKWVIII and NWN indicated with dashed red line

1.3 IGM Investigation Areas

The CONTRACTOR will be working from a set of geotechnical and geophysical data sets acquired for the NWN and HKWVIII Investigation Areas. Note that the investigation areas defined for the Integrated Ground Model may differ from the investigation areas defined in the geophysical and geotechnical contracts. The investigation areas referred to in this tender relate to the GM scope unless explicitly stated otherwise.

Section 1.3.1 and section 1.3.2 describe in detail respectively the HKWVIII IA and the NWN IA.

1.3.1 Lot 1 - Hollandse Kust West VIII Investigation Area

Figure 2 illustrates the area that relates to the ground model works defined in this SOW. It shows that the IA for the Ground Model works extend beyond the HKWVIII preliminary site boundaries and establishes some overlap with the HKWVII WFS.

Within the HKWWFZ, geophysical data for was acquired in a single pass. Data acquired were seabed (magnetometry, side scan sonar, multibeam echosounder and grab sampling) and the sub seabed (sub bottom profiler and 2D UHRS) data.

The geophysical survey provided a detailed dataset including bathymetry and backscatter survey, side-scan sonar, magnetometry, SBP, 2D-UHRS and seabed sediment sampling for the entire HKW IA. The maximum required depth of interest for the quantitative Integrated Ground Model (IGM) output data is set to 100 m below seafloor for the Geophysical Survey.

The 2D-SC UHRS, MBES, SSS, Mag and SBP geophysical survey consist of 102 survey lines with a total length of approximately 1,500 km. Main lines are spaced at 100 m and oriented 80°, and cross lines are spaced at 2,000 m and oriented 170°. The 2D-MC UHRS consists of 63 survey lines with a total length of approximately 680 km. Main lines are spaced at 400 m and oriented 80°, and cross lines are spaced at 400 m and oriented 170°. For further information on the scope of the Geophysical Survey, see section 2.2.1.

The entire Integrated Ground Model IA was extended at the north side of approximately 2 km with the HKWVII Site. The overlap was made to include nine existing CPT locations and to tie the HKWVIII ground model to the neighbouring HKWVII Site.

The target depth of the geotechnical survey will be 60 m BSF. The depth of interest for the IGM will cover the seafloor to approximately 100 m depth BSF.

The boundary coordinates of the IA for which the Integrated Ground Model will be developed, are provided in Table 1, section 1.3.2.

The Investigation Area specifically excludes any potential export cable routes.

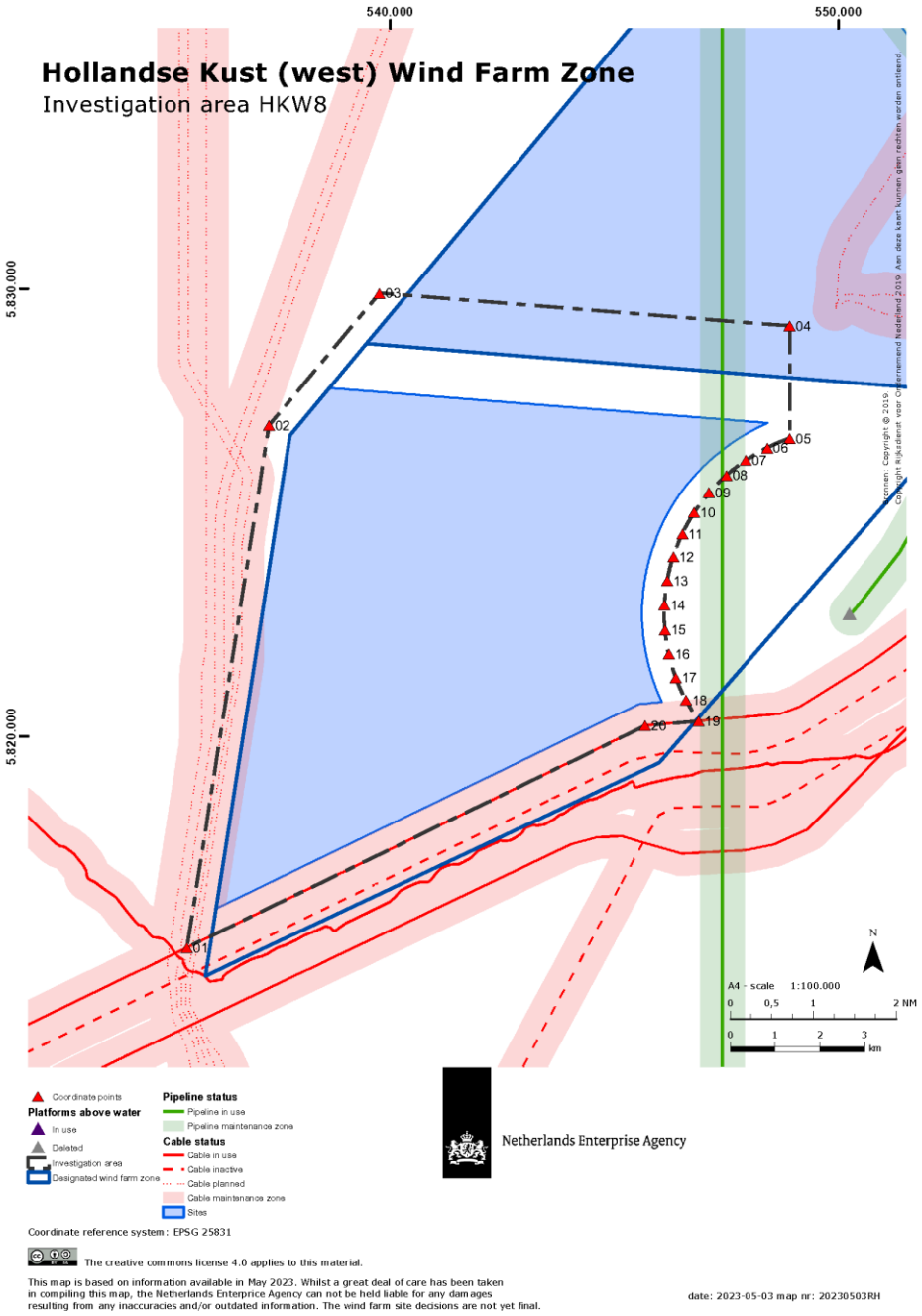

Figure 2: HKW Geophysical Survey Investigation Area and HKWVIII Investigation Area for the Integrated Ground Model

1.3.2 Lot 2 - Nederwiek (noord) Investigation Area

The Integrated Ground Model IA is illustrated in Figure 3.

Geophysical data for the IA will be acquired in a single pass and will be provided by RVO. Data acquired shall be seabed (magnetometry, side scan sonar, multibeam echosounder and grab sampling) and the sub seabed (sub bottom profiler and 2D UHRS) data.

The geophysical survey will provide a detailed dataset including bathymetry and backscatter survey, side-scan sonar, magnetometry, SBP, 2D-UHRS and seabed sediment sampling for the entire IA. The maximum depth of interest for the Integrated Ground Model (IGM) is set to 100 m below seafloor for the Geophysical Survey.

The 2D UHRS, MBES, SSS, MAG and SBP geophysical survey will consist of 484 survey lines with a total length of approximately 10300 km. Main lines will be spaced at 65 m and oriented 075°, and cross lines will be spaced at 520 m and oriented 165°. Of the 484 lines, a subset of priority lines will be acquired first with 52 main lines and 58 crosslines. For further information on the scope of the Geophysical Survey, see section 2.3.1.

A geotechnical investigation that is planned will cover the ground model Investigation Area but is planned to be *exclusive* of an approximately 500 m perimeter buffer zone, in which no wind turbines will be installed. For clarity, the geophysical IA and ground model IA include this buffer zone. Target depth of the geotechnical survey will be 60 m BSF. The depth of interest for the IGM will cover the seafloor to approximately 100 m depth.

The boundary coordinates of the IA for which the Integrated Ground Model will be developed, are provided in Table 2, section 1.3.2.

Additionally, a geological desktop study performed by a separate contractor will be available for the NWWFZ (noord and zuid). This will contain a general description of the IA and also iMOD-files of the area.

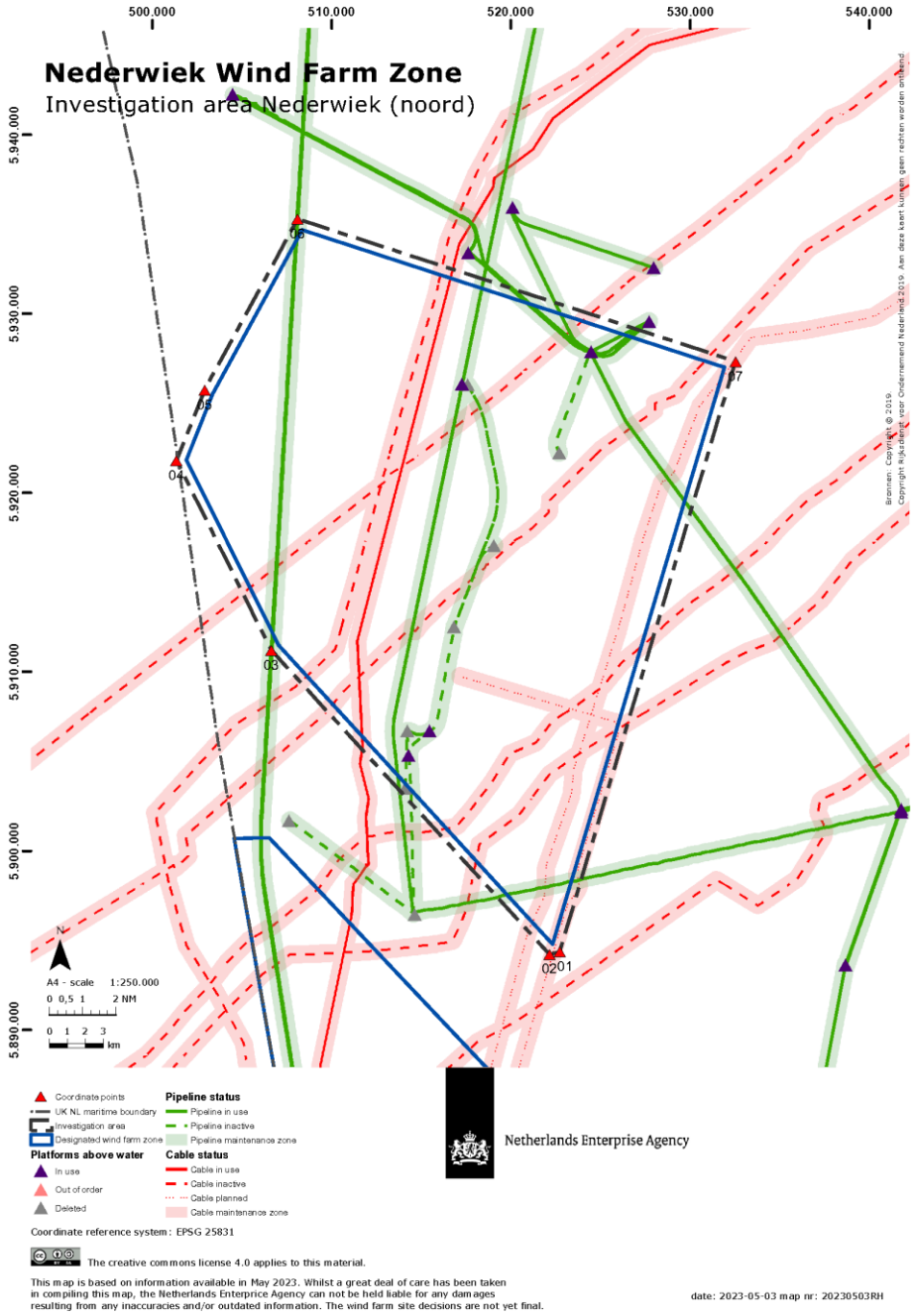

Figure 3: Geophysical Survey Investigation Area and Integrated Ground Model Area for Nederwiek (noord) Wind Farm Zone

1.3.3 *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 HKWVIII IA and Table 2 summarize the boundary coordinates for NWN IA.

Table 1 Coordinates of the Hollandse Kust (west) VIII Wind Farm Zone

Hollandse Kust West VIII Investigation Area		
Point No.	**Easting**	**Northing**
IA_01	535465.50	5815290.40
IA_02	537288.50	5826952.90
IA_03	539758.00	5829911.40
IA_04	548918.20	5829178.10
IA_05	548918.20	5826667.40
IA_06	548410.30	5826457.00
IA_07	547934.70	5826181.00
IA_08	547500.10	5825844.20
IA_09	547114.10	5825452.70
IA_10	546783.50	5825013.30
IA_11	546514.10	5824534.00
IA_12	546310.90	5824023.10
IA_13	546177.30	5823489.80
IA_14	546115.70	5822943.40
IA_15	546127.20	5822393.70
IA_16	546211.70	5821850.40
IA_17	546367.60	5821323.10
IA_18	546592.20	5820821.20
IA_19	546881.40	5820353.60
IA_20	545689.20	5820245.50
Coordinate system: ETRS_1989_UTM_Zone_31N		
EPSG 25831		

Table 2 Coordinates of the Nederwiek Wind (noord) Investigation Area

Nederwiek (noord) Investigation Area		
Point No.	**Easting**	**Northing**
IA_01	522709.80	5894356.00
IA_02	522141.30	5894225.40
IA_03	506622.80	5911208.80
IA_04	501346.00	5921814.40
IA_05	502898.60	5925735.60
IA_06	508096.30	5935303.90
IA_07	532515.80	5927346.30
Coordinate system: ETRS_1989_UTM_Zone_31N		
EPSG 25831		

1.4 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 works[1]:

- Geological desk study
- Base map (MPK) containing information on location, attached to Annex 5: Starting Points and Assumptions
- Archaeological desk study

The results of the soil characterisation investigations carried out for Borssele, HKZ, HKW, HKN, TNW WFZ and IJV Wind Farm Sites 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 NWWFZ geotechnical survey as well as the IGM contents of the ongoing investigations for the IJV Wind Farm Sites 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.

The knowledgebase (DTS, geophysical data and partial coverage of geotechnical data) for HKWWFZ is made available online by the CONTRACTING AUTHORITY 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 definition for the project milestones, input parameters, activities and required deliverables for the IGM and GIR CONTRACTOR. The definitions here are binding, further options and flexibilities are explicitly assigned.

All projected dates in section 2.2 and in section 2.3 are approximate and may be changed. Refer to Annex 4a (HKWVIII) and Annex 4b (NWN) for further details on key input and deliverable dates.

2.2 Workflow and deliverables – Lot 1 - HKWVIII

2.2.1 Project Documentation

Milestone: Project documentation (PD) outlining CONTRACTOR's understanding of the WORK. This documentation will include method statements for quality, safety, health and wellbeing, environmental management, the identification of risks and mitigation measures within the scope of the PROJECT.

The CONTRACTOR is required to provide with Tender Project Documentation (PD) in which the approach, methodologies and schedule proposed to complete the WORK are set out and explained in adequate detail to describe the offer. Elements that are expected to be detailed post award may be flagged with a time bound commitment to make project specific. Upon award of the WORK, the CONTRACTOR is required to update the PD to a fully working version which represents the roadmap for the duration of the CONTRACT. Items listed as milestones in the following sub-sections are expected to be included in the PD.

Periodic updates to the PD by the CONTRACTOR are expected within the course of the project, reacting to events, changes, data inputs and evaluations and dependent upon the achievement of specific milestones. The PD should be maintained to be as current, accurate, detailed, and specific as is reasonably practicable.

The schedule for the delivery of PD updates will be determined by the CONTRACTING AUTHORITY during the project phase (exemplary milestones for updates are indicated below, up to two updates additional to the exemplary update points provided may be required at no additional cost). 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, approved by the CONTRACTING AUTHORITY prior to the geotechnical site investigation planning of the GT-Lot 2 soil investigations (see 2.2.5). The project specific Project Documentation (PD) 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 (available at https://offshorewind.rvo.nl/).
- Geological Desk study HKWWFZ is available at the website https://offshorewind.rvo.nl/
- This scope of work and other Tender documentation
- Input for PD update after milestone 2.2.1 is completed:
    - Knowledge Base from HKW
    - Raw and interpreted sub-seabed data from both the desktop study and geophysical survey (2D-SC UHRS, 2D-MC UHRS, SBP) as well as preliminary velocity model and seismic processing methods of the GP.
    - Seabed assessment
    - Shallow seabed and zonation classification

- Input for PD update along with milestone 2.2.6
    - Activities of the CONTRACTOR performed up to this project state
    - Incoming data and information of the geotechnical field campaign
- Input for PD update along with milestone 2.2.13
    - 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 PD as well as PD updates:

- Detailed sections outlining the strategy in which the CONTRACTOR will meet the desired criteria for each project milestone deliverable outlined in the sections 2.2.2- 2.2.20.
- The preparation of a time schedule of the CONTRACTOR for the execution of all project activities
- A Quality Plan 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 PD is to be delivered as text with comprehensive descriptions of the above assigned issues, including:
    - Method statements
    - Quality Assurance processes, metrics and deliverables
    - References for any identified critical methods
    - Process flow charts
    - GANTT charts as required
- One meeting to discuss the contents of the PD with the CONTRACTING AUTHORITY and to initiate further workflow steps.

2.2.2 Review Geophysical Site Investigation

Milestone: Review geophysical site investigation reporting; desktop study; HKWVI&VII geotechnical report (ground model); seabed sampling report.

The CONTRACTING AUTHORITY has appointed a geological desk study contractor to perform a Desktop Study (DTS) and a geophysical contractor to carry out the geophysical survey scope (GP). Both these activities are complete with data available and a ground model including geotechnical data has been prepared for the site adjacent to the north.

The existing knowledgebase will be made available to the CONTRACTOR and includes an initial ground model delivered as a report, seismic interpretation products and a GIS data package. Processed and reported geotechnical data are available as part of the HKWVI&VII geotechnical report.

The execution of the geophysical investigations at HKWWFZ was performed in 2019. The geophysical survey includes a comprehensive geophysical data acquisition campaign with associated seabed sampling at selected locations.

Input:

The results of the geophysical campaign include the following items:

- High resolution bathymetric and backscatter survey
- Side scan sonar survey

- Magnetometer survey
- Shallow Penetration Sub-Bottom Profiler (SBP) survey
- 2D-multi-channel UHRS at 400 m x 400 m line spacing
- 2D single channel UHRS at 100 m x 2000 m line spacing
- 11 seabed (grab) sampling locations for ground truthing purposes
- A Geophysical report 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 (*e.g.* faulting, shallow gas, peat, channel infills, sub-glacial and glaciotectonic structures);
    - correlation to the other geophysical and geotechnical interpretations available in this region;
    - a comprehensive report with geohazard risk assessment.
- Extent of interpreted sub-seabed geological units, geohazards and seabed classification

Beside the interpreted data package of the geophysical report and geotechnical ground model, raw datasets and will be made available to evaluate, reprocess, reinterpret, and rework. Beside digital data formats (*e.g.*, SGY, ASCII, xyz etc.), the deliverables will include GIS files and a single seismic workstation project (Kingdom).

Activities:

The CONTRACTOR is expected to perform following tasks:

For the purpose of validation and refinement of project plans and schedules:

- Review of all data (raw and interpreted) and statistics from the geophysical site investigation
- Review of all site investigation documentations and reports
- Review of the PGM project contents and the accompanying report provided by the GP contractor.

For the purpose of update to Project documentation with specific detail:

- Assessment and presentation of requirements, potential methods and timings for reprocessing of the 2D-MC UHRS and 2D-SC UHRS data 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, adaptation of proposed methods to suit input data.

Quality Assurance Interface:

- Interactive dialogue with CONTRACTING AUTHORITY
- TN review and Document Response Form (DRF)

Deliverables:

The CONTRACTOR is expected to deliver the following services:

- Technical Note documenting:
  - Evaluation of geophysical and (where available) geotechnical data quality, uncertainty (structural and parametrical), geological complexity, prominent geological features (*e.g.* channel infills, glaciotectonic features, peat horizons) and degree of correlation to nearby wind farm investigations.
  - Evaluation of data suitability for the processes anticipated to be applied in development of the GIR and IGM datasets, and updates to method statements for these processes where required.
  - Description of geophysical data reprocessing operations to be implemented.
- One meeting with the CONTRACTING AUTHORITY to discuss results, PD updates 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-MC UHRS 2D-SC UHRS and SBP) are anticipated to require re-processing per the outcome of section 2.2.1 and 2.2.2. In view of the findings of 2.2.2 and the proposed reprocessing methodology outlined in the PEP, the CONTRACTING AUTHORITY will assess the proposed value 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, demultiple. 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 2.2.8.

Inputs:

- 2D-MC UHRS, 2D-SC UHRS, SBP, see 2.2.1
- PGM, see 2.2.1

Activities:

- Evaluation, parameterisation and application of data within the HKWWFZ 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 Technical note documenting results.
- One meeting with the CONTRACTING AUTHORITY to discuss the proposed reprocessing sequence, PD updates and deliverables.

Deliverables:

- Reprocessed pre-stack seismic data for input to velocity analysis and QC as required
- Reprocessed stacked seismic data (2D-SC UHRS and 2D-MC UHRS) as SEGY 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.

2.2.4 Laboratory Testing Strategy

Milestone: Document outlining laboratory testing strategy (LTS for Lot-2).

CONTRACTING AUTHORITY will appoint the execution of the laboratory testing to one geotechnical contractor (GT). The laboratory testing will include standard and advanced (dynamic/cyclic) soil testing on soils recovered during seabed and downhole investigation phases (referred to as GT-Lot 1 and GT-Lot 2 in the GT Contract, and hereafter in this document). Due to time constraints, the CONTRACTING AUTHORITY shall define the laboratory testing strategy for soil samples acquired during the GT-Lot 1 soil investigations.

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 without restricting the developers to certain design philosophies. The CONTRACTOR is required to develop a geotechnical laboratory testing strategy for the GT-Lot 2 soil investigations to obtain relevant geotechnical, chemical, and thermal parameters for monopile foundations. The CONTRACTING AUTHORITY requests from the GT that both undrained and drained cyclic strength testing is carried out.

The CONTRACTOR shall provide a comprehensive laboratory test strategy that outlines the type of tests, applicable and test frequency for various soil types. The laboratory strategy should clearly outline the testing requirements such that it can be used by the GT to enable the scheduling of laboratory tests programs during both offshore and onshore phases of work. The CONTRACTOR shall use the laboratory testing quantities from the GT Contractor (to be provided upon award) and define a workflow that enables the GT Contractor to establish a geographical coverage and depth interval that is in line with the requirements of the CONTRACTOR. The strategy document should provide clear guidance to the GT when preparing the laboratory test schedule sheets for the standard and advanced testing (section 2.2.7, 2.2.9). Test specifications shall be provided by the CONTRACTOR (see sections 2.2.7 and 2.2.9). The CONTRACTOR will clearly state the appropriate standards for all proposed tests and provide a list of minimum deliverables per test in the LTS document. The results of all GT lab results are to be interpreted by the CONTRACTOR (sections 2.2.13 and 2.2.16).

As the understanding of the site develops, the requirements of the LTS may change and it is expected that any required changes to the LTS will be updated by the CONTRACTOR.

The LTS shall include a proposal for a practical workflow for interaction between GT acquisition contractor, CONTRACTOR and CONTRACTING AUTHORITY in the development and timely delivery of approved test conditions parameters to the onshore laboratory.

More details on the geotechnical parameters and the requirements of the requested GIR are given in sections 2.2.11, 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, PD document
- Content of activities of 2.2.1 and 2.2.3
- Information of geotechnical site investigation of nearby WFZ, see section 1.4

Activities:

- Definition of a geotechnical soil testing strategy, clearly outlining the type, reference method, quantity, testing frequency and intervals 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. Offshore and onshore laboratory work is to be included.
- The CONTRACTOR will determine and provide all required and appropriate test conditions, including, but not limited to, consolidation pressures for estimation of in-situ conditions specific to the site, sample conditioning requirements, shear rates, etc., to the RVO and the GT contractor within a timescale acceptable to RVO, typically within a week.
- Identification and notification of any need for early classification testing required for the execution of the laboratory tests in the programme (*e.g.,* identification of batching requirements).
- Proposal for appropriate methodology for assessing sample quality for specific undisturbed tests.

Quality Assurance interface:

The CONTRACTING AUTHORITY is responsible for reviewing and approving of the laboratory test strategy for the GT-Lot 2 soil investigation through a document review process.

Deliverables:

A technical note including, but not limited to:

- As provided by the CONTRACTING AUTHORITY: The methodology statements, clear tables, workflow, process map, specifying the types of laboratory tests to be undertaken on GT-Lot 1 (seabed) samples.
- Method statements, clear tables, workflow, process map for reviewing the laboratory test schedules as they are issued during the fieldwork. A method statement including forward guidance for selecting samples to be obtained during the GT-Lot 2 (borehole) investigation, for geotechnical purposes, Age Dating testing/analysis, and Microbially Induced Corrosion (MIC) testing/analysis.
- Method statement and description of processes for the advanced testing program. This may include anticipation of the batching requirements of course grained samples, strength reference testing and cyclic/dynamic strength testing. It must include a clear stipulation of the test conditions regarding the stress state and drainage conditions.
- Statement to preferred data formats for digital data deliveries of the GT contractor. It is preferable that these formats anticipate and/or align with those proposed in 2.2.6.
- Examples of 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, at each geotechnical location. The laboratory test schedule review and subsequent specification of test conditions and specific requirements shall be the responsibility of the CONTRACTOR and is further specified in sections 2.2.7 and 2.2.9 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 prepare a site investigation location plan for the GT for the GT-Lot 1 (seabed) investigations.

The CONTRACTING AUTHORITY will appoint one GT CONTRACTOR for the execution of a site investigation, laboratory testing and associated factual reporting. The site investigation comprises two Lots, which will be executed sequentially:

- GT-Lot 1: seabed phase, comprising seabed *in-situ* PCPTs, SCPTs, shallow sampling techniques, ecological sampling, thermal testing, dissipation testing and an initial offshore laboratory testing programme.
- GT-Lot 2: borehole phase, comprising of boreholes with *in-situ* PCPT testing (including SCPT, P-S, SGR and/or DMR wireline logging), sampling, or a combination of both. Microbially Induced Corrosion (MIC) and Geological Age Dating tests (anticipated in the order of 100 tests) will be also part of the geotechnical survey.

It is currently anticipated that for GT-Lot 1 approximately up to 35 seabed PCPT (SB PCPT) tests will be carried out. An additional 15 CPTs will be including seismic measurements (SB SCPT) and 10 may be performed with in situ temperature measurements (TC). It is estimated that up to 37 vibrocores (VC) will be carried out. Dissipation tests (DT) will be carried out on selected intervals during the seabed PCPT investigation. The testing interval and quantity of DT will be decided during field execution. Ecological and water samples will be collected at 11 locations. The CONTRACTING AUTHORITY will determine the location plans for the GT seabed investigation survey.

For the downhole investigations (GT-Lot 2), limited time will be available for the CONTRACTOR to specify the borehole plan. As such, RVO will specify the borehole locations building upon the seabed CPT and sampling plan in order to proceed with UXO clearing works. CONTRACTOR is requested to propose in-situ testing and sampling intervals, specify age dating intervals and nominate boreholes for geophysical logging, if required. It is currently anticipated that up to 30 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 60 m beneath seafloor. It is a requirement that a number of boreholes will be logged using downhole geophysical logging techniques and seismic CPTs (SCPT).

The CONTRACTING AUTHORITY is responsible for the final site investigation plans and communicating these to the GT.

Input:

- Content of activities of 2.2.1, Project Documentation
- Content of activities of 2.2.1 and 2.2.3
- Location information (trackplots) for SBP, UHRS and Magnetometry
- Information of geotechnical site investigation of nearby WFZ, including HKW sites VI and VII , see section 1.4

Activities:

The CONTRACTING AUTHORITY is responsible for developing the following items with support of the CONTRACTOR:

- A proposal for the downhole geotechnical investigation as part of a detailed program for the GT-Lot 2 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.
  There will be insufficient time for the CONTRACTOR to determine the coordinates of the borehole locations. However, the CONTRACT will be requested to detail the sampling and testing regime in each borehole.

The CONTRACTOR shall:

- Support the definition of sampling depths for geological age dating (Geochronological analysis) and Microbially Induced Corrosion (MIC) testing.
- Include consideration for the requirements (if any) for hazard clearance to be provided by the GT Contractor via the CONTRACTING AUTHORITY, including but not limited to seabed obstructions, sub seabed obstructions and UXO.
- Prepare *prognosis sheets* for each geotechnical investigation location illustrating expected conditions (geological and hazard) at seabed and below. The prognosis sheets shall contain, but not limited to:
    - A high-resolution plot of the available seismic data and interpretation with annotated soil units and expected conditions at the location with a horizontal distance of 250 m either side of the location, and a depth of 100 m below the seabed.
    - Seabed conditions, obstructions, objects, bathymetry and slope at a suitable distance.
    - A table of expected geological formations and/or soil types, with expected depths with appropriate uncertainty bounds.

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.

Deliverables:

The CONTRACTOR shall provide the following:

- Prognosis sheets for each GT-Lot 2 geotechnical investigation location illustrating expected conditions (geological and hazard) at seabed and below.
- A Technical Note with recommendations for the locations of GT-Lot 2 in-situ testing, sampling, MIC testing and age dating.
- Tabular (.csv) and GIS format listing of the proposed GI locations including comments.
- Workshops and meetings as reasonably required by the CONTRACTING AUTHORITY.

2.2.6 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 dataset may include, but is not limited to:

- AGS 4.0 (or higher) format
- ASCII
- Excel or csv
- Log ASCII Standard (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. 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 database to set up their workflows, to confirm compatibility.
- CONTRACTING AUTHORITY shall review and respond to pilot data delivery using a DRF approach.

Deliverables:

- Example data files of every data format to be used in final deliverables.
- Written confirmation of acceptance of format.

2.2.7 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 contents of each lot are:

- GT-Lot 1: not applicable. The offshore data acquisition phase is scheduled to be completed prior to GM Contract award. GM Contractor will be requested to provide input for the onshore laboratory testing where required.
- GT-Lot 2: borehole phase, comprising of boreholes with *in-situ* testing (including PCPT, SCPT, P-S, SGR and/or DMR and/or other wireline logging), sampling, or a combination of both and an initial offshore laboratory testing programme. Microbially induced corrosion (MIC) and Geological Age Dating tests (anticipated in the order of 200 samples) will be also part of the geotechnical survey.

The CONTRACTOR is expected to be available to provide input to potential modifications to the prognosis sheets (after GT-Lot-1 investigations) 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 investigations
- Confirmation that the requirements for the proposed methods for IGM and GIR creation can be fulfilled.
- Proposal for any actions or modifications to be made if any concerns exist.
- Accompanying assessment of data in combination with the supplied geophysical data interpretation (see section 2.2.1) and ongoing reprocessing procedure of the 2D-MC UHRS, 2D-SC UHRS and SBP data from the GP, for the specific purpose of data integration, time-depth correlation and QI.

Quality Assurance interface:

- Interactive dialogue with CONTRACTING AUTHORITY during activities.
- Interactive dialogue with the GT during activities.

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.

2.2.8 Integration of borehole and CPT data into the Ground Model

Milestone: Integration of geotechnical field data. Correlation of the geotechnical data and the sub-seabed geophysical data for the Geological Ground Model. Revision following laboratory testing may be required.

The integration of the geotechnical field work data into the geophysical ground model and shall be used as a key component of the Geological Ground Model for which requirements are outlined in section 2.2.13.

It is expected that of the order of 17 no. geotechnical/geological units may be required to characterise the HKWVIII 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 2.2.7.

Activities:

The CONTRACTOR is expected to perform following work:

- Preparation of geotechnical field data and integration into a single seismic workstation project (S&P Kingdom)
- Initial correlation of geotechnical and geophysical data to deliver time-depth pairs representing each geotechnically relevant layer interface.
- Structural interpretation of all relevant additional geological units and refinement of the interpretation provided by the geophysical contractor.
- Detect and interpret (proximal to the GI location) as appropriate: sub-layers, and design-sensitive horizons (peat, channel infills, glaciotectonic features) as well as any potential geohazards.
- Assessment of the potential benefit and methods of further reprocessing of the geophysical data.

Quality Assurance interface:

- Prepare cross-sections and other drawings showing the integration of 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 Seismic workstation project (S&P Kingdom).
- Correlation drawings illustrating the geophysical and geotechnical data correlation corresponding to initial unitisation of the soil/rock columns.
- Update of the unitisation with any relevant findings of the ongoing lab testing.
- Time-depth pairs, inferred interval velocity and seismic imaging velocity profile at each geotechnical investigation location.
- Technical note to accompany the correlation drawings and velocity data describing the unitisation and observations therein.

2.2.9 Laboratory Test Schedule and Specification of Test Parameters

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

Upon completion of each geotechnical sampling location the CONTRACTING AUTHORITY, through input from the GT, will propose a laboratory test schedule for each location. The schedule will be prepared by the GT based on CONTRACTOR's laboratory strategy and location prognosis sheets. A review of the schedule by the CONTRACTOR will be requested by the CONTRACTING AUTHORITY. Once the schedule is reviewed and approved, the GT can commence testing activities. For some tests, additional information (test conditions) for each sample interval will be required. This information (*e.g.* consolidation pressures, rates of shearing, density) will be required in a timely delivery from the CONTRACTOR ensuring that the appropriate test conditions will be specified in the context of the GIR and IGM. The CONTRACTING AUTHORITY will review laboratory test schedules for the GT-Lot 1 soil investigations, however if offshore work progress allows, the CONTRACTOR may have an opportunity to be included in the review of the GT-Lot 1 laboratory test schedules. If this is feasible then the OPTION to request a review of the GT-Lot 1 laboratory test schedules will be specified by the CONTRACTING AUTHORITY. It is required that the CONTRACTOR will fully review the laboratory test schedules and provide specification of test conditions for all GT-Lot 2 locations on a timescale that does not cause delay to the laboratory work.

Input:

- Contents of 2.2.1 and 2.2.3.
- Deliverables 2.2.4, and 2.2.7.
- Provisional laboratory test schedule from the GT.
- Test pressure and conditions sheet template.

Activities:

Accompanying to the ongoing review activities as described in section 2.2.7, the standard laboratory test progress shall be accompanied and reviewed by the CONTRACTOR, and advised, if needed. The activities of the CONTRACTOR shall include following aspects explicitly:

- Reviewing the provisional laboratory test schedule prepared by the GT for early standard testing which shall serve as input for the specification of test conditions *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 laboratory test schedule 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 laboratory test schedule 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. These test conditions shall be provided by the CONTRACTOR.

Quality Assurance interface:

- Approval of output by CONTRACTING AUTHORITY.

Deliverables:

The CONTRACTOR is expected to provide following services:

- Review / confirmation of laboratory test schedule sheet per geotechnical location within 48hrs of receipt (except weekends)
- Completion of specification of test parameters (Word or Excel sheets) within no later than 3 days of request
- Contact as required (online meeting, email, call), typically weekly, with GT and CONTRACTING AUTHORITY to clarify progress and identify and commit to actions. Can be combined with meetings of 2.2.7, if this is beneficial for all parties (CONTRACTOR, GT and CONTRACTING AUTHORITY)

2.2.10 Geological Ground Model

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

It is expected that of the order of 17 no. geotechnical/geological units may be required to characterise the HKWVIII 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: The work performed in 2.2.8 using 2.2.1 through to 2.2.8.

Activities:

The CONTRACTOR is expected to perform following activities in an appropriate sequence:

- Site-wide propagation of local interpretation updates performed in 2.2.8 to all seismic lines of all types within their depth of applicability.
- Site-wide (on all seismic data types) interpretation of all identified geohazard and intra-soil-unit interfaces.
- Correlation of further (litho-)stratigraphical sequences to other nearby WFZ.
- Correlation (or revision) and integration of Age Dating and SGR results to confirm the geochronological order, if already available.
- Completion of site-wide update of stacking velocity analyses incorporating updates indicated by ground investigation and unitisation in section 2.2.8.
- Test, parameterise, and apply further pre-stack reprocessing as appropriate.
- Test, parameterise, and apply re-migration / stack and post-stack processing as appropriate.
- Specification, parameterisation, and production of seismic attribute set for input to CPT prediction methods.

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, at significant soil unit boundaries throughout depth range.
- Structural interpretation QA as *e.g.* selected profiles with geotechnical locations.
- Parameter test panels and notes for all significant data processing operations to be agreed with CONTRACTING AUTHORITY.

Deliverables:

The CONTRACTOR shall provide the following:

- Horizons and grids representing all interpreted unit boundaries and geohazards;
- Seismic Processing Update Technical Note including description of testing, decisions, parameters and final processing sequence applied;
- Description of derived Seismic Attributes and the data processing used to create them as a Technical Note;
- Reprocessed multi-channel (SC) and single-channel (SC) seismic UHRS data as SEGY with fully populated header;

- Additional Seismic Attribute datasets as SEGY with fully populated header, representing all input datasets used in the prediction of geotechnical parameters (section 2.2.15);
- Stacking and Interval velocity as SEGY trace data at every seismic trace location and ASCII data in ESSOV2 format at intervals to be defined;
- At least one workshop with the CONTRACTING AUTHORITY presenting the Interim version of the Geological Ground Model;
- Geological description(s) provided as a TN or short note.

2.2.11 Advanced Laboratory Test Assignment Form and Specification of Test Parameters

Milestone: Advanced Laboratory Test Schedules and Test Conditions 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 shall provide the advanced laboratory test schedules for review by the CONTRACTOR. Following the approval, the CONTRACTOR is required to fill out the test conditions sheets 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 and the monopile use case. The advanced laboratory test programme shall include cyclic tests accompanied by associated static and classification tests and may also include dynamic testing.

Input:

- Advanced laboratory test schedules
- Test conditions 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 clearly stated.
- Review of the advanced laboratory test schedules 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 conditions 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:

- Interactive dialogue with CONTRACTING AUTHORITY during activities.
- Provision of justifications and/or data used to define batching, parameters and specialist testing.
- 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) within no more than 3 days of request.

2.2.12 Review of Factual Reports GT and Digital Data

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

The delivery of the GT reports will comprise of (refer to Annex 4a):

- GT-Lot 1 seabed *in-situ* testing report
- GT-Lot 1 seabed sampling report
- GT-Lot 2 downhole testing and sampling report.
- GT-Lot 2 cyclic testing report.

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 GT-Lot 1 (seabed phase).
- Factual reports and digital laboratory data associated with the GT-Lot 2 (borehole) campaign for which input is provided by CONTRACTOR.
- Factual Reports and digital laboratory data associated with the cyclic testing for which input is provided by CONTRACTOR.
- Final MIC and Geological Age Dating factual reports provided by the GT.
- Contents and plan as provided in PD.

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

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 laboratory test results must be performed before or at least in early stages of the advanced laboratory test programme as assigned in section 2.2.9 and already planned in section 2.2.7.

Input: sections 2.2.5, 2.2.7 *and 2.2.8*.

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, establish 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, mean and median values of selected laboratory tests results

- Statistical description 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) for each parameter and covariance in-between individual parameters. The derived values of the geotechnical parameters shall include the parameters as proposed and approved with the PD document and updates for, but not limited to, the basic soil types (i.e. cohesive, non-cohesive, transitional soils).

Deliverables:

The CONTRACTOR is expected to deliver following:

- Overview with short descriptions about performed work.

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 (2.2.16) such that all geotechnical Soil Unit boundaries are represented within the structural model defined by the geophysics. The Soil Units shall represent bodies of common geotechnical behaviour and/or properties in the context of wind farm and cable foundation/installation design. Time-depth pairs are to be updated as required, and nomenclature is to be common between the geological and geotechnical unitisation.

Input:

- Section 2.2.10 and 2.2.13 using information from sections 2.2.1 through to 2.2.9.
- factual reports of the GT,
- final MIC and Age Dating results.

Activities:

The CONTRACTOR is expected to finalize the Geological Ground Model, updating the structural model with the geophysical-geotechnical correlation implemented in the GIR. The structural model must include all units included in the GIR. 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.

A time-to-depth conversion strategy is required, with the velocity field developed (or inferred) for this process included as a deliverable.

Addition or modification of unit interfaces following Geotechnical Interpretation Reporting.

Quality Assurance interface:

Bi-weekly update meetings, working data deliveries, summary documents and up to two workshops with CONTRACTING AUTHORITY.

CONTRACTING AUTHORITY shall review geophysical horizon picking, time-to-depth conversion, structural model integrity and geotechnical unitisation and correlation with geophysical data (in an update loop with section 2.2.8 and 2.2.9).

Deliverables:

The CONTRACTOR is expected to deliver following items and services:

- ASCII pick files for each interpreted horizon (including seabed and interfaces/features that were of too small extent or too sparse to be gridded within the resolution specified below) in an exchangeable format with at minimum columns for XY coordinates, survey line name, shot point/trace number, time and elevation
- Elevation surfaces as regular grid (raster) files for all interpreted horizons at an appropriate resolution (~0.25-1 x line spacing, to be agreed with CONTRACTING AUTHORITY) reduced to datum, as an xyz text file (*.xyz/*.pts) and a raster/grid;
- Vertical thickness as regular grid (raster) files for all interpreted units at the same resolution as the elevation grids, as an xyz text file (*.xyz/*.pts) anda raster/grid;
- Depth below seabed information for all interpreted unit boundaries at the same resolution as the elevation grids, as an xyz text file (*.xyz/*.pts) and a raster/grid;
- Updated velocity sections (as SEGY 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 and any additional relevant workstation loading parameters;
- Horizon depth uncertainty information, spatially variable or constant per interface as appropriate (to be agreed with CONTRACTING AUTHORTY);
- A single seismic workstation project (Kingdom required) including:
    - Soil profiles for every CPT and borehole location;
    - All CPT traces with each measured parameter loaded with T-D conversion included;
    - Interpretation of seismic data (UHRS and SBP) supplied as picks on seismic sections or as spatial point/line components (format to be agreed with CONTRACTING AUTHORITY) and as gridded surfaces, for each soil unit boundary in the GIR;
    - All geohazards and intra-formational interfaces as gridded interfaces or pick plots (format to be agreed with CONTRACTING AUTHORITY) depending on their extent and continuity;
    - Clear metadata information for all included workstation items.
- A GIS project, 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 soil unit boundaries ;
    - 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 pertinent geological features including but not limited to channels, escarpments and potential glaciotectonic features;
    - Faulting as linear features (individual faults at their most shallow extent) and/or polygons (areas of faulting);
    - Metadata for all GIS project deliverables compliant with Annex 5 'Starting Points and Assumptions'.
- A comprehensive report in digital format (*e.g.* .pdf), five (5) copies on physical media (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 and geophysical field data into the model;
    - Summary of reprocessing methods used;
    - 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;
    - P- and/or S-wave velocity (or velocity field if data support variability) for each soil unit from time-depth pairs, stacking velocity analysis and geophysical borehole logging results;
    - 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 representative 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 representative cross-line sections through geotechnical location (superimposed), time/depth corrected and additionally in time-space, and fully annotated;
    - (Appendix) Charts illustrating the base surface of each soil unit identified and as assigned above. Scale to be approved by CONTRACTING AUTHORITY;
    - (Appendix) Charts illustrating the vertical thickness of each of the Soil 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 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 or constant as appropriate.
- One set of continuously variable (vertically and laterally) geotechnical 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.

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

The 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 with approval of the CONTRACTING AUTHORITY and with the input of the CERTIFIER.
- 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:
  - q_t, corrected cone resistance,
  - f_s, sleeve friction,
- Optional output predicted parameters as SGY at all input seismic trace locations including, but not limited to:
  - G_{max}, small strain shear modulus,
  - u_2, pore pressure or equivalent derived pore-pressure property (B_q etc.)
- Output all predicted parameters at Geotechnical locations as AGS 4.0 or later, including but not limited to:
  - q_t, corrected cone resistance,
  - f_s, sleeve friction,
- Reporting of data preparation including full description of the development of each and all seismic attributes used as contributors to the predicted parameter calculations.
- 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.
- 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 prior sections.

The CONTRACTOR shall develop the contents of the GIR concurrently, precisely in an iterative supporting way, to the GGM and IGM compilation (2.2.14, 2.2.17), so that the contents and the results of the GIR, GGM and the IGM are fully coherent and complementary. 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 CONTRACTOR is expected to perform the following tasks in accordance to the delivered and approved PD by the CONTRACTING AUTHORITY:

- Derivation of the design relevant parameters for the identified geological units for the purpose of providing ranges to allow the preliminary design and installation assessment of monopiles under static and cyclic loading conditions.
- Present clear methodology for selecting characteristic values of geotechnical parameters. 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 and profiles 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, including installation analyses.
- 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 microbially induced corrosion (MIC) of steel piles that can be used as input into durability limit states for pile design (ISO, 2008; ISO, 2015; CEN, 2003b; DNVGL, 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.

The ranges in characteristic values of geotechnical parameters shall consider 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.

Quality Assurance interface:

- Interactive dialogue with CONTRACTING AUTHORITY during course of activity.
- Review and approval cycle by CONTRACTING AUTHORITY through DRF process.
- Review and approval cycle by independent verification body through DRF process.

Deliverables:

The GIR document shall include in accordance with ISO 19901-8, EC-7:

- A full description and interpretation of relevant geotechnical parameters suitable for the design and installation of WTG monopile 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 easily-readable figures 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.

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 2.2.16.

The CONTRACTOR shall develop the contents of the IGM. 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 HKWVIII IA into Geotechnical Provinces for depth intervals as proposed and approved with the PD. The Geotechnical Provinces must align 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.
- If necessary, an update of the reprocessed 2D-MC UHRS and 2D-SC UHRS data of 2.2.13 (Geological Ground Model) with focus on the correlation between processed seismic signals and geotechnical measurements.
- 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 and in coherence to the litho-genetic design established with the Geological Ground Model.
- 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 innovations for dynamic 3D multi-attribute model deliveries. One set of linear approximations of derived CPT and any geotechnical parameter measurements is to be produced, 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. Description and quantification of all structural and parametric uncertainties of the transformed geotechnical property distribution for each set of estimations accounting as well for the results of the laboratory tests.

Deliverables:

The CONTRACTOR is expected to deliver following items and services:

- A single seismic workstation project, using S&P Kingdom.
- A Geological Ground Model including at a minimum but not limited to:
    - 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 (seabed and downhole) showing at least cone resistance, pore pressure ratio and friction ratio versus depth profiles including their statistical description.
    - Profiles in cross-section showing downhole particle size analysis 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 PD.
    - Implementation of additional parameters 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 and version 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 from 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 Annex 5 'Starting Points and Assumptions'
- 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 shapefile).
- Provision of the 3D IGM Voxel model as a structured multi-dimensional data volume containing all essential and design relevant contents that can be represented spatially in a single file. This should be a fully documented and readily readable non-proprietary file format and preference is given towards the use of Network Common Data Form (NetCDF). Other non-proprietary formats will be considered provided that they are open, machine and software independent, file formats, and documentation and read/write instructions are provided. This can exclude non-voxel data (profiles, sections etc.), but must contain all voxel-based properties in a single structured file.

2.2.18 Integrated Ground Model Report

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

Input: sections 2.2.1 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. Where components are deliverables of prior work packages, it is anticipated that these will be compiled into the IGM report with minimal additional editorial or review work.

Activities:

The CONTRACTOR is expected to prepare a document with following content:

- Full description of the geophysical integration and (re-)interpretation explicitly mentioning these aspects:
    - Description of the gridding methods and parameters used to generate interface grids from the original pick files. Relevant gridding information included in the label for each chart. Detailed descriptions of the gridding methods should be presented in appendices.
    - Description of how a final cumulative gridded interface of a seismic data interpretation was derived from the picks of each seismic dataset. A quantitative description 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 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.
- Full description of the spatial variability of geotechnical relevant parameters is to be added, *e.g.* per variography, as global assessment (entire area) and for each individual Soil Unit.
- 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
    - Sensitivity analysis for use or choice of different methodologies as well as for parametrical uncertainty assessment.
    - Information about the 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, in the context of the 3D integrated model. 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 Geological Age Dating Analysis incorporated into the IGM and descriptive comparison to Geological Age Dating results in nearby WFZs.
- Identification of areas within the HKWVIII IA that can be qualified in terms of suitability and quantified in terms of reduced or elevated development and installation costs.
- Identification and definition of the likelihood of the suitability of or possible constraints across the HKWVIII IA regarding:
    - Monopile capacity, stability and installation considerations
    - Microbially induced corrosion (MIC),
    - piling of foundations *e.g.* presence of boulders, rocks or other hard substrate,
    - the use of jack-ups, the design and installation of intra array 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 and/or base of each major Soil Unit surface identified
- The mapped vertical thickness of each of the major Soil Unit
- User guide for the 3D IGM, delivered as a short note, appendix to the report, and digital documentation provided with the chosen digital deliverable of 2.2.17.

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 Certification

Milestone: CONTRACTOR shall participate in workshops and support the certification process for all deliverables as required. Assist the CONTRACTING AUTHORITY during the certification process including final review cycle(s). Certification will follow the process outlined in the appropriate section of the latest version of document DNV-SE-0190 *Project Certification of wind power plants* and documentation referenced therein.

CONTRACTING ATHORITY will submit approved deliverables for review by a certification provider which may return requests for clarification and/or amendment. The certification provider may require support to develop sufficient understanding of the methods applied and CONTRACTING AUTHORITY may be proactive in introducing personnel from the certification provider into selected meetings and workshops (by mutual agreement with CONTRACTOR). Up to 3 no. ½ day workshops in addition to other project meetings should be included in the workshops allocation of the cost to accommodate requirements in support of certification.

2.2.20 Final Delivery IGM, GGM and GIR

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

Input: sections 2.2.14, 2.2.16 and 2.2.17.

Activities:

The CONTRACTOR must ensure there is version control across all presented data. The CONTRACTOR shall provide a method of data validation for electronic and physical deliverables, *i.e. validation of data completeness and integrity.*

Quality Assurance interface:

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

All data deliveries must pass validation and version checks.

Deliverables:

The deliverables comprise all deliverables requested with sections 2.2.14, 2.2.16 and 2.2.17 in a reviewed, revised and accepted version, which is verified and prepared for publication.

A validation tool (*e.g.* checksum or file hash listing) with instruction guide to qualify successful transfer of digital data, suitable for both CONTRACTING AUTHORITY and third-party use. Open tools are preferable, where proprietary tools are proposed licences and software will be made available by the CONTRACTOR to the CONTRACTING AUTHORITY and any third-party users.

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. Provisional rates for additional required meetings with the CONTRACTING AUTHORITY should be considered and proposed.

2.3 Workflow and deliverables – Lot 2 – NWN IA

2.3.1 Project Documentation

Milestone: Project documentation (PD) outlining CONTRACTOR's understanding of the WORK. This documentation will include method statements for quality, safety, health and wellbeing, environmental management, the identification of risks and mitigation measures within the scope of the PROJECT.

The CONTRACTOR is required to provide with Tender Project Documentation (PD) in which the approach, methodologies and schedule proposed to complete the WORK are set out and explained in sufficient detail to describe the offer. Elements that are expected to be detailed post award may be flagged with a time bound commitment to make project specific. Upon award of the WORK, the CONTRACTOR is required to update the PD to a fully working version which represents the roadmap for the duration of the CONTRACT. Items listed as milestones in the following sub-sections are expected to be included in the PD.

Periodic updates to the PD by the CONTRACTOR are expected within the course of the project, reacting to events, changes, data inputs and evaluations and dependent upon the achievement of specific milestones. The PD should be maintained to be as current, accurate, detailed, and specific as is reasonably practicable.

The schedule for the delivery of PD updates will be determined by the CONTRACTING AUTHORITY during the project phase (exemplary milestones for updates are indicated below, up to two updates additional to the exemplary update points provided may be required at no additional cost). Requirements of the various deliverables are discussed in the following sections. 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 of the GT-Lot 2 soil investigations (see 2.3.5). The project specific Project Documentation (PD) 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 (available at https://offshorewind.rvo.nl/)
- Geological Desk study NWN is available at the website https://offshorewind.rvo.nl/
- Input for PD update after milestone 2.3.1 is completed:
    - Complete PGM
    - Raw and interpreted sub-seabed data from both the desktop study and geophysical survey (2D-MC UHRS, SBP) as well as preliminary velocity model and seismic processing methods of the GP. The CONTRACTOR will be asked to assess this data as an OPTION under the contract.
    - Seabed assessment
    - Shallow seabed and zonation classification
- Input for PD update along with milestone 2.3.6
    - Activities of the CONTRACTOR performed up to this project state
    - Incoming data and information of the geotechnical field campaign
- Input for PD update along with milestone 2.3.13
    - 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 PD as well as PD updates:

- Detailed sections outlining the strategy in which the CONTRACTOR will meet the desired criteria for each project milestone deliverable outlined in the sections 2.3.2 - 2.3.20.
- The preparation of a time schedule of the CONTRACTOR for the execution of all project activities
- A Quality Plan 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 PD is to be delivered as text with comprehensive descriptions of the above assigned issues, including:
  - Method statements
  - Quality Assurance processes, metrics and deliverables
  - References for any identified critical methods
  - Process flow charts
  - GANTT charts as required.
- One meeting to discuss the contents of the PD with the CONTRACTING AUTHORITY and to initiate further workflow steps.

2.3.2 Review Geophysical Site Investigation

Milestone: Review geophysical site investigation; Preliminary Ground Model (PGM); desktop study Legacy Data Ground Model (LDGM); seabed sampling report.

The CONTRACTING AUTHORITY has appointed a geological desk study contractor to perform a Desktop Study (DTS) and a geophysical contractor to carry out the geophysical survey scope (GP).

The DTS is available and will be supplied to the CONTRACTOR and includes reprocessing and interpretation of current and legacy seismic data and will include an initial ground model delivered as a report, seismic interpretation products and a GIS data package.

The execution of the geophysical investigations at NWN is planned for completion in Q3 2023, therefore it is expected to be in progress at the initiation of this IGM scope. The geophysical survey will include a comprehensive geophysical data acquisition campaign with associated seabed sampling at selected locations. The CONTRACTOR shall be invited, where feasible, to interact with CONTRACTING AUTHORITY 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 on all lines:

- High resolution bathymetric and backscatter survey
- Side scan sonar survey
- Magnetometer survey
- Shallow Penetration Sub-Bottom Profiler (SBP) survey
- Multi-channel Ultra High Resolution Seismic (UHRS) data at 65 m x 520 m
- At least 12 seabed (grab) sampling locations for ground truthing 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 glaciotectonic structures);
    - correlation to the other geophysical and geotechnical interpretations available in this region;
    - a comprehensive report with geohazard risk assessment.
- Extent of interpreted sub-seabed geological units, geohazards and seabed classification.

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

Activities:

The CONTRACTOR is expected to perform following tasks:

For the purpose of validation and refinement of project plans and schedules:

- Review of all data (raw, intermediate, and interpreted) and statistics from the geophysical site investigation
- Review of all site investigation documentations and reports
- Review of the PGM project contents and the accompanying report provided by the GP contractor.

For the purpose of update to Project documentation with specific detail:

- Assessment and presentation of requirements, potential methods and timings for reprocessing of the 2D-MC UHRS and SBP data 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, adaptation of proposed methods to suit input data.

Quality Assurance Interface:

- Interactive dialogue with CONTRACTING AUTHORITY
- TN review and Document Response Form (DRF)

Deliverables:

The CONTRACTOR is expected to deliver the following services:

- Technical Note documenting:
    - Evaluation of geophysical and (where available) geotechnical data quality, uncertainty (structural and parametrical), geological complexity, prominent geological features (*e.g.* channel infills, glaciotectonic features, peat horizons) and degree of correlation to nearby wind farm investigations.
    - Evaluation of data suitability for the processes anticipated to be applied in development of the GIR and IGM datasets, and updates to method statements for these processes where required.
    - Description of geophysical data reprocessing operations to be implemented.
- One meeting with the CONTRACTING AUTHORITY to discuss results, PD updates and deliverables.

2.3.3 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-MC UHRS and SBP) are anticipated to require some re-processing per the outcome of section 2.3.1 and 2.3.2. Based on the quality of the data set and the proposed reprocessing methodology outlined in the PEP, CONTRACTING AUTHORITY will assess the proposed value 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, demultiple. 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 2.3.8.

Inputs:

- 2D-MC UHRS, SBP, see 2.3.1
- PGM, see 2.3.1

Activities:

- Evaluation, parameterisation and application of data within the NWN 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 (2D MC UHRS) as SEGY 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.

2.3.4 Laboratory Testing Strategy

Milestone: Document outlining laboratory testing strategy (LTS for GT-Lot-1 and GT-Lot 2).

CONTRACTING AUTHORITY will appoint the execution of the laboratory testing to one geotechnical contractor (GT). The laboratory testing will include standard and advanced (dynamic/cyclic) soil testing on soils recovered during seabed and downhole investigation phases (referred to as GT-Lot 1 and GT-Lot 2 in the GT Contract, and hereafter in this document).

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 without restricting the developers to certain design philosophies. The CONTRACTOR is required to develop a geotechnical laboratory testing strategy for the Lot 1&2 soil investigations to obtain relevant geotechnical, chemical, and thermal parameters for piled foundations, specifically monopile foundations. The CONTRACTING AUTHORITY requests from the GT that both undrained and drained cyclic strength testing is carried out.

The CONTRACTOR shall provide a comprehensive laboratory test strategy that outlines the type of tests, applicable and test frequency for various soil types. The laboratory strategy should clearly outline the testing requirements such that it can be used by the GT to enable the scheduling of laboratory tests programs during both offshore and onshore phases of work. The CONTRACTOR shall use the laboratory testing quantities from the GT Contractor (to be provided upon award) and define a

workflow that enables the GT Contractor to establish a geographical coverage and depth interval that is in line with the requirements of the CONTRACTOR. The strategy document should provide clear guidance to the GT when preparing the laboratory test schedule sheets for the standard and advanced testing (section 2.3.7 and 2.3.9). Test specifications shall be provided by the CONTRACTOR (see sections 2.3.7 and 2.3.9). The CONTRACTOR will clearly state the appropriate standards for all proposed tests and provide a list of minimum deliverables per test in the LTS document. The results of all GT lab results are to be interpreted by the CONTRACTOR (sections 2.3.13 and 2.3.16).

As the understanding of the site develops, the requirements of the LTS may change and it is expected that any required changes to the LTS will be updated by the CONTRACTOR.

The LTS shall include a proposal for a practical workflow for interaction between GT acquisition contractor, CONTRACTOR and CONTRACTING AUTHORITY in the development and timely delivery of approved test conditions parameters to the onshore laboratory.

More details on the geotechnical parameters and the requirements of the requested GIR are given in sections 2.3.11, 2.3.12, 2.3.13 and 2.3.16.

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

Input:

- Content of activities of 2.3.1, PD document
- Content of activities of 2.3.1 and 2.3.3
- Information of geotechnical site investigation of nearby WFZ, see section 1.4

Activities:

- Definition of a geotechnical soil testing strategy, clearly outlining the type, reference method, quantity, testing frequency and intervals 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. Offshore and onshore laboratory work is to be included.
- The CONTRACTOR will determine and provide all required and appropriate test conditions, including, but not limited to, consolidation pressures for estimation of in-situ conditions specific to the site, sample conditioning requirements, shear rates, etc., to RVO and the GT contractor within a timescale acceptable to RVO, typically within a week.
- Identification and notification of any need for early classification testing required for the execution of the laboratory tests in the programme (*e.g.,* identification of batching requirements).
- Proposal for appropriate methodology for assessing sample quality for specific undisturbed tests.

Quality Assurance interface:

The CONTRACTING AUTHORITY is responsible for reviewing and approving of the laboratory test strategy for the GT-Lot 1&2 soil investigations through a document review process.

Deliverables:

A technical note including, but not limited to:

- The methodology statements, clear tables, workflow, process map, specifying the types of laboratory tests to be undertaken on GT-Lot 1 (seabed) samples.
- Method statements, clear tables, workflow, process map for reviewing the laboratory test schedules as they are issued during the fieldwork. A method statement including forward guidance for selecting samples for samples obtained during the GT-Lot 2 (borehole) investigation for geotechnical purposes, Age Dating testing/analysis, and microbially induced corrosion (MIC) testing/analysis.
- Method statement and description of processes for the advanced testing program. This may include anticipation of the batching requirements of course grained samples, strength reference testing and cyclic/dynamic strength testing. It must include a clear stipulation of the test conditions regarding the stress state and drainage conditions.
- Statement to preferred data formats for digital data deliveries of the GT contractor. It is preferable that these formats anticipate and/or align with those proposed in 2.3.6.
- 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, at each geotechnical location. The laboratory test schedule review and subsequent specification of test conditions and specific requirements is the responsibility of the CONTRACTOR and is further specified in sections 2.3.7 and 2.3.9 for the standard borehole testing programme and advanced/cyclic testing program respectively.

2.3.5 Geotechnical Location Plans

Milestone: Planning of geotechnical site investigation.

The CONTRACTOR is required to prepare a site investigation location plan for the GT for the GT-Lot 1 (seabed) and GT-Lot 2 (downhole) investigations.

The CONTRACTING AUTHORITY may appoint one or two GT CONTRACTORs for the execution of the site investigations, laboratory testing and associated factual reporting. The site investigation comprises two Lots, which will be executed sequentially:

- GT-Lot 1: seabed phase, comprising seabed *in-situ* PCPTs, SCPTs, shallow sampling techniques, ecological sampling, thermal testing, dissipation testing and an initial offshore laboratory testing programme.
- GT-Lot 2: borehole phase, comprising of boreholes with *in-situ* PCPT testing (including SCPT, P-S, nuclear and/or DMR wireline logging), sampling, or a combination of both. Microbially Induced Corrosion (MIC) and Geological Age Dating tests (anticipated in the order of 100 tests) will be also part of the geotechnical survey.

For the seabed investigations (GT-Lot 1), CONTRACTOR is requested to specify the location plan. It is currently anticipated that for GT-Lot 1 approximately up to 150 seabed PCPT (SB PCPT) tests will be carried out. It is estimated that there will be 50 seismic CPT measurements (SB SCPT) and 50 thermal conductivity measurements (TCPT or TVC). It is estimated that up to 100 vibrocores (VC) will be carried out. Dissipation tests (DT) will be carried out on selected intervals during the seabed PCPT investigations. The testing intervals and quantity of DT will be decided during field execution. Ecological and water samples will be collected at 35 locations.

For the downhole investigations (GT-Lot 2), CONTRACTOR is requested to specify the borehole plan building upon the seabed CPT and sampling plan, propose in-situ testing and sampling intervals, specify age dating intervals and nominate boreholes for geophysical logging, if required. It is currently anticipated that up to approximately 100 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 60 m beneath seafloor. It is a requirement that a number of boreholes (~5x) will be logged using downhole geophysical logging techniques and seismic CPTs (SCPT).

The CONTRACTING AUTHORITY is responsible for the final site investigation plans and communicating these to the GT.

Input:

- Content of activities of 2.3.1, Project Documentation
- Content of activities of 2.3.1 and 2.3.3
- Location information (trackplots) for SBP, UHRS and Magnetometry
- Information of geotechnical site investigation of nearby WFZ, especially IJVWFZ, see section 1.4
- Execution guidance as provided by the CONTRACTING AUTHORITIY and broadly outlined above.

Activities:

The CONTRACTOR shall:

- Prepare a proposal location plan for the seabed geotechnical investigation as part of a detailed program for the GT-Lot 1 execution targeting relevant geological layers, seismic facies and/or important horizons, mapped channels, etc.
- Prepare a proposal location plan for the downhole geotechnical investigation as part of a detailed program for the GT-Lot 2 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.
- Support the definition of sampling locations and depths for geological age dating (Geochronological analysis) and Microbially Induced Corrosion (MIC) testing.
- Include consideration for the requirements (if any) for hazard clearance to be provided by the GT Contractor via the CONTRACTING AUTHORITY, including but not limited to seabed obstructions, sub seabed obstructions and UXO.
- Prepare *prognosis sheets* for each geotechnical investigation location illustrating expected conditions (geological and hazard) at seabed and below. The prognosis sheets shall contain, but not limited to:
    - A high-resolution plot of the available seismic data and interpretation with annotated soil units and expected conditions at the location with a horizontal distance of 250 m either side of the location, and a depth of 100 m below the seabed.
    - Seabed conditions, obstructions, objects, bathymetry and slope at a suitable distance.
    - A table of expected geological formations and/or soil types, with expected depths with appropriate uncertainty bounds

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.

Deliverables:

The CONTRACTOR shall provide the following:

- Prognosis sheets for each geotechnical investigation location illustrating expected conditions (geological and hazard) at seabed and below.
- A Technical Note with recommendations for the locations of in-situ testing, sampling and age dating.
- Tabular (.csv) and GIS format listing of the proposed GI locations including comments.
- Workshops and meetings as reasonably required by the CONTRACTING AUTHORITY.

2.3.6 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 dataset may include, but is not limited to:

- AGS 4.0 (or higher) format
- ASCII
- Excel or csv
- Log ASCII Standard (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. 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 database to set up their workflows, to confirm compatibility.
- CONTRACTING AUTHORITY shall review and respond to pilot data delivery using a DRF approach.

Deliverables:

- Example data files of every data format to be used in final deliverables.
- Written confirmation of acceptance of format.

2.3.7 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 contents of each lot are:

- GT-Lot 1: seabed phase, comprising seabed *in-situ* PCPTs, shallow sampling techniques, ecological sampling, thermal testing, dissipation testing and an initial offshore laboratory testing programme.
- GT-Lot 2: borehole phase, comprising of boreholes with *in-situ* PCPT testing (including SCPT, P-S, SGR and/or DMR, and/or wireline logging), sampling, or a combination of both and an initial offshore laboratory testing programme. Microbially Induced Corrosion (MIC) and Geological Age Dating

tests (anticipated in the order of 200 samples) will be also part of the geotechnical survey.

The CONTRACTOR is expected to be available to provide input to potential modifications to the prognosis sheets (after GT-Lot-1 investigations) within the context of providing support to the ongoing site investigation in dialogue with CONTRACTING AUTHORITY.

Input:

- Deliverables as assigned in 2.3.4, 2.3.5 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 investigations
- Confirmation that the requirements for the proposed methods for IGM and GIR creation can be fulfilled.
- Proposal for any actions or modifications to be made if any concerns exist.
- Accompanying assessment of incoming field data in combination with the PGM (see section 2.3.1) and ongoing reprocessing procedure of the 2D-MC UHRS data from the GP.

Quality Assurance interface:

- Interactive dialogue with CONTRACTING AUTHORITY during activities.
- Interactive dialogue with the GT during activities.

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.

2.3.8 Integration of borehole and CPT data into the Ground Model

Milestone: Integration of geotechnical field data. Correlation of the geotechnical data and the sub-seabed geophysical data for the Geological Ground Model. Revision following laboratory testing may be required.

The integration of the geotechnical field work data into the geophysical ground model and shall be used as a key component of the Geological Ground Model for which requirements are outlined in section 2.3.13.

It is expected that of the order of 17 no. geotechnical/geological units may be required to characterise the NWN IA (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 2.3.1 through to 2.3.7.

Activities:

The CONTRACTOR is expected to perform following work:

- Preparation of geotechnical field data and integration into a single seismic workstation project (S&P Kingdom)
- Initial correlation of geotechnical and geophysical data to deliver time-depth pairs representing each geotechnically relevant layer interface.
- Structural interpretation of all relevant additional geological units and refinement of the interpretation in the PGM.
- Detect and interpret (proximal to the GI location) as appropriate: sub-layers, and design-sensitive horizons (peat, channel infills, glaciotectonic features) as well as any potential geohazards.

- Assessment of the potential benefit and methods of further reprocessing of the GP.

Quality Assurance interface:

- Prepare cross-sections and other drawings showing the integration of 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 Seismic workstation project (S&P Kingdom).
- Correlation drawings illustrating the geophysical and geotechnical data correlation corresponding to initial unitisation of the soil/rock columns.
- Update of the unitisation with any relevant findings of the ongoing lab testing.
- Time-depth pairs, inferred interval velocity and seismic imaging velocity profile at each geotechnical investigation location.
- Technical note to accompany the correlation drawings and velocity data describing the unitisation and observations therein.

2.3.9 Laboratory Test Schedules and Specification of Test Parameters

Milestone: Review of Laboratory Test Schedules 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 Laboratory Test Schedules for each location. The Laboratory Test Schedule will be prepared by the GT based on CONTRACTOR's laboratory strategy and location prognosis sheets. A review of the Laboratory Test Schedule will be requested by the CONTRACTOR. Once the Laboratory Test Schedule is reviewed and approved, the GT can commence testing activities. For some tests, additional information (test conditions) 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. The CONTRACTING AUTHORITY will review Laboratory Test Schedules for the GT-Lot 1 soil investigations, however if offshore work progress allows, the CONTRACTOR may have an opportunity to be included in the review of the GT-Lot 1 Laboratory Test Schedules. If this is feasible then the OPTION to request a review of the GT-Lot 1 Laboratory Test Schedules will be specified by the CONTRACTING AUTHORITY. It is required that the CONTRACTOR will fully review the Laboratory Test Schedule for all GT-Lot 2 locations on a timescale that does not cause delay to the laboratory work.

Input:

- Contents of 2.3.1 and 2.3.3.
- Deliverables 2.3.4, and 2.3.7.
- Provisional laboratory test schedules from the GT.
- Test pressure and conditions sheet template.

Activities:

Accompanying to the ongoing review activities as described in section 2.3.7, the standard laboratory test progress shall be accompanied and reviewed by the CONTRACTOR, and advised, if needed. The activities of the CONTRACTOR shall include following aspects explicitly:

- Reviewing the provisional laboratory test schedule 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 laboratory test schedule 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 laboratory test schedule 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. These test conditions shall be provided by the CONTRACTOR.

Quality Assurance interface:

- Approval of output by CONTRACTING AUTHORITY.

Deliverables:

The CONTRACTOR is expected to provide following services:

- Review / confirmation of laboratory test schedule sheet per geotechnical location within 48hrs of receipt (except weekends)
- Completion of specification of test parameters (Word or Excel sheets) within no later than 3 days of request
- Contact as required (online meeting, email, call), typically weekly, with GT and CONTRACTING AUTHORITY to clarify progress and identify and commit to actions. Can be combined with meetings of 2.3.7, if this is beneficial for all parties (CONTRACTOR, GT and CONTRACTING AUTHORITY)

2.3.10 Geological Ground Model

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

It is expected that of the order of 17 no. geotechnical/geological units may be required to characterise the NWN IA (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: The work performed in 2.3.8 using 2.3.1 through to 2.3.8.

Activities:

The CONTRACTOR is expected to perform following activities:

- Site-wide propagation of local interpretation updates performed in 2.3.8 to all seismic lines of all types within their depth of applicability.
- Site-wide interpretation on all seismic data types of all identified geohazard and intra-soil unit interfaces.
- Correlation of further (litho-)stratigraphical sequences to other nearby WFZ.
- Correlation (or revision) and integration of Age Dating and SGR results to confirm the geochronological order, if already available.
- Completion of site-wide update of stacking velocity analyses incorporating updates indicated by ground investigation and unitisation in section 2.2.8.
- Test, parameterise, and apply further pre-stack reprocessing as appropriate.

- Test, parameterise, and apply re-migration / stack and post-stack processing as appropriate.
- Specification, parameterisation, and production of seismic attribute set for input to CPT prediction methods.

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, at significant soil unit boundaries throughout depth range.
- Structural interpretation QA as *e.g.* selected profiles with geotechnical locations.
- Parameter test panels and notes for all significant data processing operations to be agreed with CONTRACTING AUTHORITY.

Deliverables:

The CONTRACTOR shall provide the following:

- Horizons and grids representing all interpreted unit boundaries and geohazards.
- Seismic Processing Update Technical Note including description of testing, decisions, parameters and final processing sequence applied.
- Description of derived Seismic Attributes and the data processing used to create them as a Technical Note;
- Reprocessed multi-channel as SEGY with fully populated header.
- Additional Seismic Attribute datasets as SEGY with fully populated header, representing all input datasets used in the prediction of geotechnical parameters (section 2.3.15);
- Stacking and Interval velocity as SEGY trace data at every seismic trace location and ASCII data in ESSOV2 format at intervals to be defined.
- At least one workshop with the CONTRACTING AUTHORITY presenting the Interim version of the Geological Ground Model.
- Geological description(s) provided as a TN or short note.

2.3.11 Advanced Laboratory Test Schedule and Specification of Test Parameters

Milestone: Advanced Laboratory Test Assignment Schedule and Test Conditions 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 shall provide the advanced laboratory test schedule for review by the CONTRACTOR. Following the approval, the CONTRACTOR is required to fill out the test conditions sheets 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 and the monopile use case. The advanced laboratory test programme shall include cyclic tests accompanied by associated static and classification tests and may also include dynamic testing.

Input:

- Advanced laboratory test schedules
- Test conditions sheet template
- Laboratory testing strategy (section 2.3.4)

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 clearly stated.
- Review of the advanced laboratory test schedules 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 conditions sheets will be 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:

- Interactive dialogue with CONTRACTING AUTHORITY during activities.
- Provision of justifications and/or data used to define batching, parameters and specialist testing.
- 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) within no more than 3 days of request.

2.3.12 Review of Factual Reports GT and Digital Data

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

The delivery of the GT reports will comprise of (refer to Annex 4b):

- GT-Lot 1 seabed *in-situ* testing report
- GT-Lot 1 seabed sampling report
- GT-Lot 2 downhole testing and sampling report.
- GT-Lot 2 cyclic testing report.

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 GT-Lot 1 (seabed phase).
- Factual reports and digital laboratory data associated with the GT-Lot 2 (borehole) campaign for which input is provided by CONTRACTOR.
- Factual Reports and digital laboratory data associated with the cyclic testing for which input is provided by CONTRACTOR.
- Final MIC and Geological Age Dating factual reports provided by the GT.
- Contents and plan as provided in PD.

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.

2.3.13 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 laboratory test results must be performed before or at least in early stages of the advanced laboratory test programme as assigned in section 2.3.9 and already planned in section 2.3.7.

Input: sections 2.3.5, 2.3.7 and 2.3.8.

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, establish 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, mean and median values of selected laboratory tests results
- Statistical description 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) for each parameter and covariance in-between individual parameters. The derived values of the geotechnical parameters shall include the parameters as proposed and approved with the PD document and updates for, but not limited to, the basic soil types (i.e. cohesive, non-cohesive, transitional soils).

Deliverables:

The CONTRACTOR is expected to deliver following:

- Overview with short descriptions about performed work.

2.3.14 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 (2.3.16) such that all geotechnical Soil Unit boundaries are represented within the structural model defined by the geophysics. The Soil Units shall represent bodies of common geotechnical behaviour and/or properties in the context of wind farm and cable foundation/installation design. Time-depth pairs are to be updated as required, and nomenclature is to be common between the geological and geotechnical unitisation.

Input:

- Section 2.3.10 and 2.3.13 using information from sections 2.3.1 through to 2.3.9.
- factual reports of the GT,
- final MIC and Age Dating results.

Activities:

The CONTRACTOR is expected to finalize the Geological Ground Model, updating the structural model with the geophysical-geotechnical correlation implemented in the GIR. The structural model must include all units included in the GIR. 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.

A time-to-depth conversion strategy is required, with the velocity field developed (or inferred) for this process included as a deliverable.

Addition or modification of unit interfaces following Geotechnical Interpretation Reporting.

Quality Assurance interface:

Bi-weekly update meetings, working data deliveries, summary documents and up to two workshops with CONTRACTING AUTHORITY.

CONTRACTING AUTHORITY shall review geophysical horizon picking, time-to-depth conversion, structural model integrity and geotechnical unitisation and correlation with geophysical data (in an update loop with section 2.3.8 and 2.3.9).

Deliverables:

The CONTRACTOR is expected to deliver following items and services:

- ASCII pick files for each interpreted horizon (including seabed and interfaces/features that were of too small extent or too sparse to be gridded within the resolution specified below) in an exchangeable format with at minimum columns for XY coordinates, survey line name, shot point/trace number, time and elevation;
- Elevation surfaces as regular grid (raster) files for all interpreted horizons at an appropriate resolution (~0.25-1 x line spacing, to be agreed with CONTRACTING AUTHORITY) reduced to datum, as an xyz text file (*.xyz/*.pts) and a raster/grid;
- Vertical thickness as regular grid (raster) files for all interpreted units 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 unit boundaries at the same resolution as the elevation grids, as an xyz text file (*.xyz/*.pts) and a raster/grid;
- Updated velocity sections (as SEGY 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 and any additional relevant workstation loading parameters;
- Horizon depth uncertainty information, spatially variable or constant per interface as appropriate (to be agreed with CONTRACTING AUTHORTY)
- A single seismic workstation project (Kingdom required) including:
    - Soil profiles for every CPT and borehole location
    - All CPT traces with each measured parameter loaded with T-D conversion included;
    - Interpretation of seismic data (UHRS and SBP) supplied as picks on seismic sections or as spatial point/line components (format to be agreed with CONTRACTING AUTHORITY) and as gridded surfaces, for each soil unit boundary in the GIR;
    - All geohazards and intra-formational interfaces as gridded interfaces or pick files (format to be agreed with CONTRACTING AUTHORITY) depending on their extent and continuity;
    - Clear metadata information for all included workstation items.
- A GIS project, 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 soil unit boundaries
    - 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 pertinent geological features including but not limited to channels, escarpments and potential glaciotectonic features.
    - Faulting as linear features (individual faults mapped at their most shallow extent) and/or polygons (areas of faulting)
    - Metadata for all GIS project deliverables compliant with Annex 5 'Starting Points and Assumptions'
- A comprehensive report in digital format (*e.g.* .pdf), five (5) copies on physical media (*e.g.* 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 and geophysical field data into the model
    - Summary of reprocessing methods used.
    - 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.
    - P- and/or S-wave velocity (or velocity field if data support variability) for each soil unit from time-depth pairs, stacking velocity analysis and geophysical borehole logging results.
    - 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 representative 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 representative cross-line sections through geotechnical location (superimposed), time/depth corrected and additionally in time-space, and fully annotated
- (Appendix) Charts illustrating the base surface of each soil unit identified and as assigned above. Scale to be approved by CONTRACTING AUTHORITY
- (Appendix) Charts illustrating the vertical thickness of each of the Soil 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

2.3.15 Prediction of CPT and correlated measurements at seismic trace locations

Milestone: The production of estimated CPT measurements at seismic trace locations for 2D 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 or constant as appropriate.
- One set of continuously variable (vertically and laterally) geotechnical 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.

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

The 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 with approval of the CONTRACTING AUTHORITY and with the input of the CERTIFIER.
- 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:
    - q_t, corrected cone resistance,
    - f_s, sleeve friction,
- Optional output predicted parameters as SGY at all input seismic trace locations including, but not limited to:
    - G_{max}, small strain shear modulus,
    - u_2, pore pressure or equivalent derived pore-pressure property (B_q etc.)
- Output all predicted parameters at Geotechnical locations as AGS 4.0 or later, including but not limited to:
    - q_t, corrected cone resistance,
    - f_s, sleeve friction,
- Reporting of data preparation including full description of the development of each and all seismic attributes used as contributors to the predicted parameter calculations.
- 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.
- Workshops required to discuss progress and preliminary findings.

2.3.16 Geotechnical Interpretation Report (GIR)

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

Input: Contents and deliverables of prior sections.

The CONTRACTOR shall develop the contents of the GIR concurrently, precisely in an iterative supporting way, to the GGM and IGM compilation, so that the contents and the results of the GIR, GGM and the IGM are fully coherent and complementary. 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 CONTRACTOR is expected to perform the following tasks in accordance to the delivered and approved PD by the CONTRACTING AUTHORITY:

- Derivation of the design relevant 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.
- Present clear methodology for selecting characteristic values of geotechnical parameters. 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 and profiles 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, including installation analyses.
- 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 microbially 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.

The ranges in characteristic values of geotechnical parameters shall consider 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.

Quality Assurance interface:

- Interactive dialogue with CONTRACTING AUTHORITY during course of activity
- Review and approval cycle by CONTRACTING AUTHORITY through DRF process
- Review and approval cycle by independent verification body through DRF process.

Deliverables:

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 WTG (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 easily-readable figures 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.

2.3.17 Integrated Ground Model (IGM)

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

Input: All contents and deliverables of sections 2.3.1 through to 2.3.16.

The CONTRACTOR shall develop the contents of the IGM. 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 NWN IA into Geotechnical Provinces for depth intervals as proposed and approved with the PD. The Geotechnical Provinces must align 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.
- If necessary, an update of the reprocessed 2D-MC UHRS and SBP data of 2.3.13 (Geological Ground Model) with focus on the correlation between processed seismic signals and geotechnical measurements.
- 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 and in coherence to the litho-genetic design established with the Geological Ground Model.
- 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 innovations for dynamic 3D multi-attribute model deliveries. One set of linear approximations of derived CPT and any

geotechnical parameter measurements is to be produced, using the linear estimations developed in 2.3.15. 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 2.3.15. Description and quantification of all structural and parametric uncertainties of the transformed geotechnical property distribution for each set of estimations accounting as well for the results of the laboratory tests.

Deliverables:

The CONTRACTOR is expected to deliver following items and services:

- A single seismic workstation project, using S&P Kingdom.
- A Geological Ground Model including at a minimum but not limited to:
    - 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 (seabed and downhole) showing at least cone resistance, pore pressure ratio and friction ratio versus depth profiles including their statistical description.
    - Profiles in cross-section showing downhole particle size analysis 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 PD.
    - Implementation of additional parameters 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 and version 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 Annex 5 'Starting Points and Assumptions'
- 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 shapefile).
- Provision of the 3D IGM Voxel model as a structured multi-dimensional data volume containing all essential and design relevant contents that can be represented spatially. This should be a fully documented and readily

readable non-proprietary file format and preference is given towards the use of Network Common Data Form (NetCDF). This can be a single file containing all design properties, or multiple files provided that they share common data structure and dimensionality and are readily accessible for the extraction and comparison of data. Other non-proprietary formats will be considered provided that they are machine and software independent open file formats, and documentation and read/write instructions are provided. This can exclude non-voxel data (vector data, profiles, sections etc.), provided they are provided in another suitable non-proprietary format.

2.3.18 Integrated Ground Model Report

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

Input: sections 2.3.1 through to 2.3.17.

The CONTRACTOR is expected to deliver a report to document all performed work to create the IGM in a comprehensive, informative way. Where components are deliverables of prior work packages, it is anticipated that these will be compiled into the IGM report with minimal additional editorial or review work.

Activities:

The CONTRACTOR is expected to prepare a document with following content:

- Full description of the geophysical integration and (re-)interpretation explicitly mentioning these aspects:
    - Description of the gridding methods and parameters used to generate interface grids from the original pick files. Relevant gridding information included in the label for each chart. Detailed descriptions of the gridding methods should be presented in appendices.
    - Description of how a final cumulative gridded interface of a seismic data interpretation was derived from the picks of each seismic dataset. A quantitative description 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 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.
- Full description of the spatial variability of geotechnical relevant parameters is to be added, *e.g.* per variography, as global assessment (entire area) and for each individual Soil Unit. 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 2.3.15 and 2.3.16
    - Sensitivity analysis for use or choice of different methodologies as well as for parametrical uncertainty assessment.
    - Information about the 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, in the context of the 3D integrated model. 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 Geological Age Dating Analysis incorporated into the IGM and descriptive comparison to Geological Age Dating results in nearby WFZs.
- Identification of areas within the NWN IA that can be qualified in terms of suitability and quantified in terms of reduced or elevated development and installation costs.
- Identification and definition of the likelihood of the suitability of or possible constraints across the NWN IA regarding:
    - Monopile capacity, stability and installation consideration
    - Microbially induced corrosion (MIC),
    - piling of foundations *e.g.* presence of boulders, rocks or other hard substrate,
    - the use of jack-ups,
    - the design and installation of intra array 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 and/or base of each major Soil Unit surface identified.
- The mapped vertical thickness of each of the major Soil Unit
- User guide for the 3D IGM, delivered as a short note or appendix to the report, and digital documentation provided with the chosen digital deliverable of 2.3.17.

Charts are to be provided in PDF and with the same layout as implemented within the GIS project as assigned in section in 2.3.17.

2.3.19 Certification

Milestone: CONTRACTOR shall participate in workshops and support the certification process for all deliverables as required. Assist the CONTRACTING AUTHORITY during the certification process including final review cycle(s). Certification will follow the process outlined in the appropriate section of the latest version of document DNV-SE-0190 *Project Certification of wind power plants* and documentation referenced therein.

CONTRACTING ATHORITY will submit approved deliverables for review by a certification provider which may return requests for clarification and/or amendment. The certification provider may require support to develop sufficient understanding of the methods applied and CONTRACTING AUTHORITY may be proactive in introducing personnel from the certification provider into selected meetings and workshops (by mutual agreement with CONTRACTOR). Up to 3 no. ½ day workshops in addition to other project meetings should be included in the workshops allocation of the cost to accommodate requirements in support of certification.

2.3.20 Final Delivery IGM and GIR

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

Input: sections 2.3.14, 2.3.16 and 2.3.17.

Activities:

The CONTRACTOR must ensure there is version control across all presented data. The CONTRACTOR shall provide a method of data validation for electronic and physical deliverables, *i.e. validation of data completeness and integrity.*

Quality Assurance interface:

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

All data deliveries must pass validation and version checks.

Deliverables:

The deliverables comprise all deliverables requested with sections 2.3.14, 2.3.16 and 2.3.17 in a reviewed, revised and accepted version, which is verified and prepared for publication.

A validation tool (*e.g.* checksum or file hash listing) with instruction guide to qualify successful transfer of digital data, suitable for both CONTRACTING AUTHORITY and third-party use. Open tools are preferable, where proprietary tools are proposed licences and software will be made available by the CONTRACTOR to the CONTRACTING AUTHORITY and any third-party users.

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. Provisional rates for additional required meetings with the CONTRACTING AUTHORITY should be considered and proposed.

2.4 Additional Activities

The following paragraphs are a common requirement for both Lots and should be presented as standalone items included in the PD for each lot.

2.4.1 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 at least on a bi-weekly basis for 1.5 hrs. 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 24 hrs 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 (1.5 hrs per meeting).

2.4.2 Workshops/Meetings to discuss outside of WPM

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, workshops and regular meetings will be required and the CONTRACTOR is expected to cost these appropriately.

2.4.3 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 the Netherlands or, if it is not possible to travel, 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.

2.4.4 Project and Site Description

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.

2.4.5 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.

2.5 HSE and team redundancy

CONTRACTOR shall provide adequate cover, team and IT redundancy in order to adequately manage the impact of unforeseen events, *e.g*. restrictions on travel and entry, availability of personnel. 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 4a (HKWVIII) and Annex 4b (NWN).