Netherlands Enterprise Agency

IJmuiden Ver Wind Farm Zone

Sites Gamma-A and Gamma-B

Project and Site Description

Version November 2024

>> Sustainable. Agricultural. Innovative. International.

Version November 2024

Contents

Foreword

With the two large 2 GW offshore wind projects awarded in June 2024 at IJmuiden Ver Wind Farm Sites Alpha and Beta (IJV Alpha and Beta), the Netherlands took a big 4 GW step this year towards achieving our goal for 21 GW of offshore wind by end 2032. Our next tender round in 2025 is set to award another 2 GW at IJV Gamma-A and Gamma-B. This means our plan to accelerate offshore wind development and meet our climate change commitments to be carbon neutral by 2050 and reduce greenhouse gas emissions is on track.

By working together, we will ensure a successful energy transition and sustainable green growth in terms of our energy supply and demand, new jobs and the economy.

To support industry and reduce risks, the Netherlands Enterprise Agency already conducts wind farm site location studies while TenneT is responsible for building the grid connections.

We also learn from each tender round, working proactively with all vested interests to ensure we stay on track in the Netherlands as we march forward. For example, we are encouraging innovation in wind power system integration through our tenders and have raised project standards when it comes to ecological impact and enhancements, human rights in the supply chain and the circularity of a wind farm.

Of course, to ensure our long-term goals are achieved, creating market certainty and boosting investor confidence in our domestic offshore wind market is vital. So, following in-depth market consultation, the Ministry of Climate Policy and Green Growth has decided to increase support for developers and mitigate risks even further for the upcoming tenders. We are doing this by modifying our plans in a small but meaningful way.

We are still offering the same amount of capacity for development as planned. But, in line with industry feedback, the 2 GW IJV Gamma site has been split into two smaller 1 GW sites (IJV Gamma-A and IJV Gamma-B).

While still big projects in their own right, building smaller 1 GW wind farms reduces the investment required by each potential developer and cuts the overall financial risks involved per project. This may increase the attractiveness to compete in the tenders.

As a result, there will be greater opportunity for innovation to enable better system integration and enhance our North Sea ecology while safeguarding our plan towards 21 GW of offshore wind and sustainable green growth.

Thanks to the changes we have made, I am confident the industry will respond with a range of innovative offshore wind project proposals for IJV Gamma-A and -B.

Together we can ensure a thriving green economy powered by abundant flows of sustainable green energy from wind farms in the Dutch North Sea.

Esther Pijs

The Quartering Director General for Realisation Green Growth
Ministry of Climate Policy and Green Growth

1. Objectives and reading guide

This Project and Site Description (PSD) is for any party interested in participating in the two planned tenders to develop and operate Wind Farm Sites IJmuiden Ver Gamma-A and IJmuiden Ver Gamma-B in the IJmuiden Ver Wind Farm Zone (IJVWFZ) in the Netherlands. A separate PSD will be published for the Nederwiek Sites included in the next tender round planned for Q3 2025.

IJmuiden Ver Wind Farm Site (IJVWFS) Gamma comprises the previously designated IJVWFS V & VI.

This PSD has been streamlined to provide a direct focus on project specifications and development requirements along with site data (including maps and tables) and site characterisation results. This PSD summarises:

- A description, surroundings, and characteristics of IJVWFS Gamma-A and IJVWFS Gamma-B;
- Data collected by the Netherlands Enterprise Agency (RVO) regarding the physical environment of selected areas within the IJVWFS Gamma-A and -B;
- A selection of constraints, technical requirements, and permit related issues deemed to be most relevant for development of IJVWFS Gamma-A en -B.

This document has been produced for information purposes only and is not intended to replace any legal or formally communicated, regulations, or requirements. More information on the site characterisation studies, including all reports and other deliverables mentioned in this PSD, can be found on the website offshorewind.rvo.nl.

Readers should note that information relating to the tender and permit process itself, as well as to the overarching legal frameworks and regulatory decisions pertinent to development of offshore wind projects in the IJVWFZ, will be made available after official publication in the Netherlands Government Gazette. Furthermore, publication of relevant laws and related tender documents and information can be found at rvo.nl/offshorewind. When the tenders are officially open, application forms and related documents will be available to download at mijnrvo.nl.

The appendices related to this PSD (Applicable Law, Environmental Impact Assessment and Memo Boundaries and Coordinates) will be made available when completed. These appendices can be found on the website offshorewind.rvo.nl.

1.2 Reading guide

This PSD is for IJVWFS Gamma-A and -B. It presents an overview of all relevant project requirements and site information for parties interested in preparing to bid for a permit to build and operate a wind farm at these sites. The PSD covers the following aspects:

Chapter 1: *Objectives and reading guide*

Chapter 2: *Offshore wind power development in the Netherlands*

Chapter 3: *IJmuiden Ver Wind Farm Zone – Site description and Offshore Grid.*

General information on the IJVWFZ, its location, and surroundings. Work on the offshore grid connection system by transmission system operator (TSO) TenneT is also discussed.

Chapter 4: *Site characterisation – studies and investigations*
An updated overview of all the studies, surveys, and measuring campaigns performed to date on IJVWFS Gamma-A and -B, as follows:

- Soil: Archaeological desk study, UXO risk assessment desk study, Geological desk study, Geophysical survey, Archaeological assessment of the Geophysical survey Results, Baseline survey of Benthic Ecology, Geotechnical Site Investigation, Integrated Ground Model and Geotechnical Interpretative Report, Morphodynamics and Scour Mitigation desk study;
- Wind and Water: Metocean Measurement Campaign, Metocean assessment, Wind Resource Assessment

Chapter 5: *Further reading*
Useful links to more information.

1.3 Site characterisation – quality and certification

1.3.1 Procedure

Assisted by independent experts, RVO managed the process for site characterisation of IJVWFS Gamma-A and -B. It maintained a quality assurance procedure to provide accurate, practical, high quality studies.

First, the scope of the different studies was determined using the following steps:

1. RVO determined the preliminary scope of the different studies. Lessons learned from previous work on site characterisations for other wind farm zones were taken into account;
2. Where applicable, input was provided on these scope descriptions by internal experts, other government departments, agencies, external experts, and the industry;

3. During market consultation sessions, the scope descriptions were discussed with interested parties, with input on completeness provided by attendees;
4. The site characterisation deliverables were reviewed by internal experts from other government departments and independent external experts;
5. For studies where the results are inherently critical to developers for fundamental project design, the accredited certifying body DNV was contracted to confirm the completeness of the scope and results.

1.3.2 Procurement
The procurement of the different studies was carried out in compliance with the applicable procurement procedures within RVO and according to the Dutch Law. The desk studies have been procured through a limited tender where, for each study, at least two parties were invited to submit a proposal. Most of the site characterisations were procured through a public European tender. All proposals have been assessed by internal experts, other government departments, agencies, and external experts. Contractors were selected on the basis of determining the most economic advantageous offer, with safety, quality, and track record as the primary award criteria.

1.3.3 Quality assurance
After procurement, whilst work was being conducted by the specific contractor, quality assurance was performed as follows:
1. A project team, comprising RVO and external experts, was assigned for each study. The project team monitored the execution of the scope to ensure it was in compliance with the scope description;
2. Draft reports and other deliverables were reviewed by internal and independent external experts;
3. Where applicable, accredited certifying body DNV reviewed reports and other deliverables and provided a Verification Letter to assure the results were acquired in compliance with DNV-SE-0190:2023-03 and other applicable industry standards. Certification deliverables are added to the published reports where applicable.

At the time of publication of this PSD, some site characterisation studies were still ongoing. RVO expects to secure an overall Statement of Compliance for the complete set of site studies once all final site characterisation studies are completed and the results published. This will also be reflected in the final version of this PSD when it is updated. An overview of the current status of the site studies and the certification process is provided in Section 1.3.4 of this PSD.

1.3.4 Certification status
Several site characterisation studies and investigations for the IJVWFZ have been conducted. Table 1.1 shows the status of individual and overall certification by DNV.

Site characterisation studies and DNV certification status

Site characterisations	Certification status	Overall Certification
Archaeological desk study	Quality approved	To be expected in Q2 2025
UXO desk study	Quality approved	
Geological desk study	Quality approved	
Geophysical survey	Quality approved	
Archaeological assessment	Quality approved	
Baseline survey of Benthic Ecology	Quality approved	
Geotechnical site investigation	Study ongoing	
Integrated Ground Model	Study ongoing	
Morphodynamics and Scour Mitigation desk study	Quality approved	
Metocean measurement campaign	Quality approved	
Metocean assessment	Quality approved	
Wind Resource Assessment	Quality approved	

1.4 Experts and contractors

Experts and contractors that have provided input in the process include:
- AFRY Management Consulting (project management, experts);
- DNV Netherlands B.V. – Royal Haskoning/DHV (experts);
- The Cultural Heritage Agency (experts, Archaeological desk study);
- Rijkswaterstaat (experts, UXO desk study risk assessment);
- Arcadis Nederland B.V. (project management, experts, Geological desk study);
- REASeuro (UXO desk study);
- Periplus (Archaeological desk study);
- Fugro (Geophysical survey);
- Stichting Deltares (Morphodynamical & Scour Mitigation desk study);
- Fugro (Geotechnical survey, Ground Model);
- DHI A/S (Metocean assessment);
- RPS Energy Ltd. (client reps Geophysical and Geotechnical survey);
- RPS | Metocean Science & Technology (Metocean measurement campaign);
- DNV Denmark (Certification deliverables).

1.5 PSD development

This Project and Site Description is developed and improved in cooperation with its users. We welcome feedback. Please send your feedback to woz@rvo.nl.

2. Offshore wind power development in the Netherlands

The Netherlands' offshore wind tenders have been successful and the country is on track to have 21 gigawatts (GW) of operating capacity by end 2032, up from 4.7 GW today. Even with difficult global market conditions in recent years. Our collaborative approach with industry is working well to minimise risk and ensure sustainable development of our planned project pipeline. In working together, we have carefully developed a flexible strategy to ensure we turn our green growth, ambitions and emissions reductions goals into reality.

2.1 Setting new standards together with the industry

This collaborative strategy has seen the industry come a long way since the first Dutch offshore wind farm, Egmond aan Zee, was completed in 2007. Totalling 108 MW, that pioneering project comprised 36 turbines, each rated at 3 MW.

Today, thanks to the success of our last tender round in March 2024, we will see two more huge 2 GW subsidy-free projects use turbines rated at 15 MW and above at Sites Alpha and Beta in the IJmuiden Ver Wind Farm Zone (IJVWFZ). For a combined capacity of 4 GW, that round was the biggest in the world for offshore wind. It also represented a significant step forward in raising standards for the global industry. It did this by incorporating new criteria to safeguard the environment and human rights while stimulating innovation in both ecological enhancements in the Dutch North Sea and system integration of the power generated by the wind farms into our national grid.

The success of the IJV Sites Alpha and Beta tender round is all the more significant when you consider it took place at a difficult time for the industry globally, which was facing increasing costs and a supply chain crunch. We received multiple applications, which included financial offers from developers to build and operate the wind farms.

It shows that by constantly listening to and working closely together with the industry, the Netherlands is getting its offshore wind policy right. Our adaptable approach and our supportive tender regime provides market certainty for the industry and boosts investor confidence in the Netherlands. It significantly reduces risk for developers by providing a clear project pipeline and by the State taking on responsibility for both site characterisation studies (through the Netherlands Enterprise Agency) and grid development (through transmission system operator Tennet).

2.2 Building on past successes: Updated roadmaps for accelerated development to 2032

Our initial goal to have 4.5 GW operating by end 2023 and reduce costs by 40%, set in our first Offshore Wind Energy Roadmap in 2014, was achieved on time.

With each tender round, we have learned from our collective experience. The industry has also developed new technology for the market (including bigger, more powerful turbines and improved methods for system integration) and we have increased our climate ambitions in line with European agreements (see Table 1). Our offshore wind targets have therefore also been revised upwards in subsequent roadmaps to 11.5 GW and then 21 GW by 2030/31, with additional zones designated for development to fulfil our commitments (see Table 2 and map).

There are still supply chain pressures in the global wind industry. Developers need sufficient time to source equipment for the successful project delivery of all our planned offshore wind farms. Therefore, as announced in a Letter to Parliament on 25 April 2024, the Government took the pragmatic decision to extend the 21 GW completion date by a year to 2032. So new dates for all future project tenders planned under the revised 21 GW Offshore Wind Energy Roadmap (in the IJmuiden Ver, Nederwiek and Doordewind Wind Farm Zones) were also published (see map).

Our updated timetable also ensures we can help boost demand from energy-intensive industries in the Netherlands for the electricity generated from the planned wind farms, or find interim solutions such as energy storage.

Table 1: Key legislation and agreements

Dutch Energy Agreement (2013)	Coalition agreement for the Dutch energy transition, with targets set to raise the share of renewables in the energy mix to 14% by 2020 and 16% by 2023. The Agreement also included a commitment for the country to aim to be fully climate neutral by 2050 with a net zero energy supply and put offshore wind power at the heat of its strategy to achieve this. As part of the Energy Agreement, the Government introduced a more proactive and supportive regulatory framework for offshore wind development.
Dutch Offshore Wind Energy Act (1 July 2015, updated in 2021)	Legal regulatory framework for implementation of projects under the Offshore Wind Energy Roadmap 2023.
Dutch Climate Act (2019)	Designed to meet the Netherlands' commitments under the Paris Agreement, targeting a 49% reduction in Dutch CO2 emissions by 2030 and 95% by 2050, compared to 1990 levels. For electricity production specifically, the target was for net zero emissions by 2050.
European Green Deal (2020)	Goal for all EU Member States to be climate neutral by 2050.
EU Fit-for-55 policy package (2021)	Increased the 2030 greenhouse gas emissions reduction target for Member States to a cut of 55% on 1990 levels.
RePowerEU (2022)	EU targets for 90 GW offshore wind by 2030 and 300 GW by 2050.
Esbjerg Declaration (19 May 2022)	The Netherlands, Belgium, Denmark and Germany committed to reaching a combined target for installed offshore wind capacity of at least 65 GW by 2030 and 150 GW by 2050
Dublin Declaration (12 September 2022)	The members of the North Seas Energy Cooperation (the Netherlands, Belgium, Denmark, Germany, Ireland, France, Norway and Luxembourg) agreed to reach a combined target of at least 260 GW of offshore wind by 2050.
Ostend Declaration (24 April 2023)	A follow up to the Esbjerg Declaration, with the United Kingdom, France, Ireland, Norway and Luxembourg joining the Netherlands, Belgium, Denmark and Germany in signing an updated agreement. The nine nations committed to reaching 120 GW of combined offshore wind capacity by 2030 and 300 GW by 2050. This will make the North Sea the world's biggest green power plant, the declaration noted.

As this PSD outlines, we have also heeded market feedback after our last tender to ensure even more effective competition in our next tender round and we have taken current global market conditions into account too. For our upcoming tenders, we have modified our plans slightly to help developers mitigate their financial risks and better secure their supply chains.

So, as announced in early September 2024, instead of two more big 2 GW wind farms at IJV Site Gamma and Site I in the Nederwiek Wind Farm Zone, the Government has decided to offer four smaller 1 GW sites within those locations. IJV Site Gamma has been split into IJV Site Gamma-A (eastern site, 1 GW) and IJV Site Gamma-B (western site, 1 GW). Nederwiek Site I has been split into Nederwiek Site I-A (1 GW) and Nederwiek Site I-B (1 GW).

Table 2: Roadmaps - Development zones and project tender schedules

Offshore Wind Energy Roadmap 2023 (2014)	Set out tender schedule to add 3.5 GW across three designated offshore wind farm zones – Borssele, Hollandse Kust (zuid) (HKZ) and Hollandse Kust (noord) (HKN) – to reach 4.5 GW installed offshore wind capacity by end 2023.
Offshore Wind Energy Roadmap 2030 (2019)	Target set to achieve 11.5 GW operational offshore wind by end 2030. Three new offshore wind farm zones were allocated under the 2030 Roadmap – Hollandse Kust (west) (HKW, 1.4 GW, subsidy-free tenders held in 2022), IJmuiden Ver (IJV, 4 GW, tender held in first half of 2024), and Ten noorden van de Waddeneilanden (TNW, 0.7 GW and recently designated for the world's largest offshore wind-to-hydrogen project to date, with the tender planned for 2027).
Additional Offshore Wind Energy Roadmap 2030/31 (2022)	Plan to add 10.7 GW extra capacity to reach around 21 GW in 2031. Three new wind farm zones (Nederwiek, Lagelander and Doordewind) were designated for development of some of the extra capacity. This was also reflected in the Additional Draft North Sea Programme 2022-2027 published by the Department of Infrastructure and Water Management in November 2021.
21 GW Offshore Wind Energy Roadmap (2024)	Still targeting 21 GW operational capacity, but roadmap completion date pushed back one year to end 2032. The Government also decided that more time is required to optimise the spatial planning for the Lagelander Wind Farm Zone, with the potential for it to be used as an offshore 'multi-energy zone' post 2030 being investigated. It is therefore not included in this Roadmap.
Longer-term outlook to 2050	Increased the 2030 greenhouse gas emissions reduction target for Member States to a cut of 55% on 1990 levels.
Rolling roadmap planned to reach 50 GW and 70 GW targets	On 16 September 2022, the Dutch Ministry of Economic Affairs and Climate Policy announced new offshore wind goals for the Netherlands specifically – 50 GW by 2040 and 70 GW by 2050. These goals will be set in the National Energy System Plan. Going forward, a rolling roadmap will be used, updated regularly and as soon as new Wind Farm Zones are identified. Insights from the Partial Revision of the North Sea Programme will be used as input to supplement the roadmap. The Partial Revision of the North Sea Programme will be published in 2025.

Amending our plans in this way shows the Government's full commitment to achieving the goals of the 21 GW Roadmap by supporting the wind industry. This will ensure green growth across our nation - boosting green energy generation and use as well as creating secure long term jobs in our growing green economy.

It is important to note that the 1 GW IJV Gamma-A and -B wind farms, as with the bigger ones at IJV Sites Alpha and Beta, will be connected to TenneT's standardised, 2 GW high voltage direct current (HVDC) offshore grid connection system. The development of the standardised HVDC system by Tennet helps minimise costs and maximise efficiency in the Dutch offshore grid build-out.

As explained fully in Chapter 3, the two 1 GW wind farms at IJV Sites Gamma-A and Gamma-B will be connected to the same converter platform. This means they will only be able to start fully operating once both wind farms are ready.

2.3 Post 2030 development: Partial Revision of the North Sea Programme

While these projects will help achieve our 21 GW target, we are looking longer term too. Future scenarios for Dutch energy systems (supply and demand) and the North Sea Energy Outlook (Noordzee Energie Outlook) published in 2020 indicated that the Netherlands will need 38-72 GW of cumulative offshore wind capacity by 2050.

So, we are actively working on strategic plans to more than triple offshore wind capacity from 2032 to 2050, to reach 70 GW, with an interim target of 50 GW by 2040 before then, as announced by the Dutch Ministry of Economic Affairs and Climate Policy on 16 September 2022. These goals will be set in the National Energy System Plan. This will also fulfil our commitments under various European agreements for offshore wind growth (Table 1) and ensure we meet our 2050 target for net zero emissions in our electricity supply.

A rolling roadmap will be used going forward. This will be updated regularly and as soon as new wind farm zones are identified. Insights from the Partial Revision of the North Sea Programme, due to be published in 2025, will be used as input to supplement the roadmap.

The Government expects post-2030 offshore wind farms are likely to produce both electricity and hydrogen. Projects will also be located in larger areas further out in the North Sea. A hub-based approach will be adopted, with a full assessment made for these larger areas regarding the form (electrons or molecules) in which the energy generated can best be brought ashore.

The North Sea Energy Infrastructure Plan 2050 (EIPN), currently being worked on, will include a strategic picture of where the Government expects energy hubs to be located. It will also identify what infrastructure, including interconnectors to neighbouring countries, will be needed.

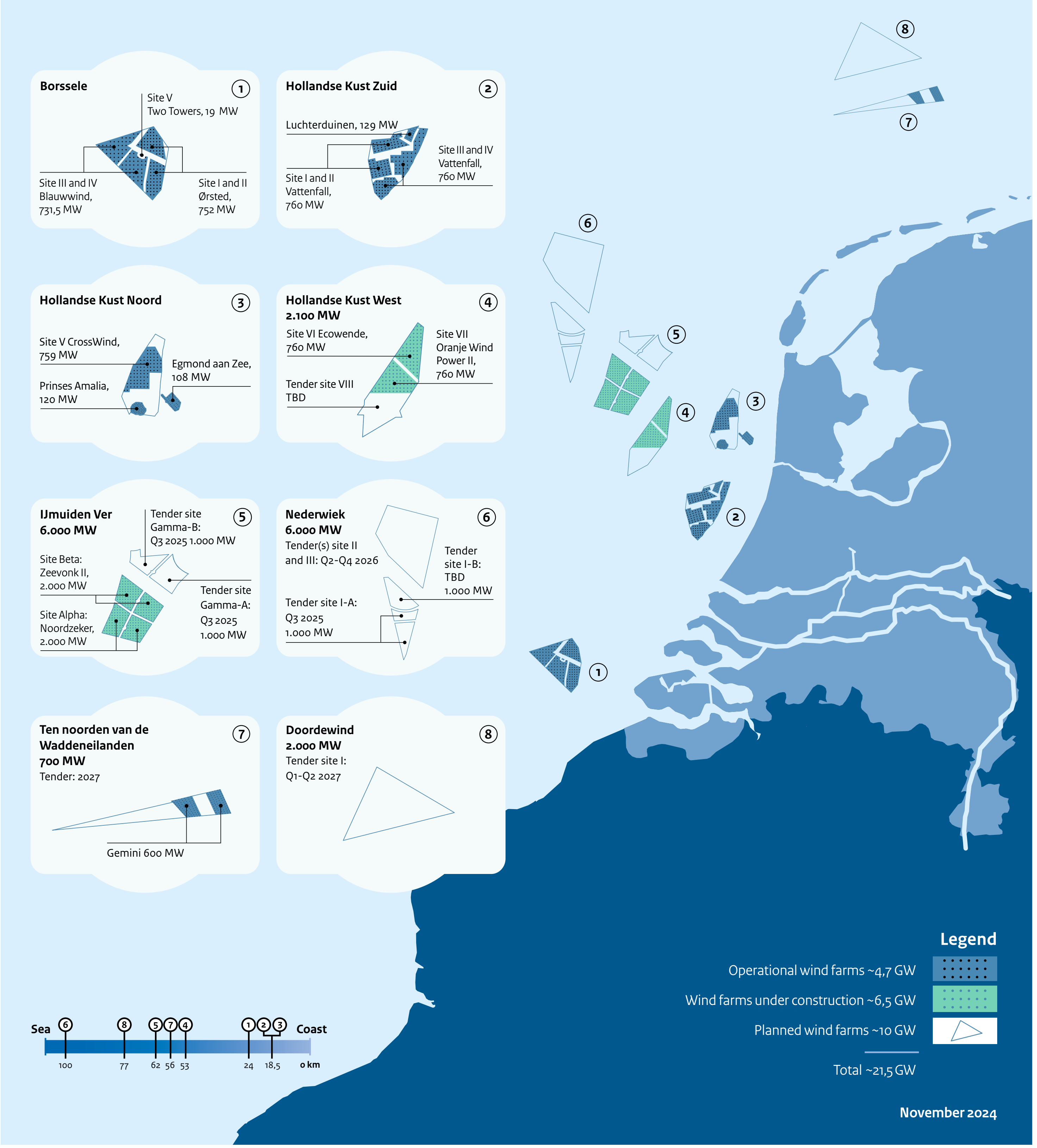
For the latest policy updates, please check Offshore wind energy (rvo.nl)

2.4 Wind & water works

The Dutch Government participates in active knowledge sharing with foreign government agencies. It also works with the industry, knowledge institutions and trade organisations to create new opportunities for the supply chain in the Netherlands and across the globe. Each year, we welcome foreign delegations and guests to the Netherlands for the Offshore Energy Exhibition and Conference (OEEC) in Amsterdam. During this two-day event, we share knowledge, network, present our innovative supply chain and showcase new findings.

If you would like to connect with the Dutch Government, specific businesses, or knowledge institutions within our supply chain, please visit the wind & water works website (windandwaterworks.com) to find out more. We are keen to learn and share our knowledge with others.

Offshore Wind Energy Roadmap 21 GW



3. Site description and offshore grid

3.1 General description of the IJmuiden Ver Wind Farm Zone

The IJmuiden Ver Wind Farm Zone (IJVWFZ) is located 33.4 nautical miles (62 km) off the west coast of the Netherlands in the Dutch North Sea. Four sites have been designated in the IJVWFZ: Alpha (formerly IJVWFS I - II), Beta (formerly IJVWFS III - IV), Gamma-A (formerly IJVWFS V) and Gamma-B (formerly IJVWFS VI). The upcoming permit tenders are for IJVWFS Gamma-A and Gamma-B.

3.2 Layout and coordinates

The total surface area of IJVWFS Gamma-A and Gamma-B (including the maintenance and safety zones) is approximately 227 km². The area includes safety zones and maintenance zones of infrastructure, for example active cables crossing the sites. This reduces the effective area available for new wind farm construction. The netto surface is 192 km².

Sites Gamma-A and Gamma-B will each accommodate 1 GW of offshore wind capacity.

TSO TenneT will construct one offshore substation platform with grid connections for IJVWFS Gamma-A and Gamma-B.

A table with coordinates for the boundaries of IJVWFS Gamma-A and Gamma-B, maintenance zones, infield cable corridors, and safety zones will be published in Appendix C: Memo Boundaries and Coordinates. Once finalized, this Appendix will be published on offshorewind.rvo.nl.

3.3 Existing infrastructure

3.3.1 Cables and pipelines

There are several active and inactive existing cables and pipelines crossing IJVWFS Gamma-A and Gamma-B. (Figure 3.1)
The description of pipelines and cables in the IJVWFZ can be found in Appendix C, which can be downloaded on offshore-wind.rvo.nl.

3.3.2 Nearby wind farms

Sites within the Hollandse Kust (west), Hollandse Kust (noord) and Hollandse Kust (zuid) Wind Farm Zones are currently finished or in final steps of finalisation. Please consult developers of the projects within these zones when conducting activities in these areas. Coordinates can be found in Appendix C.

3.3.3 Offshore platforms and other nearby activities

There are several existing (mining) platforms and boreholes (both active and inactive) in or around the IJVWFZ. Coordinates can be found in Appendix C.

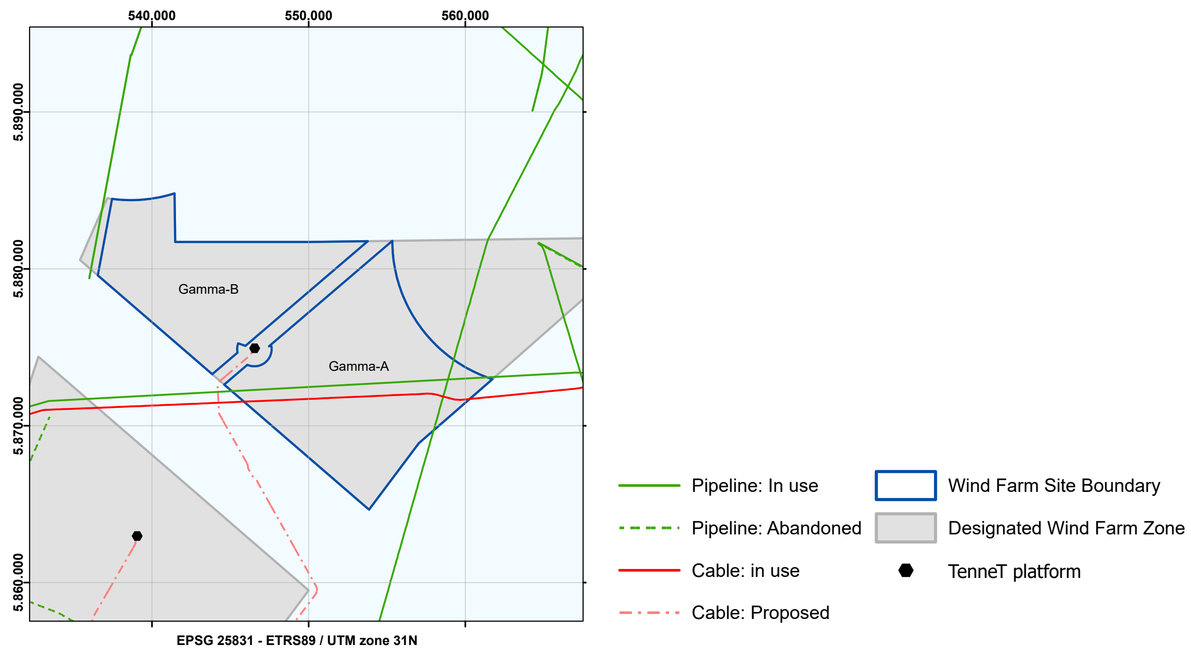


Figure 3.1 *IJmuiden Ver Wind Farm Sites Gamma-A and Gamma-B and surrounding areas*

3.3.4 Exclusion zones
A 500 m safety zone is defined around the IJVWFZ. No construction ships or building activities are allowed in this safety zone. Pipelines and cables, including their maintenance zones (500 m on both sides of the pipelines/cables), are also excluded from the safety zone. Turbines need to be constructed and located in such a way that blade tips are within the site boundaries and outside the maintenance and safety zones.

There is a new shipping corridor (Newcastle – IJmuiden) across the IJVWFZ. Under the National Water Programme 2022- 2027, vessels up to 46 m can cross the entire area (under conditions).

3.4 TenneT offshore grid connection system

The Ministry of Economic Affairs and Climate Policy formally designated TenneT as offshore grid operator in the Netherlands on 6 September 2016. The Electricity Act 1998 introduced a 'Development Framework for the offshore grid', which provides a technical framework and outlines future development of offshore wind in the Netherlands.

The Development Framework for the offshore grid was published by the Ministry of Economic Affairs and Climate Policy and is updated on a regular base.

As prescribed in the Development Framework, TenneT will build grid connections for the new capacity required to meet the offshore wind target planned under the 21 GW Offshore Wind Energy Roadmap.

To create economies of scale, TenneT will construct a standardised substation platform, also called Gamma with a capacity of 2 GW. The planned location of the platform is shown in Figure 3.1, while Table 3.1 shows its coordinates.

Infield cables for electricity transmission from IJVWFS Gamma-A and Gamma-B will connect directly to this platform. Cable entry zones are designated as the area to place infield cables connecting the wind farm to the platform.

The IJmuiden Ver platforms will transform the output from the wind farms from 66 kV to 525 kV and transmit the electricity to shore through two 525 kV export cables. The export cables will connect to the onshore substations and the 380 kV onshore grid. Details are in the Development Framework, which will be included in Appendix A of the PSD. Contracts for platforms and cables have successfully been tendered by TenneT. A table in Appendix C shows the border coordinates of the export cable corridors.

3.5 Realisation Agreement and Connection and Transmission Agreement

In close consultation with the offshore wind industry, the Ministry of Economic Affairs and Climate Policy, the Authority for Consumers & Markets (ACM), and representatives of the Dutch energy market, TenneT has developed an offshore legal framework consisting of so-called model agreements. Consultation sessions on these model agreements were open to all stakeholders and completed ahead of the first subsidy tender process (2016). For IJmuiden Ver platform Gamma, TenneT has updated the model agreements to reflect the characteristics of the 2 GW HVDC system and organised additional information sessions and a Q&A process.

The model agreements consist of a Realisation Agreement and a Connection and Transmission Agreement, supported by Offshore General Terms and Conditions, in line with onshore practice. All model agreements are available online (see tennet.eu/information-wind-farm-developers).

The model for these agreements will basically be the same for all winners of the tenders (past, present, and future). All agreements will enter into force according to the model agreements published by TenneT. The agreements will be concluded on an equal basis with the parties concerned. For the sake of completeness, the content of these agreements is non-negotiable. The final data in these agreements will be completed in close consultation with the parties with whom TenneT enters into agreements. For clarity, each of the 1 GW winners of the wind farm site will have their own contracts with TenneT.

Table 3.1 *Planned TenneT substation platform for IJmuiden Ver WFS Gamma-A and Gamma-B*

Platform center	Easting (x)	Northing (y)
Site Gamma (platform gamma)	546553.6	5874940.2

Spatial reference: ETRS_1989_UTM_Zone_31N. WKID: 25831 Authority: EPSG.

3.6 Applicable codes

The generic technical requirements for offshore wind farm connections are established as technical code requirements and, as such, are based on public law. In December 2018, ACM concluded and published a major revision of codes, affecting both onshore and offshore technical regulations. Further generic technical requirements by TenneT can be found in the annexes to the model agreements.

3.7 Step-by-step process to connection

RVO will, when requested, introduce the winner(s) of the tenders to the Ministry of Climate Policy and Green Growth, Directorate General for Public Works and Water Management (Rijkswaterstaat), and TenneT. After this introduction, TenneT will invite the winner(s) for bilateral meetings to start the connection process. The necessary steps for connecting a wind farm to the offshore grid are as follows:
- The winner of the tender will provide TenneT with the data as indicated by TenneT in the Realisation Agreement and the Connection and Transmission Agreement;
- In case TenneT's 525 kV export cables and the offshore wind farm 66 kV cables should cross or are near each other, cable crossing and/or proximity agreements will need to be arranged between TenneT and the tender winner. TenneT will process the data received in the agreements and provide fully completed agreements to the winner;
- Before the parties have signed the agreements, they will consult on the joint planning. Further information exchange and coordination will take place after signing in the project working group (as referred to in Article 6 of the Realisation Agreement);
- The dates for completion of the platform for IJmuiden Ver Gamma will be in the updated Development Framework, which will be included in Appendix A of the PSD;
- RVO will hand over all remaining samples of the Geotechnical survey;
- Directorate General for Public Works and Water Management (Rijkswaterstaat) will coordinate the Maritime Information Services. Several sensors for public use will be placed on the platform. The opportunity exists for the winner to add individual systems for its offshore wind farm operation.

Timely conclusion of the agreements and exchange of interface data is vital to ensure connection to the offshore transmission grid in line with the planning and to maximise cost reduction opportunities during the construction of the offshore grid, especially with regards to the platform.

4. Site Characterisation

The Netherlands Enterprise Agency (RVO) is responsible for publishing the site information which companies require to prepare bids for the permit tender for the IJmuiden Ver Wind Farm Sites Gamma-A and Gamma-B. The site information package has sufficient detail and quality to be used as input for preliminary engineering design studies.

Results from previous tenders show this approach provides the basis for an optimal tender result. In providing a more comprehensive data package, risk is significantly reduced for the developer, as is the need for conservatism in the assumptions of the tender design, while the business case for the project and the overall planning can be optimised. In this chapter, the scope of work and results of the individual studies and investigations are summarised, covering the following:

- Soil: Archaeological desk study, UXO risk assessment desk study, Geological desk study, Geophysical survey, Archaeological assessment of the Geophysical survey results, Baseline survey of Benthic Ecology, Geotechnical site investigation, Integrated Ground Model and Geotechnical Interpretative Report, Morphodynamical and Scour Mitigation desk study;
- Wind and Water: Metocean measurement campaign, Metocean assessment, Wind Resource Assessment.

The findings of the Archaeological, UXO and Geological desk studies were used to define the scope of work and basis of the Geophysical site characterisation.

The results of this comprehensive Geophysical site characterisation refine and partly supersede those of the three earlier desk studies and further feeds into the main Archaeological assessment, the Geotechnical site investigation and the Morphodynamical study.

Meanwhile, the Metocean Assessment, as a combination of the Wind Resource Assessment and the Metocean desk study, will take into account the findings of the Metocean measurement campaign.

Figure 4.1 shows how the various studies and investigations relate to each other as well to which element of the wind farm design they feed into.

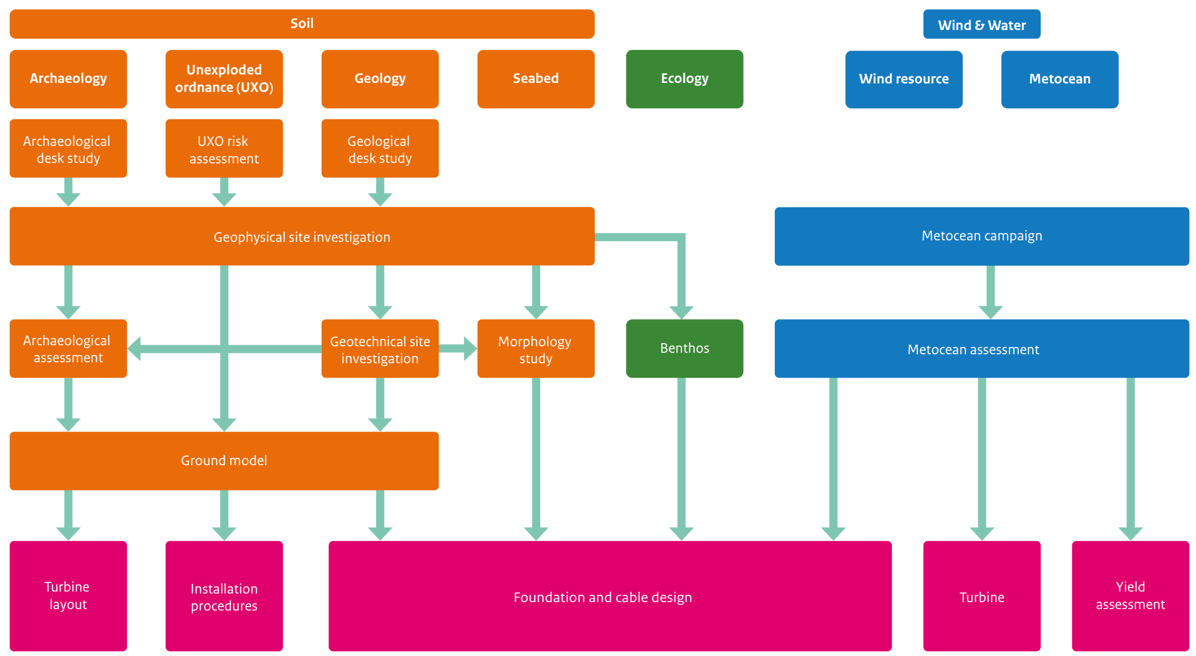


Figure 4.1 *Site studies and investigations for IJmuiden Ver Wind Farm Sites Gamma-A and Gamma-B*

4.1 Archaeological desk study IJmuiden Ver Wind Farm Zone

4.1.1 Aims and Objectives

The aim of the Archaeological desk study was to determine whether any archaeological remains are present in the IJVWFZ, sites Alpha, Beta and Gamma, and, if so, whether they could be impacted by the development of the planned wind farms. The aim of the study was to assess the cultural-historical value of any discovered wrecks and objects of potential archaeological interest, prehistoric campsites, and inhumations.

4.1.2 Approach

The investigated area covered 1349 km² located in the North Sea, 67 km off the coast of Petten. The desk study is the first step in the archaeological process and was conducted according to the Heritage Act 2016 (Erfgoedwet 2016). The research relied on database sources, as the Wind Farm Zone had not yet been investigated by detailed geophysical surveys. The team explored the presence of shipwrecks and WWII plane wrecks, as well as the likelihood of intact prehistoric landscapes, in situ remains of Palaeolithic and Early Mesolithic campsites, and inhumations. Further research was needed to determine the cultural-historical value of any discovered wrecks and objects of potential archaeological interest and to assess whether undiscovered shipwrecks are present.

4.1.3 Supplier

Periplus Archeomare was contracted by RVO to conduct the Archaeological desk study.

4.1.4 Results

The study identified 37 contacts in database sources within the investigated area. Of those, 19 are shipwrecks and 18 are objects, with just 1 wreck and 7 of the objects being of known archaeological value. The archaeological value of the remaining 18 shipwrecks and 11 objects is unknown. Further research is needed to determine the nature, extent, location, and age of the remains found at these sites.

Additionally, remains of in situ prehistoric campsites and inhumations are expected in the area, with the Boxtel Formation and Brown Bank Member being of particular interest. Along with these, the remains of Neanderthal campsites in the Brown Bank Member can be expected and reworked flint artefacts from Lower and Middle Palaeolithic times in the ice-pushed deposits of the Formation 4.1.1. and Egmond Ground Formation. However, it is unlikely that prehistoric campsites will be identified with sufficient certainty to impose restrictions on wind farm developments. Instead, the focus should be on the pragmatic employment of geophysical techniques to obtain a better insight into the Pleistocene landscape.

To summarise, the area may contain undiscovered ship and plane wrecks and remains of prehistoric campsites, artefacts and inhumations.

4.1.5 Advice

In accordance with the AMZ (Archeologische Monumenten Zorg) cycle, a geophysical and geotechnical investigation is recommended. This should test the archaeological predictive model and further specify the type, vertical and lateral extent, age, integrity and potential archaeological levels.

4.1.6 Webinar

The results of the Archaeological desk study and the Archaeological assessment of the Geophysical survey results were presented and discussed at a webinar on 16 May 2023. Please refer to offshorewind.rvo.nl for details.

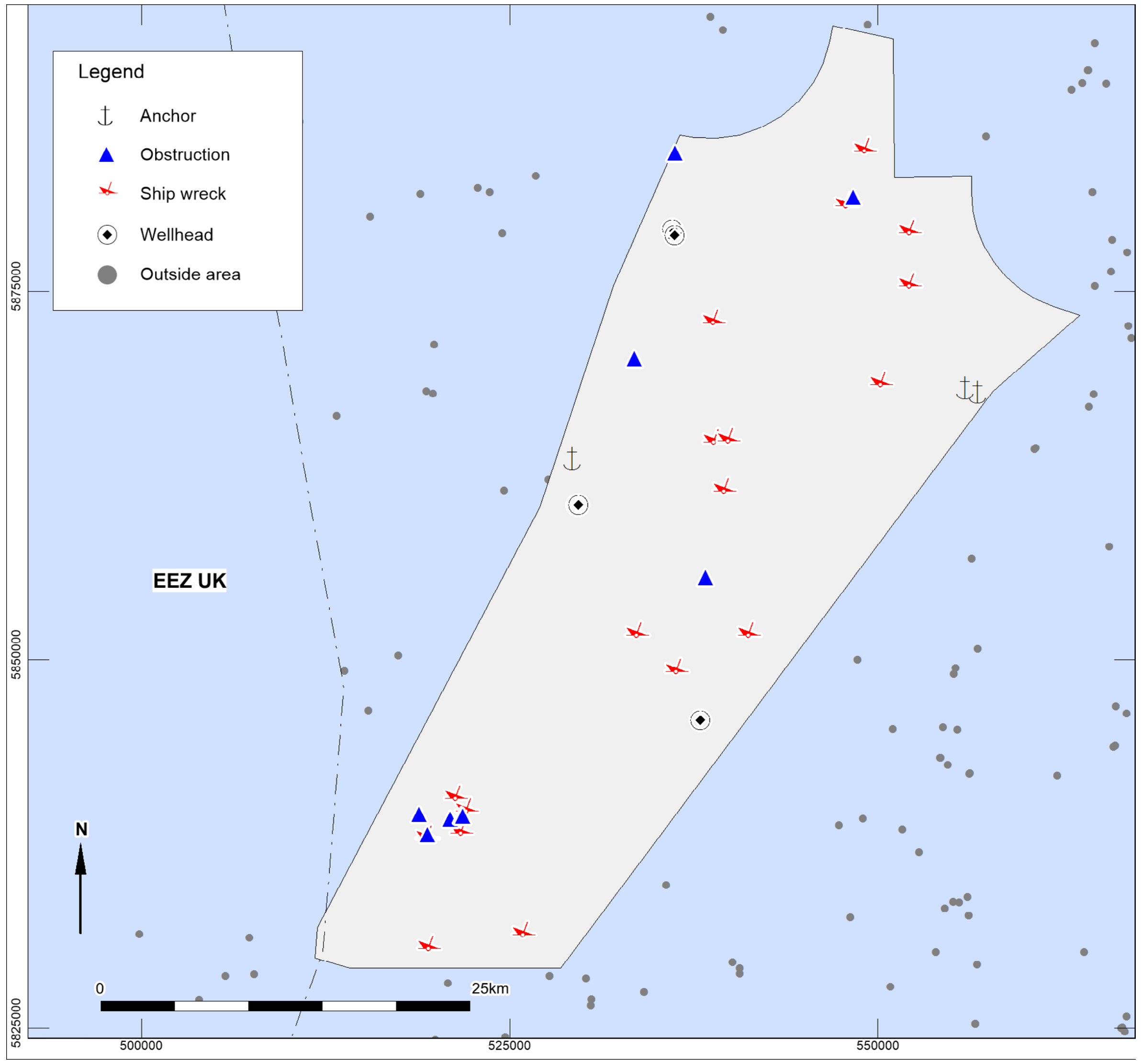


Figure 4.1.1 *Summary of known contacts within the investigated area of the IJVWFZ*

4.2 Unexploded ordnance (UXO) risk assessment desk study IJmuiden Ver Wind Farm Zone

4.2.1 Overview - aims, objectives, and approach

The UXO desk study, performed in Q2 of 2019, provides initial insight into the risk of encountering unexploded ordnance (UXO). The main objectives of this study are:

1. Identify possible constraints for offshore wind farm related activities in the IJVWFZ as a result of the presence of UXO.
2. Define specific requirements related to the presence of UXO for any wind farm related activity to be carried out in the IJVWFZ. And identify areas within the IJVWFZ that should preferably not be used for the installation of offshore wind farms and/or cables or any other structure.
3. Identify possible requirements from the UXO point of view that should be taken into account for:
   a. Determining the different sites in the WFZ.
   b. Conducting geophysical and geotechnical investigations.
   c. Specific requirements (legal obligations, specific procedures) to be taken into account when finding UXO.
   d. Installation of wind turbine foundations.
   e. Installation of cables.
4. Identify whether any further investigations should be carried out regarding the presence of UXO and define the scope of these investigations, including their spatial extent and timing within the overall site development programme – all relevent investigation methods will be considered for the project, from site investigation to installation.

4.2.2 Supplier

REASeuro performed the UXO desk study. The company specialises in (offshore) UXO desk studies, risk assessments, and UXO clearance operations. Since 2012, REASeuro has been involved with several offshore projects in the North Sea, performing data analysis, project risk assessments, and coordination of UXO clearance activities. Moreover, the company performed the UXO desk studies for the Borssele and Hollandse Kust (zuid), Hollandse Kust (noord) and Hollandse Kust (west) WFZs and export cable routes.

4.2.3 Results

The UXO risk assessment study consists of two sequential phases: historical research (1) and UXO risk assessment (2). The historical research delivers essential input for the risk assessment and subsequent mitigation strategies.

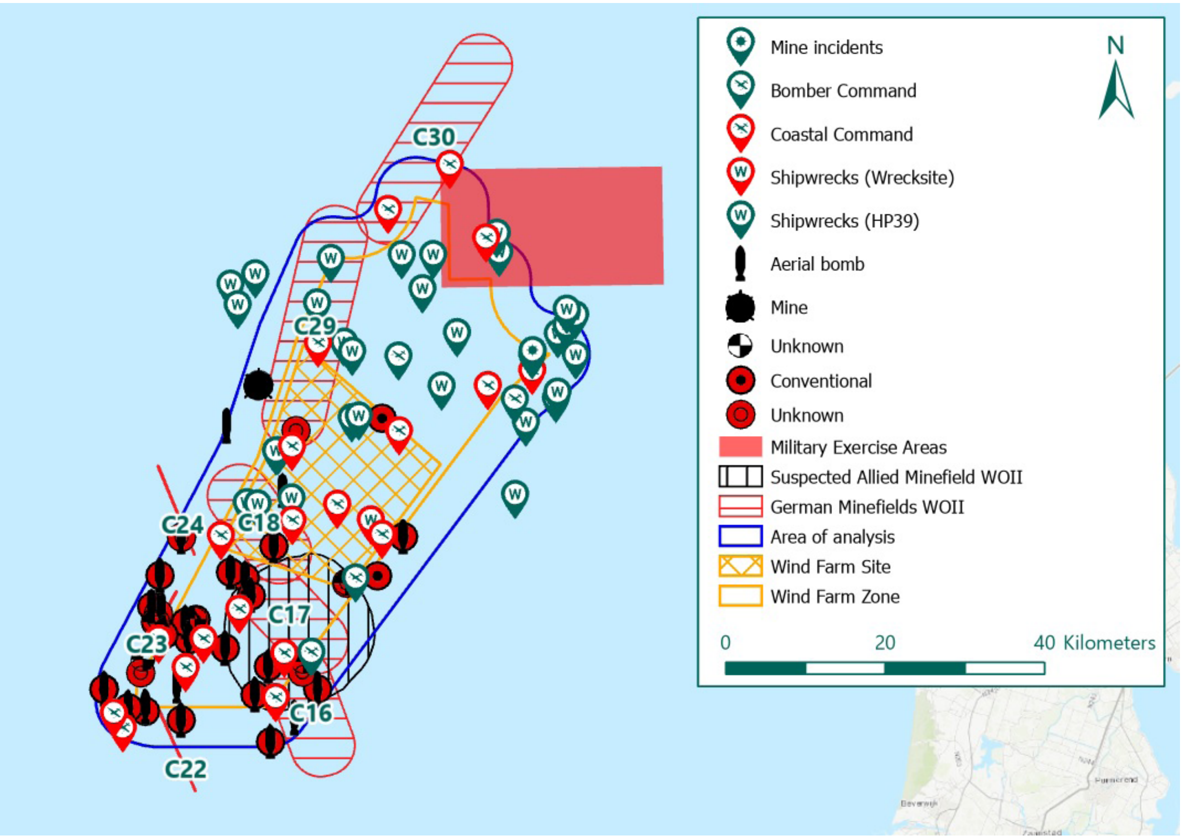


Figure 4.2.1 *Overview of war related events within the IJVWFZ (Source basemap: ESRI)*

According to the historical research, the IJVWFZ and surrounding areas were the scene of war-related activities during World War I (WWI) and World War II (WWII).

Historical research in The National Archives (London, United Kingdom) and Bundesarchiv-Militärarchiv (Freiburg, Germany) has shown that mining operations took place in and near the IJVWFZ in WWI and WWII (Figure 4.2.1), but the mines were only partially recovered after both wars. The types of mines which may be present are German and British moored/contact mines from both WWI and WWII. It must be taken into account that this overview is based on the minefields actually present in (the vicinity of) the IJVWFZ. Since the war, some ordnance is likely to have moved as a result of fishing, currents, and seabed dynamics. Other naval mines could be encountered, but is assessed as highly unlikely. The historical sources also state several incidents in regard to naval battles and submarine activity within the IJVWFZ. As a result, UXO such as artillery shells and torpedoes are also likely to be encountered.

During the Allied bomber raids in WWII, a great many bombers flew towards targets in Germany or German occupied territory. In emergency situations or if finding the target failed, bomber crews often ditched remaining aerial bombs in the North Sea before returning to base. Furthermore, during WWII, German convoy routes were targeted by Allied bomber planes. To defend their shipping activities, the German navy (Kriegsmarine) used anti-aircraft artillery on small vessels such as their fast attack E-boats (Schnellboote). Taking into account the amount of air strikes on ships, jettisoned bombs and the use of anti-aircraft weapons, UXO such as aerial bombs, rockets, small calibre munition and artillery shells might be present in the IJVWFZ.

Based on this information, the entire WFZ is considered an area where a UXO encounter is possible (Figure 4.2.1).

After the historical research was performed, the risk assessment was conducted. The following parameters were assessed:

- Source, pathway and receptor
- Likelihood of presence
- Type of encounter
- Likelihood of occurrence
- Hazard severity

In assessing the overall UXO risks for the project, a Semi Quantitative Risk Assessment (SQRA) process was applied. The results of the risk assessment are shown in Table 4.2.1.

There is sufficient and indisputable evidence that naval mines might be present within the IJVWFZ. There is also strong evidence indicating the presence of aerial bombs. The planned construction works may cause an aerial bomb or naval mine to detonate. A detonation is assessed to be 'possible' and may be

Table 4.2.1 *Risk assessment results for the IJVWFZ*

Source	Likelihood of presence	Pathway	Receptor	Type of encounter	Likelihood of occurrence	Hazard severity	Risk result
Small Calibre Munition	Remote	Touch	Personnel Equipment	Primary	1 = Very unlikely	1 = Negligible	1 = LOW
Rockets	Remote	Touch	Personnel Equipment	Primary	2 = Unlikely	1 = Negligible	1 = LOW
Artillery shells	Feasible	Touch	Personnel Equipment	Primary	2 = Unlikely	1 = Negligible	1 = LOW
Torpedoes	Feasible	Touch, Movement, Vibrations, Magnetism	Personnel Equipment	Primary Secondary	3 = Possible	5 = Very High	15 = HIGH
Naval mines (WWI)	Feasible	Touch, Movement, Vibrations, Magnetism	Personnel Equipment	Primary Secondary	3 = Possible	5 = Very High	15 = HIGH
Naval mines (WWII)	Probable	Touch, Movement, Vibrations, Magnetism	Personnel Equipment	Primary Secondary	3 = Possible	5 = Very High	15 = HIGH
Allied aerial bombs	Probable	Touch, Movement, Vibrations	Personnel Equipment	Primary Secondary	3 = Possible	5 = Very High	15 = HIGH

initiated by, for example, crushing by a cable trencher during cable lay operations, a kinetic energy created during pile foundation operations, etc.

In case of a detonation under water, the water column provides protection against fragmentation. The bubble jet and shock effect, however, may cause damage to vessels, compromising the integrity of the ship. Also personnel may be injured or killed due to the shock or sinking of a vessel. Artillery shells originating from naval attacks or dumping are likely to be present. These shells do not pose a significant threat for installation operations.

4.2.4 Conclusions and recommendations

Based upon the analysis of historical sources, it is evident that different war related events took place within and within the IJVWFZ. Due to these events, the entire IJVWFZ is considered a UXO risk area. A variety of UXO are likely to be present which includes aerial bombs, naval mines and artillery shells. The likely presence of UXO in the area, however, is not a constraint for offshore wind farm development. By applying professional UXO risk management, these risks can be reduced to a level that is considered As Low As Reasonably Practicable (ALARP).

Within the proposed area, there are no UXO risk free areas identified. However, since the entire IJVWFZ is to be considered a UXO risk area and the risks posed by the presence of UXO can be sufficiently mitigated to ALARP, the entire IJVWFZ can be selected for the installation of offshore wind farms and/or cables.

The possible effects of a detonation to vessels, equipment, personnel, and surroundings may form an intolerable risk. This means mitigation measures are required to reduce the risks to ALARP. In order to reduce the risk to ALARP, a dedicated UXO geophysical survey must be carried out to identify objects on the seabed that could potentially be UXO. The mitigation measures consist of UXO survey, identification of potential UXO objects, re-routing or re-location of cables and structure if possible, and disposal of UXO items if required.

Due to the highly dynamic soil morphology and possible associated migration and burial of UXO, it is recommended that companies conduct UXO search (and removal) operations immediately prior to construction activities at the intended construction locations. The limited temporal validity of the collected survey data should be taken into account when planning survey and construction operations.

Taking the results of the SQRA into account, it is assessed that the 250 lb bomb is deemed the smallest ferrous threat item for an ALARP sign-off. These items are cylindrical/tear-drop in shape, made of steel and, depending on the variant, contain between 30 and 60 kg of helium (HE). The ferrous weight can range from 50 to 83 kg dependent on the make, modification and type of munition. Assuming these items can be successfully detected and identified within the geophysical datasets, larger objects will also be detectable. The provisional magnetometer (MAG) threshold is set at 50 kg ferrous mass. This threshold is also sufficient to detect ferrous naval mines which are likely to be present in the area. The risk also posed by the possible presence of depth charges, torpedoes and large calibre artillery shells will be mitigated sufficiently by applying the recommended threshold value.

4.2.5 UXO removal procedure

Within the Dutch Exclusive Economic Zone (EEZ), the Netherlands Explosive Disposal Authority ("Explosieven Opruimingsdienst", EOD) is responsible for all maritime UXO disposal operations. If a wind farm developer identifies a UXO at a location where activities are planned, it needs to be removed. This should be reported to the Dutch Coastguard. The Royal Dutch Navy will dispose of the UXO. No disposal costs will be charged to the wind farm developer.

4.2.6 Webinar

The results of the UXO desk study were presented and discussed at a webinar on 16 May 2023. Please refer to offshorewind.rvo.nl for details.

4.3 Geological desk study IJmuiden Ver Wind Farm Zone

This study was the starting point for several other studies. However, more in-depth Geophysical and Geotechnical site investigations have since been conducted hence the desk study is not described further in this PSD.

4.4 Geophysical survey IJmuiden Ver Wind Farm Sites Gamma-A and Gamma-B

4.4.1 Overview – aim, objectives and approach

The aim of the Geophysical survey was to gain an understanding of the seafloor and sub-seafloor conditions in the IJmuiden Ver Gamma-A and Gamma-B investigation area (IJV Gamma-A and -B IA). Information from this survey forms the basis for further geotechnical investigation planning and morphodynamical studies and serves as input for an integrated ground model of the site.

The objectives of the geophysical survey were to provide:
- An accurate bathymetric dataset;
- Information on the presence of seafloor features of significance to the construction of wind farm facilities, including:
  - Seafloor sediments and seafloor morphology (including morphodynamics);
  - Natural objects, such as boulders and pockmarks;
  - Identify or confirm the (as-found) positions of man-made objects, such as cables, pipelines and wrecks;
- Soil and water samples for a To (baseline) ecological campaign to serve as a reference for changes in species composition of soft substrate fauna that occur after the installation of a wind farm;
- Sub-seafloor datasets of sufficient quality to support construction of an integrated ground model to at least 100 m below seafloor (BSF);
- A coherent preliminary ground model of the site, including:
  - Elevation and depth BSF for a set of interfaces between important selected seismostratigraphic units;
  - The locations of geological features or geohazards, such as shallow gas accumulations, peat, faults and buried channels;
  - Correlation with existing geophysical and geotechnical interpretation at IJmuiden Ver Alpha and IJmuiden Ver Beta WFS and elsewhere, as available;
- A comprehensive interpretative report on the survey results obtained, describing the preliminary ground model; and
- A preliminary zonation of the site for input into the specifications and scope for a geotechnical sampling and testing programme.

Equipment used to carry out the investigation included multibeam echosounder (MBES), side scan sonar (SSS), magnetometer (MAG), sub-bottom profiler (SBP), 2D ultra-high resolution seismic (2D-UHRS), 3D ultra-high resolution seismic (3D-UHRS), grab sampler (GS) and box corer (BC). There was also a preliminary programme of geotechnical testing, including vibrocoring (VC) and (thermal) cone penetration testing ((T)CPT).

The geophysical site investigation was divided into four work packages;
1. A main geophysical work package within IJV Gamma-A and -B IA that included MBES, SSS, MAG, SBP and 2D-UHRS;
2. An additional geophysical work package extending outside of IJV Gamma-A and -B IA that included MBES, SSS, MAG, SBP and 2D-UHRS;
3. A geophysical work package within IJV Gamma-A and -B IA that included 3D-UUHRS;
4. A preliminary geotechnical work package within and extending outside of IJV Gamma-A and -B IA that included GS, BC, VC and (T)CPT.

Work packages 1 and 2 were carried out using Fugro's purpose-built, geophysical vessel Fugro Pioneer between 27 March and 2 July 2022. Work package 3 was carried out using the same vessel in the periods 12 August to 13 September 2022 and 13 April to 5 June 2023. Work package 4 was performed from third-party vessel Energy Scout from 11 to 18 June 2022 (VC and (T)CPT) and Fugro Pioneer on 20 June 2022 (GS and BC).

4.4.2 Supplier

Fugro was contracted by RVO to conduct the Geophysical survey at IJV Gamma-A and -B IA. Through integrated data acquisition, analysis and advice, Fugro provides information on the Earth's surface, subsurface and man-made structures. With expertise in site characterisation and asset integrity, clients are supported in the safe, sustainable and efficient design, construction, operation and decommissioning of their assets throughout the full life cycle. The company serves clients around the globe, predominantly in the energy, infrastructure and water industries, both onshore and offshore.

4.4.3 Results

Bathymetry and seafloor morphology

Elevation at the time of the Geophysical survey ranged from -22.9 m to -34.3 m LAT (Figure 4.4.1).

The seafloor in IJV Gamma-A and -B IA is characterised by a dynamic morphology with (mobile) sedimentary bedforms. The type of bedforms identified at the site, in order of decreasing magnitude, are sand banks, sand waves, megaripples, ripples and hummocks (irregular seafloor with small local depressions). Numerous trawl marks were also identified across the investigation area, which are evidence of fishing activity (Figure 4.4.2).

The site is characterised by gentle seafloor slopes, on average ranging between approximately 0° and 6°. Localised gradients exceeding 6° were observed on the lee side of sand banks and sand waves.

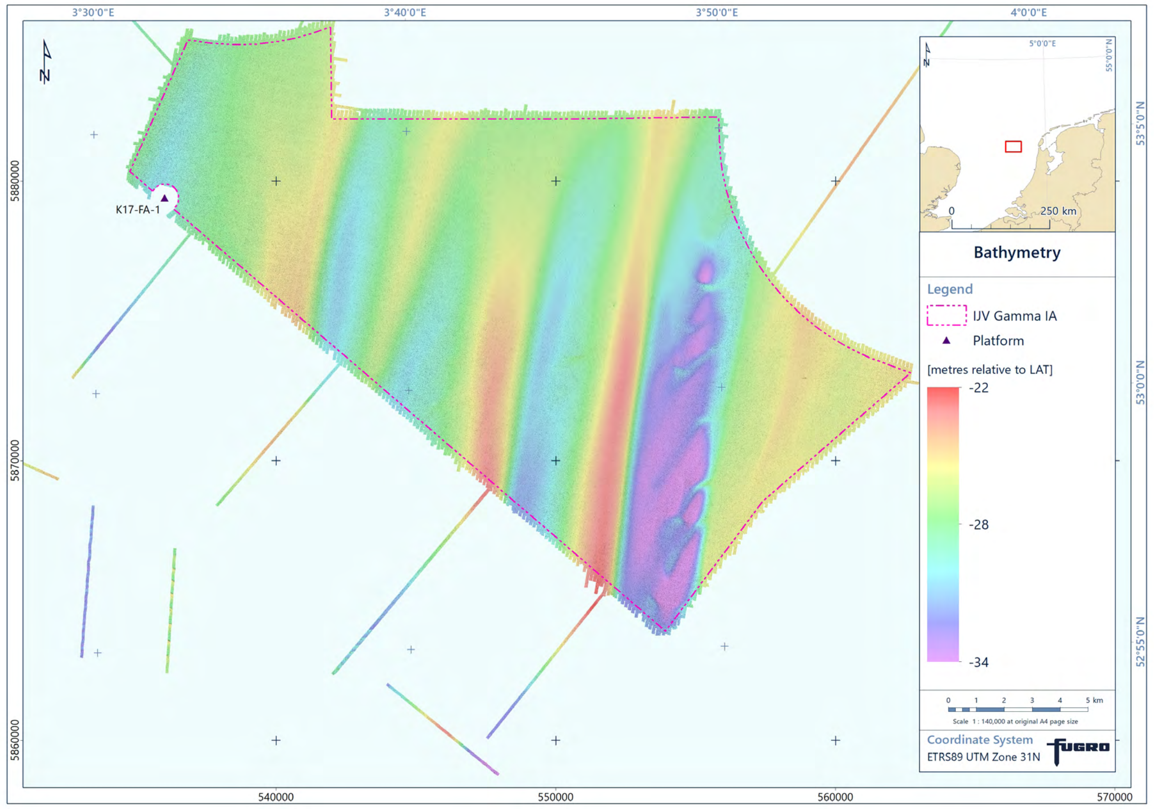


Figure 4.4.1 *Bathymetry at the IJV Gamma IA*

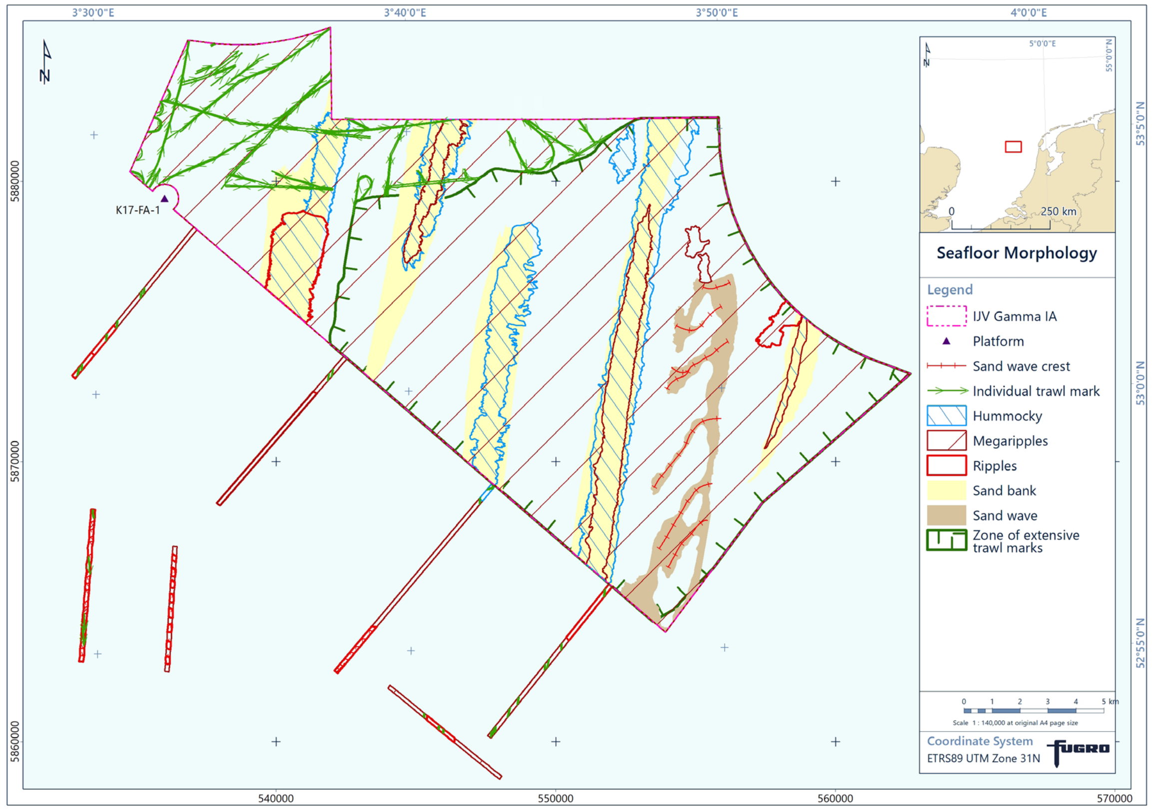


Figure 4.4.2 *Seafloor morphology classification*

Based on the results of the backscatter data, grab samples and box core samples, the dominant seafloor sediment type in IJV Gamma-A and -B IA is sand with a small percentage of gravel, silt and/or clay. The gravel is mainly composed of shell and shell fragments (Figure 4.4.3).

Seafloor contacts

A total of 342 seafloor contacts were identified from SSS data and, where possible, rationalised to the MBES position. The contacts include: 4 wrecks, 2 cables, 3 pipelines, 221 items of debris, 87 boulders and 'other' contacts (Figure 4.4.4).

A total of 9156 magnetic anomalies were interpreted from the MAG data and, where possible, cross-correlated with SSS and/or MBES contacts within a 2 m radius. Where correlation could be made, classifications were assigned with known seafloor objects or where a linear trend existed. This resulted in the correlation of 352 magnetic anomalies associated with 3 pipelines, 2 with wrecks, 8 with items of debris, 1 with an anchor chain, and 258 with 2 unknown cables.

The selection limit (≥5 nT; nanotesla) for magnetic anomalies was relatively low, which resulted in a large number of anomalies (7662 out of 9156 had a peak-to-peak amplitude of ≤15 nT) compared to the number of identified SSS contacts.

Two areas within IJV Gamma-A and -B IA were found to have background noise levels occasionally exceeding 2 nT. This is interpreted to be related to sub-seafloor conditions. In these areas, Unit A is relatively thin (<1 m) and Unit B is either thin (<1 m) or absent.

Sub-seafloor conditions

Seismic interpretation was carried out on 2D-UHRS data, while SBP data was used to support the interpretation of the shallow horizons. Four main horizons were interpreted, each representing a significant acoustic interface consistent across IJV Gamma-A and -B IA, which form the bases of seismostratigraphic units. Interpretation of the seismostratigraphic units was correlated with existing geological, geophysical and geotechnical data at IJV Gamma-A and -B IA and elsewhere, as available. A summary of the mapped units is provided in Table 4.4.1. Figure 4.4.5 and Figure 4.4.6 illustrate the geology in the form of a schematic seismostratigraphic model and 2D-UHRS data example, respectively.

The uppermost 100 m of sediments in IJV Gamma-A and -B IA were deposited during the Late Pleistocene to Holocene and are expected to be predominantly sand with occasional intervals of silt, clay and peat. This sequence has been deposited under the influence of an alternating pattern of glacial and interglacial periods which resulted in a complex interplay of glacial, deltaic and marine environments.

The mapped seismostratigraphic unit bases are all erosive in nature and internal erosive surfaces occur inside most of the units. Horizon H02 (at the base of Unit A) forms a planar erosion surface, H05 (base Unit B) is an irregular erosion surface, H20 (base Unit C) is a major truncation surface and H25 (base Unit D) forms the base of deeply incised tunnel valleys.

The most significant contrast in the seismostratigraphic units may be at the interface between the Yarmouth Roads Formation (Unit E) and its overburden (mapped with Horizons H20 and H25). Unit E underwent compaction by the Elsterian ice sheet, whereas the younger deposits have not undergone direct ice loading.

The seismic reflection data displays evidence of geohazards that may be relevant to wind farm planning. The geohazards identified include buried channels, layers of potential peat, layers of coarse material and glacially deformed areas. Results from the Geophysical site investigation preceded and supplied information to a Geotechnical investigation. Geophysical and geotechnical data were subsequently integrated into a geological ground model that supersedes the seismic interpretation that was carried out as part of this Geophysical survey.

4.4.4 Webinar

The results of the Geophysical survey conducted at IJV Gamma-A and -B IA were presented and discussed during a webinar on 28 May 2024. Refer to offshorewind.rvo.nl for details.

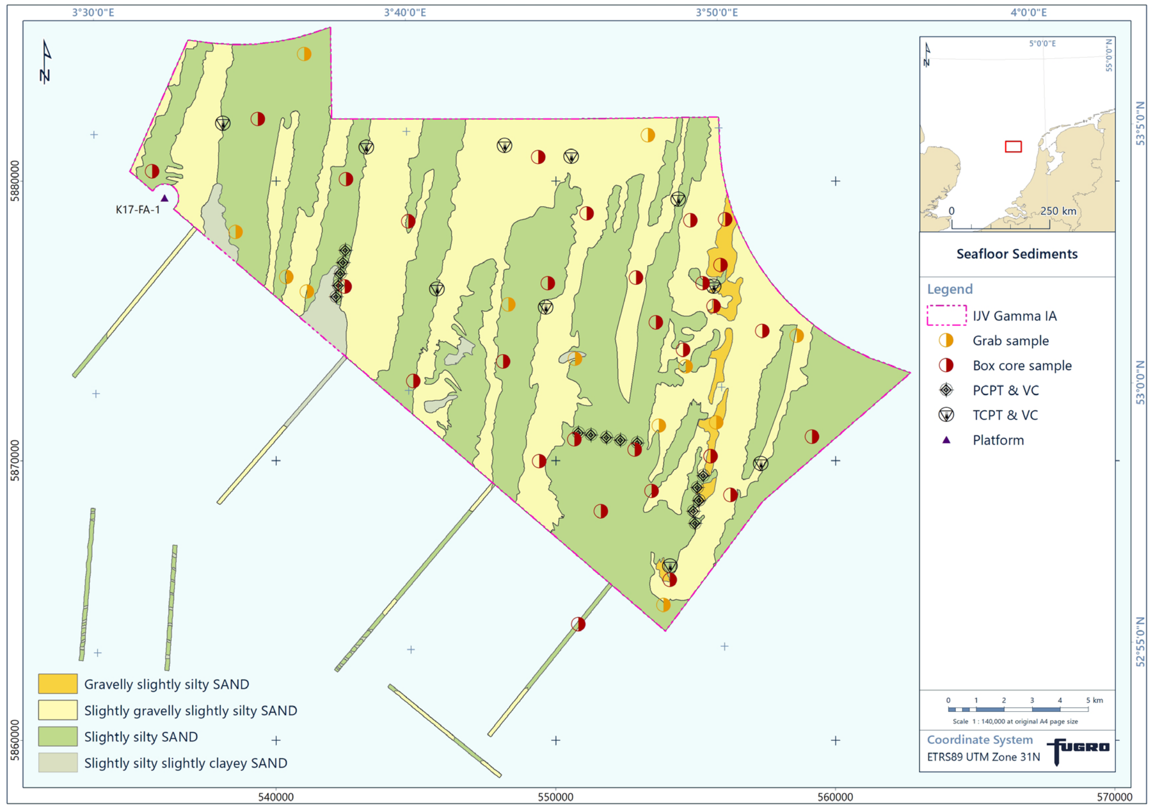


Figure 4.4.3 *Seafloor sediments classification*

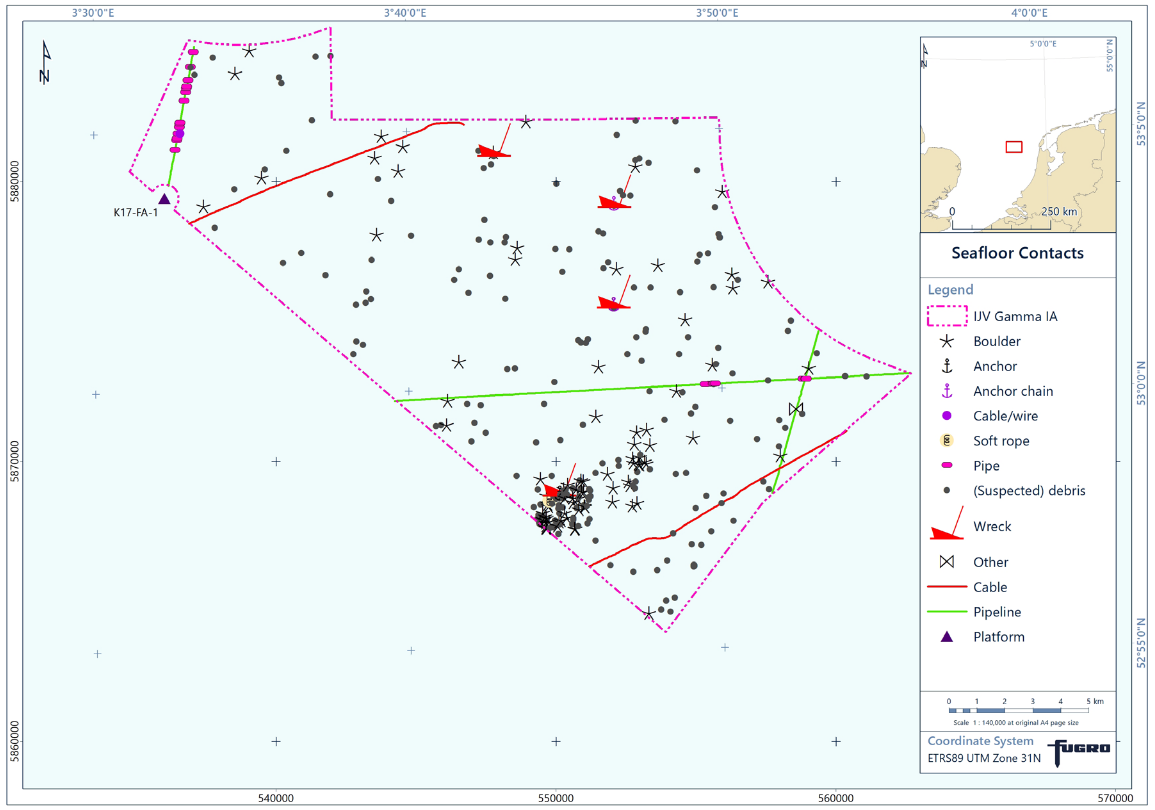


Figure 4.4.4 *Seafloor contacts*

Table 4.4.1 *Preliminary Geological units identified in the survey area*

Unit	Horizon		Base Geometry	Seismic Character	Expected Lithology	Tentative Depositional Environment	Tentative Geological Formation and (Age)
	Top	Base					
A	H00	H02	Subhorizontal erosional surface	Acoustically transparent	Loose to very dense slightly silty fine and medium SAND, with shells and shell fragments	Open marine	Southern Bight (Holocene)
B	H02	H05	Irregular to undulating erosional surface	Chaotic, with internal channels and high negative amplitude anomalies	Medium dense to very dense slightly silty SAND, with laminations and beds of clay, silt and peat	Coastal to tidal	Naaldwijk (Early Holocene)
C	H02 H05	H20	Subhorizontal erosional surface, locally forming channels	Semi-transparent and low to medium-amplitude subparallel reflections	SAND and CLAY alternations or SAND	Open marine, brackish marine, lagoonal to lacustrine	Boxtel (Late Weichselian) Brown Bank (Late Weichselian) Eem (Eemian) Egmond Ground (Holsteinian)
D	H20	H25	U-shaped channel	High-amplitude base, semi-transpa-rent infill with occasional amplitude anomalies and internal channels near the top	CLAY, with frequent (silty) SAND interbeds	Glacial, glaciofluvial (infill of valleys) to glaciolacustrine	Peelo (Elsterian)
E	H20 H25	BPD	BPD	Wavy and steeply inclined reflections, multiple levels of channel-like features, and occasional high amplitude anomalies	SAND with occasional CLAY interbeds and local beds of PEAT	Fluvio-deltaic to marine	Yarmouth Roads (Early to Middle Pleistocene)

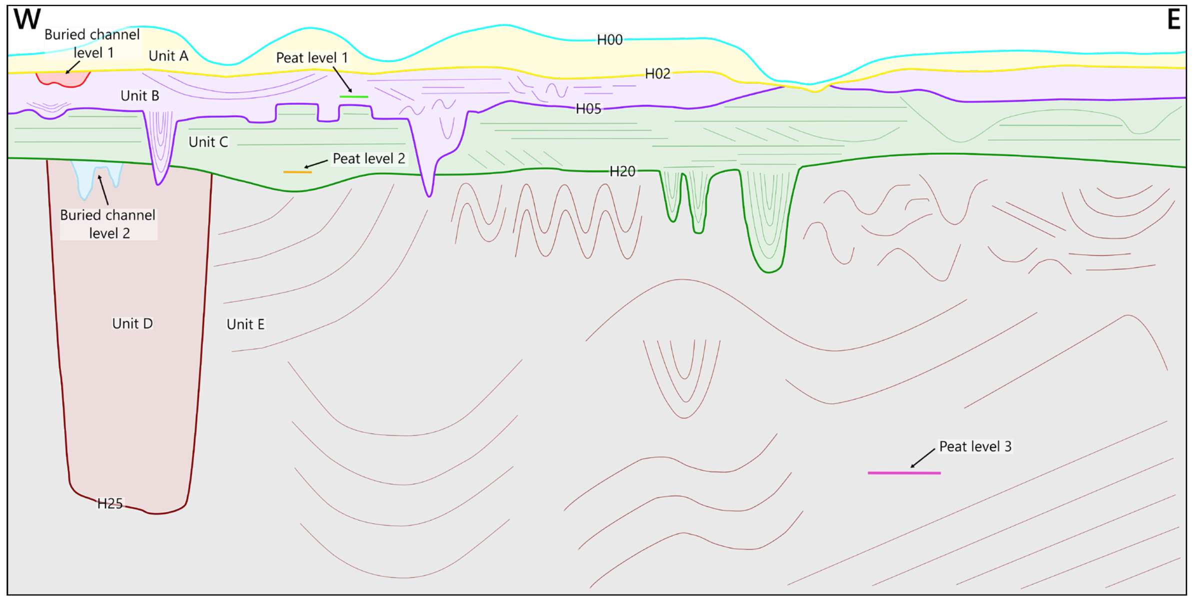


Figure 4.4.5 *Schematic seismostratigraphic model of IJV Gamma-A and -B IA*

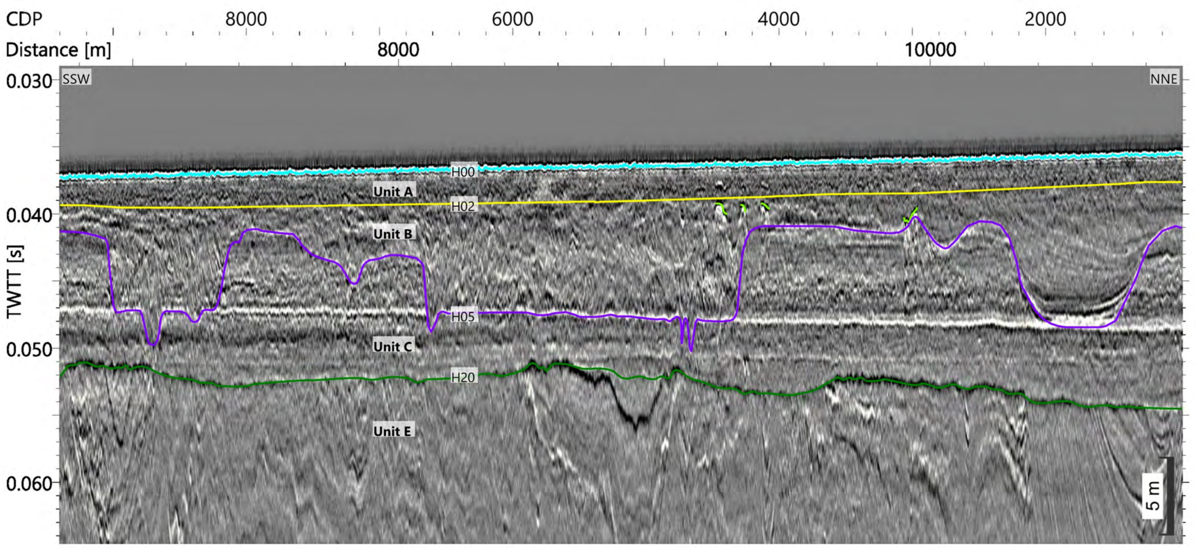


Figure 4.4.6 *2D-UHRS data example with interpreted horizons delineating seismostratigraphic units*

4.5 Archaeological assessment of the Geophysical results IJmuiden Ver Wind Farm Sites Gamma-A and Gamma-B

4.5.1 Aims

Following on from its initial work on the Archaeological desk study, Periplus Archeomare conducted an Archaeological assessment of geophysical data to further investigate the presence of archaeological remains in the IJmuiden Ver Wind Farm Sites Gamma-A and Gamma-B.

The survey was conducted by Fugro and, although it was not primarily designed for archaeological research, a scan of the survey data acquired showed that the data is fit for an archaeological assessment. The overall goal of this assessment is to test the expectancy (based on the desk study) for archaeological remains in the area, including shipping-related objects (wrecks), World War II airplanes and prehistoric settlements.

4.5.2 Objectives

The objectives of this assessment are:

- To determine the historical or archaeological value of contacts found in the geophysical survey.
- To validate the locations of known wrecks.
- To assess the prehistoric landscape based on the seismic data.

4.5.3 Approach

The approach for this Archaeological assessment involved analysing the geophysical survey data obtained by Fugro using a range of methods, including side scan sonar (SSS), magneto-meter (MAG), multibeam echo sounder (MBES), sub-bottom profiler (SBP) and ultra-high resolution seismic (UHR). Before conducting the Archaeological assessment, the quality and completeness of the delivered survey data were evaluated. It was concluded that the data is of high quality and fit for the purpose of the Archaeological assessment. The approach for the assessment involved reviewing and analysing the survey data to identify potential archaeological features and remains, conducting desk-based research to contextualise the identified features and remains, validating the locations of known wrecks through comparison with historical records and additional research, assessing the prehistoric landscape through the analysis of seismic data and producing a report of the findings that includes recommendations for further research or management of any identified remains.

4.5.4 Supplier

Periplus Archeomare was contracted by RVO to conduct an Archaeological assessment of the geophysical data acquired by Fugro.

4.5.5 Results

The investigation involved an analysis of geophysical survey results as part of an Archaeological assessment. The survey covered a total area of 277 km² within the IJmuiden Ver Wind Farm Zone.

Nine contacts are known from database sources within the combined IJmuiden Ver WFS Gamma-A and Gamma-B survey area (refer to the report of the Archaeological desk study). The known contacts are registered in the NCN database as shipwreck (four), obstruction (three) and anchor (two).

Six out of nine known NCN contacts have been found during the geophysical survey: four known shipwrecks plus one known obstruction that is re-assessed as possible shipwreck. All five shipwrecks are of potential archaeological value. One known obstruction is a rock dump at the crossing of the 36-inch active gas pipeline from Balgzand (NL) to Bacton (GB) and the 20-inch active gas pipeline from P6-A to L10-AR.

Three out of nine known NCN contacts (one obstruction and two anchors) have not been found during the geophysical survey. These objects possibly are covered by sediments and could be of archaeological value.

Apart from the six known objects found during the geophysical survey, 342 newly found SSS contacts have been reported. At five locations, objects and structures have been identified which - based on their shapes and dimensions - are interpreted as wrecks (three) or anchors (two) of possible archaeological value.

The survey revealed 9156 magnetic anomalies. Of these, 224 anomalies have peak-to-peak values of 50 nT or more and are not related to known infrastructure, NCN contacts or objects that are visible at the seabed. The buried iron-bearing objects that induced these 224 anomalies are, along with the 13 objects found exposed at the seabed, of potential archaeological interest.

Possible prehistoric remains in the area include campsites of hunter-gatherer communities, burials, log boats and lost or dumped flint and bone artefacts.

The physical quality, integrity and preservation of remains are highly dependent on the extent to which the prehistoric landscapes have been affected by erosion. The seismic data indicate that a major part of the stacked sequence of Pleistocene landscapes has eroded during the Early Holocene marine ingression, potentially affecting the integrity of possible prehistoric settlements. However, the interpretation of lithostratigraphic units and the character of the layer boundaries (erosive versus non-erosive) from the seismic data is based on best professional judgement utilising an uncertain geological framework. The seismic interpretation shall therefore be ground-truthed by a combination of cone penetration tests and borehole and vibrocore sampling.

Areas of potential archaeological interest listed below.

Formation	Paleolandscape / Area of potential archaeological interest	Time of deposition	Archaeological period
Boxtel	Peat-covered aeolian and small scale fluvial deposits	Late Glacial and Early Holocene	Late Paleolithic and Early Mesolithic
Eem	Shores of lakes and lagoons	Early Weichselian	Middle Paleolithic to Early Mesolithic
Drente	Remnants of moraine ridges	Saalian	Middle Paleolithic
Drachten	Aeolian, small scale fluvial and lacustrine deposits	Saalian	Middle Paleolithic

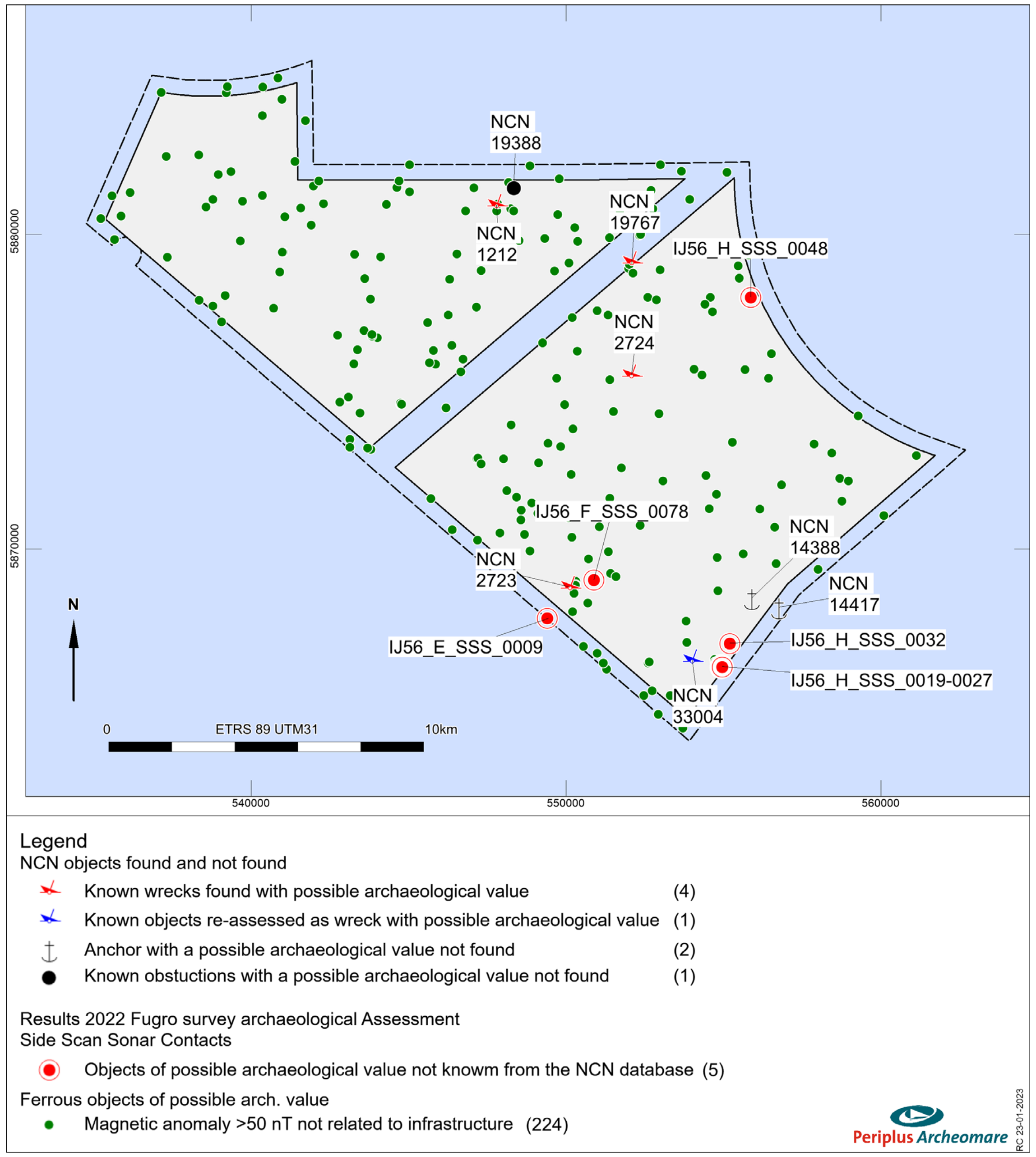


Figure 4.5.1 *Summary of the Archaeological assessment*

4.5.6 Advice

Regarding shipwrecks, shipping related objects and WWII aircraft

It is recommended to avoid seabed disturbing activities within an area of 100 m around the 237 sites of potential archaeological interest (13 exposed sites and 224 buried iron-bearing objects) until their value is determined (see Figure 4.5.1). If it is not feasible to avoid these locations, additional research is required to determine the archaeological value.

If the above mentioned 224 magnetic anomalies are part of an UXO survey, it is advised that this survey is carried out under archaeological supervision. Depending on the outcome of the UXO survey, it can be decided if additional research (for instance by means of ROV or dive investigations) is needed.

If the UXO research indicates an object has no archaeological value, the location can be omitted as a potential archaeological site. The buffer zone may be reduced with Rijkswaterstaat approval, based on evidence that the applied disturbance has no effect on the archaeological object.

Regarding prehistoric landscapes and related archaeological remains

It is recommended that vibrocore and borehole samples are collected to further assess the (integrity of) aquatic and terrestrial prehistoric landscapes and related archaeological remains. The proposed locations for vibrocore (7) and borehole sampling (1) are shown in Figure 4.5.2.

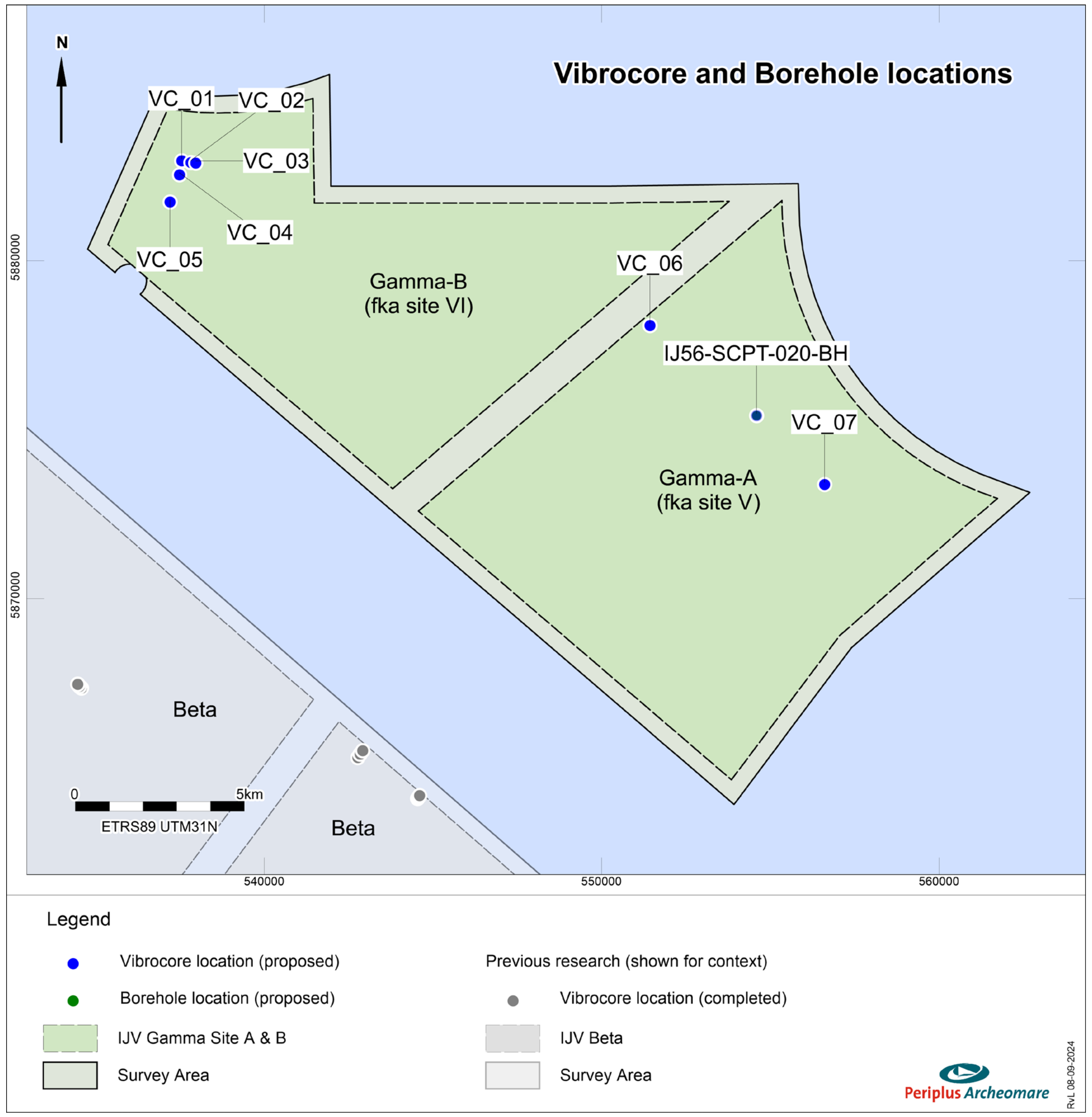


Figure 4.5.2 *Proposed locations for vibrocore and borehole sampling for the assessment of prehistoric landscapes*

4.6 Baseline survey of Benthic Ecology in IJmuiden Ver Wind Farm Sites Gamma-A and Gamma-B

4.6.1 Aims and Objectives
The aim of the study is to identify which species occur in the area and whether additional research is required in relation to biodiversity, nature conservation and possibly the limitation and/or mitigation of human activities.

4.6.2 Approach
During the Geophysical campaign, 30 box corer, 30 sediment and 60 (duplicate) environmental DNA (eDNA) samples were collected to investigate benthic life. In addition, 30 water samples were collected for eDNA analysis, focused on fish.

The detailed description of the sampling method is described in Campbell, 2022 [1]. Sample locations were chosen based on potential habitat to ensure that every unique species community was sampled within IJmuiden Ver (IJV) Sites Gamma-A and -B. Within each habitat, six samples were collected.

The macrofauna analyses from the box corers were carried out in accordance with Rijkswaterstaat regulations. DNA extraction, amplification, clean-up, sequencing and data analysis were performed as described in Doorenspleet et al., 2023 [2]. For the box corer and eDNA analyses a few minor changes have taken place which are described in this report (Cuperus, 2024).

4.6.3 Supplier
Waardenburg Ecology and Marine Animal Ecology Group, Wageningen University, were contracted by RVO to conduct the benthic macrofauna and eDNA analyses.

4.6.4 Results
In the boxcorer study, 100 species of benthic macrofauna were identified, all of which are relatively common to the Brown Bank area. An average of 17 species were identified per sample, with worms (Polychaeta), amphipods (Crustacea, Amphipoda) and bivalves (Bivalvia) being the most common taxonomic groups. Very rare species were not observed.

About two-thirds of the species abundance was found in sample GS23. Sample GS23 contained a bucket full (7.5 litres) of the colonial bryozoan species *Electra pilosa agg*. Among the bryozoa, very few species that inhabit soil were found.
All locations sampled contained medium grain sand, except GS31 (fine sand). We could not find a clear relationship between the crest, slope and trench and the species composition. This can probably be explained by the fact that the sediment composition is comparable everywhere.

For sediment eDNA, in total 74 species were identified after removing non-target hits. Most DNA fragments identified matched algae and diatoms. The eDNA samples contained an average of three and a maximum of six species which could also be found with the box corer.

In total, 30 species of marine fish were found in the water samples. Many common benthic and pelagic fish species were identified.

4.6.5 Advice
For benthic research, samples full of pelagic bryozoans should not be included in the analysis.

Furthermore, eDNA-based monitoring of all benthic species from sediment samples is not recommended. Instead, it is recommended that bulk benthos samples are collected for DNA-based monitoring. If sediment eDNA is used, it will be helpful to focus on specific taxonomic groups rather than all eukaryotic species simultaneously.

4.6.6 Conclusion
Among the box core samples and eDNA samples, the differences were very small. For the box cores, only sample GS23 was different, because the floating bryozoa *Electra pilosa agg* was found in large numbers.

4.6.7 Webinar
The results of the Baseline survey of Benthic Ecology were presented and discussed at a webinar on 28 May 2024, together with the Geophysical Survey Results. Please refer to offshorewind.rvo.nl for details.

[1] Campbell, P., 2022. IJmuiden Ver Wind Farm Sites V and VI – Dutch Sector, North Sea. Field and Environmental Data Report. Environmental Sampling Locations. Fugro, Netherlands

[2] Doorenspleet, K., Jansen, L., Oosterbroek, S., Kamermans, P., Bos, O., Wurz, E., Murk, A.J., Nijland, R. (2023). The long and the short of it: Nanopore based eDNA metabarcoding of marine vertebrates works; sensitivity and specificity depend on amplicon lengths bioRxiv 2021.11.26.470087

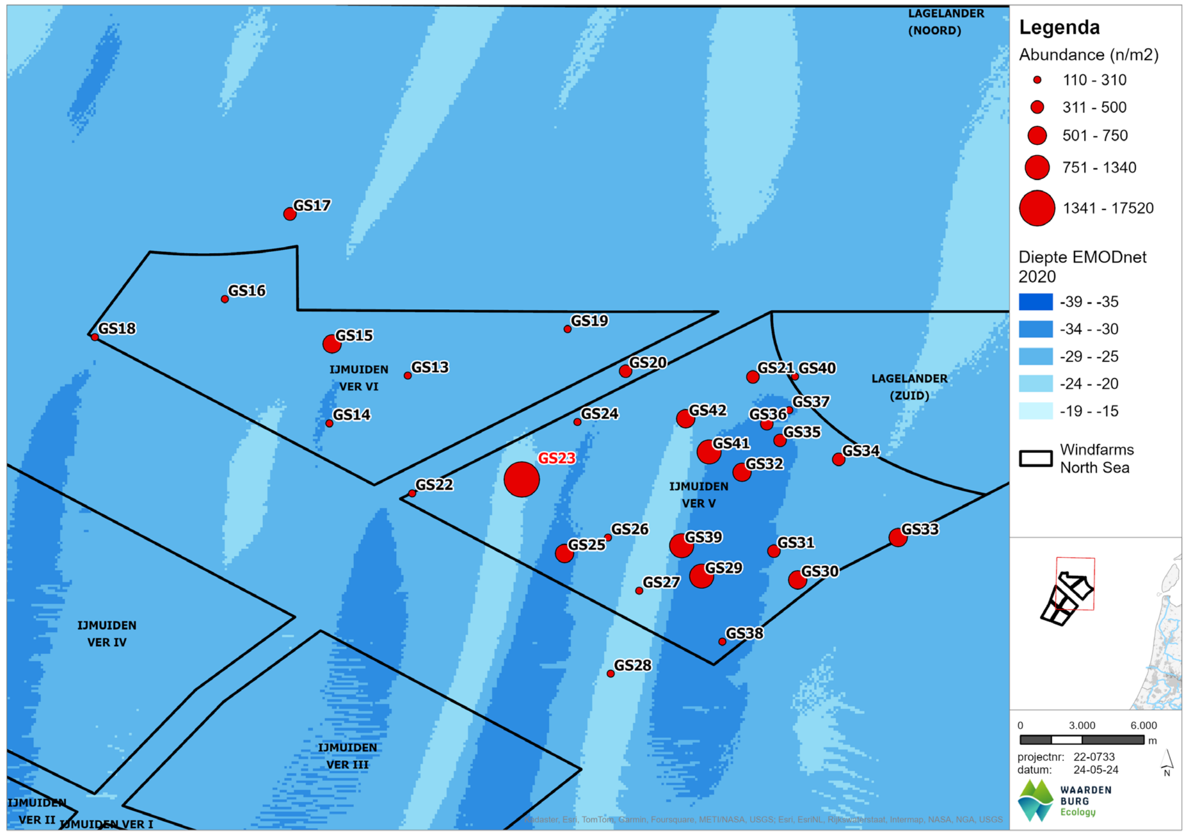


Figure 4.6.1 *Map showing abundances of specimen in IJmuiden Ver Sites Gamma-A and -B*

4.7 Geotechnical site investigation Wind Farm Sites IJmuiden Ver Gamma-A and Gamma-B

4.7.1 Overview

The Geotechnical site investigation intends to provide geological and geotechnical information for the Investigation Area (IA) for IJmuiden Ver (IJV) Wind Farm Sites Gamma-A and Gamma-B. The area investigated has been designated IJV Gamma-A and -B IA. The acquired data will allow the development of a detailed ground model of IJV Gamma-A and -B IA, which will help to progress the design and installation requirements for offshore wind farms, including, but not limited to, foundations and cables.

The Geotechnical campaign for IJV Gamma-A and -B IA used intrusive techniques to gain insight into the characteristics of the subsoil. Three types of investigation techniques were used: (1) in situ testing from the seafloor, consisting of (standard, seismic, and temperature) cone penetration testing, pore pressure dissipation testing, seismic velocity testing, and temperature equilibrium testing performed from geotechnical vessel Normand Mermaid; (2) sampling from the seafloor using a High Performance Corer® (HPC) sampling device, also performed from the Normand Mermaid; and (3) geotechnical borehole drilling with downhole sampling, in situ testing consisting of (standard and seismic) cone penetration testing, seismic velocity testing, recording of drilling parameters, and borehole geophysical logging (caliper, natural gamma radiation, spectral gamma radiation, P and S suspension logger, downhole magnetic resonance) performed from geotechnical drilling vessel Fugro Voyager. Onsite geotechnical laboratory testing was performed on recovered samples. An office programme of geotechnical laboratory testing and reporting of results followed the site phase.

The site investigation at IJV Gamma-A and -B IA comprised the following:

- A total of 73 seafloor piezocone penetration tests (PCPTs) at 65 target locations to depths ranging from 8.9 m to 55.6 m below seafloor (BSF). Twenty-six (26) tests include pore pressure dissipation tests (PPDTs) at selected depths within the seafloor PCPT stroke;
- A total of 30 seafloor seismic cone penetration tests (SCPTs) at 25 target locations to depths ranging from 9.5 m to 46.4 m BSF. Twenty-nine (29) tests include seismic velocity tests (SVTs) at selected depths within the seafloor SCPT stroke;
- A total of 33 seafloor temperature cone penetration tests (TCPT) at 25 target locations to depths ranging from 0.3 m to 6.4 m BSF. Thirty-two (32) tests include temperature equilibrium tests (TETs) at selected depths within the seafloor TCPT stroke;
- A total of 65 vibrocores at 60 target locations to depths ranging from seafloor to 6.4 m BSF;
- A total of 66 geotechnical boreholes at 36 target locations to depths ranging from seafloor to 60.8 m BSF. Boreholes including any combination of the following: open hole rotary drilling, recording of drilling parameters, downhole in situ testing, downhole (over)sampling, or alternating downhole in situ testing and (over)sampling, and/or borehole geophysical logging;
- Ten boreholes included sampling for biogeochemical analyses and 13 boreholes included sampling for geological dating analyses;
- Five boreholes at five target locations included borehole geophysical logging.

The term 'location' used in this document refers to a specified target location. A location can consist of a single or multiple boreholes, test points or sample points whereby the term 'borehole' is defined as a geotechnical borehole with associated downhole sampling, downhole in situ testing and/or borehole geophysical logging, 'test point' as a seafloor cone penetration test (CPT) and 'sample point' as a sampling from seafloor operation. Boreholes, test points and sample points designated with a suffix 'A' or 'B' refer to additional operations at a specific location.

An overview of the standard and advanced laboratory test programmes can be found in Table 4.7.1 and Table 4.7.2. Note that determinations of water content and unit weight, and torvane and pocket penetrometer tests, are not presented in these tables.

Table 4.7.1 *Overview of Standard Laboratory Test Programme*

Test Type	Test Quantity
Geotechnical Index	
Plasticity index	165
Particle size distribution: image analyses	382
Particle size distribution: sieve	430
Particle size distribution: sedimentation	320
Particle density	246
Minimum and maximum index dry density: (modified) shaker method	396
Microscopy	302
Geochemical	
Organic matter	159
Loss on ignition	55
Total organic carbon	154
Carbonate content of soil	164
Salinity (calculated)	36
Strength and Stiffness	
Consolidated Drained (CD) triaxial in compression	786
Consolidated Undrained (CU) triaxial in compression	20
CU triaxial in compression – with bender element measurements	20
CU triaxial in compression – with cyclic pre-shear	6
CU triaxial in compression – with cyclic pre-shear and with bender element measurements	47
CU triaxial in extension	19
Dynamic Response	
Resonant column	95
Interface Shear	
Ring shear – soil/soil interface	33
Ring shear – soil/steel interface	34
Direct simple shear (DSS) under constant volume	33
DSS under constant volume – with cyclic pre shear	21
DSS under constant stress – with cyclic pre shear	19
One-dimensional Consolidation	
Incremental loading	98
Constant rate of strain	30
Permeability	
Constand head permeability – permeameter	79
Constand head permeability – triaxial cell*	14
Other	
Electrical resistivity	35
Thermal conductivity – needle probe	144
Thermal conductivity – hot disk	8
Age dating	128†
Microbiologically influenced corrosion	10

Notes
* = Performed in triaxial cell as standalone test
† = Various analyses performed

Table 4.7.2 *Overview of Advanced Laboratory Test Programme*

Test Type	Test Quantity*
Geotechnical Index	
Plasticity index	1
Particle size distribution: sieve	7
Particle size distribution: sedimentation	7
Particle density	6
Minimum and maximum index dry density: (modified) shaker method	6
Geochemical	
Organic matter	3
Carbonate content of soil	3
Strength and Stiffness	
CD triaxial in compression	9
CD triaxial in compression – with cyclic pre-shear and with bender element measurements	6
CD triaxial in extension – with cyclic pre-shear and with bender element measurements	6
CU triaxial in compression	13
CU triaxial in compression – with cyclic pre-shear and with bender element measurements	6
CU triaxial in extension – with cyclic pre-shear and with bender element measurements	6
Dynamic Response	
Resonant column	9
Interface Shear	
Ring shear - soil/steel interface	9
DSS under constant volume – with cyclic pre-shear	9
DSS under constant stress – with cyclic pre-shear	9
One-dimensional Consolidation	
Incremental loading	9
Permeability	
Constand head permeability – permeameter	9
Constand head permeability – triaxial cell†	-
Cyclic Strength and Response – Triaxial	
CU cyclic triaxial	14
CU cyclic triaxial – with cyclic pre-shear	60
CD cyclic triaxial	18
Cyclic Strength and Response – Direct Simple Shear (DSS)	
Cyclic DSS under constant volume	12
Cyclic DSS under constant volume – with cyclic pre-shear	63

Notes
* = Number of scheduled tests at time of publishing
† = Performed in triaxial cell as standalone test

4.7.2 Supplier

Fugro was contracted to perform this Geotechnical site investigation, which was performed according to ISO 19901-8:2014 and conducted in two separate phases. The seafloor phase was performed from geotechnical vessel Normand Mermaid between 16 February and 29 March 2023. The downhole phase was performed from geotechnical drilling vessel Fugro Voyager between 5 June and 14 August 2023, on 19 December 2023, and from 12 to 20 February 2024.

A SEACALF® 20 tons MkV Constant Drive System (CDS) was used for seafloor in situ testing. PCPTs, SCPTs and PPDTs were performed using piezocone penetrometers with a 1500 mm² cone tip area. TCPTs were performed using temperature cone penetrometers with a 1500 mm² cone tip area. The SEACALF® CDS provided a reliable, safe and efficient test unit for high quality data acquisition. Sampling from the seafloor was performed using a High Performance Corer® sampling device equipped with a 6.4 m core barrel and an inner PVC liner to contain the sample.

The geotechnical boreholes were performed using open hole rotary drilling in combination with Pure Bore®, bentonite and/or water as drill fluids. Borehole drilling included the use of a SEACLAM MK2 seabed frame to facilitate re-entry of the drill string in the borehole and for axial and lateral support of the drill string at seafloor. Downhole push sampling and in situ testing employed WIPSAMPLER® and WISON® downhole tools. The sampler was fitted with flush stainless steel Shelby tubes. Downhole tools were operated and retrieved by a hydraulic-electrical umbilical system which provides real-time control of the in situ testing and sampling process. Downhole CPTs were performed using cone penetrometers with a 1000 mm² or 500 mm² cone tip area. Downhole SCPTs were performed using dual array seismic cone penetrometers. The seismic source consisted of a hydraulic underwater shear wave hammer, consisting of a spring-driven steel mass hammered to a steel striking plate, mounted on the seabed frame.

For a selection of geotechnical boreholes, following completion of open hole drilling, downhole sampling and/or in situ testing, the drill bit was pulled up to a minimum safe depth with respect to the risk of borehole collapse. This allowed open hole acquisition of borehole geophysical data by lowering the downhole geophysical tools through the bit into the open hole. At each location multiple runs were executed, employing a suite of wireline conveyed downhole geophysical tools (caliper, natural gamma radiation, spectral gamma radiation, P and S suspension logger, downhole magnetic resonance).

4.7.3 Results

Results of the Geotechnical site investigation are presented in the following reports:

- A geotechnical report containing geotechnical logs based on CPT results and results from seafloor in situ testing, including:
  - Interpretation of soil profiles and CPT-derived parameters including relative density and undrained shear strength;
  - Measured and derived CPT parameters including cone resistance, sleeve friction, pore pressure, temperature, friction ratio, pore pressure ratio, where applicable;
  - Results of SVTs, i.e. recorded seismic traces (X- and Y- channel) and derived shear wave velocity and small strain shear modulus;
  - Results of TETs, i.e. temperature versus time and derived thermal conductivity;
  - Results of PPDTs, i.e. cone resistance and pore pressure versus time.

Figure 4.7.1 presents an example of a geotechnical log based on CPT results.

- A geotechnical report containing geotechnical logs and results from seafloor sampling and laboratory testing, including:
  - Interpretation of soil profile and strata descriptions based on available data sources, including sample descriptions and laboratory tests;
  - Results of laboratory tests.

Figure 4.7.2 presents an example geotechnical log based on results from seafloor sampling, in situ testing and standard laboratory testing.

- A geotechnical report containing geotechnical logs and results from downhole sampling and in situ testing, borehole geophysical logging and standard laboratory testing, including:
  - Interpretation of soil profiles, strata descriptions and CPT-derived parameters including relative density, undrained shear strength and effective angle of internal friction;
  - Measured and derived CPT parameters including cone resistance, sleeve friction, pore pressure, friction ratio and pore pressure ratio, where applicable;
  - Results of SVTs, i.e. recorded seismic traces (X- and Y- channel) and derived shear wave velocity and small strain shear modulus;
  - Results of borehole geophysical logging including natural gamma radiation measurements, caliper measurements, spectral gamma radiation measurements, P- and S-wave velocities, as well as derived porosity, derived hydraulic conductivity and derived soil unit weight;

- Results of laboratory tests;
- An examination report containing an estimation of microbially influenced mass loss rates of steel-based foundation structures in marine sediments on the basis of chemical and microbiological soil parameters.

Figure 4.7.3 presents an example geotechnical log based on results from downhole sampling, in situ testing and standard laboratory testing.

- A geotechnical report containing results of the advanced laboratory testing programme, including:
  - Results of geotechnical and geochemical index tests;
  - Results of static triaxial tests;
  - Results of monotonic direct simple shear tests;
  - Results of permeability tests;
  - Results of resonant column tests;
  - Results of one-dimensional compression tests;
  - Results of interface ring shear tests;
  - Results of cyclic triaxial tests;
  - Results of cyclic direct simple shear tests;

- A dating analysis report containing results of dating analyses and results of a geochronology and paleoenvironmental assessment for selected seafloor sample locations.

- A dating analysis report containing results of dating analyses and results of a geochronology study for selected geotechnical borehole locations.

In addition to the above, digital data files accompanying the various reports are also issued. These data files comprise the following data types:
- AGS 4.0: Geotechnical borehole data;
- AGS 4.1: CPT data;
- ASCII: SVT data, TET data, PPDT data, particle shape data;
- ACI: shear wave velocity trace data;
- LAS: borehole geophysical logging data;
- Excel: coordinates and water depths, overview of laboratory test results, individual laboratory test results.

4.7.4 Webinar
The results of the Geotechnical site investigations performed at IJV Gamma-A and -B IA will be presented and discussed in a webinar to be held in Q1 2025.
Please refer to offshorewind.rvo.nl for details.

4.7.5 Conclusion
The Geotechnical site investigation and associated laboratory testing programme provide high quality geotechnical data suitable for improving the geological and geotechnical understanding of IJV Gamma-A and -B IA and to progress the design and installation requirements for offshore wind farms, including, but not limited to, foundations and cables. The samples remaining after the laboratory testing phase will be available to the tender winners, e.g. to perform additional testing. The reports were certified by DNV.

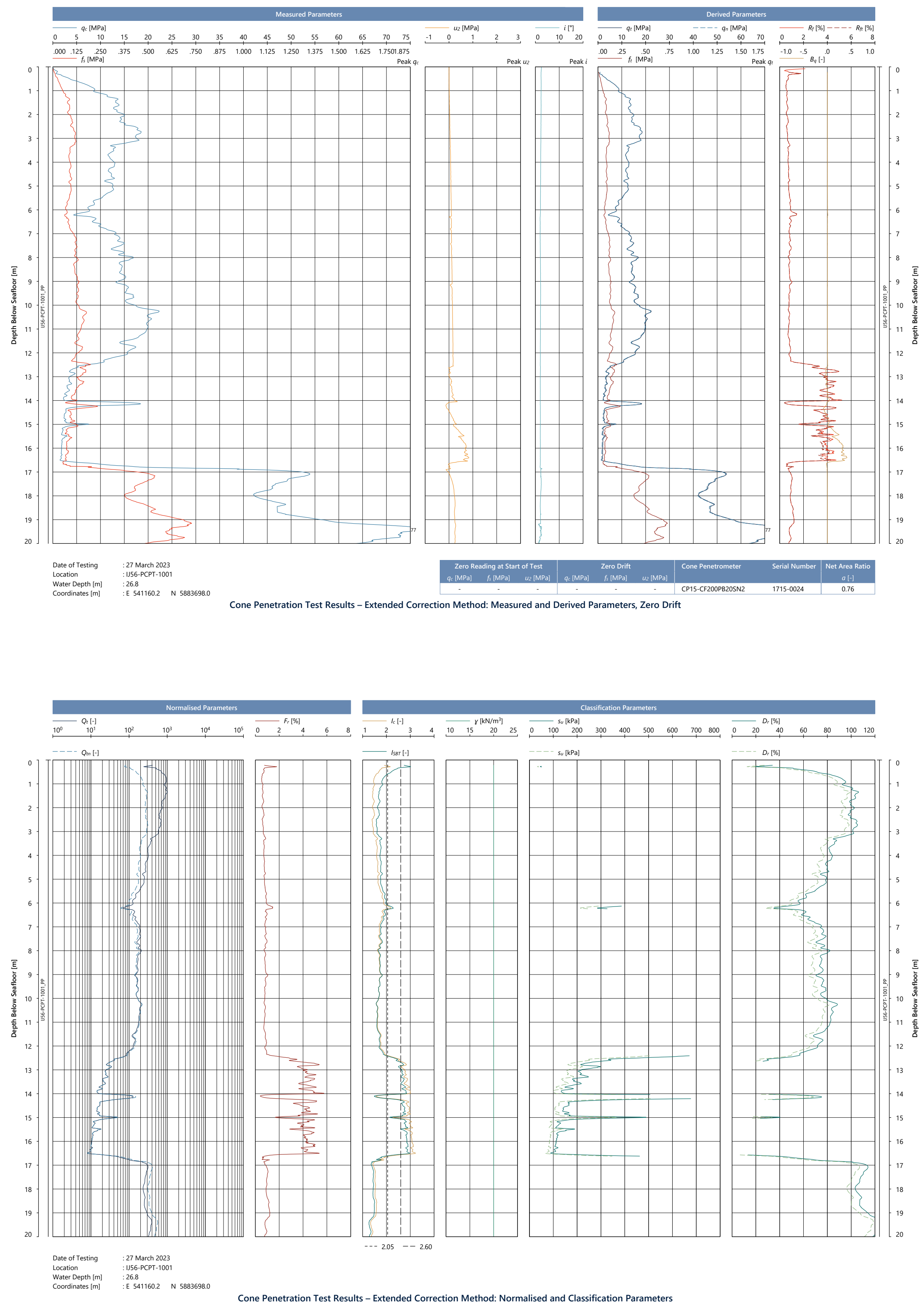
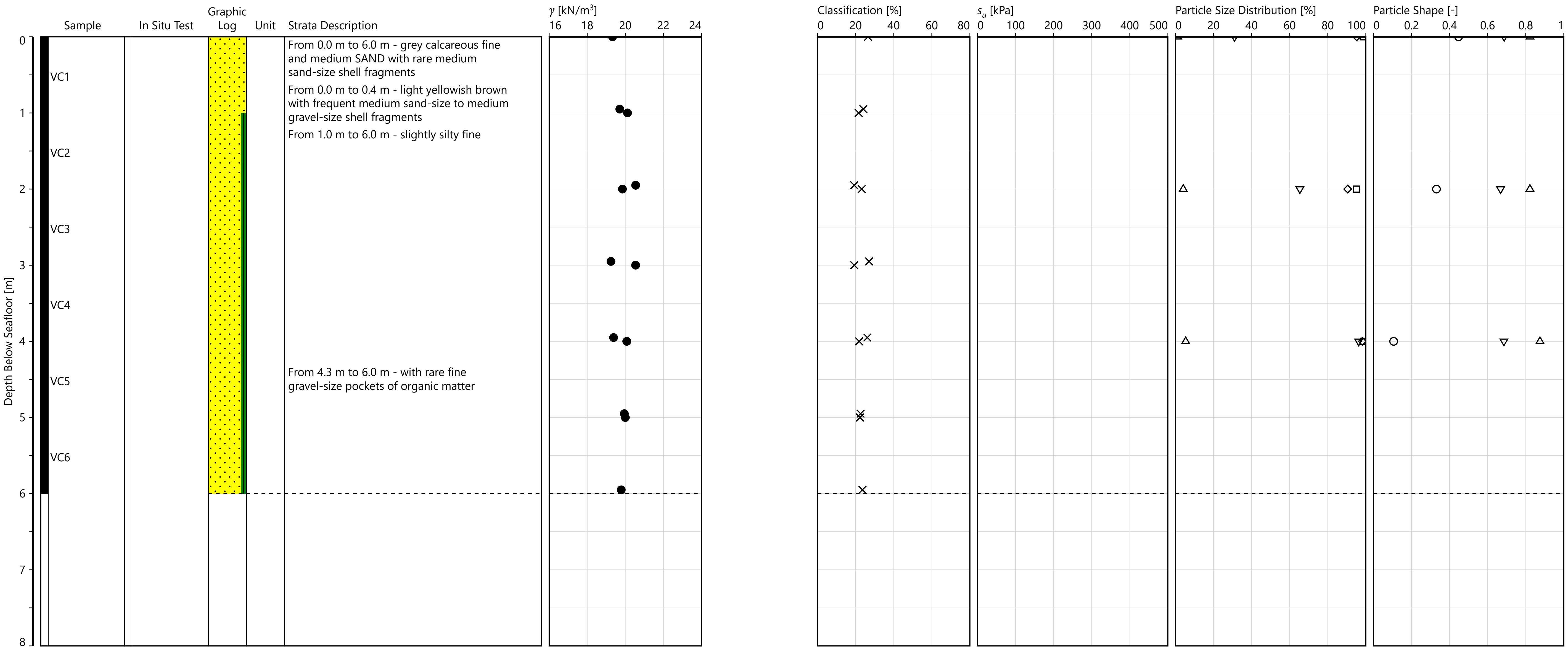


Figure 4.7.1 *Geotechnical log presenting interpretation of soil profile and measured and derived parameters based on CPT results*



Start date : 27 February 2023
Deployment method : Vibrocore sampling
Recovery depth : 6.0 m below seafloor
Penetration depth : 6.0 m below seafloor
Water depth : 27.7 m
Coordinates : E 538173 m N 5884188 m

Sample Point/Test Point
IJ56-VC-4121

● Unit weight from water content

× Water content

Slashed symbol refers to test on remoulded soil

△ Percentage < 0.063 mm
▽ Percentage < 0.2 mm
◇ Percentage < 0.63 mm
□ Percentage < 2 mm

○ Mean Krumbein roundness
△ Mean sphericity
▽ Mean Krumbein sphericity

Figure 4.7.2 *Geotechnical log presenting interpretation of soil profile, strata descriptions, measured and derived parameters based on in situ test data (TCPT), sampling and laboratory test results*

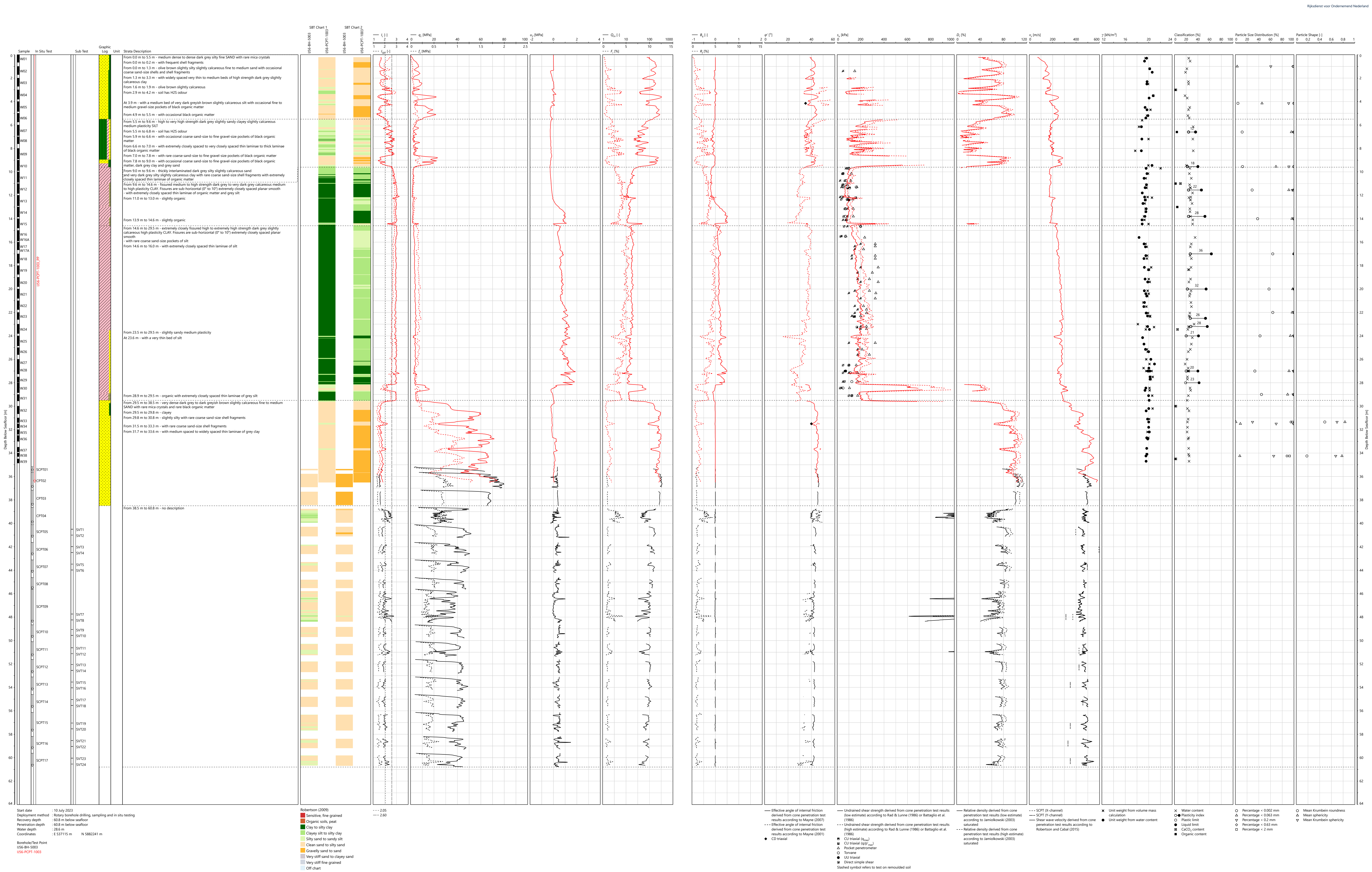


Figure 4.7.3 *Geotechnical log presenting interpretation of soil profile, strata descriptions, measured and derived parameters based on in situ test data (CPT and SVT), sampling and laboratory test results*

4.8 Integrated Ground Model and Geotechnical Interpretative Report IJmuiden Ver Wind Farm Sites Gamma-A and Gamma-B

4.8.1 Overview - aims, objectives, and approach
The primary aim of the integrated ground model (IGM) is to quantitatively predict characteristic soil parameters and their uncertainty in 3D across the wind farm development zone. Such a quantitative ground model can then be used by developers for preliminary wind turbine foundation and cable design.

The IGM is the final output from a data-driven ground modelling workflow which consists of three main elements: the geological ground model (GGM); the geotechnical interpretation report (GIR); and, ultimately, the integrated ground model (IGM).

The first step is to develop a consistent GGM based on the integrated interpretation of the geological history of the site, the geophysical data and geotechnical borehole and cone penetration test (CPT) data. The GGM defines the soil units across the area. These soil units are used in the geotechnical interpretation to calibrate relevant soil parameters for each soil unit. The GGM and the geotechnical interpretation are then used to predict CPTs across the whole site, which are subsequently transformed into soil parameter predictions.

An important part of the development of the IGM is to properly incorporate the different uncertainty sources that propagate through the workflow. All soil parameters are therefore presented with associated uncertainties. These uncertainty estimates are evaluated using blind predictions (cross-validations).

4.8.2 Supplier
The Norwegian Geotechnical Institute (NGI) was awarded the contract by RVO to create the IGM for IJmuiden Ver (IJV) Wind Farm Sites Gamma-A and Gamma-B. All the necessary work related to the IGM was performed by NGI and its subcontractor SAND Geophysics (SAND).

4.8.3 Results
The systematic development of the GGM for IJV Gamma-A and -B is the first part of the IGM. It combines geophysical and geotechnical data in order to define a sequence of seismostratigraphic (sub-)facies that are characterised in terms of the seismic architecture, basic lithology and chronostratigraphic origin. These units capture the complex geological evolution of the study area through four principal phases.

These phases are listed below in chronological order, from base to top:
1. Pre-Elsterian; Yarmouth Roads Formation.
2. Elsterian; Peelo Formation.
3. Holsteinian and early Saalian; Egmond Ground and Urk Formations
4. Holocene; Naaldwijk, Southern Bight, Kreftenheye and/or Singraven Member

This stratigraphic interpretation is complemented with a geological hazard analysis which takes into account the spatial variability of soil properties, post-depositional deformation, boulder density and free gas potential. The implications of these were placed into a context appropriate for both cable design/installation and infrastructure foundation design/installation.

A probabilistic seismic hazard assessment carried out for the sites revealed that the peak ground acceleration (PGA) values for IJV Gamma-A and -B are less than the values for the Investigation Areas at Hollandse Kust (west) and IJV WFS Alpha and Beta and similar or a bit larger than for Ten noorden van de Waddeneilanden, which was expected based on past regional studies.

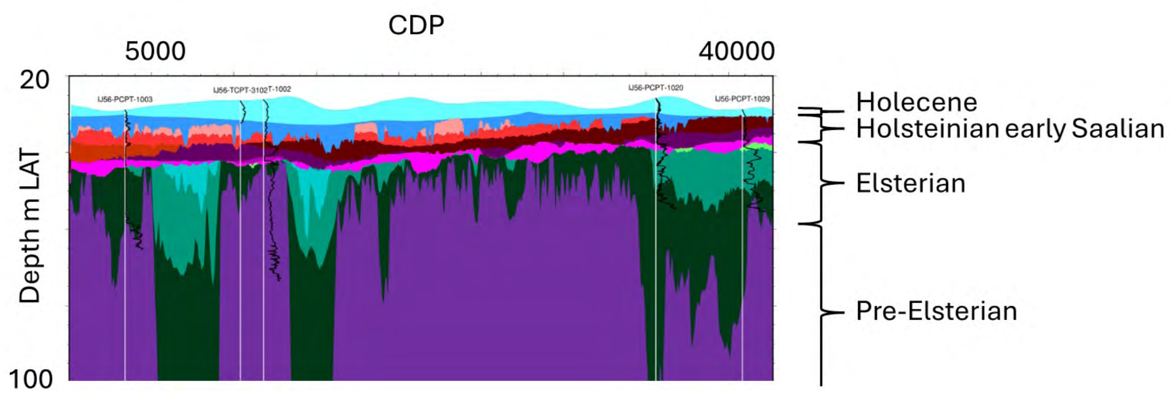


Figure 4.8.1 *Shows a conceptual cross section through the IJV Gamma-A and -B ground model*

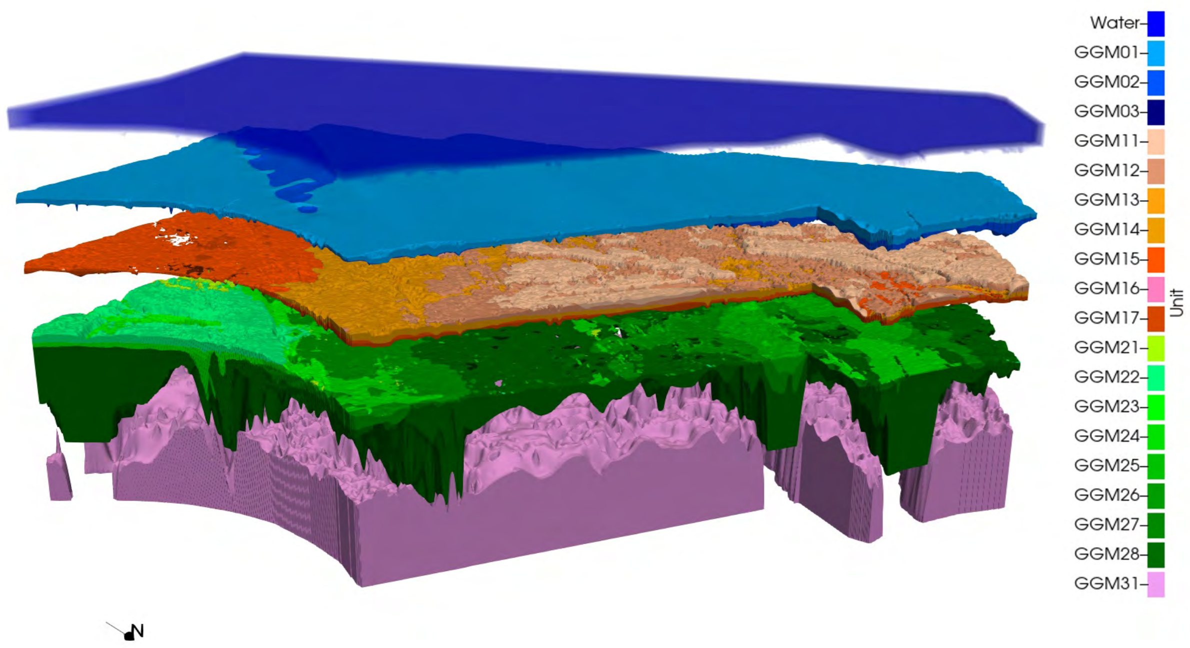


Figure 4.8.2 *Overview of the geological ground model*

The GIR, scheduled to be published in 2025, presents the interpretation and evaluation of the data from boreholes with sampling, vibrocores and CPTs carried out during two site investigation campaigns.

The main interpretation and evaluation work includes: (i) an approach for the selection of characteristic geotechnical parameters; (ii) geotechnical descriptions of soil units corresponding to the ground model, based on additional soil classification test data, see Table 4.8.1; and (iii) an evaluation of data and results, with interpretation methods and procedures. The developed site-specific CPT correlations are particularly important for the integrated ground model.

Ultimately, the IGM allows the development of geotechnical design profiles at any location within IJV Gamma-A and -B. The IGM report (when completed) presents three different ways with increasing complexity to do this:
1. **Geotechnical design profiles for zones:** The evaluation of zones and the corresponding geotechnical profiles and tables are given in the IGM report.
2. **Geotechnical design profiles for borehole/CPT locations:** A description on how to generate the geotechnical design profiles at the BH/CPT locations, is presented in the report. Soil layering per BH/CPT location is given in the GIR.
3. **Geotechnical design profiles for non-borehole/CPT locations**: A description on how to generate the geotechnical design profiles using the digital deliveries is given in the report. To generate profiles in the complete area of IJV Gamma-A and -B, the accompanying digital deliverables are required.

To create a detailed 3D IGM, the following steps were performed:
1. Developing a structural model based on soil units and layering from the GGM and GIR;
2. Assess uncertainties in the structural model;
3. Testing of different CPT prediction models and their associated uncertainties;
4. Based on the evaluations, two models for predicting CPT were selected:
   a. A simple model based on linear fitting of CPT values at CPT locations and kriging of the associated slope and intercept between CPT locations. The kriging of slope and intercepts were done per soil unit as given in the structural model;
   b. An advanced model based on acoustic impedance (AI) inversion and an artificial neural network (ANN) to predict CPT values along seismic lines:
5. Define zonation across IJV Sites Gamma-A and -B with a similar foundation response;
6. Development of geotechnical design profiles for a selected BH/CPT location within each zone.

Table 4.8.1 *Geotechnical description of the identified soil units*

Unit	Age	Formation	Main soil component
GGM01	Holocene	Southern Bight	Sand
GGM02	Holocene	Naaldwijk (possibly Kreftenheye/ Singraven)	Sand
GGM03	Holocene	Kreftenheye/Singraven)	Sand
GGM11	Weichselian	Kreftenheye	Transitional
GGM12	Weichselian	Kreftenheye	Sand
GGM13	Eemian	Eem	Clay
GGM14	Saalian	Urk/Drachten	Sand
GGM15	Saalian	Urk/Drachten	Sand
GGM16	Holsteinian	Egmond Ground	Clay
GGM17	Holsteinian	Egmond Ground	Sand
GGM21	Late Elsterian/ Early Holsteinian	Appelscha	Sand
GGM22	Late Elsterian/ Early Holsteinian	Appelscha	Transitional
GGM23	Late Elsterian/ Early Holsteinian	Appelscha	Clay
GGM24	Late Elsterian	Peelo/Appelscha	Transitional
GGM25	Elsterian	Peelo	Sand
GGM26	Elsterian	Peelo	Sand
GGM27	Elsterian	Peelo	Clay
GGM28	Elsterian	Peelo	Sand
GGM31	Cromerian	Yarmouth Roads	Sand

The most advanced CPT prediction model follows a two-step approach. First, a genetic algorithm (GA) to perform AI inversion for all seismic data was used, as well as deriving a complementary set of seismic attributes (e.g., Q, instantaneous attributes). Subsequently, these attributes were fed into an ANN and trained for CPT prediction. The combination of the GA and ANN allows the prediction of the CPT parameters in a stochastic manner, capturing an estimate of the uncertainty as part of the process. Figure 4.8.3 shows an example of the best estimate prediction of CPT parameters along a small part of a seismic line. The high degree of accuracy of the prediction model and the associated uncertainty allows for high-quality CPT predictions along all seismic lines. All these predictions are included in the digital deliveries.

The IGM deliverables consist of a technical report as well as a series of digital deliverables that are needed to establish geotechnical design profiles for the entire 3D area. Such profiles can be established using the structural model that defines the soil unit volumes, the CPT prediction model, the soil unit soil parameters, and the CPT-based relationships developed in the GIR. The report presents a stepwise and detailed description on how to establish geotechnical design profiles based on the digital delivery.

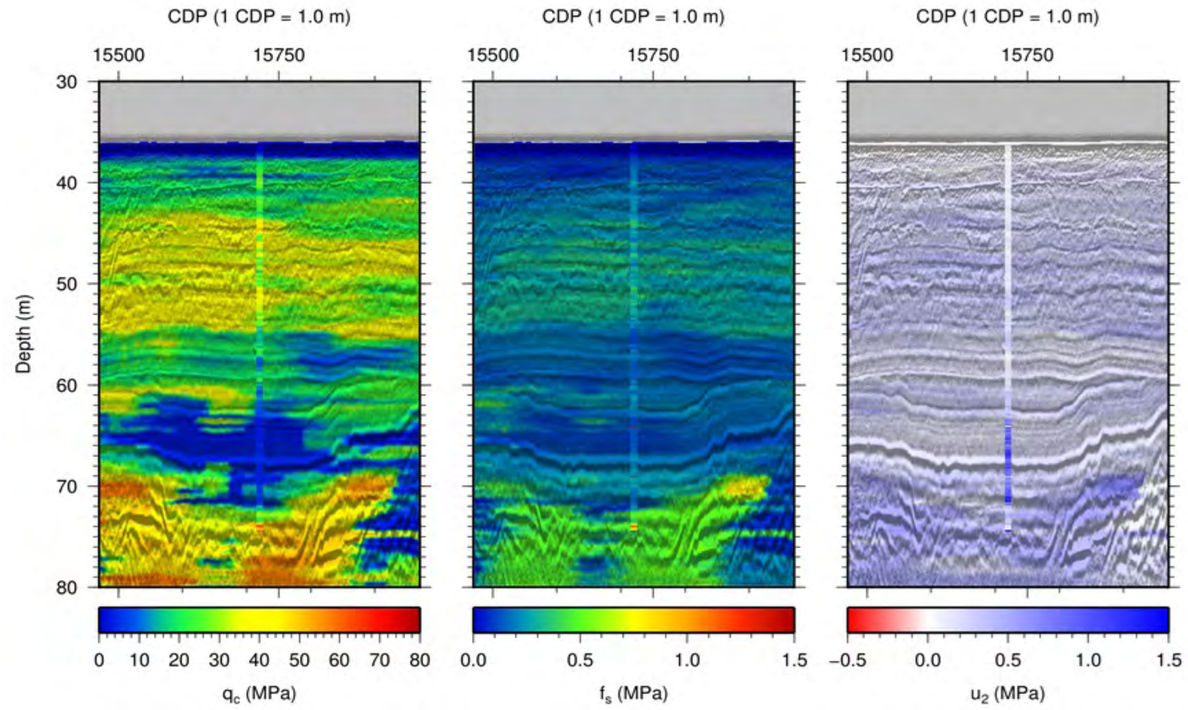


Figure 4.8.3 *Blind CPT prediction on part of a seismic line. The central line presents the measured colour-coded CPT response at the given site (which was excluded in the training of the CPT prediction model)*

4.8.4 Deliverables

The results of the IGM are summarised in three reports:
1. Geological ground model (publication end of 2024);
2. Geotechnical interpretation (publication planned in Q2 2025);
3. Integrated ground model (publication planned in Q2 2025).

These reports, together with a set of digital deliverables, form the basis of the integrated foundation model. The digital delivery includes:
- Kingdom project in depth domain including CPTs, geotechnical layering interpretation, interpreted seismic horizons, the structural model (3D), and the predicted CPT tip resistance.
- ArcGIS project in depth
- Reprocessed 2D SEG-Y files
- ASCII files with horizons

4.8.5 Webinar

The study results will be presented and discussed during webinars. Refer to offshorewind.rvo.nl for details.

4.9 Morphodynamics and Scour Mitigation assessment IJmuiden Ver Wind Farm Zone

4.9.1 Study Overview

This desk study comprises two parts: i) site morphodynamics and ii) scour mitigation. The assessment of site morphodynamics addresses autonomous seabed dynamics in the entire IJVWFZ. The second part provides general considerations on how to deal with scour development and scour mitigation in IJVWFZ, taking into account the morphodynamics of the area and a range of potential foundation types. In addition, general considerations for cable routing in a morphodynamically active environment are provided. The analysis utilises and relies upon existing historical data and newly acquired data collected during recent site-specific surveys commissioned by RVO.

The aim of this combined study was to:

1. Assess site morphodynamics and characterise the seabed at IJVWFZ;
2. Characterise the shallow geological and sedimentological site conditions to a depth of 20 m below the measured seabed level as well as the seabed features at the IJVWFZ;
3. Predict the change in seabed levels at IJV over the lifetime of a wind farm (considered period: 2020 – 2072) to support the design, installation and maintenance of wind turbines, inter array cables, platforms and their support structures.
4. Provide guidance on the depths at which UXOs may be encountered, based on a hindcast of historic seabed levels (1945-2022);
5. Describe scour conditions that may be expected at IJVWFZ for typical wind farm-related structures;
6. Provide a state-of-the-art overview of scour mitigation measures and their applicability at IJVWFZ for various foundation types;
7. Provide guidance on how the site morphodynamics could be accounted for in the selection and design of wind farm infrastructure, cable routing and scour mitigation strategies.

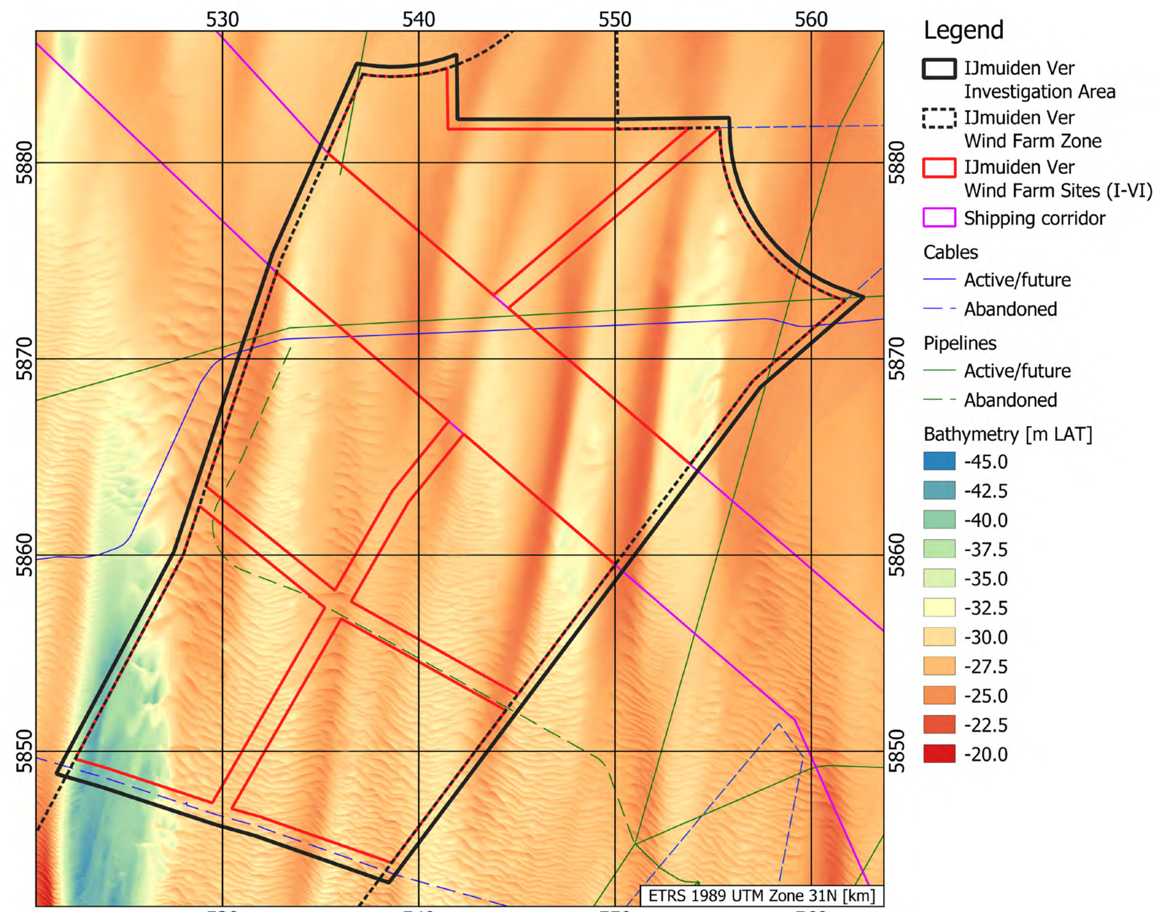


Figure 4.9.1 *Map view of the IJVWFZ bathymetry as measured during the most recent surveys*

The information presented should provide prospective developers with a detailed understanding of site morphodynamics and scour risk suitable to assist with the design, installation and maintenance of wind turbines, inter-array cables, substations and their support structures.

In recent years, methods and tools have been improved through the past morphodynamic and scour studies in the area. These improvements have been incorporated in the present study. Compared to Hollandse Kust (west) and Ten noorden van de Waddeneilanden, the analysis was extended with probabilistic ranges in historic trends, new methods for extrapolation of seabed levels, updated cable routing methodology and the inclusion of the impact of an extreme event on the seabed based on hydrodynamic and wave modelling. For scour mitigation strategies, more emphasis and detail is given to eco-friendly scour protections.

4.9.2 Supplier

Research institute Deltares was awarded the contract by RVO to conduct this desk study for the IJVWFZ. Deltares has considerable experience in these types of studies having previously conducted morphodynamic studies for other offshore wind farms in the Dutch North Sea region, including Hollandse Kust (west, noord and zuid), Ten noorden van de Waddeneilanden, and Borssele, and various wind farm sites in the wider North Sea, Irish Sea, US East Coast, Taiwan Strait and the Baltic Sea. In addition, Deltares has performed scour assessments, developed scour mitigation strategies and executed physical model testing campaigns for many offshore wind farm sites in the North Sea, Irish Sea, US East Coast, Taiwan Strait and the Baltic Sea and for various TenneT platforms in the Dutch and German North Sea.

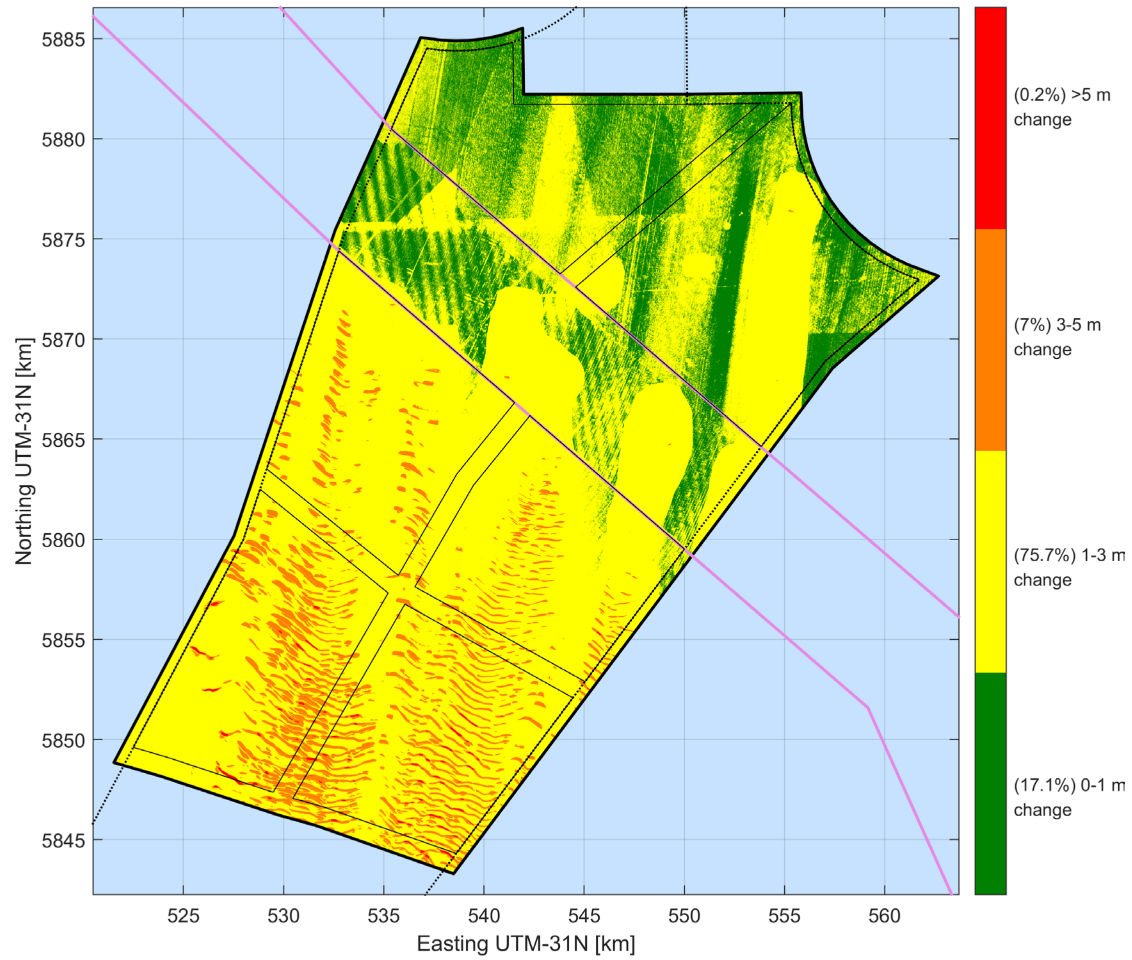


Figure 4.9.2 *Classification of seabed level changes (in metres) that have been predicted*

4.9.3 Results of the Morphodynamic assessment

The bathymetry in IJVWFZ has a non-uniform morphology including several prominent sand banks influencing sand wave dynamics. Sand waves, with megaripples on top, are found in IJVWFS Alpha and IJVWFS Beta. These features display a pronounced asymmetry towards the north-northeast indicating migration in that direction (Figure 4.9.1). The seabed in IJVWFS Gamma is almost entirely devoid of sand waves and megaripples.

Considering the entire IJVWFZ the sand waves have wavelengths in the range of 170 to 620 m, heights of 0.9 to 3.5 m and migration speeds up to 2.7 m/year with a median speed of 1.6 m/year. Locally, sand waves are higher in IJVWFS Alpha and longer in Site Gamma (although here only a few sand waves are found). Spatial variability in migration rates and directions are assumed to be attributable to the presence of sand banks. On the western slope of the sand bank migration rates are highest, whereas sand waves on the eastern slopes are migrating at a slower rate. An analysis of the large-scale seabed variations shows that the underlying seabed may be considered broadly static over the lifetime of the wind farm. geological and geophysical data indicates that non-erodible layers exist, but that they are located too deep to influence the sand wave migration. A numerical analysis of the prevailing hydrodynamic and sediment transport regime in the area indicated that the net sediment transport is aligned with the residual tidal flow and is directed towards the north-northeast. Directions of transport generally agree with the observed migration direction of sand waves. Simulation of storms with a return period of 50 and 100 years demonstrated that the impact of extreme events on the seabed across IJVWFZ is limited and that sediment transport is mostly tidally driven.

Based on the morphodynamic analysis, the Best Estimate Bathymetry (BEB), predicted lowest seabed level (LSBL) and predicted highest seabed level (HSBL) were determined for different timesteps across the lifetime of the wind farm. The LSBL and HSBL indicate, respectively, the lowest and highest seabed levels that are predicted to occur during the lifetime of the wind farm (2020-2072). These seabed levels include a spatially and temporally varying uncertainty analysis. Finally, classification zones were provided grouping predicted seabed level changes to several classes (See Figure 4.9.2).

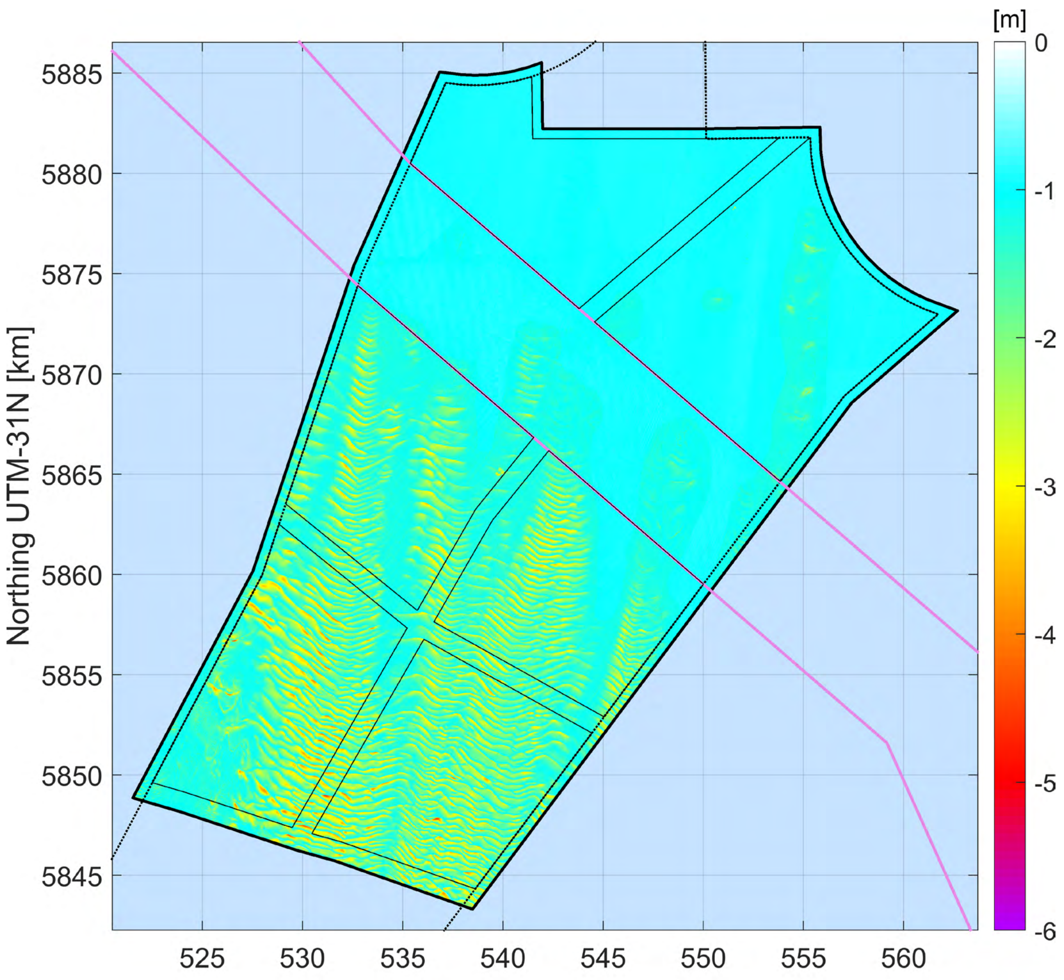


Figure 4.9.3 *Predicted seabed lowering (in metres) over the period 2020 to 2072 including uncertainties*

Comparison of the LSBL with the most recent measured bathymetry from 2020-2022 shows a predicted maximum local seabed level lowering of approximately -3.6 m as the 99.9%-non exceedance value. As expected, the largest lowering is found at the location of the existing sand wave crests, while minimal lowering is experienced at the location of the sand wave troughs. The most significant seabed lowering was found at IJVWFS Alpha (respectively -3.7 and -3.9 m as the 99.9% non-exceedance value), where sand waves are highest. Seabed lowering in IJVWFS Gamma (respectively -1.2 and -1.9 m as the 99.9% non-exceedance value) is predicted to be significantly lower compared to IJVWFS Alpha and IJVWFS Beta because of the absence of sand waves.

Comparison of the HSBL with the most recent measured bathymetry from 2020-2022 shows a bathymetric shape similar to the existing static part of the bathymetry, but typically several metres higher with +5.5 m as the 99%-non exceedance value. Opposite to seabed lowering, the largest potential rise seabed level is found at the current locations of the troughs just in front of the steep sand wave lee sides, with minimal rising at locations of the present sand wave crests.

The most significant seabed rise was found at IJVWFS Alpha (respectively 5.8 and 7.0 m as the 99.9% non-exceedance value), where sand waves are highest. Seabed rise in IJVWFS Gamma (respectively 1.2 and 2.3 m as the 99.9% non-exceedance value) is predicted to be significantly lower compared to IJVWFS Alpha and IJVWFS Beta because of the absence of sand waves.

Furthermore, a hindcast of seabed levels is made to assess the possible levels at which Unexploded Ordnances (UXOs) may be located. An important assumption in this method is that an UXO will never travel upwards and a typical UXO will self-bury to about half its height. To take into account the full range of possible object levels, the Lowest Object Level (LOL), the Highest Object Level (HOL) and the Best-Estimate Object Level (BEOL) over the period 1945-2022 were calculated.

The predicted seabed level changes presented in this study follow from the applied morphological analysis techniques, describing the physics and the natural variability of the analysed morphological system. No additional safety margins for design purposes have been applied. To support developers, this report discusses general considerations for cable routing in IJVWFZ. It is expected

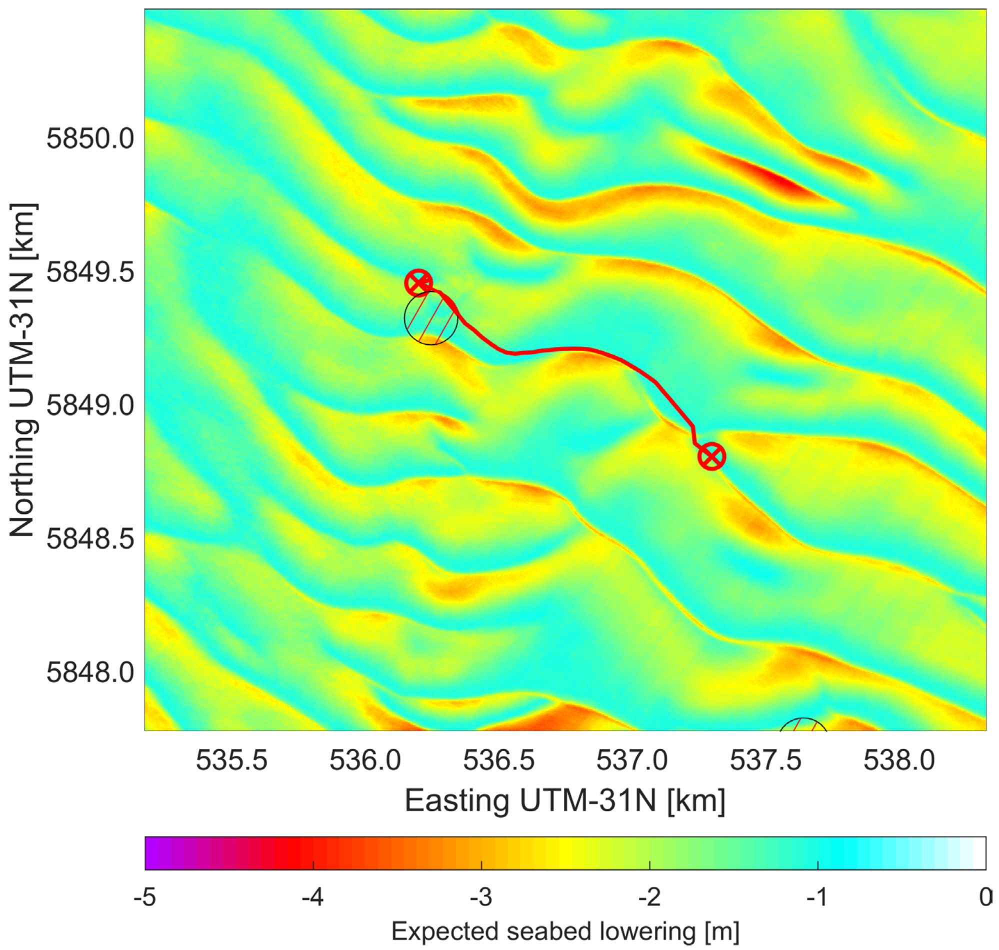


Figure 4.9.4 *Example of cable route optimisation taking into account seabed dynamics*

that cables can be buried sufficiently deep to avoid cable exposure (Figure 4.9.4), when smart cable routing techniques are adopted, which avoid the higher risk areas where the greatest variability in the seabed level is predicted.

4.9.4 Results for Scour mitigation assessment

In most situations, offshore structures can either be protected against scour or be designed such that scour development can be permitted. To decide which strategy is preferable for a certain foundation type and specific location, information was presented on how to predict the scour depth (when not protected) and how to protect against scour, both taking into account the morphodynamic scenarios of stable, lowering and rising seabeds.

It was concluded that for monopiles, an easily applicable, well-proven solution is to place the monopiles in either: 1) areas which display limited seabed dynamics; 2) to the north-east of the sand wave crests; or 3) on top of the sand wave crests and to apply a scour protection to maintain a more or less fixed seabed level around the foundation. In the second case, a slightly longer pile is needed, while in the third case, a longer or thicker scour protection is recommended to cater for the lowering seabed. Other solutions are also possible, though, such as leaving out the scour protection completely at locations with a rising seabed, when scour protection costs outweigh the costs for additional steel consumption.

To illustrate the choice for a proper scour mitigation strategy, for monopiles, dynamic equilibrium scour depths (Figure 4.9.5), stable rock gradings (Figure 4.9.6) and required scour protection volumes were computed for the entire IJVWFZ. Based on hydrodynamic timeseries scour calculations were made for the entire IJVWFZ for three monopile diameters (10, 12 and 14 m). For the IJVWFZ, scour depths between 9.3 and 12.3 m (95% non-exceedance values) were calculated for a monopile diameter of 12 m. This corresponds to 0.8 to 1.0 times the monopile diameter in which the relative scour depth decreases, and absolute scour depths increases with increasing diameters. Indicative calculations showed that, depending on the location

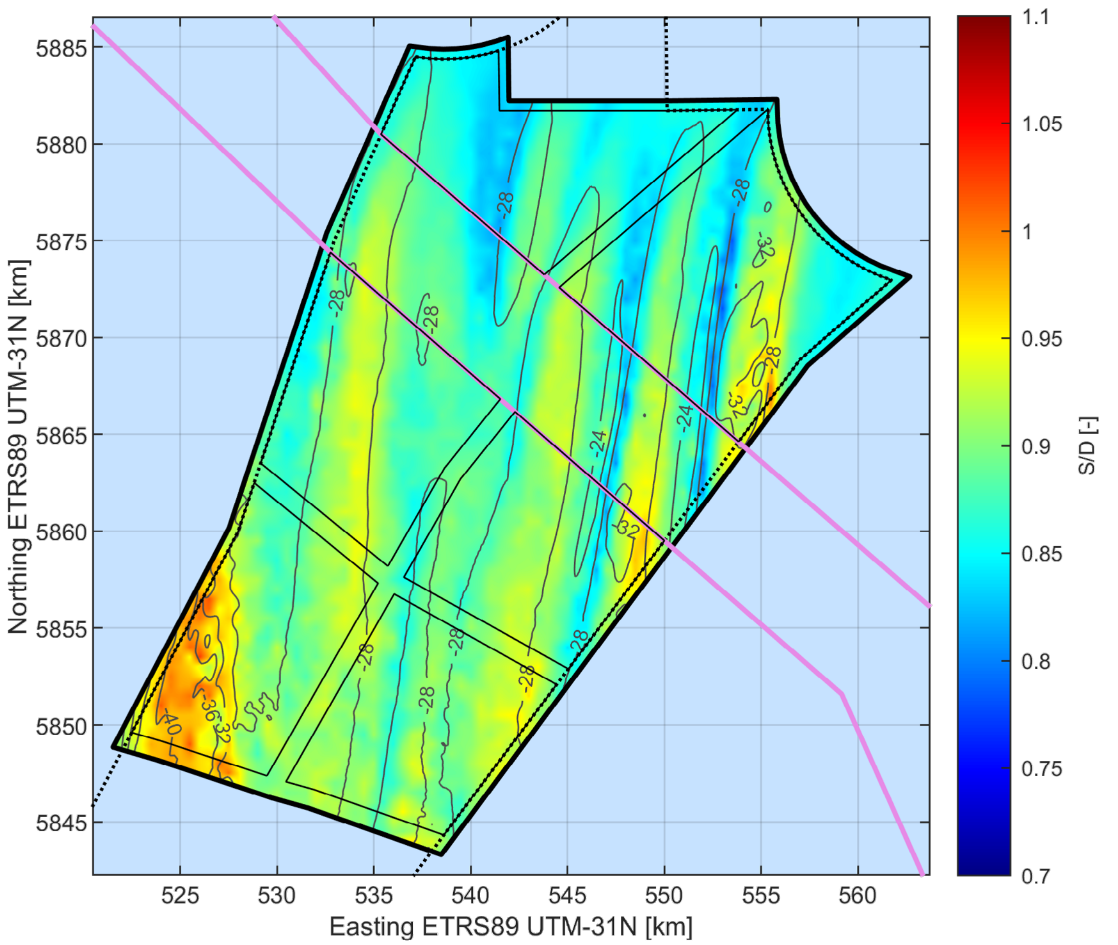


Figure 4.9.5 *Estimated scour depth/monopile diameter of 10 m with a 95% non-exceedance probability*

in IJVWFZ a rock grading varying between 3-9" and 10-200 kg is sufficiently stable (during a design event with a return period of 50 years). In general, larger gradings are required in shallower waters. Smallest gradings are expected in the southwest of Site II and between the sand banks.

Gravity-Based-Structures (GBS) will typically need scour protection due to the severity of scour predicted to develop in the mobile seabeds in IJVWFZ and the low tolerance of GBS to scour due to undermining risks. Locations where significant lowering of the seabed level was predicted are best avoided for GBS. Similarly, jacket structures are expected to experience significant scour development, but as long as they are not located in areas where the seabed is predicted to lower significantly and cable free spanning risks are mitigated by proper cable protection measures (such as application of cable stiffeners), the possibility exists for jacket structures to be designed for scour-free development. This does not hold for Suction Bucket Jackets where scour protection is, in most cases, recommended due to the limited penetration depth of the suction cans and the large scour potential in IJVWFZ. Other more cost-effective solutions (e.g, self-installable systems) look promising here and it is recommended they should be given due consideration by the developer.

With the provided maps for water depth, maximum seabed lowering, predicted scour depth, stable rock gradings and required scour protection volumes for each location, it can be computed which pile length is required, both for the situation that the pile will be protected and for the situation that the pile will be left unprotected. In case of protection, Figure 4.9.6 provides an indication of which scour protection is required. The provided information can assist the wind farm designer with optimising the locations for the wind turbine foundations and the selection of a cost-efficient and suitable scour mitigation strategy for each foundation.

The conclusions of this study can be used for a first estimate study only and more detailed studies would be required for the final designs. No additional safety margins for design purposes

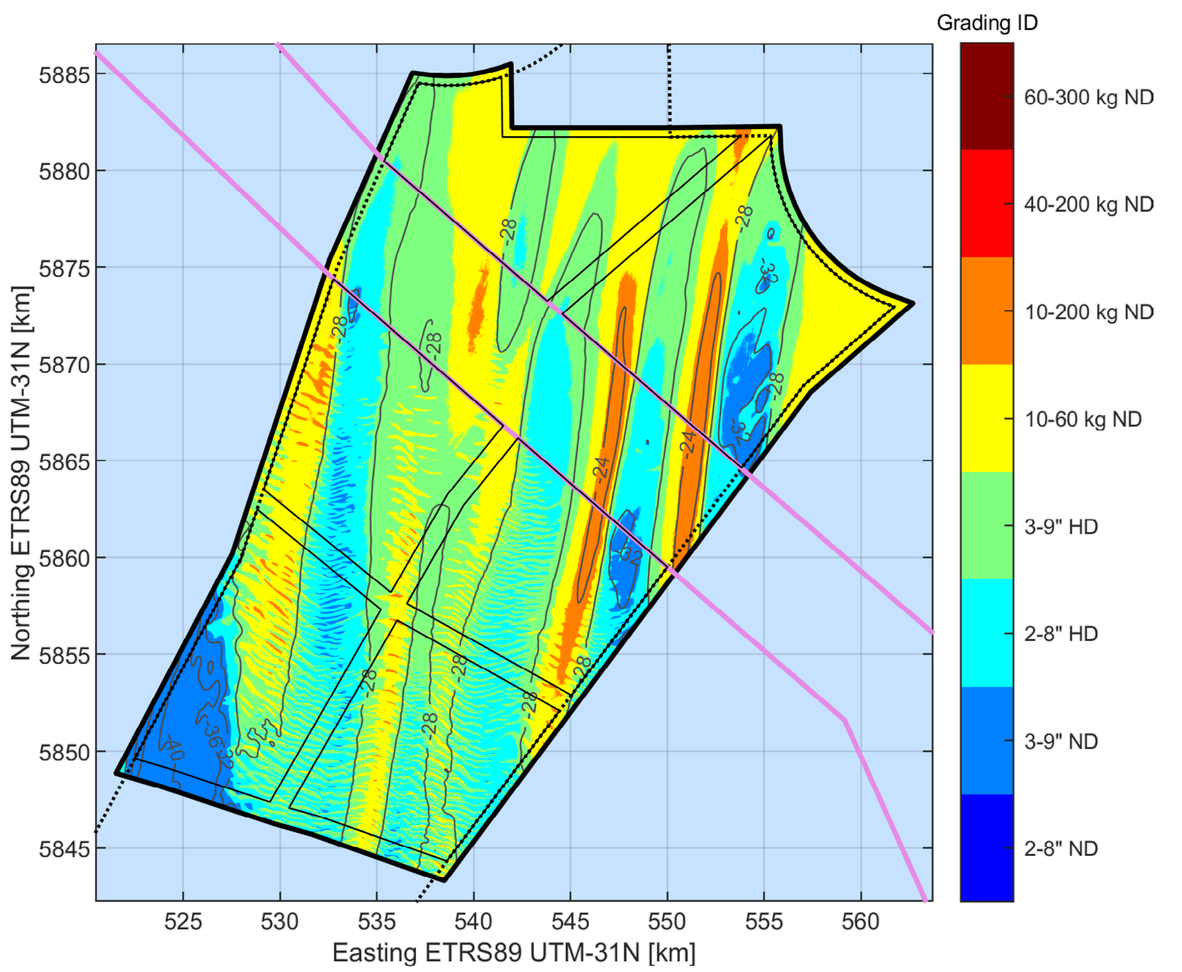


Figure 4.9.6 *Indicative rock gradings in case of using scour protection consisting of rock for monopile foundations during a design storm with a return period of 50 years*

have been applied. Further optimisation for scour predictions and/or scour protection designs can be achieved by means of physical model testing. In a morphodynamic area such as IJVWFZ, it is strongly recommended to account for predicted seabed changes from the beginning of the design process.

4.9.5 Deliverables

The results of the morphodynamics and scour mitigation study are published on offshorewind.rvo.nl.
They are summarised in a desk study report and associated data package (including a GIS archive and xyz data). The deliverables include:

- General background information regarding morphodynamic seabed features, of which sand waves are the most prominent in IJVWFZ;
- Geological and geophysical characterisation of the zone relevant to the dynamics of the seabed;
- Analysis regarding bed form migration speed and direction, including storm effects;
- Summary of performed numerical modelling for tides and sediment transport;
- Predicted future seabed levels (LSBL, HSBL, BEB);
- Predicted levels where UXOs can be expected (LOL, HOL, BEOL);
- Predicted maximum seabed slopes;
- Classification zones and considerations for cables and foundations;
- Description of how to deal with cable routing in dynamic seabed environments.
- Recommendations regarding possible scour mitigation strategies for IJVWFZ;
- Scour predictions for selected foundation types, e.g. monopiles, jacket structures and Gravity Based Structures;
- Map-based estimates for scour depths around monopiles, taking into account spatially varying hydrodynamics and water depth;
- Scour predictions for selected jack-up platforms (for installation purposes);
- Implications of edge scour around scour protections;
- Design requirements for scour protection;
- Description of currently available scour protection methods, e.g. rocks, mattresses, gabions, artificial vegetation, filter units;
- Map-based estimates for required rock gradings and rock volumes for scour prtotection, taking into account spatially varying hydrodynamic design conditions, water depth and seabed variations;
- Recommendations for eco-friendly scour protection designs.

4.9.6 Webinar

The study was discussed during a webinar on 1 June 2023. The webinar can be found on offshorewind.rvo.nl.

4.10 Metocean measurement campaign IJmuiden Ver Wind Farm Zone

4.10.1 Overview - Aims, Objectives, and Approach

The Metocean measurement campaign at IJVWFZ aims to provide two sets of continuous meteorological and oceanographic (metocean) data that includes wind profiles with excellent quality and high availability. The campaign aims to enable stakeholders to carry out more accurate calculations of the annual energy yield and improve/validate metocean models that serve as input for the overall wind farm design. The data gathered during the campaign is also expected to lead to a lower uncertainty in wind and metocean data, resulting in a lower cost of capital in the business case for an offshore wind farm.

The campaign started in May 2022 and lasted for 24 months. RPS (a Tetra Tech Group Company) has been commissioned to measure, validate and provide these key meteorological and oceanographic (metocean) parameters in the North Sea, approximately 60 to 100 km west of Den Helder, the Netherlands. The data from the two buoys are validated against each other using correlation plots, demonstrating excellent agreement (Figure 4.10.1). The efficacy of the data is further confirmed by validation against independent data sources, thereby eliminating the possibility of measurement errors common to the two buoys.

During the planned 24-month programme, metocean data was obtained from these fields using instruments fixed on floating systems. Measurement parameters include wind, wave, current, water-level, atmospheric pressure, and air temperature.

4.10.2 Supplier

RPS, a subsidiary of Tetra Tech, operates in six industries worldwide: real estate, energy, transportation, water, resources and defense and government services. Its services are divided into twelve clusters: project and programme management, design and development, water management, environment, management consultancy services, operation and development, planning and permits, health and safety, marine and coastal works, laboratories, training and communication and creative services. For this project, RPS Consultancy and Engineering BV in the Netherlands leads the project locally supported by global metocean expertise in the RPS Group.

4.10.3 Information about the buoys

RPS has been designing metocean buoys since the 1990's. It delivers 10-minute averaged wind data which is transmitted near real time and daily transmission of raw data (figure 4.10.2). The buoy features a ZX 300M LiDAR sensor, with proven reliability. The company's buoys are:

- Highest **HSE** standards;
- 100% powered by renewable energy - **zero CO_2 emissions**;
- Certified to **Stage 2** by the Carbon Trust (2019);
- **Successful** deployments in Europe, United States, and APAC;
- **Onboard redundancy** for power, logging and data transmission;
- **Remote** monitoring and intervention capability;
- **Wave measurements**, currents, met, tides on same platform;
- **Mooring** designs expertise and measurement track record through recent typhoons.

4.10.4 Deliverables

The results of the metocean campaign are published on offshorewind.rvo.nl.

The data package includes data, a data report and pre-deployment validation and verification reports of the measurement systems, which can be found under "Validation Metocean Campaign." Monthly reports and datasets are disclosed under "Metocean Campaign Monthly Data & Reports." RPS provided an OceansMonitor Web that delivered real-time data for the buoys measuring at IJmuiden Ver and Nederwiek.

Separate data and reports are available for each month within the 24-month measurement period. For the first full year of the measurement campaign (May 2022 - May 2023), the data is summarised in a 12-month comprehensive dataset and published in October 2023. A final dataset and campaign report over all 24 months of data (May 2022 - May 2024) summarising all processed wind, wave and current data were disclosed in October 2024. Both 12-month and 24-month data are available on offshorewind.rvo.nl.

4.10.5 Webinar

A webinar was held on 21st September 2023 where RVO, supported by RPS and DNV, presented the outcome of the first 12 months of Metocean measurements at the IJVWFS. The campaign achieved 95.5% average QC data return, underpinned by the excellent reliability of the RPS LiDAR buoy and after technical review of all reports and data by DNV. The webinar is available for viewing at offshorewind.RVO.nl.

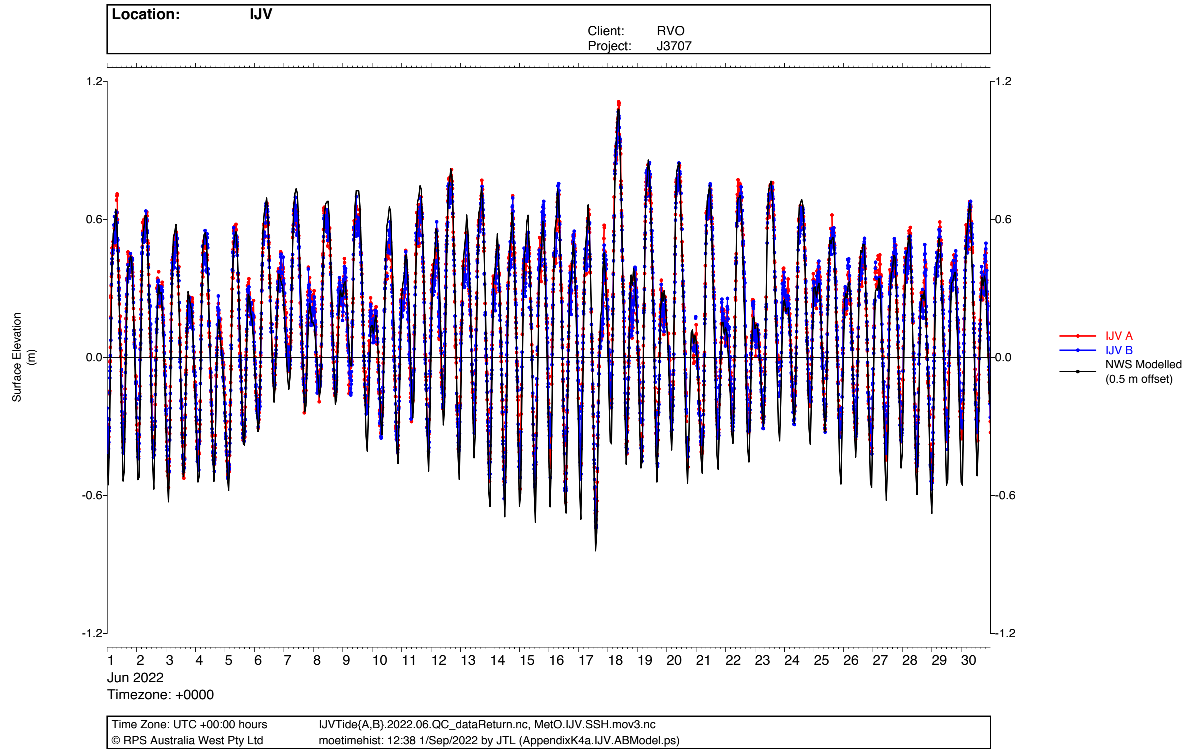


Figure 4.10.1 *2 lidar buoys A and B vs NWS modelled tide*

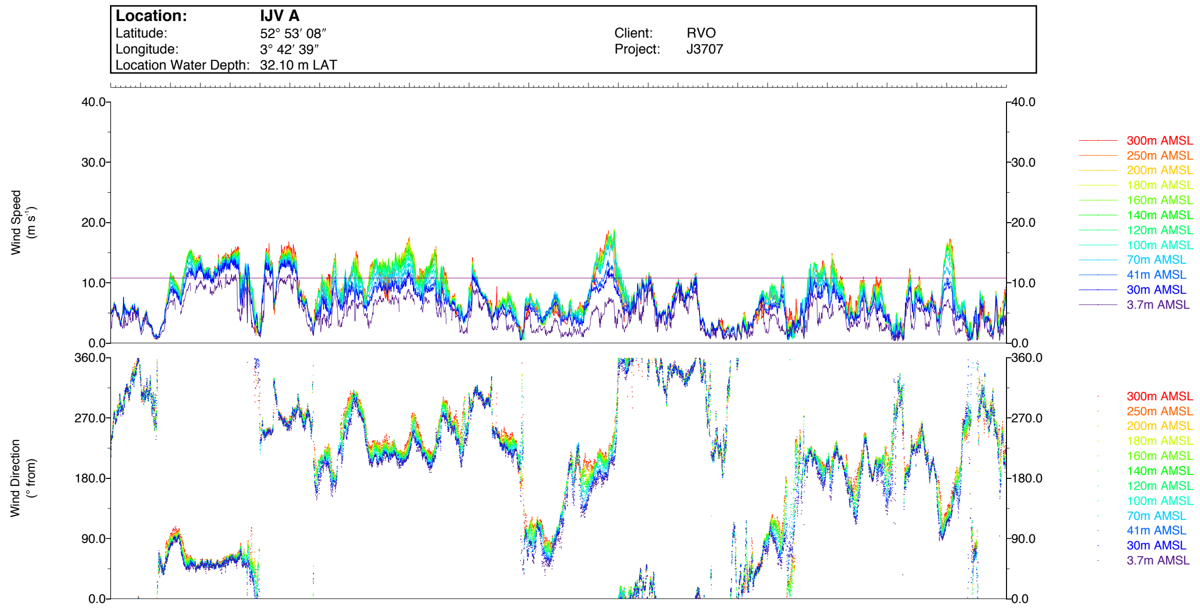


Figure 4.10.2 *Example of wind profile data from RPS LiDAR Buoy in the IJVWFZ*

4.11 Metocean assessment IJmuiden Ver Wind Farm Zone

4.11.1 Overview - Aims, Objectives, and Approach

RVO requires the establishment of meteorological and oceanographic (metocean) conditions to serve as a crucial input for the safe and cost-efficient design, installation and maintenance of wind turbines and their related structures. The novelty of the study was to have a unified WRF model as input for both the wind resource assessment and the metocean assessment, thereby seeking alignment between the two assessments.

4.11.2 Supplier

The overall objective of the study undertaken by DHI is to provide accurate metocean conditions (wind, wave, water level and current) for IJMuiden Ver offshore wind farm. To establish the metocean conditions, DHI performed high-resolution numerical modelling for the period 1979-2022 covering not only the IJmuiden Ver wind farm zone but also all offshore wind farm search areas spanning across the Dutch Exclusive Economic Zone (EEZ). The numerical modelling was validated against the 8 months of measurement data at the IJmuiden Ver, covering the period from May until December 2023. Performance of the model has been very good as can be seen in Figure 4.11.1.

Normal and extreme conditions are established for winds, water levels, currents, and waves. The extreme conditions are established using the most advanced Joint Extreme Value Analysis (J-EVA) method. The analyses of normal and extreme metocean conditions are based on the same period of model data, 1979-15-01 to 2022-12-31 (44 years). Marginal and joint extreme values are established for return periods up to 10,000 years.

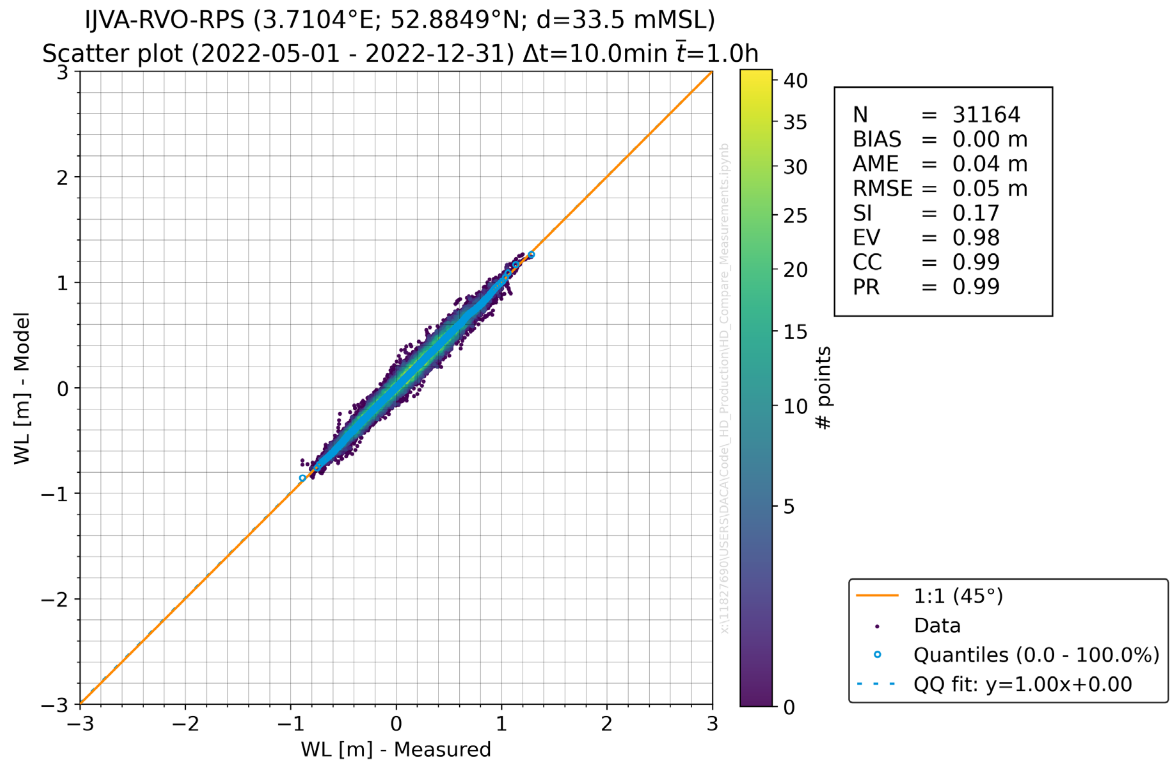
4.11.3 Results

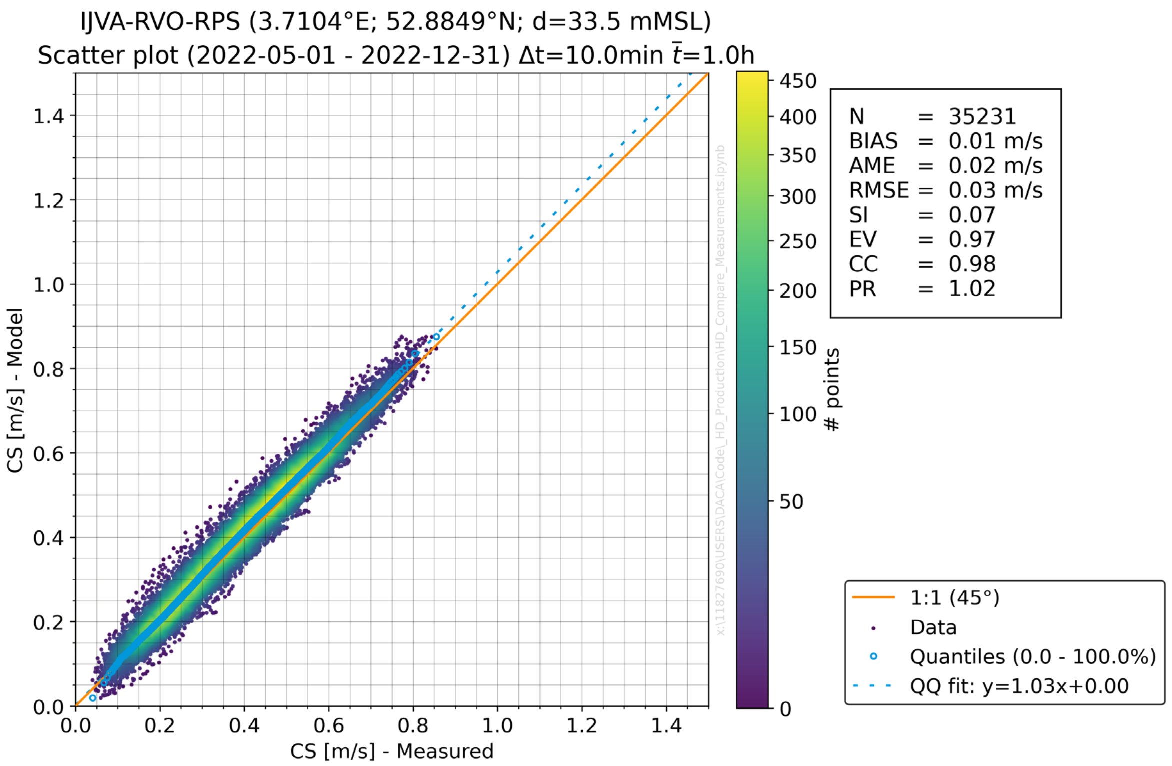
The results of the meteorological and oceanographic (metocean) conditions in IJmuiden Ver will serve as input for the design, installation, and maintenance of wind turbines, inter array cables, substations and their support structures for companies submitting bids to develop the wind farm.

A comprehensive web-based MOOD database is provided to RVO, which enables users to access the modelling data and the analysis results through a user-friendly interface as shown in Figure 4.11.2.

4.11.4 Webinar

The study was presented and discussed in a webinar on 28 September 2023. The webinar is available on: offshorewind.rvo.nl. On December 5, 2024, a concluding webinar will be held on Metocean Assessment for IJmuiden Ver and Nederwiek Wind Farm Zones. Please refer to offshorewind.rvo.nl for details.





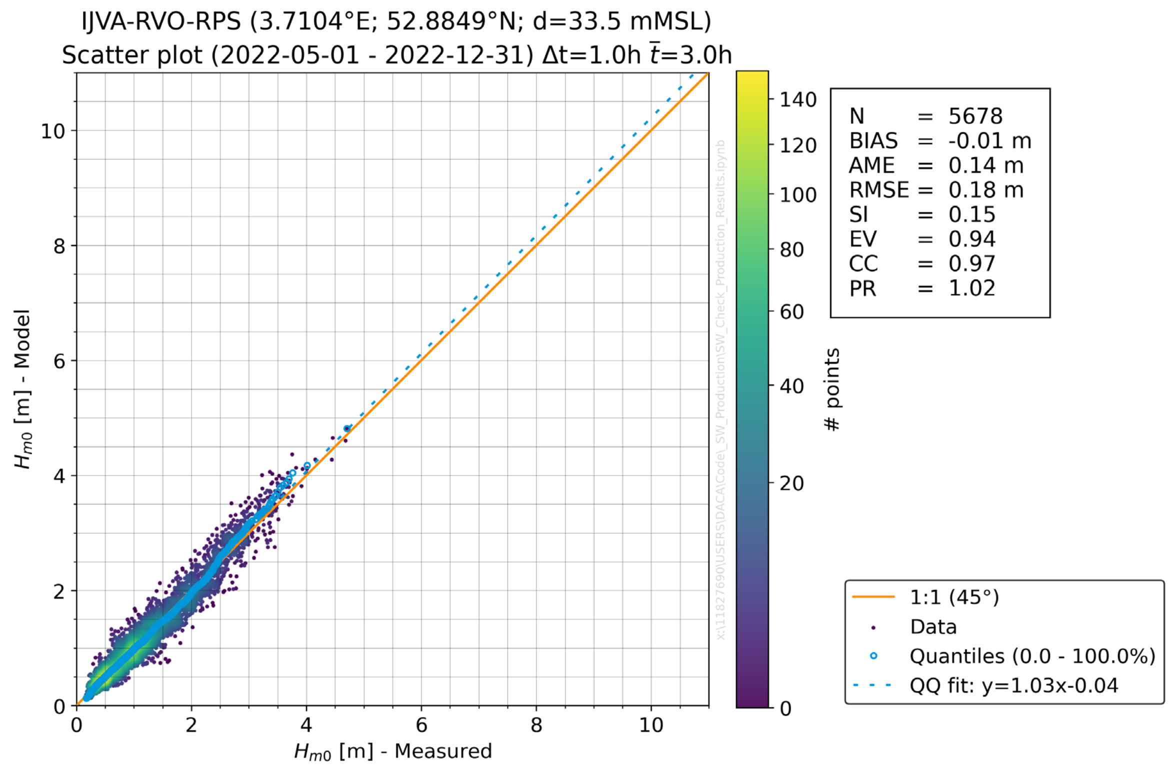


Figure 4.11.1 *Validation plots indicating performance of the models*

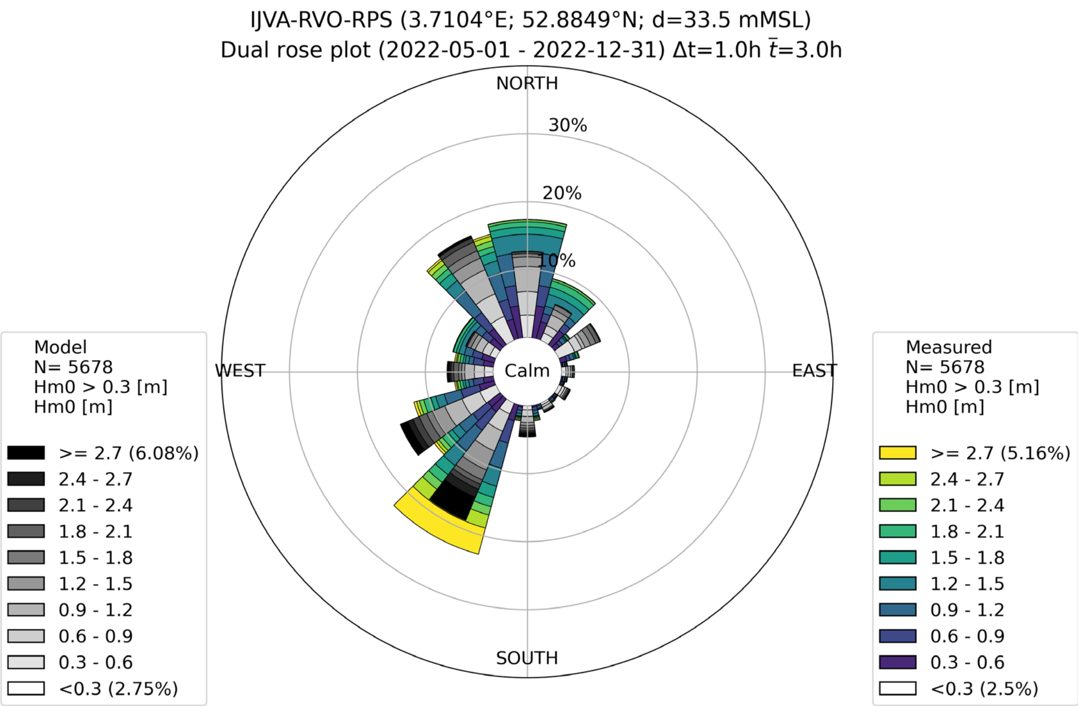


Figure 4.11.2 *Validation plots indicating performance of the models*

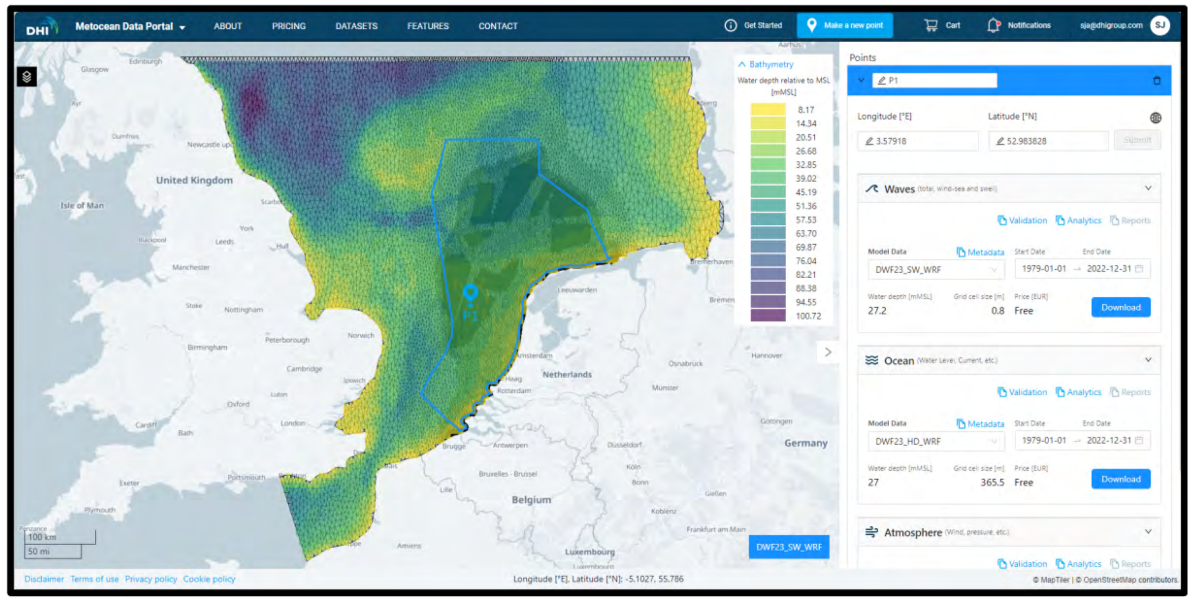


Figure 4.11.3 *Snapshot of the MOOD database showing the feasibility area*

4.12 Wind Resource Assessment IJmuiden Ver Wind Farm Zone

4.12.1 Overview - Aims, Objectives, and Approach

The DHI-led project consortium and the Wind Resource Assessment (WRA) package, directed by OWC and including collaboration with ProPlanEn, ArcVera, Innosea and C2Wind, has meticulously conducted a WRA for the IJVWFZ, located approximately 62 km west of the Netherlands in the Dutch EEZ of the North Sea. The study aimed to evaluate the wind resource potential and develop a mesoscale model, Unified-WRF, to inform future offshore wind energy development within the three designated sites: IJVWFS Alpha, IJVWFS Beta and IJVWFS Gamma.

A comprehensive review of 14 offshore datasets from the Dutch and German North Sea was undertaken, classifying them into primary and secondary categories based on proximity, measurement integrity and duration. Four primary datasets, including on-site floating lidar systems (FLS IJV and FLS HKW), offshore met masts (MM IJmuiden) and vertical profiling lidars (Lidar K13-A), were deemed highly representative of the project area and were subjected to thorough analysis and quality checks by OWC.

The project involved a novel approach to obtaining long-term wind climate information, by creating a unified, gridded wind dataset (Unified-WRF) capable of satisfying the requirements of both WRA and Metocean Assessment. The Unified-WRF model aimed to integrate and streamline wind resource and metocean analysis processes, enhancing the project's analytical accuracy.

The model was rigorously validated against short-term measurement datasets and other mesoscale models, exhibiting superior performance and alignment with long-term climate patterns.

The study incorporated a forward-looking climate change assessment using CORDEX projections under Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 scenarios, providing insights into future wind speed predictions and energy yield implications. A comprehensive uncertainty assessment was also conducted, addressing uncertainties in measurement, extrapolation, historical wind resource, spatial variation and climate change implications. The combined uncertainties were meticulously evaluated, ensuring a robust understanding of the project's potential and limitations.

The WRA delivers a thorough and nuanced analysis of IJVWFZ's potential for offshore wind energy development. The integration of primary datasets, development of the Unified-WRF model, climate change projections and a detailed uncertainty assessment collectively provide a reliable and comprehensive resource for informing future developments in the region.

Table 4.12.1 *IJVWFZ nodal location mean wind speeds*

Height [m]	Mean wind speed [m/s]					
	N1_ Alpha1	N2_ Alpha2	N3_ Beta1	N4_ Beta2	N5_ Gamma1	N6_ Gamma2
300	10.50	10.54	10.51	10.54	10.51	10.54
250	10.42	10.47	10.43	10.47	10.43	10.46
200	10.29	10.34	10.30	10.35	10.30	10.34
160	10.14	10.19	10.14	10.19	10.14	10.18
140	10.04	10.10	10.05	10.10	10.05	10.09
120	9.92	9.97	9.93	9.98	9.93	9.97
100	9.75	9.80	9.76	9.80	9.76	9.80
60	9.31	9.34	9.31	9.34	9.32	9.33
30	8.75	8.78	8.76	8.78	8.77	8.78
10	7.97	7.99	7.98	8.00	7.99	8.00

4.12.2 Results

The long-term wind speed at N3_Beta1 (FLS IJV location) at the height of 160 m was found to be 10.14 m/s, with a total associated combined uncertainty of 2.1% for the historical period. The uncertainty in the wind speed for the near-future scenario was found to be 0.2%. For future projections, the combined total uncertainty in long-term wind speed for the 10-year period was identified to be 2.7%.

Based on the Unified-WRF, a detailed output at 10-minute intervals was generated for the long-term climate of 13 years, including variables vital to wind energy analysis; wind speed, direction, air temperature and humidity, represented across ten different heights within the rotor layer. The long-term wind speed at the N2_Alpha2 node (MM IJmuiden location) was found to be 10.19 m/s at the height of 160 m, with the prevailing west-southwest (225°) direction. The vertical and horizontal variation in long-term wind speed in the IJVWFZ is shown in Table 4.12.1 and the wind frequency rose is shown in Figure 4.12.1.

The Unified-WRF model can represent the mean wind speed and wind speed distribution at the primary measurement locations across the observed short-term period very well. Its performance is also very similar to KNW and DOWA, which are trusted mesoscale modelled datasets available across the Netherlands and the Dutch North Sea. The spatial variation of wind speed across IJVWFZ is around 0.05 m/s, as shown in Figure 4.12.2.

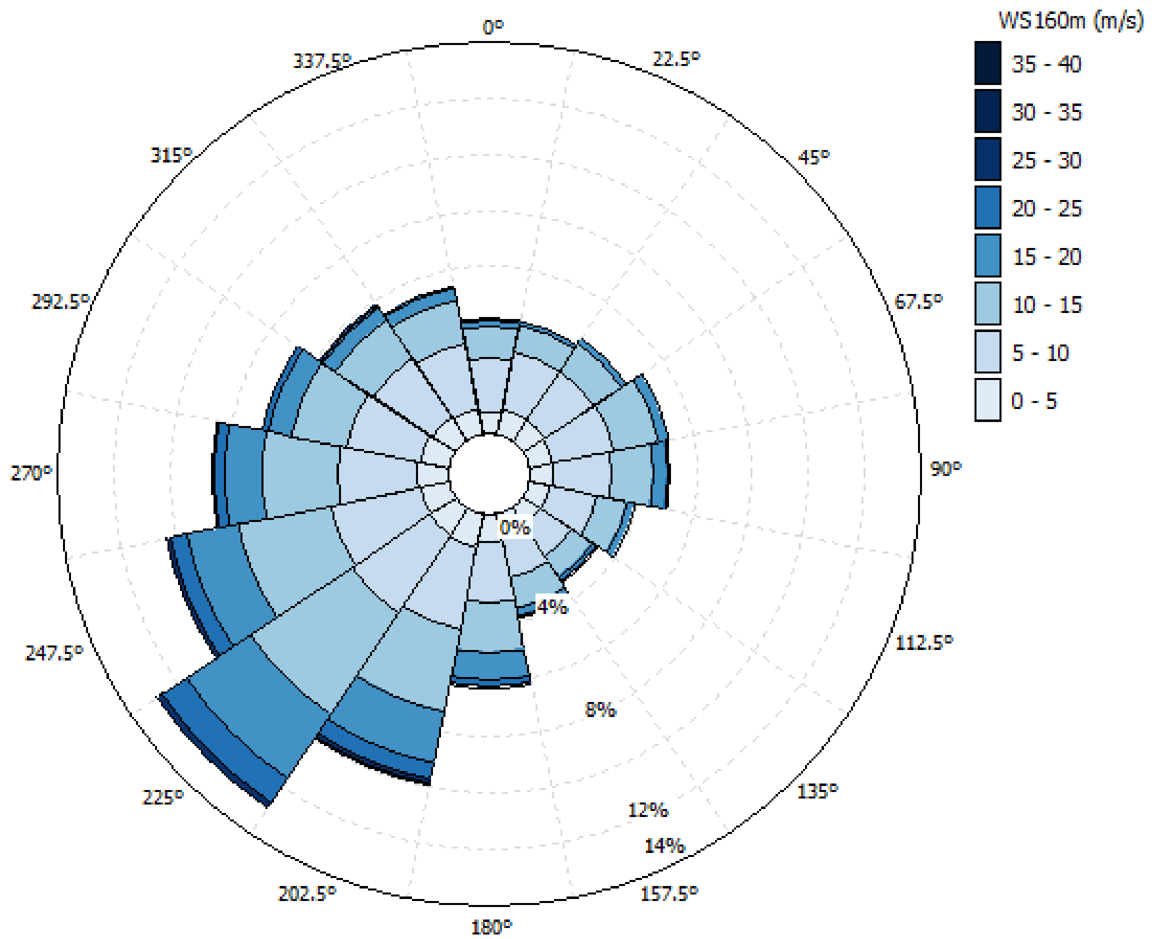


Figure 4.12.1 *N2_Alpha2 160 m frequency wind rose*

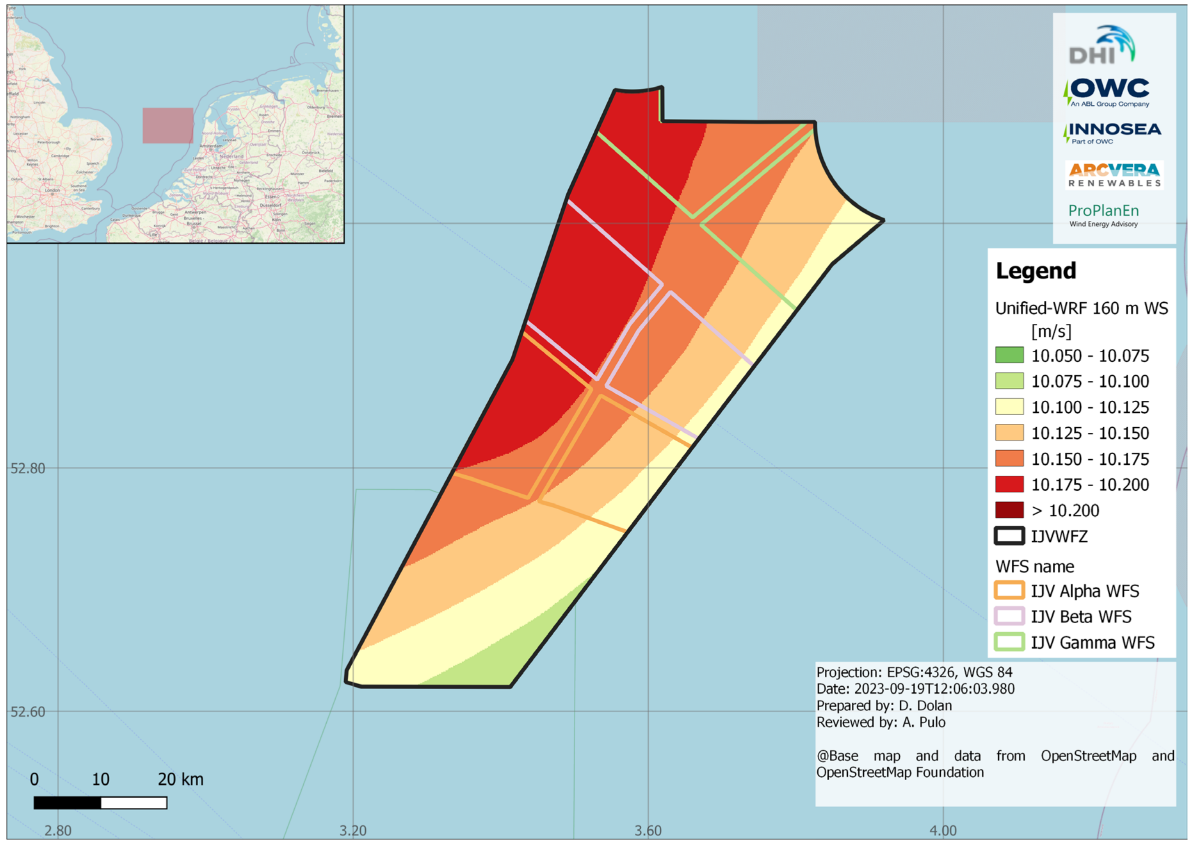


Figure 4.12.2 *IJVWFZ wind speed gradient map at 160 m*

4.12.3 Deliverables

The results of the WRA are summarised in a desk study report, published in November 2023. The report presents results for the following, at six specified output locations within the IJVWFZ, for the 13-year period spanning from 01 January 2010 to 31 December 2022:

- Long-term mean wind speeds at heights from 10 m to 300 m;
- Long-term mean wind speeds at the height of 160 m at various probability levels (P10 – P90);
- Long-term direction frequency wind rose and long-term wind shear;
- Omni and directional mean wind speed distributions, including Weibull parameters;
- Long-term diurnal, monthly and year-to-year variations of mean wind speed;
- Comprehensive uncertainty assessment.

In addition, the complied Unified-WRF dataset is available on MetOcean On Demand (MOOD) with a granularity of 1.67 km, capturing 44 years of information with a 10-minute output cadence.

4.12.4 Webinar

The study was presented and discussed at two webinars on 28 September 2023. The webinars are available at:

- Unified-WRF: offshorewind.rvo.nl.
- WRA: offshorewind.rvo.nl.

5. Further reading

Several websites provide the most up-to-date information and status of all relevant studies, legal framework, and the application process for a permit. The most important of these are listed below.

- The most up-to-date information on site data can be found at offshorewind.rvo.nl. The site also contains maps, recordings of webinars and workshops, news, a Q&A, and revision log.
- More information on the permit, the Wind Farm Site Decisions and the FAQ can be found at rvo.nl/offshorewind and in Dutch at rvo.nl/windopzee.
- Noordzeeloket provides information on several spatial topics concerning the North Sea, including offshore wind. Please visit noordzeeloket.nl/en/functions-and-use/.
- Windopzee.nl provides information in Dutch for the general public. Read more on windopzee.nl (Dutch only)
- Information by TSO TenneT, regarding the offshore grid connection, can serve as background information for offshore wind farm developers. Offshore grid documents (English) can be found at tennet.eu/information-wind-farm-developers.
- Interested in connecting with specific businesses or knowledge institutions within our supply chain? For more information on Dutch businesses and knowledge institutes working in the offshore wind branch the portal WindWaterWorks can be a good start. Please visit windandwaterworks.com

Appendices

The appendices related to this PSD (Applicable Law, Environmental Impact Assessment and Memo Boundaries and Coordinates) will be made available when completed. These documents can be found at offshorewind.rvo.nl.

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