



Netherlands Enterprise Agency

Nederwiek Wind Farm Zone

Site I-A (NW I-A)

Project and Site Description

Version June 2025

>> Sustainable. Agricultural. Innovative. International.



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

Version June 2025

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Foreword

Welcome to the Project and Site Description (PSD) for Nederwiek Wind Farm Site I-A (NW I-A), where 1 GW of offshore wind capacity will be issued to tender in October 2025. This PSD provides a complete overview of the enhanced site studies conducted on behalf of the Government for NW I-A and information about the offshore grid connection for the site, which is managed by transmission system operator TenneT. It also provides information on other sites within the Nederwiek Wind Farm Zone¹.

By providing this one-stop-shop data service for developers, the Government is again taking a proactive role to support the offshore wind industry and help developers optimise their project plans for the NW I-A site and minimise risk. Critically, our collaborative approach will enable them to bid confidently in the upcoming 1 GW tender.

Our open and transparent approach to offshore wind development means we have worked closely with industry to ensure a level playing field for all potential participants. We have used the insights from previous tender rounds and a subsequent public consultation to improve the information we are providing in our site studies and the attractiveness of our tender rounds, starting with NW I-A.

Planned under our 2.1 GW Offshore Wind Energy Roadmap, the NW I-A tender of course follows the award of two large 2 GW offshore wind projects in June 2024 at IJmuiden Ver Wind Farm Sites Alpha and Beta (IJV Alpha and Beta). They represented a big 4 GW step towards achieving our sustainable energy and climate change goals. But we recognise that market conditions have become more turbulent in recent times.

The decision to offer smaller 1 GW sites going forward, starting with NW I-A, was made to support the industry and safeguard the success of our national offshore wind programme. While still big projects, building smaller 1 GW wind farms will reduce the investment required by each potential developer and cut the overall financial risks involved per project. For the NW I-A site, a key focus of the permit tender is on safeguarding and improving the ecology of the Dutch North Sea. With this PSD and our enhanced site studies, we aim to support potential developers in that quest.

The feedback we have received suggests the changes we have made should increase the attractiveness for developers to compete in this tender and offers greater opportunity for innovation.

So, I look forward to innovative wind farm proposals that will stimulate economic green growth for the Netherlands, produce sustainable green energy while at the same time help our wildlife populations and marine environment thrive and reduce ecological impact.

By working together and adapting our approach accordingly, we will ensure the Dutch nation continues to power forward successfully and sensitively in our collectively bid to achieve all our long-term green energy, environment and economic goals.

Esther Pijs

*Directorate-General for Achievement Green Growth
Ministry of Climate Policy and Green Growth*

¹ Most of the site characterisation studies discussed in this PSD (Chapter 4) have been conducted for both Nederwiek Sites I-A and I-B combined. Others cover the whole Nederwiek Wind Farm Zone. Nederwiek Sites I-B, II and III will be issued to tender in a later stage.

1. Objectives and reading guide



1.1 About this Project and Site Description

This Project and Site Description (PSD) is for Nederwiek Wind Farm Site I-A (NW I-A) in the Netherlands. The site will be offered for tender in Autumn 2025. Please note that some studies described in this PSD are conducted for NW Wind Farm Sites I-A and I-B together or for the whole NW Wind Farm Zone. Nederwiek Sites I-B, II and III will be offered to tender at a later stage, so this PSD is meant for NW I-A only. A new PSD will be published for NW I-B, II and III at a later stage.

This PSD is for any party interested in participating in the permit tender to develop and operate a wind farm at NW I-A.

This PSD provides a description of the project specifications and development requirements along with site data (including maps and tables) and site characterisation study results.

This PSD summarises:

- An overview of general offshore wind developments in the Netherlands (Chapter 2).
- A description of NW I-A, its location and surroundings (Chapter 3).
- A description of the offshore grid connection system by transmission system operator TenneT (Chapter 3).
- An overview of all the site characterisation studies, surveys and measuring campaigns performed to date for NW I-A (Chapter 4), as follows:
 - Soil: UXO Risk Assessment Desk Study; Archaeological Desk Study, Archaeological Assessment of the Geophysical Survey results, Geological Desk Study, Geophysical Survey, Geotechnical Survey, Morphodynamical and Scour Mitigation Desk Study, Integrated Ground Model, Ecological analyses;
 - Wind and Water: Metocean Measuring Campaign, Metocean Assessment, Wind Resource Assessment.

1.2 Disclaimer

This document has been produced for information purposes only and does not replace any legal or formally communicated rules, regulations, or requirements.

Readers should note that official government 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 at the NW I-A site, will be made available after official publication in the Netherlands Government Gazette.

The related document to this PSD, Memo Boundaries and Coordinates, is available on the website offshorewind.rvo.nl.

1.3 Procedures, procurement, quality and certification

1.3.1 Procedure

Assisted by independent experts, the Netherlands Enterprise Agency (*Rijksdienst voor Ondernemend Nederland*, RVO) managed the process for site characterisation of NW I-A. So we made sure that the studies were accurate, practical and of the highest quality.

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 participants;
4. The site characterisation deliverables were reviewed by internal experts from other government departments and 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 and quality of the scope and the results.

1.3.2 Procurement

The procurement of the different studies was carried out in compliance with the applicable procurement procedures within RVO. 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 independent 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:

- A project team, comprising RVO and independent 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;
- Draft reports and other deliverables were reviewed by internal and independent external experts;
- 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 are still ongoing. RVO expects to secure an overall Statement of Compliance for the complete set of site studies for the NW I-A and -B sites combined 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.

1.3.4 Certification status

Several site characterisation studies and investigations for NW I-A have been certified. Table 1 shows the status of approval and individual and overall certification by DNV.

1.4 Experts and contractors

During the site characterisation process, RVO has consulted several experts to ensure the highest quality standards have been maintained. The following organisations have been involved in this process:

- Vestigia Archeologie & Cultuurhistorie (Archaeology, all phases)
- REASeuro (UXO Desk Study)
- Fugro Netherlands Marine B.V. (Geophysical Survey)
- Waardenburg Ecology (ground samples) and Wageningen University (water samples)
- ARUP (Ground Model)
- Svašek Hydraulics (Morphodynamics and Scour Mitigation Assessment)
- RPS Consultancy and Engineering Bureau B.V. (Metocean Campaign)
- DNV Netherlands B.V. (Quality expert support Metocean Campaign, Client representatives Metocean Campaign)
- DNV (Certification)
- TNO-Deltares (Geological Desktop Study)
- Fugro (Geotechnical Campaign)
- AFRY Management Consulting (Wind and Water experts)
- The Cultural Heritage Agency (Rijksdienst voor Cultureel Erfgoed) (experts archaeology)
- Arcadis Nederland B.V. (experts soil)
- DHI A/S (Metocean Assessment and Wind Resource Assessment)
- RPS Energy Ltd, (client representatives Geophysical and Geotechnical Survey)

1.5 Further reading

More relevant information on the studies, legal framework, and the application process for a subsidy and permit can be found on websites managed by the RVO. The most important of these are listed below.

- [Offshorewind.rvo.nl](https://offshorewind.rvo.nl) offers up-to-date information on site data, as well as maps, presentations, webinar recordings, newsletters, Q&A and Revision Log. Also to be found on this website is the Memo Boundaries and Coordinates of NW I-A.
- [RVO/Offshorewindenergy](https://rvo.nl/offshorewindenergy) offers information on the Dutch offshore wind policy and permit procedures. The Dutch version of this website ([rvo/windenergieopzee](https://rvo.nl/windenergieopzee)) is however more comprehensive.
- [Windopzee.nl](https://windopzee.nl) provides information in Dutch for the general public. The website is in Dutch only.

The following external websites also offer valuable information for the offshore wind branch:

- [Noordzeeloket.nl](https://noordzeeloket.nl). This website provides information on several spatial topics concerning the North Sea, including offshore wind. Please visit noordzeeloket.nl/en/functions-and-use/.
- [Tennet.eu](https://tennet.eu). 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.
- [Windandwaterworks.com](https://windandwaterworks.com). For companies which are interested in connecting with specific businesses or knowledge institutions within the Dutch supply chain for offshore wind.

Table 1 Nederwiek I-A and I-B Site characterisation; Quality approval and certification status.

Site characterisations	Certification status	Overall certification by DNV
Archaeological desk study	Quality approved	Expected Q3 2025
UXO desk study	Quality approved	
Geological desk study	Quality approved	
Geophysical survey	Certification received	
Archaeological assessment of the Geophysical survey results	Quality approved	
Baseline survey of Benthic Ecology	Quality approved	
Geotechnical Survey	Certification pending	
Integrated Ground Model	Certification received	
Archaeological assessment of the Geotechnical survey results	Quality approved	
Morphodynamics and Scour Mitigation desk study	Certification received	
Metocean measurement campaign	Certification received	
Metocean assessment	Certification updated with 24M data (Q3 2025)	
Wind Resource Assessment	Certification updated with 24M data (Q3 2025)	

2. Offshore wind power developments in the Netherlands

The Netherlands' offshore wind tenders have been successful even though we face challenges due to current global market conditions. Our collaborative approach with the 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 emission reduction 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 2 GW subsidy-free projects use turbines rated at 15 MW and more in the Sites Alpha and Beta in the IJmuiden Ver Wind Farm Zone (IJVWFZ). For a combined capacity of 4 GW, that round was, at that time, the biggest in the world for offshore wind energy.

New criteria are incorporated to safeguard the environment and human rights while innovation is stimulated in both ecological enhancements and system integration of the power generated by the wind farms.

While writing this PSD, we notice however that market conditions have changed. The Dutch government aims to be flexible in adapting to the market where needed while at the same time developing offshore wind where possible. The government significantly reduces risks for developers by providing a clear project pipeline and by the State taking on responsibility for both site characterisation studies (through RVO) and grid development (through transmission system operator TenneT).

2.2 Updated roadmaps for offshore wind development in the Netherlands

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 learn from the 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 also been revised upwards with additional areas designated for development to fulfil our commitments (see Table 2 and map on page 15).



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 heart 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 CO ₂ 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 (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 (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 (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 tender, we have modified our plans to help developers mitigate their financial risks and better secure their supply chains.

So, as announced in September 2024, instead of two more 2 GW wind farms at IJmuiden Ver Site Gamma and Site I in the Nederwiek Wind Farm Zone, the Dutch Government has decided to create four smaller 1 GW sites within the designated area. 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 designated under the 2030 Roadmap – Hollandse Kust (west) (HKW, 1.4 GW, subsidy-free tenders held in 2022), IJmuiden Ver (IJV Alpha and Beta, 4 GW, subsidy-free tenders held in first half of 2024), and Ten noorden van de Waddeneilanden (TNW, 0.7 GW).
Additional Offshore Wind Energy Roadmap 2030/31 (2022)	Plan to add 10.7 GW extra capacity to reach around 21 GW in 2030/2031. Three new wind farm zones (IJVER Gamma, Nederwiek and Doordewind) were designated for development of the extra capacity. This was also reflected in the North Sea Programme 2022-2027 published by the Ministry 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 Dutch Government also decided that more time is required to optimise the spatial planning for the Lagelandier 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	
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 the ambition to realise up to 70 GW in 2050. The exact capacity targets depend on several aspects, such as electricity demand and available space. Going forward, a rolling roadmap will be used. 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 increase our energy independence and ensure green growth. At the same time it will also create new jobs in a green economy and boost a green energy generation.

The wind farms NW I-A and -B will both have a grid connection (by TenneT’s platform Nederwiek I) with Borssele.

The Development Framework in which the grid connection planning is described, is being updated on a regular basis.

NW I-A and I-B will be connected to TenneT’s standardised, 2 GW High Voltage Direct Current (HVDC) offshore grid connection system (called Nederwiek I). The development of the standardised HVDC system by TenneT helps minimise costs and maximise efficiency in the Dutch offshore grid build-out.

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

While these projects will help achieve our 21 GW target, longer term interests are important 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.

We are working on strategic plans to continuously increase our offshore wind capacity after 2032. 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, planned to be published at the end of 2025, will be used as input to supplement the roadmap.

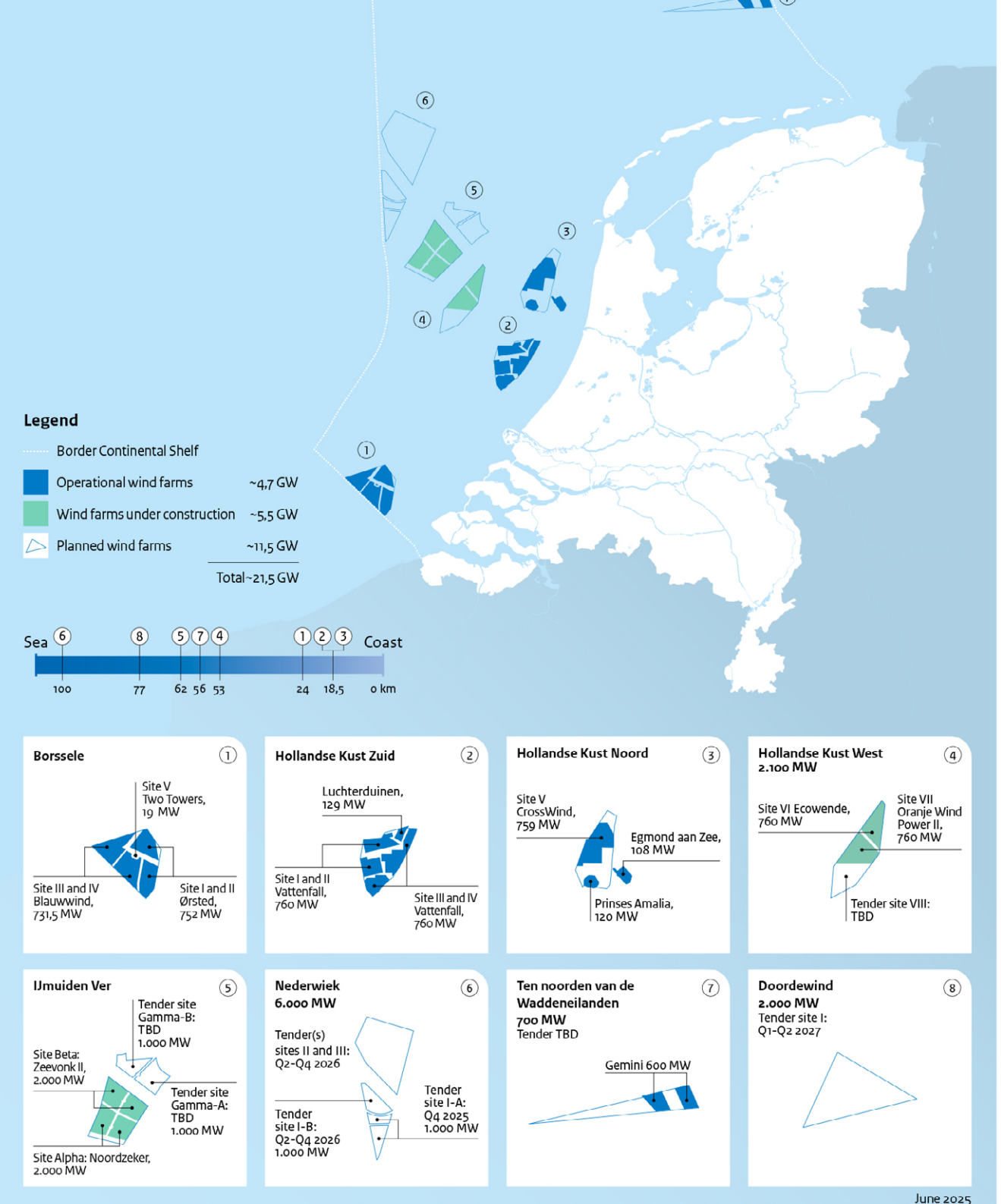
For the latest policy updates, please check [Offshore wind energy \(rvo.nl\)](https://offshorewind.energy.rvo.nl).

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.

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.

Roadmap Offshore Wind Energy 21 GW



3.

Site description and offshore grid

3.1 General description of the Nederwiek Wind Farm Zone

The Nederwiek Wind Farm Zone (NWWFZ) is located 95 kilometres (km) off the west coast of the Netherlands in the Dutch North Sea. Four wind farm sites have been designated in this zone: Nederwiek I-A (NW I-A), Nederwiek I-B (NW I-B), Nederwiek II (NW II) and Nederwiek III (NW III).

The upcoming permit tender is for NW I-A. This PSD provides the site description for NW I-A unless explicitly stated otherwise.

3.2 Layout and coordinates

The total surface area of NW I-A is approximately 149,2 km². This includes the safety zones and maintenance zones for infrastructure, for example active cables crossing the sites. This reduces the effective area available for new wind farm construction. The netto surface is 71,6 km².

Transmission system operator TenneT will construct one offshore substation platform with grid connections for Sites NW I-A and -B. However, the tender for a permit to develop and operate a wind farm at NW I-B will take place at a later stage.

Tables with coordinates for the boundaries of NW I-A, maintenance zones, infield cable corridors, and safety zones have been published in the Memo Boundaries and Coordinates on offshorewind.rvo.nl.

3.3 Existing infrastructure

3.3.1 Cables and pipelines

There are several active and inactive cables and pipelines crossing the NWWFZ. These can be seen in Figure 3.1.

The description of pipelines and cables in the NWWFZ can be found in the Memo Boundaries and Coordinates, which can be downloaded at offshorewind.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 under development or in operation. Please consult developers of the projects within these zones when conducting activities in these areas. Coordinates can be found in the Memo Boundaries and Coordinates.

3.3.3 Offshore platforms and other nearby activities

There are several existing (mining) platforms and bore-holes (both active and inactive) in or around the NWWFZ. Coordinates can be found in the Memo Boundaries and Coordinates at offshorewind.rvo.nl.

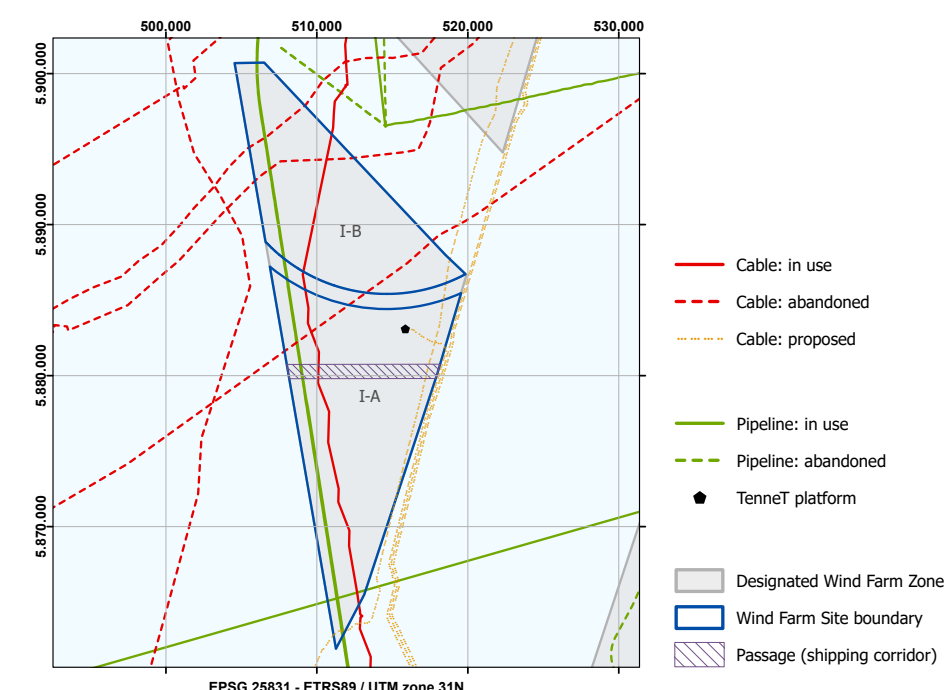


Figure 3.1 Active and inactive cables and pipelines crossing the NWWFZ.

3.3.4 Exclusion zones

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

A new clearway (Newcastle – IJmuiden) is being planned across the NWWFZ.

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 Dutch government 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 Offshore Grid Development Framework is updated on a regular basis. With these updates, TenneT can proceed with the necessary investments.

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

To create economies of scale, TenneT has started with the construction of the standardised substation platform, also called Nederwiek I, with a capacity of 2 GW. The planned location of the platform is shown in Figure 3.1, while Table 3.1 shows the coordinates.

Infield cables for electricity transmission from NW I-A 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. As already stated, the tender and project development for NW I-B will take place separately, at a later stage.

The Nederwiek I platform will transform the output from the wind farm at NW I-A from 66 kV to 525 kV and transmit the electricity to shore through two 525 kV direct current (DC) export cables. The export cables will connect to one onshore substation and the 380 kV onshore grid at Borssele. Details are in the Development Framework, which is published on rvo.nl/offshorewind. Contracts to develop the platform and place the cables have successfully been tendered by TenneT. A table in the Memo Boundaries and Coordinates 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 Climate Policy and Green Growth, 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.

For NW I-A and -B, TenneT has updated the model agreements to reflect the characteristics of the 2 GW high voltage direct current (HVDC) system and held 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 tender winners (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.

Table 3.1 Planned TenneT substation for Nederwiek I-A and I-B.

	Easting	Northing
TenneT platform Nederwiek I	515860,7	5883116,9

Spatial reference: ETRS_1989_UTM_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 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 of the tender to the Ministry of Climate Policy and Green Growth, the Directorate General for Public Works and Water Management (Rijkswaterstaat) and TenneT. After this introduction, TenneT will invite the winner 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. After signing, further information exchange and coordination will take place in the project working group (as referred to in Article 6 of the Realisation Agreement);
- The dates for completion of the platform for NW I-A (and I-B) will be in the updated Development Framework, which will be published on rvo.nl/offshorewind.
- RVO will hand over all remaining samples of the Geotechnical Survey;

- Rijkswaterstaat will coordinate the Maritime Information Services. Several sensors for public use will be placed on the substation platform.

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 schedule 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 companies require to prepare bids for the permit tender for Nederwiek I-A. 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 will provide the basis for an optimal tender result. In providing a 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, Archaeological assessment of Paleolandscapes, 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. In the final Ground Model all soil data are integrated.

Meanwhile, the Metocean Assessment will take into account the intermediate findings of the Metocean measurement campaign.

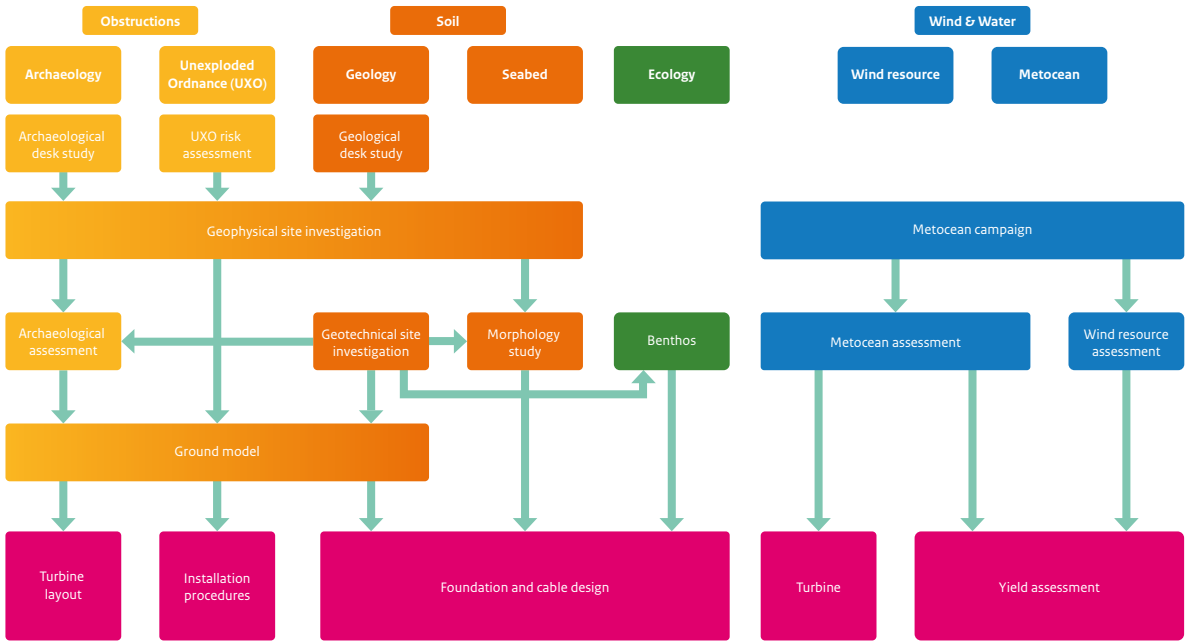


Figure 4.1 Site studies and investigations for Nederwiek I-A.

4.1 Archaeological Desktop Study

4.1.1 Aims and objectives

Vestigia Archeologie & Cultuurhistorie and MSDS Marine have been contracted by RVO to conduct a number of archaeological assessments for various Wind Farm Zones on the Dutch Continental Shelf (DCS) or Dutch Exclusive Economic Zone (EEZ). The assessments are carried out in three phases: a desktop assessment (Phase 1); an assessment of geophysical survey data (Phase 2); and an assessment of geotechnical survey data (Phase 3).

The Nederwiek Wind Farm Zone (NWWFZ) consists of two separate areas located on the most western part of the Dutch EEZ, adjacent to the UK EEZ. The research areas have a combined surface of 947 km². The study area of this assessment incorporates the full extent of the NWWFZ area, plus an extended 500 m area surrounding the WFZ.

The purpose of the archaeological desk-based assessment is to specify the known and potential archaeological resources within the two areas. This study is to establish whether archaeological remains are, or are likely to be, present within Nederwiek Wind Farm Sites I-A and I-B (NW I-A and -B), Site II (NW II) and Site III (NW III). It also aims to determine whether these (possible) remains could be affected by the construction of wind turbines and cables in both these areas.

In terms of general archaeological expectancy, a distinction has been made between the expectancy for early prehistoric archaeological remains on, or more likely, buried under the seabed, and the remains of historic ships and aircraft on or directly beneath the seabed.

4.1.2 Results

To date, no prehistoric findings or archaeological sites have been identified within the NWWFZ or the 500m buffer zone. Archaeological expectancy has been shown to be limited to sites and concentrations of findings from hunter-gatherer groups of the (Middle and Late) Paleolithic and (Early) Mesolithic periods. After ca. 7000 BC, human occupation will have been impossible in the then drowned landscape of the expanding North Sea. The density of archaeological sites is extremely low. Paleolithic and Early Mesolithic occupation sites would have been situated mainly on higher parts within the landscape, and/or on river banks and tidal gully systems, which consequently were also more exposed to later erosion. The archaeological expectancy is strongly related to the geo-genesis of the two areas and remaining lithostratigraphic units. Current available geological information suggests that archaeologically relevant layers and deposits are covered

by seabed sand with a thickness varying between 5 m and 10 m. Specific knowledge is, however, limited due to the low numbers of borehole and geotechnical data. The focus of any additional geological survey should therefore be on gathering additional information to broaden the general geoarchaeological information on this part of the North Sea, as outlined in the North Sea Prehistory Research and Management Framework (NSPRMF).

A total of 14 historic shipwrecks are known to be in the Investigation Area, of which four have been identified so far. Three of these are recent wrecks and are of limited archaeological value. Two wrecks are certainly of archaeological value (of which one has been identified). The first of those two is the German WW1 era U97 submarine which sank in 1918, and the other is a wooden sternpost containing depth markings. A search within the register of WW2 aircraft losses using certain parameters resulted in nine potential crash locations in or near the NW Investigation area. This does not mean these plane wrecks are within these areas, but it provides a first indication and reminder that aircraft remains can be present and thus expected.

4.1.3 Recommendations

In the report, recommendations have been made for next steps in the archaeological assessment process. Both a Geophysical and a Geotechnical Survey will be required to provide essential additional data for further archaeological analysis. However, the scope of works for the NWWFZ Geophysical Survey had been compiled before the start of this desktop survey (see below). This comprised a combination of multibeam, side scan sonar, magnetometer and seismic surveys. To ensure the specification of the survey meets the requirements for archaeological assessment and interpretation, this scope of works has been reviewed by MSDS/Vestigia. The survey specification and requirements cover all considerations that are required from an archaeological perspective. The positions of wrecks and obstructions detailed within the Archaeological Desktop Study have been communicated to the surveyor and particular attention has been paid to these areas to ensure the data meets or exceeds expectations. Where possible, additional crosslines will be run over wrecks identified during the survey, to 'box' them in to minimise any potential effects of acoustic shadow.

Recommendations for additional geo-archaeological prospection (non-destructive ways to investigate the subsurface for archaeological structures) at NW I-A and -B, NW II, NW III by means of borehole/CPT drilling and vibrocores will be made in a separate document, the Written Scheme of Investigation for the Geo-Archaeological Survey by Vestigia. Further explanation and motivation, as well as the operational requirements can be found in that.



4.2 Unexploded Ordnance (UXO) Risk Assessment Desk Study

4.2.1 Overview – aims, objectives, approach

The UXO Desk Study, performed in Q1 of 2023, 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 Nederwiek Wind Farm Zone (NWWFZ), which includes Sites NW I-A and I-B, 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 NWWFZ and identify areas within the zone that should preferably not be used for 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 zone.
 - b. Carrying out geophysical and geotechnical investigations.
 - c. Specific requirements (legal obligations, specific procedures) to be considered when finding UXOs.
 - d. Installation of wind turbine foundations.

- e. Installation of cables and pipelines.
- 4. Identify whether any further investigations should be carried out regarding the presence of UXOs and define the scope of these investigations, including their spatial extent and their timing within the overall site development programme – consideration of all relevant investigation methods shall be made for various stages of the project, from site investigation up to installation.
- 5. Identification of the sources that have been consulted for carrying out the assessment;
- 6. Description of the historical context and the likelihood of finding UXOs in the NWWFZ;
- 7. Description of known presence of UXOs in the zone;
- 8. If present: A map showing the areas with an increased risk regarding the presence of UXOs and the characteristics of the UXOs that could be found in these areas;
- 9. Recommendations on further geophysical and geotechnical site investigations.

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 coordi-

nation of UXO clearance activities. Moreover, the company has performed the UXO desk studies for the Borssele and Hollandse Kust (zuid, west and noord) Wind Farm Zones and export cable routes, and the IJmuiden Ver Wind Farm Zone.

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.

According to historical research, the NWWFZ and surrounding areas were the scene of war-related activities during World War I and World War II. Historical research in The National Archives (London, United Kingdom) and Bundesarchiv-Militärarchiv (Freiburg, Germany) has shown that the Nederwiek WfZ and its surrounding areas were the scene of several war related events during World War I (WWI) and World War II (WWII). Among these are multiple airstrikes on German shipping, the presence of minefields, the sinking of multiple ships, airplane crashes and the jettisoning of bombs during both World Wars. Due to these events, the entire NWWFZ is to be considered a UXO risk area.

At sea, several relevant incidents took place during the wars in or near the NW I-A and -B Investigation Area. A Dutch trawler sank due to a submarine attack, a British Motor Gunboat was hijacked and towed back to the Dutch coast by a German E-Boat (Schnellboote), and German E-Boats were attacked with British 40 mm guns within or near the Investigation Area.

Several aerial attacks and the jettisoning of bombs also took place in and near the Investigation Area. Furthermore, a few instances have reported the use of flak (fire from German anti-aircraft artillery) within the area. It is also probable that more than the reported jettisons, attacks and experienced flak took place during WW II.

Regarding mines, the Investigation Area intersects several historical minefields. A suspected German minefield from WWI intersects within the Investigation Area. Multiple mine related incidents occurred in and near the area outside of this suspected minefield. During WWII, the British navy laid two minefields directly in the Investigation Area and three immediately near it. Furthermore, two German minefields were laid in the area, with seven others nearby. No direct information on the clearance of these fields is known to REASeuro.

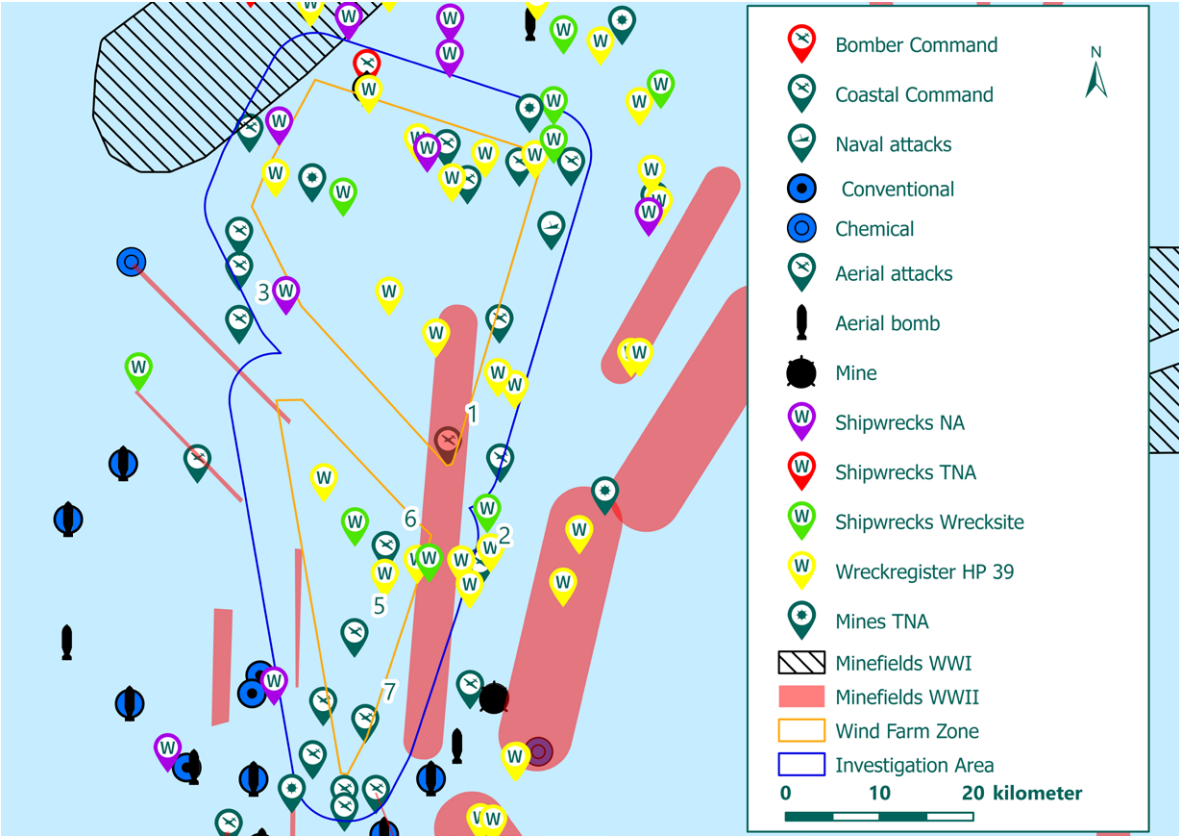


Figure 4.2.1 Overview of war related events within and near the NWWFZ (Source basemap: ESRI).



Post-war minesweeping succeeded in securing the shipping lanes but did not manage to dispose of all mines. Many mines still litter the seabed, with mechanical fusing mechanisms still in place. Sweeping, trawling and extreme tidal and weather conditions caused these mines to migrate over the years, resulting in a situation in which there is no longer a clear link between the original minefields and the current positions of naval mines. As a result of this, UXO can possibly still be encountered within the Investigation Area. Because of minefields laid during WWI, E-mine Type IV (German) and contact mines Vickers Elia and Type H Mk II (UK) can be found. During WWII, moored mines Mk XX (UK), contact mines Mk XIV and XVII (UK), EMD- and EMC contact mines (German), Explosive Floats ‘Sprengboje’ (German), and static cutters (German) were laid in or near the Investigation Area. These types can also therefore be found.

Based upon this information, the entire NWWFZ 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 for this:

- 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 the table below.

There is sufficient and indisputable evidence that naval mines might be present within the Investigation Area. There is also strong evidence indicating the presence of aerial bombs or torpedoes in the area. The planned construction works may cause an aerial bomb or naval mine or torpedo to detonate. Artillery shells originating from naval attacks or dumping are likely to be present. These shells do not pose a significant threat for installation operations.

Table 4.2.1 Risk assessment results for the NWWFZ.

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
Anti-ship bombs	Remote	Touch	Personnel Equipment	Primary	1 = Very unlikely	5 = Very High	5 = LOW/MODERATE
Artillery shells	Feasible	Touch	Personnel Equipment	Primary	2 = Unlikely	1 = Negligible	1 = LOW
Torpedoes	Feasible	Touch, Movement, Magnetism	Personnel Equipment	Primary Secondary	3 = Possible	5 = Very High	15 = HIGH
Naval mines (WWI)	Probable	Touch, Movement, Magnetism	Personnel Equipment	Primary Secondary	3 = Possible	5 = Very High	15 = HIGH
Naval mines (WWII)	Probable	Touch, Movement, 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

4.2.4 Conclusions and recommendations

Based on the analysis of historical sources, it is evident that different war related events took place within and nearby the Investigation Area. Due to these events, the entire Investigation Area is considered a UXO risk area. A variety of UXO are likely to be present, including 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 NWWFZ 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 NWWFZ can be selected for the installation of offshore wind farms and/or cables and pipelines.

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. 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 a 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 high explosives (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 on 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 caliber 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 Netherlands Navy will dispose of the UXO. No disposal costs will be charged to the wind farm developer.

4.3 Geological desk study

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

4.4.1 Overview – aim, objectives and approach

The aim of the Geophysical Survey was to contribute to the bathymetrical, morphological and geological understanding of the Nederwiek Sites I-A and I-B (NW I-A and -B) Investigation Area. 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 Investigation Area.

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;
 - The current (as found) location of man-made objects, such as cables, pipelines and wrecks;
- 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 below seafloor for a set of interfaces between the main 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 the NW I-A and -B sites 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.

The geophysical investigation was carried out utilising Fugro's purpose-built, geophysical survey vessel 'Fugro Discovery' between 23 January 2023 and 6 May 2023. Details on the vessel mobilisation, equipment verifications and operations are available in dedicated reports available at offshorewind.rvo.nl.

Equipment used to carry out the investigation included multibeam echosounder (MBES), side scan sonar (SSS), transverse gradiometer (TVG) using a dual magnetometer (MAG) solution, sub-bottom profiler (SBP), 2D ultra-high resolution seismic (2D-UHRS) and double Van Veen grab sampler (GS).

4.4.2 Supplier

Fugro was contracted by RVO to conduct the geophysical investigation at NW I-A and -B. 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 lifecycle.

4.4.3 Results

Bathymetry and seafloor morphology

Elevation at the time of the Geophysical Survey ranged from approximately -24.2 m to -33.9 m LAT (Figure 4.4.1).

The seafloor at NW I-A and -B is characterised by a dynamic morphology with (mobile) sedimentary bedforms. The type of bedforms identified at the Investigation Area, in order of decreasing magnitude, are sand banks, sand waves, megaripples, ripples and hummocks (irregular seafloor with small local depressions). Sand waves are the dominant bedforms, with wavelengths ranging between 200 m and 700 m and wave heights ranging between 2 m and 5 m. Trawl marks were also identified in the investigation area, indicating fishing activity (Figure 4.4.2).

Much of the area is characterised by seafloor slopes ranging from 0° to 10°. Localised gradients between 10° and 15° were observed on the lee side of sand waves.

Based on the results of the bathymetry, backscatter, SSS and grab sample data, the dominant seafloor sediment type in the area investigated is determined to be fine to medium sand, with small fractions of gravel (0–3%) and/or silt (1–5%). The gravel is mainly composed of shell and shell fragments (Figure 4.4.3).

Seafloor contacts

In total, 623 seafloor contacts were picked on SSS data and rationalised to the MBES position, where possible. The contacts include: 146 potential boulders, 46 isolated depressions, two wrecks, three pipelines, seven cable wires, 395 items of suspected debris, three rock dumps and three 'unidentified' contacts (Figure 4.4.4).

An automatic picking routine was used to identify magnetic anomalies from MAG data, after which they were manually checked and cross-correlated with SSS and/or MBES contacts within a 2 m radius, where possible. A total of 712 magnetic anomalies were identified. Classifications were assigned where correlation could be made with known seafloor objects or where a linear trend existed. This resulted in the correlation of 2276 magnetic anomalies; 1139 magnetic anomalies associated with six cables, 1131 with three pipelines and six with two wrecks.

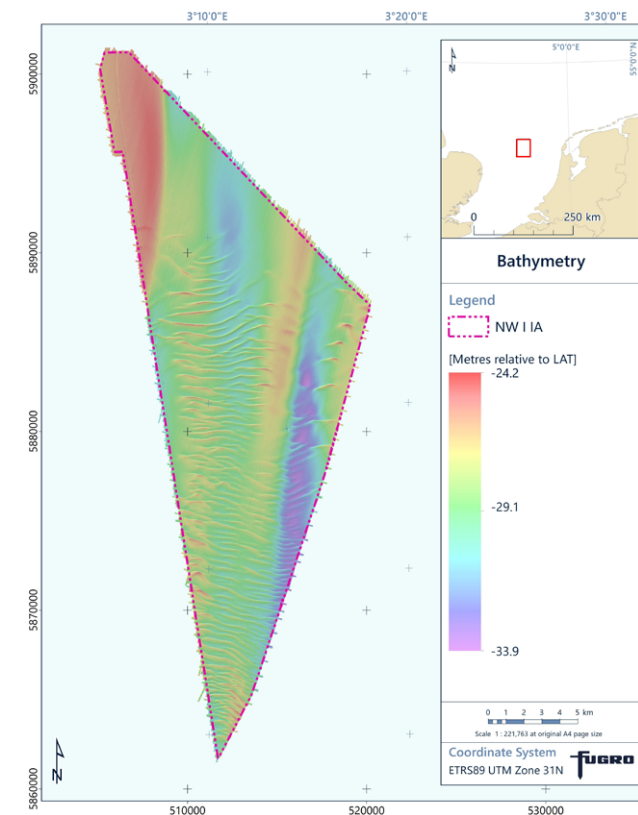


Figure 4.4.1 Shaded relief bathymetry at the NW I-A.

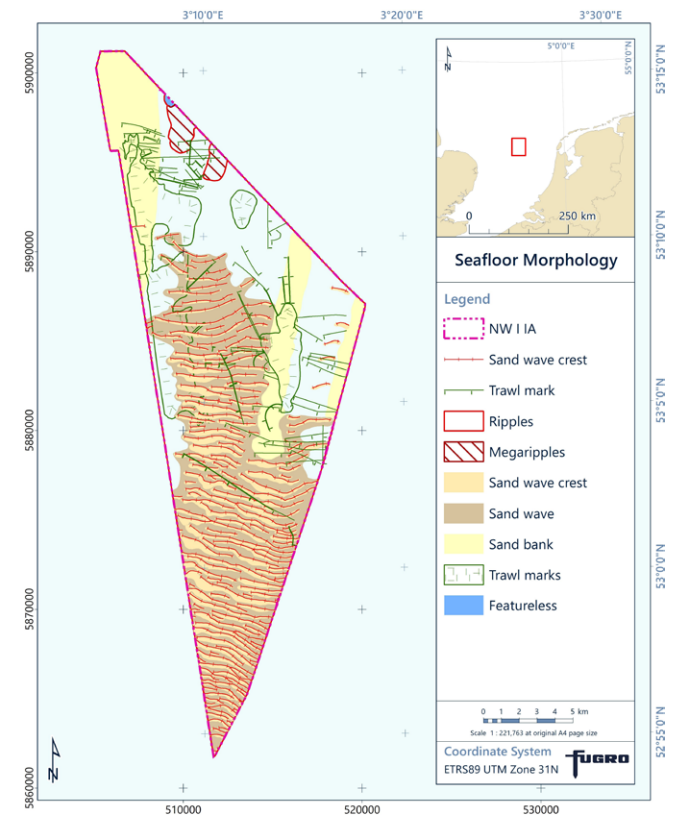


Figure 4.4.2 Seafloor morphology classification.

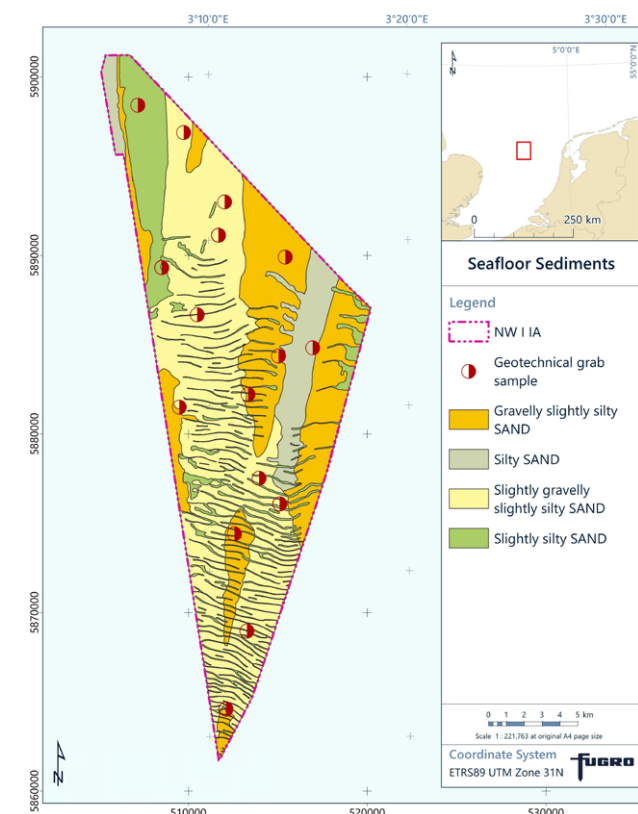


Figure 4.4.3 Seafloor sediment classification.

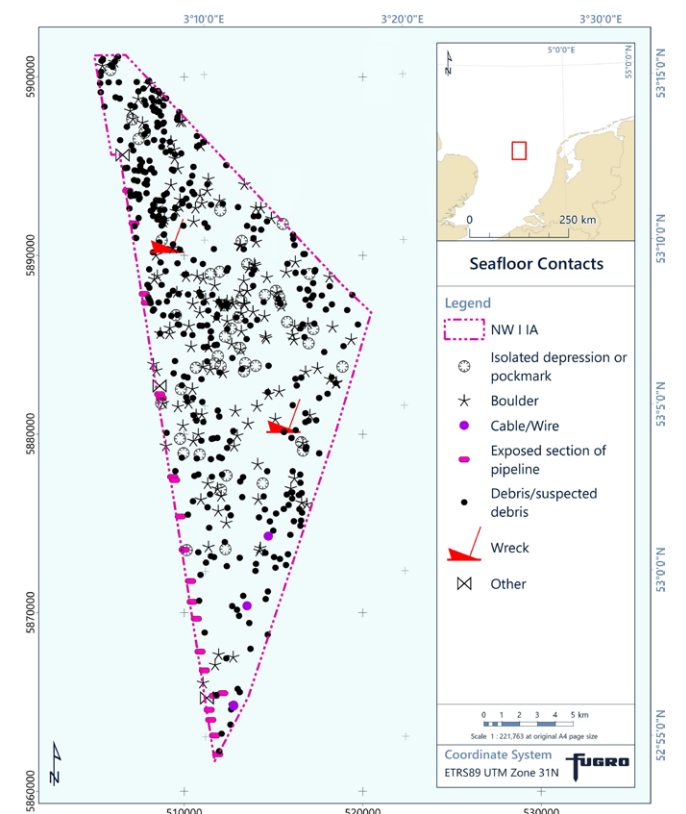


Figure 4.4.4 Seafloor contacts.

In addition to confirming the presence and providing the current (as found) position of known infrastructure, two unknown cables were observed in the area. These two unknown cables are part of the six cables identified in total.

Sub-seafloor conditions

Preliminary Seismic interpretation was carried out on 2D-UHRS data, while SBP data were used to support the interpretation of the shallow horizons. Five main horizons were interpreted, each

representing a significant acoustic interface consistent across NW I-A and -B, which form the bases of seismostratigraphic units. Interpretation of the seismostratigraphic units was correlated with existing geological, geophysical and geotechnical data in the Investigation Area 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 at NW I-A and -B were deposited during the Early 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.

Except for Horizon H10 (at the base of Unit C), the mapped seismostratigraphic unit bases are all erosive in nature and internal erosive surfaces occur inside most of the units. H02 (base Unit A) forms a planar erosion surface, H05 (base Unit B) is a highly 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.

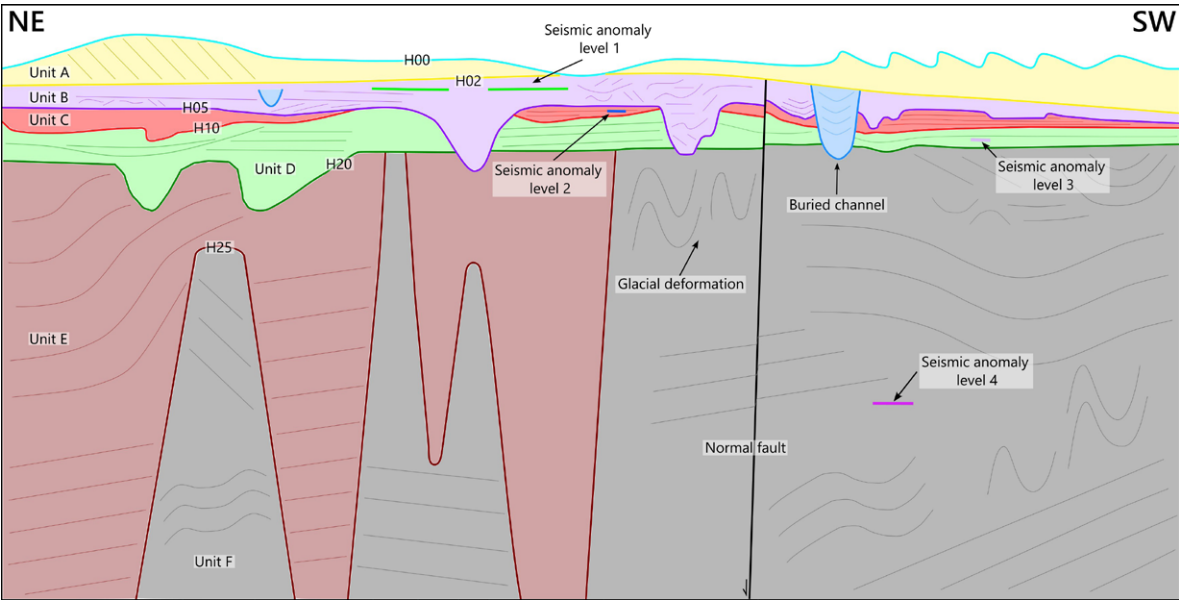


Figure 4.4.5 Schematic seismostratigraphic model of the NW I-A and -B Investigation Area.

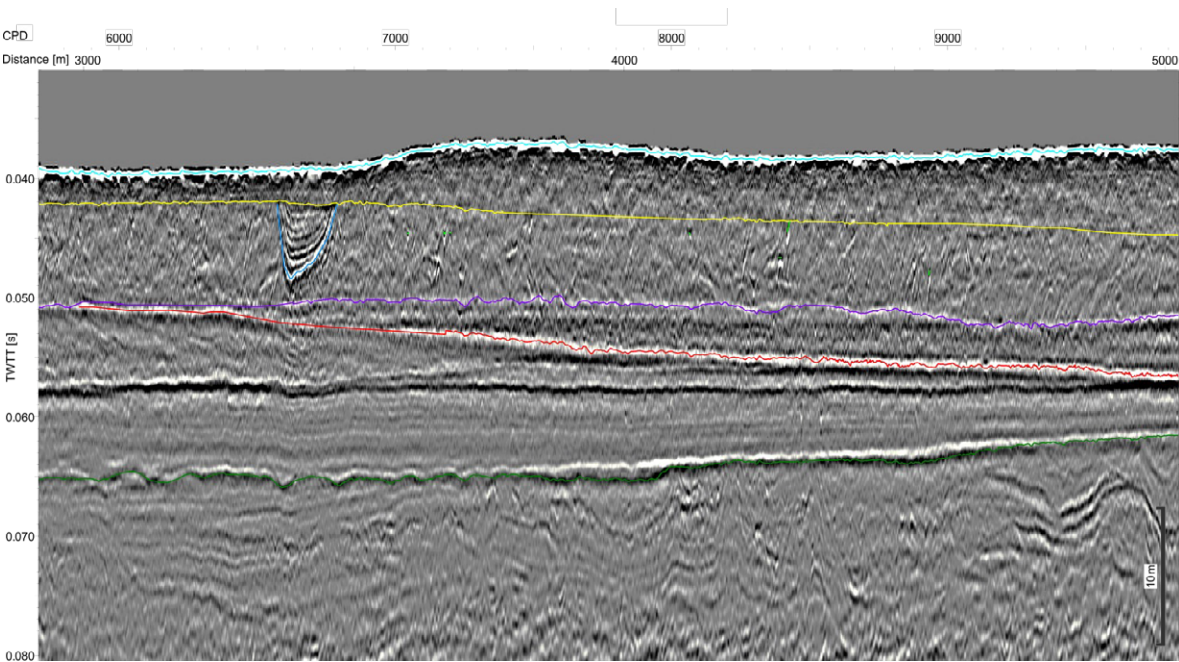


Figure 4.4.6 2D-UHRS data example with interpreted horizons delineating seismostratigraphic units.

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, with clinoforms in the north	Loose to very dense slightly silty fine to medium SAND, with shells and shell fragments	Open marine	Southern Bight (Holocene)
B	H00 H02	H05	Subhorizontal to irregular erosional surface, locally forming channels	Semi-transparent to chaotic, with internal channels and high negative amplitude anomalies	SAND with beds of silt, clay and peat	Coastal to tidal	Naaldwijk (Early Holocene)
C	H05	H10	Subhorizontal to slightly undulating surface	Semi-transparent to well-layered sub-parallel reflectors	CLAY	Brackish marine, lagoonal to lacustrine	Brown Bank (early Weichselian)
D	H05 H10	H20	Subhorizontal erosional surface	Semi-transparent to subparallel low to high-amplitude reflections	SAND with interbeds of CLAY	Shallow to open marine	Eem (Eemian) Egmond Ground (Holsteinian)
E	H05 H20	H25	U-shaped channel	Transparent in the south to well-layered prograding structures in the north	CLAY with (silty) SAND interbeds	Glacial, glaciofluvial to glaciolacustrine	Peelo (Elsterian)
F	H05 H20 H25	-	-	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)

The most significant contrast in the seismostratigraphic units may be at the interface between the Yarmouth Roads Formation (Unit F) and its overburden (mapped with Horizons Ho5, H2o 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 for geohazards that may be relevant to wind farm planning. The geohazards identified include shallow gas indicators, buried channels, layers of potential peat, layers of potential coarse material, faults, and glacially deformed areas.

Results from the Geophysical Site Investigation preceded and then contributed 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 NW I-A and -B were presented and discussed during a live webinar on 28 November 2024. See offshorewind.rvo.nl for details.



4.5 Archaeological Assessment of geophysical and hydrographic survey data

4.5.1 Aims

After completion of the Phase I archaeological desk-based assessment, Vestigia Archeologie & Cultuurhistorie and MSDS Marine undertook a Phase II Archaeological Assessment of geophysical and hydrographic survey data for NW I-A and -B.

The principle aim of the archaeological review of geophysical and hydrographic data is to establish the presence of material of potential archaeological significance on the seabed. The identification of material allows for strategies to be recommended to mitigate against any negative effects that may be caused by the wind farm development process.

4.5.2 Objectives

The objectives of the archaeological interpretation can be summarised as follows;

- Establish the presence of anthropogenic material (i.e. those created by human activities) of archaeological potential;
- Interpret the identified anomalies as to their potential to be of archaeological significance;
- To recommend mitigation strategies for the anomalies appropriate to their archaeological potential;
- To recommend further works that may be required and their specifications.

4.5.3 Methodology

The geophysical and hydrographic data was collected by Fugro and consisted of side scan sonar, multibeam bathymetry, sub-bottom profiler, and magnetometer data. The specification of the data and the collection strategy were considered appropriate to undertake the archaeological assessment.

The data was systematically reviewed by an experienced marine archaeologist. All features of potential anthropogenic origin were identified and recorded. An assessment was made as to the potential of the features to be of archaeological significance, with a rating of high, medium or low potential assigned. The results were analysed alongside the Phase I data and, where required, additional research was undertaken to establish the potential.

Mitigation strategies were recommended for each of the identified features based on the assessed potential.

4.5.4 Supplier

Vestigia Archeologie & Cultuurhistorie and MSDS Marine were contracted by RVO to conduct a Phase II Archaeological Assessment of geophysical and hydrographic survey data collected by Fugro.

4.5.5 Results

The investigation area for NW I-A and -B covered an area of 271 km². Two small areas – one at the north-western most extents and one at the eastern most extents – were not covered during the survey. Therefore, these areas have not been subject to archaeological assessment.

The Phase I archaeological desk-based assessment identified ten records of relevance to the assessment of geophysical and hydrographic data: six obstructions, three wrecks and one report of wreck. Of the three wrecks, two were identified in the data and one was determined not to exist at the stated location. All six of the records of obstructions were determined to relate to seabed infrastructure in the form of wells and therefore of no archaeological interest.

The Archaeological Assessment identified 154 visible surface anomalies of potential archaeological interest. These are;

- 145 low potential anomalies;
- Six medium potential anomalies; and
- Three high potential anomalies, including two wrecks identified during Phase I and one potential previously unrecorded wreck.

Furthermore, the assessment of magnetometer data identified 3629 anomalies with no definitive seabed expression and no correlation to known infrastructure. Magnetic anomalies indicate the presence of ferrous material and thus are typically anthropogenic in origin. However, where there is no surface expression, interpretation is often more subjective. The archaeological potential of the anomalies was assessed based on the recorded amplitude and the calculated ferrous mass. Of the 3629 magnetic anomalies, 70 were interpreted as of medium potential to be of archaeological interest and eight were deemed of high potential to be of archaeological interest.

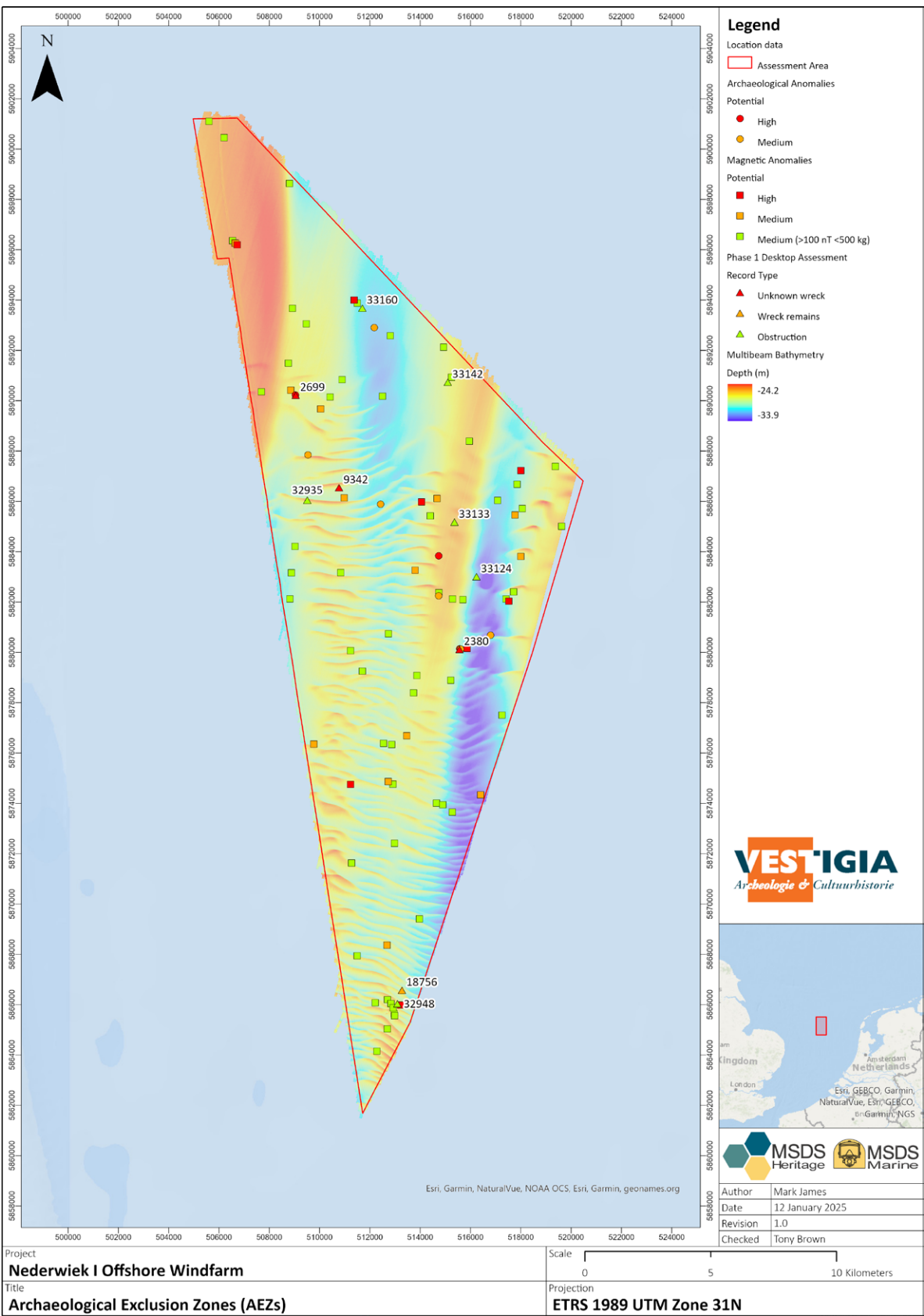


Figure 4.5.1 Summary of known contacts within the investigated area of Nederwiek I-A and -B.

4.5.6 Recommendations

Eight Archaeological Exclusion Zones (AEZs) have been recommended around the visible high and medium potential archaeological anomalies. One medium potential anomaly lies within the extents of a high potential anomaly and has not been recommended as a separate AEZ. The AEZs should be 100 m from the extents of the anomaly. Seventy-eight (78) AEZs of 100 m radius have been recommended around the positions of the high and medium potential magnetic anomalies (see Figure 4.5.1).

Should an AEZ impact the development programme, it is recommended that a programme of ground truthing is being undertaken to establish the identity of an anomaly in order that the potential archaeological significance can be assessed by a qualified and experienced archaeologist. Following a programme of assessment, and where revisions to AEZs are considered appropriate, they should be made in consultation with the Cultural Heritage Agency of the Netherlands (Rijksdienst voor het Cultureel Erfgoed, RCE).

Unexpected discoveries of potential archaeological interest can occur during any phase of development where the seabed is visualised. This can include the collection of geophysical and hydrographic data, visualisation of the seabed, typically whilst using remotely operated vehicles, but also, for example, through cameras mounted on cable installation tools. Unexpected discoveries can also occur when material is recovered to the surface following snagging on equipment such as anchors or pre-lay grapnels. All discoveries should be reported immediately to RCE.

4.6 Archaeological Assessment of geotechnical survey data

Following on from the initial work on the Archaeological Desk Study, vibrocore samples have been collected to further assess the (integrity of) aquatic and terrestrial prehistoric landscapes and related archaeological remains. The vibrocore sampling locations are shown in Figure 4.6.1. The analysis of the corings showed that neither the deeper corings nor the vibrocores contained any primary or secondary archaeological indicators for human occupancy. Both the lithological description and the analyses carried out on selected samples from the corings provided more insight in the palaeolandscape development and the distribution of remnants of the geoarchaeologically relevant landscapes of the Palaeolithic and (Early) Mesolithic within the Nederwiek I Site.

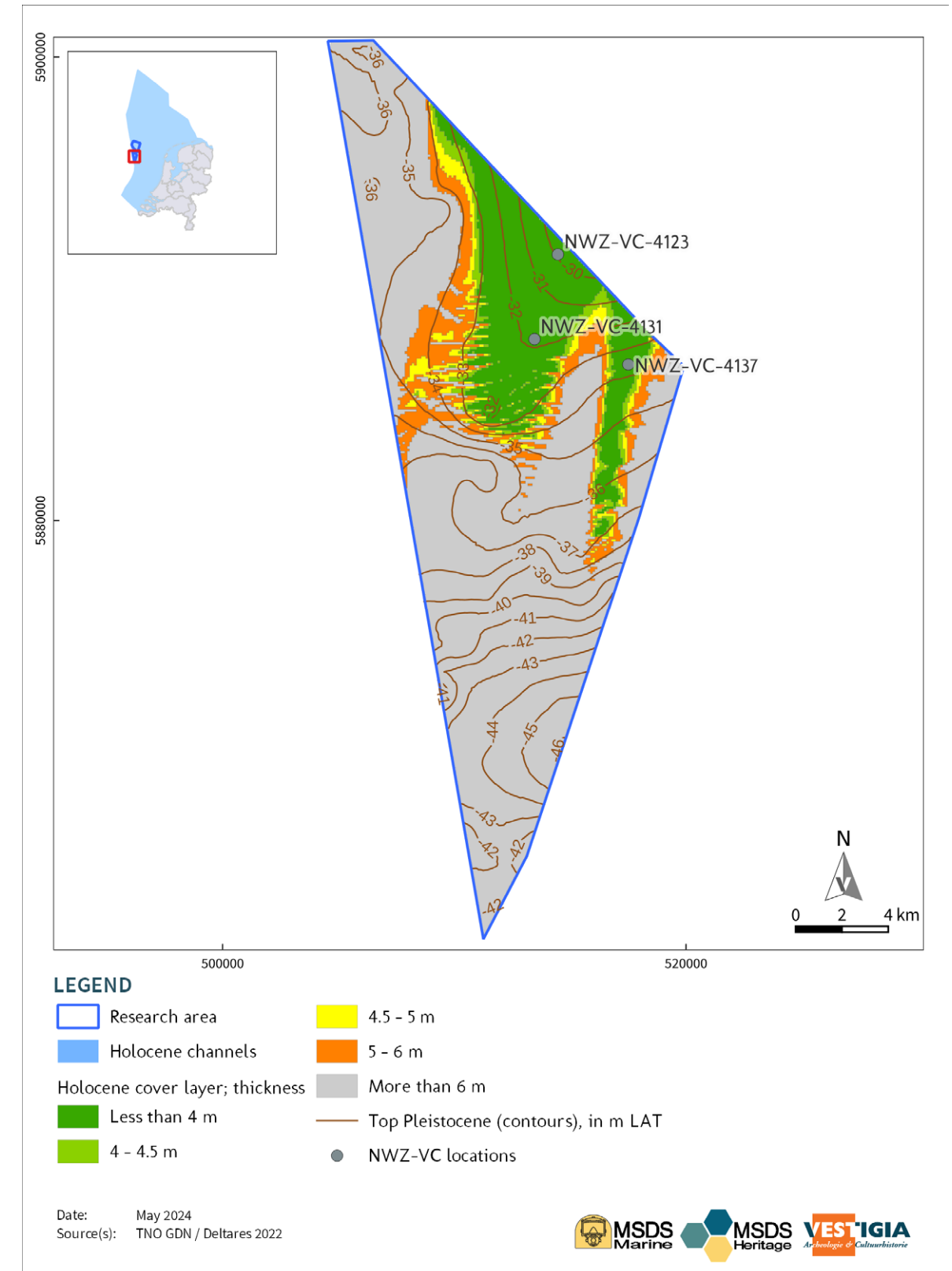


Figure 4.6.1 Vibrocore sampling locations for the Archaeological Assessment.

4.7 Baseline survey of Benthic Ecology

RVO has recently started to include ecological studies as part of their site study package, as ecology is playing an increasingly large role in offshore wind development. This study is focused on the benthic ecology of Nederwiek I.

To collect data, the geophysical campaign at Nederwiek Wind Farm Sites I-A and I-B (NW I-A and -B) was conducted in the period May – June 2023. During the campaign, 24 (USNEL-type) box corer and 24 sediment samples were collected to investigate benthic life. The sample locations were determined jointly by RVO and the Directorate General for Public Works and Water Management (Rijkswaterstaat). When determining the locations, account was taken of the soil structure (crest, slope and trench) and the fact that the locations are spread throughout the entire area. Fieldwork was organised by Fugro Netherlands Marine B.V. and the analysis of benthic macrofauna and statistical analyses was organised by Waardenburg Ecology.

4.7.1 Methods

An acceptable grab sample was subsampled using a 0.1 m² stainless steel divider and retained for sediment Particle Size Distribution (PSD) and macrofauna analysis. Once sieved, samples were photographed and transferred to containers labelled and fixed in 10% buffered formal saline. All organisms and fragments thereof were removed from the samples and sorted by species group (Polychaeta, Crustacea, Mollusca,

Echinodermata and other). Where possible, all organisms were identified to species level. Biomass was determined for each taxon in each sample, expressed in ash-free dry weight (AFDW). Dendrograms were created to investigate the difference between locations for both sediment and abundance. A principal component analysis was performed to determine to what extent a cluster explained the variance between locations.

4.7.2 Results

A total of 75 different taxa were found, of which at least 46 species were present in the 24 samples. This is approximately 50% less than what is found between Bruine Bank and Nederwiek. On average, 12 different taxa were found per sample. The most abundant species group is the Annelida (21 species) followed by seven species of Amphipod and seven species of Bivalvia. None of the samples differ significantly from each other in terms of number of species and taxa. Some rare species in the Dutch North Sea were found during this campaign, including the polychaete worm *Aglaophamus agilis* and the dwarf swimming crab *Liocarcinus pusillus*. A total AFDW biomass of 10.8 grammes was measured at NW I-A and -B. Echinodermata represent the highest biomass.

The sediment layer at NW I-A and -B is statistically homogeneous. All locations sampled contained a grain size with an average of 220 micrometers (fine/medium sand) with 1.8% silt. The area is fairly homogeneous in terms of benthic composition and sediment. No major differences between samples were observed in the statistical analyses.

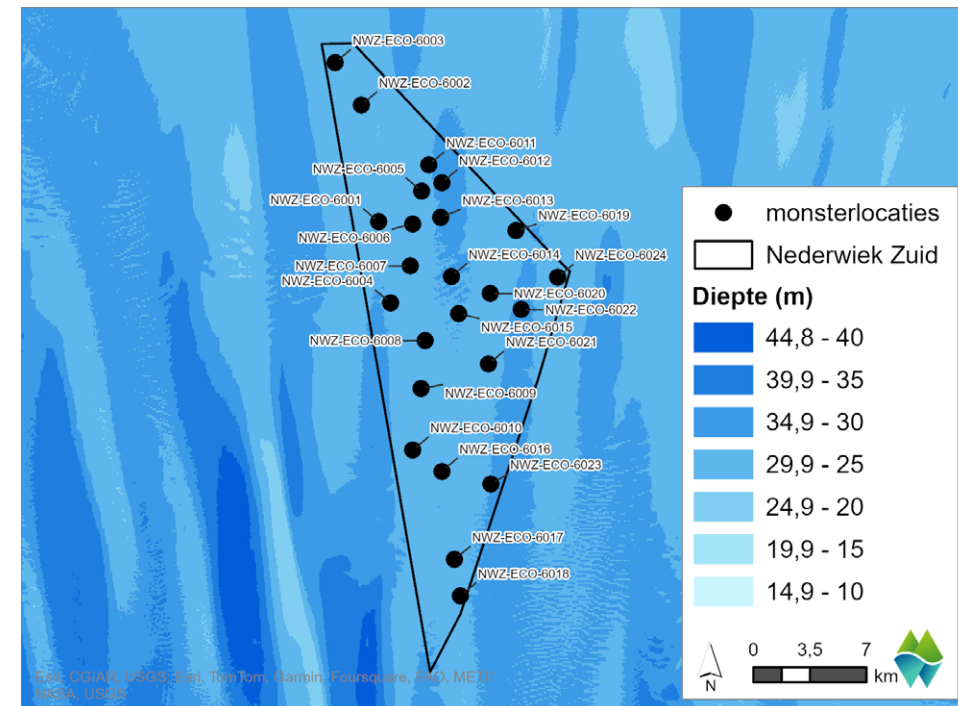


Figure 4.7.1 Sampling locations at NW I-A and -B and water depth (EMODnet Digital Bathymetry (DTM 2022) in meters.

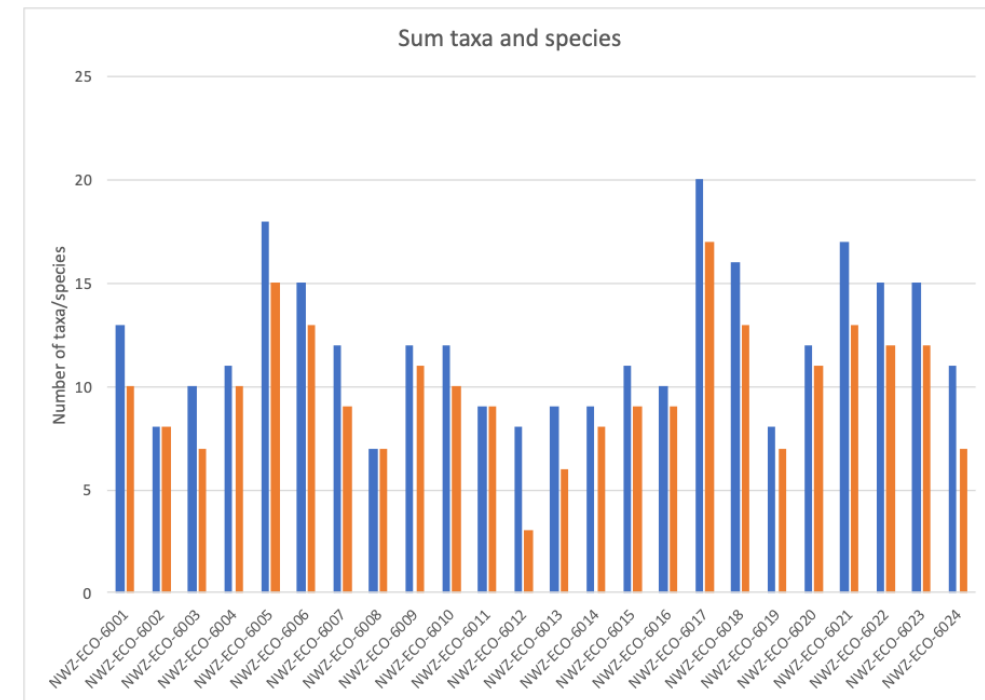


Figure 4.7.2 Number of taxa (blue) and species (orange) per sample, collected at Nederwiek I-A and -B.



Figure 4.7.3 Photo left: *Aglaophamus agilis* and photo right: *Liocarcinus pusillus*.

4.8 Geotechnical Site Investigation

4.8.1 Overview

The Geotechnical Site Investigation intends to provide geological and geotechnical information for the Nederwiek Site I-A and I-B (NW I-A and -B) Investigation Area. The acquired data will allow the development of a detailed ground model of the area, to progress the design and installation requirements for offshore wind farms, including, but not limited to, foundations and cables.

The geotechnical campaign for NW I-A and -B used intrusive techniques to gain insight into the characteristics of the subsoil. Three types of investigation techniques were used: (1) in situ testing from seafloor, consisting of (standard, seismic and temperature) cone penetration testing, pore pressure dissipation testing, seismic velocity testing, and temperature equilibrium testing, (2) sampling from seafloor using a High Performance Corer® (HPC) sampling device, (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). In situ testing and seafloor sampling from seafloor were performed from geotechnical vessel ‘Normand Mermaid’ and geotechnical borehole drilling was performed from geotechnical drilling vessel ‘Fugro Voyager’. On-site 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 NW I-A and -B comprised the following:

- A total of 64 seafloor piezocone penetration tests (PCPTs) at 60 target locations to depths ranging from 12.3 m to 54.0 m below seafloor (BSF). Twenty-nine (29) tests include pore pressure dissipation tests (PPDTs) at selected depths within the seafloor PCPT stroke;

- A total of six additional seafloor PCPTs at five target locations for comparison with the synthetic CPTs;
- A total of 27 seafloor seismic cone penetration tests (SCPTs) at 25 target locations to depths ranging from 12.3 m to 53.7 m BSF. Twenty-seven (27) tests include seismic velocity tests (SVTs) at selected depths within the seafloor SCPT stroke;
- A total of 27 seafloor temperature cone penetration tests (TCPT) at 25 target locations to depths ranging from 2.1 m to 7.0 m BSF. Twenty-five (25) tests include temperature equilibrium tests (TETs) at selected depths within the seafloor TCPT stroke;
- A total of 57 vibrocores at 57 target locations to depths ranging from 3.3 to 6.2 m BSF;
- A total of 68 geotechnical boreholes at 53 target locations to depths ranging from seafloor to 80.0 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;
- Eight boreholes included sampling for biogeochemical analyses and eight 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. 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 4.8.1, 4.8.2 en 4.8.3. Note that determinations of water content and unit weight, as well as torvane and pocket penetrometer tests, are not presented in these tables.

Table 4.8.1 Overview of standard laboratory test programme of the seafloor sample locations.

Test Type	Test Quantity
Geotechnical Index	
Plasticity index	3
Particle size distribution: Image analyses	151
Particle size distribution: Sieve	22
Particle size distribution: Sedimentation	7
Particle density	150
Minimum and maximum index dry density: (modified) shaker method	38
Microscopy	17
Geochemical	
Organic matter	12
Loss on Ignition	12
Total organic carbon	12
Carbonate content of soil	12
Salinity (calculated)	20
Strength and Stiffness	
Unconsolidated undrained triaxial in compression: undisturbed	3
Unconsolidated undrained triaxial in compression: remoulded	3
Direct shear	38
Other	
Electrical resistivity	20
Thermal conductivity: Needle probe	60
Thermal conductivity: Hot disk	22

Table 4.8.2 Overview of standard laboratory test programme of the geotechnical borehole locations.

Test Type	Test Quantity Reported	Test Quantity Outstanding
Geotechnical Index		
Plasticity index	228	-
Particle size distribution: Image analyses	518	-
Particle size distribution: Sieve	117	-
Particle size distribution: Sedimentation	69	-
Particle size distribution: Sieve and sedimentation	262	-
Particle density	229	-
Minimum and maximum index dry density: (modified) shaker method	202	-
Microscopy	78	-

Test Type	Test Quantity Reported	Test Quantity Outstanding
Geochemical		
Organic matter	127	-
Loss on ignition	25	-
Total organic carbon	186	-
Carbonate content of soil	165	-
Salinity (calculated)	57	-
Strength and Stiffness		
Unconsolidated undrained triaxial: undisturbed and remoulded specimen	39	-
Unconsolidated undrained triaxial: undisturbed and remoulded specimen [field]	23	-
Isotropically consolidated drained triaxial in compression	179	52
Isotropically consolidated drained triaxial in compression: With cyclic pre-shear	19	4
Isotropically consolidated undrained triaxial in compression	20	1
Anisotropically consolidated undrained triaxial in compression	96	33
Bender elements as part of (An)isotropically consolidated undrained triaxial in compression	13	32
Isotropically Cconsolidated drained triaxial in extension	1	-
Anisotropically consolidated drained triaxial in extension	21	-
Bender elements as part of (An)isotropically consolidated undrained triaxial in extension	5	-
Dynamic Response		
Resonant column	51	1
Interface Shear		
Ring shear: Soil/soil interface	15	16
Ring shear: Soil/steel interface	164	4
Direct simple shear (constant volume)	183	2
Direct shear (set of 3 specimens)	105	-
One-dimensional Consolidation		
Incremental loading	24	-
Constant rate of strain	44	59
Permeability		
Constand head permeability: Permeameter	74	-
Constand head permeability: Triaxial cell*	25	1
Other		
Electrical resistivity	72	-
Thermal conductivity: Needle probe	68	-
Thermal conductivity: Hot disk	13	-
Age dating	150	-
Microbiologically influenced corrosion	16	-

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

Table 4.8.3 Overview of advanced laboratory test programme.

Test Type	Test Quantity*
Geotechnical Index	
Plasticity index	27
Particle size distribution: Sieve	6
Particle size distribution: Sedimentation	29
Particle density	-
Minimum and maximum index dry density: (modified) shaker method	6
Microscopy	6
Geochemical	
Organic matter	-
Carbonate content of soil	-
Strength and Stiffness	
Consolidated undrained triaxial in compression	1
Consolidated undrained triaxial in extension	1
Consolidated undrained triaxial in compression: With cyclic pre-shear and with bender element measurements	6
Consolidated undrained triaxial in extension: With cyclic pre-shear and with bender element measurements	6
Dynamic Response	
Resonant column	12
Interface Shear	
Ring shear: Soil/steel interface	-
Direct simple shear under constant volume	5
Direct simple shear under constant volume: with cyclic pre-shear	6
One-dimensional Consolidation	
Incremental loading	-
Permeability	
Constand head permeability: Permeameter	-
Constand head permeability: Triaxial cell†	-
Cyclic Strength and Response – Triaxial	
Consolidated undrained cyclic triaxial	10
Consolidated undrained cyclic triaxial: With cyclic pre-shear	60
Consolidated drained cyclic triaxial	-
Cyclic Strength and Response – Direct Simple Shear	
Cyclic direct simple shear under constant volume	55
Cyclic direct simple shear under constant volume: With cyclic pre-shear	60

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

4.8.2 Supplier

Fugro was contracted to perform this Geotechnical Site Investigation. It was performed according to ISO 19901-8:2014 and was conducted in two separate phases. The seafloor phase was performed from geotechnical vessel Normand Mermaid between 6 and 29 May 2023. The downhole phase was performed from geotechnical drilling vessel Fugro Voyager between 14 August and 31 October 2023.

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. A SEACALF® CDS provided a reliable, safe and efficient test unit for high quality data acquisition to depths up to 54 m BSF. Sampling from 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, comprising 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. Multiple runs were executed at each location, employing a suite of wireline conveyed downhole geophysical tools (caliper, natural gamma radiation, spectral gamma radiation, P and S suspension logger, downhole magnetic resonance).

4.8.3 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 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 TETs, i.e. temperature versus time, and derived thermal conductivity;
- Results of PPDTs, i.e. cone resistance and pore pressure versus time.

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.

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 estimation of microbially influenced mass loss rates of steel-based foundation structures in marine sediments based on chemical and microbiological soil parameters.

A geotechnical report containing results of the advanced laboratory testing programme, including:

- Geotechnical index tests;
- Static triaxial tests;
- Monotonic direct simple shear tests;
- Resonant column tests;
- Cyclic triaxial tests;
- Cyclic direct simple shear tests;

A dating analysis report containing results of dating analyses and results of a geochronology and palaeoenvironmental 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.

4.8.4 Webinar

The results of the Geotechnical Site Investigations performed at NW I-A and -B were presented and discussed in a webinar held on 18 February 2025. Please refer to offshorewind.rvo.nl for details.

4.8.5 Conclusion

The Geotechnical Site Investigation and associated laboratory testing programme provide high quality geotechnical data suitable for improving the geological and geotechnical understanding of the NW I-A and -B sites, 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 winning developers, e.g. to perform additional testing. The reports were certified by DNV.



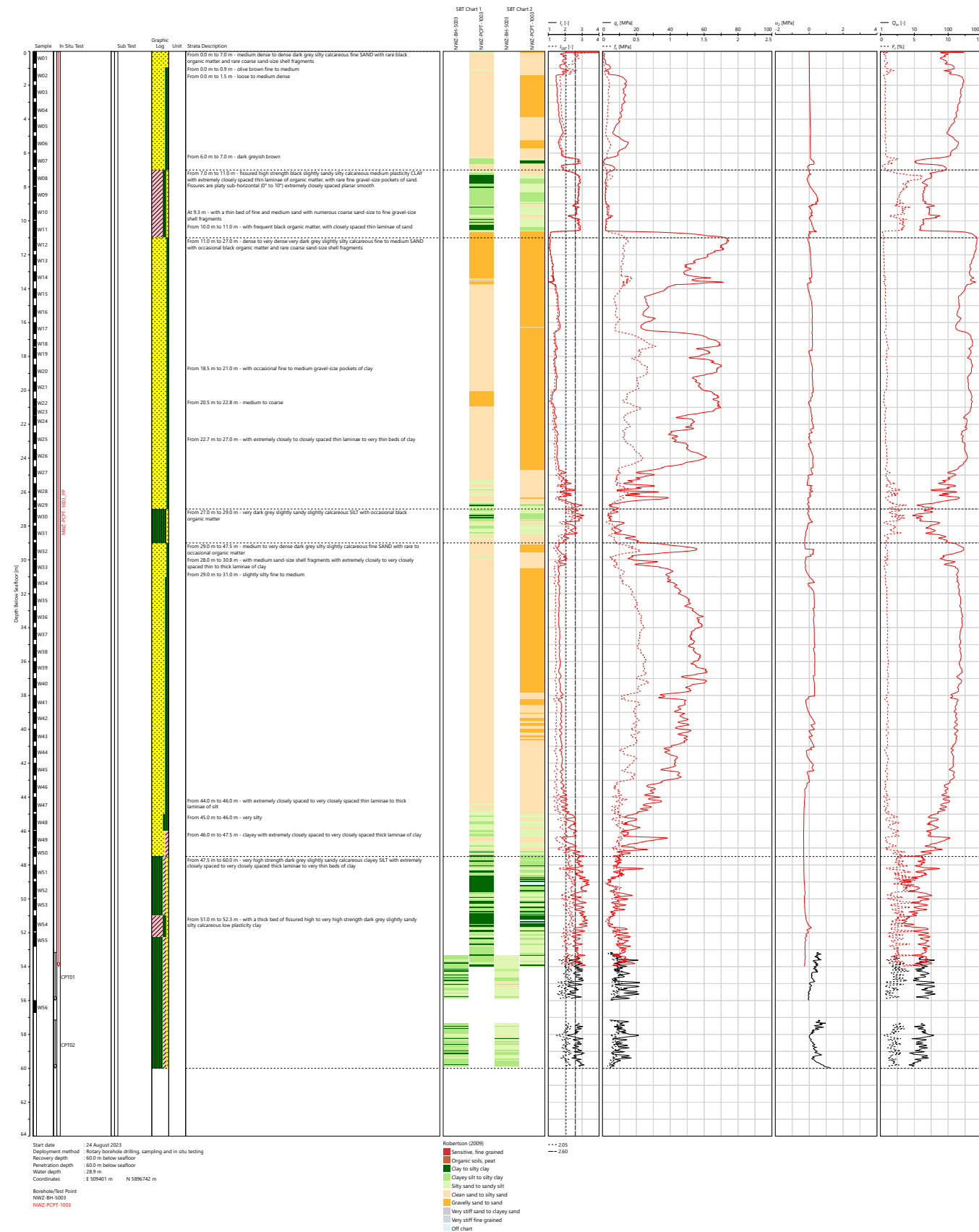
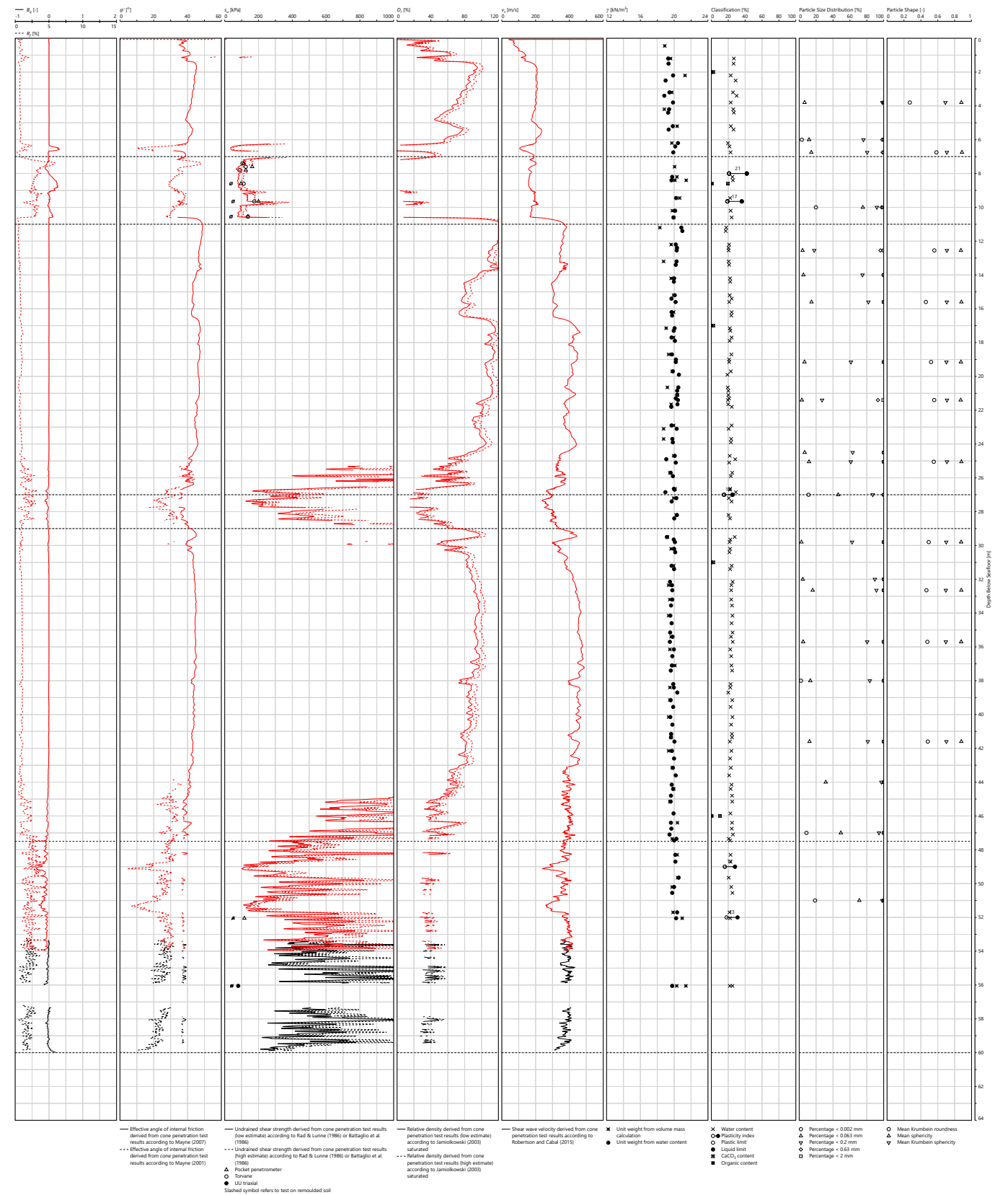


Figure 4.8.3 Geotechnical log presenting interpretation of soil profile, strata descriptions, measured and derived parameters based on in situ test data (CPT and SVT),



sampling and laboratory test results.

4.9 Integrated Ground Model and Geotechnical Interpretative Report

4.9.1 Overview - aims, objectives and approach

The primary aim of the integrated ground model (IGM) for Nederwiek Wind Farm Sites I-A and I-B (NW I-A and -B) is to give offshore wind farm developers the ability to intelligently plan foundation and cabling for the site and efficiently construct an offshore wind farm. The IGM encompasses both qualitative and quantitative outputs to communicate geotechnical variability and risk.

Point-source geotechnical data integrated with site-wide geophysics over an area of 273 km² is critical to understand the influence of changing ground conditions on design.

The IGM is composed of three distinct elements, all of which reference a consistent evolutionary geological framework.

The geological ground model (GGM) contains a stratigraphic assessment based on a geophysical survey integrated with geotechnical investigation data (e.g. PCPT, SCPT). The geotechnical interpretative report (GIR) presents a derived and characteristic assessment of geotechnical parameters based on standard and advanced laboratory testing results. The Integrated Ground Model (IGM) combines the results of the previous studies with predicted parameters based on quantitative pre-stack seismic inversion, with a 3D voxel output of geotechnical conditions across NW I-A and -B.

A model is a representation of true ground conditions, therefore the IGM necessarily incorporates uncertainty and confidence to allow engineering end users to understand limitations in the underlying datasets and interpretation methods. Any predictions that are used should be considered in the context of the uncertainty values stated and the underlying method of formulation.

4.9.2 Supplier

Arup International Projects (Arup) was awarded the contract by RVO to create the IGM for NW I-A and -B. Arup and partners; the British Geological Survey (BGS), Inosys, RockWave and SolidGround delivered various elements of the project collaboratively through 2023, 2024 & 2025.

4.9.3 Results

Geological Ground Model (GGM)

The GGM for NW I-A and -B was centred around an evolutionary ground model for the site that combines geophysical and geotechnical data to understand the distribution of soil conditions in the surface and subsurface. Geophysical data (2D UHRS and SBP, see Section 4.4) was used to demarcate seismostratigraphic facies with corresponding lithology and depositional/post-depositional origin. Where possible, these were correlated using chronostratigraphic principles to capture the complex evolutionary history of the site, demonstrating repeated glacial advance and retreat in the North Sea, with accompanying sea level change during the Quaternary period to present day (Figure 4.9.1).

Table 4.9.1 presents an overview of the geological formation, seismostratigraphic unit and resulting soil unit with dominant lithology present.

To accompany the stratigraphic interpretation, geological hazards were assessed based on the data available, linked to planned infrastructure (i.e. wind turbine foundations and cables). This includes organic sediments, shallow drilling hazard, sediment variability, mobile bedforms, boulders and geotechnical variability.

Geotechnical Interpretative Report (GIR)

The GIR presents interpretation, derivation and evaluation of geotechnical data from seabed mode (i.e. PCPT, SCPT, vibro-core, Geotechnical section 4.8) and borehole mode (i.e. BGL, sampling, in situ-testing, Geotechnical section) data sources carried out across two field investigation campaigns.

The GIR contains

- a. engineering summary of soil provinces and profiles,
- b. evaluation of data and results, with interpretation methods and procedures,
- c. geotechnical parameters per geotechnical unit, and
- d. advanced cyclic test parameters.

Site specific derived CPT parameters are influential to the creation of the IGM, due to the continuous nature of the input dataset, and the ability to influence concept foundation design in sand-dominated profiles. Therefore, the correlation of these data with laboratory testing results is a keen component of the GIR.

A probabilistic seismic hazard assessment was performed for NW I-A and -B and determined that spectral acceleration values were higher than those computed for IJmuiden Ver Sites Alpha, Beta and Gamma. The assessment was based on the new seismic source characterisation released in 2024 by the British Geological Survey for the UK sector of the North Sea (including for NW I-A and -B), which revised and updated previous estimates of the seismic activity rates in the area. The spectral acceleration values for infrastructure planning can still be considered as low.

Table 4.9.1 Integrated stratigraphy for Nederwiek Wind Farm Sites I-A and I-B.

Geological Formation	Depositional Environment	Seismostrat. Unit	Geotech. Soil Unit	Dominant Lithology
Southern Bight	Marine	A	U1	Sand
Nieuwkoop [Naaldwijk]	Fluvial, coastal plain, periglacial	B	U2	Sand, peat, organic matter
Brown Bank Mb [Eem]	Marine	C	U3	Clay
Eem	Marine – tidal	D-1	U4	Sand
	Marine	D-2		Clay
	Marine – tidal	D-3/5	U5	Sand
	Marine	D-4		Clay
	Terrestrial to Marine	D-5		Sand
Drente*	Pro- to periglacial	E-1	U6	Sand (+ Clay)
Urk/Egmond Ground*	Fluvial to marine	E-2		Sand (+ Clay)
	Marine	E-3		Interbedded
	Marine	E-4	U7	Interbedded
Urk / Peelo*	Sub-glacial to marine	E-5		Interbedded
Yarmouth Roads	Fluvial, deltaic, marine	F	U7	Sand and Silt

Notes: * Formation uncertain from biostratigraphic results, inferred based on geological history

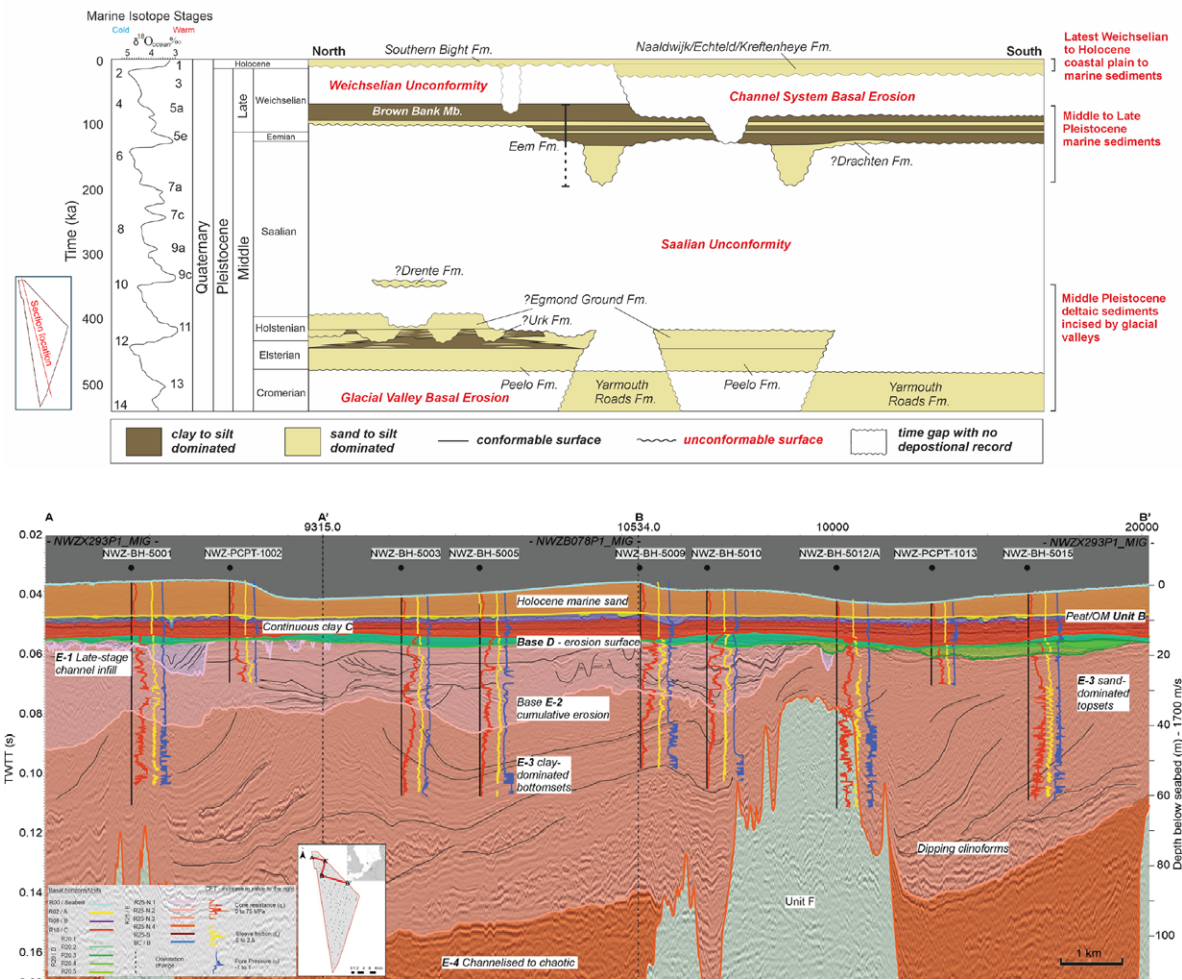


Figure 4.9.1 TOP: chronostratigraphic conceptual cross-section, BASE: annotated cross-section, north-south through NW I-A and -B.

For concept foundation design of offshore wind turbines at NW I-A and -B, the data acquired and the analysis performed is in line with the requirements of IEC 61400-3-1:2019, ISO 19901-8:2014 and ISO 19901-10:2021.

Integrated Ground Model (IGM)

Soil provinces and profiles

Six distinct soil provinces were identified at NW I-A and -B. A soil province represents the spatial extent of a soil profile, composed of a sequence of soil units to 100 m BSF (Figure 4.9.2). Soil Province 2 covers 27% of the NW I-A and -B Investigation Area, representing the Northern Tunnel Valley (U5) of Urk or Egmond Ground Formation interbedded sand/ clay; Soil Province 6 covers (48.6%) of the area and represents typical conditions outside of Tunnel Valley fill, with Yarmouth Roads Formation (U7) deltaic sands and interbedded clay being the dominant unit within the profile.

Pre-stack seismic inversion, predictive CPT parameters, uncertainty and 3D modelling

Seismic inversion converts the acoustic to the elastic domain and allows correlation of material properties (density, bulk modulus, shear modulus) present at every trace in the 2D-UHR dataset.

AVO-compliant reprocessing was performed on all pre-stack (raw) 2D-UHR geophysical data, including the definition of angle stacks up to 50 degrees, prior to utilising the Aki Richard (1980) three term reflectivity model for seismic inversion. Through a probabilistic framework of material properties derived from seismic inversion, CPT parameters (qc, fs, K and Gmax) were then predicted and compared with 'true' CPTs to understand variance and uncertainty in the predictions.

Each predicted value considers the uncertainty generated from the various processing and inversion steps and presents these for each geotechnical unit following DNV-RP-C207 (2021).

Two 3D models were produced to assist users in understanding ground condition variance across the Investigation Area: a) stratigraphic model, b) geotechnical model. The geotechnical model produces a continuous 3D volume of interpolated parameters based on the intrusive site investigation and non-intrusive surveys to assess ground conditions at any point across NW I-A and -B. It is expected that this model will be used for preliminary engineering assessments, e.g. optioneering studies ahead of further confirmatory investigations. The resolution of the final model is 20 m, 20 m, 0.5 m (XYZ) and based on interpolation using an Empirical Bayesian Kriging (EBK) methodology.

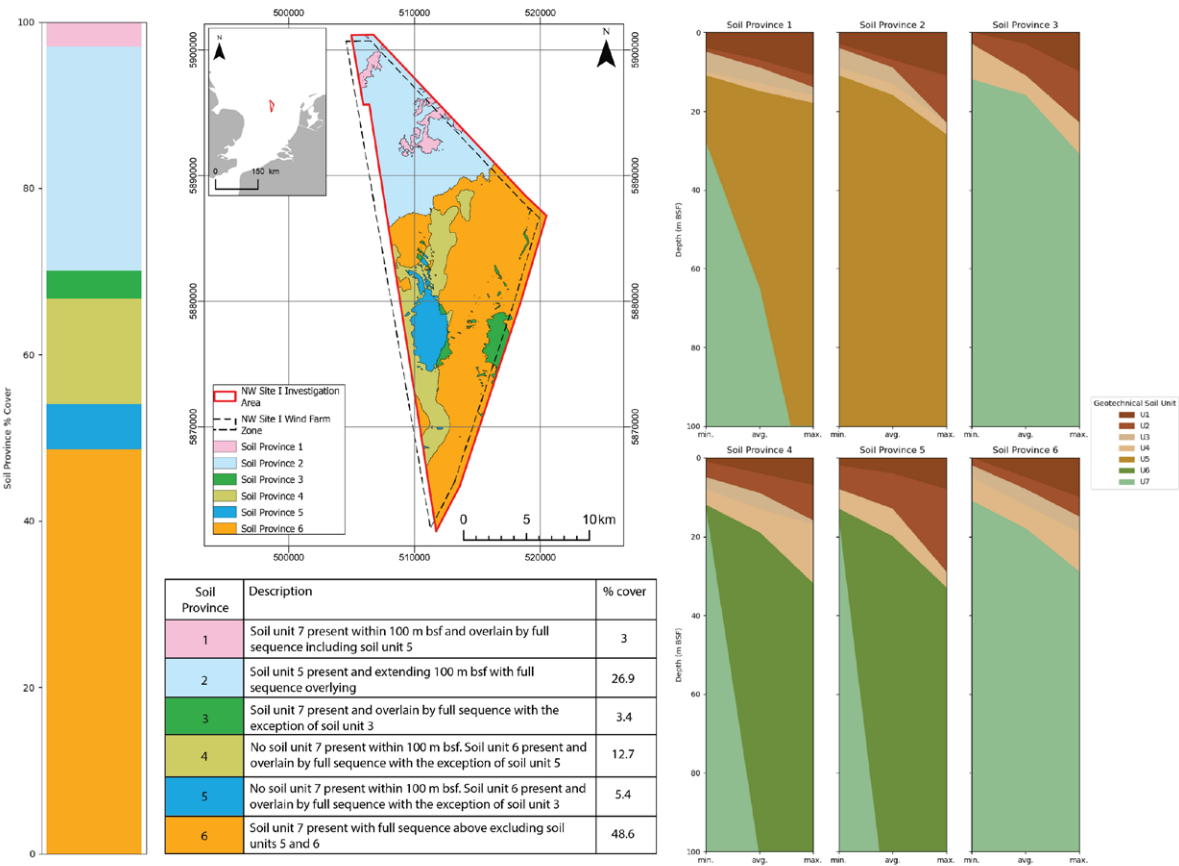


Figure 4.9.2 Soil provinces and corresponding profiles for Nederwiek Wind Farm Sites I-A and I-B.

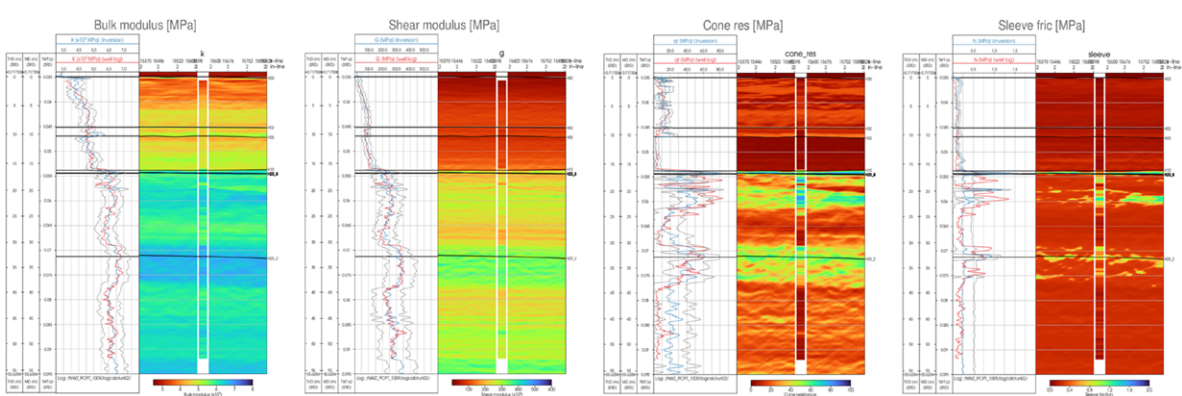


Figure 4.9.3 Example of a seismic inversion result for predicted CPT parameters (blue) compared to a 'real' location (red).

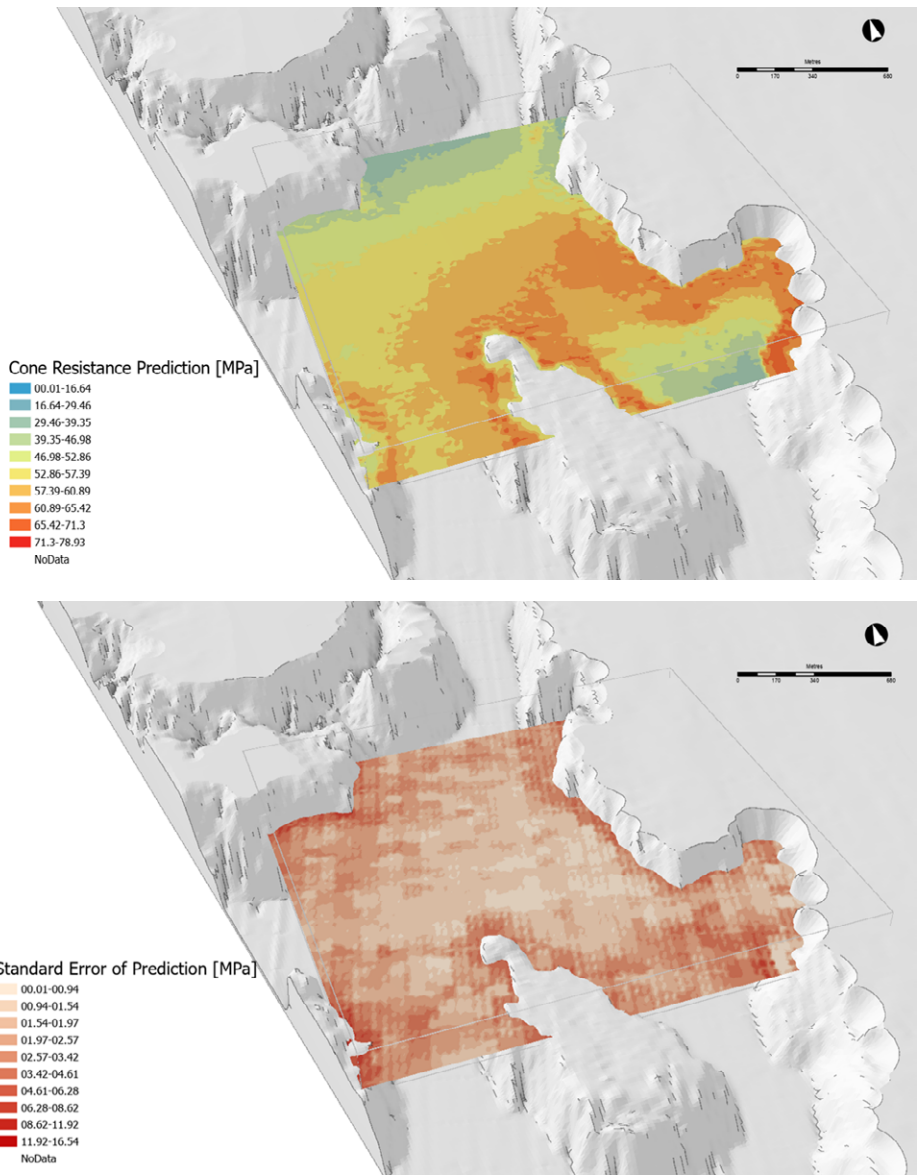


Figure 4.9.4 3D-interpolated qc geostatistical layer of Southern Tunnel Valley trial area. Left: cone resistance prediction; Right: standard error of cone resistance prediction.

Figure 4.9.4 shows the results of 3D interpolation in the Southern Tunnel Valley (STV) trial area for cone resistance. The image depicts a depth slice in a 3D volume showing the Peel Fm. within the Yarmouth Roads (shown in white). The left-hand image shows the predicted cone resistance values from the interpolation at a given depth slice within a 3D volume; the right-hand image shows the standard error on the prediction from the interpolation at the same depth”

4.9.4 Deliverables

The results of the IGM are summarised as part of three distinct reports:

1. Geological Ground Model – published end 2024
2. Geotechnical Interpretative Report – published March 2025
3. Integrated Ground Model Report – planned Q2 2025

The reports listed above, will be accompanied by digital deliverables that form the basis of the spatially derived model for further interrogation. This includes:

- S&P Global Kingdom Project
- SEG-Y data of predicted parameters along seismic lines
- AGS 4 data for predicted parameters at geotechnical investigation locations
- ArcPro GIS Project
- Leapfrog 3D ground models:
 - 3D seismostratigraphic model
 - 3D geotechnical soil unit model
- Reprocessed 2D UHRS SEG-Y

4.9.5 Webinar

The study results were presented and discussed during a webinar. You can find a review link of this webinar, the presentation and a Q&A document on offshorewind.rvo.nl.



4.10 Morphodynamics and Scour Mitigation Assessment

The Nederwiek Wind Farm Zone (NWWFZ) scour and morphology study aims to improve understanding of the zone's seabed morphology, morphodynamics and infrastructure-related scour potential. These objectives are separated into two parts. The first part focuses on seabed morphology and morphodynamics. The second part focuses on the infrastructure-related scour and potential scour protections. The objectives of this study are:

- To characterise the prevailing hydrodynamic, wave and sediment (transport) regimes;
- To identify and characterise the seabed morphology, bedforms, associated features and morphodynamics;
- To assess and interpret the surficial sedimentology and shallow geology focused on the implications for sediment transport and future morphological response of the seabed;
- To assess, predict and quantify the likely changes (spatio-temporal variability) in seabed levels over the proposed life cycle of a wind farm to support the design, installation and maintenance of wind turbines, substations, foundations and inter-array cables;
- To identify and categorise (based on the scour magnitude and extent) the investigation area in relation to the scour potential that may be anticipated due to the installation and long-term presence of typical wind farm infrastructure;
- To provide an overview of potential scour mitigation measures deemed applicable and appropriate at the investigation area for different wind farm infrastructure types.

4.10.1 Supplier

Svašek Hydraulics was contracted by RVO to conduct the NWWFZ scour and morphology study. Svašek Hydraulics is a specialist consulting firm in coastal engineering, harbour design and river engineering. It has extensive process knowledge of waves, currents and sediment transport, as well as hands-on experience with surveys and their analysis. This fundamental knowledge is supported by years of expertise in (in-house) advanced numerical models.

4.10.2 Results of the morphodynamic assessment

Seabed morphology characteristics

One multi-beam historical bathymetry of 2003 and 2005 and a recent high-resolution bathymetry of 2023 and 2024 are available for the analysis of bed forms in the NWWFZ. Different state-of-the-art techniques are used to analyse the seabed morphology and characteristics.

The investigation area can be characterised as an area with a few large sandbanks, with migrating sand waves and megaripples on top of them, mostly in the southern half of the investigation area (Sites NW I-A and I-B). In the northern half of the investigation area (Sites NW II and III), sand waves are absent and seabed dynamics are limited. The occurrence and absence of bedforms are most likely caused by variations in environmental conditions, such as bed composition and tidal currents, rather than sediment supply.

Three main sandbanks are found in the area, extending almost the entire length of the NWWFZ. Some eastward migration of the sandbanks is visible, but this is unclear due to the uncertainties from historical surveys. Furthermore, the related vertical bed level variations are minor.

Sand waves are present throughout NW I-A and -B except for the northernmost end. Generally, the sand wave height varies from 1 m – 3 m and the sand wavelength varies from 200 m – 400 m. Sand wave migration rates mostly range from 1 m/yr – 3 m/yr, with higher rates in the southern part and lower rates in the northern part of NW I-A and -B. The migration directions for NW I-A and -B vary between NNW (northern part) and NE (southern part). In NW II and III, sand waves are absent.

Megaripples are present throughout NW I-A and -B and in the southeast and northwest of NW II and III. The spatial variation of the megaripples is limited. The megaripple height is approximately 0.25 m in NW I-A and -B and approximately 0.1 m in NW II and III. Megaripples have high migration rates, which cause them to pass over wind turbine foundations several times in their lifetime.

Surficial sedimentology and shallow geology

From several available geological models and sediment samples, it can be concluded that the NWWFZ is a sediment-rich environment. The top layers of the investigation area consist of fine sand. The grain size D₅₀ (median diameter) decreases from about 0.220 mm in the south to 0.120 mm in the north. Clayish (NW I-A and -B) and silty to clayish (NW II and III) material is present at larger depths, which are considered too deep to limit mobile sediment availability for migrating bedforms. A higher fine content is only found locally in NW I-A and -B. The northern half of NW II and III has a higher fine content of around 12–17%.

Hydrodynamic, wave and sediment (transport) regimes

A residual transport analysis based on the metocean data time series leads to the conclusion that the tidal currents are the most consistent drivers of sediment mobility at the NWWFZ. The wave heights are often too small to mobilise the bed material, especially during calm periods. However, during storm conditions, the sediment mobilisation due to the waves can be significantly higher than mobilisation resulting from currents. The current velocity reduces from the southern part of the investigation area to the northern part. The wave height slightly increases from south to north.

The long-term residual sediment transport patterns in the NW I-A and -B sites are directed towards the north-northeast, which aligns with the dominant flood tidal currents and the sand waves' migration direction. The residual sediment transport directions can change depending on storm timing and tidal flow direction. NW II and III display more variability in flow velocities, with a general trend of decreasing flow velocities towards the north. As a result, the magnitude of the residual sediment transport is significantly lower in the northern part of NW II and III and the direction of the long-term residual sediment transport changes from north-northeast towards east.

Future seabed level predictions

The results from the morphodynamic site analysis are used to provide the best estimate of the future seabed (BEB, Figure 4.10.1) and the highest/lowest seabed level (HSBL, Figure 4.10.2, and LSBL, Figure 4.10.3) that can be expected over the lifetime of the wind farm. Several relevant uncertainties (bathymetry data collection, megaripple migration, grid resolution, sand wave reshaping) are identified and accounted for. This results in a maximum upward and downward uncertainty band of 0.67 m and an upward and downward megaripple band of around 0.1 m to 0.15 m at NW I-A and -B. Seabed level changes range between -3.68 m to +3.95 m (including uncertainties) in 2073 with respect to the 2023 bathymetry at the highly dynamic NW I-A and -B (Figure 4.10.3).

The seabed dynamics at NW II and III are limited and no sand waves are present in the area. Hence, the bed level predictions consist of the background bed in combination with the megaripple and uncertainty bandwidth, leading to bed level differences between -0.42 m and +0.41 m with respect to the 2024 bathymetry (Figure 4.10.3). The applied upward and downward uncertainty amounts to 0.27 m, and the megaripple band spatially varies between -0.03 m and -0.05 m downward and +0.03 m and +0.06 m upward.

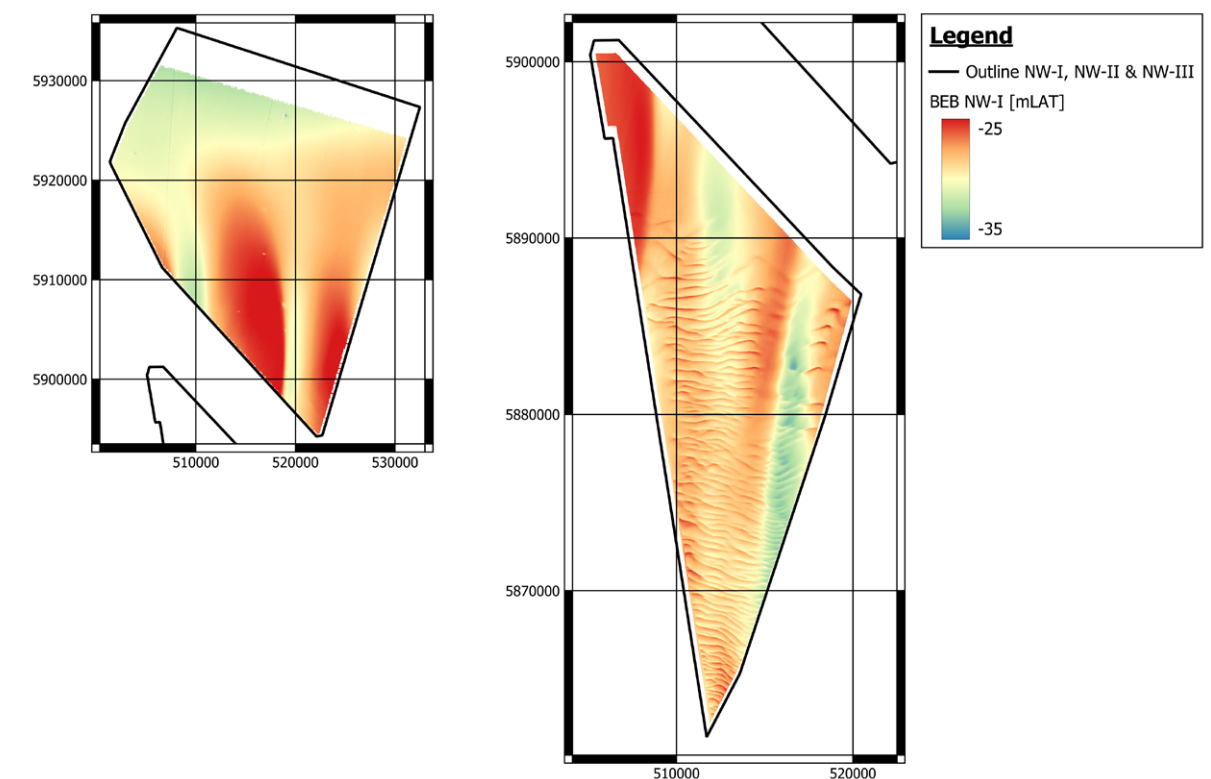


Figure 4.10.1 Results of the BEB in 2073 for NW I-A and -B (right panel) and NW II and III (left panel).

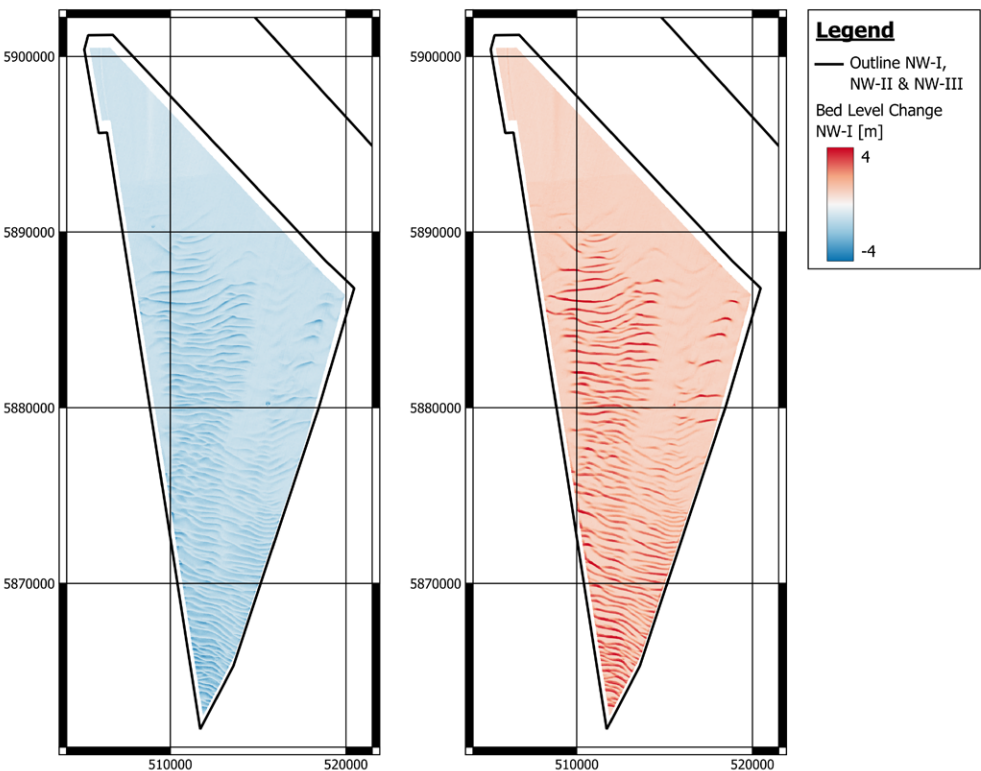


Figure 4.10.2 Spatial plots of the changes in bed level between the most recent bathymetry and the LSBL (left) and HSBL (right) between 2023 - 2073, including uncertainties, for NW I-A and -B.

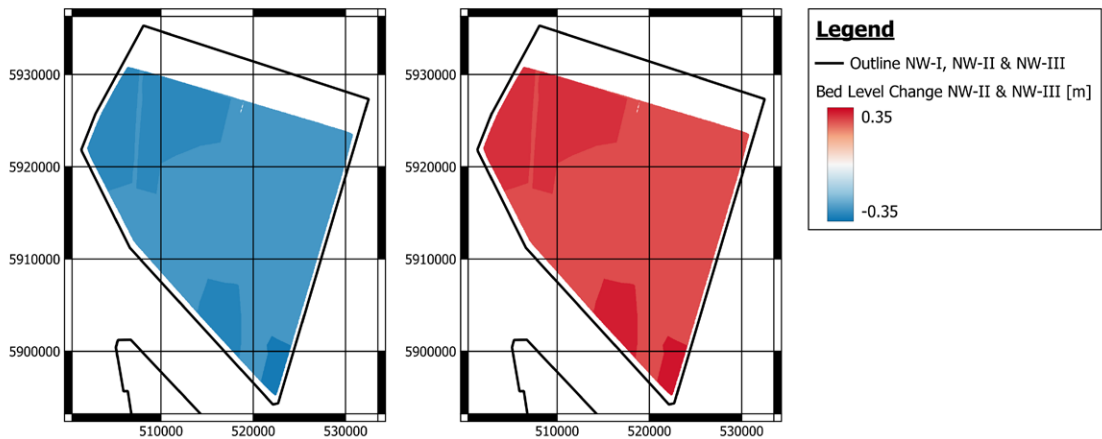


Figure 4.10.3 Spatial plots of the changes in bed level between the most recent bathymetry and the LSBL (left) and HSBL (right) between 2023 - 2073, including uncertainties, for NW II and III.

The BEB, LSBL and HSBL are assessed every five years from 2023 up to 2073 and supplemented to the report via a GIS database on offshorewind.rvo.nl. The seabed level predictions do not explicitly account for the possible impact of structures such as wind turbines on the development of the seabed. Still, their effects are considered and included in the range of migration rates and directions used to arrive at the HSBL and LSBL.

A long-term backward prediction to 1945 is also performed to assess the lowest possible seabed level (LPSBL) to identify potential unexploded ordnances (UXOs) from WWII. It is estimated that UXOs from WWII can be at a depth of up to -4.1 m LAT at NW I-A and -B and up to -0.42 m for NW II and III. Note that this LPSBL is based only on natural bathymetric changes and that the presence of UXOs even deeper below the seabed (e.g., because of self-burial) cannot be ruled out.

The results of the morphodynamic assessment are summarised in Table 4.10.1.

4.10.3 Results for Scour Mitigation Assessment

This study delivers a general order of magnitude on a feasibility level of the expected scour at the NWWFZ. The scour analysis is performed for monopiles with a pile diameter of $D = 12$ m, using a time-dependent scour development model. The maximum scour hole depths for ‘non-exceedance values’ are summarised in Table 4.10.2.

Figure 4.10.4 shows the spatial distribution of S_{max} , 50% in the entire NWWFZ. The scour depths in NW I-A and -B are generally higher than in NW II and III, mostly due to the higher flow velocities. As the flow and waves within NW I-A and -B are relatively uniform, the highest scour depths are found at the deepest waters between the sandbanks. The lowest scour depths are found on the crests of the sandbanks.

The flow and the waves within NW II and III are less uniform. The lowest scour depths occur in the northeast corner of the area, where the waves are the most dominant, the water depth is average and flow velocities are low. The effect of the sandbanks becomes prevalent more towards the south of NW II and III. The highest scour depths are located at the deeper

Table 4.10.1 Summary of the site-specific findings for NW I-A and -B and NW II and III.

Aspect	NW I-A and I-B	NW II and III
Bedforms	Sandbanks, sand waves and megarijppels in most of the area	Sandbanks in most of the area, megarijppels in part of the area. No sand waves.
Sediment type	Fine sand, clayish material at >5 m depth	Fine sand, silty clayish material at >8 m depth
D50	0.220 mm in the south to 0.160 mm in the north	0.160 mm in the south to 0.120 mm in the north. Higher fine content 12 – 17% in northern half.
Sand wave properties		
Height	1 m – 3 m	-
Length	200 m – 400 m	-
Migration rate	1 m/yr – 3 m/yr. Highest rates in the south, lowest rates in the north.	-
Migration direction	Between NNW (northern part) and NE (southern part)	-
Megarijppel bandwidth	Downward -0.1 m. Upward 0.15 m.	Downward -0.05 m/-0.03 m. Upward 0.03 m/0.06 m.
Uncertainty bandwidth	Upward and downward 0.67 m	Upward and downward 0.27 m
Seabed level changes 2073	Maximum -3.68 m to +3.95 m (including uncertainties)	Maximum -0.42 m to +0.41 m (including uncertainties)
Seabed level changes 1945	Maximum -4.1 m (including uncertainties)	Maximum -0.42 m (including uncertainties)

Table 4.10.2 Predicted scour depths across the NWWFZ. The percentage values indicate the non-exceedance values. Indicated scour depths are the maximum scour depth during the entire simulation. The simulations are based on monopiles with a pile diameter of $D = 12$ m. $S_n\%$ stands for the $n\%$ non-exceedance scour depth.

Location	$S_{5\%}$ [m]	$S_{5\%}/D$ [-]	$S_{50\%}$ [m]	$S_{50\%}/D$ [-]	$S_{95\%}$ [m]	$S_{95\%}/D$ [-]
Total NWWFZ	5.0 – 8.4	0.4 – 0.7	10.7 – 14.9	0.9 – 1.2	18.2 – 21.8	1.5 – 1.8
NW I-A and I-B	7.0 – 8.4	0.6 – 0.7	13.1 – 14.9	1.1 – 1.2	20.1 – 21.8	1.7 – 1.8
NW II and III	5.0 – 8.1	0.4 – 0.7	10.7 – 14.4	0.9 – 1.2	18.2 – 21.4	1.5 – 1.8

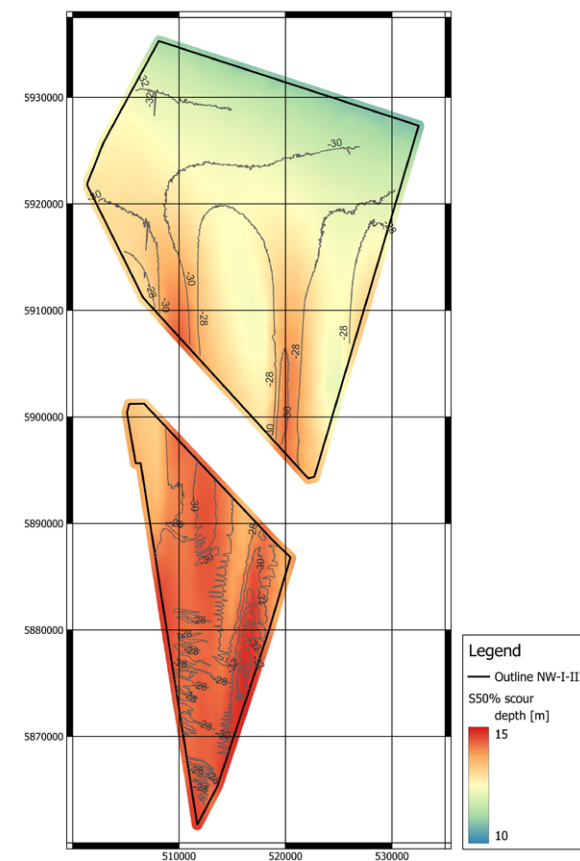


Figure 4.10.4 50% non-exceedance scour depths predicted at the NWWFZ. Scour depths are the maximum scour depths during the simulations. Simulations are performed for monopiles with $D = 12$ m.

points between the sandbanks, whereas the scour depth is lower on the crests of the sandbanks.

The scour holes will develop quicker in NW I-A and -B due to the more frequent high flow velocities. Equilibrium scour hole depths are predicted to be reached five to ten years after construction. The scour hole development in NW II and III varies spatially, with slower scour development towards the north and faster scour development towards the south. The equilibrium scour hole depths are generally reached in five to 25 years in NW II and III. Using the typical slopes of 1:2 and 1:3 and the expected scour hole depths (50%) from Figure 4.10.4, the lateral scour hole extent at the NWWFZ varies between 20 – 45 m.

Multi-legged structures, such as the piled jacked and multi-bucket structures, are subject to global and local scour. The global scour is estimated to be in the order of a few metres. Suction bucket and gravity-based structures are especially vulnerable to destabilisation due to scour. As the scour depths for monopiles are predicted to be significant for the entire NWWFZ, it is expected that both structure types will require scour protections. For other foundation types, it can be

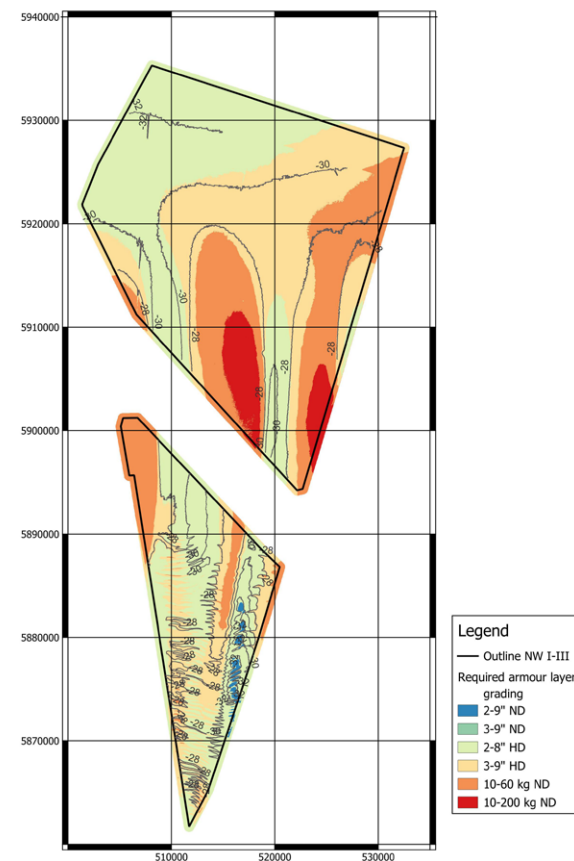


Figure 4.10.5 Required armour layer grading to achieve a maximum deformation of 0.5 m in the NWWFZ with 90% confidence. ND = normal density rock; HD = high density rock.

decided whether to adapt the design to the predicted scour depths, to protect the foundation immediately or to monitor the scour development and react accordingly.

This study demonstrates the design approach of a dynamically stable, loose rock scour protection at the NWWFZ using the deformation model of JIP HaSPro (2023) to estimate the 90% non-exceedance required rock protection. The deformation limit is set at 0.5 m. A simplified extreme value analysis is performed to derive preliminary design conditions for the scour protection design, which are based on the 50-year return period wave conditions.

This design aims to provide the reader with a general estimate of the required rock gradings for the armour layer that can be used for a feasibility analysis. However, this is not to say that other protection methods are not feasible at the NWWFZ.

Figure 4.10.5 shows the required gradings for a dynamically stable scour protection with a maximum deformation of 0.5 m. The shallower locations require heavier protection than deeper areas. This is most evidently visible on the crest

of the sandbanks, where the largest stones are required for the armour layer. A 2-8" or 3-9" grading of high-density rock can effectively protect most of NW I-A and -B and the north-western sections of NW II and III. These gradings are commonly used as single-layer scour protections, if the grading width meets the internal stability criteria. Only the shallower areas strictly require a double-layered scour protection based on external stability.

The scour protection in NW I-A and -B should be designed with the predicted seabed level changes due to bedform migration. The migrating sand waves in these sites can cause bed level variances of several metres. Scour protection will prevent the bed from lowering close to the foundation but will not stop the seabed from lowering at some distance. This can result in an increased load on the scour protection due to sill-like behaviour and problems with the cable touch-down point.

4.10.4 Deliverables

The results of the Morphodynamics and Scour Mitigation Assessment 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 at NW I-A and -B;
- Geological and geophysical characterisation of the NWWFZ relevant to the dynamics of the seabed;
- Analysis regarding bed form migration speed and direction, including storm effects;
- Predicted future seabed levels (LSBL, HSBL, BEB);
- Predicted levels where UXOs can be expected (LPSBL);
- Classification zones and considerations for cables and foundations;
- Recommendations regarding possible scour mitigation strategies for the NWWFZ;
- Probabilistic estimates for scour depths around monopiles, taking into account spatially varying hydrodynamics, grain size and water depth;
- 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;
- Feasibility level estimates of required rock gradings for scour protection, taking into account spatially varying hydrodynamic design conditions, water depth, grain size and seabed variations;

4.10.5 Webinar

The study was discussed during a webinar on 21 November 2024. The webinar can be found on offshorewind.rvo.nl.

4.11 Metocean Measurement Campaign

4.11.1 Overview - Aims, Objectives and Approach

The Metocean Measurement Campaign for the Nederwiek Wind Farm Zone (NWWFZ), which includes Nederwiek Wind Farm Sites I-A and I-B (NW I-A and -B) provided two sets of continuous meteorological and oceanographic (metocean) data that include wind profiles with excellent quality and high availability. The campaign aimed 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 less uncertainty in wind and metocean data, resulting in reduced cost of capital in the business case for an offshore wind farm.

The campaign started in June 2022 and lasted just over 24 months. RPS (a Tetra Tech Group Company) was commissioned to measure, validate and provide these key metocean parameters in the North Sea, west of Den Helder, the Netherlands. The data from the two buoys is validated against each other using correlation plots, demonstrating excellent agreement. 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 24-months programme, metocean data was obtained from these fields using instruments fixed on floating systems. Measurement parameters include wind, wave, current, water-level, water temperature, atmospheric pressure and air temperature.

The campaign achieved an average of 90.4% and 94.4% data return from the two buoys and almost complete data coverage from the buoy combination.

4.11.2 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 the widget “Validation Metocean Campaign.” Monthly reports and datasets are disclosed under “Metocean Campaign Monthly Data & Reports.”

Separate data and reports are available for each month within the 24-months measurement period. For the first full year of the measurement campaign (May 2022 - May 2023), the data was summarised in a 12-months comprehensive dataset and published September 2023. A final dataset and campaign report, covering all 24 months of data (June 2022 - May 2024) and summarising all processed wind, wave and current data, was published in October 2024.

4.11.3 Supplier

For this project, the RPS Consultancy and Engineering Bureau BV in the Netherlands lead the project locally supported by global metocean expertise in the RPS Group.

RPS is a Tetra Tech company and operates in six industries worldwide: real estate, energy, transportation, water, resources and defense and government services. Its services are divided into 12 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.

RPS has been designing and improving its metocean buoys since 1990s. The company delivers 10-minute averaged wind data, which is transmitted near real time, and daily transmission of raw data. Its buoys features a ZX 300M LiDAR sensor, with proven reliability via multiple deployments around the globe.

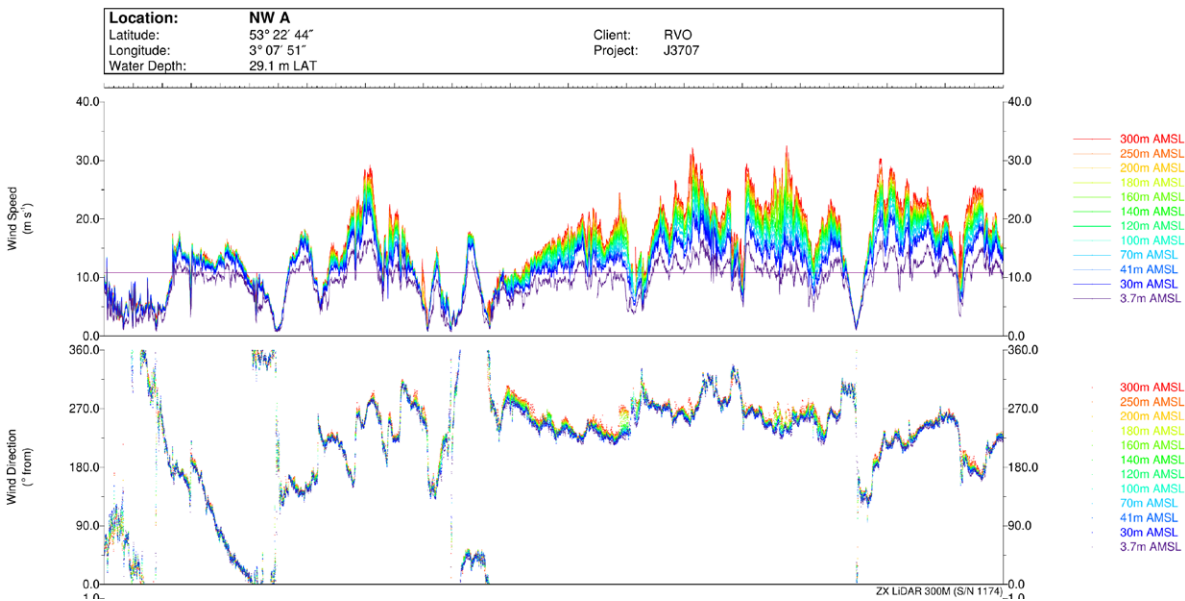


Figure 4.11.1 Example time series of wind profile data from RPS LiDAR Buoy at NW December 2023.

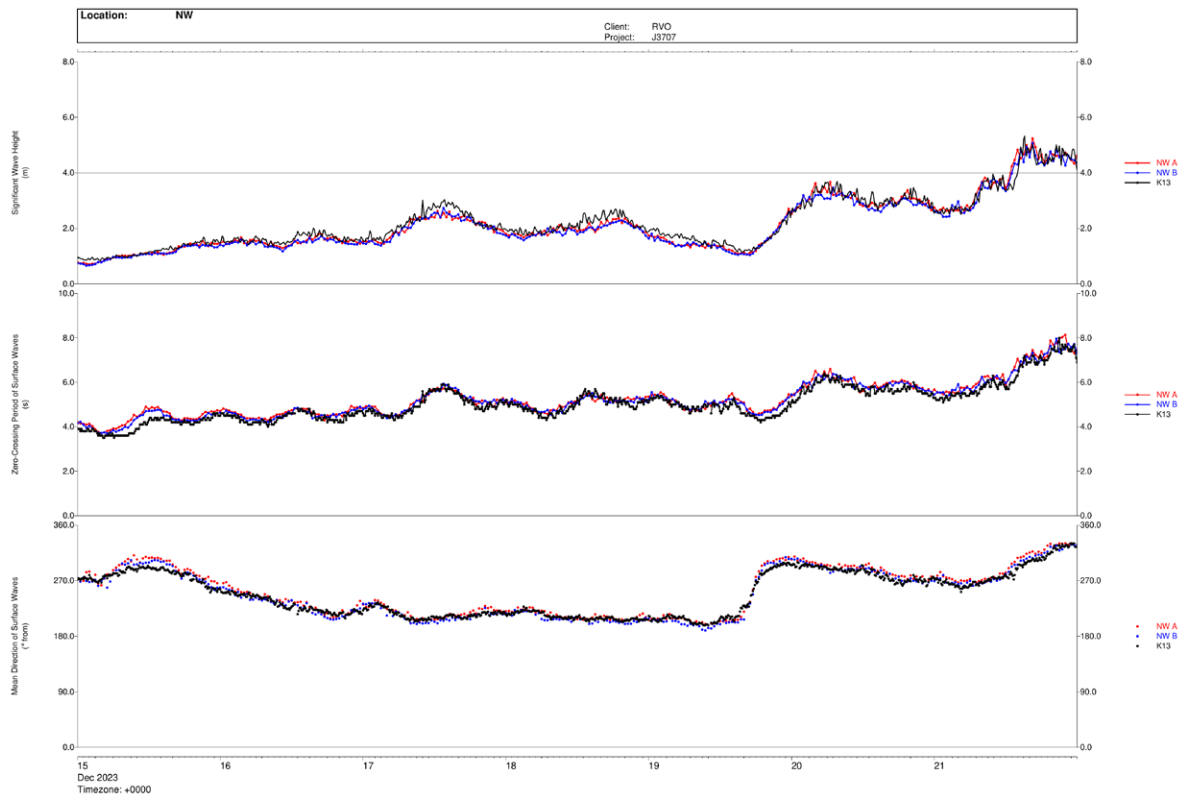


Figure 4.11.2 Example time series of wave data from two RPS LiDAR Buoys at NW and third party data at K13, December 2023.

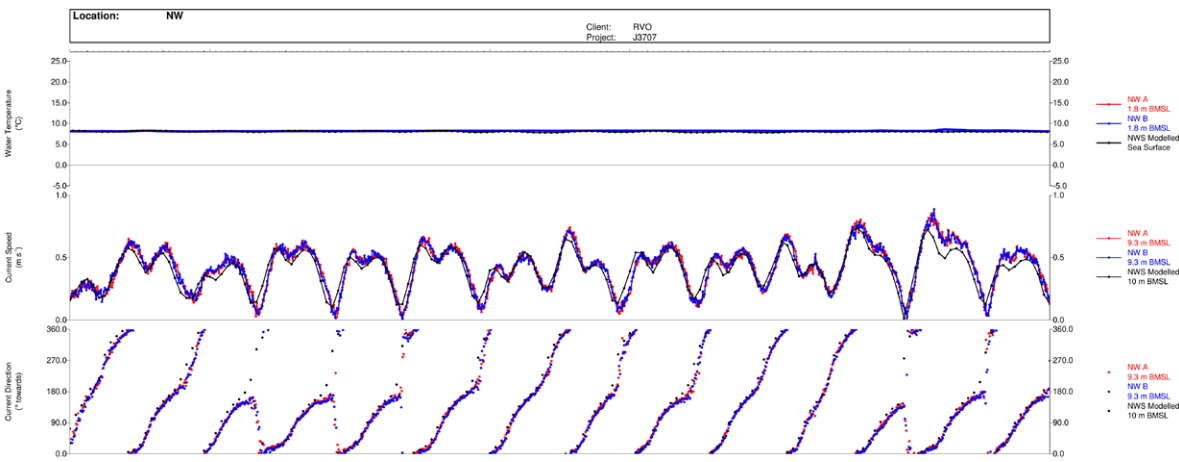


Figure 4.11.3 Example time series of Current data from two RPS LiDAR Buoys at NW and the NWS model, December 2023.

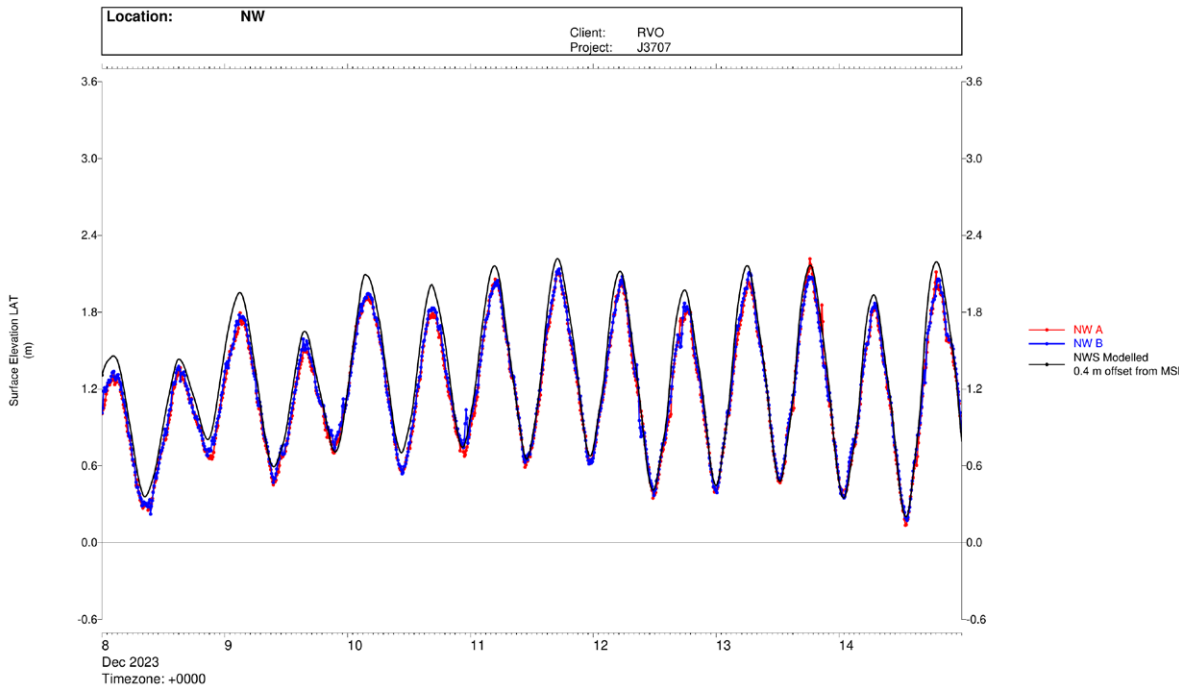


Figure 4.11.4 Example time series of Tide data from two RPS LiDAR Buoys at NW and the NWS model, December 2023.



4.12 Metocean Assessment

RVO requires the establishment of meteorological and oceanographic (metocean) conditions to serve as 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 Weather Research and Forecasting (Unified-WRF) model as input for both the Wind Resource Assessment and the Metocean Assessment, thereby seeking alignment between the two.

The overall objective of the study, which was conducted by DHI, is to provide accurate metocean conditions (wind, wave, water level and current) for the Nederwiek Wind Farm Zone (NWWFZ), which includes Sites NW I-A and I-B. To

establish the metocean conditions, DHI performed high-resolution numerical modelling for the period 1979 – 2023 (up to end September), covering not only the NWWFZ, but also all offshore wind farm search areas spanning the Dutch Exclusive Economic Zone (EEZ), shown by the magenta color in Figure 4.12.1.

The numerical modelling was validated against 16 months of measurement data at Nederwiek, covering the period from June 2022 to end September 2023. The model aligns with the measurements indicated by the low bias and small root mean square error (RMSE), as shown in Figure 4.12.2.

Normal and extreme conditions are established for winds, water levels, currents and waves. The extreme conditions are

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

For companies submitting bids to develop the wind farm in the NWWFZ, the results of the Metocean Assessment will serve as input for the design, installation and maintenance of wind turbines, inter array cables, substations and their support structures.

A comprehensive online Metocean on-Demand (MOOD) database has been produced, which enables users to access the modelling data and the analysis results through a user-friendly interface, as shown in Figure 4.12.3. Precalculated J-EVA results for any point inside the EEZ are available through the Reports section of the [MOOD database](https://offshorewind.rvo.nl). Modelling and analysis reports are available on offshorewind.rvo.nl.

4.12.1 Webinar

The study was presented and discussed during a webinar on 5 December 2024. The webinar is available via offshorewind.rvo.nl.

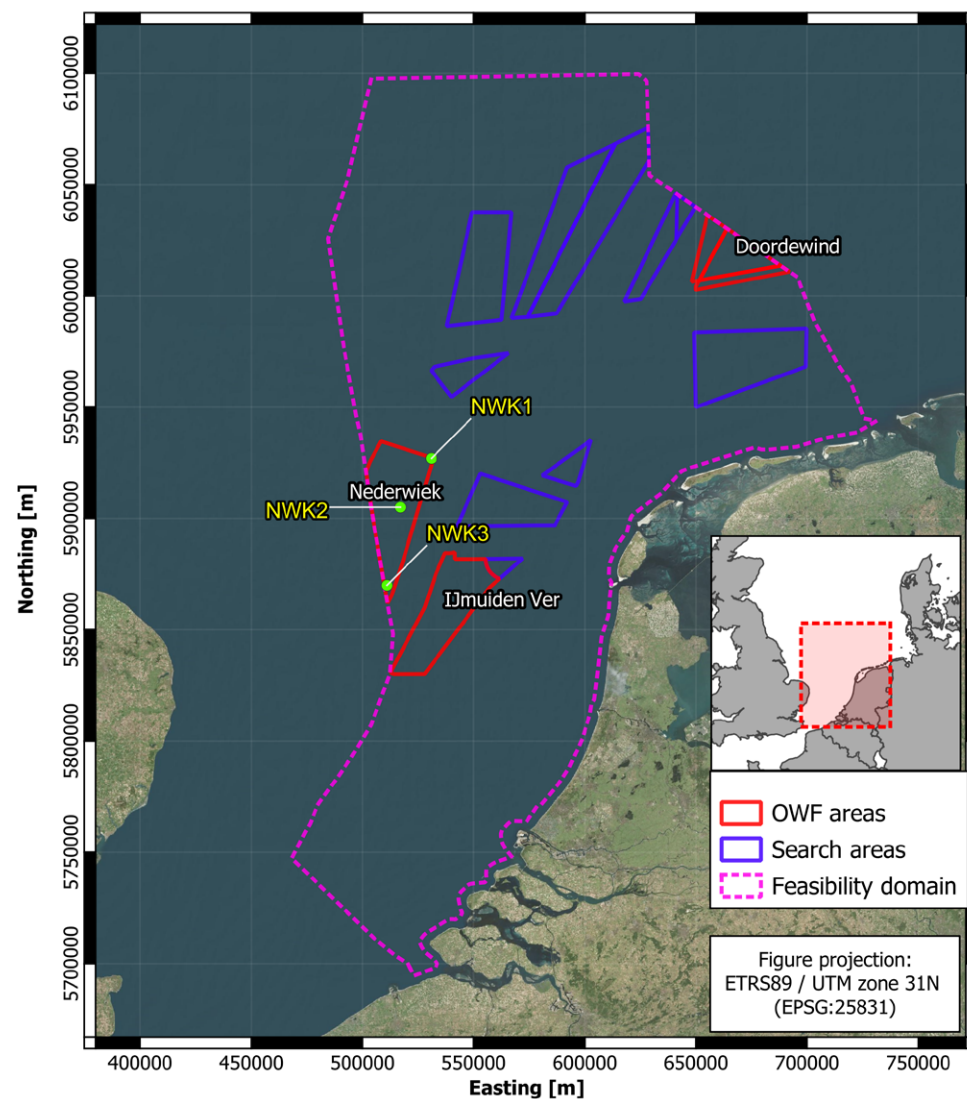


Figure 4.12.1 The Metocean study area in the Dutch EEZ shown by the magenta color polygon. The modelling is carried out for the feasibility domain, and the analysis is carried out at three locations in the NWWFZ.

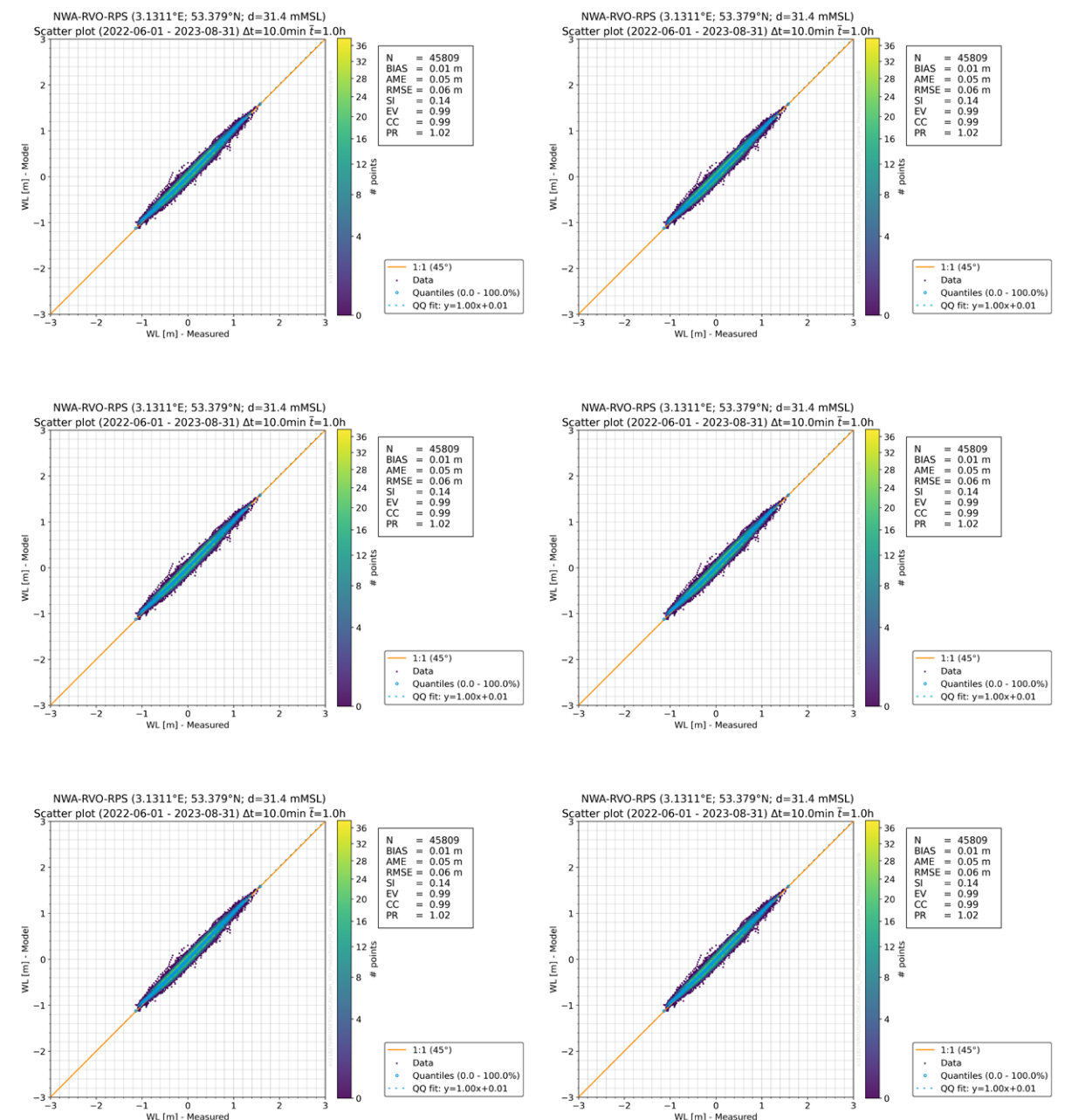


Figure 4.12.2 Validation plots indicating performance of the models.

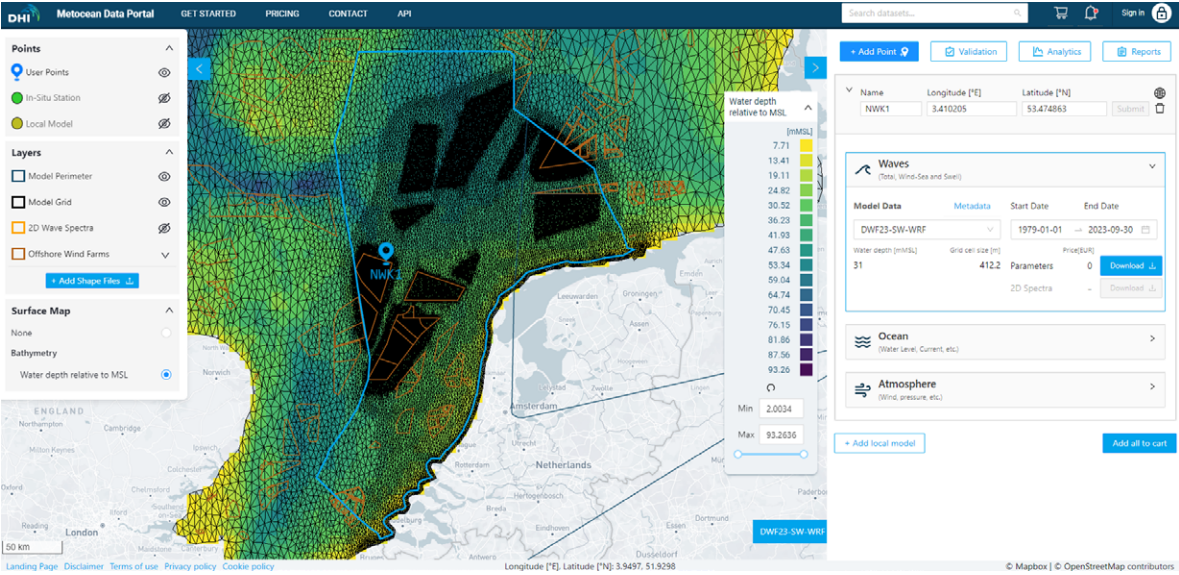


Figure 4.12.3 Snapshot of the MOOD database showing the Dutch EEZ studied for the Metocean Assessment.



4.13 Wind Resource Assessment

The Wind Resource Assessment (WRA) for the Nederwiek Wind Farm Zone (NWWFZ) was conducted by a project consortium led by DHI, with the WRA package directed by OWC with the collaboration of ProPlanEn, ArcVera, Innosea and C2Wind. The study aimed to evaluate the wind resource potential and develop a Unified Weather Research and Forecasting (Unified-WRF) meso-scale model to inform future offshore wind energy development within NWWFZ. A planned 24-months update will present results for four sites in the Wind Farm Zone: NW Sites I-A and I-B, each 1 000 MW, and NW Sites II and III, each 2000 MW.

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 NW and FLS IJV), 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 obtain the long-term wind climate for the Investigation Area, creating a unified, gridded wind dataset (Unified-WRF) capable of satisfying the requirements of both WRA and metocean analysis. 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 meso-scale models, exhibiting better performance and alignment with long-term climate patterns.

The study incorporated a forward-looking climate change assessment using Coordinated Regional Climate Downscaling Experiment CORDEX projections under Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 scenarios (as defined by The Intergovernmental Panel on Climate Change), 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 analysis of the potential for offshore wind energy development in the NWWFZ. 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 4.13.1 NWWFZ nodal location mean wind speeds.

Height (m)	Nodal locations: mean wind speed (m/s)					
	N1	N2	N3	N4	N5	N6
300	10.61	10.57	10.53	10.57	10.51	10.51
250	10.53	10.49	10.45	10.49	10.43	10.44
200	10.41	10.38	10.35	10.38	10.33	10.33
160	10.25	10.23	10.20	10.22	10.18	10.19
140	10.15	10.13	10.10	10.12	10.09	10.09
120	10.02	10.00	9.98	10.00	9.97	9.97
100	9.84	9.84	9.82	9.83	9.80	9.81
60	9.32	9.32	9.30	9.30	9.29	9.30
30	8.76	8.77	8.75	8.74	8.74	8.75
10	7.97	7.98	7.95	7.95	7.94	7.96

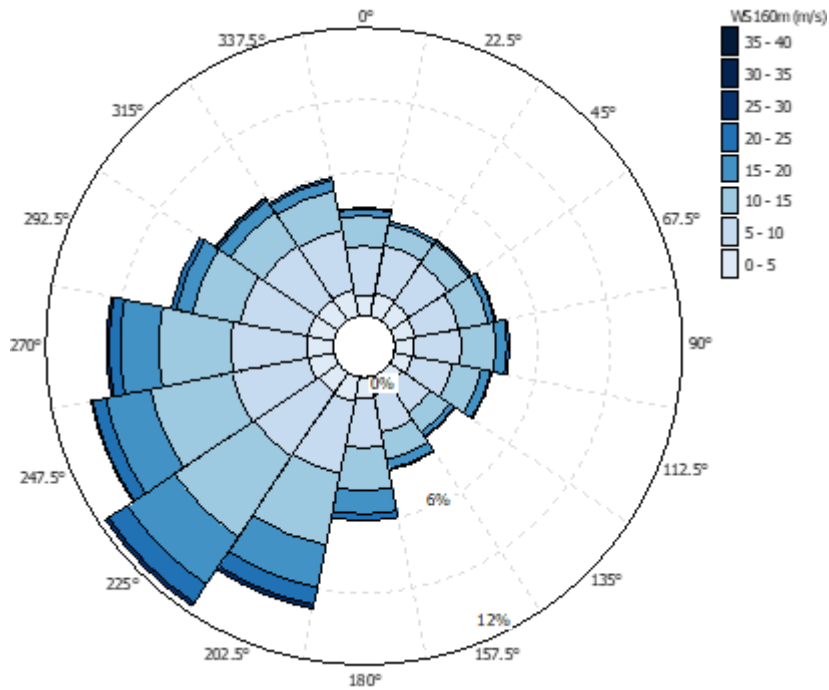


Figure 4.13.1 N4 160 m wind frequency rose.

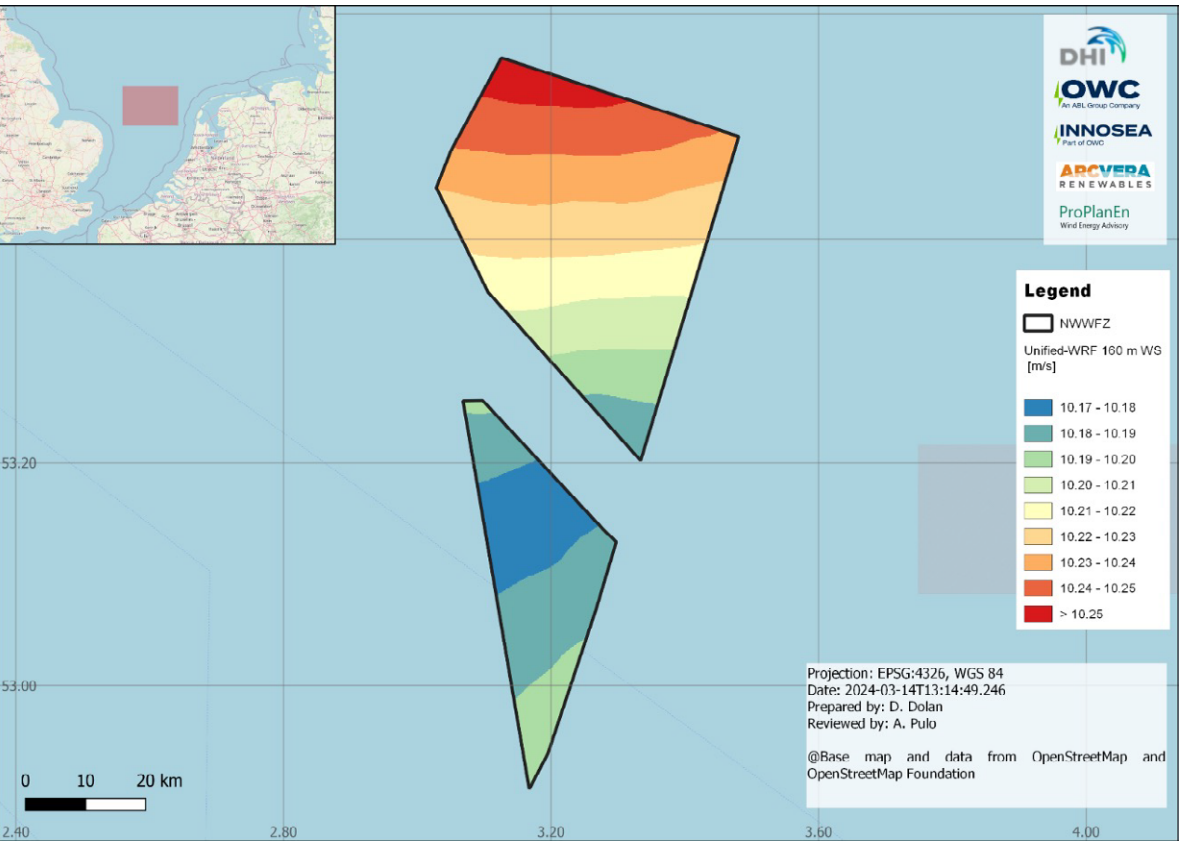


Figure 4.13.2 NWWFZ wind speed gradient map at 160 m.

4.13.1 Results

The long-term wind speed at the N5 node (NW FLS location) at the height of 160 m was found to be 10.18 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 0.3%. For future projections, the combined total uncertainty in long-term wind speed for the 10-year period was found 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 N1 node (the northernmost location in the NWWFZ) was found to be 10.25 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 NWWFZ is shown in Table 1. The wind frequency rose is shown in Figure 4.13.1.

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 well. It also has a similar performance 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 the NWWFZ is around 0.07 m/s, as shown in Figure 4.13.2 below and Table 1 above.

4.13.2 Deliverables

The results of the WRA are summarised in a Desk Study report. The report presents results for the following, at six specified output locations within the NWWFZ, for the 13-year period spanning 1 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 the [MetOcean On-Demand \(MOOD\) website](#), with a granularity of 1.67 km, capturing 44 years of information with a 10-minute output cadence.

4.13.3 Webinar

The modelling aspect of the study was presented and discussed during a webinar in September 2023. A webinar focusing on the WRA was held in April 2025. The webinar on the Unified-WRF is available at:

Unified-WRF: offshorewind.rvo.nl



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