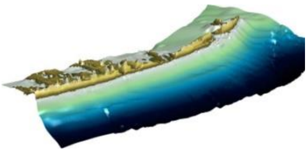
HAWA-III JIP,
Shallow Water Initiative

Detailed Project Plan (Rev. 1.4, June 2022)




The objective of the HAWA-III JIP is to extend and validate the overall design methodology of nearshore terminals based on model scale measurements and to provide practical tools and guidelines to apply the methodology.

Research Partners:

MARIN

Deltares
Enabling Delta Life

BUREAU VERITAS

EXECUTIVE SUMMARY

From 2006 to 2012 the HAWA-I and HAWA-II Joint Industry Projects provided a better understanding of the effect of infragravity waves on nearshore LNG facilities. This resulted in the development of a methodology to take infragravity waves into account in the design of such a facility in specific nearshore locations. Since then, most new projects consisted of developments in deeper water. However, in recent years the focus of projects in the field has shifted again to shallow water, and the design of LNG terminals in a nearshore environment has become a critical topic again. Also, the design of permanently moored offshore structures in shallow water has been found especially challenging in practice due to the lack of detailed guidelines. Failures of mooring systems have been observed in the field due to infragravity waves, which show that the infragravity waves remain a critical aspect in design methodologies for shallow-water developments.

There are multiple reasons why it remains difficult to take long waves into account in terminal designs, even with the developed dedicated methodology in place. This is mainly because (1) the workflow of the methodology is relatively complex and time-consuming, (2) taking infragravity waves into account is not always a requirement from authorities and regulations, (3) the uncertainties involved in the methodology need to be assessed, (4) the methodology has been developed for open terminal configurations, and is not applicable yet for cases where breakwaters are involved. Furthermore, the physics involved remain quite complex.

① **WE DEVELOP AND DELIVER TOOLS**

We develop, verify, validate and deliver appropriate numerical tools to be able to apply the design methodology for nearshore terminals. The tools, as much as possible open-source, will be made available to the participants, together with an online documentation and forum platform.

② **WE CARRY OUT MODEL TESTS**

We carry out model tests in order to gain knowledge and generate validation data for the design methodology. The model tests will be conducted for different configurations (bathymetry, coastline, breakwater). Tests will be conducted with waves only (wave propagation) as well as with the vessel moored (vessel response).

③ **WE SHARE EXPERIENCE ON FULL SCALE MEASUREMENTS OF IG WAVES**

We share experience on full scale measurement of infragravity waves in a nearshore environment, based on existing full scale data. Optionally, we carry out additional full scale measurements of infragravity waves with a realistic bathymetry and coastline. We will provide guidelines on how to measure and analyse infragravity waves.

④ **WE COMPARE DIFFERENT WAVE MODELS IN A NUMERICAL BENCHMAK STUDY**

We will verify and validate wave models for various configurations. The configurations will involve an open configuration with a flat bottom, with a sloping bottom and a coastline, with a breakwater (validation based on model test data), and possibly with a complex bathymetry and coastline (full scale measurement).

⑤ **WE EXTEND THE METHODOLOGY FOR BREAKWATERS**

We will do research on how to account for a breakwater on the motion response of a moored vessel in a nearshore environment. A literature study will be done focusing on the effect of breakwater on the vessel hydrodynamics. Then, the design methodology will be extended in order to include the effect of breakwater.

⑥ **WE PROVIDE SUMMARY GUIDELINES AND DELIVER WORKSHOPS**

We will write summary guidelines related to the design of vessels moored in shallow water. The guidelines will focus on how to apply the established and validated methodology. Optionally, we will provide hands-on workshops to the participants on how to go through the guidelines and use the tools delivered.

The objective of the HAWA-III JIP is to extend and validate the overall design methodology of nearshore terminals based on model scale measurements, and to provide practical tools and guidelines to apply the methodology. The results from the previous two JIP phases will be used as a starting point and they will be expanded to reach this objective.

The JIP is proposed to be executed as a 2.5-year project starting in 2022. The deliverables of the HAWAIII JIP will be as follows:

- Guidance Note from Classification Societies
- Pros and cons of full scale measurement campaigns of infragravity waves
- HAWAIII diffraction tool (as much as possible open-source) to compute wave loads on LNG terminals due to infragravity waves provided by nearshore wave models
- Tutorial to apply the design methodology with and without breakwater
- Validation of the design methodology based on model scale measurements
- Extension of the design methodology to include situations with breakwaters

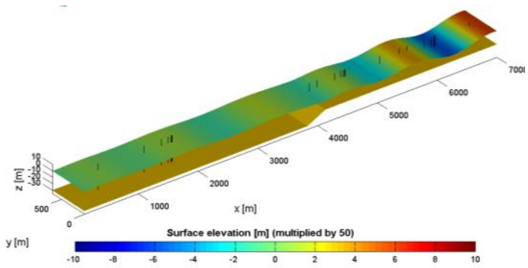
1. BACKGROUND

This document describes the HAWA-III Joint Industry Project. This project is a follow-up of the HAWA-I (2006-2008) and HAWA-II (2009-2012) JIPs. A short introduction to both previous JIPs and the motivation for a third phase of this project is provided below. The detailed contents of the HAWAII-3 project are described in later sections of this document.

HAWA-I JIP (2006-2008)

In 2006 a Joint Industry Project was started that aimed to explore shallow water wave dynamics and related vessel responses for optimal offshore LNG facility designs. The project, which was called HAWAI[1] ran from 2006 to 2008. The objective of HAWAI JIP was to improve the reliability of offshore (LNG) terminals in shallow water by using the combined expertise from the fields of offshore hydrodynamics and coastal engineering.

In HAWAI it was recognised that the development of reliable offshore LNG terminals in shallow water locations requires an improved insight into the complex wave conditions and ship hydrodynamics in such areas, which can differ strongly from deep water wave conditions. Particularly in shallow waters, long waves, although hardly visible, can cause large problems for moored ships. Low frequency wave effects (also called set-down/surfbeat and infragravity-waves) can result in significant excitation of streamlined LNG carrier hulls that have very low damping against low frequency resonant motions such as surge. The combination of excitation and low damping can result in significant resonant motions and related mooring loads. As more and more LNG terminals were built in shallow water at the time, with water depths of approximately 15 m – 40 m, a better understanding of these shallow water hydrodynamics was desired.



HAWAI investigated not only wave conditions at a number of representative mooring locations, but also ship motions and mooring loads that could be expected in such environments. Variables such as water depth, ship draught, seabed contours (bathymetry) and wave frequencies were also accommodated. In addition, the project investigated the applicability of model testing techniques for shallow water operational scenarios. By using the combined expertise from the knowledge fields of offshore hydrodynamics and coastal engineering, the project resulted in an improvement of knowledge of shallow water physics that is important for the design of offshore LNG terminals. The results provided the participants a better understanding of ship motions and mooring prediction methods in sea conditions common to such areas.

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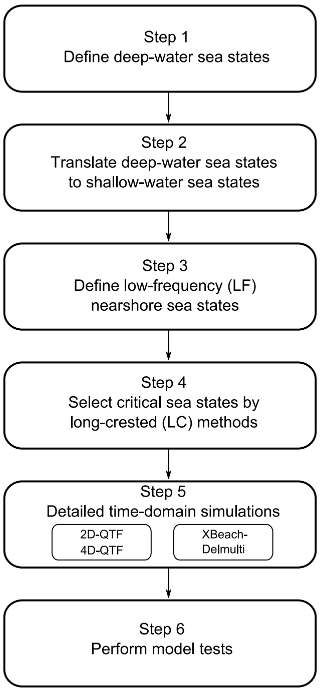
[1] HAWAI stands for sHAllow WAter InItiative

HAWA-II JIP (2009-2012)

Although the first HAWAI project already provided much insight in the complexity of the wave conditions in shallow water areas and their influence on ships moored under such conditions, a methodology on how to apply that knowledge systematically in the design of a terminal was still missing. From a designer point-of view, there was a need for practical and generic guidelines on a methodology to cover these long waves. Therefore, in 2009 a follow-up of the HAWAI project was started, named HAWA-II. The aim of the HAWA-II JIP was to develop a practical design methodology for nearshore shallow water LNG terminals, making use of the insights gained in the first HAWAI JIP.

A design methodology was developed, providing practical guidelines for a step-by-step design approach. In each step the relevant physical processes were identified and guidelines were provided on how to account for those. This methodology was illustrated in a case study involving the design of a LNG terminal at a shallow water mooring location at a fictitious but realistic location. In this case study, each step of the developed design methodology was performed, starting with obtaining the offshore wave climate and concluding with a final estimate of the expected downtime at the nearshore mooring location. This case study showed how the design methodology can be applied in a practical, realistic situation. Next to this stepwise design methodology, also several tools have been developed within the project, which were shared with the participants. These tools consist of methods to (1) (quick-)estimate low-frequency wave conditions at a nearshore mooring location; (2) coupling scripts to couple wave model XBeach to diffraction code Delmulti.



The application of the design methodology in the case study in JIP HAWAII showed the relevance of correctly predicting the nearshore shallow water wave conditions and that these should receive ample attention as part of the design of such facilities. It was shown that low-frequency waves can have a significant effect on the expected downtime. Therefore, a correct prediction of the LF wave spectra at the mooring location is critical for correct downtime estimates.

Motivation for HAWA-III JIP

In the years following the HAWAII JIP, most new projects in the industry consisted of developments in deeper water. However, in recent years the focus of projects in the field has shifted again to shallow water, and the design of LNG terminals in a nearshore environment has become a critical topic again. Also, the design of permanently moored offshore structures in shallow water has been found especially challenging due to the lack of detailed guidelines. Failures of mooring systems have been observed in the field due to infragravity waves, which show that the infragravity waves remain a critical aspect in design methodologies.

Figure 1: Permanent mooring solutions in shallow water pose a challenge due to lack of guidelines.

There are multiple reasons why it remains difficult to take long waves into account in terminal designs, even with the developed dedicated methodology in place. This is mainly because (1) the workflow of the methodology is relatively complex and time-consuming, (2) taking infragravity waves into account is not always a requirement from authorities and regulations, (3) the uncertainties involved in the methodology need to be assessed (4) the methodology has been developed for open configurations, and is not applicable yet for cases where breakwaters are involved. Furthermore, the physics involved remain quite complex.

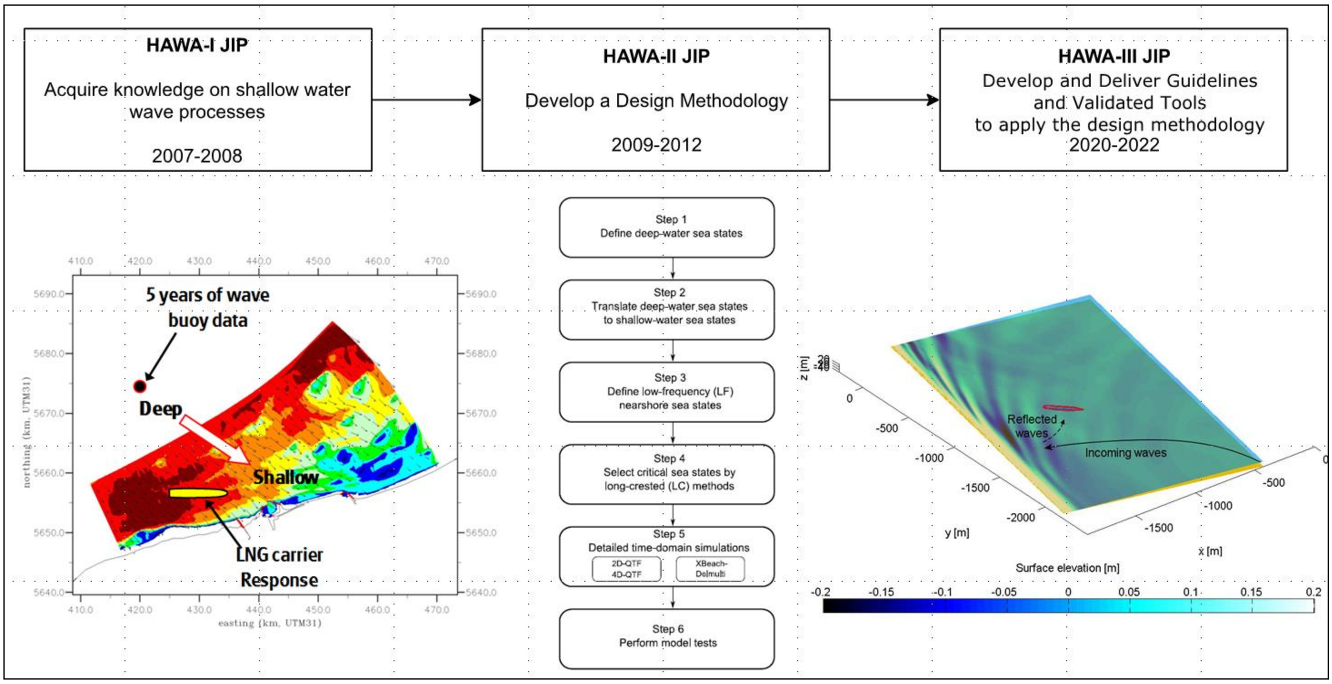


Figure 2: objectives of the different HAWAII JIP Series

2. OBJECTIVES

The objective of the HAWA-III JIP is to validate the overall design methodology of nearshore terminals based on model scale measurements and to provide practical tools and guidelines to apply the methodology. The results from the previous two JIP phases will be used and expanded to reach this objective.

3. SCOPE OF WORK

In order to achieve these objectives, the JIP will combine model scale measurement, state of the art numerical calculations and collected existing data from full scale measurement campaigns and information available in the literature. At the beginning of the JIP, one representative case study will be selected together with the participants. Within interactive workshop sessions, the design methodology will be followed and executed with numerical methods that are delivered within the JIP. A detailed tutorial will be provided such that the knowledge can be spread easily within each participating company. Using the verified, validated and documented methodology, the participants would be able to verify the mooring configurations in their projects with respect to infragravity waves, including for example the presence of breakwaters. Quantifying the benefits of such breakwater with respect to other mooring configurations will allow the participants to assess the benefits in terms of workability, safety and costs. Figure 3 gives an overview of the project by summarizing the scope of work of the six work packages.

1

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We share experience on full scale measurement of infragravity waves in a nearshore environment, based on existing full scale data. Optionally, we carry out additional full scale measurements of infragravity waves with a realistic bathymetry and coastline. We will provide guidelines on how to measure and analyse infragravity waves.

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We will verify and validate wave models for various configurations. The configurations will involve an open configuration with a flat bottom, with a sloping bottom and a coastline, with a breakwater (validation based on model test data), and possibly with a complex bathymetry and coastline (full scale measurement).

5

WE EXTEND THE METHODOLOGY FOR BREAKWATERS

We will do research on how to account for a breakwater on the motion response of a moored vessel in a nearshore environment. A literature study will be done focusing on the effect of breakwater on the vessel hydrodynamics. Then, the design methodology will be extended in order to include the effect of breakwater.

6

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We will write summary guidelines related to the design of vessels moored in shallow water. The guidelines will focus on how to apply the established and validated methodology. Optionally, we will provide hands-on workshops to the participants on how to go through the guidelines and use the tools delivered.

Figure 3: summary of the Work Packages

The total scope of work of the proposed JIP has been separated into the following main work packages:

WP1: Development and Delivery of Tools (Lead MARIN)

WP1.1 - Development of the HAWAIII Tool

Purpose: develop a well-documented and ready-to-use tool that allows to apply the methodology in a time-efficient way

- Make a specific version of diffraction code for the project
- When scripts are required, they will be written in Python
- Write a user manual of the HAWAIII tool
- Make a Graphical User Interface (OPTION)

WP1.2 - Delivery of the HAWAIII Tool

Purpose: deliver the tools on a platform accessible by the participants

- Deliver the tool with Installer
- Deliver documentation online (Installation Guidelines, Tutorials, Theoretical Documentation)

WP1.3 – Testing/Review of the HAWAIII Tool

Purpose: Test the Tool, Verification Study, User Guidelines

- Test the Tool
- Investigate the effect of input parameters on the calculation results
- Deliver user guidelines including pro’s and con’s

WP1.4 – Development / Extension of REEF3D

Purpose: Develop and Extend the REEF3D open-source framework for IG Waves

- Develop and Extend the Tool for IG Waves
- Include delivery of inputs for the calculation of loads
- Deliver user guidelines including pro’s and con’s

WP2: Model Scale Measurements (Lead DELTARES)

WP2.1 - Flat bottom tests

Purpose: validation of excitation loads or motion response (TBC) for the directional QTF

- Regular waves, bi-chromatic waves, focused waves, and long-crested irregular seas (TBC)
- Possibly directional seas (TBC)
- Wave measurements (low frequency wave content)
- Tests in waves only
- WF and LF wave loads measurements (captive setup, priority/preferred approach) or motion response (soft-moored) measurements

WP2.2 - Parallel bathymetry and coastline

Purpose: validation of excitation loads or motion response (TBC) on plain slope bathymetry

- Regular waves, bi-chromatic waves, focused waves, and long-crested irregular seas (TBC)
- Possibly directional seas
- Wave measurements (low frequency wave energy content)
- Tests in waves only
- WF and LF wave loads measurements (captive setup, priority/preferred approach) or motion response (soft-moored) measurements

WP2.3 - Parallel bathymetry and coastline, with breakwater

Purpose: validation of excitation loads or motion response (TBC) with effect of breakwater

- Regular waves, bi-chromatic waves, focused waves, and long-crested irregular seas (TBC)
- Possibly directional seas
- Wave measurements (low frequency wave energy content)

- Tests in waves only
- WF and LF wave loads measurements (captive setup, priority/preferred approach) or motion response (soft-moored) measurements

WP2.4 – Additional Analysis of the model tests measurements

- Wave splitting analysis using SINTEF method, and comparison to the splitting analysis of Deltares
- Estimate of empirical QTFs using cross bi-spectral analysis

WP2.5 – Forced Oscillation Model Tests near Quay (OPTION)

Purpose: validation data for hydrodynamic loads in calm shallow water, with effect of a (possibly inclined and porous) quay

- Regular oscillations
- Different quay configurations (gap to the quay, porosity of quay, slope of the quay)

WP3: Full Scale Measurements (Lead MARIN)

WP3.1 – Guidelines on Full Scale Measurement of IG Waves without Breakwater

Purpose: share experience and guidelines on best approach to measure and analyse infragravity waves, w/o breakwater involved

- Share Experience gained on a full scale measurement campaign of infragravity wave field
- Pros and cons for the measurement and analysis of infragravity waves in a nearshore environment

WP3.2 - Guidelines on Full Scale Measurement of IG Waves and Vessel Motions, with Breakwater (OPTION)

Purpose: share experience and guidelines on best approach to measure and analyse infragravity waves, with breakwater involved

- Share Experience gained on a full scale measurement campaign of infragravity wave field, with breakwater
- Pros and cons for the measurement and analysis of infragravity waves in a nearshore environment with breakwater

WP3.3 – Dedicated Full Scale Measurements in a Nearshore Environment for Complex Bathymetry and Coastline (OPTION)

Purpose: full scale measurement campaign and validation of wave models on a complex bathymetry and coastline

- Measurements of offshore sea states (boundary of wave models)
- Measurements of nearshore sea states (typical mooring location), with focus on infragravity wave content
- Comparison of full scale measurement results with wave model

WP4: Numerical Model Benchmark Study (Lead MARIN)

WP4.1 - Open Configuration, flat bottom, without coastline (open domain)

Purpose: verify the numerical setup of the different participants for a simple case

- Calculate bi-chromatic wave and irregular sea state
- Assess reflection coefficients for each wave model
- Assess sensitivity of the numerical results to numerical settings (domain size, mesh, bottom friction, boundary conditions…)
- Compare the results obtained by different wave models/participants
- Compare the calculated infragravity waves to theoretical set-down
- Compare the wave loads calculated by the HAWAIII tool to the QTF approach

WP4.2 - Open Configuration, parallel bathymetry, with coastline

Purpose: validate the calculated IG wave content and ship response based on model test data

- Calculate selected wave only model tests
- Calculate selected model tests with excitation loads and/or vessel response
- Assess sensitivity of the numerical results to numerical settings (domain size, mesh, bottom friction, boundary conditions…)
- Validate the wave models and ship response models by comparing the numerical results to model tests results

WP4.3 - Breakwater Configuration, parallel bathymetry, with coastline

Purpose: validate the calculated IG wave content and ship response based on model test data

- Calculate selected wave only model tests

- Calculate selected model tests with vessel response
- Assess sensitivity of the numerical results to numerical settings (domain size, mesh, bottom friction, boundary conditions…)
- Validate the wave models and ship response models by comparing the numerical results to model tests results

WP4.4 - Open Configuration, complex bathymetry, with coastline (OPTION)

Purpose: validate the calculated IG wave content based on full scale data shared with MARIN/DELTARES within WP3.1

- Calculate selected wave only full scale measurements
- Assess sensitivity of the numerical results to numerical settings (domain size, mesh, bottom friction, boundary conditions…)
- Validate the wave models and ship response models by comparing the numerical results to the full scale results

WP5: Breakwater (Lead Deltares)

WP5.1 - Literature Study

Purpose: summarize the aspects that should be considered related to the effect of breakwater on ship response

- Report state of the art and state of the practice (length, positioning, orientation)
- Report literature study focusing on the effect of breakwaters on the vessel hydrodynamics, i.e. wave excitation and vessel response
- Delivery of papers and MSc. Thesis that compare the performance of different wave models including breakwaters

WP5.2 - Extension of the methodology for breakwaters

Purpose: extend the existing methodology when diffraction effects around breakwaters are to be considered

- Research which wave models are capable of calculating with a fitting level of accuracy the wave field around a breakwater
- Assess sensitivity of the numerical results to numerical settings (mesh, bottom friction, boundary conditions…)
- Validate the selected wave model and ship response models by comparing the numerical results to model tests results. One wave model will be focused on in the base scope of work to limit the complexity and provide more focus on the research scope.
- Compare the results obtained with 4D-QTF with the results obtained with the wave model-diffraction coupling

WP5.3 - Calculation of Wave Loads using second-order potential

Purpose: compare the wave loads due to the bound wave on the moored vessel behind a breakwater with both the HAWAIII tool (i.e. coupling wave model – diffraction code) and the QTF method with exact calculation of the second-order potential

- Report difference between the different methods

WP5.4 - Additional Development of Tools that account for Breakwaters (OPTION)

Purpose: if positive results are obtained in this research study, extend the tool and methodology to account for breakwater

- Extend the methodology and guidelines for breakwaters
- Develop and deliver tool extension based on extended methodology

WP6: Summary Guidelines and Workshop Sessions (Lead BV)

WP6.1 - Summary Guidelines

Purpose: write summary guidelines on how to consider shallow water effects when designing nearshore terminals

- Guidelines on the use of the overall methodology
- Guidelines on the use of the wave models, coupling tools and ship-response models
- Guidelines on the setup to be used for full scale measurements and analysis

WP6.2 - Workshop Sessions (OPTION)

Purpose: participants will get familiar with the methodology, the guidelines and the delivered tool

- Give a hands-on workshop about the HAWAIII methodology

These work packages are described in more detail in Appendix, at the end of this document.

WP7: JIP Management (Lead MARIN)

4. PROJECT DELIVERABLES

Below an overview is given of the HAWA-III JIP deliverables:

- Summary Guidelines written by a Classification Society
- HAWAIII diffraction tool (as much as possible open-source) to compute wave loads on terminals due to infragravity waves provided by nearshore wave models
- Tutorial to apply the design methodology with and without breakwater
- Validation of the design methodology based on model scale measurements
- Extension of the design methodology to include breakwaters
- Pros and cons of full scale infragravity wave measurement campaigns

5. ORGANISATION AND SCHEDULE

The HAWA-III JIP will kick-off in 2022 and will be conducted as a 2.5 year Joint Industry Project in close co-operation with energy companies, offshore design companies, shipyards, operators and offshore contractors. MARIN will act as JIP manager and sign participation agreements with all members, and form together with Deltares and BV the initiating partners of the JIP. All participating companies will be represented in the JIP Steering Group with meetings every 6 months within the FPSO JIP week. Presentations, reports and other relevant info will be posted on the confidential project website.

6. BUDGET AND PARTICIPATION FEES

For the HAWAIII JIP we aim for a total project scope of 840kEuro for the base scope of work.

The present proposal is based on that assumed minimal total budget. To reach that total budget we propose the following participation fees:

- Energy companies and Operators: 60 k€ for the participants to HAWA-I and HAWA-II JIPs, 80 k€ for the others.
- Others: 40 k€ for the participants to HAWAI and HAWAII JIPs, 60 k€ for the others.

It is noted that the participants will receive the reports of previous HAWA-I and HAWA-II JIPs upon request after the start of the project.

Participants can join the JIP until October 1st, 2022. After that a late participation fee of 125% applies. The final budgets and scope of work will be fixed in accordance with the JIP participants during the kick-off meeting.

Because we believe it is very important to start up this project even if the available budget is limited we have decided to make some of the Work Packages optional. If there are sufficient participants, we foresee also to add some of the optional items to the scope of work. The optional items to be included will be selected by the group of participants. The starting costs for the project are about 50kEUR. These starting costs are not covered by the budget mentioned in this proposal and are on MARIN and DELTARES risk (own investment). Therefore, if additional participants join the JIP at a later stage, the starting costs will be compensated first prior to include extra scope.

Table of Expenditures for the Minimum Scope of Work

Work Package	MAR	DEL	BV	BP	AKT	ARC	SINTEF	NTNU	TOTAL
WP1: Development and Delivery of Tools									90
WP1.1 Development of the HAWAIII Tool	60	20							80
WP1.2 Delivery of the HAWAIII Tool	10								10
WP1.3 Test/Review/Sensitivity Studies of the HAWAIII Tool						5			5
WP2: Model Scale Measurement									295
WP2.1 Flat Bottom Tests	10	50							60
WP2.2 Parallel bathymetry and coastline	10	100							110
WP2.3 Parallel bathymetry and coastline, with breakwater	10	100							110
WP2.4 Analysis and Comparison of Splitting Methodologies and Estimate of QTF							15		15
WP2.5 Forced Oscillation Model Tests in Nearshore Environment (Shallow Water, Quay) - OPTION									
WP3: Full Scale Measurements									20
WP3.1 Guidelines Full Scale Measurements IG Waves w/o breakwater				20					20
WP3.2 Guidelines Full Scale Measurements IG Waves & Vessel Motions, with breakwater - OPTION									-
WP3.3 Dedicated Full Scale Tests Nearshore Environment & Complex Bathymetry - OPTION									-
WP4: Benchmark Numerical Study									235
WP4.1 Open Configuration, flat bottom, w/o coastline (open domain)	10	15			10	10	10	10	65
WP4.2 Open Configuration, parallel bathymetry, with coastline (Validation Model Tests)	10	15			25	10	25	25	110
WP4.3 Breakwater Configuration, parallel bathymetry, with coastline (Validation Model Tests)					20	10	10	20	60
WP4.4 Open Configuration, complex bathymetry, with coastline (Validation Full Scale Data) - OPTION									-
WP5: Breakwater									100
WP5.1 Literature Study Breakwater		20							20
WP5.2 Extension of the methodology to account for breakwaters	30	30							60
WP5.3 Calculation of Wave Loads using second-order potential			20						20
WP5.4 Additional Development of the HAWAIII Tool for Breakwaters - OPTION									-
WP6: Summary Guidelines and Workshop									30
WP6.1 Summary Guidelines			20		5	5		5	30
WP6.2 Workshop Sessions - OPTION									-
WP7: Project Management									60
WP7.1 Management MARIN	60								60
Budget Total	**210**	**350**	**40**	**20**	**60**	**40**	**60**	**60**	**840**

7. CONTACT

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9. DEFINITIONS / CLARIFICATION LIST

1D Wave spectrum	Irregular wave spectrum defined for one wave direction
2D Wave spectrum	Directional wave spectrum that describes wave energy for each incoming wave direction
0D QTF	Quadratic Transfer Function of the classical type that describes the 2nd order mean drift forces. This method can be used to estimate the wave drift forces in deep water (Newman approximation)
2D QTF	Quadratic Transfer Function of the classical type that describes the 2nd order mean and low frequency drift forces for each incoming wave direction, **without** taking into account wave drift forces related to the interaction between different wave directions. (full matrix)
4D QTF	Quadratic Transfer Function as the 1DQTF but **with** taking into account wave drift forces related to the interaction between different wave directions.
Surfbeat	Time domain shallow water wave model.
Diffraction code	Software that uses linear frequency domain potential theory to solve the diffraction of waves on a vessel or bathymetry and computes the related wave forces
Bound Wave/ Setdown	Second order low frequency wave that is bound to the wave groups. Note: the amplitude of the bound wave is generally larger in shallower water.
LF Free wave	A low frequency free wave that obeys the dispersion relation (and is not bound to a wave group). These waves initiate when a bound wave reflects back from a beach or in the process where deeper water waves enter shallow water.
Bathymetry	An uneven, non-uniform, sea bottom that may influence the wave celerity and travelling direction. In this process the directional wave spectrum may changes its shape and bound and free waves may be initiated. The bathymetry as investigated in this project is varying in space, but not in time.
Local varying bathymetry	An uneven sea bottom in the vicinity of a vessel that may affect the response (added mass and damping) and low frequency wave forces on the vessel
Response	The motions and forces related to a moored vessel in waves.
Infragravity Waves (IG waves)	Surface gravity waves with frequency lower than wind waves (wind sea and swell), typically with periods between 30sec and 500sec.

WORK PACKAGE 1
Development and Delivery of the HAWAIII Tool (lead MARIN)

General Description

During the project appropriate numerical tools will be selected, developed, tested and validated to be able to apply the design methodology for nearshore LNG terminals developed during HAWA-II. These tools will be made available to the participants. This includes (1) a wave model that calculates the low-frequency wave content (2) a potential flow code that can be coupled to the wave model to calculate the infragravity wave excitation on the LNGC terminal and that calculates the hydrodynamic database of the vessel, and (3) a time-domain code that calculates the vessel response of the moored vessel. The time-domain code is required to represent the non-linear mooring equipment and wave drift forces. The schematic representation of the HAWAIII methodology and the HAWAIII-Tool that will be delivered is shown in Figure 10.

In the project, a number of wave models will be investigated and the most suitable wave model will be selected to be focused on in the tool that will be developed. The focus will be on open-source methods which can freely be made available to all participants. It should be noted that the effect of breakwaters can only be investigated with wave models that also resolve short waves, this is further described in WP 5. The following wave models are likely candidates:

1. **XBeach**

   XBeach (Roelvink, van Dongeren, van Thiel de Vries, McCall, & Lescinski, 2009) is a two-dimensional open-source model for wave propagation, long waves and mean flow, sediment transport and morphological changes of the nearshore area developed by Deltares. Xbeach has been used in the Hawa-II JIP by Deltares to study low-frequency wave content in shallow water related to possible exposed locations for LNG terminals. Since promising results were obtained, a logical step is to use and investigate the suitability of this model further in the Hawa-III JIP. Figure 4 shows an example of the low-frequency wave content in some typical shallow water areas obtained during the HAWA-II JIP.

   Xbeach can be run in the “surfbeat” mode and in the “nonhydrostatic” mode. In the former case the short wave variations on the wave group scale (short wave envelope) and the long waves associated with them are resolved resulting in very fast simulations. In the latter case a combination of the non-linear shallow water equations with a pressure correction term is applied, allowing to model the propagation and decay of individual waves which is required to study wave interaction with breakwaters, see WP5. More details on Xbeach can be found here: https://oss.deltares.nl/web/xbeach/

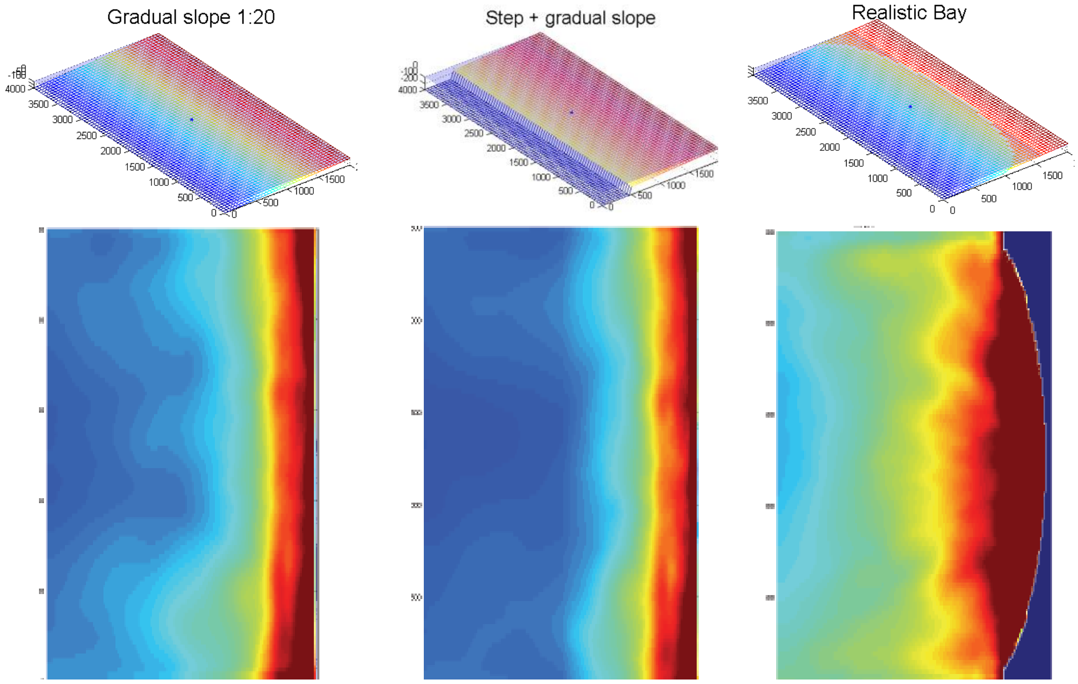


Figure 4: Low-frequency waves in coastal areas obtained with Xbeach simulations during HAWA-II JIP

2. SWASH

SWASH is a general-purpose open-source numerical tool for simulating unsteady, non-hydrostatic, free-surface, rotational flow and transport phenomena in coastal waters as driven by waves, tides, buoyancy and wind forces. It provides a general basis for describing wave transformations from deep water to a beach, port or harbour, complex changes to rapidly varied flows, and density driven flows in coastal seas, estuaries, lakes and rivers. The SWASH model is developed by Delft University of Technology. The SWASH model is similar to XBEACH-nonhydrostatic, but it has a wider range of application, since specific modelling choices make it more accurate in deeper water than XBeach (intermediate water depths 15 m -40 m). It resolves both short and long waves simultaneously. This makes it computationally more intense than the Xbeach-surfbeat mode. More details on SWASH can be found here:
https://www.tudelft.nl/citg/over-faculteit/afdelingen/hydraulic-engineering/sections/environmental-fluid-mechanics/research/swash/

3. REEF3D-SFLOW

REEF3D is an open-source hydrodynamics program developed by NTNU with the focus on wave modelling (https://reef3d.wordpress.com/). It has several hydrodynamic models, one of which is the SFLOW model: a depth-averaged shallow water equations model, that solves the non-hydrostatic pressure. The REEF3D-SFLOW model is in theory very similar to SWASH and the Xbeach non-hydrostatic model. Initial investigations by MARIN with this model were made in 2019 and Figure 5 shows for example bi-chromatic waves interacting with a sloped beach.

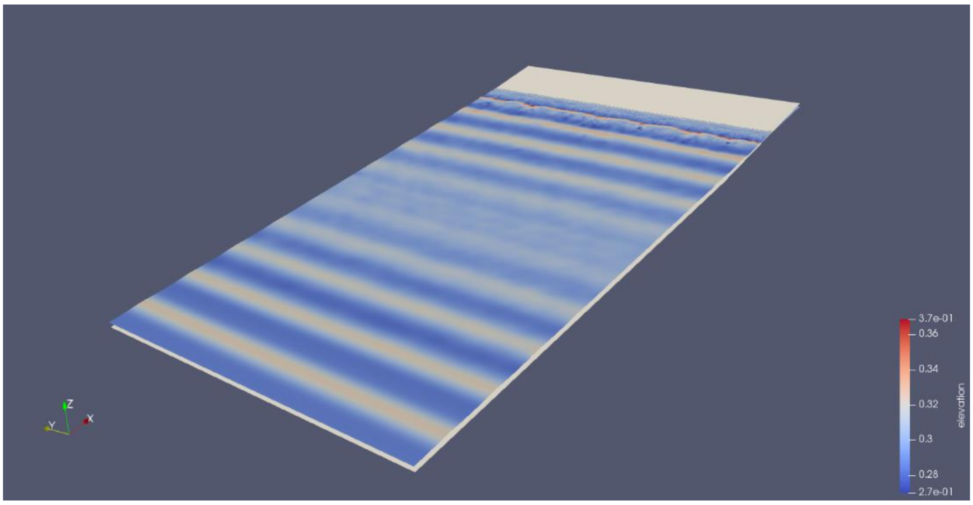


Figure 5:REEF3D-SFLOW simulations of wave groups running on to a beach.

Within WP4, participants may bring into the project results from other wave models that they have run and analysed. In this case, the participants working on additional wave models will also compare the results (wave field and vessel response) to the wave models used in the base scope of this JIP.

All these wave models export their results (wave elevations, water velocities etc.) in a model-specific output format. In the HAWA-III project a coupling between a wave model and a diffraction code will be made for one selected wave model and delivered to the participants. For this coupling procedure one common database format will be defined for storing the water wave kinematics from these wave models. For the most promising wave model, the output format will be converted to produce the required input for coupling with the diffraction analysis to obtain the wave forcing on the LNGC terminal. The format will be discussed and decided during the project.

To obtain the wave loading related to nearshore waves on moored vessels a potential-flow based linear diffraction code is very well suited (van der Hout, de Jong, Jaouen, & Waals, 2015). For that purpose, MARIN's linear diffraction code DIFFRAC will be used in this project (https://www.marin.nl/storage/uploads/23825/files/DIFFRAC.pdf). A special project version of this program, with the name HAWAIII, will be prepared and delivered to the participants including databases of test cases that have been investigated in the JIP.

A standard diffraction analysis assumes monochromatic Airy waves as input and applies the corresponding water velocities as boundary condition on surface panels that describe the wetted part of a ship's hull. Due to the fact that water cannot penetrate the ship's hull a diffracted wave is generated and the wave loading on the ship is a combination of the undisturbed and diffracted wave field. For coupling with a nearshore wave model the Airy wave assumption is no longer valid. Instead the Airy wave water velocities have to be replaced by the water velocities predicted by the nearshore wave model. This will be accomplished by importing these water velocities from the wave database resulting from the nearshore wave model. The resulting output of the diffraction analysis are time traces of the wave loading on the modelled ship(s), including the forcing due to the long waves which are present in the wave model. These time traces can easily be imported into time-domain models like MARIN's aNySIM. The potential flow diffraction code DIFFRAC, based on which the HAWAIII-Tool will be based, can handle multiple bodies, so offloading simulations with multiple vessels and/or a breakwater can be dealt with as well.

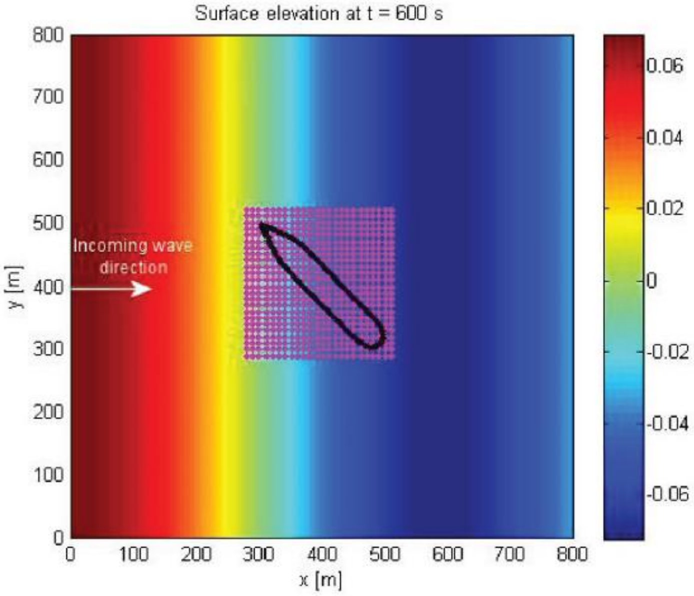


Figure 6: The principle behind coupling a wave model with a diffraction code: export and interpolation of water wave kinematics onto the panel surface mesh.

It should be noted that DIFFRAC is a frequency-domain program. Therefore, the time traces of water velocities have to be transformed into Fourier components. After the computation is finished the frequency dependent wave force transfer functions have to be converted back from frequency domain to time domain. The HAWAIII Tool DIFFRAC will take care of all these transformations. To limit the number of frequency components wave kinematics time traces will be divided into smaller half-overlapping windows, resulting in much less frequency components. The additional work due to the increase of the number of time traces is only marginal. The length of the time window will be a user-input value and must be chosen such that it is larger than the longest period of interest (natural period of the moored vessel).

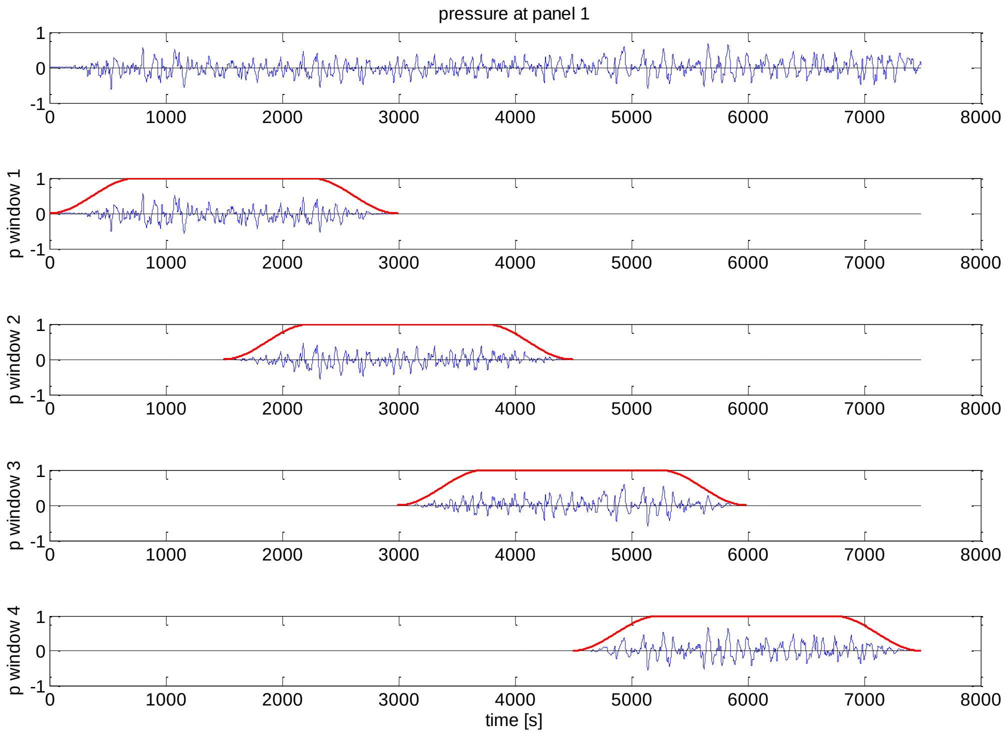


Figure 7: Windowing method for coupling of wave kinematics to frequency-domain diffraction code: pressure and water velocities on panels are divided into half-overlapping windows to reduce number of frequency components.

Low-frequency forcing is not only caused by long waves but also by second order forcing related to wave groups formed by short waves (drift forces). These forces must also be added to a time-domain simulation. The HAWA-II design methodology is based on wave simulations with long waves only (Xbeach-surfbeat). The short waves are phase averaged and only the wave spectrum is computed and known at the terminal location. To obtain the wave drift force, a random wave realization from this spectrum is then generated which is not phase-correlated with the long waves. For the QTF components I to IV (i.e. all QTF contributions but QTF-V, that corresponds to the bound wave excitation and already included in the wave model), the theoretical drift force Quadratic Transfer Functions (QTF's) from a standard diffraction analysis (assuming linear superposition of Airy waves and constant water depth) are then used to obtain wave drift realizations corresponding to this random wave.

DIFFRAC also produces a database with hydrodynamic reaction forces (added mass, damping) which should be used in a time-domain simulation to derive retardation functions.

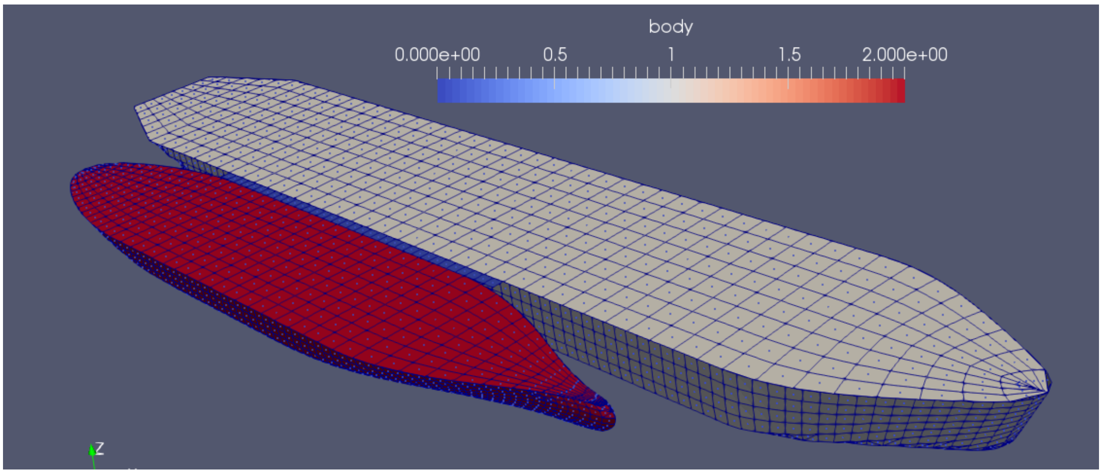


Figure 8: DIFFRAC panel mesh for a side-by-side analysis

The format of the wave force time traces and database with reaction forces will be discussed with the JIP participants so they can use it easily in their own time-domain simulation tools. During the project the feasibility of the design methodology will be shown by means of coupling with MARIN's aNySIM program. At the end of the project a so-called aNySIMpro version (https://www.marin.nl/storage/uploads/3611/files/aNySIMpro.pdf) will be delivered, dedicated to the cases studied in the JIP. An aNySIMpro version is dedicated to a certain project/vessel configuration. So typically the terminal details are fixed but the environmental conditions, lines and fenders can be varied.

Interactive workshop sessions will be organized in which the participants will be made familiar with all these tools (WP6) and tutorials will be provided based on the case study which has been selected at the beginning of the JIP.

The HAWAIII tool will be delivered for Windows Operating System and will be maintained by MARIN. The wave model used within the JIP will be as much as possible open-source, and therefore freely available on the Internet. Eventual coupling tools (if not already integrated in the tool itself for simplicity and performance) will be programmed in Python, which is also available for all participants. The HAWAIII tool and the time domain code aNySIM (in an aNySIMpro version) will be delivered within the project. Updates of the software in the years following the JIP (necessary when migrating to a new Windows platform for example) will be available in the years following the completion of the JIP for a cost of 3,500EUR, which correspond to the maintenance costs.

Summary of Scope of Work

WP1.1: Development of the HAWAIII Tool (Lead MARIN)

The objective of this package is to develop the HAWAIII tool, consisting of the diffraction code accepting user-defined waves, and with clear interfaces with the wave model and the ship response model. The tool will be based on the use of an open-source wave model. The documentation of the tool will also be prepared within this work package, and will include the installation guide, the tutorials and the theory documentation.

WP1.2: Delivery of the HAWAIII Tool (Lead MARIN)

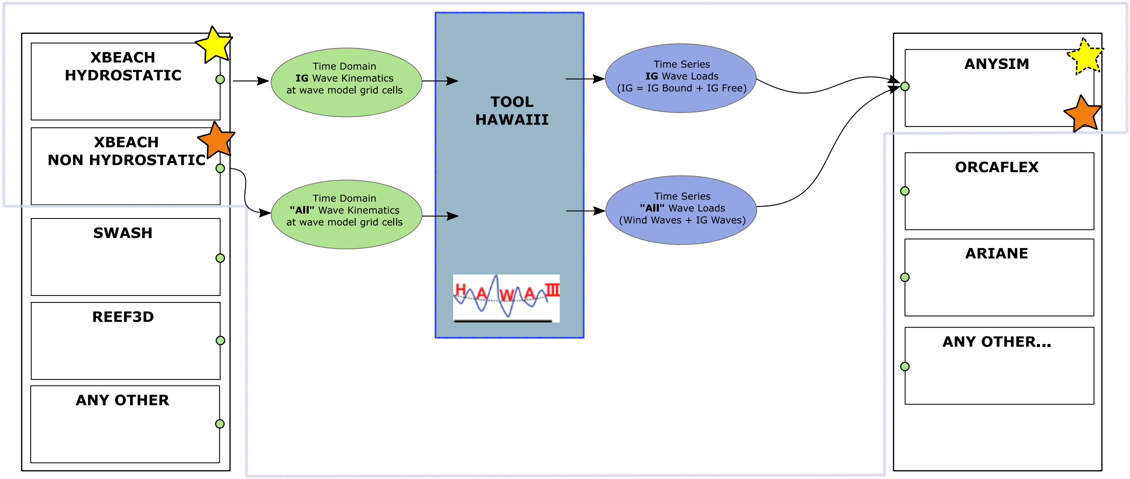
The objective of this package is to deliver the tool to the participants on an online platform, on which a forum can be hold between the participants. The tools and documentation will be made available.

WP1.3: Testing/Review of the HAWAIII Tool (Lead ARCADIS)

ARCADIS will contribute in writing the specifications of the HAWAIII Tool together with MARIN. ARCADIS will act as a Tester/Reviewer/Advisor of the HAWAIII Tool and documentation. ARCADIS will investigate the sensitivity of the results to the input parameters of the HAWAIII Tool, using the wave model data delivered by the benchmark participants (see WP4) as input data. ARCADIS will deliver user guidelines for the HAWAIII -Tool, informing the user about pro's and con's, and will suggest possible improvements of the tools. These suggested improvements may be implemented if technically feasible within the foreseen budget. The guidelines delivered by ARCADIS can be used by BV in WP6 for the summary guidelines of the overall methodology.

WP1.4: Wave Model REEF3D (Lead NTNU)

NTNU develops and extends the REEF3D open-source hydrodynamic framework for the identification of infra-gravity waves and provide inputs for the calculation of the forces and motions of the moored ships. The framework consists of different types of wave models, including the high-resolution computational fluid dynamics (CFD) model REEF3D::CFD, the shallow water model with a quadratic non-hydrostatic pressure approximation REEF3D::SFLOW, the fully nonlinear potential flow (FNPF) model REEF3D::FNPF and the three dimensional (3D) non-hydrostatic Navier-Stokes solver REEF3D::NHFLOW. These models combine the strengths of different strategies and can be used for multi-scale marine hydrodynamic phenomena at different water depths. The comprehensive numerical framework provides a practical tool for the study of infra-gravity waves in coastal regions. Possible coupling among the different models can be examined, should the need arises. The software developed by NTNU during the project will be delivered to the project by means of an open-source framework and will therefore also be publicly available. The software REEF3D is thus not restricted by term 10 confidentiality. The NTNU-developed software REEF3D and its source code shall remain open-source and be published under GNU GPL v3.



Legend

—	The base scope of the project focuses on these items
—	This is the Plug & Play HAWAIII Tool that will be delivered, the user can focus essentially on the input and output of the tool, not anymore on getting things working.
☆	Delivered as open-source or freely available on the Internet (WP1)
☆	Delivered within the project (license), but not open-source (WP1)
★	Tool Extension, delivered within the project if proven successful (WP5)

Figure 9: description of the HAWAIII tool delivered within the JIP

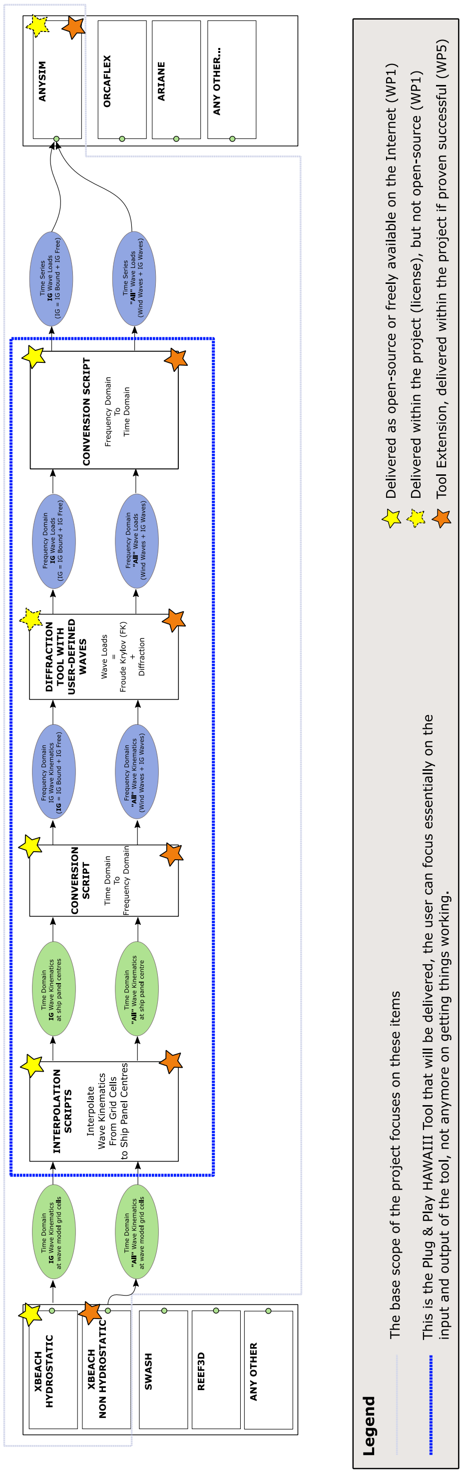


Figure 10: schematic representation of the HAWAIII tool - the principle behind coupling of wave models, diffraction code and time-domain simulation models.

WORK PACKAGE 2
Model Scale Measurements (Lead Deltares)

General Description

The main activity of the Work Package 2 is to prepare, execute and analyse shallow water wave basin model tests, including the presence of a bathymetry, coastline and possibly breakwater. The following sub-packages are foreseen:

- WP2.1 – Flat Bottom Model Tests
- WP2.2 – Parallel bathymetry and coastline
- WP2.3 – Parallel bathymetry and coastline, with breakwater
- WP2.4 – Extra QA/Analysis of the model tests
- WP2.5 – Forced Oscillation Model Tests in Calm Water near Quay/Breakwater

The design methodology demonstrated in the second HAWAII JIP has not been validated due to lack of suitable experimental data including bathymetry, coastline and breakwater. Therefore new model test experiments will be carried out within the HAWA-III JIP. The experiments will be carried out in the Delta Basin of Deltares (https://www.deltares.nl/nl/faciliteiten/delta-basin/) which is very well suited for these type of experiments. Wave generators are equipped with online Active Reflection Compensation, which effectively eliminates re-reflections of waves from the wave board. A physical scale model test program is chosen to acquire validation material because 1) it provides good control over the (environmental) conditions, 2) systematic variations are possible, and 3) extreme conditions, exceeding design limits, can be considered.

Figure 11: Deltares' Delta basin which will be used for the HAWA-III validation experiments

The following variations in the test program are foreseen:

- One bathymetry/coastline
- Several types of waves (regular, bi-chromatic, wave groups, wave spectra) and wave directions (perpendicular to the coast and under an angle)
- Tests with and without breakwater
- Wave only tests (no vessel installed), and tests with captive vessel (preferred approach) or soft-moored vessel (TBC)

The following measurements are foreseen:

- Surface elevations (combined with horizontal flow velocity at a limited number of gauges) at multiple locations in the basin
- Excitation loads (including measurements of IG waves loads) on the captive vessel (preferred approach)
- If a soft-mooring arrangement is applied, Motions of the moored vessel and Mooring loads will be measured

The details of the test program will be discussed during the JIP meetings and participants can give their input prior to the execution of the tests.

Prior to the experiments, wave simulations will be performed to select a suitable test setup (breakwater main dimensions and orientation, water depth location etc.), interesting test conditions (wave spectra, wave direction), most suitable force frame for the captive measurements, possibly the soft mooring system. The preparation of the model test campaign will be supported by the numerical benchmark studies carried out in WP4.

Summary of Scope of Work

The objective of the model scale measurements is to measure the nearshore wave field including the infragravity waves, the excitation wave loads (WF+IG), or the mooring line loads and the vessel motions (as an alternative to the captive measurements). These measurements are intended as reference for validating numerical models. The bathymetry considered will be as in the case study of HAWAII-JIP, i.e. alongshore uniform sloping beach, including realistic reflections off the coast. The lessons learnt from the previous JIPs will be used to prepare the experimental setup. The focus will be on shore-normal wave conditions. The wave conditions will be gradually increased in complexity:

- Regular waves
- Unidirectional bi-chromatic
- Bi-chromatic waves, components with different directions (one entry in the 4D-QTF on flat bottom)
- Irregular long-crested waves
- Short-crested wave spectrum

The execution of the model tests will be divided into the following phases:

WP2.1 – Flat Bottom Model Tests (Lead Deltares)

WP2.2 – Parallel bathymetry and coastline (Lead Deltares)

WP2.3 – Parallel bathymetry and coastline, with breakwater (Lead Deltares)

The measurements and analysis of the LF waves in the basin, including reflections of long waves off the sloping beach, will use advanced wave splitting techniques to verify the amount of (free) LF waves in the basin, and the possibility of making directional analyses for the LF waves investigated by van Essen (2D splitting) will be evaluated.

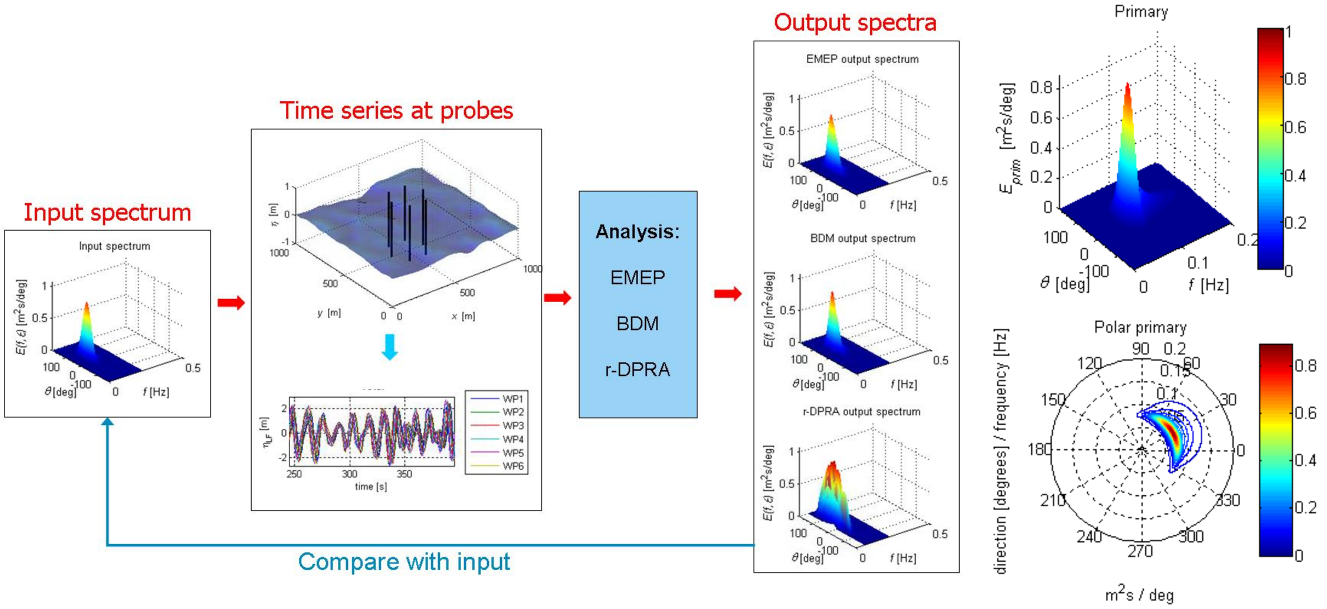


Figure 12: 2D wave analysis procedure (left) and 2D spectra in Cartesian and polar coordinates (right)

WP2.4 – Analysis (Lead SINTEF OCEAN)

Sintef Ocean (SO) will perform additional analysis of the wave basin measurement, compared to the analysis performed by Deltares in the preceding work packages. SINTEF will contribute to the planning and analysis of the wave basin measurement. The SO's wave splitting method will be applied to the wave elevation measurements. SINTEF will compare the results of the Deltares splitting methodology to the SO's wave splitting methodology. Some details are given below.

Wave splitting method

The aim is to apply a new wave splitting method [5] to separate and identify the different low frequency (LF) wave systems in the wave basin. The input are the time records of the wave elevations measured during the calibration of waves from a large set of wave sensors distributed along the wave propagation direction (SO should ideally be involved in the planning of the wave calibration phase). The result are time series of split LF wave elevations namely the: bound wave, incoming free parasitic wave, reflected wave and additional very long waves related to the modes of the basin. The analysis will be performed for the long-crested wave cases and the data from the flat bottom tests and parallel bathymetry tests. Extending the method and analysis to short-crested waves may be considered, depending on the relevance and the available resources.

The wave splitting method follows two steps. The objective of the first is to separate the wave signal into an incident and a reflected component, which is achieved by decomposition of the signal in the $(kk,\omega\omega)$-Fourier space to discriminate between components with positive phase velocity and those with a negative one. The second step of the splitting method consists of separating the incident wave into a bound wave component and a free wave component. The free wave includes the parasitic waves and re-reflected waves. The separation is achieved by computing the bound wave and subtracting it from the incident wave. The bound wave is computed from the first order wave elevation and the difference frequency quadratic transfer function (QTF). The methodology can also handle varying bathymetry, and is therefore not limited to flat bottom configurations.

Cross bi-spectral analysis

Sintef Ocean (SO) has been applying for many years the cross bi-spectral analysis to model test data to identify the wave drift force QTFs. Experience has shown that the procedure works well in deep and intermediate water depths, especially for horizontal forces. In shallow water, and especially in varying bathymetry, challenges increase given the additional complexity associated to several low frequency wave systems influencing the measured motions. So one main purpose of this task is to assess the accuracy and challenges of using the cross-bi-spectral analysis in shallow water. The technique will be applied for the HAWA-III shallow water conditions with the aim of identifying surge and sway empirical QTFs. The empirical results will be compared with the potential flow second order solution, and results will be interpreted with regard to possible unwanted disturbances and whether they can be avoided/disregarded/mitigated.

The method known as cross-bi spectral analysis estimates characteristics of second-order responses (quadratic transfer functions – QTFs). The identified drift coefficients include mainly the quadratic contents of the experimental signals, but they may also include higher-order contributions. While a brief explanation is given in the following paragraphs, details of the method can be found in [6] and [7]. Application to model test data acquired in shallow water conditions is reported in [8]. The procedure follows two major steps[2]:

- First, identify the second order wave exciting force signal from the measured low frequency (LF) motion response. One assumes a linear mass-damper-spring system represents the LF motion. The system natural frequency, mass and linear spring constants are known. Decay tests provide information for initial assumption of system damping, which is adjusted through an iterative process. The second order excitation force is the only unknown to be determined.
- Second, use the undisturbed incident wave elevation and the estimated second order force, together with cross bi-spectral analysis, to identify the difference frequency wave exciting QTF matrix:

$$H^{(2)}(f_m, f_n) = \frac{S_{\zeta\zeta g}(f_m, f_n)}{S_{\zeta\zeta}(f_m) S_{\zeta\zeta}(f_n)}$$

Where $H^{(2)}(f_m, f_n)$ is the wave drift force coefficient corresponding to the wave frequency pair (f_m, f_n), $S_{\zeta\zeta}(f_m)$ represents the wave spectrum and $S_{\zeta\zeta g}(f_m, f_n)$ is the cross bi-spectrum of the second order excitation with respect to the incident wave elevation.

Because the total IG loads consist of first order loads due to IG free waves, and to second order loads (due to IG bound waves, but also other QTF contributions I to IV), the first order IG loads should be corrected in a way or another in this analysis.

Deliverables:

SINTEF OCEAN (SO) will deliver a report of the splitting and cross-bi spectral analysis that clearly explains how the analysis should be carried out in projects, the pro's and con's of the method, and the expected accuracy. This will provide input to the participants involved in WP6 for the summary guidelines.

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[2] In case a captive setup is used (which is the preferred approach), this first step is not needed as the forces are directly measured.

WP2.5 – Forced Oscillations (Lead MARIN) - OPTION

The model tests activities proposed in WP2.1 tot WP2.4 focus on the measurement of waves and wave loads due to waves in a nearshore environments (varying bathymetry, coastline, breakwater). These model tests provide essential data to validate the wave elevations calculated in wave models and the corresponding wave excitation on vessels in a nearshore environment. Besides the wave loads, the response side is also relevant to predict the response of ships accurately, i.e. the calculation of the added mass and damping of vessels in the vicinity of a bathymetry and opaque or porous quay. The objective of this work package is to provide validation data for numerical methods with respect to added mass and damping coefficients. The effect of the distance to the quay and porosity of the quay will be investigated. For different degrees of freedom, different amplitudes and periods will be investigated.

An hexapod will be used to apply the regular motions on the captive vessel. These tests can be carried out in the shallow water basin of MARIN (BT) in order to take the limited water depth into account. For these tests, MARIN will design a new frame to mount the existing hexapod 6 DoF oscillator on the shallow water basin floor.

In the forced oscillation tests, the same vessel as tested in WP2.1 to WP2.3 will be connected to the hexapod (see picture opposite) through a 6 component measurement frame. The 6 component measurement frame allows to measure the forces and moments (FX, FY, FZ, MX, MY and MZ) on the floater, which allows to derive the added mass and damping coefficients of the floater for the degrees of motions considered. The amplitude and period of the motion can be adjusted in the software settings of the oscillator controls. Furthermore time traces can be loaded to play a user-defined trajectory. With this feature a white noise spectrum can be implemented.

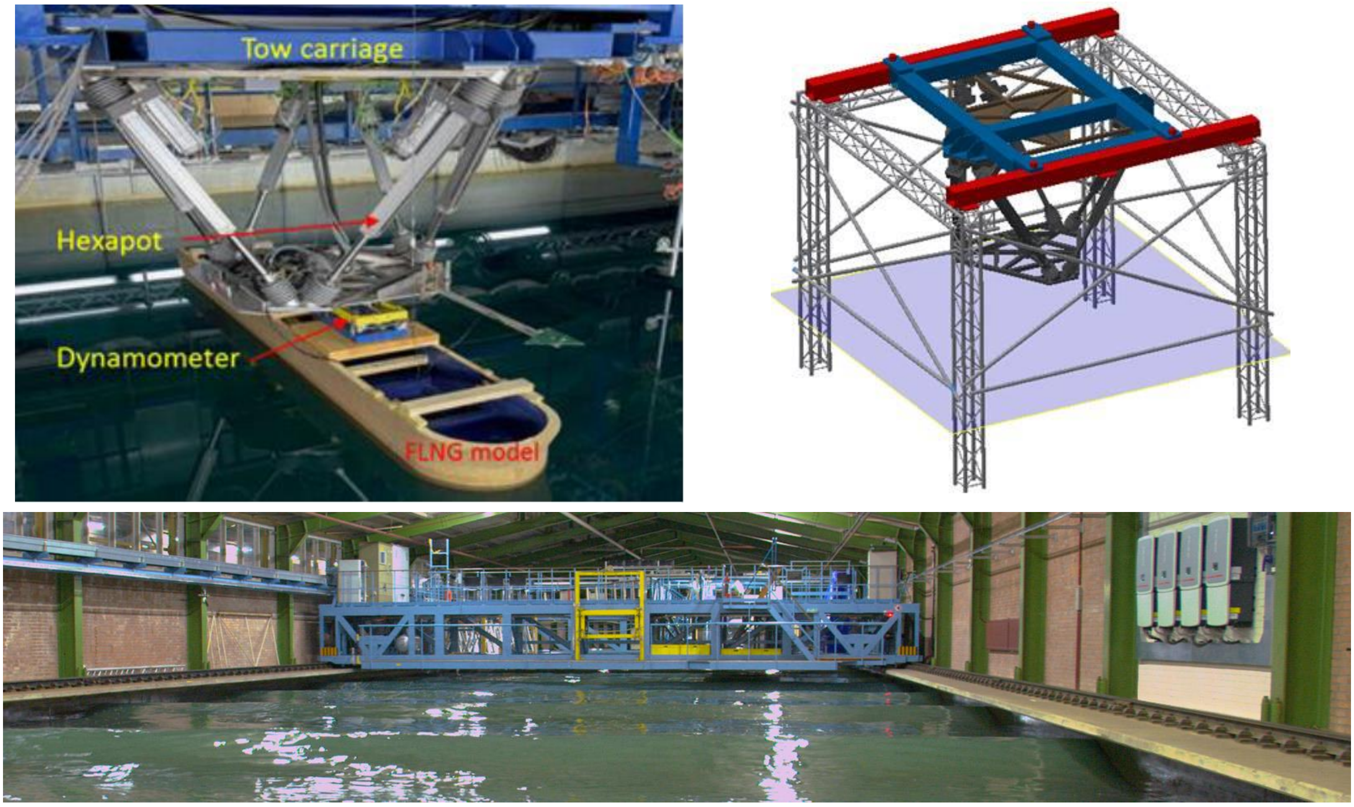

Figure 13: Experimental Setup with a Hexapod used to apply forced motion on a vessel in the Shallow Water Basin (BT)

WORK PACKAGE 3
Pros and Cons of Full Scale Wave Measurements (lead MARIN)

General Description

In the HAWA-II JIP results from Xbeach were compared against open-source full scale measurements performed at Duck in Northern Carolina, USA. Good results were obtained. Unfortunately, waves at Duck are measured at 4 relatively shallow locations (5, 6, 8 and 11m water depth) which is less than the typical water depths at LNG terminals (15-30 m). This means that no data is available to validate wave models in a nearshore environment (bathymetry, coastline). Therefore, in this work package, the focus will be on full scale measurements of infragravity waves at a water depth corresponding more closely to a typical LNG terminal location.

The main objective of the Work Package 3 is to gain insight on how to perform and analyse full scale measurements of infragravity waves, and to obtain full scale data for validation purposes. Experience from participants will be used to establish guidelines on the measurement and analysis of infragravity waves. The different techniques that can be used to measure infragravity waves in a nearshore environment, and the performances of those techniques, will be discussed. This will be done based on existing full scale measurement data or experience that can be shared by participants. If budget allows, this may also be supported by dedicated full scale measurements in a nearshore environment. Pros and cons on the measurement and analysis of infragravity waves will be delivered on how a full scale measurement campaign of infragravity waves should be carried out, and how the results should be analysed and used. The following sub-packages are proposed:

- WP3.1 – State of the art, State of the Practice and Experience from Full Scale Measurement of IG waves without breakwater
- WP3.2 – State of the art, State of the Practice and Experience from Full Scale Measurement of IG waves with breakwater (OPTION)
- WP3.3 – Dedicated Full Scale Measurements in a Nearshore Environment for Complex Bathymetry and Coastline (OPTION)

Figure 14: **AWAC system for measuring tidal variation or infragravity waves.**

Summary of Scope of Work

WP3.1: State of the art, State of the Practice and Experience from Full Scale Measurement of IG waves without breakwater (Lead MARIN[3], BP)

The objective of this work package is to share experience on how to (and on how not to) perform full scale measurements and analysis of infragravity waves in a nearshore environment. We will discuss different available measurement techniques to measure the infragravity waves in a nearshore environment, and we will share experience that has been gained from full scale measurement campaigns. Nowadays, many companies can offer services to measure wave conditions in shallow water, but the measurements often focus on the gravity waves, which are relatively easy to measure using wave buoys or radars. Because the infragravity waves are long and relatively small, they are challenging to measure accurately. The scope of work of this sub-package will include the comparison of technical specifications of the different measuring techniques, and sharing experience on full scale measurement campaigns.

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[3] It is noted that this work package may be partly delegated to parties that are willing to share both analyzed data and experience in the measurement of infragravity waves. At the moment this proposal is written, several companies have shared their willingness to share data and experience in this field, and to play a role in this work package.

Contribution BP

BP will provide measurements from instruments deployed on an ocean coastal shelf location. This will include the following:

1. Directional wave measurements in 30m of water from a wave recorder over a continuous period of 9 months. The instrument simultaneously measured 'u' and 'v' horizontal current velocities, pressure and water temperature. The raw burst data was accumulated into 4096 second profiles, and then spectrally analysed in 31 overlapping blocks of 256 seconds (256 samples). The spectra were then ensemble averaged, yielding a 128 ordinate spectrum with an ordinate width of 0.004 Hz. Each raw wave burst file together with the corresponding derived wave spectrum were simultaneously visually inspected for data quality and subsequent removal (or interpolation) of spurious data points. Any corrupt values due to instrument faults, sensor drift or timing errors were excluded from further analysis.
2. Directional wave measurements in 30m and 125m of water from wave buoy. Measurements are available for the same time period as for the wave recorder (see 1 above). Raw heave, horizontal North-South and horizontal East-West data were sampled at 2 Hz (0.5 s). Each raw profile was then quality checked before spectral analysis to provide the directional wave spectra. Finally, the wave spectra were visually inspected for quality.
3. A description of the bathymetry sufficient to allow MARIN or DELTARES to validate numerical models based on the full scale data provided. The bathymetry description does not need to be detailed, and can be simplified, but numerical validation requires the typical seabed slope, the distance to the shore, the coastline description and characteristics.

BP will also provide within this work package a summary of Best Practice, describing BP's experience in measuring infragravity waves on an ocean coastal shelf location. This will include guidance on:

- Best instrument types and configuration;
- Post-processing of results;
- Strategies for avoiding fishing interference.

It is noted that the measured data shared by BP shall not be used for any other purpose than executing the scope of work described in this JIP (see section WP4.4), and the data shall not be released outside of MARIN or DELTARES. Within the scope of work of WP4.4, the data shall be anonymised in all information shared or presented to other PARTICIPANTS. All reports, presentations or other content produced by MARIN or DELTARES containing or referring to the measurements shall be subject to approval from BP before being shared or presented with any others to verify it has been suitably anonymised. Note that BP's approval relates solely to the anonymization of the data and not any other aspect of the content produced by MARIN or DELTARES using the data.

BP will deliver:

1. Participant will deliver the agreed data and a first draft of the summary of best practice for WP3 within 6 months of the first JIP Steering Group meeting;
2. The final summary of best practice for WP3 will be delivered no later than 3 months after receiving all review comments on the first draft.

WP3.2: State of the art, State of the Practice and Experience from Full Scale Measurement of IG waves with breakwater (lead MARIN[4]) - OPTION

The objective of this work package is to similar to WP3.1, but now including the presence of a breakwater. This is an optional scope of work, that will be activated if a party is willing to share existing full scale measurement data as an in-kind contribution for the project.

WP3.3: Full Scale Measurements in a Nearshore Environment for Complex Bathymetry and Coastline, without breakwater (lead MARIN) - OPTION

The objective of this work package is to measure and analyse the infragravity wave field at a nearshore location. A water depth of approximately 15 m is aimed for, in an area where bathymetry and coastline play a role. A suitable location and measurement system will be selected, which means that the bathymetry should be available, and infragravity waves should be present. It is important that both the offshore incident waves and the shallow water waves at the terminal location are measured. The former wave system can be used as boundary condition to the wave models and the latter measurement can be used to validate the proper low-frequency wave content in these shallow water wave models. Waves at the Duck site are measured using an AWAC system, see Figure 14. MARIN owns and has experience with an AWAC system and this is expected to be the preferred candidate for measuring the infragravity waves. However, as a first step for the full scale measurement campaign, the performances of different measurement techniques will be compared (AWAC, radars, buoys, pressure sensors…). The offshore incident waves are preferably measured using a wave radar on a fixed platform, but such a platform must of course be available. As an alternative a wave rider buoy can be used but these are often lost in bad weather. The scope of work will include the measurement and analysis using different measuring methods. This scope of work is proposed as an option at the moment, since a location needs to be determined first. Furthermore, the cost for the study also depend also on the most suitable instrumentation and lessons learnt shared in WP 3.1.

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[4] It is noted that this work package may be partly delegated to parties that are willing to share both analyzed data and experience in the measurement of infragravity waves.

WORK PACKAGE 4

Numerical Model Benchmark Study (Lead MARIN)

General Description

The main objective of the Work Package 4 is to compare the practices and results obtained by different numerical wave models and different participants when calculating the infragravity wave field for different configurations. The ship response will also be calculated using the tools delivered in WP1 for the different wave models used. The following sub-packages are foreseen:

- WP4.1 – Flat Bottom Configuration, no coastline
- WP4.2 – Wave Basin Configuration, without breakwater, with parallel bathymetry (sloping bottom) and coastline
- WP4.3 – Wave Basin Configuration, with breakwater, with parallel bathymetry (sloping bottom) and coastline
- WP4.4 – Full Scale Measurement Data Configuration, with (more) complex bathymetry and coastline (OPTION)

In this work package, the various wave models used in the existing HAWA-II design methodology (see WP1) will be validated against the model tests and full scale measurements. This will illustrate how well the low-frequency wave content at the mooring location can be determined, and the corresponding calculations times. The comparison of the wave models will give insight in the accuracy-costs compromise that can be made. It will also show how accurate the wave model is without calibration, which in many locations may be inevitable in absence of local long wave measurements. Then, the excitation loads predicted using the design methodology described in WP1, will be validated against the model scale measurements done in WP2. This will show the uncertainties of the numerical model that are involved in the calculation of the vessel motions.

At the moment, it is expected that the most likely candidate to be investigated is the wave model XBeach, which was also used in HAWAII-JIP. Other wave models such as SWASH, REEF3D and MIKE21 may also be investigated depending on the participants involved, the interests and the availability of the participants to perform, analyse and report those runs. The wave models used depend on the executing parties in this WP.

Summary of Scope of Work

WP4.1: Benchmark – Open Configuration – Flat Bottom (MARIN, DELTARES, AKTIS, NTNU, SINTEF, ARCADIS)

The objective of the benchmark study is to compare different wave models. First, a blind test will be organized between different participants to compare the practices and results obtained by different participants. The experimental results will not be known at this stage. After the blind tests, the participants will be able to update their computations by improving the numerical modelling and settings. This phase will provide valuable information on the scattering of the results between different wave models when no tuning of the model is applied. The scope will consist of a few computations only, such that the differences between the different models can be investigated in detail and understood. This package will be executed in several phases, gradually increasing in complexity. For example, a flat bottom will be first considered for two different domain sizes to investigate the effect of wave reflections at the domain boundaries. Then a second case will include a sloping bathymetry and coastline. The deliverable will consist in a report in which the wave field obtained with different wave models are compared, as well as the consequence on the ship response.

WP4.2: Benchmark – Open Configuration – Parallel bathymetry and coastline - Validation based on Model Tests (MARIN, DELTARES, AKTIS, NTNU, SINTEF, ARCADIS)

The objective of this package is to compare the different wave models for a few wave conditions tested in the basin for the open-configuration, i.e. including the bathymetry and coastline, but without a breakwater. The scope of work will consist of a few tests such that the differences between the wave models can be investigated in detail. The calculations will first be carried out without knowing the model test results (blind), and can be repeated later on after tuning based on the model tests results. The deliverable will consist in a report in which the wave field obtained with different wave models are compared, as well as the consequence on the ship response.

WP4.3: Benchmark - Breakwater Configuration – Parallel bathymetry and coastline - Validation based on Model Tests (MARIN, DELTARES, AKTIS, NTNU, SINTEF, ARCADIS)

The objective of this package is to compare the different wave models for a few wave conditions tested in the basin for the open-configuration, i.e. including the bathymetry and coastline, and with the breakwater. The scope of work will consist of a few tests such that the differences between the wave models can be investigated in detail. The calculations will first be carried out without knowing the model test results (blind), and can be repeated later on after tuning based on the model tests results. The deliverable will consist in a report in which the wave field obtained with different wave models are compared, as well as the consequence on the ship response.

WP4.4: Benchmark – Open Configuration – Complex bathymetry and coastline - Validation based on Full Scale Data - OPTION

The objective of this package is to compare the different wave models for a few wave conditions measured in the full scale measurement campaign, for the open-configuration, i.e. including the bathymetry and coastline, but without a breakwater. The main difference with the work package 4.2 is that the coastline and bathymetry will be more realistic (more complex) since they are based on full scale data shared by BP within the project. The scope of work will consist of a few measured sea states such that the verification and validation can be performed in detail. The deliverable will consist of a report in which the wave field obtained with different wave models are compared. Some aspects of the full scale data shared by BP within WP3.1 will be made anonymous for the project and shared exclusively with MARIN and DELTARES as independent research institutes. See Appendix for more detail. The conclusions and lessons learned from the verification and validation study will be shared with all participants though.

Contributions of Participants

In this proposal, it is assumed that the following parties are contributing to the benchmark study:

Contribution AKTIS

With the XBeach, AKTIS will perform numerical simulations on the relevant scenarios within the scope of the JIP, see WP4.1, WP4.2, and WP4.3 below. The numerical results will be compared with the experimental measurements. This validation process provides numerical benchmarks for the guidelines. The deliverable will consist of the calculation results and a report that summarizes the method and numerical settings used, describes the effect of the key numerical settings on the results, and compares the numerical results to the experimental results.

Aktis will participate in the WP4 for numerical Benchmark Study. Aktis will focus on infragravity wave modelling and model the different academic benchmarks (WP4.1 to 4.3) with XBeach in 1D and 2D mode for the breakwater configuration. In addition, Aktis is willing to contribute and test the real/complex open bathymetry configuration (WP4.4) if they are provided with the proper boundary conditions and bathymetry (this will be discussed with BP). Aktis will focus on the sensitivity of the model to mesh size, numerical and physical settings to reproduce theoretical solutions as well to compare against the experimental measurements. During these evaluations, Aktis will also aim to optimize and document the computational time required for each case, keeping in mind that a large array of computations are required to derive accurate long term nearshore IG wave conditions in real life engineering applications, thus making the computational time of each case a very important factor to deliver an accurate answer in a timely manner. Aktis will use their experience in the modelling of IG wave and associated ship response to optimize the model set-up and the coupling with the HAWA III tool.

Aktis has evaluated many terminals, (detached) breakwater layouts and harbours where long waves and harbour resonance interactions affected vessel operations, both in pre-feasibility & FEED as well as in forensic investigations providing expert witness support. Embarking on this experience, Aktis will also aim to contribute to the overall tool design and documentation, by commenting on the work of other participants and by testing the HawaIII Tool looking for bugs or possible sources of human errors. In doing so we will bring our experience as model users and software developers

Contribution NTNU

With the REEF3D framework, NTNU will perform numerical simulations on the relevant scenarios within the scope of the JIP, see WP4.1, WP4.2, and WP4.3 below. Concerning the WP4.3. (breakwater), several of the numerical models within the REEF3D framework have already been used for fluid-structure interactions, including wave impacts on breakwaters and other similar constructions in the coastal area. NTNU plans to perform numerical simulations to study the impacts of the breakwaters on the flow field by including breakwater structures in the numerical wave tanks. These numerical simulations performed within WP4.1, WP4.2 and WP4.3 will be compared with the experimental measurements (wave elevations, wave kinematics, wave loading on vessel), and provide numerical benchmarks for the guidelines. The deliverable will consist of the calculation results and a report that summarizes the method and numerical settings used, describes the effect of the key numerical settings on the results, and compares the numerical results to the experimental results.

In addition, NTNU will also perform preliminary simulations with REEF3D to assist the design of the physical experiments and ensure the consistency between the experiments and numerical simulations and thus the quality of the numerical benchmarks. The deliverable will consist of the calculation results and a memo describing the results obtained for the basin setup.

Contribution SINTEF OCEAN

SINTEF OCEAN will use REEF3D to participate in the Benchmark study on wave propagation benchmark studies of WP4.1 – Flat bottom and WP4.2 – Parallel bathymetry and coastline. The open-source hydrodynamic model REEF3D::FNPF will be used to carry out the wave simulation in the same conditions as the experiments. The numerical wave model FNPF of REEF3D solves the Laplace equation for the potential flow and the nonlinear kinematic and dynamic free surface boundary conditions [9]. Very promising results are seen for the reproduction of the experimental regular and bi-chromatics waves over a constant water depth as well as with complex bottom topography. Results have been presented using this model in [10] and [11]. This approach requires reduced computational resources compared to CFD based NWTs. The REEF3D::FNPF module can use the already implemented functionality of REEF3D [12], where solid boundaries are incorporated through a ghost cell immersed boundary method. Therefore, it is capable of simulating wave-structure interaction such as complex sea bottom topography by solving the non-linear potential theory problem. The Laplace equation together with the enclosure of the boundary conditions are solved with a finite difference method on a stretched σ-coordinate system similar to OceanWave3D [13]. Then, SINTEF will calculate the excitation on the vessel (and possibly the motion response if measured in the basin). The deliverable will consist of the calculation results and a report that summarizes the method and numerical settings used, describes the effect of the key numerical settings on the results, and compares the numerical results to the experimental results.

SINTEF also aims to calculate the excitation on the vessel based on the calculated results, using SINTEF OCEAN splitting method. The aim is to apply the method presented in [5] to calculate the vessel LF wave excitation (captive setup) and the motion responses in shallow water and compare this LF excitation (and possibly the response) with the model test data. This activity is part of WP4.1, WP4.2 and WP4.3. The method uses as input the wave elevation time histories corresponding to the split wave systems and the wave elevation corresponding to the incoming wave spectrum. The experimental LF wave systems and LF wave excitation are identified in the scope of WP2, i.e. the captive setup model tests. If a soft-mooring system is used instead, motions will be compared.

The vessel motions are calculated in the time domain by the nonlinear simulation code SIMO/RIFLEX. The method to simulate the total motions, including the LF components, includes the following steps:

1. Split the LF wave elevation into: bound wave, free parasitic wave, reflected wave.
2. The measured wave spectrum is high-pass filtered to remove the set-down, before it is used to compute wave drift forces from potential flow full QTFs.
3. Linear wave exciting forces result from:
    a. Incident wave (WF)
    b. Parasitic wave (LF)
    c. Reflected wave (LF).
4. Superposition of 2. and 3. gives the total wave forces.
5. Solve the equations of motion with the total wave forces.

Results from the simulations will be compared to the model test data and reported.

Contribution ARCADIS

ARCADIS will gather the results of the wave models of the different participants to the benchmark (AKTIS, NTNU, SINTEF), and will use the HAWAIII-Tool to convert the kinematics into excitation loads (and possibly motions if measured in the basin), will compare the numerical results of the different benchmark contributors to each other (first step) and to the model test results (second step). ARCADIS delivers a benchmark report in which the wave model results (wave elevations, kinematics) and wave excitation load results from the HAWAIII-Tool are compared to each other and the differences obtained between the results are illustrated. This report will also include the validation results, i.e. the comparison of the numerical results to the experimental results. Differences obtained between the results (wave elevations, wave loads) will be investigated and explained where possible. In addition, ARCADIS will investigate the sensitivity of the results to the input parameters (verification study and testing of input parameters).

Contribution Deltares

Prior to the basin measurements Deltares will perform numerical simulations using the SWASH model. Simulations will be aimed at identifying an optimized physical model setup and will include computations of hydrodynamic loads. Based on the results informed choices can be made on:

- placement and orientation of the vessel in the basin with respect to wave maker and sloping bathymetry;
- shape, layout and placement of the breakwater;
- wave conditions to be considered, to obtain a ratio of LF and WF wave forces such that both can be measured accurately;

- expected forces on a captive model setup or expected motions for a soft-moored setup.

After the basin tests have been conducted, numerical results and measurements results will be compared as part of the benchmark validation study.

WORK PACKAGE 5
Breakwater (lead Deltares)

General Description

The main objective of the Work Package 5 is to do research on how to account for a breakwater on the motion response of a moored vessel. This includes a literature study summarizing the relevant aspects to consider related to the effect of the breakwater on the vessel hydrodynamics, i.e. on the wave excitation loads on the vessel and the vessel response. The largest part of the scope consists of a verification and validation study of wave models and ship response models, in order to assess how the existing methodology can be extended to account for the presence of a breakwater. The following sub-packages are foreseen:

- WP5.1 – Literature study
- WP5.2 – Extension of the methodology to account for breakwater
- WP5.3 – Comparison between 4D-QTF approach with exact calculation of the full second order potential, and the wave model approach
- WP5.4 – Additional development and delivery of tools to account for breakwaters

Breakwaters are structures designed to provide shelter from incoming offshore waves and to reduce excitation of the moored vessels. Although usually effective for short waves, breakwaters may not sufficiently protect against the incoming infragravity waves, or against infragravity waves that reflect from the coast. In addition, their effectiveness for incoming long waves needs to be assessed: if not properly located, a breakwater improperly applied may actually even deteriorate the long-wave conditions at the berth. In the HAWA-II JIP, the design methodology has been demonstrated for a case without breakwater. In this WP the methodology will be extended for the case where a breakwater is present. If the effect of diffraction of short waves around the breakwater is relevant, this might imply that wave models resolving the short waves need to be used, in order to capture diffraction effects from the breakwater and the corresponding effect on the short waves. This will be investigated in this work package.

Figure 15: Bird’s eye view of several breakwaters.

Summary of Scope of Work

WP5.1: Breakwater – Literature Study [Lead Deltares]

First, a summary will be made of available literature dealing with breakwaters and their effect on infragravity waves and motions of moored ships. The objective of the literature study on breakwater is to summarize the relevant information concerning the effect of breakwater, focusing exclusively on the aspects that have an effect on the motion response of moored vessels, i.e. related to the hydrodynamic aspect of breakwaters. It does NOT aim to provide general design guidelines for breakwater. The deliverable will consist of a summary of literature study about the effect of breakwater on the ship response. The report will also include the state of the art and state of the practice concerning the modelling the effect of breakwater on ship’s hydrodynamics, both for the wave modelling part as for the ship response modelling part.

WP5.2: Extension of the overall methodology to account for breakwater - Research - [Lead Deltares]

The objective of this package is to extend the methodology for cases where a breakwater (or complex coastline involving significant diffraction effects) affects the wave field and ship motion response. This involves an evaluation and validation of wave models which are suited for the modelling of breakwaters and their effect on long-wave penetration. The wave models described below are likely candidates for this scope of work. Prior to the start of the work, the best candidate will be selected. Focusing on one wave model for the breakwater case will allow to go more in depth.

1. **Xbeach**

   Xbeach can be run in the "surfbeat" mode and in the "nonhydrostatic" mode. In the former case the short wave variations on the wave group scale (short wave envelope) and the long waves associated with them are resolved resulting in very fast simulations. The HAWA-II design methodology is based on this option. In the latter case a combination of the non-linear shallow water equations with a pressure correction term is applied, allowing to model the propagation and decay of individual waves. The non-hydrostatic mode can be used to study the diffraction effect of breakwaters and seems a possible candidate for the extended design methodology. It should be noted however that this mode requires more grid resolution and smaller time steps and is therefore much more computationally intense compared to the "surfbeat" mode.

2. **SWASH**

   SWASH is a general-purpose open-source numerical tool for simulating unsteady, non-hydrostatic, free-surface, rotational flow and transport phenomena in coastal waters as driven by waves, tides, buoyancy and wind forces. It provides a general basis for describing wave transformations from deep water to a beach, port or harbour, complex changes to rapidly varied flows, and density driven flows in coastal seas, estuaries, lakes and rivers. The SWASH model is developed by Delft University of Technology.

   The SWASH model is similar to XBEACH-nonhydrostatic, so it resolves both short and long waves simultaneously. This makes it computationally more intense than the Xbeach-surfbeat mode. Multiple fluid layers can be defined making it suitable for deeper waters also. More details on SWASH can be found here:

   https://www.tudelft.nl/citg/over-faculteit/afdelingen/hydraulic-engineering/sections/environmental-fluid-mechanics/research/swash/

   Figure *16* shows an example of wave penetration behind a breakwater. A SWASH animation can be found here: https://www.youtube.com/watch?time_continue=21&v=azst4rvGzk0&feature=emb_logo

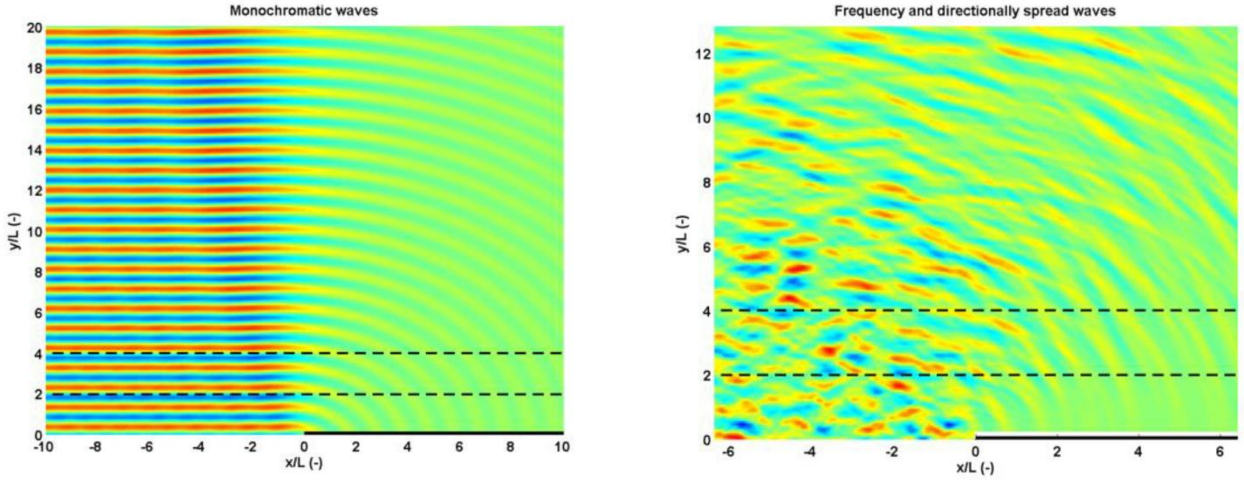


Figure 16: Wave penetration behind a semi-infinite breakwater computed by SWASH, monochromatic (left) and irregular (right) waves *(van Vledder & Zijlema, 2014)*

3. **REEF3D**

   REEF3D is an open-source hydrodynamics program developed by NTNU with the focus on wave modelling (https://reef3d.wordpress.com/). It has several hydrodynamic models, one of which is the SFLOW model: a depth-averaged shallow water equations model, that solves the non-hydrostatic pressure. The REEF3D-SFLOW model is in theory very similar to SWASH and the Xbeach non-hydrostatic model. Figure 17 for example shows bichromatic waves interacting with a breakwater and a sloped beach.

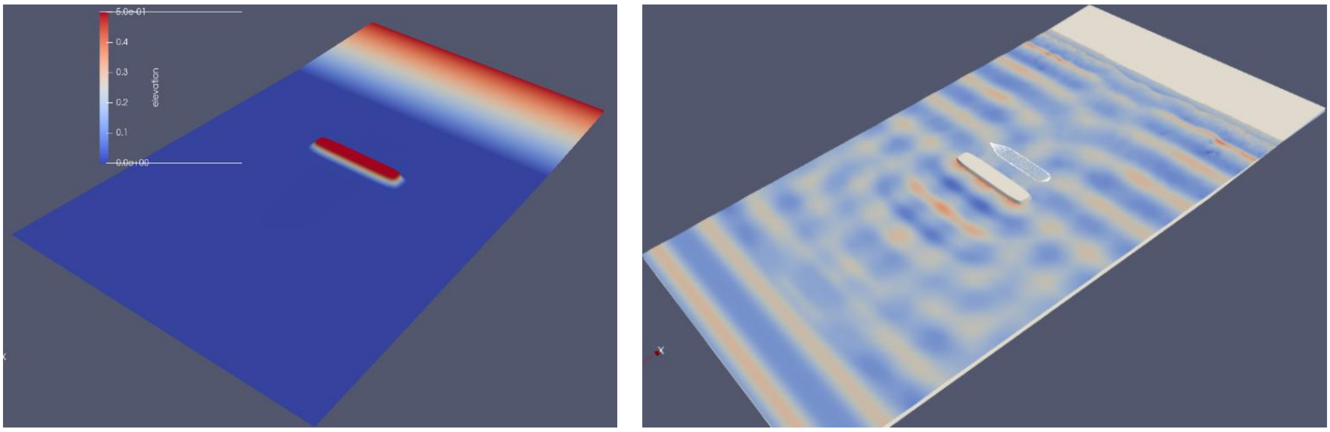


Figure 17:Snapshot of seabed bathymetry (left) and wave elevation (right) for bi-chromatic wave simulations with breakwater and 1:20 slope using REEF3D. The location of the LNGC is shown where the wave kinematics are computed and exported to the diffraction code.

Participants may bring into the project results from other wave models that they have run and analysed. In this case, the participants working on additional wave models will also compare the results (wave field and vessel response) to the wave models used in the base scope of this JIP.

It should be noted that when a breakwater is present it probably also needs to be modelled in the diffraction analysis because it will have an effect of the diffracted and radiated waves generated by the moored vessel. This will also be investigated in this WP and if needed be included in the design methodology.

When the output of a wave model also contains short waves (like SWASH, REEF3D or Xbeach-nonhydrostatic) it is theoretically possible to compute the phase-resolved second-order wave force time signals directly with a diffraction model. Short-wave information is for example available when a breakwater is present, but also cases with only a nearshore bathymetry/shore line could be evaluated with a wave model resolving the short waves. This approach will be investigated as well during the JIP and included in the design methodology when proven successful.

The extended design methodology will be validated against model tests with breakwater from WP2.

Finally, this work package will be executed prior to WP6 such that the lessons learnt can be included in the Guidance Notes as well.

WP5.3: Calculation of wave loads using second-order potential [Lead BV]

The most advanced method of the HAWAII-JIP consists of the coupling methodology between wave models and the diffraction tool. When the bathymetry and reflections of infragravity waves from the coast can be neglected, the IG waves would then fully consist of the bound wave. In such a case, the coupling with a wave model may not be necessary, and calculating the LF wave loads using the QTF approach (Quadratic Transfer Functions) can be a relevant approach as well. For such a configuration, it can be interesting to compare the infragravity wave loads as calculated by the coupling tool with the wave models, and as calculated with the QTF-V approach. When a breakwater is involved in the computation, the fifth contribution of the QTF cannot be approximated using Pinkster approximation anymore, because this approach does not take the diffraction effects around the breakwater into account. In that case, the second order potential should be calculated exactly. The objective of this package is to compare the wave loads due to the bound wave on the moored vessel behind a breakwater with both the HAWAIII tool (i.e. coupling wave model – diffraction code) and the QTF method. The vessel will be located on a flat bottom, with breakwater, using the QTF method with direct calculation of the second order potential and to compare the results obtained to the coupling method.

WP5.4: Additional Development and Delivery of Tools that account for Breakwaters [Lead MARIN] - OPTION

If positive results are obtained in the research study on how to extend the methodology to include the effect of a breakwater, additional development and delivery of tools may be required. This may for example consist in updating the coupling tools such that they are well suited for wave models including the short waves as well. It is difficult to define the scope of work exactly at this stage, since it would be based on the results obtained in the previous sub-packages. So this is the reason why this sub-package is proposed as an option.

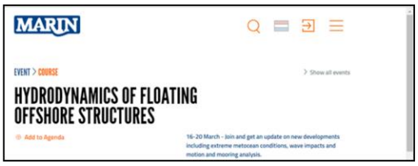
WORK PACKAGE 6
Summary Guidelines and Workshop Sessions (lead BV)

The main objective of the Work Package 6 is to deliver classification society guidelines related to the design of vessels moored in shallow water, and to provide hands-on workshops to the participants on how to go through the guidelines and use the tools delivered in WP1. The focus in this work package is on the open-jetty configuration, i.e. without breakwater. The following sub-packages are foreseen:

- WP6.1 – Summary Guidelines
- WP6.2 – Workshop Sessions - OPTION

Classification rules exist for permanent mooring offshore and for temporary mooring nearshore. However, also nearshore LNG terminals require clear rules for permanent mooring. Such step-by-step summary guidelines are not available presently, and the objective of this WP is to develop such guidance notes in detail. Guidance notes can be established by the classification societies involved in the project, in consultation with the other partners and participants, to clarify how to take shallow water effects (complex wave conditions and ship hydrodynamics, breakwaters, innovative mooring techniques) into account for permanent mooring in a nearshore environment.

Although the design methodology has been applied to an example situation in the HAWA-II JIP, the industry has expressed a need for more practical guidance. The methodology requires the combination of several tools, and the interfaces between tools need to be streamlined to ease the application of the methodology. This will be done as part of this task. Furthermore, guidelines will be made on how to calibrate and use the tools involved in the design methodology. The summary guidelines will include the delivery of streamlined and (as much as possible open-source) interfaces such that the workflow is optimized for the different tools used by the participants.



HYDRODYNAMICS OF FLOATING OFFSHORE STRUCTURES

16-20 March - Join and get an update on new developments including extreme metocean conditions, wave impacts and motion and mooring analysis.

WP6.1: Summary Guidelines [Lead BV, NTNU, AKTIS, ARCADIS]

The objective of this sub-package is to deliver summary step-by-step guidelines on how to account for shallow water effects in the design of shallow water terminals, how to use the tools delivered, how to measure and analyse full scale measurements of IG waves. The scope of work will consist of writing and discussing the guidelines based on discussion with the participants. The deliverables will be a guideline that can be become the industry standard as soon as the confidentiality period of the JIP is ended. NTNU and AKTIS will join a workshop to advise BV on how to include the numerical modelling practice into the guidelines, as part of the final deliverables defined by the JIP. ARCADIS will also join the workshop to advise BV on how to use the HAWAIII-Tool (pro's and con's) and on how to predict extreme values of excitation loads and motions. Finally, ARCADIS will review the guidelines delivered by BV.

WP6.2: Workshop Sessions [Lead Deltares] - OPTION

Using the guidelines delivered in WP6.1 and the tools delivered in WP1, one or two workshops will be organized to make the participants familiar with the design methodology and the associated tools. The workshops may be combined with existing events such as the International Delft Software Days, the FPSO Jip week and the MARIN course on hydrodynamics of floating offshore structures. The objective is to guide the users through the guidelines and provide support in the use of the HAWAIII tool delivered in WP1. The tutorials will be also delivered after the workshops such that other employees can learn the tools as well, even after completion of the JIP. One wave model will be chosen for the workshop session.

If REEF3D is successfully validated against the experiment and shows the capability of identifying the infra-gravity waves and simulating the shallow water nearshore wave field accurately, NTNU plans to arrange a digital workshop on how to install and use REEF3D and how to set up the simulations for the relevant scenarios for other JIP participants.

APPENDIX : RESPONSE FORM / LETTER OF INTENT FOR HAWA-III JIP

Please e-mail to : MARIN, Frédérick Jaouën

Project reference 31662

Fax +31 317 493 245
f.jaouen@marin.nl
Tel: +31-317 493 509 (direct)

Company/organization : ………………………………………….

Contact person : ………………………………………….

E-mail address : ………………………………………….

Signature : ………………………………………….

Please tick:

0 We intend to become a HAWA-III JIP participant.
However, we have the following comments to proposed scope of work:

0 We do not have interest in this JIP, please remove us from the contact list.