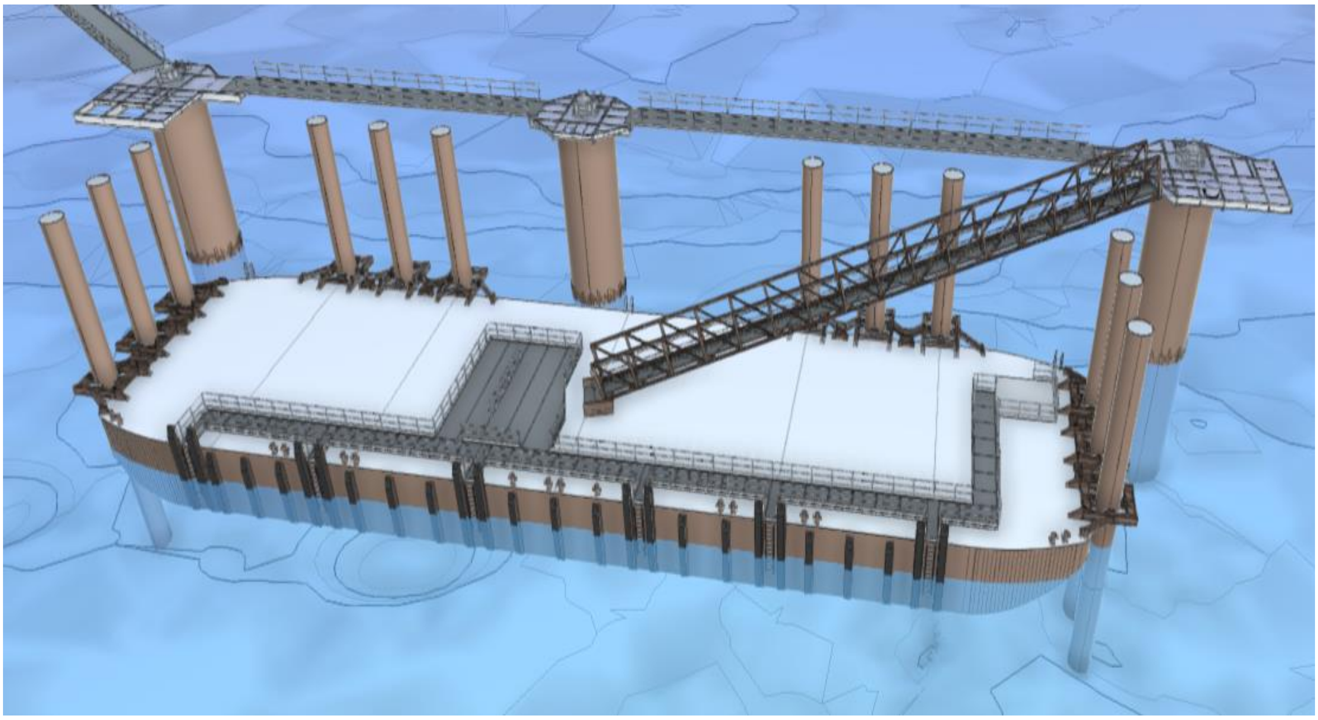
Wilhelmshaven

Basis of Design Pontoon Facility



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Delta Marine Consultants

Wilhelmshaven

Pontoon Facility

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1. Introduction

1.1 General

The *Client* (ENGIE / TES) is planning a new Green Hub in front of the TES plot on the western banks in the mouth of the Jade river within the port area of Wilhelmshaven. The phased development of the Green Hub will include a first phase, with a Floating Storage and Regasification Unit (FSRU) to import LNG. The terminal will be connected to the German gas grid providing a facility to start importing LNG.

Figure 1 Overview project area

The marine facility includes an island type jetty to accommodate the 138,000 m^3 FSRU Excelsior as can be seen in the figure above. The FSRU will be moored on the facility for a period of several years and will receive LNG via an LNGC moored alongside. Products will be transferred to shore trough a subsea pipe line. The facility will be unmanned, control will be done from the FRSU.

1.2 Scope of the report

This report provides an overview of the functional requirements, starting points and design criteria that will be used for the development of the concept design of the Pontoon Facility. It shall form the basis for further engineering during the various design stages.

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1.3 Abbreviations

Abbreviation	Unit	Description
ALS		Accidental limit state
API		American Petroleum Institute
B	m	Beam of the ship
CoG		Centre of Gravity
D	m	Depth to the main deck of the ship
DNV		Det Norske Veritas
DMA		Dynamic Mooring Analysis
EAU		Empfehlungen des Arbeitsausschusses Ufereinfassungen
DDF		Damage Fatigue Factor
FLS		Fatigue limit state
FSRU		Floating Storage and Regasification Unit
GM_T	m	Transverse metacentric height
GM_L	m	Longitudinal metacentric height
H_s	m	Significant wave height
h	m	Water depth
LNGC		Liquified natural gas carrier
LR		Lloyds Register
MBL	kN	Minimum Breaking Load
MD		Mooring Dolphin
NHN		Normalhöhennull
OCIMF		Oil Companies International Marine Forum
PIANC		Permanent International Commission for Navigation Congresses
SI		Systeme International Units
SKN		Seekartennull
SWL	kN	Safe Working Load
SCF		Stress Concentration Factor
T_p	s	Peak wave period
ULS		Ultimate limit state
WLL	kN	Working Load Limit
Δ	t	Water displacement of the ship

Note: To be completed and updated during preparation of this document.

Table 1 Used abbreviations

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2. Reference documents

2.1 Codes and standards

[1] DIN EN 1990, Eurocode: Basis of structural design
[2] DIN EN 1991, Eurocode: Actions on structures
[3] DIN EN 1992, Design of concrete structures
[4] DIN EN 1993 , Design of steel structures
[5] DIN EN 1997 , Geotechnical Design
[6] DIN EN 1090-2 Execution of steel structures and aluminium structures - Part 2: Technical requirements for steel structures
[7] EAU 2020, Recommendations of the committee for waterfront structures, harbors and waterways, December 2020
[8] DIN 4085:2017-8 Baugrund – Berechnung des Erddrucks
[9] PIANC Working group 24, Criteria for movement of moored ships in harbors a practical guide 1995.
[10] PIANC Working group 33, Guidelines for the design of fender systems 2002
[11] DNV-GL-RP-C203 Fatigue design of offshore steel structures, April 2023
[12] DNV-OS-C401 Fabrication and testing of offshore structures, July 2023
[13] DNV-OS-C101 Offshore Standard
[14] ASR A1.8 Verkehrswege, Ausgabe: November 2012 zuletzt geändert GMBl 2018
[15] ASR A2.3 Fluchtwege und Notausgänge, Flucht- und Rettungsplan Ausgabe: August 2007 zuletzt geändert GMBl 2017, S. 8

2.2 Project studies

[16] IMDC (2023). Bericht über die Umgebungsverhältnisse. TES-WHV-VGN-FSRU-ENV-DOC-2014.06
[17] Entwursgrundlagen version 3.0 TES-WHV-VGN-ST-DOC-2001.09
[18] FSRI Pontoon WHV – Geotechnischer Bericht 23A012.00.02
[19] Wilhelmshaven FSRU mooring study document number: TES-WHV-VGN-FSRU-ENV-DOC.2021_06.
[20] Smit barge E3004 Stability booklet for a deckload upto 10 m height
[21] International Load Line Certificate HEBO-P63

2.3 Drawings

[22] Kolkschutz-Design für FSRU-Liegeplatz drawing number: TES-WHV-VGN-FSRU-ST-DWG.2039_05
[23] Allgemeine layout-Zeignung drawing number: TES-WHV-VGN-FRSU-ST-DWG-2013.11

2.4 Order of precedence of codes and standards

The following order of precedence is applicable:

1) German codes and standards (DIN EN)
2) German maritime design recommandations (EAU 2020)
3) In case the German codes provide insufficient guidance, other internationally recognised codes, standards or guidelines for marine structure (such as PIANC, BS6349)

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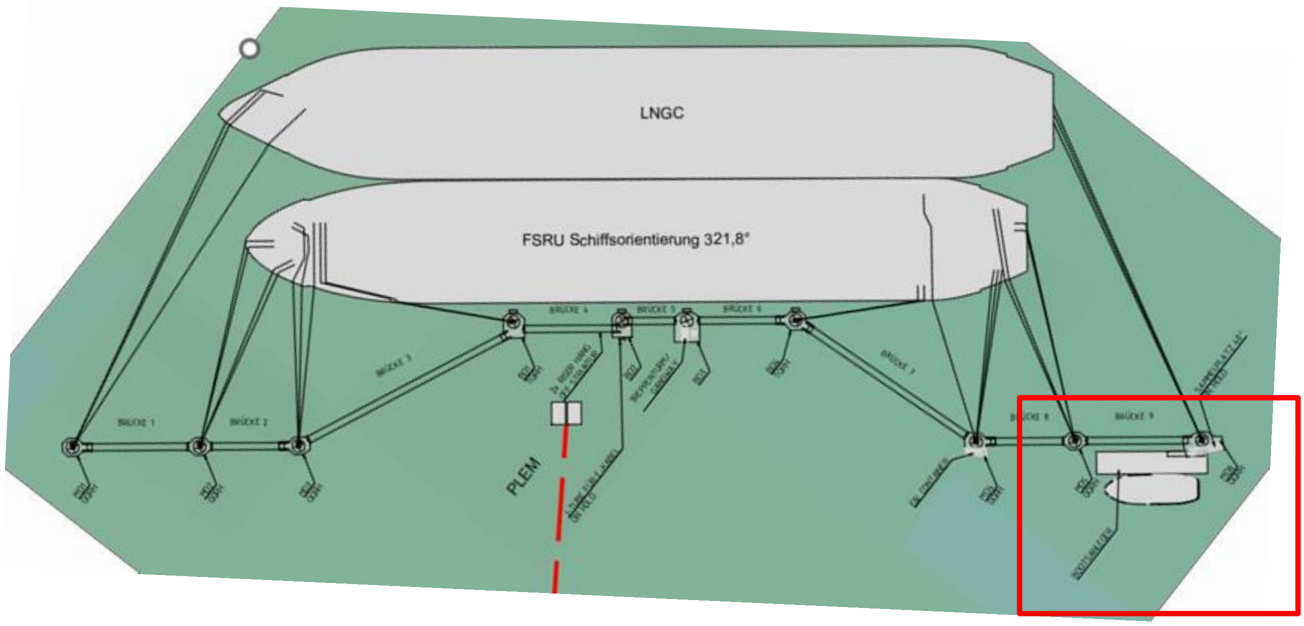
3. Layout of the berth and location of the Pontoon Facility

3.1 Location of the Pontoon Facility

The location of the Pontoon Facility is presented in figure 1. The pontoon is situated near the outer most dolphin of the berth MD 6 as shown below.



For details of the Pontoon Facility in the red box see chapter 3.2.
Figure 2 Location Pontoon Facility

3.2 Layout of the Pontoon Facility

In the figure below a schematic layout of the Pontoon Facility is provided. The Pontoon Facility consist of a floating pontoon, which is moored against driven piles. For fixation of the pontoon pile clamps/pile guides will be used. This concept is under development and may be adapted at certain points during the various design stages.

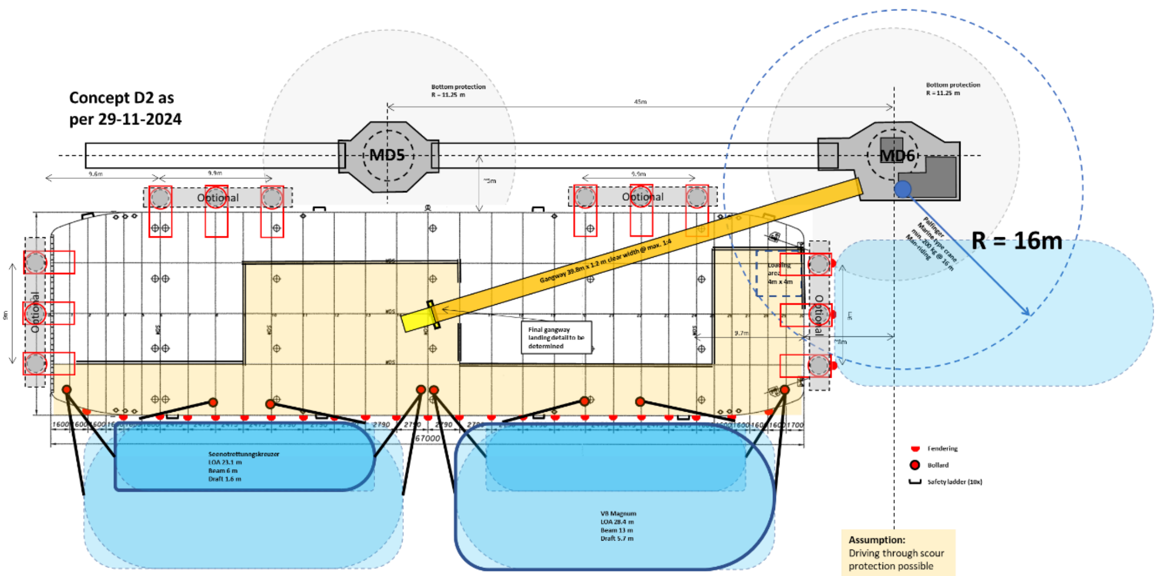


Figure 3 Layout Pontoon Facility

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3.3 Functional requirement for the Pontoon Facility

In the point below a summary for the requirements of the Pontoon Facility is provided in bullet form. In the next chapters the requirement will be further detailed. Refer to figure 3 for a visual impression of these requirements.

3.3.1 Operational requirements:

- The pontoon shall provide access under normal/operational conditions for crew transfer and supply (everyday use) via a crew vessel;
- The pontoon facility shall provide an escape route for people on the marine facility in case of an emergency;
- The pontoon shall provide access in case of emergencies (e.g. fire brigade intervention and evacuation of FSRU crew) - simultaneous use by fire boats and lifeboats;
- The pontoon facility shall be able to resist extreme environmental conditions with 100-year return interval: Survival conditions as for FSRU;
- The life time that the pontoon facility shall be in operation is 5 years.
- The design live of the pontoon facility shall be 10 years;
- Pontoon must not collide with platform structure of the landing terminal;
- Pontoon must have railings on the sides for safety reasons;
- Intended positioning of the pontoon for maximum operational readiness: frontal in main flow and wave direction (direction approximately NNW 321,5°);
- Ballast in the pontoon can be applied if required for maximum operational stability;
- The minimum available area according to ref [17] on the pontoon 62 m^2;
- The pontoon shall have a dedicated area for lifting of 4x4 m. It shall be possible to lift objects from this area on MD 6 having a weight of 200 kg or vice-versa; The crane shall be suitable for man riding.
- Minimum deck load that the pontoon shall be able to bear is 1 ton /m^2 ;
- Design vessels:
  -Tug: L 28.4 m × W 13 m × Draught 5.63 m;
  -Sea rescue boat: L 23.1 m × W 6 m × draught 1.6 m;

3.3.2 Pontoon piling:

- Pontoon is not moored to the monopiles of the FSRU facility, but to separate piles dedicated to mooring of the pontoon. These piles are top-closed and permanent piles;
- When determining the pile diameter, wall thickness and length, the loads acting on the piles from the pontoon must be taken into account;
- The piles shall be able to resists loads acting on the pontoon induced by environmental influences (wind, waves, current) as well as any mooring/moored vessels to the pontoon;
- Dynamic behavior of the pontoon shall be considered

3.3.3 Walkway / ramp to pontoon:

- The mooring pontoon should also be accessible from the assembly point on MD6.
- The slope of the ramp and the length should be kept as small as possible as it also serves as an escape route as requested in the applicable codes EAU ref [7];
- The clear width of the walkway in-between the handrail should be minimum 1,2 m (refer to the next chapters for a motivation)
- Gangway is supported on by Mooring dolphin MD 6 and the deck of the pontoon. (top of walkway design level +11.680mCD)

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4. Site data

4.1 Units, reference levels and coordinate system

SI units shall be used. All dimensions in meters or millimetres. All horizontal positions are relative to geographic coordinates “WGS 84 UTM zone32 N”.

All vertical levels are relative to SKN (Seekartennull) which is equal to Chart Datum (CD)

Remarks:
At other sources also NHN (Normalhöhennull) or NN (Normalnull) might be used the difference between NHN and SKN estimated at +0.00 m NHN = +2.49 m SKN (at Hooksiel).

4.2 Scope boundary

The Scope boundary for the scope for the pontoon facility is at the fixation of the gangway to the dolphin deck.
The main facilities require for mooring the FSRU is evaluated under separate cover.

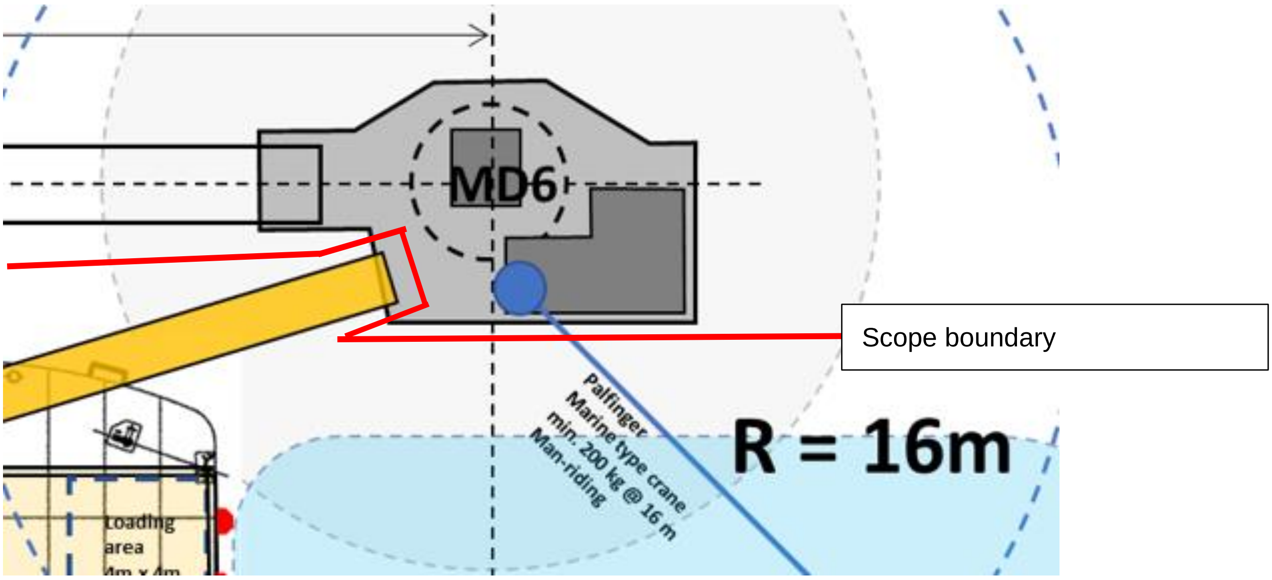

Figure 4 Scope boundary for the Pontoon Facility

Currently it is discussed to outsource the gangway and the crane to suppliers functional requirements for these items is included in this document.

4.3 Metocean conditions

The metocean conditions at the project site including Extreme Value Analysis are described in [17]. A short summary is given in the next sections.

4.3.1 Water levels

The following design water levels are derived in ref [16] at the project site:

- 100-year high water level (conservative approach) at CD +7.16 m.
- 5-year high water level at CD +6.15 m.

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- The 100-year extreme low water is -1.03m CD.

Tidal levels for other return periods are presented in the table below.

Wiederkehrzeiträume [Jahre]	Leuchtturm Alte Weser				Projektstandort			
	Oberer Pegelstand [m MW]	Oberer Pegelstand [m SKN]	Unterer Pegelstand [m MW]	Unterer Pegelstand [m SKN]	Oberer Pegelstand [m MW]	Oberer Pegelstand [m SKN]	Unterer Pegelstand** [m MW]	Unterer Pegelstand** [m SKN]*
100	4,40	6,89	−3,21	-0,72	4,67	7,16	−3,52	-1,03
50	4,18	6,67	−3,13	-0,64	4,44	6,93	−3,41	-0,92
20	3,89	6,38	−3,01	-0,52	4,14	6,63	−3,30	-0,81
10	3,67	6,16	−2,92	-0,43	3,91	6,40	−3.2	-0,71
5	3,45	5,94	−2,81	-0,32	3,68	6,17	−3.1	-0,61
2	3,15	5,64	−2,68	-0,19	3,37	5,86	−2,98	-0,49
1	2,90	5,39	−2,58	-0,09	3,11	5,60	−2.92	-0,43

* Am Projektstandort beträg : NHN [m] = SKN [m] + 2,49 [m]..

** Die 95%-Konfidenzintervall-Linie verwendet, um der niedrigen Wasserstände abzuschätzen

Table 2 Tidal levels for various return periods.

In the table below the tidal water levels provided as used in public resources for Hoeksiel. More information for these values is provided in enclosure 2.

Tidal level	Explanation	Tidal water level [m NHN]	Tidal water level [m CD / SKN]
MHWS	Mean high water spring	+ 1.8	+ 4.3
MHW	Mean high water	+ 1.6	+ 4.1
MHWN	Mean high water neap	+ 1.3	+ 3.8
MSL	Mean sea level	+ 0.0	+ 2.5
MLWN	Mean low water neap	- 1.5	+ 1.0
MLW	Mean low water	- 1.8	+ 0.7
MLWS	Mean low water spring	- 2.0	+ 0.5

Table 3 Tidal levels as available on public sources refer to Enclosure 2.

4.3.2 Currents

The extreme current in the turning basin in the FRSU mooring area are shown in the table below. By absence of more advanced data however it will be used in the design.

Direction Going to (°N)	Speed (m/s) - within the turning basin	Speed (m/s) -near the FSRU
(Low tide)	1,88	1,60
(tide)	1,81	1,70

Figure 5 Current condition without dredging after ref [16]

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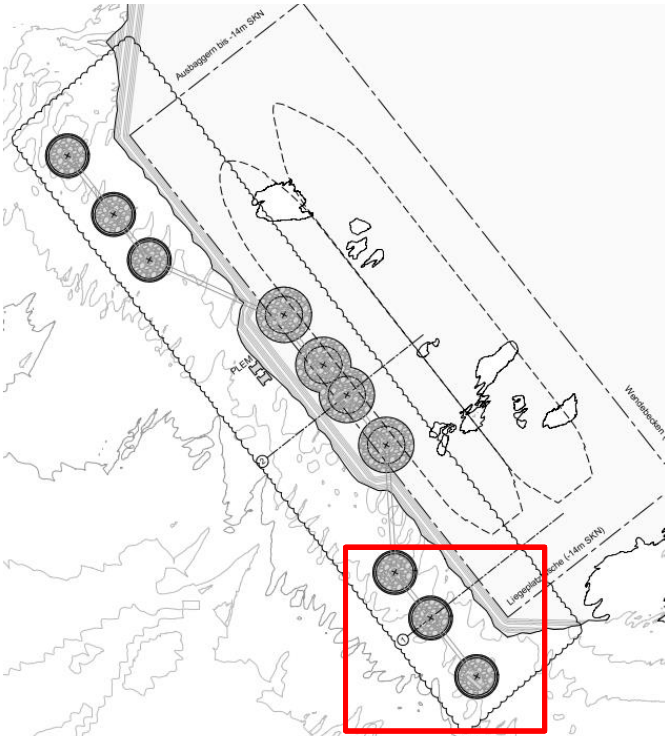
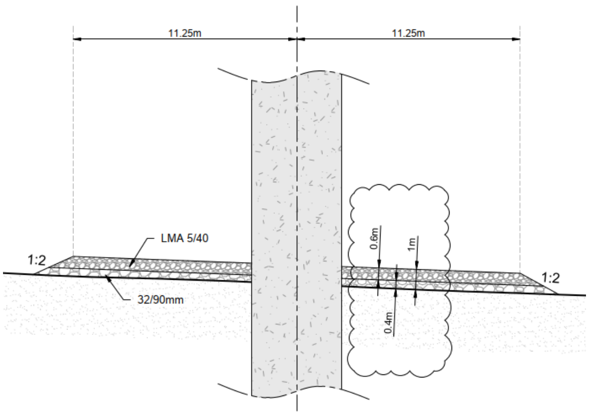
4.3.3 Seabed levels

The berth pocket seabed level is -14.0 m SKN. The seabed level at the mooring dolphins is higher than the level at the berth for the FSRU. The piles of the pontoon facility are situated at locations with and without scour protection which is applied around the mooring dolphin piles. (see the figure below) The design seabed levels at the pontoon facility are:

- Without scour protection -10,80 [m SKN].
- With scour protection -9,80 [m SKN].

Allowance will be made for local scour around the pile of 1 x D, in which D stand for the diameter of the pile, for locations without scour protection.





Installed scour protection around the dolphins

Details of the applied scour protection is provided in the insert detail right.

Figure 6 Installed scour protection around the dolphins

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4.4 Wind and wave data

Wind and wave data of the 1/100 year condition is presented in the table below. This will be used for verifying the structural strength of the berth. The table presents wave heights having various return periods. The cells marked in grey indicate conditions at the which the FSRU cannot be moored and have to leave the berth. Is observed that waves having a wave height Hm0 of 2,1 m from the North can occur with the FRSU still on the berth. So access for serving vessels under these conditions is required. Values for other return periods are provided in Enclosure 2.

Wind		Wind waves					
Direction Coming from (°N)	Speed (m/s)	Mdir Coming from (°N)	Hm0 (m)	Tp (s)	Gamma (Jonswap)	Directional spreading (°)	Directional spreading (s)
0	27.2	347.2	2.1	5.1	2.3	9.6	24.7
30	22.6	9.4	1.6	4.4	2.8	5.4	32.4
60	18.0	51.1	1.2	3.8	3.3	5.5	32.1
90	21.0	94.2	1.3	3.8	3.4	5.7	31.6
120	17.9	122.8	1.1	3.7	3.5	7.5	27.7
150	16.8	138.8	1.0	3.7	2.4	10.3	24.0
180	21.6	149.9	0.6	3.2	1.7	7.9	27.0
210	24.2	171.0	1.2	3.8	1.5	4.5	35.0
240	26.4	239.5	1.0	3.0	2.9	1.9	46.5
270	26.0	314.3	1.3	4.3	1.5	4.9	33.8
300	26.8	333.5	1.8	4.9	1.9	11.5	22.8
330	27.8	339.0	2.1	5.2	2.0	13.7	21.1

Table 4 Wind and wave data. Return period 1/100 year

The following Swell conditions are applicable:

Swell waves						
Sector	Mdir Coming from (°N)	Hm0 (m)	Tp (s)	Gamma (Jonswap)	Directional spreading (s)	Directional spreading (°)
West	345	0.1	13.5	1.8	34.0	13.5
WNW	348	0.1	14.7	1.8	29.9	14.5
NNW	356	0.2	15.4	1.8	19.2	18.1
North	358	0.4	8.7	1.1	12.6	21.9
NNE	0	0.4	6.7	1.7	9.4	25.0

Table 5 Swell condition corresponding with the 100 years conditions.

For design conditions wind wave and swell waves should be combined based on an energy balance. Taking the quadratic square. However the influence of the swell component is very small as will be demonstrated in the motion analysis.

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4.5 Ice conditions

Ice loads do not have to be combined with wave loads. The following parameters are to be considered in the design to account for loads induced by ice blocks drifting:

- Maximum ice thickness of 0.4 m at Wilhelmshaven [Table 4.14 EAU 2020]
- Salinity of estuaries at North Sea is 3.0% [Table 4.13 EAU 2020]
- Mean ice temperature on the underside of ice thickness -2 Celsius degree [Section 4.11.2 EAU 2020]

The relevant tables are shown below.

Nordsee	Maximale *h* [cm]	Ostsee	Maximale *h* [cm]
Helgoland	30–50	Nord-Ostsee-Kanal	60
Wilhelmshaven	40	Flensburg (Außenförde)	32
Leuchtturm „Hohe Weg“	60	Flensburg (Innenförde)	40
Büsum	45	Schleimünde	35
Meldorf (Hafen)	60	Kappeln	50
Tönning	80	Eckernförde	50

Note: h = 40 cm.

Table 6 Measured maximum ice thickness (h) according to table 4.14 of ref [7]

Nordsee	Salinität Wasser[‰]	Salinität Ei[‰]	Ostsee	Salinität Wasser [‰]	Salinit[‰]
Deutsche Bucht	32–35	14–18	Beltsee	15–20	10–12
Flussmündungen	25–30	12–14	Kieler Bucht	15	8–10
			Mecklenburger Bucht	15	8–10
			Arkonabecken und	8–10	5–7
			Bornholmsee		
			Gotlandsee	5–7	a)
			Finnischer und	1–5	a)
			Botnischer Meerbusen		

Note Salinity is max 3 % in estuaries at the North sea

Table 7 Salinity at estuaries at the North Sea according to table 4.13 of ref [7]

4.6 Soil investigation

For the project several CPT's and boreholes are executed. An overview of the executed soil investigation is presented in the figure below.

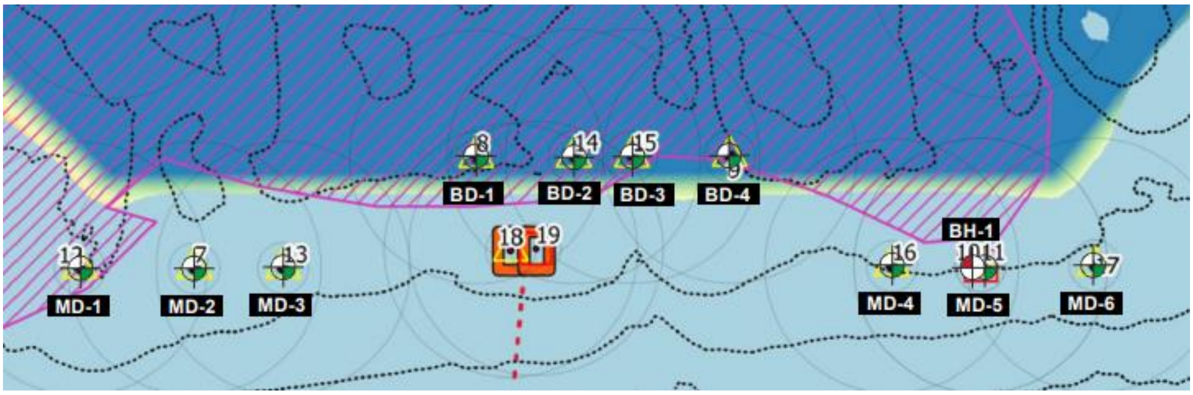


Figure 7 Executed soil investigation at the project location

The pontoon facility is situated at mooring dolphin MD-4 till 6. In report ref [18] a geotechnical advice for the location of the pontoon facility is provided. The soil profile and soil parameters are taken from: Anlage 3 Rechnerische Bodenprofile für erdstatische Berechnungen from document [18]. Upper and Lower boundaries from stiffness and strength point of view will be considered.

Bereich: **FSRU - Ponton-Dalben ohne Kolkschutzschüttung (pontoon dolphins w/o armor layer)**
Rechnerische Wassertiefe (DSL): -10,80 [m SKN]

Charakteristische Bodenkennwerte (BE in "fett") und Bandbreite (LE - HE)

Schicht Nr.	Tiefe unter Meeresboden	Höhe	Spitzenwiderstand	Bodenart	Bezogene Lagerungsdichte	Auftriebswichte des Bodens	Effektiver Reibungswinkel	Effektive Kohäsion	Undränierte Kohäsion	Steifemodul
	z		q_c	-	I_D	γ'	φ'	c'	c_u	E_s
[-]	[m]	[m SKN]	[MPa]	[-]	[%]	[kN/m³]	[°]	[kN/m²]	[kN/m²]	[MN/m²]
1 [1]	0,00 2,63	-10,80 -13,43	-	**Sand/Schluff** locker	-	**7,5** 6,5 - 8,5	**25,0** 25,0 - 30,0	-	-	-
2	2,63 5,70	-13,43 -16,50	**2,0** 0,2 - 10,0	**Sand/Schluff** locker	**25,0** 28,0 - 31,0	**7,5** 6,5 - 8,5	**27,5** 25,0 - 30,0	**2** 1 - 5	**40** 20 - 60	**2** 1 - 4
3	5,70 12,48	-16,50 -23,28	**20,0** 12,0 - 22,0	**Sand** mitteldicht	**58,8** 51,2 - 61,3	**8,5** 7,0 - 10,0	**35,4** 31,0 - 37,0	**0** - - -	**0** - - -	**19** 10 - 26
4	12,48 19,00	-23,28 -29,80	**18,0** 16,0 - 20,0	**Sand** mitteldicht	**55,4** 53,4 - 64,2	**9,5** 9,0 - 11,0	**34,6** 32,3 - 38,0	**0** - - -	**0** - - -	**31** 27 - 35
5	19,00 26,98	-29,80 -37,78	**23,0** 20,0 - 25,0	**Sand** dicht	**83,0** 77,0 - 86,0	**10,5** 10,0 - 11,0	**38,0** 37,4 - 42,0	**0** - - -	**0** - - -	**44** 38 - 49
6	26,98 29,78	-37,78 -40,58	**16,0** 14,0 - 19,0	**Sand** mitteldicht	**63,0** 56 - 71	**10,5** 9,5 - 11,0	**35,0** 34,2 - 37,1	**0** - - -	**0** - - -	**47** 46 - 48
7	29,78 40,38	-40,58 -51,18	**26,0** 22,0 - 34,0	**Sand** dicht	**78,0** 73 - 85	**11,5** 11,0 - 12,0	**38,4** 37,6 - 39,9	**0** - - -	**0** - - -	**60** 53 - 69
8	40,38 45,42	-51,18 -56,22	**33,0** 24,0 - 47,0	**Sand** dicht	**81,0** 69 - 95	**11,5** 11,0 - 12,0	**38,6** 36,2 - 41,1	**0** - - -	**0** - - -	**72** 67 - 79
9 [2]	*45,42* *65,00*	*-56,22* *-75,80*	-	***Sand*** *mitteldicht*	-	***10,0***	***32,5***	***0***	***0***	**40**

[1] (Teilweise) vorgebohrte schluffige Sande, keine vollständigen CPT-Daten verfügbar, Bodenparameter konservativ angenommen gemäß Interpolation benachbarten Daten.
[2] Keine CPT-Daten verfügbar. Bodenparameter konservativ angenommen gemäß Bohr-Daten.

Bereich: **FSRU - Ponton-Dalben mit Kolkschutzschüttung (pontoon dolphins w/ armor layer)**
Rechnerische Wassertiefe (DSL): -9,80 [m SKN]

Charakteristische Bodenkennwerte (BE in "fett") und Bandbreite (LE - HE)

Schicht Nr.	Tiefe unter Meeresboden	Höhe	Spitzenwiderstand	Bodenart	Bezogene Lagerungsdichte	Auftriebswichte des Bodens	Effektiver Reibungswinkel	Effektive Kohäsion	Undränierte Kohäsion	Steifemodul
	z		q_c	-	I_D	γ'	φ'	c'	c_u	E_s
[-]	[m]	[m SKN]	[MPa]	[-]	[%]	[kN/m³]	[°]	[kN/m²]	[kN/m²]	[MN/m²]
0 [3]	0,00 1,00	-9,80 -10,80	-	**Steinschüttung** aufbauend	- - - -	**0,0 / 9,0** [4] 0,0 - 10,0	**0,0 / 37,5** [4] 0,0 - 55,0	**0** - - -	**0** - - -	**0,0 / 10,0** [4] 0 - 10
1 [1]	1,00 3,63	-10,80 -13,43	-	**Sand/Schluff** locker	-	**7,5** 6,5 - 8,5	**25,0** 25,0 - 30,0	-	-	-
2	3,63 6,70	-13,43 -16,50	**2,0** 0,2 - 10,0	**Sand/Schluff** locker	**25,0** 28,0 - 31,0	**7,5** 6,5 - 8,5	**27,5** 25,0 - 30,0	**2** 1 - 5	**40** 20 - 60	**2** 1 - 4
3	6,70 13,48	-16,50 -23,28	**20,0** 12,0 - 22,0	**Sand** mitteldicht	**58,8** 51,2 - 61,3	**8,5** 7,0 - 10,0	**35,4** 31,0 - 37,0	**0** - - -	**0** - - -	**19** 10 - 26
4	13,48 20,00	-23,28 -29,80	**18,0** 16,0 - 20,0	**Sand** mitteldicht	**55,4** 53,4 - 64,2	**9,5** 9,0 - 11,0	**34,6** 32,3 - 38,0	**0** - - -	**0** - - -	**31** 27 - 35
5	20,00 27,98	-29,80 -37,78	**23,0** 20,0 - 25,0	**Sand** dicht	**83,0** 77,0 - 86,0	**10,5** 10,0 - 11,0	**38,0** 37,4 - 42,0	**0** - - -	**0** - - -	**44** 38 - 49
6	27,98 30,78	-37,78 -40,58	**16,0** 14,0 - 19,0	**Sand** mitteldicht	**63,0** 56 - 71	**10,5** 9,5 - 11,0	**35,0** 34,2 - 37,1	**0** - - -	**0** - - -	**47** 46 - 48
7	30,78 41,38	-40,58 -51,18	**26,0** 22,0 - 34,0	**Sand** dicht	**78,0** 73 - 85	**11,5** 11,0 - 12,0	**38,4** 37,6 - 39,9	**0** - - -	**0** - - -	**60** 53 - 69
8	41,38 46,42	-51,18 -56,22	**33,0** 24,0 - 47,0	**Sand** dicht	**81,0** 69 - 95	**11,5** 11,0 - 12,0	**38,6** 36,2 - 41,1	**0** - - -	**0** - - -	**72** 67 - 79
9 [2]	*46,42* *66,00*	*-56,22* *-75,80*	-	***Sand*** *mitteldicht*	-	***10,0***	***32,5***	***0***	***0***	**40**

[1] (Teilweise) vorgebohrte schluffige Sande, keine vollständigen CPT-Daten verfügbar, Bodenparameter konservativ angenommen gemäß Interpolation benachbarten Daten.
[2] Keine CPT-Daten verfügbar. Bodenparameter konservativ angenommen gemäß Bohrungsdaten.
[3] Kolkschutzschüttung (Steinschüttung 50-200 mm mit Filterschicht, aufbauend auf Seeboden), angenommene Mächtigkeit: 1 m (OK -9,80 mSKN).
[4] Zur Berücksichtigung einer Kolkschutzschüttung im Pfahl-Design siehe Hinweise in Abschnitt 3.3

Figure 8 Soil parameters to be used in the design according to anlage 3 of ref [18]

The soil profile can be described as a sandy profile so drained behaviour of the soil will be assumed. It is mention that analyzing undrained conditions for sand leads to an over estimation of the strength.

5. Vessel data

In this chapter the characteristics of the pontoon and the service vessels will be provided.

5.1 Pontoon

Als richtig vorausgesetzt.

The pontoon will be HEBO 63. This is an existing pontoon that will be (semi-) permanently moored at the marine facility. Prior the installation it will be classified by an certification agency. The barge is a Flat top pontoon. The deck will be used for landing of the gangway running to the mooring dolphin.

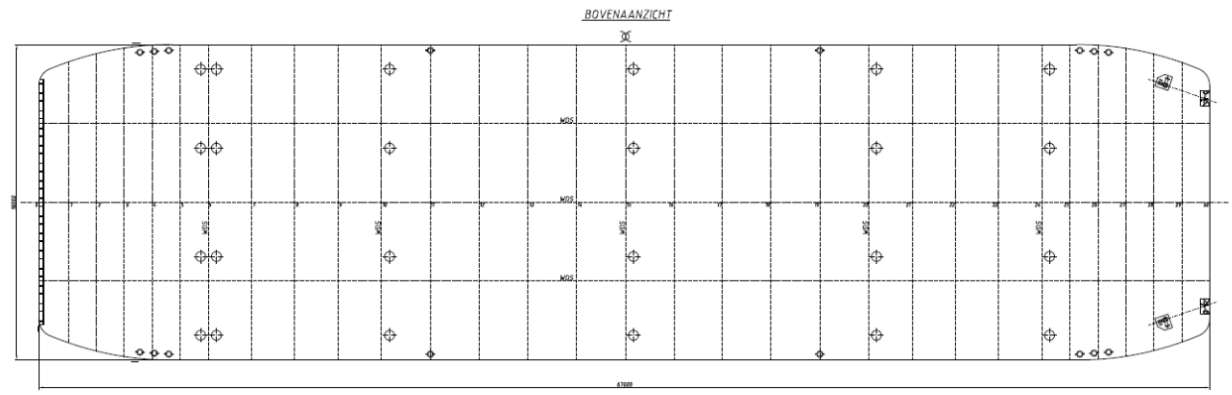
Length	67.00 m
Breadth moulded	18.00 m
Depth	4.50 m
Maximum draught	2.385 m from baseline 2.400 m from underside keel

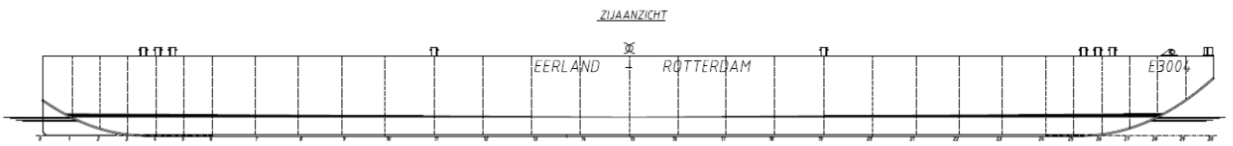
Note:
Based on information as received from HEBO according to the LR international load line certificates the minimum freeboard shall be
2230 mm as applicable for winter North Atlantic conditions.

LIGHTSHIP DETAILS

Lightship weight	739.891	tonnes
Longitudinal centre of gravity (LCG)	32.734	meters from AP

Note: The displacement in tonnes will be lower @2.23m freeboard (max draft allowed).





Note: More detailed drawings of the pontoon are available.

Figure 9 Particulars of Flat top Barge HEBO data taken from ref [20]

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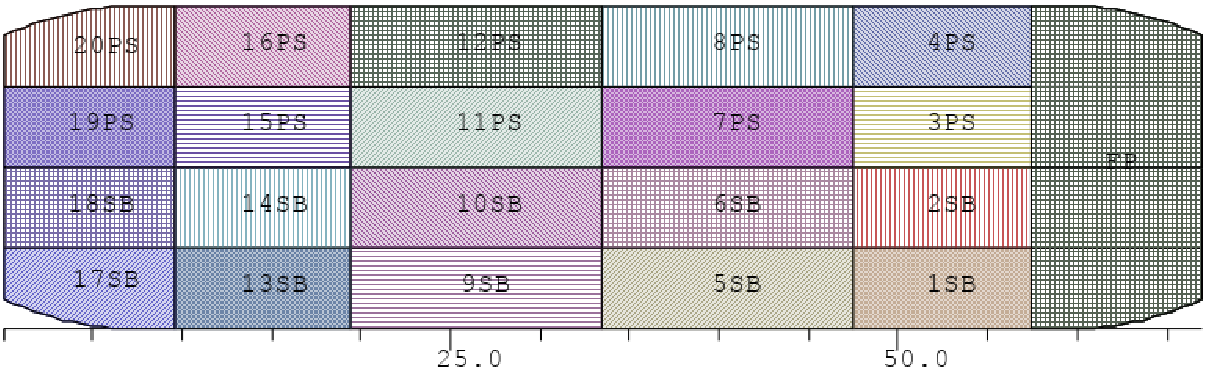

E3004
Summary of maximum tankvolumes 03 sep 2011 16:33:35

Compartment	Volume	Weight	VCG	LCG	TCG	Mom.In.T	S.W.
Forepeak fr.24-30	600.309	615.316	2.522	61.422	0.000	3993.763	1.025
1 SB fr.20-24	196.457	201.369	2.250	52.450	6.750	73.820	1.025
2 SB fr.20-24	196.463	201.375	2.250	52.450	2.250	73.707	1.025
3 PS fr.20-24	196.463	201.375	2.250	52.450	-2.250	73.707	1.025
4 PS fr.20-24	196.457	201.369	2.250	52.450	-6.750	73.820	1.025
5 SB fr.15-20	277.819	284.764	2.250	40.500	6.750	104.464	1.025
6 SB fr.15-20	277.827	284.773	2.250	40.500	2.250	104.283	1.025
7 PS fr.15-20	277.827	284.773	2.250	40.500	-2.250	104.283	1.025
8 PS fr.15-20	277.819	284.764	2.250	40.500	-6.750	104.464	1.025
9 SB fr.10-15	277.818	284.764	2.250	26.500	6.750	104.431	1.025
10SB fr.10-15	277.827	284.773	2.250	26.500	2.250	104.287	1.025
11PS fr.10-15	277.827	284.773	2.250	26.500	-2.250	104.287	1.025
12PS fr.10-15	277.818	284.764	2.250	26.500	-6.750	104.431	1.025
13SB fr.6-10	196.457	201.369	2.250	14.550	6.750	73.826	1.025
14SB fr.6-10	196.463	201.375	2.250	14.550	2.250	73.711	1.025
15PS fr.6-10	196.463	201.375	2.250	14.550	-2.250	73.711	1.025
16PS fr.6-10	196.457	201.369	2.250	14.550	-6.750	73.826	1.025
17SB fr.0-6	159.281	163.263	2.385	5.398	6.592	57.141	1.025
18SB fr.0-6	173.391	177.726	2.413	5.131	2.250	71.555	1.025
19PS fr.0-6	173.391	177.726	2.413	5.131	-2.250	71.555	1.025
20PS fr.0-6	159.281	163.263	2.385	5.398	-6.592	57.141	1.025

Figure 10 Overview of ballast tanks taken from ref [20]

Als richtig vorausgesetzt.

tonnage	draft in m	tonnage	draft in m
Empty	0,72	2501,5	2,80
109,0	0,82	2623	2,90
257,8	0,90	2744,4	3,00
370,8	1,00	2865,9	3,10
485,5	1,10	2987,5	3,20
600,3	1,20	3109,3	3,30
715,5	1,30	3231,2	3,40
832,0	1,40	3353,1	3,50
948,6	1,50	3475,0	3,60
1065,3	1,60	3596,9	3,70
1183,6	1,70	3718,9	3,80
1301,9	1,80	3840,8	3,90
1420,4	1,90	3962,7	4,00
1539,2	2,00	4084,6	4,10
1658,9	2,10	4200,0	4,20
1778,7	2,20		
1898,5	2,30		
2018,7	2,40		
2139,3	2,50		
2259,9	2,60		
2380,7	2,70		

Table 8 Draft versus tonnage

Als richtig vorausgesetzt.

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5.2 Service vessels and firefighting tug

Design vessels:

Particulars of the design vessels using the Pontoon Facility are presented in the table below.

1. Fire Fighting Tug, VB Magnum length 28,40 m
2. The Rescue boat Hooksiel length 23,10 m

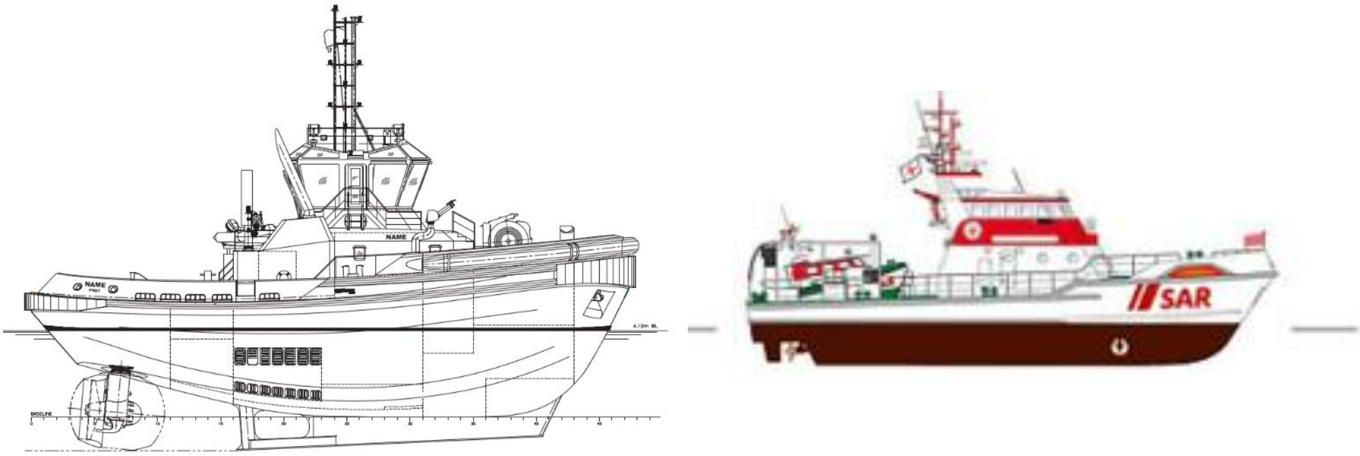

Figure 11 Service vessels using the boat access. Als richtig vorausgesetzt.

Ship particular	Fire Fighting tug VB magnum	Rescue boat Hooksiel
Length	28,40 m	23,10 m
Width	13,00 m	6,00 m
Draft	5,70 m	1,60 m
Water displacement/ Gross tonnage	< 500 Tons	80 Ton

Table 9 Design vessel using the Pontoon Facility Als richtig vorausgesetzt.

It shall be possible to moor both service vessels simultaneously.
For berthing velocities EAU 2020 [7] make reference to PIANC guidelines ref [10]
For the service vessel an approach velocity of 0.50 m/s is selected. (curve C) this will be used for the design of the fendering of the pontoon.

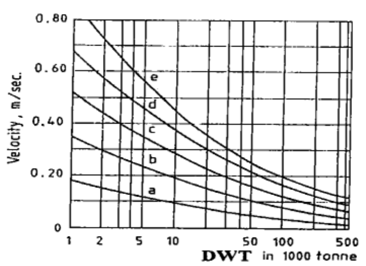

Figure 4.2.1. Design berthing velocity (mean value) as function of navigation conditions and size of vessel (Brolsma et al. 1977)

a. Good berthing conditions, sheltered
b. Difficult berthing conditions, sheltered
c. Easy berthing conditions, exposed
d.* Good berthing conditions, exposed
e.* Navigation conditions difficult, exposed

Figure 12 Berthing velocities according to ref [10] Als richtig vorausgesetzt.

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6. Design criteria

6.1 Design philosophy

DIN/Eurocodes do not explicitly cover environmental, operational, and accidental loadings for maritime works. In the absence of other guidance therefore, EAU ref [7] provides recommendations on the application of the Eurocodes to marine facilities. For this reason EAU ref [7] will be used for the design of the pontoon. For some aspects such as fatigue and allowable displacement form other codes.

In most cases, maritime facilities are classified as consequence and reliability class 2. EAU does not explicitly mention the consequence class but provides safety factors and material factors to be used in the design which are in line with Consequence class 2.

6.2 Design life

The design life of the pontoon facility shall be 10 years. This deviates from ref [17]. This is agreed between IMDC and the client Engie in order to make the concept feasible after issuing of the document.

6.3 Execution class

There is a relation between the consequence class and the execution class. If subjected to fatigue, which is applicable, then the execution class according to Eurocode is taken one class higher.

For fabrication of the mooring piles for the pontoon facility execution class 3 according to DIN EN 1090-2 ref [6]. For fatigue, specifically for the amount of testing of the welds, also criteria according to ref [12] DNV-GL-RP-C203: “Fatigue design of offshore steel structures” are applicable.

6.4 Maximum slope angle and functional requirements gangway

6.4.1 Slope of the gangway

According to ref [7], in case of floating pontoons, tidal water differences shall be considered. The incline of the access jetty should not be steeper than

- Mean tide not steeper than 1:6 which equals 9 degrees
- Extreme water level not steeper than 1:4 which equals 14 degrees*

*Calculated at worse case - maximum allowable draft 2.27m (freeboard 2.23m) and +11.680mCD MD6 connection walkway level.

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6.4.2 Requirements for the gangway bridge

The following requirements apply for the gangway system:

- Minimum clear width of a one-piece gangway: 1,2 m;
- Gangway designed only for pedestrians
- A rolling raft, (750mm high), at the base of the gangway on the pontoon deck and the pivot at the mooring dolphin MD6 steel deck.
- A design weight in the order of of 25t – 27t is expected.
- Material: S355J2 steel (coated) will be used for gangway. Alternatively aluminum can be used.
- Minimum load: minimum distributed line load of q=2.0 kN/m² is considered, in addition a concentrated load of Q_i = 1.5 KN in the center of a free span must be considered as alternative load.
- A horizontal design spar load (incl. load factor) of H_d = 0.525 kN/m is applied at the top of all handrails.
- Fundamental modes will be verified according to HIVOSS guidelines.

The Design of the gangway is outside the scope of this document.

6.5 Minimum required freeboard of the pontoon

EAU article 7.2.14.2 requires the following free boards of the pontoon and states that the freeboard shall increase with the size of the pontoon.

- Pontoons having a length of 30 m a and a width in the order of 3 to 6 m a free board in the range of 0,80 till 1,2 m
- Pontoons having a length of 60 m a and a width in till 16 m a free board in the range of 1,20 till 1,5 m

Based on information as received from HEBO according to the load line certificates the minimum freeboard shall be 2230 mm as applicable for Winter North Atlantic conditions.

Higher freeboard of the pontoon will result in a shallower slope of the gangway. During basis design this will be investigated in more dept considering operational and stability requirements.

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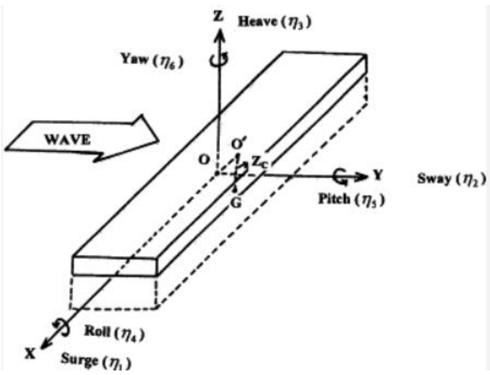
6.6 Acceptable movement of the pontoon

In the table below the acceptable movements according to ref [9] are presented. The ship type Ferries RO-RO is the most applicable due to the gangways landing on the pontoon. These criteria are assumed to be on the safe side given the use of the gangway by most likely better trained and instructed personnel.



Ship Type	Cargo Handling Equipment	Surge (m)	Sway (m)	Heave (m)	Yaw (°)	Pitch (°)	Roll (°)
Fishing vessels	Elevator crane Lift-on-lift-off suction pump	0.15 1.0 2.0	0.15 1.0 1.0	0.4	3	3	3
Freighters, coasters	Ship's gear Quarry cranes	1.0 1.0	1.2 1.2	0.6 0.8	1 2	1 1	2 3
Ferries, Ro-Ro	Side ramp[2] Dew/storm ramp linkspan Rail ramp	0.6 0.8 0.4 0.1	0.6 0.6 0.6 0.1	0.6 0.8 0.8 0.4	1 1 3 -	1 1 2 1	2 4 4 1
General cargo	-	2.0	1.5	1.0	3	2	5
Container vessels	100% efficiency 50% efficiency	1.0 2.0	0.6 1.2	0.8 1.2	1 1.5	1 2	3 6
Bulk carriers	Cranes Elevator/bucket-wheel Conveyor belt	2.0 1.0 5.0	1.0 0.5 2.5	1.0 1.0	2 2 3	2 2	6 2
Oil tankers	Loading arms	3.0[3]	3.0				
Gas tankers	Loading arms	2.0	2.0		2	2	2

Remarks: 1) Motions refer to peak-peak values (except for sway: zero-peak).
2) Ramps equipped with rollers.
3) For exposed locations 5.0 m (regular loading arms allow large movements)

Table 10 Recommended Motion Criterion for Safe Working Conditions.

The criteria defined above will be verified for the 1/1 year wave conditions.

Ref [7] requires stricter criteria however given the relatively exposed nature of the pontoon the criteria of +/-150 mm for sway is not realistic.

In document ref [9] are also values for <u>velocities</u> in the direction of movement are provided. Given the size of the pontoon (DWT) , the velocity criteria are appropriate restrictions for the dynamic behavior of the moving pontoon.

Ship size (DWT)	Surge (m/s)	Sway (m/s)	Heave (m/s)	Yaw (°/s)	Pitch (°/s)	Roll (°/s)
1,000	0.6	0.6	-	2.0	-	2.0
2,000	0.4	0.4	-	1.5	-	1.5
8,000	0.3	0.3	-	1.0	-	1.0

1) These criteria are applicable for fishing vessels, coasters, freighters, ferries and Ro-Ro vessels.

Table 1.3 - Recommended Velocity Criteria[1] for Safe Mooring Conditions.

Table 11 Recommended Velocity criteria according to ref [9]

If movement appears to be critical, it can be verified by a motion analysis using Ansys AQWA if the pontoon meets these criteria.

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6.7 Starting points for fatigue design of the mooring piles.

6.7.1 General

Fatigue design will be caried out according to DNV-GL-RP-C203 Fatigue design of offshore steel structures, April 2023 ref [11]. Given the marine environment of the faculty and the use of the piles. The criteria defined in this DNV standard are more appropriate and supplementary to the criteria the criteria defined in Eurocode. Below the starting used for the fatigue design will be provided. The “chart design method” as defined in this standard will be used this results in a stress range Δ_s (not amplitude) that will be verified in the design for the mooring piles to ensure fatigue life of the piles.

Die Ermüdungsnachweise müssen die Erfordernisse der 1993-1-9 abdecken.

For design of the bracket piles different fatigue curves and correction for mean stress might be applicable. This will be address in further detail in the design of the bracket frames.

6.7.2 Wave characterises

For determination for damage under fatigue conditions the scatter diagram as presented in the figure below will be used. It shows the significant wave height versus direction the wave is coming from.

Significant wave height, Hm0 [m]	Mean wave direction																
	North	NNE	NE	ENE	East	ESE	SE	SSE	South	SSW	SW	WSW	West	WNW	NW	NNW	ALL
]0.0-0.1]	1.73%	0.73%	0.54%	0.59%	0.96%	1.13%	6.09%	4.08%	0.64%	0.70%	0.41%	0.41%	0.23%	0.58%	1.39%	14.05%	34.25%
]0.1-0.2]	2.03%	1.43%	1.04%	1.40%	2.10%	1.95%	6.92%	5.91%	0.99%	0.51%	0.23%	0.27%	0.37%	0.52%	1.39%	11.99%	39.05%
]0.2-0.3]	1.04%	0.89%	0.52%	0.54%	0.54%	0.51%	1.39%	1.30%	0.15%	0.055%	0.041%	0.027%	0.041%	0.055%	0.40%	6.39%	13.89%
]0.3-0.4]	0.48%	0.29%	0.12%	0.082%	0.082%	0.082%	0.14%	0.34%	0.027%		0.014%				0.055%	4.31%	6.02%
]0.4-0.5]	0.26%	0.041%		0.014%				0.069%	0.014%		0.014%				0.069%	3.35%	3.83%
]0.5-0.6]	0.14%	0.014%						0.014%								1.80%	1.96%
]0.6-0.7]	0.027%							0.014%								0.60%	0.64%
]0.7-0.8]	0.069%															0.22%	0.29%
]0.8-0.9]																0.041%	0.041%
]0.9-1.0]																0.014%	0.014%
]1.0-1.1]																	
]1.1-1.2]																0.014%	0.014%
ALL	5.78%	3.39%	2.22%	2.62%	3.68%	3.66%	14.53%	11.73%	1.82%	1.26%	0.71%	0.71%	0.64%	1.15%	3.29%	42.78%	100%

Note: For the 1/10 year significant wave condition per direction see enclosure 1 wave data.

Table 12 Wave spectra to be used for fatigue verification.

A wave rose and intensity plot of the waves is presented in the figure below

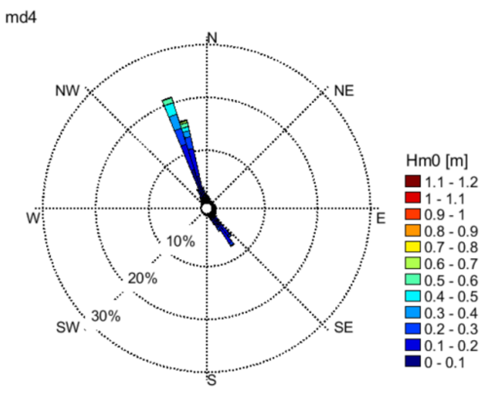


Figure 6-9 Wave rose at output location md4.

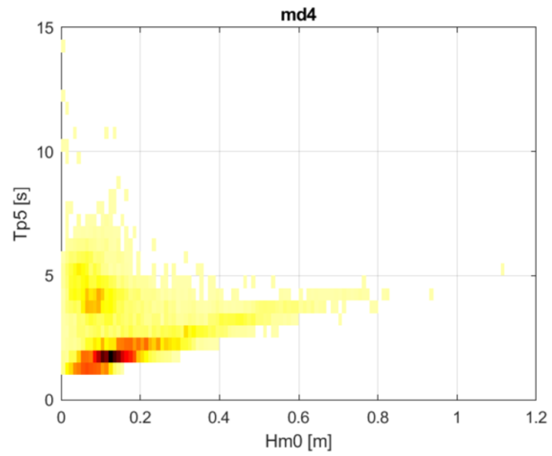


Figure 13 wave rose and intensity plot.

From the wave data it can be concluded that there the following sectors are relevant:

NW+NNW+SE+SSE = 3.29+42.78+14.53+11.73 = 72%
These sectors combined represent 72 % of the time.

Based on the intensity plot the average time period of the waves is estimated as 2.5 seconds which will be used for calculation the number of load cycles.

6.7.3 Selection of the Applicable damage fatigue factor (DDF)

In Offshore Standard DNV-OS-C101 table 5-1 ref [13] a table is provided that gives guidance for the section of the Design Fatigue Factor. The Design fatigue factors (DFFs) is partial safety factor on the number of load cycles to take care of uncertainties associated with the design process. DFFs are related to the fatigue failure probability and ultimately proportional to reliability against fatigue failure.

It depends on critically and inspectability of the structural element.

Table 5-1 Design fatigue factors (DFF)

DFF	*Structural element*
1	Internal structure, accessible and not welded directly to the submerged part.
1	External structure, accessible for regular inspection and repair in dry and clean conditions.
2	Internal structure, accessible and welded directly to the submerged part.
2	External structure not accessible for inspection and repair in dry and clean conditions.
3	Non-accessible areas, areas not planned to be accessible for inspection and repair during operation.

Guidance note:

Units intended to follow normal inspection schedule according to class requirements, i.e. the 5-yearly inspection interval in sheltered waters or drydock, may apply a Design Fatigue Factor (DFF) of 1. Units that are planned to be inspected afloat at a sheltered location the DFF for areas above 1 m above lowest inspection waterline should be taken as 1, and below this line the DFF is 2 for the outer shell. Splash zone is defined as non-accessible area (see splash zone definition in Sec.9 [2.2]).

Table 13 Offshore Standard DNV-OS-C101 table 5-1

The maximum moment in the mooring piles for the pontoon facility is occurring in the soil and can not be inspected after installation even with divers. For this reason a Design Fatigue Factor DFF=3 is selected. For the bracket frame situated above water level that can be inspected a DFF lower factor of 2 can be used.

The design live for fatigue in years used will be 10 years.

6.7.4 Selecting of the appropriate S-N Curve and weld details

The maximum bending moment is occurring in the soil were the amount of corrosion is limited. A relatively high DFF is selected that allows for certain amount of uncertainty. (See also comment F 6 of ref [11])
For this reason the seawater curve with cathodic protection can be used in lack of documented S-N curves in seawater in free corrosion for coated joints (in the high cycle region above 10 ^{6} cycles).
At locations where corrosion is occurring at the low water line the bending stresses will be significantly lower as will be demonstrated in the pile design report.

According to ref [11] paragraph 2.4.13 S-N data for piles, the transition of the weld to base material on the outside of tubular girth welds can normally be classified to S-N curve E. If welding is performed in a flat position, it can be classified as D. If welding is performed from outside only, it should be classified as F3. From pile fabrication point of view it is preferred to execute welling from the outside only.

In appendix A 6 of ref [11] criteria for transverse butt welds made from one side are provided. Relevant figures from this appendix are presented below.

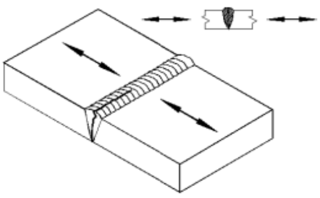
W3	1. 	1. Butt weld made from one side only and without backing strip.	1. — With the root proved free from defects larger than 1-2 mm (in the thickness direction) by non-destructive testing, detail 1 may be categorised to F3 (it is assumed that this is fulfilled by inspection category I). See also commentary section. If it is likely that larger defects may be present after the inspection the detail may be downgraded from F3 based on fatigue life calculation using fracture mechanics. The analysis should then be based on a relevant defect size.

Figure 14 But welds welded from one side without backing-stip.

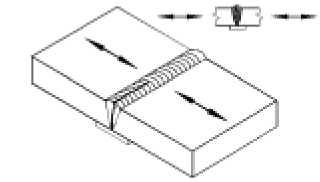
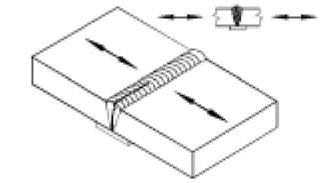
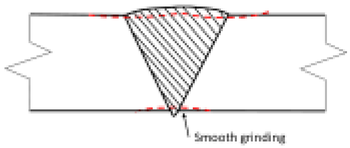
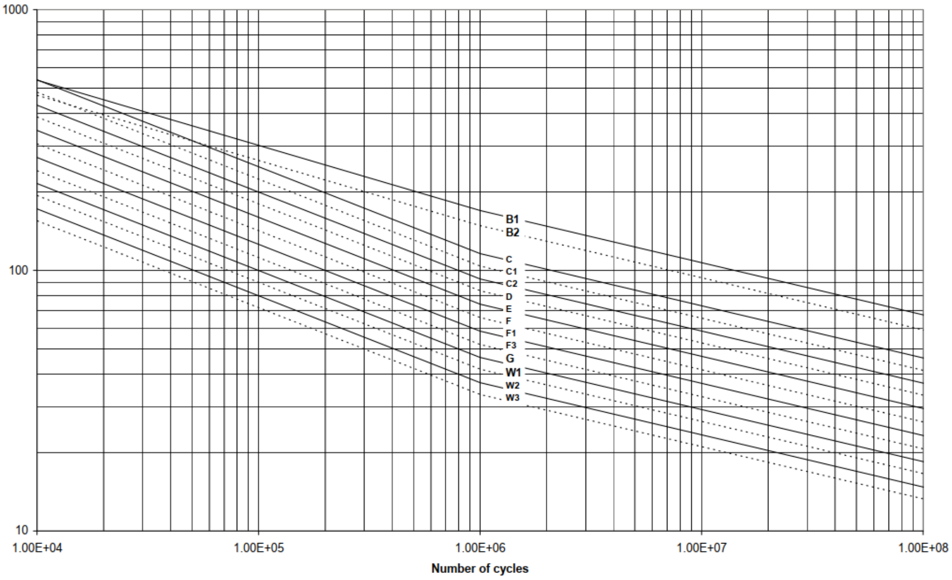
Detail category	*Constructional details*	*Description*	*Requirement*
F	2. 	2. Transverse butt weld on a temporary or a permanent backing strip without fillet welds.	
G	3. 	3. Transverse butt weld on a backing strip fillet welded to the plate.	
C1		4. Transverse butt weld where the weld toes and weld root is ground or machined to a smooth transition from the weld to the base material. The grinding should be minimum 0.2 mm below any imperfection both for weld toes and the weld root. A typical maximum grinding depth is 1.0 mm, however, the planned actual grinding depth should be used for calculation of nominal stress range at the connection.	4. — The detail classification may be increased to category C when high quality welding is performed using a qualified welding procedure and the weld proved free from defects by non-destructive testing. Note that special consideration with respect to NDT and acceptance criteria are required for butt welds where a higher classification than D is used. See App.F.

Figure 15 But welds welded from one side with backing-strip or grinding

As fatigue curve, curve F corresponding to a butt welded from one side with a **non welded** backing strip Is selected. Grinding of the transverse welds of the pile joints is judged to be too time consuming.



S-N curve	$N \le 10^6$ cycles		$N > 10^6$ cycles $\log \bar{a}_2$ $m_2 = 5.0$	Fatigue limit at 10^7 cycles (MPa) *)	Thickness exponent k	Structural stress concentration embedded in the detail (S-N class), see also equation (2.3.2)
	m_1	$\log \bar{a}_1$				
B1	4.0	14.917	17.146	106.97	0	
B2	4.0	14.685	16.856	93.59	0	
C	3.0	12.192	16.320	73.10	0.05	
C1	3.0	12.049	16.081	65.50	0.10	
C2	3.0	11.901	15.835	58.48	0.15	
D	3.0	11.764	15.606	52.63	0.20	1.00
E	3.0	11.610	15.350	46.78	0.20	1.13
F	3.0	11.455	15.091	41.52	0.25	1.27
F1	3.0	11.299	14.832	36.84	0.25	1.43
F3	3.0	11.146	14.576	32.75	0.25	1.61
G	3.0	10.998	14.330	29.24	0.25	1.80
W1	3.0	10.861	14.101	26.32	0.25	2.00
W2	3.0	10.707	13.845	23.39	0.25	2.25
W3	3.0	10.570	13.617	21.05	0.25	2.50
*) see also [2.11]						

Note in curve F a structural stress concentration of 1,27 is included.

Table 14 S-N curves in seawater with cathodic protection taken over from figure 2.9 of ref [11]

<u>SCF for the Groove welds</u>

The additional stress due to fabrication tolerances should be small, the SCF is set equal 1.0.

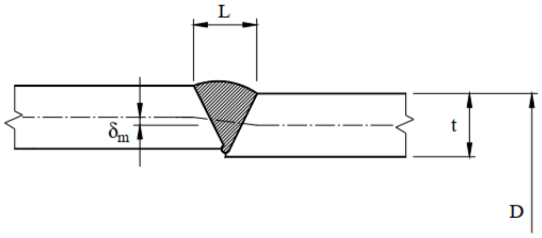


Figure 16 V - Groove welds after figure 3-8 of ref [11]

The stress concentration can be calculated using article 3.1.2 of ref [11] DNV-GL-RP-C203 Fatigue design of offshore steel structures, April 2023.

At the transition between plates with the same thickness there is stress concentration when there is misalignment.

The eccentricity(δ_m) between welded plates with a similar thickness may be accounted for in the calculation of the stress concentration factor. The following formula applies for a butt weld in an unstiffened plate:

$$SCF = 1 + \frac{3(\delta_m - \delta_0)}{t}$$

Where δ_m is eccentricity (misalignment) and t is plate thickness, see Figure 15.

δ_0 = 0.05t is misalignment inherent in the S-N data for butt welds and analysis procedure for plated structures with an expected fabrication tolerance that is lower than that allowed in fabrication specification and as used in design, see also Table 3-1 of ref [11]

The stress concentration for the weld between plates with different thickness in a plate field

For a SCF of 1 the eccentricity due to misalignment should be smaller than 0.05 t = 0.05 x 50 = 2.5 mm

This requires strict tolerances for pile fabrication.

6.7.5 Determination of the allowable stress range under fatigue conditions

The stress range in the mooring piles of the pontoon facility will be larger than the fatigue limit as shown in the figure below so a detailed fatigue assessment is required.

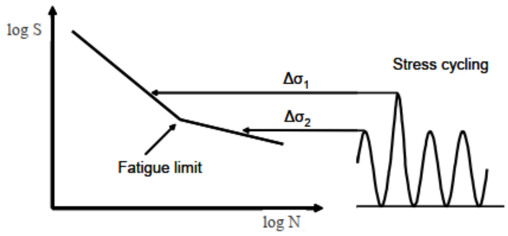


Figure 17 Applicable stresses in the pile

The allowable stress range in the mooring piles is determined according to [11] Chapter 5 Simplified Fatigue analysis. The wall thickness of the steel plates of the mooring piles is 50.0 mm.
This method makes use of design charts.

These design charts have been derived based on an assumption of an allowable fatigue damage η = 1.0 During 10^8 cycles (20 years service life which corresponds to an average cycling period of 6.3 sec.).
For design with other allowable fatigue damages, η, the allowable stress from the design charts should be reduced by factors derived from tables or formula's.

Correction factors apply for:
- The usage factor.
- Wall thickness.

Determination of the applicable usage factors η

- Average wave period = 2.5 seconds; (based on intensity plot)
- Number of load cycles based on lifetime for fatigue analyses = 10*365*24*3600/2.5*0.72 = $0.9*10^8$ (Division by 0,72 correct to 100% life time)
- The number of load cycles 10^8 as per design chart is reached after 1/0.9 = 11 years.
- Table 15 present utilization factors for 1.00 for 10^8 load cycles in 20 years.
- This leads to 0,9 * 20 = 18 years as per table via interpolation (2*0.44+3*0.33)/5
- This leads to a usage factor η of 0.37

DFF	*Design life in years*						
	5	*10*	*15*	*20*	*25*	*30*	*50*
1	4.0	2.0	1.33	1.00	0.80	0.67	0.40
2	2.0	1.0	0.67	0.50	0.40	0.33	0.20
3	1.33	0.67	0.44	0.33	0.27	0.22	0.13
5	0.80	0.40	0.27	0.20	0.16	0.13	0.08
10	0.40	0.20	0.13	0.10	0.08	0.07	0.04

Table 15 Usage factors η as function of design life and design fatigue factor table 5-8 of ref [11]

Weibull shape factor
The shape parameter gives the Weibull distribution its flexibility. By changing the value h, b in the figure below of the shape parameter, the Weibull distribution can model a wide variety of data. If h = 1 the Weibull distribution is identical to the exponential distribution, if h = 2, the Weibull distribution is identical to the Rayleigh distribution; if h is between 3 and 4 the Weibull distribution approximates the normal distribution.

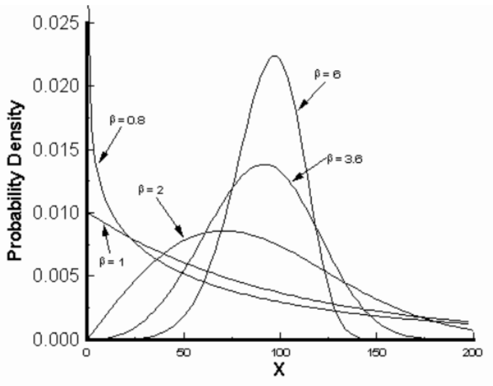


Figure 18 Shape of the probability distribution in relation to the shape parameter

A Weibull shape parameter equal 1.00 is assumed which is reasonable to assume by absence of detail information.

The following allowable stress range is derived for h =1,0 for S-N curve F is obtained see the table below:

S-N curves	Weibull shape parameter h							
	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20
B1	1309.8	996.0	793.0	655.2	557.4	485.3	430.5	387.6
B2	1146.0	871.5	693.9	573.3	487.7	424.7	376.6	339.1
C	1038.5	745.5	573.6	464.3	389.8	336.7	297.0	266.5
C1	930.5	668.0	513.9	415.8	349.3	301.5	266.1	238.7
C2	830.7	596.3	458.7	371.3	311.7	269.2	237.6	213.1
D and T	747.8	536.7	413.0	334.2	280.7	242.4	213.9	191.9
E	664.3	476.9	367.0	297.0	249.3	215.3	190.1	170.5
F	589.8	423.4	325.8	263.6	221.4	191.1	168.6	151.3
F1	523.3	375.7	289.0	233.9	196.4	169.6	149.6	134.3
F3	465.3	334.0	257.0	208.0	174.6	150.9	133.1	119.3
G	415.3	298.2	229.4	185.7	155.9	134.6	118.8	106.6
W1	373.9	268.3	206.6	167.1	140.3	121.2	106.9	95.9
W2	332.3	238.4	183.5	148.5	124.7	107.7	95.0	85.3
W3	299.1	214.7	165.2	133.4	112.2	96.9	85.6	76.7

Table 16 Allowable extreme stress range in MPa during 10^8 cycles for components in seawater with cathodic protection

Fatigue damage utilisation η	Weibull shape parameter h							
	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20
0.10	0.535	0.558	0.577	0.593	0.605	0.613	0.619	0.623
0.20	0.640	0.659	0.676	0.689	0.699	0.707	0.713	0.717
0.22	0.657	0.675	0.691	0.703	0.713	0.721	0.727	0.731
0.27	0.694	0.710	0.725	0.736	0.745	0.752	0.758	0.762
0.30	0.714	0.729	0.743	0.754	0.763	0.769	0.775	0.779
0.33	0.732	0.747	0.760	0.770	0.779	0.785	0.790	0.794
0.40	0.772	0.785	0.796	0.805	0.812	0.818	0.822	0.825
0.50	0.821	0.831	0.840	0.847	0.853	0.858	0.862	0.864
0.60	0.864	0.872	0.879	0.885	0.889	0.893	0.896	0.898
0.67	0.892	0.898	0.903	0.908	0.912	0.915	0.917	0.919
0.70	0.903	0.908	0.913	0.917	0.921	0.924	0.926	0.927
0.80	0.938	0.941	0.945	0.947	0.949	0.951	0.953	0.954
1.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

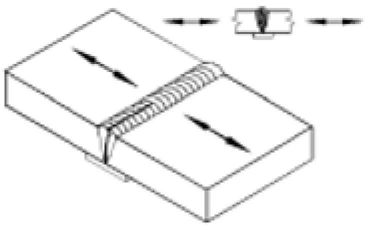
Table 17 Reduction factor on stress to correspond with utilisation factor η for C - W3 curves in seawater with cathodic protection taken over from table 5-7 of ref [11] seawater with cathodic protection

The allowable extreme stress range = 191,1 MPa. See table 15. (without reduction)

Then from Table 16 a reduction factor is obtained by linear interpolation between the utilisation factors for h-values 1.0 (for η = 0.37) A reduction factor of 0.804 is obtained.
0.804 * 191,1 = 153.64 MPa.

$$\sigma_{0,t} = \sigma_{0,tref}\left(\frac{t_{ref}}{t}\right)^{k}$$

t_{ref} = reference thickness equal 25 mm for welded connections other than tubular joints. For tubular joints the reference thickness is 25 mm.
the allowable stress range for the 50 mm thick plate is obtained as: $153{,}7 \cdot (25/50)^{0{,}25}$
The allowable stress range (Δ_s) is: 0.84 * 153.64 = **129 N/mm² (between loading and unloading)**
For the weld detail as shown below.

2. 	2. Transverse butt weld on a temporary or a permanent backing strip without fillet welds.

As simplified verification the stress range for the 1/10 year conditions will be compared against the allowable stress. No load factors have to be applied.

6.8 Corrosion allowance

Above the permanent immersion zone a corrosion allowance of 2 mm will be considered as simplified approach. (See figure 16)
According to EAU 2020 ref [7] the corrosion rate for steel in non aggressive soils when micro biological corrosion can be excluded in 0,01 mm/ year/ per side for 10 years this would be 0.10 mm.
The top of the piles will be sealed by an end plate for safety purposes. This also reduces the amount of oxygen in the pile and reduces the corrosion inside the pile to neglectable values.
The bending moment in the pile gives maximum bending moment in the soil where corrosion is marginal. No CP system will applied to the piles at the regions where corrosion occurs the bending stresses under fatigue conditions will be significantly lower and higher stress concentration factors at these locations can be accepted.

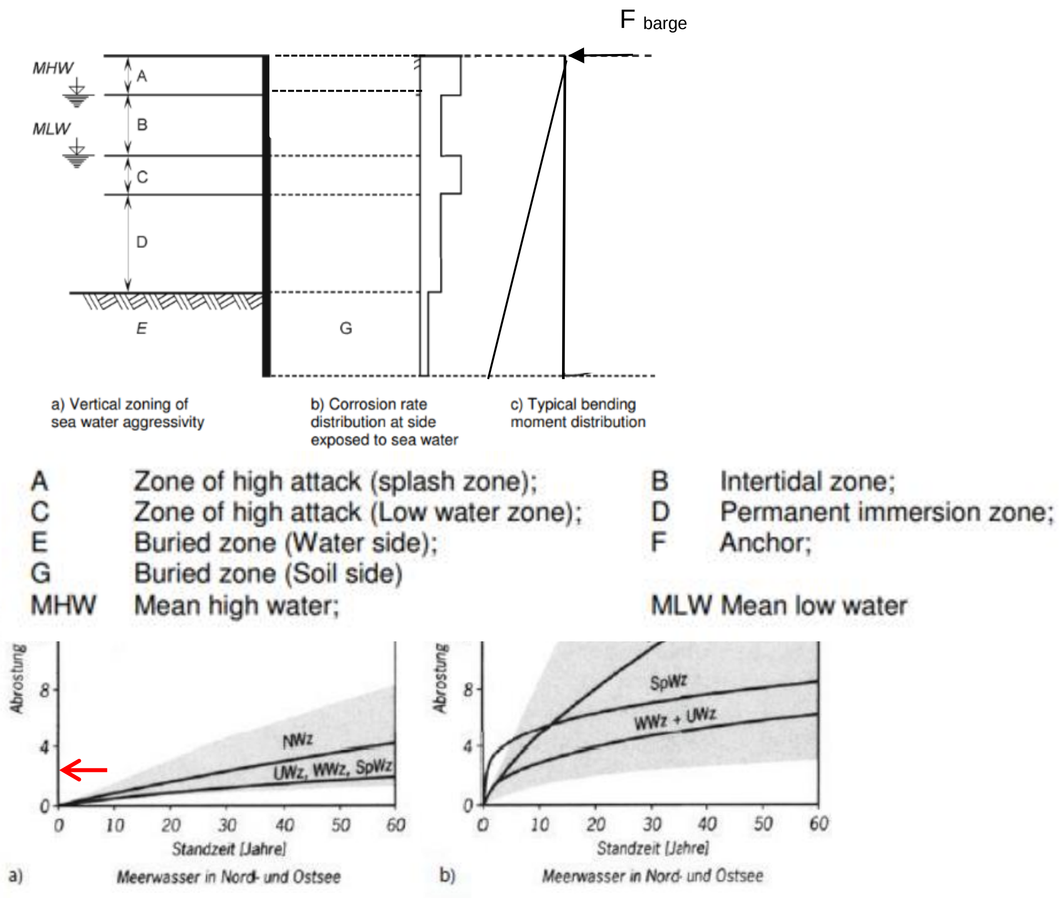


Figure 19: Corrosion rate distribution according to DIN EN 1993-5 and EAU 2020

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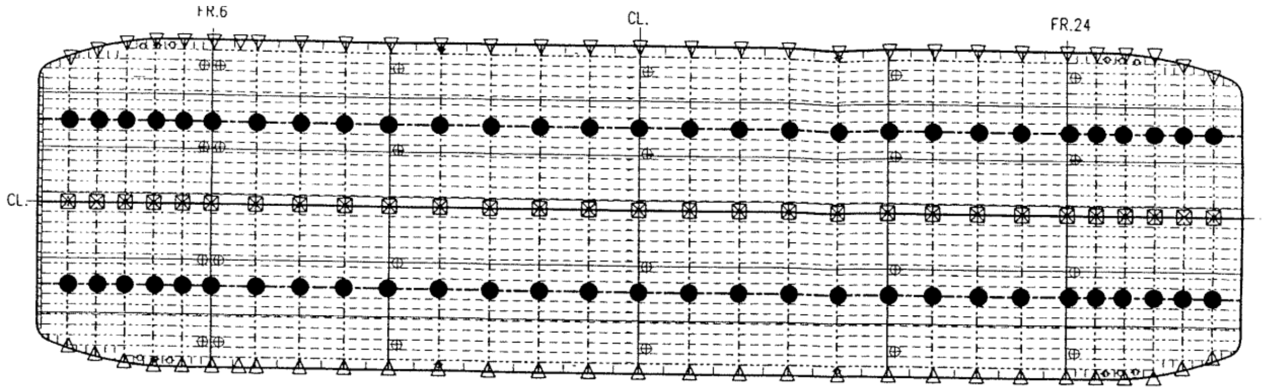
6.9 Deck load diagram of the pontoon

Als richtig vorausgesetzt.

The pontoon have to provide support for the gangway for connection to the pile guides have to be provided. Beside this for mooring of the service vessels locally bollards of fenders have to be provided. In the figure below a deck load diagram is provided showing loads that the pontoon is capable to resist. The maximum height for the deck load on the pontoon according to ref [20] is 10 m. The figure provides values for the deck load only not for the hull pressure on the side faces.



MAXIMUM PERMISSIBLE CONCENTRATED LOADING

POSITION	LOAD STATIC	LOAD DYNAMIC
DECK TRANSVERSES	53.6 t	64.3 t
DECK LONGITUDINALS AFT. FR.6 FORW.24	20.7 t	24.7 t
DECK LONGITUDINALS BETWEEN FR.6- FR.24	12.2 t	14.7 t
⊠ CROSSING CL. BULKHEAD WITH WEB FRAME/TRANSV. BULKHEAD	262 t	315 t
● CROSSING 4.5m BULKHEAD WITH WEB FRAME/TRANSV. BULKHEAD.	209 t	251 t
△ CROSSING SIDE SHELL WITH WEB FRAME/TRANSV. BULKHEAD.	310 t	372 t

MAXIMUM PERMISSABLE UNIFORM LOADING:

POSITION	LOAD STATIC	LOAD DYNAMIC
MAIN DECK	10 t/m²	12 t/m² ✷
LONGITUDINAL BULKHEADS CL.	78 t/m	89 t/m
LONGITUDINAL BULKHEADS 4.5m	23 t/m	26 t/m
TRANSVERSE BULKHEADS	189 t/m	227 t/m
SIDE SHELL	160 t/m	183 t/m
BOW	22 t/m	26 t/m
TRANSOM	45 t/m	54 t/m
DECK TRANSVERSES	23.7 t/m	28.4 t/m
LONGITUDINAL AFT. FR.6-FORW. FR.24	19.4 t/m	23.2 t/m
LONGITUDINAL BETWEEN FR.6-FR.24	6.6 t/m	7.9 t/m

Remarks:

- *Permissible concentrated loading are uniform loadings can not be combined without further analysis*
- *Concentrated loads can be applied anywhere along the specified members*
- *The maximum permissible loads may be applied provided suitable deck seating will be fitted to ensure a proper fitting will be used to ensure proper distribution of loads into the hull structure*
- *The deck load diagram is not applicable for forces pulling out the deck plate*

Figure 20 Allowable deck loads for the HEBO 63 pontoon

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7. Loads and load combinations

7.1 Mooring forces

Mooring forces action on the piles are the result of wind, current and wave forces action on the pontoon. For this project is defined to use the environmental return periods having a 100 year interval as given in earlier paragraphs.

- For verification of ULS conditions the 1/100 year conditions will be used.
- For verification of serviceability conditions (displacement) the 1/1 year conditions will be used.

This is higher than the return period of 1/50 year as recommended in EAU see:

- For wind load see chapter 4.8.2 in EAU with title: “Maßgebende wind Geschwindigkeit“
- For wave loads see chapter 4.3.3 in EAU with title. “Bemessungskonzepte und Festlegung der Bemessungsparameter“

For ULS the safety factors will be used as listed in chapter 7.4.

The mooring forces will be calculated using Ansys AQWA. Mooring forces will be calculated for various directions and for sea states representing various return periods as defined above and intermediate states.

It shall be realised that the design wave height varies per direction. Head on waves result in a different force in the piles compared to beam on waves

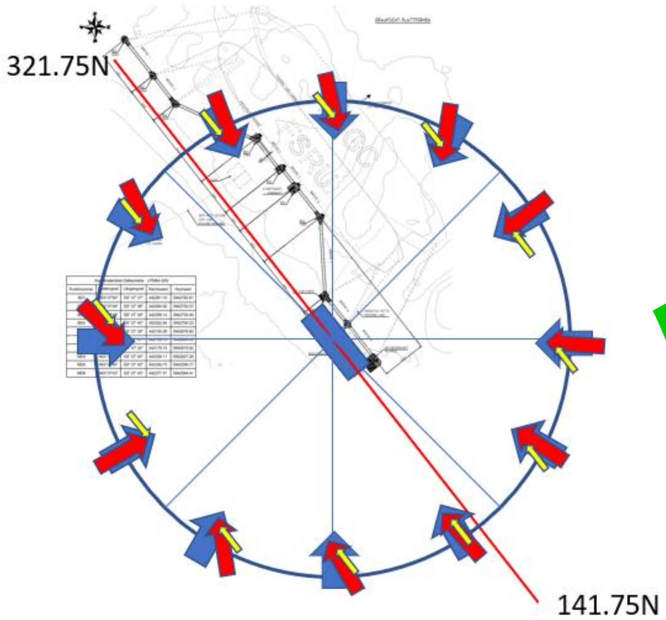

Figure 21 Force Output from Ansys AQWA model

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7.2 Wave loads acting directly on the piles

Wave load on pontoon is included via the mooring forces acting on the piles via the Ansys AQWA model. The direct wave and current forces on the piles however are not included in this model. These direct wave are determined separately.

According to EAU the wave loads on the pile should be determined using Morisons equations.

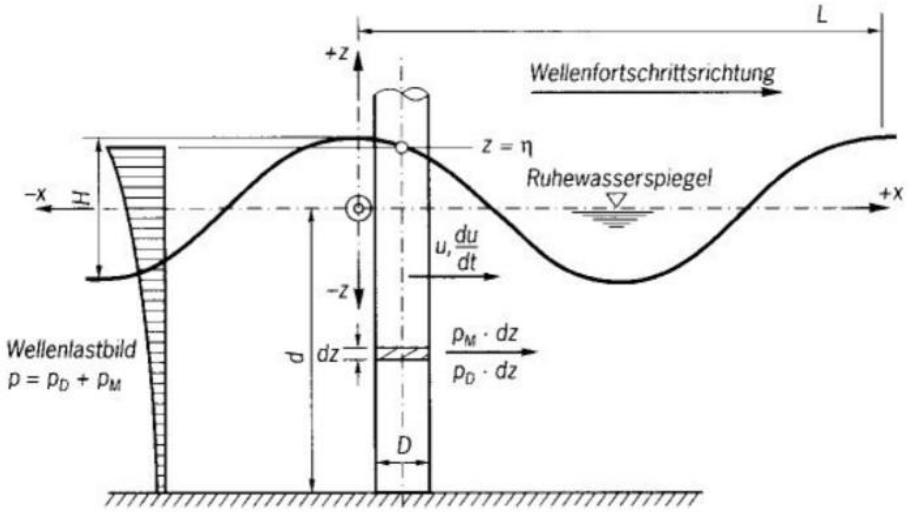

Figure 22 Wave action on a slender structure according to figure 4.11 EAU ref [7]

For the determination of the wave and current forces on the piles a method has been chosen that is a simplification of the Morison equation. According to The “Shore Protection Manual” (CERC 1984)

$$F_{max} = F_I + F_D = C_I K_I H \rho g \frac{\pi D^2}{4} + C_D K_D H^2 \frac{1}{2} \rho g D$$

$$M_{max} = F_I d S_I + F_D d S_D$$

where:

C_I	[-]	=	inertia coefficient ≈ 2,0
C_D	[-]	=	drag coefficient (for small flow velocities C_D ≈ 1,2 , see Section 20.3)
K_I	[-]	=	correction for extent of inertia force
K_D	[-]	=	correction for extent of drag force
S_I	[-]	=	correction for position of resultant inertia force
S_D	[-]	=	correction for position of resultant drag force
H	[m]	=	wave height
D	[m]	=	diameter pile
d	[m]	=	depth

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7.3 Ice loads

In this paragraph the loads induced by ice will be calculated.

From EAU paragraph 4.11.2 Bestimung des eisdrucksfesigkeit:

$$\sigma_0 = 2700\dot{\varepsilon}^{1/3} \cdot \varphi_B^{-1}$$

Darin sind

σ_0	horizontale einachsige Eisdruckfestigkeit [MN/m²],
$\dot{\varepsilon}$	spezifische Dehnungsgeschwindigkeit [s^{-1}], ε = 0,001
φ_B	Porosität [$^o/_{oo}$].

σ_0 = (2700*0.001^0,33) / 233,22 = 1.18 MN/m²

Bei Ansatz von Salinität des Eises 1,4% statt 3,0% ist die horizontale einachsige Eisdruckfestigkeit um 85% höher.

$$\varphi_B = 19{,}37 + 36{,}18 S^{0,91}{}_B \cdot |\vartheta_m|^{-0,6}$$

Darin sind

φ_B	Porosität [$^o/_{oo}$],
S_B	Salinität [$^o/_{oo}$],
ϑ_m	$(\vartheta_o + \vartheta_u)/2$, mittlere Eistemperatur [°C],
ϑ_u	Temperatur an Eisunterseite (ϑ_u = −1 °C deutsche Ostsee und ϑ_u = −2°C deutsche Nordsee) [°C],
ϑ_o	Temperatur an Eisoberseite (entspricht Lufttemperatur) [°C].

V_m= (-2-16)/2 = -9 °C
S_B = 30 $^0/_{00}$
φ_B = 19.37+(36.18*30 ^{0,91} * 9$^{-0,6}$)= 19.37+ 213.85 = 233,22

For ice loads on flat structures, the load perpendicular to the structure can be estimated using the following formula:

$$p_0 = k \cdot h \cdot \sigma_0$$

Darin sind

p_0	mittlere Linienlast [MN/m],
k	Kontaktbeiwert [–], k = 0, 33
h	Dicke des Eises [m],
σ_0	einaxiale Eisdruckfestigkeit [MN/m²]

P_o= 0.33 * 0.4*1.18= 0.156 MN.m'
In tidal area's:
P'_0= 0.4*Po= 0.4*155= 62 kN/m'

Table 18 Calculation Ice loads according to EAU chapter 4.11.2

For a pontoon length of 67 m this will be 67* 62 = 4154 kN divided over 6 piles this is 692 kN/pile. Conservatively only the piles along to the longitudinal edge of the pontoon are taken in to account.
The safety factor to be applied on this load will be 1.00. This load will not be combined with mooring loads. Most likely this load will be conservative since the ice might be thinner in estuaries and broken by Ice-breakers. Verification for the pontoon for ice loads is out side the scope of the document.

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7.4 Load factors and material factors

The load factors as presented in the table below taken from chapter 12 of ref [7] will be used. This approach is identical to design approach 2 according to ref [5].

	Einwirkungen	**Widerstände Boden**	**Stahl**
	γQ	$\gamma_{R,e}$	γ_M
Lasten aus Anlegemanövern	1,00	1,00	1,00
Vertäukräfte (Trossenzug) und Anlehnkräfte	1,20	1,15	1,10
Kräfte aus Wellen, Wind und Strömung	1,20	1,15	1,10
Eislasten (siehe auch Abschn. 4.12)	1,00	1,10	1,10

Figure 23 Safety factors for the design of the mooring piles taken over from table 12.1 of ref [7]

Ice loads will be treated as a separate case and will not be combined with mooring load and wave loads acting on the piles.

geprüft

8. Modelling

8.1 Floating behaviour of the moored barge

The modelling of the floating behaviour is performed with Ansys AQWA, a 3D diffraction program. The initial modelling in the RAO’s module will give the ratio between the response of the free floating barge (roll, pitch, heave, surge, sway, yaw) in relation to the incoming wave height for the range of wave periods.

After this analysis the actual geometry is analyzed in the hydrodynamic module. The modelled pontoon geometry is shown in the figure below. The panel size varies between 0.5m and 1m, which gives the possibility to simulate wave periods varying from 3 to 60 seconds

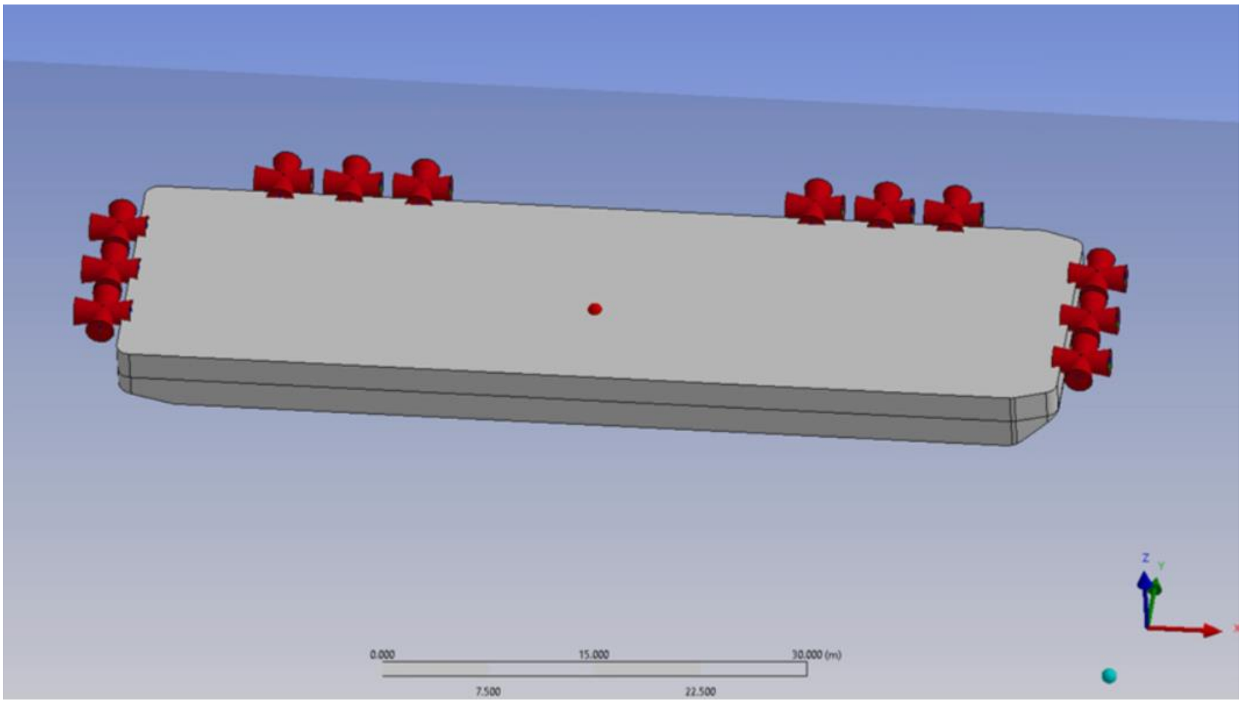

Figure 24 Ansys AQUA model

The pontoon is restrained by means of 12 piles. In the Ansys AQWA model each pile has 4 press only supports as shown in the figure above. Two in the direction perpendicular (one for tension and one for compression) to the ponton in opposite direction en two in the direction parallel to the pontoon in opposite direction. This means that each pile is able to withstand sway and surge and that the whole pile system is able to withstand yaw. Heave, pitch and roll do not significantly impact the pile design.

The stiffnesses of the supporting piles varies depending on the water level which can be high or low,
For the considered return period the boundaries of the stiffness range are investigated, several stiffnesses are reviewed to find peak values in the stiffness response of the system.
Dynamic Amplification Factors are included in the Ansys AQWA model.

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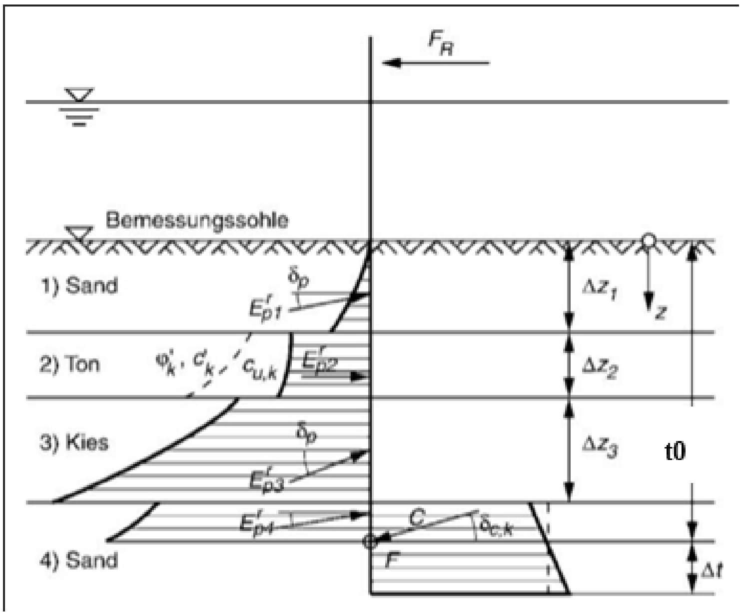
8.2 Determination of internal pile forces

The pile has been designed with method Blum in accordance with documents [7] and [8]. In its simplest form Blum assumes full passive mobilisation of one soil type for a sheet pile wall as shown in the figure below. The original method was formulated for sheet pile walls that are supported at the top. Horizontal equilibrium is assured by a theoretical horizontal force at the toe of the wall. The Blum method is a force driven method. From the static equilibrium the internal forces shear and bending moment are derived.

The Blum method was adapted for flexible dolphins by introducing multiple soil layers and factors (formbeiwerte) that take into account the spatial effect of soil pressure on circular shaped sections. At the location where the bending moment becomes zero (M=0) a force is assumed that makes horizontal equilibrium. That force, with symbol C, is called Ersatzkraft (German for replacement force). The total pile depth is t0+Δt where t0 is the distance between the top of the soil to the M=0 level in meter and Δt is the required depth under level M=0. In document [7] Δt is calculated as shown in figure 25.
For calculation the passe soil-pressure for the angle of the passive δ c:k wedge of 2/3 will be used. This is based on correlations made for benchmark calculations using Plaxis software.



$$\Delta t = \frac{1}{2} \cdot C_{\mathrm{h,k,Blum}} \cdot \gamma_{\mathrm{Q}} \cdot \frac{\gamma_{\mathrm{R,e}}}{e^{\mathrm{r}}_{\mathrm{ph,k}}}$$

mit

$e^{\mathrm{r}}_{\mathrm{ph,k}}$	Ordinate des charakteristischen räumlichen Erddrucks in Höhe der ErsatzkrafC.

Figure 25 Ersatzkraft C at M=0 for mono pile in multiple soil layers from document [7]

For determination of the load distribution in the pile the In the DMC Blum sheet will be used.
Finally the maximum moments and corresponding stresses are to be checked to the allowable ones.

8.3 Pile ponton connection

The piles will be connected to the pontoon by means of a bracket as shown in the figure below. This bracket will be further developed during the basic and detail design. Sliding devices will be used to minimize normal forces in the piles which can be both tension or compression.
These forces are marginal compared the lateral load, but bearing capacities will be verified for completeness

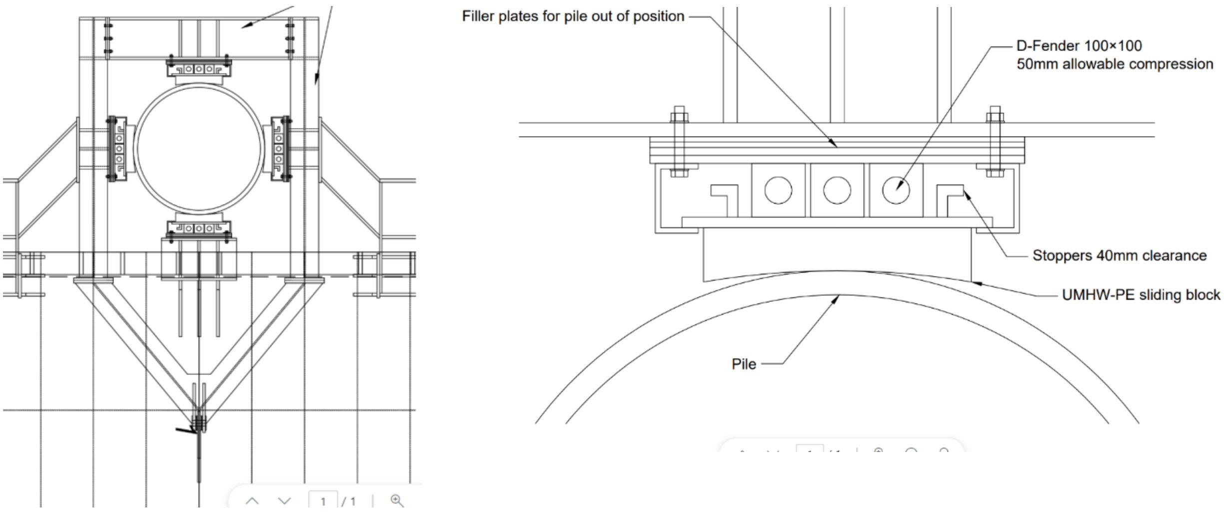


Figure 26 Pile pontoon connection

Tight tolerances for verticality and position of the piles are applicable which might call for the need of templates. This will be further investigated in detail in the detailed design stage.

Wind and wave data

The data in this enclose is taken over from ref [19] annex B

Enclosure 1.

100-year return period

Wind		Wind waves					
Direction Coming from (°N)	Speed (m/s)	Mdir Coming from (°N)	Hm0 (m)	Tp (s)	Gamma (Jonswap)	Directional spreading (°)	Directional spreading (s)
0	27.2	347.2	2.1	5.1	2.3	9.6	24.7
30	22.6	9.4	1.6	4.4	2.8	5.4	32.4
60	18.0	51.1	1.2	3.8	3.3	5.5	32.1
90	21.0	94.2	1.3	3.8	3.4	5.7	31.6
120	17.9	122.8	1.1	3.7	3.5	7.5	27.7
150	16.8	138.8	1.0	3.7	2.4	10.3	24.0
180	21.6	150.7	1.3	4.1	1.7	7.9	27.0
210	24.2	171.0	1.2	3.8	1.5	4.5	35.0
240	26.4	239.5	1.0	3.0	2.9	1.9	46.5
270	26.0	314.3	1.3	4.3	1.5	4.9	33.8
300	26.8	333.5	1.8	4.9	1.9	11.5	22.8
330	27.8	339.0	2.1	5.2	2.0	13.7	21.1

Swell waves						
Sector	Mdir Coming from (°N)	Hm0 (m)	Tp (s)	Gamma (Jonswap)	Directional spreading (s)	Directional spreading (°)
West	345	0.1	13.5	1.8	34.0	13.5
WNW	348	0.1	14.7	1.8	29.9	14.5
NNW	356	0.2	15.4	1.8	19.2	18.1
North	358	0.4	8.7	1.1	12.6	21.9
NNE	0	0.4	6.7	1.7	9.4	25.0

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50-year return period

Wind		Wind waves					
Direction Coming from (°N)	Speed (m/s)	Mdir Coming from (°N)	Hm0 (m)	Tp (s)	Gamma (Jonswap)	Directional spreading (°)	Directional spreading (s)
0	25.4	345.6	2.0	5.0	2.3	10.1	24.2
30	21.3	8.7	1.5	4.3	2.8	5.3	32.7
60	17.1	51.0	1.1	3.7	3.2	5.3	32.7
90	19.7	93.7	1.2	3.7	3.4	5.6	31.7
120	17.0	122.5	1.1	3.6	3.7	7.5	27.7
150	16.1	138.6	0.9	3.6	2.4	10.2	24.0
180	20.5	150.7	1.2	4.1	1.8	8.3	26.4
210	23.0	171.1	1.1	3.7	1.5	4.5	35.0
240	25.0	239.6	1.0	2.9	2.8	1.9	46.4
270	24.6	314.2	1.3	4.2	1.6	4.8	34.0
300	25.3	333.5	1.7	4.8	1.9	11.5	22.8
330	26.2	339.1	2.0	5.1	2.0	13.8	21.0

20-year return period

Wind		Wind waves					
Direction Coming from (°N)	Speed (m/s)	Mdir Coming from (°N)	Hm0 (m)	Tp (s)	Gamma (Jonswap)	Directional spreading (°)	Directional spreading (s)
0	22.9	347.0	1.8	4.9	2.4	9.6	24.8
30	19.4	9.5	1.4	4.2	2.8	5.2	32.9
60	15.9	51.2	1.0	3.5	3.3	5.3	32.5
90	17.9	92.7	1.1	3.6	3.5	5.7	31.5
120	15.7	122.7	1.0	3.5	3.5	7.5	27.8
150	15.1	138.7	0.9	3.5	2.2	10.1	24.1
180	18.9	151.0	1.1	4.0	1.7	8.3	26.5
210	21.5	171.4	1.0	3.6	1.5	4.5	35.0
240	23.1	239.8	0.9	2.9	2.8	2.0	45.9
270	22.7	313.9	1.2	4.1	1.7	4.8	34.1
300	23.3	334.2	1.6	4.6	1.9	11.3	23.0
330	24.1	339.1	1.9	5.0	2.0	13.8	21.0

10-year return period

Wind		Wind waves					
Direction Coming from (°N)	Speed (m/s)	Mdir Coming from (°N)	Hm0 (m)	Tp (s)	Gamma (Jonswap)	Directional spreading (°)	Directional spreading (s)
0	21.0	347.7	1.7	4.7	2.4	9.4	24.9
30	18.1	10.2	1.3	4.1	2.8	5.2	32.9
60	15.1	51.1	1.0	3.5	3.3	5.4	32.4
90	16.6	91.9	1.0	3.5	3.2	5.8	31.4
120	14.7	122.6	0.9	3.4	3.5	7.3	28.0
150	14.4	138.9	0.8	3.4	2.2	10.1	24.1
180	17.7	151.1	1.1	3.8	1.7	8.3	26.5
210	20.3	171.5	1.0	3.5	1.5	4.5	35.0
240	21.7	239.8	0.8	2.8	2.8	2.0	45.8
270	21.4	313.5	1.1	4.0	1.7	4.8	34.2
300	21.9	334.2	1.5	4.5	1.9	11.1	23.2
330	22.4	339.7	1.7	4.9	2.1	13.7	21.1

5-year return period

Wind		Wind waves					
Direction Coming from (°N)	Speed (m/s)	Mdir Coming from (°N)	Hm0 (m)	Tp (s)	Gamma (Jonswap)	Directional spreading (°)	Directional spreading (s)
0	19.1	348.1	1.5	4.5	2.4	9.3	25.1
30	16.7	10.9	1.2	3.9	2.8	5.3	32.8
60	14.2	51.2	0.9	3.4	3.3	5.5	32.2
90	15.3	91.3	1.0	3.4	3.2	5.8	31.3
120	13.7	122.2	0.8	3.3	3.5	7.4	28.0
150	13.6	139.0	0.8	3.4	2.2	10.1	24.2
180	16.6	151.3	1.0	3.7	1.7	8.3	26.4
210	19.1	171.9	0.9	3.4	1.5	4.5	35.0
240	20.3	241.5	0.8	2.7	2.8	1.9	46.3
270	20.0	313.5	1.0	3.8	1.7	4.7	34.3
300	20.4	335.0	1.4	4.5	1.9	11.0	23.3
330	20.8	339.3	1.6	4.7	2.1	13.8	21.0

2-year return period

Wind	Wind waves

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Direction Coming from (°N)	Speed (m/s)	Mdir Coming from (°N)	Hm0 (m)	Tp (s)	Gamma (Jonswap)	Directional spreading (°)	Directional spreading (s)
0	16.7	349.1	1.3	4.3	2.4	9.1	25.4
30	14.9	12.3	1.1	3.8	2.8	5.3	32.7
60	13.0	51.7	0.8	3.7	3.3	7.2	28.3
90	13.6	90.4	0.8	3.2	3.2	5.9	31.1
120	12.4	121.9	0.7	3.1	3.5	7.2	28.2
150	12.7	138.7	0.7	3.3	2.2	10.0	24.3
180	15.0	151.7	0.9	3.6	1.7	8.3	26.5
210	17.6	172.5	0.8	3.3	1.5	4.5	35.2
240	18.4	240.3	0.7	2.6	2.8	2.1	45.3
270	18.1	312.6	0.9	3.7	1.7	4.6	34.7
300	18.4	334.6	1.3	4.3	1.9	10.6	23.6
330	18.7	339.6	1.4	4.5	2.1	13.7	21.1

1-year return period

Wind		Wind waves					
Direction Coming from (°N)	Speed (m/s)	Mdir Coming from (°N)	Hm0 (m)	Tp (s)	Gamma (Jonswap)	Directional spreading (°)	Directional spreading (s)
0	14.8	349.1	1.2	4.1	2.4	9.1	25.4
30	13.5	12.3	1.0	3.7	2.8	5.3	32.7
60	12.1	51.7	0.7	3.5	3.3	7.2	28.3
90	12.3	90.4	0.7	3.0	3.2	5.9	31.1
120	11.4	121.9	0.7	3.1	3.5	7.2	28.2
150	12.0	138.7	0.6	3.1	2.2	10.0	24.3
180	13.8	151.7	0.9	3.6	1.7	8.3	26.5
210	16.4	172.5	0.8	3.2	1.5	4.5	35.2
240	17.0	240.3	0.6	2.5	2.8	2.1	45.3
270	16.7	312.6	0.9	3.6	1.7	4.6	34.7
300	16.9	334.6	1.2	4.2	1.9	10.6	23.6
330	17.0	339.6	1.4	4.4	2.1	13.7	21.1

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Delta Marine Consultants

Comparison of water levels

Encl

German		Hooksiel Nautical Almanac Reeds	Hooksiel BSH Kalender	Hooksiel BSH Kalender
		Water level [m SKN]	**Water level [m NHN]**	**Water level [m SKN]**
	MHWS	+4.3		
MThw = MHW			+1.6	+4.1
	MHWN	+3.7		
NHN	MSL		+0.0	+2.5
	MLWN	+1.0		
MTnw = MNW			-1.8	+0.7
	MLWS	+0.5		

geprüft

[Reeds Nautical Almanac 2021 - Perrin Towler, Mark Fishwick - Google Boeken](#)

AREA 15 – Germany

RIVER WESER

(AC 1875, 3617, 3622, 3623) The River Weser is a major waterway leading to **Bremerhaven, Nordenham, Brake**, and **Bremen** where it connects with the inland waterways. The upper reaches, *Unterweser*, run from Bremen to Bremerhaven and then the *Aussenweser* flows into a wide estuary (split by two main chans: *Neue Weser* and *Alte Weser*). The position and extent of sandbanks vary: the W side tends to be steep-to, the E side has extensive drying shoals (eg Tegeler Plate).

The Jade-Weser SWM lt buoy marks the approach from NW to Neue Weser (the main fairway, recommended) and Alte Weser (not well lit) which are separated by Roter Sand and Roter Grund, marked by the disused Roter Sand lt tr (conspic). Both chans are well marked and converge about 3M S of Alte Weser lt tr (conspic). From this junction *Hohewegrinne* (buoyed) leads inward in a SE direction past Tegeler Plate lt tr (conspic) on the NE side and Hohe Weg lt tr (conspic) to the SSE. The Nordegründe Windfarm (18 turbines, 53°50'·07N 08°10'·17E) lies midway between Alte Weser and Tegeler Plate lt twrs. From Robbenplate to Wremer Tief (part way towards Bremerhaven) it is constrained by training walls, which may cause tidal accelerations. ►*In the Aussenweser the stream (>3kn at sp) often sets towards the banks and the branch chans which traverse them.*◄

The Weser-Elbe Wattfahrwasser is a demanding, extremely shallow inshore passage between Rivers Weser and Elbe. It leads NNE from the Wurster Arm (E of Hohe Weg) keeping about 3M offshore; SE of Neuwerk and around Cuxhaven training wall. It is tricky, normally requires two or three spring tides for a vessel drawing up to 1·2m, and is not recommended for visitors.

9.15.16 HOOKSIEL (RIVER JADE)

Niedersachsen **53°38'·61N 08°05'·19E**

CHARTS AC 3618; Imray C26; D 7

TIDES +0034 Dover; ML no data; Duration 0605

Standard Port WILHELMSHAVEN (⟶)

Times				Height (metres)			
High Water		Low Water		MHWS	MHWN	MLWN	MLWS
0200	0800	0200	0900	4·7	4·3	1·1	0·5
1400	2000	1400	2100				
Differences HOOKSIEL							
–0023	–0022	–0008	–0012	–0·4	–0·5	–0·1	0·0
SCHILLIG							
–0031	–0025	–0006	–0014	–0·6	–0·6	–0·1	0·0

SHELTER Temp in the Vorhafen (approx 1m, soft mud, at MLWS) but very commercial and uncomfortable in E winds. Beyond the lock there is complete shelter in the Binnentief, 2M long and 2·0–3·5m deep. Best for visitors is Alter Hafen Yacht Hbr in the town; max draft 2m. Larger yachts go to YCs; see lockmaster. Do not enter Watersports Area due to water-ski cables.

NAVIGATION WPT 53°39'·33N 08°06'·52E (No 37/Hooksiel 1 SHM buoy, IQ G 13s), 217°/9ca to H3 SHM buoy, Fl G 4s, 350m E of ent.

Caution: aquaculture N of H3, seasonal HS ferry, strong cross-tide, transhipment pier and restricted area to SE of ent.

Appr via chan 2·1m deep to Vorhafen (beware shoaling) enclosed by two moles. Inner ldg daymarks 276·5°, two RW bcns, lead through ent, but are obsc'd when ferry berthed on N pier.

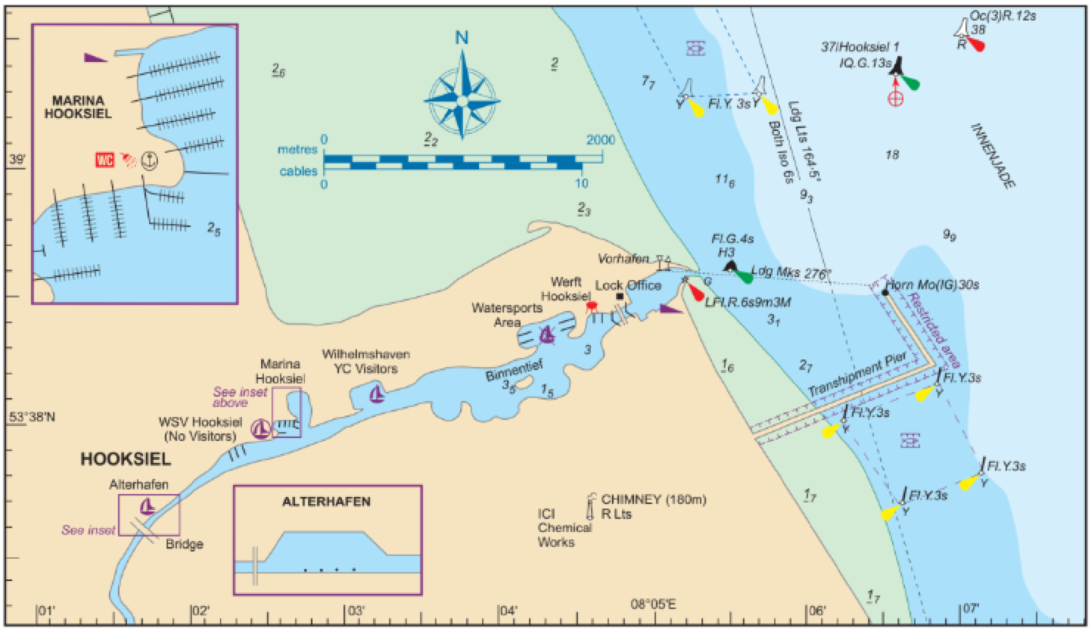
For lock and bridge opening times, see: www.wangerland.de/Media/Attraction/Schleuse-Hooksiel.(open:Schleusenzeiten). Secure well in lock; pay at control office €1·00/ m (each way).

LIGHTS AND MARKS Ldg lts 164·5°, as chartlet. Conspic chys of chemical works and oil refinery SSE of lock. ☆ L Fl R 6s on dayglo R pile on S mole and street lamp on N mole. R/G tfc lts at lock.

COMMUNICATIONS (Code 04425) Coast Guard (0421) 5550555; (0190) 116047; Police 269; 1302; Brit Consul (030) 204570; (04421) 2080; Dr 1080; HM/Lockmaster, no VHF, ☎430.
Jade River VTS, inbound, VHF Ch 63, Ch 20 from buoy 33.

FACILITIES **Werft BY** ☎95850, (25t). **Wilhelmshaven YC** ☎ 04421 22983, 50 berths () €1·00. **Alter Hafen** berth on quays, first night free then €1·00. **Marina Hooksiel** ☎958050 hafenmeister@wangerland.de. www.wangerland.de/media/attraction/marina-hooksiel. €1·00p/m, 1st night free.

Town ✕ (Wilhelmshaven and Bremen). **Wangersiel**, 3·4M NNW (53°41'·0N 8°01'·5E) has small marina ☎(04463) 1515, ✕.



Germany

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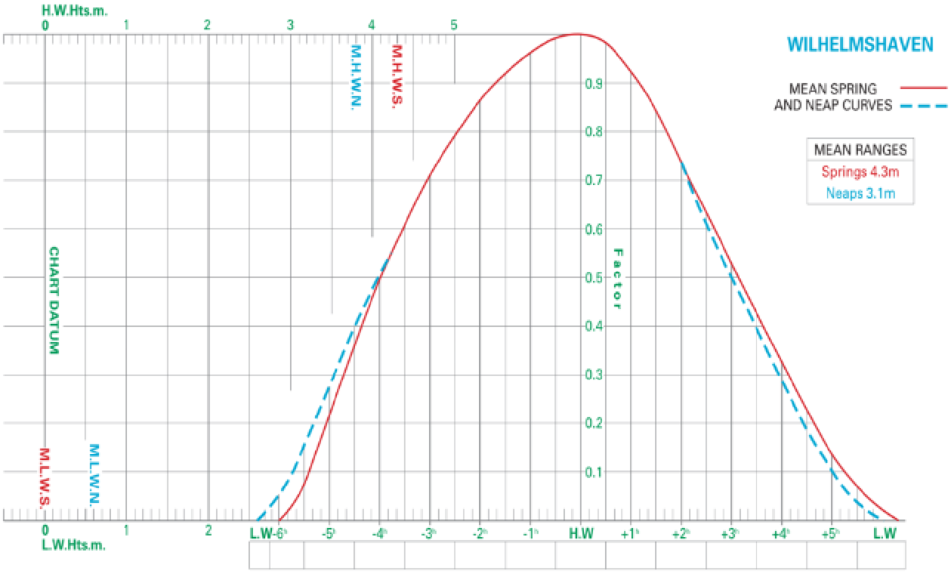
AREA 15 – Germany



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