N05-A Pipeline design

Basic Design Report

DOCUMENT NUMBER:

N05A-7-10-0-70029-01

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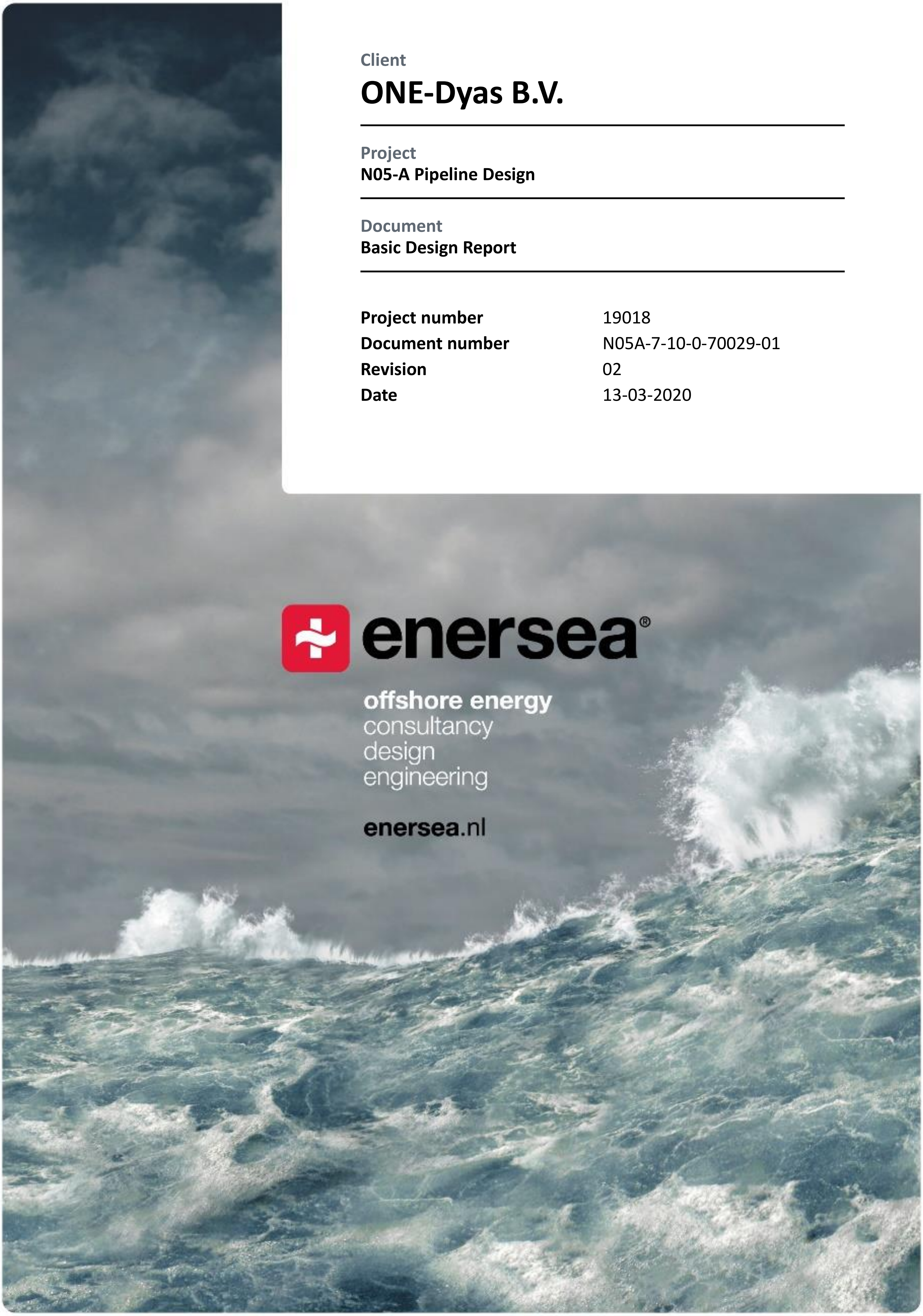

Client

ONE-Dyas B.V.

Project

N05-A Pipeline Design

Document

Basic Design Report

Project number	19018
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01	For client comments	31-01-2020				
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Table of content

1. Introduction

1.1. Project Introduction

One-Dyas plans to develop a successfully drilled well in block N05-A of the North Sea Dutch Continental Shelf. More wells will be drilled at this location through the same jacket. It is planned to develop the wells by installing a platform and a gas export pipeline with a connection to the NGT pipeline @KP142.1. The approximate length of the pipeline is 14.7 km.

In addition, a power cable will be installed from the Riffgat Windpark to the N05-A platform.

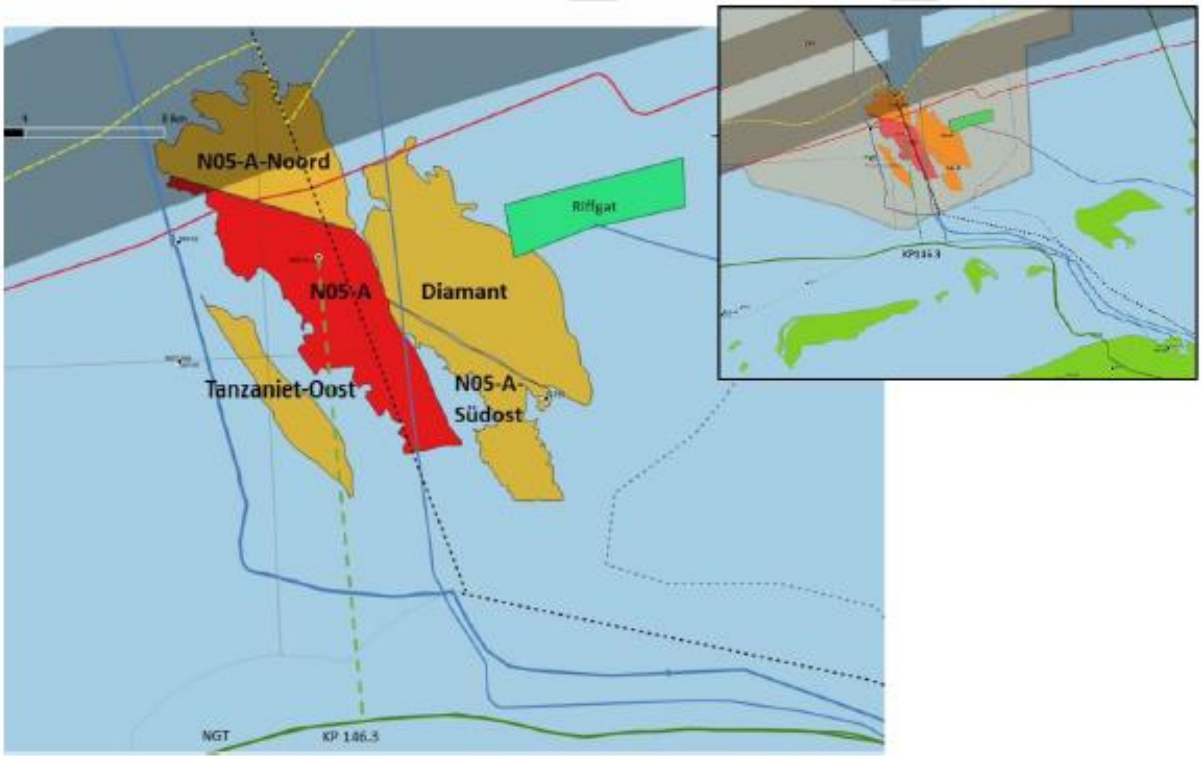


Figure 1, N05A Field layout

1.2. Purpose and Scope Document

The Basic Design Report documents the results of the calculations for the flowline, including:

- Wall Thickness analysis
- On-Bottom Stability analysis
- Buckling & Collapse analysis
- Static & Dynamic Free Span analysis
- Bottom roughness analysis
- Upheaval buckling analysis

1.3. System of Units

All dimensions and calculations shall be documented using the International System of Units (SI) unless noted otherwise.

1.4. Abbreviations

BoD = Basis of Design

FEA = Finite Element Analysis

LAT = Lowest Astronomical Tide

MTO = Material Take Off

TB = Target Box

TOP = Top of Pipe

VIV = Vortex Induced Vibrations

WD = Water Depth

1.5. References

1.5.1. Regulations, Codes, Standards and Guidelines

[1] NEN3656:2015 “Eisen voor stalen buisleidingsystemen op zee” December 2015

[2] DNV-OS-F101. “Submarine Pipeline Systems.” October 2010.

[3] DNV-RP-F105. “Free Spanning Pipelines.” June 2017.

[4] DNV RP-F107. “Risk Assessment of Pipeline Protection.” May 2017.

[5] DNV-RP-F109. “On-Bottom Stability Design of Submarine Pipelines.” May 2017

[6] DNV-RP-F110. “Global Buckling of Submarine Pipelines” April 2018.

[7] DNV-RP-C203. “Fatigue Design of Offshore Steel Structures.” April 2016.

[8] DNV-RP-C204. “Design against accidental loads.” November 2014.

[9] 21. American Lifelines Alliance. “Guidelines for the Design of Buried Steel Pipe.

ASCE July 2001.

[10] ASME Boiler and Pressure Vessel Code. Section VIII Rules for Construction of Pressure vessels. Division 1. July 2013.

[11] Design of Submarine Pipelines Against Upheaval Buckling OTC 6335 by A.C. Palmer e.a. May 1990

[12] DNVGL-RP-F114 – “Pipe-soil interaction for submarine pipelines”, May 2017

1.5.2. Company Engineering Standards and Specifications

1.5.3. Project Reference Documents

[i] N05A-7-10-0-70028-01-02 – “Basis of Design Flowline”

[ii] N05A-7-10-0-70031-01-01 – “Route Selection Report”

[iii] N05A-7-51-0-72510-01-04 – “Overall field layout drawing”

[iv] N05A-7-50-0-72019-01-02 – Approach drawing @N05A

[v] N05A-7-10-0-70032-01-02 – “Approach drawing @NGT

[vi] N05A-7-10-0-70027-01-03 – “Flow Assurance Design Report”

[vii] N05A-7-10-0-70036-01-01 – “Flow Assurance Design report - Transient Analysis”

[viii] N05A-7-10-0-70035-01-01 – “On Bottom Stability Analysis Design Report”

[ix] Metocean Criteria for the N05A Platform – 181892_1_R2

[x] Metocean criteria for the N05A Platform Side Tap – 191146_1_R2

[xi] N5A VC-C-7 S-3 0300m CID

[xii] N5A VC-P-3 S-2 0405m CID

[xiii] N5A VC-P-8 S-4 0240m CID

[xiv] No5A-7-10-0-70030-01-02 Risk assessment dropped object analysis

[xv] 19018-10-PRE-01001-02-02 N05-A Progress meeting + Minutes of meeting, 2019-11-07

1.6. Holds

2. Summary

This document reports on the basic design stage of the flowline from the N05-A platform to the tie-in with the NGT pipeline. This includes:

- Wall Thickness analysis
- On-Bottom Stability analysis
- Buckling & Collapse analysis
- Static & Dynamic Free Span analysis
- Bottom roughness analysis
- Upheaval buckling analysis

The wall thickness analysis showed that a wall thickness of approximately 15mm would be required. It was chosen to select a wall thickness of 20.62 mm. The extra steel weight will assist the stability of the pipeline, which is further documented in a separate report (ref. [viii]).

The maximum allowable spans following from buckling & collapse and static and dynamic span analyses are determined for three depths: 8, 17, and 26 m (LAT), which corresponds to the water depths at the end, approximate middle, and start of the pipeline, respectively.

Criterion	8 m	17 m	26 m
B&C – bending and external pressure – Maximum span	62.6m (install/hydrotest) 76.7m (operation)	59.2m (install/hydrotest) 53.3m (operation)	56.0m (install/hydrotest) 43.8m (operation)
Static free span	66.3m (install/hydrotest) 91.3m (operation)	63.1m (install/hydrotest) 61.4m (operation)	60.1m (install/hydrotest) 52.1m (operation)
Dynamic free span: in-line VIV	21.9m (install/hydrotest) 20.9m (operation)	22.9m (install/hydrotest) 21.6m (operation)	25.2m (install/hydrotest) 23.7m (operation)
Dynamic free span: cross-flow VIV	36.0m (install/hydrotest) 35.3m (operation)	33..0m (install/hydrotest) 30.8m (operation)	37.2m (install/hydrotest) 30.7m (operation)

The bottom roughness analysis showed that the as-surveyed seabed will result in 1 span that is of unacceptable length during the installation phase. This span (27m) is present at KP0.4 at 26 m of water depth (section 9.3). The span criterion is based on in-line VIV, which could be mitigated if the pipeline dynamic response is investigated in the detail design phase.

Finally, an analytical upheaval buckling analysis was performed to determine a relation between the sand cover, imperfection heights and vulnerability to buckling under operational conditions (section 8.1).

3. Design Parameters

This chapter describes the design data to be considered for the pipeline (incl. spool pieces near the riser and the hot tap) from the new N05A-Platform to the NGT pipeline.

3.1. Pipe Data

The basic line pipe design and spool piece data to be considered in the analysis for the export gas line are presented in Table 3-1. Steel material properties considered in the design are presented in Table 3-2.

Property	
Product transported	Natural gas (dry)
Design life (years)	25
Approx. length (km)	14.7
Material grade	L360 NB
Manufacturing process	HFIW
Pipe outside diameter (“)	20”
Pipe outside diameter (mm)	508
Pipe internal diameter	466.76
Wall thickness (mm)	20.62 (Sch60)
Wall thickness tolerance (%)	7.3
Wall thickness tolerance (mm)	+/- 1.5mm
Internal corrosion allowance (mm)	3
Anti-corrosion coating	3LPP
Anti-corrosion coating thickness (mm)	3
Anti-corrosion coating density (kg/m^3)	930
(Concrete) weight coating thickness (mm)	N.A
concrete weight coating density (kg/m^3)	3300
Minimum hot bend radius (mm)	2540 (5D)

Table 3-1 Pipeline data

Property	
Material	L360NB
Density (kg/m3)	7850 kg/m^3
Specified Minimum Yield Strength at 20°C (MPa)	360
Specified Minimum Yield Strength at 50°C (MPa)	360
Specified Minimum Tensile Strength (MPa)	460
Young’s modulus (Pa)	2.07×10^{11}
Poisson ratio (-)	0.3
Thermal expansion coefficient (m/m·ºC)	1.17×10^{-5}

Table 3-2 Material properties

3.2. Process Conditions

Table 3-3 presents the pipeline and spool design process parameters considered in the analysis.

Property	Export gas line
Design pressure	111.1 bar(g)
Operating pressures	95 bar(g)
Design temperature (min / max)	-20 °C / 50 °C
Operating temperature (min / max)	1 / 43 °C
Ambient (air / surface) temperature	-6.8°C / +24.2 °C
Content density (arrival, nominal operation)	88.7 / 96.1 kg/m^3
Design flowrate (min/max)	0.14 / 6.0 MMNm3/d

Table 3-3 Process design parameters

Figure 3-1 shows the operational thermal profile along the pipeline, ref. [vii] .

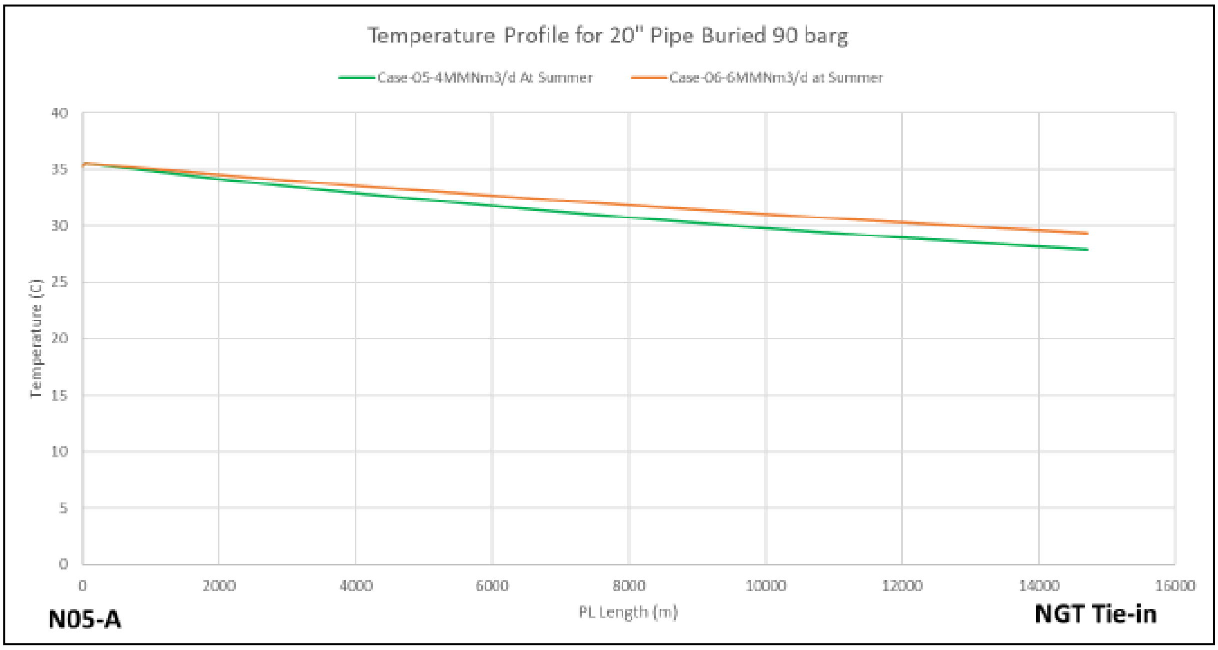


Figure 3-1 Operational thermal profile, nominal operation in summer

3.3. Coating Material Properties

Typical material properties of the coating are given in Table 3-4.

Property	Value
Anti-corrosion material type	3LPP
Anti-corrosion coating density	930 kg/m^3
Anti-corrosion coating thermal conductivity	0.22 W/m°C
Anti-corrosion coating specific heat capacity	2000 J/kg°C

Table 3-4 Steel pipe coating material properties

3.4. Flange Properties

Table 3-5 presents the flange classes and main characteristics. The flange loads will be checked by using the ASME BPVC [10] flange integrity check. Note that table 3-5 is applicable to all flanges on the flowline and spool pieces.

Property	**Export gas line**
Flange rating	ANSI/ASME Class 1500
Flange type	RTJ Swivel / Weld Neck
Weld end thickness	20.62mm

Table 3-5 Flange properties

3.5. Environmental Data

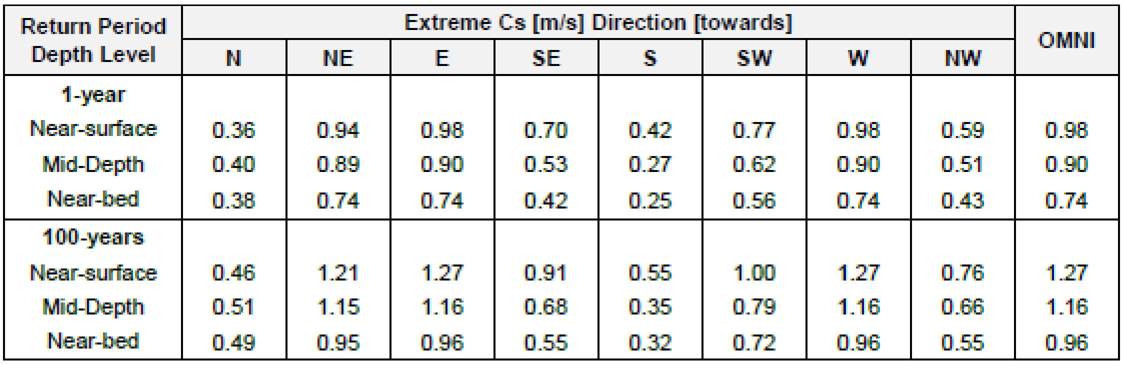
For the design of the pipeline, environmental data has been taken from Ref. [ix] and [x]. Where Ref [ix] contains the metocean data for the platform (water depth 26 m); Ref [x] contains the Metocean data for the NGT tie-in (water depth 8 m) target box. Tables 3-6 to 3-11 present the relevant metocean data for the 1 and 100 year design conditions for the applicable locations.

The shallow water depths encountered along the pipeline route pose problems in determining the hydrodynamics loads encountered by the pipeline. Enersea has developed a calculation method based on Stokes 5th order wave theory, however in shallow waters this method is not applicable. The metocean reports [ix, x] provide a wave orbital velocity at 1 m above the sea bed, denoted as U_{1m}. For the water depth of 26 m, the Stokes theorem is at the limit of applicability and produces wave velocity approximately 10% higher than provided in the metocean report for this depth. To remain conservative, the higher velocity has been used for the location of 26 m water depth.

In order to establish environmental conditions at an intermediate pipeline location with a water depth of 17m, current and wave particle velocities have been averaged. This approach has been agreed with One-Dyas [xv].

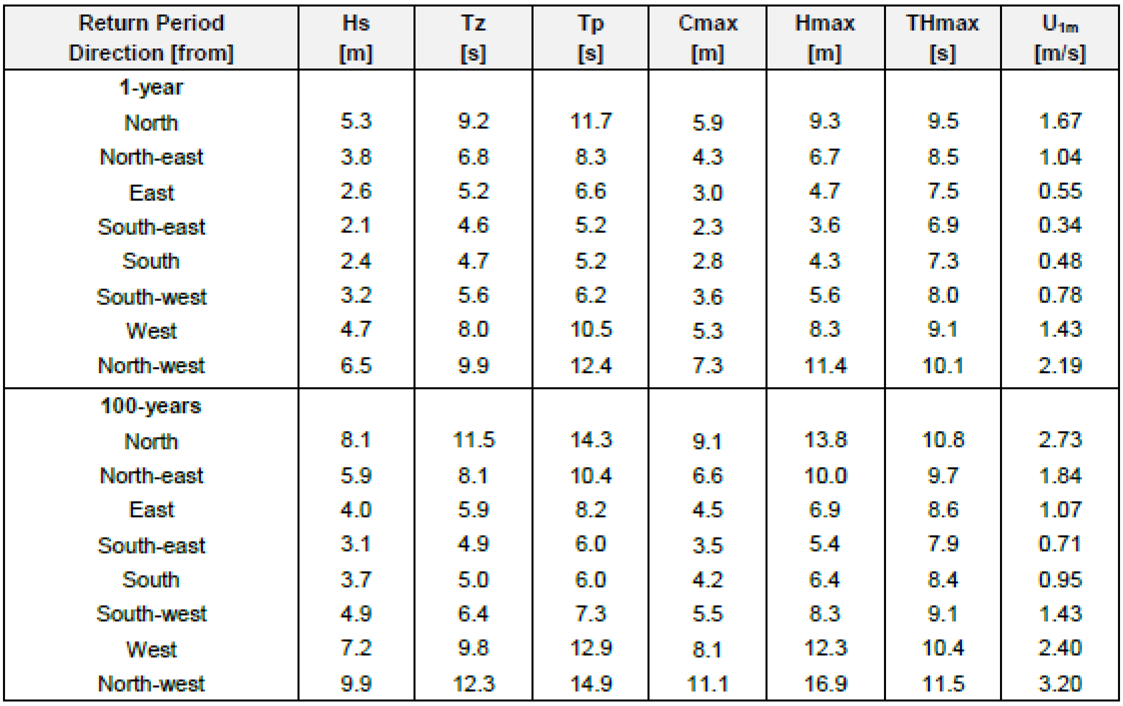
Property	**1-year return period**	**100-year return period**
Positive surge (m) @26m	1.58	3.04
Negative surge (m)	-1.02	-1.79
LAT with respect to MSL (m)	-1.41	
HAT with respect to MSL (m)	1.31	

Table 3-6 Near platform extreme water level data [ref. II]



Return Period Depth Level	Extreme Cs [m/s] Direction [towards]								OMNI
	N	NE	E	SE	S	SW	W	NW	
1-year									
Near-surface	0.36	0.94	0.98	0.70	0.42	0.77	0.98	0.59	0.98
Mid-Depth	0.40	0.89	0.90	0.53	0.27	0.62	0.90	0.51	0.90
Near-bed	0.38	0.74	0.74	0.42	0.25	0.56	0.74	0.43	0.74
100-years									
Near-surface	0.46	1.21	1.27	0.91	0.55	1.00	1.27	0.76	1.27
Mid-Depth	0.51	1.15	1.16	0.68	0.35	0.79	1.16	0.66	1.16
Near-bed	0.49	0.95	0.96	0.55	0.32	0.72	0.96	0.55	0.96

Table 3-7- Near platform design current data [ref. II]

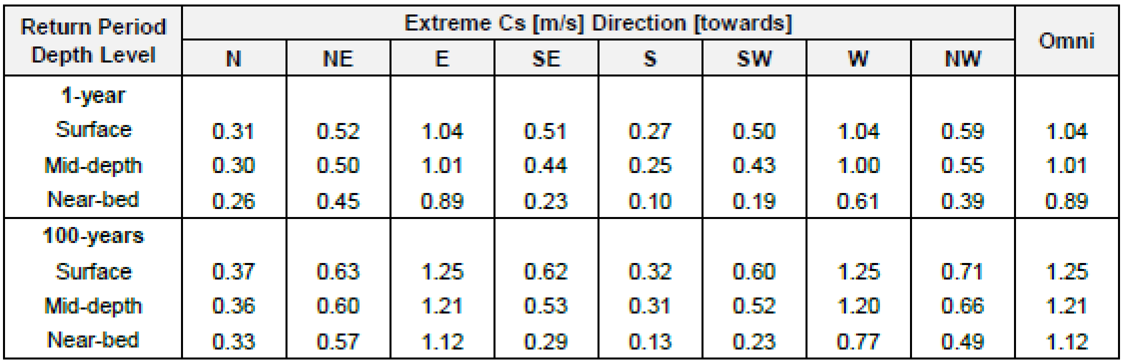


Return Period Direction [from]	Hs [m]	Tz [s]	Tp [s]	Cmax [m]	Hmax [m]	THmax [s]	U_{1m} [m/s]
1-year							
North	5.3	9.2	11.7	5.9	9.3	9.5	1.67
North-east	3.8	6.8	8.3	4.3	6.7	8.5	1.04
East	2.6	5.2	6.6	3.0	4.7	7.5	0.55
South-east	2.1	4.6	5.2	2.3	3.6	6.9	0.34
South	2.4	4.7	5.2	2.8	4.3	7.3	0.48
South-west	3.2	5.6	6.2	3.6	5.6	8.0	0.78
West	4.7	8.0	10.5	5.3	8.3	9.1	1.43
North-west	6.5	9.9	12.4	7.3	11.4	10.1	2.19
100-years							
North	8.1	11.5	14.3	9.1	13.8	10.8	2.73
North-east	5.9	8.1	10.4	6.6	10.0	9.7	1.84
East	4.0	5.9	8.2	4.5	6.9	8.6	1.07
South-east	3.1	4.9	6.0	3.5	5.4	7.9	0.71
South	3.7	5.0	6.0	4.2	6.4	8.4	0.95
South-west	4.9	6.4	7.3	5.5	8.3	9.1	1.43
West	7.2	9.8	12.9	8.1	12.3	10.4	2.40
North-west	9.9	12.3	14.9	11.1	16.9	11.5	3.20

Table 3-8 Near platform design wave data [ref. II]

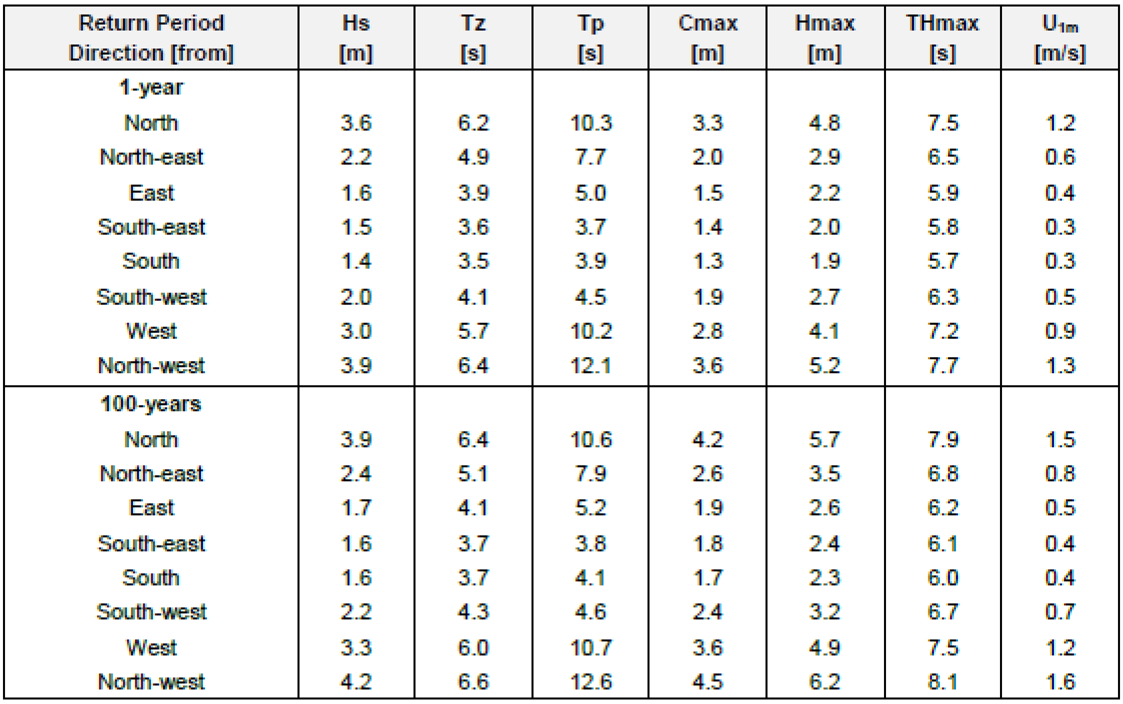
Property	1-year return period	100-year return period
Positive surge (m) @8m	1.48	2.72
Negative surge (m)	-0.90	-1.26
LAT with respect to MSL (m)	-1.89	
HAT with respect to MSL (m)	1.61	

Table 3-9 Near tie-in extreme water level data [ref. III]



Return Period Depth Level	Extreme Cs [m/s] Direction [towards]								Omni
	N	NE	E	SE	S	SW	W	NW	
1-year									
Surface	0.31	0.52	1.04	0.51	0.27	0.50	1.04	0.59	1.04
Mid-depth	0.30	0.50	1.01	0.44	0.25	0.43	1.00	0.55	1.01
Near-bed	0.26	0.45	0.89	0.23	0.10	0.19	0.61	0.39	0.89
100-years									
Surface	0.37	0.63	1.25	0.62	0.32	0.60	1.25	0.71	1.25
Mid-depth	0.36	0.60	1.21	0.53	0.31	0.52	1.20	0.66	1.21
Near-bed	0.33	0.57	1.12	0.29	0.13	0.23	0.77	0.49	1.12

Table 3-10 Near tie-in design current data [ref. III]



Return Period Direction [from]	Hs [m]	Tz [s]	Tp [s]	Cmax [m]	Hmax [m]	THmax [s]	U_{1m} [m/s]
1-year							
North	3.6	6.2	10.3	3.3	4.8	7.5	1.2
North-east	2.2	4.9	7.7	2.0	2.9	6.5	0.6
East	1.6	3.9	5.0	1.5	2.2	5.9	0.4
South-east	1.5	3.6	3.7	1.4	2.0	5.8	0.3
South	1.4	3.5	3.9	1.3	1.9	5.7	0.3
South-west	2.0	4.1	4.5	1.9	2.7	6.3	0.5
West	3.0	5.7	10.2	2.8	4.1	7.2	0.9
North-west	3.9	6.4	12.1	3.6	5.2	7.7	1.3
100-years							
North	3.9	6.4	10.6	4.2	5.7	7.9	1.5
North-east	2.4	5.1	7.9	2.6	3.5	6.8	0.8
East	1.7	4.1	5.2	1.9	2.6	6.2	0.5
South-east	1.6	3.7	3.8	1.8	2.4	6.1	0.4
South	1.6	3.7	4.1	1.7	2.3	6.0	0.4
South-west	2.2	4.3	4.6	2.4	3.2	6.7	0.7
West	3.3	6.0	10.7	3.6	4.9	7.5	1.2
North-west	4.2	6.6	12.6	4.5	6.2	8.1	1.6

Table 3-11 Near tie-in design wave data [ref. III]

3.6. Marine Growth

The following marine growth has been assumed, in accordance with NEN 3656 [1]

From	To	Thickness	Density
+2m LAT	Seabed	50mm	1300 kg/m3

Table 3-12 Assumed marine growth properties

3.7. Geotechnical Data

Three lab result reports , Refs [xi] through [xiii], present properties of soil samples taken. These classify the soil as fine to medium sand. The soil properties are listed in Table 3-13, data has been taken from the lab reports and recommended values as per NEN3656 table H.1 ref[1] based on the soil description as presented in. A SBP data example of the north end of the proposed route is presented in figure 3-14.

Soil type	Applicable area	Submerged Unit Weight (kN/m³)	Angle of internal friction (°)
Medium sand (measured)		10.2-10.5	32.5-34.9
Medium sand	Pipe on surface	10	32.5
	Trench backfill	8.5	28
Rock dump	Crossing / Tie-in	10	40

Table 3-13 Assumed soil geotechnical properties

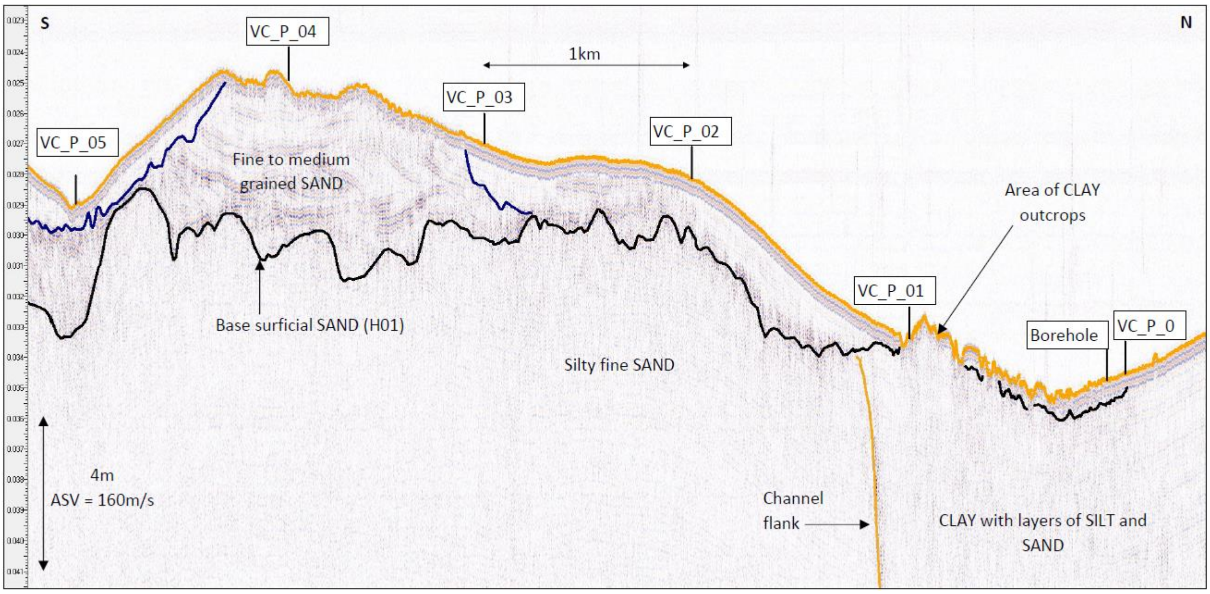


Figure 3-2 Soil profile from KP 0.0 to KP 6.0

4. Pipeline Route Data

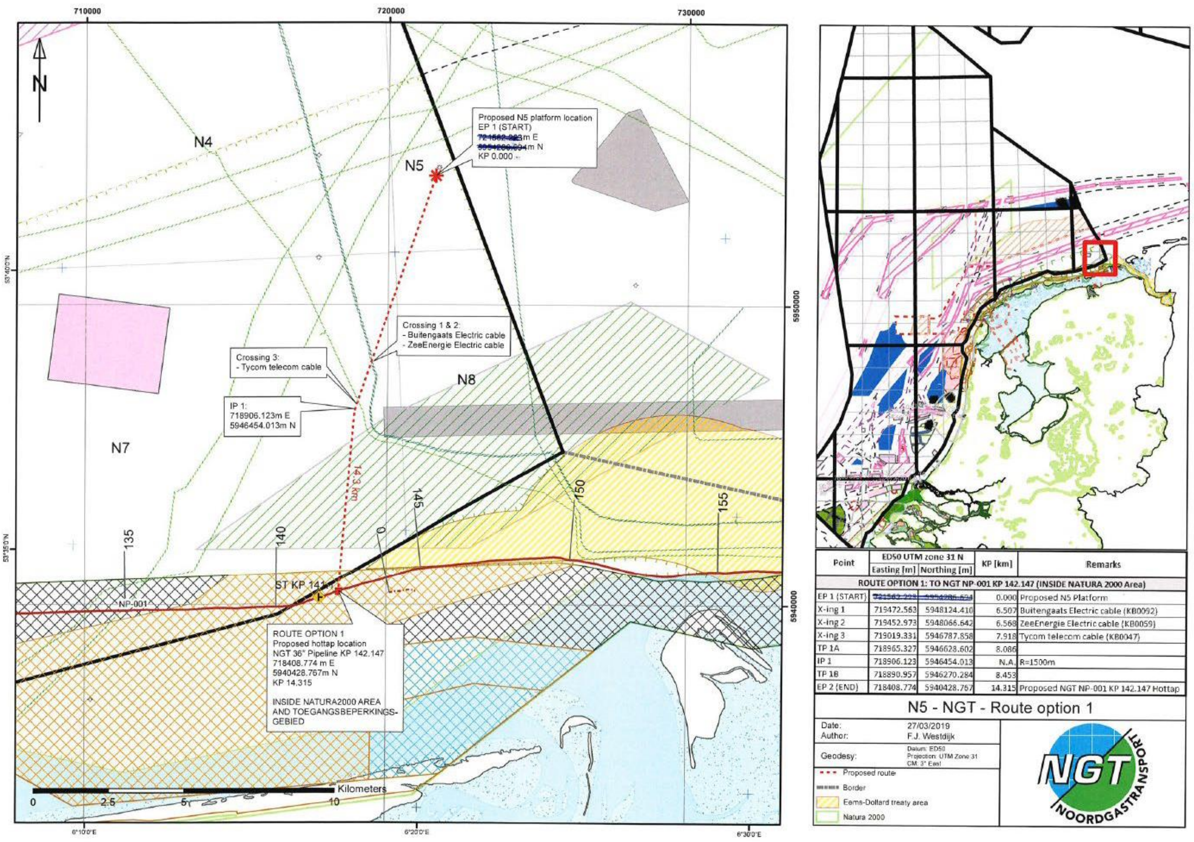
This chapter deals with the pipeline route data describing the starting and end point of the pipeline, the used coordinate system, pipeline route coordinates and key facilities as well as the route bathymetry and contacts detected along the pipeline route. Based on this info the most optimal pipeline routing has been selected (ref. [ii].

4.1. General

The new pipeline to be installed originates at the new N05-A Platform and terminates at the NGT platform via a dedicated tie-in connection. The pipeline length is approx. 14.7 km.

An installation of the pipeline on top of the seabed has been indicated as an opportunity. The final cover height, or required concrete coating thickness will be determined based on the results of a risk assessment study [xiv], the on-bottom stability analysis [viii] and the upheaval buckling analysis.

Two pipeline/cable crossings are foreseen along the route. An overview of the field lay out is given in Figure 4-1.



Point	ED50 UTM zone 31 N		KP [km]	Remarks
	Easting [m]	Northing [m]		
ROUTE OPTION 1: TO NGT NP-001 KP 142.147 (INSIDE NATURA 2000 Area)				
EP 1 (START)	[redacted]	[redacted]	0.000	Proposed N5 Platform
X-ing 1	719472.563	5948124.410	6.507	Buitengaats Electric cable (KB0092)
X-ing 2	719452.973	5948066.642	6.568	ZeeEnergie Electric cable (KB0059)
X-ing 3	719019.331	5946787.858	7.918	Tycom telecom cable (KB0047)
TP 1A	718965.327	5946628.602	8.086	
IP 1	718906.123	5946454.013	N.A.	R=1500m
TP 1B	718890.957	5946270.284	8.453	
EP 2 (END)	718408.774	5940428.767	14.315	Proposed NGT NP-001 KP 142.147 Hottap

N5 - NGT - Route option 1

Date: 27/03/2019
Author: F.J. Westdijk
Geodesy: Datum: ED50
Projection: UTM Zone 31
CM: 3° East

Figure 4-1 Overview N05A platform to the tie-in location

4.2. Coordinate System

The parameters of the geodetic system to be used for horizontal positions are listed in Table 4-1.

Item	Value
Datum	European Datum 1950 (ED50)
Projection	ED50 / UTM zone 31 N
Ellipsoid name	International 1924
Semi major axis	6 378 388 m
Inverse flattening	297.000
Central Meridian	03º00"00' E
Latitude of Origin	00º00"00' N
False Northing	0 mN
False Easting	500 000 mE
Scale Factor	0.9996

Table 4-1: Geodetic parameters

The vertical position is given relative to the Lowest Astronomical Tide (LAT).

4.3. Key Facility Coordinates

The following platform and tie in locations have been derived from Ref. [ii] and are presented in Table 4-2.

Item	Northing (m)	Easting (m)
N05A Platform target box	5 954 608	721 622
NGT target box	5 940 549	718 738
NGT hot tap location KP142.1	5 940 532	718 766
Water depth at N05A Platform	26 m LAT	
Water depth at NGT hot tap	9.8 m LAT	

Table 4-2 Key Facility coordinates

4.4. Bathymetry

Figure 4-3 shows the bathymetry along the surveyed flowline route. The water depths recorded during survey along the proposed N05-A platform and the NGT pipeline hottap location ranges between 9.8 m LAT and 26.4 m LAT.

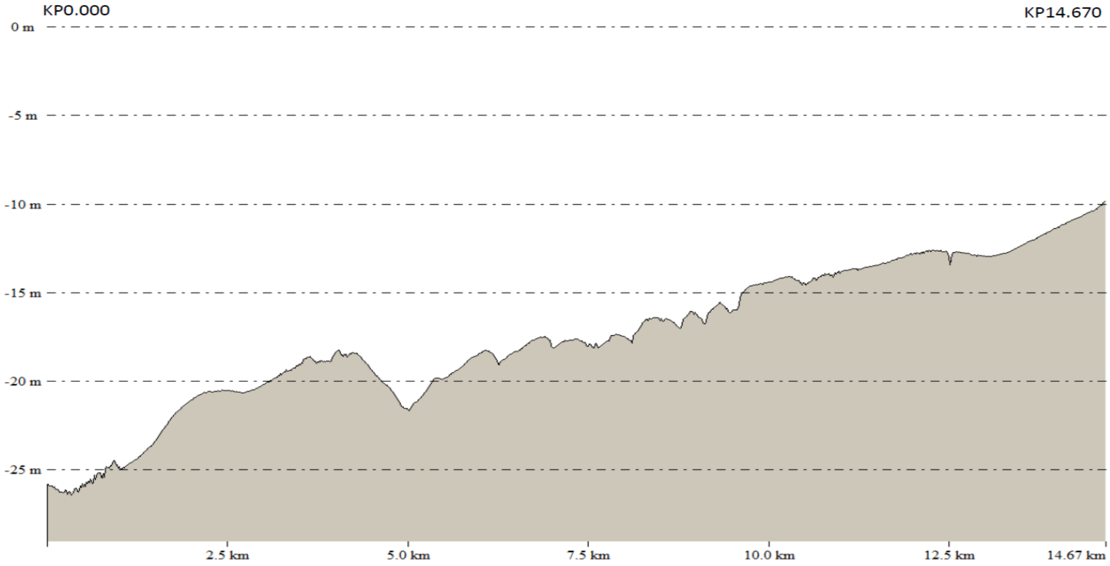


Figure 4-3 Seabed profile along pipeline route from P11-Unity Platform to Wye

4.5. Side Scan Sonar Contacts & Magnetometer Anomalies

Ref. [5] describes the seafloor sediments across the N05-A to the proposed NGT hottap location survey area to consist of a top layer of fine to coarse sand, with occasional areas of coarse sand and clay with gravel and shell fragments. Photographs taken along the proposed route show the presence of small ripples covering the majority of the seabed within the survey corridor area.

Numerous boulders and items of debris are observed in the survey area. Most of the boulders occur in the north of the survey area and coincide with areas of clay exposure.

4.5.1. Magnetometer Anomalies

A total of 241 magnetic anomalies (appendix A) were picked within the surveyed N05-A platform to the 36” NGT Tie-in and N05-A platform to Riffgat Tie-in route corridor. Most of these anomalies can be attributed to unknown identified seabed features the following seabed infrastructures are known, one (1) pipeline and four (4) cables. However, one (1) unknown linear feature.

The following existing pipelines and cable are detected:

- 36” Pipeline from L10-AR to Uithuizen
- Tycom Telecom cable
- Buitengaats Power cable
- Zeeenergie Power cable
- Norned Power cable

4.5.2. Side Scan Sonar Contacts

Eight-Hundred-Thirty (830) side scan sonar contacts were observed within the route survey. Most of the contacts are boulders located around the N05-A platform and stretching to the east side to Riffgat, besides the bolders the following contacts are found, twenty-six (26) debris items, two (2) wrecks.

4.6. Pipeline and Cable Crossings

The following crossings along the pipeline route are envisaged:

Infrastructure Name	KP	Northing (m)	Easting (m)
Buitengaats Electric cable	6.412	719 346	5 948 729
ZeeEnergie Electric cable	6.487	719 327	5 948 655
Tycom Telecom Cable Hunmanby GAP - Eemshaven	8.180	718 915	5 947 014

*) The N05A Pipeline will be connected to the NGT Pipeline with a Hot tap. This hot tap is not part of the scope of the design report.

4.7. Approach

Near the platform a T-piece will be installed including 2 ball valves for the purpose of a future pipeline connection. At the NGT tie-in location 2 ball valves and a check valve will be placed for tie-in purposes. Figures 4-4 and 4-5 present an overview of respectively the platform and the tie-in location.

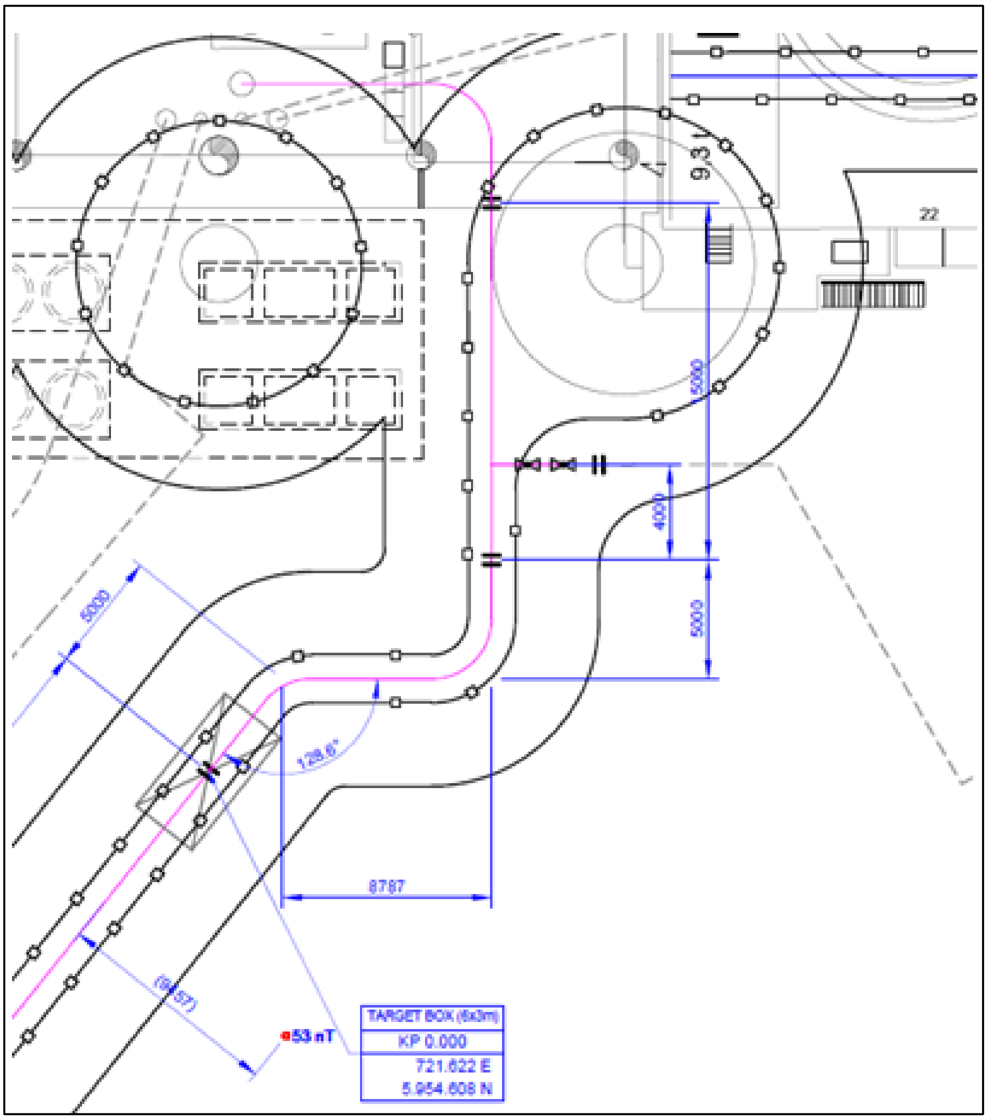


Figure 4-4 approach layout near the platform

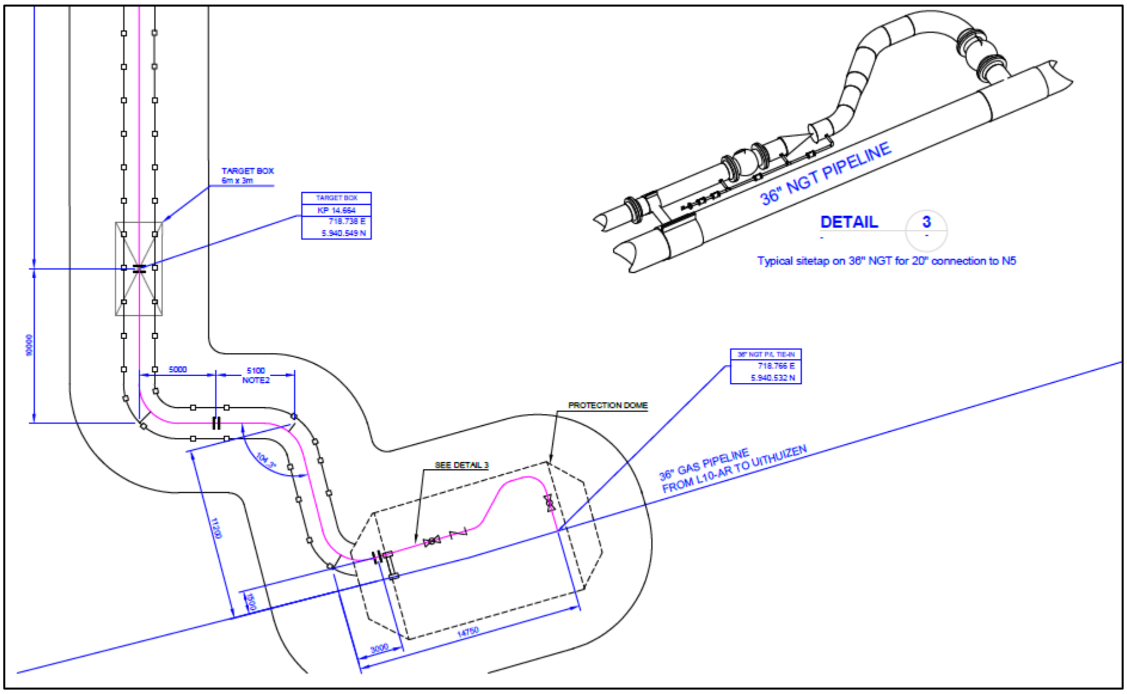


Figure 4-5 approach layout near the tie-in

5. Stress Criteria & Load Factors

5.1. Stress Criteria

Stresses in the flowline will be assessed according NEN 3656 (Ref. [1])
The analysis will account for the load history of the pipe over the design life by considering the following three load cases:

- Installation
- Hydrotest
- Operational

Considering the design cases listed above the following design loads will be considered when performing the stress analysis, see Table 5-1. The hydrodynamic loads for pipeline stability and maximum span are included via analytical calculations, see chapters 6 and 7.

Load	**Installation**	**Hydrotest**	**Operation**
Pressure	N/A	Hydrotest Pressure	Operational Pressure
Temperature	Seawater Temperature	Seawater Temperature	Operational Temperature
Internal Fluid	Seawater	Seawater	Product Filled
Wall Thickness	Nominal	Nominal	Nominal / Fully corroded
Hydrodynamic Loads	1-year wave + 1-year current	1-year wave + 1-year current	100/10-year wave + 10/100-year current

Table 5-1 Design loads

Calculated equivalent stresses for the various design conditions will be checked against the allowable stress values, as per NEN3656 (Ref. [1]), see Table 5-2.

Case	**Load Combination As Per NEN3656 Table 3.**	**Limit Stress**	**Allowable Equivalent Stress** (L360NB)
Installation	LC1	$R_{e(\theta)} / \gamma_m$	327 MPa
Hydrotest	LC4	$0.85\ (R_e + R_{e(\theta)}) / \gamma_m$	556 MPa
Operation (Nominal / Corroded)	LC4	$0.85\ (R_e + R_{e(\theta)}) / \gamma_m$	556 MPa

Table 5-2 Applied stress limits

Where:

Re = specified minimum yield strength at 20ºC (N/mm^2).

$R_{e(\theta)}$ = the yield strength of the material at design temperature.

γ_m = material factor (for steel 1.1).

5.2. Load Factors

All design loads applied will be factored as per the requirements of NEN 3656 (Ref. [1]), see Table 5-3.

Loads	**Load factors for load combinations (a)**								
Load combinations	LC 1	LC 2	LC 3	LC 4	LC 5	LC 6	LC 7a	LC 7b	LC 8
Internal pressure (design pressure)	-	1.25	-	-	-	-	1.0		1.0
Internal pressure (In combination)	-	-	-	1.15	1.15	-	-	1.0	1.15
Internal pressure (max. Incidental pressure)	-	1.10	-	-	-	-	-		1.1
Temperature differences (c g)	1.0	-	-	1.10	1.10	-	1.0	1.0	-
Soil parameters (d)	-	-	(d)	(d)	(d)	-	-	Low	-
Forced deformation (e)	-	-	1.1	1.1	1.1	1.1	-		-
Own weight	1.1	-	1.1	1.1	1.1	1.1	1.0		1.0
(Possible) coating (h)	1.2	-	1.2	1.2	1.2	1.2	1.0	1.2	1.0
Pipe contents (h)	1.1	-	1.1	1.1	1.1	1.1	1.0	1.1	1.0
Installation loads (f)	1.1	-	1.10	-	-	1.1	-		-
Hydrostatic pressure	1.1	-	1.1	1.1	1.1	1.1	1.0	1.1	
Marine growth (h)	-	-	1.2	1.2	1.1	-	1.0	1.0	1.0
Hydrodynamic forces	1.1	-	1.2	1.2	1.1	1.1	1.0	1.2	1.0

(a)	If a load has a favorable influence on the considered case this will not be considered if the load is variable and for a permanent load a multiplication factor of 0.9 is applied.
(b)	The maximum incidental pressure does not need to be checked separately however must be ascertained by the pressure control system.
(c)	During calculations of stress variations caused by temperature differences the highest and lowest occurring operation temperature should be considered. The displacements loads and moments exerting on connected equipment and/or structures are to be considered based on the design temperatures i.e. the temperature difference between the installation temperature and the maximum operational temperature.
(d)	Reference is made to ref. [1] – K.4 to determine load spreading factors
(e)	Forced deformations can be caused by: settling differences trench roughness execution sacking differences deformations due to prevented thermal expansion distortions in horizontal drilling and bottom-tow installation.
(f)	Examples of installation loads are those applied during pipelay tie-ins trenching landfalls and HDD etc.
(g)	Combined with measurements.
(h)	In the stability check (BC 7b) the most unfavorable combination must be chosen. If necessary divide by the relevant factor.

Table 5-3 Load factors

A description of the load combinations is shown below;

LC 1: Installation

LC 2: Only internal pressure, operating pressure, incidental pressure

LC 3: External load with zero internal pressure

LC 4: External load with internal pressure and temperature difference

LC 5: Variable load (primarily static load, e.g., temperature changes and pressure)

LC 6: External pressure, external load and internal pressure zero

LC 7a: Incidental load (other than internal pressure)

LC 7b: Incidental load (meteorological)

LC 8: Dynamic loading

5.3. Hydrodynamic Loads

Hydrodynamic loads arise from the relative motions between pipe and seawater. They consist of drag, lift and inertia forces.

The drag force F_D is given by:

$$F_D = C_D \cdot OD_{tot} \cdot \frac{1}{2} \cdot \rho \cdot V \cdot |V|$$

Where:

C_D = drag force coefficient (-)

OD_{tot} = total diameter of coated pipe (m)

ρ = mass density of surrounding fluid (kg/m^3)

V = velocity of the fluid normal to the pipe axis (m/s)

The lift force F_L is calculated by the following equation:

$$F_L = C_L \cdot OD_{tot} \cdot \frac{1}{2} \cdot \rho \cdot V^2$$

Where:

C_L = lift force coefficient (-)

The inertia force F_I is determined by the following equation:

$$F_I = \rho \cdot C_I \cdot \frac{\pi}{4} \cdot OD_{tot}^{\ 2} \cdot a$$

Where:

C_I = inertia force coefficient (-)

a = Fluid particle acceleration (m/s^2)

The recommended values of hydrodynamic coefficients for the on-bottom stability design as a function of the embedment of the pipeline are listed in Table 5-4.

Coefficient	Pipe embedment		
	0%	**10%**	**20%**
Drag	0.70	0.63	0.53
Lift	0.90	0.90	0.81
Inertia	3.29	2.80	2.30

Table 5-4 Overview hydrodynamic coefficients

Typically, the peak hydrodynamic load is experienced just after the peak wave particle velocity, due to the additional inertia contribution. As stated in Section 3.5, wave models are not used in the shallow water depths, but only the peak velocity from the metocean report. No information on the particle acceleration is provided, however. The contribution of the inertia term is typically <10% of the drag term at peak velocity. To be conservative, a 20% margin is added to the drag term.

6. Wall Thickness Analysis

Several phenomena are to be investigated prior to finalising the selected wall thickness. Elements to be taken into account:

- pressure containment;
- on-bottom stability;
- implosion;
- progressive plastic collapse;
- local buckling;
- bar buckling;

6.1. Pressure Containment

6.1.1. Design Condition

NEN 3656, states that for every load combination the design resistance (R_d) must be greater than or equal to the loading effect (S_d) or:

$$R_d \geq S_d$$

R_d is defined as:

$$R_d = R_{e(\Theta)} / \gamma_m$$

Where:

$R_{e(\Theta)}$ = yield strength of the material at design temperature (N/mm^2)

γ_m = material factor (1.1 for steel)

For load combination LC2 (internal pressure only), the equation for hoop stress can be expressed as:

$$\sigma_h = \frac{\gamma_p \cdot P_d \cdot (OD - t_{\min})}{2 \cdot t_{\min}}$$

Where:

S_h = hoop stress (N/mm^2)

γ_p = load factor as per Table 5-3 (-) => 1.25

Pd = design pressure (N/mm^2)

OD = outside diameter of steel pipe (mm)

t_{min} = minimum wall thickness (mm)

The selected wall thickness (t_{nom}) is then determined by:

$$t_{nom} = \left\{ \frac{t_{\min} + CA}{1 - f_{tol}} \right\}$$

Where:

CA = applicable corrosion Allowance (mm)

f_{tol} = fabrication tolerance (%)

Further to this, NEN 3656 specifies additional requirements for bends with a bending radius $R_b < 10$ OD, to adjust the hoop stress of straight pipe (torus effect).

$$S_h(bi) = \frac{2R_b - \frac{1}{2}OD}{2R_b - OD} \cdot S_h \quad \text{(for inside bend)}$$

$$S_h(bo) = \frac{2R_b + \frac{1}{2}OD}{2R_b + OD} \cdot S_h \quad \text{(for outside bend)}$$

6.1.2. Hydrostatic Testing

The hydrostatic testing of pipeline / riser systems has two objectives:

- verify the strength of the system
- verify that there are no leaks from the system

The test pressure, P_t, will be determined as per as per Section 10.18.3 of NEN 3656 (Ref. [1]).

$$P_{t.\min} = C_p \cdot P_d \cdot \frac{R_e}{R_{ev}}$$

Where:

C_p = pressure test coefficient (-) => 1.30 for gas lines; 1.25 for others

P_d = design operating pressure (N/mm^2)

R_e = minimum yield stress at 20 °C (N/mm^2)

R_{ev} = minimum yield stress at design temperature (N/mm^2)

The maximum hydrostatic test pressure is based on the weakest part of the pipeline/riser system to be tested. The pressure shall not exceed either $P_{t,\max}$ or $P_{T,mill}$, the mill test pressure. Respectively, these are defined as:

$$P_{t.\max} = \frac{2.R_e \cdot t_{\min}}{(OD - t_{\min})}$$

$$P_{T,mill} = 0.9 \cdot \frac{2 \cdot R_e \cdot t_{nom}}{OD}$$

Where:

$$t_{nom} = \left\{ \frac{t_{\min} + CA}{1 - f_{tol}} \right\}$$

Where:

t_{nom} = nominal wall thickness (mm)

t_{min} = minimum wall thickness (mm)

CA = applicable corrosion Allowance (mm)

f_{tol} = fabrication tolerance (%)

6.1.3. Results

An overview of the results of the wall thickness calculations is given in Table 6-1.

Property	**Inside 500 m**	**Outside 500 m**
Minimum WT (mm)	11.50	10.55
Minimum WT inside bend (mm)	12.13	11.14
Minimum WT outside bend (mm)	10.97	10.07
Nominal (with corrosion allowance) minimum WT (mm)	14.50	13.55
Nominal WT inside bend (mm)	15.13	14.14
Nominal WT outside bend (mm)	13.97	13.07
Selected minimum WT	20.62	20.62
Hoop stress (MPa)	232	212
Hoop stress inside bend (MPa)	244	224
Hoop stress outside bend (MPa)	221	203
Allowable stress at design temperature (MPa)	327	327
Minimum hydrotest pressure (barg)	144	144
Maximum hydrotest pressure (barg)	281	281
Mill test pressure (barg)	263	263

Table 6-1 Overview wall thickness analysis results

Reference is made to Appendix A for the detailed calculations.

6.2. On-Bottom Stability

The aim of the stability analysis is to verify that the submerged weight of the pipeline ensures lateral stability against environmental loading.

Reference is made to report “N05A-7-10-0-70035-01 N05A On Bottom Stability Analysis Design Report” (ref. [viii]) for detailed OBS analyses.

From this report it can be seen that in order to provide absolute stability during the pipeline lifetime, in which the 100-year storm conditions are applied (non-buried pipeline), an excessively thick concrete weight coating would be required (>> 500 mm). Relaxation of the displacement criterium to allow up to 10D displacement would require a minimal concrete weight coating of over 130 mm. As the determined pipeline displacements are for a single storm only, it cannot be guaranteed that the pipeline will settle in a final position. Hence the pipeline can displace even further during a next storm, potentially causing (too) high stresses/strain.

This, in combination with shallow water depths and installation limitations, results in the recommendation to bury the pipeline.

A buried pipeline is exposed to 1-year return period conditions, but still absolute stability cannot be guaranteed. However viable designs are possible when 0.5D - 10D displacements are allowed. As the timespan between the flooded lay of the pipe and trenching thereof will be minimum, it is deemed acceptable that for a buried pipeline, no additional weight coating is applied.

6.3. Implosion

6.3.1. External Overpressure

The collapse pressure p_c causing implosion (radial instability) can be determined using:

$$(P_c - P_e) \cdot (P_c{}^2 - P_p{}^2) = P_c \cdot P_e \cdot P_p \cdot 2 \cdot \delta_0 \cdot \frac{D_g}{t}$$

Where:

D_g = nominal diameter of pipe (mm)

P_c = critical external pressure for collapse (N/mm2)

P_e = critical external pressure for elastic deformation (N/mm^2)

P_p = critical external pressure for plastic deformation (N/mm^2)

P_L = actual external pressure (N/mm^2)

δ_0 = initial deformation (mm)

t = nominal wall thickness (mm)

$$D_g = \frac{1}{2} \cdot \{OD_{nom} - (OD_{nom} - 2 \cdot t_{min})\}$$

The critical external pressure for plastic deformation is calculated from:

$$P_p = \frac{2 \cdot R_e \cdot t}{D_{nom}}$$

The critical external pressure for elastic deformation is calculated from:

$$P_e = \frac{2 \cdot E}{1 - \nu^2} \cdot \left(\frac{t}{D_{nom}}\right)^3$$

Where:

ν = Poisson's ratio for elastic deformation (-) => 0.3

As a part of this the initial deformation is derived from:

$$\delta_0 = \frac{D_{\max} - D_{\min}}{D_{\max} + D_{\min}}$$

Where:

D_{max} = largest diameter of the ovalized pipe cross section

D_{min} = smallest diameter of the ovalized pipe cross section

The maximum allowable external pressure is defined as:

$$\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$$

Where:

$\gamma_{g,p}$ = load factor (-) => 1.05

γ_M = model factor (-) => 0.93

$\gamma_{m,p}$ = material factor (-) => 1.45

6.3.2. Bending Moment

In case of a bending moment on the pipe, the moment which will cause buckling is calculated from the plastic moment of the pipe section.

$$M_c = D_{nom}{}^2 \cdot t \cdot R_e$$

The maximum allowable bending moment is defined as:

$$\gamma_{g,M} \cdot M_L \le \frac{\gamma_M \cdot M_c}{\gamma_{m,M}}$$

Where:

$\gamma_{g,M}$ = load factor (-) => 1.1

γ_M = model factor (-) => 1.0

$\gamma_{m,M}$ = material factor (-) => 1.3

M_L = allowable bending moment for buckling (Nm)

M_c = critical bending moment for buckling (Nm)

6.3.3. Combined External Pressure and Bending Moment

When external pressure exists in combination with a bending moment besides the checks above the condition for combined stresses as shown below shall be fulfilled.

$$\frac{\gamma_{g,p} \cdot P_L}{P_c / \gamma_{m,p}} + \left(\frac{\gamma_{g,m} \cdot M_L}{M_c / \gamma_{m,M}} \right)^n \leq \gamma_M$$

Where:

$$n = 1 + 300 \cdot \frac{t}{D_{nom}}$$

Where:

$\gamma_{g,p}$ = load factor for pressure (-) => 1.05

$\gamma_{g,m}$ = load factor for bending (-) => 1.55

γ_M = model factor (-) => 0.93

$\gamma_{m,p}$ = material factor for pressure (-) => 1.25

$\gamma_{m,M}$ = material factor for bending (-) =>1.15

M_L = allowable bending moment for buckling (Nm)

M_c = critical bending moment for buckling (Nm)

6.4. Progressive Plastic Collapse

Progressive plastic deformation load cycle will lead to extreme deformation, collapse and cracks initiation through the wall.

The condition for avoiding buckle propagation is:

$$\varepsilon_{\max} = \alpha \cdot \Delta T \leq \left[\frac{R_{ev}}{E} \cdot \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_h}{R_{ev}}\right)^2} + \frac{R_e}{E} \sqrt{0.9 - \frac{3}{4}\left(\frac{\sigma_h}{R_e}\right)^2} \right]$$

Where:

α = coefficient of linear thermal expansion (m/ m/ ° C)

ΔT = temperature differential [° C] (design – installation)

Parameters have to be factored as defined in section 5.

6.5. Local Buckling

In accordance with NEN 3656, if OD / t < 55, an assessment on local buckling can generally be omitted.

For this project it would mean that a local buckling check is required for a wall thickness of minimal 9.2 mm, which will be much smaller than the anticipated wall thickness. This will be checked during detailed design.

6.6. Bar Buckling

In a free span the pipeline will be susceptible to bar buckling. Bar buckling may occur due to an effective axial compressive force (N) in the pipeline. The compressive force in an axially restrained pipeline is based on the longitudinal stress:

$$N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$$

Where:

A = cross sectional area of steel (mm^2)

ν = Poisson's ratio for elastic deformation (-) => 0.3

S_h = factored hoop stress (N/mm^2)

γ_t = load factor as given in Table 5-3 (-)

α = coefficient of thermal expansion (m/m/°C)

ΔT = pipeline temperature differential (° C) (design – installation)

The factored hoop stress (S_h) is calculated from:

$$S_h = \gamma_P \cdot \sigma_h$$

and

$$\sigma_h = \frac{P_d \cdot (OD - t_{\min})}{2 \cdot t_{\min}}$$

Where:

P_d = design pressure (N/mm^2)

t_{min} = minimum pipe wall thickness (mm)

OD = outside diameter of steel pipe (mm)

γ_P = load factor as given in Table 5-3 (-)

The buckling length is based on the Euler buckling load definition, defined in Ref. [3]. Bar buckling is avoided if the span length fulfils:

$$L \leq \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$$

Where:

L = allowable span length (mm)

I = moment of inertia (mm^4)

6.7. Results Buckling & Collapse

Appendix B contains the calculation sheet for the buckling and collapse calculations discussed in the previous sub-sections. The results are also summarized in Table 6-3 (8m WD), Table 6-4 (17m WD) and Table 6-5 (26m WD).

Property	Install (flooded	Hydrotest	Operation
Material	L360		
Temperature (deg. C)	15	15	65
Yield at temperature (N/mm2)	360	360	360
Pressure (barg)	2	144	111
Content density (kg/m3)	1025	1025	96
Storm surge (m)	-0.14		-0.78
Hmax (m)	5.2		6.2
Tass (s)	7.7		8.1
Current velocity @ 1m ASB (m/s)	0.89		1.12
Collapse – external pressure only			
Actual external pressure (MPa)	0.19		
Allowable external pressure (MPa)	16.0		
Check	OK		
Collapse – bending moment only			
Maximum allowable bending moment (kNm)	1256		
Collapse – external pressure & bending moment			
Maximum allowable bending moment (kNm)	1001		1001
Maximum span length collapse (m)	62.6	62.6	76.7
Progressive plastic collapse			
Actual strain (-)	0.0001	0.0001	0.0005
Allowable strain (-)	0.0033	0.0028	0.0030
Check	OK	OK	OK
Local buckling			
OD/t ratio	23.9		
Allowable ratio	55		
Check	OK		
Bar buckling			
Maximum span length (m)	93.1	- (No compressive force)	61.7

Table 6-3 Buckling & Collapse analysis - result summary – 8 m water depth

Property	Install (flooded	Hydrotest	Operation
Material	L360		
Temperature (deg. C)	15	15	65
Yield at temperature (N/mm2)	360	360	360
Pressure (barg)	2	144	111
Content density (kg/m3)	1025	1025	96
Storm surge (m)	-0.58		-1.29
Hmax (m)	8.3		11.55
Tass (s)	8.9		9.8
Current velocity @ 1m ASB (m/s)	0.82		1.04
Collapse – external pressure only			
Actual external pressure (MPa)	0.30		
Allowable external pressure (MPa)	16.0		
Check	OK		
Collapse – bending moment only			
Maximum allowable bending moment (kNm)	1256		
Collapse – external pressure & bending moment			
Maximum allowable bending moment (kNm)	1000		1000
Maximum span length collapse (m)	59.2	59.2	53.3
Progressive plastic collapse			
Actual strain (-)	0.0001	0.0001	0.0005
Allowable strain (-)	0.0033	0.0028	0.0030
Check	OK	OK	OK
Local buckling			
OD/t ratio	23.9		
Allowable ratio	55		
Check	OK		
Bar buckling			
Maximum span length (m)	93.1	- (No compressive force)	61.7

Table 6-4 Buckling & Collapse analysis - result summary – 17 m water depth

Property	Install (flooded	Hydrotest	Operation
Material	L360		
Temperature (deg. C)	15	15	65
Yield at temperature (N/mm2)	360	360	360
Pressure (barg)	2	144	111
Content density (kg/m3)	1025	1025	96
Storm surge (m)	-1.02		-1.79
Hmax (m)	11.4		16.9
Tass (s)	10.1		11.5
Current velocity @ 2m ASB (m/s)	0.74		0.96
Collapse – external pressure only			
Actual external pressure (MPa)	0.42		
Allowable external pressure (MPa)	16.0		
Check	OK		
Collapse – bending moment only			
Maximum allowable bending moment (kNm)	1256		
Collapse – external pressure & bending moment			
Maximum allowable bending moment (kNm)	999.4		999.4
Maximum span length collapse (m)	56.0	56.0	43.8
Progressive plastic collapse			
Actual strain (-)	0.0001	0.0001	0.0005
Allowable strain (-)	0.0033	0.0028	0.0030
Check	OK	OK	OK
Local buckling			
OD/t ratio	23.9		
Allowable ratio	55		
Check	OK		
Bar buckling			
Maximum span length (m)	93.1	- (No compressive force)	61.7

Table 6-5 Buckling & Collapse analysis - result summary – 26 m water depth

7. Free Span Analysis

Spanning of a pipeline on the seabed causes forces and stresses in the pipe. The criterion for accepting a pipeline configuration is that the pipe should not be subjected to over-stressing, nor to excessive dynamic loading because of resonant oscillations of the pipe caused by the vortex shedding phenomenon during installation, testing and throughout its operating life.

The pipeline span assessment includes the following items:

- Static span analysis
- Dynamic span analysis.

The static analysis concerns the determination of the pipe stresses under functional- and static environmental loads for a given span length.

The dynamic span analysis is based on criteria for prevention of vortex induced vibrations (VIV) as outlined in NEN 3656 considering both current- and wave induced velocities.

In addition, operational limits of the trenching equipment, limits the span gap (distance between the pipe and the seabed).

Although the pipeline will be buried below the seabed prior to its operation, the pipeline must be checked for spanning for the period between installation and burial.

In the analysis, along with the seabed topography, both functional and environmental loads are taken into consideration to check pipeline structural integrity under the considered load cases.

7.1. Static Span

Combining hoop, longitudinal and bending stresses in the pipeline, which shall satisfy criteria for equivalent stresses, gives the maximum allowable static span lengths. Checks are to be made for the installation, hydro test and operational load case.

The maximum bending moment is calculated from the (vector) combination of the pipelines’ own weight and hydrodynamic forces for the maximum wave condition:

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Where:

γ_W = load factor as per Table 5-3 (-)

γ_H = load factor as per Table 5-3 (-)

End fixity of an actual span is commonly assumed between fixed - fixed and fixed – pinned and the bending moment (M) calculated from:

$$M = \frac{q \cdot L^2}{10}$$

Where:

L = Maximum allowable span length [m]

The maximum allowable bending moment (M_{all}) is given by:

$$M_{all} = \frac{2 \cdot I \cdot \sigma_b}{OD}$$

Where:

I = moment of inertia (m^4)

OD = pipeline outside diameter (m)

s_b = maximum allowable bending stress

The maximum allowable static span can then be determined by:

$$L\max = \sqrt{\frac{20 \cdot \sigma_b \cdot I}{OD \cdot q}}$$

The maximum allowable span length follows from the condition that the equivalent stress (S_e) from the load combination satisfies the following conditions:

For the operational and hydrotest cases:

$$S_e \le 0.85 \times (R_e + R_{ev}) / \gamma_m$$

For the installation case:

$$S_e \le R_e / \gamma_m$$

Where:

R_e = minimum yield stress at 20 °C (N/mm^2)

R_{ev} = minimum yield stress at design temperature (N/mm^2)

γ_m = material factor (-) => 1.1

7.1.1. Load Cases

The maximum static span will be determined for the load cases, and considering the environmental load return periods, as detailed in Table 7-1:

Condition	Wave Height Return Period	Current velocity Return Period
Installation	$H_{max,1yr}$	1 yr
Hydrotest	$H_{max,1yr}$	1 yr
Operational,1	$H_{max,100yr}$	10 yr
Operational,2	$H_{max,10yr}$	100 yr

Table 7-1 Load Cases for Span Assessment

7.1.2. Results

Tables 7-2 thru 7-5 show the results for the maximum allowable static span lengths during installation, hydrotest and operational phase. The calculation can be found in Appendix C.

7.1.2.1. Flooded installation

Property	Unrestrained pipe		Restrained pipe	
	Tension	Compression	Tension	Compression
Hoop stress (MPa)	2.9	2.9	2.9	2.9
Max. longitudinal stress (MPa)	328.7	-325.8	328.7	-325.8
Longitudinal hoop stress (MPa)	1.2	1.2	0.9	0.9
Thermal expansion stress (MPa)	N/A	N/A	-26.8	-26.8
Max. allowable bending stress (MPa)	327.3	-327.1	327.3	-299.9
Max. allowable span (m) – 8 m WD	69.3	69.3	69.3	66.3
Max. allowable span (m) – 17 m WD	65.9	65.9	65.9	63.1
Max. allowable span (m) – 26 m WD	62.8	62.7	62.8	60.1

Table 7-2 Maximum span for flooded pipe

7.1.2.2. Hydrotest

Property	Unrestrained pipe		Restrained pipe	
	Tension	Compression	Tension	Compression
Hoop stress (MPa)	249.7	249.7	249.7	249.7
Max. longitudinal stress (MPa)	637.5	-387.8	637.5	-387.8
Longitudinal hoop stress (MPa)	85.8	85.8	74.9	74.9
Thermal expansion stress (MPa)	N/A	N/A	-29.5	-29.5
Max. allowable bending stress (MPa)	551.6	-473.6	556.4	-433.2
Max. allowable span (m) – 8 m WD	89.3	82.6	89.7	79.0
Max. allowable span (m) – 17 m WD	84.4	78.2	84.8	74.8
Max. allowable span (m) – 26 m WD	79.9	74.2	80.3	70.9

Table 7-3 Maximum span during hydrotest

7.1.2.3. Operation LC1

Property	Unrestrained pipe		Restrained pipe	
	Tension	Compression	Tension	Compression
Hoop stress (MPa)	191.8	191.8	191.8	191.8
Max. longitudinal stress (MPa)	626.9	-435.1	626.9	-435.1
Longitudinal hoop stress (MPa)	66.2	66.2	57.6	57.6
Thermal expansion stress (MPa)	N/A	N/A	-123.3	123.3
Max. allowable bending stress (MPa)	556.4	-501.2	556.4	-369.4
Max. allowable span (m) – 8 m WD	112.2	106.4	112.2	91.3
Max. allowable span (m) – 17 m WD	75.4	71.5	75.4	61.4
Max. allowable span (m) – 26 m WD	63.9	60.7	63.9	52.1

Table 7-4 Maximum span for Load Case 1

7.1.2.4. Operation LC2

Property	Unrestrained pipe		Restrained pipe	
	Tension	Compression	Tension	Compression
Hoop stress (MPa)	191.8	191.8	191.8	191.8
Max. longitudinal stress (MPa)	626.9	-435.1	626.9	-435.1
Longitudinal hoop stress (MPa)	66.2	66.2	57.6	57.6
Thermal expansion stress (MPa)	N/A	N/A	-123.3	123.3
Max. allowable bending stress (MPa)	556.4	-501.2	556.4	-369.4
Max. allowable span (m) – 8 m WD	112.4	106.5	112.4	91.5
Max. allowable span (m) – 17 m WD	84.3	80.0	84.3	68.7
Max. allowable span (m) – 26 m WD	73.6	70.0	73.6	60.0

Table 7-5 Maximum span for Load Case 2

7.2. Dynamic Span

Flow of water particles induced by currents and waves perpendicular to a spanning pipeline or riser span can lead to vortices being shed. This will disrupt the flow around the pipe and thereby potentially cause periodic loads on the pipeline or riser, also known as Vortex Induced Vibration (VIV).

The natural frequency of a span being close to the vortex shedding frequency can result in a resonant oscillation, possibly resulting in fatigue failure of the pipeline or riser.

The oscillations of the span may occur in two directions:

- in line with the flow (parallel to the flow direction of the water particles)
- in cross flow direction (perpendicular to the flow direction of the water particles)

When assessing VIV, the span should be confirmed to be within acceptable limits set by either avoidance of VIV or an acceptable fatigue life for both the installation and operational condition.

Relevant dimensionless parameters governing the VIV phenomenon are the reduced velocity (V_r) and stability parameter (K_s).

The reduced velocity (V_r) parameter is defined by:

$$V_r = \frac{V_s}{f_{n \cdot OD_{tot}}}$$

Where,

V_s = water particle velocity due to current and significant wave (m/s)

f_n = 1st natural frequency of the pipe span (1/s)

OD_{tot} total outside diameter of the pipe (m)

The 1st natural frequency can be calculated from:

$$f_n = \frac{a}{2\pi} \cdot \sqrt{\frac{E \cdot I}{m_e \cdot L^4}}$$

Where,

a = frequency factor (-) => 15.4 for a fixed-pinned beam, which is used for the pipe

E = Young’s modulus (N/m^2)

I = moment of inertia (m^4)

L = length of span in pipeline / riser (m)

The stability parameter (K_s) is defined by:

$$K_s = \frac{2 \cdot m_e \cdot \delta}{\rho_{sw} \cdot OD_{tot}^2}$$

Where,

m_e = effective mass of pipe (kg/m)

ρ_{sw} = density seawater (kg/m^3)

δ = logarithmic decrement of damping (-) => δ = 0.126 for steel

The effective mass of the pipe can be calculated as:

$$m_e = m + {}^{\pi}\!/_{4} \cdot C_M \cdot \rho_{sw} \cdot OD_{tot}{}^2$$

Where,

m = Pipeline / riser mass (kg/m)

Cm = added mass coefficient (-)

NEN 3656 states that In-line oscillations will occur if $K_s \leq 1.8$ and cross flow oscillations will occur if $K_s \leq 16$.

7.2.1. In-line VIV

NEN 3656 furthermore states that in-line oscillations of the span occur if the reduced velocity is within the range of: $1.0 \leq Vr \leq 3.5$

Vortices around a spanning pipe occur in a relatively steady state environment. The wave induced velocity varies from a maximum at t=0, to zero at t=1/4*Twave. Furthermore, the system does not respond instantaneously to the applied forcing. To ignore the wave induced velocity in assessing the allowable dynamic span length would be too optimistic, to account for the maximum induced value would be too conservative, therefore reference is made to DNV-RP-F105. “Free Spanning Pipelines.” (ref. [3]).

According to Ref. [3], fatigue damage due to in-line VIV can be neglected if the current flow velocity ratio α, as defined by the equation below is smaller than 0.5. In the domain 0.5< α<0.8, in-line VIV is described as ‘reduced’ and requires additional work in determining the response amplitude. This additional work is left for the detail design phase.

$$\alpha = \frac{v_{cur}}{v_{cur} + v_{wave}}$$

Where,

v_{cur} = Particle velocity due to current [m/s]

v_{wave} = Particle velocity due to waves [m/s]

7.2.2. Cross-flow VIV

The occurrence of cross flow oscillations depends on the magnitude of the Reynolds number, Re, and the reduced velocity as given in Figure 7-1.

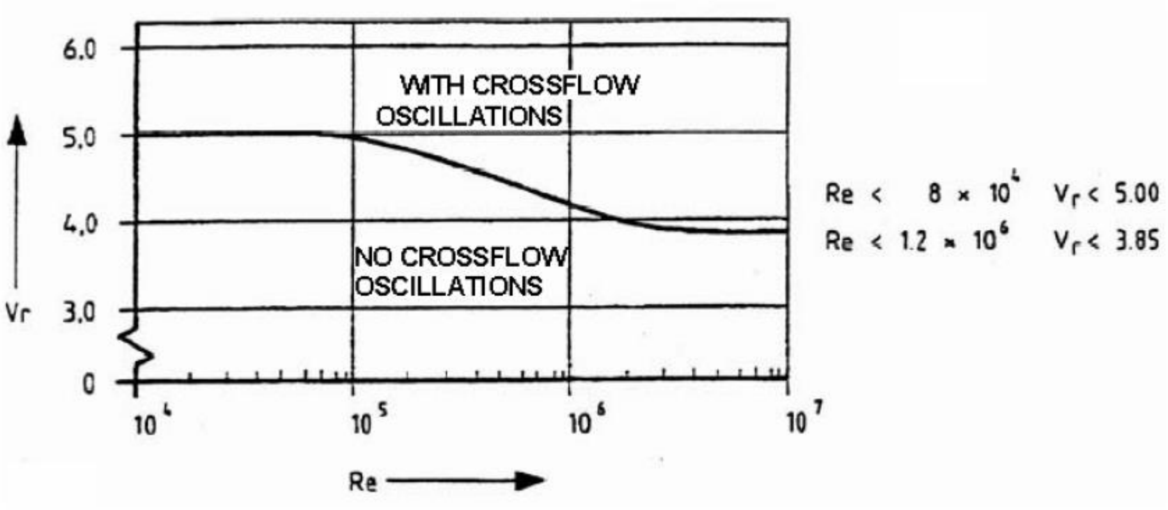


Figure 7-1 Reduced velocity for cross flow oscillations

$$\mathrm{Re} = \frac{\mathrm{v} \cdot OD_{tot}}{\nu}$$

Where,

v = particle velocity (m/s)

OD_{tot} = pipeline outside diameter (m)

n = Kinematic viscosity water (m^2/s) => 1,307 x 10^{-6} (at 10 °C)

7.2.3. Results

The results for the VIV analyses are presented in Tables 7-6 through 7-8. Reference is made to appendix C for more detailed calculations.

In-line VIV:

Property	Installation (flooded)	Hydrotest	Operation LC1	Operation LC2
8m WD - Wave hor. particle velocity (m/s)	1.3	1.3	1.6	1.5
8m WD - Current hor. particle velocity (m/s)	0.71	0.71	0.79	0.81
8m WD - Current velocity ratio (-)	0.35	0.35	0.35	0.37
17m WD - Wave hor. particle velocity (m/s)	1.33	1.33	2.08	1.76
17m WD - Current hor. particle velocity (m/s)	0.65	0.65	0.73	0.83
17m WD - Current velocity ratio (-)	0.33	0.33	0.26	0.32
26m WD - Wave hor. particle velocity (m/s)	1.35	1.35	2.56	2.01
26m WD - Current hor. particle velocity (m/s)	0.53	0.53	0.60	0.69
26m WD - Current velocity ratio (-)	0.28	0.28	0.19	0.26

Table 7-6 Current velocity ratio per load case

The current flow velocity ratio (α) is <0.5 for all load cases. Below this ratio, in-line VIV due to vortex shedding becomes negligible (DNV-RP-F105, Ref [3]). In the limit of $\alpha = 0.5$, the acceptable span is determined below:

Property	Installation (flooded)	Hydrotest	Operation LC1	Operation LC2
Effective mass (kg/m)	682.9	682.9	522.7	522.7
Stability parameter (-)	0.63	0.63	0.49	0.49
Reduced velocity limit (-)	1	1	1	1
Outer P/L diameter (mm)	514	514	514	514
8m WD				
Wave hor. particle velocity (m/s)	0.71	0.71	0.79	0.81
Current hor. particle velocity (m/s)	0.71	0.71	0.79	0.81
Current velocity ratio (-)	0.5	0.5	0.5	0.5
Span frequency (1/s)	2.75	2.75	3.09	3.46
Allowable span length (m)	21.9	21.9	22.1	20.9
17m WD				
Wave hor. particle velocity (m/s)	0.65	0.65	0.73	0.83
Current hor. particle velocity (m/s)	0.65	0.65	0.73	0.83
Current velocity ratio (-)	0.5	0.5	0.5	0.5
Span frequency (1/s)	2.52	2.52	2.84	3.21
Allowable span length (m)	22.9	22.9	23.0	21.6
26m WD				
Wave hor. particle velocity (m/s)	0.53	0.53	0.60	0.69
Current hor. particle velocity (m/s)	0.53	0.53	0.60	0.69
Current velocity ratio (-)	0.5	0.5	0.5	0.5
Span frequency (1/s)	2.07	2.07	2.35	2.69
Allowable span length (m)	25.2	25.2	25.3	23.7

Table 7-7 Allowable span due to in-line VIV

There is relatively little difference between the allowable span in the various conditions. This is because the VIV phenomenon is governed by the steady current, which is of similar magnitude at all locations. The selected limit of current flow velocity ratio, α=0.5, is also a significant factor. If this is increased to α=0.6, the allowable span (in-line VIV) for installation condition at 26m water depth is increased from 25.2m to 27.6m. Selecting a higher current flow velocity ratio requires that the pipeline amplitude response is further investigated, this is left to the detail design phase.

Cross flow VIV:

Property	Installation (flooded)	Hydrotest	Operation LC1	Operation LC2
8m WD				
Wave hor. particle velocity (m/s)	1.3	1.3	1.6	1.5
Current hor. particle velocity (m/s)	0.71	0.71	0.79	0.81
Reynolds nr. (-)	2.07 * 10^6	2.07 * 10^6	2.47 * 10^6	2.46 * 10^6
Reduced velocity limit (-)	3.85	3.85	3.85	3.85
Span frequency (1/s)	1.01	1.01	1.21	1.21
Allowable span length (m)	36.0	36.0	35.3	35.3
17m WD				
Wave hor. particle velocity (m/s)	1.33	1.33	2.08	1.76
Current hor. particle velocity (m/s)	0.65	0.65	0.73	0.83
Reynolds nr. (-)	2.03 * 10^6	2.03 * 10^6	2.90 * 10^6	2.66 * 10^6
Reduced velocity limit (-)	3.85	3.85	3.85	3.85
Span frequency (1/s)	1.00	1.00	1.42	1.30
Allowable span length (m)	36.4	36.4	32.6	34.0
26mWD				
Wave hor. particle velocity (m/s)	1.35	1.35	2.56	2.01
Current hor. particle velocity (m/s)	0.53	0.53	0.60	0.69
Reynolds nr. (-)	1.94 * 10^6	1.94 * 10^6	3.26 * 10^6	2.78 * 10^6
Reduced velocity limit (-)	3.85	3.85	3.85	3.85
Span frequency (1/s)	0.95	0.95	1.60	1.36
Allowable span length (m)	37.2	37.2	30.7	33.2

Table 7-7 Allowable span due to cross-flow VIV

8. Upheaval Buckling – Analytical

Buried pipelines exposed to compressive effective axial forces may get unstable beyond its anchor point and move vertically out of the seabed if the cover has insufficient resistance. An out-of-straightness configuration will result in forces acting on the cover, perpendicular to the pipeline. In case these vertical forces exceed the cover resistance the pipeline will buckle upwards.

The relation between minimum required cover height and the imperfection height (out-of-straightness) will be established in accordance with ref. [11].

Parameters used in the assessment of upheaval buckling are the dimensionless imperfection length parameter (Φ_{L}):

$$\Phi_L = L \cdot \sqrt{\frac{N_e}{EI}}$$

Where:

L = exposure length (m)

N_e = effective axial compressive force (N)

EI = bending stiffness (N m^2)

And the dimensionless maximum download parameter (Φ_w):

$$\Phi_w = \frac{w \cdot E \cdot I}{\Delta_{calc} \cdot N_e^{\,2}}$$

Where:

w = required download [N/m]

Δ_{calc} = imperfection height [m]

Depending on the Φ_L value the required download is derived from Φ_w in accordance with:

$$\Phi_w = 0.0646 \quad \text{for} \quad \Phi_L < 4.49$$

$$\Phi_w = \frac{5.68}{\phi_L^{\,2}} - \frac{88.35}{\phi_L^{\,4}} \quad \text{for} \quad 4.49 < \Phi_L < 8.06$$

$$\Phi_w = \frac{9.6}{\phi_L^{\,2}} - \frac{343}{\phi_L^{\,4}} \quad \text{for} \quad \Phi_L > 8.06$$

In cohesionless soils the uplift resistance (q) due to the cover of the pipe can be calculated from:

$$q = \gamma \cdot H \cdot OD \cdot \left(1 + f \cdot \frac{H}{OD}\right)$$

Where:

γ = effective under water weight of soil (N/m^3)

H = depth of cover (m)

OD = outside diameter of pipe (m)

f = uplift coefficient
0.5 for dense material
0.1 for loose material

The calculated required download (w) shall be smaller than the actual combination of the submerged weight and uplift resistance of the pipeline.

The simplified method from Reference [11] is conservative, in that it does not model a number of mitigating factors such as:

- The finite axial stiffness of the pipeline, which determines how rapidly the axial force diminishes as the pipeline moves upwards
- The pipeline resistance to axial movement through the soil determines how far the pipeline can slide towards a developing buckle.

Both the above factors may cause progressive upheaval buckling, as predicted by the analysis method in Reference [11], not to occur.

Further, the sinusoidal imperfection profile assumed in the model is envisaged to yield conservative download requirements.

8.1. Results

The results are presented as the minimum safe length for a given imperfection height and cover height, at the maximum operational temperature of 43°C and operational pressure of 95 barg. An ‘x’ denotes that there is no risk of upheaval buckling for the given condition. An excerpt of the calculations is presented in Appendix D.

Minimum required Imperfection Length (m)		**Cover Height to TOP [m]**													
		1.4	1.3	1.2	1.1	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Available Download, q [N/m]		9929	9232	8553	7889	7243	6613	6000	5403	4823	4260	3714	3184	2671	2174
Imperfection Height [m]	0.05	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0.1	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0.15	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0.2	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0.25	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0.3	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0.35	x	x	x	x	x	x	x	x	x	x	x	x	x	42.6
	0.4	x	x	x	x	x	x	x	x	x	x	x	x	x	50.9
	0.45	x	x	x	x	x	x	x	x	x	x	x	x	46.3	56.3
	0.5	x	x	x	x	x	x	x	x	x	x	x	x	51.8	70.5
	0.55	x	x	x	x	x	x	x	x	x	x	x	47.7	56.0	78.0
	0.6	x	x	x	x	x	x	x	x	x	x	43.0	52.1	68.2	84.0
	0.65	x	x	x	x	x	x	x	x	x	x	48.4	55.7	75.2	89.2
	0.7	x	x	x	x	x	x	x	x	x	44.5	52.1	65.4	80.5	94.0
	0.75	x	x	x	x	x	x	x	x	x	48.7	55.2	72.6	85.1	98.5
	0.8	x	x	x	x	x	x	x	x	45.2	51.9	58.0	77.6	89.4	>100
	0.85	x	x	x	x	x	x	x	x	48.8	54.6	70.1	81.8	93.3	>100
	0.9	x	x	x	x	x	x	x	45.5	51.6	57.1	74.9	85.6	97.0	>100
	0.95	x	x	x	x	x	x	x	48.7	54.1	67.3	78.8	89.1	>100	>100
	1	x	x	x	x	x	x	45.6	51.2	56.3	72.3	82.4	92.4	>100	>100

Table 8-1 Out of straightness table

9. Bottom Roughness Analysis

9.1. General

The pipeline route experiences significant undulations in the sea bed, which may create free spans of the pipeline. In order to assess if the pipeline spans are greater than allowed in the time between installation and burial, a bottom roughness analysis. A FEA model is created which incorporates the surveyed sea floor profile, the interaction between pipe and sea floor, and the structural behaviour of the pipeline.

The finite element calculation is carried out using industry proven software package ANSYS. The analysis is at this stage of the design is limited to identifying locations with more than critical span length between installation and burial, no modifications to the sea floor are determined.

The pipeline will be modelled by ANSYS' PIPE288 element. This is a 3D pipe element consisting of 3 'layers': an internal layer to account for the weight of the internal fluid, a structural layer used for the structural calculations, and an outer layer to account for the coating. Additionally, the buoyancy of the displaced seawater is accounted for.

The pipeline is modelled with an element length of 1 m and accounts for undulations in the vertical direction. Pipe-soil interaction is simulated using three independent non-linear spring elements attached to each pipe element. The springs represent the soil frictional resistance in the axial and lateral directions and the soils bearing capacity in the vertical direction.

Seabed roughness will be simulated by displacing the vertical springs representing the soil bearing capacity to the correct depth based on the bathymetric data and allowing the pipe to move and rest on the vertical springs.

When the support force of a vertical spring is 0, a free span is identified. Similar succeeding points indicate a larger span. The length of the free span is determined by subtracting the coordinates of the beginning of the span from the coordinates of the span end. Based on the acceptable spans identified in this document, the locations where spans are larger than the critical span are found and reported.

9.2. Definition of Soil Springs

The characteristics of the springs which simulate the pipe-soil interaction are defined through non-linear force-deflection curves. These force-deflection curves describe the frictional restraint provided by the soil to the pipeline in axial, lateral and vertical direction.

Axial and lateral restraint for the unburied pipeline is included as Coulomb friction. The amount of restraint per length of pipeline depends on the friction coefficient and the submerged weight of the pipeline. A friction coefficient of 0.6 was used in both directions, this excludes the effect of soil berms created by lateral movement of the pipeline. In accordance with DNV-RP-F109, the friction coefficient of a pipe on sand is set to 0.6. The maximum friction force is only reached when a nominal displacement has been reached, the mobilization displacement. In the present analysis, mobilization displacement is set to 5 mm. A third point in the spring reaction diagram is set at a displacement of 1m with a reaction force of 1.001 time the maximum friction force, this prevents extrapolation of the first section of the spring slope.

Vertical support follows from the bearing capacity of the idealized 2D strip foundation theory. A touchdown lay factor k_{lay} of 2 has been considered during the installation load case, according to DNV-RP-F114, ref [12]. The 'installation' type supports do not provide resistance against upwards movement of the pipe.

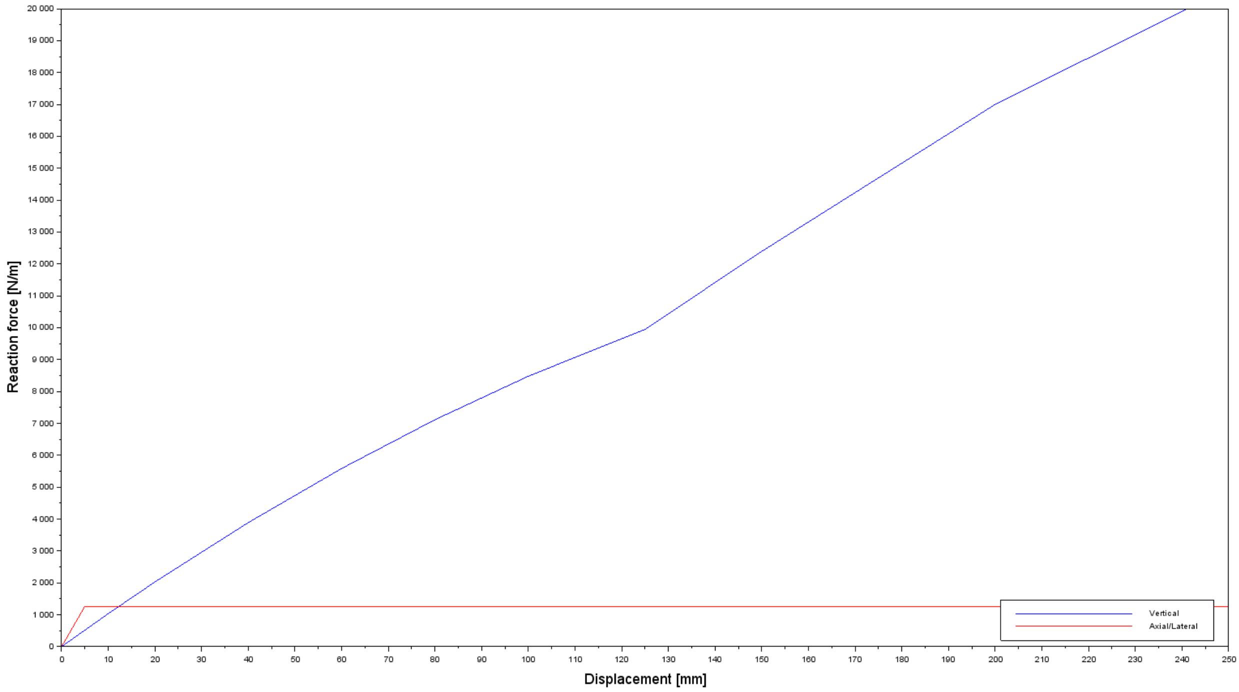


Figure 8-1 Vertical and axial support

9.3. Results

The result of pipeline installation on the as-surveyed sea bed profile is given in Table 8-1, and Figures 8-2 through 8-4. Three (3) spans longer than 20 m were found, all in the first kilometre of the pipeline. If the critical span criterium is set as 25m between KP0 and KP2, 23m between KP2 and KP10, and 22 m from KP10 to the end of the pipeline, only the span of 27 m between KP0.406-0.433 violates these criteria. These criteria are based on on the 1-year environmental conditions, for the installation and hydrotest condition.

Table 8-1 Overview largest spans

Span #	Start of span [m]	End of span [m]	Span length [m]
1	406	433	27
2	455	478	23
3	707	729	22

The design criterion of span length is only marginally exceeded, and as noted in Section 7.2, additional investigation in the dynamic response of the pipeline could extend the allowable span to more than 27m. This would remove the need for sea bed modifications. The additional investigations are left for the detail design phase of the pipeline.

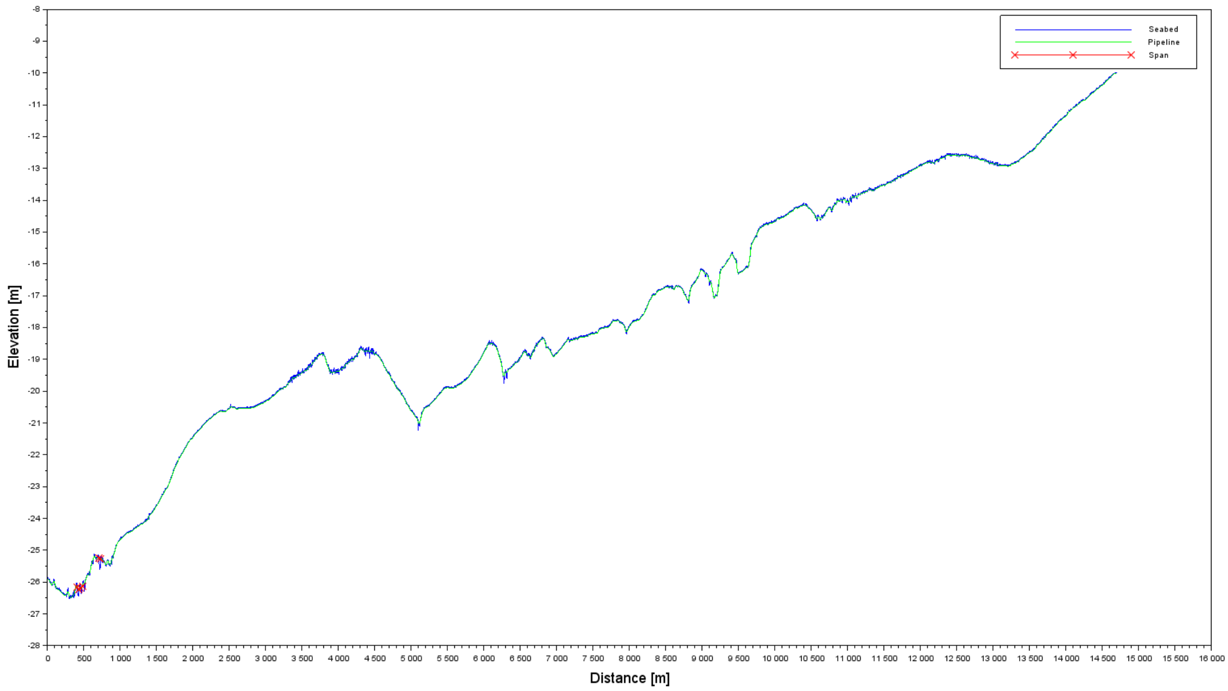


Figure 8-2 Pipeline on sea floor, complete route

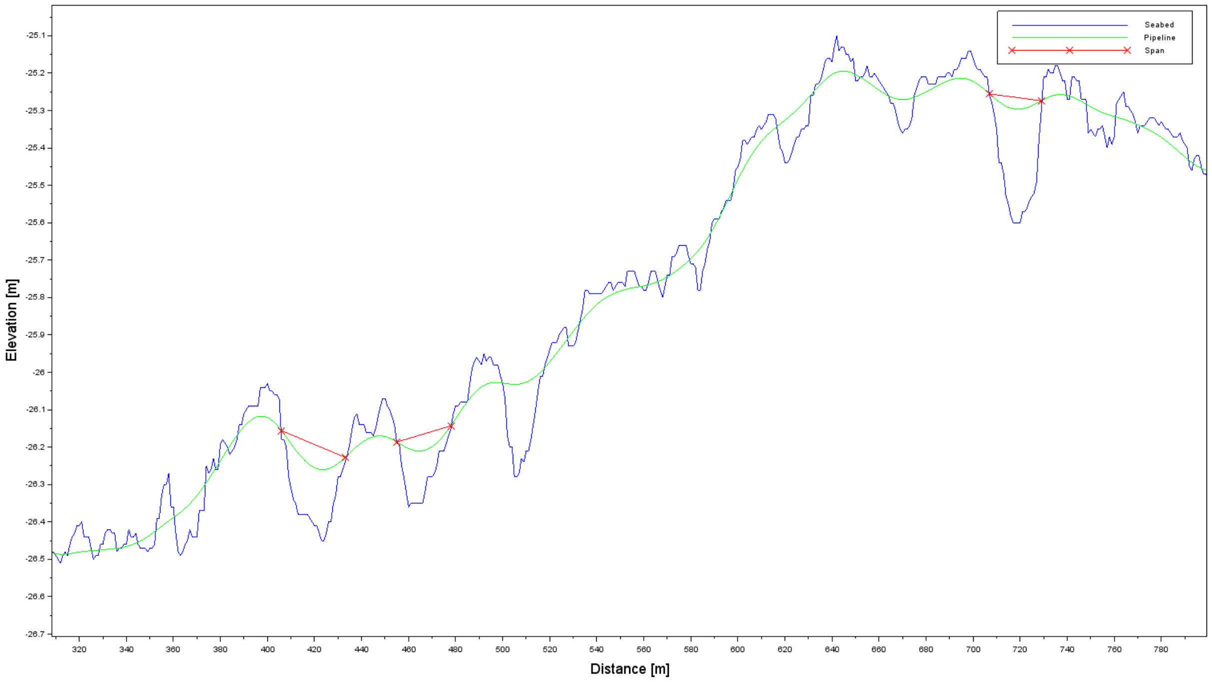


Figure 8-3 Pipeline on sea floor – section with spans >20m

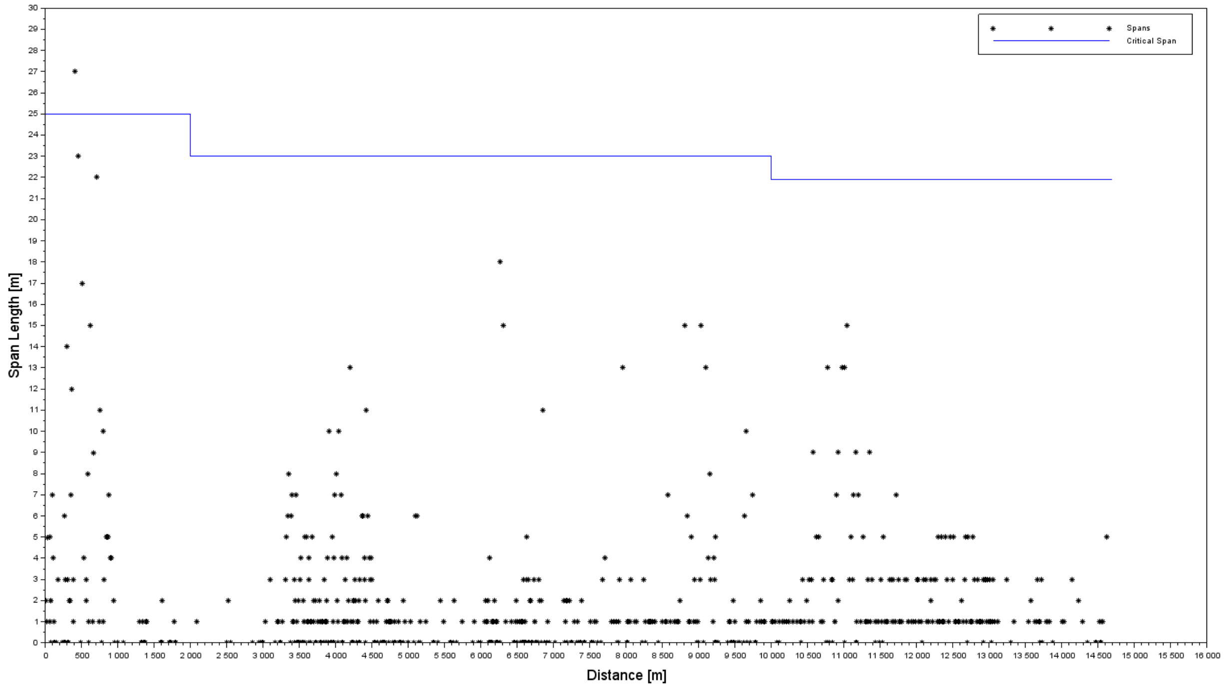


Figure 8-4 Overview of all spans and critical span

A. Wall Thickness Analysis

The following Wall Thickness Analyses were performed:

- 19018-60-CAL-01001-01-01 20” x 20.6 mm – inside 500m zone
- 19018-60-CAL-01001-01-01 20” x 20.6 mm – outside 500m zone

(4 pages)

enersea®

Project : **N05-A Pipeline basic design**
Project # : 19018
Subject : Wall thickness calculation N05-A Pipeline
File # : #N/A

Client : ONE-Dyas
Client File # :

Originator : HvH
Checked : PF
Date : 21.10.2019
Revision : 01

20" Pipeline - Inside 500m zone

Material properties

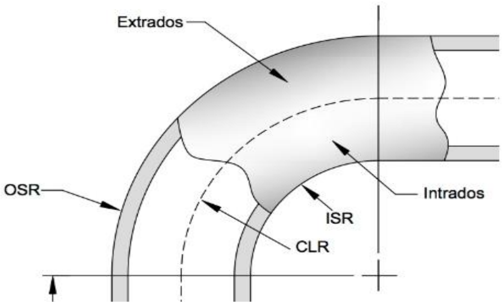
Material			=	L360NB	
Design temperature		T_d	=	50	°C
Yield at ambient temperature		R_e	=	360.00	N/mm^2
Yield at design temperature		R_{ed}	=	360.00	N/mm^2
Material factor (Table 4 NEN 3656)		γ_m	=	1.10	-
Allowable stress	$\sigma_v = \frac{R_{ed}}{\gamma_m}$	σ_v	=	327.27	N/mm^2

Pipeline properties

Outside diameter		OD	=	508	mm
Design pressure		P_d	=	111.1	barg
Minimum outside presssure		P_o	=	0	barg
Fabrication Tolerance		f_{tol}	=	7.3	%
Corrosion allowance		CA	=	3	mm
Pipeline within the 500 meter zone?				y	(Y or N)
Load factor (Table 3 NEN 3656): 1,25 outside 500m zone; 1,364 inside 500m zone		γ_s	=	1.364	-
Bend radius				2540	mm
Fabrication tolerance bends		f_{tolB}	=	7.3	%
Inside bend factor	$\frac{2R-0.5D_e}{2R-D_e}$		=	1.06	
Outside bend factor	$\frac{2R+0.5D_e}{2R+D_e}$		=	0.95	

Minimum wall thickness determination, d_{min}

minimum wall thickness (excl. CA):	$d_{\min} = \frac{\gamma_m \cdot \gamma_s \cdot P_d^* \cdot D_e}{2 \cdot R_e(T_d) + \gamma_m \cdot \gamma_s \cdot P_d^*}$	=	11.50	mm
Inside bend		=	12.13	mm
Outside bend		=	10.97	mm



Minimum required wall thickness (incl. CA) after bending, d_{min} [Note 2]

Straight part / along bend radius @ CLR	=	14.50	mm
Inside bend @ ISR	=	15.13	mm
Outside bend @ OSR	=	13.97	mm

Selected nominal wall thickness = 20.6 mm

Project : **N05-A Pipeline basic design**
Project # : 19018
Subject : Wall thickness calculation N05-A Pipeline
File # : #N/A

Client : ONE-Dyas
Client File # :

Originator : HvH
Date : 21.10.2019
Revision : 01
Checked : PF

20" Pipeline - Inside 500m zone

Hoop stress

Hoop stress straight parts $\sigma_{hoop} = \frac{\gamma_s \cdot P_d^* \cdot (D_e - d_{\min})}{2 \cdot d_{\min}}$ = 231.56 N/mm^2

Hoop stress inside bend $\sigma_{hoop}(\mathrm{BI}) = \frac{2 \cdot R - \frac{1}{2} \cdot D_e}{2 \cdot \mathrm{R} - D_e} \cdot \sigma_{hoop}$ = 244.42 N/mm^2

Hoop stress outside bend $\sigma_{hoop}(\mathrm{BO}) = \frac{2 \cdot R + \frac{1}{2} \cdot D_e}{2 \cdot \mathrm{R} + D_e} \cdot \sigma_{hoop}$ = 221.03 N/mm^2

Stress Check

Hoop stress (N/mm2)	Occurring	Allowable
Straight parts	231.56	327.27
Inside bend	244.42	327.27
Outside bend	221.03	327.27

Test pressure

Hydrotest temperature = 15 °C
Yield at hydrotest temperature = 360 N/mm^2

Product (gas / others) gas
Design factor, CP (1.3 for gas; 1.25 for others) 1.30

Minimum hydrotest pressure $P_{T,\min} = C_p \cdot P_d \cdot \frac{R_e(20^o C)}{R_e(T_d)}$ = 144.43 barg

Maximum allowable hydrotest pressure $P_{T,\max} = \frac{2 \cdot d_{nom} \cdot (1 - f_{tol}) \cdot R_e(20^\circ C)}{(D_e - d_{nom} \cdot (1 - f_{tol}))}$ = 281.23 barg

Mill test pressure $P_{T,mill} = 0.9 \cdot \frac{2 \cdot R_e \cdot d_{nom}}{D_e}$ = 262.77 barg

Max. allowable hydro test pressure exceeds mill test pressure!!

Note 1: Outside 500m zone: Pd***** = (Pd - Pe)
Within 500m zone: Pd***** = Pd

Note 2: The bend manufacturer to ensure that the finished products does meet with these minimum WT. requirements.

Project : **N05-A Pipeline basic design**
Project # : 19018
Subject : Wall thickness calculation N05-A Pipeline
File # : 19018-60-CAL-01001-02-01a_Wall thickness_20x20.6_L360_outside 500m.xlsx

Client : ONE-Dyas
Client File # :

Originator : HvH
Checked : PF
Date : 21.10.2019
Revision : 01

20" Pipeline - Outside 500m zone

Material properties

Material = L360NB
Design temperature T_d = 50 °C
Yield at ambient temperature R_e = 360.00 N/mm^2
Yield at design temperature R_{ed} = 360.00 N/mm^2

Material factor (Table 4 NEN 3656) γ_m = 1.10 -
Allowable stress $\sigma_v = \frac{R_{ed}}{\gamma_m}$ σ_v = 327.27 N/mm^2

Pipeline properties

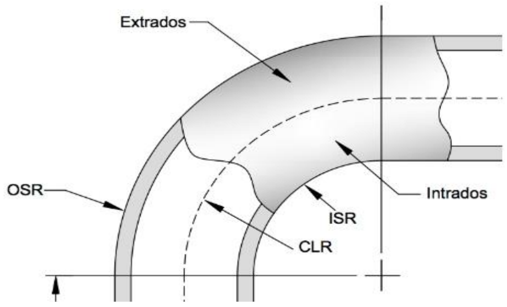
Outside diameter OD = 508 mm
Design pressure P_d = 111.1 barg
Minimum outside presssure P_o = 0 barg
Fabrication Tolerance f_{tol} = 7.3 %
Corrosion allowance CA = 3 mm
Pipeline within the 500 meter zone? n (Y or N)
Load factor (Table 3 NEN 3656): γ_s = 1.250 -
1,25 outside 500m zone; 1,364 inside 500m zone
Bend radius 2540 mm
Fabrication tolerance bends f_{tolB} = 7.3 %
Inside bend factor $\frac{2R-0.5D_e}{2R-D_e}$ = 1.06
Outside bend factor $\frac{2R+0.5D_e}{2R+D_e}$ = 0.95

Minimum wall thickness determination, d_{min}

minimum wall thickness (excl. CA): $d_{min} = \frac{\gamma_m \cdot \gamma_s \cdot P_d^* \cdot D_e}{2 \cdot R_e(T_d) + \gamma_m \cdot \gamma_s \cdot P_d^*}$ = 10.55 mm

Inside bend = 11.14 mm

Outside bend = 10.07 mm



Minimum required wall thickness (incl. CA) after bending, d_{min} [Note 2]

Straight part / along bend radius @ CLR = 13.55 mm
Inside bend @ ISR = 14.14 mm
Outside bend @ OSR = 13.07 mm

Selected nominal wall thickness = 20.6 mm

Project : **N05-A Pipeline basic design**
Project # : 19018
Subject : Wall thickness calculation N05-A Pipeline
File # : 19018-60-CAL-01001-02-01a_Wall thickness_20x20.6_L360_outside 500m.xlsx

Client : ONE-Dyas
Client File # :

Originator : HvH
Checked : PF
Date : 21.10.2019
Revision : 01

20" Pipeline - Outside 500m zone

Hoop stress

Hoop stress straight parts	$\sigma_{hoop} = \frac{\gamma_s \cdot P_d^* \cdot (D_e - d_{\min})}{2 \cdot d_{\min}}$	=	212.20	N/mm^2
Hoop stress inside bend	$\sigma_{hoop}(\text{BI}) = \frac{2 \cdot R - \frac{1}{2} \cdot D_e}{2 \cdot \text{R} - D_e} \cdot \sigma_{hoop}$	=	223.99	N/mm^2
Hoop stress outside bend	$\sigma_{hoop}(\text{BO}) = \frac{2 \cdot R + \frac{1}{2} \cdot D_e}{2 \cdot \text{R} + D_e} \cdot \sigma_{hoop}$	=	202.56	N/mm^2

Stress Check

Hoop stress (N/mm2)	Occurring	Allowable
Straight parts	212.20	327.27
Inside bend	223.99	327.27
Outside bend	202.56	327.27

Test pressure

Hydrotest temperature		=	15	°C
Yield at hydrotest temperature		=	360	N/mm^2
Product (gas / others)			gas	
Design factor, CP (1.3 for gas; 1.25 for others)			1.30	
Minimum hydrotest pressure	$P_{T,\min} = C_p \cdot P_d \cdot \frac{R_e(20^\circ C)}{R_e(T_d)}$	=	144.43	barg
Maximum allowable hydrotest pressure	$P_{T,\max} = \frac{2 \cdot d_{nom} \cdot (1 - f_{tol}) \cdot R_e(20^\circ C)}{(D_e - d_{nom} \cdot (1 - f_{tol}))}$	=	281.23	barg
Mill test pressure	$P_{T,mill} = 0.9 \cdot \frac{2 \cdot R_e \cdot d_{nom}}{D_e}$	=	262.77	barg

Max. allowable hydro test pressure exceeds mill test pressure!!

Note 1:	Outside 500m zone:	Pd***** = (Pd - Pe)
	Within 500m zone:	Pd***** = Pd

Note 2: The bend manufacturer to ensure that the finished products does meet with these minimum WT. requirements.

B. Buckling & Collapse Analysis

The following buckling and collapse analyses were performed:

- 19018-60-CAL-01003-01-01 Buckling & Collapse calculation – 26m – operation
- 19018-60-CAL-01003-02-01 Buckling & Collapse calculation – 26m – installation flooded
- 19018-60-CAL-01003-03-01 Buckling & Collapse calculation – 26m - hydrotest
- 19018-60-CAL-01003-04-01 Buckling & Collapse calculation – 8m - operation
- 19018-60-CAL-01003-05-01 Buckling & Collapse calculation – 8m - installation flooded
- 19018-60-CAL-01003-06-01 Buckling & Collapse calculation – 8m - hydrotest
- 19018-60-CAL-01003-07-01 Buckling & Collapse calculation – 17m - operation
- 19018-60-CAL-01003-08-01 Buckling & Collapse calculation – 17m - installation flooded
- 19018-60-CAL-01003-09-01 Buckling & Collapse calculation – 17m - hydrotest

(66 pages) only 26m with Stokes+hydroload pages

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-01-01 - Buckling & Collapse calculations - 26m - operation.xlsx

Client : ONE-Dyas
Client File # :

Originator : EvW
Date : 24/01/2020
Revision : 01
Checked :

Buckling and Collapse - 20in x 20.62mm - Operational

Situation

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

4
Operational

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom} =	20	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$ =	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$ =	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max} =	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min} =	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0 =	0.014	-
Cross sectional area of steel		A =	31572	mm^2
Moment of Inertia		I =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$ =	0	mm
Nominal wall thickness	$d_{nom,p}$ =	0.0	mm

Coating data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Project	:	**N05-A Pipeline design**
Project #	:	19018
Subject	:	Buckling and Collapse
File #	:	19018-60-CAL-01003-01-01 - Buckling & Collapse calculations - 26m - operation.xlsx
Client	:	ONE-Dyas
Client File #	:	

enersea®

Originator : EvW Checked :
Date : 24/01/2020
Revision : 01

Material		=	L360NB	
Design temperature	T_d	=	50	°C
Yield at ambient temperature	R_e	=	360.00	N/mm^2
Yield at design temperature	R_{ed}	=	360.00	N/mm^2
Density	ρ_{st}	=	7850	kg/m^3
Youngs modulus	E_s	=	210000	N/mm^2
Poisson's ratio	u	=	0.3	-
Linear thermal expansion coefficient	a	=	1.16E-05	m/m/^{o}C

Contents

Sea water density		1025	kg/m^3
Pipeline product density		96.1	kg/m^3
Pipeline content density used for this case:	Operational	96.1	kg/m^3

Pipeline Weights

$$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$$

Pipeline weight in air	$W_{pl,a}$	=	2636.6	N/m
Piggyback weight in air	$W_{pg,a}$	=	0.0	N/m

$$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$$

Buoyancy force pipeline	$F_{B,pl}$	=	2086.5	N/m
Buoyancy force piggyback	$F_{B,pb}$	=	0.0	N/m
Submerged pipeline weight,empty	$W_{pl,s,e}$	=	388.8	N/m
Submerged piggyback weight	$W_{pg,s}$	=	0.0	N/m
Total submerged bundle weight,empty	$W_{T,s,e}$	=	388.8	N/m
Total submerged bundle weight,water filled	$W_{T,s,f}$	=	2109.4	N/m

Soil

Submerged density		ρ_{ss}	=	1000	kg/m^3
Depth of burial		d_b	=	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss}$ x d_b x g	SC_{pres}	=	0.008	N/mm^2

Environmental conditions

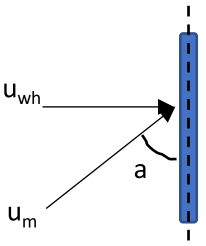
Water depths:

Seawater density		ρ_{sw}	=	1025	kg/m3
Maximum water depth		WD_{max}	=	29.68	m LAT
Minimum water depth		WD_{min}	=	26	m LAT
Other water depth (to be used for calculations)		WD	=	26	m LAT
Storm surge, RP1 yr		ss_{1yr}	=	-1.02	m LAT
Storm surge, RP100 yr		ss_{100yr}	=	-1.79	m LAT
Storm surge water level	SSWL = WD + ss	SSWL	=	24.21	m LAT
Highest Astronomical Tide		HAT	=	2.72	m

Waves (H_{max} & T_{max}):

Maximum wave height, RP1 yr - installation/hydrotes	$H_{max,1}$	=	11.4	m
Associated maximum wave period, RP1 yr	$T_{ass,1}$	=	10.1	s
Maximum wave height, RP100 yr - operational	$H_{max,100}$	=	16.9	m
Associated maximum wave period, RP100 yr	$T_{ass,100}$	=	11.5	s

Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")	$\frac{H_{max}}{g \cdot T_z^2} =$	0.0130	
	$\frac{SWL}{g \cdot T_z^2} =$	0.0187	
Wave theory selected:			
1. Airy/linear wave; 2. Stokes 5th	**2**	Stokes 5th	
Maximum wave particle velocity	u_{wm} =	4.00	m/s
Angle of attack relative to pipeline axis	α_{uw} =	90	deg
Horizontal wave velocity ⊥ to P/L	u_{wh} =	4.00	m/s



Current:

Height above seabed at which velocity is known	z* =	2	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.74	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	0.84	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	0.96	m/s
Current velocity at reference height	U_{czr} =	0.96	m/s
Angle of attack relative to pipeline axis	α_{uc} =	90	deg
Horizontal current velocity ⊥ to P/L $\frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc}) =$	u_{ch} =	0.69	m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-

Maximum absolute hydrodynamic force 4320 N/m

Temperatures:

Ambient temperature T_{amb} = 4 deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by:

$$(p_c - p_e)\cdot(p_c^2 - p_p^2) = p_c \cdot p_e \cdot p_p \cdot 2 \cdot \delta_o \cdot \frac{OD_g}{d_{nom}}$$

External elastical pipe collapse pressure (P_e): $P_e = \frac{2E_s}{1-\nu^2}\left(\frac{d_{nom}}{OD_{av}}\right)^3$ = 34.0 N/mm^2

External plastic pipe collapse pressure (P_p): $P_p = \frac{2\,R_e\,d_{nom}}{OD_{nom}}$ = 29.2 N/mm^2

External implosion pipe collapse pressure (P_c): P_c = 16.0 N/mm^2

Maximum water column above mudline (WC_{max}) $WC_{max} = WD_{max} + 0.5 \cdot H_{max,100} + HAT$ = 40.85 m
0.4085 N/mm^2

Actual external pressure (P_L) $WC_{max} + SC_{pres}$ = 0.42 N/mm^2

Assessment: $\gamma_{g,p} \cdot P_L \le \dfrac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656
$g_{g,p}$ = 1.05 -
g_M = 0.93 -
$g_{m,p}$ = 1.45 -

Assessment: $\gamma_{g,p} \cdot P_L \le \dfrac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **=** **OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \le \dfrac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656
$g_{g,M}$ = 1.1 -
g_M = 1 -
$g_{m,M}$ = 1.3 -

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\dfrac{\gamma_{g,p} \times P_L}{P_c / \gamma_{m,p}} + \left(\dfrac{\gamma_{g,M} \times M_L}{M_c / \gamma_{m,M}} \right)^n \le \gamma_M$ **Where,**

Table 4 - NEN3656
$g_{g,p}$ = 1.05 -
$g_{g,M}$ = 1.55 -
$g_{m,p}$ = 1.25 -
$g_{m,M}$ = 1.15 -
g_M = 0.93 -
n = 1 + 300 · d_{nom} / OD_g n = 13.6 -

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 9.994E+05 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \dfrac{q \cdot L^2}{10}$ **Where,**

q = load acting on pipe
L = span length

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight; Ws = 389 N/m
$F_D + F_I$ = 4320 N/m
g_w = 1.1 -
g_h = 1.2 -
Table 3 - NEN3656
q = 5202 N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 9.99E+05 N·m

Maximum span length, L_{max} = 43.8 m

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-01-01 - Buckling & Collapse calculations - 26m - operation.xlsx

Client : ONE-Dyas
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Progressive plastic collapse (K.3.3.6)

Assessment: $\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E} \sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$

Temperature difference with ambient; DT = 46 -
R_e = 360.00 N/mm^2
R_{ed} = 360.00 N/mm^2

$$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$$

s_p = 169.3 N/mm^2

$$\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E} \sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$$

Assessment: 0.0005 < 0.0030 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment: $L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$ Table 3 - NEN3656 - BC4

g_p = 1.15 -
g_t = 1.1 -
N = -2.05E+06 N

$L_{max,bb}$ = 61.7 m

Stokes 5th order wave theory

Water depth	WD =	26	m (LAT)
Storm surge	ss =	-1.79	m
Storm surge water level	$SWL = WD + ss$ =	24.21	m
Wave height	H =	16.9	m
Wave period	T =	11.5	s
Grav. Acceleration	g =	9.81	m/s^2
Deep water wave length	$L_o = \frac{g\cdot T^2}{2\cdot\pi}$ =	206.5	m

Solving for wave length (L) and λ

$$\frac{\pi\cdot H}{SWL} - \frac{L}{SWL}\left\{\lambda + \lambda^3\cdot B_{33} + \lambda^5\cdot\left(B_{35}+B_{55}\right)\right\}=0 \quad \text{(I)}$$

$$\frac{SWL}{L_O} - \frac{SWL}{L}\cdot\tanh\left(\frac{2\cdot\pi\cdot SWL}{L}\right)\cdot\left\{1+\lambda^2\cdot C_1+\lambda^4\cdot C_2\right\}=0 \quad \text{(II)}$$

Choosing L and solving for λ in (II) results in 4 roots for λ

Estimate actual wave length, L **184.228** **m**

$$A = SWL/L_O = 0.1172$$

$$B = \frac{SWL}{L}\cdot\tanh\left(\frac{2\cdot\pi\cdot SWL}{L}\right) = 0.0891$$

$$\lambda = \pm\sqrt{X}$$

$$X = \frac{-C_1\cdot B \pm\sqrt{D}}{2\cdot C_2\cdot B}$$

$$D = \left(C_1\cdot B\right)^2 - 4\cdot\left(C_2\cdot B\right)\cdot\left(-\left(A-B\right)\right) = 0.5724$$

	-	eq. (I)	eq. (II)
λ1	0.227	-0.0004	0.0000
λ2	Numerator of X < 0		
λ3	-0.227	4.3864	0.0000
λ4	Numerator of X < 0		

Item	Formula	Value	Unit
s	$s = \sinh\left(\frac{2 \cdot \pi \cdot WL}{L}\right) =$	0.9228	-
c	$c = \cosh\left(\frac{2 \cdot \pi \cdot WL}{L}\right) =$	1.3607	-
A11	$A_{11} = \frac{1}{s} =$	1.0837	-
A13	$A_{13} = \frac{-c^2 \cdot (5 \cdot c^2 + 1)}{8 \cdot s^5} =$	-3.5482	-
	$A_{15} = -\frac{1184 \cdot c^{10} - 1440 \cdot c^8 - 1992 \cdot c^6 + 2641 \cdot c^4 - 249 \cdot c^2 + 18}{1536 \cdot s^{11}} =$	-7.5755	-
A22	$A_{22} = \frac{3}{8 \cdot s^4} =$	0.5172	-
A24	$A_{24} = \frac{192 \cdot c^8 - 424 \cdot c^6 - 312 \cdot c^4 + 480 \cdot c^2 - 17}{768 \cdot s^{10}} =$	-1.8403	-
A33	$A_{33} = \frac{13 - 4 \cdot c^2}{64 \cdot s^7} =$	0.1534	-
	$A_{35} = \frac{512 \cdot c^{12} + 4224 \cdot c^{10} - 6800 \cdot c^8 - 12808 \cdot c^6 + 16704 \cdot c^4 - 3154 \cdot c^2 - 107}{4096 \cdot s^{13} \cdot (6 \cdot c^2 - 1)} =$	0.1815	-
A44	$A_{44} = \frac{80 \cdot c^6 - 816 \cdot c^4 + 1338 \cdot c^2 - 197}{1536 \cdot s^{10} \cdot (6 \cdot c^2 - 1)} =$	-0.0013	-

$$A_{55} = -\frac{2880 \cdot c^{10} - 72480 \cdot c^{8} + 324000 \cdot c^{6} - 432000 \cdot c^{4} + 163470 \cdot c^{2} - 16245}{61440 \cdot s^{11} \cdot (6 \cdot c^{2} - 1) \cdot (8 \cdot c^{4} - 11 \cdot c^{2} + 3)} =$$ -0.0282 -

B22 $$B_{22} = \frac{(2 \cdot c^{2} + 1) \cdot c}{4 \cdot s^{3}} =$$ 2.0361 -

B24 $$B_{24} = \frac{c \cdot (272 \cdot c^{8} - 504 \cdot c^{6} - 192 \cdot c^{4} + 322 \cdot c^{2} + 21)}{384 \cdot s^{9}} =$$ -0.3177 -

B33 $$B_{33} = \frac{3 \cdot (8 \cdot c^{6} + 1)}{64 \cdot s^{6}} =$$ 3.9311 -

$$B_{35} = \frac{88128 \cdot c^{14} - 208224 \cdot c^{12} + 70848 \cdot c^{10} + 54000 \cdot c^{8} - 21816 \cdot c^{6} + 6264 \cdot c^{4} - 54 \cdot c^{2} - 81}{12288 \cdot s^{12} \cdot (6 \cdot c^{2} - 1)} =$$
= 5.1509 -

B44 $$B_{44} = c \cdot \frac{768 \cdot c^{10} - 488 \cdot c^{8} - 48 \cdot c^{6} + 48 \cdot c^{4} + 106 \cdot c^{2} - 21}{384 \cdot s^{9} \cdot (6 \cdot c^{2} - 1)} =$$ 7.9561 -

$$B_{55} = \frac{192000 \cdot c^{16} - 26720 \cdot c^{14} + 83680 \cdot c^{12} + 20160 \cdot c^{10} - 7280 \cdot c^{8} + 7160 \cdot c^{6} - 1800 \cdot c^{4} - 1050 \cdot c^{2} + 225}{12288 \cdot s^{10} \cdot (8 \cdot c^{4} - 11 \cdot c^{2} + 3) \cdot (6 \cdot c^{2} - 1)} =$$
= 19.0981 -

C1 $$C_{1} = \frac{8 \cdot c^{4} - 8 \cdot c^{2} + 9}{8 \cdot s^{4}} =$$ 3.7260 -

$$C_{2} = \frac{3840 \cdot c^{12} - 4096 \cdot c^{10} + 2592 \cdot c^{8} - 1008 \cdot c^{6} + 5944 \cdot c^{4} - 1830 \cdot c^{2} + 147}{512 \cdot s^{10} \cdot (6 \cdot c^{2} - 1)} =$$ 46.0838 -

C3 $$C_{3} = -\frac{1}{4 \cdot c \cdot s} =$$ -0.1991 -

C4 $$C_{4} = \frac{12 \cdot c^{8} + 36 \cdot c^{6} - 162 \cdot c^{4} + 141 \cdot c^{2} - 27}{192 \cdot c \cdot s^{9}} =$$ 0.3806 -

K1 $$K_{1} = \lambda \cdot A_{11} + \lambda^{3} \cdot A_{13} + \lambda^{5} \cdot A_{15} =$$ 0.2001 -

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K2	$K_2 = \lambda^2 \cdot A_{22} + \lambda^4 \cdot A_{24} =$	0.0218	-
K3	$K_3 = \lambda^3 \cdot A_{33} + \lambda^5 \cdot A_{35} =$	0.0019	-
K4	$K_4 = \lambda^4 \cdot A_{44} =$	0.0000	-
K5	$K_5 = \lambda^5 \cdot A_{55} =$	0.0000	-

Originator : EvW
Date : 24/01/2020
Revision : 01
Checked :

Horizontal wave particle velocities

Water depth at which data required, z (w.r.t. seabed) 0.5080 m

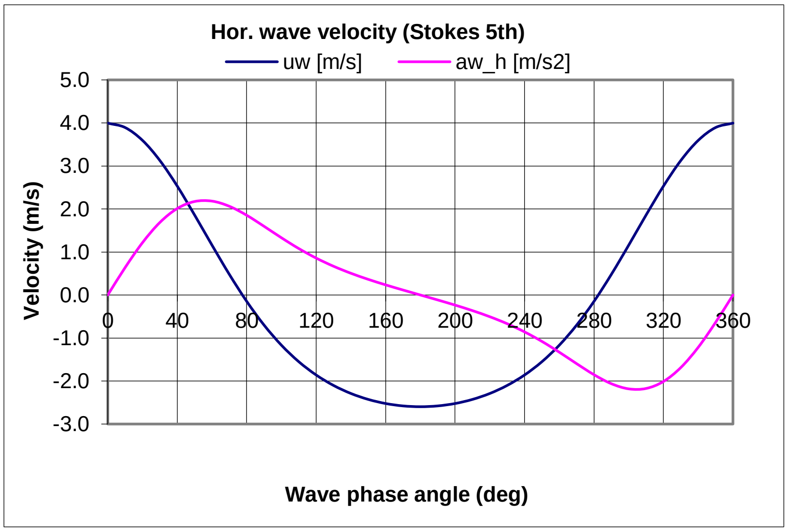
Horizontal velocity, u_w

$$u_w = \frac{L}{T}\cdot\sum_{n=1}^{5} n\cdot K_n\cdot\cosh\left(n\cdot\frac{2\cdot\pi}{L}\cdot z\right)\cdot\cos(n\cdot\varphi)$$

Horizontal acceleration, $a_{w,h}$

$$a_{w,h} = \frac{2\cdot\pi\cdot L}{T^2}\cdot\sum_{n=1}^{5} n^2\cdot K_n\cdot\cosh\left(n\cdot\frac{2\cdot\pi}{L}\cdot z\right)\cdot\sin(n\cdot\varphi)$$

ϕ [deg.]	uw [m/s]	aw_h [m/s^2]
0.00	3.9954	0.0000
10.00	3.8927	0.6377
20.00	3.5942	1.2167
30.00	3.1271	1.6861
40.00	2.5326	2.0102
50.00	1.8601	2.1734
60.00	1.1605	2.1823
70.00	0.4796	2.0627
80.00	-0.1478	1.8534
90.00	-0.6996	1.5968
100.00	-1.1669	1.3301
110.00	-1.5511	1.0793
120.00	-1.8596	0.8578
130.00	-2.1025	0.6679
140.00	-2.2893	0.5054
150.00	-2.4276	0.3633
160.00	-2.5229	0.2353
170.00	-2.5788	0.1156
180.00	-2.5972	0.0000
190.00	-2.5788	-0.1156
200.00	-2.5229	-0.2353



210.00	-2.4276	-0.3633
220.00	-2.2893	-0.5054
230.00	-2.1025	-0.6679
240.00	-1.8596	-0.8578
250.00	-1.5511	-1.0793
260.00	-1.1669	-1.3301
270.00	-0.6996	-1.5968
280.00	-0.1478	-1.8534
290.00	0.4796	-2.0627
300.00	1.1605	-2.1823
310.00	1.8601	-2.1734
320.00	2.5326	-2.0102
330.00	3.1271	-1.6861
340.00	3.5942	-1.2167
350.00	3.8927	-0.6377
360.00	3.9954	0.0000

U_{wm} = max. wave particle velocity = 4.00 m/s

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-01-01 - Buckling & Collapse calculations - 26m - operation.xlsx

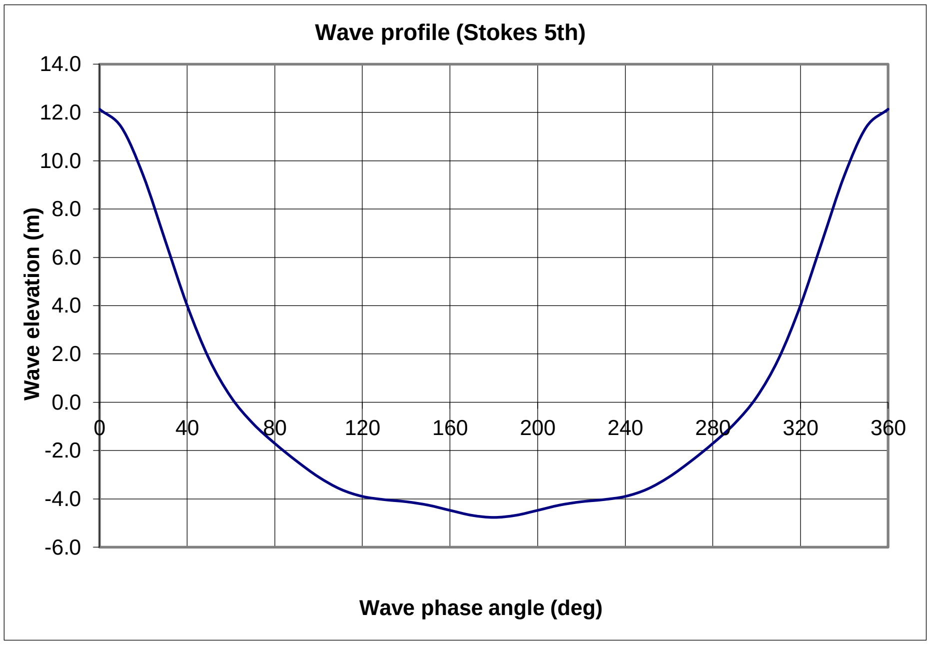
Client : ONE-Dyas
Client File # :

Originator : EvW
Date : 24/01/2020
Revision : 01
Checked :

Wave profile h(t)

$$\eta(t)=\frac{L}{2\cdot\pi}\left\{\lambda\cdot\cos(\varphi)+\left(\lambda^2\cdot B_{22}+\lambda^4\cdot B_{24}\right)\cdot\cos(2\varphi)+\left(\lambda^3\cdot B_{33}+\lambda^5\cdot B_{35}\right)\cdot\cos(3\varphi)+\lambda^4\cdot B_{44}\cdot\cos(4\varphi)+\lambda^5\cdot B_{55}\cdot\cos(5\varphi)\right\}$$

ϕ (deg.)	η(t) (m)
0.00	12.1350
10.00	11.3883
20.00	9.3802
30.00	6.6968
40.00	4.0097
50.00	1.7992
60.00	0.2151
70.00	-0.8738
80.00	-1.7036
90.00	-2.4374
100.00	-3.0936
110.00	-3.5987
120.00	-3.8987
130.00	-4.0330
140.00	-4.1177
150.00	-4.2594
160.00	-4.4749
170.00	-4.6819
180.00	-4.7680
190.00	-4.6819
200.00	-4.4749
210.00	-4.2594
220.00	-4.1177
230.00	-4.0330
240.00	-3.8987
250.00	-3.5987
260.00	-3.0936
270.00	-2.4374
280.00	-1.7036
290.00	-0.8738
300.00	0.2151
310.00	1.7992
320.00	4.0097
330.00	6.6968
340.00	9.3802
350.00	11.3883
360.00	12.1350



Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-02-01 - Buckling & Collapse calculations - 26m - installation flooded.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-02-01 - Buckling & Collapse calculations - 26m - installation flooded.xlsx

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Originator : EvW
Date : 24/01/2020
Revision : 01
Checked :

Buckling and Collapse - 20in x 20.62mm - Installation: filled

Situation

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

2
Installation: filled

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom}	=	20	
Nominal diameter		OD_{nom}	=	508	mm
Nominal wall thickness		d_{nom}	=	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$	=	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$	=	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max}	=	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min}	=	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0	=	0.014	-
Cross sectional area of steel		A	=	31572	mm^2
Moment of Inertia		I	=	939135656	mm^4
Corrosion allowance		CA	=	3	mm
Fabrication Tolerance		f_{tol}	=	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min}	=	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g	=	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$	=	0	mm
Nominal wall thickness	$d_{nom,p}$	=	0.0	mm

Coating data

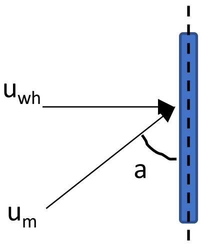
Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration g = 9.81 m/s^2

Material			=	L360NB	
Design temperature		T_d	=	15	°C
Yield at ambient temperature		R_e	=	360.00	N/mm^2
Yield at design temperature		R_{ed}	=	360.00	N/mm^2
Density		ρ_{st}	=	7850	kg/m^3
Youngs modulus		E_s	=	210000	N/mm^2
Poisson's ratio		u	=	0.3	-
Linear thermal expansion coefficient		a	=	1.16E-05	$m/m/^oC$
Contents					
Sea water density				1025	kg/m^3
Pipeline product density				96.1	kg/m^3
Pipeline content density used for this case:	Installation: filled			1025	kg/m^3
Pipeline Weights					
Pipeline weight in air	$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$	$W_{pl,a}$	=	4195.8	N/m
Piggyback weight in air		$W_{pg,a}$	=	0.0	N/m
Buoyancy force pipeline	$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$	$F_{B,pl}$	=	2086.5	N/m
Buoyancy force piggyback		$F_{B,pb}$	=	0.0	N/m
Submerged pipeline weight,empty		$W_{pl,s,e}$	=	388.8	N/m
Submerged piggyback weight		$W_{pg,s}$	=	0.0	N/m
Total submerged bundle weight,empty		$W_{T,s,e}$	=	388.8	N/m
Total submerged bundle weight,water filled		$W_{T,s,f}$	=	2109.4	N/m
Soil					
Submerged density		ρ_{ss}	=	1000	kg/m^3
Depth of burial		d_b	=	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss}$ x d_b x g	SC_{pres}	=	0.008	N/mm^2
Environmental conditions					
Water depths:					
Seawater density		ρ_{sw}	=	1025	kg/m3
Maximum water depth		WD_{max}	=	29.68	m LAT
Minimum water depth		WD_{min}	=	26	m LAT
Other water depth (to be used for calculations)		WD	=	26	m LAT
Storm surge, RP1 yr		ss_{1yr}	=	-1.02	m LAT
Storm surge, RP100 yr		ss_{100yr}	=	-1.79	m LAT
Storm surge water level	SSWL = WD + ss	SSWL	=	24.98	m LAT
Highest Astronomical Tide		HAT	=	2.72	m
Waves (H_{max} & T_{max}):					
Maximum wave height, RP1 yr - installation/hydrotes		$H_{max,1}$	=	11.4	m
Associated maximum wave period, RP1 yr		$T_{ass,1}$	=	10.1	s
Maximum wave height, RP100 yr - operational		$H_{max,100}$	=	16.9	m
Associated maximum wave period, RP100 yr		$T_{ass,100}$	=	11.5	s

Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")		$\frac{H_{max}}{g\cdot T_z^2} =$	0.0114	
		$\frac{SWL}{g\cdot T_z^2} =$	0.0250	
Wave theory selected:				
1. Airy/linear wave; 2. Stokes 5th		**2**	Stokes 5th	
Maximum wave particle velocity		u_{wm} =	2.39	m/s
Angle of attack relative to pipeline axis		α_{uw} =	90	deg
Horizontal wave velocity ⊥ to P/L		u_{wh} =	2.39	m/s



Current:				
Height above seabed at which velocity is known		z* =	2	m
Spring tide		u_{st} =	0	m/s
Storm surge, RP1 yr		$u_{ss,1}$ =	0.74	m/s
Storm surge, RP10 yr		$u_{ss,10}$ =	0.84	m/s
Storm surge, RP100 yr		$u_{ss,100}$ =	0.96	m/s
Current velocity at reference height		U_{czr} =	0.74	m/s
Angle of attack relative to pipeline axis		α_{uc} =	90	deg
Horizontal current velocity ⊥ to P/L	$\frac{7}{8}\cdot U_{czr}\cdot\left(\frac{OD_{nom}}{z_r}\right)^{1/7}\cdot\sin\left(\alpha_{uc}\right) =$	u_{ch} =	0.53	m/s
Hydrodynamic coefficients:				
Drag coefficient		C_D =	0.7	-
Lift coefficient		C_L =	0.9	-
Inertia coefficient		C_I =	3.29	-
Maximum absolute hydrodynamic force			1822	N/m
Temperatures:				
Ambient temperature		T_{amb} =	4	deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by:	$(p_c - p_e)\cdot\left(p_c^2 - p_p^2\right) = p_c\cdot p_e\cdot p_p\cdot 2\cdot\delta_o\cdot\frac{OD_g}{d_{nom}}$			
External elastical pipe collapse pressure (P_e):	$P_e = \frac{2E_s}{1-\nu^2}\left(\frac{d_{nom}}{OD_{av}}\right)^3$	=	34.0	N/mm^2
External plastic pipe collapse pressure (P_p)	$P_p = \frac{2R_e d_{nom}}{OD_{nom}}$	=	29.2	N/mm^2
External implosion pipe collapse pressure (P_c):		P_c =	16.0	N/mm^2
Maximum water column above mudline (WC_{max})	$WC_{max} = WD_{max} + 0.5\cdot H_{max,100} + HAT$	=	40.85	m
			0.4085	N/mm^2
Actual external pressure (P_L)	$WC_{max} + SC_{pres}$	=	0.42	N/mm^2

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656
$g_{g,p}$ = 1.05 -
g_M = 0.93 -
$g_{m,p}$ = 1.45 -

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ = **OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \le \frac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656
$g_{g,M}$ = 1.1 -
g_M = 1 -
$g_{m,M}$ = 1.3 -

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\frac{\gamma_{g,p} \times P_L}{P_c / \gamma_{m,p}} + \left(\frac{\gamma_{g,M} \times M_L}{M_c / \gamma_{m,M}} \right)^n \le \gamma_M$ **Where,**

Table 4 - NEN3656
$g_{g,p}$ = 1.05 -
$g_{g,M}$ = 1.55 -
$g_{m,p}$ = 1.25 -
$g_{m,M}$ = 1.15 -
g_M = 0.93 -
n = 1 + 300 · d_{nom} / OD_g n = 13.6 -

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 9.994E+05 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \frac{q \cdot L^2}{10}$ **Where,**

q = load acting on pipe
L = span length

$$q = \sqrt{\gamma_W^2 \cdot W_S^2 + \gamma_H^2 \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight; Ws = 2109 N/m
$F_D + F_I$ = 1822 N/m
g_w = 1.1 -
g_h = 1.2 -
Table 3 - NEN3656
q = 3188 N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 9.99E+05 N·m

Maximum span length, L_{max} = 56.0 m

Progressive plastic collapse (K.3.3.6)

Assessment:

$$\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E}\sqrt{1-\frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9-\frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2}\right]$$

Temperature difference with ambient; DT = 11 -

R_e = 360.00 N/mm^2

R_{ed} = 360.00 N/mm^2

$$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$$

s_p = 3.1 N/mm^2

$$\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E}\sqrt{1-\frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9-\frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2}\right]$$

Assessment: 0.0001 < 0.0033 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment:

$$L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$

Table 3 - NEN3656 - BC4

g_p = 1.15 -

g_t = 1.1 -

N = -8.97E+05 N

$L_{max,bb}$ = 93.1 m

Stokes 5th order wave theory

Water depth	WD =	26	m (LAT)
Storm surge	ss =	-1.02	m
Storm surge water level	$SWL = WD + ss$ =	24.98	m
Wave height	H =	11.4	m
Wave period	T =	10.1	s
Grav. Acceleration	g =	9.81	m/s^2
Deep water wave length	$L_o = \frac{g \cdot T^2}{2 \cdot \pi}$ =	159.3	m

Solving for wave length (L) and λ

$$\frac{\pi \cdot H}{SWL} - \frac{L}{SWL}\left\{\lambda + \lambda^3 \cdot B_{33} + \lambda^5 \cdot (B_{35} + B_{55})\right\} = 0 \quad (\text{ I })$$

$$\frac{SWL}{L_O} - \frac{SWL}{L} \cdot \tanh\left(\frac{2 \cdot \pi \cdot SWL}{L}\right) \cdot \left\{1 + \lambda^2 \cdot C_1 + \lambda^4 \cdot C_2\right\} = 0 \quad (\text{ II })$$

Choosing L and solving for λ in (II) results in 4 roots for λ

Estimate actual wave length, L **143.093** **m**

$$A = SWL/L_O = 0.1568$$

$$B = \frac{SWL}{L} \cdot \tanh\left(\frac{2 \cdot \pi \cdot SWL}{L}\right) = 0.1395$$

$$\lambda = \pm\sqrt{X}$$

$$X = \frac{-C_1 \cdot B \pm \sqrt{D}}{2 \cdot C_2 \cdot B}$$

$$D = (C_1 \cdot B)^2 - 4 \cdot (C_2 \cdot B) \cdot (-(A - B)) = 0.1581$$

	-	eq. (I)	eq. (II)
$\lambda 1$	0.228	0.0005	0.0000
$\lambda 2$	Numerator of X < 0		
$\lambda 3$	-0.228	2.8669	0.0000
$\lambda 4$	Numerator of X < 0		

Item	**Formula**	**Value**	**Unit**
s	$s = \sinh\left(\frac{2 \cdot \pi \cdot WL}{L}\right) =$	1.3304	-
c	$c = \cosh\left(\frac{2 \cdot \pi \cdot WL}{L}\right) =$	1.6643	-
A11	$A_{11} = \frac{1}{s} =$	0.7516	-
A13	$A_{13} = \frac{-c^2 \cdot (5 \cdot c^2 + 1)}{8 \cdot s^5} =$	-1.2336	-
	$A_{15} = -\frac{1184 \cdot c^{10} - 1440 \cdot c^8 - 1992 \cdot c^6 + 2641 \cdot c^4 - 249 \cdot c^2 + 18}{1536 \cdot s^{11}} =$	-2.4101	-
A22	$A_{22} = \frac{3}{8 \cdot s^4} =$	0.1197	-
A24	$A_{24} = \frac{192 \cdot c^8 - 424 \cdot c^6 - 312 \cdot c^4 + 480 \cdot c^2 - 17}{768 \cdot s^{10}} =$	0.0907	-
A33	$A_{33} = \frac{13 - 4 \cdot c^2}{64 \cdot s^7} =$	0.0041	-
	$A_{35} = \frac{512 \cdot c^{12} + 4224 \cdot c^{10} - 6800 \cdot c^8 - 12808 \cdot c^6 + 16704 \cdot c^4 - 3154 \cdot c^2 - 107}{4096 \cdot s^{13} \cdot (6 \cdot c^2 - 1)} =$	0.1402	-
A44	$A_{44} = \frac{80 \cdot c^6 - 816 \cdot c^4 + 1338 \cdot c^2 - 197}{1536 \cdot s^{10} \cdot (6 \cdot c^2 - 1)} =$	-0.0025	-

$$A_{55} = -\frac{2880\cdot c^{10} - 72480\cdot c^{8} + 324000\cdot c^{6} - 432000\cdot c^{4} + 163470\cdot c^{2} - 16245}{61440\cdot s^{11}\cdot\left(6\cdot c^{2}-1\right)\cdot\left(8\cdot c^{4}-11\cdot c^{2}+3\right)} =$$

-0.0003 -

B22

$$B_{22} = \frac{\left(2\cdot c^{2}+1\right)\cdot c}{4\cdot s^{3}} =$$

1.1556 -

B24

$$B_{24} = \frac{c\cdot\left(272\cdot c^{8} - 504\cdot c^{6} - 192\cdot c^{4} + 322\cdot c^{2} + 21\right)}{384\cdot s^{9}} =$$

1.5737 -

B33

$$B_{33} = \frac{3\cdot\left(8\cdot c^{6}+1\right)}{64\cdot s^{6}} =$$

1.4457 -

$$B_{35} = \frac{88128\cdot c^{14} - 208224\cdot c^{12} + 70848\cdot c^{10} + 54000\cdot c^{8} - 21816\cdot c^{6} + 6264\cdot c^{4} - 54\cdot c^{2} - 81}{12288\cdot s^{12}\cdot\left(6\cdot c^{2}-1\right)} =$$

= 5.1727 -

B44

$$B_{44} = c\cdot\frac{768\cdot c^{10} - 488\cdot c^{8} - 48\cdot c^{6} + 48\cdot c^{4} + 106\cdot c^{2} - 21}{384\cdot s^{9}\cdot\left(6\cdot c^{2}-1\right)} =$$

2.0428 -

$$B_{55} = \frac{192000\cdot c^{16} - 26720\cdot c^{14} + 83680\cdot c^{12} + 20160\cdot c^{10} - 7280\cdot c^{8} + 7160\cdot c^{6} - 1800\cdot c^{4} - 1050\cdot c^{2} + 225}{12288\cdot s^{10}\cdot\left(8\cdot c^{4}-11\cdot c^{2}+3\right)\cdot\left(6\cdot c^{2}-1\right)} =$$

= 3.3386 -

C1

$$C_{1} = \frac{8\cdot c^{4} - 8\cdot c^{2} + 9}{8\cdot s^{4}} =$$

1.9240 -

$$C_{2} = \frac{3840\cdot c^{12} - 4096\cdot c^{10} + 2592\cdot c^{8} - 1008\cdot c^{6} + 5944\cdot c^{4} - 1830\cdot c^{2} + 147}{512\cdot s^{10}\cdot\left(6\cdot c^{2}-1\right)} =$$

8.9142 -

C3

$$C_{3} = -\frac{1}{4\cdot c\cdot s} =$$

-0.1129 -

C4

$$C_{4} = \frac{12\cdot c^{8} + 36\cdot c^{6} - 162\cdot c^{4} + 141\cdot c^{2} - 27}{192\cdot c\cdot s^{9}} =$$

0.1419 -

K1

$$K_{1} = \lambda\cdot A_{11} + \lambda^{3}\cdot A_{13} + \lambda^{5}\cdot A_{15} =$$

0.1552 -

K2	$K_2 = \lambda^2 \cdot A_{22} + \lambda^4 \cdot A_{24} =$	0.0065	-
K3	$K_3 = \lambda^3 \cdot A_{33} + \lambda^5 \cdot A_{35} =$	0.0001	-
K4	$K_4 = \lambda^4 \cdot A_{44} =$	0.0000	-
K5	$K_5 = \lambda^5 \cdot A_{55} =$	0.0000	-

Originator : EvW
Date : 24/01/2020
Revision : 01

Checked :

Horizontal wave particle velocities

Water depth at which data required, z (w.r.t. seabed) 0.5080 m

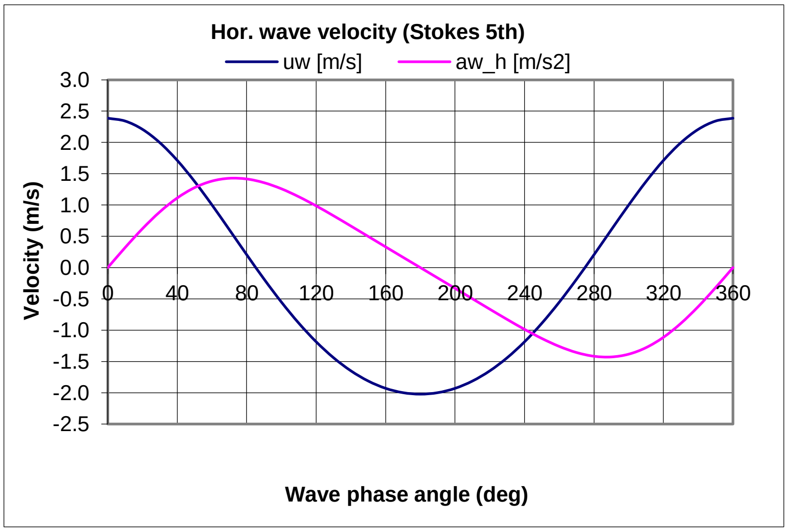
Horizontal velocity, u_w

$$u_w = \frac{L}{T} \cdot \sum_{n=1}^{5} n \cdot K_n \cdot \cosh\left(n \cdot \frac{2 \cdot \pi}{L} \cdot z\right) \cdot \cos(n \cdot \varphi)$$

Horizontal acceleration, $a_{w,h}$

$$a_{w,h} = \frac{2 \cdot \pi \cdot L}{T^2} \cdot \sum_{n=1}^{5} n^2 \cdot K_n \cdot \cosh\left(n \cdot \frac{2 \cdot \pi}{L} \cdot z\right) \cdot \sin(n \cdot \varphi)$$

ϕ [deg.]	uw [m/s]	aw_h [m/s^2]
0.00	2.3878	0.0000
10.00	2.3427	0.3202
20.00	2.2098	0.6227
30.00	1.9965	0.8913
40.00	1.7141	1.1129
50.00	1.3773	1.2783
60.00	1.0025	1.3832
70.00	0.6068	1.4278
80.00	0.2066	1.4167
90.00	-0.1836	1.3575
100.00	-0.5515	1.2596
110.00	-0.8877	1.1329
120.00	-1.1853	0.9867
130.00	-1.4402	0.8286
140.00	-1.6498	0.6646
150.00	-1.8129	0.4982
160.00	-1.9293	0.3316
170.00	-1.9990	0.1655
180.00	-2.0222	0.0000
190.00	-1.9990	-0.1655
200.00	-1.9293	-0.3316



210.00	-1.8129	-0.4982
220.00	-1.6498	-0.6646
230.00	-1.4402	-0.8286
240.00	-1.1853	-0.9867
250.00	-0.8877	-1.1329
260.00	-0.5515	-1.2596
270.00	-0.1836	-1.3575
280.00	0.2066	-1.4167
290.00	0.6068	-1.4278
300.00	1.0025	-1.3832
310.00	1.3773	-1.2783
320.00	1.7141	-1.1129
330.00	1.9965	-0.8913
340.00	2.2098	-0.6227
350.00	2.3427	-0.3202
360.00	2.3878	0.0000

U_{wm} = max. wave particle velocity = 2.39 m/s

Originator : EvW Checked :
Date : 24/01/2020
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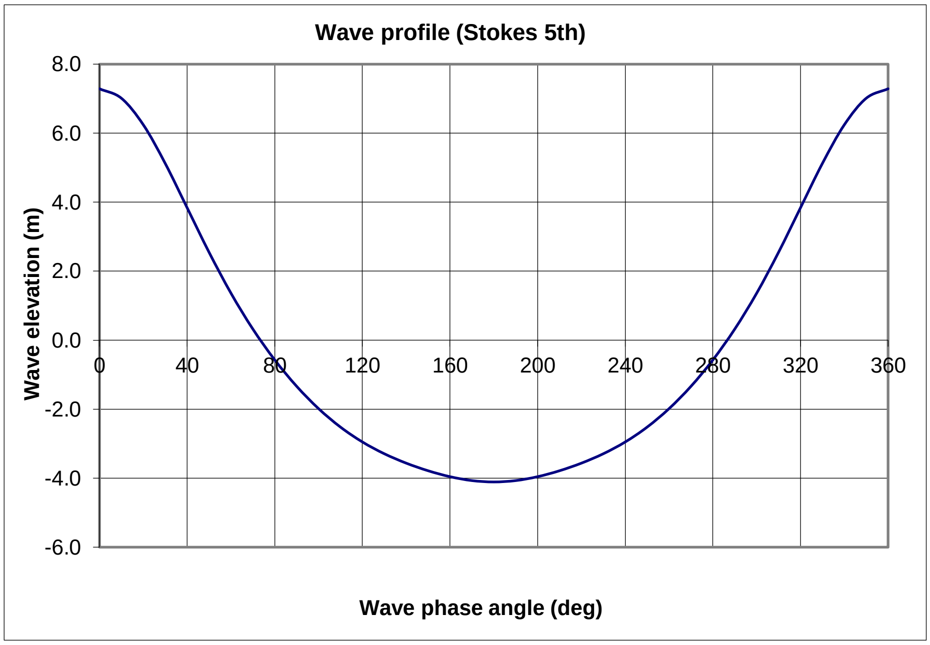
Wave profile h(t)

$$\eta(t)=\frac{L}{2\cdot\pi}\{\lambda\cdot\cos(\varphi)+(\lambda^2\cdot B_{22}+\lambda^4\cdot B_{24})\cdot\cos(2\varphi)+(\lambda^3\cdot B_{33}+\lambda^5\cdot B_{35})\cdot\cos(3\varphi)+\lambda^4\cdot B_{44}\cdot\cos(4\varphi)+\lambda^5\cdot B_{55}\cdot\cos(5\varphi)\}$$

ϕ (deg.)	$\eta(t)$ (m)
0.00	7.2865
10.00	7.0115
20.00	6.2418
30.00	5.1225
40.00	3.8366
50.00	2.5478
60.00	1.3619
70.00	0.3219
80.00	-0.5728
90.00	-1.3376
100.00	-1.9847
110.00	-2.5198
120.00	-2.9504
130.00	-3.2916
140.00	-3.5642
150.00	-3.7849
160.00	-3.9567
170.00	-4.0697
180.00	-4.1095
190.00	-4.0697
200.00	-3.9567
210.00	-3.7849
220.00	-3.5642
230.00	-3.2916
240.00	-2.9504
250.00	-2.5198
260.00	-1.9847
270.00	-1.3376
280.00	-0.5728
290.00	0.3219
300.00	1.3619
310.00	2.5478
320.00	3.8366
330.00	5.1225
340.00	6.2418
350.00	7.0115
360.00	7.2865



Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-03-01 - Buckling & Collapse calculations - 26m - hydrotest.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-03-01 - Buckling & Collapse calculations - 26m - hydrotest.xlsx

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Originator : EvW
Checked :
Date : 24/01/2020
Revision : 01

Buckling and Collapse - 20in x 20.62mm - Hydrotest

Situation

3
Hydrotest

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom} =	20	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$ =	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$ =	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max} =	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min} =	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0 =	0.014	-
Cross sectional area of steel		A =	31572	mm^2
Moment of Inertia		I =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$ =	0	mm
Nominal wall thickness	$d_{nom,p}$ =	0.0	mm

Coating data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Material	=	L360NB	
Design temperature	T_d =	15	°C
Yield at ambient temperature	R_e =	360.00	N/mm^2
Yield at design temperature	R_{ed} =	360.00	N/mm^2
Density	ρ_{st} =	7850	kg/m^3
Youngs modulus	E_s =	210000	N/mm^2
Poisson's ratio	u =	0.3	-
Linear thermal expansion coefficient	a =	1.16E-05	$m/m/^oC$

Contents

Sea water density	1025	kg/m^3
Pipeline product density	96.1	kg/m^3
Pipeline content density used for this case: Hydrotest	1025	kg/m^3

Pipeline Weights

$$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$$

$$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$$

Pipeline weight in air	$W_{pl,a}$ =	4195.8	N/m
Piggyback weight in air	$W_{pg,a}$ =	0.0	N/m
Buoyancy force pipeline	$F_{B,pl}$ =	2086.5	N/m
Buoyancy force piggyback	$F_{B,pb}$ =	0.0	N/m
Submerged pipeline weight,empty	$W_{pl,s,e}$ =	388.8	N/m
Submerged piggyback weight	$W_{pg,s}$ =	0.0	N/m
Total submerged bundle weight,empty	$W_{T,s,e}$ =	388.8	N/m
Total submerged bundle weight,water filled	$W_{T,s,f}$ =	2109.4	N/m

Soil

Submerged density		ρ_{ss} =	1000	kg/m^3
Depth of burial		d_b =	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss}$ x d_b x g	SC_{pres} =	0.008	N/mm^2

Environmental conditions

Water depths:

Seawater density		ρ_{sw} =	1025	kg/m3
Maximum water depth		WD_{max} =	29.68	m LAT
Minimum water depth		WD_{min} =	26	m LAT
Other water depth (to be used for calculations)		WD =	26	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-1.02	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-1.79	m LAT
Storm surge water level	SSWL = WD + ss	SSWL =	24.98	m LAT
Highest Astronomical Tide		HAT =	2.72	m

Waves (H_{max} & T_{max}):

Maximum wave height, RP1 yr - installation/hydrotes	$H_{max,1}$ =	11.4	m
Associated maximum wave period, RP1 yr	$T_{ass,1}$ =	10.1	s
Maximum wave height, RP100 yr - operational	$H_{max,100}$ =	16.9	m
Associated maximum wave period, RP100 yr	$T_{ass,100}$ =	11.5	s

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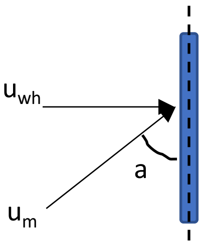
Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

$\frac{H_{max}}{g \cdot T_z^2} =$ 0.0114

$\frac{SWL}{g \cdot T_z^2} =$ 0.0250

Wave theory selected:
1. Airy/linear wave; 2. Stokes 5th **2** Stokes 5th



Maximum wave particle velocity	u_{wm} =	2.39	m/s
Angle of attack relative to pipeline axis	α_{uw} =	90	deg
Horizontal wave velocity ⊥ to P/L	u_{wh} =	2.39	m/s

Current:

Height above seabed at which velocity is known	z* =	2	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.74	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	0.84	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	0.96	m/s
Current velocity at reference height	U_{czr} =	0.74	m/s
Angle of attack relative to pipeline axis	α_{uc} =	90	deg
Horizontal current velocity ⊥ to P/L $\frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc}) =$	u_{ch} =	0.53	m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-

Maximum absolute hydrodynamic force 1822 N/m

Temperatures:

Ambient temperature T_{amb} = 4 deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by:

$$(p_c - p_e)\cdot(p_c^2 - p_p^2) = p_c \cdot p_e \cdot p_p \cdot 2 \cdot \delta_o \cdot \frac{OD_g}{d_{nom}}$$

External elastical pipe collapse pressure (P_e): $P_e = \frac{2E_s}{1-\nu^2}\left(\frac{d_{nom}}{OD_{av}}\right)^3 =$ 34.0 N/mm^2

External plastic pipe collapse pressure (P_p) $P_p = \frac{2 R_e d_{nom}}{OD_{nom}} =$ 29.2 N/mm^2

External implosion pipe collapse pressure (P_c): P_c = 16.0 N/mm^2

Maximum water column above mudline (WC_{max}) $WC_{max} = WD_{max} + 0.5 \cdot H_{max,100} + HAT =$ 40.85 m
0.4085 N/mm^2

Actual external pressure (P_L) $WC_{max} + SC_{pres} =$ 0.42 N/mm^2

Assessment: $\gamma_{g,p} \cdot P_L \le \dfrac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656
$g_{g,p}$ = 1.05 -
g_M = 0.93 -
$g_{m,p}$ = 1.45 -

Assessment: $\gamma_{g,p} \cdot P_L \le \dfrac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ = **OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \le \dfrac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656
$g_{g,M}$ = 1.1 -
g_M = 1 -
$g_{m,M}$ = 1.3 -

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\dfrac{\gamma_{g,p} \times P_L}{P_c / \gamma_{m,p}} + \left(\dfrac{\gamma_{g,M} \times M_L}{M_c / \gamma_{m,M}}\right)^n \le \gamma_M$ **Where,**

Table 4 - NEN3656
$g_{g,p}$ = 1.05 -
$g_{g,M}$ = 1.55 -
$g_{m,p}$ = 1.25 -
$g_{m,M}$ = 1.15 -
g_M = 0.93 -
$n = 1 + 300 \cdot d_{nom} / OD_g$ n = 13.6 -

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 9.994E+05 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \dfrac{q \cdot L^2}{10}$ **Where,**

q = load acting on pipe
L = span length

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight; Ws = 2109 N/m
$F_D + F_I$ = 1822 N/m
g_w = 1.1 -
g_h = 1.2 -
Table 3 - NEN3656
q = 3188 N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 9.99E+05 N·m

Maximum span length, L_{max} = 56.0 m

Progressive plastic collapse (K.3.3.6)

Assessment: $\varepsilon_{max} = \alpha \times \Delta T \le \left[\frac{R_e(\theta)}{E}\sqrt{1-\frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2}+\frac{R_e}{E}\sqrt{0{,}9-\frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2}\right]$

Temperature difference with ambient; DT = 11 -

R_e = 360.00 N/mm^2

R_{ed} = 360.00 N/mm^2

$$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$$

s_p = 219.6 N/mm^2

$$\varepsilon_{max} = \alpha \times \Delta T \le \left[\frac{R_e(\theta)}{E}\sqrt{1-\frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2}+\frac{R_e}{E}\sqrt{0{,}9-\frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2}\right]$$

Assessment: 0.0001 < 0.0028 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment: $L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$ Table 3 - NEN3656 - BC4

g_p = 1.15 -

g_t = 1.1 -

N = 1.46E+06 N

$L_{max,bb}$ = No compressive force m

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-03-01 - Buckling & Collapse calculations - 26m - hydrotest.xlsx

Client : ONE-Dyas
Client File # :

Originator : EvW
Checked :
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Stokes 5th order wave theory

Water depth	WD =	26	m (LAT)
Storm surge	ss =	-1.02	m
Storm surge water level	$SWL=WD+ss$ =	24.98	m
Wave height	H =	11.4	m
Wave period	T =	10.1	s
Grav. Acceleration	g =	9.81	m/s^2
Deep water wave length	$L_o=\frac{g\cdot T^2}{2\cdot\pi}$ =	159.3	m

Solving for wave length (L) and λ

$$\frac{\pi\cdot H}{SWL}-\frac{L}{SWL}\left\{\lambda+\lambda^3\cdot B_{33}+\lambda^5\cdot\left(B_{35}+B_{55}\right)\right\}=0 \quad (\text{ I })$$

$$\frac{SWL}{L_O}-\frac{SWL}{L}\cdot\tanh\left(\frac{2\cdot\pi\cdot SWL}{L}\right)\cdot\left\{1+\lambda^2\cdot C_1+\lambda^4\cdot C_2\right\}=0 \quad (\text{ II })$$

Choosing L and solving for λ in (II) results in 4 roots for λ

Estimate actual wave length, L **143.093 m**

$A=SWL/L_O$ = 0.1568

$B=\frac{SWL}{L}\cdot\tanh\left(\frac{2\cdot\pi\cdot SWL}{L}\right)$ = 0.1395

$$\lambda=\pm\sqrt{X}$$

$$X=\frac{-C_1\cdot B\ \pm\sqrt{D}}{2\cdot C_2\cdot B}$$

$D=\left(C_1\cdot B\right)^2-4\cdot\left(C_2\cdot B\right)\cdot\left(-\left(A-B\right)\right)$ = 0.1581

	-	eq. (I)	eq. (II)
λ1	0.228	0.0005	0.0000
λ2	Numerator of X < 0		
λ3	-0.228	2.8669	0.0000
λ4	Numerator of X < 0		

Item	Formula	Value	Unit
s	$s = \sinh\left(\frac{2 \cdot \pi \cdot WL}{L}\right) =$	1.3304	-
c	$c = \cosh\left(\frac{2 \cdot \pi \cdot WL}{L}\right) =$	1.6643	-
A11	$A_{11} = \frac{1}{s} =$	0.7516	-
A13	$A_{13} = \frac{-c^2 \cdot (5 \cdot c^2 + 1)}{8 \cdot s^5} =$	-1.2336	-
	$A_{15} = -\frac{1184 \cdot c^{10} - 1440 \cdot c^8 - 1992 \cdot c^6 + 2641 \cdot c^4 - 249 \cdot c^2 + 18}{1536 \cdot s^{11}} =$	-2.4101	-
A22	$A_{22} = \frac{3}{8 \cdot s^4} =$	0.1197	-
A24	$A_{24} = \frac{192 \cdot c^8 - 424 \cdot c^6 - 312 \cdot c^4 + 480 \cdot c^2 - 17}{768 \cdot s^{10}} =$	0.0907	-
A33	$A_{33} = \frac{13 - 4 \cdot c^2}{64 \cdot s^7} =$	0.0041	-
	$A_{35} = \frac{512 \cdot c^{12} + 4224 \cdot c^{10} - 6800 \cdot c^8 - 12808 \cdot c^6 + 16704 \cdot c^4 - 3154 \cdot c^2 - 107}{4096 \cdot s^{13} \cdot (6 \cdot c^2 - 1)} =$	0.1402	-
A44	$A_{44} = \frac{80 \cdot c^6 - 816 \cdot c^4 + 1338 \cdot c^2 - 197}{1536 \cdot s^{10} \cdot (6 \cdot c^2 - 1)} =$	-0.0025	-

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$$A_{55} = -\frac{2880\cdot c^{10} - 72480\cdot c^{8} + 324000\cdot c^{6} - 432000\cdot c^{4} + 163470\cdot c^{2} - 16245}{61440\cdot s^{11}\cdot\left(6\cdot c^{2}-1\right)\cdot\left(8\cdot c^{4}-11\cdot c^{2}+3\right)} =$$

-0.0003 -

B22

$$B_{22} = \frac{\left(2\cdot c^{2}+1\right)\cdot c}{4\cdot s^{3}} =$$

1.1556 -

B24

$$B_{24} = \frac{c\cdot\left(272\cdot c^{8} - 504\cdot c^{6} - 192\cdot c^{4} + 322\cdot c^{2} + 21\right)}{384\cdot s^{9}} =$$

1.5737 -

B33

$$B_{33} = \frac{3\cdot\left(8\cdot c^{6}+1\right)}{64\cdot s^{6}} =$$

1.4457 -

$$B_{35} = \frac{88128\cdot c^{14} - 208224\cdot c^{12} + 70848\cdot c^{10} + 54000\cdot c^{8} - 21816\cdot c^{6} + 6264\cdot c^{4} - 54\cdot c^{2} - 81}{12288\cdot s^{12}\cdot\left(6\cdot c^{2}-1\right)} =$$

= 5.1727 -

B44

$$B_{44} = c\cdot\frac{768\cdot c^{10} - 488\cdot c^{8} - 48\cdot c^{6} + 48\cdot c^{4} + 106\cdot c^{2} - 21}{384\cdot s^{9}\cdot\left(6\cdot c^{2}-1\right)} =$$

2.0428 -

$$B_{55} = \frac{192000\cdot c^{16} - 26720\cdot c^{14} + 83680\cdot c^{12} + 20160\cdot c^{10} - 7280\cdot c^{8} + 7160\cdot c^{6} - 1800\cdot c^{4} - 1050\cdot c^{2} + 225}{12288\cdot s^{10}\cdot\left(8\cdot c^{4}-11\cdot c^{2}+3\right)\cdot\left(6\cdot c^{2}-1\right)} =$$

= 3.3386 -

C1

$$C_{1} = \frac{8\cdot c^{4} - 8\cdot c^{2} + 9}{8\cdot s^{4}} =$$

1.9240 -

$$C_{2} = \frac{3840\cdot c^{12} - 4096\cdot c^{10} + 2592\cdot c^{8} - 1008\cdot c^{6} + 5944\cdot c^{4} - 1830\cdot c^{2} + 147}{512\cdot s^{10}\cdot\left(6\cdot c^{2}-1\right)} =$$

8.9142 -

C3

$$C_{3} = -\frac{1}{4\cdot c\cdot s} =$$

-0.1129 -

C4

$$C_{4} = \frac{12\cdot c^{8} + 36\cdot c^{6} - 162\cdot c^{4} + 141\cdot c^{2} - 27}{192\cdot c\cdot s^{9}} =$$

0.1419 -

K1

$$K_{1} = \lambda\cdot A_{11} + \lambda^{3}\cdot A_{13} + \lambda^{5}\cdot A_{15} =$$

0.1552 -

K2	$K_2 = \lambda^2 \cdot A_{22} + \lambda^4 \cdot A_{24} =$	0.0065	-
K3	$K_3 = \lambda^3 \cdot A_{33} + \lambda^5 \cdot A_{35} =$	0.0001	-
K4	$K_4 = \lambda^4 \cdot A_{44} =$	0.0000	-
K5	$K_5 = \lambda^5 \cdot A_{55} =$	0.0000	-

Horizontal wave particle velocities

Water depth at which data required, z (w.r.t. seabed)	0.5080	m

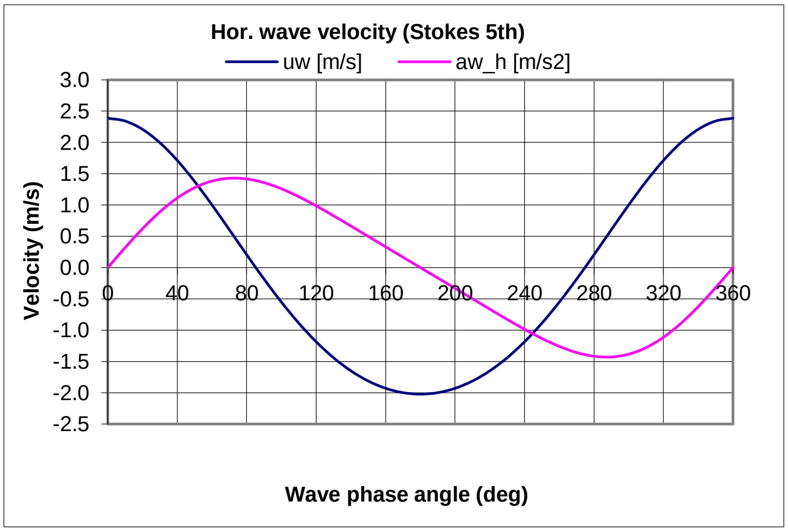
Horizontal velocity, u_w

$$u_w = \frac{L}{T} \cdot \sum_{n=1}^{5} n \cdot K_n \cdot \cosh\left(n \cdot \frac{2 \cdot \pi}{L} \cdot z\right) \cdot \cos(n \cdot \varphi)$$

Horizontal acceleration, $a_{w,h}$

$$a_{w,h} = \frac{2 \cdot \pi \cdot L}{T^2} \cdot \sum_{n=1}^{5} n^2 \cdot K_n \cdot \cosh\left(n \cdot \frac{2 \cdot \pi}{L} \cdot z\right) \cdot \sin(n \cdot \varphi)$$

ϕ [deg.]	uw [m/s]	aw_h [m/s^2]
0.00	2.3878	0.0000
10.00	2.3427	0.3202
20.00	2.2098	0.6227
30.00	1.9965	0.8913
40.00	1.7141	1.1129
50.00	1.3773	1.2783
60.00	1.0025	1.3832
70.00	0.6068	1.4278
80.00	0.2066	1.4167
90.00	-0.1836	1.3575
100.00	-0.5515	1.2596
110.00	-0.8877	1.1329
120.00	-1.1853	0.9867
130.00	-1.4402	0.8286
140.00	-1.6498	0.6646
150.00	-1.8129	0.4982
160.00	-1.9293	0.3316
170.00	-1.9990	0.1655
180.00	-2.0222	0.0000
190.00	-1.9990	-0.1655
200.00	-1.9293	-0.3316



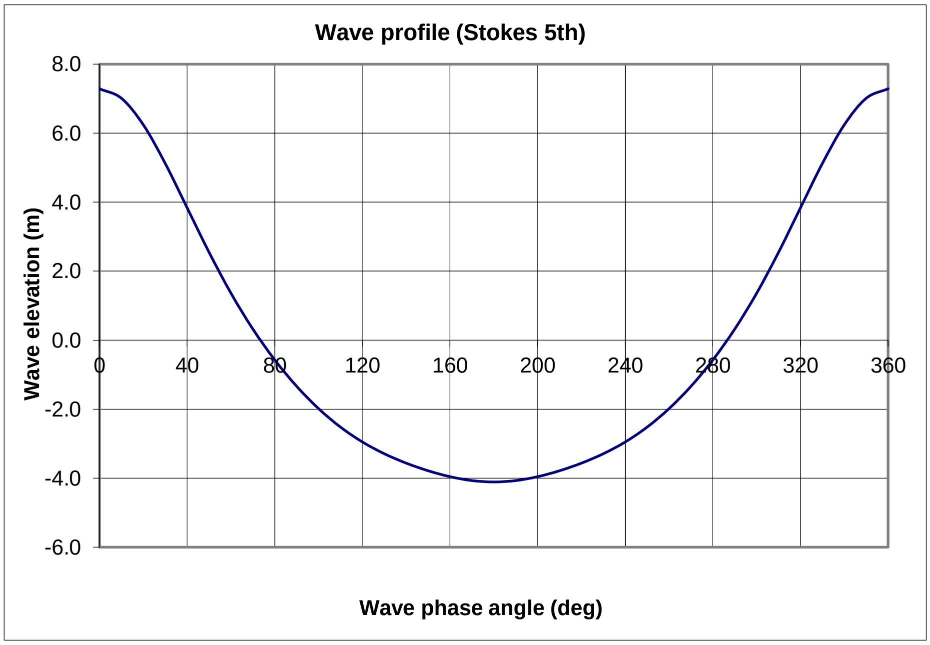
210.00	-1.8129	-0.4982
220.00	-1.6498	-0.6646
230.00	-1.4402	-0.8286
240.00	-1.1853	-0.9867
250.00	-0.8877	-1.1329
260.00	-0.5515	-1.2596
270.00	-0.1836	-1.3575
280.00	0.2066	-1.4167
290.00	0.6068	-1.4278
300.00	1.0025	-1.3832
310.00	1.3773	-1.2783
320.00	1.7141	-1.1129
330.00	1.9965	-0.8913
340.00	2.2098	-0.6227
350.00	2.3427	-0.3202
360.00	2.3878	0.0000

U_{wm} = max. wave particle velocity = 2.39 m/s

Wave profile h(t)

$$\eta(t)=\frac{L}{2\cdot\pi}\left\{\lambda\cdot\cos(\varphi)+\left(\lambda^2\cdot B_{22}+\lambda^4\cdot B_{24}\right)\cdot\cos(2\varphi)+\left(\lambda^3\cdot B_{33}+\lambda^5\cdot B_{35}\right)\cdot\cos(3\varphi)+\lambda^4\cdot B_{44}\cdot\cos(4\varphi)+\lambda^5\cdot B_{55}\cdot\cos(5\varphi)\right\}$$

ϕ (deg.)	η(t) (m)
0.00	7.2865
10.00	7.0115
20.00	6.2418
30.00	5.1225
40.00	3.8366
50.00	2.5478
60.00	1.3619
70.00	0.3219
80.00	-0.5728
90.00	-1.3376
100.00	-1.9847
110.00	-2.5198
120.00	-2.9504
130.00	-3.2916
140.00	-3.5642
150.00	-3.7849
160.00	-3.9567
170.00	-4.0697
180.00	-4.1095
190.00	-4.0697
200.00	-3.9567
210.00	-3.7849
220.00	-3.5642
230.00	-3.2916
240.00	-2.9504
250.00	-2.5198
260.00	-1.9847
270.00	-1.3376
280.00	-0.5728
290.00	0.3219
300.00	1.3619
310.00	2.5478
320.00	3.8366
330.00	5.1225
340.00	6.2418
350.00	7.0115
360.00	7.2865



Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-04-01 - Buckling & Collapse calculations - 8m - operation.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-04-01 - Buckling & Collapse calculations - 8m - operation.xlsx

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Originator : EvW Checked :
Date : 27/01/2020
Revision : 01

Buckling and Collapse - 20in x 20.62mm - Operational

Situation

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

4
Operational

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom}	=	20	
Nominal diameter		OD_{nom}	=	508	mm
Nominal wall thickness		d_{nom}	=	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$	=	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$	=	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max}	=	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min}	=	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0	=	0.014	-
Cross sectional area of steel		A	=	31572	mm^2
Moment of Inertia		I	=	939135656	mm^4
Corrosion allowance		CA	=	3	mm
Fabrication Tolerance		f_{tol}	=	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min}	=	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g	=	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$	=	0	mm
Nominal wall thickness	$d_{nom,p}$	=	0.0	mm

Coating data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-04-01 - Buckling & Collapse calculations - 8m - operation.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-04-01 - Buckling & Collapse calculations - 8m - operation.xlsx

Originator : EvW
Date : 27/01/2020
Revision : 01
Checked :

Material		=	L360NB	
Design temperature		T_d =	50	°C
Yield at ambient temperature		R_e =	360.00	N/mm^2
Yield at design temperature		R_{ed} =	360.00	N/mm^2
Density		ρ_{st} =	7850	kg/m^3
Youngs modulus		E_s =	210000	N/mm^2
Poisson's ratio		u =	0.3	-
Linear thermal expansion coefficient		a =	1.16E-05	$m/m/^oC$
Contents				
Sea water density			1025	kg/m^3
Pipeline product density			96.1	kg/m^3
Pipeline content density used for this case:	Operational		96.1	kg/m^3
Pipeline Weights				
Pipeline weight in air	$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$	$W_{pl,a}$ =	2636.6	N/m
Piggyback weight in air		$W_{pg,a}$ =	0.0	N/m
Buoyancy force pipeline	$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$	$F_{B,pl}$ =	2086.5	N/m
Buoyancy force piggyback		$F_{B,pb}$ =	0.0	N/m
Submerged pipeline weight,empty		$W_{pl,s,e}$ =	388.8	N/m
Submerged piggyback weight		$W_{pg,s}$ =	0.0	N/m
Total submerged bundle weight,empty		$W_{T,s,e}$ =	388.8	N/m
Total submerged bundle weight,water filled		$W_{T,s,f}$ =	2109.4	N/m
Soil				
Submerged density		ρ_{ss} =	1000	kg/m^3
Depth of burial		d_b =	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss}$ x d_b x g	SC_{pres} =	0.008	N/mm^2
Environmental conditions				
Water depths:				
Seawater density		ρ_{sw} =	1025	kg/m3
Maximum water depth		WD_{max} =	11.5	m LAT
Minimum water depth		WD_{min} =	8	m LAT
Other water depth (to be used for calculations)		WD =	8	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-0.14	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-0.78	m LAT
Storm surge water level	SSWL = WD + ss	SSWL =	7.22	m LAT
Highest Astronomical Tide		HAT =	3.5	m
Waves (H_{max} & T_{max}):				
Maximum wave height, RP1 yr - installation/hydrotes		$H_{max,1}$ =	5.2	m
Associated maximum wave period, RP1 yr		$T_{ass,1}$ =	7.7	s
Maximum wave height, RP100 yr - operational		$H_{max,100}$ =	6.2	m
Associated maximum wave period, RP100 yr		$T_{ass,100}$ =	8.1	s

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-04-01 - Buckling & Collapse calculations - 8m - operation.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-04-01 - Buckling & Collapse calculations - 8m - operation.xlsx

Originator : EvW　　Checked :
Date : 27/01/2020
Revision : 01

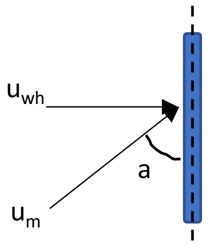
Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

$\frac{H_{max}}{g \cdot T_z^2} =$ 0.0096

$\frac{SWL}{g \cdot T_z^2} =$ 0.0112

Wave theory selected:

1. Airy/linear wave; 2. Stokes 5th



Wave particle velocity from metocean data

Maximum wave particle velocity u_{wm} = 1.60 m/s
Angle of attack relative to pipeline axis α_{uw} = 90 deg
Horizontal wave velocity ⊥ to P/L u_{wh} = 1.60 m/s

Current:
Height above seabed at which velocity is known z^* = 1 m
Spring tide u_{st} = 0 m/s
Storm surge, RP1 yr $u_{ss,1}$ = 0.89 m/s
Storm surge, RP10 yr $u_{ss,10}$ = 1 m/s
Storm surge, RP100 yr $u_{ss,100}$ = 1.12 m/s
Current velocity at reference height U_{czr} = 1.12 m/s
Angle of attack relative to pipeline axis α_{uc} = 90 deg
Horizontal current velocity ⊥ to P/L $\frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc}) =$ u_{ch} = 0.89 m/s

Hydrodynamic coefficients:
Drag coefficient C_D = 0.7 -
Lift coefficient C_L = 0.9 -
Inertia coefficient C_I = 3.29 -

Maximum absolute hydrodynamic force 1372 N/m

Temperatures:
Ambient temperature T_{amb} = 4 deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by: $(p_c - p_e) \cdot (p_c^2 - p_p^2) = p_c \cdot p_e \cdot p_p \cdot 2 \cdot \delta_o \cdot \frac{OD_g}{d_{nom}}$

External elastical pipe collapse pressure (P_e): $P_e = \frac{2E_s}{1-\nu^2} (\frac{d_{nom}}{OD_{av}})^3$ = 34.0 N/mm^2

External plastic pipe collapse pressure (P_p) $P_p = \frac{2 R_e d_{nom}}{OD_{nom}}$ = 29.2 N/mm^2

External implosion pipe collapse pressure (P_c): P_c = 16.0 N/mm^2

Maximum water column above mudline (WC_{max}) $WC_{max} = WD_{max} + 0.5 \cdot H_{max,100} + HAT$ = 18.1 m
0.181 N/mm^2

Actual external pressure (P_L) $WC_{max} + SC_{pres}$ = 0.19 N/mm^2

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656
$g_{g,p}$ = 1.05 -
g_M = 0.93 -
$g_{m,p}$ = 1.45 -

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **=** **OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \le \frac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656
$g_{g,M}$ = 1.1 -
g_M = 1 -
$g_{m,M}$ = 1.3 -

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\frac{\gamma_{g,p} \times P_L}{P_c/\gamma_{m,p}} + \left(\frac{\gamma_{g,M} \times M_L}{M_c/\gamma_{m,M}}\right)^n \le \gamma_M$ **Where,**

Table 4 - NEN3656
$g_{g,p}$ = 1.05 -
$g_{g,M}$ = 1.55 -
$g_{m,p}$ = 1.25 -
$g_{m,M}$ = 1.15 -
g_M = 0.93 -
$n = 1 + 300 \cdot d_{nom} / OD_g$ n = 13.6 -

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 1.001E+06 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \frac{q \cdot L^2}{10}$ **Where,**

q = load acting on pipe
L = span length

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight; Ws = 389 N/m
$F_D + F_I$ = 1372 N/m
g_w = 1.1 -
g_h = 1.2 -
Table 3 - NEN3656
q = 1700 N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 1.00E+06 N·m

Maximum span length, L_{max} = 76.7 m

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-04-01 - Buckling & Collapse calculations - 8m - operation.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-04-01 - Buckling & Collapse calculations - 8m - operation.xlsx

Originator : EvW
Date : 27/01/2020
Revision : 01
Checked :

Progressive plastic collapse (K.3.3.6)

Assessment: $\varepsilon_{max} = \alpha \times \Delta T \le \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E} \sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$

Temperature difference with ambient; DT = 46 -
R_e = 360.00 N/mm^2
R_{ed} = 360.00 N/mm^2

$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$ s_p = 169.3 N/mm^2

$\varepsilon_{max} = \alpha \times \Delta T \le \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E} \sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$

Assessment: 0.0005 < 0.0030 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment: $L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$ Table 3 - NEN3656 - BC4
g_p = 1.15 -
g_t = 1.1 -
N = -2.05E+06 N

$L_{max,bb}$ = 61.7 m

Project	**: N05-A Pipeline design**
Project #	: 19018
Subject	: Buckling and Collapse
File #	: 19018-60-CAL-01003-05-01 - Buckling & Collapse calculations - 8m - installation flooded.xlsx
Client	: ONE-Dyas
Client File #	: 19018-60-CAL-01003-05-01 - Buckling & Collapse calculations - 8m - installation flooded.xlsx

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Originator : EvW   Checked :
Date : 27/01/2020
Revision : 01

Buckling and Collapse - 20in x 20.62mm - Installation: filled

Situation

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

2
Installation: filled

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom} =	20	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$ =	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$ =	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max} =	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min} =	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0 =	0.014	-
Cross sectional area of steel		A =	31572	mm^2
Moment of Inertia		I =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$ =	0	mm
Nominal wall thickness	$d_{nom,p}$ =	0.0	mm

Coating data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-05-01 - Buckling & Collapse calculations - 8m - installation flooded.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-05-01 - Buckling & Collapse calculations - 8m - installation flooded.xlsx

Originator : EvW Checked :
Date : 27/01/2020
Revision : 01

Material		=	L360NB	
Design temperature		T_d =	15	°C
Yield at ambient temperature		R_e =	360.00	N/mm^2
Yield at design temperature		R_{ed} =	360.00	N/mm^2
Density		ρ_{st} =	7850	kg/m^3
Youngs modulus		E_s =	210000	N/mm^2
Poisson's ratio		u =	0.3	-
Linear thermal expansion coefficient		a =	1.16E-05	m/m/^{o}C
Contents				
Sea water density			1025	kg/m^3
Pipeline product density			96.1	kg/m^3
Pipeline content density used for this case:	Installation: filled		1025	kg/m^3
Pipeline Weights				
Pipeline weight in air	$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$	$W_{pl,a}$ =	4195.8	N/m
Piggyback weight in air		$W_{pg,a}$ =	0.0	N/m
Buoyancy force pipeline	$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$	$F_{B,pl}$ =	2086.5	N/m
Buoyancy force piggyback		$F_{B,pb}$ =	0.0	N/m
Submerged pipeline weight,empty		$W_{pl,s,e}$ =	388.8	N/m
Submerged piggyback weight		$W_{pg,s}$ =	0.0	N/m
Total submerged bundle weight,empty		$W_{T,s,e}$ =	388.8	N/m
Total submerged bundle weight,water filled		$W_{T,s,f}$ =	2109.4	N/m
Soil				
Submerged density		ρ_{ss} =	1000	kg/m^3
Depth of burial		d_b =	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss}$ x d_b x g	SC_{pres} =	0.008	N/mm^2
Environmental conditions				
Water depths:				
Seawater density		ρ_{sw} =	1025	kg/m3
Maximum water depth		WD_{max} =	11.5	m LAT
Minimum water depth		WD_{min} =	8	m LAT
Other water depth (to be used for calculations)		WD =	8	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-0.14	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-0.78	m LAT
Storm surge water level	SSWL = WD + ss	SSWL =	7.86	m LAT
Highest Astronomical Tide		HAT =	3.5	m
Waves (H_{max} & T_{max}):				
Maximum wave height, RP1 yr - installation/hydrotes		$H_{max,1}$ =	5.2	m
Associated maximum wave period, RP1 yr		$T_{ass,1}$ =	7.7	s
Maximum wave height, RP100 yr - operational		$H_{max,100}$ =	6.2	m
Associated maximum wave period, RP100 yr		$T_{ass,100}$ =	8.1	s

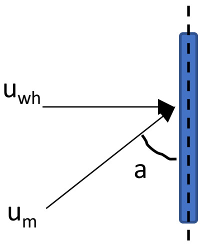
Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

$$\frac{H_{max}}{g \cdot T_z^2} = 0.0089$$

$$\frac{SWL}{g \cdot T_z^2} = 0.0135$$

Wave theory selected:

1. Airy/linear wave; 2. Stokes 5th



Wave particle velocity from metocean data

Maximum wave particle velocity u_{wm} = 1.30 m/s
Angle of attack relative to pipeline axis α_{uw} = 90 deg
Horizontal wave velocity ⊥ to P/L u_{wh} = 1.30 m/s

Current:
Height above seabed at which velocity is known z^* = 1 m
Spring tide u_{st} = 0 m/s
Storm surge, RP1 yr $u_{ss,1}$ = 0.89 m/s
Storm surge, RP10 yr $u_{ss,10}$ = 1 m/s
Storm surge, RP100 yr $u_{ss,100}$ = 1.12 m/s
Current velocity at reference height U_{czr} = 0.89 m/s
Angle of attack relative to pipeline axis α_{uc} = 90 deg
Horizontal current velocity ⊥ to P/L $\frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc}) =$ u_{ch} = 0.71 m/s

Hydrodynamic coefficients:
Drag coefficient C_D = 0.7 -
Lift coefficient C_L = 0.9 -
Inertia coefficient C_I = 3.29 -

Maximum absolute hydrodynamic force 891 N/m

Temperatures:
Ambient temperature T_{amb} = 4 deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by:

$$(p_c - p_e)\cdot\left(p_c^2 - p_p^2\right) = p_c \cdot p_e \cdot p_p \cdot 2 \cdot \delta_o \cdot \frac{OD_g}{d_{nom}}$$

External elastical pipe collapse pressure (P_e): $P_e = \frac{2E_s}{1-\nu^2}\left(\frac{d_{nom}}{OD_{av}}\right)^3$ = 34.0 N/mm^2

External plastic pipe collapse pressure (P_p) $P_p = \frac{2 R_e d_{nom}}{OD_{nom}}$ = 29.2 N/mm^2

External implosion pipe collapse pressure (P_c): P_c = 16.0 N/mm^2

Maximum water column above mudline (WC_{max}) $WC_{max} = WD_{max} + 0.5 \cdot H_{max,100} + HAT$ = 18.1 m
0.181 N/mm^2

Actual external pressure (P_L) $WC_{max} + SC_{pres}$ = 0.19 N/mm^2

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-05-01 - Buckling & Collapse calculations - 8m - installation flooded.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-05-01 - Buckling & Collapse calculations - 8m - installation flooded.xlsx

Originator : EvW
Checked :
Date : 27/01/2020
Revision : 01

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656
$g_{g,p}$ = 1.05 -
g_M = 0.93 -
$g_{m,p}$ = 1.45 -

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ = **OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \le \frac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656
$g_{g,M}$ = 1.1 -
g_M = 1 -
$g_{m,M}$ = 1.3 -

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\frac{\gamma_{g,p} \times P_L}{P_c / \gamma_{m,p}} + \left(\frac{\gamma_{g,M} \times M_L}{M_c / \gamma_{m,M}} \right)^n \le \gamma_M$ **Where,**

Table 4 - NEN3656
$g_{g,p}$ = 1.05 -
$g_{g,M}$ = 1.55 -
$g_{m,p}$ = 1.25 -
$g_{m,M}$ = 1.15 -
g_M = 0.93 -
$n = 1 + 300 \cdot d_{nom} / OD_g$ n = 13.6 -

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 1.001E+06 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \frac{q \cdot L^2}{10}$ **Where,**

q = load acting on pipe
L = span length

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight; Ws = 2109 N/m
$F_D + F_I$ = 891 N/m
g_w = 1.1 -
g_h = 1.2 -
Table 3 - NEN3656
q = 2555 N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 1.00E+06 N·m

Maximum span length, L_{max} = 62.6 m

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-05-01 - Buckling & Collapse calculations - 8m - installation flooded.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-05-01 - Buckling & Collapse calculations - 8m - installation flooded.xlsx

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Originator : EvW
Checked :
Date : 27/01/2020
Revision : 01

Progressive plastic collapse (K.3.3.6)

Assessment:

$$\varepsilon_{max} = \alpha \times \Delta T \le \left[\frac{R_e(\theta)}{E}\sqrt{1-\frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9-\frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2}\right]$$

Temperature difference with ambient; DT = 11 -

R_e = 360.00 N/mm^2

R_{ed} = 360.00 N/mm^2

$$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$$

s_p = 3.1 N/mm^2

$$\varepsilon_{max} = \alpha \times \Delta T \le \left[\frac{R_e(\theta)}{E}\sqrt{1-\frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9-\frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2}\right]$$

Assessment: 0.0001 < 0.0033 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment:

$$L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$ Table 3 - NEN3656 - BC4

g_p = 1.15 -

g_t = 1.1 -

N = -8.97E+05 N

$L_{max,bb}$ = 93.1 m

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-06-01 - Buckling & Collapse calculations - 8m - hydrotest.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-06-01 - Buckling & Collapse calculations - 8m - hydrotest.xlsx

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Originator : EvW
Checked :
Date : 27/01/2020
Revision : 01

Buckling and Collapse - 20in x 20.62mm - Hydrotest

Situation

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

3
Hydrotest

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom} =	20	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$ =	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$ =	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max} =	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min} =	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0 =	0.014	-
Cross sectional area of steel		A =	31572	mm^2
Moment of Inertia		I =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$ =	0	mm
Nominal wall thickness	$d_{nom,p}$ =	0.0	mm

Coating data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-06-01 - Buckling & Collapse calculations - 8m - hydrotest.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-06-01 - Buckling & Collapse calculations - 8m - hydrotest.xlsx

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Originator : EvW
Date : 27/01/2020
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Material			=	L360NB	
Design temperature		T_d	=	15	°C
Yield at ambient temperature		R_e	=	360.00	N/mm^2
Yield at design temperature		R_{ed}	=	360.00	N/mm^2
Density		ρ_{st}	=	7850	kg/m^3
Youngs modulus		E_s	=	210000	N/mm^2
Poisson's ratio		u	=	0.3	-
Linear thermal expansion coefficient		a	=	1.16E-05	$m/m/^oC$

Contents

Sea water density		1025	kg/m^3
Pipeline product density		96.1	kg/m^3
Pipeline content density used for this case:	Hydrotest	1025	kg/m^3

Pipeline Weights

$$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$$

Pipeline weight in air	$W_{pl,a}$	=	4195.8	N/m
Piggyback weight in air	$W_{pg,a}$	=	0.0	N/m

$$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$$

Buoyancy force pipeline	$F_{B,pl}$	=	2086.5	N/m
Buoyancy force piggyback	$F_{B,pb}$	=	0.0	N/m

Submerged pipeline weight,empty	$W_{pl,s,e}$	=	388.8	N/m
Submerged piggyback weight	$W_{pg,s}$	=	0.0	N/m
Total submerged bundle weight,empty	$W_{T,s,e}$	=	388.8	N/m
Total submerged bundle weight,water filled	$W_{T,s,f}$	=	2109.4	N/m

Soil

Submerged density		ρ_{ss}	=	1000	kg/m^3
Depth of burial		d_b	=	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss} \text{ x } d_b \text{ x } g$	SC_{pres}	=	0.008	N/mm^2

Environmental conditions

Water depths:

Seawater density		ρ_{sw}	=	1025	kg/m3
Maximum water depth		WD_{max}	=	11.5	m LAT
Minimum water depth		WD_{min}	=	8	m LAT
Other water depth (to be used for calculations)		WD	=	8	m LAT
Storm surge, RP1 yr		ss_{1yr}	=	-0.14	m LAT
Storm surge, RP100 yr		ss_{100yr}	=	-0.78	m LAT
Storm surge water level	SSWL = WD + ss	SSWL	=	7.86	m LAT
Highest Astronomical Tide		HAT	=	3.5	m

Waves (H_{max} & T_{max}):

Maximum wave height, RP1 yr - installation/hydrotes	$H_{max,1}$	=	5.2	m
Associated maximum wave period, RP1 yr	$T_{ass,1}$	=	7.7	s
Maximum wave height, RP100 yr - operational	$H_{max,100}$	=	6.2	m
Associated maximum wave period, RP100 yr	$T_{ass,100}$	=	8.1	s

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-06-01 - Buckling & Collapse calculations - 8m - hydrotest.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-06-01 - Buckling & Collapse calculations - 8m - hydrotest.xlsx

Originator : EvW
Date : 27/01/2020
Revision : 01
Checked :

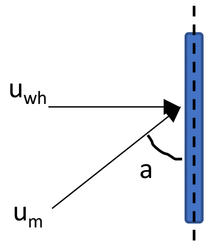
Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

$$\frac{H_{\max}}{g \cdot T_z^2} = 0.0089$$

$$\frac{SWL}{g \cdot T_z^2} = 0.0135$$

Wave theory selected:
1. Airy/linear wave; 2. Stokes 5th

Wave particle velocity from metocean data



Maximum wave particle velocity u_{wm} = 1.30 m/s
Angle of attack relative to pipeline axis α_{uw} = 90 deg
Horizontal wave velocity ⊥ to P/L u_{wh} = 1.30 m/s

Current:
Height above seabed at which velocity is known z^* = 1 m
Spring tide u_{st} = 0 m/s
Storm surge, RP1 yr $u_{ss,1}$ = 0.89 m/s
Storm surge, RP10 yr $u_{ss,10}$ = 1 m/s
Storm surge, RP100 yr $u_{ss,100}$ = 1.12 m/s
Current velocity at reference height U_{czr} = 0.89 m/s
Angle of attack relative to pipeline axis α_{uc} = 90 deg
Horizontal current velocity ⊥ to P/L $\frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r} \right)^{1/7} \cdot \sin(\alpha_{uc}) =$ u_{ch} = 0.71 m/s

Hydrodynamic coefficients:
Drag coefficient C_D = 0.7 -
Lift coefficient C_L = 0.9 -
Inertia coefficient C_I = 3.29 -

Maximum absolute hydrodynamic force 891 N/m

Temperatures:
Ambient temperature T_{amb} = 4 deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by:

$$(p_c - p_e) \cdot (p_c^2 - p_p^2) = p_c \cdot p_e \cdot p_p \cdot 2 \cdot \delta_o \cdot \frac{OD_g}{d_{nom}}$$

External elastical pipe collapse pressure (P_e): $P_e = \frac{2E_s}{1-\nu^2} (\frac{d_{nom}}{OD_{av}})^3$ = 34.0 N/mm^2

External plastic pipe collapse pressure (P_p) $P_p = \frac{2 R_e d_{nom}}{OD_{nom}}$ = 29.2 N/mm^2

External implosion pipe collapse pressure (P_c): P_c = 16.0 N/mm^2

Maximum water column above mudline (WC_{max}) $WC_{max} = WD_{max} + 0.5 \cdot H_{max,100} + HAT$ = 18.1 m
0.181 N/mm^2

Actual external pressure (P_L) $WC_{max} + SC_{pres}$ = 0.19 N/mm^2

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656

$g_{g,p}$	=	1.05	-
g_M	=	0.93	-
$g_{m,p}$	=	1.45	-

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **=** **OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \le \frac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656

$g_{g,M}$	=	1.1	-
g_M	=	1	-
$g_{m,M}$	=	1.3	-

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\frac{\gamma_{g,p} \times P_L}{P_c / \gamma_{m,p}} + \left(\frac{\gamma_{g,M} \times M_L}{M_c / \gamma_{m,M}} \right)^n \le \gamma_M$ **Where,**

Table 4 - NEN3656

$g_{g,p}$	=	1.05	-
$g_{g,M}$	=	1.55	-
$g_{m,p}$	=	1.25	-
$g_{m,M}$	=	1.15	-
g_M	=	0.93	-

n = 1 + 300 · d_{nom} / OD_g n = 13.6 -

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 1.001E+06 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \frac{q \cdot L^2}{10}$ **Where,**

q = load acting on pipe
L = span length

$$q = \sqrt{\gamma_W^2 \cdot W_S^2 + \gamma_H^2 \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight; Ws = 2109 N/m
$F_D + F_I$ = 891 N/m
g_w = 1.1 -
g_h = 1.2 -
Table 3 - NEN3656
q = 2555 N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 1.00E+06 N·m

Maximum span length, L_{max} = 62.6 m

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-06-01 - Buckling & Collapse calculations - 8m - hydrotest.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-06-01 - Buckling & Collapse calculations - 8m - hydrotest.xlsx

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Originator : EvW
Checked :
Date : 27/01/2020
Revision : 01

Progressive plastic collapse (K.3.3.6)

Assessment:

$$\varepsilon_{max} = \alpha \times \Delta T \le \left[\frac{R_e(\theta)}{E}\sqrt{1-\frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9-\frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2}\right]$$

Temperature difference with ambient; DT = 11 -

R_e = 360.00 N/mm^2

R_{ed} = 360.00 N/mm^2

$$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$$

s_p = 219.6 N/mm^2

$$\varepsilon_{max} = \alpha \times \Delta T \le \left[\frac{R_e(\theta)}{E}\sqrt{1-\frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9-\frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2}\right]$$

Assessment: 0.0001 < 0.0028 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment:

$$L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$

Table 3 - NEN3656 - BC4

g_p = 1.15 -

g_t = 1.1 -

N = 1.46E+06 N

$L_{max,bb}$ = No compressive force m

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-07-01 - Buckling & Collapse calculations - 17m - operation.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-07-01 - Buckling & Collapse calculations - 17m - operation.xlsx

Originator : EvW   Checked :
Date : 27/01/2020
Revision : 01

Buckling and Collapse - 20in x 20.62mm - Operational

Situation

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

4
Operational

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom} =	20	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$ =	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$ =	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max} =	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min} =	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0 =	0.014	-
Cross sectional area of steel		A =	31572	mm^2
Moment of Inertia		I =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$ =	0	mm
Nominal wall thickness	$d_{nom,p}$ =	0.0	mm

Coating data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-07-01 - Buckling & Collapse calculations - 17m - operation.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-07-01 - Buckling & Collapse calculations - 17m - operation.xlsx

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Originator : EvW Checked :
Date : 27/01/2020
Revision : 01

Material		=	L360NB	
Design temperature		T_d =	50	°C
Yield at ambient temperature		R_e =	360.00	N/mm^2
Yield at design temperature		R_{ed} =	360.00	N/mm^2
Density		ρ_{st} =	7850	kg/m^3
Youngs modulus		E_s =	210000	N/mm^2
Poisson's ratio		u =	0.3	-
Linear thermal expansion coefficient		a =	1.16E-05	m/m/^{o}C
Contents				
Sea water density			1025	kg/m^3
Pipeline product density			96.1	kg/m^3
Pipeline content density used for this case:	Operational		96.1	kg/m^3
Pipeline Weights				
Pipeline weight in air	$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$	$W_{pl,a}$ =	2636.6	N/m
Piggyback weight in air		$W_{pg,a}$ =	0.0	N/m
Buoyancy force pipeline	$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$	$F_{B,pl}$ =	2086.5	N/m
Buoyancy force piggyback		$F_{B,pb}$ =	0.0	N/m
Submerged pipeline weight,empty		$W_{pl,s,e}$ =	388.8	N/m
Submerged piggyback weight		$W_{pg,s}$ =	0.0	N/m
Total submerged bundle weight,empty		$W_{T,s,e}$ =	388.8	N/m
Total submerged bundle weight,water filled		$W_{T,s,f}$ =	2109.4	N/m
Soil				
Submerged density		ρ_{ss} =	1000	kg/m^3
Depth of burial		d_b =	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss}$ x d_b x g	SC_{pres} =	0.008	N/mm^2
Environmental conditions				
Water depths:				
Seawater density		ρ_{sw} =	1025	kg/m3
Maximum water depth		WD_{max} =	20.6	m LAT
Minimum water depth		WD_{min} =	17	m LAT
Other water depth (to be used for calculations)		WD =	17	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-0.58	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-1.29	m LAT
Storm surge water level	SSWL = WD + ss	SSWL =	15.72	m LAT
Highest Astronomical Tide		HAT =	3.11	m
Waves (H_{max} & T_{max}):				
Maximum wave height, RP1 yr - installation/hydrotes		$H_{max,1}$ =	8.3	m
Associated maximum wave period, RP1 yr		$T_{ass,1}$ =	8.9	s
Maximum wave height, RP100 yr - operational		$H_{max,100}$ =	11.55	m
Associated maximum wave period, RP100 yr		$T_{ass,100}$ =	9.8	s

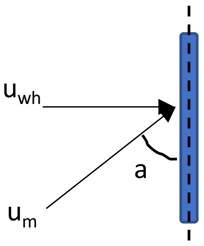
Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

$\frac{H_{max}}{g \cdot T_z^2} =$ 0.0123

$\frac{SWL}{g \cdot T_z^2} =$ 0.0167

Wave theory selected:
1. Airy/linear wave; 2. Stokes 5th

Wave particle velocity from interpolated data



Maximum wave particle velocity u_{wm} = 2.80 m/s
Angle of attack relative to pipeline axis α_{uw} = 90 deg
Horizontal wave velocity ⊥ to P/L u_{wh} = 2.80 m/s

Current:
Height above seabed at which velocity is known z^* = 1 m
Spring tide u_{st} = 0 m/s
Storm surge, RP1 yr $u_{ss,1}$ = 0.82 m/s
Storm surge, RP10 yr $u_{ss,10}$ = 0.92 m/s
Storm surge, RP100 yr $u_{ss,100}$ = 1.04 m/s
Current velocity at reference height U_{czr} = 1.04 m/s
Angle of attack relative to pipeline axis α_{uc} = 90 deg
Horizontal current velocity ⊥ to P/L $\frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r} \right)^{1/7} \cdot \sin(\alpha_{uc}) =$ u_{ch} = 0.83 m/s

Hydrodynamic coefficients:
Drag coefficient C_D = 0.7 -
Lift coefficient C_L = 0.9 -
Inertia coefficient C_I = 3.29 -

Maximum absolute hydrodynamic force 2909 N/m

Temperatures:
Ambient temperature T_{amb} = 4 deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by:

$$(p_c - p_e) \cdot \left(p_c^2 - p_p^2\right) = p_c \cdot p_e \cdot p_p \cdot 2 \cdot \delta_o \cdot \frac{OD_g}{d_{nom}}$$

External elastical pipe collapse pressure (P_e): $P_e = \frac{2E_s}{1-\nu^2}(\frac{d_{nom}}{OD_{av}})^3$ = 34.0 N/mm^2

External plastic pipe collapse pressure (P_p) $P_p = \frac{2 R_e d_{nom}}{OD_{nom}}$ = 29.2 N/mm^2

External implosion pipe collapse pressure (P_c): P_c = 16.0 N/mm^2

Maximum water column above mudline (WC_{max}) $WC_{max} = WD_{max} + 0.5 \cdot H_{max,100} + HAT$ = 29.485 m
0.29485 N/mm^2

Actual external pressure (P_L) $WC_{max} + SC_{pres}$ = 0.30 N/mm^2

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656
$g_{g,p}$ = 1.05 -
g_M = 0.93 -
$g_{m,p}$ = 1.45 -

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ = **OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \le \frac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656
$g_{g,M}$ = 1.1 -
g_M = 1 -
$g_{m,M}$ = 1.3 -

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\frac{\gamma_{g,p} \times P_L}{P_c/\gamma_{m,p}} + \left(\frac{\gamma_{g,M} \times M_L}{M_c/\gamma_{m,M}}\right)^n \le \gamma_M$ **Where,**

Table 4 - NEN3656
$g_{g,p}$ = 1.05 -
$g_{g,M}$ = 1.55 -
$g_{m,p}$ = 1.25 -
$g_{m,M}$ = 1.15 -
g_M = 0.93 -
$n = 1 + 300 \cdot d_{nom} / OD_g$ n = 13.6 -

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 1.000E+06 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \frac{q \cdot L^2}{10}$ **Where,**

q = load acting on pipe
L = span length

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight; Ws = 389 N/m
$F_D + F_I$ = 2909 N/m
g_w = 1.1 -
g_h = 1.2 -
Table 3 - NEN3656
q = 3517 N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 1.00E+06 N·m

Maximum span length, L_{max} = 53.3 m

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-07-01 - Buckling & Collapse calculations - 17m - operation.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-07-01 - Buckling & Collapse calculations - 17m - operation.xlsx

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Originator : EvW Checked :
Date : 27/01/2020
Revision : 01

Progressive plastic collapse (K.3.3.6)

Assessment: $\varepsilon_{\max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$

Temperature difference with ambient; DT = 46 -
R_e = 360.00 N/mm^2
R_{ed} = 360.00 N/mm^2

$$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$$

s_p = 169.3 N/mm^2

$$\varepsilon_{\max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$$

Assessment: 0.0005 < 0.0030 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment: $L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$ Table 3 - NEN3656 - BC4
g_p = 1.15 -
g_t = 1.1 -
N = -2.05E+06 N

$L_{max,bb}$ = 61.7 m

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-08-01 - Buckling & Collapse calculations - 17m - installation flooded.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-08-01 - Buckling & Collapse calculations - 17m - installation flooded.xlsx

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Originator : EvW
Date : 27/01/2020
Revision : 01
Checked :

Buckling and Collapse - 20in x 20.62mm - Installation: filled

Situation

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

2
Installation: filled

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom} =	20	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$ =	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$ =	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max} =	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min} =	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0 =	0.014	-
Cross sectional area of steel		A =	31572	mm^2
Moment of Inertia		I =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$ =	0	mm
Nominal wall thickness	$d_{nom,p}$ =	0.0	mm

Coating data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-08-01 - Buckling & Collapse calculations - 17m - installation flooded.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-08-01 - Buckling & Collapse calculations - 17m - installation flooded.xlsx

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Originator : EvW
Checked :
Date : 27/01/2020
Revision : 01

Material		=	L360NB	
Design temperature		T_d =	15	°C
Yield at ambient temperature		R_e =	360.00	N/mm^2
Yield at design temperature		R_{ed} =	360.00	N/mm^2
Density		ρ_{st} =	7850	kg/m^3
Youngs modulus		E_s =	210000	N/mm^2
Poisson's ratio		u =	0.3	-
Linear thermal expansion coefficient		a =	1.16E-05	$m/m/^oC$
Contents				
Sea water density			1025	kg/m^3
Pipeline product density			96.1	kg/m^3
Pipeline content density used for this case:	Installation: filled		1025	kg/m^3
Pipeline Weights				
Pipeline weight in air	$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$	$W_{pl,a}$ =	4195.8	N/m
Piggyback weight in air		$W_{pg,a}$ =	0.0	N/m
Buoyancy force pipeline	$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$	$F_{B,pl}$ =	2086.5	N/m
Buoyancy force piggyback		$F_{B,pb}$ =	0.0	N/m
Submerged pipeline weight,empty		$W_{pl,s,e}$ =	388.8	N/m
Submerged piggyback weight		$W_{pg,s}$ =	0.0	N/m
Total submerged bundle weight,empty		$W_{T,s,e}$ =	388.8	N/m
Total submerged bundle weight,water filled		$W_{T,s,f}$ =	2109.4	N/m
Soil				
Submerged density		ρ_{ss} =	1000	kg/m^3
Depth of burial		d_b =	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss}$ x d_b x g	SC_{pres} =	0.008	N/mm^2
Environmental conditions				
Water depths:				
Seawater density		ρ_{sw} =	1025	kg/m3
Maximum water depth		WD_{max} =	20.6	m LAT
Minimum water depth		WD_{min} =	17	m LAT
Other water depth (to be used for calculations)		WD =	17	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-0.58	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-1.29	m LAT
Storm surge water level	SSWL = WD + ss	SSWL =	16.42	m LAT
Highest Astronomical Tide		HAT =	3.11	m
Waves (H_{max} & T_{max}):				
Maximum wave height, RP1 yr - installation/hydrotes		$H_{max,1}$ =	8.3	m
Associated maximum wave period, RP1 yr		$T_{ass,1}$ =	8.9	s
Maximum wave height, RP100 yr - operational		$H_{max,100}$ =	11.55	m
Associated maximum wave period, RP100 yr		$T_{ass,100}$ =	9.8	s

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-08-01 - Buckling & Collapse calculations - 17m - installation flooded.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-08-01 - Buckling & Collapse calculations - 17m - installation flooded.xlsx

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Originator : EvW
Date : 27/01/2020
Revision : 01
Checked :

Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

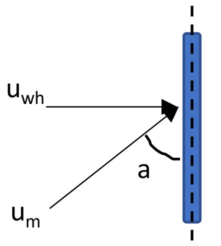
$$\frac{H_{max}}{g\cdot T_z^{\ 2}} = 0.0107$$

$$\frac{SWL}{g\cdot T_z^{\ 2}} = 0.0211$$

Wave theory selected:

1. Airy/linear wave; 2. Stokes 5th

Wave particle velocity from interpolated data



Maximum wave particle velocity	u_{wm} =	1.85	m/s
Angle of attack relative to pipeline axis	α_{uw} =	90	deg
Horizontal wave velocity ⊥ to P/L	u_{wh} =	1.85	m/s

Current:

Height above seabed at which velocity is known	z* =	1	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.82	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	0.92	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	1.04	m/s
Current velocity at reference height	U_{czr} =	0.82	m/s
Angle of attack relative to pipeline axis	α_{uc} =	90	deg
Horizontal current velocity ⊥ to P/L $\frac{7}{8}\cdot U_{czr}\cdot\left(\frac{OD_{nom}}{z_r}\right)^{1/7}\cdot\sin(\alpha_{uc}) =$	u_{ch} =	0.65	m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-
Maximum absolute hydrodynamic force		1380	N/m

Temperatures:

Ambient temperature	T_{amb} =	4	deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by:

$$(p_c - p_e)\cdot\left(p_c^{\ 2} - p_p^{\ 2}\right) = p_c\cdot p_e\cdot p_p\cdot 2\cdot\delta_o\cdot\frac{OD_g}{d_{nom}}$$

External elastical pipe collapse pressure (P_e): $P_e = \frac{2E_s}{1-v^2}\left(\frac{d_{nom}}{OD_{av}}\right)^3$ = 34.0 N/mm^2

External plastic pipe collapse pressure (P_p) $P_p = \frac{2\,R_e\,d_{nom}}{OD_{nom}}$ = 29.2 N/mm^2

External implosion pipe collapse pressure (P_c): P_c = 16.0 N/mm^2

Maximum water column above mudline (WC_{max}) $WC_{max} = WD_{max} + 0.5\cdot H_{max,100} + HAT$ = 29.485 m
0.29485 N/mm^2

Actual external pressure (P_L) $WC_{max} + SC_{pres}$ = 0.30 N/mm^2

Assessment: $\gamma_{g,p} \cdot P_L \le \dfrac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656
$g_{g,p}$ = 1.05 -
g_M = 0.93 -
$g_{m,p}$ = 1.45 -

Assessment: $\gamma_{g,p} \cdot P_L \le \dfrac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ = **OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \le \dfrac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656
$g_{g,M}$ = 1.1 -
g_M = 1 -
$g_{m,M}$ = 1.3 -

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\dfrac{\gamma_{g,p} \times P_L}{P_c/\gamma_{m,p}} + \left(\dfrac{\gamma_{g,M} \times M_L}{M_c/\gamma_{m,M}}\right)^n \le \gamma_M$ **Where,**

Table 4 - NEN3656
$g_{g,p}$ = 1.05 -
$g_{g,M}$ = 1.55 -
$g_{m,p}$ = 1.25 -
$g_{m,M}$ = 1.15 -
g_M = 0.93 -
$n = 1 + 300 \cdot d_{nom} / OD_g$ n = 13.6 -

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 1.000E+06 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \dfrac{q \cdot L^2}{10}$ **Where,**

q = load acting on pipe
L = span length

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight; Ws = 2109 N/m
$F_D + F_I$ = 1380 N/m
g_w = 1.1 -
g_h = 1.2 -
Table 3 - NEN3656
q = 2851 N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 1.00E+06 N·m

Maximum span length, L_{max} = 59.2 m

Progressive plastic collapse (K.3.3.6)

Assessment: $\varepsilon_{max} = \alpha \times \Delta T \le \left[\frac{R_e(\theta)}{E}\sqrt{1-\frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9-\frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2}\right]$

Temperature difference with ambient; DT = 11 -

R_e = 360.00 N/mm^2

R_{ed} = 360.00 N/mm^2

$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$ s_p = 3.1 N/mm^2

$$\varepsilon_{max} = \alpha \times \Delta T \le \left[\frac{R_e(\theta)}{E}\sqrt{1-\frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9-\frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2}\right]$$

Assessment: 0.0001 < 0.0033 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment: $L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$ Table 3 - NEN3656 - BC4

g_p = 1.15 -

g_t = 1.1 -

N = -8.97E+05 N

$L_{max,bb}$ = 93.1 m

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-09-01 - Buckling & Collapse calculations - 17m - hydrotest.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-09-01 - Buckling & Collapse calculations - 17m - hydrotest.xlsx

Originator : EvW
Checked :
Date : 27/01/2020
Revision : 01

Buckling and Collapse - 20in x 20.62mm - Hydrotest

Situation

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

3
Hydrotest

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom}	=	20	
Nominal diameter		OD_{nom}	=	508	mm
Nominal wall thickness		d_{nom}	=	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$	=	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$	=	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max}	=	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min}	=	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0	=	0.014	-
Cross sectional area of steel		A	=	31572	mm^2
Moment of Inertia		I	=	939135656	mm^4
Corrosion allowance		CA	=	3	mm
Fabrication Tolerance		f_{tol}	=	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min}	=	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g	=	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$	=	0	mm
Nominal wall thickness	$d_{nom,p}$	=	0.0	mm

Coating data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Project	**: N05-A Pipeline design**
Project #	: 19018
Subject	: Buckling and Collapse
File #	: 19018-60-CAL-01003-09-01 - Buckling & Collapse calculations - 17m - hydrotest.xlsx
Client	: ONE-Dyas
Client File #	: 19018-60-CAL-01003-09-01 - Buckling & Collapse calculations - 17m - hydrotest.xlsx

Originator	: EvW	Checked	:
Date	: 27/01/2020		
Revision	: 01		

Material	=	L360NB	
Design temperature	T_d =	15	°C
Yield at ambient temperature	R_e =	360.00	N/mm^2
Yield at design temperature	R_{ed} =	360.00	N/mm^2
Density	ρ_{st} =	7850	kg/m^3
Youngs modulus	E_s =	210000	N/mm^2
Poisson's ratio	u =	0.3	-
Linear thermal expansion coefficient	a =	1.16E-05	$m/m/^oC$

Contents

Sea water density		1025	kg/m^3
Pipeline product density		96.1	kg/m^3
Pipeline content density used for this case:	Hydrotest	1025	kg/m^3

Pipeline Weights

$$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$$

Pipeline weight in air	$W_{pl,a}$ =	4195.8	N/m
Piggyback weight in air	$W_{pg,a}$ =	0.0	N/m

$$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$$

Buoyancy force pipeline	$F_{B,pl}$ =	2086.5	N/m
Buoyancy force piggyback	$F_{B,pb}$ =	0.0	N/m
Submerged pipeline weight,empty	$W_{pl,s,e}$ =	388.8	N/m
Submerged piggyback weight	$W_{pg,s}$ =	0.0	N/m
Total submerged bundle weight,empty	$W_{T,s,e}$ =	388.8	N/m
Total submerged bundle weight,water filled	$W_{T,s,f}$ =	2109.4	N/m

Soil

Submerged density		ρ_{ss} =	1000	kg/m^3
Depth of burial		d_b =	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss}$ x d_b x g	SC_{pres} =	0.008	N/mm^2

Environmental conditions

Water depths:

Seawater density		ρ_{sw} =	1025	kg/m3
Maximum water depth		WD_{max} =	20.6	m LAT
Minimum water depth		WD_{min} =	17	m LAT
Other water depth (to be used for calculations)		WD =	17	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-0.58	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-1.29	m LAT
Storm surge water level	SSWL = WD + ss	SSWL =	16.42	m LAT
Highest Astronomical Tide		HAT =	3.11	m

Waves (H_{max} & T_{max}):

Maximum wave height, RP1 yr - installation/hydrotes	$H_{max,1}$ =	8.3	m
Associated maximum wave period, RP1 yr	$T_{ass,1}$ =	8.9	s
Maximum wave height, RP100 yr - operational	$H_{max,100}$ =	11.55	m
Associated maximum wave period, RP100 yr	$T_{ass,100}$ =	9.8	s

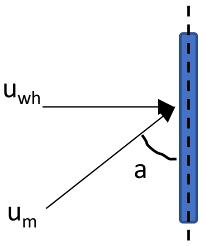
Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

$$\frac{H_{max}}{g\cdot T_z^2} = 0.0107$$

$$\frac{SWL}{g\cdot T_z^2} = 0.0211$$

Wave theory selected:

1. Airy/linear wave; 2. Stokes 5th



Wave particle velocity from interpolated data

Maximum wave particle velocity	u_{wm} =	1.85	m/s
Angle of attack relative to pipeline axis	α_{uw} =	90	deg
Horizontal wave velocity ⊥ to P/L	u_{wh} =	1.85	m/s

Current:

Height above seabed at which velocity is known	z^* =	1	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.82	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	0.92	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	1.04	m/s
Current velocity at reference height	U_{czr} =	0.82	m/s
Angle of attack relative to pipeline axis	α_{uc} =	90	deg
Horizontal current velocity ⊥ to P/L $\frac{7}{8}\cdot U_{czr}\cdot\left(\frac{OD_{nom}}{z_r}\right)^{1/7}\cdot\sin(\alpha_{uc}) =$	u_{ch} =	0.65	m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-

Maximum absolute hydrodynamic force 1380 N/m

Temperatures:

Ambient temperature T_{amb} = 4 deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by:

$$(p_c - p_e)\cdot\left(p_c^2 - p_p^2\right) = p_c\cdot p_e\cdot p_p\cdot 2\cdot\delta_o\cdot\frac{OD_g}{d_{nom}}$$

External elastical pipe collapse pressure (P_e): $P_e = \frac{2E_s}{1-\nu^2}\left(\frac{d_{nom}}{OD_{av}}\right)^3 =$ 34.0 N/mm^2

External plastic pipe collapse pressure (P_p) $P_p = \frac{2\,R_e\,d_{nom}}{OD_{nom}} =$ 29.2 N/mm^2

External implosion pipe collapse pressure (P_c): P_c = 16.0 N/mm^2

Maximum water column above mudline (WC_{max}) $WC_{max} = WD_{max} + 0.5\cdot H_{max,100} + HAT =$ 29.485 m

0.29485 N/mm^2

Actual external pressure (P_L) $WC_{max} + SC_{pres} =$ 0.30 N/mm^2

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-09-01 - Buckling & Collapse calculations - 17m - hydrotest.xlsx

Client : ONE-Dyas
Client File # : 19018-60-CAL-01003-09-01 - Buckling & Collapse calculations - 17m - hydrotest.xlsx

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Originator : EvW
Checked :
Date : 27/01/2020
Revision : 01

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656
$g_{g,p}$ = 1.05 -
g_M = 0.93 -
$g_{m,p}$ = 1.45 -

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **=** **OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \le \frac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656
$g_{g,M}$ = 1.1 -
g_M = 1 -
$g_{m,M}$ = 1.3 -

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\frac{\gamma_{g,p} \times P_L}{P_c / \gamma_{m,p}} + \left(\frac{\gamma_{g,M} \times M_L}{M_c / \gamma_{m,M}} \right)^n \le \gamma_M$ **Where,**

Table 4 - NEN3656
$g_{g,p}$ = 1.05 -
$g_{g,M}$ = 1.55 -
$g_{m,p}$ = 1.25 -
$g_{m,M}$ = 1.15 -
g_M = 0.93 -
$n = 1 + 300 \cdot d_{nom} / OD_g$ n = 13.6 -

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 1.000E+06 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \frac{q \cdot L^2}{10}$ **Where,**

q = load acting on pipe
L = span length

$$q = \sqrt{\gamma_W^{\ 2} \cdot W_S^{\ 2} + \gamma_H^{\ 2} \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight; Ws = 2109 N/m
$F_D + F_I$ = 1380 N/m
g_w = 1.1 -
g_h = 1.2 -
Table 3 - NEN3656
q = 2851 N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 1.000E+06 N·m

Maximum span length, L_{max} = 59.2 m

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-09-01 - Buckling & Collapse calculations - 17m - hydrotest.xlsx

Client : ONE-Dyas
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Originator : EvW
Date : 27/01/2020
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Progressive plastic collapse (K.3.3.6)

Assessment:
$$\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E} \sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$$

Temperature difference with ambient; DT = 11 -

R_e = 360.00 N/mm^2

R_{ed} = 360.00 N/mm^2

$$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$$

s_p = 219.6 N/mm^2

$$\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E} \sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$$

Assessment: 0.0001 < 0.0028 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment:
$$L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$

Table 3 - NEN3656 - BC4

g_p = 1.15 -

g_t = 1.1 -

N = 1.46E+06 N

$L_{max,bb}$ = No compressive force m

C. Static and Dynamic Span Analysis

The following static and dynamic span analyses were performed:

- 19018-60-CAL-01004-01-01 Allowable free span (static & dynamic) calculations -26m
- 19018-60-CAL-01004-02-01 Allowable free span (static & dynamic) calculations -8m
- 19018-60-CAL-01004-03-01 Allowable free span (static & dynamic) calculations -17m

(25pages)

Project	**: N05-A Pipeline Design**
Project #	: 19018
Subject	: Static & Dynamic Span Analysis
File #	: 19018-60-CAL-01004-01-01 - Allowable free span (static & dynamic) calculations - 26m.xlsm
Client	: ONE-Dyas
Client File #	: 19018-60-CAL-01004-01-01 - Allowable free span (static & dynamic) calculations - 26m.xlsm

Originator	: EvW	Checked	: PF
Date	: 24/01/2020		
Revision	: 01		

Static & Dynamic Span - 20" x 20.62 mm

Condition Overview

	Pressure (barg)	Temp. (deg. C)	Content (kg/m3)
Installation (P_{in}, T_{in})	2	15	1025
Hydrotest (P_t, T_t)	144	15	1025
Design (P_d, T_d)	111	50	88.7

Pipeline properties

Nominal diameter		OD_{nom} =	20"	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Internal diameter	$ID = OD_{nom} - 2 \cdot d_{nom}$	ID =	466.76	mm
Cross sectional area of steel	$A_s = \frac{\pi}{4} \cdot \{OD_{nom}^2 - ID^2\}$	A_s =	31572	mm^2
Section modulus	$W_s = \frac{\pi}{32} \cdot \frac{\{OD_{nom}^4 - ID^4\}}{OD_{nom}}$	W_s =	3697384	mm^3
Moment of Inertia	$I_s = \frac{\pi}{64} \cdot \{OD_{nom}^4 - ID^4\}$	I_s =	939135656	mm^4

Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$ =	0	mm
Nominal wall thickness	$d_{nom,p}$ =	0.0	mm

Coating and insulation data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Material

	=	L360NB	
Design temperature	T_d =	50	°C
Yield at ambient/hydrotest temperature	R_e =	360.00	N/mm^2
Yield at design temperature	R_{ed} =	360.00	N/mm^2
Density	ρ_{st} =	7850	kg/m3
Youngs modulus	E_s =	210000	N/mm^2
Poisson's ratio	u =	0.3	-
Linear thermal expansion coefficient	a =	1.16E-05	$m/m/^oC$

Weights

		installation (N/m)	hydrotest (N/m)	operation (N/m)
air	line pipe	2431.3	2431.3	2431.3
	content	1720.6	1720.6	148.9
	coating	43.9	43.9	43.9
	piggyback	0.0	0.0	0.0
	coating pb	0.0	0.0	0.0
buoyancy	line pipe	2086.5	2086.5	2086.5
	piggyback	0.0	0.0	0.0

$$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$$

$$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$$

Static & Dynamic span to be checked for the following environmental load combinations

Condition	Wave velocity	Current velocity	Comment
Installation	$H_{max,1yr}$	1 yr	
Hydrotest	$H_{max,1yr}$	1 yr	
Operational	$H_{max,100yr}$	10 yr	LC1
	$H_{max,10yr}$	100 yr	LC2

Environmental conditions

Water depths:

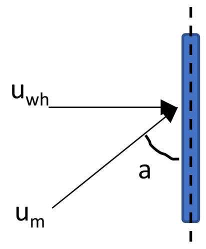
Seawater density		ρ_{sw} =	1025	kg/m³
Maximum water depth		WD_{max} =	29.68	m LAT
Minimum water depth		WD_{min} =	26	m LAT
Other water depth (user input)		WD =	26	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-1.02	m LAT
Storm surge, RP10 yr		ss_{10yr} =	-1.4	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-1.79	m LAT
Storm surge water level, RP1 yr	$SSWL_{1yr} = WD + ss_{1yr}$	$SSWL_{1yr}$ =	24.98	m LAT
Storm surge water level, RP10 yr	$SSWL_{10yr} = WD + ss_{10yr}$	$SSWL_{10yr}$ =	24.6	m LAT
Storm surge water level, RP100 yr	$SSWL_{100yr} = WD + ss_{100yr}$	$SSWL_{100yr}$ =	24.21	m LAT
Highest Astronomical Tide		HAT =	2.72	m

Waves (H_{max} & T_{max}):

Maximum wave height, RP1 yr - installation/hydrotest	$H_{max,1}$ =	11.4	m
Associated maximum wave period, RP1 yr	$T_{ass,1}$ =	10.1	s
Maximum wave height, RP10 yr - operational	$H_{max,10}$ =	14.5	m
Associated maximum wave period, RP10 yr	$T_{ass,10}$ =	10.9	s
Maximum wave height, RP100 yr - operational	$H_{max,100}$ =	16.9	m
Associated maximum wave period, RP100 yr	$T_{ass,100}$ =	11.5	s

Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

	1 yr	10 yr	100 yr
$\frac{H}{g \cdot T_{ass}^2}$	0.0114	0.0124	0.0130
$\frac{SWL}{g \cdot T_{ass}^2}$	0.0250	0.0211	0.0187
theory	Stokes	Stokes	Stokes
maximum wave particle velocity (u_{wm})	2.39	3.26	4.00
angle of attack relative to P/L axis (a)	90	90	90
horizontal wave velocity ⊥ to P/L (u_{wh})	2.39	3.26	4.00



Current:

Height above seabed at which velocity is known	z* =	2	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.74	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	0.84	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	0.96	m/s

Current velocity at reference height: $U_{czr} = u_{st} + u_{ss}$

$U_{czr,1}$ =	0.74	m/s
$U_{czr,10}$ =	0.84	m/s
$U_{czr,100}$ =	0.96	m/s

Angle of attack relative to pipeline axis α_{uc} = 90 deg

Horizontal current velocity ⊥to P/L:

$$u_{cm,perp} = \frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc})$$

$u_{cm,perp,1}$ =	0.532	m/s
$u_{cm,perp,10}$ =	0.604	m/s
$u_{cm,perp,100}$ =	0.691	m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-

Hydrodunamic forces:

Maximum absolute hydrodynamic force (F_D+F_I), RP1 yr (installation/hydrotest condition)	1824	N/m
Maximum absolute hydrodynamic force (F_D+F_I), RP100/10 yr (LC 1 operational condition)	4175	N/m
Maximum absolute hydrodynamic force (F_D+F_I), RP10/100 yr (LC 2operational condition)	3124	N/m

Temperatures:

Ambient temperature T_{amb} = 4 deg. C

Project : **N05-A Pipeline Design**
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Client : ONE-Dyas
Client File # : 19018-60-CAL-01004-01-01 - Allowable free span (static & dynamic) calculations - 26m.xlsm

Originator : EvW Checked : PF
Date : 24/01/2020
Revision : 01

Table 3 - NEN 3656 load factors

			LC 1	**LC 2**	
Load factor	**Installation**	**Hydrotest**	**Operation**	**Operation**	
Self weight & content	1.1	1.1	1.1	1.1	
Coating	1.2	1.2	1.2	1.2	
Marine growth	0	0	1.2	1.2	
Internal pressure	0	1.15	1.15	1.15	
external pressure	1.1	1.1	1.1	1.1	
temperature	1	1.1	1.1	1.1	
environmental load	1.1	1.2	1.2	1.2	
Pipe bundle weight in air	4619.8	4619.8	2891.0	2891.0	N/m; incl. load factors
Submerged bundle weight, Ws	2324.7	2324.7	595.9	595.9	N/m; incl. load factors
Factored load acting on pipe, q	3071	3193	5045	3796	N/m; $q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$
Pressure	2	144	111	111	barg
DT	11	11	46	46	deg. C
Material factor (table 3; D3.1)	1.1	1.1	1.1	1.1	
Allowable stress (table 3; D3.1)	327.3	556.4	556.4	556.4	N/mm^2

STATIC SPAN LENGTH - INSTALLATION

	Unrestrained pipe		Restrained pipe			
	tension	compression	tension	compression		
Hoop stress	4.4	4.4	4.4	4.4	N/mm^2	$\sigma_H = \frac{(\gamma i \cdot Pi - \gamma e \cdot Pe) \cdot (OD - d_{min})}{2 \cdot d_{min}}$
Max. long. Stress	329.4	-325.1	329.4	-325.1	N/mm^2	$\sigma_{max.long.stress} = \frac{\sigma_H \pm \sqrt{-3 \cdot \sigma_H^2 + 4 \cdot \sigma_{allow}^2}}{2}$
Long. hoop stress	1.8	1.8	1.3	1.3	N/mm^2	$\sigma_{long.hoop.stress} = v \cdot \sigma_H$
Thermal exp. stress	n/a	n/a	-26.8	-26.8	N/mm^2	$\sigma_{\mathrm{thermal}} = -\gamma_t \cdot \alpha \cdot E_s \cdot \Delta T$
Max. allow. bending stress	327.3	-326.8	327.3	-299.6	N/mm^2	$\sigma_{b,max} = \sigma_{max.long.stress} - \sigma_{lonh.hoop.stress} - \sigma_{thermal}$
Maximum span	62.8	62.7	62.8	60.1	m	

STATIC SPAN LENGTH - HYDROTEST

	Unrestrained pipe		Restrained pipe		
	tension	compression	tension	compression	
Hoop stress	248.2	248.2	248.2	248.2	N/mm^2
Max. long. Stress	637.3	-389.1	637.3	-389.1	N/mm^2
Long. hoop stress	85.8	85.8	74.5	74.5	N/mm^2
Thermal exp. stress	n/a	n/a	-29.5	-29.5	N/mm^2
Max. allow. bending stress	551.4	-474.9	556.4	-434.0	N/mm^2
Maximum span	79.9	74.2	80.3	70.9	m

STATIC SPAN LENGTH - OPERATION LC1

	Unrestrained pipe		Restrained pipe		
	tension	compression	tension	compression	
Hoop stress	190.3	190.3	190.3	190.3	N/mm^2
Max. long. Stress	626.6	-436.2	626.6	-436.2	N/mm^2
Long. hoop stress	66.2	66.2	57.1	57.1	N/mm^2
Thermal exp. stress	n/a	n/a	-123.3	-123.3	N/mm^2
Max. allow. bending stress	556.4	-502.4	556.4	-370.1	N/mm^2
Maximum span	63.9	60.7	63.9	52.1	m

STATIC SPAN LENGTH - OPERATION LC2

	Unrestrained pipe		Restrained pipe		
	tension	compression	tension	compression	
Hoop stress	190.3	190.3	190.3	190.3	N/mm^2
Max. long. Stress	626.6	-436.2	626.6	-436.2	N/mm^2
Long. hoop stress	66.2	66.2	57.1	57.1	N/mm^2
Thermal exp. stress	n/a	n/a	-123.3	-123.3	N/mm^2
Max. allow. bending stress	556.4	-502.4	556.4	-370.1	N/mm^2
Maximum span	73.6	70.0	73.6	60.0	m

DYNAMIC SPAN ANALYSIS (NEN 3656 - I.5.2.5)

Assessment Stability parameter, Ks < 1.8 => in-line vibration
Stability parameter, Ks < 16 => cross flow vibration

$$K_s = \frac{2m \text{ x } \delta}{\rho_w \text{ x } D_o^2}$$

Where,

d = damping factor water: 0.02 x 2 x π = 0.126 -
r_w = seawater density = 1025 kg/m^3
D_o = outer diameter (incl. coating) = 514 mm
m = effective mass
m = W_{bundle} + M_{added}

$$M_{added} = \frac{\pi}{4} \cdot C_m \cdot \rho_w \cdot D_{o,eq}^2$$

C_m = added mass coefficient = 1.2 -
$D_{o,eq}$ = equivalent diameter (incl. coating) = 514 mm

Due to the presense of 2 objects attached to eachother, velocity flow intensification occurs:

v_{tot} = (v_{wave} + v_{cur}) x (1 + f_{int});

$$f_{int} = \left\{1 + \left(\frac{D_{ob}^2}{4 \cdot CL^2}\right)\right\}$$

Where,
D_{ob} = diameter of obstruction
CL = centerline distance P/L - obstruction

IN-LINE VIV:

Given the stability factor (Ks), the horizontal particle velocity (v), possibly including vicinity factor and the reduced velocity (Vr), the first eigen frequency (f1) can be determined prior to vibration occurring.

Reduced velocity, Vr, based on NEN 3656 I.5.2.5.2

$$V_r = \frac{v}{f_1 \times D_o}$$

if $1{,}0 \leq V_r \leq 3{,}5$ then oscillation occurs => Vr<1,0 design criterium

Vr is set to 1 as conservative value; Vr = 1.0 -

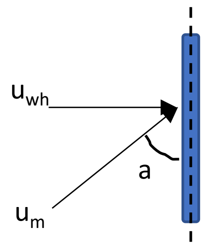
$$f_1 = \frac{a}{2\pi}\sqrt{\frac{E \times I}{m \times L^4}}$$

Where,
a = frequency factor (22 for fixed/fixed; 9.87 for pinned/pinned)
a = 15.4 for fixed/pinned a = 15.4 -

Waves (Hs & Tz):

Significant wave height, RP1 yr - installation/hydrotest	$H_{s,1}$ =	6.5	m
Associated wave period, RP1 yr	$T_{z,1}$ =	9.9	s
Significant wave height, RP10 yr - operational	$H_{s,10}$ =	8.4	m
Associated wave period, RP10 yr	$T_{z,10}$ =	11.3	s
Significant wave height, RP100 yr - operational	$H_{s,100}$ =	9.9	m
Associated wave period, RP100 yr	$T_{z,100}$ =	12.3	s

	1 yr	10 yr	100 yr
$\frac{H}{g \cdot T_{ass}^2}$	0.0068	0.0067	0.0067
$\frac{SWL}{g \cdot T_{ass}^2}$	0.0260	0.0196	0.0163
theory	Stokes	Stokes	Stokes
maximum wave particle velocity (u_{wm})	1.35	2.01	2.56
angle of attack relative to P/L axis (a)	90	90	90
horizontal wave velocity⊥ to P/L (u_{wh})	1.35	2.01	2.56



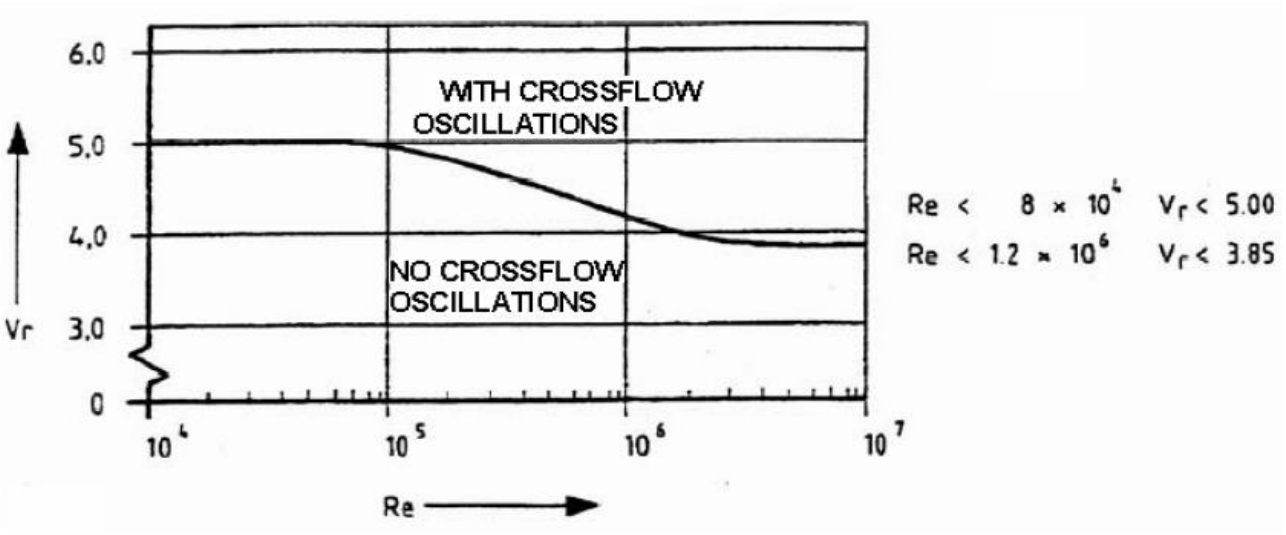
	Installation	**Hydrotest**	**LC 1 Operation**	**LC 2 Operation**	
effective mass	682.9	682.9	522.7	522.7	kg/m
K_s	0.63	0.63	0.49	0.49	-
In-line VIV	yes	yes	yes	yes	-
cross flow VIV	yes	yes	yes	yes	-
Vr	1.00	1.00	1.00	1.00	-
u_{wh}	0.53	0.53	0.60	0.69	m/s, set equal to Ucm, for velocity ratio 0.5
$u_{cm,perp}$	0.53	0.53	0.60	0.69	m/s
D_{ob}	0.0	0.0	0.0	0.0	mm
CL	294.0	294.0	294.0	294.0	mm
f_{int}	0.000	0.000	0.000	0.000	-
$(u_{wh} + u_{cm,perp}) \times (1+0.5 \cdot f_{int}) = v_{tot}$	1.06	1.06	1.21	1.38	m/s
D_o	0.5140	0.5140	0.5140	0.5140	m
f1	2.07	2.07	2.35	2.69	1/s
$L_{span,in}$	25.2	25.2	25.3	23.7	m

note: f_{int} is taken into account for 50% as system doesn't instantaneously respond and vortices occur in a relatively steady state environment, which this isn't.

CROSS FLOW VIV:
Oscillation area for cross flow is given by the figure below and depends on the Reynolds number (R_e)

$$R_e = \frac{v \cdot D_o}{v_d}$$

v = horizontal particle velocity (v_{tot})
D_o = outer diameter (incl. coating) = 514 mm
u_d = dynamic viscosity seawater u_d = 4.99E-07 m^2/s
Vr is set to 3.85 as conservative value; Vr = 3.85 -



	Installation	**Hydrotest**	**LC 1 Operation**	**LC 2 Operation**	
u_{wh}	1.35	1.35	2.56	2.01	m/s
$u_{cm,perp}$	0.53	0.53	0.60	0.69	m/s
D_{ob}	0.0	0.0	0.0	0.0	mm
CL	294.0	294.0	294.0	294.0	mm
f_{int}	0.000	0.000	0.000	0.000	-
$(u_{wh} + u_{cm,perp}) \times (1+0.5 \cdot f_{int}) = v_{tot}$	1.89	1.89	3.17	2.70	m/s
D_o	0.5140	0.5140	0.5140	0.5140	m
Reynolds nr.	1.94E+06	1.94E+06	3.26E+06	2.78E+06	-
Vr	3.850	3.850	3.850	3.850	-
f1	0.95	0.95	1.60	1.36	1/s
$L_{span,cross}$	37.2	37.2	30.7	33.2	m

SUMMARY - SPAN ANALYSIS

	Installation	**Hydrotest**	**LC 1 Operation**	**LC 2 Operation**	
$L_{span,in}$	25.2	25.2	25.3	23.7	m
$L_{span,cross}$	37.2	37.2	30.7	33.2	m

Maximum Span Length = 23.7 m

Static & Dynamic Span - 10" x 12.7mm

Water depth	WD =	26	m (LAT)
Storm surge	ss =	-1.02	m
Storm surge water level	$SWL = WD + ss$ =	24.98	m
Wave height	H =	11.4	m
Wave period	T =	10.1	s
Grav. Acceleration	g =	9.81	m/s^2
Deep water wave length	$L_o = \frac{g\cdot T^2}{2\cdot\pi}$ =	159.3	m

Solving for wave length (L) and λ

$$\frac{\pi\cdot H}{SWL} - \frac{L}{SWL}\left\{\lambda + \lambda^3\cdot B_{33} + \lambda^5\cdot\left(B_{35} + B_{55}\right)\right\} = 0 \quad (\text{ I })$$

$$\frac{SWL}{L_O} - \frac{SWL}{L}\cdot\tanh\left(\frac{2\cdot\pi\cdot SWL}{L}\right)\cdot\left\{1 + \lambda^2\cdot C_1 + \lambda^4\cdot C_2\right\} = 0 \quad (\text{ II })$$

Choosing L and solving for λ in (II) results in 4 roots for λ

Estimate actual wave length, L **143.109** **m**

$$A = SWL/L_O \quad = \quad 0.1568$$

$$B = \frac{SWL}{L}\cdot\tanh\left(\frac{2\cdot\pi\cdot SWL}{L}\right) \quad = \quad 0.1395$$

$$\lambda = \pm\sqrt{X}$$

$$X = \frac{-C_1\cdot B \ \pm\sqrt{D}}{2\cdot C_2\cdot B}$$

$$D = \left(C_1\cdot B\right)^2 - 4\cdot\left(C_2\cdot B\right)\cdot\left(-\left(A - B\right)\right) \quad = \quad 0.1583$$

	-	eq. (I)	eq. (II)
λ1	0.228	-0.0006	0.0000
λ2	Numerator of X < 0		
λ3	-0.228	2.8680	0.0000
λ4	Numerator of X < 0		

Item	Formula	Value	Unit
s	$s=\sinh\left(\frac{2\cdot\pi\cdot WL}{L}\right)=$	1.3302	-
c	$c=\cosh\left(\frac{2\cdot\pi\cdot WL}{L}\right)=$	1.6642	-
A11	$A_{11}=\frac{1}{s}=$	0.7518	-
A13	$A_{13}=\frac{-c^2\cdot\left(5\cdot c^2+1\right)}{8\cdot s^5}=$	-1.2341	-
	$A_{15}=-\frac{1184\cdot c^{10}-1440\cdot c^8-1992\cdot c^6+2641\cdot c^4-249\cdot c^2+18}{1536\cdot s^{11}}=$	-2.4111	-
A22	$A_{22}=\frac{3}{8\cdot s^4}=$	0.1198	-
A24	$A_{24}=\frac{192\cdot c^8-424\cdot c^6-312\cdot c^4+480\cdot c^2-17}{768\cdot s^{10}}=$	0.0907	-
A33	$A_{33}=\frac{13-4\cdot c^2}{64\cdot s^7}=$	0.0041	-
	$A_{35}=\frac{512\cdot c^{12}+4224\cdot c^{10}-6800\cdot c^8-12808\cdot c^6+16704\cdot c^4-3154\cdot c^2-107}{4096\cdot s^{13}\cdot\left(6\cdot c^2-1\right)}=$	0.1403	-
A44	$A_{44}=\frac{80\cdot c^6-816\cdot c^4+1338\cdot c^2-197}{1536\cdot s^{10}\cdot\left(6\cdot c^2-1\right)}=$	-0.0025	-

$$A_{55} = -\frac{2880\cdot c^{10} - 72480\cdot c^{8} + 324000\cdot c^{6} - 432000\cdot c^{4} + 163470\cdot c^{2} - 16245}{61440\cdot s^{11}\cdot\left(6\cdot c^{2}-1\right)\cdot\left(8\cdot c^{4}-11\cdot c^{2}+3\right)} =$$

-0.0003 -

B22

$$B_{22} = \frac{\left(2\cdot c^{2}+1\right)\cdot c}{4\cdot s^{3}} =$$

1.1558 -

B24

$$B_{24} = \frac{c\cdot\left(272\cdot c^{8} - 504\cdot c^{6} - 192\cdot c^{4} + 322\cdot c^{2} + 21\right)}{384\cdot s^{9}} =$$

1.5738 -

B33

$$B_{33} = \frac{3\cdot\left(8\cdot c^{6}+1\right)}{64\cdot s^{6}} =$$

1.4462 -

$$B_{35} = \frac{88128\cdot c^{14} - 208224\cdot c^{12} + 70848\cdot c^{10} + 54000\cdot c^{8} - 21816\cdot c^{6} + 6264\cdot c^{4} - 54\cdot c^{2} - 81}{12288\cdot s^{12}\cdot\left(6\cdot c^{2}-1\right)} =$$

= 5.1741 -

B44

$$B_{44} = c\cdot\frac{768\cdot c^{10} - 488\cdot c^{8} - 48\cdot c^{6} + 48\cdot c^{4} + 106\cdot c^{2} - 21}{384\cdot s^{9}\cdot\left(6\cdot c^{2}-1\right)} =$$

2.0437 -

$$B_{55} = \frac{192000\cdot c^{16} - 26720\cdot c^{14} + 83680\cdot c^{12} + 20160\cdot c^{10} - 7280\cdot c^{8} + 7160\cdot c^{6} - 1800\cdot c^{4} - 1050\cdot c^{2} + 225}{12288\cdot s^{10}\cdot\left(8\cdot c^{4}-11\cdot c^{2}+3\right)\cdot\left(6\cdot c^{2}-1\right)} =$$

= 3.3404 -

C1

$$C_{1} = \frac{8\cdot c^{4} - 8\cdot c^{2} + 9}{8\cdot s^{4}} =$$

1.9244 -

$$C_{2} = \frac{3840\cdot c^{12} - 4096\cdot c^{10} + 2592\cdot c^{8} - 1008\cdot c^{6} + 5944\cdot c^{4} - 1830\cdot c^{2} + 147}{512\cdot s^{10}\cdot\left(6\cdot c^{2}-1\right)} =$$

8.9186 -

C3

$$C_{3} = -\frac{1}{4\cdot c\cdot s} =$$

-0.1129 -

C4

$$C_{4} = \frac{12\cdot c^{8} + 36\cdot c^{6} - 162\cdot c^{4} + 141\cdot c^{2} - 27}{192\cdot c\cdot s^{9}} =$$

0.1420 -

K1

$$K_{1} = \lambda\cdot A_{11} + \lambda^{3}\cdot A_{13} + \lambda^{5}\cdot A_{15} =$$

0.1553 -

K2	$K_2 = \lambda^2 \cdot A_{22} + \lambda^4 \cdot A_{24} =$	0.0065	-
K3	$K_3 = \lambda^3 \cdot A_{33} + \lambda^5 \cdot A_{35} =$	0.0001	-
K4	$K_4 = \lambda^4 \cdot A_{44} =$	0.0000	-
K5	$K_5 = \lambda^5 \cdot A_{55} =$	0.0000	-

Horizontal wave particle velocities

Water depth at which data required, z 0.5080 m
(w.r.t. seabed)

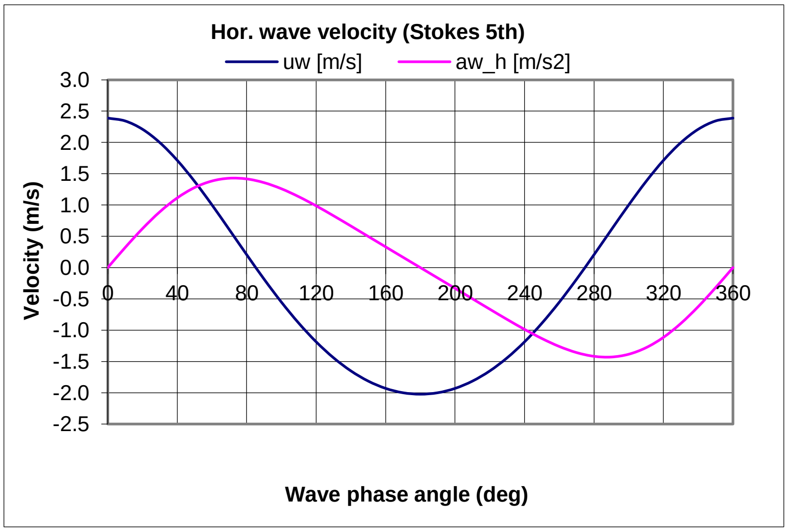
Horizontal velocity, u_w

$$u_w = \frac{L}{T} \cdot \sum_{n=1}^{5} n \cdot K_n \cdot \cosh\left(n \cdot \frac{2 \cdot \pi}{L} \cdot z\right) \cdot \cos(n \cdot \varphi)$$

Horizontal acceleration, $a_{w,h}$

$$a_{w,h} = \frac{2 \cdot \pi \cdot L}{T^2} \cdot \sum_{n=1}^{5} n^2 \cdot K_n \cdot \cosh\left(n \cdot \frac{2 \cdot \pi}{L} \cdot z\right) \cdot \sin(n \cdot \varphi)$$

ϕ [deg.]	uw [m/s]	aw_h [m/s^2]
0.00	2.3895	0.0000
10.00	2.3444	0.3205
20.00	2.2113	0.6233
30.00	1.9978	0.8921
40.00	1.7152	1.1138
50.00	1.3781	1.2793
60.00	1.0030	1.3842
70.00	0.6070	1.4288
80.00	0.2065	1.4177
90.00	-0.1839	1.3583
100.00	-0.5520	1.2602
110.00	-0.8883	1.1334
120.00	-1.1862	0.9871
130.00	-1.4411	0.8289
140.00	-1.6507	0.6647
150.00	-1.8139	0.4983
160.00	-1.9303	0.3317
170.00	-2.0000	0.1656
180.00	-2.0233	0.0000
190.00	-2.0000	-0.1656
200.00	-1.9303	-0.3317



210.00	-1.8139	-0.4983
220.00	-1.6507	-0.6647
230.00	-1.4411	-0.8289
240.00	-1.1862	-0.9871
250.00	-0.8883	-1.1334
260.00	-0.5520	-1.2602
270.00	-0.1839	-1.3583
280.00	0.2065	-1.4177
290.00	0.6070	-1.4288
300.00	1.0030	-1.3842
310.00	1.3781	-1.2793
320.00	1.7152	-1.1138
330.00	1.9978	-0.8921
340.00	2.2113	-0.6233
350.00	2.3444	-0.3205
360.00	2.3895	0.0000

U_{wm} = max. wave particle velocity = 2.39 m/s

Project : **N05-A Pipeline Design**
Project # : 19018
Subject : Static & Dynamic Span Analysis
File # : 19018-60-CAL-01004-01-01 - Allowable free span (static & dynamic) calculations - 26m.xlsm

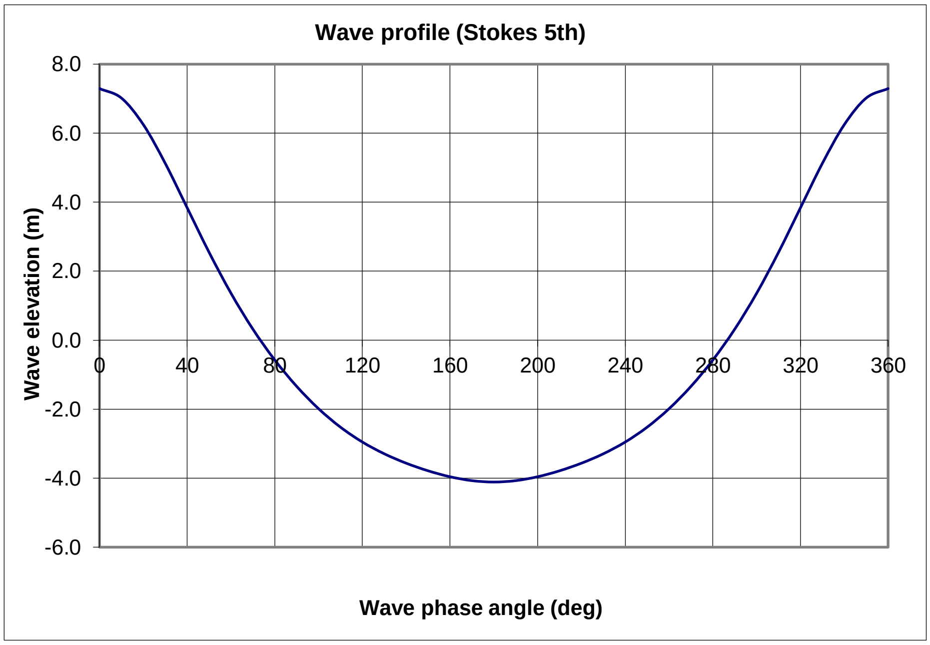
Client : ONE-Dyas
Client File # :

Originator : EvW   Checked : PF
Date : 24/01/2020
Revision : 01

Wave profile h(t)

$$\eta(t)=\frac{L}{2\cdot\pi}\{\lambda\cdot\cos(\varphi)+(\lambda^2\cdot B_{22}+\lambda^4\cdot B_{24})\cdot\cos(2\varphi)+(\lambda^3\cdot B_{33}+\lambda^5\cdot B_{35})\cdot\cos(3\varphi)+\lambda^4\cdot B_{44}\cdot\cos(4\varphi)+\lambda^5\cdot B_{55}\cdot\cos(5\varphi)\}$$

ϕ (deg.)	η(t) (m)
0.00	7.2930
10.00	7.0176
20.00	6.2468
30.00	5.1259
40.00	3.8385
50.00	2.5483
60.00	1.3614
70.00	0.3208
80.00	-0.5742
90.00	-1.3393
100.00	-1.9865
110.00	-2.5217
120.00	-2.9522
130.00	-3.2934
140.00	-3.5660
150.00	-3.7866
160.00	-3.9586
170.00	-4.0716
180.00	-4.1115
190.00	-4.0716
200.00	-3.9586
210.00	-3.7866
220.00	-3.5660
230.00	-3.2934
240.00	-2.9522
250.00	-2.5217
260.00	-1.9865
270.00	-1.3393
280.00	-0.5742
290.00	0.3208
300.00	1.3614
310.00	2.5483
320.00	3.8385
330.00	5.1259
340.00	6.2468
350.00	7.0176
360.00	7.2930



Project : **N05-A Pipeline Design**
Project # : 19018
Subject : Static & Dynamic Span Analysis
File # : 19018-60-CAL-01004-02-01 - Allowable free span (static & dynamic) calculations - 8m.xlsm

Client : ONE-Dyas
Client File # : 19018-60-CAL-01004-02-01 - Allowable free span (static & dynamic) calculations - 8m.xlsm

Originator : EvW Checked : PF
Date : 27/01/2020
Revision : 01

Static & Dynamic Span - 20" x 20.62 mm

Condition Overview

	Pressure (barg)	Temp. (deg. C)	Content (kg/m3)
Installation (P_{in}, T_{in})	2	15	1025
Hydrotest (P_t, T_t)	144	15	1025
Design (P_d, T_d)	111	50	88.7

Pipeline properties

Nominal diameter		OD_{nom} =	20"	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Internal diameter	$ID = OD_{nom} - 2 \cdot d_{nom}$	ID =	466.76	mm
Cross sectional area of steel	$A_s = \frac{\pi}{4} \cdot \{OD_{nom}^2 - ID^2\}$	A_s =	31572	mm^2
Section modulus	$W_s = \frac{\pi}{32} \cdot \frac{\{OD_{nom}^4 - ID^4\}}{OD_{nom}}$	W_s =	3697384	mm^3
Moment of Inertia	$I_s = \frac{\pi}{64} \cdot \{OD_{nom}^4 - ID^4\}$	I_s =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm
Piggyback				
Nominal diameter		$OD_{nom,p}$ =	0	mm
Nominal wall thickness		$d_{nom,p}$ =	0.0	mm

Coating and insulation data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Material

	=	L360NB	
Design temperature	T_d =	50	°C
Yield at ambient/hydrotest temperature	R_e =	360.00	N/mm^2
Yield at design temperature	R_{ed} =	360.00	N/mm^2
Density	ρ_{st} =	7850	kg/m3
Youngs modulus	E_s =	210000	N/mm^2
Poisson's ratio	u =	0.3	-
Linear thermal expansion coefficient	a =	1.16E-05	$m/m/^oC$

Weights

		installation (N/m)	hydrotest (N/m)	operation (N/m)
air	line pipe	2431.3	2431.3	2431.3
	content	1720.6	1720.6	148.9
	coating	43.9	43.9	43.9
	piggyback	0.0	0.0	0.0
	coating pb	0.0	0.0	0.0
buoyancy	line pipe	2086.5	2086.5	2086.5
	piggyback	0.0	0.0	0.0

$$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$$

$$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$$

Static & Dynamic span to be checked for the following environmental load combinations

Condition	Wave velocity	Current velocity	Comment
Installation	$H_{max,1yr}$	1 yr	
Hydrotest	$H_{max,1yr}$	1 yr	
Operational	$H_{max,100yr}$	10 yr	LC1
	$H_{max,10yr}$	100 yr	LC2

Environmental conditions

Water depths:

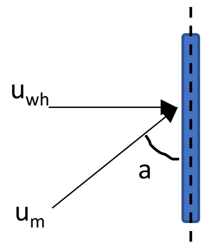
Seawater density		ρ_{sw} =	1025	kg/m³
Maximum water depth		WD_{max} =	11.5	m LAT
Minimum water depth		WD_{min} =	8	m LAT
Other water depth (user input)		WD =	8	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-0.14	m LAT
Storm surge, RP10 yr		ss_{10yr} =	-0.46	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-0.78	m LAT
Storm surge water level, RP1 yr	$SSWL_{1yr} = WD + ss_{1yr}$	$SSWL_{1yr}$ =	7.86	m LAT
Storm surge water level, RP10 yr	$SSWL_{10yr} = WD + ss_{10yr}$	$SSWL_{10yr}$ =	7.54	m LAT
Storm surge water level, RP100 yr	$SSWL_{100yr} = WD + ss_{100yr}$	$SSWL_{100yr}$ =	7.22	m LAT
Highest Astronomical Tide		HAT =	3.5	m

Waves (H_{max} & T_{max}):

Maximum wave height, RP1 yr - installation/hydrotest	$H_{max,1}$ =	5.2	m
Associated maximum wave period, RP1 yr	$T_{ass,1}$ =	7.7	s
Maximum wave height, RP10 yr - operational	$H_{max,10}$ =	5.7	m
Associated maximum wave period, RP10 yr	$T_{ass,10}$ =	7.9	s
Maximum wave height, RP100 yr - operational	$H_{max,100}$ =	6.2	m
Associated maximum wave period, RP100 yr	$T_{ass,100}$ =	8.1	s

Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

	1 yr	10 yr	100 yr
$\frac{H}{g \cdot T_{ass}^2}$	0.0089	0.0093	0.0096
$\frac{SWL}{g \cdot T_{ass}^2}$	0.0135	0.0123	0.0112
theory	Wave particle velocity directly from metocean data		
maximum wave particle velocity (u_{wm})	1.30	1.50	1.60
angle of attack relative to P/L axis (a)	90	90	90
horizontal wave velocity ⊥ to P/L (u_{wh})	1.30	1.50	1.60



Current:

Height above seabed at which velocity is known	z* =	1	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.89	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	1	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	1.12	m/s

Current velocity at reference height: $U_{czr} = u_{st} + u_{ss}$

$U_{czr,1}$ =	0.89	m/s
$U_{czr,10}$ =	1	m/s
$U_{czr,100}$ =	1.12	m/s

Angle of attack relative to pipeline axis α_{uc} = 90 deg

Horizontal current velocity ⊥to P/L:

$$u_{cm,perp} = \frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc})$$

$u_{cm,perp,1}$ =	0.707	m/s
$u_{cm,perp,10}$ =	0.794	m/s
$u_{cm,perp,100}$ =	0.890	m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-

Hydrodunamic forces:

Maximum absolute hydrodynamic force (F_D+F_I), RP1 yr (installation/hydrotest condition)	891	N/m
Maximum absolute hydrodynamic force (F_D+F_I), RP100/10 yr (LC 1 operational condition)	1269	N/m
Maximum absolute hydrodynamic force (F_D+F_I), RP10/100 yr (LC 2operational condition)	1264	N/m

Temperatures:

Ambient temperature T_{amb} = 4 deg. C

Project : **N05-A Pipeline Design**
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Originator : EvW
Date : 27/01/2020
Revision : 01
Checked : PF

Table 3 - NEN 3656 load factors

Load factor	**Installation**	**Hydrotest**	**LC 1 Operation**	**LC 2 Operation**	
Self weight & content	1.1	1.1	1.1	1.1	
Coating	1.2	1.2	1.2	1.2	
Marine growth	0	0	1.2	1.2	
Internal pressure	0	1.15	1.15	1.15	
external pressure	1.1	1.1	1.1	1.1	
temperature	1	1.1	1.1	1.1	
environmental load	1.1	1.2	1.2	1.2	
Pipe bundle weight in air	4619.8	4619.8	2891.0	2891.0	N/m; incl. load factors
Submerged bundle weight, Ws	2324.7	2324.7	595.9	595.9	N/m; incl. load factors
Factored load acting on pipe, q	2523	2559	1635	1629	N/m; $q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$
Pressure	2	144	111	111	barg
DT	11	11	46	46	deg. C
Material factor (table 3; D3.1)	1.1	1.1	1.1	1.1	
Allowable stress (table 3; D3.1)	327.3	556.4	556.4	556.4	N/mm^2

STATIC SPAN LENGTH - INSTALLATION

	Unrestrained pipe		Restrained pipe			
	tension	compression	tension	compression		
Hoop stress	1.3	1.3	1.3	1.3	N/mm^2	$\sigma_H = \frac{(\gamma i \cdot Pi - \gamma e \cdot Pe) \cdot (OD - d_{min})}{2 \cdot d_{min}}$
Max. long. Stress	327.9	-326.6	327.9	-326.6	N/mm^2	$\sigma_{max.long.stress} = \frac{\sigma_H \pm \sqrt{-3 \cdot \sigma_H^2 + 4 \cdot \sigma_{allow}^2}}{2}$
Long. hoop stress	0.7	0.7	0.4	0.4	N/mm^2	$\sigma_{long.hoop.stress} = \nu \cdot \sigma_H$
Thermal exp. stress	n/a	n/a	-26.8	-26.8	N/mm^2	$\sigma_{thermal} = -\gamma_t \cdot \alpha \cdot E_s \cdot \Delta T$
Max. allow. bending stress	327.3	327.3	327.3	-300.2	N/mm^2	$\sigma_{b,max} = \sigma_{max.long.stress} - \sigma_{lonh.hoop.stress} - \sigma_{thermal}$
Maximum span	69.3	69.3	69.3	66.3	m	

STATIC SPAN LENGTH - HYDROTEST

	Unrestrained pipe		Restrained pipe		
	tension	compression	tension	compression	
Hoop stress	251.2	251.2	251.2	251.2	N/mm^2
Max. long. Stress	637.7	-386.4	637.7	-386.4	N/mm^2
Long. hoop stress	85.8	85.8	75.4	75.4	N/mm^2
Thermal exp. stress	n/a	n/a	-29.5	-29.5	N/mm^2
Max. allow. bending stress	551.8	-472.3	556.4	-432.3	N/mm^2
Maximum span	89.3	82.6	89.7	79.0	m

STATIC SPAN LENGTH - OPERATION LC1

	Unrestrained pipe		Restrained pipe		
	tension	compression	tension	compression	
Hoop stress	193.3	193.3	193.3	193.3	N/mm^2
Max. long. Stress	627.2	-433.9	627.2	-433.9	N/mm^2
Long. hoop stress	66.2	66.2	58.0	58.0	N/mm^2
Thermal exp. stress	n/a	n/a	-123.3	-123.3	N/mm^2
Max. allow. bending stress	556.4	-500.1	556.4	-368.6	N/mm^2
Maximum span	112.2	106.4	112.2	91.3	m

STATIC SPAN LENGTH - OPERATION LC2

	Unrestrained pipe		Restrained pipe		
	tension	compression	tension	compression	
Hoop stress	193.3	193.3	193.3	193.3	N/mm^2
Max. long. Stress	627.2	-433.9	627.2	-433.9	N/mm^2
Long. hoop stress	66.2	66.2	58.0	58.0	N/mm^2
Thermal exp. stress	n/a	n/a	-123.3	-123.3	N/mm^2
Max. allow. bending stress	556.4	-500.1	556.4	-368.6	N/mm^2
Maximum span	112.4	106.5	112.4	91.5	m

DYNAMIC SPAN ANALYSIS (NEN 3656 - I.5.2.5)

Assessment Stability parameter, Ks < 1.8 => in-line vibration
Stability parameter, Ks < 16 => cross flow vibration

$$K_s = \frac{2m \text{ x } \delta}{\rho_w \text{ x } D_o^2}$$

Where,

d = damping factor water: 0.02 x 2 x π	=	0.126	-
r_w = seawater density	=	1025	kg/m^3
D_o = outer diameter (incl. coating)	=	514	mm
m = effective mass			
m = W_{bundle} + M_{added}			
$M_{added} = \frac{\pi}{4} \cdot C_m \cdot \rho_w \cdot D_{o,eq}^2$			
C_m = added mass coefficient	=	1.2	-
$D_{o,eq}$ = equivalent diameter (incl. coating)	=	514	mm

Due to the presense of 2 objects attached to eachother, velocity flow intensification occurs:

v_{tot} = (v_{wave} + v_{cur}) x (1 + f_{int});

$$f_{int} = \left\{1 + \left(\frac{D_{ob}^2}{4 \cdot CL^2}\right)\right\}$$

Where,
D_{ob} = diameter of obstruction
CL = centerline distance P/L - obstruction

IN-LINE VIV:

Given the stability factor (Ks), the horizontal particle velocity (v), possibly including vicinity factor and the reduced velocity (Vr), the first eigen frequency (f1) can be determined prior to vibration occurring.

Reduced velocity, Vr, based on NEN 3656 I.5.2.5.2

$$V_r = \frac{v}{f_1 \times D_o}$$

if $1{,}0 \leq V_r \leq 3{,}5$ then oscillation occurs => Vr<1,0 design criterium

Vr is set to 1 as conservative value; Vr = 1.0 -

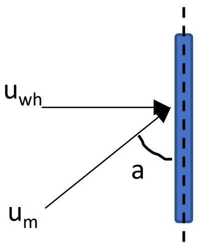
$$f_1 = \frac{a}{2\pi}\sqrt{\frac{E \times I}{m \times L^4}}$$

Where,
a = frequency factor (22 for fixed/fixed; 9.87 for pinned/pinned)
a = 15.4 for fixed/pinned a = 15.4 -

Waves (Hs & Tz):

Significant wave height, RP1 yr - installation/hydrotest	$H_{s,1}$ =	3.9	m
Associated wave period, RP1 yr	$T_{z,1}$ =	6.4	s
Significant wave height, RP10 yr - operational	$H_{s,10}$ =	4.1	m
Associated wave period, RP10 yr	$T_{z,10}$ =	6.5	s
Significant wave height, RP100 yr - operational	$H_{s,100}$ =	4.2	m
Associated wave period, RP100 yr	$T_{z,100}$ =	6.6	s

	1 yr	10 yr	100 yr
$\frac{H}{g \cdot T_{ass}^2}$	0.0097	0.0099	0.0098
$\frac{SWL}{g \cdot T_{ass}^2}$	0.0196	0.0182	0.0169
theory	Wave particle velocity directly from metocean data		
maximum wave particle velocity (u_{wm})	1.30	1.50	1.60
angle of attack relative to P/L axis (a)	90	90	90
horizontal wave velocity⊥ to P/L (u_{wh})	1.30	1.50	1.60



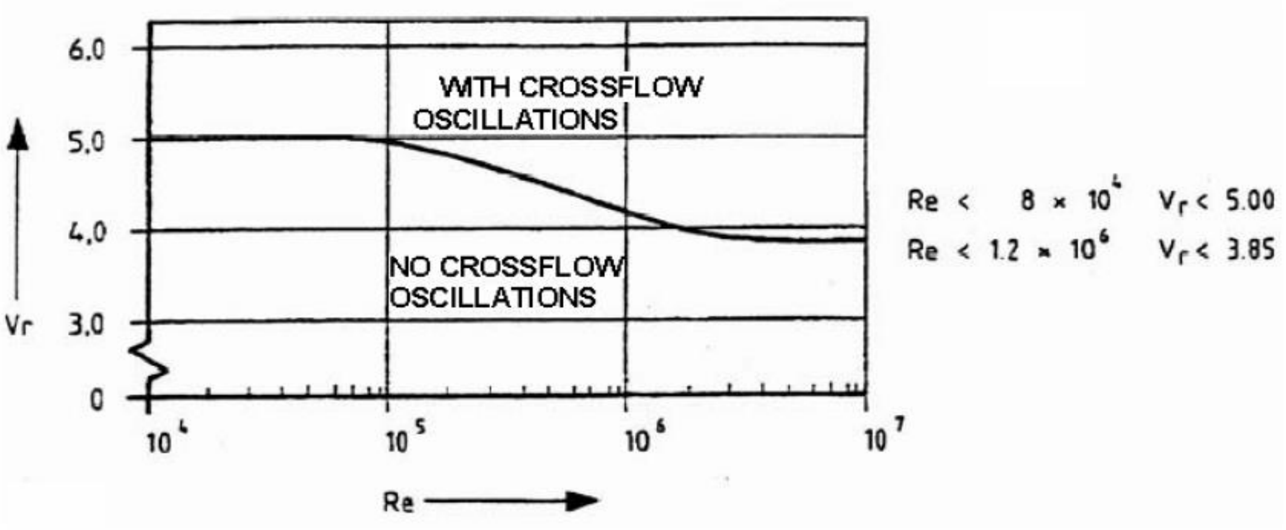
	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
effective mass	682.9	682.9	522.7	522.7	kg/m
K_s	0.63	0.63	0.49	0.49	-
In-line VIV	yes	yes	yes	yes	-
cross flow VIV	yes	yes	yes	yes	-
Vr	1.00	1.00	1.00	1.00	-
u_{wh}	0.71	0.71	0.79	0.89	m/s, set equal to Ucm, for velocity ratio 0.5
$u_{cm,perp}$	0.71	0.71	0.79	0.89	m/s
D_{ob}	0.0	0.0	0.0	0.0	mm
CL	294.0	294.0	294.0	294.0	mm
f_{int}	0.000	0.000	0.000	0.000	-
$(u_{wh} + u_{cm,perp})$ x $(1+0.5{\cdot}f_{int}) = v_{tot}$	1.41	1.41	1.59	1.78	m/s
D_o	0.5140	0.5140	0.5140	0.5140	m
f1	2.75	2.75	3.09	3.46	1/s
$L_{span,in}$	21.9	21.9	22.1	20.9	m

note: f_{int} is taken into account for 50% as system doesn't instantaneously respond and vortices occur in a relatively steady state environment, which this isn't.

CROSS FLOW VIV:
Oscillation area for cross flow is given by the figure below and depends on the Reynolds number (R_e)

$$R_e = \frac{v \cdot D_o}{\nu_d}$$

v = horizontal particle velocity (v_{tot})
D_o = outer diameter (incl. coating) = 514 mm
u_d = dynamic viscosity seawater u_d = 4.99E-07 m^2/s
Vr is set to 3.85 as conservative value; Vr = 3.85 -



	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
u_{wh}	1.30	1.30	1.60	1.50	m/s
$u_{cm,perp}$	0.71	0.71	0.79	0.89	m/s
D_{ob}	0.0	0.0	0.0	0.0	mm
CL	294.0	294.0	294.0	294.0	mm
f_{int}	0.000	0.000	0.000	0.000	-
$(u_{wh} + u_{cm,perp})$ x $(1+0.5{\cdot}f_{int}) = v_{tot}$	2.01	2.01	2.39	2.39	m/s
D_o	0.5140	0.5140	0.5140	0.5140	m
Reynolds nr.	2.07E+06	2.07E+06	2.47E+06	2.46E+06	-
Vr	3.850	3.850	3.850	3.850	-
f1	1.01	1.01	1.21	1.21	1/s
$L_{span,cross}$	36.0	36.0	35.3	35.3	m

SUMMARY - SPAN ANALYSIS

	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
$L_{span,in}$	21.9	21.9	22.1	20.9	m
$L_{span,cross}$	36.0	36.0	35.3	35.3	m

Maximum Span Length = 20.9 m

Project : **N05-A Pipeline Design**
Project # : 19018
Subject : Static & Dynamic Span Analysis
File # : 19018-60-CAL-01004-03-02 - Allowable free span (static & dynamic) calculations - 17m.xlsm

Client : ONE-Dyas
Client File # : 19018-60-CAL-01004-03-02 - Allowable free span (static & dynamic) calculations - 17m.xlsm

Originator : EvW
Checked : PF
Date : 12-3-2020
Revision : 02

Static & Dynamic Span - 20" x 20.62 mm

Condition Overview

	Pressure (barg)	Temp. (deg. C)	Content (kg/m3)
Installation (P_{in}, T_{in})	2	15	1025
Hydrotest (P_t, T_t)	144	15	1025
Design (P_d, T_d)	111	50	88.7

Pipeline properties

Nominal diameter		OD_{nom} =	20"	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Internal diameter	$ID = OD_{nom} - 2 \cdot d_{nom}$	ID =	466.76	mm
Cross sectional area of steel	$A_s = \frac{\pi}{4} \cdot \{OD_{nom}^2 - ID^2\}$	A_s =	31572	mm^2
Section modulus	$W_s = \frac{\pi}{32} \cdot \frac{\{OD_{nom}^4 - ID^4\}}{OD_{nom}}$	W_s =	3697384	mm^3
Moment of Inertia	$I_s = \frac{\pi}{64} \cdot \{OD_{nom}^4 - ID^4\}$	I_s =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm

Piggyback			
Nominal diameter	$OD_{nom,p}$ =	0	mm
Nominal wall thickness	$d_{nom,p}$ =	0.0	mm

Coating and insulation data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Material

	=	L360NB	
Design temperature	T_d =	50	°C
Yield at ambient/hydrotest temperature	R_e =	360.00	N/mm^2
Yield at design temperature	R_{ed} =	360.00	N/mm^2
Density	ρ_{st} =	7850	kg/m3
Youngs modulus	E_s =	210000	N/mm^2
Poisson's ratio	υ =	0.3	-
Linear thermal expansion coefficient	α =	1.16E-05	$m/m/^oC$

Weights

		installation (N/m)	hydrotest (N/m)	operation (N/m)
air	line pipe	2431.3	2431.3	2431.3
	content	1720.6	1720.6	148.9
	coating	43.9	43.9	43.9
	piggyback	0.0	0.0	0.0
	coating pb	0.0	0.0	0.0
buoyancy	line pipe	2086.5	2086.5	2086.5
	piggyback	0.0	0.0	0.0

$$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$$

$$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$$

Static & Dynamic span to be checked for the following environmental load combinations

Condition	Wave velocity	Current velocity	Comment
Installation	$H_{max,1yr}$	1 yr	
Hydrotest	$H_{max,1yr}$	1 yr	
Operational	$H_{max,100yr}$	10 yr	LC1
	$H_{max,10yr}$	100 yr	LC2

Environmental conditions

Water depths:

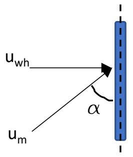
Seawater density		ρ_{sw} =	1025	kg/m³
Maximum water depth		WD_{max} =	20.59	m LAT
Minimum water depth		WD_{min} =	17	m LAT
Other water depth (user input)		WD =	17	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-0.58	m LAT
Storm surge, RP10 yr		ss_{10yr} =	-0.93	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-1.285	m LAT
Storm surge water level, RP1 yr	$SSWL_{1yr} = WD + ss_{1yr}$	$SSWL_{1yr}$ =	16.42	m LAT
Storm surge water level, RP10 yr	$SSWL_{10yr} = WD + ss_{10yr}$	$SSWL_{10yr}$ =	16.07	m LAT
Storm surge water level, RP100 yr	$SSWL_{100yr} = WD + ss_{100yr}$	$SSWL_{100yr}$ =	15.715	m LAT
Highest Astronomical Tide		HAT =	3.11	m

Waves (H_{max} & T_{max}):

Maximum wave height, RP1 yr - installation/hydrotest	$H_{max,1}$ =	8.3	m
Associated maximum wave period, RP1 yr	$T_{ass,1}$ =	8.9	s
Maximum wave height, RP10 yr - operational	$H_{max,10}$ =	10.1	m
Associated maximum wave period, RP10 yr	$T_{ass,10}$ =	9.4	s
Maximum wave height, RP100 yr - operational	$H_{max,100}$ =	11.55	m
Associated maximum wave period, RP100 yr	$T_{ass,100}$ =	9.8	s

Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

	1 yr	10 yr	100 yr
$\frac{H}{g \cdot T_{ass}^2}$	0.0107	0.0117	0.0123
$\frac{SWL}{g \cdot T_{ass}^2}$	0.0211	0.0185	0.0167
theory	interpolation between data of 8 and 26m water depth		
maximum wave particle velocity (u_{wm})	1.85	2.38	2.80
angle of attack relative to P/L axis (α)	90	90	90
horizontal wave velocity⊥ to P/L (u_{wh})	1.85	2.38	2.80



Current:

Height above seabed at which velocity is known	z* =	1	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.82	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	0.92	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	1.04	m/s

Current velocity at reference height: $U_{czr} = u_{st} + u_{ss}$

$U_{czr,1}$ = 0.82 m/s
$U_{czr,10}$ = 0.92 m/s
$U_{czr,100}$ = 1.04 m/s

Angle of attack relative to pipeline axis α_{uc} = 90 deg

Horizontal current velocity ⊥to P/L:

$$u_{cm,perp} = \frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r} \right)^{1/7} \cdot \sin(\alpha_{uc})$$

$u_{cm,perp,1}$ = 0.647 m/s
$u_{cm,perp,10}$ = 0.731 m/s
$u_{cm,perp,100}$ = 0.826 m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-

Hydrodunamic forces:

Maximum absolute hydrodynamic force (F_D+F_I), RP1 yr (installation/hydrotest condition)	1392	N/m
Maximum absolute hydrodynamic force (F_D+F_I), RP100/10 yr (LC 1 operational condition)	2976	N/m
Maximum absolute hydrodynamic force (F_D+F_I), RP10/100 yr (LC 2operational condition)	2360	N/m

Temperatures:

Ambient temperature T_{amb} = 4 deg. C

Table 3 - NEN 3656 load factors

Load factor	**Installation**	**Hydrotest**	**LC 1 Operation**	**LC 2 Operation**	
Self weight & content	1.1	1.1	1.1	1.1	
Coating	1.2	1.2	1.2	1.2	
Marine growth	0	0	1.2	1.2	
Internal pressure	0	1.15	1.15	1.15	
external pressure	1.1	1.1	1.1	1.1	
temperature	1	1.1	1.1	1.1	
environmental load	1.1	1.2	1.2	1.2	
Pipe bundle weight in air	4619.8	4619.8	2891.0	2891.0	N/m; incl. load factors
Submerged bundle weight, Ws	2324.7	2324.7	595.9	595.9	N/m; incl. load factors
Factored load acting on pipe, q	2784	2863	3621	2894	N/m; $q = \sqrt{{\gamma_W}^2 \cdot {W_S}^2 + {\gamma_H}^2 \cdot (F_D + F_I)^2}$
Pressure	2	144	111	111	barg
ΔT	11	11	46	46	deg. C
Material factor (table 3; D3.1)	1.1	1.1	1.1	1.1	
Allowable stress (table 3; D3.1)	327.3	556.4	556.4	556.4	N/mm^2

STATIC SPAN LENGTH - INSTALLATION

	Unrestrained pipe		Restrained pipe			
	tension	compression	tension	compression		
Hoop stress	2.9	2.9	2.9	2.9	N/mm^2	$\sigma_H = \frac{(\gamma i \cdot Pi - \gamma e \cdot Pe) \cdot (OD - d_{min})}{2 \cdot d_{min}}$
Max. long. Stress	328.7	-325.8	328.7	-325.8	N/mm^2	$\sigma_{max.long.stress} = \frac{\sigma_H \pm \sqrt{-3 \cdot \sigma_H^2 + 4 \cdot \sigma_{allow}^2}}{2}$
Long. hoop stress	1.2	1.2	0.9	0.9	N/mm^2	$\sigma_{long.hoop.stress} = \nu \cdot \sigma_H$
Thermal exp. stress	n/a	n/a	-26.8	-26.8	N/mm^2	$\sigma_{thermal} = -\gamma_t \cdot \alpha \cdot E_s \cdot \Delta T$
Max. allow. bending stress	327.3	-327.1	327.3	-299.9	N/mm^2	$\sigma_{b,max} = \sigma_{max.long.stress} - \sigma_{lonh.hoop.stress} - \sigma_{thermal}$
Maximum span	65.9	65.9	65.9	63.1	m	

STATIC SPAN LENGTH - HYDROTEST

	Unrestrained pipe		Restrained pipe		
	tension	compression	tension	compression	
Hoop stress	249.7	249.7	249.7	249.7	N/mm^2
Max. long. Stress	637.5	-387.8	637.5	-387.8	N/mm^2
Long. hoop stress	85.8	85.8	74.9	74.9	N/mm^2
Thermal exp. stress	n/a	n/a	-29.5	-29.5	N/mm^2
Max. allow. bending stress	551.6	-473.6	556.4	-433.2	N/mm^2
Maximum span	84.4	78.2	84.8	74.8	m

STATIC SPAN LENGTH - OPERATION LC1

	Unrestrained pipe		Restrained pipe		
	tension	compression	tension	compression	
Hoop stress	191.8	191.8	191.8	191.8	N/mm^2
Max. long. Stress	626.9	-435.1	626.9	-435.1	N/mm^2
Long. hoop stress	66.2	66.2	57.6	57.6	N/mm^2
Thermal exp. stress	n/a	n/a	-123.3	-123.3	N/mm^2
Max. allow. bending stress	556.4	-501.2	556.4	-369.4	N/mm^2
Maximum span	75.4	71.5	75.4	61.4	m

Originator : EvW
Checked : PF
Date : 12-3-2020
Revision : 02

STATIC SPAN LENGTH - OPERATION LC2

	Unrestrained pipe		Restrained pipe		
	tension	compression	tension	compression	
Hoop stress	191.8	191.8	191.8	191.8	N/mm^2
Max. long. Stress	626.9	-435.1	626.9	-435.1	N/mm^2
Long. hoop stress	66.2	66.2	57.6	57.6	N/mm^2
Thermal exp. stress	n/a	n/a	-123.3	-123.3	N/mm^2
Max. allow. bending stress	556.4	-501.2	556.4	-369.4	N/mm^2
Maximum span	84.3	80.0	84.3	68.7	m

DYNAMIC SPAN ANALYSIS (NEN 3656 - I.5.2.5)

Assessment Stability parameter, Ks < 1.8 => in-line vibration
Stability parameter, Ks < 16 => cross flow vibration

$$K_s = \frac{2m \text{ x } \delta}{\rho_w \text{ x } D_o^2}$$

Where,

δ = damping factor water: 0.02 x 2 x π = 0.126 -
ρ_w = seawater density = 1025 kg/m³
D_o = outer diameter (incl. coating) = 514 mm
m = effective mass
m = W_{bundle} + M_{added}

$$M_{added} = \frac{\pi}{4} \cdot C_m \cdot \rho_w \cdot D_{o,eq}^2$$

C_m = added mass coefficient = 1.2 -
$D_{o,eq}$ = equivalent diameter (incl. coating) = 514 mm

Due to the presense of 2 objects attached to eachother, velocity flow intensification occurs:

v_{tot} = (v_{wave} + v_{cur}) x (1 + f_{int});

$$f_{int} = \left\{1 + \left(\frac{D_{ob}^2}{4 \cdot CL^2}\right)\right\}$$

Where,
D_{ob} = diameter of obstruction
CL = centerline distance P/L - obstruction

IN-LINE VIV:

Given the stability factor (Ks), the horizontal particle velocity (v), possibly including vicinity factor and the reduced velocity (Vr), the first eigen frequency (f1) can be determined prior to vibration occurring.

Reduced velocity, Vr, based on NEN 3656 I.5.2.5.2

$$V_r = \frac{v}{f_1 \times D_o}$$

if $1{,}0 \leq V_r \leq 3{,}5$ then oscillation occurs => Vr<1,0 design criterium

Vr is set to 1 as conservative value; Vr = 1.0 -

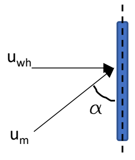
$$f_1 = \frac{a}{2\pi}\sqrt{\frac{E \times I}{m \times L^4}}$$

Where,
a = frequency factor (22 for fixed/fixed; 9.87 for pinned/pinned)
a = 15.4 for fixed/pinned a = 15.4 -

Waves (Hs & Tz):

Significant wave height, RP1 yr - installation/hydrotest	$H_{s,1}$ =	5.2	m
Associated wave period, RP1 yr	$T_{z,1}$ =	8.2	s
Significant wave height, RP10 yr - operational	$H_{s,10}$ =	6.25	m
Associated wave period, RP10 yr	$T_{z,10}$ =	8.9	s
Significant wave height, RP100 yr - operational	$H_{s,100}$ =	7.05	m
Associated wave period, RP100 yr	$T_{z,100}$ =	9.45	s

	1 yr	10 yr	100 yr
$\frac{H}{g \cdot T_{ass}^2}$	0.0080	0.0080	0.0080
$\frac{SWL}{g \cdot T_{ass}^2}$	0.0252	0.0207	0.0179
theory	interpolation between data of 8 and 26m water depth		
maximum wave particle velocity (u_{wm})	1.33	1.76	2.08
angle of attack relative to P/L axis (α)	90	90	90
horizontal wave velocity⊥ to P/L (u_{wh})	1.33	1.76	2.08



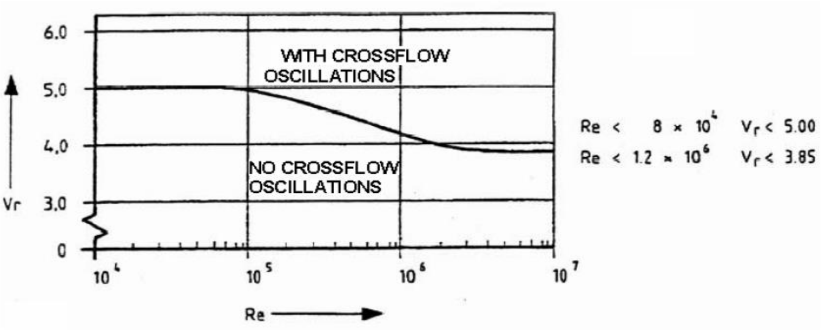
	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
effective mass	682.9	682.9	522.7	522.7	kg/m
K_s	0.63	0.63	0.49	0.49	-
In-line VIV	yes	yes	yes	yes	-
cross flow VIV	yes	yes	yes	yes	-
Vr	1.00	1.00	1.00	1.00	-
u_{wh}	0.65	0.65	0.73	0.83	m/s, set equal to Ucm, for velocity ratio 0.5
$u_{cm,perp}$	0.65	0.65	0.73	0.83	m/s
D_{ob}	0.0	0.0	0.0	0.0	mm
CL	294.0	294.0	294.0	294.0	mm
f_{int}	0.000	0.000	0.000	0.000	-
$(u_{wh} + u_{cm,perp}) \times (1+0.5 \cdot f_{int}) = v_{tot}$	1.29	1.29	1.46	1.65	m/s
D_o	0.5140	0.5140	0.5140	0.5140	m
f1	2.52	2.52	2.84	3.21	1/s
$L_{span,in}$	22.9	22.9	23.0	21.6	m

note: f_{int} is taken into account for 50% as system doesn't instantaneously respond and vortices occur in a relatively steady state environment, which this isn't.

CROSS FLOW VIV:
Oscillation area for cross flow is given by the figure below and depends on the Reynolds number (R_e)

$$R_e = \frac{v \cdot D_o}{v_d}$$

v = horizontal particle velocity (v_{tot})
D_o = outer diameter (incl. coating) = 514 mm
v_d = dynamic viscosity seawater v_d = 4.99E-07 m^2/s
Vr is set to 3.85 as conservative value; Vr = 3.85 -



	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
u_{wh}	1.33	1.33	2.08	1.76	m/s
$u_{cm,perp}$	0.65	0.65	0.73	0.83	m/s
D_{ob}	0.0	0.0	0.0	0.0	mm
CL	294.0	294.0	294.0	294.0	mm
f_{int}	0.000	0.000	0.000	0.000	-
$(u_{wh} + u_{cm,perp}) \times (1+0.5 \cdot f_{int}) = v_{tot}$	1.97	1.97	2.81	2.58	m/s
D_o	0.5140	0.5140	0.5140	0.5140	m
Reynolds nr.	2.03E+06	2.03E+06	2.90E+06	2.66E+06	-
Vr	3.850	3.850	3.850	3.850	-
f1	1.00	1.00	1.42	1.30	1/s
$L_{span,cross}$	36.4	36.4	32.6	34.0	m

SUMMARY - SPAN ANALYSIS

	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
$L_{span,in}$	22.9	22.9	23.0	21.6	m
$L_{span,cross}$	36.4	36.4	32.6	34.0	m

Maximum Span Length = 21.6 m

D. Analytical Upheaval Buckling Analysis

The following documents are included:

- 19018-60-CAL-01005-01-01 Upheaval Buckling Analysis – 43 deg

(4 pages)

Client : ONE-Dyas
Project : N05A Flowline
Project No. : 19018
Subject : Pipeline Upheaval Buckling - analytical
Doc. No. : 19018-60-CAL-01005-01
Client Doc. No. : -

Calc'd by : EvW
Checked :
Rev. : 01
Date : 24-1-2020

Upheaval buckling calculation

Pipe data

Outside pipe diameter		OD_s =	508	mm
Pipe wall thickness		t_s =	20.62	mm
Internal pipe diameter	$= OD\_s - 2 \cdot t\_s$	ID_s =	466.76	mm

Steel data

Material			L360NB	
Density steel		ρ_s =	7850	kg/m^3
Young's modulus		E_s =	206000	N/mm^2
Poisson's ratio		ν =	0.3	-
Thermal expansion coefficient		α =	1.17E-05	m/m/°C
Steel area	$= \frac{1}{4} \cdot \pi \cdot \left(OD^2\_s - ID^2\_s\right)$	A_s =	31572.3	mm^2
Internal pipe area	$= \frac{1}{4} \cdot \pi \cdot ID^2\_s$	A_i =	1.71E+05	mm^2
Moment of inertia	$= \frac{\pi}{64} \cdot \left(OD^4\_s - ID^4\_s\right)$	I_s =	9.39E+08	mm^4
Pipe weight in air		W_{pe} =	247.8	kg/m
Sea water density		r_{sw} =	1025	kg/m^3
Pipeline contents density		r_{cont} =	88.7	kg/m^3

Internal lining

Thickness		t_l =	0	mm
Density		r_l =	0	kg/m^3
Lining weight		W_l =	0.0	kg/m

Coating data

Outer coating layer 1

Thickness		t_{c1} =	3	mm
Density		ρ_{c1} =	930	kg/m^3
Layer 1 weight	$W_{l1} = \pi/4 \cdot \left\{(OD + 2 \cdot t_{c1})^2 - OD^2\right\} \cdot \rho_{c1}$	W_{l1} =	4.5	kg/m

Weight piggy back line

Piggy back weight		W_{l2} =	0.0	kg/m

Concrete coating

Thickness		t_{con} =	0	mm
Density		ρ_{con} =	0	kg/m^3
Concrete weight	$W_{con} = \pi/4 \cdot \left\{(OD + 2 \cdot t_{c1} + 2 \cdot t_{c2} + 2 \cdot t_{con})^2 - (OD + 2 \cdot t_{c1} + 2 \cdot t_{c2})^2\right\} \cdot \rho_{con}$	W_{con} =	0.0	kg/m

Client : ONE-Dyas
Project : N05A Flowline
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Calc'd by : EvW
Checked :

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Marine growth

Thickness		t_{mg} =	0	mm
Density		ρ_{mg} =	0	kg/m^3
Marine growth weight	$W_{mg} = \pi/4 \cdot \{(OD+2\cdot t_{c1}+2\cdot t_{c2}+2\cdot t_{con}+2\cdot t_{mg})^2-(OD+2\cdot t_{c1}+2\cdot t_{c2}+2\cdot t_{con})^2\}\cdot \rho_{mg}$	W_{mg} =	0.0	kg/m

Weight data

Total outside diameter	$ODtot = OD+2\cdot t\cdot +2\cdot t_{c2}+2\cdot t_{con}+2\cdot t_{mg}$	OD_{tot} =	514.0	mm
Contents weight	$W_{cont} = \pi/4\cdot(ID-2\cdot t_l)^2\cdot \rho_{cont}$	W_{cont} =	15.2	kg/m
Pipeline weight in air	$w_r = w_{pe}+w_l+w_{l1}+w_{l2}+w_{con}+w_{mg}+w_{cont}$	W_r =	267.5	kg/m
Buoyancy force, F_B	$F_B = \pi/4 \cdot OD_{tot}^2 \cdot \rho_w$	F_B =	212.7	kg/m
Submerged pipeline weight, W_{sm}	$W_{sm} = W_r - F_B$	W_{sm} =	54.8	kg/m

Soil data

Submerged soil cover density		γ' =	850	kg/m^3
Angle of internal friction		ϕ_{soil} =	28	deg.
Potyondy coeff. Soil		p_{soil} =	0.6	-
Height soil cover from top of pipe		Htop =	0.8	m
Height soil cover from center of pipe		H	1.06	
Soil uplift coefficient		f_{soil} =	0.1	-

(0.5 for dense materials and 0.1 for loose materials)

Soil weight on top of pipe	$q = \gamma' \cdot H \cdot OD_{tot} \cdot (1+f\cdot H/OD_{tot})$	q =	5461.9	N/m
Imperfection height		δ =	600	mm

Pressure data

Design pressure		P_d =	111	barg
Maximum operating pressure		P_i =	95	barg
Minimum external pressure		P_e =	1.01	barg

Temperature data

Seawater temperature, T_{sea}		T_{sea} =	3	°C
Temperature of gas, T_{gas}		T_{gas} =	43	°C

Pipeline forces

Compressive temperature force, F_T	$F_T = E\cdot A\cdot \alpha\cdot(T_{gas}-T_{sea})$	F_T =	3043822.4	N
Tensile Poisson force, F_P	$F_P = A_i \cdot \nu \cdot \frac{\{P_D - P_e\}\cdot OD_s}{2\cdot t}$	F_P =	1283345.0	N
Compressive member end force, F_e	$F_e = \{P_D - P_e\}\cdot \pi/4 \cdot ID_s^2$	F_e =	1882123.1	N
Is area under considerations within anchor zone (y/n) ?		=	n	

(y: F_T can be neglected)

Effective compressive axial force, F_{eff}	$F_{eff} = F_T - F_P + F_e$	F_{eff} =	3642600.5	N

Client : ONE-Dyas
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Client Doc. No. : -

Calc'd by : EvW
Checked :
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Date : 24-1-2020

Required down load

The required download depends on:

- dimensionless maximum download parameter, F_W
- dimensionless imperfection length parameter, F_L

$$\Phi_w = \frac{w \cdot EI}{\delta \cdot F_{eff}^2} \quad \text{and} \quad \Phi_L = L \cdot \sqrt{\frac{F_{eff}}{EI}}$$

where,

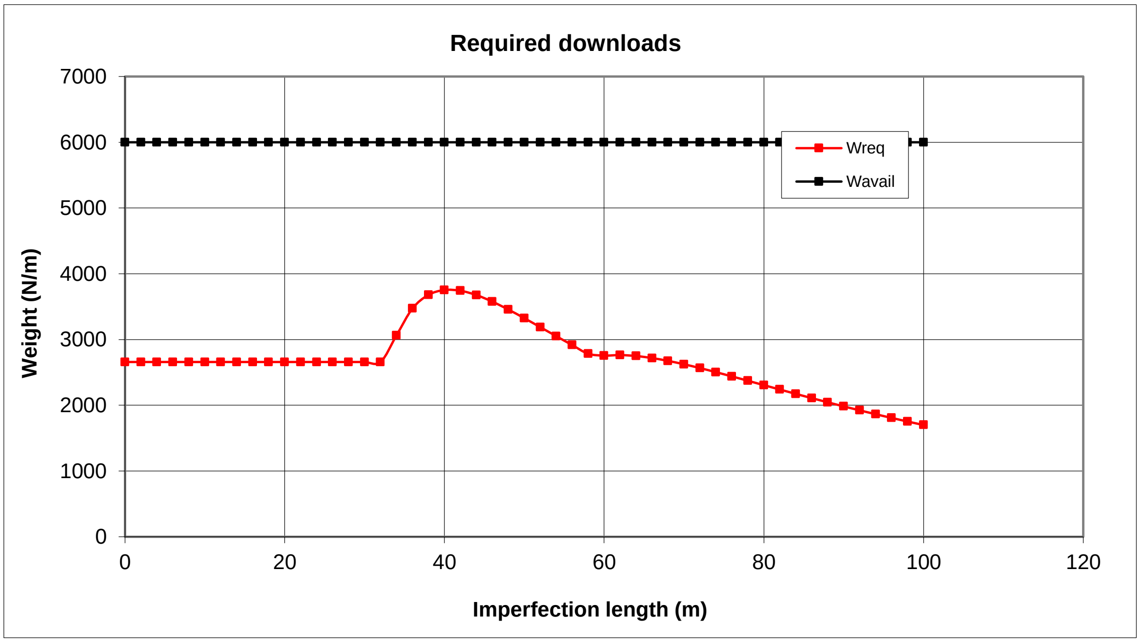
F_W = dimensionless maximum download parameter
w = required download (N/mm)
F_{eff} = effective axial force (N)
EI = bending stiffness pipeline (N/mm^2)
d = imperfection height (mm)
F_L = dimensionless imperferction length parameter
L = imperfection / exposure length (mm)

Requirements:

$$\begin{aligned} &\Phi_L \le 4.49 && \Phi_W = 0.0646 \\ &4.49 < \Phi_L \le 8.06 && \Phi_W = 5.68/\Phi_L^2 - 88.35/\Phi_L^4 \\ &\Phi_L > 8.06 && \Phi_W = 9.6/\Phi_L^2 - 343/\Phi_L^4 \end{aligned}$$

L [m]	F_L	F_w	W_{req} [N/m]	W_{avail} [N/m]
0	0.000	0.0646	2658.345	6000
2	0.274	0.0646	2658.345	6000
4	0.549	0.0646	2658.345	6000
6	0.823	0.0646	2658.345	6000
8	1.098	0.0646	2658.345	6000
10	1.372	0.0646	2658.345	6000
12	1.647	0.0646	2658.345	6000
14	1.921	0.0646	2658.345	6000
16	2.195	0.0646	2658.345	6000
18	2.470	0.0646	2658.345	6000
20	2.744	0.0646	2658.345	6000
22	3.019	0.0646	2658.345	6000
24	3.293	0.0646	2658.345	6000
26	3.568	0.0646	2658.345	6000
28	3.842	0.0646	2658.345	6000
30	4.117	0.0646	2658.345	6000
32	4.391	0.0646	2658.345	6000
34	4.665	0.0745	3064.458	6000
36	4.940	0.0844	3472.879	6000
38	5.214	0.0894	3678.596	6000
40	5.489	0.0912	3752.716	6000
42	5.763	0.0909	3741.640	6000
44	6.038	0.0893	3676.014	6000
46	6.312	0.0869	3576.265	6000
48	6.586	0.0840	3456.096	6000
50	6.861	0.0808	3324.726	6000
52	7.135	0.0775	3188.350	6000
54	7.410	0.0741	3051.110	6000

56	7.684	0.0709	2915.740	6000
58	7.959	0.0677	2784.008	6000
60	8.233	0.0670	2756.057	6000
62	8.507	0.0672	2763.740	6000
64	8.782	0.0668	2749.280	6000
66	9.056	0.0661	2718.373	6000
68	9.331	0.0650	2675.386	6000
70	9.605	0.0638	2623.669	6000
72	9.880	0.0624	2565.802	6000
74	10.154	0.0608	2503.772	6000
76	10.428	0.0593	2439.109	6000
78	10.703	0.0577	2372.987	6000
80	10.977	0.0560	2306.308	6000
82	11.252	0.0544	2239.758	6000
84	11.526	0.0528	2173.858	6000
86	11.801	0.0513	2108.996	6000
88	12.075	0.0497	2045.461	6000
90	12.350	0.0482	1983.458	6000
92	12.624	0.0467	1923.133	6000
94	12.898	0.0453	1864.581	6000
96	13.173	0.0439	1807.859	6000
98	13.447	0.0426	1752.995	6000
100	13.722	0.0413	1699.993	6000



N05-A Pipeline & Spoolpiece – Basic Design

Basis of Design Pipeline & Tie-in Spools

DOCUMENT NUMBER:

N05A-7-10-0-70028-01

Rev.	Date	Description	Originator	Checker	Approver
01	15-01-2020	Issued for Comments	HvH	PF	PF
02	17-03-2020	Issued for Approval	PF	EvW	PF

Client

ONE-Dyas B.V.

Project

ONE-Dyas N05A Pipeline & Spool piece – Basic Design

Document

Basis of Design Pipeline & Tie-in Spools

Project number	19018
Document number	N05A-7-10-0-70028-01
Revision	02
Date	17.03.2020

Revision History

Revision	Description
01	Initial Issue – For Client comments
02	Client comments incorporated

Revision Status

Revision	Description	Issue date	Prepared	Checked	Enersea approval	Client approval
01	For Client Comments	15-01-2020	HvH	PF	PF	
02	For Client Approval	17-03-2020	PF	EvW	PF	

Table of content

1. Project Introduction

1.1. Project Introduction

One-Dyas plans to develop a successfully drilled well in block N05-A of the North Sea Dutch Continental Shelf. More wells will be drilled at this location through the same jacket. It is planned to develop the wells by installing a platform and a gas export pipeline with a connection to the NGT pipeline @KP142.1. The approximate length of the pipeline is 14.7 km.

In addition, a power cable will be installed from the Riffgat Windpark to the N05-A platform.

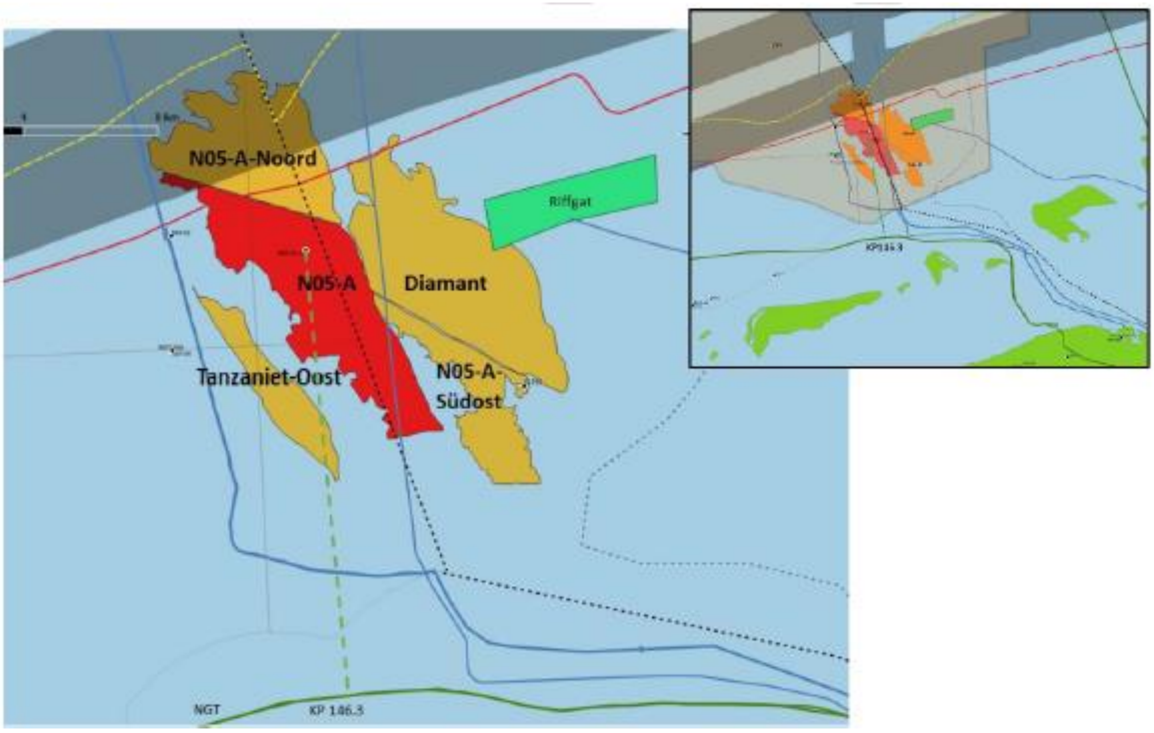


Figure 1: N05-A Field layout

1.2. Purpose Document

The Basis of Design defines the methodology and design data to be used throughout the flowline design from the new N05A platform to the connection to the NGT pipeline @KP142.1. This document is to be read in conjunction with documents as listed below in order of precedence.

Number	Title
N05A-7-10-0-70026-01-01	N05-A Pipeline Design – Basis of Design Flow Assurance

The following engineering items are described in subsequent sections of this Basis of Design report:

- Regulations, Guidelines and Specifications
- Pipeline Routing
- Seabed Geology
- Materials and Corrosion Protection
- Operational and Product Data
- Environmental Data
- Design Philosophy & Criteria

1.3. System of Units

All dimensions and calculations shall be documented using the International System of Units (SI) unless noted otherwise.

1.4. Abbreviations

BoD	Basis of Design
CWC	Concrete Weight Coating
FEA	Finite Element Analysis
LAT	Lowest Astronomical Tide
MTO	Material Take Off
PUF	Poly Urethane Foam
TB	Target Box
TOP	Top of Pipe
VIV	Vortex Induced Vibrations

2. Regulations, Guidelines and Specifications

The references, codes, regulations, guidelines and specifications used throughout the project are outlined in the following sections.

2.1. Regulations, Codes, Standards and Guidelines

[1]	NEN3656:2015 “Eisen voor stalen buisleidingsystemen op zee” December 2015
[2]	DNV-OS-F101. “Submarine Pipeline Systems.” October 2013.
[3]	DNV-RP-F105. “Free Spanning Pipelines.” June 2017.
[4]	DNV RP-F107. “Risk Assessment of Pipeline Protection.” May 2017.
[5]	DNV-RP-F109. “On-Bottom Stability Design of Submarine Pipelines.” May 2017.
[6]	DNV-RP-F110. “Global Buckling of Submarine Pipelines. Structural Design due to High Temperature/High Pressure.” April 2018.
[7]	DNV-RP-C203. “Fatigue Design of Offshore Steel Structures.” April 2016.
[8]	-
[9]	DNV-RP-F114. “Pipe-soil interaction for submarine pipelines.” May 2017.
[10]	21. American Lifelines Alliance. “Guidelines for the Design of Buried Steel Pipe. ASCE July 2001.
[11]	ASME Boiler and Pressure Vessel Code. Section VIII Rules for Construction of Pressure vessels. Division 1. July 2013.
[12]	Design of Submarine Pipelines Against Upheaval Buckling OTC 6335 by A.C. Palmer e.a. May 1990
[13]	ISO 15589-2. “Petroleum petrochemical and natural gas industries — Cathodic protection of pipeline transportation systems - Part 2: Offshore pipelines” 2nd edition - 2012
[14]	NEN-EN 1993-1-8 – Design of Steel Structures
[15]	NEN-EN-ISO 19902 – Fixed Steel Offshore Structures
[16]	ASME N16.9-2001 – Factory made wrought buttwelding fittings

2.2. Project Reference Documents

[I]	N5-1-10-0-10000-01, Statement of Requirements for Platform N05-A
[II]	Metocean Criteria for the N05A Platform – 181892_1_R2
[III]	Metocean Criteria for the N05A Platform Side Tap - 191146_1_R2
[IV]	Pipeline Bathymetry: LU0022H-553_DR-007_PR_1-4_v1.0 / 2-4 / 3-4 / 4-4
[V]	N05A-7-10-0-70018-01, N5A-Development-Pipeline Route and Platform Area Survey R1
[VI]	N05A-7-10-0-70020-01, Environmental Baseline Survey Report 1.0
[VII]	N05A-7-10-0-70027-01-03 Flow Assurance Design Report
[VIII]	N05A-7-10-0-70036-01-01 Flow Assurance Design Report -transient analysis
[IX]	N05A-7-10-0-70031-01-01 Route Selection Report
[X]	LU0022H-553-RR-03-2.1 N5a Lab Test Results Report
[XI]	N5A VC-C-7 S-3 0300m CID
[XII]	N5A VC-P-3 S-2 0405m CID
[XIII]	N5A VC-P-8 S-4 0240m CID

3. Design Parameters

This chapter describes the design data to be considered for the pipeline (incl. spool pieces near the riser and the hot tap) from the new N05A-Platform to the NGT pipeline.

3.1. Pipe Data

The basic line pipe design and spool piece data to be considered in the analysis for the export gas line are presented in Table 3-1. Steel material properties considered in the design are presented in Table 3-2.

Property	
Product transported	Natural gas (dry)
Design life (years)	25
Approx. length (km)	14.7
Material grade	L360 NB
Manufacturing process	HFIW
Pipe outside diameter (“)	20”
Pipe outside diameter (mm)	508
Pipe internal diameter	466.76
Wall thickness (mm)	20.62 (Sch60)
Wall thickness tolerance (%)	7.3
Wall thickness tolerance (mm)	+/- 1.5mm
Internal corrosion allowance (mm)	3
Anti-corrosion coating	3LPP
Anti-corrosion coating thickness (mm)	3
Anti-corrosion coating density (kg/m^3)	930
(Concrete) weight coating thickness (mm)	t.b.d
concrete weight coating density (kg/m^3)	3300
Minimum hot bend radius (mm)	2540 (5D)

Table 3-1 Pipeline data

Property	
Material	L360NB
Density (kg/m3)	7850 kg/m^3
Specified Minimum Yield Strength at 20°C (MPa)	360
Specified Minimum Yield Strength at 50°C (MPa)	360
Specified Minimum Tensile Strength (MPa)	460
Young’s modulus (Pa)	2.07 x 10^{11}
Poisson ratio (-)	0.3
Thermal expansion coefficient (m/m·ºC)	1.17 x 10^{-5}

Table 3-2 Material properties

3.2. Process conditions

Table 3-3 presents the pipeline and spool design process parameters considered in the analysis.

Property	Export gas line
Design pressure	111.1 bar(g)
Operating pressures	95 bar(g)
Design temperature (min / max)	-20 °C / 50 °C
Operating temperature (min / max)	1 / 43 °C
Ambient (air / surface) temperature	-6.8°C / +24.2 °C
Content density (arrival, nominal operation)	88.7 / 96.1 kg/m^3
Design flowrate (min/max)	0.14 / 6.0 MMNm3/d

Table 3-3 Process design parameters

Figure 3-1 shows the operational thermal profile along the pipeline, ref. [vii] .

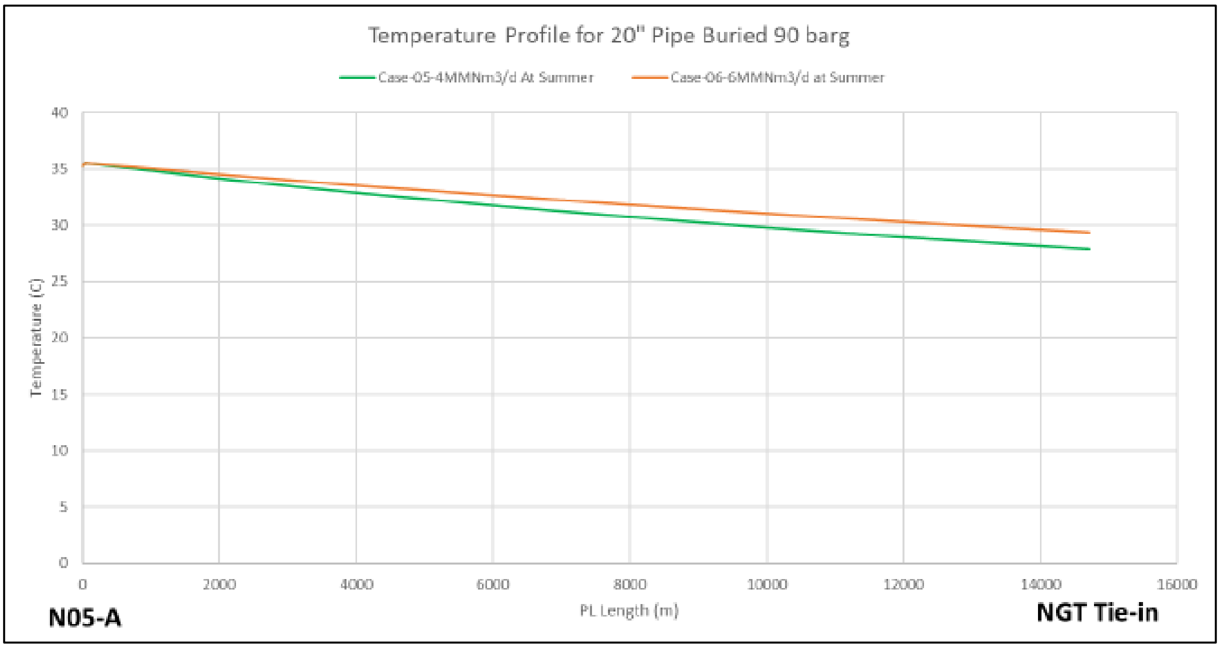


Figure 3-1 Operational thermal profile, nominal operation in summer

3.3. Coating Material Properties

Typical material properties of the coating are given in Table 3-4.

Property	Value
Anti-corrosion material type	3LPP
Anti-corrosion coating density	930 kg/m³
Anti-corrosion coating thermal conductivity	0.22 W/m°C
Anti-corrosion coating specific heat capacity	2000 J/kg°C

Table 3-4 Steel pipe coating material properties

3.4. Flange Properties

Table 3-5 presents the flange classes and main characteristics. The flange loads will be checked by using the ASME BPVC [10] flange integrity check. Note that table 3-5 is applicable to all flanges on the flowline and spool pieces.

Property	Export gas line
Flange rating	ANSI/ASME Class 1500
Flange type	RTJ Swivel / Weld Neck
Weld end thickness	20.62mm

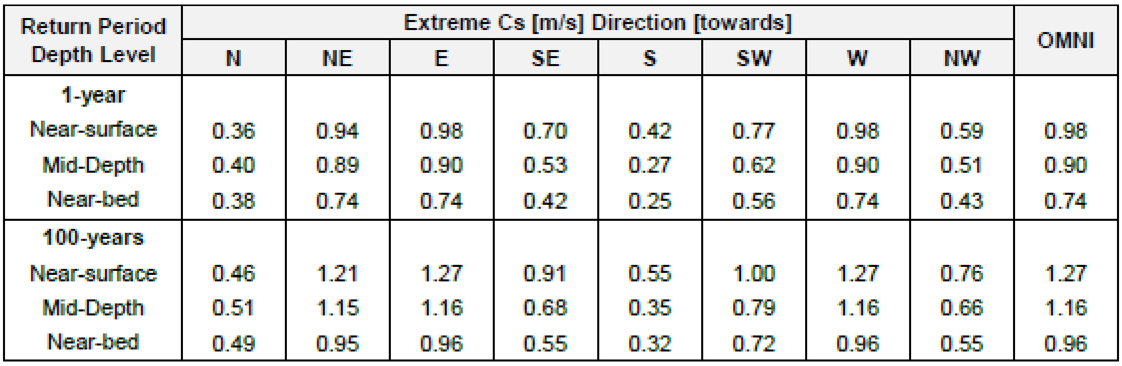
Table 3-5 Flange properties

3.5. Environmental data

For the design of the pipeline, environmental data has been taken from Ref. [II] and [III]. Where Ref [II] contains the metocean data for the platform (water depth 26 m); Ref [III] contains the Metocean data for the NGT tie-in (water depth 8 m) target box. Tables 3-6 to 3-11 present the relevant metocean data for the 1 and 100 year design conditions for the applicable locations.

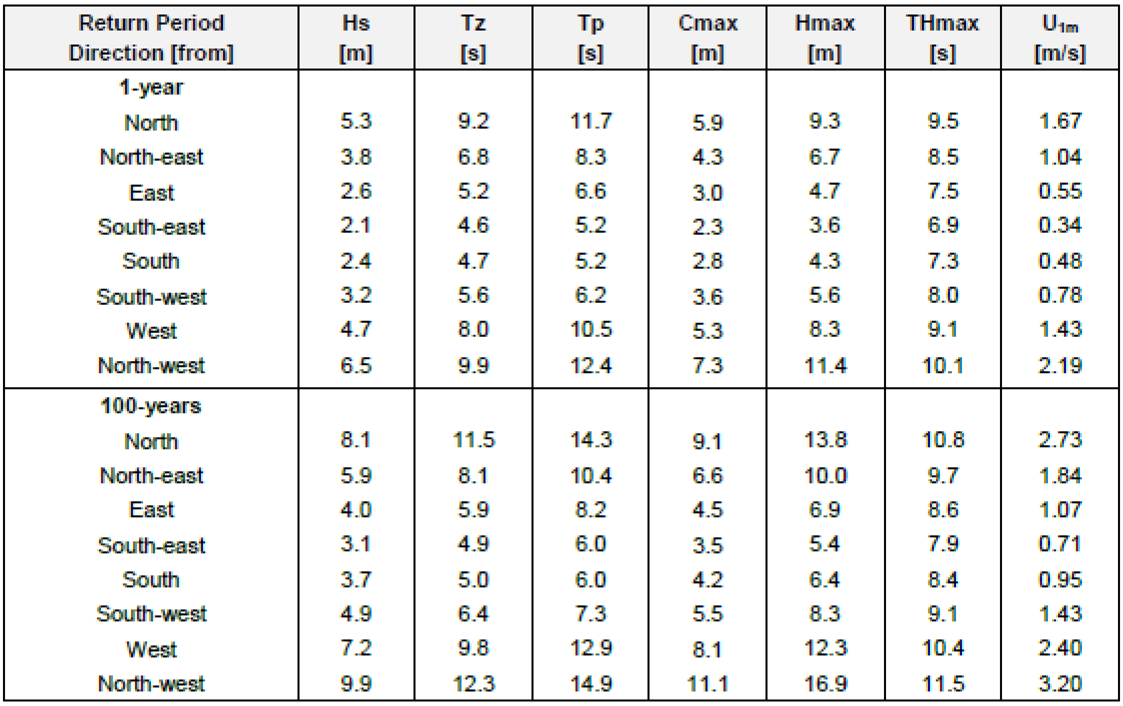
Property	1-year return period	100-year return period
Positive surge (m) @26m	1.58	3.04
Negative surge (m)	-1.02	-1.79
LAT with respect to MSL (m)	-1.41	
HAT with respect to MSL (m)	1.31	

Table 3-6 Near platform extreme water level data [ref. II]



Return Period Depth Level	Extreme Cs [m/s] Direction [towards]								OMNI
	N	NE	E	SE	S	SW	W	NW	
1-year									
Near-surface	0.36	0.94	0.98	0.70	0.42	0.77	0.98	0.59	0.98
Mid-Depth	0.40	0.89	0.90	0.53	0.27	0.62	0.90	0.51	0.90
Near-bed	0.38	0.74	0.74	0.42	0.25	0.56	0.74	0.43	0.74
100-years									
Near-surface	0.46	1.21	1.27	0.91	0.55	1.00	1.27	0.76	1.27
Mid-Depth	0.51	1.15	1.16	0.68	0.35	0.79	1.16	0.66	1.16
Near-bed	0.49	0.95	0.96	0.55	0.32	0.72	0.96	0.55	0.96

Table 3-7- Near platform design current data [ref. II]

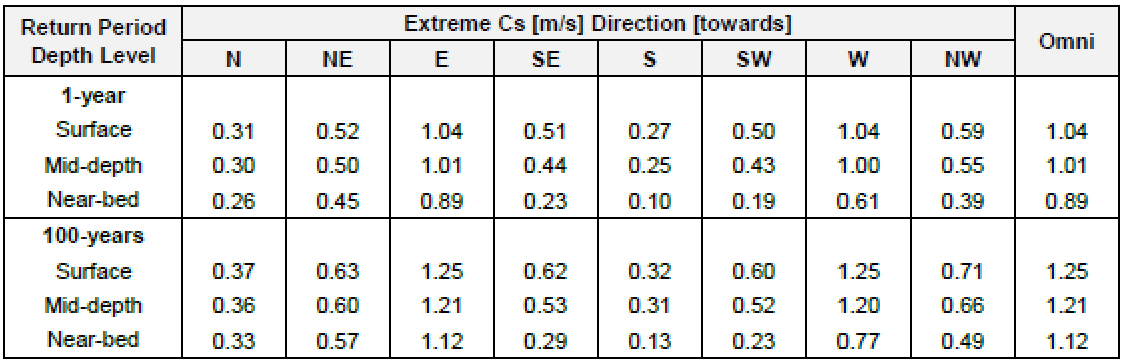


Return Period Direction [from]	Hs [m]	Tz [s]	Tp [s]	Cmax [m]	Hmax [m]	THmax [s]	U_{1m} [m/s]
1-year							
North	5.3	9.2	11.7	5.9	9.3	9.5	1.67
North-east	3.8	6.8	8.3	4.3	6.7	8.5	1.04
East	2.6	5.2	6.6	3.0	4.7	7.5	0.55
South-east	2.1	4.6	5.2	2.3	3.6	6.9	0.34
South	2.4	4.7	5.2	2.8	4.3	7.3	0.48
South-west	3.2	5.6	6.2	3.6	5.6	8.0	0.78
West	4.7	8.0	10.5	5.3	8.3	9.1	1.43
North-west	6.5	9.9	12.4	7.3	11.4	10.1	2.19
100-years							
North	8.1	11.5	14.3	9.1	13.8	10.8	2.73
North-east	5.9	8.1	10.4	6.6	10.0	9.7	1.84
East	4.0	5.9	8.2	4.5	6.9	8.6	1.07
South-east	3.1	4.9	6.0	3.5	5.4	7.9	0.71
South	3.7	5.0	6.0	4.2	6.4	8.4	0.95
South-west	4.9	6.4	7.3	5.5	8.3	9.1	1.43
West	7.2	9.8	12.9	8.1	12.3	10.4	2.40
North-west	9.9	12.3	14.9	11.1	16.9	11.5	3.20

Table 3-8 Near platform design wave data [ref. II]

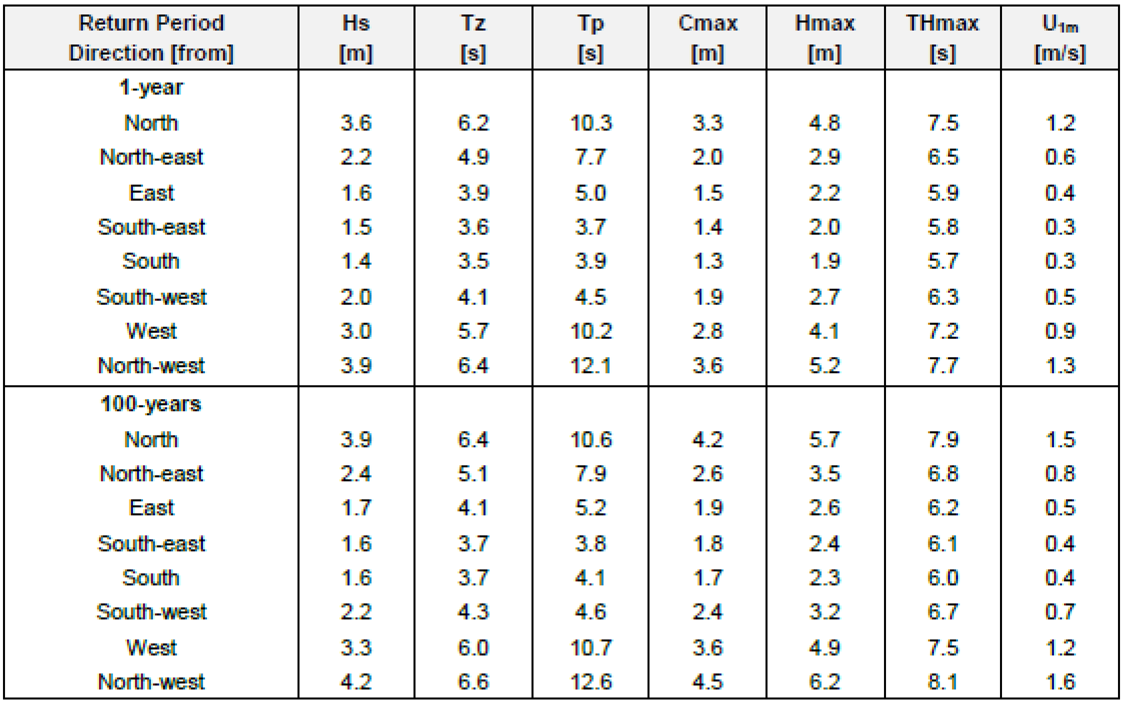
Property	1-year return period	100-year return period
Positive surge (m) @26m	1.48	2.72
Negative surge (m)	-0.90	-1.26
LAT with respect to MSL (m)	-1.89	
HAT with respect to MSL (m)	1.61	

Table 3-9 Near tie-in extreme water level data [ref. III]



Return Period Depth Level	Extreme Cs [m/s] Direction [towards]								Omni
	N	NE	E	SE	S	SW	W	NW	
1-year									
Surface	0.31	0.52	1.04	0.51	0.27	0.50	1.04	0.59	1.04
Mid-depth	0.30	0.50	1.01	0.44	0.25	0.43	1.00	0.55	1.01
Near-bed	0.26	0.45	0.89	0.23	0.10	0.19	0.61	0.39	0.89
100-years									
Surface	0.37	0.63	1.25	0.62	0.32	0.60	1.25	0.71	1.25
Mid-depth	0.36	0.60	1.21	0.53	0.31	0.52	1.20	0.66	1.21
Near-bed	0.33	0.57	1.12	0.29	0.13	0.23	0.77	0.49	1.12

Table 3-10 Near tie-in design current data [ref. III]



Return Period Direction [from]	Hs [m]	Tz [s]	Tp [s]	Cmax [m]	Hmax [m]	THmax [s]	U_{1m} [m/s]
1-year							
North	3.6	6.2	10.3	3.3	4.8	7.5	1.2
North-east	2.2	4.9	7.7	2.0	2.9	6.5	0.6
East	1.6	3.9	5.0	1.5	2.2	5.9	0.4
South-east	1.5	3.6	3.7	1.4	2.0	5.8	0.3
South	1.4	3.5	3.9	1.3	1.9	5.7	0.3
South-west	2.0	4.1	4.5	1.9	2.7	6.3	0.5
West	3.0	5.7	10.2	2.8	4.1	7.2	0.9
North-west	3.9	6.4	12.1	3.6	5.2	7.7	1.3
100-years							
North	3.9	6.4	10.6	4.2	5.7	7.9	1.5
North-east	2.4	5.1	7.9	2.6	3.5	6.8	0.8
East	1.7	4.1	5.2	1.9	2.6	6.2	0.5
South-east	1.6	3.7	3.8	1.8	2.4	6.1	0.4
South	1.6	3.7	4.1	1.7	2.3	6.0	0.4
South-west	2.2	4.3	4.6	2.4	3.2	6.7	0.7
West	3.3	6.0	10.7	3.6	4.9	7.5	1.2
North-west	4.2	6.6	12.6	4.5	6.2	8.1	1.6

Table 3-11 Near tie-in design wave data [ref. III]

3.6. Marine growth

The following marine growth has been assumed, in accordance with NEN 3656 [1]

From	To	Thickness	Density
+2m LAT	Seabed	50mm	1300 kg/m3

Table 3-12 Assumed marine growth properties

3.7. Geotechnical data

The survey report – N5A to NGT Hottap [ref. IV] indicates the soil along the route as 'fine to medium Sand, with occasional areas of coarse Sand and Clay with gravel and shell fragments. Three lab result reports [ref XI – XII] present the soil parameters for the sand in the trajectory. The soil properties are listed in Table 3-13, data has been taken from ref. X-XIII and recommended values as per NEN3656 table H.1 ref[1] based on the soil description as presented in [ref X]. A SBP data example of the north end of the proposed route is presented in figure 3-14.

Soil type	Applicable area	Submerged Unit Weight (kN/m³)	Angle of internal friction (°)
Medium sand (measured)		10.2-10.5	32.5-34.9
Medium sand	Pipe on surface	10	32.5
	Trench backfill	8.5	28
Rock dump	Crossing / Tie-in	10	40

Table 3-13 Assumed soil geotechnical properties

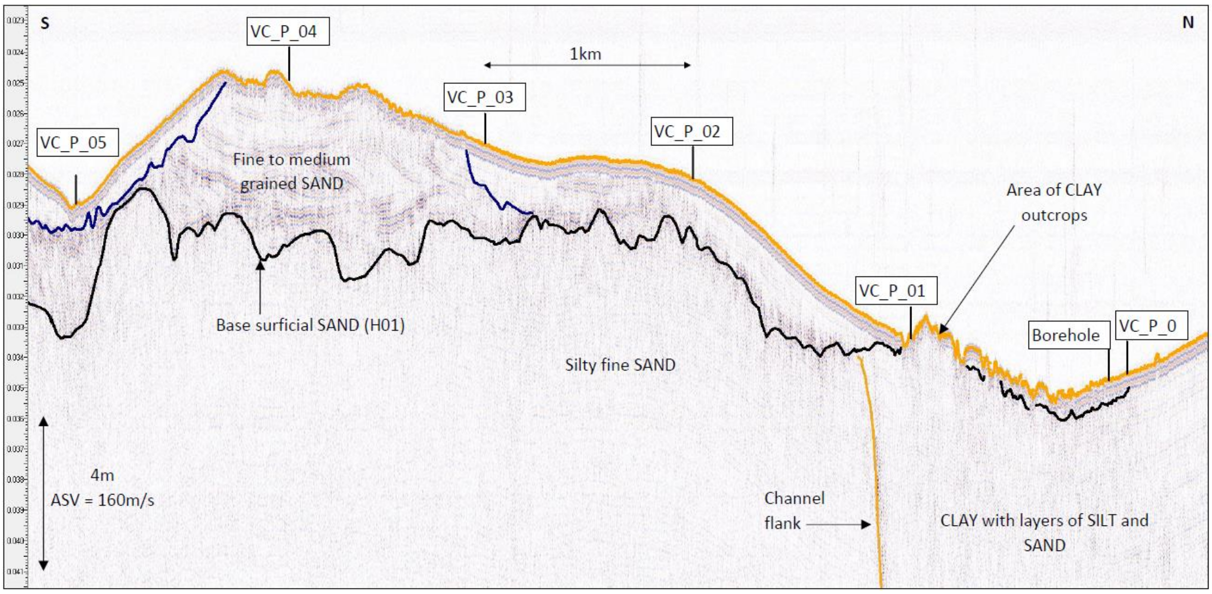


Figure 3-2 Soil profile from KP 0.0 to KP 6.0

4. Pipeline route data

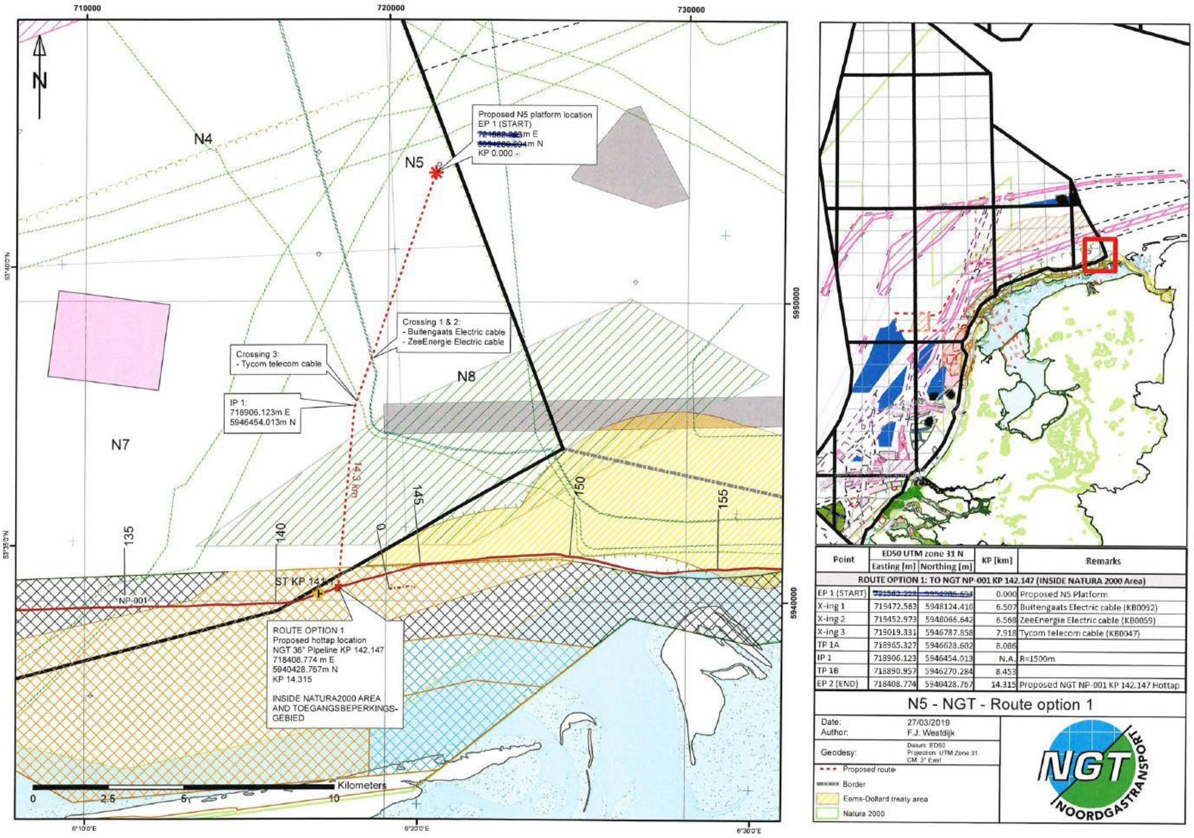
This chapter deals with the pipeline route data describing the starting and end point of the pipeline, the used coordinate system, pipeline route coordinates and key facilities as well as the route bathymetry and contacts detected along the pipeline route. Based on this info the most optimal pipeline routing has been selected (ref. [IX].

4.1. General

The new pipeline to be installed originates at the new N05-A Platform and terminates at the NGT platform via a dedicated tie-in connection. The pipeline length is approx. 14.7 km.

An installation of the pipeline on top of the seabed has been indicated as an opportunity. The final cover height, or required concrete coating thickness will be determined based on the results of a risk assessment study, the on-bottom stability analysis and the upheaval buckling analysis.

Two pipeline/cable crossings are foreseen along the route. An overview of the field lay out is given in Figure 4-1.



Point	ED50 UTM zone 31 N		KP [km]	Remarks
	Easting [m]	Northing [m]		
ROUTE OPTION 1: TO NGT NP-001 KP 142.147 (INSIDE NATURA 2000 Area)				
EP 1 (START)	[redacted]	[redacted]	0.000	Proposed N5 Platform
X-ing 1	719472.563	5948124.410	6.507	Buitengaats Electric cable (KB0092)
X-ing 2	719452.973	5948066.642	6.568	ZeeEnergie Electric cable (KB0059)
X-ing 3	719019.331	5946787.858	7.918	Tycom telecom cable (KB0047)
TP 1A	718965.327	5946628.602	8.086	
IP 1	718906.123	5946454.013	N.A.	R=1500m
TP 1B	718890.957	5946270.284	8.453	
EP 2 (END)	718408.774	5940428.767	14.315	Proposed NGT NP-001 KP 142.147 Hottap

Date: 27/03/2019
Author: F.J. Westdijk
Geodesy: Datum: ED50
Projection: UTM Zone 31
CM: 3° East

- - - Proposed route
▬ Border
▨ Eems-Dollard treaty area
🟩 Natura 2000

Figure 4-1 Overview N05A platform to the tie-in location

4.2. Coordinate system

The parameters of the geodetic system to be used for horizontal positions are listed in Table 4-1.

Item	Value
Datum	European Datum 1950 (ED50)
Projection	ED50 / UTM zone 31 N
Ellipsoid name	International 1924
Semi major axis	6 378 388 m
Inverse flattening	297.000
Central Meridian	03º00”00’ E
Latitude of Origin	00º00”00’ N
False Northing	0 mN
False Easting	500 000 mE
Scale Factor	0.9996

Table 4-1: Geodetic parameters

The vertical position is given relative to the Lowest Astronomical Tide (LAT).

4.3. Key facility coordinates

The following platform and tie in locations have been derived from Ref. [V] and are presented in Table 4-2.

Item	Northing (m)	Easting (m)
N05A Platform target box	5 954 608	721 622
NGT target box	5 940 549	718 738
NGT hot tap location KP142.1	5 940 532	718 766
Water depth at N05A Platform	26 m LAT	
Water depth at NGT hot tap	9.8 m LAT	

Table 4-2 Key Facility coordinates

4.4. Bathymetry

Figure 4-3 shows the bathymetry along the surveyed flowline route. The water depths recorded during survey along the proposed N05-A platform and the NGT pipeline hottap location ranges between 9.8 m LAT and 26.4 m LAT.

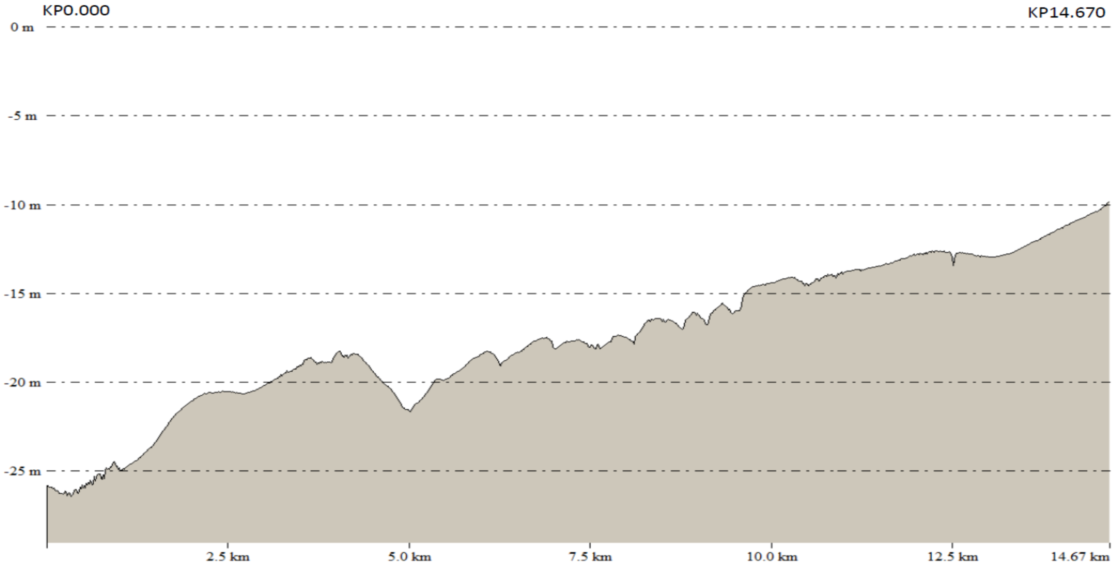


Figure 4-3 Seabed profile along pipeline route from P11-Unity Platform to Wye

4.5. Side Scan Sonar Contacts & Magnetometer Anomalies

Ref. [5] describes the seafloor sediments across the N05-A to the proposed NGT hottap location survey area to consist of a top layer of fine to coarse sand, with occasional areas of coarse sand and clay with gravel and shell fragments. Photographs taken along the proposed route show the presence of small ripples covering the majority of the seabed within the survey corridor area.

Numerous boulders and items of debris are observed in the survey area. Most of the boulders occur in the north of the survey area and coincide with areas of clay exposure.

4.5.1. Magnetometer Contacts

A total of 241 magnetic anomalies (appendix A) were picked within the surveyed N05-A platform to the 36” NGT Tie-in and N05-A platform to Riffgat Tie-in route corridor. Most of these anomalies can be attributed to unknown identified seabed features the following seabed infrastructures are known, one (1) pipeline and four (4) cables. However, one (1) unknown linear feature.

The following existing pipelines and cable are detected:

- 36” Pipeline from L10-AR to Uithuizen
- Tycom Telecom cable
- Buitengaats Power cable
- Zeeenergie Power cable
- Norned Power cable

4.5.2. Geophysical Data

Eight-Hundred-Thirty (830) side scan sonar contacts were observed within the route survey. Most of the contacts are boulders located around the N05-A platform and stretching to the east side to Riffgat, besides the bolders the following contacts are found, twenty-six (26) debris items, two (2) wrecks. Side scan sonar data can be found in Appendix A.

4.6. Cable & Pipeline Crossings

The following crossings along the pipeline route are envisaged:

Infrastructure Name	KP	Northing (m)	Easting (m)
Buitengaats Electric cable	6.412	719 346	5 948 729
ZeeEnergie Electric cable	6.487	719 327	5 948 655
Tycom Telecom Cable Hunmanby GAP - Eemshaven	8.180	718 915	5 947 014

*) The N05A Pipeline will be connected to the NGT Pipeline with a Hot tap. This hot tap is not part of the scope of the design report.

4.7. Approach

Near the platform a T-piece will be installed including 2 ball valves for the purpose of a future pipeline connection. At the NGT tie-in location 2 ball valves and a check valve will be placed for tie-in purposes. Figures 4-4 and 4-5 present an overview of respectively the platform and the tie-in location.

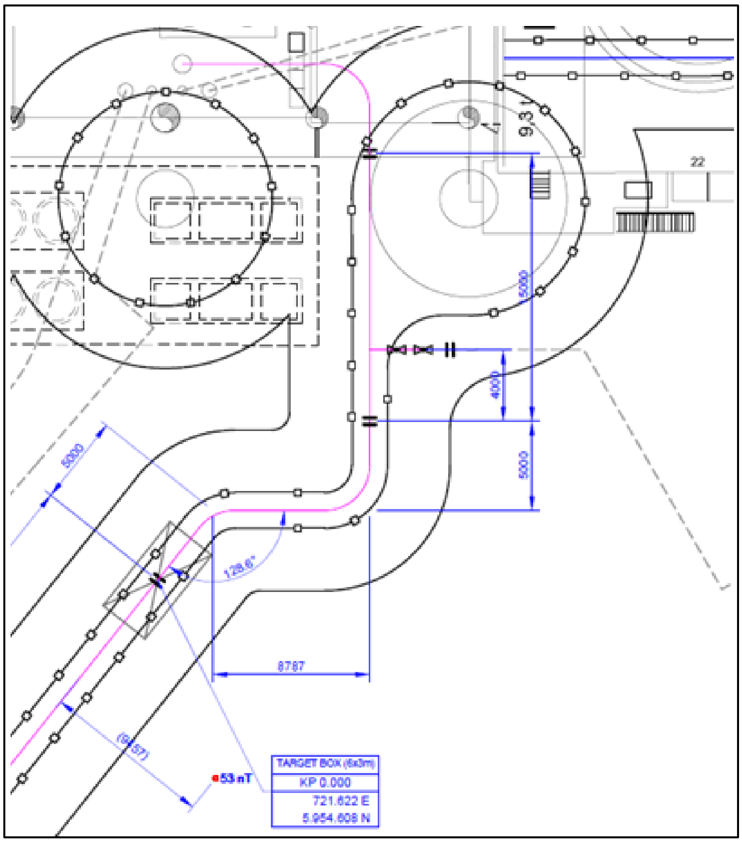


Figure 4-4 approach layout near the platform

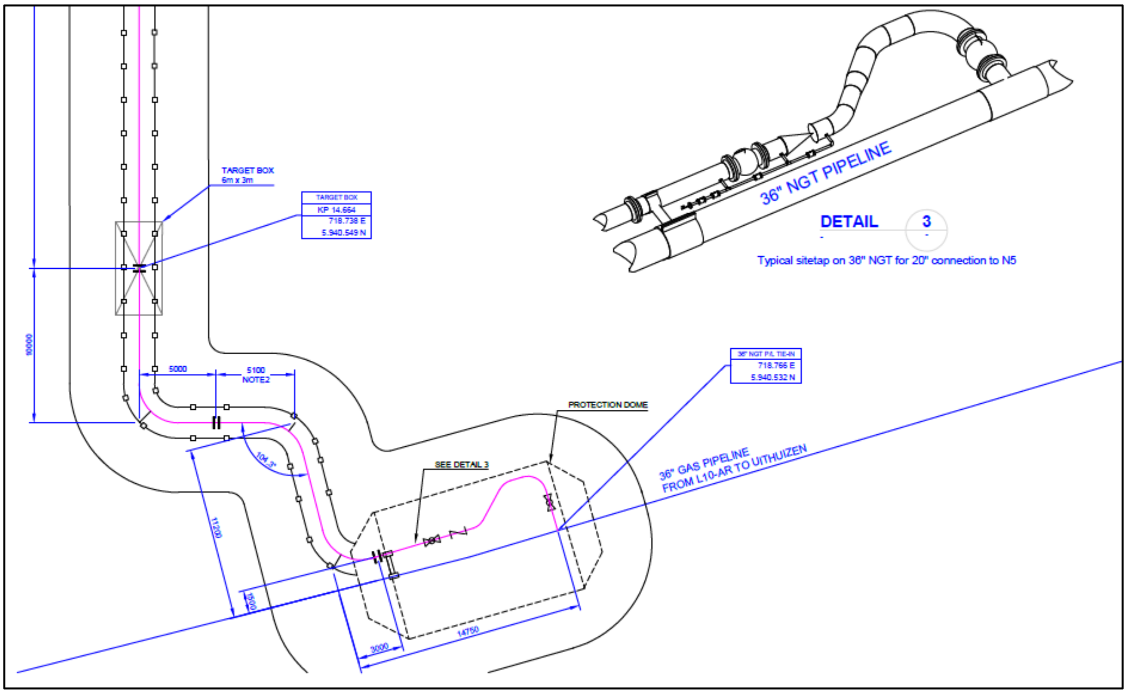


Figure 4-5 approach layout near the tie-in

5. Riser and Spool piece analysis

The purpose of the riser and expansion spool analysis at the N05A platform is to determine the combined effect of functional and environmental loads on the structural integrity of the system. The analysis consists of the stress analysis of the spool pieces on both ends of the pipeline, carried out in accordance with NEN 3656:2015 (Nederlands Normalisatie-instituut, 2012).

5.1. Stress Criteria

Stresses in the riser and tie-in spool pieces will be assessed by using the finite element software ANSYS. The analysis ensures the structural integrity of the riser/spool system by NEN 3656 (Ref. [1])

The analysis will account for the load history of the pipe over the design life by considering the following four load cases:

- Installation
- Hydrotest
- Operational – Nominal
- Operational – Corroded

Considering the design cases listed above the following design loads will be considered when performing the stress analysis, see Table 5-1.

Load	Installation	Hydrotest	Operation
Pressure	N/A	Hydrotest Pressure	Design Pressure
Temperature	Seawater Temperature	Seawater Temperature	Design Temperature
Internal Fluid	Seawater	Seawater	Product Filled
Wall Thickness	Nominal	Nominal	Nominal / Fully corroded
Hydrodynamic Loads	1-year wave + 1-year current	1-year wave + 1-year current	100-year wave + 100 year current
Pipeline End Expansion	N/A	Expansion Under Hydrotest Pressure	Expansion under design temperature and pressure

Table 5-1 Design loads

Calculated equivalent stresses for the various design conditions will be checked against the allowable stress values, as per NEN3656 (Ref. [1]), see Table 5-2.

Case	Load Combination As Per NEN3656 Table 3.	Limit Stress	Allowable Equivalent Stress (LB360)
Installation	LC1	$R_{e(\theta)} / \gamma_m$	327 MPa
Hydrotest	LC4	$0.85\ (R_e + R_{e(\theta)})/ \gamma_m$	556 MPa
Operation (Nominal / Corroded)	LC4	$0.85\ (R_e + R_{e(\theta)})/ \gamma_m$	556 MPa

Table 5-2 Applied stress limits

Where:

Re = specified minimum yield strength at 20ºC (N/mm^2).

$R_{e(\theta)}$ = the yield strength of the material at design temperature.

γ_m = material factor (for steel 1.1).

All design loads applied will be factored as per the requirements of NEN 3656 (Ref. [1]), see Table 5-3.

Loads	**Load factors for load combinations (a)**								
Load combinations	LC 1	LC 2	LC 3	LC 4	LC 5	LC 6	LC 7a	LC 7b	LC 8
Internal pressure (design pressure)	-	1.25	-	-	-	-	1.0		1.0
Internal pressure (In combination)	-	-	-	1.15	1.15	-	-	1.0	1.15
Internal pressure (max. Incidental pressure)	-	1.10	-	-	-	-	-		1.1
Temperature differences (c g)	1.0	-	-	1.10	1.10	-	1.0	1.0	-
Soil parameters (d)	-	-	(d)	(d)	(d)	-	-	Low	-
Forced deformation (e)	-	-	1.1	1.1	1.1	1.1	-		-
Own weight	1.1	-	1.1	1.1	1.1	1.1	1.0		1.0
(Possible) coating (h)	1.2	-	1.2	1.2	1.2	1.2	1.0	1.2	1.0
Pipe contents (h)	1.1	-	1.1	1.1	1.1	1.1	1.0	1.1	1.0
Installation loads (f)	1.1	-	1.10	-	-	1.1	-		-
Hydrostatic pressure	1.1	-	1.1	1.1	1.1	1.1	1.0	1.1	
Marine growth (h)	-	-	1.2	1.2	1.1	-	1.0	1.0	1.0
Hydrodynamic forces	1.1	-	1.2	1.2	1.1	1.1	1.0	1.2	1.0
(a)	If a load has a favorable influence on the considered case this will not be considered if the load is variable and for a permanent load a multiplication factor of 0.9 is applied.								
(b)	The maximum incidental pressure does not need to be checked separately however must be ascertained by the pressure control system.								
(c)	During calculations of stress variations caused by temperature differences the highest and lowest occurring operation temperature should be considered. The displacements loads and moments exerting on connected equipment and/or structures are to be considered based on the design temperatures i.e. the temperature difference between the installation temperature and the maximum operational temperature.								
(d)	Reference is made to ref. [1] – K.4 to determine load spreading factors								
(e)	Forced deformations can be caused by: settling differences trench roughness execution sacking differences deformations due to prevented thermal expansion distortions in horizontal drilling and bottom-tow installation.								
(f)	Examples of installation loads are those applied during pipelay tie-ins trenching landfalls and HDD etc.								
(g)	Combined with measurements.								
(h)	In the stability check (BC 7b) the most unfavorable combination must be chosen. If necessary divide by the relevant factor.								

Table 5-3 Load factors

A description of the load combinations is shown below;

LC 1:	Installation
LC 2:	Only internal pressure, operating pressure, incidental pressure
LC 3:	External load with zero internal pressure
LC 4:	External load with internal pressure and temperature difference
LC 5:	Variable load (primarily static load, e.g., temperature changes and pressure)
LC 6:a	External pressure, external load and internal pressure zero
LC 7a:	Incidental load (other than internal pressure)
LC 7b:	Incidental load (meteorological)
LC 8:	Dynamic loading

5.2. Model description

The riser and spool pieces will be modelled by using ANSYS dedicated submerged pipe element "PIPE59". This element is a uniaxial element with tension-compression, torsion, and bending capabilities and can account for internal pressure effects. The element is a 3D element with six degrees of freedom, translations in the x, y and z directions and rotations about the x, y and z axes. In addition the element accounts for buoyancy, wave and current loads, and is capable of large deflections and rotations.

Hot bends are modelled by using "PIPE18" elements which are elastic bend pipe elements with similar properties as the straight "PIPE59" elements described previously.

At riser clamp locations pipe nodal translation and/or rotations shall be constrained appropriately based on the physical constraints provided by the clamps (guide clamps / anchor clamps).

To incorporate pipeline end expansion into the spool pieces a representative pipeline length (greater than the anchor length) will be modelled. Note that conservatively seabed undulations are neglected while modelling these pipeline sections as this provides the greatest end expansion into the spool pieces.

Pipe-soil interaction is simulated using three independent non-linear spring elements (COMBIN39) attached to each pipe element. The springs represent the soil frictional resistance in the axial and lateral directions and the soils bearing capacity in the vertical direction. As the spool piece will be rock dumped after the hydrostatic testing, additional non-linear springs representing the uplift resistance of the rockdump / trenched backfill material, are attached to the pipe elements for the "operational" load cases. A detailed description of how the pipe soil interaction will be modelled is provided separately in section 5.3.

5.3. Pipe-soil interaction

The characteristics of the springs, which simulated the pipe-soil interaction, are defined through non-linear force-deflection curves. The force-deflection curves describe the frictional restraint provided by the soil to the pipeline in the axial and lateral direction and the soil's bearing capacity / upwards resistance in the vertical direction. The upcoming sections describe how the force-deflection curves of the springs are generated.

5.3.1. Exposed pipeline – axial soil resistance

The axial soil resistance for a pipeline / spool piece resting on the seabed, per meter pipe-length, is a function of the pipe submerged weight (vertical load) and the axial Coulomb friction coefficient. The axial friction is determined as follows:

$$F_{axial} = \mu_{Coulomb} w_s$$

Where:

- F_{axial} = Peak axial soil resistance [N/m]
- $\mu_{Coulomb}$ = Coulomb friction coefficient [-]
- w_s = Pipe submerged weight [N/m]

The axial restraint will be described through a bi-linear force-displacement relationship, as shown in Figure 5-1. The stiffness of the springs varies along the pipeline route and between load steps to account for variations in the pipe submerged weight and soil conditions.

The axial spring mobilization displacement is assumed to be 1.25 mm.

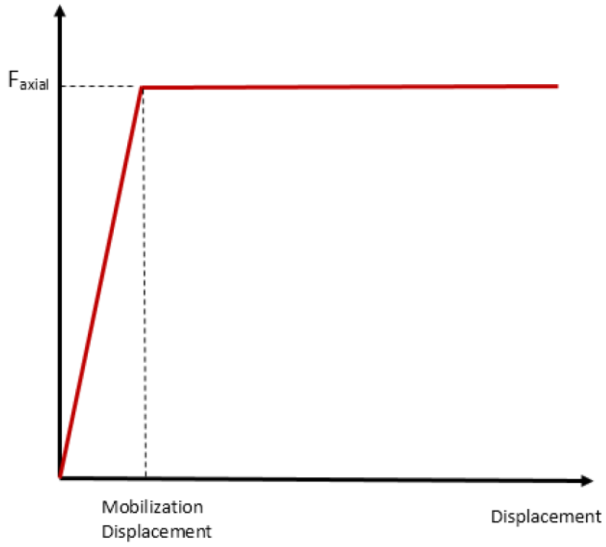


Figure 5-1 Axial resistance Force-Displacement curve

5.3.2. Exposed pipeline – lateral soil resistance

Lateral soil resistance is composed of two parts:

- Coulomb friction.
- Passive soil resistance due to the build-up of soil penetration (and hence a soil berm, as the pipe moves laterally).

To account for both components of resistance, an equivalent friction coefficient shall be used, which is defined as:

$$\mu_{equivalent} = \mu_{Coulomb} + \mu_{passive}$$

Where:

- μ_{eqv} = Equivalent lateral friction coefficient [-]
- $\mu_{Coulomb}$ = Coulomb friction coefficient [-]
- $\mu_{passive}$ = Passive soil resistance coefficient [-]

The passive soil resistance model proposed in DNV's Recommended Practice, DNV-RP-F109 (rev. [5]) will be used.

The passive soil resistance coefficient, for a pipeline resting on a sandy seabed, depends on the pipe penetration depth into the soil and can be determined by the formulation:

- $\mu_{passive} = \frac{F_R}{F_C} = (5\kappa_s - 0.15\kappa_s{}^2)\left(\frac{z_p}{D}\right)^{1.25}$ if $\kappa_s \leq 26.7$
- $\mu_{passive} = \frac{F_R}{F_C} = \kappa_s\left(\frac{z_p}{D}\right)^{1.25}$ if $\kappa_s > 26.7$

Where:

- F_R = Passive resistance force [N/m]
- F_C = Vertical contact force between pipe and soil [N/m]
- D = Pipe outside diameter, including all coatings [m]
- z_p = Total pipe penetration [m]
- κ_s = Soil parameter for sandy soils [-]
- γ'_s = Submerged unit soil weight [N/m^3]

The soil parameter for sand, κ_s, is determined as:

$$\kappa_s = \frac{\gamma'_s D^2}{F_C}$$

The total pipe penetration is taken as the sum of:

- Initial penetration due to self-weight.
- Penetration due to dynamics during laying.
- Penetration due to pipe movement under the action of waves and current.

The pipe static/initial penetration due to self-weight for pipelines resting on sandy soil will be determined using the following formula taken from DNV-RP-F109 (rev. [5]):

$$\frac{z_{pi}}{D} = 0.037 {\kappa_s}^{-0.67}$$

Just as for the axial restraint, the lateral soil resistance will be described through a bi-linear force-displacement relationship as presented in Figure 5-1. The friction forces are increased monotonically to a maximum value calculated as the product of the pipe submerged weight (w_s) and the equivalent friction coefficient (μ_{eqv}), at a mobilisation distance of 2mm.

5.3.3. Vertical soil bearing capacity (Downward resistance)

The static vertical soil reaction per unit length can be determined based on bearing capacity formulas for ideal 2-D strip foundations, as per DNV-RP-F105 (rev. [3]):

$$R_V = \gamma'_{soil} B (N_q v_{eff} + 0.5 N_\gamma B)$$

Where:

- R_V = Vertical soil reaction [N/m]
- N_q & N_γ = Bearing capacity factors [-]
- v_{eff} = Effective penetration [m] (The larger of $v - D/4$ and 0)
- v = Vertical penetration [m]
- B = Contact width for pipe-soil load transfer [m]

The bearing capacity factors are determined as follows:

$$N_q = e^{\pi \tan \varphi_s} \tan^2 \left(45 + \frac{\varphi_s}{2}\right)$$

Where:

φ_s = Angle of internal friction [°]

$$N_\gamma = 1.5 \left(N_q - 1\right) \tan \varphi_s$$

The contact width for pipe-soil load transfer, B, is given by:

- $B = 2\sqrt{(D - v)v}$ if $v \le D/2$
- $B = D$ if $v > D/2$

5.3.4. Buried pipeline – axial soil resistance

Soil resistance forces for buried pipeline sections are based on ASCE's "Guidelines for the Design of Buried Steel Pipe" [9].

The maximum axial soil force that can be transmitted to the pipe per unit length is given by:

$$T_u = \pi D\alpha c + \pi D H {\gamma'}_s \frac{1 + K_0}{2} \tan \delta$$

Where:

- c = Soil cohesion representative of soil backfill material [N/m^2] (c=0 for sand)
- H = Depth to the pipeline centreline [m]
- K_0 = Coefficient of earth pressure at rest [-] $(1 - \sin \varphi_s)$
- α = Adhesion factor [-]
- δ = Interface angle of friction for pipe and soil [°] $(f\varphi_s)$
- f = Coating dependent factor relating the internal friction angle of the soil to the friction angle at the pipe soil interface.

The axial resistance mobilisation displacement, Δ_t, is determined considering the soil type as follows:

- Δ_t = 3mm for dense sand
- Δ_t = 5mm for loose sand
- Δ_t = 8mm for stiff clay
- Δ_t = 10mm for soft sand

5.3.5. Buried pipeline – lateral soil resistance

The maximum lateral force that the soil can transmit per unit pipe length is given by:

$$P_u = N_{ch}cD + N_{qh}\gamma'_sHD$$

Where:

- N_{ch} = Horizontal bearing capacity for clay (0 for c=0).
- N_{qh} = Horizontal bearing capacity factor for sand (0 for $\varphi_s = 0$)

The bearing capacity factors are taken from figure 5-2

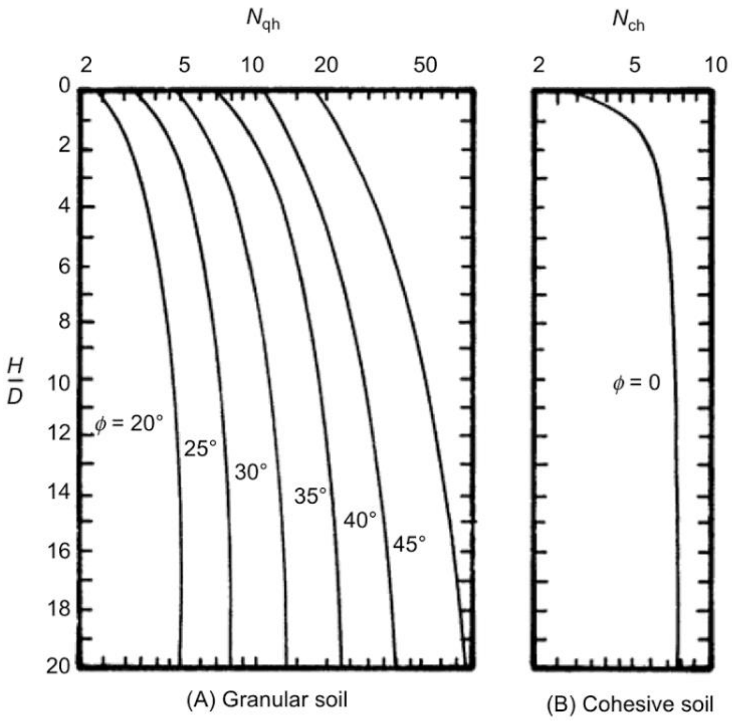


Figure 5-2 Horizontal bearing capacity factors

The lateral soil resistance mobilization displacement is given by:

$$\Delta_p = 0.04\left(H + \frac{D}{2}\right) \leq 0.10D\ to\ 0.15D.$$

5.3.6. Buried pipeline – vertical upward soil resistance

The uplift resistance R_{max} of a pipe in sand consists of two components, viz. a component owing to the weight of the soil above the pipe and a component owing to soil friction as per DNV-RP-F110 (rev. [6]). The uplift resistance can therefore be expressed as:

$$R_{max} = \left(1 + f\frac{H}{D}\right)(\gamma'_s HD)$$

The uplift resistance factor, f, is:

- $f = 0.1$ for loose sand (backfill)
- $f = 0.5$ for rockdump

The non-linear force-displacement response of a buried pipe is represented by a tri-linear curve as shown in figure 5-3.

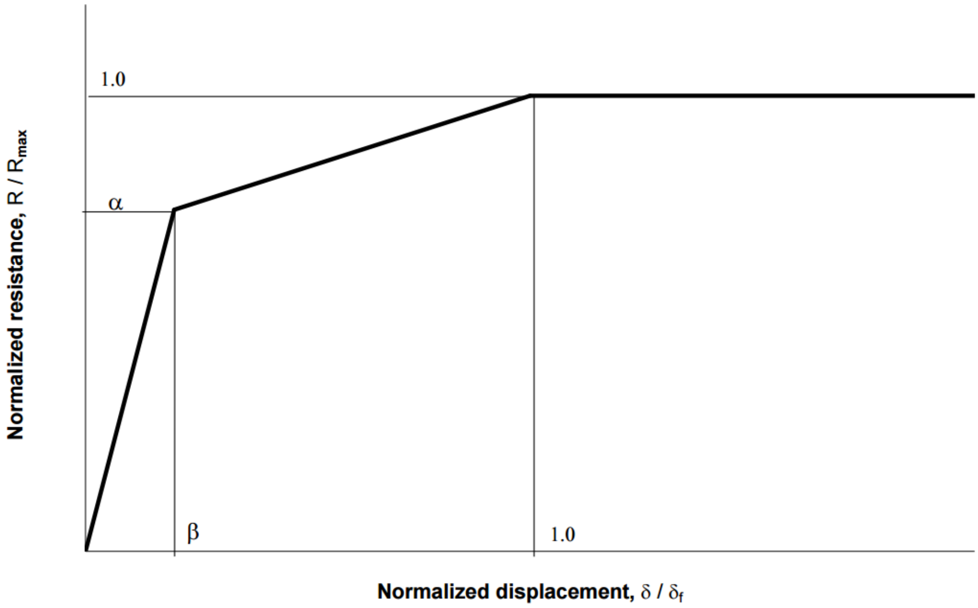


Figure 5-3 Uplift resistance Force-Deflection curve

Where:

- δ_f = Failure displacement (=0.0065H for loose sand backfill) (=20mm for rock dump)
- $\alpha = 0.8$ for loose sand (backfill) and $\alpha = 0.7$ for rock dump
- $\beta = 0.2$

5.4. Fatigue analysis

Fatigue is caused by time varying stresses resulting from applied loads to the riser and parts of the spool piece system which are exposed to hydrodynamic loads.

The riser and spool piece section are from approx. LAT +6.000m to seabed level exposed to the environment and hence are subjected to time varying loads. Three sources of time varying loads, and hence fatigue damage to the riser, are identified:

1. Vortex Induced Vibrations (VIV)
2. Direct wave loading
3. Indirect loads resulting from platform deflections

Riser guide clamps will be spaced such that the maximum span length is below the critical span length at which VIV can occur. The methodology for determining the critical span lengths are described in chapter 7 of this report.

To assess fatigue damage due to direct and indirect wave loading, platform deflections are applied, and the exposed riser section will be subjected to hydrodynamic drag and inertia forces. The drag and inertia forces are determined using the wave induced velocities and accelerations as experienced by the riser section over the lifetime of the pipeline system considering the ”Individual Wave Scatter Diagrams for Fatigue H-T” attached as appendix B.

To estimate the fatigue damage, due to direct and indirect wave loading, a detailed finite element assessment will be carried out considering the same finite element model of the riser spool system as described in Section 5.

In this case the H-T wave scatter diagram will be subdivided into a number of representative blocks, with a single sea-state selected to represent all waves in that block. For the wave height within a particular bin the mean wave height is selected and the corresponding wave period is based on the weighted average of the mean wave periods. This reduces the number of required finite element analyses. These wave blocks and the corresponding platform deflections based on the actual platform deflections will be applied to the model. The analyses will account for the directionality of the wave and the number of occurrences of the waves as per the scatter diagrams. The maximum longitudinal (= axial + bending) stress ranges are extracted from the riser elements as follows:

$$\Delta\sigma_{ax,max} = \Delta\sigma_{ax,pdeflect} + \Delta\sigma_{ax,wave} = 2 * \ \sigma_{ax,amplitude,pdeflect} + (\sigma_{ax,max,wave} - \sigma_{ax,min,wave})$$

Where:

$\Delta\sigma_{ax,pdeflect}$	=	Longitudinal stress range due to platform deflection [N/m^2]
$\Delta\sigma_{ax,wave}$	=	Longitudinal stress range due to wave [N/m^2]
$\sigma_{ax,amplitude,pdeflect}$	=	Single longitudinal stress amplitude due to platform deflection [N/m^2]
$\sigma_{ax,max,wave}$	=	Maximum longitudinal stress due to wave [N/m^2]
$\sigma_{ax,min,wave}$	=	Minimum longitudinal stress due to wave [N/m^2]

The allowable number of cycles will then be determined (N_p) in relation to the maximum longitudinal stress range in all riser elements ($\Delta\sigma_{ax,max}$) for each wave block given by:

$$\log N_p = \log a_n - m_n \log\left(\Delta\sigma_{ax,max}(t/t_{ref})^k\right)$$

Where:

- N_p = Predicted number of cycles of failure for stress range [-]
- $\Delta\sigma_{eqv,max}$ = maximum stress range [N/m^2]
- $\log a_n$ = Constant valid in the range n (see Table 5-4)
- m_n = Constant valid in the range n (see Table 5-4)
- t = Wall thickness [m]
- t_{ref} = Reference wall thickness (16mm)
- k = Thickness component (see Table 5-4)

S-N curve designation	**N<=10^6 cycles**		**N>10^6 cycles**		**Fatigue limit at 10^7 cycles**	**Thickness component (k)**
	m_1	$\log(a_1)$	m_2	$\log(a_2)$		
F (seawater with cathodic protection)	3.0	11.455	5.0	15.091	41.52	0.00

Table 5-4. Fatigue curve parameters (ref. [6])

The design S-N curve (F-curve) is selected according to Table 2.5 of DNV-RP-C203, Ref [7] based on the expected maximum misalignment δ_m, see equation 2.10.5 of Ref [7]. The expected misalignment is calculated based on the pipe diameter/wall thickness and pipe tolerances (thickness and diameter) as given in Table 3.1.

The Stress Concentration Factor (SCF), to be used in the fatigue calculations for both the corroded and non-corroded wall thickness case, is shown in Table 5.5. They are calculated based on equations 2.10.4 and 2.10.1 of DNV-RP-C203, Ref [7].

Pipeline	**Case**	**δ_m (mm)**	**SCF**
20" Export Gas	Non corroded	2.12	1.25
20" Export Gas	Corroded	2.12	1.29

Table 5-5. Overview SCFs

The total fatigue damage due to direct wave loading and platform deflections is then determined, through summation using the Palmgren-Miner rule at each element in the riser as follows:

$$FD = \sum_{1}^{k}\left(\frac{n_i}{N_i}\right)$$

Where:

- k = Number of stress/wave blocks
- n_i = Number of stress cycles/wave occurrences in stress block i
- N_i = Number of cycles to failure at constant stress range in stress block i

The acceptability of the fatigue damage is then determined by comparison with the allowable fatigue damage (α_{fat}) ratio as given in Ref. [2]:

$$\alpha_{fat} \geq FD$$

Where:

α_{fat} = Allowable damage ratio = 0.1 [2]

5.5. Low cycle analysis

The riser and spool piece system will also be checked for low cycle fatigue, i.e. stress variations due to pressure and temperature fluctuations. During the pipeline's life time the following pressure/temperature fluctuations are anticipated:

- 1x strength test
- 3x leak tests (worst case)
- 25x shut down: Dp = 75 barg and temperature to ambient (annual shut down)

The allowable cycles for the resulting stress variations are to be determined from figure K.8 of ref. [1].

6. Wall Thickness Analysis

Several phenomena are to be investigated prior to finalising the selected wall thickness. Elements to be taken into account:

- pressure containment;
- on-bottom stability;
- implosion;
- progressive plastic collapse;
- local buckling;
- bar buckling;

6.1. Pressure containment

6.1.1. Design condition

NEN 3656, states that for every load combination the design resistance (R_d) must be greater than or equal to the loading effect (S_d) or:

$$R_d \geq S_d$$

R_d is defined as:

$$R_d = R_{e(\Theta)} / \gamma_m$$

Where:

$R_{e(\Theta)}$ = yield strength of the material at design temperature (N/mm^2)

γ_m = material factor (1.1 for steel)

For load combination LC2 (internal pressure only), the equation for hoop stress can be expressed as:

$$\sigma_h = \frac{\gamma_p \cdot P_d \cdot (OD - t_{\min})}{2 \cdot t_{\min}}$$

Where:

s_h = hoop stress (N/mm^2)

γ_p = load factor as per Table 5-3 (-) => 1.25

Pd = design pressure (N/mm^2)

OD = outside diameter of steel pipe (mm)

t_{min} = minimum wall thickness (mm)

The selected wall thickness (t_{nom}) is then determined by:

$$\mathrm{t}_{nom} = \left\{ \frac{\mathrm{t}_{\min} + CA}{1 - f_{tol}} \right\}$$

Where:

CA = applicable corrosion Allowance (mm)

f_{tol} = fabrication tolerance (%)

Further to this, NEN 3656 specifies additional requirements for bends with a bending radius $R_b < 10$ OD, to adjust the hoop stress of straight pipe (torus effect).

$$S_h(bi) = \frac{2R_b - {}^1\!/_2 OD}{2R_b - OD} \cdot S_h \quad \text{(for inside bend)}$$

$$S_h(bo) = \frac{2R_b + {}^1\!/_2 OD}{2R_b + OD} \cdot S_h \quad \text{(for outside bend)}$$

6.1.2. Hydrostatic Testing

The hydrostatic testing of pipeline / riser systems has two objectives:

- verify the strength of the system
- verify that there are no leaks from the system

The test pressure, P_t, will be determined as per as per Section 10.18.3 of NEN 3656 (Ref. [1]).

$$P_{t.\min} = C_p \cdot P_d \cdot \frac{R_e}{R_{ev}}$$

Where:

C_p = pressure test coefficient (-) => 1.30 for gas lines; 1.25 for others

P_d = design operating pressure (N/mm^2)

R_e = minimum yield stress at 20 °C (N/mm^2)

R_{ev} = minimum yield stress at design temperature (N/mm^2)

The maximum hydrostatic test pressure is based on the weakest part of the pipeline/riser system to be tested. The pressure shall not exceed, $P_{t,max}$, which is defined by:

$$P_{t.\max} = \frac{2.R_e \cdot t_{\min}}{(OD - t_{\min})}$$

However, the maximum hydrotest pressure should not exceed the mill test pressure, which is given by:

$$P_{T,mill} = 0.9 \cdot \frac{2 \cdot R_e \cdot t_{nom}}{OD} \qquad \text{and}$$

$$t_{nom} = \left\{ \frac{t_{\min} + CA}{1 - f_{tol}} \right\}$$

Where:

t_{nom} = nominal wall thickness (mm)

t_{min} = minimum wall thickness (mm)

CA = applicable corrosion Allowance (mm)

f_{tol} = fabrication tolerance (%)

6.2. On-bottom Stability

6.2.1. Introduction

The aim of the stability analysis is to verify that the submerged weight of the pipeline ensures lateral stability against environmental loading. Depending on the pipeline being buried or not, the on-bottom stability analysis is carried out for the following condition(s):

- Installation – flooded
- Installation – empty
- Operation – product filled

The pipeline is to be laterally stable on the seabed for a 1 year resp. 100 year return period environmental conditions for a buried resp. unburied pipe. A buried pipeline will not be subject to any environmental loading during hydrostatic testing and operation.

6.2.2. Hydrodynamic loads

Hydrodynamic loads arise from the relative motions between pipe and seawater. They consist of drag, lift and inertia forces.

The drag force F_D is given by:

$$F_D = C_D \cdot OD_{tot} \cdot \frac{1}{2} \cdot \rho \cdot V \cdot |V|$$

Where:

C_D = drag force coefficient (-)

OD_{tot} = total diameter of coated pipe (m)

ρ = mass density of surrounding fluid (kg/m^3)

V = velocity of the fluid normal to the pipe axis (m/s)

The lift force F_L is calculated by the following equation:

$$F_L = C_L \cdot OD_{tot} \cdot \frac{1}{2} \cdot \rho \cdot V^2$$

Where:

C_L = lift force coefficient (-)

The inertia force F_I is determined by the following equation:

$$F_I = \rho \cdot C_I \cdot \frac{\pi}{4} \cdot OD_{tot}^{\;2} \cdot a$$

Where:

C_I = inertia force coefficient (-)

a = Fluid particle acceleration (m/s^2)

The recommended values of hydrodynamic coefficients for the on-bottom stability design as a function of the embedment of the pipeline are listed in Table 6-1.

Coefficient	Pipe embedment			**Riser**
	0%	**10%**	**20%**	
Drag	0.70	0.63	0.53	1.0
Lift	0.90	0.90	0.81	-
Inertia	3.29	2.80	2.30	2.0

Table 6-1 Overview hydrodynamic coefficients

The wave induced water particle velocities and accelerations will be determined using the appropriate wave theory for the design wave height, period and water depth. Phase shifts between horizontal and vertical water particle velocities will be considered.

6.2.3. Stability check

The stability of the pipelines is checked using the following relationship:

$$W_s > f_s \cdot \left(\frac{F_D + F_I}{f_w} + F_L \right) - \frac{F_P}{f_w}$$

Where:

W_s = pipeline submerged weight (N/m)

f_s = safety factor (-) => 1.1

F_D = drag force (N/m)

F_L = lift force (N/m)

f_w = friction factor (-)

F_I = inertia force (N/m)

F_P = passive soil resistance (N/m)

A safety factor (f_s) of 1.1 will be implemented. The above equation assumes absolute stability criteria. Note that the actual F_p is limited to the maximum of the combined drag and inertia forces.

The passive soil resistance is derived from:

$$F_p = 0.5 \cdot \rho_{soil} \cdot \varepsilon^2 \cdot K_p$$

Where:

ρ_{soil} = submerged soil density (kg/m^3)

ε = embedment of pipeline (m)

K_P = coefficient of passive soil resistance (-)

and K_P is calculated from :

$$K_P = \frac{1 + \sin(\phi)}{1 - \sin(\phi)} = \tan^2 \cdot \left(45 + \frac{\phi}{2} \right)$$

Where:

ϕ = angle of internal friction (°)

6.3. Implosion

6.3.1. External overpressure

The collapse pressure p_c causing implosion (radial instability) can be determined using:

$$(P_c - P_e) \cdot (P_c{}^2 - P_p{}^2) = P_c \cdot P_e \cdot P_p \cdot 2 \cdot \delta_0 \cdot \frac{D_g}{t}$$

Where:

D_g = nominal diameter of pipe (mm)

P_c = critical external pressure for collapse (N/mm2)

P_e = critical external pressure for elastic deformation (N/mm^2)

P_p = critical external pressure for plastic deformation (N/mm^2)

P_L = allowable external pressure (N/mm^2)

δ_0 = initial deformation (mm)

t = nominal wall thickness (mm)

$$D_g = \frac{1}{2} \cdot \{OD_{nom} - (OD_{nom} - 2 \cdot t_{min})\}$$

The critical external pressure for plastic deformation is calculated from:

$$P_p = \frac{2 \cdot R_e \cdot t}{D_{nom}}$$

The critical external pressure for elastic deformation is calculated from:

$$P_e = \frac{2 \cdot E}{1 - \nu^2} \cdot \left(\frac{t}{D_{nom}}\right)^3$$

Where:

ν = Poisson's ratio for elastic deformation (-) => 0.3

As a part of this the initial deformation is derived from:

$$\delta_0 = \frac{D_{\max} - D_{\min}}{D_{\max} + D_{\min}}$$

Where:

D_{max} = largest diameter of the ovalized pipe cross section

D_{min} = smallest diameter of the ovalized pipe cross section

The maximum allowable external pressure is defined as:

$$\gamma_{g,p} \cdot P_L \leq \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$$

Where:

$\gamma_{g,p}$ = load factor (-) => 1.05

γ_M = model factor (-) => 0.93

$\gamma_{m,p}$ = material factor (-) => 1.45

6.3.2. Bending moment

In case of a bending moment on the pipe, the moment which will cause buckling is calculated from the plastic moment of the pipe section.

$$M_c = D_{nom}{}^2 \cdot t \cdot R_e$$

The maximum allowable bending moment is defined as:

$$\gamma_{g,M} \cdot M_L \leq \frac{\gamma_M \cdot M_c}{\gamma_{m,M}}$$

Where:

$\gamma_{g,M}$ = load factor (-) => 1.1

γ_M = model factor (-) => 1.0

$\gamma_{m,M}$ = material factor (-) => 1.3

M_L = allowable bending moment for buckling (Nm)

M_c = critical bending moment for buckling (Nm)

6.3.3. Combined external pressure and bending moment

When external pressure exists in combination with a bending moment besides the checks above the condition for combined stresses as shown below shall be fulfilled.

$$\frac{\gamma_{g,p}\cdot P_L}{P_c/\gamma_{m,p}}+\left(\frac{\gamma_{g,m}\cdot M_L}{M_c/\gamma_{m,M}}\right)^n\le\gamma_M$$

Where:

$$n=1+300\cdot\frac{t}{D_{nom}}$$

Where:

$\gamma_{g,p}$ = load factor for pressure (-) => 1.05

$\gamma_{g,m}$ = load factor for bending (-) => 1.55

γ_M = model factor (-) => 0.93

$\gamma_{m,p}$ = material factor for pressure (-) => 1.25

$\gamma_{m,M}$ = material factor for bending (-) =>1.15

M_L = allowable bending moment for buckling (Nm)

M_c = critical bending moment for buckling (Nm)

6.4. Progressive plastic collapse

Progressive plastic deformation load cycle will lead to extreme deformation, collapse and cracks initiation through the wall.

The condition for avoiding buckle propagation is:

$$\varepsilon_{\max}=\alpha\cdot\Delta T\le\left[\frac{R_{ev}}{E}\cdot\sqrt{1-\frac{3}{4}\left(\frac{\sigma_h}{R_{ev}}\right)^2}+\frac{R_e}{E}\sqrt{0.9-\frac{3}{4}\left(\frac{\sigma_h}{R_e}\right)^2}\right]$$

Where:

α = coefficient of linear thermal expansion (m/ m/ ° C)

ΔT = temperature differential [° C] (design – installation)

Parameters have to be factored as defined in section 6.

6.5. Local buckling

In accordance with NEN 3656, if OD / t < 55, an assessment on local buckling can generally be omitted.

For this project it would mean that a local buckling check is required for a wall thickness of maximum 5.0 mm, which will be much smaller than the anticipated wall thickness based on internal pressure and on-bottom stability. This will be checked during detailed design.

6.6. Bar buckling

In a free span the pipeline will be susceptible to bar buckling. Bar buckling may occur due to an effective axial compressive force (N) in the pipeline. The compressive force in an axially restrained pipeline is based on the longitudinal stress:

$$N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$$

Where:

A = cross sectional area of steel (mm^2)

ν = Poisson's ratio for elastic deformation (-) => 0.3

S_h = factored hoop stress (N/mm^2)

γ_t = load factor as given in Table 5-3 (-)

α = coefficient of thermal expansion (m/m/°C)

ΔT = pipeline temperature differential (° C) (design – installation)

The factored hoop stress (S_h) is calculated from:

$$S_h = \gamma_P \cdot \sigma_h$$

and

$$\sigma_h = \frac{P_d \cdot (OD - t_{\min})}{2 \cdot t_{\min}}$$

Where:

P_d = design pressure (N/mm^2)

t_{min} = minimum pipe wall thickness (mm)

OD = outside diameter of steel pipe (mm)

γ_P = load factor as given in Table 5-3 (-)

The buckling length is based on the Euler buckling load definition, defined in Ref. [3]. Bar buckling is avoided if the span length fulfils:

$$L \leq \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$$

Where:

L = allowable span length (mm)

I = moment of inertia (mm^4)

7. Free Span analysis

Spanning of a pipeline on the seabed causes forces and stresses in the pipe. The criterion for accepting a pipeline configuration is that the pipe should not be subjected to over-stressing, nor to excessive dynamic loading because of resonant oscillations of the pipe caused by the vortex shedding phenomenon during installation, testing and throughout its operating life.

The pipeline span assessment includes the following items:

- Static span analysis
- Dynamic span analysis.

The static analysis concerns the determination of the pipe stresses under functional- and static environmental loads for a given span length.

The dynamic span analysis is based on criteria for prevention of vortex induced vibrations (VIV) as outlined in NEN 3656 considering both current- and wave induced velocities.

In addition, operational limits of the trenching equipment, limits the span gap (distance between the pipe and the seabed).

Although the pipeline will be buried below the seabed prior to its operation, the pipeline must be checked for spanning for the period between installation and burial.

In the analysis, along with the seabed topography, both functional and environmental loads are taken into consideration to check pipeline structural integrity under the considered load cases.

7.1. Static span

Combining hoop, longitudinal and bending stresses in the pipeline, which shall satisfy criteria for equivalent stresses, gives the maximum allowable static span lengths. Checks are to be made for the installation, hydro test and operational load case.

The maximum bending moment is calculated from the (vector) combination of the pipelines' own weight and hydrodynamic forces for the maximum wave condition:

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Where:

γ_W = load factor as per Table 5-3 (-)

γ_H = load factor as per Table 5-3 (-)

End fixity of an actual span is commonly assumed between fixed - fixed and fixed – pinned and the bending moment (M) calculated from:

$$M = \frac{q \cdot L^2}{10}$$

Where:

L = Maximum allowable span length [m]

The maximum allowable bending moment (M_{all}) is given by:

$$M_{all} = \frac{2 \cdot I \cdot \sigma_b}{OD}$$

Where:

I = moment of inertia (m^4)

OD = pipeline outside diameter (m)

s_b = maximum allowable bending stress

The maximum allowable static span can then be determined by:

$$L\max = \sqrt{\frac{20 \cdot \sigma_b \cdot I}{OD \cdot q}}$$

The maximum allowable span length follows from the condition that the equivalent stress (S_e) from the load combination satisfies the following conditions:

For the operational and hydrotest cases: $S_e \leq 0.85 \times (R_e + R_{ev}) / \gamma_m$

For the installation case: $S_e \leq R_e / \gamma_m$

Where:

R_e = minimum yield stress at 20 °C (N/mm^2)

R_{ev} = minimum yield stress at design temperature (N/mm^2)

γ_m = material factor (-) => 1.1

7.1.1. Load cases

The maximum static span will be determined for the load cases, and considering the environmental load return periods, as detailed in Table 7-1:

Condition	Wave Height Return Period	Current velocity Return Period
Installation	$H_{max,1yr}$	1 yr
Hydrotest	$H_{max,1yr}$	1 yr
Operational,1	$H_{max,100yr}$	10 yr
Operational,2	$H_{max,10yr}$	100 yr

Table 7-1 Load Cases for Span Assessment

7.2. Dynamic span

Flow of water particles induced by currents and waves perpendicular to a spanning pipeline or riser span can lead to vortices being shed. This will disrupt the flow around the pipe and thereby potentially cause periodic loads on the pipeline or riser, also known as Vortex Induced Vibration (VIV).

The natural frequency of a span being close to the vortex shedding frequency can result in a resonant oscillation, possibly resulting in fatigue failure of the pipeline or riser.

The oscillations of the span may occur in two directions:

- in line with the flow (parallel to the flow direction of the water particles)
- in cross flow direction (perpendicular to the flow direction of the water particles)

When assessing VIV, the span should be confirmed to be within acceptable limits set by either avoidance of VIV or an acceptable fatigue life for both the installation and operational condition.

Relevant dimensionless parameters governing the VIV phenomenon are the reduced velocity (V_r) and stability parameter (K_s).

The reduced velocity (V_r) parameter is defined by:

$$V_r = \frac{V_s}{f_{n} \cdot OD_{tot}}$$

Where,

V_s = water particle velocity due to current and significant wave (m/s)

f_n = 1st natural frequency of the pipe span (1/s)

OD_{tot} total outside diameter of the pipe (m)

The 1st natural frequency can be calculated from:

$$f_n = \frac{a}{2\pi} \cdot \sqrt{\frac{E \cdot I}{m_e \cdot L^4}}$$

Where,

a = frequency factor (-) => 15.4 for a fixed-pinned beam, which is used for the pipe

E = Young’s modulus (N/m^2)

I = moment of inertia (m^4)

L = length of span in pipeline / riser (m)

The effect of the CWC on the moment of inertia and the Young’s modulus is not taken into account; this is a conservative approximation. The outer diameter is including the CWC.

The stability parameter (K_s) is defined by:

$$K_s = \frac{2 \cdot m_e \cdot \delta}{\rho_{sw} \cdot OD_{tot}^2}$$

Where,

m_e = effective mass of pipe (kg/m)

ρ_{sw} = density seawater (kg/m^3)

δ = logarithmic decrement of damping (-) => δ = 0.126 for steel

The effective mass of the pipe can be calculated as:

$$m_e = m + \pi/_4 \cdot C_M \cdot \rho_{sw} \cdot OD_{tot}{}^2$$

Where,

m = Pipeline / riser mass (kg/m)

Cm = added mass coefficient (-)

NEN 3656 states that In-line oscillations will occur if $K_s \leq 1.8$ and cross flow oscillations will occur if $K_s \leq 16$.

7.2.1. In-line VIV

NEN 3656 furthermore states that in-line oscillations of the span occur if the reduced velocity is within the range of: $1.0 \leq Vr \leq 3.5$

Vortices around a spanning pipe occur in a relatively steady state environment. The wave induced velocity varies from a maximum at t=0, to zero at t=1/4*Twave. Furthermore, the system does not respond instantaneously to the applied forcing. To ignore the wave induced velocity in assessing the allowable dynamic span length would be too optimistic, to account for the maximum induced value would be too conservative, therefore reference is made to DNV-RP-F105. “Free Spanning Pipelines.” (ref. [3]).

According to Ref. [3], fatigue damage due to in-line VIV can be neglected if the current flow velocity ratio α, as defined by the equation below is smaller than 0.8.

$$\alpha = \frac{v_{cur}}{v_{cur} + v_{wave}}$$

Where,

v_{cur} = Particle velocity due to current [m/s]

v_{wave} = Particle velocity due to waves [m/s]

7.2.2. Cross-flow VIV

The occurrence of cross flow oscillations depends on the magnitude of the Reynolds number, Re, and the reduced velocity as given in Figure 7-1.

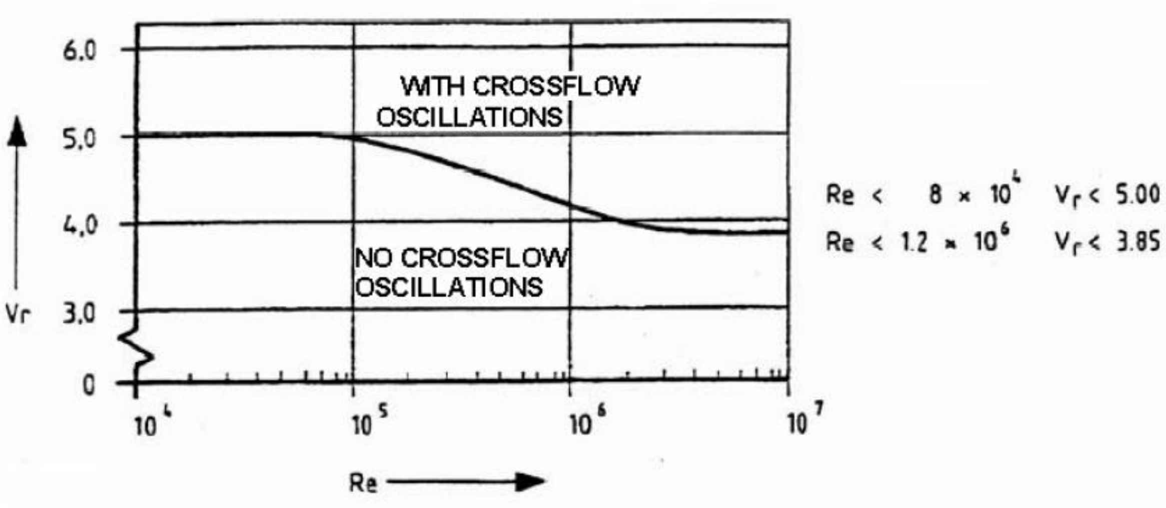


Figure 7-1 Reduced velocity for cross flow oscillations

$$\mathrm{Re} = \frac{\mathrm{v} \cdot OD_{tot}}{\nu}$$

Where,

v = particle velocity (m/s)

OD_{tot} = pipeline outside diameter (m)

n = Kinematic viscosity water (m^2/s) => 1,307 x 10^{-6} (at 10 °C)

8. Bottom roughness

8.1. General

To ensure the structural integrity of the pipeline over its entire design life finite element analyses will be carried out using industry proven software like Ansys or RFEM.

The analysis will assess the interaction between the pipeline and the supporting soil along the entire pipeline route and will be carried out in accordance with the requirements of NEN 3656 (Ref. [1]). The analysis will determine the number of spans exceeding the allowable span length and the subsequent pre-sweeping requirements. The design loads at the tie-in locations will be determined and in addition the analysis will assess the upheaval buckling response of the pipeline system under operating conditions.

The analysis will account for the load history of the pipelines over the design life by considering the following load cases:

- Installation (empty);
- Installation (flooded);
- Pipeline operation - nominal (nominal wall thickness content filling maximum operating pressure and temperature);
- Pipeline operation - corroded (corroded wall thickness content filling maximum operating pressure and temperature).

The pipeline will be modelled by uniaxial elements with tension-compression torsion and bending capabilities and can account for internal pressure effects. The element is a 3D element with six degrees of freedom translations in the x y and z directions and rotations about the x y and z axes. In addition the element needs to account for buoyancy wave and current loads and to be capable of large deflections and rotations.

The pipeline is to be modelled with a maximum element length of 0.5 – 1.0 m and accounts for all curvatures in the horizontal plane and undulations in the vertical plane. Pipe-soil interaction is simulated using three independent non-linear spring elements attached to each pipe element. The springs represent the soil frictional resistance in the axial and lateral directions and the soils bearing capacity in the vertical direction.

For sections of the pipeline which are buried additional vertical non-linear springs representing the uplift resistance of the trench backfill material will be attached to the pipe elements.

Seabed roughness will be simulated by displacing the vertical springs representing the soil bearing capacity to the correct depth based on the bathymetric data and allowing the pipe to move and rest on the vertical springs.

When the depth of the pipeline at a certain point is less than the depth of the seabed a "free span" is identified. Similar succeeding joints indicate a larger span. The length of the free span is determined by subtracting the coordinates of the beginning of the span from the coordinates of the span end.

At pipeline termination points an additional axial spring will be attached to the pipeline ends to incorporate the structural response of the subsea tie-in spool/riser and supporting piping.

8.2. Pipe-soil interaction

The characteristics of the springs which simulate the pipe-soil interaction are defined through non-linear force deflection curves. These force-deflection curves describe the frictional restraint provided by the soil to the pipeline in the axial lateral direction and the soils bearing capacity /upwards resistance in the vertical direction.

2 situations can be distinguished:

- exposed pipeline
    - axial soil resistance;
    - lateral soil resistance;
    - vertical bearing capacity (downward resistance);

- buried pipeline
    - axial soil resistance;
    - lateral soil resistance;
    - vertical bearing capacity (downward resistance);
    - vertical upward soil resistance;

Table 8-1 gives an overview of the calculation basis of the mentioned soil resistances/capacities.

Direction	Exposed pipeline	Buried pipeline
Axial	Function of pipe submerged weight and axial Coulomb friction coefficient	Function of pipe diameter, burial depth and effective unit soil weight.
Lateral	Combination of Coulomb friction part and passive soil resistance due to build-up of soil penetration (ref. [5])	Based on horizontal bearing capacity factor (ref. [9])
Vertical bearing	Based on bearing capacity formulas for ideal 2-D strip foundations ref. [3]	Based on bearing capacity formulas for ideal 2-D strip foundations ref. [3]
Vertical upward	N/A	As per ref. [6] based on burial depth pipe diameter and submerged soil weight

Table 8-1 Overview soil resistance/capacity calculation basis

9. Upheaval Buckling

Buried pipelines exposed to compressive effective axial forces may get unstable beyond its anchor point and move vertically out of the seabed if the cover has insufficient resistance. An out-of-straightness configuration will result in forces acting on the cover perpendicular to the pipeline. In case these vertical forces exceed the cover resistance the pipeline will buckle upwards.

The relation between minimum required cover height and the imperfection height (out-of-straightness) will be established in accordance with ref. [11].

Parameters used in the assessment of upheaval buckling are the dimensionless imperfection length parameter (Φ_L):

$$\Phi_L = L \cdot \sqrt{\frac{N_e}{EI}}$$

Where:

L = exposure length (m)

N_e = effective axial compressive force (N)

EI = bending stiffness (N m^2)

And the dimensionless maximum download parameter (Φ_w):

$$\Phi_w = \frac{w \cdot E \cdot I}{\Delta_{calc} \cdot N_e^2}$$

Where:

w = required download [N/m]

Δ_{calc} = imperfection height [m]

Depending on the Φ_L value the required download is derived from Φ_w in accordance with:

$$\Phi_w = 0.0646 \quad \text{for} \quad \Phi_L < 4.49$$

$$\Phi_w = \frac{5.68}{\phi_L^2} - \frac{88.35}{\phi_L^4} \quad \text{for} \quad 4.49 < \Phi_L < 8.06$$

$$\Phi_W = \frac{9.6}{\phi_L^2} - \frac{343}{\phi_L^4} \quad \text{for} \quad \Phi_L > 8.06$$

In cohesionless soils the uplift resistance (q) due to the cover of the pipe can be calculated from:

$$q = \gamma \cdot H \cdot OD \cdot \left(1 + f \cdot \frac{H}{OD}\right)$$

Where:

γ = effective under water weight of soil (N/m^3)

H = depth of cover (m)

OD = outside diameter of pipe (m)

f = uplift coefficient
0.5 for dense material
0.1 for loose material

The calculated required download (w) shall be smaller than the actual combination of the submerged weight and uplift resistance of the pipeline.

The simplified method from Reference [11] is conservative in that it does not model a number of mitigating factors such as:

- The finite axial stiffness of the pipeline which determines how rapidly the axial force diminishes as the pipeline moves upwards
- The pipeline resistance to axial movement through the soil determines how far the pipeline can slide towards a developing buckle.

Both the above factors may cause progressive upheaval buckling predicted by the analysis method in Reference [11] not to occur.

Further the sinusoidal imperfection profile assumed in the model is envisaged to yield conservative download requirements.

The results will be presented as a maximum imperfection length with respect to the cover depth and the imperfection height.

10. Cathodic Protection

As per NEN 3656 the cathodic protection system of the pipeline bundle will be designed as per ref. [12]. The characteristics of a typical anode element are given in Table 10-1.

Item	Value
Type	Half Shell Bracelet
Material	Aluminium
Cable connections	2 x @ 20” pipeline

Table 10-1 Typical anode characteristics

The cathodic protection will be designed to prevent external corrosion of the pipeline. The mass and spacing of the anodes will be such that the following criteria are met:

- Total anode mass to meet the mean and final current demand over the design life of the pipeline.
- Anode current output to meet the required current output at the end of the design life.
- Anode separation not to exceed a value of 300 m.

The pipeline will be divided in to sections where changes in conditions, such as water depth, operating temperature or burial, can give rise to variations in design current density.

From the pipeline dimensions and the coating selected, the mean current demand, I_{cm}, and the final demand, I_{cf}, shall be calculated separately as per the following:

$$I_c = A_c \cdot f_c \cdot i_c$$

Where:

I_c = the current demand for a specific pipeline section calculated for mean and final conditions (A)

A_c = the total surface area for a specific pipeline section (m^2)

f_c = the coating breakdown factor determined for mean and final conditions (-)

i_c = the current density selected for mean and final conditions (A/m^2)

For pipelines fully buried, a design current density (mean and final) of 20 mA/m^2 should be used irrespective of seawater temperature, oxygen content or depth as per Section 7.4.3 of Ref. [12].

The coating breakdown factors for mean and final conditions, f_c, taking into consideration the deign life of the pipeline, are calculated as follows.

The mean coating breakdown factor, $\overline{f_c}$, is determined by:

$$\overline{f_c} = f_i + (0.5\Delta f \cdot t_{dl})$$

And the mean coating breakdown factor, f_f , is determined by

$$f_f = f_i + (\Delta f \cdot t_{dl})$$

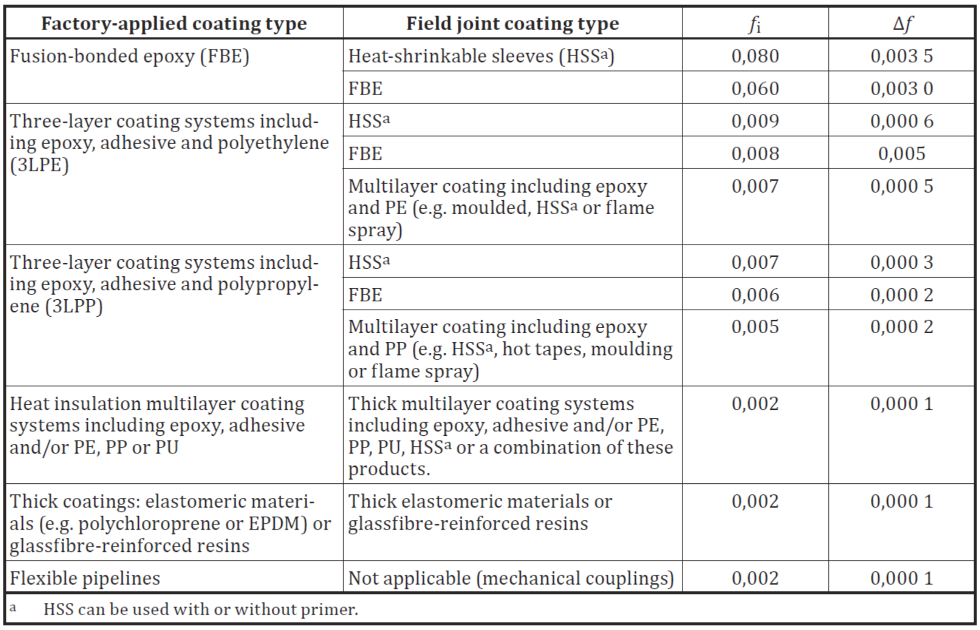
Where:

f_i = the initial coating breakdown factor at the start of pipeline operation (-)

Δf = the average yearly increase in the coating breakdown factor (-)

t_{dl} = the design life (yrs)

The initial coating breakdown factor and average yearly increase in breakdown factor are dependent on the anti-corrosion coating and field joint coating material. Values for various coating are taken from [12] and reported in Table 9-2.



Factory-applied coating type	Field joint coating type	f_i	Δf
Fusion-bonded epoxy (FBE)	Heat-shrinkable sleeves (HSS[a])	0,080	0,003 5
	FBE	0,060	0,003 0
Three-layer coating systems including epoxy, adhesive and polyethylene (3LPE)	HSS[a]	0,009	0,000 6
	FBE	0,008	0,005
	Multilayer coating including epoxy and PE (e.g. moulded, HSS[a] or flame spray)	0,007	0,000 5
Three-layer coating systems including epoxy, adhesive and polypropylene (3LPP)	HSS[a]	0,007	0,000 3
	FBE	0,006	0,000 2
	Multilayer coating including epoxy and PP (e.g. HSS[a], hot tapes, moulding or flame spray)	0,005	0,000 2
Heat insulation multilayer coating systems including epoxy, adhesive and/or PE, PP or PU	Thick multilayer coating systems including epoxy, adhesive and/or PE, PP, PU, HSS[a] or a combination of these products.	0,002	0,000 1
Thick coatings: elastomeric materials (e.g. polychloroprene or EPDM) or glassfibre-reinforced resins	Thick elastomeric materials or glassfibre-reinforced resins	0,002	0,000 1
Flexible pipelines	Not applicable (mechanical couplings)	0,002	0,000 1

[a] HSS can be used with or without primer.

Table 10-2 Coating breakdown factors [12]

Having established the mean current demand, the total required mass of anode material for a specific pipeline section is determined as follows:

$$m = I_{cm} \cdot t_{dl} \cdot \frac{8760}{\mu \cdot \varepsilon}$$

Where:

m = the total net anode mass, for the specific pipeline section (kg)

I_{cm} = the mean current demand for the specific pipeline section (A)

μ = is the utilization factor (-) = 0.8 for bracelet anodes as per Section 8.4 of Ref. [12].

ε = the electrochemical capacity of the anode material per kilogram (A/h)

The electrochemical capacity of the anode material is dependent on the surface temperature of the anode and its burial status. The applicable values are taken from Section 8.3 of Ref. [12] and reported in Table 9-3.

Having determined the total net anode mass required to meet the current demand, the minimum number of anodes required in a specific pipeline section, will be determined as follows:

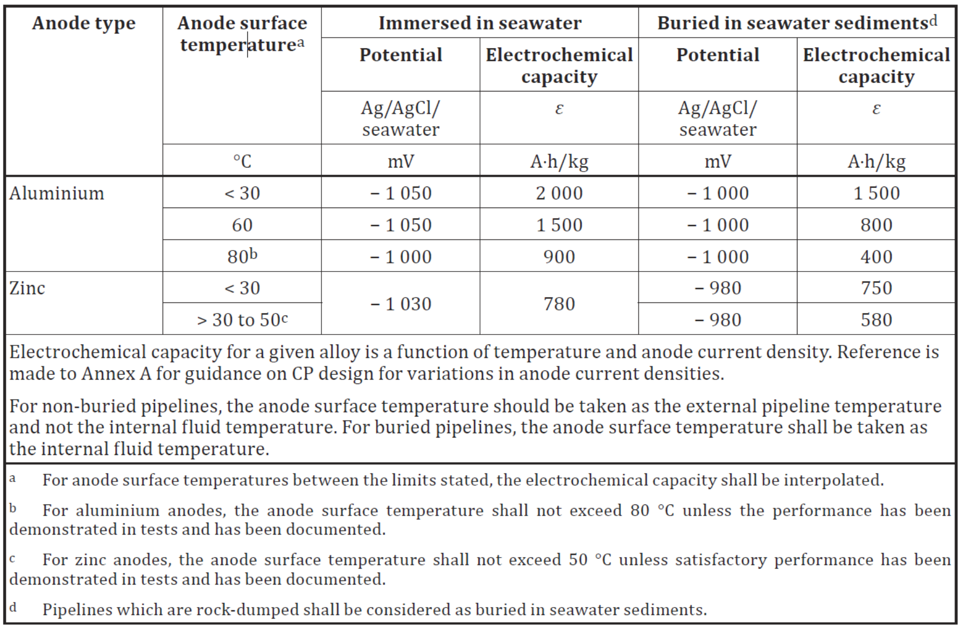
$$n = \frac{m}{m_a}$$

Where:

n = the number of anodes to be installed on the specific pipeline section (-)

m_a = the individual net anode mass (kg)

The minimum number of anodes, n, shall be determined considering the maximum allowable anode spacing of 300m as reported in Section 8.1 of Ref. [12].



Anode type	Anode surface temperature[a]	Immersed in seawater		Buried in seawater sediments[d]	
		Potential	Electrochemical capacity	Potential	Electrochemical capacity
		Ag/AgCl/ seawater	ε	Ag/AgCl/ seawater	ε
	°C	mV	A·h/kg	mV	A·h/kg
Aluminium	< 30	− 1 050	2 000	− 1 000	1 500
	60	− 1 050	1 500	− 1 000	800
	80[b]	− 1 000	900	− 1 000	400
Zinc	< 30	− 1 030	780	− 980	750
	> 30 to 50[c]			− 980	580

Electrochemical capacity for a given alloy is a function of temperature and anode current density. Reference is made to Annex A for guidance on CP design for variations in anode current densities.

For non-buried pipelines, the anode surface temperature should be taken as the external pipeline temperature and not the internal fluid temperature. For buried pipelines, the anode surface temperature shall be taken as the internal fluid temperature.

[a] For anode surface temperatures between the limits stated, the electrochemical capacity shall be interpolated.

[b] For aluminium anodes, the anode surface temperature shall not exceed 80 °C unless the performance has been demonstrated in tests and has been documented.

[c] For zinc anodes, the anode surface temperature shall not exceed 50 °C unless satisfactory performance has been demonstrated in tests and has been documented.

[d] Pipelines which are rock-dumped shall be considered as buried in seawater sediments.

Table 10-3 Design values for galvanic anodes [12]

To provide the required current, the actual anode current output shall be greater than or equal to the required current output:

$$I_{af} \geq I_f$$

Where:

I_{af} = the actual end-of-life individual current output (A)
I_f = the required end-of-life individual anode current output (A)

The required end-of-life individual anode current output, I_f, shall be calculated from the following:

$$I_f = \frac{I_{cf}}{n}$$

Where:

I_{cf} = the total current demand for the protection of the specific pipeline section at the end of life (A)

For a given anode size and mass, the actual individual anode current output at the end of life, I_{af}, is calculated from the below equation:

$$I_{af} = \frac{E_c - E_a}{R_a}$$

Where:

E_c = the design protection potential (V)
E_a = the design closed-circuit potential of the anode (V)
R_a = the total circuit resistance, which is assumed to be equivalent to the anode resistance (ohms)

The anode resistance, R_a, shall be calculated as follows:

$$R_a = 0.315 \frac{\rho}{\sqrt{A}}$$

Where:

ρ = the environmental resistivity (ohm.m)
A = the exposed surface area of the anode (m^2)

For determining the end-of-design-life anode-to-seawater resistance, the anodes shall be assumed to be consumed to an extent given by their utilization factor. The approximate anode dimensions (exposed surface area) corresponding to this degree of wastage shall be used in the anode resistance formula for R_a.

A. Environmental Data GEOxyz

Magnetic Contacts

MAG ID	Easting	Northing	Size nT
MAG_001	717953,7	5940271,5	1846
MAG_002	717991,0	5940276,5	2449
MAG_003	718039,9	5940290,0	1412
MAG_004	718041,2	5940299,0	88
MAG_005	718096,4	5940310,5	5750
MAG_006	718148,3	5942788,5	35
MAG_007	718149,5	5940331,0	2207
MAG_008	718198,9	5940350,5	4606
MAG_009	718247,8	5940365,0	878
MAG_010	718312,4	5940395,0	4218
MAG_011	718346,7	5940412,0	1847
MAG_012	718409,7	5940429,5	1254
MAG_013	718424,0	5944905,0	44
MAG_014	718444,3	5942692,5	828
MAG_015	718462,9	5941110,5	163
MAG_016	718472,4	5940453,5	1966
MAG_017	718484,8	5942724,5	4590
MAG_018	718491,8	5940449,0	962
MAG_019	718506,9	5942723,0	1900
MAG_020	718508,2	5942754,0	9330
MAG_021	718509,3	5940455,5	558
MAG_022	718516,3	5942748,5	5361
MAG_023	718534,0	5942694,0	1157
MAG_024	718548,1	5945123,5	32

MAG_025	718565,1	5940481,0	3279
MAG_026	718595,9	5942616,0	52
MAG_027	718617,5	5940493,0	5243
MAG_028	718662,3	5940506,0	613
MAG_029	718720,1	5940516,0	2386
MAG_030	718766,9	5940523,0	2963
MAG_031	718829,4	5940541,0	706
MAG_032	718856,6	5940558,0	9291
MAG_033	718875,8	5944329,5	23
MAG_034	718975,9	5941798,0	86
MAG_035	718995,8	5942736,5	67
MAG_036	719033,8	5946829,5	22
MAG_037	719274,9	5946749,5	136
MAG_038	719349,1	5948063,0	51
MAG_039	719395,2	5946438,0	14
MAG_040	719449,5	5948089,0	11
MAG_041	719489,0	5947981,0	40
MAG_042	719645,7	5947744,5	73
MAG_043	720080,7	5949053,0	11
MAG_044	720398,8	5952407,0	22
MAG_045	720432,3	5952500,5	428
MAG_046	720451,3	5952357,0	15
MAG_047	720452,1	5952553,0	197
MAG_048	720492,5	5952478,5	6757
MAG_049	720507,6	5952530,5	846
MAG_050	720589,2	5952492,5	539
MAG_051	720687,5	5951846,0	11
MAG_052	720733,6	5952469,5	17

MAG_053	720796,44	5954306,50	11
MAG_054	720823,9	5952486,5	38
MAG_055	720895,0	5952512,5	195
MAG_056	720896,6	5952528,5	258
MAG_057	720966,9	5952512,5	155
MAG_058	720972,6	5952521,0	30
MAG_059	720981,25	5955029,50	15
MAG_060	721006,69	5954892,50	18
MAG_061	721006,69	5954892,5	18
MAG_062	721043,6	5954396,5	50
MAG_063	721043,63	5954396,50	50
MAG_064	721043,6	5954396,5	50
MAG_065	721050,88	5954393,50	66
MAG_066	721050,9	5954393,5	66
MAG_067	721050,9	5954393,5	66
MAG_068	721097,9	5953584,0	8
MAG_069	721144,6	5952537,5	59
MAG_070	721224,2	5952542,0	88
MAG_071	721272	5954784,5	23
MAG_072	721272,00	5954784,50	23
MAG_073	721272,0	5954784,5	23
MAG_074	721395,3	5952547,0	97
MAG_075	721424,3	5952569,5	110
MAG_076	721424,88	5954616,50	285
MAG_077	721424,9	5954616,5	285
MAG_078	721424,88	5954616,5	285
MAG_079	721424,9	5954616,5	285
MAG_080	721430,5	5952680,5	22

MAG_081	721567,25	5954416,50	12
MAG_082	721567,3	5954416,5	12
MAG_083	721567,25	5954416,5	12
MAG_084	721567,3	5954416,5	12
MAG_085	721568,5	5954404,5	22
MAG_086	721568,50	5954404,50	22
MAG_087	721571,7	5954762,5	18
MAG_088	721571,69	5954762,50	18
MAG_089	721571,69	5954762,5	18
MAG_090	721571,7	5954762,5	18
MAG_091	721615,3	5954915,0	27
MAG_092	721615,25	5954915,00	27
MAG_093	721615,25	5954915	27
MAG_094	721615,3	5954915	27
MAG_095	721625,25	5954596,50	53
MAG_096	721625,3	5954596,5	53
MAG_097	721625,25	5954596,5	53
MAG_098	721625,3	5954596,5	53
MAG_099	721625,4	5954919,0	28
MAG_100	721625,38	5954919,00	28
MAG_101	721625,38	5954919	28
MAG_102	721625,4	5954919	28
MAG_103	721645,7	5954971,5	66
MAG_104	721645,69	5954971,50	66
MAG_105	721645,69	5954971,5	66
MAG_106	721645,7	5954971,5	66
MAG_107	721650,5	5954550	376
MAG_108	721650,50	5954550,00	376

MAG_109	721650,5	5954550,0	376
MAG_110	721657,8	5954589	358
MAG_111	721657,8	5954589,0	358
MAG_112	721657,81	5954589,00	358
MAG_113	721657,81	5954589	358
MAG_114	721658,0	5954624,0	45
MAG_115	721658,00	5954624,00	45
MAG_116	721658	5954624	45
MAG_117	721666,7	5954576,0	1100
MAG_118	721666,69	5954576,00	1100
MAG_119	721666,69	5954576	1100
MAG_120	721666,7	5954576	1100
MAG_121	721670,5	5954647,5	27
MAG_122	721670,50	5954647,50	27
MAG_123	721672,2	5954562,0	2733
MAG_124	721672,19	5954562,00	2733
MAG_125	721672,19	5954562	2733
MAG_126	721672,2	5954562	2733
MAG_127	721683,56	5954529,00	252
MAG_128	721683,6	5954529,0	252
MAG_129	721683,56	5954529	252
MAG_130	721683,6	5954529	252
MAG_131	721685,69	5954453,00	110
MAG_132	721685,7	5954453,0	110
MAG_133	721685,69	5954453	110
MAG_134	721685,7	5954453	110
MAG_135	721691,2	5954590,0	360
MAG_136	721691,19	5954590,00	360

MAG_137	721691,19	5954590	360
MAG_138	721691,2	5954590	360
MAG_139	721695,69	5954426,00	35
MAG_140	721695,7	5954426,0	35
MAG_141	721695,69	5954426	35
MAG_142	721695,7	5954426	35
MAG_143	721702,2	5954504,0	58
MAG_144	721702,19	5954504,00	58
MAG_145	721702,19	5954504	58
MAG_146	721702,2	5954504	58
MAG_147	721708,19	5954468,00	119
MAG_148	721708,2	5954468,0	119
MAG_149	721708,19	5954468	119
MAG_150	721708,2	5954468	119
MAG_151	721709,3	5954964,0	21
MAG_152	721709,25	5954964,00	21
MAG_153	721709,25	5954964	21
MAG_154	721709,3	5954964	21
MAG_155	721806,3	5954401,5	10
MAG_156	721806,3	5954401,5	10
MAG_157	721806,31	5954401,50	10
MAG_158	721806,31	5954401,5	10
MAG_159	722858,06	5954425,00	43
MAG_160	722858,1	5954425,0	43
MAG_161	722858,1	5954425	43
MAG_162	723840,1	5954855,5	31
MAG_163	723840,13	5954855,50	31
MAG_164	723843,06	5954772,50	17

MAG_165	723843,1	5954772,5	17
MAG_166	723868,19	5954698,50	23
MAG_167	723868,2	5954698,5	23
MAG_168	723879,8	5954617	25
MAG_169	723879,81	5954617,00	25
MAG_170	723905,06	5954389,00	15
MAG_171	723905,1	5954389,0	15
MAG_172	723905,1	5954389	15
MAG_173	723911,8	5954159	16
MAG_174	723911,81	5954159,00	16
MAG_175	723927,25	5954010,00	14
MAG_176	723927,3	5954010	14
MAG_177	723945,06	5953933,50	16
MAG_178	723945,1	5953933,5	16
MAG_179	724080,88	5954522,00	40
MAG_180	724080,9	5954522,0	40
MAG_181	724080,9	5954522	40
MAG_182	724147,19	5954742,00	61
MAG_183	724147,2	5954742	61
MAG_184	724181,8	5954587,5	57
MAG_185	724181,81	5954587,50	57
MAG_186	724182,56	5954368,00	43
MAG_187	724182,6	5954368,0	43
MAG_188	724182,6	5954368	43
MAG_189	724191,56	5954659,00	54
MAG_190	724191,6	5954659	54
MAG_191	724205	5954508,5	31
MAG_192	724205,00	5954508,50	31

MAG_193	724205,0	5954508,5	31
MAG_194	724223,6	5954348,5	27
MAG_195	724223,63	5954348,50	27
MAG_196	724223,6	5954348,5	27
MAG_197	724298,25	5954723,50	41
MAG_198	724298,3	5954723,5	41
MAG_199	724410,1	5954332	36
MAG_200	724410,13	5954332,00	36
MAG_201	724410,1	5954332,0	36
MAG_202	724420,9	5954339	38
MAG_203	724420,94	5954339,00	38
MAG_204	724420,9	5954339,0	38
MAG_205	724426,56	5954103,00	27
MAG_206	724426,6	5954103	27
MAG_207	724436,6	5954034	31
MAG_208	724436,63	5954034,00	31
MAG_209	724442,19	5954251,00	18
MAG_210	724442,2	5954251,0	18
MAG_211	724442,2	5954251	18
MAG_212	724449,06	5954180,50	16
MAG_213	724449,1	5954180,5	16
MAG_214	724449,1	5954180,5	16
MAG_215	724509,3	5953941,5	48
MAG_216	724509,31	5953941,50	48
MAG_217	724512,88	5954320,50	12
MAG_218	724512,9	5954320,5	12
MAG_219	724512,9	5954320,5	12
MAG_220	724611,8	5953854,5	26

MAG_221	724611,81	5953854,50	26
MAG_222	724706,25	5953751,50	26
MAG_223	724747,06	5953610,50	37
MAG_224	724772,75	5953676,00	29
MAG_225	725618,75	5953886,50	38
MAG_226	725618,8	5953886,5	38
MAG_227	726342,9	5953654	25
MAG_228	726342,94	5953654,00	25
MAG_229	727182,38	5954201,00	25
MAG_230	727182,4	5954201,0	25
MAG_231	727182,4	5954201	25
MAG_232	727518,9	5953952	5
MAG_233	727518,94	5953952,00	5
MAG_234	728994,88	5954791,50	14
MAG_235	728994,9	5954791,5	14
MAG_236	728994,9	5954791,5	14
MAG_237	729047,19	5955011,50	14
MAG_238	729047,2	5955011,5	14
MAG_239	729615,69	5955031,50	26
MAG_240	729615,7	5955031,5	26
MAG_241	729615,7	5955031,5	26

Side Sonar Scan Contacts

Contact ID	Easting	Northing	Height	Contact Type
DEB_001	718843,3	5945900,7	5.9x1.5x0.1	Debris
DEB_002	718696,2	5943976,4	3.0x0.3x0.1	Debris
DEB_003	718510,6	5942751,2	1.5x1.7xnmh	Debris
DEB_004	718689,5	5942724,0	3.0x0.5x0.3	Debris

DEB_005	718419,5	5942669,9	0.8x0.3x0.1	Debris
DEB_006	718479,3	5942653,2	2.5x1.2x0.1	Debris
DEB_007	718581,4	5942595,0	5.0x1.3x0.3	Debris
DEB_008	718582,9	5942591,3	4.1x1.0x0.6	Debris
DEB_009	718580,4	5942585,2	1.8x0.5x0.2	Debris
DEB_010	718589,2	5942584,2	5.1x2.4x0.3	Debris
DEB_011	718584,4	5942581,4	4.1x3.3x0.5	Debris
DEB_012	718550,1	5942539,3	1.4x0.8x0.2	Debris
DEB_013	718606,0	5942526,9	2.9x1.0x0.6	Debris
DEB_014	718630,6	5942524,1	2.0x0.5x0.1	Debris
DEB_015	720403,1	5952036,9	1.9x0.7x0.2	Wreck
DEB_016	718395,4	5945567,7	1.0x0.7x0.1	Wreck
DEB_017	718387,7	5945566,4	3.9x0.5x0.1	Debris
DEB_018	718282,9	5944250,1	1.6x0.7x0.3	Debris
DEB_019	718930,1	5944019,3	6.2x1.8x0.4	Debris
DEB_020	718995,4	5943832,0	2.0x0.6x0.2	Debris
DEB_021	718878,1	5943526,3	2.1x0.7x0.2	Debris
DEB_022	718167,1	5942830,6	2.2x0.8x0.2	Debris
DEB_023	718254,5	5942712,2	2.9x1.1x0.1	Debris
DEB_024	718142,1	5942390,0	3.4x1.6x0.8	Debris
DEB_025	718784,2	5941352,3	3.3x1.5xnmh	Debris
DEB_026	718687,6	5941281,5	1.4x0.6x0.1	Debris
SSS_001	720764,04	5955368,29	0,9	Debris
SSS_002	720829,13	5954453,20	0,6	Debris
SSS_003	720820,73	5954342,72	0,6	Object
SSS_004	720821,77	5954270,88	0,5	Object
SSS_005	720880,99	5954431,59	0,6	Object
SSS_006	720892,17	5954300,94	0,8	Object

SSS_007	720893,26	5954290,00	0,7	Object
SSS_008	720905,80	5954298,46	0,9	Object
SSS_009	720945,81	5954410,62	0,6	Object
SSS_010	720952,19	5954327,47	0,6	Object
SSS_011	720959,37	5954364,43	0,6	Object
SSS_012	720960,29	5954352,58	0,7	Object
SSS_013	720968,48	5954364,83	0,6	Object
SSS_014	720988,35	5954348,47	1	Object
SSS_015	720987,94	5954062,19	0,9	Object
SSS_016	721039,97	5954486,91	0,6	Object
SSS_017	720995,11	5954033,91	0,8	Object
SSS_018	721014,90	5954205,53	0,5	Object
SSS_019	721048,07	5954440,97	0,5	Object
SSS_020	721014,60	5954144,86	0,6	Object
SSS_021	721047,79	5954403,65	0,8	Object
SSS_022	721023,57	5954124,07	0,8	Object
SSS_023	721031,84	5954112,67	0,6	Object
SSS_024	721055,06	5954273,47	0,5	Object
SSS_025	721070,04	5954387,96	0,5	Object
SSS_026	721047,65	5954157,24	0,8	Object
SSS_027	721039,23	5954011,52	0,5	Object
SSS_028	721083,56	5954252,55	0,6	Object
SSS_029	721077,94	5954055,23	0,5	Object
SSS_030	721120,45	5954342,55	0,6	Object
SSS_031	721082,86	5953986,73	0,5	Object
SSS_032	721096,70	5954103,85	0,6	Object
SSS_033	721124,20	5954225,46	0,6	Object
SSS_034	721108,47	5954016,11	1	Object

SSS_035	721111,52	5954015,55	0,6	Object
SSS_036	721154,23	5954387,61	0,5	Object
SSS_037	721200,49	5954647,37	0,6	Object
SSS_038	721129,50	5954019,15	0,7	Object
SSS_039	721147,68	5954077,59	0,5	Object
SSS_040	721189,65	5954331,95	0,8	Object
SSS_041	721166,42	5954080,67	0,7	Object
SSS_042	721183,36	5954184,19	0,5	Object
SSS_043	721204,09	5954287,89	0,7	Object
SSS_044	721200,07	5954168,32	0,5	Object
SSS_045	721202,45	5954182,88	0,6	Object
SSS_046	721195,78	5953987,53	0,5	Object
SSS_047	721381,17	5955392,95	1,1	Object
SSS_048	721235,00	5954040,36	0,6	Object
SSS_049	721304,21	5954594,42	1	Object
SSS_050	721246,88	5953990,00	0,7	Object
SSS_051	721321,53	5954595,76	0,9	Object
SSS_052	721290,57	5954297,19	0,6	Object
SSS_053	721343,86	5954472,53	0,5	Object
SSS_054	721373,40	5954458,69	0,5	Object
SSS_055	721419,15	5954712,64	0,7	Object
SSS_056	721408,52	5954529,08	1,3	Object
SSS_057	721395,63	5954262,43	0,6	Object
SSS_058	721395,15	5954252,77	0,7	Object
SSS_059	721458,06	5954747,89	0,9	Object
SSS_060	721444,60	5954037,80	0,6	Object
SSS_061	721455,66	5954048,13	0,5	Object
SSS_062	721554,96	5954666,23	0,8	Object

SSS_063	721517,58	5954248,05	0,6	Object
SSS_064	721523,03	5954218,83	0,7	Object
SSS_065	721637,89	5954907,07	0,7	Object
SSS_066	721648,13	5954914,13	0,5	Object
SSS_067	721571,49	5954203,12	0,5	Object
SSS_068	721656,39	5954932,11	1	Object
SSS_069	721616,00	5954554,46	0,6	Object
SSS_070	721674,18	5955016,59	0,5	Object
SSS_071	721655,25	5954793,46	0,7	Object
SSS_072	721625,01	5954519,17	0,7	Object
SSS_073	721680,77	5955011,05	0,7	Object
SSS_074	721652,06	5954564,38	0,6	Object
SSS_075	721604,57	5954084,46	0,7	Object
SSS_076	721626,38	5954092,91	0,5	Object
SSS_077	721625,38	5954063,72	0,7	Object
SSS_078	721717,09	5954862,86	0,6	Object
SSS_079	721718,05	5954870,34	0,7	Object
SSS_080	721738,42	5955038,28	0,7	Object
SSS_081	721723,22	5954856,19	0,6	Object
SSS_082	721624,62	5953973,00	0,7	Object
SSS_083	721767,69	5955126,00	0,6	Object
SSS_084	721775,98	5955044,12	0,7	Object
SSS_085	721796,01	5955132,17	0,8	Object
SSS_086	721801,77	5955134,43	0,7	Object
SSS_087	721710,89	5954302,92	0,5	Object
SSS_088	721800,27	5955078,78	0,5	Object
SSS_089	721746,76	5954595,75	0,6	Object
SSS_090	721788,65	5954958,66	0,6	Object

SSS_091	721808,34	5955123,30	0,6	Object
SSS_092	721684,49	5953956,43	1,6	Object
SSS_093	721798,86	5954964,39	0,6	Object
SSS_094	721766,62	5954616,90	0,8	Object
SSS_095	721819,68	5955039,44	0,8	Object
SSS_096	721759,40	5954496,67	0,6	Object
SSS_097	721704,59	5954008,27	0,5	Object
SSS_098	721712,63	5954066,90	1	Object
SSS_099	721703,78	5953951,67	0,9	Object
SSS_100	721791,38	5954654,79	0,5	Object
SSS_101	721764,51	5954382,53	0,5	Object
SSS_102	721772,48	5954430,59	0,6	Object
SSS_103	721847,33	5954926,04	0,6	Object
SSS_104	721815,38	5954641,85	0,6	Object
SSS_105	721788,50	5954369,26	0,6	Object
SSS_106	721854,68	5954924,85	0,5	Object
SSS_107	721825,40	5954588,20	0,5	Object
SSS_108	721829,40	5954595,07	0,6	Object
SSS_109	721851,99	5954594,19	0,6	Object
SSS_110	721858,18	5954627,12	0,6	Object
SSS_111	721880,66	5954700,94	0,6	Object
SSS_112	721850,61	5954434,71	0,6	Object
SSS_113	721810,07	5953955,71	0,7	Object
SSS_114	721968,21	5955303,95	0,5	Object
SSS_115	721896,80	5954569,62	0,7	Object
SSS_116	721926,97	5954712,77	0,5	Object
SSS_117	721940,17	5954537,16	0,7	Object
SSS_118	721949,13	5954256,82	0,7	Object

SSS_119	722061,99	5954903,71	0,5	Object
SSS_120	722026,14	5954527,01	0,7	Object
SSS_121	721976,86	5953947,97	0,6	Object
SSS_122	722031,16	5954397,32	0,7	Object
SSS_123	722007,93	5954191,32	0,6	Object
SSS_124	722037,39	5954431,37	0,9	Object
SSS_125	722065,60	5954532,75	0,5	Object
SSS_126	722072,28	5954539,20	0,5	Object
SSS_127	722049,53	5954224,70	0,8	Object
SSS_128	722128,63	5954814,33	0,6	Object
SSS_129	722131,17	5954814,97	0,5	Object
SSS_130	722141,98	5954862,02	0,5	Object
SSS_131	722091,64	5954408,44	0,8	Object
SSS_132	722066,30	5954157,96	0,6	Object
SSS_133	722079,71	5954193,94	0,6	Object
SSS_134	722127,92	5954494,60	0,5	Object
SSS_135	722094,41	5954197,41	0,5	Object
SSS_136	722100,07	5954244,99	0,7	Object
SSS_137	722112,91	5954349,57	1	Object
SSS_138	722112,75	5954276,00	0,7	Object
SSS_139	722119,71	5954332,11	0,6	Object
SSS_140	722168,47	5954646,15	0,5	Object
SSS_141	722175,02	5954701,14	0,7	Object
SSS_142	722117,03	5954180,65	0,5	Object
SSS_143	722162,02	5954289,85	0,6	Object
SSS_144	722256,41	5954766,99	0,8	Object
SSS_145	722258,54	5954554,99	0,6	Object
SSS_146	722266,05	5954620,89	0,5	Object

SSS_147	722266,66	5954547,24	0,6	Object
SSS_148	722348,34	5955174,34	1	Object
SSS_149	722271,90	5954311,52	0,5	Object
SSS_150	722326,41	5954704,99	1,1	Object
SSS_151	722299,30	5954139,59	1	Object
SSS_152	722362,88	5954613,53	0,6	Object
SSS_153	722407,24	5954745,37	0,6	Object
SSS_154	722397,54	5954086,30	0,6	Object
SSS_155	722524,39	5954965,64	0,7	Object
SSS_156	722504,06	5954768,70	0,5	Object
SSS_157	722557,20	5954951,23	0,6	Object
SSS_158	722475,09	5954215,99	0,6	Object
SSS_159	722536,86	5954258,29	0,7	Object
SSS_160	722583,42	5954193,39	0,5	Object
SSS_161	722664,75	5954088,19	0,5	Object
SSS_162	722698,08	5954168,32	0,7	Object
SSS_163	722990,18	5955000,42	0,6	Object
SSS_164	723059,38	5954145,40	0,6	Object
SSS_165	723228,22	5954951,32	0,8	Object
SSS_166	723230,39	5954954,08	0,6	Object
SSS_167	723246,39	5954499,21	0,8	Object
SSS_168	723264,94	5954042,88	0,6	Object
SSS_169	723277,68	5953991,55	0,8	Object
SSS_170	723288,81	5953947,23	0,5	Object
SSS_171	723312,59	5954027,25	0,5	Object
SSS_172	723325,45	5954026,92	0,6	Object
SSS_173	723346,77	5954092,76	0,5	Object
SSS_174	723383,38	5954065,30	0,7	Object

SSS_175	723532,73	5954134,02	0,6	Object
SSS_176	723718,13	5954854,97	0,5	Object
SSS_177	723711,89	5954061,63	0,8	Object
SSS_178	723715,87	5954080,48	0,7	Object
SSS_179	723716,67	5954083,25	0,9	Object
SSS_180	723754,52	5953968,95	1,1	Object
SSS_181	723862,13	5954493,02	1	Object
SSS_182	723808,64	5953913,20	0,8	Object
SSS_183	723809,10	5953901,40	0,7	Object
SSS_184	723849,19	5954109,37	0,6	Object
SSS_185	723845,06	5953991,78	0,6	Object
SSS_186	723854,66	5954067,59	0,5	Object
SSS_187	723853,79	5954050,54	0,5	Object
SSS_188	723862,24	5954111,86	0,5	Object
SSS_189	723857,63	5954050,68	0,6	Object
SSS_190	723852,05	5953876,48	0,6	Object
SSS_191	723881,22	5953902,89	0,7	Object
SSS_192	723905,57	5954059,20	0,6	Object
SSS_193	723903,64	5953887,23	0,6	Object
SSS_194	723926,72	5954041,65	0,5	Object
SSS_195	723960,42	5954035,26	0,5	Object
SSS_196	723975,07	5954068,32	0,5	Object
SSS_197	724277,58	5954747,16	0,6	Object
SSS_198	724476,72	5953817,57	0,5	Object
SSS_199	724644,94	5954411,18	0,5	Object
SSS_200	724661,78	5954539,65	0,6	Object
SSS_201	724579,57	5953602,83	0,7	Object
SSS_202	724731,05	5954433,07	0,7	Object

SSS_203	724642,24	5953636,41	0,6	Object
SSS_204	724766,83	5954450,51	0,6	Object
SSS_205	724783,12	5954517,10	0,6	Object
SSS_206	724778,58	5954449,53	0,6	Object
SSS_207	724778,70	5954349,32	0,6	Object
SSS_208	724780,26	5953558,96	0,5	Object
SSS_209	724942,39	5954328,74	0,7	Object
SSS_210	724989,45	5954393,95	0,6	Object
SSS_211	725009,84	5954374,67	0,7	Object
SSS_212	725048,36	5954528,27	0,6	Object
SSS_213	724985,69	5953718,56	1,2	Object
SSS_214	725096,72	5954515,79	0,5	Object
SSS_215	725124,32	5954241,75	0,6	Object
SSS_216	725134,42	5954237,50	0,6	Object
SSS_217	725144,69	5954278,59	0,6	Object
SSS_218	725092,50	5953770,38	0,5	Object
SSS_219	725150,03	5954266,54	0,5	Object
SSS_220	725152,17	5954277,48	0,5	Object
SSS_221	725178,56	5954225,18	0,5	Object
SSS_222	725124,87	5953745,24	0,6	Object
SSS_223	725115,87	5953501,85	0,5	Object
SSS_224	725172,54	5953894,35	0,5	Object
SSS_225	725246,91	5954420,97	0,7	Object
SSS_226	725261,74	5954467,16	0,7	Object
SSS_227	725212,52	5953937,96	0,6	Object
SSS_228	725244,46	5954123,17	0,5	Object
SSS_229	725262,43	5954046,93	0,6	Object
SSS_230	725276,31	5954136,17	0,5	Object

SSS_231	725288,51	5954240,26	0,6	Object
SSS_232	725285,49	5954061,94	0,9	Object
SSS_233	725327,30	5954221,86	0,7	Object
SSS_234	725336,55	5954215,62	0,8	Object
SSS_235	725341,32	5954252,77	0,6	Object
SSS_236	725346,39	5954204,15	0,5	Object
SSS_237	725390,80	5954497,76	0,6	Object
SSS_238	725361,58	5954030,67	0,7	Object
SSS_239	725387,33	5954238,49	0,5	Object
SSS_240	725361,50	5953844,71	0,8	Object
SSS_241	725428,26	5954348,17	0,6	Object
SSS_242	725473,83	5954428,28	0,7	Object
SSS_243	725407,58	5953805,92	0,7	Object
SSS_244	725447,98	5953818,37	0,8	Object
SSS_245	725500,73	5954077,67	0,6	Object
SSS_246	725469,00	5953705,87	0,7	Object
SSS_247	725502,53	5953777,01	0,6	Object
SSS_248	725503,43	5953676,67	0,5	Object
SSS_249	725549,47	5953801,34	0,7	Object
SSS_250	725568,76	5953790,04	1,1	Object
SSS_251	725654,15	5954532,82	0,5	Object
SSS_252	725650,48	5954214,47	0,5	Object
SSS_253	725671,55	5954313,50	0,6	Object
SSS_254	725663,15	5954214,40	0,6	Object
SSS_255	725649,37	5953785,79	0,6	Object
SSS_256	725831,42	5954364,25	0,5	Object
SSS_257	725785,29	5953766,44	0,6	Object
SSS_258	725827,13	5953653,81	0,6	Object

SSS_259	725928,37	5954476,41	0,6	Object
SSS_260	725965,90	5954322,62	0,7	Object
SSS_261	725997,41	5953887,92	0,5	Object
SSS_262	726052,22	5954102,79	0,5	Object
SSS_263	726057,41	5954141,89	0,6	Object
SSS_264	726125,63	5954417,63	0,7	Object
SSS_265	726114,48	5954190,77	0,6	Object
SSS_266	726107,63	5954125,64	0,7	Object
SSS_267	726119,61	5954110,39	0,6	Object
SSS_268	726091,62	5953851,33	0,7	Object
SSS_269	726190,19	5954548,21	0,6	Object
SSS_270	726173,34	5954150,49	0,5	Object
SSS_271	726253,07	5954394,21	0,9	Object
SSS_272	726319,83	5954354,42	0,5	Object
SSS_273	726386,30	5954389,49	0,7	Object
SSS_274	726412,12	5954380,81	0,6	Object
SSS_275	726385,89	5954146,61	0,9	Object
SSS_276	726544,54	5954494,79	0,5	Object
SSS_277	726502,03	5954104,70	0,8	Object
SSS_278	726506,85	5954107,53	0,7	Object
SSS_279	726592,04	5954486,38	0,7	Object
SSS_280	726742,62	5954423,38	0,7	Object
SSS_281	726870,97	5954279,25	0,6	Object
SSS_282	726958,22	5954177,60	0,6	Object
SSS_283	726989,51	5954175,50	0,7	Object
SSS_284	727046,94	5954189,82	0,5	Object
SSS_285	727104,19	5954382,52	1,1	Object
SSS_286	729697,53	5955104,13	0,6	Object

SSS_287	729774,83	5955004,78	0,7	Object
SSS_288	729767,36	5955100,95	0,5	Object
SSS_289	729791,72	5955056,65	0,9	Object
SSS_290	729990,54	5955191,79	0,6	Object
SSS_291	730162,26	5955230,58	0,5	Object
SSS_292	730317,76	5955207,78	0,6	Object
SSS_293	730309,61	5955222,10	1,2	Object
SSS_294	730297,63	5955291,03	0,5	Object
SSS_295	730324,81	5955286,64	0,5	Object
SSS_296	730359,44	5955287,63	0,7	Object
SSS_297	730418,89	5955242,55	0,5	Object
SSS_298	730417,60	5955276,24	0,6	Object
SSS_299	730463,81	5955245,45	0,5	Object
SSS_300	730506,71	5955235,50	0,5	Object
SSS_301	730516,10	5955237,56	0,5	Object
SSS_302	730541,92	5955229,90	0,9	Object
SSS_303	730556,17	5955284,38	0,6	Object
SSS_304	730578,58	5955257,66	0,9	Object
SSS_305	730574,39	5955355,60	0,5	Object
SSS_306	721419,2	5954712,6	0,7	Object
SSS_307	721408,5	5954529,1	1,3	Object
SSS_308	721458,1	5954747,9	0,9	Object
SSS_309	721555,0	5954666,2	0,8	Object
SSS_310	721616,0	5954554,5	0,6	Object
SSS_311	721655,2	5954793,5	0,7	Object
SSS_312	721625,0	5954519,2	0,7	Object
SSS_313	721652,1	5954564,4	0,6	Object
SSS_314	721746,8	5954595,7	0,6	Object

SSS_315	721766,6	5954616,9	0,8	Object
SSS_316	721759,4	5954496,7	0,6	Object
SSS_317	721791,4	5954654,8	0,5	Object
SSS_318	721772,5	5954430,6	0,6	Object
SSS_319	721815,4	5954641,9	0,6	Object
SSS_320	721825,4	5954588,2	0,5	Object
SSS_321	721829,4	5954595,1	0,6	Object
SSS_322	721852,0	5954594,2	0,6	Object
SSS_323	721858,2	5954627,1	0,6	Object
SSS_324	721880,7	5954700,9	0,6	Object
SSS_325	721850,6	5954434,7	0,6	Object
SSS_326	721896,8	5954569,6	0,7	Object
SSS_327	721927,0	5954712,8	0,5	Object
SSS_328	721940,2	5954537,2	0,7	Object
SSS_329	722026,1	5954527,0	0,7	Object
SSS_330	722037,4	5954431,4	0,9	Object
SSS_331	722065,6	5954532,7	0,5	Object
SSS_332	722072,3	5954539,2	0,5	Object
SSS_333	722091,6	5954408,4	0,8	Object
SSS_334	722127,9	5954494,6	0,5	Object
SSS_335	722168,5	5954646,2	0,5	Object
SSS_336	722175,0	5954701,1	0,7	Object
SSS_337	722256,4	5954767,0	0,8	Object
SSS_338	722258,5	5954555,0	0,6	Object
SSS_339	722266,1	5954620,9	0,5	Object
SSS_340	722266,7	5954547,2	0,6	Object
SSS_341	722326,4	5954705,0	1,1	Object
SSS_342	722362,9	5954613,5	0,6	Object

SSS_343	722407,2	5954745,4	0,6	Object
SSS_344	723246,4	5954499,2	0,8	Object
SSS_345	723862,1	5954493,0	1	Object
SSS_346	724644,9	5954411,2	0,5	Object
SSS_347	724731,1	5954433,1	0,7	Object
SSS_348	724766,8	5954450,5	0,6	Object
SSS_349	724778,6	5954449,5	0,6	Object
SSS_350	724778,7	5954349,3	0,6	Object
SSS_351	724942,4	5954328,7	0,7	Object
SSS_352	724989,4	5954394,0	0,6	Object
SSS_353	725009,8	5954374,7	0,7	Object
SSS_354	725124,3	5954241,8	0,6	Object
SSS_355	725134,4	5954237,5	0,6	Object
SSS_356	725144,7	5954278,6	0,6	Object
SSS_357	725150,0	5954266,5	0,5	Object
SSS_358	725152,2	5954277,5	0,5	Object
SSS_359	725178,6	5954225,2	0,5	Object
SSS_360	725246,9	5954421,0	0,7	Object
SSS_361	725244,5	5954123,2	0,5	Object
SSS_362	725262,4	5954046,9	0,6	Object
SSS_363	725276,3	5954136,2	0,5	Object
SSS_364	725288,5	5954240,3	0,6	Object
SSS_365	725285,5	5954061,9	0,9	Object
SSS_366	725327,3	5954221,9	0,7	Object
SSS_367	725336,5	5954215,6	0,8	Object
SSS_368	725341,3	5954252,8	0,6	Object
SSS_369	725346,4	5954204,1	0,5	Object
SSS_370	725361,6	5954030,7	0,7	Object

SSS_371	725387,3	5954238,5	0,5	Object
SSS_372	725428,3	5954348,2	0,6	Object
SSS_373	725500,7	5954077,7	0,6	Object
SSS_374	725650,5	5954214,5	0,5	Object
SSS_375	725671,5	5954313,5	0,6	Object
SSS_376	725663,1	5954214,4	0,6	Object
SSS_377	725831,4	5954364,2	0,5	Object
SSS_378	725965,9	5954322,6	0,7	Object
SSS_379	726052,2	5954102,8	0,5	Object
SSS_380	726057,4	5954141,9	0,6	Object
SSS_381	726114,5	5954190,8	0,6	Object
SSS_382	726107,6	5954125,6	0,7	Object
SSS_383	726119,6	5954110,4	0,6	Object
SSS_384	726173,3	5954150,5	0,5	Object
SSS_385	726385,9	5954146,6	0,9	Object
SSS_386	726502,0	5954104,7	0,8	Object
SSS_387	726506,9	5954107,5	0,7	Object
SSS_388	726871,0	5954279,2	0,6	Object
SSS_389	726958,2	5954177,6	0,6	Object
SSS_390	726989,5	5954175,5	0,7	Object
SSS_391	727046,9	5954189,8	0,5	Object
SSS_392	727104,2	5954382,5	1,1	Object
SSS_393	729697,5	5955104,1	0,6	Object
SSS_394	729774,8	5955004,8	0,7	Object
SSS_395	729767,4	5955101,0	0,5	Object
SSS_396	729791,7	5955056,7	0,9	Object
SSS_397	729990,5	5955191,8	0,6	Object
SSS_398	721343,9	5954472,5	0,5	Object

SSS_399	721373,4	5954458,7	0,5	Object
SSS_400	721517,6	5954248,1	0,6	Object
SSS_401	721290,6	5954297,2	0,6	Object
SSS_402	721395,6	5954262,4	0,6	Object
SSS_403	721571,5	5954203,1	0,5	Object
SSS_404	721523,0	5954218,8	0,7	Object
SSS_405	721395,2	5954252,8	0,7	Object
SSS_406	721626,4	5954092,9	0,5	Object
SSS_407	721604,6	5954084,5	0,7	Object
SSS_408	721455,7	5954048,1	0,5	Object
SSS_409	721444,6	5954037,8	0,6	Object
SSS_410	721235,0	5954040,4	0,6	Object
SSS_411	721246,9	5953990,0	0,7	Object
SSS_412	721195,8	5953987,5	0,5	Object
SSS_413	721388,2	5953864,3	0,6	Object
SSS_414	721246,8	5953887,4	0,6	Object
SSS_415	721227,5	5953868,5	0,7	Object
SSS_416	721343,0	5953829,2	0,5	Object
SSS_417	721224,7	5953846,8	0,6	Object
SSS_418	721379,4	5953792,7	0,6	Object
SSS_419	721392,0	5953769,8	0,7	Object
SSS_420	721261,2	5953798,9	0,8	Object
SSS_421	721418,9	5953687,4	0,6	Object
SSS_422	721338,8	5953691,8	0,8	Object
SSS_423	721339,8	5953688,0	0,8	Object
SSS_424	721351,0	5953668,2	0,8	Object
SSS_425	721357,9	5953583,8	0,5	Object
SSS_426	721410,7	5953535,3	0,6	Object

SSS_427	718503,9	5942263,9	0,8	Object
SSS_428	720988,4	5954348,5	1	Object
SSS_429	721040	5954486,9	0,6	Object
SSS_430	721048,1	5954441	0,5	Object
SSS_431	721047,8	5954403,6	0,8	Object
SSS_432	721055,1	5954273,5	0,5	Object
SSS_433	721070	5954388	0,5	Object
SSS_434	721083,6	5954252,5	0,6	Object
SSS_435	721120,5	5954342,5	0,6	Object
SSS_436	721124,2	5954225,5	0,6	Object
SSS_437	721154,2	5954387,6	0,5	Object
SSS_438	721200,5	5954647,4	0,6	Object
SSS_439	721189,7	5954332	0,8	Object
SSS_440	721204,1	5954287,9	0,7	Object
SSS_441	721304,2	5954594,4	1	Object
SSS_442	721321,5	5954595,8	0,9	Object
SSS_443	721290,6	5954297,2	0,6	Object
SSS_444	721343,9	5954472,5	0,5	Object
SSS_445	721373,4	5954458,7	0,5	Object
SSS_446	721419,2	5954712,6	0,7	Object
SSS_447	721408,5	5954529,1	1,3	Object
SSS_448	721395,6	5954262,4	0,6	Object
SSS_449	721395,2	5954252,8	0,7	Object
SSS_450	721458,1	5954747,9	0,9	Object
SSS_451	721555	5954666,2	0,8	Object
SSS_452	721517,6	5954248,1	0,6	Object
SSS_453	721523	5954218,8	0,7	Object
SSS_454	721637,9	5954907,1	0,7	Object

SSS_455	721648,1	5954914,1	0,5	Object
SSS_456	721571,5	5954203,1	0,5	Object
SSS_457	721656,4	5954932,1	1	Object
SSS_458	721616	5954554,5	0,6	Object
SSS_459	721674,2	5955016,6	0,5	Object
SSS_460	721655,2	5954793,5	0,7	Object
SSS_461	721625	5954519,2	0,7	Object
SSS_462	721680,8	5955011	0,7	Object
SSS_463	721652,1	5954564,4	0,6	Object
SSS_464	721717,1	5954862,9	0,6	Object
SSS_465	721718,1	5954870,3	0,7	Object
SSS_466	721738,4	5955038,3	0,7	Object
SSS_467	721723,2	5954856,2	0,6	Object
SSS_468	721767,7	5955126	0,6	Object
SSS_469	721776	5955044,1	0,7	Object
SSS_470	721710,9	5954302,9	0,5	Object
SSS_471	721800,3	5955078,8	0,5	Object
SSS_472	721746,8	5954595,7	0,6	Object
SSS_473	721788,7	5954958,7	0,6	Object
SSS_474	721808,3	5955123,3	0,6	Object
SSS_475	721798,9	5954964,4	0,6	Object
SSS_476	721766,6	5954616,9	0,8	Object
SSS_477	721819,7	5955039,4	0,8	Object
SSS_478	721759,4	5954496,7	0,6	Object
SSS_479	721791,4	5954654,8	0,5	Object
SSS_480	721764,5	5954382,5	0,5	Object
SSS_481	721772,5	5954430,6	0,6	Object
SSS_482	721847,3	5954926	0,6	Object

SSS_483	721815,4	5954641,9	0,6	Object
SSS_484	721788,5	5954369,3	0,6	Object
SSS_485	721854,7	5954924,8	0,5	Object
SSS_486	721825,4	5954588,2	0,5	Object
SSS_487	721829,4	5954595,1	0,6	Object
SSS_488	721852	5954594,2	0,6	Object
SSS_489	721858,2	5954627,1	0,6	Object
SSS_490	721880,7	5954700,9	0,6	Object
SSS_491	721850,6	5954434,7	0,6	Object
SSS_492	721896,8	5954569,6	0,7	Object
SSS_493	721927	5954712,8	0,5	Object
SSS_494	721940,2	5954537,2	0,7	Object
SSS_495	721949,1	5954256,8	0,7	Object
SSS_496	722062	5954903,7	0,5	Object
SSS_497	722026,1	5954527	0,7	Object
SSS_498	722031,2	5954397,3	0,7	Object
SSS_499	722007,9	5954191,3	0,6	Object
SSS_500	722037,4	5954431,4	0,9	Object
SSS_501	722065,6	5954532,7	0,5	Object
SSS_502	722072,3	5954539,2	0,5	Object
SSS_503	722049,5	5954224,7	0,8	Object
SSS_504	722128,6	5954814,3	0,6	Object
SSS_505	722131,2	5954815	0,5	Object
SSS_506	722142	5954862	0,5	Object
SSS_507	722091,6	5954408,4	0,8	Object
SSS_508	722066,3	5954158	0,6	Object
SSS_509	722079,7	5954193,9	0,6	Object
SSS_510	722127,9	5954494,6	0,5	Object

SSS_511	722094,4	5954197,4	0,5	Object
SSS_512	722100,1	5954245	0,7	Object
SSS_513	722112,9	5954349,6	1	Object
SSS_514	722112,7	5954276	0,7	Object
SSS_515	722119,7	5954332,1	0,6	Object
SSS_516	722168,5	5954646,2	0,5	Object
SSS_517	722175	5954701,1	0,7	Object
SSS_518	722117	5954180,7	0,5	Object
SSS_519	722162	5954289,9	0,6	Object
SSS_520	722256,4	5954767	0,8	Object
SSS_521	722258,5	5954555	0,6	Object
SSS_522	722266,1	5954620,9	0,5	Object
SSS_523	722266,7	5954547,2	0,6	Object
SSS_524	722271,9	5954311,5	0,5	Object
SSS_525	722326,4	5954705	1,1	Object
SSS_526	722299,3	5954139,6	1	Object
SSS_527	722362,9	5954613,5	0,6	Object
SSS_528	722407,2	5954745,4	0,6	Object
SSS_529	722397,5	5954086,3	0,6	Object
SSS_530	722524,4	5954965,6	0,7	Object
SSS_531	722504,1	5954768,7	0,5	Object
SSS_532	722557,2	5954951,2	0,6	Object
SSS_533	722475,1	5954216	0,6	Object
SSS_534	722536,9	5954258,3	0,7	Object
SSS_535	722583,4	5954193,4	0,5	Object
SSS_536	722664,8	5954088,2	0,5	Object
SSS_537	722698,1	5954168,3	0,7	Object
SSS_538	723059,4	5954145,4	0,6	Object

SSS_539	723228,2	5954951,3	0,8	Object
SSS_540	723230,4	5954954,1	0,6	Object
SSS_541	723246,4	5954499,2	0,8	Object
SSS_542	723264,9	5954042,9	0,6	Object
SSS_543	723277,7	5953991,5	0,8	Object
SSS_544	723312,6	5954027,2	0,5	Object
SSS_545	723325,5	5954026,9	0,6	Object
SSS_546	723346,8	5954092,8	0,5	Object
SSS_547	723383,4	5954065,3	0,7	Object
SSS_548	723532,7	5954134	0,6	Object
SSS_549	723718,1	5954855	0,5	Object
SSS_550	723711,9	5954061,6	0,8	Object
SSS_551	723715,9	5954080,5	0,7	Object
SSS_552	723716,7	5954083,2	0,9	Object
SSS_553	723754,5	5953969	1,1	Object
SSS_554	723862,1	5954493	1	Object
SSS_555	723808,6	5953913,2	0,8	Object
SSS_556	723809,1	5953901,4	0,7	Object
SSS_557	723849,2	5954109,4	0,6	Object
SSS_558	723845,1	5953991,8	0,6	Object
SSS_559	723854,7	5954067,6	0,5	Object
SSS_560	723853,8	5954050,5	0,5	Object
SSS_561	723862,2	5954111,9	0,5	Object
SSS_562	723857,6	5954050,7	0,6	Object
SSS_563	723881,2	5953902,9	0,7	Object
SSS_564	723905,6	5954059,2	0,6	Object
SSS_565	723903,6	5953887,2	0,6	Object
SSS_566	723926,7	5954041,6	0,5	Object

SSS_567	723960,4	5954035,3	0,5	Object
SSS_568	723975,1	5954068,3	0,5	Object
SSS_569	724277,6	5954747,2	0,6	Object
SSS_570	724644,9	5954411,2	0,5	Object
SSS_571	724661,8	5954539,6	0,6	Object
SSS_572	724731,1	5954433,1	0,7	Object
SSS_573	724766,8	5954450,5	0,6	Object
SSS_574	724783,1	5954517,1	0,6	Object
SSS_575	724778,6	5954449,5	0,6	Object
SSS_576	724778,7	5954349,3	0,6	Object
SSS_577	724942,4	5954328,7	0,7	Object
SSS_578	724989,4	5954394	0,6	Object
SSS_579	725009,8	5954374,7	0,7	Object
SSS_580	725048,4	5954528,3	0,6	Object
SSS_581	725096,7	5954515,8	0,5	Object
SSS_582	725124,3	5954241,8	0,6	Object
SSS_583	725134,4	5954237,5	0,6	Object
SSS_584	725144,7	5954278,6	0,6	Object
SSS_585	725092,5	5953770,4	0,5	Object
SSS_586	725150	5954266,5	0,5	Object
SSS_587	725152,2	5954277,5	0,5	Object
SSS_588	725178,6	5954225,2	0,5	Object
SSS_589	725172,5	5953894,4	0,5	Object
SSS_590	725246,9	5954421	0,7	Object
SSS_591	725261,7	5954467,2	0,7	Object
SSS_592	725212,5	5953938	0,6	Object
SSS_593	725244,5	5954123,2	0,5	Object
SSS_594	725262,4	5954046,9	0,6	Object

SSS_595	725276,3	5954136,2	0,5	Object
SSS_596	725288,5	5954240,3	0,6	Object
SSS_597	725285,5	5954061,9	0,9	Object
SSS_598	725327,3	5954221,9	0,7	Object
SSS_599	725336,5	5954215,6	0,8	Object
SSS_600	725341,3	5954252,8	0,6	Object
SSS_601	725346,4	5954204,1	0,5	Object
SSS_602	725390,8	5954497,8	0,6	Object
SSS_603	725361,6	5954030,7	0,7	Object
SSS_604	725387,3	5954238,5	0,5	Object
SSS_605	725361,5	5953844,7	0,8	Object
SSS_606	725428,3	5954348,2	0,6	Object
SSS_607	725473,8	5954428,3	0,7	Object
SSS_608	725407,6	5953805,9	0,7	Object
SSS_609	725448	5953818,4	0,8	Object
SSS_610	725500,7	5954077,7	0,6	Object
SSS_611	725502,5	5953777	0,6	Object
SSS_612	725549,5	5953801,3	0,7	Object
SSS_613	725568,8	5953790	1,1	Object
SSS_614	725654,1	5954532,8	0,5	Object
SSS_615	725650,5	5954214,5	0,5	Object
SSS_616	725671,5	5954313,5	0,6	Object
SSS_617	725663,1	5954214,4	0,6	Object
SSS_618	725649,4	5953785,8	0,6	Object
SSS_619	725831,4	5954364,2	0,5	Object
SSS_620	725785,3	5953766,4	0,6	Object
SSS_621	725928,4	5954476,4	0,6	Object
SSS_622	725965,9	5954322,6	0,7	Object

SSS_623	725997,4	5953887,9	0,5	Object
SSS_624	726052,2	5954102,8	0,5	Object
SSS_625	726057,4	5954141,9	0,6	Object
SSS_626	726125,6	5954417,6	0,7	Object
SSS_627	726114,5	5954190,8	0,6	Object
SSS_628	726107,6	5954125,6	0,7	Object
SSS_629	726119,6	5954110,4	0,6	Object
SSS_630	726091,6	5953851,3	0,7	Object
SSS_631	726190,2	5954548,2	0,6	Object
SSS_632	726173,3	5954150,5	0,5	Object
SSS_633	726253,1	5954394,2	0,9	Object
SSS_634	726319,8	5954354,4	0,5	Object
SSS_635	726386,3	5954389,5	0,7	Object
SSS_636	726412,1	5954380,8	0,6	Object
SSS_637	726385,9	5954146,6	0,9	Object
SSS_638	726544,5	5954494,8	0,5	Object
SSS_639	726502	5954104,7	0,8	Object
SSS_640	726506,9	5954107,5	0,7	Object
SSS_641	726592	5954486,4	0,7	Object
SSS_642	726742,6	5954423,4	0,7	Object
SSS_643	726871	5954279,2	0,6	Object
SSS_644	726958,2	5954177,6	0,6	Object
SSS_645	726989,5	5954175,5	0,7	Object
SSS_646	727046,9	5954189,8	0,5	Object
SSS_647	727104,2	5954382,5	1,1	Object
SSS_648	729697,5	5955104,1	0,6	Object
SSS_649	729774,8	5955004,8	0,7	Object
SSS_650	729767,4	5955101	0,5	Object

SSS_651	729791,7	5955056,7	0,9	Object
SSS_652	729990,5	5955191,8	0,6	Object
SSS_653	730162,3	5955230,6	0,5	Object
SSS_654	730317,8	5955207,8	0,6	Object
SSS_655	730309,6	5955222,1	1,2	Object
SSS_656	730297,6	5955291	0,5	Object
SSS_657	730324,8	5955286,6	0,5	Object
SSS_658	730359,4	5955287,6	0,7	Object
SSS_659	730418,9	5955242,5	0,5	Object
SSS_660	730417,6	5955276,2	0,6	Object
SSS_661	730463,8	5955245,5	0,5	Object
SSS_662	730506,7	5955235,5	0,5	Object
SSS_663	730516,1	5955237,6	0,5	Object
SSS_664	721968,2	5955304,0	0,5	Object
SSS_665	721381,2	5955392,9	1,1	Object
SSS_666	721801,8	5955134,4	0,7	Object
SSS_667	721796,0	5955132,2	0,8	Object
SSS_668	721808,3	5955123,3	0,6	Object
SSS_669	721767,7	5955126,0	0,6	Object
SSS_670	721800,3	5955078,8	0,5	Object
SSS_671	721819,7	5955039,4	0,8	Object
SSS_672	721776,0	5955044,1	0,7	Object
SSS_673	721738,4	5955038,3	0,7	Object
SSS_674	722062,0	5954903,7	0,5	Object
SSS_675	721674,2	5955016,6	0,5	Object
SSS_676	722142,0	5954862,0	0,5	Object
SSS_677	721680,8	5955011,0	0,7	Object
SSS_678	721798,9	5954964,4	0,6	Object

SSS_679	721788,7	5954958,7	0,6	Object
SSS_680	721854,7	5954924,8	0,5	Object
SSS_681	721847,3	5954926,0	0,6	Object
SSS_682	722131,2	5954815,0	0,5	Object
SSS_683	722128,6	5954814,3	0,6	Object
SSS_684	721656,4	5954932,1	1	Object
SSS_685	721648,1	5954914,1	0,5	Object
SSS_686	721637,9	5954907,1	0,7	Object
SSS_687	721718,1	5954870,3	0,7	Object
SSS_688	721717,1	5954862,9	0,6	Object
SSS_689	721723,2	5954856,2	0,6	Object
SSS_690	722031,2	5954397,3	0,7	Object
SSS_691	721200,5	5954647,4	0,6	Object
SSS_692	721321,5	5954595,8	0,9	Object
SSS_693	721304,2	5954594,4	1	Object
SSS_694	721764,5	5954382,5	0,5	Object
SSS_695	721788,5	5954369,3	0,6	Object
SSS_696	721949,1	5954256,8	0,7	Object
SSS_697	721710,9	5954302,9	0,5	Object
SSS_698	721040,0	5954486,9	0,6	Object
SSS_699	721048,1	5954441,0	0,5	Object
SSS_700	721154,2	5954387,6	0,5	Object
SSS_701	721047,8	5954403,6	0,8	Object
SSS_702	721070,0	5954388,0	0,5	Object
SSS_703	721189,7	5954332,0	0,8	Object
SSS_704	721120,5	5954342,5	0,6	Object
SSS_705	721204,1	5954287,9	0,7	Object
SSS_706	720988,4	5954348,5	1	Object

SSS_707	721712,6	5954066,9	1	Object
SSS_708	721055,1	5954273,5	0,5	Object
SSS_709	721083,6	5954252,5	0,6	Object
SSS_710	721625,4	5954063,7	0,7	Object
SSS_711	721124,2	5954225,5	0,6	Object
SSS_712	721202,4	5954182,9	0,6	Object
SSS_713	721183,4	5954184,2	0,5	Object
SSS_714	721704,6	5954008,3	0,5	Object
SSS_715	721200,1	5954168,3	0,5	Object
SSS_716	721810,1	5953955,7	0,7	Object
SSS_717	721014,9	5954205,5	0,5	Object
SSS_718	721703,8	5953951,7	0,9	Object
SSS_719	721684,5	5953956,4	1,6	Object
SSS_720	721624,6	5953973,0	0,7	Object
SSS_721	721047,7	5954157,2	0,8	Object
SSS_722	721014,6	5954144,9	0,6	Object
SSS_723	721096,7	5954103,8	0,6	Object
SSS_724	721166,4	5954080,7	0,7	Object
SSS_725	721023,6	5954124,1	0,8	Object
SSS_726	721147,7	5954077,6	0,5	Object
SSS_727	721031,8	5954112,7	0,6	Object
SSS_728	721077,9	5954055,2	0,5	Object
SSS_729	721129,5	5954019,2	0,7	Object
SSS_730	720987,9	5954062,2	0,9	Object
SSS_731	721567,9	5953867,9	0,6	Object
SSS_732	721111,5	5954015,6	0,6	Object
SSS_733	721108,5	5954016,1	1	Object
SSS_734	720995,1	5954033,9	0,8	Object

SSS_735	721039,2	5954011,5	0,5	Object
SSS_736	721082,9	5953986,7	0,5	Object
SSS_737	721072,1	5953895,1	0,6	Object
SSS_738	720316,0	5950031,5	0,9	Object
SSS_739	720114,5	5948971,1	0,8	Object
SSS_740	719671,1	5947933,0	0,6	Object
SSS_741	718851,9	5942574,8	0,5	Object
SSS_742	722065,602	5954532,748	0,5	Object
SSS_743	721847,333	5954926,036	0,6	Object
SSS_744	721718,052	5954870,335	0,7	Object
SSS_745	721723,219	5954856,189	0,6	Object
SSS_746	721523,033	5954218,829	0,7	Object
SSS_747	721517,576	5954248,052	0,6	Object
SSS_748	721717,093	5954862,856	0,6	Object
SSS_749	721395,154	5954252,774	0,7	Object
SSS_750	721395,633	5954262,425	0,6	Object
SSS_751	721321,532	5954595,757	0,9	Object
SSS_752	721738,417	5955038,276	0,7	Object
SSS_753	721767,685	5955125,998	0,6	Object
SSS_754	721800,267	5955078,779	0,5	Object
SSS_755	721200,485	5954647,373	0,6	Object
SSS_756	721710,894	5954302,916	0,5	Object
SSS_757	721759,398	5954496,665	0,6	Object
SSS_758	721815,378	5954641,854	0,6	Object
SSS_759	721940,171	5954537,155	0,7	Object
SSS_760	722072,284	5954539,197	0,5	Object
SSS_761	721571,489	5954203,118	0,5	Object
SSS_762	722031,163	5954397,323	0,7	Object

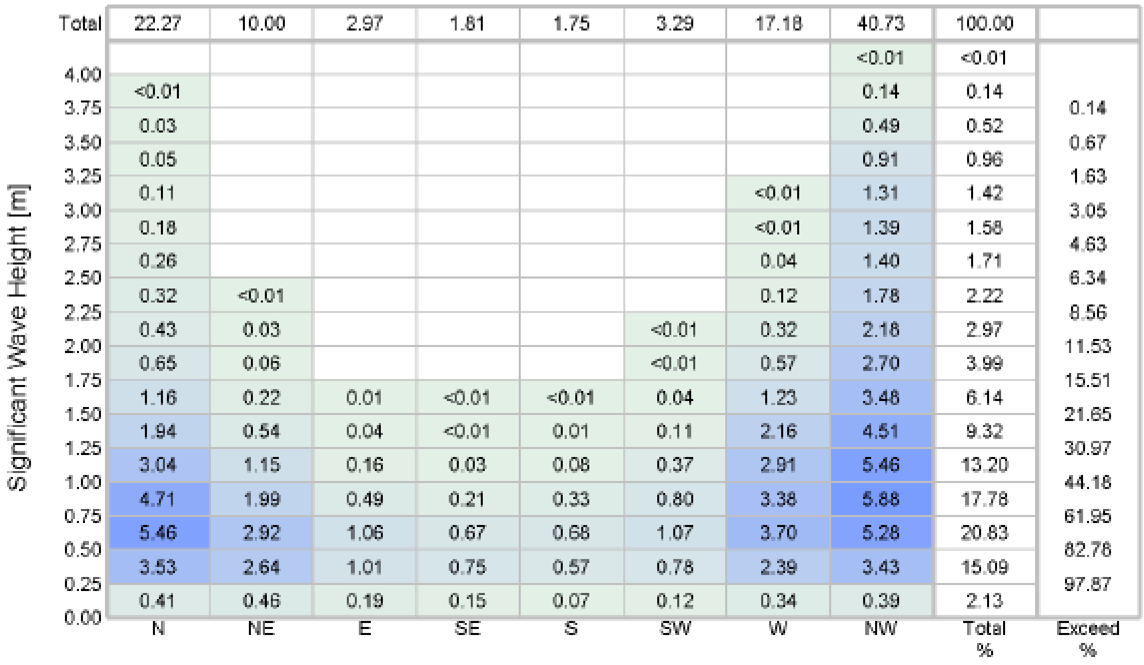
SSS_763	721764,507	5954382,525	0,5	Object
SSS_764	721788,498	5954369,264	0,6	Object
SSS_765	722112,914	5954349,566	1	Object
SSS_766	721656,392	5954932,107	1	Object
SSS_767	721788,653	5954958,655	0,6	Object
SSS_768	721896,799	5954569,624	0,7	Object
SSS_769	721819,678	5955039,442	0,8	Object
SSS_770	721775,982	5955044,12	0,7	Object
SSS_771	721808,335	5955123,298	0,6	Object
SSS_772	721458,055	5954747,893	0,9	Object
SSS_773	721880,655	5954700,943	0,6	Object
SSS_774	721554,962	5954666,225	0,8	Object
SSS_775	722119,708	5954332,113	0,6	Object
SSS_776	721637,887	5954907,072	0,7	Object
SSS_777	721625,005	5954519,167	0,7	Object
SSS_778	721419,153	5954712,644	0,7	Object
SSS_779	721746,755	5954595,746	0,6	Object
SSS_780	721766,615	5954616,901	0,8	Object
SSS_781	721825,401	5954588,196	0,5	Object
SSS_782	721851,994	5954594,191	0,6	Object
SSS_783	721854,677	5954924,845	0,5	Object
SSS_784	722037,385	5954431,371	0,9	Object
SSS_785	722026,142	5954527,01	0,7	Object
SSS_786	721290,573	5954297,188	0,6	Object
SSS_787	721343,864	5954472,532	0,5	Object
SSS_788	721373,402	5954458,692	0,5	Object
SSS_789	721408,521	5954529,082	1,3	Object
SSS_790	721829,398	5954595,074	0,6	Object

SSS_791	721652,063	5954564,38	0,6	Object
SSS_792	721791,384	5954654,785	0,5	Object
SSS_793	721798,859	5954964,393	0,6	Object
SSS_794	721648,134	5954914,129	0,5	Object
SSS_795	721796,007	5955132,171	0,8	Object
SSS_796	721655,249	5954793,462	0,7	Object
SSS_797	721304,212	5954594,415	1	Object
SSS_798	721674,177	5955016,59	0,5	Object
SSS_799	721949,132	5954256,82	0,7	Object
SSS_800	721850,605	5954434,709	0,6	Object
SSS_801	721680,772	5955011,048	0,7	Object
SSS_802	721858,183	5954627,117	0,6	Object
WRECK_001	720537,7	5952510,7	19.1x12.9x0.2	Wreck
WRECK_002	720467,1	5952450,6	40.1x12.8x1.1	Wreck

B. Directional wave scatter

Monthly and All-year Joint Frequency Distributions of Hs and Mdir

All-Year



Significant Wave Height [m]	N	NE	E	SE	S	SW	W	NW	Total %	Exceed %
Total	22.27	10.00	2.97	1.81	1.75	3.29	17.18	40.73	100.00	
4.00								<0.01	<0.01	
3.75	<0.01							0.14	0.14	0.14
3.50	0.03							0.49	0.52	0.67
3.25	0.05							0.91	0.96	1.63
3.00	0.11						<0.01	1.31	1.42	3.05
2.75	0.18						<0.01	1.39	1.58	4.63
2.50	0.26						0.04	1.40	1.71	6.34
2.25	0.32	<0.01					0.12	1.78	2.22	8.56
2.00	0.43	0.03				<0.01	0.32	2.18	2.97	11.53
1.75	0.65	0.06				<0.01	0.57	2.70	3.99	15.51
1.50	1.16	0.22	0.01	<0.01	<0.01	0.04	1.23	3.48	6.14	21.65
1.25	1.94	0.54	0.04	<0.01	0.01	0.11	2.16	4.51	9.32	30.97
1.00	3.04	1.15	0.16	0.03	0.08	0.37	2.91	5.46	13.20	44.18
0.75	4.71	1.99	0.49	0.21	0.33	0.80	3.38	5.88	17.78	61.95
0.50	5.46	2.92	1.06	0.67	0.68	1.07	3.70	5.28	20.83	82.78
0.25	3.53	2.64	1.01	0.75	0.57	0.78	2.39	3.43	15.09	97.87
0.00	0.41	0.46	0.19	0.15	0.07	0.12	0.34	0.39	2.13	

Mean Wave Direction [°T From]

All-Year

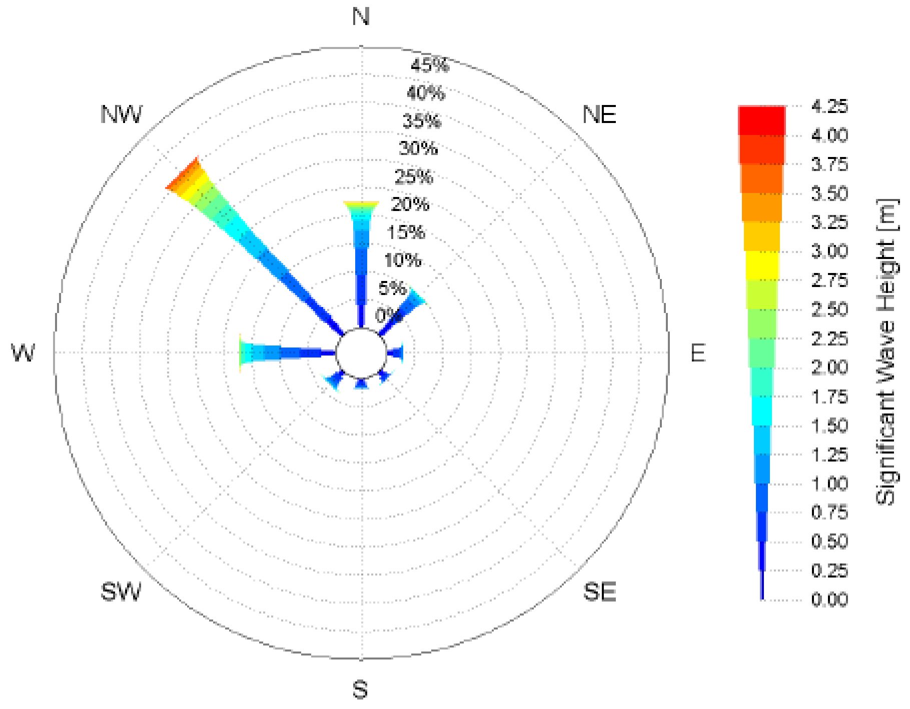
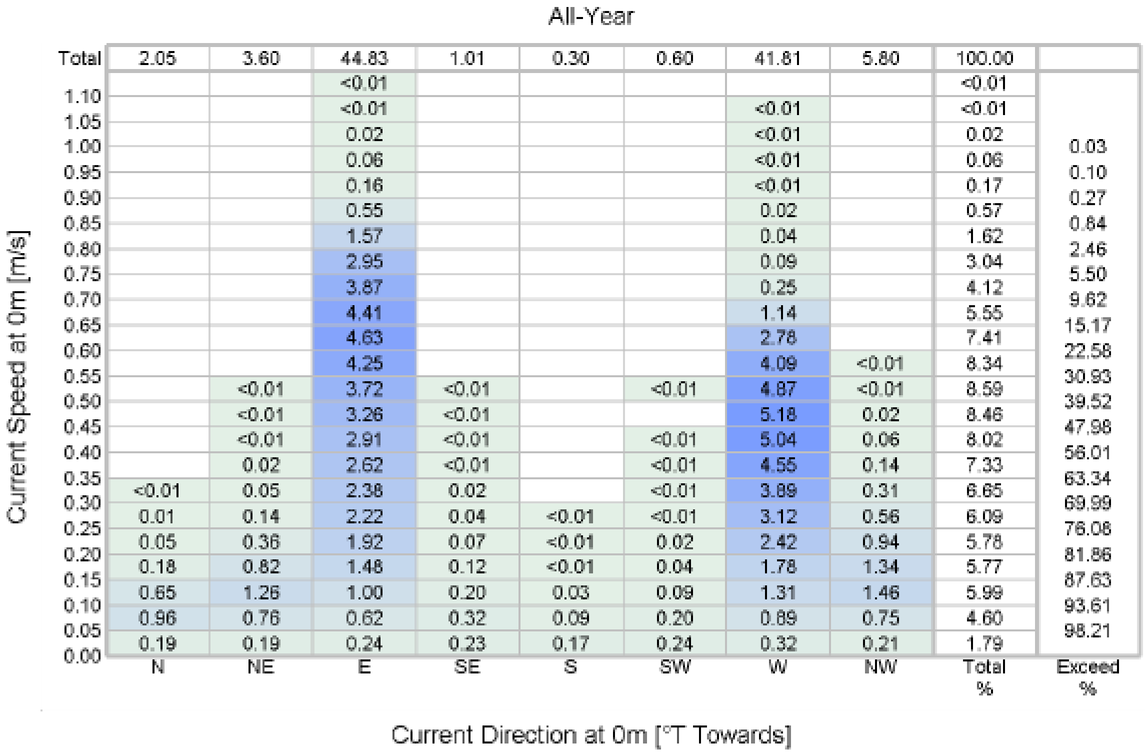


Figure B-1: Near platform wave scatter [ref II]



All-Year

Current Speed at 0m [m/s]	N	NE	E	SE	S	SW	W	NW	Total %	Exceed %
Total	2.05	3.60	44.83	1.01	0.30	0.60	41.81	5.80	100.00	
1.10			<0.01						<0.01	
1.05			<0.01				<0.01		<0.01	
1.00			0.02				<0.01		0.02	0.03
0.95			0.06				<0.01		0.06	0.10
0.90			0.16				<0.01		0.17	0.27
0.85			0.55				0.02		0.57	0.84
0.80			1.57				0.04		1.62	2.46
0.75			2.95				0.09		3.04	5.50
0.70			3.87				0.25		4.12	9.62
0.65			4.41				1.14		5.55	15.17
0.60			4.63				2.78		7.41	22.58
0.55			4.25				4.09	<0.01	8.34	30.93
0.50		<0.01	3.72	<0.01		<0.01	4.87	<0.01	8.59	39.52
0.45		<0.01	3.26	<0.01			5.18	0.02	8.46	47.98
0.40		<0.01	2.91	<0.01		<0.01	5.04	0.06	8.02	56.01
0.35		0.02	2.62	<0.01		<0.01	4.55	0.14	7.33	63.34
0.30	<0.01	0.05	2.38	0.02		<0.01	3.89	0.31	6.65	69.99
0.25	0.01	0.14	2.22	0.04	<0.01	<0.01	3.12	0.56	6.09	76.08
0.20	0.05	0.36	1.92	0.07	<0.01	0.02	2.42	0.94	5.78	81.86
0.15	0.18	0.82	1.48	0.12	<0.01	0.04	1.78	1.34	5.77	87.63
0.10	0.65	1.26	1.00	0.20	0.03	0.09	1.31	1.46	5.99	93.61
0.05	0.96	0.76	0.62	0.32	0.09	0.20	0.89	0.75	4.60	98.21
0.00	0.19	0.19	0.24	0.23	0.17	0.24	0.32	0.21	1.79	

Current Direction at 0m [°T Towards]

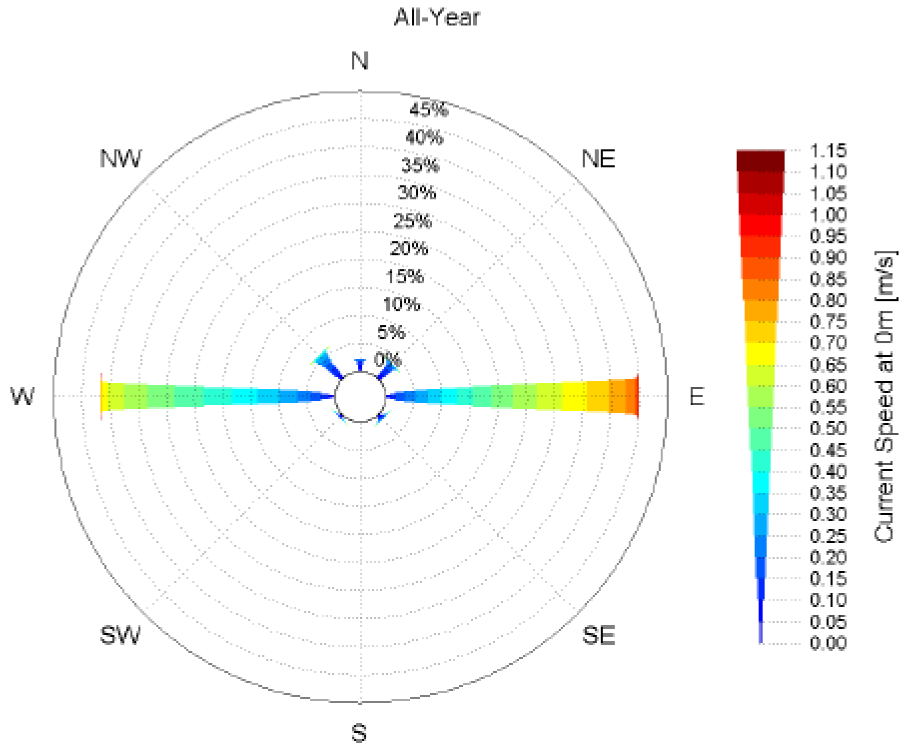
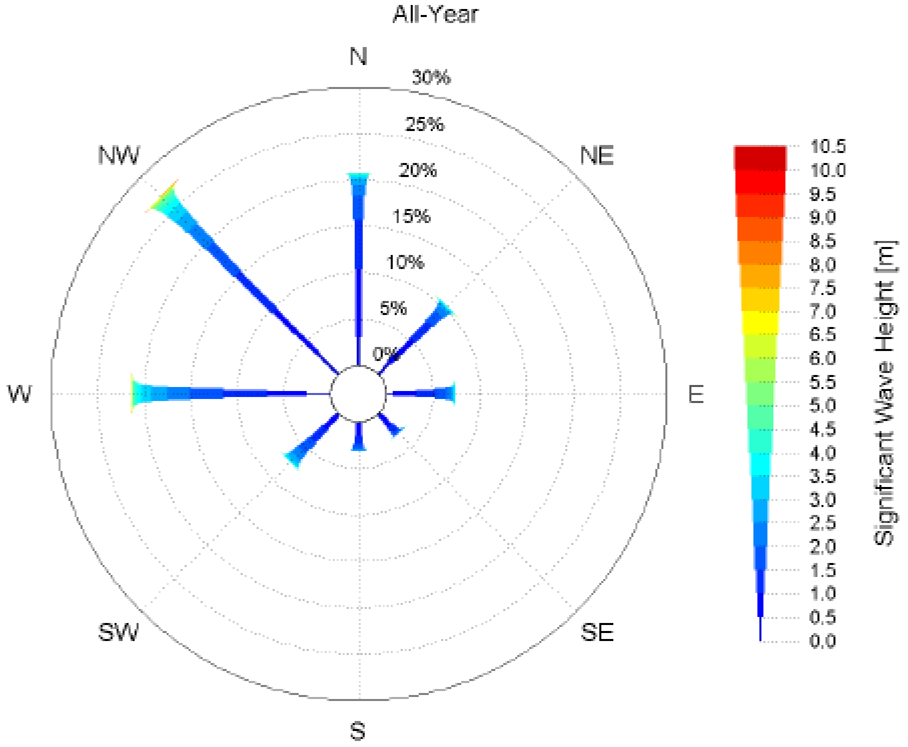
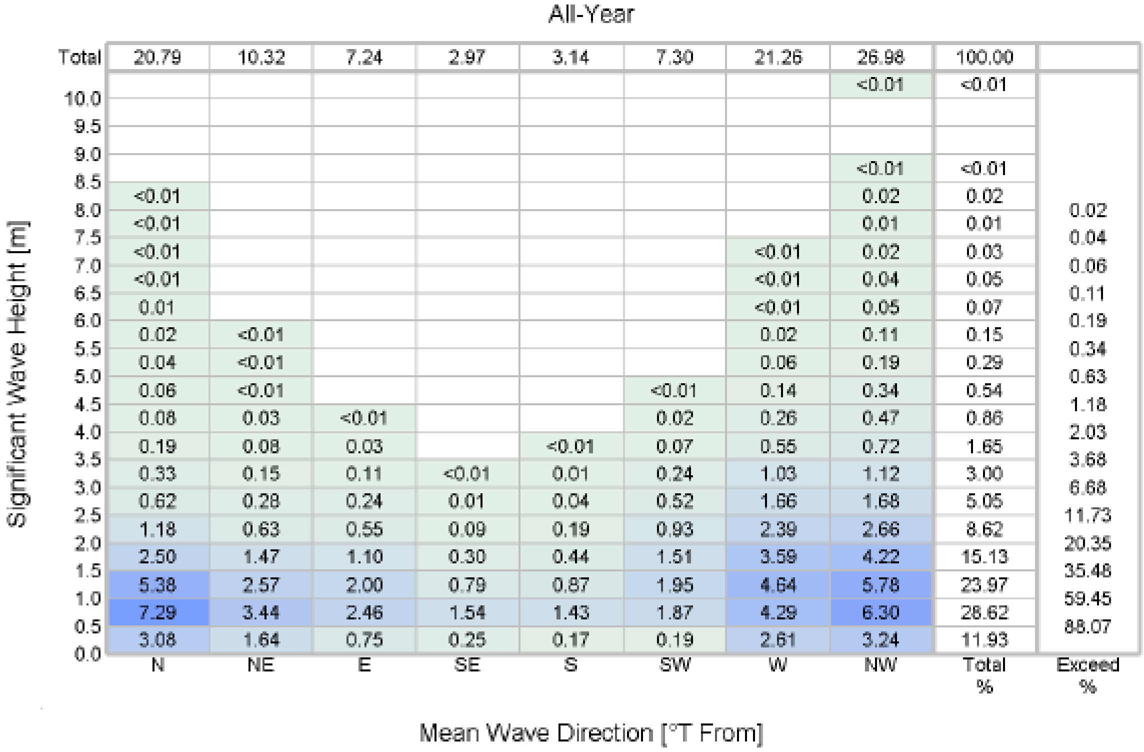


Figure B-2: Near platform current scatter [ref II]





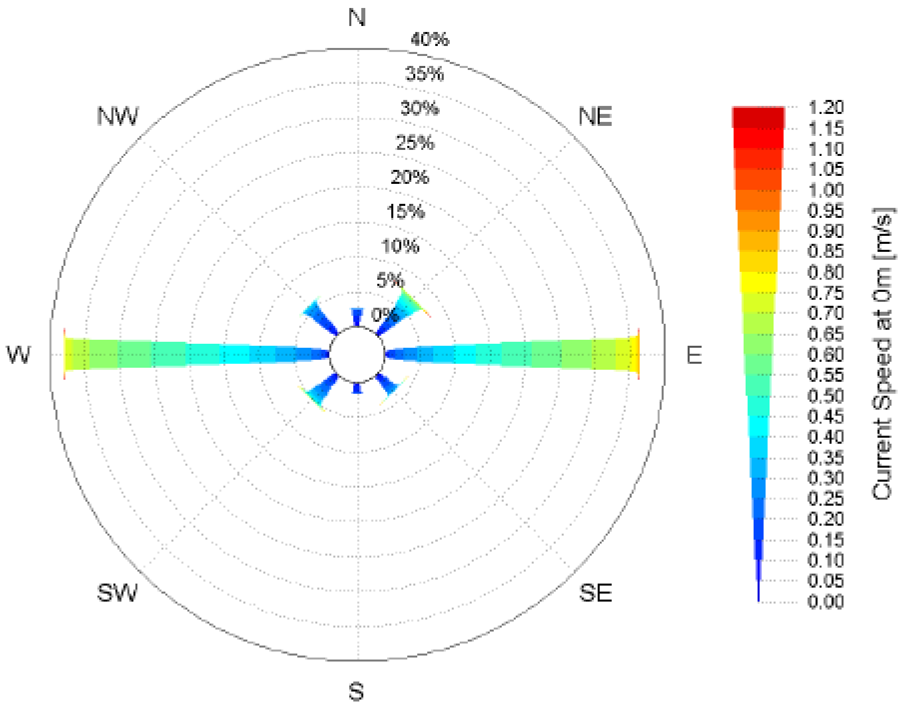
All-Year

Significant Wave Height [m]	N	NE	E	SE	S	SW	W	NW	Total %	Exceed %
Total	20.79	10.32	7.24	2.97	3.14	7.30	21.26	26.98	100.00	
10.0								<0.01	<0.01	
9.5										
9.0										
8.5								<0.01	<0.01	
8.0	<0.01							0.02	0.02	0.02
7.5	<0.01							0.01	0.01	0.04
7.0	<0.01						<0.01	0.02	0.03	0.06
6.5	<0.01						<0.01	0.04	0.05	0.11
6.0	0.01						<0.01	0.05	0.07	0.19
5.5	0.02	<0.01					0.02	0.11	0.15	0.34
5.0	0.04	<0.01					0.06	0.19	0.29	0.63
4.5	0.06	<0.01				<0.01	0.14	0.34	0.54	1.18
4.0	0.08	0.03	<0.01			0.02	0.26	0.47	0.86	2.03
3.5	0.19	0.08	0.03		<0.01	0.07	0.55	0.72	1.65	3.68
3.0	0.33	0.15	0.11	<0.01	0.01	0.24	1.03	1.12	3.00	6.68
2.5	0.62	0.28	0.24	0.01	0.04	0.52	1.66	1.68	5.05	11.73
2.0	1.18	0.63	0.55	0.09	0.19	0.93	2.39	2.66	8.62	20.35
1.5	2.50	1.47	1.10	0.30	0.44	1.51	3.59	4.22	15.13	35.48
1.0	5.38	2.57	2.00	0.79	0.87	1.95	4.64	5.78	23.97	59.45
0.5	7.29	3.44	2.46	1.54	1.43	1.87	4.29	6.30	28.62	88.07
0.0	3.08	1.64	0.75	0.25	0.17	0.19	2.61	3.24	11.93	

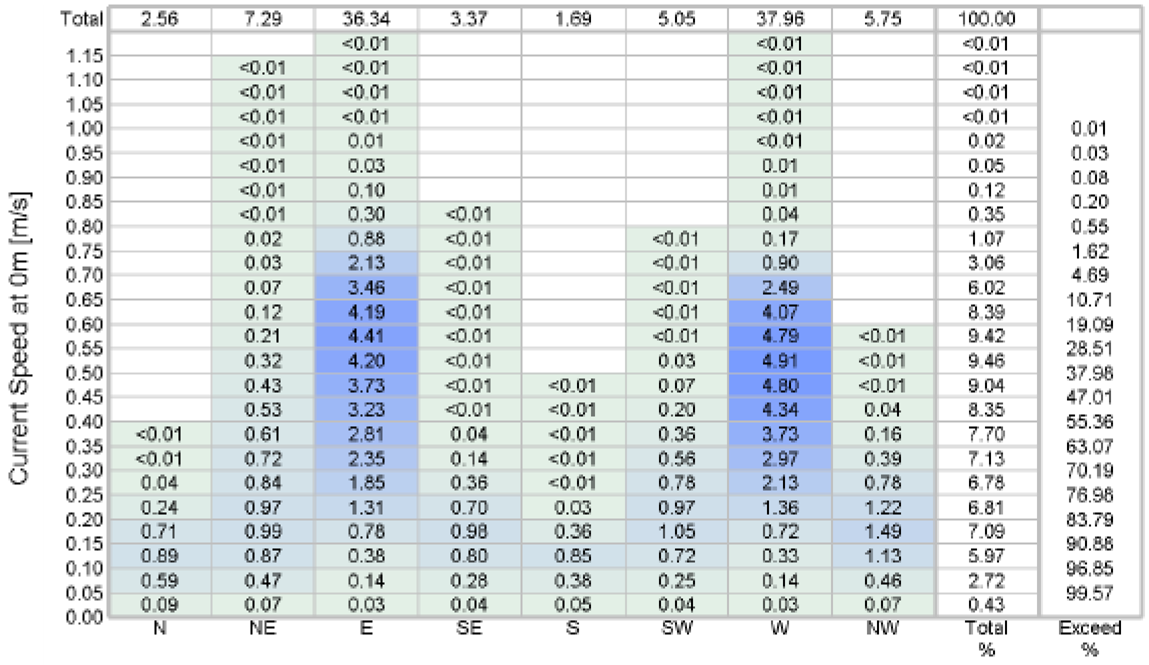
Mean Wave Direction [°T From]

Figure B-3: Near tie-in wave scatter [ref III]

All-Year



All-Year



Current Speed at 0m [m/s]	N	NE	E	SE	S	SW	W	NW	Total %	Exceed %
Total	2.56	7.29	36.34	3.37	1.69	5.05	37.96	5.75	100.00	
1.15			<0.01				<0.01		<0.01	
1.10		<0.01	<0.01				<0.01		<0.01	
1.05		<0.01	<0.01				<0.01		<0.01	
1.00		<0.01	<0.01				<0.01		<0.01	0.01
0.95		<0.01	0.01				<0.01		0.02	0.03
0.90		<0.01	0.03				0.01		0.05	0.08
0.85		<0.01	0.10				0.01		0.12	0.20
0.80		<0.01	0.30	<0.01			0.04		0.35	0.55
0.75		0.02	0.88	<0.01		<0.01	0.17		1.07	1.62
0.70		0.03	2.13	<0.01		<0.01	0.90		3.06	4.69
0.65		0.07	3.46	<0.01		<0.01	2.49		6.02	10.71
0.60		0.12	4.19	<0.01		<0.01	4.07		8.39	19.09
0.55		0.21	4.41	<0.01		<0.01	4.79	<0.01	9.42	28.51
0.50		0.32	4.20	<0.01		0.03	4.91	<0.01	9.46	37.98
0.45		0.43	3.73	<0.01	<0.01	0.07	4.80	<0.01	9.04	47.01
0.40		0.53	3.23	<0.01	<0.01	0.20	4.34	0.04	8.35	55.36
0.35	<0.01	0.61	2.81	0.04	<0.01	0.36	3.73	0.16	7.70	63.07
0.30	<0.01	0.72	2.35	0.14	<0.01	0.56	2.97	0.39	7.13	70.19
0.25	0.04	0.84	1.85	0.36	<0.01	0.78	2.13	0.78	6.78	76.98
0.20	0.24	0.97	1.31	0.70	0.03	0.97	1.36	1.22	6.81	83.79
0.15	0.71	0.99	0.78	0.98	0.36	1.05	0.72	1.49	7.09	90.88
0.10	0.89	0.87	0.38	0.80	0.85	0.72	0.33	1.13	5.97	96.85
0.05	0.59	0.47	0.14	0.28	0.38	0.25	0.14	0.46	2.72	99.57
0.00	0.09	0.07	0.03	0.04	0.05	0.04	0.03	0.07	0.43	

Current Direction at 0m [°T Towards]

Figure B-4: Near tie-in current scatter [ref III]

N05A Development Project

Pipeline Design and Installation Options

DOCUMENT NUMBER:

N05A-7-10-0-70037-01

Rev.	Date	Description	Originator	Checker	Approver
00	06-12-2019	For internal review	FGR	JWA	JWA
01	20-12-2019	For internal use	FGR	JWA	JWA
02	07-01-2020	Approved for Internal use	FGR	JWA	JWA
03	27-01-2020	Updated for Internal use	FGR	JWA	JWA

TABLE OF CONTENTS:

1.0 INTRODUCTION

One-Dyas plans to develop a successfully drilled well in block N5a of the North Sea Dutch Continental Shelf. More wells will be drilled at this location through the same jacket. It is planned to develop the wells by installing a platform and a gas export pipeline with a connection to the NGT pipeline. Various alternatives for the export pipeline route have been evaluated and a preferred route has been selected for further development; Pipeline route from the future N5A platform location to a subsea hot-tap tie-in at the NGT pipeline near KP 142.1.
In addition, a power cable will be installed from the Riffgat Windpark to the N05A platform.

Regarding installation of the N05a gas export pipeline many stakeholders are involved. In order to select the best technical solution for installation of the pipeline, with consideration of stakeholder requirements, this document has been written.

2.0 SELECTED PIPELINE DIAMETER

Our pipeline design contractor has carried out flow assurance analyses for 16 inch, 20 inch and 24 inch pipeline diameters. Based on these analyses a 20 inch pipeline diameter has been selected, which has more than sufficient capacity for the predicted N05a gas production.
An overview of the flow assurance results is given in table 2.1 below.

Table 2.1: Flow assurance results overview for 90 bar NGT pipeline pressure

		ND	ID	Gas flow		
#	Cases	inch	mm	MMNm^3/d	Graphic Legend	Colour
1	16inch-001 Design	16	0.3635	6.0	Design-16"-6.0MMNm3d	🟩
2	20inch-002 Design	20	0.4556	6.0	Design-20"-6.0MMNm3d	
40	24inch-040 Design	24	0.54808	6.0	Design-24"-6.0MMNm3d	
3	16inch-003 SOL	16	0.3635	4.0	SOL-16"-4.0MMNm3d	🟧
4	20inch-004 SOL	20	0.4556	4.0	SOL-20"-4.0MMNm3d	
41	24inch-041 SOL	24	0.54808	4.0	SOL-24"-4.0MMNm3d	
7	16inch-007 EOL	16	0.3635	0.1	EOL-16"-0.1MMNm3d	🟥
8	20inch-008 EOL	20	0.4556	0.1	EOL-20"-0.1MMNm3d	
43	24inch-043 EOL	24	0.54808	0.1	EOL-24"-0.1MMNm3d	
9	16inch-009 Max OP	16	0.3635	5.2	MaxOP-16"-5.2MMNm3d	🟦
10	20inch-010 max OP	20	0.4556	9.3	MaxOP-20"-9.3MMNm3d	
44	24inch-044 max OP	24	0.54808	15.0	MaxOP-24"-15.0MMNm3d	
11	16inch-011 Max Design	16	0.3635	7.8	MaxD-16"-7.8MMNm3d	⬛
12	20inch-012 Max Design	20	0.4556	14.0	MaxD-20"-14.0MMNm3d	
45	24inch-045 Max Design	24	0.54808	22.7	MaxD-24"-22.7MMNm3d	

3.0 PIPELINE ROUTE

A pipeline and cable route survey has been carried out comprising of the following elements:

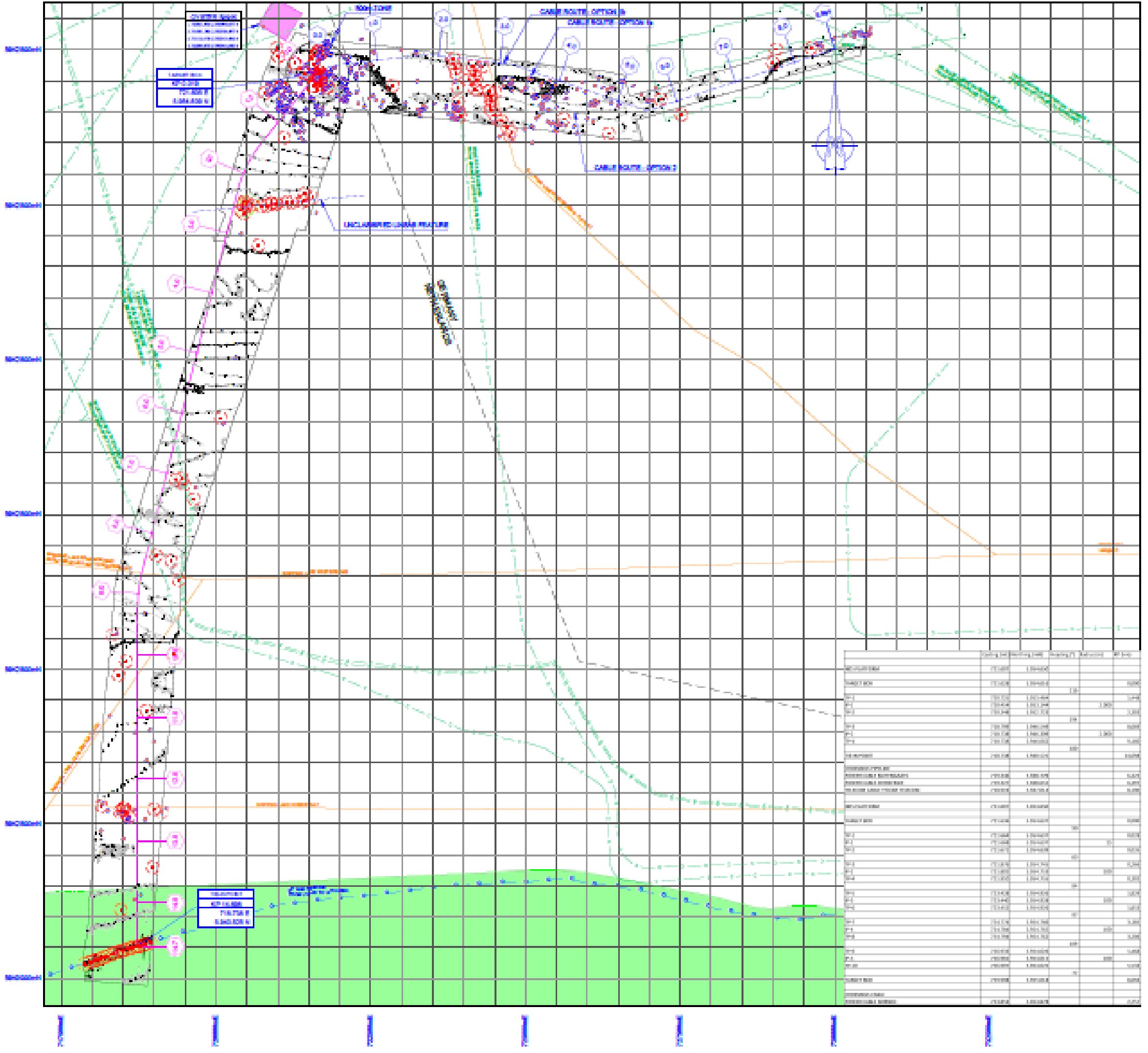
- Geophysical survey of a 1km wide corridor
- Geotechnical survey at 1km intervals
- Environmental baseline survey
- Archaeological desk top study using database information and recent survey information.

Based on the survey results pipeline and power cable route has been selected taking the following in consideration:

- 100m minimum distance to magnetic contacts
- 150m minimum distance to wrecks
- 25m minimum distance to remaining anomalies such as boulders

RWS have confirmed that they have no objections to the selected pipeline route and Periplus, who performs the archaeological study, have verbally confirmed that the route is acceptable with respect to possible archaeological values.

Figure 3.1: Selected pipeline and cable routes (ref. drawing nr. N05A-7-51-0-72510-01)



4.0 PIPELINE STABILITY

4.1 Unburied Pipeline Stability

Due to high currents and waves along the N05a pipeline route, specifically in the shallow part, a thick concrete weight coating is required to make an unburied pipeline stable. The calculated required concrete weight coating thickness is 140mm, with a density of 3300kg/m3. Even with this heavy weight coating the pipeline moves considerably. Based on DNV rules the pipeline moves over a distance of 10 times OD which is approximately 5m. To determine pipeline movement more accurately a finite element method has been used with an estimated pipeline embedment of 25%. Even with this embedment it was calculated that the pipeline moves more than 8m in the 10000 year storm conditions. To make the pipeline stable an even thicker concrete weight coating will be required beyond 200mm, which is a technically not achievable, as confirmed by pipe coaters Renania/Conline.

4.2 Buried Pipeline Stability

A buried pipeline does not require weight coating to be stable. During installation, when laying on the seabed before it is buried, a 20 inch pipeline without concrete weight coating is not stable in the 1 year storm. However, this can and will be managed by the installation contractor, using a favorable installation weather window. The pipeline will be buried directly after installation and it will then be stable in the 10.000 year storm. To enhance pipeline trenching it will be beneficial to apply a thin layer of 40mm concrete weight coating on the pipeline. This will also improve impact protection, pipeline stability before trenching and mitigate possible liquefaction.

5.0 RISK ASSESMENT

A risk assessment has been carried out by our pipeline design Contractor, for the buried and unburied pipeline options. Detailed results are given in document number N05A-7-10-0-70030-01 “Risk assessment & dropped object analysis”. A 1m deep buried pipeline without concrete weight coating is a safer option than an unburied pipeline with 140mm concrete weight coating. The latter option is not in accordance with the NEN3656 fail chance threshold of 1 x 10^{-6} per km of pipeline, per year.

Table 5.1 Quantitative Risk Assessment Results (ref. doc. Nr. N05A-7-10-0-70030-01)

		Failure chance per km per year				
Ship density /1000 km$_2$	**Un-buried case 140 mm CWC**	**Buried 0.6 m**	**Buried 0.7 m**	**Buried 0.8 m**	**Buried 1.0 m**	**NEN 3656 compliant**
45	3.39 10$_{-6}$	1.21 10$_{-6}$	1.00 10$_{-6}$	0.79 10$_{-6}$	0.78 10$_{-6}$	No / Yes

6.0 REQUIRED INSTALLATION SPREAD

6.1 General

Due to the limited waterdepth of 8m LAT near the future NGT pipeline tie-in point it is not feasible to install the pipeline with a dynamic positioned pipelay vessel. The thrusters underneath DP vessels they require a minimum waterdepth of approximately 17m LAT. Hence, the N05a pipeline will have to be installed by a shallow water pipelay barge operating on anchors.

These barges are towed to location by tugs, which will be used to position and relocate anchors when the vessel is on location. The range of shallow water pipelay barges available in the North Sea is limited to the Allseas Tog Mor and the Stingray owned by Van Oord. Possibly the Saipem owned Castoro Sei can also operate in this shallow water.

It may be possible to perform alternative installation by positioning a dynamic positioned (DP) pipelay vessel, e.g. Allseas' Lorelay in 17m waterdepth, approximately 5km away from the NGT pipeline target box. The DP vessel will then produce the pipeline from this position and the pipeline end will be towed to the target box by a suitable tug or it will be pulled in by a winch on a barge, located near the target box. When the pipeline head is positioned in the target box near NGT, the DP vessel continues pipeline installation on DP towards the target box near the N05A platform. It requires more work by Allseas to confirm whether this option can be executed, but they have **provisionally** priced it.

Survey will be performed by a 3rd party survey vessel. Pigging and pressure testing could be performed from a third party multicat or using a dedicated vessel such as Allseas' Calamity Jane.

6.2 Unburied Pipeline Installation Spread

The Tog Mor has a tensioner capacity of 100T, which is not sufficient to install a 20 inch schedule 60 pipeline, with 140mm concrete weight coating, in 26m waterdepth. The Tog Mor can install a 20 inch pipeline with 140mm CWC up to 17m waterdepth, at which point DP pipelay vessel Lorelay or Audacia can pick the pipeline up and continue installation towards the N05a location.

Van Oord's shallow water pipelay vessel Stingray has a tensioner capacity of 140T, which is likely to be sufficient to install the pipeline with 140mm concrete weight coating up to the maximum waterdepth of 26m. This will have to be confirmed by analyses. It must be noted that the Stingray is currently stored and has not been used for quite some time.

The Castoro Sei is a large semi-sub pipelay vessel operating on anchors, it has more than sufficient capacity to install a concrete coated 20 inch pipeline but it is large for our N05a pipeline and it is expected that it will not be priced attractively.

Due to the weight of the concrete coated pipeline it will not be possible to install it with a DP vessel in a stationary position as described above. For the cost estimate it has been assumed that an unburied pipeline will be installed by a combination of the Tog Mor and Lorelay installation vessels for shallow and deeper water sections respectively.

6.2 Buried Pipeline installation Spread

A buried pipeline with no- or maximum 40mm thick concrete weight coating can be installed completely from 8m water depth to 26m water depth by the Tog Mor, the Stingray or the Castoro Sei. Alternatively it may be possible to install this lighter pipeline with a DP pipelay vessel from a stationary position, as described in section 6.1. This will be substantially more cost efficient than installation with an anchor operated pipelay barge, due to much higher pipelay speed resulting in shorter duration.

To bury the pipeline Allseas would use a subcontractor’s mass flow excavator operated from a multicat vessel. A picture of such equipment is given in appendix D.
It is unclear whether Van Oord and Saipem would use their own equipment to bury the pipeline or whether they would subcontract that work.

7.0 INSTALLATION COST COMPARISON

A cost comparison between buried pipeline installation and unburied pipeline installation is given below. As base case the Allseas provided prices have been used for the Tog Mor and Lorelay, since those are the most viable options. For the buried pipeline it may be possible to optimize the costs by installing the pipeline without concrete weight coating, this will be determined during detailed design. Please note that the costs below do not include tie-in spool installation.

	Buried Lorelay	**Buried Tog Mor**	**Unburied Tog Mor & Lorelay**	**Budget**
Materials	**€ 6,610,750**	**€ 6,610,750**	**€ 9,083,000**	**€ 6,465,263**
20 inch Line pipe + FBE coating	€ 4,673,250	€ 4,673,250	€ 4,673,250	
Concrete weight coating	€ 1,937,500	€ 1,937,500	€ 4,409,750	
Installation	**€ 12,680,000**	**€ 17,702,000**	**€ 17,148,000**	**€ 10,200,000**
PM & Engineering	€ 723,000	€ 723,000	€ 1,800,000	
Mob/demob + fixed costs	€ 3,266,000	€ 3,179,000	€ 5,400,000	€ 3,900,000
Pipeline installation	€ 5,393,000	€ 9,526,000	€ 6,300,000	€ 3,900,000
Survey	€ 1,570,000	€ 2,326,000	€ 2,326,000	€ 1,300,000
Trenching	€ 516,000	€ 516,000	€ 0	
Flooding/gauging and testing	€ 992,000	€ 992,000	€ 992,000	€ 1,100,000
Guard vessels	€ 150,000	€ 300,000	€ 225,000	
Northsea pilots	€ 70,000	€ 140,000	€ 105,000	
Total	**€ 19,290,750**	**€ 24,312,750**	**€ 26,231,000**	**€ 16,665,263**
Impact compared to budget	€ 2,625,487	€ 7,647,487	€ 9,565,737	

8.0 CONCLUSION

After evaluation of advantages and disadvantages of the buried and unburied pipeline options it has been concluded that a buried N05a gas export pipeline is the best option, based on the following:

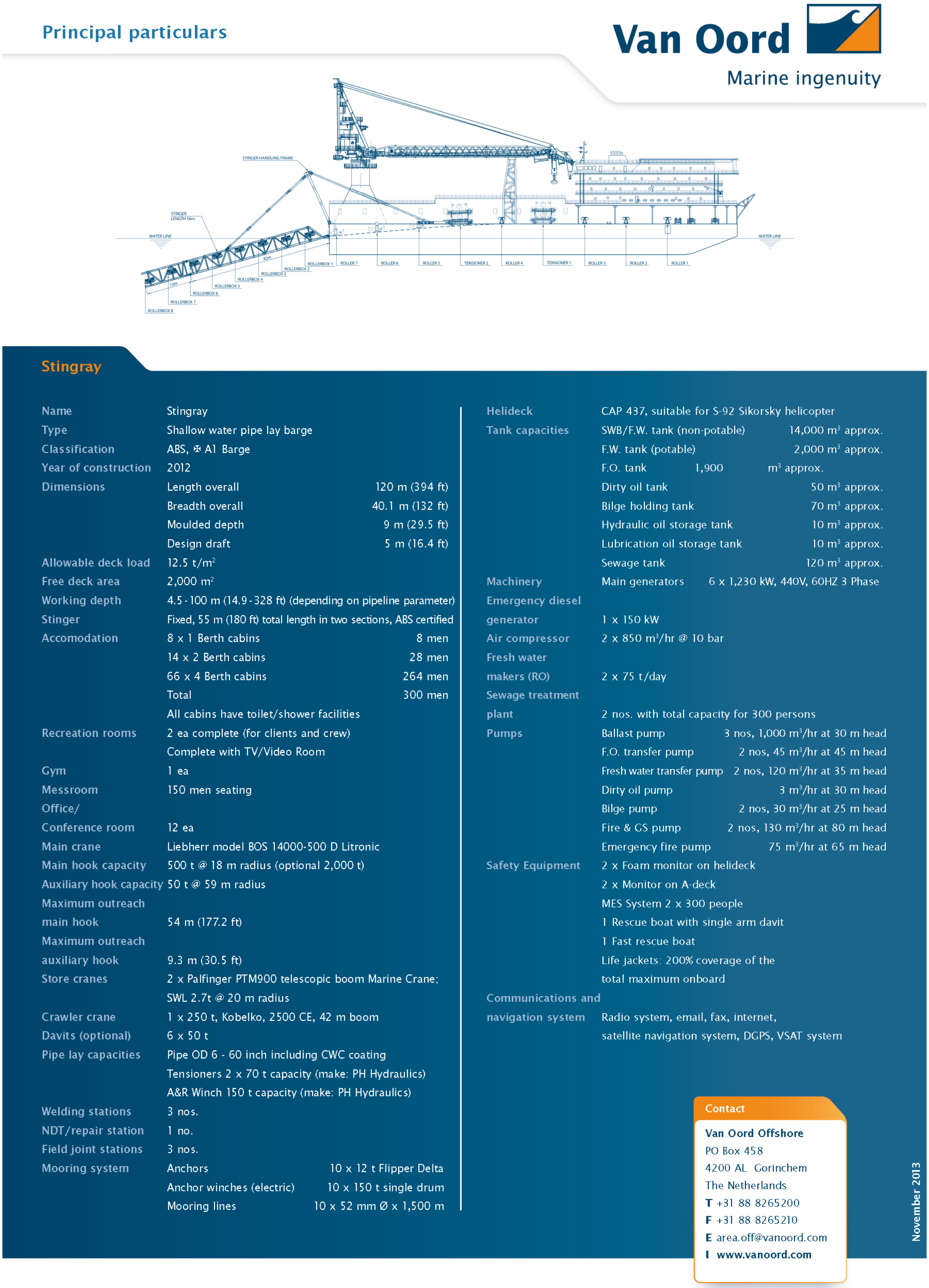
- Unacceptable failure risk of an unburied pipeline by dragging anchors, fishing activities or sinking ships. An unburied pipeline does not fulfil the failure risk requirements of NEN3656. To reduce the failure risk in accordance with NEN3656 the pipeline must be buried minimum 0.8m deep.
- An unburied pipeline with 140mm concrete weight coating is not stable in the 10000 year storm conditions, it moves considerably even when 25% natural embedment is taken into account. The required concrete weight coating thickness of 240mm to make an unburied pipeline stable is thicker than the 150mm maximum thickness that can be fabricated. A buried pipeline is stable in the 10000 year storm conditions.
- Better pipeline install-ability. Due to the lower weight of the pipeline without concrete weight coating it can be installed by several shallow water pipelay vessels. For a heavy concrete weight coated pipeline the available installation vessels are limited and may not be available for the desired installation window. Alternatively it may be possible to install the lighter pipeline by a DP operated pipelay barge, which will be more cost effective.
- Lower overall costs. Concrete weight coating of 140mm thickness is more expensive than pipeline trenching. Moreover a larger number of installation vessels are available to install a pipeline without weight coating, which will result in more competition and better prices.

APPENDIX A DATA SHEET PIPELINE INSTALLATION VESSEL TOG MOR

TOG MOR
Vessel specifications

Length overall (incl. stinger)	154 m (505 ft)
Length overall (excl. stinger)	111 m (364 ft)
Breadth	27 m (89 ft)
Depth to main deck	6 m (20 ft)
Operating draught	2 m (7 ft)
Mooring system	Flipper Delta anchors, 10 points: Forward: 4 x 10 t (20 kips) and 2 x 8.5 t (20 kips) Aft: 4 x 7 t (15 kips)
Total installed power	3750 kW
Accomodation	144 persons
Helideck	Maximum take-off weight 11.1 t, suitable for Sikorsky S-92 and Puma 100 helicopters
Deck cranes	Main crane of 300 t (660 kips) at 17 m (55 ft) main hoist Crawler crane of 79 t (170 kips) at 8 m (26 ft) main hoist
Work stations	3 (single joint) welding stations, 1 NDT station and 1 coating stations
Installed tension capacity	1 x 100 t
Pipe cargo capacity on main deck	10 t/m²
Pipe diameters	From 2" to 60" OD
Clear deck space	1000 m²
Classifications	LR A1 Barge, crane pontoon
Port of registry	Valletta

APPENDIX B DATA SHEET PIPELINE INSTALLATION VESSEL STINGRAY



Principal particulars

Van Oord
Marine ingenuity

Stingray

Name	Stingray	
Type	Shallow water pipe lay barge	
Classification	ABS, ✠ A1 Barge	
Year of construction	2012	
Dimensions	Length overall	120 m (394 ft)
	Breadth overall	40.1 m (132 ft)
	Moulded depth	9 m (29.5 ft)
	Design draft	5 m (16.4 ft)
Allowable deck load	12.5 t/m^2	
Free deck area	2,000 m^2	
Working depth	4.5 - 100 m (14.9 - 328 ft) (depending on pipeline parameter)	
Stinger	Fixed, 55 m (180 ft) total length in two sections, ABS certified	
Accomodation	8 x 1 Berth cabins	8 men
	14 x 2 Berth cabins	28 men
	66 x 4 Berth cabins	264 men
	Total	300 men
	All cabins have toilet/shower facilities	
Recreation rooms	2 ea complete (for clients and crew)	
	Complete with TV/Video Room	
Gym	1 ea	
Messroom	150 men seating	
Office/ Conference room	12 ea	
Main crane	Liebherr model BOS 14000-500 D Litronic	
Main hook capacity	500 t @ 18 m radius (optional 2,000 t)	
Auxiliary hook capacity	50 t @ 59 m radius	
Maximum outreach main hook	54 m (177.2 ft)	
Maximum outreach auxiliary hook	9.3 m (30.5 ft)	
Store cranes	2 x Palfinger PTM900 telescopic boom Marine Crane; SWL 2.7t @ 20 m radius	
Crawler crane	1 x 250 t, Kobelko, 2500 CE, 42 m boom	
Davits (optional)	6 x 50 t	
Pipe lay capacities	Pipe OD 6 - 60 inch including CWC coating	
	Tensioners 2 x 70 t capacity (make: PH Hydraulics)	
	A&R Winch 150 t capacity (make: PH Hydraulics)	
Welding stations	3 nos.	
NDT/repair station	1 no.	
Field joint stations	3 nos.	
Mooring system	Anchors	10 x 12 t Flipper Delta
	Anchor winches (electric)	10 x 150 t single drum
	Mooring lines	10 x 52 mm Ø x 1,500 m

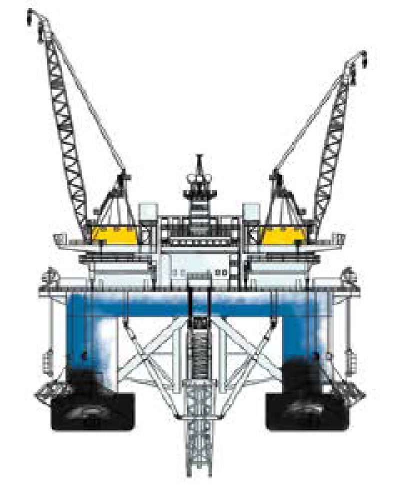
Helideck	CAP 437, suitable for S-92 Sikorsky helicopter	
Tank capacities	SWB/F.W. tank (non-potable)	14,000 m^3 approx.
	F.W. tank (potable)	2,000 m^3 approx.
	F.O. tank	1,900 m^3 approx.
	Dirty oil tank	50 m^3 approx.
	Bilge holding tank	70 m^3 approx.
	Hydraulic oil storage tank	10 m^3 approx.
	Lubrication oil storage tank	10 m^3 approx.
	Sewage tank	120 m^3 approx.
Machinery	Main generators	6 x 1,230 kW, 440V, 60HZ 3 Phase
Emergency diesel generator	1 x 150 kW	
Air compressor	2 x 850 m^3/hr @ 10 bar	
Fresh water makers (RO)	2 x 75 t/day	
Sewage treatment plant	2 nos. with total capacity for 300 persons	
Pumps	Ballast pump	3 nos, 1,000 m^3/hr at 30 m head
	F.O. transfer pump	2 nos, 45 m^3/hr at 45 m head
	Fresh water transfer pump	2 nos, 120 m^3/hr at 35 m head
	Dirty oil pump	3 m^3/hr at 30 m head
	Bilge pump	2 nos, 30 m^3/hr at 25 m head
	Fire & GS pump	2 nos, 130 m^3/hr at 80 m head
	Emergency fire pump	75 m^3/hr at 65 m head
Safety Equipment	2 x Foam monitor on helideck	
	2 x Monitor on A-deck	
	MES System 2 x 300 people	
	1 Rescue boat with single arm davit	
	1 Fast rescue boat	
	Life jackets: 200% coverage of the total maximum onboard	
Communications and navigation system	Radio system, email, fax, internet, satellite navigation system, DGPS, VSAT system	

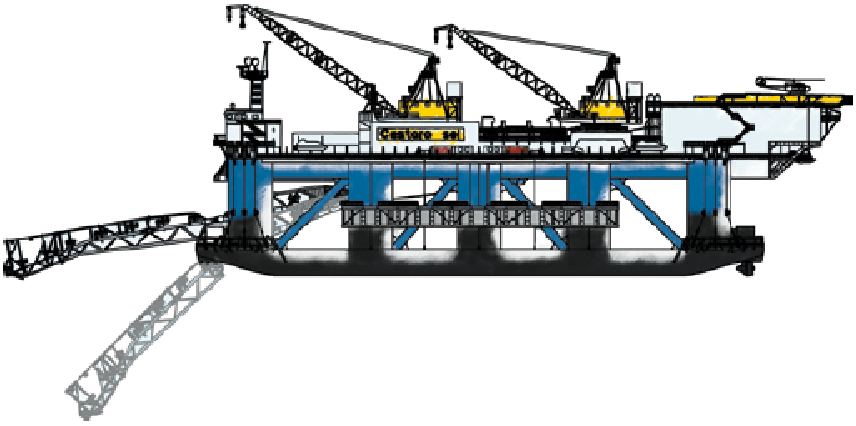
Contact

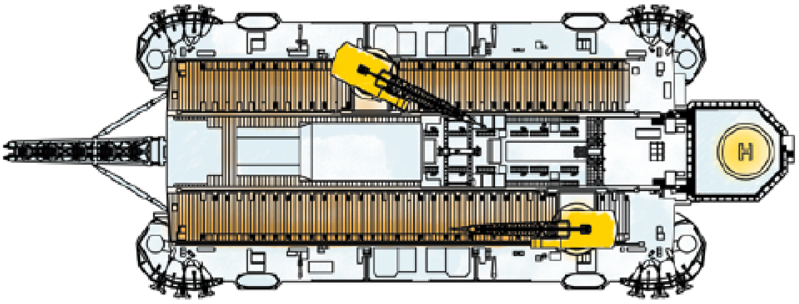
Van Oord Offshore
PO Box 458
4200 AL Gorinchem
The Netherlands
T +31 88 8265200
F +31 88 8265210
E area.off@vanoord.com
I www.vanoord.com

November 2013

APPENDIX C DATA SHEET PIPELINE VESSEL CASTORO SEI







HULL TYPE

Column stabilised semi-submersible

VESSEL FEATURES

Length overall excluding ramps	152.0 m
Breadth overall	70.5 m
Depth to main deck	29.8 m
Transit draft	9.5 m
Operating draft (typical)	14.0 m
Survival draft	12.5 m
Dedicated pipe storage space	1,195 sq.m
Additional deck space	1,525 sq.m
Deck load	3,600 tonnes

CLASSIFICATION

American Bureau of Shipping

COMPLIANCE

NMA, HSE

PROPULSION / POSITIONING SYSTEM

Four 37 tonne Azimuthal thrusters
Twelve 25 tonne anchors
Twelve 124 tonne anchor winches
3,000 m anchor wire on each winch of 76 mm

PIPELAY EQUIPMENT

2 Rotating gantry cranes 134 tonnes capacity
Longitudinal conveyor, gantry transfer conveyors, line-up station
Three 130 tonne pipe tensioners
Fixed ramp, articulated ramp, mini ramp extension
Bevelling stations
Double jointing system
Welding stations utilising a semi automatic system
X-ray or AUT equipped NDT stations
Field joint coating system
Abandonment & recovery winch (400 tonnes)
Piggyback lay welding line facility
Dual-lay welding line and ramp

HELIDECK

Suitable for helicopters up to and including the Sikorsky S61N type

NAVIGATION & COMMUNICATIONS

Fully equipped radio room GMDSS
Satellite communications & TV
2 ARPA radars
GPS / DGPS navigation & positioning
Echosounder

POWER GENERATION

6 Main generators	20.5 Mw total
1 Emergency generator	800 Kw

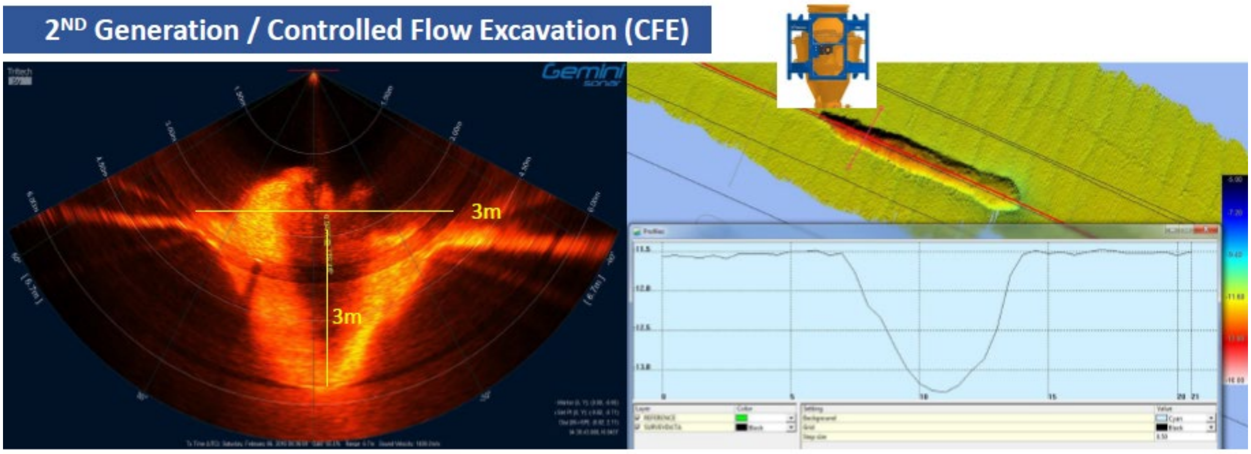
BUNKER CAPACITY

Ballast capacity	11,518 cu.m
Lube oil capacity	138 cu.m
Fuel oil capacity	3,123 cu.m
Potable water capacity	1,000 cu.m
Fresh water generators	
180 tonnes / day	

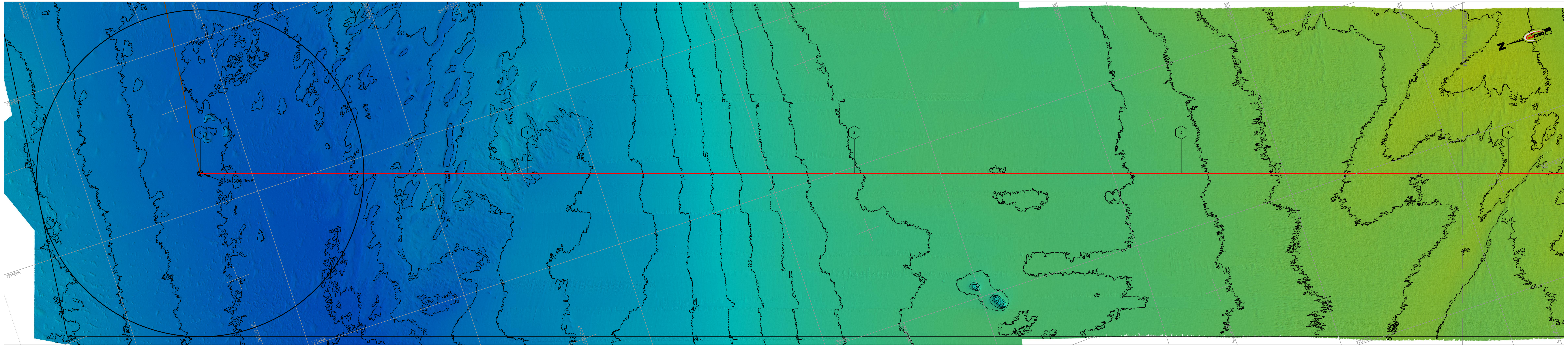
CREW FACILITIES

Accommodation for 347 people
Client offices
Conference rooms
Hospital
Gymnasium
Galley mess room
Coffee bar
Cinema
Recreation rooms
Satellite television

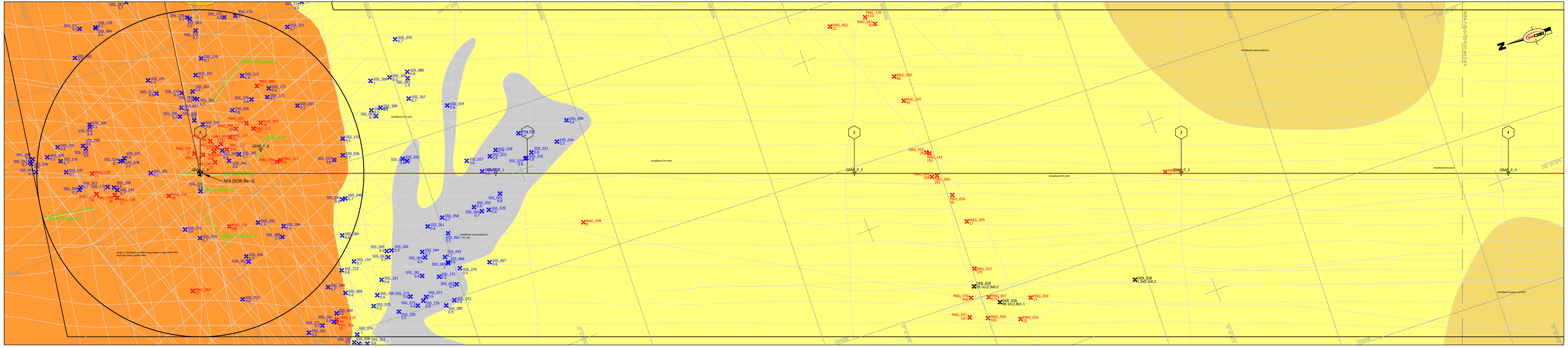
APPENDIX D MASS FLOW EXCAVATOR EXAMPLE



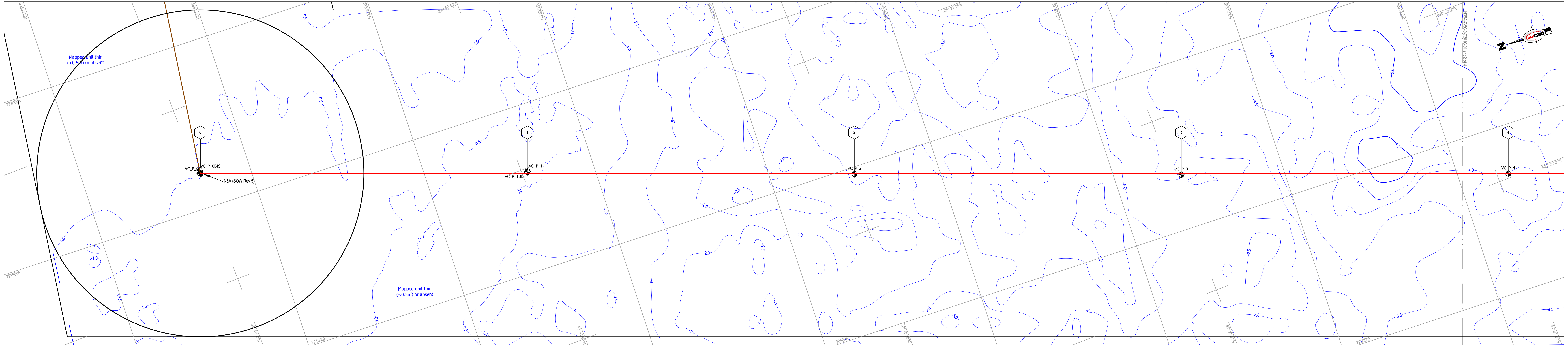
BATHYMETRY



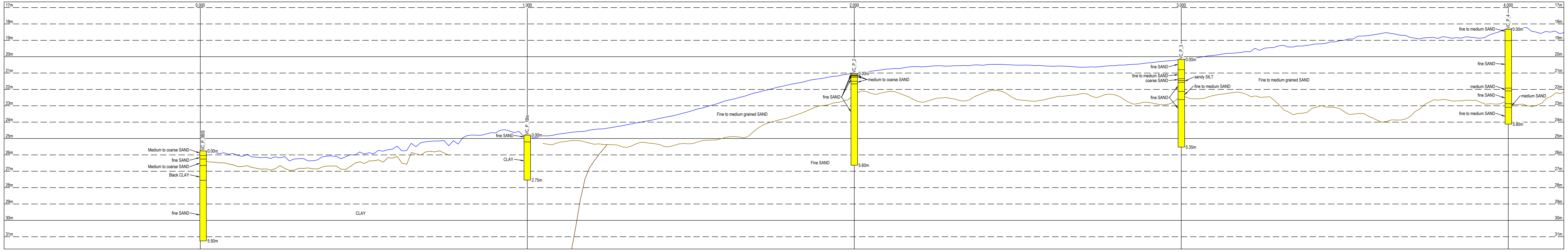
SEABED FEATURES



ISOPACH



LONGITUDINAL PROFILE



LEGEND

Kilometer point
Theoretical pipeline position
Chart match lines
Survey Area (500m at each side of proposed pipeline/cable)
Proposed pipeline route
Proposed cable route
Natura 2000
Cables
Pipelines
500m zone
Proposed new location for N5A platform
Internal cables Riffgat
Monopile location Riffgat
Graticule grid
U.T.M. grid

SCALE 1:5000
0 50 100 150 200 250 500 meters
0 200 400 800 1600 feet

BATHYMETRY:

All Bathymetry reduced to Lowest Astronomical Tide (LAT)

20 Depth contour at 0.5 meter intervals
Gridsize used for contours: 0.5m

-35m -30 -25 -20 -15 -10 -5m
Gridsize: 0.5m
Height (m)

SEABED FEATERS:

Vessel track
Linear debris
Camera transects
SSS_266 0.8 Object ID
SSS contact/object: Unit value: m
MAG_158 0.6 Object ID
Magnetic contact: Unit value: nT
DEB_023 1.4 x 0.5 x 0.3 Object ID
Debris: Unit value: m (Nmh: No measurable height)
GRAB_P_12 Position of grab sample

🟨 Infralittoral fine sand (A5.23)
🟨 Infralittoral coarse sediment (A5.13)
🟧 Infralittoral mixed sediment (A5.43) - no clay
🟧 Dense L. conchilega and other polychaetes in tide-swept infra. Sandand mixed gravelly sand (A5.137)
⬜ Infralittoral mixed sediment (A5.43) - Incl. clay

ISOPACH:

1. Time depth conversion carried out using an assumed seismic velocity (ASV) of 1600m/s.
2. The mapped unit is expected to comprise dense SAND

1.0 contour at 0.5 metre intervals
Data extents
Shallow gas
VC_C_4 Position of vibrocore

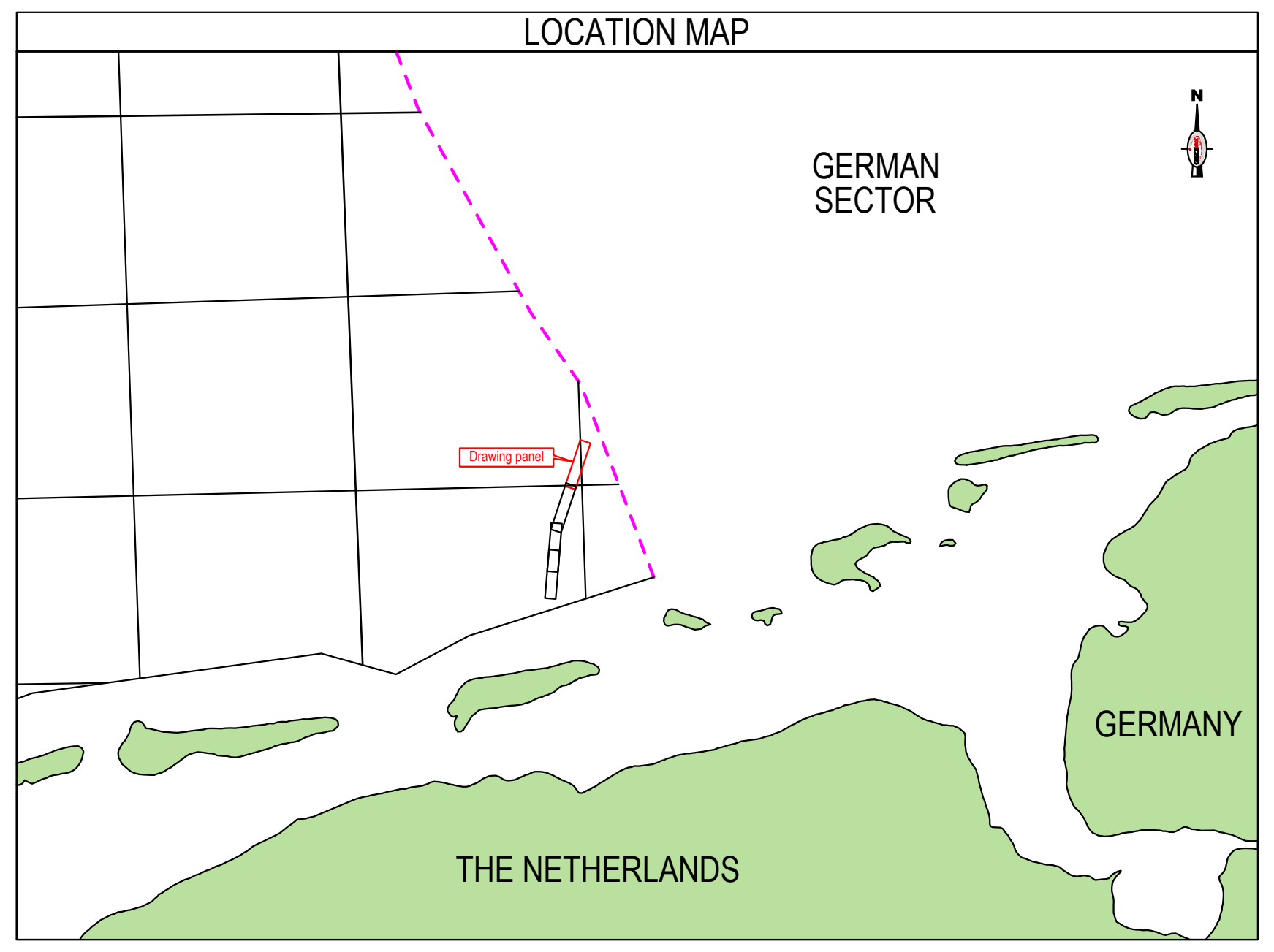
LONGITUDINAL PROFILE:

Seabed
Base surfical sand
Clay
4.000 Kilometer point

VC_C_1 Name of vibrocore
0.00m
4.10m Bottom - depth below seabed

ONE INFORMATION PANEL

LOCATION MAP



SURVEY EQUIPMENT

Positioning:	Fugro seastar 9205
Multibeam:	R2Sonic 2024
Motion sensor:	POS-MV OceanMaster
Sound velocity probe:	Valeport - Swift
Side scan sonar:	Edgetech - 4200
USBL:	Sonardyne Ranger 2
Magnetometer:	Geometrics - G882
Sub Bottom Profiler	Massa TR1075D
Seismic source:	GSO 180 Sparker

SURVEY SOFTWARE

Online/offline survey suite:	QINSy / Version 8.1
SSS Acquisition:	Edgetech Discover
SSS Processing:	CODA Survey Engine V. 4.3
SBP Acquisition:	Stema SILAS Acquisition
SBP Processing:	Stema SILAS Processing
MAG Acquisition:	QINSy / Version 8.1
MAG Processing:	Oasis Montaj

GEODETIC INFORMATION

Horizontal datum:	European datum 1950 (ED 50)
Spheroid:	International 1924
Semi-major axis:	a = 6378388.00m
Semi-minor axis:	b = 6356911.95m
First eccentricity squared:	e2 = 0.006723
Inverse flattening:	1/f = 297.000
EPSG code:	23031
Projection:	UTM31N
Central meridian:	03° east
Latitude of origin:	0°
False easting:	500000.00m
False northing:	0.00m
Scale factor at central meridian:	0.9996
Units:	Metres
Vertical datum:	Lowest astronomical tide (LAT)

SURVEY DATES

Geophysical acquisition (MBES, MAG, SSS, SBP):
Geo Ocean III: 29/04/2019 untill 15/05/2019

HYDROGRAPHIC SURVEY

N5A development - pipeline route & platform area survey

N5A TO NGT HT ROUTE

Pipeline route
KP 0.000 to 4.170

Bathymetry - Seabed features - Isopach - Longitudinal profile

Chart: 001/004
Scale: 1/5000
LAT

Drawing made by:

GEOXYZ OFFSHORE
2 Route D'Arlon
Windhof Business center block A
L-8388 WINDHOF
Luxembourg

Client:

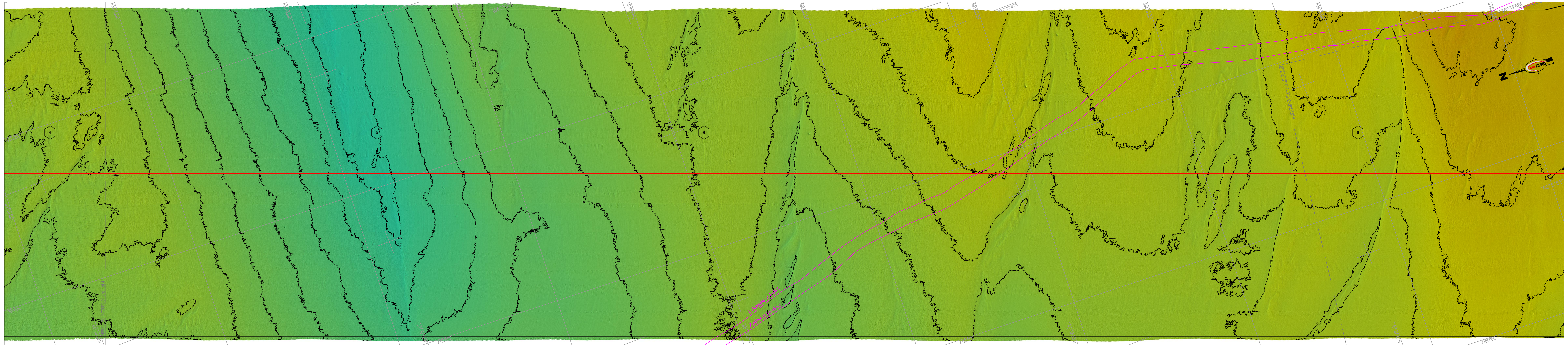
Oranje-Nassau Energie B.V.
UNStudio, 7th floor
Parnassusweg 815
1082 LZ Amsterdam (The Netherlands)

Tel: +31 20 535 41 00
Fax: +31 20 535 41 22

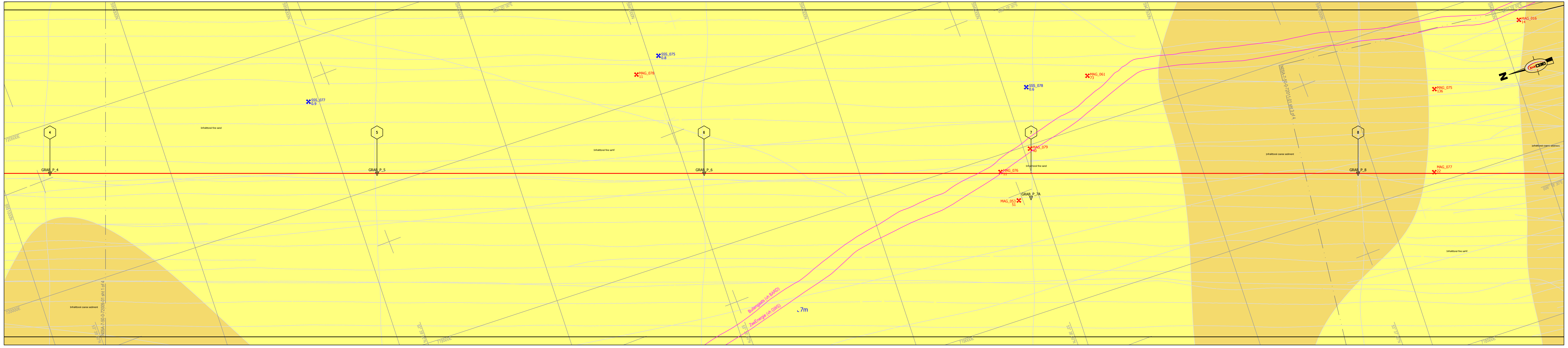
Issue no:	Date:	Description:	Drawn:	Checked:
1	12/06/2019	Second internal review	STH	RSP/TDB
2	15/07/2019	Issued for use	STH	RSP/TDB
3	05/09/2019	Client remarks	STH	RSP/TDB
4	01/10/2019	Client remarks	STH	RSP/TDB

Planname: LU0022H-553_DR-007_PR_1-4_v4.0
Project ref: N05A-7-50-0-72009-01 sht 1 of 4

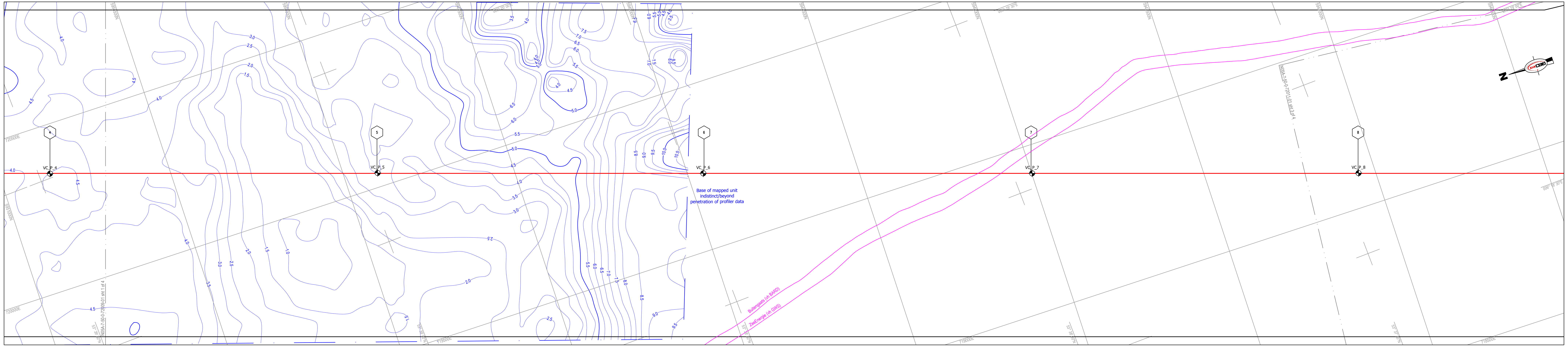
BATHYMETRY



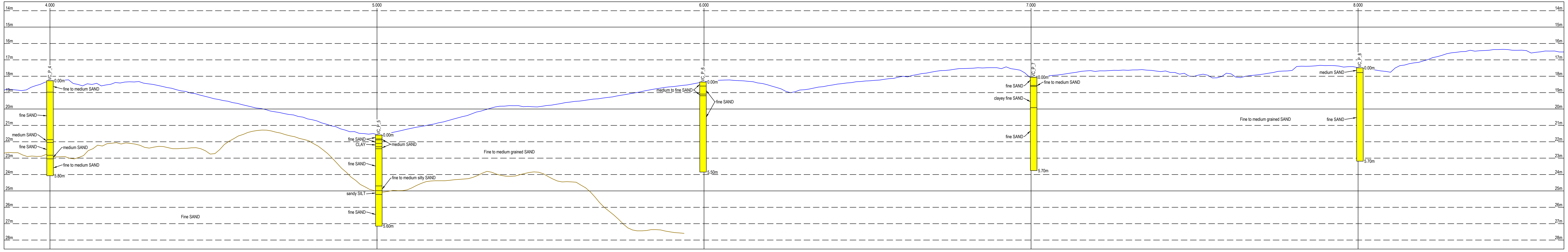
SEABED FEATURES



ISOPACH



LONGITUDINAL PROFILE



LEGEND

Kilometer point

Theoretical pipeline position

Chart match lines

Survey Area (500m at each side of proposed pipeline/cable)

Proposed pipeline route

Proposed cable route

Natura 2000

Cables

Pipelines

500m zone

Proposed new location for N5A platform

Internal cables Riffgat

Monopile location Riffgat

Graticule grid

U.T.M. grid

SCALE 1:5000

0 50 100 150 200 250 500 meters

0 200 400 800 1600 feet

BATHYMETRY:

All Bathymetry reduced to Lowest Astronomical Tide (LAT)

Depth contour at 0.5 meter intervals

Gridsize used for contours: 0.5m

-35m -30 -25 -20 -15 -10 -5m

Gridsize: 0.5m

Height (m)

SEABED FEATERS:

Vessel track

Linear debris

Camera transects

SSS_266 0.8 — Object ID
SSS contact/object: Unit value: m

MAG_158 0.6 — Object ID
Magnetic contact: Unit value: nT

DEB_023 1.4 x 0.5 x 0.3 — Object ID
Debris: Unit value: m (Nmh: No measurable height)

GRAB_P_12 — Position of grab sample

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- Dense L. conchilega and other polychaetes in tide-swept infra. Sandand mixed gravelly sand (A5.137)
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ISOPACH:

1. Time depth conversion carried out using an assumed seismic velocity (ASV) of 1600m/s.
2. The mapped unit is expected to comprise dense SAND

contour at 0.5 metre intervals

Data extents

Shallow gas

VC_C_4 — Position of vibrocore

LONGITUDINAL PROFILE:

Seabed

Base surfical sand

Clay

Kilometer point

VC_C_1 — Name of vibrocore

0.00m

4.10m — Bottom - depth below seabed

ONE INFORMATION PANEL

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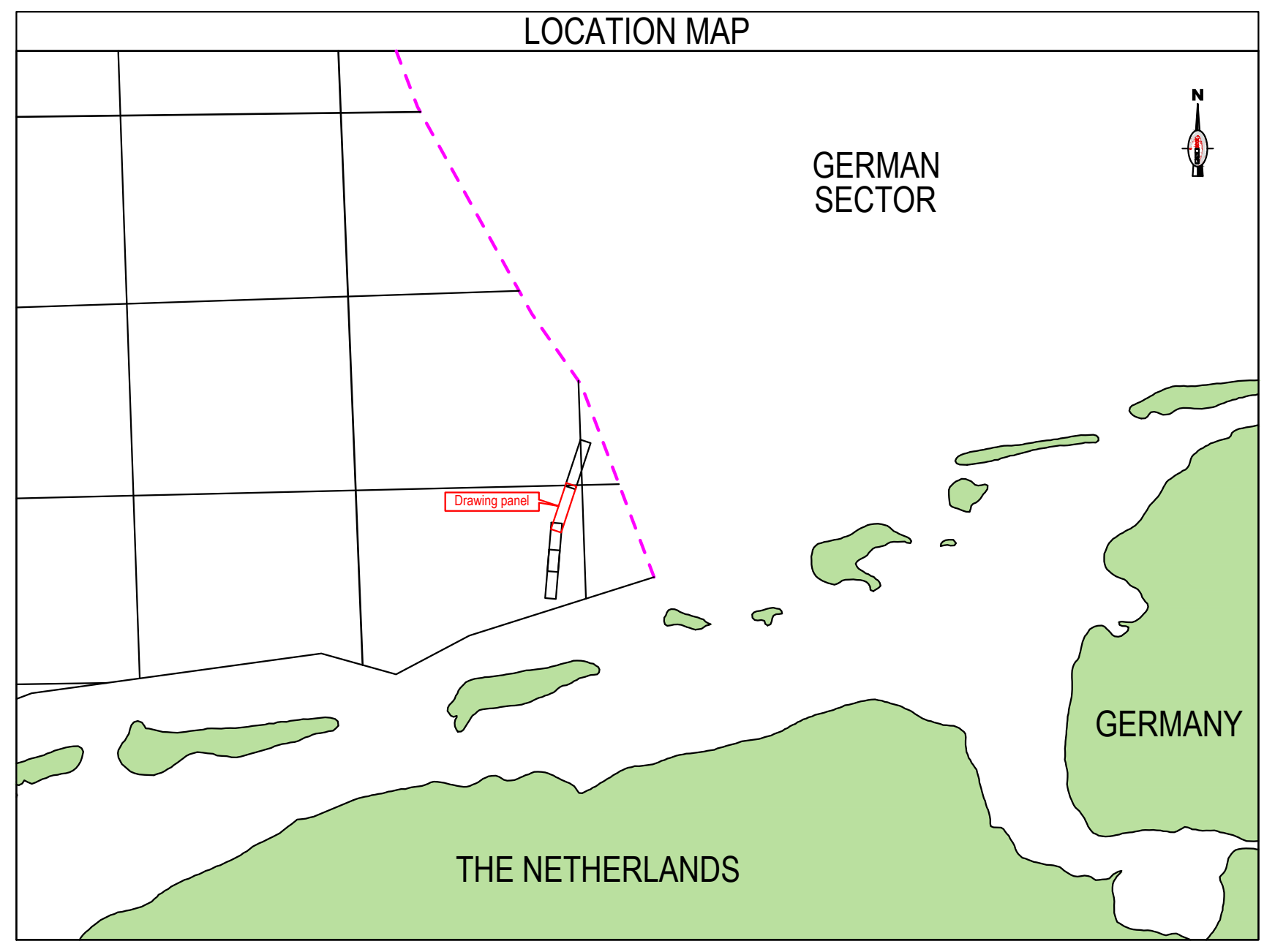
LOCATION MAP



SURVEY EQUIPMENT

Positioning:	Fugro seastar 9205
Multibeam:	R2Sonic 2024
Motion sensor:	POS-MV OceanMaster
Sound velocity probe:	Valeport - Swift
Side scan sonar:	Edgetech - 4200
USBL:	Sonardyne Ranger 2
Magnetometer:	Geometrics - G882
Sub Bottom Profiler	Massa TR1075D
Seismic source:	GSO 180 Sparker

GEODETIC INFORMATION

Horizontal datum:	European datum 1950 (ED 50)
Spheroid:	International 1924
Semi-major axis:	a = 6378388.00m
Semi-minor axis:	b = 6356911.95m
First eccentricity squared:	e2 = 0.006723
Inverse flattening:	1/f = 297.000
EPSG code:	23031
Projection:	UTM31N
Central meridian:	03° east
Latitude of origin:	0°
False easting:	500000.00m
False northing:	0.00m
Scale factor at central meridian:	0.9996
Units:	Metres
Vertical datum:	Lowest astronomical tide (LAT)

SURVEY SOFTWARE

Online/offline survey suite:	QINSy / Version 8.1
SSS Acquisition:	Edgetech Discover
SSS Processing:	CODA Survey Engine V. 4.3
SBP Acquisition:	Stema SILAS Acquisition
SBP Processing:	Stema SILAS Processing
MAG Acquisition:	QINSy / Version 8.1
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Geo Ocean III: 29/04/2019 untill 15/05/2019

HYDROGRAPHIC SURVEY

N5A development - pipeline route & platform area survey

N5A TO NGT HT ROUTE

Pipeline route

KP 3.860 to 8.630

Bathymetry - Seabed features - Isopach - Longitudinal profile

Chart: 002/004

Scale: 1/5000

LAT

Drawing made by:

GEOXYZ OFFSHORE
2 Route D'Arlon
Windhof Business center block A
L-8388 WINDHOF
Luxembourg

Client:

Oranje-Nassau Energie B.V.
UNStudio, 7th floor
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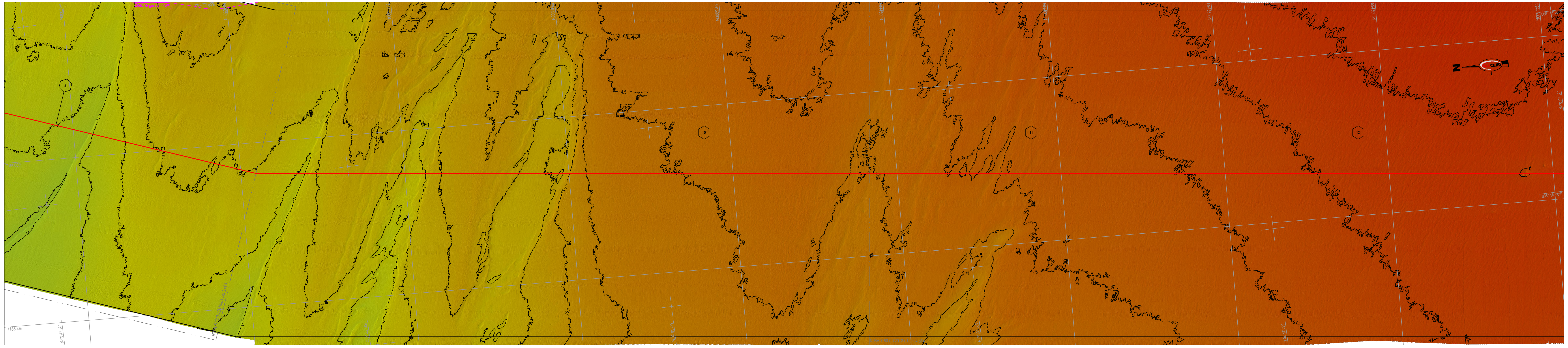
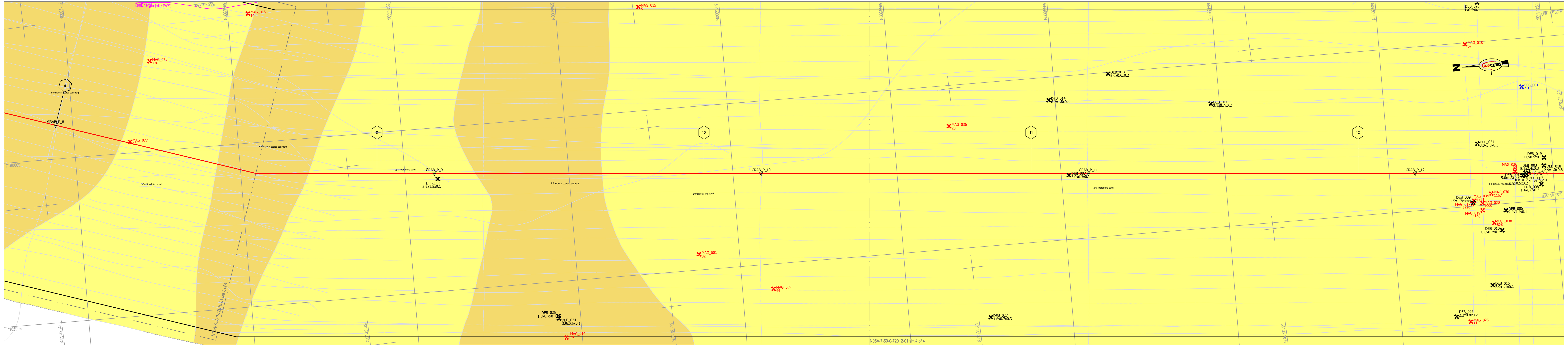
Planname:	LU0022H-553_DR-008_PR_2-4_v4.0	**Project ref:**	N05A-7-50-0-72010-01 sht 2 of 4

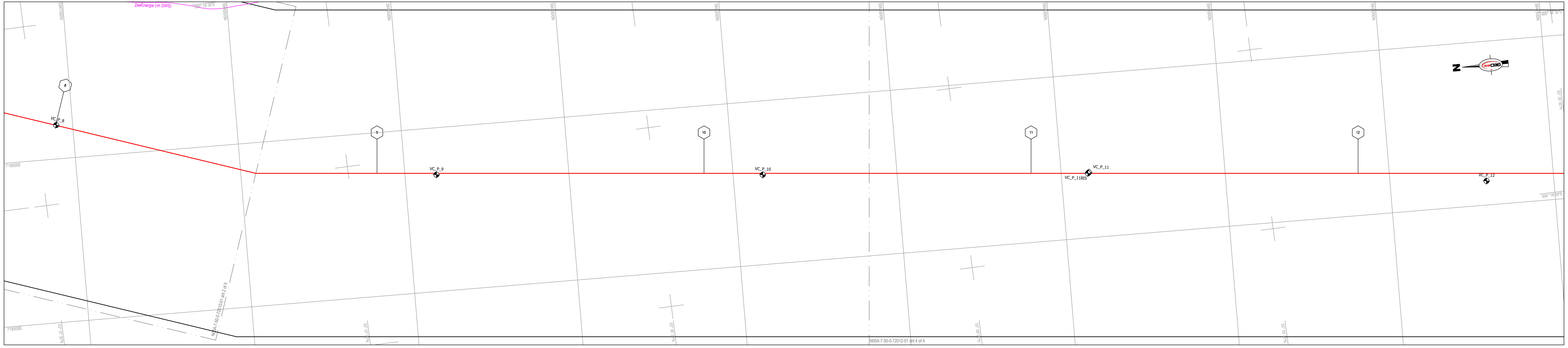
BATHYMETRY



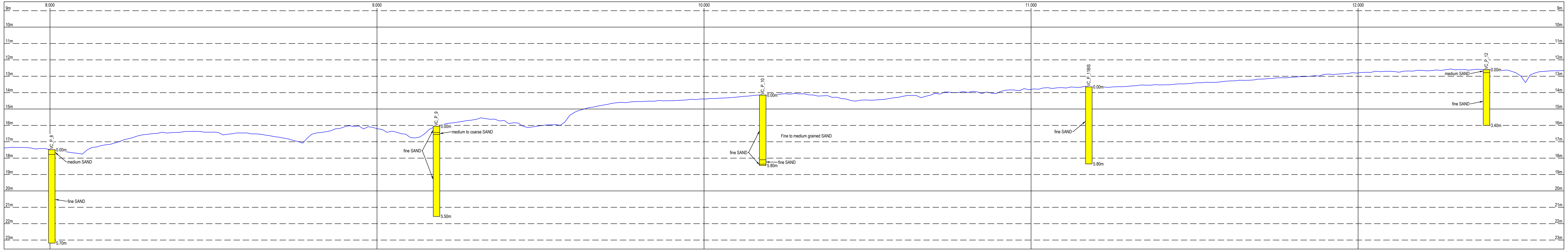
SEABED FEATURES



ISOPACH



LONGITUDINAL PROFILE



LEGEND

SCALE 1:5000

0 50 100 150 200 250 500 meters

0 200 400 800 1600 feet

Kilometer point

Theoretical pipeline position

Chart match lines

Survey Area (500m at each side of proposed pipeline/cable)

Proposed pipeline route

Proposed cable route

Natura 2000

Cables

Pipelines

500m zone

Proposed new location for N5A platform

Internal cables Riffgat

Monopile location Riffgat

Graticule grid

U.T.M. grid

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Depth contour at 0.5 meter intervals
Gridsize used for contours: 0.5m

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Data extents

Shallow gas

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LONGITUDINAL PROFILE:

Seabed

Base surfical sand

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VC_C_1 — Name of vibrocore

0.00m

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ONE INFORMATION PANEL

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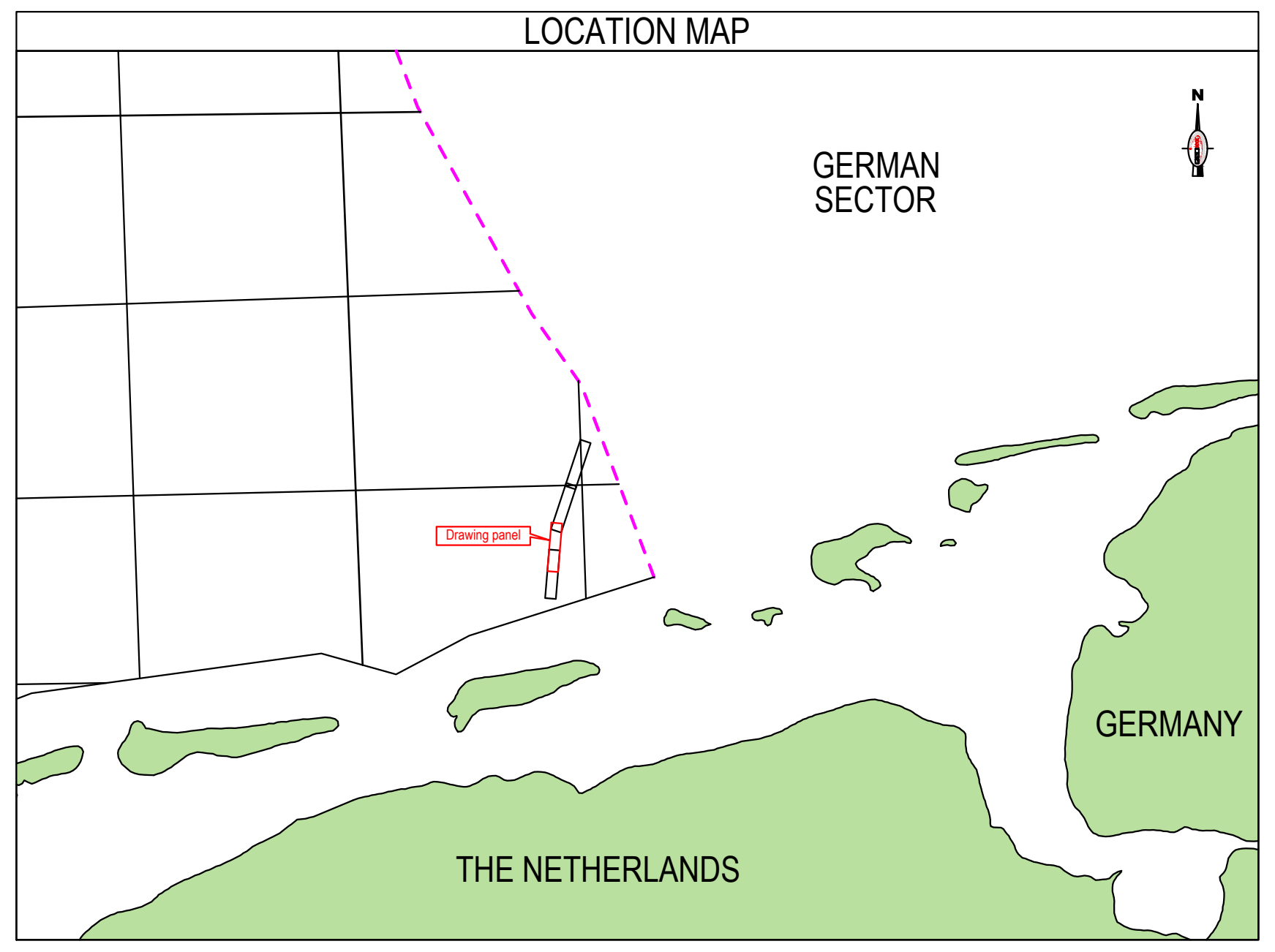
LOCATION MAP



SURVEY EQUIPMENT

Positioning:	Fugro seastar 9205
Multibeam:	R2Sonic 2024
Motion sensor:	POS-MV OceanMaster
Sound velocity probe:	Valeport - Swift
Side scan sonar:	Edgetech - 4200
USBL:	Sonardyne Ranger 2
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Sub Bottom Profiler	Massa TR1075D
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GEODETIC INFORMATION

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Semi-major axis:	a = 6378388.00m
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N5A TO NGT HT ROUTE

Pipeline route
KP 7.860 to 12.630

Bathymetry - Seabed features - Isopach - Longitudinal profile

Chart: 003/004	Scale: 1/5000	LAT

Drawing made by:

GEOXYZ OFFSHORE
2 Route D'Arlon
Windhof Business center block A
L-8388 WINDHOF
Luxembourg

Client:

Oranje-Nassau Energie B.V.
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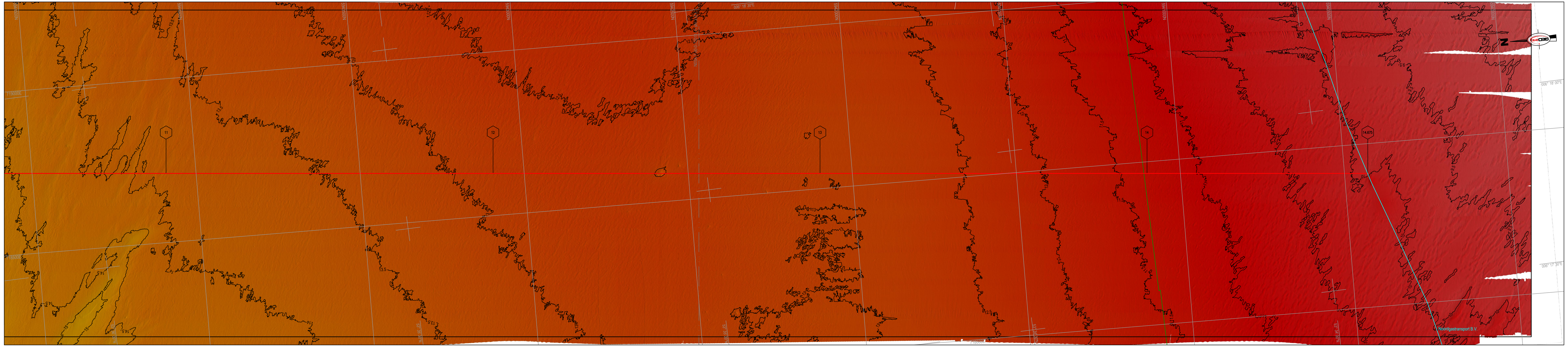
Planname:	LU0022H-553_DR-009_PR_3-4_v4.0	**Project ref:**	N05A-7-50-0-72011-01 sht 3 of 4

BATHYMETRY



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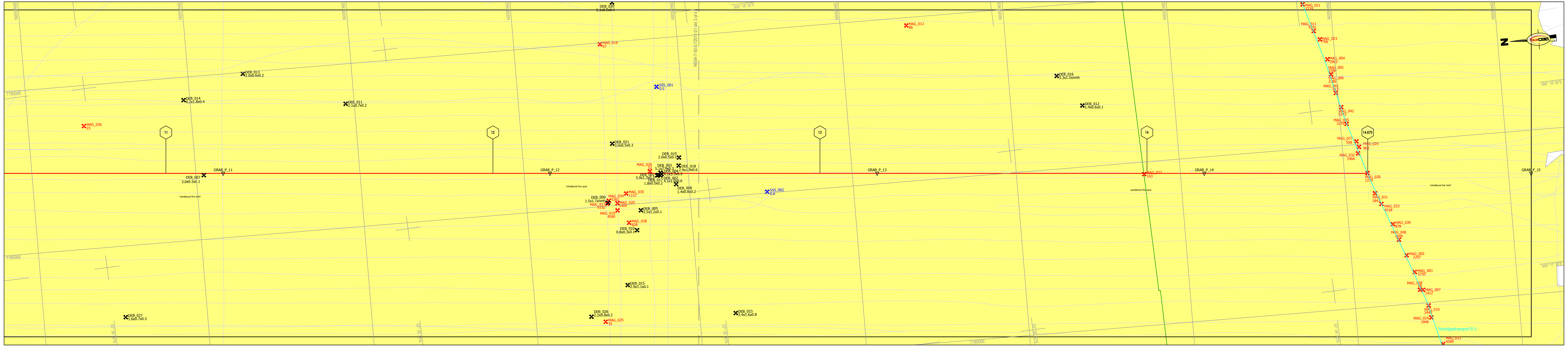

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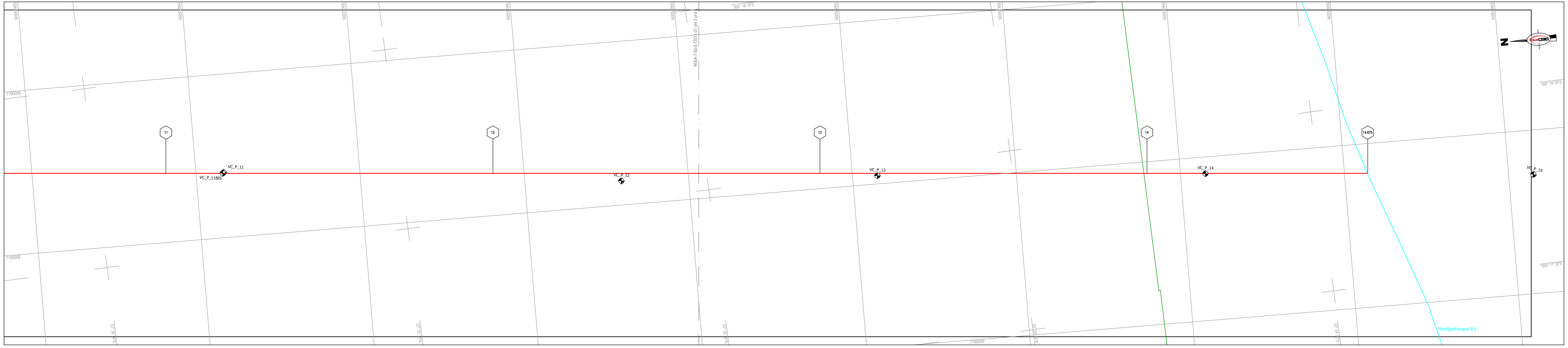
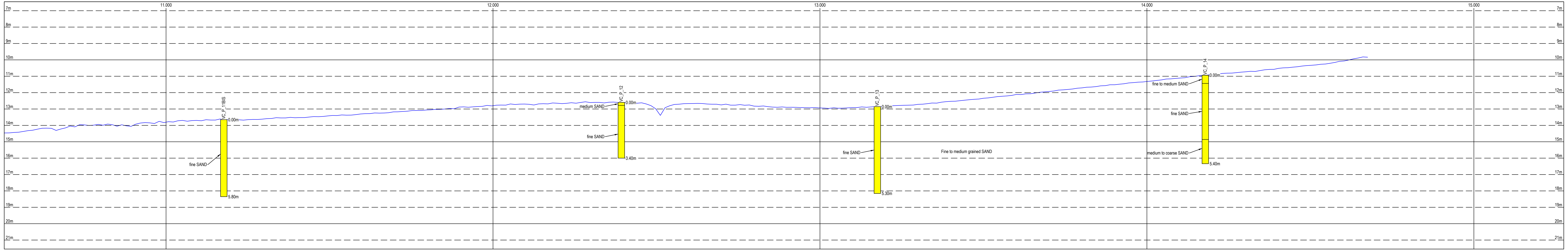


LONGITUDINAL PROFILE



LEGEND

Kilometer point

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LONGITUDINAL PROFILE:

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Base surfical sand

Clay

4.000 Kilometer point

VC_C_1 Name of vibrocore

0.00m

4.10m Bottom - depth below seabed

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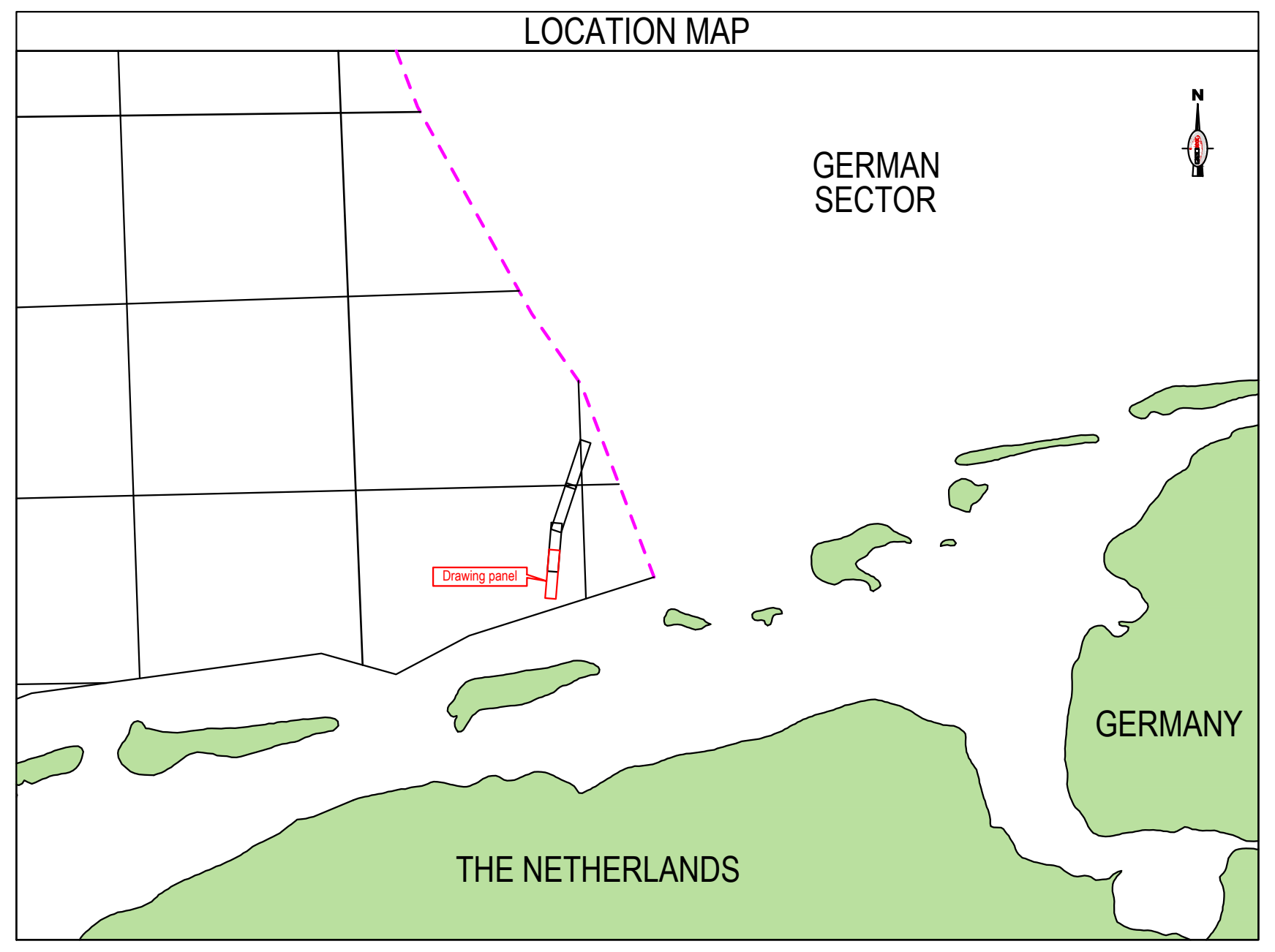
LOCATION MAP



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Central meridian:	03° east
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Geo Ocean III: 29/04/2019 untill 15/05/2019

HYDROGRAPHIC SURVEY

N5A development - pipeline route & platform area survey

N5A TO NGT HT ROUTE

Pipeline route

KP 10.505 to 14.675

Bathymetry - Seabed features - Isopach - Longitudinal profile

Chart: 004/004

Scale: 1/5000

LAT

Drawing made by:

GEOXYZ OFFSHORE
2 Route D'Arlon
Windhof Business center block A
L-8388 WINDHOF
Luxembourg

Client:

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4	01/10/2019	Client remarks	STH	RSP/TDB

Planname:	LU0022H-553_DR-010_PR_4-4_v4.0	Project ref:	N05A-7-50-0-72012-01 sht 4 of 4

N05-A Pipeline design

Risk assessment & dropped object analysis

DOCUMENT NUMBER:

N05A-7-10-0-70030-01

Rev.	Date	Description	Originator	Checker	Approver
01	02-01-2020	For Comments	[redacted]	[redacted]	[redacted]
02	24-01-2020	For Approval	[redacted]	[redacted]	[redacted]
03	12-10-2020	Extra CWC options	[redacted]	[redacted]	[redacted]

Client

ONE-Dyas B.V.

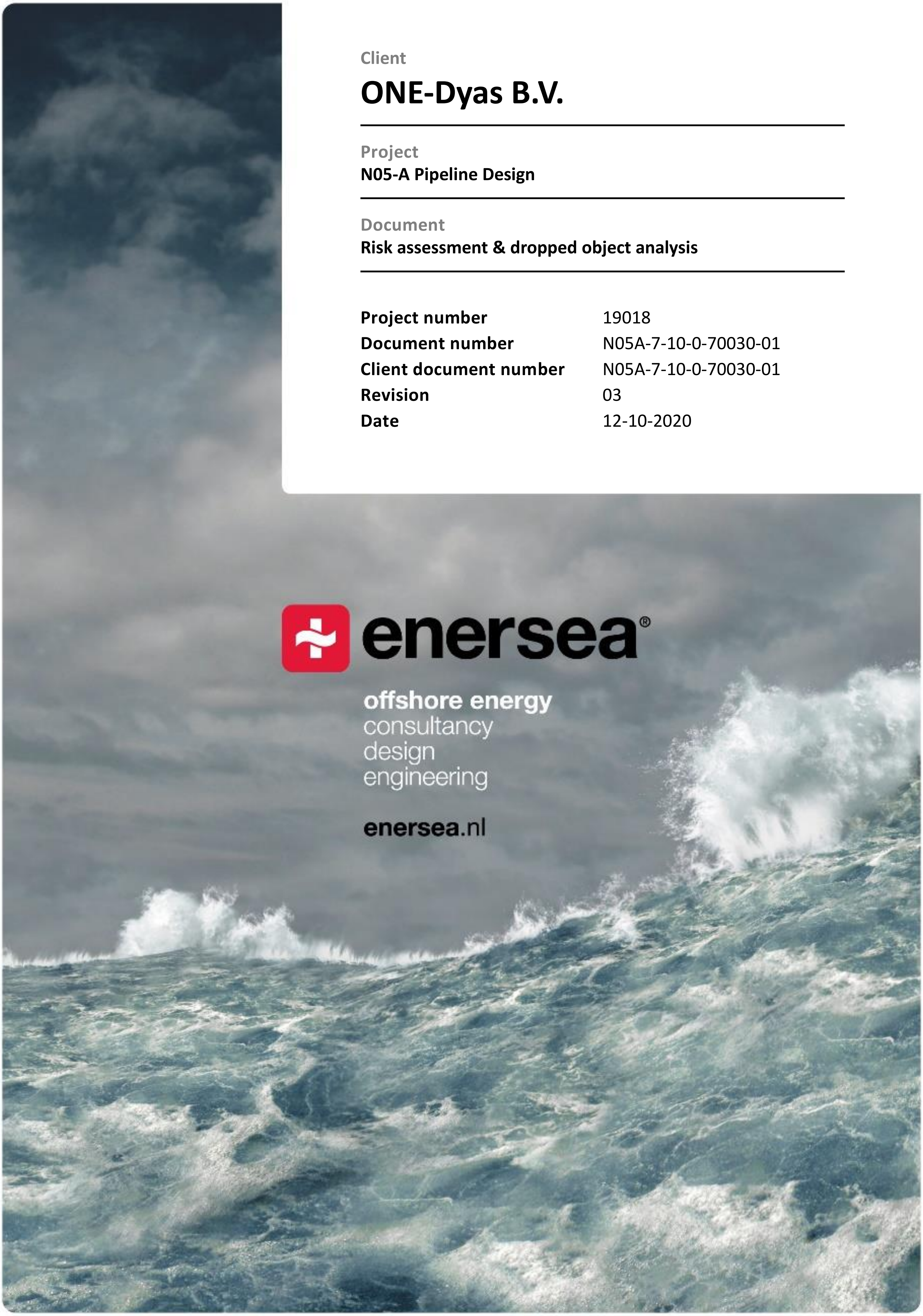
Project

N05-A Pipeline Design

Document

Risk assessment & dropped object analysis

Project number	19018
Document number	N05A-7-10-0-70030-01
Client document number	N05A-7-10-0-70030-01
Revision	03
Date	12-10-2020



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Revision History

Revision	Description
01	For Client Comments
02	Client comments incorporated
03	Extra CWC options

Revision Status

Revision	Description	Issue date	Prepared	Checked	Enersea approval	Client approval
01	For Client Comments	02-01-2020				
02	For Client Approval	24-01-2020				
03	Extra CWC options	12-10-2020				

Table of content

1. Introduction

1.1. Project Introduction

One-Dyas plans to develop a successfully drilled well in block N05-A of the North Sea Dutch Continental Shelf. More wells will be drilled at this location through the same jacket. It is planned to develop the wells by installing a platform and a gas export pipeline with a connection to the NGT pipeline @KP142.1. Approximate length of the pipeline is 14.7 km.

In addition, a power cable will be installed from the Riffgat Windpark to the N05-A platform.

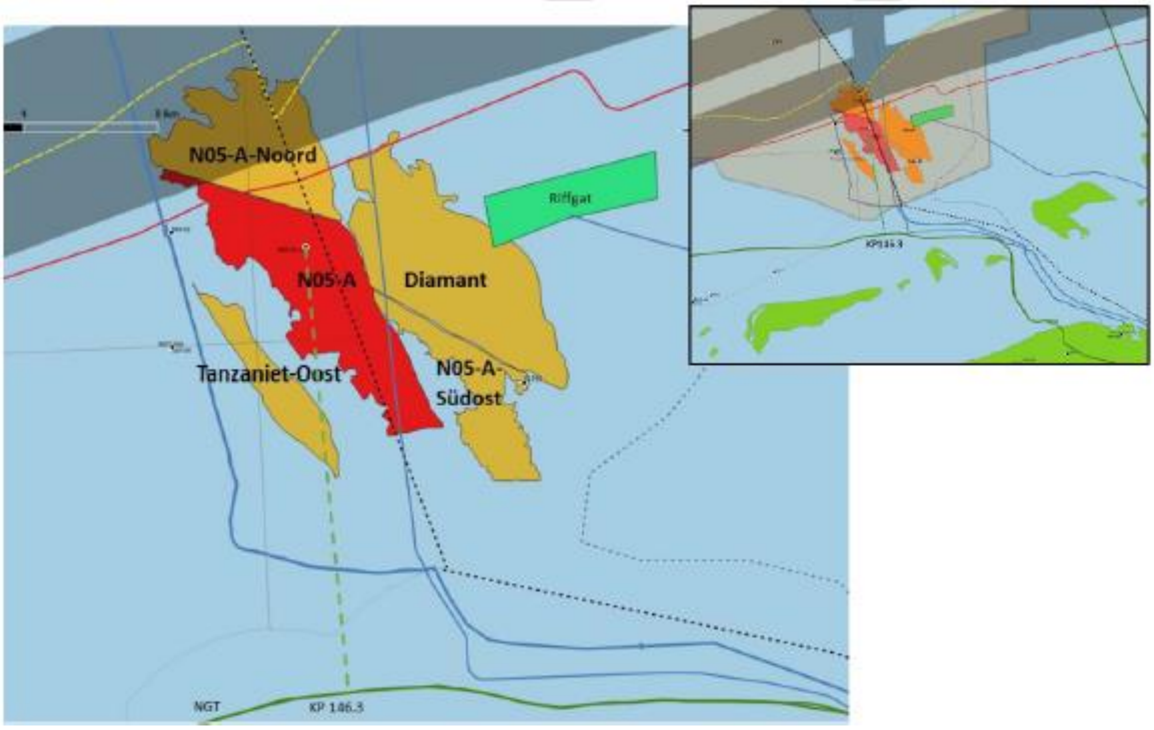


Figure 1, N05A Field layout

1.2. Purpose and scope of Document

This document fulfils the requirements for risk assessments for the 20” pipeline from the N05-A platform to the tie-in location on the NGT, and to comply with Dutch codes (ref [3]) and regulations. The report contains the outcome of the RIE workshop. The risk register is captured in Appendix B.

The quantitative risk assessment for the typical subsea Third Party threats are based on the general practice of industry, engineering judgements and AIS shipping data has been applied to determine the ships density.

The analyses presented, both contain the buried pipeline case and the un-buried pipeline case.

1.3. System of Units

All dimensions and calculations applied are based on the International System of Units (SI) unless noted otherwise.

1.4. Abbreviations

AIS	Automatic Identification System
ALARP	As Low As Practical Achievable
BoD	Basis of Design
CWC	Concrete Weight Coating
DWT	Dead Weight Tonnage
DFI	Design Fabrication and Installation
DNV	Det Norsk Veritas
DNVGL	Det Norsk Veritas &Germanisher Lloyds
DWT	Dead Weight Tonnage
ESDV	Emergency shutdown valve
NEN	Nederlands Normalisatie-Instituut
NGT	Noord-Gas-Transport B.V.
PIMS	Pipeline Integrity management System
RIE	Risk Inventarisation and Evaluation
ToP	Top of Pipe
TPI	Third Party Interference

1.5. References

[1] Overheidsbeleid inzake de aanleg van offshore pijpleidingen voor het transport van olie en/of gas, letter to NOGEPA from the Dutch Ministery of Economic Affairs, dated 03 November 1987;

[2] Risk analyses and burial requirements for Dutch Continental Shelf pipelines, D.Schaap a.o., 1987;

[3] Eisen voor Stalen Transportleidingsystemen, NEN 3656 (Requirement for Steel Pipeline Transportation Systems);

[4] Veiligheidsanalyse voor zeeleidingen, Rijkswaterstaat Directie Noordzee;

[5] -;

[6] Monitoring-nautische-veiligheid-2013-noordzee;

[7] Beleidsnota Scheepvaartverkeer Noordzee “Op Koers”, no 17408-26, Ministerie van Verkeer en Waterstaat, Januari 1987;

[8] Snelle reparatie Unocal-pijp volgens het boekje verlopen, Offshore Visie Magazine, Juni 1988;

[9] Mooring Anchors, The society of Naval Architects and Marine Engineers Transactions, Vol 67, 1959;

[10] Lloyd’s “Register of Ships”;

[11] DNV RP-F107 - Risk Assessment of Pipeline Protection - October 2010;

[12] DNV-RP-C204 – Design against accidental loads- November 2014;

[13] DNV-RP-F111 (2010)- Interference between trawl gear and pipelines;

[14] N05A-1-10-0-10001-01 FEED BOD platform facility;

[15] Marin Study, platform collision N05A, 32287-1-MO-rev0, November 2019;

[16] Geo XYZ, Surveys, 2019 LU0022H-553-RR-04-2.1, LU0022H-553-RR-05-1.1, LU0022H-553-RR-02;

[17] N05A-7-51-0-72510-01-03 - Overall field layout drawing;

[18] N05A-7-10-0-70031-01-01 – Route Selection Report;

2. Summary

This report presents the results of the pipeline risk assessments, for the export pipeline connecting the future ONE-Dyas platform N05A to NGT. Due to shipping traffic along the Southern shipping lanes and inbound and outbound traffic of the Eems-Dollard ports, the ship density in the whole area is high.

The pipeline Third Party shipping threats associated with high ship density, like dropped and dragging anchors, require additional measures to protect the pipeline and spools.

A pipeline RIE workshop was held on 3rd December 2019 and the following list contain in brief the outcome and highlights. Reference is also made to appendix A and B.

- Installation threats, due to installation, trenching and tie-in feasibilities;
- Third Party threats. Common subsea pipeline threats as dropped objects, dropped and dragging anchors and fishing gear impact;
- Natural hazards, related to on-bottom stability;

In this report the subsea pipeline third party threats are analysed in detail.

The dropped and dragging anchors are the most dominant threat. Table 1 shows the required minimal cover depth and probability of unacceptable damage per year per km of pipeline, as a function of ship traffic densities along the route and the applied CWC.

Table 1 Overview Pipeline leak probability (dropped and dragging anchors)

KP section	**Ship density /1000 km^2**	**No CWC**		**40 mm CWC**		**140 mm CWC**	
		Cover ToP [m]	Probalility [10^{-6}]	Cover ToP [m]	Probalility [10^{-6}]	Cover ToP [m]	Probalility [10^{-6}]
0.0 - 2.7	45	0.7	0.97	0.6	0.97	0.5	0.90
2.7 - 8.0	15	0.0	0.74	0.0	0.54	0.0	0.52
8.0 - 12.7	45	0.7	0.97	0.6	0.97	0.5	0.90
12.7 – 14.7	27	0.3	0.89	0.0	0.97	0.0	0.93

*Noe: calculated cover heights are excluding any potential natural sea bottom variations which might occur over the operational lifetime.

Within the shipping lane and for a pipeline without CWC, the pipeline Top of Pipe cover should be 0.7 m, to meet the acceptable risk level (≤ $1.00 \cdot 10^{-6}$ per year per km of pipeline). The minimum cover depth for shipping lane or anchor zone is 0.6 m when 40 mm of CWC is considered, and 0.5m when 140 mm of CWC is applied. In lower density traffic zones, pipeline burial may not be required if a CWC is applied.

The determined cover depth for 140mm CWC in the shipping lane considers an update to NEN 3656, expected to be in effect by the time of pipeline installation, where the cover depth in a shipping lane is based on a risk assessment instead of the minimum requirement of 0.6m cover in the 2015 edition.

Fish gear interference for pipe diameters larger than 400 mm is negligible, according to NEN 3656 Section 9.4.2.6. Sinking ships are regarded as low risk due to the low probability of occurring in the vicinity of the pipeline.

The risk of dropped objects near the platform is fully mitigated with a rock berm height on top of pipe of 0.65 m. This risk is analyzed in section 8.

3. Dutch Authority Safety Criteria

The policy with regard to safety criteria for offshore pipelines is laid down in [1], effective 1987 and [3].

The Dutch Authorities require a minimum soil cover of 0.2 [m] for pipelines with a diameter smaller than 16-inch based on the maximum penetration depth of trawl gear into the sea bottom, consequently avoiding any contact between fishing gear and offshore pipelines. For areas denoted as shipping routes and anchor drop areas, a minimum cover depth of 0,6 [m] is required according to the 2015 edition in NEN 3656. In an update to this standard, expected to be in effect by the time of pipeline installation, the minimum required cover in shipping lanes is 0.2 m plus what is required to sufficiently reduce probability of failure.

Pipelines equal or larger than 400mm OD do not have to be buried according to NEN 3656 Section 9.4.2.6, as in practice they are not affected by fishing gear.

If natural sea bottom variations over the operational lifetime might occur, an appropriate extra cover is to be added to the minimum required cover.

In any case the following conditions must be fulfilled:

- The expected frequency of pipeline damage, due to third parties and resulting in a leak, should be less than 10^{-6} per km of pipeline per year;
- The resulting spillage of liquid hydrocarbons should be less than 100 m^3, 400 m^3, 700 m^3 for a pipeline located within respectively 12 nautical miles of shore, between 12 miles and 25 miles from shore and beyond 25 miles from shore,

3.1. NEN 3656

NEN 3656 provides guidance on the pipeline risk assessment, according the Dutch Authority regulations. The risk investigation and evaluation (RIE) methodology as suggested by NEN 3656 [3] has been applied. Reference is made to Appendix A and B.

4. Design data

All design data considered for the risk and safety calculations for the pipeline are presented in the following subsections and have been extracted from the Basis of Design ref [14]. It should be noted that the pipeline design is still on-going and the pipeline data may change.

4.1. Pipeline Data

The basic pipeline design data considered in the analysis are presented in the tables below. Table 2 presents the data of the pipeline, while Table 3 presents the material properties of the steel used.

Table 2, Pipeline data

Property	Value	
Product transported	Natural gas (dew-pointed gas and condensate)	
Design life	25 years	
Approximate length	14.637 km	
Steel material grade (ISO3183-NEN 3656)	L360 / X52	
Pipe outside diameter	20"/508 mm	
Wall thickness	20.62 mm	
Wall thickness tolerance	-/+ 1.5mm (HFI)	
Corrosion Allowance	5mm	
Minimum subsea hot bend radius	2540 mm (5D)	
Coatings and insulation		
Anti-corrosion coating	3 Layer Poly-Propylene	
Anti-corrosion coating thickness	3 mm	
Anti-corrosion coating density	900 kg/m3	
Heat insulation	NA	
	Un-buried	**Buried**
Outer coating type	Concrete Weight Coating	none
Outer coating thickness	140 mm	-
Outer coating density	3300 kg/m^3	-

Table 3, Material properties

Property	Value
Material (ISO 3183)	L360
Density (kg/m3)	7850
Specified Minimum Yield Strength at 20C (MPa)	360
Specified Minimum Yield Strength at 50C (MPa)	360
Specified Minimum Tensile Strength at (MPa)	460
Youngs Modulus (GPa)	207
Poisson ratio (-)	0.3
Thermal expansion coefficient (m/m C)	1.17 x 10^{-5}

Additional line pipe properties.

NEN 3656, require a number of pipeline material mechanical properties. These un-quantified measures provide additional safety margins (plastically, ductility and cracking) to resist the pipeline against damages and prevent catastrophic ruptures. These measures are among others:

- Ratio Yield/tensile strength ≤ 0.90, to allow plasticity margin for installation purposes;
- Charpy-V-test additional to line pipe code, to prevent ductile propagation and brittle fracture;
- Low carbon equivalents in material composition and weld zones to prevent hardness and reducing cracking susceptibility;

4.2. Key facility coordinates

The following platform and target box locations have been derived from Ref. [17] and are presented in Table 4.

Table 4, Key Facility coordinates

Item	Northing (m)	Easting (m)
N05A Platform	5 954 650	721 607
NGT hot tap location	5 940 532	718 766
N05A Platform target box	5 954 608	721 622
NGT hot tap target box	5 940 549	718 738
Water depth at N05A Platform	Ca. 26 m LAT	
Water depth at NGT hot tap	9.8 m LAT	

4.3. Pipeline Bathymetry and Route

The intended target boxes at the ONE-Dyas platform and the NGT hot tap are shown in Figure 2.

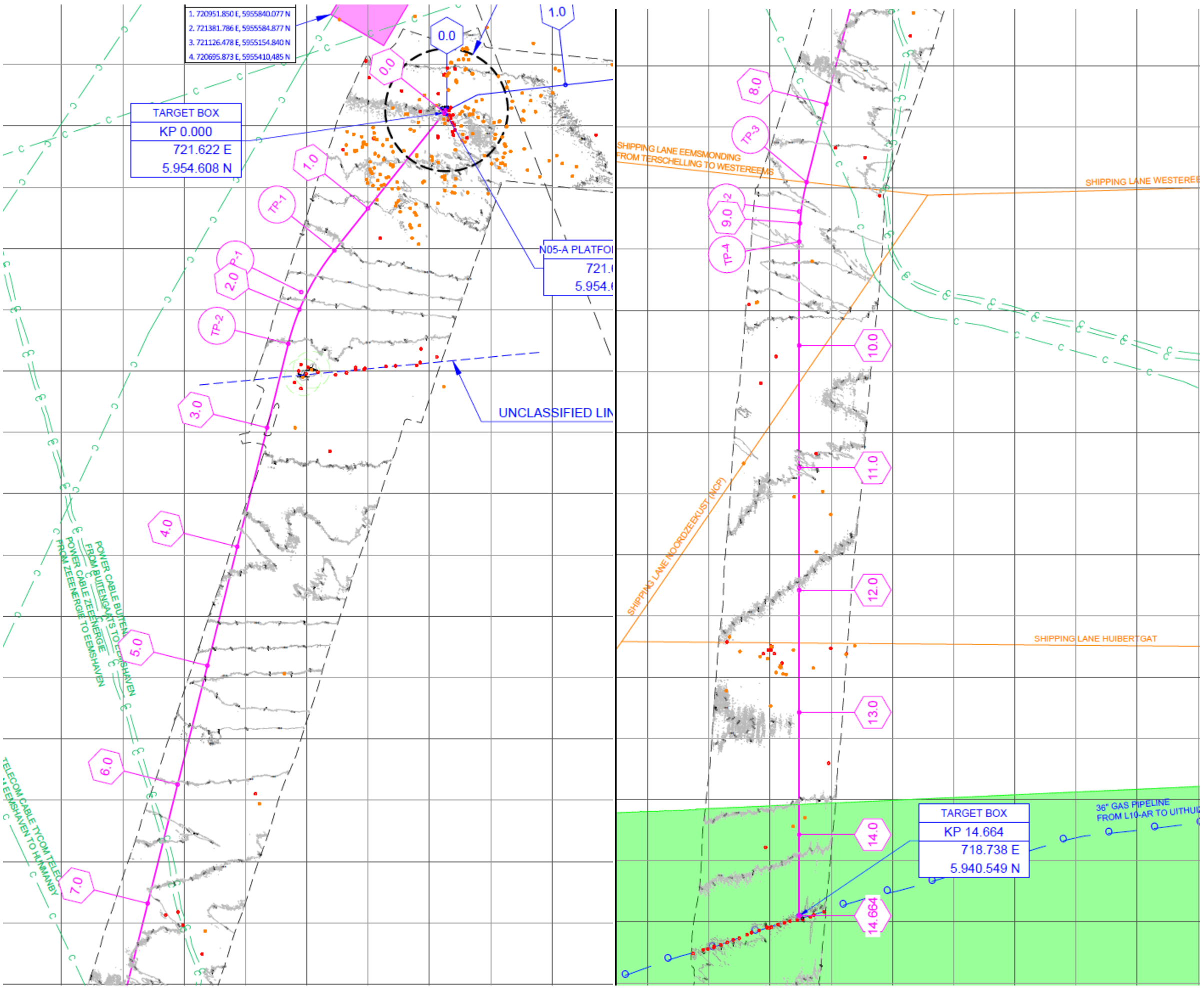


Figure 2, Pipeline route overview

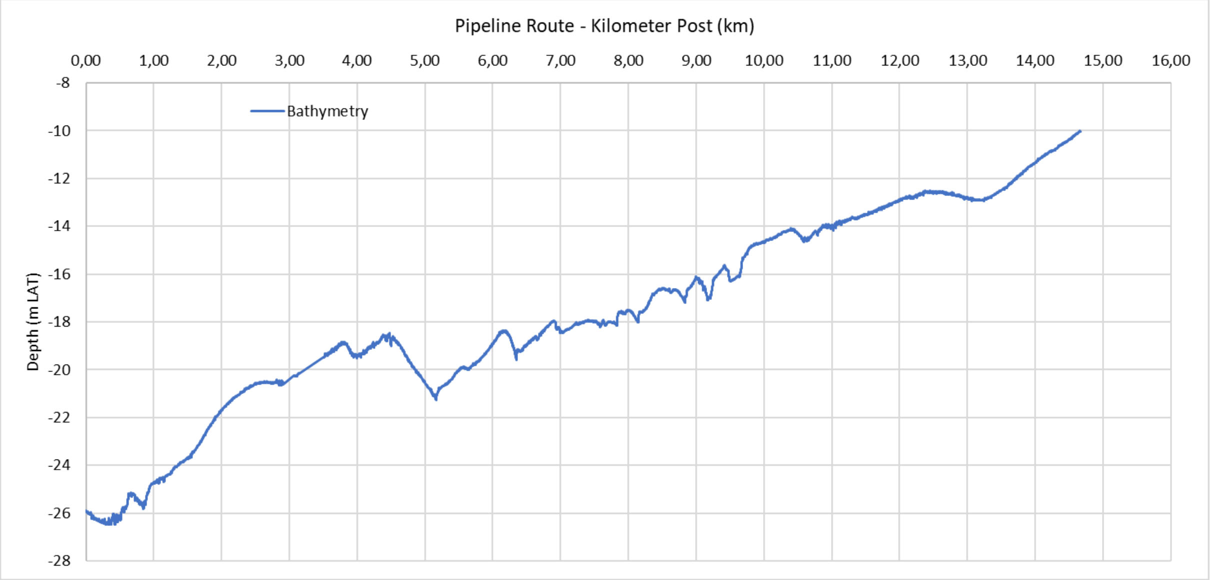


Figure 3, Bathymetric profile along the proposed pipeline route from platform N05A to NGT hot tap, ref [18].

4.4. Seabed Characteristics

The seabed is covered with fine to medium grained SAND generally thickening towards the South ref [16]. Sand was absent (or less than 0.5m thick) from KP 0.430 to KP 0.450, KP 0.757 to KP 1.045 and near KP 5.0 (channel), where the subsoil consists of sand with layers of clay. The soil properties are based on assumptions with reference to the geo-surveys reports, ref [16]. The 0.5 m top layer consists of mobile and loose sand properties. The clay outcrops are regarded as hard soil and to the South the subsoil sands are assumed to be medium.

4.5. Backfill and Rock berm properties

Backfill.

The natural backfilling of the trench is assumed to be loose sands.

Table 5, Properties of backfill material

Property	Value
Soil type	Sand
Submerged weight (kg/m3)	850
Angle of internal friction ϕ, [deg]	28

Rock Dump.

The following properties are considered for the rock dump, as given in Table 6.

Table 6, Rock dump properties

Property	Value
Rock Density [kg/m3]	2650
Porosity [%]	30
Submerged Weight γ, [kN/m^3]	11.4
Angle of internal friction ϕ, [deg]	40

5. Hazards

The N05A pipeline hazards have been qualified in the risk assessment (RIE) workshop. Appendixes A and B presents the workshop attendees, Risk matrix, Risk register and Action list.

5.1. Hazards

Submarine pipelines are subject to various hazards, and are generally divided in the following categories:

- Design, Fabrication and Installation hazards;
- Natural hazards (slope instability, seismic activity, severe storm, erosion);
- Third Party damage (navigation, fishing);
- Corrosion threats;
- Structural threats;
- Operational and Process hazards;

During the workshop, all the threats were considered and assessed whether these are plausible, what potentially causes them and with what potential effects, which initial barriers are regarded in the design, assessing the risk being the combination of likelihood and severity and which controls and safeguards measures will be taken to mitigate the risk to an acceptable level or if an ALARP analysis is required.

It should be noted that this risk assessing is a “dynamic” process that requires updating, when the project is progressing into the following phases.

5.2. Classification of damage

The potential effect of hazards will be pipeline damage and ultimately loss of containment. The main topic of this report is Third Party damage and in order to perform analyses, damages are divided in four classes varying in severity according [11], see Figure 4.

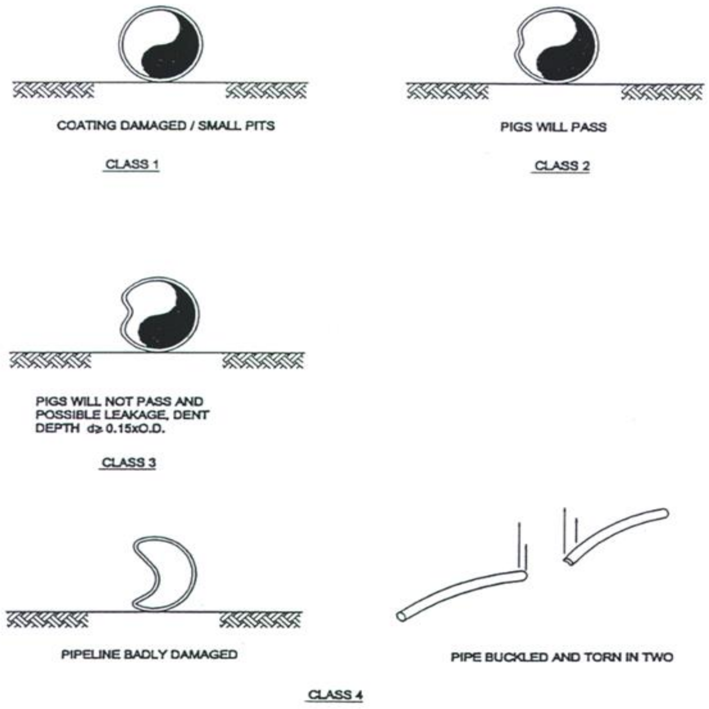


Figure 4, Damage classification

All consequences of third party threats like dropped objects and dropped and dragging anchors are modelled such that they will result in one of the damage classes.

CLASS 1:

Damage to the coating system is denoted as class 1 damage. This type of damage is not serious on the short term, basically limited to damage to the pipeline coating. On the long term, it may have serious consequences such as over-stressing or fatigue due to spanning, forced corrosion due to simultaneous damage of the corrosion coating or loss of anodes and pits in the steel. Such deficiencies, however, will be discovered in time during routine inspections of the pipeline.

CLASS 2:

Small plastic deformations with dents up to 15% of the pipe diameter, 76 mm for the 20-inch pipeline under consideration for this project is denoted as class 2 damage.

Dents up to 10% of the pipe diameter (50.8 mm) are hard to detect and require a caliper pig for detecting. Gauging pigs will pass such dents without being deformed.

Dents up to 15% of the pipe diameter can be nominated as small plastic deformations but are certainly not an immediate jeopardy for the pipeline operation and will not lead to pipeline damage resulting in a leak.

CLASS 3:

Plastic deformations with dents more than 76 mm (15 percent of the pipe diameter for the 20-inch pipeline) is denoted as class 3 damage.

This type of damage becomes serious for the operator, as pigs may not any longer pass the damaged section. Moreover, the possibility of a leak in the pipeline due to damage cannot be excluded. A study from Rijkswaterstaat, Directie Noordzee specifies that for deformations more than 15% of the outside diameter the probability of damage resulting in a leak by dropping anchors is 1.0.[1]

CLASS 4:

Class 4 damage refers to large pipeline deformations and total rupture of the pipeline.

Obviously, Class 4 damage is more serious than Class 3 damage for both operator and controlling agency. The occurrence of a leak in the pipeline is very likely.

Objective of the risk assessment is to determine likelihood of occurrence of Class 3 damage due to third parties and the probability of pipeline damage resulting in a leak.

The safety of the pipeline shall be in accordance with the rules stipulated by the Dutch Authorities as discussed in section 3.

5.3. Dropped object classification Methodology

Methodology and object classification of dropped objects is taken from Table 7, DNV RP-F107 [11]:

Table 7 Overview object classification

No	Description	Weight in air (mT)	Typical objects
1	Flat/Long shaped	< 2	Drill collar/casing/scaffolding
2		2 – 8	Drill collar/casing
3		> 8	Drill riser, crane boom
4	Box/Round shaped	< 2	Container (food, spare parts), basket, crane block
5		2 – 8	Container (spare parts), basket, crane block
6		> 8	Container (equipment), basket
7	Box/round shaped	>> 8	Massive objects, e.g. BOP, pipe reel etc.

With the hydrodynamic properties as specified in Table 8..

Table 8, Overview hydrodynamic coefficients

No	Description	Drag (Cd)	Inertia (Ci)	Added Mass (Ca)
1,2,3	Slender shape	0.7 – 1.5	1.0	0.1 – 1.0
4,5,6,7	Box shaped	1.2 – 1.3	1.0	0.6 – 1.5
All	Misc. shapes	0.6 – 2.0	1.0	1.0 – 2.0

The crane on the N05A platform is located on the North side of the platform, ref Appendix G. All load handling will take place at that side. However the crane can reach the other side, but with reduced lifting capacities of 5 mT. A low probability for dropped objects will remain.

Box shaped objects such as containers typically have a relatively large frontal area for its mass, resulting in a low impact velocity. The most probable objects to damage the spool are therefore pipe-shaped objects. A range of typical tubular and non tubular objects and the relevant properties are listed in Table 9.

Table 9, Dropped object properties

Object	Unit	1	2	3	4	5
Outside diameter, OD	[m]	0.47	0.54	0.6	0.64	2
Mass object in air, M	[kg]	650	1038	1495	5000	12000
Length	[m]	0.74	0.85	0.95	1	1.2
Volume steel, V_{steel}	[m^3]	0.083	0.132	0.190	0.637	1.6
Steel cross area, Ac	[m^2]	0.112	0.156	0.200	0.637	1.274
Wall thickness, WT	[m]	0.076	0.092	0.106	0.317	0.203
Internal diameter, ID	[m]	0.318	0.357	0.387	0.416	1.6
Added mass, M_a	[kg]	84.9	135.5	195.2	783.4	1880

5.4. Dropped and Dragging anchor methodology

All ships crossing the pipeline pose a threat that its anchor will be applied for emergency or for regular anchoring. The weight of the anchors has a more or less defined relation with ships DWT's. The damage is caused by dropping directly on the pipeline, similar to dropped objects. The damage is caused by dragging whereby the anchor is penetrating in the seabed and moved forward by ships kinetic energy and/or its propulsion.

Both damages may result in dents and follow the presented damage classes. Hooking anchors especially for exposed or shallow buried pipelines may get damaged by overstress, buckle and large displacements. The damage criteria is a maximum allowable strain of 5%. A hooked pipeline will display multiple damage features, e.g. dents and strain.

6. Risks analysis of other hazards

In this section the other than third Party interference hazards are briefly discussed.

For the detailed risk assessment reference is made to Appendix B.

During all pipeline phases, a pipeline integrity management system (PIMS) should be in-place. In general this is a risk-based system of inspecting and monitoring, whereby continuous enhancement keep the risk levels within the acceptance levels.

6.1. Design, Fabrication & Installation (DFI)

The pipeline design is based on the pipeline code, NEN 3656. By complying to a code all design aspects will be addressed and guidance is provided how the design analyses shall be made. The final design will result in a reliable pipeline, meeting its intended service life.

DFI threats should not result in pipeline damages if addressed in early stages. Main threats are related to project risks as schedule delay and increased costs.

6.2. Natural hazards

Natural hazards like liquefaction and scour require attention. Natural hazards to a pipeline are slope instability, seismic activity, severe storms, and erosion.

Main natural threats considered in this project are related to the wave-induced impact of the shallow water parts and the sand mobility of the Eems-Dollard Estuary. Impact of these dynamics need to be analyzed.

Typical natural hazard pipeline damages are buckling and ruptures as a result of large displacements. Fatigue can be an issue when pipeline get exposed due to scour.

6.3. Corrosion

The fluid in the pipeline is water dew-pointed wet gas, where liquids were separated, with only condensate added to the gas for export to shore. Corrosion inhibition is considered.

Pipeline corrosion in general comes with different corrosion morphologies and failure modes, from local and general metal loss to cracking.

External corrosion is mainly the exposure when third party damages occur that effects the pipeline coating and potentially lead to external corrosion threats.

6.4. Structural

Riser clamping is a common point of interest. Too much rock berm loads may lead to structural threats. Often structural threats originated from other root causes.

6.5. Operational/process error

Operational hazards will be managed by general company procedures, captured in PIMS.

Hydrate blockage might be a threat to consider.

7. Risk analysis of third party hazards

7.1. General

Potential damage to the pipeline by marine traffic can be caused by the following hazards:

- Riser damage caused by platform collision;
- Damage due to the fishing gear;
- Dropped and dragging anchors;
- Sinking of vessels;
- Damage of dropped objects near a platform;

The probability of these threats are related to the ship traffic density ate the location. The consequence of all of these impacts result in pipeline dents. Whereby a dent of ≥ 15% of the pipeline diameter has a consequence damage of class 3 and will lead to loss of containment.

The analyses are performed in this section. The analyses consider the pipeline protection by examining the resistance of a single barrier or combinations of bare steel of the pipe wall, CWC, sand cover and/or rock berm as protection measure.

7.2. Shipping traffic

Figure 5 indicates the density of sea traffic. The map originates from Marin report, ref [15] used for the platform collision study. The AIS data is collected over full 2017 of all ships equipped with (active) AIS transponder. Ships above 300 DWT and fishing vessels > 15 m, have a mandatory requirement for applying the AIS transponder.

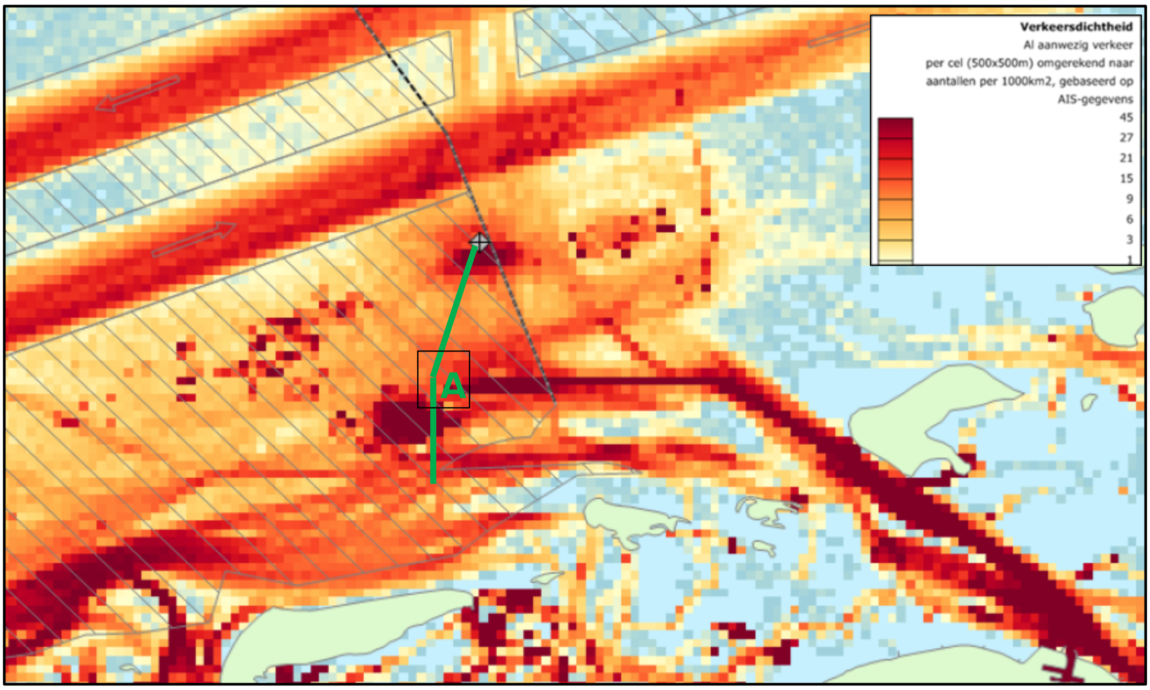


Figure 5, Vessel density maps, based on AIS over 2017 ref [15]], with platform and pipeline. All vessel sizes are shown.

For analyses performed in this report the density map of Figure 5 is applied, as the methodology is based on ships density and on a ship DWT composition typical for the Dutch sector of the North Sea. It should be noted that many of the smaller vessels do not pass this area. They will remain near shore or take the routes South of the Wadden islands.

The maximum ship density applied in this study is 45 per 1000 km^2. It is assumed that the average ship speed is 4.5 knots. Ships entering the anchor or fairway will have a reduced speed. Leaving vessels will be faster.

The N05A pipeline, from the platform in the North to the NGT hot tap in the South, is situated in the Eems-Dollard estuary, which has a fairway to Dutch and German ports. The fairway is a 200 m wide, dredged and maintained at approx. 14.5 m below LAT, channel. The fairway is a highly regulated corridor, where entering or leaving vessels are regulated by a traffic control centre. There is a requirement for pilotage and tug boat assistance from DWT ≥ 10.000. Whereby the rendez-vous point is at the point A (Figure 5) at the North Sea side of the fairway. This regulation results in ships waiting in the pilot waiting zone to get permission to enter the fairway.

The current projected pipeline route is outside the fairway, but it can be seen from the Figure 5 that ships wait at the entrance of the fairway.

7.3. Ships classification data

Ships are divided by ship classification systems.

Table 10, ship composition

Vessel size	Anchor weight	Percentage
DWT ≤ 3.000	625 kg	74.0
3.000 < DWT ≤ 10.000	2000 kg	6.3
10.000 < DWT ≤ 100.000	13500 kg	18.2
DWT > 100.000	17000 kg	1.5
Total		100.0

In Table 10 the classes of ships and ship composition, considered to be representative for the North Sea and for this area, are given.

7.4. Ship accidents

Table 11 presents the numbers of incidents , relevant for the Dutch sector North Sea , Ref[6].

Table 11, incidents and emergency numbers

Incident	Number of incidents	
	2004-2012	per year
Total 2004 – 2012: Sea and delta	346	38,4
Number fishing + shipping + Ferries total Netherlands	534	59,3
Total number of shipping incidents	834	93
Number fishing + shipping + Ferries total sea and Delta	221,5	24,6
Sinking	1,0	0,1

7.5. Riser damage caused by platform collision

A platform collision study has been performed, by Marin [15]. This collision report has determined the collision frequency caused by passing ships. The high risk of collision is dominated by the large vessels passing at high speeds in the Southern main shipping lanes, North of the platform. The collision is determined on drifting and ramming ships hitting the platform, resulting in a total risk of 3.66 10^{-3}/year or once every 273 years.

The study has excluded the consequence of a collision, however stated that an energy impact of ≥200 MJ has a catastrophic impact on the platform. This occurs 1.04 10^{-3} or once every 961 years.

Risers follow the pipeline code, NEN 3656 and shall comply with the failure frequency of 10^{-6}/year.

Even if the risers are located inside the jacket and shielded from direct collision impact, it is likely that Class 3 damage will occur when 200 MJ energy impacts the platform.

The platform is subject to risk mitigation or ALARP assessments where the outcome is not yet available to implement in this report. It is assumed that the riser along with other pressure contained equipment is captured in these assessments.

7.6. Risk analysis fishing gear impact

Fishing gear impact is considered a third party threat to the un-buried pipeline and to the pipeline coating. It also presents a threat to the fishing gear, the vessel and its crew.

According to NEN3656 Section 9.4.2.6, pipelines larger than 400 mm in diameter are in practice not affected by fishing gear, which is applicable to the current pipeline with an outer diameter of the steel pipe of 508 mm plus possible additional CWC.

A further mitigating measure is that the pipeline will be unburied for a short period of time during installation and during this time the position will be clearly identified to marine traffic, including fishing boats. Guard vessel(s) will also be used to safeguard the pipeline from external impacts.

7.7. Sinking ships

The average number of sinking ships is 1 per 9 years according [6] and the total distance sailed by ships is 21.6 x 10^6 nautical miles, the frequency of ships sinking is 24.6/year. Consequently, the probability that a ship will sink is equal to $P_{accidental}$ = 5.14 x 10^{-9} per sailed nautical mile per year.

Approximately 85% of all sunken ships had a DWT of less than 500. Taking 500 DWT as an average, the characteristic length of the ships is 50m. The critical corridor in which a vessel can sink and hit the pipeline is 100m wide, with the pipeline in the center.

The course of a ship in an emergency has a random orientation, not all the ships which sink in the critical corridor, will hit the pipeline. Only a fraction of $1/\pi$ of the ships sinking in the critical area will hit the pipeline.

As stated section 7.2, a shipping density of 45 ships per 1000 km² is assumed within the area of the North Sea where the pipeline will be placed.

The average sailing speed is 4.5 nautical miles per hour, this means that an average vessel will sail 24 x 365 x 4.5 = 39420 nautical miles per year. The sailed distance (L_s) within the area of 1000 km² is therefore equal to the number of nautical miles per year multiplied by the shipping density:

$$L_s = 39420 \cdot 45 = 1.77 \cdot 10^6 \; nm$$

The distance sailed in the critical pipeline corridor of 100m per km pipeline length equals to

$$L_c = L_s \frac{0.1}{1000} = 177.4 \; nm$$

The probability of sinking ships on the pipeline (P_s) is equal to the frequency of sinking ships, $P_{accidental}$, multiplied by the sailed nautical miles in the critical pipeline corridor L_c.

Consequently, $P_s = P_{accidental} \cdot L_c = 5.14 \cdot 10^{-9} \cdot 177.4 = 9.13 \cdot 10^{-7}$ accidents per km per year in the critical pipeline corridor due to sinking ships. Taking the random directionality into account, the probability of a sinking ship on top of the pipeline is $\frac{P_s}{\pi} = 2.90 \cdot 10^{-7}$ per km per year and well below the NEN 3656 acceptance criterium of 1.0 x 10^{-6} /year.

When a ship sinks, it will eventually come to rest on the seabed. If this occurs just above the pipeline, it would depend on the local strength of the shell of the ship whether the pipeline would be dented or damaged with leakage.

Due to the relatively low vertical velocity of the sinking ship when hitting the pipeline, one can consider the loading on the pipeline as quasi static. The kinetic energy carried by a sinking ship of 3000 DWT (74% of the vessels) is in the order of 6kJ per m². The energy resistance capacity of the un-buried pipeline with CWC is indicative 120kJ, refer to section 7.10. A sunken ship will likely provide a more even load distribution.

To penetrate 0.2m cover approximately 30kJ of kinetic energy per m² contact area is required. It is unlikely that the buried pipeline with a depth of cover of 0.6 m will be affected by a sinking ship.

The un-buried pipeline with 140 mm CWC has a significant impact resistance. However impact cannot be excluded.

7.8. Frequency of dropped and dragging anchors

Dropping anchors near the pipeline pose a risk, as it can potentially hit and damage the pipeline.

Anchoring of work boats outside platform areas is not expected to be hazardous to the pipeline as the crews of such vessels are always fully aware of obstacles in their work sector and anchoring is consequently carefully planned. Furthermore, anchoring of a workboat is often done with assistance of a special anchor vessel.

Reasons for anchoring can be divided in two groups, including:

- Regular anchoring, to await the boarding of a pilot or permission for entering the harbor, waiting for further sailing orders of the owner or for cleaning and maintenance.
- Emergency anchoring, following an accident such as fire, engine failure or collision.

In case of regular anchoring, a ship’s captain will inspect his sea charts, avoid obstacles and preferably choose an area assigned for anchoring. For that reason, regular anchoring is not considered to be a risk factor for the safe operation of a pipeline.

In the event of an emergency, it may be expected that most of the ship’s captains will inspect their sea charts before dropping an anchor. In addition, many captains prefer not to anchor at all in emergency situations. However, it cannot entirely be ruled out that some of them decide to drop an anchor impulsively. Following this reasoning, it is assumed in this study that in 25 percent of emergency situations, anchors are dropped without prior inspection of the sea charts. In such case, the anchors are considered to be dropped at random; some of them will land in the vicinity of the pipeline and may create a critical situation for the pipeline.

The probability of anchor drops or dragging of the anchor near the pipeline is a function of the following factors:

- The chance that a ship faces an emergency.
- The width of the corridor, wherein anchor drop or drag becomes a risk factor for the pipeline.
- The length of the hazardous zone, this being a function of the angle between the vessels’ course and pipeline.
- Traffic density and composition in the identified region.
- Critical ship DWT causing Class 3 damage in the case of drop/drag.
- Type and mass of anchor used

The traffic density/composition and the chance that a ship faces an emergency is a function of the registered accidents and emergency situations ref.[6] and listed in in section7.3 and 7.4.

The probability that a vessel will be involved in an accident or will face an emergency depends on the distance sailed by a vessel. Using the data presented in ref. [6], the cumulative distance sailed per day by all vessels is determined being 21.6 million nautical miles.

Considering the total number of ships involved minus the ships running aground 24.5/year (24.6/year–sinking 0.1 /year). The frequency of an accident or emergency is:

$P_{accidental} = \frac{24.6-0.1}{21.6 \cdot 10^6} = 1.13 \cdot 10^{-6}$ accidents per sailed nautical mile per year.

The maximum dragging distance of an anchor depends on the type, mass, and the soil conditions. For smaller anchors in sand the dragging distance is less than 10m, for heavier anchors it is 10–15m. In this study, the critical corridor is taken as 30m (15m each side of the pipeline) for all anchors.

When the anchor is dropped in the inner part of the critical zone it will hit the pipeline directly. The width of this anchor drop sector is a function of the anchor width. The width of a large anchor is taken as 2.5m (see also Appendix C for anchor sizes) resulting in a sector width for anchor drop of 5.0m.

The probability that an anchor, when dropped in the critical zone, will directly fall on top of the pipe is therefore 5/30. Consequently, the probability that dropping an anchor in the critical zone will result in anchor drag towards the pipeline is 25/30.

The frequency of accidents per year occurring in the critical zone is calculated as follows:

It is assumed that in 25 percent of the events that an accident occurs, an anchor will be dropped without first consulting any charts, as discussed above. Furthermore, it was shown that the probability that a dropped anchor within in the critical zone directly hits the pipeline is 5/30. The frequency directly hitting the pipeline per km per year can thus be calculated.

The direction of the dragging anchor is variable and the portion of dropped anchors that are dragged towards the pipeline is accounted by multiplying the total number by a factor 1/π.

The distance sailed per year in the critical pipeline corridor of 30m per km pipeline length is equal to:

$L_c = L_s \frac{0.03}{1000} = 53.2\ nm$

The probability of an accident due to emergency anchoring P_{anchor} per km per year in the corridor is equal to the probability of accidents per sailed nautical mile P_{acc} multiplied by the sailed nautical miles per year in the corridor L_c and apply the factors 0.25 and 5/30 to account for the probability of anchor drop and anchors directly falling on the pipe P_{drop}:

$P_{anchor} = P_{accidental} \cdot L_c = 6.04 \cdot 10^{-5}$ emergency anchoring per kilometer per year

$P_{drop} = P_{anchor} \cdot \frac{5}{30} \cdot 0.25 = 2.52 \cdot 10^{-6}$ anchors falling on the pipeline per kilometer per year.

The probability of an accident due to dragging anchors P_{drag} outside the shipping lane is equal to the probability of emergency anchoring multiplied by 25/30 accounting for the anchor drag length of 25m relative to the length of the critical area 30m. Further factors of 1/π and 0.25 are applied to account for the directionality and the probability of anchoring.

$P_{drag} = P_{anchor} \cdot \frac{25}{30} \cdot \frac{1}{\pi} \cdot 0.25 = 4.00 \cdot 10^{-6}$ accidents per km of pipe per year due to dragging anchors

7.9. Damage due to dropping and dragging anchors

Not all anchors dropped or dragged in the critical zone will result in leakage. There are two major factors contributing to this. First is the absorption of energy by the soil covering the pipeline, second is the allowable deformation of the pipeline before leakage occurs.

An anchor dropped from a ship first penetrates vertically into the seabed. The depth of penetration depends on the weight and shape of the anchor and characteristics of the seabed soils.

As the ship continues to move after the anchor has reached the seabed, the anchor chain tightens and pulls the anchor over until it reaches a horizontal position on the seabed. From this position the flukes gradually work down into the soil until the body of the anchor is either partly or wholly embedded in the seabed and the anchor attains its maximum holding power.

To represent the entire range of anchors, anchors with masses of respectively 1000kg, 5000kg, 10000kg, and 15000kg have been considered in this study. Typical anchor parameters are given in Appendices C. Based on published test results an average drag distance of 10m has been selected as appropriate for the sizes of anchors considered. [9]

The passive soil resistance determines the maximum holding power of an anchor. When this holding power is exceeded, some anchors drag horizontally through the soil, while others rotate and will break out and dig in again. When an anchor attains its maximum holding power at the end of dragging, it also has embedded a certain depth below the sea bottom.

A pipeline, which is resting in or on the seabed, is hit by an anchor either vertically when the anchor is dropped on top of it, or horizontally when the anchor is dragged towards the side of the pipeline.

Both types of loading deform the pipeline differently and are discussed below.

7.10. Damage due to anchor drop

The kinetic energy of the falling anchor is absorbed by the soil and by deformation of the pipeline. To visualize the plastic deformation energy, the model in Appendix D is used.

The energy required for plastic deformation is a function of the pipeline characteristics and extent of deformation in accordance with equation:

$$E_p = 2\,\sigma_t\,t_{EOL}^2\,\delta\,\sqrt{2},$$

in which:

$$t_{EOL} = (1 - wtt) \cdot wt - t_{cor},$$

where

- t_{EOL} is the wall thickness of the pipeline at the end of life;
- wtt is the wall thickness tolerance, as defined in Table 2 (50% taken into account);
- t_{cor} is the internal corrosion allowance, as defined in Table 2 (50% taken into account);
- δ is 15% of the pipeline OD, so 41 [mm];

For the given material properties and wall thickness, provided in section 4.1. This leads to a plastic energy of 20.16 [kJ]. It should be noted that the CWC of 40 and 140 mm provides an additional energy absorption resistance of 34 and 120 [kJ], respectively (indicative). This is based on linear extrapolation of concrete coating absorption energy, as indicated in section 4.6 of ref[11].

The maximum allowable deformation (δ) is 15 % of the pipeline diameter, further deformation is associated with leakage. To establish the impact velocity of the anchor it is necessary to determine the impact velocity of the anchor when it reaches the seabed. During its descend to the sea floor, the anchor is subjected to the forces of gravity and drag. Drag can be computed from:

$$F_d = \frac{1}{2}\rho V^2 C_d A$$

If the anchor is released from sufficient height, drag and gravity will be in balance at a certain speed of descend, known as terminal velocity. Terminal velocity can be calculated from:

$$v_T = \sqrt{\frac{2 \cdot g \cdot (m - V \cdot \rho_{water})}{\rho_{water} \cdot C_d \cdot A}},$$

in which:

- m is the mass of the dropped object;
- g is the gravitational constant;
- V is the volume of the object (the volume of the displaced water);
- ρ_{water} is the sea water density, 1025 [kg/m^3];
- Cd is the drag coefficient, which is a function of the dropped object shape;
- A is the projected area of the object in the flow direction;
- v_T is the terminal velocity;

The kinetic energy of the anchor is computed from

$$E_k = 0.5(M + M_a) \cdot v_T^2$$

With the added mass given by

$$m_a = \rho_{water} \cdot V \cdot C_a,$$

in which:

- C_a is the added mass coefficient, which is a function of the object shape;

The calculation of the kinetic energy as a function of the anchor mass is provided in Appendix E.

The absorption of energy (E_{pen}) by the seabed can be derived with the Brinch-Hansen method for the soil bearing capacity

$$E_{pen} = \int_0^{d_p} F(y)dy$$

Where:

y is the penetration depth [m]

d_p is the depth of the soil cover above the top of the pipeline [m]

$F(y)$ is the soil bearing capacity at a certain depth [N], given by:

$$F(y) = A \cdot \left(c\ N_c\ S_C\ D_c + q_0\ N_q\ S_q\ D_q + 0.5\ \gamma\ B\ N_\gamma\ S_\gamma\ D_\gamma\right)$$

Where:

A is the frontal area of the anchor [m^2]

c is the cohesion of the soil [N/m^2], for the project under consideration $c = 0$ (ref. [14]);

q_0 is the overburden load at depth y [N/m^2], $q_0 = \gamma\ g\ y$

γ is the submerged density of the soil [kg/m^3], as given in Table 5;

ϕ is the angle of soil internal friction [deg], as given in Table 5;

B is the width of the anchor frontal area [m];

L is the length of the anchor frontal area [m];

N, S and D are dimensionless factors related to the soil bearing capacity, shape of the frontal area, and the depth respectively

$$N_c = \frac{N_q - 1}{\tan \phi}$$

$$S_c = 1 + 0.2\frac{B}{L}$$

$$D_c = 1 + 0.4 \operatorname{atan}\frac{y}{B}$$

$$N_q = e^{\pi \tan \phi} \tan^2 \left(45 + \frac{\phi}{2}\right)\text{F}$$

$$S_q = 1 + \sin \phi \frac{B}{L}$$

$$D_q = 1 + 2 \tan \phi \ (1 - \sin \phi)^2 \operatorname{atan}\frac{y}{B}$$

$$N_\gamma = 2\left(N_q - 1\right) \tan \phi$$

$$S_\gamma = 1 - 0.4\frac{B}{L}$$

$$D_\gamma = 1$$

Damage will be beyond the 15 % acceptable deformation when:

$$E_k - E_{pen} > E_p$$

Appendix C shows a relation between anchor mass and the frontal area of the anchor.

The calculated absorption energy as a function of the cover height is provided in Appendix E.

Using a representative set of anchor masses, a relation between anchor mass and the required minimum soil cover was established, as presented in Figure 6.

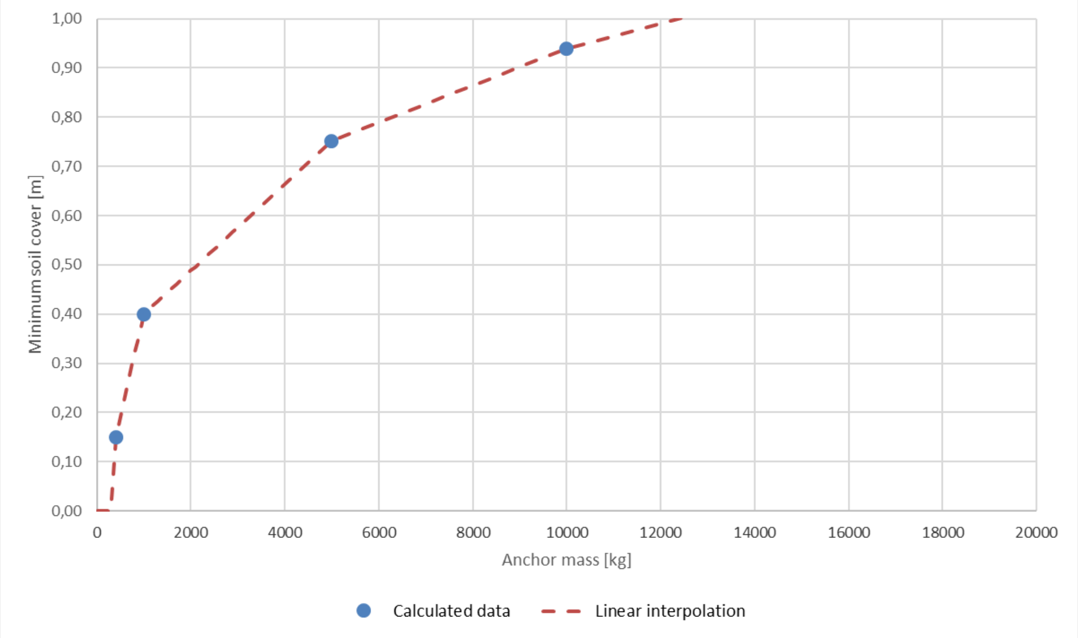


Figure 6 Required minimum soil cover as function of anchor mass (valid > 1200kg)

Impact from dropped anchors start at 1100 kg for pipeline without CWC and 4150 kg for pipelines with 140 mm CWC (this last figure is only indicative).

7.11. Damage due to anchor drag

If the pipeline is hit by a dragging anchor, it first experiences an impact load, followed by a sustained load when the anchor hooks behind the pipeline and the anchor chain/cable is straightened.

The impact loading and its consequence for the pipeline can be found from the results above. It is logical to expect that the velocity of the dragged anchor is very low and of the same order as the surface current velocity, which keeps the ship without engine power moving. With an anchor drag velocity of 1m/s the effect of the impact load is negligible due to the anchor velocity at the time of a direct drop.

For that reason, the pipeline damage assessment following an anchor drag is only done for the second phase of loading, when the anchor hooks and starts to drag the pipeline. The ultimate load to which the pipeline is exposed is assumed to be equal to the design load of the anchor chain.

If a pipeline has sufficient cover it is possible that the dragging anchor will not reach it. This cover depth is equal to the depth of anchor embedment after being dragged minus half of the pipe diameter, as an anchor which hits the pipe on its top half will be dragged over the pipeline without causing any serious damage.

The depth of penetration or embedment as a function of the anchor size is illustrated in Appendix C. This relationship is valid for sandy soils like those found along the considered pipeline route. To investigate the uniformly supported pipeline exposed to a concentrated load, a mechanical model is selected based on the following assumptions:

- The pipeline is supported by soil which will yield, and therefore, the soil resistance equals the ultimate soil resistance.
- Three plastic hinges represent the deflection pattern of the pipeline.
- The maximum load capacity of the pipeline is reached when the stress level in the fully plastic cross section reaches the breaking strength of steel.

Based on the above assumptions, the maximum load capacity can be determined by considering an energy balance.

The ultimate load bearing capacity due to energy absorbed by the plastic hinges and soil is equal to:

$$F = 4\sqrt{M_p R}$$

Where:

M_p is the plastic moment [Nm], $M_p = D^2\ t\ \sigma_t$

D is the outside pipe diameter [m]

t is the pipe wall thickness at end of life [m]

σ_t is tensile strength of steel [N/m^2]

R is the resistance of the soil behind the pipe [N/m],

$$R = \gamma\ g\ z\ N_q\ D$$

z is the depth of the centerline of the pipe

γ is the submerged density of the soil [kg/m^3], as given in Table 4

$$N_q = e^{\pi \tan\phi} \tan^2\left(45 + \frac{\phi}{2}\right)$$

The maximum anchor drag force to which the pipeline will be exposed is taken to be half of the breaking strength of the chain. According to Lloyd’s register of Shipping, the mass of an anchor is related to the link breaking strength of the anchor chain. Appendix C shows a plot of this relationship.

The tension force in the chain is equal to the anchor drag force plus drag of the chain itself on the sea floor and the gravity component up to the ship anchor chain attachment point. To account for these forces the following approximate linear relation is used:

$$T = K \cdot F$$

The factor K depends on whether the pipeline is buried or not, and on the type of anchor considered. For anchors used on merchant vessels, K = 1.1 for an unburied pipeline and K = 1.3 for a buried pipeline. For this project a buried pipeline is considered.

7.12. Probability of damage due to anchor drop and drag

Accounting for the associated vessel Dead Weight Tonnage (DWT), the probability of a dropped anchor resulting in unacceptable damage has been determined. The distribution of marine traffic split into the four groups as discussed earlier in this chapter has been utilized to establish this probability (in percentage) according to:

$P(d) = 100 - \frac{DWT}{3000} P_{0,group1}$; valid for DWT<3,000 mT

$P(d) = 100 - \frac{DWT-3000}{7000} P_{0,group2} - P_{0,group1}$; valid for 3,000 mT < DWT < 10,000 mT

$P(d) = 100 - \frac{DWT-10000}{100000} P_{0,group3} - P_{0,group1} - P_{0,group2}$; valid for 10,000 mT < DWT < 100,000 mT

$P(d) = P_{0,group4}$; valid for DWT >100,000 mT

Dropped anchors

The DWT of the ships which anchors can cause Class 3 damage when directly dropped on top of the pipeline were calculated in section 7.9,. For the associated DWT ranges, the percentage of a group which causes damage by a dropped anchor can be determined, as given in Table 12 (calculation as per Appendix E)

Table 12, Probability of a leak as a function of the critical anchor mass and ToP cover

ToP cover [m]	Critical anchor mass [kg]	Critical DWT [mT]	Traffic > Crit. DWT [%]	Probability of leak X10^{-6}
No CWC				15/27/45 vessels /1000km^2
0.0	1000	4870	41.9	0.39 / 0.70 / 1.17
0.2	1300	6388	35.3	0.33 / 0.59 / 0.99
0.4	2000	10032	19.7	0.18 / 0.33 / 0.55
0.6	3500	18321	18.0	0.17 / 0.30 / 0.50
0.8	7500	44278	12.8	0.12 / 0.21 / 0.36
1.0	13000	95040	2.5	0.01 / 0.03 / 0.04
40 mm CWC				
0.0	2000	10032	19.7	0.18 / 0.33 / 0.55
0.2	3000	15483	18.6	0.17 / 0.31 / 0.52
0.4	4000	21237	17.4	0.16 / 0.29 / 0.49
0.6	5000	27322	16.2	0.15 / 0.27 / 0.45
0.8	8500	51920	11.2	0.10 / 0.19 / 0.31
1.0	14500	113631	1.5	0.04 / 0.04 / 0.04
140 mm CWC				
0.0	4000	21237	17.4	0.16 / 0.29 / 0.49
0.2	4500	24236	16.8	0.16 / 0.28 / 0.47
0.4	6000	33778	14.9	0.14 / 0.25 / 0.42
0.6	8000	48029	12.0	0.11 / 0.20 / 0.34
0.8	12000	83977	4.7	0.04 / 0.08 / 0.13
1.0	16500	142817	1.5	0.04 / 0.04 / 0.04

Dragging anchors

The DWT of the ships which anchors can cause Class 3 damage when directly dragged towards the pipeline were calculated in section 7.9. The relevant properties calculated for anchor drag, can be found in Appendix F. The contribution of the CWC on the resistance against anchor drag is not known, as such the calculation is conservatively performed for the steel pipeline only.

Table 13, Probability of a leak as a function of the critical anchor mass and cover depth

ToP cover [m]	Critical anchor mass [kg]	Critical DWT [mT]	Traffic > Crit. DWT [%]	Probability of leak X10^{-6} 15/27/45 vessels /1000km^2
0.0	1097	5358	39.8	0.35 / 0.64 / 1.06
0.2	1520	7520	30.4	0.27 / 0.49 / 0.81
0.4	1887	9435	22.1	0.20 / 0.35 / 0.59
0.6	2226	11235	19.5	0.17 / 0.31 / 0.52
0.8	2543	12955	19.1	0.17 / 0.31 / 0.51
1.0	2832	14547	18.8	0.17 / 0.30 / 0.50

7.13. Cumulated dropped and dragged anchor damage

The cumulated probability is shown in Table 14.

Table 14, Cumulative probability of anchor drop and drag for buried pipeline

ToP cover [m]	Probability of leak: anchor drop x10^{-6}	Probability of leak: anchor drag x10^{-6}	Total Probability of leak: (anchor drop + anchor drag) x10^{-6}
No CWC	15/27/45 vessels /1000km^2	15/27/45 vessels /1000km^2	15/27/45 vessels /1000km^2
0.0	0.39 / 0.70 / 1.17	0.35 / 0.64 / 1.06	0.74 / 1.34 / 2.23
0.2	0.33 / 0.59 / 0.99	0.27 / 0.49 / 0.81	0.60 / 1.08 / 1.80
0.4	0.18 / 0.33 / 0.55	0.20 / 0.35 / 0.59	0.38 / 0.68 / 1.14
0.6	0.17 / 0.30 / 0.50	0.17 / 0.31 / 0.52	0.34 / 0.61 / 1.02
0.8	0.12 / 0.21 / 0.36	0.17 / 0.31 / 0.51	0.29 / 0.52 / 0.87
1.0	0.01 / 0.03 / 0.04	0.17 / 0.30 / 0.50	0.18 / 0.33 / 0.54
40 mm CWC			
0.0	0.18 / 0.33 / 0.55	0.35 / 0.64 / 1.06	0.54 / 0.97 / 1.61
0.2	0.17 / 0.31 / 0.52	0.27 / 0.49 / 0.81	0.44 / 0.80 / 1.33
0.4	0.16 / 0.29 / 0.49	0.20 / 0.35 / 0.59	0.36 / 0.65 / 1.08
0.6	0.15 / 0.27 / 0.45	0.17 / 0.31 / 0.52	0.32 / 0.58 / 0.97
0.8	0.10 / 0.19 / 0.31	0.17 / 0.31 / 0.51	0.27 / 0.49 / 0.82
1.0	0.04 / 0.04 / 0.04	0.17 / 0.30 / 0.50	0.21 / 0.34 / 0.54
140 mm CWC			
0.0	0.16 / 0.29 / 0.49	0.35 / 0.64 / 1.06	0.52 / 0.93 / 1.55
0.2	0.16 / 0.28 / 0.47	0.27 / 0.49 / 0.81	0.43 / 0.77 / 1.28
0.4	0.14 / 0.25 / 0.42	0.20 / 0.35 / 0.59	0.34 / 0.60 / 1.01
0.6	0.11 / 0.20 / 0.34	0.17 / 0.31 / 0.52	0.28 / 0.51 / 0.85
0.8	0.04 / 0.08 / 0.13	0.17 / 0.31 / 0.51	0.21 / 0.39 / 0.64
1.0	0.04 / 0.04 / 0.04	0.17 / 0.30 / 0.50	0.21 / 0.34 / 0.54

7.14. Shipping Densities

Along the selected pipeline route different shipping densities occur. The pipeline route has been divided into 4 sections for which the highest shipping density will be governing, see figure 7 below and table 15.

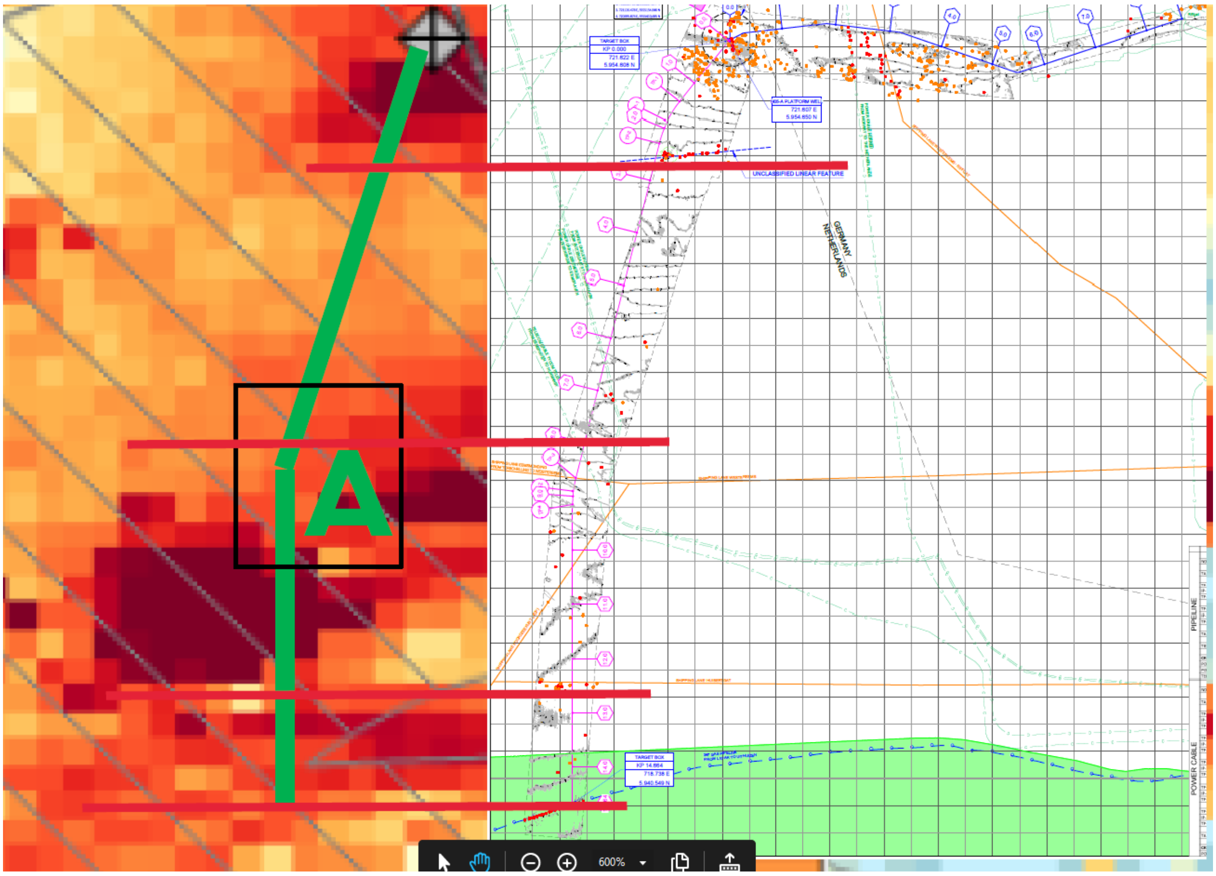


Figure 7 Shipping densities along the pipeline route

Table 15 Shipping densities along the pipeline route

From KP	To KP	Shipping density
0.0	2.7	45
2.7	8.0	15
8.0	12.7	45
12.7	14.7	27

The effect on the shipping density on the minimum burial depth is summarized in table 16.

It should be noted that the CWC thickness of 140 mm has already reached its maximum thickness from manufacturing, handling and installation perspective.

Table 16 Minimum required cover depth

Ship density /1000 km^2	No CWC		40 mm CWC		140 mm CWC	
	Depth ToP [m]	Probability 10^{-6}	Depth ToP [m]	Probability 10^{-6}	Depth ToP [m]	Probability 10^{-6}
45	0.7	0.97	0.6	0.97	0.5**	0.90
27	0.3	0.89	0.0	0.97	0.0	0.93
15	0.0	0.74	0.0	0.54	0.0	0.52

Note **: The determined cover depth for 140 mm CWC in the shipping lane considers an update to NEN 3656, expected to be in effect by the time of pipeline installation, where the cover depth in a shipping lane is based on a risk assessment instead of the minimum requirement of 0.6m cover in the 2015 edition.

8. Dropped object analysis

This section describes the used methodology for determining the impact energy due to the dropped objects and the amount of energy absorbed by the rock dump as a function of its height. This approach excludes probabilistic data and is merely a comparison between impact energy of the dropped object and absorbed energy by the cover layer. It is assumed that the spool has the same properties as the pipeline, as a result the same acceptable amount of plastic deformation energy has been used.

The required height of the rock dump near the platforms and tie-in, to withstand the impact energy generated by dropped objects because of crane handling from and on(to) the platform/supply vessel (containers, equipment, pipes etc.), is determined following DNV-RP-F107 [11].

8.1. Dropped object impact energy

Calculation of the kinetic energy (E_k) of a dropped object is performed using the same method as described in section 7.8. As discussed in chapter 5.3, the most likely objects to damage the pipeline are tubular objects such as pipe elements.

Using the data on typical dropped objects as presented in Table 9, the terminal velocity and kinetic energy upon impact are calculated and the results are presented in Table 17. The maximum drop height (Hd) in air is estimated not to exceed 50 [m].

The impact velocity at sea level can be determined using section 4 of ref. [12]:

$$v_{i,a} = \sqrt{2 \times g \times Hd}$$

The characteristic water depth is determine using 4 of ref. [12]:

$$sc = \frac{M + Ma}{\rho_w \, * \, C_d \, * \, A_p}$$

Knowing the minimum water depth of 28 [m], (s) and having determined the characteristic distance (s_c) and terminal velocity (v_t) for a specific object, the actual impact subsea velocity (v) and thus the impact energy can be calculated using above given 8.

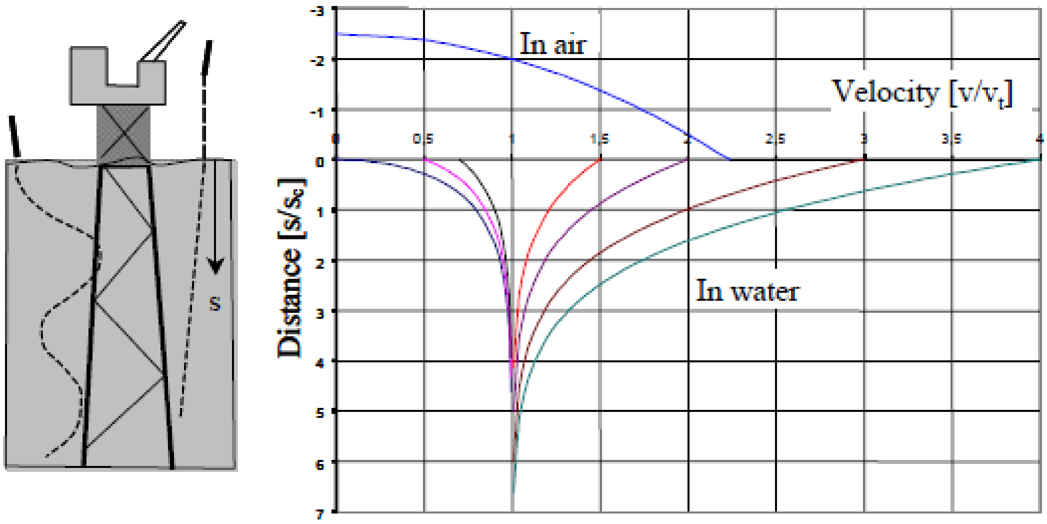


Figure 8, Velocity profile for objects falling in water [12]

Table 17 Kinetic impact energies for design dropped objects

Object	Unit	1	2	3	4	5
Impact vi,a at waterline. Sa=50 m	[m/s]	31.3	31.3	31.3	31.3	31.3
Terminal velocity in water, vt. S=26m	[m/s]	8.98	9.62	10.17	12.5	11.43
Kinetic impact energy, Ek	[kJ]	35.8	65.7	105.8	453.3	1097
Bearing capacity, p(h)	[tonnes/m^2]	41.8	65.7	58.7	108.6	108.2
Absorption energy Rock dump, (Epd)	[kJ]	36.4	65.2	105.0	443.1	1095.5
Absorption energy Rock spool, (Eps)	[kJ]	26.1	26.1	26.1	26.1	26.1
h,$_{critical}$	[m]	**0.24**	**0.28**	**0.32**	**0.65**	**0.43**

It should be noted that the absorption energy of the spool, is not contributing to the total absorption energy. The rockberm should provide all the absorption energy, such that the pipeline is fully protected and not contribution to the absorption.

8.2. Rock dump energy capacity

The properties of the rock dump as presented in Table 6, are used as input for the dropped object calculation.

The bearing force which can be taken by the rock dump is evaluated according the Brinch-Hansen method.

The energy absorption capacity of a rock dump is defined by:

$$E_p = \text{p} \cdot g \cdot \left\{ \frac{1}{2} \cdot (B_r + B_o) \cdot \frac{1}{2} (L_r + L_o) \cdot h \right\}$$

Whereas, Br, Lr=breadth/length influence zone rock dump at top of pipe .

$$Br = Bo + 2 \cdot h \cdot \tan{(90 - \varphi)}$$

$$Lr = Lo + 2 \cdot h \cdot \tan{(90 - \varphi)}$$

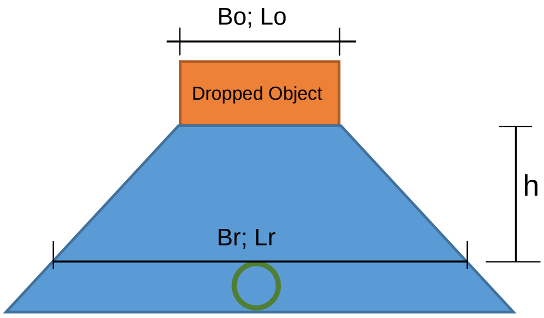


Figure 9 Rock dump geometric annotations

Where both Br and Lr are calculated per object, based on the rock dump properties as provided in Table 6 and the pipe diameter, which is equal to Bo and Lo.

Cylindrical objects will find a stable falling orientation in a horizontal position. As the longest object considered is 1.2 m in length and the width of the rock cover is typically 2 meters, it is assumed that the object contacts the rock cover along its full length. The contact area is then equal to the outer diameter times the length.

The absorption energy calculated for the objects dropped on the and 20” for both the rock dump and the spool is presented in Table 16, where the maximum value for the rock dump cover is highlighted. The absorption energy of the spool is identical to the absorption energy of the pipeline (Ep = 26.1 [kJ]), as calculated in section 7.10.

As can be seen, object 4 is most critical regarding the required rock dump height, above pipeline, which should be more than 0.65 m.

9. Conclusions

Conclusions.

The Eems-Dollard to North Sea area is busy ship traffic area with high ship densities. Generally high ship densities induces higher accidents rates for collision and sinking. Ship accidents result into the higher pipeline risks for dropped and dragging anchors.

The ships frequenting the Eems-Dollard ports are generally smaller ships, as the Eems-Dollard ports cannot receive the very large vessels (max draught approx. 14 m), all larger vessel arrival and departures are controlled by a traffic control centre. And will enter or leave the fairway with the mandatory pilotage and tug boat assistance.

The N05A pipeline has a relative large wall thickness and is for stability purposes provided with a combination of measures like rock berm, CWC and burying. These additional measures provide additional protection against third party interference.

Dropped and dragging anchors

Generally, dropped and dragging anchors are the dominant threat for the pipeline. Just because ships need to navigate in the narrow shipping lane, means that anchors are easily deployed in case of emergency. The minimum soil cover to achieve a failure probability of less than 10^{-6} per km per year is determined.

When no CWC is applied, a minimum burial depth of 0.7 m (ToP) is to be applied in ranges KP 0-2.7 and 8.0-12.7 with high density shipping, 0.3 m of cover is required for the section KP 12.7-14.7, in the remainder between KP2.7-8.0, no cover is required.

With 40 mm of CWC, the burial depth in the designated shipping lanes (KP 0-2.7 and 8.0-12.7) must be 0.6 m, outside the shipping lanes no cover is required in relation to protection of the pipeline against anchors.

Increasing the CWC to 140 mm requires a cover height of 0.5m in the shipping lane. The determined cover for 140 mm CWC in the shipping lane considers an update to NEN 3656, expected to be in effect by the time of pipeline installation, where the cover depth in a shipping lane is based on a risk assessment instead of the minimum requirement of 0.6m cover in the 2015 edition.

The energy absorption capabilities of the CWC referred in this document are just indicative and require confirmation.

Dropped Objects

The pipeline spools near platform N05A , require full protection against dropped objects. This is done by rock berm with a required rock berm height of 0.65 m above the spools.

Fishing gear and sinking ships

Fishing gear interference damage and sinking ships are both relative less critical pipeline risks. The un-buried pipeline case is more exposed but still the risk is below acceptance level.

Consequence of damage

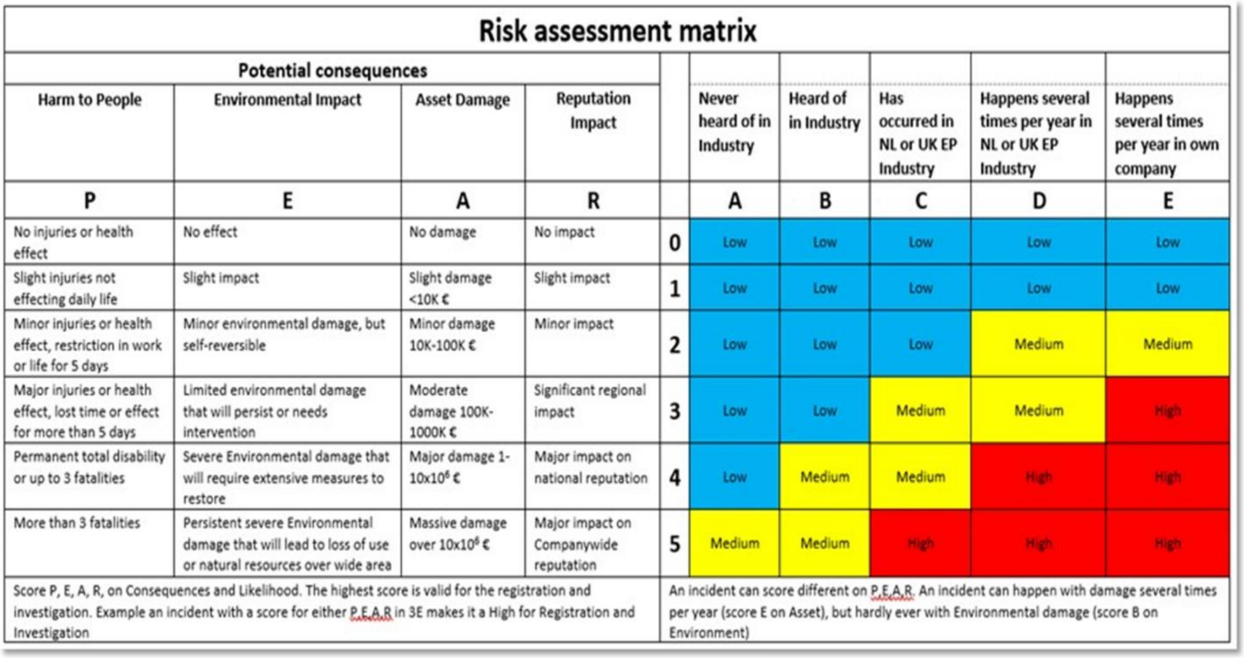
The calculated probabilities are for damage 3 categories. This is a loss of containment of natural gas with a fraction condensate. With the maximum liquid hold-up of approximately 137 m^3 a part of this volume could be released.

A. Risk Investigation and Evaluation

The following attendees have participated in the pipeline RIE, held on 3 December 2019 at One-Dyas office Amsterdam

Jan Willem in 't Anker	Engineering ManagerONEDyas
Frits Gremmen	Pipeline EngineerONEDyas
Michel van der Beek	HSE EngineerONEDyas
Pascal Ferier	Project ManagerEnersea
Jan van den Berg	Pipeline EngineerEnersea

Applied Risk Matrix



Risk assessment matrix									
Potential consequences									
Harm to People	Environmental Impact	Asset Damage	Reputation Impact		Never heard of in Industry	Heard of in Industry	Has occurred in NL or UK EP Industry	Happens several times per year in NL or UK EP Industry	Happens several times per year in own company
P	E	A	R		A	B	C	D	E
No injuries or health effect	No effect	No damage	No impact	0	Low	Low	Low	Low	Low
Slight injuries not effecting daily life	Slight impact	Slight damage <10K €	Slight impact	1	Low	Low	Low	Low	Low
Minor injuries or health effect, restriction in work or life for 5 days	Minor environmental damage, but self-reversible	Minor damage 10K-100K €	Minor impact	2	Low	Low	Low	Medium	Medium
Major injuries or health effect, lost time or effect for more than 5 days	Limited environmental damage that will persist or needs intervention	Moderate damage 100K-1000K €	Significant regional impact	3	Low	Low	Medium	Medium	High
Permanent total disability or up to 3 fatalities	Severe Environmental damage that will require extensive measures to restore	Major damage 1-10x10⁶ €	Major impact on national reputation	4	Low	Medium	Medium	High	High
More than 3 fatalities	Persistent severe Environmental damage that will lead to loss of use or natural resources over wide area	Massive damage over 10x10⁶ €	Major impact on Companywide reputation	5	Medium	Medium	High	High	High
Score P, E, A, R, on Consequences and Likelihood. The highest score is valid for the registration and investigation. Example an incident with a score for either P.E.A.R in 3E makes it a High for Registration and Investigation				An incident can score different on P.E.A.R. An incident can happen with damage several times per year (score E on Asset), but hardly ever with Environmental damage (score B on Environment)					

RIE Outcome, action list

The following actions were recorded during the workshop

	Action	response	Action holder	Date
Design based on faulty metocean and environmental data, or faulty application	Comparison with other locations		OneDyas	
Installation, tie-in NGT defect	separate evaluation of risk required		OneDyas	
Liquefaction	ALARP. Can we find similar projects	.. Email 04 dec 2019 to Frits Gremmen	Enersea	
Scour, loss of cover, exposure (freespan), buoyancy	Captured in MER		OneDyas	
Dropped and dragging anchor	Contact RWS to investigate legitimacy anchoring zone. ALARP. Assessing effcetiveness of measures.		OneDyas	
Ship traffic	ALARP. To be performed for platform		OneDyas	
Dredging waterway	Contact RWS		OneDyas	

B. Risk Register

(3 pages)

Generic Hazard	Specific Hazard	Pipeline section	Cause	Potential Effect	Initial Barriers	Initial Risk			Control / Safeguard	Reference Document	Residual Risk			Action
						S	L	RR			S	L	RR	
DFI (design, fabrication and installation errors)														
	Design and material, specifying properties	**general**	Inadequate material properties to meet design requirements	Non-compliance to codes and regulations, delays, costs	Design Standards,	2	C	L	Design review, Verification by Certifier		2	B	L	
	Design and material, fracture control	**general**	Inadequate specified brittle and ductile toughness properties.	Non-compliance to codes and regulations, delays, costs	Design Standards,	2	C	L	Design review, Verification by Certifier		2	B	L	
	Design based on faulty process parameters	**general**	Process parameters and conditions are unconfirmed, not consistent	Non-compliance to codes and regulations, delays, costs	Design Standards,	2	C	L	Design (peer) review, Verification by Certifier		2	B	L	
	Design based on faulty metocean and environmental data, or faulty application	**general**	The water depth varies from 26.5 to 9.5 m with significant stability issue. Poor geotechnical interpretations	Pipeline stability at risk. Non-compliance to codes and regulations, delays, costs.	Design Standards, Design focusses specifically on stability, metocean data.	3	C	M	Design (peer) review, Verification by Certifier,		3	B	L	
	Design and material defects, design life	**general**	Fatigue, corrosion rates, material degradation.	Anticipated design life is not met. Non-compliance to codes and regulations, delays, costs.	Design Standards. Design incorporates fatigue life, corrosion rate, degradation predictions.	2	C	L	Design review, Verification by Certifier.		2	B	L	
	Fabrication material defects, wrong properties of materials	**general**	Manufacturing defects, inadequate material inspection and test procedures	Non-compliance to codes and regulations/company specs, delays, costs	Design Standards, QA/QC policy, Company Standards.	2	C	L	Inspection and Supervision		2	B	L	
	Installation, construction defects		Installation defects	Pipeline buckle, dents, any type of damage. Causing delays and costs.	Design Standards, installation design and procedures, QA/QC policy	2	C	L	Inspection and Supervision		2	B	L	
Buried	**Installation** trenching problem	**pipeline**	inadequate trench depth, boulders in trench, UHB risk, suitability of soil	Non-compliance to required burial depth, delays, costs	Design Standards, QA/QC policy, Site surveys: seabed objects, likeboulders, wrecks and magnetic objects are surveyed and incorpated in the routing design.	3	C	M	Perform trenching and installation feasibility determining suitable installation equipment.		3	B	L	
Unburied	**Installation** stability problem	**pipeline**	Insufficient submerged weight (steel wall thickness and / or CWC)	Non-compliance to stability requirements, delays, costs	Design Standards, QA/QC policy, Soil surveys and metocean data.	3	B	L			3	B	L	
	Installation (environmental restrictions)	**pipeline**	Unforeseen limitations	Delay and cost	Pipeline is part of the environmental assessment (MER)	2	C	L	Follow-up on MER outcome		2	C	L	
	Installation clash, error	**at platform**	Unforeseen SIMPOS, Loss of control, colission with platform, workover rig, Target box too close to platform. Magnetic contacts close to platform.	Delay, costs, safety	Planning, interface management. Design incorporates potential clashes or avoids obstacles.	3	D	M	Managing stakeholder and interfaces. Perform installation feasibility Manage contracts and installation contractor windows, to avoid clashes.		3	C	M	
	Installation, tie-in NGT defect	**at NGT Tie-in**	Not able to establish tie-in. Unforeseen issues, eg Reduced wall thickness at Hot tap location, etc.	Non-compliance to installation specs, delays, costs, loss of containment.	Planning, interface management.	5	C	H	Managing stakeholder and interfaces. Perform feasibility study. Will be executed by NGT. To be managed by contracting reputable contractor and will be risk assessed separately.		5	B	M	Separate evaluation of risk required
	Pre-commissioning error		Any failure related to pre-commission the pipeline. Inadequate cleaning and drying	Non-compliance, delays, costs.	Design Standards, QA/QC policy	2	C	L	Inspection and Supervision, as-laid information		2	B	L	
Natural Event/Hazards														
	Land slide, debris flow	**general**	Soil and slope instability. Not captured in geotech reports	pipeline rupture, pipeline large displacements, resulting in buckling and loss of containment	Geotech data interpreted and no significant exposure found	2	C	L	PIMS, perform event-based inspection. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar)		2	C	L	
	Seismic loading, fault lines	**general**	Seismic and fault movement	pipeline overstress, buckling resulting in loss of containment	Geotech data interpreted and no known seismic risks found	2	C	L	PIMS, perform event-based inspection		2	C	L	
	Subsidence	**platform**	Subsidence due to well drilling, historic sand extraction	unforeseen pipeline displacements, resulting in buckling and loss of containment	Geotech data interpreted and no subsidence expected	2	C	L	PIMS, perform event-based inspection. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar)		2	C	L	
Buried	Liquefaction	**pipeline**	Wave induced liquefaction	Floatation of pipeline, resulting in buckling. Interruption production	Trench right back-fill material. Apply high specific gravity.	3	C	M	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar). Perform trenching and backfill analyses. Remedial works (re-trenching, backfilling e.g. rock dumping)		3	C	M	ALARP

Generic Hazard	Specific Hazard	Pipeline section	Cause	Potential Effect	Initial Barriers	Initial Risk			Control / Safeguard	Reference Document	Residual Risk			Action
						S	L	RR			S	L	RR	
Buried	Uncontrolled Pipeline movement (vertical)	**pipeline**	Loss of cover, Loss of stability	Overstress, buckling, resulting in loss of containment	Design standards. Trenching providing controlled pipeline stability. Depth of cover.	3	C	**M**	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI), pipe tracking and seabed scanning (e.g. multibeam sonar). Perform trenching and backfill analyses. Remedial works (e.g. rock dumping)		**3**	**B**	**L**	
Un-buried	Uncontrolled Pipeline movement (vertical, lateral)	**pipeline**	Loss of stability	Excessive displacement, Overstress, buckling, resulting in loss of containment	Design standards. Concrete Weight coating =140 mm,	3	C	**M**	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar). Perform state-of-art stability analyses . Remedial works (e.g. rock dumping)		**3**	**B**	**L**	
Un-buried	Scour, loss of cover, exposure (free span), buoyancy	**pipeline**	Mobility of seabed	Developing free spans resulting in overstress, fatigue, hooking of fishing gear, excessive displacements	Design standards.	3	C	**M**	PIMS, perform inspections. Seek geotechnical/hydro-morphological advise. Remedial works (e.g. rock dumping)		**3**	**B**	**L**	MER states a requirement for morphological study
	Severe weather	**pipeline**	Unpredicted severe weather conditions	Any damage	Sufficient knowledge of weather and environmental data	2	C	**L**	PIMS, perform event-based inspection.		**2**	**C**	**L**	
Third party damage/interference														
	Dropped objects	**near platform**	Dropped Object from vessel/rig/platform	Damaging coating and pipeline. Dent, Loss of containment. (effect can extend to platform)	The rock berm is designed for full protection against dropped objects (and rig anchors) on spools. Lifting activities at North end of platform	**3**	**D**	**M**	PIMS, maintaining procedures for lifting, approaches and position of vessels and dril rig. Periodically visual inspect rock berm/protection or sidescan sonar. Remedial works (e.g. rock dumping). Procedure for platform abandonment.	Risk assessment study capturing dropped objects	**3**	**B**	**L**	
buried	Dropped and dragging anchor	**pipeline**	Dropped/dragging anchor Pipeline route crosses anchor zone.	Damaging coating and pipeline. Damage to pipeline, rupture. Loss of containment	Trenching and large diameter reduces risk of hooking. Depth of cover = 1m.	**4**	**D**	**H**	PIMS, periodic pipe tracking survey and active AIS monitoring. Regulations in fairway for marine traffic on Eems (pilotage and tug assistance). Remedial works (e.g. rock dumping). Regulatory restriction for anchoring outside designated anchor zones.	Risk assessment study capturing dropped and dragging anchors	**4**	**C**	**M**	Contact RWS to investigate legitimacy anchoring zone. ALARP. Assessing effcetiveness of measures.
un-buried	Dropped and dragging anchor	**pipeline**	Dropped/dragging. Pipeline route crosses anchor zone.	Damaging coating and pipeline. Damage to pipeline, rupture. Loss of containment	Concrete weight coating (CWC=140 mm) reduces some impact of denting or hooking.	**4**	**D**	**H**	PIMS, periodic pipe tracking survey and active AIS monitoring. Regulations in fairway for marine traffic on Eems (pilotage and tug assistance). Remedial works (e.g. rock dumping). Regulatory restriction for anchoring outside designated anchor zones.	Risk assessment study capturing dropped and dragging anchors	**4**	**C**	M	Contact RWS to investigate legitimacy anchoring zone. ALARP. Assessing effcetiveness of measures.
buried	Foundering, ship sinking	**pipeline (shallow section)**	Sinking, stranding ship	damage to pipeline, likely only buckling	Trenching provide some minor protection	**3**	**C**	**M**	PIMS, and active AIS monitoring. Regulation for marine traffic on Eems (piloting and towing service (mandatory DWT >10.000)). Safeguard pipeline. Remedial works (e.g. rock dumping)	Risk assessment study capturing sinking ships	**3**	**B**	**L**	
unburied	Foundering, ship sinking	**pipeline (shallow section)**	Sinking, stranding ship	damage to pipeline, likely only buckling		**3**	**C**	**M**	PIMS, and active AIS monitoring. Regulation for marine traffic on Eems (piloting and towing service (mandatory DWT >10.000)). Safeguard pipeline. Remedial works (e.g. rock dumping)	Risk assessment study capturing sinking ships	**3**	**B**	**L**	
*buried **/unburied***	Dropped and dragging anchor	**riser**	Main cause are drifted ships from main shipping lane	Colission with platform, damaging riser. Damage to riser, loss of containment	Platform is projected near shipping lanes. Riser(s) situated within jacket	**5**	**C**	**H**	Managing exclusion zone, Navigation Aids, Active AIS monitoring with possibility to warn off ships, Subsea check valve near platform, platform abandonment procedure	32287-1-MO, Platform collision report	**5**	**B**	**M**	ALARP. To be performed for platform
buried	Fishing gear	**pipeline**	pulling and hooking of pipeline	Damage to pipeline, dents, displacements	Trenching provides adequate protection against fishing gear	**2**	**B**	**L**	PIMS. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar)		**2**	**B**	**L**	
unburied	Fishing gear	**pipeline**	pulling and hooking of pipeline	Damage to pipeline, dents, displacements	Concrete weight coating = 140 mm. CWC provide protection against denting. (CWC damage)	**2**	**C**	**L**	PIMS. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar)	Risk assessment study capturing fishing interaction	**2**	**B**	**L**	
buried/unburied	Unexploded ordinance	**pipeline**	undetected UXO	damage to pipeline, loss of containment	Surveys contain magnetic anomalies and safety distance of 200 m is kept.	**2**	**C**	**L**	PIMS. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar)		**2**	**B**	**L**	
buried/unburied	Wrecks, boulders and obstructions	**pipeline**	Presence of anomalies.	Potential clash and damage to pipeline, non-compliance (ecological/archeological values)	Ship wrecks and other objects are identified and separation distances are maintained	**2**	**C**	**L**	PIMS. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar)	N05A-7-51-0-72510-01-01_Overall field layout drawing	**2**	**B**	**L**	
buried/unburied	Mining, sand extraction, dredging	**pipeline**	Mining, sand extraction or dredging activities.	Potential clash and damage to pipeline	No clashes are foreseen	**2**	**C**	**L**	Stakeholder and right of way management. PIMS, perform inspections		**2**	**B**	**L**	
buried/unburied	Dredging waterway	**pipeline vaargeul**	Future extension of port entrance, with dredging fairway	Non-compliance, loss of license to operate	Obtain and implement permit conditions for crossing fairway/shipping channel extention.	**4**	**C**	**M**	PIMS, Stakeholder and right of way management. Manage permits.	N05A-7-51-0-72510-01-01_Overall field layout drawing	**4**	**B**	**M**	Contact RWS
buried/unburied	Sabotage	**general**	Sabotage	damage to pipeline		**2**	**C**	**L**			**2**	**C**	**L**	
	Pipeline (future) crossing(s)	**pipeline**	unfavourable design	Additional/excessive loading onto pipeline system.	Design standards.	**2**	**C**	**L**	PIMS, Stakeholder and right of way management		**2**	**B**	**L**	
Corrosion														
	Internal corrosion	**general**	Changing composition of Production fluids. Water dewpoint too high	Higher corrosion rate than anticipated, not meeting service life, resulting in loss of containment	CA= 3mm, no corrosion is expected (treated and dew pointed fluids)	**2**	**C**	**L**	PIMS, perform inspections and monitoring. Periodic wall thickness measurements. Monitoring fluid properties , spec water content and dew point, inhibition rate.		**2**	**B**	**L**	

Generic Hazard	Specific Hazard	Pipeline section	Cause	Potential Effect	Initial Barriers	Initial Risk			Control / Safeguard	Reference Document	Residual Risk			Action
						S	L	RR			S	L	RR	
	Internal corrosion	**general**	Inadequate inhibition.	Inhibition not adequate result in higher corrosion rate than anticipated, not meeting service life	CA= 3mm	**2**	**C**	**L**	PIMS, perform inspections and monitoring. Monitoring fluid properties inhibition rate and periodic inhibition efficiency control.		**2**	**B**	**L**	
	Galvanic corrosion	**general**	Different materials in pipeline system.	Local corrosion near material changes, resulting in loss of containment	Transition by isolation between different metals.	**2**	**C**	**L**	PIMS, perform inspections and monitoring		**2**	**B**	**L**	
	External corrosion (coating damage)	**pipeline**	Coating damage (due to e.g. dropped objects, dragging anchors)	Local corrosion, resulting in loss of containment	CA= 3mm, 3LPE coating with anodes	**3**	**C**	**M**	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI) and CP stabbing.		**3**	**B**	**L**	
	External corrosion (coating damage)	**riser**	Coating damage (due to e.g. dropped objects, vessel impact)	High corrosion rate in splash zone, due to oxygen and seawater, resulting in loss of containment	CA= 3mm, neoprene (extra mechanical strength) in splash zone	**2**	**C**	**L**	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI) and CP stabbing.		**2**	**B**	**L**	
	External corrosion (CP failure)	**general**	Anode depletion, faulty contacts	Too low protection levels resulting in external corrosion, resulting in loss of containment	Anode design includes contingency.	**2**	**C**	**L**	PIMS, perform inspections and monitoring		**2**	**B**	**L**	
	Erosion	**general**	particles in production fluid	Loss of wall thickness, resulting in loss of containment	Design standards. CA= 3mm, sand particles and high fluid velocities are not foreseen. Peer review.	**2**	**C**	**L**	PIMS, perform inspections and monitoring . Wall thickness measurements and fluid properties (velocity and sand particles).	TR-19018-ONE002 FA Steady state analysis CRS Flow Assurance N05A Steady State PEER Review	**2**	**B**	**L**	
	Fatigue	**pipeline**	Unforeseen fatigue, free spans,	Cracking in material, resulting in loss of containment	Design standards. Fatigues analyses to be performed and acceptable span lengths determined.	**2**	**C**	**L**	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI) and side scan sonar		**2**	**B**	**L**	
	Fatigue	**riser**	Unforeseen fatigue, loose clamps/guides	Cracking in material, resulting in loss of containment	Design standards. Fatigues analyses to be performed.	**2**	**C**	**L**	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI).		**2**	**B**	**L**	
	Brittle fracture	**general**	During Cold-start-up or changing operation modes.	Brittle fracture results in rupture and loss of containment	Min. material design temperature set at - 20 C for Charpy value.	**2**	**C**	**L**	PIMS, monitoring operation modes. Procedures for changing operation modes (incl cold-starts)	TR-19018-ONE002 FA Steady state analysis CRS Flow Assurance N05A Steady State PEER Review	**2**	**B**	**L**	
Structural Threats														
	Uncontrolled riser movement	**riser**	Loss of clamp or guiding	Overloading, non-compliance to codes and regulations, loss of containment	Captured in design	**3**	**C**	**M**	PIMS, Procedures for monitoring and periodic inspections (specific for clamping). Visual inspections and incorporate (top rope) inspection of riser clamp tightness during platform inspection. Procedures for monitoring and periodic inspections (specific for clamping).		**3**	**B**		
	Excessive riser displacement / loads	**general**	Excessive temperature or pressure.	Overloading, non-compliance to operating design envelopes	Captured in design, spools take the expansion	**2**	**B**	**L**	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar). Monitor and analyse temperature and pressure excursion.		**2**	**B**	**L**	
	On bottom stability	**general**	Any cause. Malfunction of CWC	Large displacements, Overloading or buckling, non-compliant	Captured in design, pipeline is buried	**2**	**B**	**L**	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar).		**2**	**B**	**L**	
	Static Overload	**general**	Any cause. Excessive rockdump.	Overloading, non-compliance to design envelopes, loss of containment	Captured in design	**2**	**B**	**L**	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar).		**2**	**B**	**L**	
	Fatigue	**general**	Any cause. Excessive spans, scour.	Overloading, non-compliance to design envelopes, cracking, rupture. Loss of containment.	Captured in design	**2**	**B**	**L**	PIMS, perform inspections , Monitor and analyse pressure and temp cycles.		**2**	**B**	**L**	
Operational & Process errors														
	Export to NGT	**general**	Compliance or contractual issue	Non-compliance/non-conformity to agreements, problem with exporting gas	Implement contracting conditions	**2**	**C**	**L**	PIMS, Contract and stakeholder management. Develop procedure for periodic exchange of data.		**2**	**B**	**L**	
	Export to NGT	**general**	Off-spec gas, fluid in N05A pipeline.	Non-compliance/non-conformity to technical requirements	Defined export fluid properties	**2**	**C**	**L**	PIMS, Monitor fluids and develop off-spec fluid procedure. Assure that process envelopes are set in systems (DCS)		**2**	**B**	**L**	
	Process envelope	**general**	Process conditions (and operationing outside envelope)	Non-compliance/non-conformity to agreed process envelopes, higher corrosion rates than foreseen, hydrate blockage. Loss of containment	Defined process and operating conditions	**3**	**C**	**M**	PIMS, Monitor fluids and inhibition. Maintain operations procedures for applicable operation modes. Assure that process envelopes are set in systems (DCS)	TR-19018-ONE002 FA Steady state analysis. CRS Flow Assurance N05A Steady State PEER Review	**3**	**B**	**L**	
	Process parameters envelope	**general**	Exceeding design pressure (DP = 111 barg) and temperatures (DT = -20 and 50 C)	non-compliance to design parameters, overstress, larger displacement than foreseen. Loss of containment	Defined process and operating conditions	**2**	**C**	**L**	PIMS, Monitor fluids and procedure. Maintain operations procedures. Assure that process envelopes are set in systems (DCS)		**2**	**B**	**L**	
	Operator errors	**general**	Unable to follow or inadequate procedures and systems of work	High risk, high costs and safety threat	Established operator	**3**	**C**	**M**	PIMS. Operational company standards & systems. Periodic check and update procedures, check lessons learned		**3**	**B**	**L**	
	Operator errors	**pipeline**	Inadequate and Incorrect IRM	High risk, high cost and safety threat	Established operator	**3**	**C**	**M**	PIMS. Operational company standards & systems. Periodic check and update procedures, check lessons learned		**3**	**B**	**L**	

C. Reference graphs for dropped and dragging anchors

Data was gathered on several types of anchor configurations (stockless and Baldt) in a mass range of 550 to 15400 kg. The length and width dimension projected to the oncoming flow during the descend to the sea floor were obtained. A polynomial curve has been fitted through the data and this was used to estimate the dimensions of an anchor for which only the mass was specified.

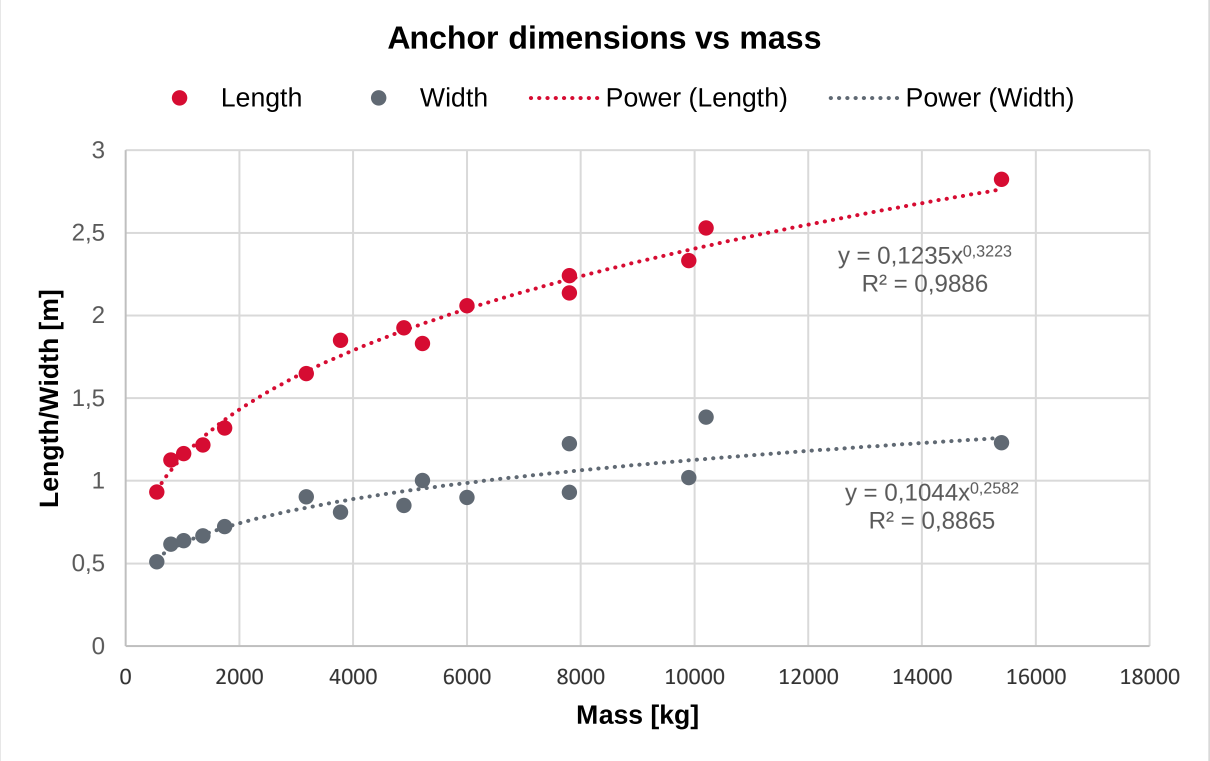


Figure 7, anchor size determination.

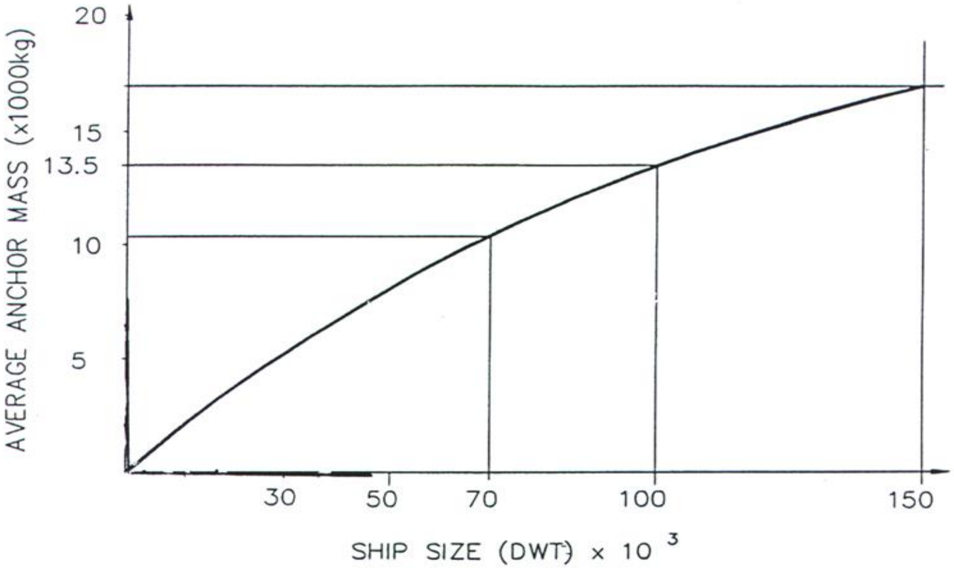


Figure 8, A.Ship size versus anchor mass

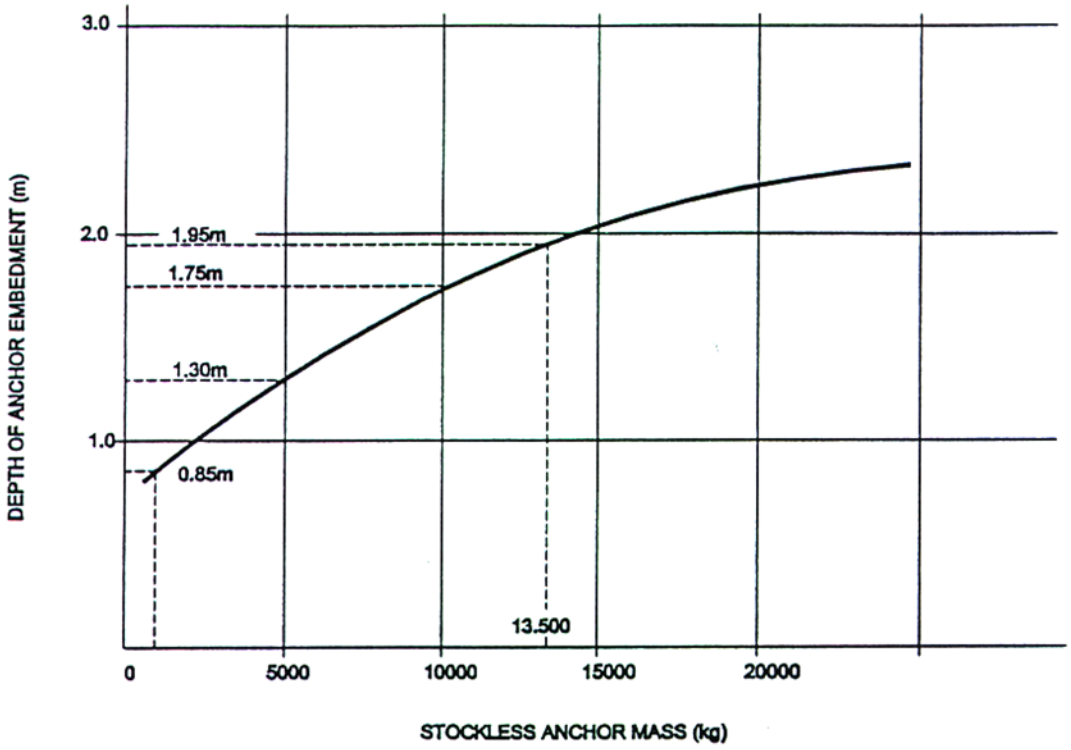
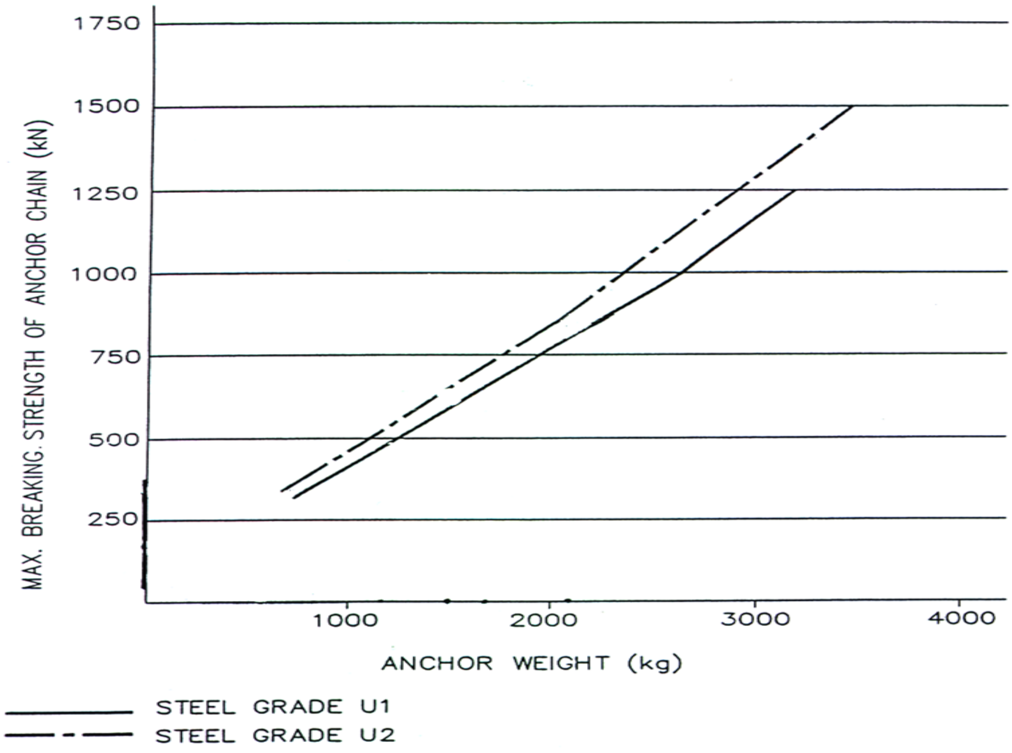


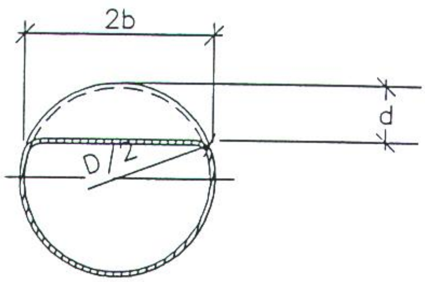
Figure 9, A.Penetration depths due to anchor drag versus anchor size



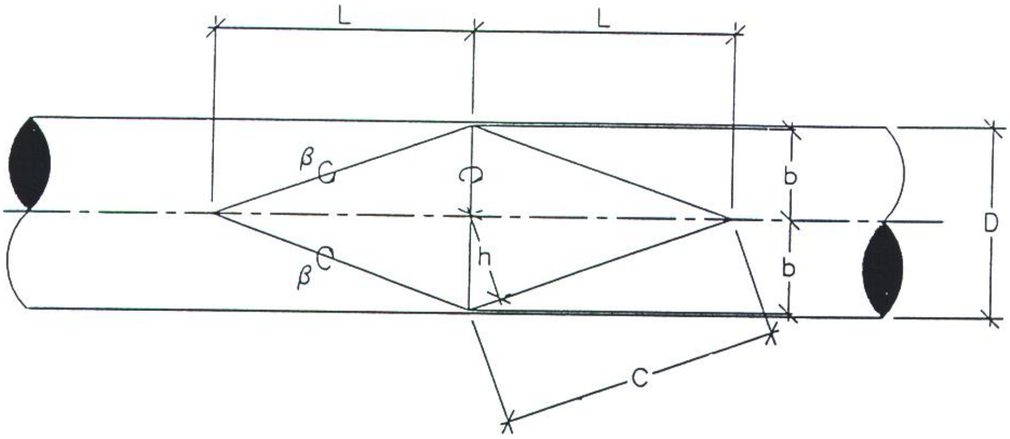
SOURCE: LLOYD'S "REGISTER OF SHIPS"

Figure 10, A.Anchor mass versus maximum breaking strength of anchor chain

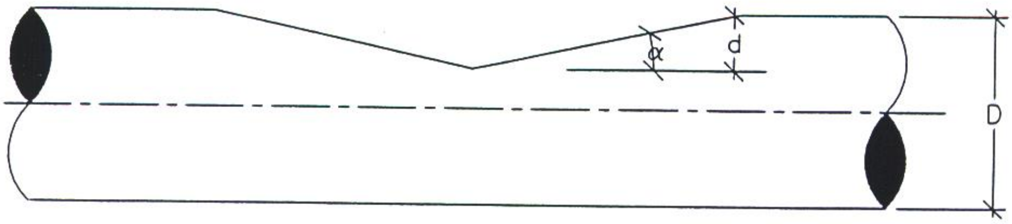
D. Plastic deformation model



A. PIPE CROSS-SECTION THROUGH DENT



B. PLAN VIEW OF SIMPLIFIED DENT SHAPE



C. SIDE VIEW OF SIMPLIFIED DENT SHAPE

$\tan \alpha = d/L$
$\tan \beta = d/h$

E. Dropped anchor calculations

The following calculations were performed for the no CWC situation

Table 18, Kinetic energy calculation per anchor mass group

Symbol	Description	unit	Anchor 1	Anchor 2	Anchor 3	Anchor 4	Anchor 5
g	grav. Acceleration	m/s^2	9,81	9,81	9,81	9,81	9,81
M	anchor mass	kg	1100	2000	4500	10000	15000
w	width frontal	m	0.64	0.74	0.92	1.13	1.25
L	length frontal	m	1.18	1.43	1.86	2.40	2.74
A	anchor frontal area	m2	0.75	1.06	1.70	2.71	3.43
V anchor	anchor volume	m3	0.14	0.25	0.57	1.27	1.91
vt	Terminal velocity	m/s	5.90	6.25	7.41	8.77	9.54
Ma	added mass	kg	143.63	261.15	587.58	1305.73	1958.60
Ek	kinetic energy total	kJ	21.6	44.2	139.8	434.3	772.3

Table 19, Calculation of the absorption energy as a function of the burial depth

Symbol	Description	unit	Anchor mass 1	Anchor mass 2	Anchor mass 3	Anchor mass 4	Anchor mass 5
Nq	Bearing capacity factor	[-]	14.72	14.72	14.72	14.72	14.72
Nc	Bearing capacity factor	[-]	25.80	25.80	25.80	25.80	25.80
Sc	Shape factor	[-]	1.27	1.37	1.46	1.57	1.63
Ng	Bearing capacity factor	[-]	10.94	10.94	10.94	10.94	10.94
Fy (z)	Force at sea bed (z=0,0m)	[N]	1.75E+04	4.13E+04	1.06E+05	2.67E+05	4.28E+05
Epen (z)	kinetic energy absorbed (z=0.0m)	[kJ]	3.49	8.25	21.15	53.46	85.61
	kinetic energy absorbed (z=0.2m)	[kJ]	12.13	24.08	54.92	128.10	198.90
	kinetic energy absorbed (z=0.4m)	[kJ]	25.91	47.49	101.31	223.90	339.89
	kinetic energy absorbed (z=0.6m)	[kJ]	44.83	78.48	160.32	340.88	508.56
	kinetic energy absorbed (z=0.8m)	[kJ]	68.90	117.05	231.94	479.03	704.92

Cover depth	Anchor mass	Critical DWT	P > Cr.DWT	Prob. Drop anchor
[m]	[kg]			x 10^{-6}
0.0	1000	4870	41.9	0.39
0.2	1300	6388	35.3	0.33
0.4	2000	10032	19.7	0.18
0.6	3500	18321	18.0	0.17
0.8	7500	44278	12.8	0.12
1.0	13000	95040	2.5	0.01

Notes:

- Z is the penetration depth and is assumed the thickness of backfill material in the trench.
- A 15% dent requires 20.16 kJ of energy
- The probability in the above table is determined for 15 ships per 1000 km2, the relationship between probability and traffic density is linear.

F. Anchor drag calculations

Table 20, Critical anchor weight as a function of the ToP cover

Cover depth [m]	z [m]	z/D [-]	Nq [-]	Qu [N/m^2]	R [N/m]	Mp [N/m]	F [N]	F [kN]	T=K*F [kN]	Tbreaking (Tb=T) [kN]	Anchor weight [kg]	Crit. DWT [kg]	P>Cr.DWT [%]	Prob drag anchor x 10^{-6}
0.0	0.254	0.5	4.80	10156	5159	1.50E+06	3.52E+05	352	457	457	1097	5358	39.8%	0.64
0.2	0.454	0.9	5.15	19509	9910	1.50E+06	4.87E+05	487	633	633	1520	7520	30.4%	0.49
0.4	0.654	1.3	5.51	30056	15269	1.50E+06	6.05E+05	605	786	786	1887	9435	22.1%	0.35
0.6	0.854	1.7	5.87	41799	21234	1.50E+06	7.13E+05	713	927	927	2226	11235	19.5%	0.31
0.8	1.054	2.1	6.21	54579	27726	1.50E+06	8.15E+05	815	1060	1060	2543	12955	19.1%	0.31
1.0	1.254	2.5	6.47	67694	34389	1.50E+06	9.08E+05	908	1180	1180	2832	14547	18.8%	0.30

G. Platform approach

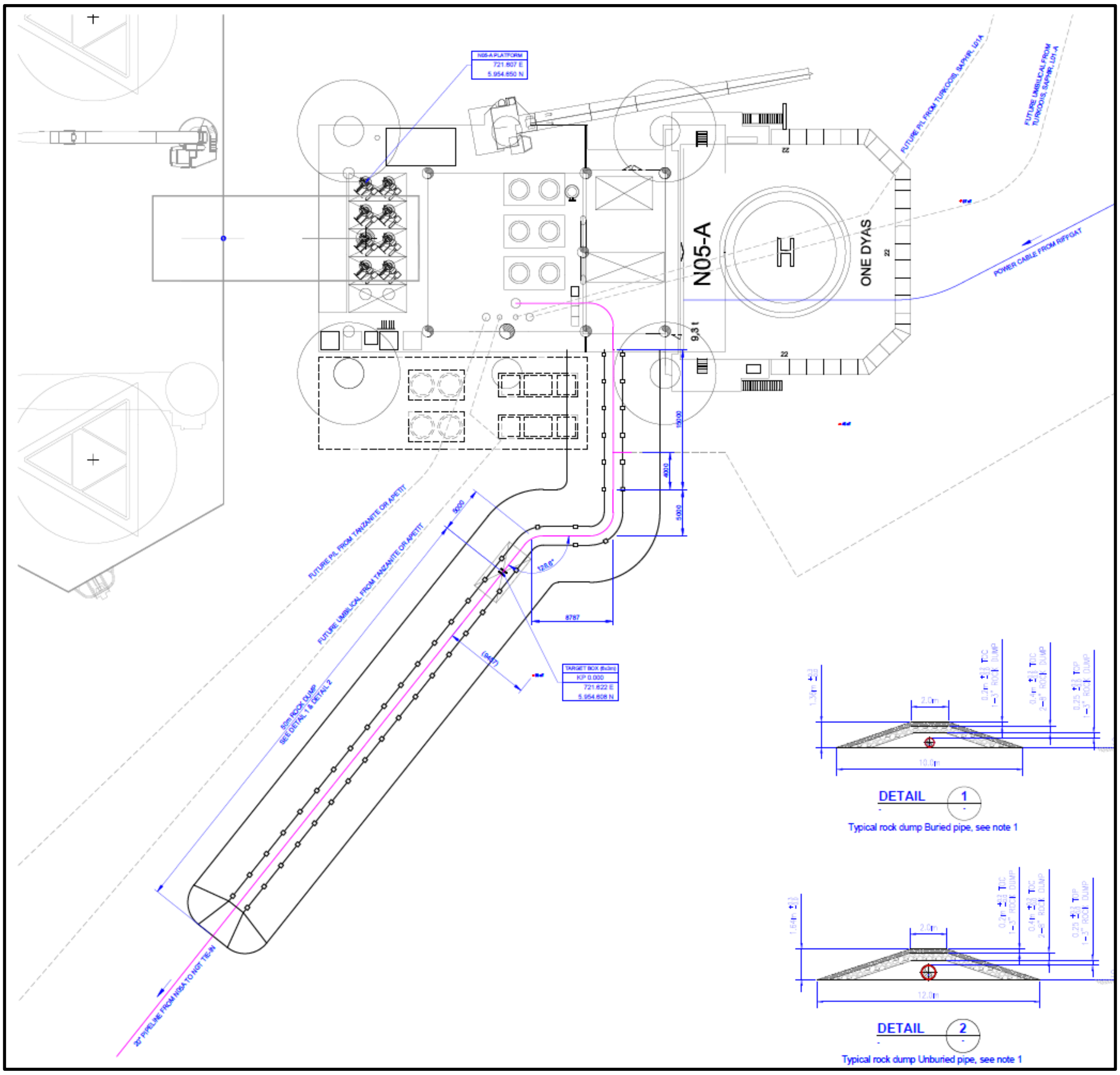


Figure 11, N05A-7-50-0-72019-01, Approach at N05A,

Memorandum

DATE	10 October 2019		
TO	Frits.Gremmen (ONE-Dyas), Jan Willem in't Anker (ONE-Dyas)		
FROM	Erik Koolstra		
COPY	Jeroen Timmermans, VanChuong Ha		
PROJECT	N05A Pipeline On-bottom Stability Check		
SUBJECT	Pipeline stability		
DOC NO	416010-00210-EM-001	**REV**	B

1 Introduction

ONE Dyas BV is performing design activities for a new pipeline from the future N05A platform to a tie-in to the NGT pipeline. ONE Dyas has requested INTECSEA to perform independent confirmation of the stability requirements for the pipeline. Based on the input provided by ONE Dyas, INTECSEA has assessed the stability requirements for the pipeline section near N05A, and this technical note provides the determined results to ONE Dyas for their comparison with in-house determined values. ONE Dyas prefers to not bury the pipeline and therefore the operational design case is governing for stability design.

2 Basis of Analysis

The input parameters and values that form the basis for this analysis are presented in **Table 1**, and are extracted from the N5-NGT Route option 1 drawing, the metocean design criteria report for N05A and the Survey report N5A to NGT Hot tap, see Ref. [1] to Ref. [3].

Table 1 Input for Stability Design

Parameter	Value
Outside Diameter, inch	16 / 20 / 24
Wall thickness, assumed Sch 60, mm $^{1)}$	16.7 / 20.6 / 24.6
Pipe heading rel to North, deg	From 20° to 200°
Anti-corrosion coating, assumed 3LPP/ 3LPE, mm	3 (@ 950 kg/m^3)

Concrete density, kg/m^3	3300
Content density, assumed, kg/m^3	50
Marine growth, assumed	None
Wave data, H_s, m / Tp, sec [2)] - 100 year return period - 10 year return period - 1 year return period	 9.9 / 14.9 8.4 / 13.8 6.5 / 12.4
Current, near bed value, m/s [3)] - 100 year return period - 10 year return period - 1 year return period	 0.96 0.84 0.74
Water depth for design, m (max depth near platform 26.4 m LAT, minimum 9.8 m LAT near tie-in)	25
Soil type	Fine to coarse sand
Notes: 1) Assumed there is no corrosion allowance on the wall thickness 2) The highest waves approach from direction North-West, this is also near perpendicular to the pipe heading and thus governing for stability design 3) The highest currents are going towards East, this is also close to perpendicular to the pipe	

The environmental data is valid for the platform location and the local water depth (26 to 27 m LAT). Some of the source data is obtained at a water depth of 16 m LAT and converted to values for the platform location depth. Considering the fact that water depth at the NGT tie-in is notably less than at the platform location and the fact that the approach of a complex coast line will significantly affect the design wave and current parameters, it is considered of great value to the project if environmental data is developed for the tie-in location and an intermediate point. For the intermediate point the source data at 16 m water depth could be the basis.

3 Calculation Results

The calculated results are presented in **Table 2**.

Table 2 Required Concrete Weight Coating Thickness per DNV RP F109

Design condition	Required CWC, mm	
	16 – inch	24 – inch
Absolute stability	>> 500	>>500
0.5 OD displ	450	425
6 a 8 OD displ	200	180
10 OD displ	170	160

For the first kilometre of pipeline (from N05A; KP 0 to KP 1) and from approximately KP 6 to the tie-in with NGT (KP 14.3), it is not recommended to allow significant lateral displacements, for various reasons; tie-in to fixed structure, crossings with existing infrastructure or the crossing of nature areas. Absolute stability or very small lateral displacements under the maximum design load would result in unrealistic concrete weight coating thicknesses when calculated in accordance with DNVGL-RP-F109. Achievable weight coating thicknesses are associated with maximum allowable lateral displacements of 10 OD or more.

To get confirmation for the high values determined with DNVGL-RP-F109, additional calculations have been performed. The results of a "traditional Morrison equation" based analysis and PRCI software (previously AGA software) analysis are shown in **Table 3**.

Table 3 Required Concrete Weight Coating Thickness - Additional analysis results

Design condition	Required CWC, mm	
	16 - inch	24 – inch
Traditional Morison-equation analysis [1)]	210	200
PRCI level 2 [2)]	150 a 175	150 a 175
Notes: 1) This type of analysis does not provide information about likely lateral displacements 2) This thickness fulfils the Level 2 requirements but requires Level 3 (dynamic stability) analysis confirmation and determination of lateral displacements that can be expected for this weight coating thickness.		

It is not considered economical to increase the steel wall thickness to a value that would result in a more feasible concrete weight coating thickness with the DNVGL-RP-F109 method. Trenching is likely the more economical solution. When looking at it from an environmental point of view; trenching in a Natura 2000 area may not be desirable and complicate permitting, however, the environmental effects of one-time trenching (post installation narrow trench) should be evaluated against large lateral pipeline displacements over the seabed during the design life.

Another consideration is the evidence for a dynamic seabed (NGT self-burial, ripple forms and small dunes). A dynamic seabed could result in future self-burial, span development, future exposure of actively buried sections, etc. This could be a reason, as an example; to design for lower design loads, such as 50- or 10-year return period data and determine in the 2 to 5 years after installation if active trenching is required to ensure long term stability.

Finally, design criteria and philosophy as well as developments since installation of the NGT pipe section where the tie-in is planned can be of great value in making design decisions for the N05A pipeline.

4 References

Ref. [1] Noordgastransport NGT, N5 – NGT – Route option 1, 27/03/2019
Ref. [2] Fugro, Final report, Metocean criteria for the N05A platform, 181892_1_R1, 22 May 2019
Ref. [3] Geo XYZ offshore, N5A Development, N05A-7-10-0-70017-01, Rev 1, 14-06-2019

N05A Development Project

Pipeline Trenching Options

DOCUMENT NUMBER:

N05A-7-10-0-70038-01

Rev.	Date	Description	Originator	Checker	Approver
00	19-12-2019	For internal review	FGR	JWA	JWA

TABLE OF CONTENTS:

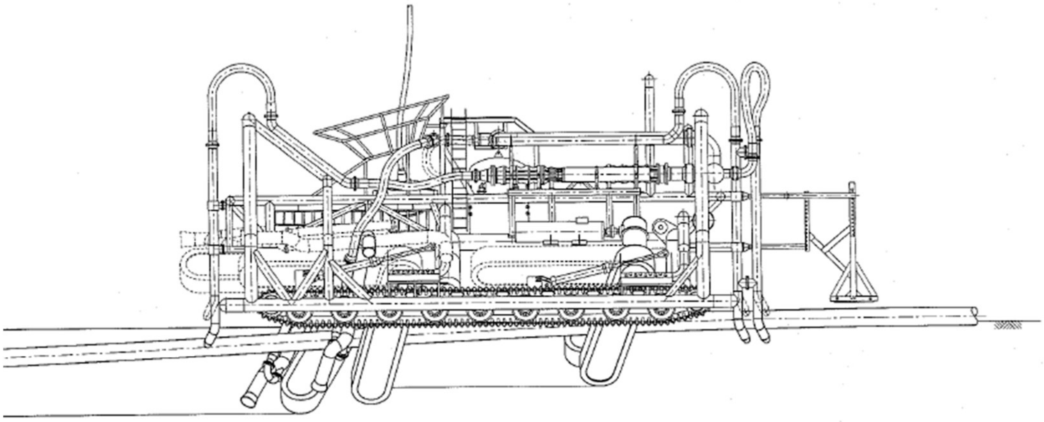
1.0 INTRODUCTION

One-Dyas plans to develop a successfully drilled well in block N5A of the North Sea Dutch Continental Shelf. More wells will be drilled at this location through the same template. It is planned to develop the wells by installing a platform and a gas export pipeline with a connection to the NGT pipeline. Various alternatives for the export pipeline route have been evaluated and a preferred route has been selected for further development; Pipeline route from the future N5A platform location to a subsea hot-tap tie-in at the NGT pipeline near KP 142.1.
In addition, a power cable may be installed from the Riffgat Windpark to the N05A platform.

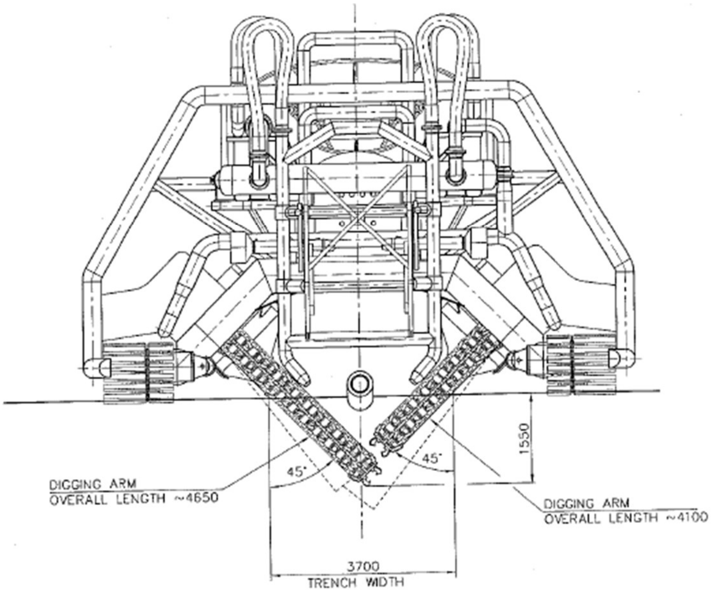
This document describes the different profiles of available pipeline trenching techniques.

2.0 Mechanical Trenching

An example of a mechanical trencher is the Allseas owned Digging Donald. It produces a trench profile slightly wider than its digging arms, depending on soil conditions. Spoil heaps next to the trench are minimal. Drawings of the Digging Donald and typical trench profile are given below.

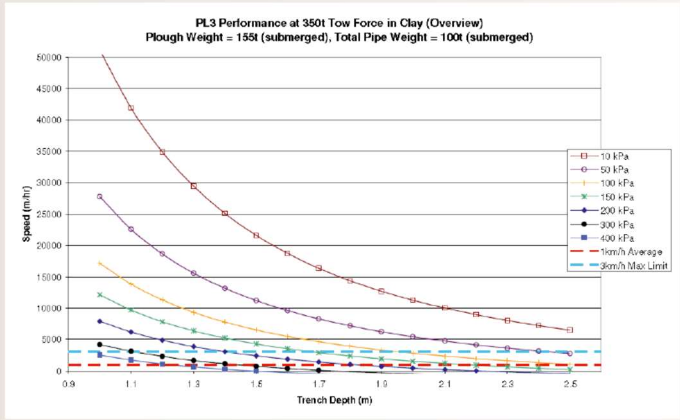


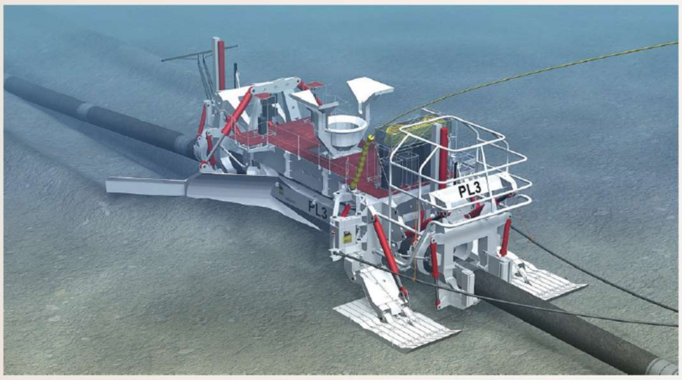
SIDE VIEW "DIGGING DONALD"

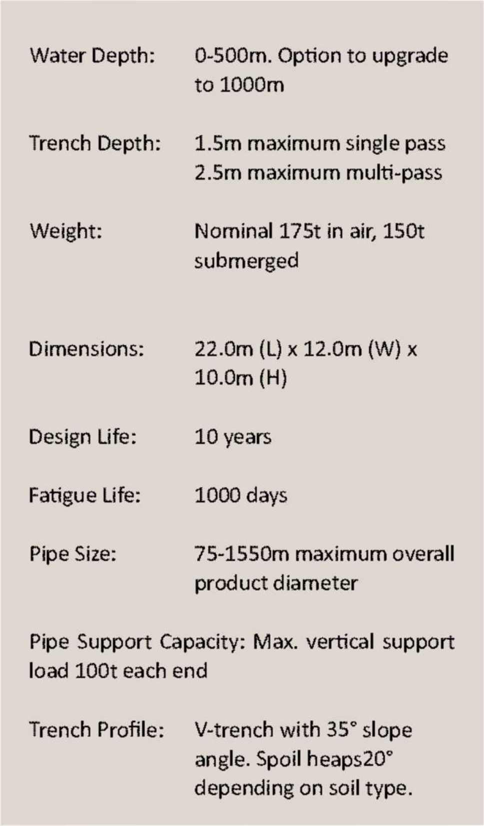


3.0 PIPELINE PLOUGH

A pipeline plough is towed behind a trenching support vessel and produces a typically wider profile than a mechanical trencher with slopes of 35 degrees approximately. Next to the trench considerable spoil heaps will be present directly after trenching, with an approximate slope of 20 degrees. An example is given below.







Water Depth:	0-500m. Option to upgrade to 1000m
Trench Depth:	1.5m maximum single pass 2.5m maximum multi-pass
Weight:	Nominal 175t in air, 150t submerged
Dimensions:	22.0m (L) x 12.0m (W) x 10.0m (H)
Design Life:	10 years
Fatigue Life:	1000 days
Pipe Size:	75-1550m maximum overall product diameter
Pipe Support Capacity:	Max. vertical support load 100t each end
Trench Profile:	V-trench with 35° slope angle. Spoil heaps20° depending on soil type.

4.0 JETTING

The jetting method involves using a high-pressure water and air or water educator jet sled. The jet sled is placed over a previously laid pipeline. The jetting process cuts the seabed with high volume pressurized water “jetted out” through typically 100 or more nozzles at the leading edge of the sled and across the bottom of the trench while soil is extracted from beneath the sled via the educator system, which then disperses the fine particles into the water column. While jetting, gravity lowers the pipeline to the bottom of the jetted trench behind the sled. Jetting sleds are generally buoyant and work well in areas where the seabed is composed of the softest fine gained “fluidized” silts as well as in the stiffest clays. Jetting success is directly proportional to the output volume and pressure of the water and air relative to the type of seabed. The higher the water and/or air pressures and/or volumes, the better the jetting performance in most cases.

5.0 TRENCH PROFILE OVERVIEW

An overview of different trenching methods and associated profiles is given below.

Technique	**Trench depth [m]**	**Trench width [m]**	**Volume of soil replaced [m3/m]**	**Spoil heaps**
Mechanical trenching	1.5	4.0	3.0	Minimal
Ploughing	1.5	4.5	3.4	Large spoil heaps
Jetting	1.5	3.0	2.3	Negligible

6.0 FINDINGS

Jetting seems to be the most favorable method for pipeline burial based on the amount of material removed from the trench compared to a plough and mechanical trenching. A disadvantage of jetting is dispersion of the fine particles in the water column. With a mechanical trencher and plough more soil is moved but less is brought in dispersion compared to the jetting method.

N05a Development

Titel	**Habitat Assessment Survey Report - Addendum**
GEOxyz Bericht Nr.	2039-N05A-HAS-A
ONE Bericht Nr.	N05A-7-10-0-70019-01
Revision	0.1

0.1	15/10/2020	Erste Ausgabe	PC	PC	SR	
Revision	Datum	Beschreibung der Revision	Autor	Geprüft	Freigegeben	Freigegebener Client

REVISION HISTORIE

Die Bildschirmversion dieses Dokuments ist immer die KONTROLLIERTE KOPIE. Wenn sie ausgedruckt wird, gilt sie NUR ZUR INFORMATION, und es liegt in der Verantwortung des Inhabers, dass er die neueste gültige Version besitzt.

Die Tabelle auf dieser Seite kann verwendet werden, um den Grund für die Überarbeitung zu erklären und was sich seit der letzten Überarbeitung geändert hat.

Rev.	Grund für die Überarbeitung	Änderungen gegenüber der Vorgängerversion
1.0	Erste Ausgabe	N/A

INHALTSVERZEICHNIS

TABELLENVERZEICHNIS

ABBILDUNGSVERZEICHNIS

ABKÜRZUNGEN

Die in Table 1 aufgeführten Abkürzungen werden in diesem Bericht verwendet. Werden in diesem Dokument Abkürzungen verwendet, die nicht in Table 1 enthalten sind, kann davon ausgegangen werden, dass es sich entweder um Markennamen von Geräten oder Firmennamen handelt.

Tabelle 1 In diesem Dokument verwendete Abkürzungen

	Beschreibung		Beschreibung
2DHR	2-Dimensionale hohe Auflösung	OSPAR	Oslo/Paris-Konvention (zum Schutz der Meeresumwelt des nordästlichen Atlantiks)
BSL	Benthische Lösungen Limited	OWF	Offshore-Windpark
CNS	Zentrale Nordsee	PC	Physikalisch-chemische Sammelprobe
CPT	Konuspenetrometer-Test	PPP	Präzise Punktpositionierung
EBS	Umwelt-Grundlagenerhebung	PPS	Impuls pro Sekunde
ED50	Europäisches Datum 1950	ROV	Ferngesteuertes Fahrzeug
F1/F2/F3	Fauna Greifproben 1, 2 und 3	SBP	Sub-Bottom Profiler
GNSS	Globales Navigationssatellitensystem	SSS	Side-Scan-Sonar
HAT	Habitat-Bewertung Untersuchung	UHR	Ultra-Hochauflösung
KP	Kilometerposten	UKCS	Vereinigtes Königreich Kontinentalschelf
LAT	Lowest Astronomical Tide	USBL	Ultrakurze Grundlinie
LED	Lichtemittierende Diode	UTC	Koordinierte Weltzeit
MAG	Magnetometer	UTM	Universal-Transversal-Mercator
MBES	Fächerecholot	VC	Vibro-Kern
NGT	Noordgastransport	VORF	Vertikale Offshore-Referenzrahmen
MSL	Durchschnittlicher Meeresspiegel	WGS84	Weltgeodätisches System 1984
ONE	Oranje-Nassau Energie		

1 EINFÜHRUNG

1.1 PROJEKTÜBERSICHT

GEOxyz wurde von Oranje Nassau Energie (ONE) beauftragt, eine Reihe von geophysikalischen, geotechnischen und umwelttechnischen Untersuchungen in Block N5A des niederländischen Sektors durchzuführen. Diese umfassen eine Standortuntersuchung und zwei Streckenuntersuchungen (Abbildung 1 und Table 2), die zwischen dem$^{1.}$ und$^{15.}$ Mai 2019 an Bord des Vermessungsschiffs Geo-Ocean III durchgeführt wurden.

- Trassenvermessung (1 km x 1 km) über der Explorationsbohrung N5A, die durch die Einlagerung der N5A-Plattform erschlossen wird.
- Vermessung der Kabeltrasse (9 km x 1 km) von der vorgeschlagenen N5A-Plattform zur Transformer Station der Offshore-Windfarm (OWF) Riffgat.
- Vermessung der Pipelinetrasse (15 km x 1 km) für die vorgeschlagene Gasexportpipeline von der N5A-Plattform bis zu einem vorgeschlagenen Kabeltrassenkorridor zwischen dem Standort der N5A-Plattform und dem Standort des Hot Tap von Noordgastransport (NGT).

Die geophysikalischen Untersuchungen umfassten die Erfassung von Fächerecholot- (MBES), Side-Scan-Sonar- (SSS), Magnetometer- (MAG) und Sub-Bottom-Profiler- (SBP) Daten über das Gelände und die Routen, wobei auch Sparker-Multichannel-Seismikdaten über das Untersuchungsgebiet erfasst wurden. Eine zusätzliche Vermessung der Kabeltrasse (4 km x 1 km) und des Bohrplatzes (1 km x 1 km) wurde für einen möglichen alternativen Standort der Plattform N5a durchgeführt.

Die Umweltuntersuchungsarbeiten umfassten eine Habitatbewertung und eine ökologische Grundlagenerhebung und wurden von GeoXYZ Offshore UK Limited mit Unterstützung von Benthic Solutions Ltd (BSL) durchgeführt. Die Ziele der Umweltuntersuchung waren wie folgt:

- Identifizieren Sie empfindliche ökologische Lebensräume und Arten des UKCS (z. B. Anhang-I-Habitate).
- Erfassen Sie Basisdaten zur Beurteilung der physikalisch-chemischen und biologischen Eigenschaften des Sediments im Untersuchungsgebiet.

Der letzte Teil der Pipelinetrasse zum NGT-Hot-Tap-Standort wurde nachträglich überarbeitet, um einen bestehenden Einbindepunkt an der NGT-Pipeline (NP-001) nutzen zu können. Diese überarbeitete Route reichte über den ursprünglichen Vermessungskorridor aus dem Jahr 2018 hinaus. Im Jahr 2020 wurden jedoch zusätzliche geophysikalische Vermessungsdaten zur NGT-Pipeline erfasst, die eine vollständige Abdeckung der SSS-Daten und eine teilweise Abdeckung der MBES-Bathymetriedaten für diesen Routenabschnitt lieferten.

Tabelle 2: Vorgeschlagene Standorte der Plattform N5A, der Kabeltrasse N5A zu Riffgat und der Trasse N5A zu NGT Hot Tap

ED50, UTM 31N, CM 3° E					
Vorgeschlagener Standort	**KP**	**Ostwert (m)**	**Nordwert (m)**	**Breitengrad**	**Längengrad**
N5A-Plattform	0.000	721 607.00	5 954 650.00	53° 41' 32.347" N	06° 21' 23.281" E
Ende der Route – Standort der Transformer Station Riffgat Windpark	8.681	730 081.00	5 954 988.00	53° 41' 30.080" N	06° 29' 05.312" E
Ursprüngliches Ende der Route – NGT Hot-Tap-Standort	14.675	718 409.00	5 940 429.00	53° 33' 57.806" N	06°17' 53.314" E

ED50, UTM 31N, CM 3° E					
Vorgeschlagener Standort	**KP**	**Ostwert (m)**	**Nordwert (m)**	**Breitengrad**	**Längengrad**
Geänderte Position des Endes der Route	15.167	717 769.00	5 940 236.00	53° 33' 52.524" N	06°17' 18.043" E

Dieser Zusatzbericht enthält die Ergebnisse der Umwelt-Habitat-Bewertung über die N5a-Standortuntersuchungsgebiete (ursprünglich und alternativ) und die zugehörigen Kabel- und Pipelinetrassen-Untersuchungskorridore, wobei sich speziell auf den überarbeiteten Trassenabschnitt von KP 15.0 bis KP15.167 bezogen wird.

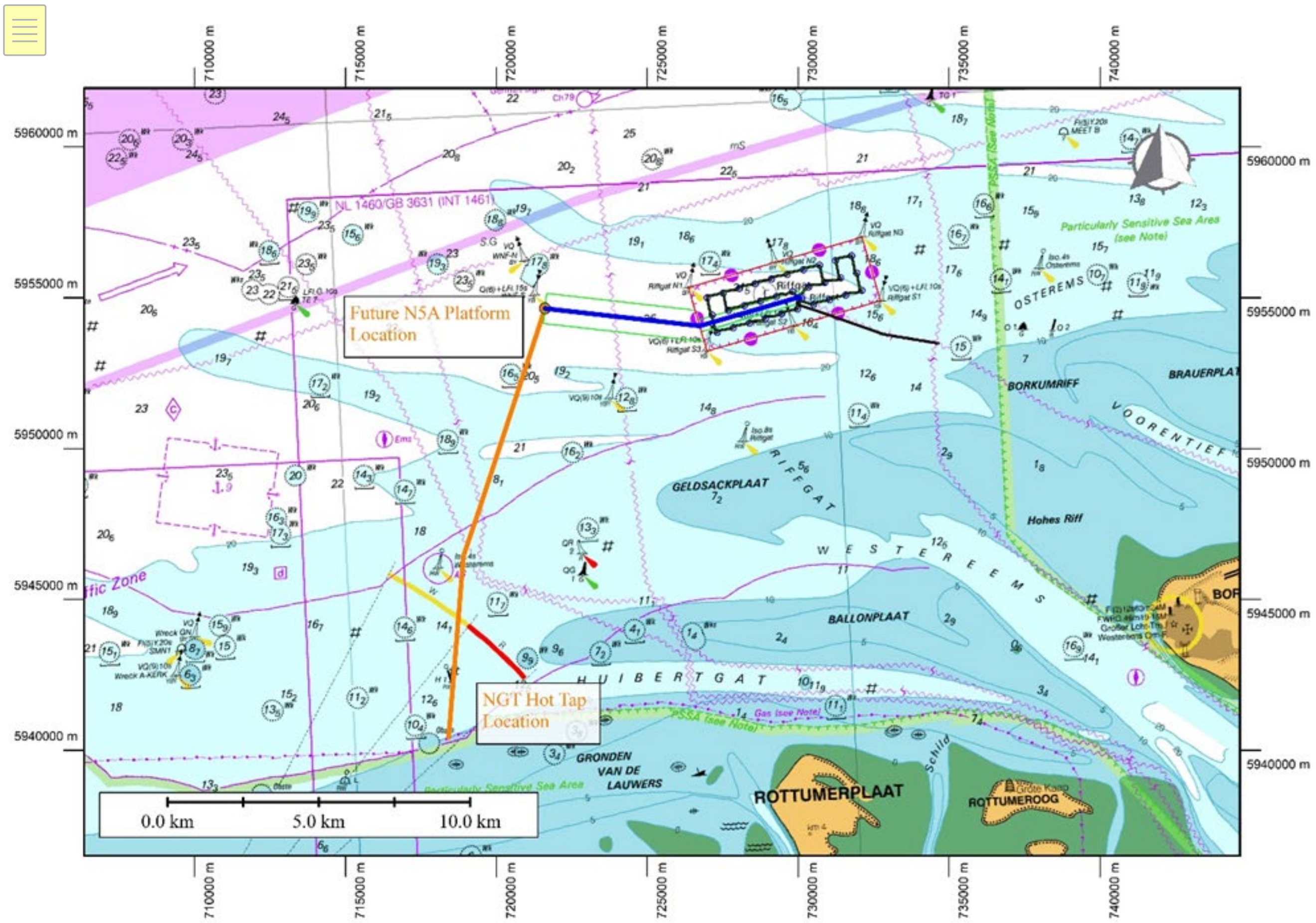


Abbildung 1: Projektstandortübersicht

1.2 ARBEITSUMFANG

Es gab drei Hauptarbeitsbereiche für geophysikalische, geotechnische und umwelttechnische Untersuchungen, wie in N5A-7-10-0-70000-01-05 - Pipeline Route and Platform Area Survey Scope beschrieben. Diese waren:

- Plattformvermessung Zukünftiger N5A-Standort;
- Vermessung der Pipeline-Route vom zukünftigen Standort der N5A-Plattform zu einem bestehenden Einbindungspunkt an der NGT-Pipeline in der Nähe von KP 15.167;
- Kabeltrassenvermessung vom zukünftigen N5A-Bahnsteigstandort zur Transformer-Station Riffgat.

Die folgenden Untersuchungen wurden von ONE angefordert und werden unter Table 3 näher beschrieben:

- Geophysikalische Trassenvermessung von Pipelines und Stromkabeln;
- Geotechnische Vermessung von Pipelines und Stromkabeltrassen;
- Umweltverträgliche Vermessung der Pipeline- und Stromkabeltrasse einschließlich des Plattformbereichs;
- Geophysikalische Vermessung des Plattformbereichs.

Tabelle 3: Detaillierter Arbeitsumfang für jeden Bereich

Umfang	N5A Plattform Site	Hot Tap Pipeline Route	Riffgat Kabel Route
Geophysikalisches Analogon	MBES, SSS, MAG, SBP	MBES, SSS, MAG, SBP	MBES, SSS, MAG, SBP
Geophysikalisch Digital	Multi-channel Zündspule 80 m Tiefe		
Umwelt	Zwei Schürfproben innerhalb des Untersuchungsgebiets der Plattform	Probenahme pro km	Probenahme pro km (auch innerhalb von Riffgat OWF)
Flache Geotechnik		VC pro km	VC pro km

Die geophysikalischen Vermessungsarbeiten 2018 wurden auf zwei Schiffe aufgeteilt, wobei die Geo Ocean III die Arbeiten in Wassertiefen von etwa 10 bis 15 m LAT durchführte und die Geo Surveyor VIII die Arbeiten in den flacheren Abschnitten. Nachfolgende geophysikalische Vermessungen zur NGT-Pipeline, die den überarbeiteten Abschnitt der Pipelinetrasse von KP 15,0 bis KP15,167 abdecken, wurden von Fugro im Jahr 2020 durchgeführt.

1.2.1 Ziele

Die ursprünglichen Ziele der Untersuchung 2018 waren:

- Bestimmen Sie Wassertiefen und die Topografie des Meeresbodens genau;
- Bereitstellung von Informationen über die Bedingungen auf dem Meeresboden und unter dem Meeresboden, um die sichere Verlegung und den Betrieb der geplanten Pipeline, Kabeltrasse und Plattform zu gewährleisten;
- Beurteilung des Gebiets in Bezug auf das Vorhandensein potenziell empfindlicher Lebensräume oder Arten, einschließlich der in Anhang I der EG-Habitatrichtlinie (97/62/EG) aufgeführten Lebensräume sowie der bedrohten und im Rückgang begriffenen OSPAR-Habitate und/oder Arten (OSPAR, 2008);
- Erfassen von Umwelt-Referenz-Proben im gesamten Untersuchungsgebiet, um einen Maßstab zu schaffen, anhand dessen potenzielle zukünftige Auswirkungen bewertet werden können;
- Beurteilung des Trassenkorridors in Bezug auf ein eventuelles Vorkommen von Anomalien und Gesteinsbrocken/Schutt, die die Rohrverlegung oder Kabelinstallation behindern könnten;
- Identifizierung aller Merkmale oder Hindernisse auf und unter dem Meeresboden.

Das Ziel des aktuellen Zusatzberichts zur Habitatbewertung ist die Extrapolation der vorangegangenen Habitatbewertung aus dem Jahr 2018 auf den überarbeiteten Trassenkorridor, unter Verwendung der verfügbaren geophysikalischen Datensätze aus den Jahren 2018/2020, der Daten der Bodenuntersuchung aus dem Jahr 2018 sowie der öffentlich verfügbaren großmaßstäblichen Umweltdatensätze (EMODNet, 2019).

1.3 GEODÄTISCHE PARAMETER

1.3.1 Horizontale Referenz

Tabelle 4: Geodätische Parameter

Geodätische Parameter	
Sphäroid	International 1924
Semi-Major-Achse	6378388.297
Semi-Minor-Achse	6356911.946
Datum	Europäisches Datum 1950 (ED50)
Projektion	Universal Transverse Mercator (UTM)
Falscher Ostwert	500000.00
Falscher Nordwert	0.00
Zentral Meridian	3° Ost
Zentraler Skalenfaktor	0.9996
ursprünglich bestimmter Breitengrad	0°
Raster Zone	31 Nord
Datumstransformation WGS84 – ED50	
dx	+ 89.5m
dy	+93.8m
dz	+123.1m
Rx	0.0
Ry	0.0
Rz	-0.156
Skala	-1,2ppm

1.3.2 Vertikale Referenz

Alle Wassertiefen für die ursprünglichen Vermessungsdaten von 2018 wurden unter Verwendung des UKHO VORF-Modells auf LAT reduziert. Das MSL liegt im Untersuchungsgebiet 1,6 m über dem LAT.

Die letzten Untersuchungsdaten für 2020 wurden reduziert auf NAP und nicht auf LAT bereitgestellt. Diese Daten wurden anschließend um +1,95 m versetzt, um eine ungefähre Übereinstimmung mit den ursprünglichen Daten von 2018 zu erreichen.

2 ÜBERPRÜFUNG DER UNTERSUCHUNGSDATEN

2.1 GEOPHYSIKALISCHE DATEN

Analoge geophysikalische Daten, die von GEOxyz während der Vermessung erfasst wurden, wurden für die Standortauswahl verwendet, da keine früheren geophysikalischen Daten für das Vermessungsgebiet verfügbar waren. Diese Daten wurden von BSL an Bord überprüft und Kameratransekte wurden ausgewählt, um alle Habitate und Grenzen im gesamten Untersuchungsgebiet zu erfassen, wobei besonderes Augenmerk auf die Untersuchung potenzieller Habitate in Anhang-I gerichtet wurde, die nach der EU-Habitatrichtlinie geschützt sind. Wenn interessante Merkmale in unmittelbarer Nähe zu einer der Umweltmessstationen auftraten, sollte diese Station auf der Grundlage der im Arbeitsumfang dargelegten Überlegungen leicht verschoben werden, um zusätzliche Daten zur Bodenuntersuchung für das betreffende Merkmal zu erhalten.

Die folgenden Datensätze standen bei der Erstellung dieses Berichts zur Verfügung:

- Bathymetrie, reduziert und verarbeitet, um ein digitales Geländemodell zu erstellen, in dem wichtige bathymetrische Merkmale und kleinere bathymetrische Änderungen identifiziert und hervorgehoben werden können. Dazu gehörte die Identifizierung von großen Merkmalen (z. B. linear Steine und Felsblöcke) und der Infrastruktur am Meeresboden (z. B. vorhandene Pipelines).
- Side-Scan-Sonar (SSS) mit Daten, die sowohl bei hohen (400kHz) als auch bei niedrigen (100kHz) Frequenzen in Bereichen von 75m bis 125m mit digitalem Rendern auf ein Meeresbodenmosaik des Gebiets (100KHz) zur Überprüfung durchgeführt wurden. Änderungen des Sedimenttyps und der Härte sowie Merkmale, die durch ein flaches Relief und einzelne Objekte beobachtet wurden, konnten ebenfalls abgegrenzt werden.

2.2 ENVIRONMENTAL GROUND-TRUTHING UND PROBEN

Die Strategie der Umweltprobe-Entnahme wurde vom Auftraggeber vor Beginn der Untersuchung festgelegt. Die Probe-Entnahmestellen entlang der Pipeline- und Kabeltrassen wurden in einem Abstand von einem Kilometer von den vorgeschlagenen N5a-Bohrlochstandorten zur Küste und zum Offshore-Windpark Riffgat (Figure 2) positioniert. Zwei Stationen (Greifer_P_0 und Greifer_P_7) entlang der Pipelinetrasse wurden neu positioniert, um Bereiche von Interesse abzudecken, die anhand der Side-Scan-Sonar-Aufzeichnung identifiziert wurden (Table 5). An jeder dieser Probe-Entnahmestellen wurde vor der Probe-Entnahme eine Videobewertung durchgeführt, wobei an allen Stationen mit Ausnahme von Greifer_P_14, wo die Sicht stark eingeschränkt war, Videomaterial aufgenommen wurde. Zusätzliche Kameratransekte wurden über den vorgeschlagenen Standorten der N5a-Bohrung durchgeführt und zusätzliche Bereiche von Interesse nach Überprüfung der Side-Scan-Sonar-Aufzeichnung identifiziert (Table 6).

Videomaterial vom Meeresboden wurde entlang von acht Kameratransekten mit einem Seabug-Kamerasystem aufgenommen, das in einem BSL-Kameraschlittenrahmen montiert und mit einem separaten Stroboskop und LED-Lampen ausgestattet war. Die Kameraeinheit selbst ist in der Lage, Bilder mit einer Auflösung von 14,7 MP aufzunehmen, wurde aber auf eine Auflösung von 5 MP (2592 x 1944 Pixel) eingestellt, um die Bildladezeiten im Kamerabetrieb zu optimieren.

Für die Probe-Entnahmen aus dem Meeresboden wurde ein BSL-Doppelgreifer (double-Van-Veen) verwendet, der an jeder Stelle zweimal erfolgreich eingesetzt werden musste. An jeder Station waren maximal drei Einsätze ohne Probe erlaubt, bevor sie aufgegeben wurde. Beim ersten Einsatz wurde ein 0.1m^2 großer Tagesgreifer verwendet, bevor auf Wunsch des Kunden für alle weiteren Einsätze auf den BSL-Doppelgreifer umgestellt wurde.

Tabelle 5: Zusammenfassung der Standorte der Dropdown-Kamera- und Probe-Entnahmen für das Untersuchungsgebiet

ED50, UTM 31N, CM 3° E								
Station	Grundlage	Typ	Ostwert (m)	Nordwert (m)	PC	F1	F2	F3
Greifer_P_0	Pipeline-Route - Positionierung im Abstand von 1 km	EBS/HAS	721619	5954453	Y	Y	Y	Y
Greifer_P_1	Wurde von KP verschoben, um einen Bereich mit stark reflektierendem Sediment zu untersuchen	EBS/HAS	721325	5953791	Y	Y	Y	Y
Greifer_P_2	Pipeline-Route - Positionierung im Abstand von 1 km	EBS/HAS	720981	5952752	Y	Y	Y	Y
Greifer_P_3	Pipeline-Route - Positionierung im Abstand von 1 km	EBS/HAS	720669	5951801	Y	Y	Y	Y
Greifer_P_4	Pipeline-Route - Positionierung im Abstand von 1 km	EBS/HAS	720355	5950850	Y	Y	Y	Y
Greifer_P_5	Pipeline-Route - Positionierung im Abstand von 1 km	EBS/HAS	720041	5949900	Y	Y	Y	Y
Greifer_P_6	Pipeline-Route - Positionierung im Abstand von 1 km	EBS/HAS	719729	5948950	Y	Y	Y	Y
Greifer_P_7	Von KP verschoben, um gemischtes Reflektionssediment zu untersuchen	EBS/HAS	719347	5948023	Y	Y	Y	Y
Greifer_P_8	Pipeline-Route - Positionierung im Abstand von 1 km	EBS/HAS	719105	5947052	Y	Y	Y	Y
Greifer_P_9	Pipeline-Route - Positionierung im Abstand von 1 km	EBS/HAS	718861	5945912	Y	Y	Y	Y
Greifer_P_10	Pipeline-Route - Positionierung im Abstand von 1 km	EBS/HAS	718779	5944917	Y	Y	Y	Y
Greifer_P_11	Pipeline-Route - Positionierung im Abstand von 1 km	EBS/HAS	718695	5943920	Y	Y	Y	Y
Greifer_P_12	Pipeline-Route - Positionierung im Abstand von 1 km	EBS/HAS	718614	5942923	Y	Y	Y	Y
Greifer_P_13	Pipeline-Route - Positionierung im Abstand von 1 km	EBS/HAS	718532	5941927	Y	Y	Y	Y
Greifer_P_14	Pipeline-Route - Positionierung im Abstand von 1 km	EBS/HAS	718450	5940930	Y	Y	Y	Y
Greifer_P_15	Pipeline-Route - Positionierung im Abstand von 1 km	EBS/HAS	718366	5939933	Y	Y	Y	Y
Greifer_C_0	Ursprüngliche Kabeltrasse und Standort der N5a-Brunnenmitte	EBS/HAS	721610	5954652	Y	Y	Y	Y
Greifer_C_1	Ursprüngliche Kabeltrasse – Positioniert im Abstand von 1 km	EBS/HAS	722604	5954538	Y	Y	Y	Y
Greifer_C_2	Ursprüngliche Kabeltrasse – Positioniert im Abstand von 1 km	EBS/HAS	723596	5954425	Y	Y	Y	Y
Greifer_C_3	Ursprüngliche Kabeltrasse – Positioniert im Abstand von 1 km	EBS/HAS	724588	5954315	Y	Y	Y	Y
Greifer_C_4	Ursprüngliche Kabeltrasse – Positioniert im Abstand von 1 km	EBS/HAS	725579	5954203	Y	Y	Y	Y
Greifer_C_5	Ursprüngliche Kabeltrasse – Positioniert im Abstand von 1 km	EBS/HAS	726575	5954089	Y	Y	Y	Y
Greifer_C_6	Ursprüngliche Kabeltrasse – Positioniert im Abstand von 1 km	EBS/HAS	727355	5954245	Y	Y	Y	Y

ED50, UTM 31N, CM 3° E								
Greifer_C_7	Ursprüngliche Kabeltrasse – Positioniert im Abstand von 1 km	EBS/HAS	728149	5954477	Y	Y	Y	Y
Greifer_C_8	Ursprüngliche Kabeltrasse – Positioniert im Abstand von 1 km	EBS/HAS	729107	5954756	Y	Y	Y	Y
Greifer_C3_0	Sekundäre Kabeltrasse und N5a zweiter potenzieller Standort des Brunnenzentrums	EBS/HAS	722288	5953018	Y	Y	Y	Y
Greifer_C3_1	Sekundäre Kabeltrasse – Positioniert, um gemischtes Reflektionssediment zu untersuchen	EBS/HAS	723809	5953378	Y	Y	Y	Y
Greifer_C3_2	Sekundäre Kabeltrasse – Positioniert zur Untersuchung von Sediment mit hohem Reflexionsvermögen	EBS/HAS	725337	5953741	Y	Y	Y	Y

Tabelle 6: Zusammenfassung der Kameratransekt-Standorte für das Untersuchungsgebiet

ED50, UTM 31N, CM 3° E								
Transekt	Grundlage	SOL/ EOL	Datum und Uhrzeit	Tiefe (m)	Ostwert (m)	Nordwert (m)	Nr. Bilder	Videomaterial (mm:ss)
Greifer P_0	Untersuchungsbereich für Sediment mit gemischtem Reflexionsvermögen	SOL	02/05/2019	30	721647	5954430	27	07:13
		EOL	02/05/2019 17:22:21	31	721591	5954476		
Nord Transekt 1	Untersuchung des Übergangs von gemischtem zu hochreflektierendem Sediment	SOL	11/05/2019	29	721486	5954680	30	10:11
		EOL	11/05/2019 00:59:10	29	721363	5954634		
Nord Transekt 2	Untersuchung des Übergangs von Sediment mit geringer zu gemischter Reflektivität	SOL	11/05/2019	30	721609	5954992	41	12:49
		EOL	11/05/2019 00:18:59	28	721631	5955152		
Nord Transekt 3	Untersuchung des Übergangs von gemischtem zu hochreflektierendem Sediment	SOL	11/05.2019	29	721902	5954407	50	12:29
		EOL	11/05/2019 02:17:13	29	721802	5954550		
N5a Transekt 1	Transekt über den ursprünglichen Standort des Brunnens N5a	SOL	11/05/2019	29	721585	5954588	35	08:37
		EOL	11/05/2019	29	721626	5954708		
N5a Transekt 2	Transekt über den ursprünglichen Standort des Brunnens N5a	SOL	11/05/2019	28	721668	5954631	39	09:13
		EOL	11/05/2019	29	721544	5954667		
Greifer_C3_0	Transekt über den zweiten vorgeschlagenen N5a-Bohrlochstandort	SOL	14/05/2019	24	722231	5952983	36	09:15
		EOL	14/05/2019 22:00:14	25	722335	5953047		
Greifer_C3_2	Untersuchung des Bereichs mit hoher Sedimentreflektivität	SOL	14/05/2019	25	725366	5953610	37	12:36
		EOL	14/05/2019	25	725326	5953785		

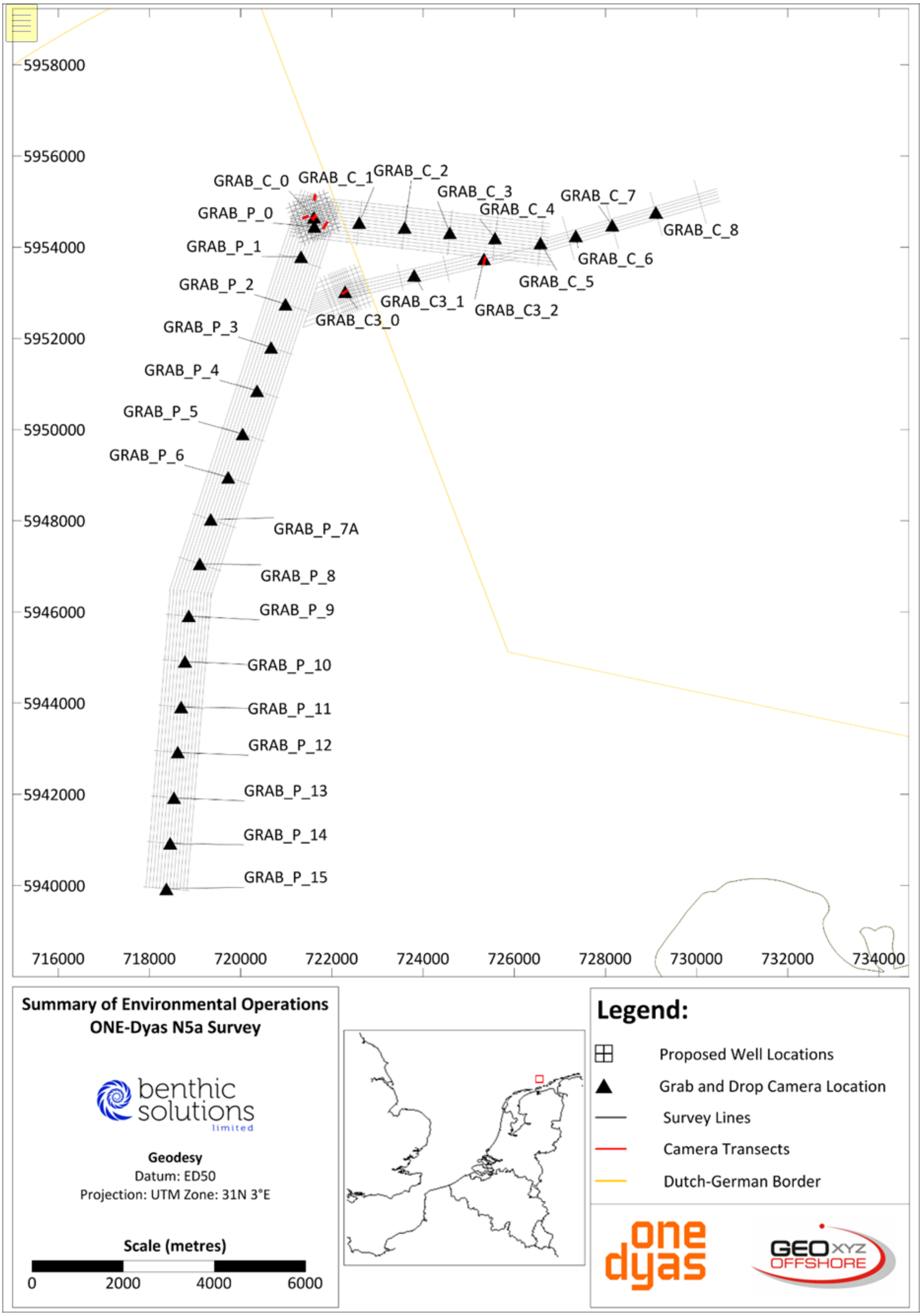


Abbildung 2: Übersicht der Untersuchungsstrategie

2.3 HABITAT-UNTERSUCHUNG

2.3.1 Habitat-Klassifizierung

Ein marines Biotop-Klassifizierungssystem für britische Gewässer wurde von Connor *et al.* (2004) aus Daten entwickelt, die während des JNCC Marine Nature Conservation Review (MNCR) erfasst wurden, und anschließend von Parry *et al.* (2015) überarbeitet, um eine verbesserte Klassifizierung von Tiefsee-Lebensräumen zu ermöglichen. Das daraus resultierende kombinierte Klassifizierungssystem des JNCC (2015) bildet die Grundlage für die Habitat-Klassifizierung des European Nature Information Service (EUNIS, 2013), wenn auch mit einer abweichenden Nomenklatur für die Habitat-Codierung, die Habitat-Informationen aus ganz Europa in einer einzigen Datenbank zusammengestellt hat. Die beiden Klassifizierungssysteme basieren beide auf der gleichen hierarchischen Analyse. Zunächst werden abiotische Lebensräume auf vier Ebenen definiert. Biologische Gemeinschaften werden dann mit diesen (auf zwei niedrigeren Ebenen) verknüpft, um eine Biotopklassifizierung zu erstellen. (Connor *et al*., 2004; EUNIS, 2013).

Die Habitatbeschreibungen wurden aus den während der aktuellen Untersuchung gewonnenen Side-Scan-Sonar- und bathymetrischen Daten in Verbindung mit zusätzlichen Informationen über die Sedimenttypen und Faunengemeinschaften des Meeresbodens aus Meeresbodenfotografien und Greifproben interpretiert. Die GIS-Software Global Mapper V21 wurde verwendet, um das Side-Scan-Sonar-Mosaik (Geotiff) und die Fächerecholot-Bathymetriedaten (Geotiff und xyz) zu überprüfen und die Bereiche mit unterschiedlichen Meeresbodenhabitaten abzugrenzen.

Zur weiteren Unterstützung der Interpretation wurden Vergleiche mit der vorhergesagten großräumigen Bathymetrie (1/16 Bogenminuten Auflösung) und den Daten zur Verteilung der Lebensräume auf dem Meeresboden durchgeführt, die vom European Marine Observation and Data Network (EMODnet) erstellt wurden. EMODnet ist eine langfristige Meeresdaten-Initiative, die durch einen schrittweisen Ansatz entwickelt wurde, um Daten zu sammeln und auf bestehenden Datenbanken aufzubauen, um den Zugang zu europäischen Meeresdaten über sieben disziplinäre Themen zu ermöglichen: Bathymetrie, Geologie, Meeresboden-Habitate, Chemie, Biologie, Physik und menschliche Aktivitäten (EMODnet, 2019). Die großmaßstäbliche Habitatkarte des Meeresbodens ist eine vorhersagbare Habitat-Abgrenzung innerhalb aller europäischen Meere nach dem EUNIS-Klassifikationssystem (EMODnet, 2019). Die im Rahmen internationaler (OSPAR) und nationaler Überwachungsprogramme in Zusammenarbeit mit europäischen Projekten wie MESH oder Mesh Atlantic erstellte Karte der vorhergesagten Lebensräume am Meeresboden ist eine nützliche Ressource, um weiteres Vertrauen in die Zuordnung von Biotopen innerhalb des Untersuchungsgebiets zu schaffen, auch für alle Gebiete, in denen die geophysikalischen Vermessungsdaten von 2018 und 2020 (Fächerecholot-Bathymetrie und Side-Scan-Sonar) unvollständig erfasst sind.

2.3.2 Bewertung empfindlicher Lebensräume

Die Niederlande sind Unterzeichner des Übereinkommens über die Erhaltung der europäischen wild lebenden Pflanzen und Tiere und ihrer natürlichen Lebensräume (Berner Konvention, 1979). Um ihren Verpflichtungen aus der Konvention nachzukommen, wurde 1992 die Habitat-Richtlinie der Europäischen Gemeinschaft verabschiedet. Nach den Bestimmungen dieser Richtlinie müssen die Mitgliedstaaten eine Reihe von Maßnahmen einführen, einschließlich des Schutzes der in den Anhängen aufgeführten Arten; sie müssen die Lebensräume und Arten überwachen und alle sechs Jahre einen Bericht über die Durchführung der Richtlinie erstellen. Die 189 Lebensräume, die in Anhang I der Richtlinie aufgeführt sind, und die 788 Arten, die in Anhang II aufgeführt sind, sollen durch ein Netzwerk von Gebieten geschützt werden. Jeder Mitgliedstaat ist verpflichtet, eine nationale Liste von Gebieten zu erstellen und vorzuschlagen, die bewertet werden, um ein europäisches Netzwerk von Gebieten von gemeinschaftlicher Bedeutung (SCI) zu bilden. Diese werden schließlich von den Mitgliedstaaten als besondere Schutzgebiete (Special Areas of Conservation, SACs) ausgewiesen und bilden zusammen mit den besonderen Schutzgebieten (Special Protection Areas, SPAs), die unter der EG-Vogelschutzrichtlinie (2009) klassifiziert wurden, ein Netzwerk von Schutzgebieten, das als Natura 2000 bekannt ist. Die Richtlinie wurde 1997 durch eine Richtlinie zur technischen Anpassung und zuletzt durch das Umweltkapitel des Beitrittsvertrags 2003 geändert.

Auf der Grundlage der obigen Ausführungen sind die OSPAR-Liste der bedrohten und/oder im Rückgang begriffenen Arten und Lebensräume sowie die Lebensräume nach Anhang I von besonderer Bedeutung für diese Region der britischen Gewässer:

- Biogene Riffe, die von *Sabellaria spinulosa* (der Röhren-Sandkoralle) gebildet werden; und,
- Sandbänke, die die ganze Zeit leicht vom Meerwasser bedeckt sind

Steinriffe sind ein Anhang-I-Habitat und stehen unter dem Schutz der EU-Habitatrichtlinie. Die Probe-Entnahmestelle Greifer_C3_2 wies einen hohen Anteil an Steinen und Geröll auf, so dass eine Bewertung des Steinriffs durchgeführt wurde. Die Bodenkameradaten wurden anhand der von Irving (2009) vorgeschlagenen Kriterien auf potenzielle Steinriffe untersucht. Während die Kriterien von Irving (2009) von den britischen Aufsichtsbehörden genehmigt wurden, wurden sie von den niederländischen Behörden nicht explizit genehmigt, werden aber hier verwendet, um eine halbquantitative Bewertung des potenziellen Anhang-I-Steinriffhabitats vorzunehmen. Die Methode von Irving (2009) schlüsselt die Bewertungskriterien in Maße für die "Qualität" oder "Riffigkeit" des Riffs auf, basierend auf dem Vorhandensein einer minimalen Steingröße von 64 mm und der Angabe eines Reliefs über dem natürlichen Meeresboden, bei dem >10 % der Matrix aus Stein bestehen und eine minimale Fläche von etwa 25 m^2 erfasst wird (siehe Bericht LU-0022H-553-RR-04 für weitere Details).

3 ERGEBNISSE UND INTERPRETATION

3.1 BATHYMETRIE

Der folgende Text wurde aus den Vermessungsberichten von 2018 für den Standort N5A (LU-0022H-553-RR-01), die Pipelinetrasse N5A bis NGT Hot Tap (LU-0022H-553-RR-02) und die Kabeltrasse N5A bis Riffgat (LU-0022H-553-RR-07) übernommen, um einen Überblick über die Bathymetrie am Vermessungsstandort und in den Trassenkorridoren zu geben, ergänzt durch die Überprüfung der Bathymetriedaten von 2020 über den überarbeiteten Abschnitt KP15.0 bis KP15.167 Abschnitt der Pipelinetrasse.

Die Bathymetriedaten 2018 wurden mit einem R2 Sonics 2022 Multibeam-Echolot für den Standort und einem R2Sonic 2024 Multibeam-Echolot für die beiden Routenvermessungen erfasst. Alle Bathymetriedaten des Jahres 2018 wurden auf LAT reduziert, was innerhalb des Vermessungsgebiets 1,6 m unter MSL lag, und werden in einer Bin-Größe von 0,5 m x 0,5 m dargestellt. Das Fächerecholotsystem, das zur Erfassung der Bathymetriedaten 2020 verwendet wurde, ist nicht bekannt. Die Bathymetriedaten von 2020 wurden auf NAP reduziert und um +1,95 m versetzt bereitgestellt, um eine ungefähre Übereinstimmung mit den LAT-Daten von 2018 zu erreichen.

Um die Interpretation weiter zu erleichtern und die verfügbaren Vermessungsdaten in einen regionalen Kontext zu stellen, wurden Vergleiche mit der vorhergesagten großräumigen Bathymetrie (1/16 Bogenminuten Auflösung) durchgeführt, die vom European Marine Observation and Data Network (EMODnet, 2019) erstellt wurde. Diese Daten sind auch zuverlässig bei der Beurteilung von Gebieten mit unvollständiger Abdeckung der MBES-Erhebungsdaten von 2018 und 2020 (Figure 3).

3.1.1 N5A zu NGT Pipeline (NP-001) Einbindungsstrecke

Die Wassertiefen entlang der vorgeschlagenen Pipelinetrasse von N5A nach NGT Hot Tap lagen zwischen 26,4 m LAT bei KP0,000 und 8,5 m LAT bei KP15,167 auf einer Felshalde, die den bestehenden Einbindungspunkt der NGT-Pipeline schützt, wobei der Meeresboden zum südlichen Ende der vorgeschlagenen Pipelinetrasse hin leicht abfällt. Eine Reihe von natürlichen Trögen, die von West-Nordwest nach Ost-Südost verlaufen, traten innerhalb des Vermessungskorridors auf und kreuzten die vorgeschlagene Pipelinetrasse, von denen der größte etwa 250 m breit war.

Während es einen kleinen dreieckigen Bereich der vorgeschlagenen N5A zur NGT Pipeline (NP-001) Tie-In-Route Untersuchungskorridors gab, der nicht von den verfügbaren 2018 und 2020 MBES Bathymetriedaten abgedeckt wurde, wurde dieser Bereich von den entsprechenden Side Scan Sonar Daten abgedeckt, die keine Hinweise auf bathymetrische Merkmale von Interesse in diesem Bereich zeigten (Figure 3). Darüber hinaus zeigten die großräumigen Bathymetriedaten für die Region keine Hinweise auf bathymetrische Merkmale, die der oben genannten Interpretation widersprechen könnten.

Auf den Bathymetriedaten waren eine Vielzahl von anthropogenen Trümmern/Wracks und Bereiche mit gestörtem Meeresboden zu erkennen:

- Zwei markante Merkmale, die als Schiffswracks interpretiert wurden, waren von Kolkbildung am Meeresboden umgeben; das größte (40,1 m x 12,8 m x 1,1 m) befand sich etwa bei KP2.462, 369 m west-nordwestlich der vorgeschlagenen Route und das andere (19,1 m x 12,9 m x 0,2 m) befand sich etwa bei KP2.373, 339 m west-nordwestlich der vorgeschlagenen Route.
- Auf den Bathymetriedaten wurden drei halbkreisförmige Merkmale mit 1 m positivem Relief beobachtet, von denen man annimmt, dass sie mit früherer Bohraktivität zusammenhängen. Diese wurden zu Beginn der vorgeschlagenen Trasse zwischen KP0.009 und KP0.089 beobachtet, die bei

ihrer nächsten Annäherung um 90 m nach Ost-Süd-Ost versetzt waren. Diese Befunde lagen in einem Radius von 30 m zueinander und wiesen eine durchschnittliche Größe von 30 m x 30 m auf.

- Es wurde erwartet, dass drei bestehende Kabel und eine Rohrleitung die vorgeschlagene Pipelinetrasse kreuzen, aber sie wurden in den Bathymetriedaten nicht beobachtet.

- Am revidierten südlichen Ende der Pipelinetrasse befand sich ein Bereich mit einer Gesteinshalde, die den bestehenden Einbindungspunkt der NGP-Pipeline (NP-001) bei KP15.167 (Figure 3) überlagerte. Die Felshalde erstreckte sich über 170 m von Nordwesten nach Südosten, war an ihrer breitesten Stelle 42 m breit und lag zwischen 1,4 m und 2,4 m über dem umgebenden Meeresboden.

3.1.2 N5A nach Riffgat Kabelstrecke

Der Meeresboden ist in Richtung des Ost-Nordost-Endes der vorgeschlagenen Kabeltrasse von N5A nach Riffgat sanft abfallend, wobei die Wassertiefen zwischen 26,0 m bei KP0.280 und 19,6 m bei KP7.941 liegen. Eine Reihe von natürlichen Trögen, die überwiegend von Nordwesten nach Südosten verlaufen, kreuzten die vorgeschlagene Kabeltrasse von etwa KP5.158 bis KP8.681 und wurden als mit Gezeiten-/Stromprozessen zusammenhängend interpretiert.

In den Bathymetriedaten wurden drei halbkreisförmige Merkmale mit 1 m positivem Relief abgebildet, von denen man annimmt, dass sie mit früheren Bohraktivitäten zusammenhängen. Diese wurden am Anfang der vorgeschlagenen Trasse zwischen KP0.085 und KP0.168 positioniert; bei ihrem minimalen Versatz von der Trasse lagen sie ca. 27 m in süd-süd-westlicher Richtung. Sie wurden in einem Radius von 30 m positioniert und hatten eine durchschnittliche Größe von 30 m x 30 m.

Es wurde beobachtet, dass das Norned-Kabel die vorgeschlagene Kabeltrasse bei KP 2.313 kreuzt und von Nord-Nordwest nach Süd-Südost verläuft.

3.2 MERKMALE DES MEERESBODENS

Der folgende Text wurde aus den Vermessungsberichten 2018 für den Standort N5A (LU-0022H-553-RR-01), die Pipelinetrasse N5A bis NGT Hot Tap (LU-0022H-553-RR-02) und die Kabeltrasse N5A bis Riffgat (LU-0022H-553-RR-07) übernommen, um einen Überblick über die Merkmale des Meeresbodens im gesamten Vermessungsgebiet zu geben, wobei der Schwerpunkt auf den Merkmalen liegt, die für die Umweltgrundlagen und die Habitatbewertung des Vermessungsgebiets besonders relevant sind. Die Interpretation der Merkmale des Meeresbodens wurde durch die Überprüfung der 2020-Side-Scan-Sonardaten über den überarbeiteten Abschnitt KP15.0 bis KP15.167 der Pipelinetrasse (Figure 4) weiter ergänzt.

Die Side-Scan-Sonardaten von 2018 wurden mit einem Edgetech 4200 System erfasst, das mit 100kHz/400kHz mit einer Reichweite zwischen 75m und 200m pro Kanal arbeitet. Ergänzt wurden diese Daten durch Bathymetriedaten, die auf 0,5 m gerastert wurden. Das Side-Scan-Sonarsystem, die Betriebsfrequenz und die Reichweite, die zur Erfassung der Sonardaten von 2020 verwendet wurden, sind nicht bekannt.

3.2.1 N5A Standort

Es wurde erwartet, dass die Meeresbodensedimente im gesamten N5A-Untersuchungsgebiet aus "feinem Sand mit Muschelfragmenten" bestehen. Ein Bereich mit "grobem Sand und Muscheln mit einer hohen Dichte an Bäumchenröhrenwürmern und Schwertmuscheln" war im Norden des Untersuchungsgebiets zu finden, während im Süden ein Bereich mit "grobem Sand mit Kieselsteinen und Steinen" vorhanden war. Bei der obersten Sandschicht handelte es sich lediglich um eine dünnen Schicht und die Grenze zwischen dem Sand und den darunter liegenden Tonaufschlüssen war willkürlich, wobei in den Bereichen, die als Sand interpretiert wurden, auch etwas Ton auftauchen konnte.

Innerhalb des Untersuchungsgebiets wurden Tonaufschlüsse interpretiert, die ein positives Relief von bis zu 0,5 m über dem Hintergrundniveau des Meeresbodens aufwiesen. Andernorts wurden auf der Bathymetrie auch Anhäufungen von grobem Sand und Kies beobachtet, die ein positives Relief über dem umgebenden Meeresboden aufwiesen, wobei einige Anhäufungen wahrscheinlich durch die stabilisierende Wirkung von Bäumchenröhrenwurm- und Schwertmuschelnfeldern auf dem Meeresboden verursacht wurden.

Innerhalb des Untersuchungsgebiets gab es außer der zuvor gebohrten N5-Bohrung keine vorhandene Infrastruktur. Auf den Bathymetrie- und Side-Scan-Sonardaten wurden bis zu 1,1 m hohe Meeresbodennarben von der Bohrinsel über der N5-Ruby-Bohrstelle beobachtet. In diesem Bereich wurden zahlreiche Magnetometeranomalien beobachtet, jedoch konnte kein Bohrlochkopf oder ein anderer Hinweis auf die Bohrstelle am Meeresboden festgestellt werden.

3.2.2 N5A zu NGT Pipeline (NP-001) Einbindungsstrecke

Es wurde erwartet, dass die Meeresbodensedimente entlang des vorgeschlagenen Pipelinetrassenkorridors aus "feinem Sand und Muschelfragmenten" bestehen, mit gelegentlichen Bereichen von "grobem Sand und Muschelfragmenten". In den Side-Scan-Sonar-Aufzeichnungen für die Vermessungsdatensätze 2018 und 2020 wurden visulle Unterschiede beobachtet, was jedoch auf mögliche Unterschiede bei den Erfassungssystemen, den Wetterbedingungen während der Vermessung und der Datenverarbeitung zurückgeführt wurde.

Die Relieffe von 2018 und 2020 überlappten sich auf einer Strecke von ca. 1,3 km entlang der NGT-Pipeline (NP-001), wobei beide Relieffe das Vorhandensein einer relativ homogenen akustischen Fazies zeigten, was auf eine geringe oder keine Veränderung der Meeresbodensedimente zwischen dem ursprünglichen und dem überarbeiteten Pipeline-Routenkorridor hinweist.

Bodenformen wurden in den Sonar- oder Bathymetrie-Aufzeichnungen nicht abgebildet. Fotos, die im Rahmen der Umweltverträglichkeitsprüfung entlang der Route aufgenommen wurden, zeigten jedoch eine deutliches Wellenmuster des Meeresbodens über den Großteil des Prüfkorridors.

Zahlreiche Objekte, die als Felsbrocken und Trümmerteile interpretiert werden, wurden innerhalb des vorgeschlagenen Trassenkorridors der Pipeline beobachtet. Die meisten der als Geröllteile interpretierten Objekte traten im Norden des Untersuchungskorridors auf und fielen mit Bereichen mit Lehmaufschlüssen zusammen.

Die bedeutendsten Objekte, die auf den Sonaraufzeichnungen identifiziert wurden, waren zwei interpretierte Schiffswracks, von denen das größte (40,1 m x 12,8 m x 1,1 m) bei etwa KP2.462, 369 m west-nordwestlich der vorgeschlagenen Route und das andere (19,1 m x 12,9 m x 0,2 m) bei etwa KP2.373, 339 m west-nordwestlich der vorgeschlagenen Route liegt.

Am revidierten südlichen Ende der Pipelinetrasse war ein Bereich mit hochreflektierenden Sonardaten vorhanden, der das Vorhandensein einer großen Gesteinshalde hervorhob, die den bestehenden Einbindungspunkt der NGP-Pipeline (NP-001) bei KP15.167 überlagert (Figure 4). Die Gesteinshalde erstreckte sich etwa 170 m von Nordwest nach Südost und war an ihrer breitesten Stelle 42 m breit.

Es wurde erwartet, dass drei bestehende Kabel und eine Rohrleitung die vorgeschlagene Pipelinetrasse kreuzen, aber sie wurden in den Bathymetriedaten nicht beobachtet.

3.2.3 N5A nach Riffgat Kabelstrecke

Es wurde erwartet, dass die Sedimente auf dem Meeresboden entlang des vorgeschlagenen Pipelinetrassenkorridors aus feinem bis grobem SAND bestehen, mit gelegentlichen Bereichen aus "grobem Sand und Ton mit Kieseln und Steinen" und "grobem Sand mit Kieseln und Steinen". Bei der Annäherung an den Windpark Riffgate wurden die Sedimente auf dem Meeresboden von "grobem Sand und Muschelfragmenten" dominiert, mit gelegentlichen Flecken von "grobem Sand mit Kieselsteinen und Steinen".

Bodenformen wurden in den Sonar- oder Bathymetrie-Aufzeichnungen nicht abgebildet. Fotos, die im Rahmen der Umweltverträglichkeitsprüfung entlang des vorgeschlagenen Trassenkorridors aufgenommen wurden, zeigten jedoch deutlich, dass der Großteil des Meeresbodens im Bereich des Trassenkorridors von Wellenmustern bedeckt ist.

Innerhalb des vorgeschlagenen Trassenkorridors der Pipeline gab es zahlreiche Objekte, die als Felsbrocken interpretiert wurden. Die meisten Objekte, die als Felsbrocken interpretiert werden, kommen im Norden des Untersuchungskorridors in einem Bereich vor, der mit Bereichen mit Lehmaufschlüssen übereinstimmt.

3.3 FLACHE BÖDEN

Der folgende Text wurde aus den Vermessungsberichten 2018 für den Standort N5A (LU-0022H-553-RR-01), die Pipelinetrasse N5A bis NGT Hot Tap (LU-0022H-553-RR-02) und die Kabeltrasse N5A bis Riffgat (LU-0022H-553-RR-07) angepasst, um einen Überblick über die flachen Böden im gesamten Vermessungsgebiet zu geben, wobei der Schwerpunkt auf den oberen Schichten liegt, die für die Interpretation der Sedimentverteilung am Meeresboden und der bathymetrischen Merkmale relevant sind.

Die Interpretation der flachen Böden im gesamten Untersuchungsgebiet basierte auf Pinger- und Sparker-Daten. Zusätzliche Informationen wurden aus Vibrocore-Protokollen und dem Bohrloch N5-1, 90 m südlich des vorgeschlagenen Plattformstandorts, gewonnen, das von Fugro im November 2016 erworben wurde. Vibrocore VC_P_0 befindet sich am vorgeschlagenen Plattformstandort.

3.3.1 N5A Standort

Die oberste kartierbare Einheit wurde in den Vibrocore-Protokollen als SAND bestätigt. Wo diese Einheit im westlichen Teil des Untersuchungsgebiets kartiert wurde, war sie weniger als 1,5 m dick. Diese oberflächliche SAND-Einheit konnte nur kartiert werden, wenn sie dicker als 0,5 m war, und war wahrscheinlich auch außerhalb des kartierten Bereichs vorhanden, aber in unter 0,5 m dick.

Basierend auf der akustischen Beschaffenheit der Funkerdaten wurden drei Untereinheiten innerhalb der quartären Abfolge in diesem Gebiet interpretiert. Die oberste Einheit (neben dem Oberflächensand, der aus den Pinger-Daten kartiert wurde), die innerhalb des Untersuchungsgebiets interpretiert wird, ist eine chaotische Einheit, die als dichter bis sehr dichter mittlerer bis grober SAND mit Spuren von Muschelfragmenten interpretiert wird (wie auch Bohrloch-Proben ergeben). Innerhalb des Untersuchungsgebiets verläuft der Reflektor, der mit der Basis dieser Einheit in Beziehung steht, wellenförmig zwischen 1,2 m und 18,0 m unter dem Meeresboden.

3.3.2 N5A zu NGT Pipeline (NP-001) Einbindungsstrecke

Diese Einheit aus fein- bis mittelkörnigem SAND verdickt sich im Allgemeinen nach Süden. Sie war von KP 0,430 bis KP 0,450 und KP 0,757 bis KP 1,045 nicht vorhanden (oder weniger als 0,5 m dick). Südlich von KP 5.951 wird die Basis der kartierten Einheit undeutlich, bis zu dem Punkt, an dem sie nicht mehr kartiert werden kann; an diesem Punkt war die Einheit etwa 9 m dick.

Die kartierte Einheit wurde durch eine Sequenz mit variabler Zusammensetzung unterteilt. Vibrocore-Protokolle zeigen, dass dieser Teilbereich überwiegend aus schammigem Feinsand besteht, mit Ausnahme des Bereichs nördlich von KP 1.246, wo der Teilbereich eher lehmhaltig ist und als Füllung einer breiten Rinne interpretiert wurde.

3.3.3 N5A nach Riffgat Kabelstrecke

Diese Einheit aus fein- bis mittelkörnigem SAND verdickte sich im Allgemeinen nach Osten. Westlich der Trasse AC am KP 5.156 war die Einheit etwa 0,5 bis 1 m dick oder fehlend/unmerklich dünn, östlich dieses Punktes überschreitet die Einheit lokal eine Dicke von 2 m.

Vibrocore-Protokolle zeigten, dass die kartierte Einheit von KP0 bis KP 3.357 tonhaltigen Ablagerungen unterlag, die als Füllung eines breiten Kanals interpretiert wurden. Von KP 3.357 bis zum Ende der Route wurde die kartierte Einheit von feinem SAND bedeckt.

3.3.4 N5A Standort

Der Meeresboden innerhalb des N5A-Untersuchungsgebiets fällt leicht nach Westen ab. Die minimale Wassertiefe betrug 23,7 m LAT im NNE des Untersuchungsgebiets, während die maximale Tiefe 26,6 m LAT im WSW betrug. Auf den Bathymetriedaten wurden kleine Bereiche mit einem Relief von bis zu 0,4 m beobachtet, an deren Flanken Steigungen von bis zu 6 ° gemessen wurden, die größtenteils auf das Vorkommen von Lehm zurückzuführen sind.

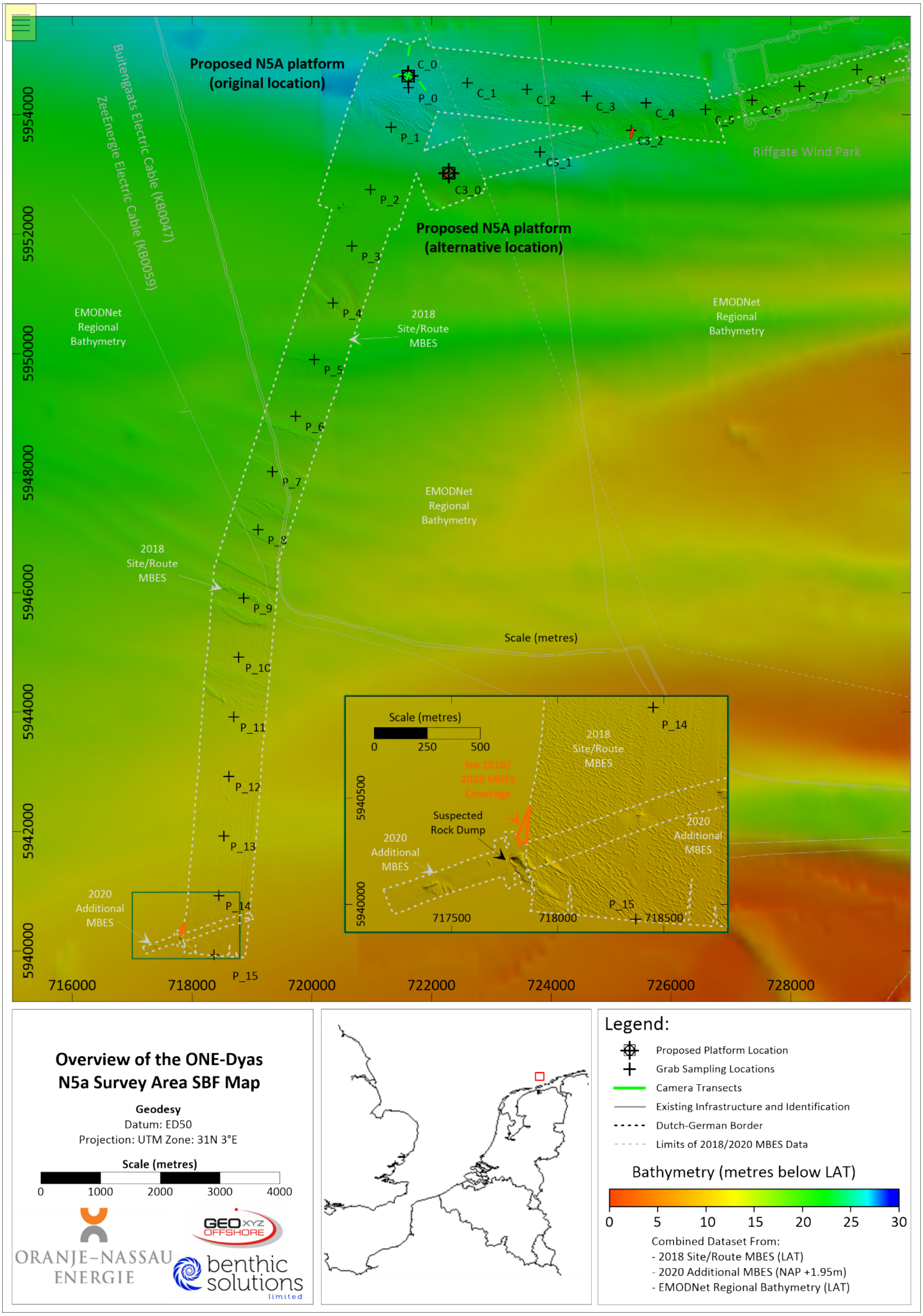


Abbildung 3: Bathymetrie des N5A-Standorts und der Route

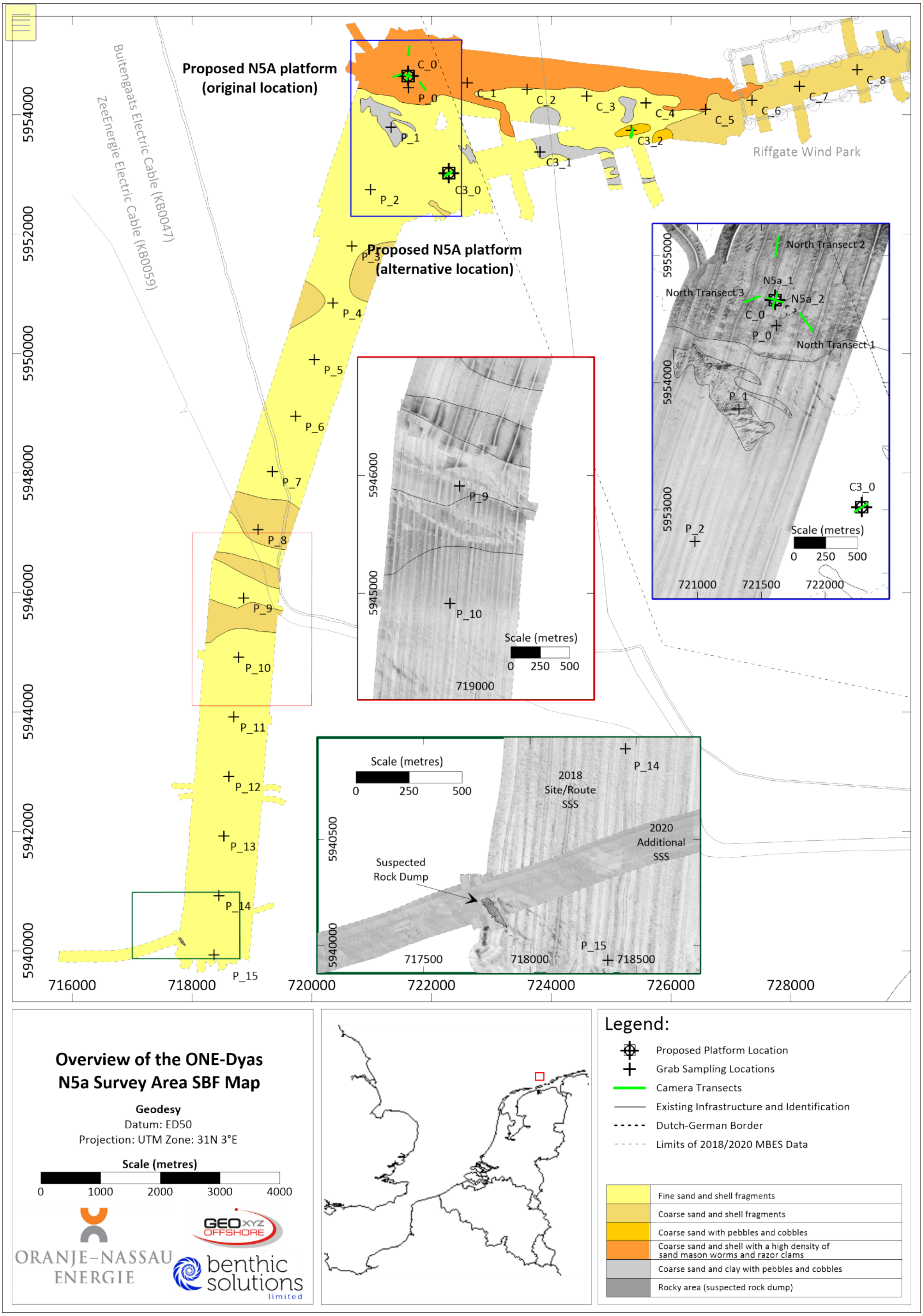


Abbildung 4: Interpretierte N5A-Standort- und Routenmerkmale am Meeresboden

3.4 HABITAT BEWERTUNG

3.4.1 Video-/Fotografieübersicht

Insgesamt wurden achtundzwanzig Dropdown-Kameraeinsätze und acht Kameratransekte innerhalb des kombinierten N5A-Erschließungsgebiets und des Trassenvermessungsgebiets durchgeführt. Die Greiferproben mit der Kamera wurden durchgeführt, um die Verteilung der verschiedenen Lebensräume am Meeresboden und der dazugehörigen Fauna zu untersuchen und gleichzeitig das Vorhandensein oder Fehlen potenziell empfindlicher Lebensräume und Arten zu bewerten. Drop-Down-Kamera-Einsätze wurden durchgeführt, um zusätzliche Daten über die Zusammensetzung des Meeresbodensediments und der damit verbundenen sichtbaren Fauna zu erhalten. Im Gegensatz dazu wurden die Kameratransekte ausgewählt, um Bereiche mit unterschiedlichen akustischen Fazies auf der Side-Scan-Sonar-Aufzeichnung und/oder bathymetrischen Merkmalen, die auf den MBES-Daten ersichtlich sind, zu untersuchen. Die Bodenuntersuchungsstationen und Transekte werden in Table 5 bzw. Table 6 aufgelistet, und ihre Standorte werden in Figure 2 bis Figure 4 dargestellt, mit zusammenfassenden Fotoseiten in Anhang D.

Video- und Fotodaten vom Meeresboden wurden mit einem Seabug-Kamerasystem erfasst, das in einem BSL-Kameraschlittenrahmen montiert und mit einem separaten Stroboskop und LED-Lampen ausgestattet war. Die Seabug ist in der Lage, Bilder mit einer Auflösung von 14,7 MP aufzunehmen, wurde aber auf eine Auflösung von 5 MP (2592 x 1944 Pixel) eingestellt, um die Bildladezeiten während des Kamerabetriebs zu optimieren.

Video- und Kameruntersuchungen entlang aller Transekte bestätigten das Vorhandensein von sanddominiertem Substrat im gesamten Gelände und in den Untersuchungsgebieten der Routen. Während der vorherrschende Sedimenttyp "feiner Sand und Muschelfragmente" war, gab es im gesamten Untersuchungsgebiet mehrere Stellen mit gröberem Sediment. Der N5A-Standort und der Trassenkorridor zum Windpark Riffgat zeigten zunehmend grobe Sedimente, darunter Bereiche mit Kies (>2 mm), Kiesel (>4 mm) und Steinen (>64 mm) sowie vereinzeltes Lehmvorkommen. Der Bereich mit gröberem Substrat entlang des nördlichen Randes des N5A-Geländes und des Korridors der Trassenuntersuchung zum Windpark Riffgat beherbergte ebenfalls signifikante Bäumchenröhrenwurm-*(Lanice conchilega*) und Schwertmuschelfelder*(Ensis* sp., möglicherweise *E. leei*). Obwohl sowohl *L. conchilega* als auch *E. leei* an anderen Stellen innerhalb des N5A-Geländes und entlang des Weges zum Windpark beobachtet wurden, waren sie außerhalb des abgegrenzten Bereichs "grober Sand und Muscheln mit einer hohen Dichte an Bäumchenröhrenwürmern und Schwertmuscheln" weniger zahlreich und stellenweise verteilt. Protokolle zur Habitatbewertung für jeden der neunzehn Kameratransekt-Standorte sind in Anhang B enthalten.

Die auffällige Epifauna zeigte eine mäßige Diversität und Dichte für einen überwiegend mobilen, sandigen Meeresboden. Kamerastationen und Transekte in allen kartierten Lebensräumen des Meeresbodens zeigten eine ähnliche Artenzusammensetzung, einschließlich häufiger Beobachtungen von Bäumchenröhrenwürmern*(Lanice conchilega*) und Gemeinen Seesternen*(Asterias rubens*). Andere Arten, die eher sporadisch im kombinierten N5A-Standort- und Routenuntersuchungsgebiet beobachtet wurden, waren unter anderem Schwertmuscheln*(Ensis* sp., möglicherweise *E. leei*), Zylinderrosen (Cerianthidae), Schwimmkrabben*(Liocarcinus* sp.), Helmkrabben*(Corystes cassivelaunus*), Einsiedlerkrebse (Paguridae sp.), Taschenkrebse*(Cancer pagurus*), Schlangensterne (Ophiuridae), Grundeln (Gobiidae), gestreifte Leierfische*(Callionymus lyra*), Plattfische (Pleuronectiformes) und Sandaale*(Ammodytes* sp.).

Bereiche mit gröberem Substrat, einschließlich des abgegrenzten Bereichs mit "grobem Sand und Muscheln mit einer hohen Dichte an Bäumchenröhrenwürmern*(L. conchilega*) und Schwertmuscheln (vermutlich *E. leei*)", zeichneten sich durch höhere Abundanzen der gesamten oben genannten Fauna aus, mit zusätzlichen Beobachtungen von Seenelken*(Metridium senile*), nicht identifizierten Anemonen (Actiniaria), Tintenfischen

(Sepiidae), Europäischen Kalmaren*(Loligo vulgaris*), Kliesche*(Limanda limanda*) und Grauen Knurrhähnen*(Eutriglia gurnardus*).

Beispielfotos der häufigen und/oder auffälligen Faunengruppen, die während der N5A-Entwicklungsuntersuchung angetroffen wurden, finden Sie in Anhang D.

3.4.2 Allgemeine Lebensräume

Video- und Standbildauswertungen von achtundzwanzig Drop-Down-Kamera-Einsätzen und acht Kameratransekten bestätigten das Vorhandensein eines überwiegend sandigen Meeresbodens mit räumlicher Variabilität in den Anteilen von Muschelfragmenten, grobem Substrat (Kies, Kiesel und Steine) und Lehmvorkommen. Darüber hinaus wies ein Bereich mit grobem Substrat entlang des nördlichen Randes des Untersuchungsgebiets hohe Dichten von Bäumchenröhrenwürmern*(Lanice conchilega*) und Schwertmuscheln (vermutlich *Ensis leei*) auf.

Die Lebensräume wurden durch eine Kombination aus Feldbeobachtungen, detaillierter Überprüfung von Videoaufnahmen und Standbildern identifiziert. Auf der Grundlage der Bodenuntersuchungsdaten aus dem N5A-Entwicklungsgebiet und dem Trassenuntersuchungsgebiet wurden vier EUNIS-Habitatklassifizierungen zugewiesen: "Infralitoraler Feinsand" (A5.23), "Infralitorales Grobsediment" (A5.13), "Infralitorales Mischsediment" (A5.43) und "Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem infralitoralem Sand und kiesigem Mischsand" (A5.137). Ein zusätzlicher Bereich einer vermuteten Gesteinshalde wurde identifiziert, der über dem Einbindungspunkt der NGP (NP-001) Pipeline liegt. Die Habitatklassifizierungen für das N5A-Entwicklungserhebungsgebiet werden in Figure 9 dargestellt.

Die Habitatkartierung und -interpretation, die unter Verwendung einer Kombination aus den geophysikalischen Vermessungsdaten von 2018/2020 und den Bodenuntersuchungsdaten von 2018 durchgeführt wurde, zeigte eine gute allgemeine Übereinstimmung mit den vorhergesagten EMODNet (2019)-Grenzen für die Region. Wie aus den Daten von 2018/2020 hervorgeht, besteht die gesamte Region aus sandigen Sedimenten. Während die von EMODNet (2019) vorhergesagte Habitatverteilung weniger sandige Habitatvarianten enthielt als die aus den Vermessungsdaten interpretierten, gab es Hinweise darauf, dass die vorhergesagten kleineren EMODNet-Habitatgrenzen mit denen übereinstimmten, die aus den Vermessungsdaten interpretiert wurden; z. B. Bereiche mit abgegrenztem "Infralittoralen Grobsediment" (A5.13), die sich in der Mitte der Pipelinetrasse befanden. Bereiche des von EMODNet (2019) vorhergesagten groben Sediments in nördliche Richtung des Standorts zeigten ebenfalls eine enge Übereinstimmung mit den interpretierten Grenzen von "Infralitoral Mixed Sediment" (A5.43) und "Dense *Lanice conchilega* und anderen Polychaetes in tidegespültem infralitoralem Sand und gemischtem kiesigem Sand" (A5.137).

Infralitoraler Feinsand" (A5.23)

Lebensräume, die von feinem Sand mit unterschiedlichem Anteil an Muschelschutt dominiert werden, waren im gesamten Untersuchungsgebiet vorherrschend und wurden auf den meisten Umweltkamerastrecken und Transekten im Untersuchungsgebiet der N5A und der Route beobachtet. Diese Bereiche wurden durch relativ glatte und wenig reflektierende Side-Scan-Sonardaten wiedergegeben und wurden als Typ "Feinsand und Muschelfragmente" des Meeresbodens (Abschnitt 3.2 und Figure 4) und als EUNIS-Level-4-Lebensraumtyp "Infralitoraler Feinsand" (A5.23) klassifiziert (Figure 9).

Mit Ausnahme des Bereichs der Gesteinhalde, die die NGT-Pipeline (NP-001) überlagert, wird der überarbeitete Abschnitt der vorgeschlagenen Pipelinetrasse von KP15 bis KP15.167 ebenfalls als "infralitoraler Feinsand"-Habitat interpretiert. Die Homogenität des südlichen Abschnitts der Sonaraufzeichnung von 2018 und der Sonaraufzeichnung von 2020, einschließlich eines Abschnitts von ca. 1,3 km mit überlappenden Daten, bietet ein hohes Vertrauen in die Konsistenz des Meeresbodenhabitats in diesem Bereich. Außerdem lagen die Stationen P10 bis P15 alle in diesem einheitlichen Bereich des Meeresbodenhabitats und jede Station zeigte das Vorhandensein von "infralitoralem Feinsand" (siehe Figure 5 und Anhang D).

Der Lebensraum "Infralitoraler Feinsand" wird typischerweise durch sauberen Sand gekennzeichnet, der in Flachgewässern vorkommt, entweder an der offenen Küste oder in gezeitenabhängigen Kanälen von Meeresbuchten in Wassertiefen von etwa 0 bis 20 m. Der Lebensraum weist typischerweise keine signifikante Algenkomponente auf und zeichnet sich durch eine robuste Fauna aus, insbesondere durch Amphipoden*(Bathyporeia)* und robuste Polychaeten wie *Nephtys cirrosa* und *Lanice conchilega*. Innerhalb des Untersuchungsgebiets der N5A-Entwicklung umfasste dieser Lebensraum sauberen Sand mit Wellenmuster in Wassertiefen von etwa 13 bis 30 m, was leicht über dem typischerweise erwarteten Bereich liegt.

Die sichtbare Fauna, die mit der Kamera in den Bereichen des "infralitoralen Feinsandes" erfasst wurde, umfasste durchweg geringe bis mäßige Dichten des Bäumchenröhrenwurms *(L. conchilega*), zusätzlich zu mehreren anderen Taxa, die für diesen EUNIS-Habitat charakteristisch sind, einschließlich des Gemeinen Seesterns *(Asterias rubens*), der Schwimmkrabbe*(Liocarcinus)* und der Einsiedlerkrebse (Paguridae). Andere in diesem Habitat beobachtete Tiere waren Wattwürmer *(Arenicola* sp.), Helmkrabben *(Corystes cassivellaunus*), Taschenkrebse *(Cancer pagurus*), Schwertmuscheln*(Ensis* sp.), Schlangensterne (Ophiuridae), Grundeln (Gobiidae), gestreifte Leierfische *(Callionymus lyra*), Plattfische (Pleuronectiform). Weitere Taxa, die in den Greifproben nachgewiesen wurden, waren gelegentlich Sandaal (Ammodytidae), Herzseeigel *(Echinocardium cordatum)*, Seeringelwürmer *(Nereis* spp.), nicht identifizierte Seeigel (Spatangoid) und Porzellankrebse (Portunidae).

Die Überprüfung der Daten der Meeresbodenkamera und der Schürfproben ergab, dass die kartierte Verteilung des Lebensraums "infralitoraler Feinsand" (A5.23) ziemlich genau war. Nur die Station P_9 zeigt mehr grobsandiges Sediment, als für den Lebensraum "infralitoraler Feinsand" zu erwarten wäre, aber da diese Probenahmestation in einem Gebiet mit abwechselnden Bändern aus "infralitoralem Feinsand" und "infralitoralem Grobsand" liegt, ist zu erwarten, dass es in diesem Bereich einige Diskrepanzen gibt. Einige sporadische Bereiche mit *L. conchilega-Feldern* waren auf den Daten der Meeresbodenkamera aus kartierten Gebieten mit "infralitoralem Feinsand" zu erkennen, aber diese waren nicht weit genug verbreitet oder dicht genug, um eine Einstufung als "Dense Lanice conchilega and other polychaetes in tide-swept infralittoral sand and mixed gravelly sand" (A5.137) habitat zu rechtfertigen.

Beispielbilder des Lebensraums "Infralitoraler Feinsand (A5.23)" sind unten in Figure 5 aufgeführt, die erwartete Ausdehnung des Lebensraums ist in Figure 9 kartiert und Beispielbilder für auffällige Fauna und jeden Bodenuntersuchungseinsatz sind in den Anhängen F bzw. H enthalten.

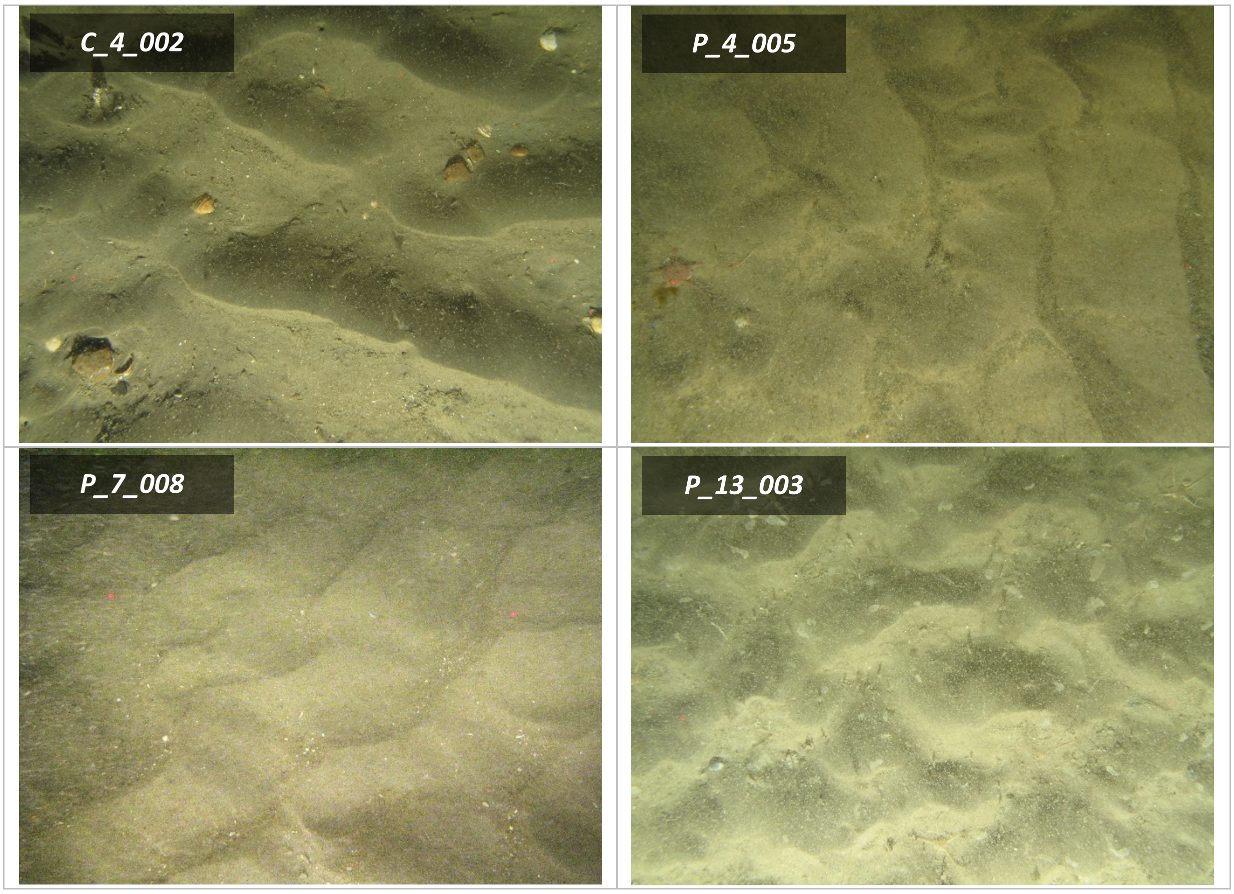


Abbildung 5: Beispielbilder von 'Infralittoraler Feinsand' (A5.23)

Infralitorales Grobsediment" (A5.13)

Lebensräume, die von grobem Sand und mäßigen Mengen an Muschelschutt und gelegentlich mit Kies und Geröll dominiert werden, wurden in mehreren Bereichen des kombinierten N5A-Erschließungsgebiets und Trassenuntersuchungsgebiets gefunden, die von den Stationen C_5 bis C_7, P_8 und P_9 erkundet wurden. Diese Bereiche wurden durch relativ glatte, aber niedrig bis mäßig reflektierende Side-Scan-Sonardaten repräsentiert und wurden als der Typ "grober Sand und Muschelfragmente" (Abschnitt 3.2 und Figure 4) und als der EUNIS-Level-4-Lebensraumtyp "infralitorales Grobsediment" (A5.13) klassifiziert (Figure 9). Sieben Stellen mit "infralitoralem Grobsediment" wurden kartiert, darunter eine große Stelle im Trassenkorridor um den Windpark Riffgat und weitere sechs kleinere Stellen entlang der Pipelineroute von N5A zu NGT Hot Tap.

Der Lebensraum "Infralitorale Grobsedimente" ist typischerweise durch groben Sand, kiesigen Sand, Kies oder Schotter gekennzeichnet, die in Wassertiefen von ca. 0 bis 20 m durch Gezeitenströme und Wellenschlag gestört werden. Das Habitat zeichnet sich durch eine robuste Fauna aus infaunalen Polychaeten wie *Chaetozone setosa* und *Lanice conchilega*, cumacean crustacea wie *Iphinoe trispinosa* und *Diastylis bradyi* und veneriden Muscheln aus. Innerhalb des Untersuchungsgebiets der N5A-Entwicklung bestand dieser Lebensraum aus gekräuselten groben Muschelsanden, manchmal mit einem erkennbaren Kies- und/oder Kieselanteil in Wassertiefen von etwa 19 bis 30 m, was den typischerweise erwarteten Bereich leicht überschreitet.

Die sichtbare Fauna der Kameruntersuchungen in den Bereichen des "infralitoralen Feinsandes" umfasste durchweg geringe bis mittlere Dichten des Bäumchenröhrenwurms *(L. conchilega*) sowie des Gemeinen Seesterns *(Asterias rubens*), beides charakteristische Arten für diesen EUNIS-Lebensraum. Die Mehrheit der anderen charakterisierenden Taxa für diesen Lebensraum sind infaunale Arten, die nicht effektiv durch Bodenaufnahmen mit der Meeresbodenkamera erfasst werden.

Die Überprüfung der Daten der Meeresbodenkamera und der Schürfproben ergab, dass die kartierte Verteilung des Lebensraums "infralitorales Grobsediment" (A5.13) ziemlich genau war, allerdings mit zwei Ausnahmen. Station C_0 wurde als "infralitoraler Grobsediment"-Habitat klassifiziert, befand sich aber innerhalb eines Gebiets mit "Dichten *Lanice conchilega* und anderen Polychaeten in gezeitenabhängigem infralitoralen Sand und gemischtem kiesigen Sand" (A5.137), während Station C_8 als "infralitoraler Feinsand"-Habitat klassifiziert wurde, sich aber innerhalb eines Gebiets mit "infralitoralem Grobsediment" befand. Beide Ausnahmen spiegeln die heterogene Beschaffenheit der Meeresbodenhabitate innerhalb des Untersuchungsgebiets wider.

Beispielbilder des "infralitoralen Grobsediment-Habitats (A5.13)" sind unten in Figure 6 angegeben, die erwartete Ausdehnung des Habitats ist in Figure 9 kartiert und Beispielbilder für auffällige Fauna und jeden Ground-Truthing-Einsatz sind in den Anhängen F bzw. H enthalten.

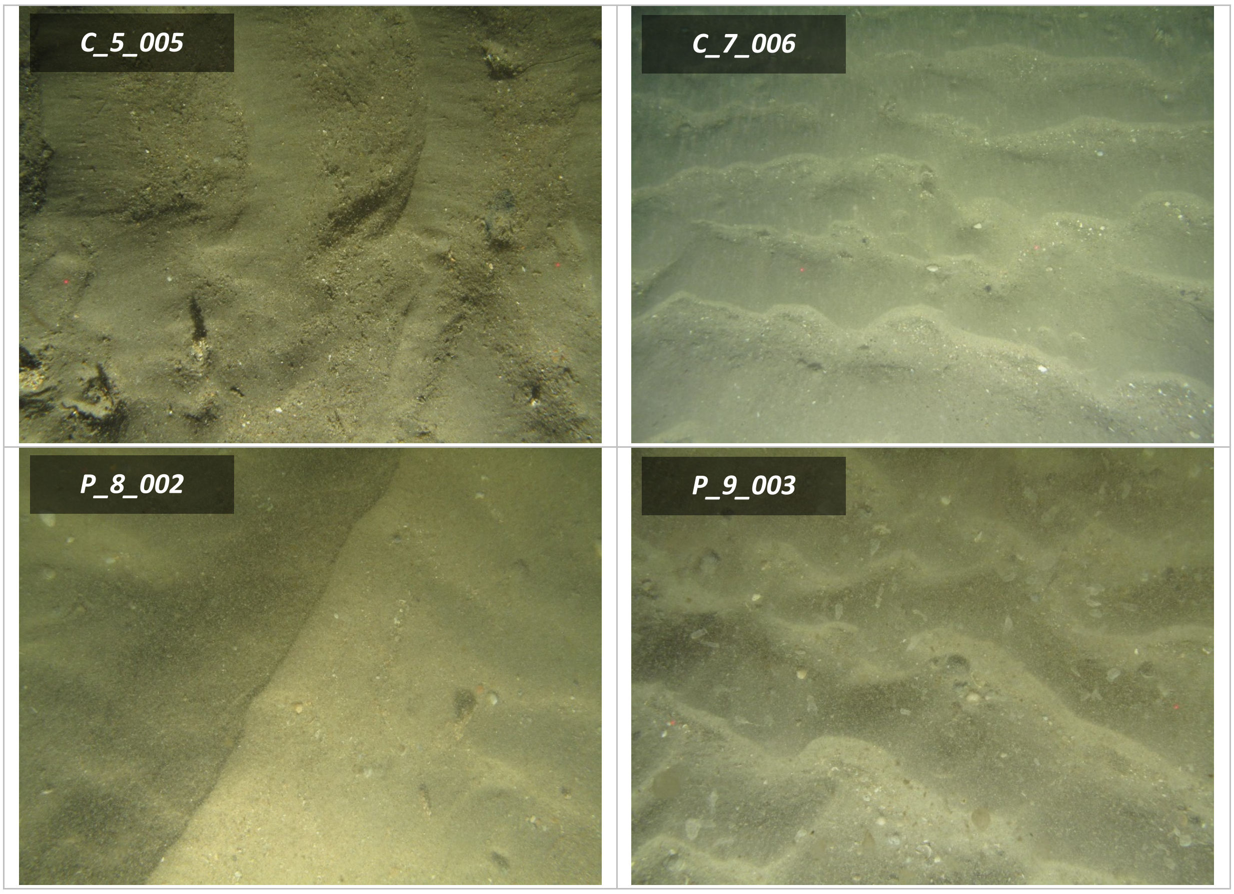


Abbildung 6: Beispielbilder von "Infralitorales Grobsediment" (A5.13)

Infralitorales gemischtes Sediment" (A5.43)

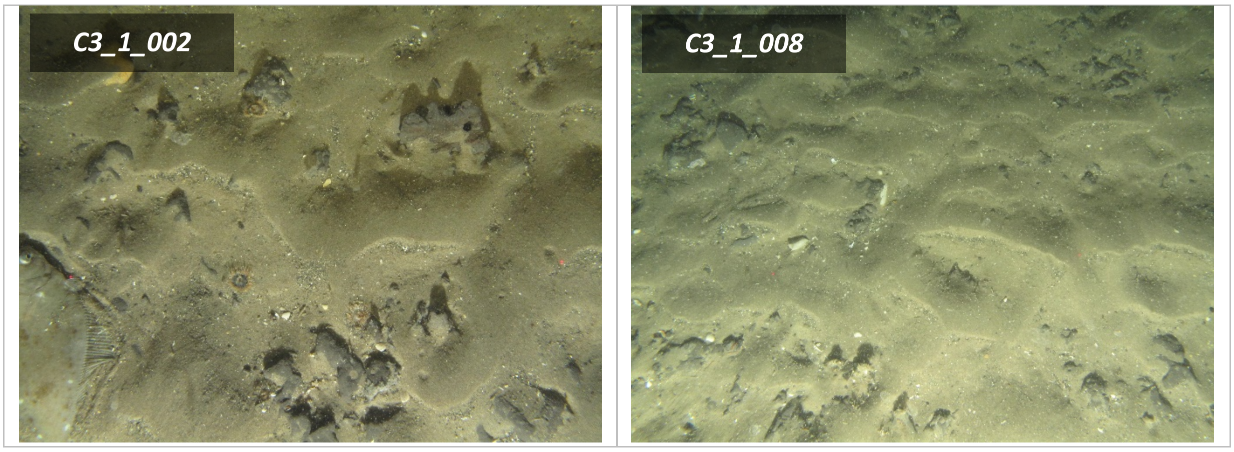
Lebensräume, die von grobkörnigem Sand mit Kieselsteinen, Steinen und in einigen Bereichen freiliegenden Tonklasten dominiert werden, wurden in zehn Stellen im gesamten Untersuchungsgebiet der N5A-

Erschließung und der N5A-Route nach Riffgat gefunden. Diese Bereiche wurden dem Meeresbodentyp "Grobsand mit Kieseln und Steinen" (Abschnitt 3.2 und Figure 4) und dem EUNIS-Level-4-Lebensraumtyp "Infralitorales gemischtes Sediment" (A5.43) zugeordnet (Figure 9). Zwei Stellen auf halber Strecke entlang der Kabeltrasse von N5A nach Riffgat zeigten mäßige bis hohe Reflektivitäts-Side-Scan-Sonar-Signaturen, aber keine Anzeichen von Lehm auf den Ground-Truthing-Daten von Station C3_2. Weitere zehn Stellen entlang der N5A-Route nach Riffgat zeigten ähnliche fleckige Side-Scan-Sonar-Signaturen und könnten freiliegenden Lehm enthalten, wie aus Bodenmessungen an den Stationen P_1 und C3_1 über zwei der Stellen hervorgeht.

Der Lebensraum "Infralitorales Mischsediment" ist typischerweise durch gemischte schlammig-kiesige Sande oder sehr schlecht sortierte Mosaike aus Muscheln, Steinen und Kieseln gekennzeichnet, die in Schlamm, Sand oder Kies in Wassertiefen von etwa 0 bis 30 m eingebettet sind. Aufgrund der variablen Beschaffenheit des Sedimenttyps wird berichtet, dass in Bereichen mit gemischtem Sediment eine breite Palette von Lebensgemeinschaften zu finden ist, einschließlich solcher, die durch Muscheln, Polychaeten und Feilenmuscheln gekennzeichnet sind. Innerhalb des Erschließungsgebiets N5A bestand dieser Lebensraum aus grobkörnigem Sand mit Kieselsteinen, Steinen und manchmal auch freiliegenden Lehmklasten in Wassertiefen von ca. 24 bis 27 m, was leicht über dem typischerweise erwarteten Bereich liegt.

Die sichtbare Fauna, die mit der Kamera in den Bereichen des "infralittoralen Feinsandes" erfasst wurde, umfasste den Gemeinen Seestern*(Asterias rubens)* und die Zylinderrose (Cerianthidae), die beide charakteristische Arten für diesen EUNIS-Lebensraum sind. Fotos des Meeresbodens und der Schürfproben von Station C3_1 zeigen zahlreiche Löcher in den freiliegenden Lehmklasten, die auf das Vorhandensein von bohrenden Piddock-Muscheln (typischerweise *Pholas dactylus* oder *Barnea candida*) hinweisen könnten, obwohl keine lebenden Individuen auf den Fotos des Meeresbodens oder der Schürfproben zu erkennen waren. Obwohl Piddocks nicht gesetzlich geschützt sind, sind sie in der Meeresumwelt nicht weit verbreitet und wären daher erwähnenswert, wenn sie im Datensatz der Makrofauna-Analyse an diesen Stationen erfasst würden. In Ermangelung eines bestätigten Vorkommens von Piddocks an diesen Stationen wurde der Lebensraum "Infralitorales gemischtes Sediment" (A5.43) zugewiesen; dies sollte jedoch in den Lebensraum "Piddocks mit spärlicher Begleitfauna in sublitoraler sehr weichem Kalk oder Lehm" (A4,231) geändert werden, wenn Piddocks in den Greifproben identifiziert werden.

Beispielbilder des "infralitoralen Grobsediment-Habitats (A5.13)" sind unten in Figure 7 angegeben, die erwartete Ausdehnung des Habitats ist in Figure 9 kartiert und Beispielbilder für auffällige Fauna und jeden Ground-Truthing-Einsatz sind in den Anhängen F bzw. H enthalten.



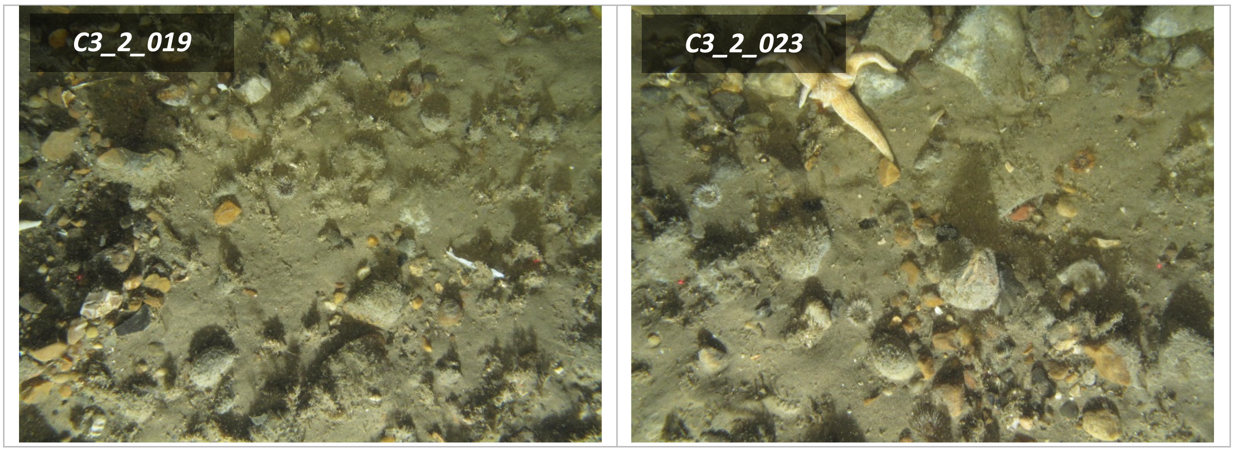


Abbildung 7: Beispielbilder für "Infralitorales Mischsediment" (A5.43)

Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und kiesigem Mischsand" (A5.137)

Lebensräume, die von kiesigem, muscheligem Grobsand mit mäßigen bis hohen Dichten von *Lanice conchilega* dominiert werden, wurden an mehreren Standorten (Stationen C_1, C_2 und P_0 sowie Transekte N5A_1, N5A_2, NT_1, NT_2 und NT_3) innerhalb des N5A-Geländes und im Osten entlang der Route von N5A zum Riffgate Wind Park nachgewiesen. Diese Bereiche wurden durch fleckige Side-Scan-Sonardaten mit niedriger bis hoher Reflektivität dargestellt und wurden dem Typ "Grober Sand und Muscheln mit einer hohen Dichte an Bäumchenröhrenwürmern und Schwertmuscheln" (Abschnitt 3.2 und Figure 4) und dem EUNIS-Level-4-Lebensraumtyp "Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem infralitoralen Sand und gemischtem kiesigem Sand" (A5.137) zugeordnet (Figure 9). Dieser Lebensraum wurde in einem einzigen großen Gebiet entlang des nördlichen Randes des kombinierten N5A-Untersuchungsgebiets abgegrenzt.

Der Lebensraum "Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem infralitoralem Sand und kiesigem Mischsand" ist typischerweise durch groben Sand, kiesigen Sand, Kies oder Schotter gekennzeichnet, die in Wassertiefen von etwa 0 bis 20 m durch Gezeitenströme und Wellenschlag gestört werden. Der Lebensraum ist durch hohe Dichten von *L. conchilega* gekennzeichnet, von denen man annimmt, dass sie den Meeresboden stabilisieren und die Entwicklung einer vielfältigeren assoziierten Faunengemeinschaft ermöglichen. Innerhalb des Untersuchungsgebiets der N5A-Entwicklung umfasste dieser Lebensraum kiesige, schlammige Grobsande in Wassertiefen von ca. 28 bis 29 m, was leicht über dem typischerweise erwarteten Bereich liegt.

Die sichtbare Fauna, die bei der Bodenuntersuchung mit der Kamera in Bereichen mit "dichter *Lanice conchilega* und anderen Polychaeten in gezeitenabhängigem infralitoralem Sand und gemischtem kiesigem Sand" festgestellt wurde, umfasste durchweg mäßige bis hohe Dichten des Bäumchenröhrenwurms *(L. conchilega*). Schwertmuscheln *(Ensis* sp.) werden ebenfalls mit diesem Habitat assoziiert und wurden bei den meisten Bodenuntersuchungen für dieses Habitat in sehr hohen Dichten gesehen. Vorläufige Überprüfungen von Makrofaunendaten haben ergeben, dass es sich bei den meisten, wenn nicht sogar bei allen Schwertmuscheln um die Amerikanische Schwertmuschel *(Ensis leei* –, Synonyme: *Ensis arcuatus* und *Ensis americanus*) handelt. Darüber hinaus wurden eine Reihe weiterer charakteristischer Taxa für diesen EUNIS-Lebensraum beobachtet, darunter Gemeine Seesterne *(Asterias rubens)*, Wattwürmer *(Arenicola* sp.), Einsiedlerkrebse (Paguridae) und Schwimmkrabben *(Liocarcinus*). Die Mehrheit der anderen charakterisierenden Taxa für diesen Lebensraum sind infaunale Arten, die nicht effektiv durch Bodenaufnahmen mit der Meeresbodenkamera erfasst werden.

Die Überprüfung der Daten der Meeresbodenkamera und der Schürfproben ergab, dass die kartierte Verteilung von "dichten *Lanice conchilega* und anderen Polychaeten in gezeitenabhängigem infralitoralem Sand und kiesigem Mischsand" (A5.137) ziemlich genau war, mit Ausnahme der Station C_0, die als "infralitoraler Grobsediment"-Habitat klassifiziert wurde, aber innerhalb eines Gebiets mit "dichten Lanice *Conchilega* und anderen Polychaeten in gezeitenabhängigem infralitoralen Sand und gemischtem kiesigen Sand" (A5.137) lag. Es ist jedoch davon auszugehen, dass die kartierte Fläche dieses Lebensraums sehr heterogen ist und wahrscheinlich Flächen aller anderen kartierten Lebensräume aus dieser Untersuchung umfasst.

Beispielbilder für das Habitat "dichte *Lanice conchilega* und andere Polychaeten in gezeitengeprägtem infralitoralem Sand und kiesigem Mischsand" (A5.137) werden unten in Figure 8 aufgeführt, die erwartete Ausdehnung des Habitats wird in Figure 9 kartiert und Beispielbilder für auffällige Fauna und jeden Bodenuntersuchungseinsatz sind in den Anhängen F bzw. H enthalten.

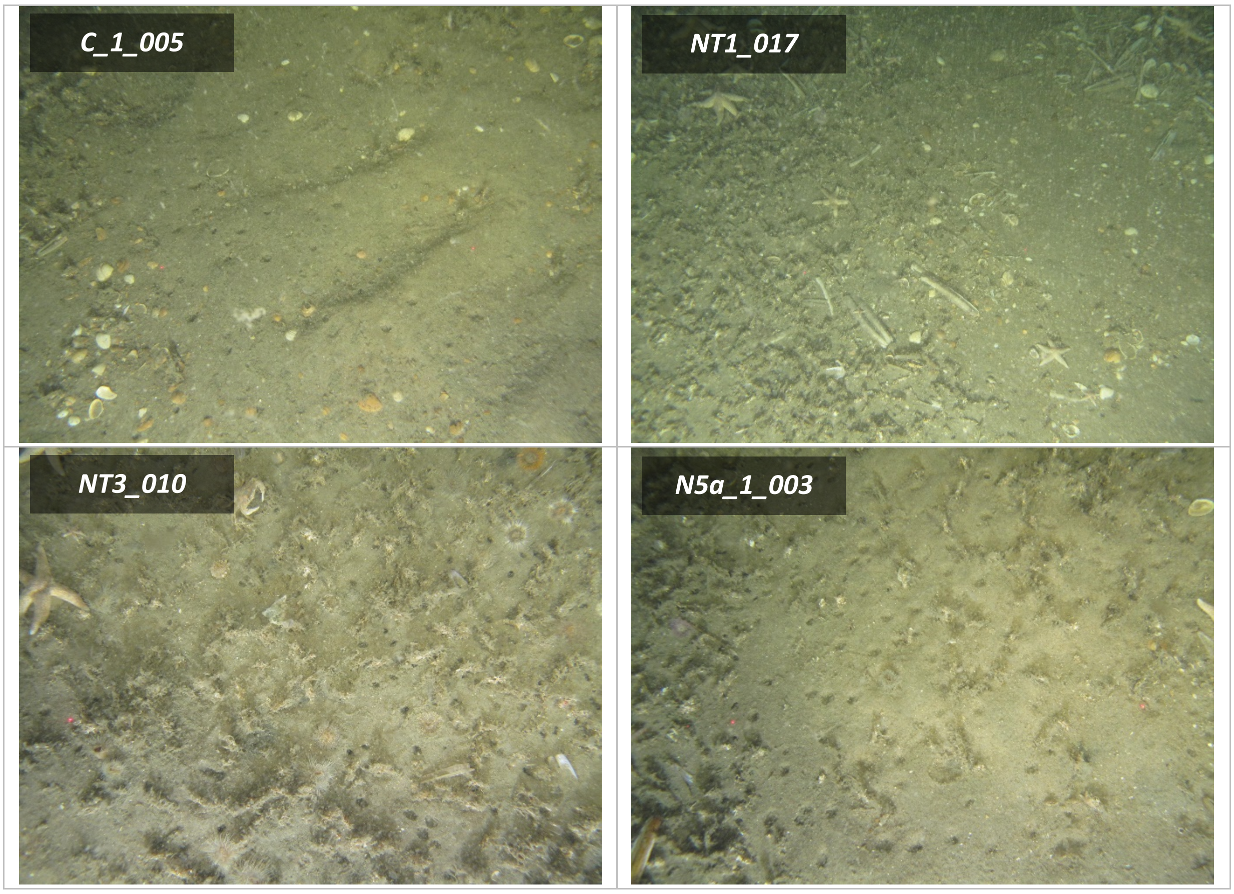


Abbildung 8: Beispielbilder von Dichte von *Lanice conchilega* und anderen Polychaetes in tidebeeinflusstem infralittoralem Sand und kiesigem Mischsand" (A5.137)

3.4.3 Potenziell empfindliche Lebensräume und Arten

Es gibt eine Reihe potenziell empfindlicher Lebensräume und Arten, die in einer oder mehreren internationalen Konventionen, europäischen Richtlinien oder britischen Rechtsvorschriften aufgeführt sind und von denen bekannt ist, dass sie in der weiteren Region (südliche Nordsee) vorkommen, darunter:

- Biogene Riffe, die durch die Röhren-Sandkoralle*Sabellaria spinulosa* gebildet werden (EG-Habitatrichtlinie Anhang I und OSPAR bedrohter und rückläufiger Lebensraum);

- Steinige Riffe, die durch Ansammlungen von Steinen und/oder Felsbrocken gebildet werden (EG-Habitatrichtlinie Anhang I);
- Sandbänke, die ständig leicht vom Meerwasser bedeckt sind" (EG-Habitatrichtlinie Anhang I).

Biogenes Riff Habitat

Die wahrscheinlichsten biogenen Riffe, die in sandigen Habitaten in der südlichen Nordsee vorkommen, sind biogene Riffe, die von dem Polychaetenwurm *Sabellaria spinulosa*, auch bekannt als Röhren-Sandkoralle, gebildet werden. Röhren-Sandkorallen bauen Röhren aus Sand und Muschelfragmenten und können in großer Zahl Riffe bilden. *Sabellaria spinulosa* bilden riffartige oder agglomerierte Sandröhren, die zur Stabilisierung von Kies-, Stein- und Schotterhabitaten dienen und einen konsolidierten Lebensraum für epibenthische Arten bieten. Die Aggregate des röhrenbildenden Polychaeten-Wurms sind solide (wenn auch zerbrechlich) und können große, mindestens mehrere Zentimeter dicke Strukturen bilden, die sich über den umgebenden Meeresboden erheben und über viele Jahre bestehen bleiben. Als solche bieten sie einen biogenen Lebensraum, der es vielen anderen assoziierten Arten ermöglicht, sich zu etablieren (Holt et al., 1998 Foster-Smith und White, 2001, Gubbay, 2007).

Diese Riffe sind ökologisch wichtig, da sie einen Lebensraum für eine Vielzahl von anderen am Meeresboden lebenden Organismen bieten und somit eine größere Artenvielfalt als die Umgebung aufweisen können. Aufgrund ihrer Bedeutung für den Naturschutz sind sie als Anhang-I-Habitat der EG-Habitatrichtlinie (FFH-Richtlinie 1992 & 1997) und als OSPAR (2008) bedrohter und abnehmender Lebensraum aufgeführt. Auf keinem der Videotransektdaten aus dem Untersuchungsgebiet wurden jedoch Anzeichen von *S. spinulosa-Feldern* gesehen, auch nicht auf Transekten über Bereichen mit hoher oder variabler Reflektivität von Grob- oder Mischsedimenten.

Obwohl *Lanice conchilega-Bänke* weder in der EG-Habitat-Richtlinie (EC, 2013) noch in OSPAR (2008) als geschützte Lebensräume aufgeführt sind, haben Rabaut et al. (2007) die Rolle von L . *conchilega* als "Ökosystem-Ingenieure" hervorgehoben, die zur Stabilisierung ansonsten mobiler Meeresboden-Substrate beitragen und die Entwicklung vielfältigerer Makrofauna-Gemeinschaften erleichtern (Rabaut et al., 2007). Darüber hinaus wurde vorgeschlagen, dass *Lanice conchilega-Bänke* die Qualifikationskriterien für die Aufnahme als Anhang-I-Habitat der EG-Habitatrichtlinie erfüllen (Rabaut et al., 2009).

Lebensraum Steiniges Riff

Steinige Riffe werden von der FFH-Richtlinie definiert als "Gebiete mit Felsblöcken (>256 mm Durchmesser) oder Steine (64 mm – 256 mm Durchmesser), die aus dem Meeresboden aufsteigen und ein geeignetes Substrat für die Ansiedlung von Algen und/oder Tierarten bieten" (EC, 2013).

Das Videomaterial vom Meeresboden wurde analysiert, um die allgemeinen Habitatveränderungen im gesamten Untersuchungsgebiet zu bewerten und Bereiche mit Potenzial für Steinriffhabitate zu identifizieren (siehe Anhang B). Nur ein Meeresboden-Kameratransekt (Station C3_2) innerhalb des Untersuchungsgebiets der N5A-Entwicklung wies ein Potenzial auf, das als potenzielles Steinriff in Frage kommt (EC, 2013). Daher wurde das Videomaterial der Station C3_2 weiter mit der BSL-modifizierten Methode zur Bewertung von Steinriffen (nach Irving, 2009) ausgewertet. Während die Kriterien von Irving (2009) von den britischen Aufsichtsbehörden für die Anwendung in britischen Gewässern genehmigt wurden, wurden sie von den niederländischen Behörden nicht ausdrücklich genehmigt. Diese Methode wurde hier jedoch als nützliche Grundlage für eine halbquantitative Bewertung des potenziellen Anhang-I-Steinriffhabitats verwendet.

Die Ergebnisse der Analyse der Riffstruktur sind vollständig im Habitat Assessment Report (Report LU-0022H-553-RR-04) enthalten und betonen das begrenzte Potenzial für das Gebiet, als steiniges Riff klassifiziert zu werden, aufgrund der geringen prozentualen Bedeckung und Höhe der Steine (>64mm Durchmesser) in diesem Gebiet. Daher wird dieses Gebiet nicht als ausreichend bemerkenswert angesehen, um als Steinriff des Anhangs I der EG-Habitatrichtlinie eingestuft zu werden.

Lebensraum flache Sandbänke

Sandbänke, die ständig leicht von Meerwasser bedeckt sind, sind sandige Sedimente, die permanent von Meerwasser bedeckt sind und sich typischerweise in Tiefen von weniger als 20 m (LAT) befinden. Sie sind von naturschutzfachlichem Wert, da sie Mergelbänke beherbergen können und typischerweise von einer Reihe von Wühltieren, Epifauna und Sandaalen besiedelt werden, die eine wichtige Nahrungsquelle für viele Vögel darstellen. Obwohl ein Großteil des Untersuchungsgebietes flacher als 20 m LAT ist, gab es in diesem Bereich keine definierten Sandbankmerkmale (Figure 1).

Aufgrund der Vielfalt der H1110-Habitate in den Niederlanden hat die niederländische Regierung beschlossen, diese in drei Untertypen zu unterteilen; H1110_A Wattenmeer, H1110_B Nordsee und H1110_C Offshore (Noordzeeloket, 2019). Der Lebensraum H1110_C ist für das aktuelle Untersuchungsgebiet am relevantesten, da er permanent überflutete Sandbänke in Wassertiefen von bis zu 40 m darstellt, wobei die Doggerbank das Hauptgebiet ist, das derzeit unter diesem Lebensraum-Subtyp vor der Küste der Niederlande geschützt ist. Für den Habitat-Subtyp H1110_C wurde noch kein Habitat-Profil-Dokument erstellt. Einige Schlüsselmerkmale für die Erstellung dieses Profildokuments sind jedoch in Jak et al., (2009) zu finden, mit Anforderungen wie dem Vorhandensein von sandigem Meeresboden und Arten, die für den Lebensraum H1110_C charakteristisch sind (Table 7).

Da die Sedimente innerhalb des Untersuchungsgebiets in eine der drei Folk-Bezeichnungen "Sand", "leicht kiesiger Sand" und "kiesiger Sand" eingeordnet werden, können die Sedimente der N5A-Entwicklungsstudie als ausreichend sandig angesehen werden, um die Anforderungen des Habitat-Subtyps H1110_C zu erfüllen. Die Überprüfung des Makrofauna-Arten-Datensatzes zusammen mit den Greifproben- und Meeresboden-Videoprotokollen für die aktuelle Untersuchung zeigte, dass mehrere der für den Habitat-Subtyp H1110_C charakteristischen Arten im Untersuchungsgebiet vorhanden waren. Insbesondere Bäumchenröhrenwürmer *(Lanice conchilega*) und bathyporeide Amphipoden *(Bathyporeia guilliamsoniana*, *B. elegans* und *Bathyporeia* spp.) wurden in fast allen Greifproben aus dem Untersuchungsgebiet nachgewiesen. Weitere charakterisierende Arten für den im Untersuchungsgebiet vorkommenden, permanent überfluteten Sandbank-Subtyp H1110_C waren die Polychaeten *Sigalion mathildae* und Sandaale *(Ammodytes marinus*).

Da sowohl der Sedimenttyp als auch die zugehörige Fauna innerhalb des Untersuchungsgebiets die von Jak et al. (2009) beschriebenen Anforderungen erfüllen, ist es möglich, dass das Untersuchungsgebiet als Lebensraumsubtyp H1110_C (permanent überflutete Sandbank) des Anhangs I der FFH-Richtlinie im gesamten Untersuchungsgebiet des N5A-Entwicklungsgebiets und der Trasse angesehen wird. Allerdings gibt es derzeit keine ausreichenden Informationen im öffentlichen Bereich, um dieser Entscheidung vorzugreifen.

Tabelle 7: Artencharakteristik der permanent überfluteten Sandbank – Niederlande Lebensraum-Subtyp H1110_C

Spezies Gruppe	Allgemeiner Name	Spezies Name	Beschreibung
Polychaeten	**Bäumchenröhrenwurm**	***Lanice conchilega***	**Auf Sandsubstrat vorkommende Arten**
Polychaeten	**na**	***Sigalion mathildae***	**Die Art kommt hauptsächlich in sauberen, sandigen Substraten vor, unter anderem auf der Doggerbank.**
Krustentiere	**Sandbagger-Garnele**	***Bathyporeia guilliamsoniana***	**Epiphyten in sauberem Sand und auf der Doggerbank**

Spezies Gruppe	Allgemeiner Name	Spezies Name	Beschreibung
Krustentiere	**Sandbagger-Garnele**	***Bathyporeia elegans***	**Vorkommen in groben, sauberen, feinsandigen Sedimenten**
Krustentiere	Kumaceen	*Iphinoe trispinosa*	Speziell für Sand von der Doggerbank
Stachelhäuter (Echinodermata)	Schlangenstern	*Acrocnida brachiata*	Vorkommen in hohen Dichten in sauberem Sand bis zu einer Tiefe von 40 m
Stachelhäuter (Echinodermata)	Seeigel	*Echinocyamus pusillus*	Gefunden in grobem Sand und feinem Kies, angereichert mit Detritus
Mollusca	Ozean Quahog	*Arctica islandica*	Kommt an den Rändern der Doggerbank vor - langlebige Art
Mollusca	Wellhornschnecke	*Buccinum undatum*	Kommt auf gemischtem Substrat vor – Langlebige Arten
Mollusca	Muschel	*Mactra coralina*	Langlebige Art, die sich von Partikeln aus der Wassersäule ernährt. Gefunden in feinem bis grobem Sand
Fische	**Kleiner Sandaal**	***Ammodytes marinus***	**Vorkommen im Feinsand. Eine wichtige Nahrungsquelle für Vögel, Fische und Meeressäugetiere**
Fische	Viperqueise	*Trachinus vipera*	Spezifisch für Sand, wo sie unter der Oberfläche vergraben liegen
Rochen	Dornenstrahl	*Raja clavata*	Restbevölkerung. Langlebige Arten
Fische	Scholle	*Pleuronectes platessa*	Im Allgemeinen auf sandigem Substrat zu finden. Häufige Arten

Hinweis: Arten, die innerhalb des Untersuchungsgebiets der N5a-Entwicklung vorkommen, werden **dickgedruckt** wiedergegeben.

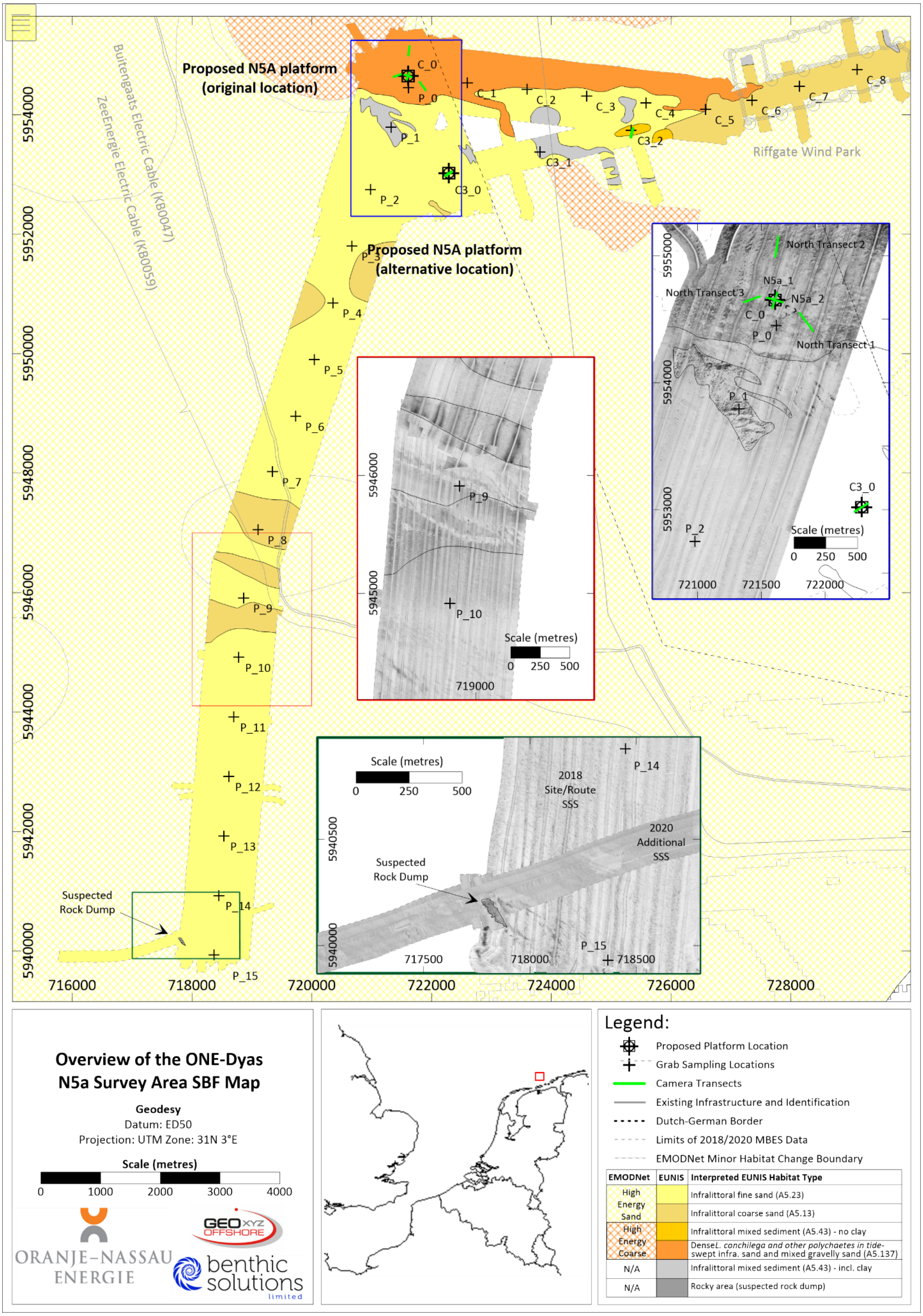


Abbildung 9: N5A Standort- und Routen-Lebensraumverteilung

4 FAZIT

Das Meeresbodensediment innerhalb des kombinierten N5A-Standort- und Trassenuntersuchungsgebiets reichte von einem Maximum von ca. 26,4 m LAT bei KP0,000 und 8,5 m LAT bei KP15,167 auf einer Felshalde, die den bestehenden Einbindepunkt der NGT-Pipeline schützt. Sowohl die Einbindungsroute von N5A an die NGT-Pipeline (NP-001) als auch die Kabeltrasse von N5A nach Riffgat wurden von einer Reihe natürlicher Tröge gekreuzt, die von West-Nord-West nach Ost-Süd-Ost verlaufen.

Die Merkmale des Meeresbodens innerhalb des kombinierten Standort- und Routenuntersuchungsgebiets wurden anhand einer Kombination aus geophysikalischen und umweltbezogenen Bodenuntersuchungsdaten so interpretiert, dass sie sechs Haupttypen von Merkmalen des Meeresbodens umfassen:

- Feinsand und Muschelfragmente" war der vorherrschende Sedimenttyp im gesamten Untersuchungsgebiet, einschließlich des Bereichs der überarbeiteten Einbindungsstrecke von N5A zur NGT-Pipeline (NP-001) zwischen KP15 und KP15.167;
- Grober Sand und Muschelfragmente" wurde in einem großen Bereich um den Riffgat Wind Park und in sechs kleineren Bereichen entlang der Routen abgegrenzt;
- Grober Sand mit Kieselsteinen und Steinen" war in zwei kleinen Bereichen auf halber Strecke entlang der Kabeltrasse von N5A nach Riffgat Wind Park vorhanden;
- Grober Sand und Muscheln mit einer hohen Dichte an Bäumchenröhrenwürmern und Schwertmuscheln" wurde in einem einzigen großen Bereich entlang des nördlichen Randes des N5A-Geländes und der Kabeltrasse von N5A zum Riffgat Wind Park festgestellt;
- Grober Sand und Lehm mit Kieselsteinen und Steinen" wurde als in zehn kleinen Bereichen innerhalb des N5A-Geländes und entlang der Kabeltrasse von N5A zum Riffgat Wind Park vorhanden interpretiert.
- Über dem Einbindungspunkt der NGT-Pipeline (NP-001) bei KP15.167 wurde eine "Gesteinhalde" festgestellt.

Basierend auf der Überprüfung der Daten der Meeresbodenkamera und der Schürfproben, die während der Erkundung des N5A-Entwicklungsgeländes und des Trassengebiets gewonnen wurden, wurden vier EUNIS-Habitatklassifizierungen zugewiesen: "Infralitoraler Feinsand" (A5.23), "Infralitorales Grobsediment" (A5.13), 'Infralitorales gemischtes Sediment' (A5.43) und 'Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem infralitoralem Sand und gemischtem kiesigem Sand' (A5.137) sowie als Nicht-EUNIS-Habitat 'Gesteinhalde' von. Jeder der zugewiesenen EUNIS-Lebensraumtypen entsprach einem der interpretierten Typen von Meeresbodenmerkmalen, mit Ausnahme des EUNIS-Lebensraums "Infralitorales gemischtes Sediment" (A5.43), der zwei Typen von Meeresbodenmerkmalen – "Grober Sand mit Kieselsteinen und Steinen" und "Grober Sand und Ton mit Kieselsteinen und Steinen" zugewiesen wurde.

Obwohl innerhalb des Untersuchungsgebiets eine einzelne Stelle mit Steinen beobachtet wurde, wurde die Bedeckung oder die Höhe der Steine als unzureichend erachtet, um eine Betrachtung als potenzielles Steinriffhabitat nach Anhang I der FFH-Richtlinie zu rechtfertigen (nach Irving, 2009).

Die Meeresbodensedimente innerhalb des Untersuchungsgebiets waren sanddominiert und beherbergten mehrere Arten, die von Jak et al. (2009) als charakteristisch für den Anhang I der EG-Flora-Fauna-Habitat-Richtlinie (Subtyp H1110_C) aufgelistet wurden. Derzeit gibt es nicht genügend öffentlich verfügbare Informationen, um die Klassifizierung des Untersuchungsgebiets als Lebensraumsubtyp H1110_C zu bestätigen, aber es ist möglich, dass das Untersuchungsgebiet als solcher klassifiziert wird.

Obwohl *Lanice conchilega-Bänke* derzeit nicht als geschützte Habitate gelistet sind, sind sie dafür bekannt, als "Ökosystem-Ingenieure" zu fungieren (Rabaut et al., 2007) und wurden für die Aufnahme als Anhang-I-Habitate der EG-Habitatrichtlinie vorgeschlagen (Rabaut et al., 2009).

Basierend auf der Überprüfung der erfassten geophysikalischen Daten und der ökologischen Bodenuntersuchung durch Schürfproben und Meeresbodenfotografie wurden keine weiteren geschützten Lebensräume oder Arten innerhalb des Untersuchungsgebiets beobachtet.

5 REFERENZEN

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ANHANG A – LOG-SHEETS

Guss	Station	Verwendeter Probenehmer	Wassertiefe (m)	Zeit	Datum	Zurückgewonnenes Volumen (mm Boxentiefe)	Probe Name	Behältertyp und Menge	Kommentare	Sediment Beschreibung/Stratifikation	Auffällige Fauna/Kommentare
1	Greifer_P_0	Tagesgreifer	29	17:43:00	06/05/2019	85%	F1	2 x 3L Eimer		Muscheln, Sand	*Lanice. conchilega, Asterias rubens, Nereis*
2	Greifer_P_0	DVV	29	18:20:00	06/05/2019	60% 50%	F2 PC	2 x 3L Eimer Säcke und Behälter		Sand, kleine Stücke von Muscheln	*L. conchilega, A. rubens, Nereis*
3	Greifer_P_0	DVV	29	18:45:00	06/05/2019	60%	F3	3 x 3L Eimer		Sand, kleine Stücke von Muscheln	*L. conchilega, A. rubens, Nereis*
4	Greifer_P_1	DVV	27	20:12:00	06/05/2019	50% 50%	PC F1	1 x 3L Eimer Säcke und Behälter		Lehm	*L. conchilega*
5	Greifer_P_1	DVV	27	20:26:00	06/05/2019	N/S	N/S	N/S	Steine		
6	Greifer_P_1	DVV	27	20:40:00	06/05/2019	70% 50%	F2 F3	1 x 3L Eimer 1 x 3L Eimer		Sand und Ton	Polychaeten, Muschelfragmente
7	Greifer_P_2	DVV	24	21:15:00	06/05/2019	50% 50%	PC F1	1 x 1L Eimer Säcke und Behälter		Feinsand	*Echinocardium cordatum*, Sandaale
8	Greifer_P_2	DVV	24	21:50:00	06/05/2019	60% 50%	F2 F3	1 x 1L Eimer 1 x 1L Eimer	Plattfisch in Greiferbecken, fotografiert, über Bord geworfen. Greiferdichtung nicht beeinträchtigt, daher für Fauna verwendet	Feinsand	Sandaal, Polychaeten, Plattfisch evtl. Steinbutt
9	Greifer_P_3	DVV	23	22:56:00	06/05/2019	N/S	N/S	N/S	Block kam herunter, Stropps gebrochen, Betrieb gestoppt		
10	Greifer_P_3	DVV	24	02:05:00	08/05/2019	50% 50%	PC F1	1 x 1L Eimer Säcke und Behälter	Zusätzliches Gewicht an den Armen	Feinsand	*E. cordatum*
11	Greifer_P_3	DVV	24	02:15:00	08/05/2019	60% 50%	F2 F3	1 x 1L Eimer 1 x 1L Eimer		Feinsand	Sandaal, *E. cordatum*

Guss	Station	Verwendeter Probenehmer	Wassertiefe (m)	Zeit	Datum	Zurückgewonnenes Volumen (mm Boxentiefe)	Probe Name	Behältertyp und Menge	Kommentare	Sediment Beschreibung/Stratifikation	Auffällige Fauna/Kommentare
12	Greifer_P_4	DVV	22	02:45:00	08/05/2019	60% 50%	PC F1	1 x 1L Eimer Säcke und Behälter		Feinsand	*L. conchilega*
13	Greifer_P_4	DVV	21	03:03:00	08/05/2019	50% 50%	F2 F3	1 x 1L Eimer 1 x 1L Eimer		Feinsand	*L. conchilega*
14	Greifer_P_5	DVV	20	03:31:00	08/05/2019	50% 50%	PC F1	1 x 1L Eimer Säcke und Behälter		Sand und Muschel	*E. cordatum*, Scheidenmuschel
15	Greifer_P_5	DVV	20	03:42:00	08/05/2019	50% 50%	F2 F3	1 x 1L Eimer 1 x 1L Eimer		Sand und Muschel	*L. conchilega*
16	Greifer_P_6	DVV	21	04:29:00	08/05/2019	50% 50%	PC F1	1 x 1L Eimer Säcke und Behälter		Feiner Sand	*E. cordatum* (beschädigt)
17	Greifer_P_6	DVV	22	04:41:00	08/05/2019	50% 50%	F2 F3	1 x 1L Eimer 1 x 1L Eimer		Feinsand mit geringen Muschelfragmenten	Polychaeten, *Nereis*, *L. conchilega*, Fisch (beschädigt)
18	Greifer_P_7	DVV	22	05:09:00	08/05/2019	N/S	N/S	N/S	Keine Probe, ausgelöst aber leer		
19	Greifer_P_7	DVV	22	05:22:00	08/05/2019	N/S	N/S	N/S	Keine Probe, hat nicht ausgelöst		
20	Greifer_P_7	DVV	21	05:25:00	08/05/2019	N/S	N/S	N/S	Keine Probe, hat nicht ausgelöst		
21	Greifer_P_7	DVV	21	05:27:00	08/05/2019	50% 50%	PC F1	1 x 1L Eimer Säcke und Behälter		Feinsand mit geringen Muschelresten	*L. conchilega*, Polychaeten
22	Greifer_P_7	DVV	21	05:37:00	08/05/2019	50% 50%	F2 F3	1 x 1L Eimer 1 x 1L Eimer		Feinsand mit geringen Muschelresten, geringe Mengen an Schlamm/Lehm	Reichlich *L. conchilega*, Polychaeten
23	Greifer_P_8	DVV	21	06:01:00	08/05/2019	N/S	N/S	N/S			
24	Greifer_P_8	DVV	21	06:03:00	08/05/2019	N/S	N/S	N/S			
25	Greifer_P_8	DVV	20	06:04:00	08/05/2019	70% 70%	PC F1	1 x 5L Eimer Säcke und Behälter		Grober Sand mit Muschelfragmenten	Polychaeten

Guss	Station	Verwendeter Probenehmer	Wassertiefe (m)	Zeit	Datum	Zurückgewonnenes Volumen (mm Boxentiefe)	Probe Name	Behältertyp und Menge	Kommentare	Sediment Beschreibung/Stratifikation	Auffällige Fauna/Kommentare
26	Greifer_P_8	DVV	21	06:12:00	08/05/2019	70% 60%	F2 F3	1 x 5L Eimer 1 x 5L Eimer		Grober Sand mit Muschelfragmenten	*L. conchilega*
27	Greifer_C_8	DVV	24	19:00:00	09/05/2019	80% 80%	PC F1	1 x 1L Eimer Säcke und Behälter		Grober Sand mit Muschelfragmenten	*L. conchilega*
28	Greifer_C_8	DVV	24	19:15:00	09/05/2019	80% 80%	F2 F3	1 x 1L Eimer 1 x 1L Eimer		Grober Sand mit Muschelfragmenten	*L. conchilega*
29	Greifer_C_7	DVV	24	19:30:00	09/05/2019	70%, 70%	PC F1	3 x 3L Eimer Säcke und Gläser		Grober Sand mit Muschelfragmenten	Keine auffällige Fauna
30	Greifer_C_7	DVV	24	19:45:00	09/05/2019	N/S	N/S	N/S	Eingesetzt, aber keine Probe, nicht auslösend		
31	Greifer_C_7	DVV	24	20:05:00	09/05/2019	70% 80%	F2 F3	2 x 5L Eimer 2 x 5L Eimer		Grober Sand mit Muschelfragmenten	Keine auffällige Fauna
32	Greifer_C_6	DVV	24	20:27:00	09/05/2019	60% 80%	PC F1	1 x 3L Eimer Säcke und Behälter		Grober Sand mit Muschelfragmenten	Keine auffällige Fauna
33	Greifer_C_6	DVV	24	21:05:00	09/05/2019	80%, 80%	F2 F3	1 x 3L Eimer 1 x 3L Eimer		Grober Sand mit Muschelfragmenten	Urchel
34	Greifer_C_5	DVV	25	05:37:00	11/05/2019	40% 70%	PC F1	1 x 3L + 1x5L Eimer Säcke und Behälter		Grober Sand mit Muschelfragmenten	Gobidae, *Asterias*, Lancelet. *L. conchilega*
35	Greifer_C_5	DVV	25	05:42:00	11/05/2019	70% 70%	F2 F3	2 x 5L Eimer 1 x 5L + 1x 3L Eimer		Grober Sand mit Muschelfragmenten	*L. conchilega*, Polychaeten, spatangoid
36	Greifer_C_4	DVV	28	06:40:00	11/05/2019	60% 60%	PC F1	1 x 1L Eimer Säcke und Behälter		Feinsand mit Muschelresten	*L. conchilega*, Polychaeten, spatangoid
37	Greifer_C_4	DVV	28	07:01:00	11/05/2019	70% 70%	F2 F3	1 x 1L Eimer 1 x 1L Eimer		Feinsand mit Muschelresten	*L. conchilega*, Polychaeten, spatangoid
38	Greifer_C_3	DVV	28	07:29:00	11/05/2019	N/S	N/S	N/S	Hat nicht ausgelöst		

Guss	Station	Verwendeter Probenehmer	Wassertiefe (m)	Zeit	Datum	Zurückgewonnenes Volumen (mm Boxentiefe)	Probe Name	Behältertyp und Menge	Kommentare	Sediment Beschreibung/Stratifikation	Auffällige Fauna/Kommentare
39	Greifer_C_3	DVV	28	07:36:00	11/05/2019	70% 70%	PC F1	1 x 1L Eimer Säcke und Behälter		Sehr feiner Sand mit geringen Muschelresten	*L. conchilega*, Polychaeten
40	Greifer_C_3	DVV	28	07:47:00	11/05/2019	N/S	N/S	N/S	Getriggert, aber keine Probe		
41	Greifer_C_3	DVV	28	07:49:00	11/05/2019	70% 70%	F2 F3	1 x 1L Eimer 1 x 1L Eimer		Sehr feiner Sand mit geringen Muschelresten und weichem Ton	Anemonen, *L. conchilega*, Polychaeten, A rubens, spatangoid
42	Greifer_C_2	DVV	27	08:15:00	11/05/2019	70% 70%	PC F1	1 x 5L Eimer Säcke und Behälter		Grober Sand und Ton	*L Conchilega* und Polychaeten
43	Greifer_C_2	DVV	28	08:27:00	11/05/2019	70% 40%	F2 F3	1 x 5L Eimer 1 x 3L Eimer	Schwertmuscheln im Behälter (F3)	Grober Sand	Schwertmuscheln, *L. conchilega*, Polychaeten. Lancelet
44	Greifer_C_1	DVV	28	08:55:00	11/05/2019	60% 60%	PC F1	1 x 3L + 1x5L Eimer Säcke und Behälter		Grober Sand und reichlich Muschelschutt	Lanzettfischchen und Polychaeten
45	Greifer_C_1	DVV	28	09:04:00	11/05/2019	60% 40%	F2 F3	1 x 5L Eimer 1 x 5L Eimer	Schwertmuscheln im Behälter (F3)	Grober Sand und reichlich Muschelschutt	*L. conchilega*, Lanzettfischchen, Polychaeten, Porzellankrabbe
46	Greifer_C_0	DVV	29	09:32:00	11/05/2019	90% 90%	PC F1	2 x 5L Eimer Säcke und Behälter	Etikett für F2 im F1-Eimer (2 von 2)	Grober Sand	*L. conchilega*, Schwertmuscheln und Polychaeten
47	Greifer_C_0	DVV	29	09:41:00	11/05/2019	90% 90%	F2 F3	2 x 5L Eimer 2 x 5L Eimer	Etikett für F3 im F2-Eimer (1 von 2)	Grobsand	*L. conchilega*, Schwertmuscheln und Polychaeten
48	Greifer_P_15	DVV	13	02:15:00	12/05/2019	60% 60%	PC F1	1 x 1L Eimer Säcke und Behälter		Feinsand mit Muschel	Polychaeten
49	Greifer_P_15	DVV	13	02:20:00	12/05/2019	60% 60%	F2 F3	1 x 1L Eimer 1 x 1L Eimer		Feinsand mit Muschel	Polychaeten, Sandaale

Guss	Station	Verwendeter Probenehmer	Wassertiefe (m)	Zeit	Datum	Zurückgewonnenes Volumen (mm Boxentiefe)	Probe Name	Behältertyp und Menge	Kommentare	Sediment Beschreibung/Stratifikation	Auffällige Fauna/Kommentare
50	Greifer_P_14	DVV	14	03:05:00	12/05/2019	60% 60%	PC F1	1 x 3L Eimer Säcke und Behälter		Feinsand mit Muschel	*Asterias*, Spatangoid, *Ophiura*
51	Greifer_P_14	DVV	14	03:10:00	12/05/2019	60% 60%	F2 F3	1 x 3L Eimer 1 x 3L Eimer		Feinsand mit Muschel	Spatangoid, *Ophiura*
52	Greifer_P_13	DVV	16	03:30:00	12/05/2019	60% 60%	PC F1	1 x 1L Eimer Säcke und Behälter		Feinsand mit geringen Muschelresten	Polychaeten
53	Greifer_P_13	DVV	16	03:45:00	12/05/2019	60% 60%	F2 F3	1 x 1L Eimer 1 x 1L Eimer		Feinsand mit geringen Muschelresten	*Nereis*, *L. conchilega*, *Ophiura*, Spatangoiden
54	Greifer_P_12	DVV	16	04:32:00	12/05/2019	60% 60%	PC F1	1 x 3L Eimer Säcke und Behälter		Feinsand mit Muschelresten	*Nereis*, *L. conchilega*, Spatangoiden
55	Greifer_P_12	DVV	16	04:42:00	12/05/2019	60% 60%	F2 F3	1 x 3L Eimer 1 x 3L Eimer		Feinsand mit Muschelresten	*Nereis*, *L. conchilega*, Spatangoiden
56	Greifer_P_11	DVV	17	05:03:00	12/05/2019	70% 70%	PC F1	1 x 3L Eimer Säcke und Behälter		Feinsand mit erheblichen Muschelresten	*L. conchilega*
57	Greifer_P_11	DVV	17	05:13:00	12/05/2019	70% 70%	F2 F3	1 x 3L Eimer 1 x 3L Eimer		Feinsand mit erheblichen Muschelresten	*L. conchilega*
58	Greifer_P_10	DVV	17	05:35:00	12/05/2019	60% 60%	PC F1	1 x 1L Eimer Säcke und Behälter		Feinsand mit Muschelresten	Polychaeten, *L. conchilega*, *Nereis*
59	Greifer_P_10	DVV	17	05:44:00	12/05/2019	60% 60%	F2 F3	1 x 1L Eimer 1 x 1L Eimer		Feinsand mit Muschelresten	Polychaeten, *L. conchilega*
60	Greifer_P_9	DVV	19	06:05:00	12/05/2019	60% 60%	PC F1	1 x 3L Eimer Säcke und Behälter		Feinsand mit Muschelresten	*Nereis*
61	Greifer_P_9	DVV	19	06:13:00	12/05/2019	60% 60%	F2 F3	1 x 3L Eimer 1 x 3L Eimer		Feinsand mit Muschelresten	Polychaeten
62	Greifer_C3_0	DVV	24	22:43:00	14/05/2019	60% 60%	PC F1	1x1L Eimer		Feinsand mit Muschelresten	*E. cordatum*
63	Greifer_C3_0	DVV	24	22:59	14/05/2019	50% 50%	F2 F3	1 x 1L Eimer 1 x 1L Eimer		Feinsand mit Muschelresten	*E. cordatum*

Guss	Station	Verwendeter Probenehmer	Wassertiefe (m)	Zeit	Datum	Zurückgewonnenes Volumen (mm Boxentiefe)	Probe Name	Behältertyp und Menge	Kommentare	Sediment Beschreibung/Stratifikation	Auffällige Fauna/Kommentare
64	Greifer_C3_1	DVV	25	23:36:00	14/05/2019	50% 50%	PC F1	1 x 3L Eimer Säcke und Behälter		Feiner Sand mit darunter liegendem Lehm	Polychaeten. Evtl. Piddock-Löcher im Lehm, aber keine Piddocks erkennbar
65	Greifer_C3_1	DVV	25	23:45:00	14/05/2019	50% 50%	F2 F3	1 x 3L Eimer 1 x 3L Eimer		Feiner Sand mit darunter liegendem Lehm	Polychaeten. Evtl. Piddock-Löcher im Lehm, aber keine Piddocks erkennbar
66	Greifer_C3_2	DVV	25	00:13:00	15/05/2019	NS NS			Steine im Behälter		
67	Greifer_C3_2	DVV	25	00:20:00	15/05/2019	50% 50%	PC F1	1 x 3L Eimer Säcke und Behälter		sandiger Schotter	Polychaeten Hydroiden
68	Greifer_C3_2	DVV	25	00:29:00	15/05/2019	50% NS	F2	1x5L Eimer	Steine im Behälter eines Eimers	sandiger Schotter	Polychaeten Hydroiden
69	Greifer_C3_2	DVV	25	00:36:00	15/05/2019	45%	F3	1x1L Eimer	Steine im Behälter eines Eimers	sandiger Schotter	Polychaeten Hydroiden

ANHANG B – HABITAT BEWERTUNG

ED50, UTM 31N, CM 3° E												
Station	Ostwert (m)	Nordwert (m)	Datum & Uhrzeit	Beispielfoto (Dateiname)	Sediment-Typ	Auffällige Fauna	Tiefe (m)	Steinige Riffigkeit (nach Irving 2009)			Gesamtstruktur des Riffs	EUNIS Habitat-Klassifizierung mit SBF/Habitat-Karte Farbcode
								Zusammensetzung (% Bedeckung mit Steinen/Geröllen)	Höhe (von Steinen/Geröll in cm)	Riffstruktur Matrix		
Greifer_C_0				N5a_1_018.jpg, N5a_1_019.jpg, N5a_2_021.jpg, N5a_1_022.jpg	Grober Sand und Muschelfragmente	*Asterias rubens*, *Lanice conchilega*	30	k.A.	k.A.	k.A.	k.A.	Infralitorales grobes Sediment (A5.13)
Greifer_C_1	722598	5954539	11/05/19 02:56:48	Greifer_C_1_005.jpg	Grober Sand und Muschelfragmente mit *Lanice conchilega-Ansammlungen*	*Asterias rubens*, *Liocarcinus* sp., *Lanice conchilega*, Decapoda	28	k.A.	k.A.	k.A.	k.A.	Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und kiesigem Mischsand (A5.137)
	722599	5954538	11/05/19 02:57:27									
Greifer_C_2	723694	5954422	11/05/19 03:28:13	Greifer_C_2_002.jpg	Grober Sand und Muschelfragmente mit *Lanice conchilega-Ansammlungen*	*Asterias rubens*, *Liocarcinus* sp., *Lanice conchilega*, *Loligo vulgaris*	28	k.A.	k.A.	k.A.	k.A.	Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und kiesigem Mischsand (A5.137)
	723596	5954422	11/05/19 03:29:04									
Greifer_C_3	724589	5954311	11/05/19 04:08:03	Greifer_C_3_003.jpg	Feine bis mittlere Sandrippel mit Muschelfragmenten, die sich zwischen den Rippeln angesammelt haben	*Asterias rubens*, *Liocarcinus* sp., *Lanice conchilega*	28	k.A.	k.A.	k.A.	k.A.	Infralitoraler Feinsand (A5.23)
	724590	5954310	11/05/19 04:10:35									
Greifer_C_4	725582	5954199	11/05/19 04:34:40	Greifer_C_4_002.jpg	Feine bis mittlere Sandrippel mit Muschelfragmenten, die sich zwischen den Rippeln angesammelt haben	*Asterias rubens*, *Lanice conchilega*, *Arenicola* sp., Decapoda	28	k.A.	k.A.	k.A.	k.A.	Infralitoraler Feinsand (A5.23)
	725581	5954200	11/05/19 04:37:18									

ED50, UTM 31N, CM 3° E												
Station	Ostwert (m)	Nordwert (m)	Datum & Uhrzeit	Beispielfoto (Dateiname)	Sediment-Typ	Auffällige Fauna	Tiefe (m)	Steinige Riffigkeit (nach Irving 2009)			Gesamtstruktur des Riffs	EUNIS Habitat-Klassifizierung mit SBF/Habitat-Karte Farbcode
								Zusammensetzung (% Bedeckung mit Steinen/Geröllen)	Höhe (von Steinen/Geröll in cm)	Riffstruktur Matrix		
Greifer_C_5	726576	5954086	11/05/19 05:01:59	Greifer_C_5_002.jpg	Grobe Wellenmuster mit kleinen Muschelfragmenten, die sich zwischen den Wellen angesammelt haben	*Asterias rubens, Liocarcinus sp., Lanice conchilega,* evtl. *Callionymus lyra*	25	k.A.	k.A.	k.A.	k.A.	Infralitorales grobes Sediment (A5.13)
	726573	5954088	11/05/19 05:05:12									
Greifer_C_6	727352	5954243	09/05/19 17:05:54	Greifer_C_6_002.jpg	Grobe Wellenmuster mit kleinen Muschelfragmenten, die sich zwischen den Wellen angesammelt haben	*Lanice conchilega*	24	k.A.	k.A.	k.A.	k.A.	Infralitorales grobes Sediment (A5.13)
	727353	5954242	09/05/19 17:06:30									
Greifer_C_7	728147	5954477	09/05/19 17:33:39	Greifer_C_7_004.jpg	Grobe Wellenmuster mit kleinen Muschelfragmenten, die sich zwischen den Wellen angesammelt haben	*Lanice conchilega, Asterias rubens*	24	k.A.	k.A.	k.A.	k.A.	Infralitorales grobes Sediment (A5.13)
	728148	5954477	09/05/19 17:34:26									
Greifer_C_8	729105	5954755	09/05/19 18:00:57	Greifer_C_8_005.jpg	Feine bis mittlere Wellenmuster mit kleinen Muschelfragmenten, die sich zwischen den Wellen angesammelt haben	Möglich. Gobiidae, Asterias*rubens, Lanice conchilega*	24	k.A.	k.A.	k.A.	k.A.	Infralitoraler Feinsand (A5.23)
	729108	5954757	09/05/19 18:01:58									
Greifer_C3_0	722231	5952984	14/05/19 21:51:01	Greifer_C3_0_002.jpg	Feine bis mittlere Wellenmuster mit	*Asterias rubens, Lanice conchilega,*	24	k.A.	k.A.	k.A.	k.A.	Infralitoraler Feinsand (A5.23)

ED50, UTM 31N, CM 3° E												
Station	Ostwert (m)	Nordwert (m)	Datum & Uhrzeit	Beispielfoto (Dateiname)	Sediment-Typ	Auffällige Fauna	Tiefe (m)	Steinige Riffigkeit (nach Irving 2009)			Gesamtstruktur des Riffs	EUNIS Habitat-Klassifizierung mit SBF/Habitat-Karte Farbcode
								Zusammensetzung (% Bedeckung mit Steinen/Geröllen)	Höhe (von Steinen/Geröll in cm)	Riffstruktur Matrix		
	722336	5953047	14/05/19 22:00:16		kleinen Muschelfragmenten, die sich zwischen den Wellen angesammelt haben	Decapoda, *Ammodytes* sp., *Corystes cassivelaunus*, Gobiidae, *Ophiura ophiura*						
Greifer_C3_1	723807	5953379	14/05/19 21:23:19	Greifer_C3_1_001.jpg	Grober Muschelsand mit teilweise eingegrabenen Kieselsteinen und leichtem Wellenmuster	Pleuraektiform, *Asterias rubens*	24	k.A.	k.A.	k.A.	k.A.	Infralitorales Mischsediment (A5.43) – inkl. Ton
	723808	5953379	14/05/19 21:24:23									
Greifer_C3_2	725366	5953610	14/05/19 20:46:00	Greifer_C3_2_0014jpg	Feine bis mittlere Wellenmuster mit kleinen Muschelfragmenten, die sich zwischen den Wellen angesammelt haben	*Lanice conchilega*, *Asterias rubens*, evtl. *Callionymus lyra*, Pleuronectiformes, *Ammodytes* sp., Paguridae, Decapoda, *Metridium senile*, *Cancer pagurus*, Actiniaria, *Liocarcinus* sp., Cerianthidae, *Sertularia* sp.	25	Nicht ein Riff	Kein Riff	Nicht Riff	Kein Riff	Infralitoraler Feinsand (A5.23)
	725352	5953670	14/05/19 20:51:34									
	725352	5953670	14/05/19 20:51:35	Greifer_C3_2_020.jpg	Steine über grobem Sand mit gelegentlichen Felsbrocken			25	10	Niedrig	Niedrig	Infralitorales Mischsediment (A5.43) - kein Ton
	725347	5953687	14/05/2019 20:52:38									
	725347	5953688	14/05/2019 20:52:39	Greifer_C3_2_021.jpg	Grober Sand mit Steinen			10	5	Kein Riff	Kein Riff	Infralitorales Mischsediment (A5.43) - kein Ton
	725343	5953712	14/05/2019 20:54:08									
	725343	5953712	14/05/2019 20:54:09	Greifer_C3_2_028.jpg	Gelegentliche Steine über liegendem groben Sand und gelegentlich Felsbrocken			10	5	Kein Riff	Kein Riff	Infralitorales Mischsediment (A5.43) - kein Ton
	725333	5953755	14/05/2019 20:57:02									
	725333	5953755	14/05/2019 20:57:03	Greifer_C3_2_035.jpg	Steine über grobem Sand mit gelegentlichen Felsbrocken			30	20	Niedrig	Niedrig	Infralitorales Mischsediment (A5.43) - kein Ton
	725326	5953785	14/05/2019 20:58:50									

ED50, UTM 31N, CM 3° E												
								Steinige Riffigkeit (nach Irving 2009)				
Station	Ostwert (m)	Nordwert (m)	Datum & Uhrzeit	Beispielfoto (Dateiname)	Sediment-Typ	Auffällige Fauna	Tiefe (m)	Zusammensetzung (% Bedeckung mit Steinen/Geröllen)	Höhe (von Steinen/Geröll in cm)	Riffstruktur Matrix	Gesamtstruktur des Riffs	EUNIS Habitat-Klassifizierung mit SBF/Habitat-Karte Farbcode
Greifer_P_0	721647	5954431	02/05/19 17:15:09	Greifer_P_0_021.jpg	Grober Sand, übersät mit Muschelfragmenten und *Lanice conchilega-Ansammlungen*	*Asterias rubens*, *Lanice conchilega*, Decapoda, Paguridae, Actiniaria, Gobiidae, Cerianthidae	29	k.A.	k.A.	k.A.	k.A.	Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und kiesigem Mischsand (A5.137)
	721595	5954473	02/05/19 17:22:22									
Greifer_P_1	721323	5953795	02/05/19 19:00:12	Greifer_P_1_006.jpg	Grober Sand mit Steinen	Cerianthidae, *Asterias rubens*, Bryozoen	27	k.A.	k.A.	k.A.	k.A.	Infralitorales Mischsediment (A5.43) – inkl. Ton
	721325	5953794	02/05/19 19:01:32									
Greifer_P_2	720981	5952753	02/05/19 20:00:37	Greifer_P_2_002.jpg	Feiner bis mittelschwerer Muschelsand mit Wellenmuster	*Lanice conchilega*, *Corystes cassivelaunus*	24	k.A.	k.A.	k.A.	k.A.	Infralitoraler Feinsand (A5.23)
	720980	5952752	02/05/19 20:02:04									
Greifer_P_3	720668	5951799	06/05/19 15:43:57	Greifer_P_3_007.jpg	Feiner bis mittlerer Sand, der Wellenmuster bildet	*Corystes cassivelaunus*, *Asterias rubens*, *Lanice conchilega*	24	k.A.	k.A.	k.A.	k.A.	Infralitoraler Feinsand (A5.23)
	720666	5951799	06/05/19 15:47:09									
Greifer_P_4	720245	5950807	03/05/19 15:07:42	Greifer_P_4_005.jpg	Feiner bis mittlerer Sand, der Wellenmustern bildet	Asteroidea, Ophiuroidea	22	k.A.	k.A.	k.A.	k.A.	Infralitoraler Feinsand (A5.23)
	720355	5950855	03/05/19 15:10:32									
Greifer_P_5	720036	5949903	03/05/19 13:36:49	Greifer_P_5_004.jpg	Feiner bis mittlerer Muschelsand gelegentlich mit Kieselsteinen	Paguridae, *Lanice conchilega*, *Asterias rubens*	20	k.A.	k.A.	k.A.	k.A.	Infralitoraler Feinsand (A5.23)
	720036	5949903	03/05/19 13:38:12									
Greifer_P_6	719725	5948952	03/05/19 13:04:18	Greifer_P_6_004.jpg	Feiner bis mittlerer Sand mit unregelmäßigem Wellenmuster	*Lanice conchilega*, Pleuronectiform	22	k.A.	k.A.	k.A.	k.A.	Infralitoraler Feinsand (A5.23)
	719729	5948948	03/05/19 13:08:36									
Greifer_P_7	719412	5948000	03/05/19 11:18:23	Greifer_P_7_005.jpg			21	k.A.	k.A.	k.A.	k.A.	Infralitoraler Feinsand (A5.23)

ED50, UTM 31N, CM 3° E												
Station	Ostwert (m)	Nordwert (m)	Datum & Uhrzeit	Beispielfoto (Dateiname)	Sediment-Typ	Auffällige Fauna	Tiefe (m)	Steinige Riffigkeit (nach Irving 2009)			Gesamtstruktur des Riffs	EUNIS Habitat-Klassifizierung mit SBF/Habitat-Karte Farbcode
								Zusammensetzung (% Bedeckung mit Steinen/Geröllen)	Höhe (von Steinen/Geröll in cm)	Riffstruktur Matrix		
	719411	5948003	03/05/19 11:22:22		Feiner bis mittlerer Sand mit unregelmäßigem Wellenmuster	*Lanice conchilega, Callionymus lyra,* Ophiuroide						
Greifer_P_8	719099	5947048	03/05/19 12:05:32	Greifer_P_8_005.jpg	Grober Sand und Muschelschutt mit unregelmäßigem Wellenmuster	*Lanice conchilega*	21	k.A.	k.A.	k.A.	k.A.	Infralitorales grobes Sediment (A5.13)
	719094	5947051	03/05/19 12:07:34									
Greifer_P_9	718861	5945913	11/05/19 22:31:48	Greifer_P_9_002.jpg	Grober Sand und Muschelschutt mit unregelmäßigem Wellenmuster	*Asterias rubens, Lanice conchilega, Corystes cassivelaunus,* Actinopterygii	19	k.A.	k.A.	k.A.	k.A.	Infralitorales grobes Sediment (A5.13)
	718862	5945911	11/05/19 22:33:08									
Greifer_P_10	718778	5944917	11/05/19 23:01:57	Greifer_P_10_003.jpg	Feiner bis mittlerer Sand	*Asterias rubens, Lanice conchilega*	17	k.A.	k.A.	k.A.	k.A.	Infralitoraler Feinsand (A5.23)
	718778	5944917	11/05/19 23:04:14									
Greifer_P_11	718697	5943920	11/05/19 23:30:17	Greifer_P_11_009.jpg	Feiner bis mittlerer Sand und Muschelschutt mit unregelmäßigem Wellenmuster	Brachyura, *Lanice conchilega*	17	k.A.	k.A.	k.A.	k.A.	Infralitoraler Feinsand (A5.23)
	718697	5943920	11/05/19 23:32:11									
Greifer_P_12	718614	5942925	11/05/19 23:58:12	Greifer_P_12_002.jpg	Feiner bis mittlerer Sand und Muschelschutt mit unregelmäßigem Wellenmuster	*Asterias rubens, Lanice conchilega, Callionymus lyra,* Gobiidae, *Actiniaria,* Brachyura, *Cancer pagurus, Liocarcinus sp.*	16	k.A.	k.A.	k.A.	k.A.	Infralitoraler Feinsand (A5.23)
	718615	5942922	12/05/19 00:00:03									
Greifer_P_13	718531	5941926	12/05/19 00:30:02	Greifer_P_13_005.jpg	Feiner bis mittlerer Sand mit unregelmäßigem Wellenmuster	*Asterias rubens,* Ophiuroiden, *Lanice conchilega*	16	k.A.	k.A.	k.A.	k.A.	Infralitoraler Feinsand (A5.23)
	718533	5941928	12/05/19 00:31:30									
			Keine Sichtbarkeit									

ED50, UTM 31N, CM 3° E												
								Steinige Riffigkeit (nach Irving 2009)				
Station	Ostwert (m)	Nordwert (m)	Datum & Uhrzeit	Beispielfoto (Dateiname)	Sediment-Typ	Auffällige Fauna	Tiefe (m)	Zusammensetzung (% Bedeckung mit Steinen/Geröllen)	Höhe (von Steinen/Geröll in cm)	Riffstruktur Matrix	Gesamtstruktur des Riffs	EUNIS Habitat-Klassifizierung mit SBF/Habitat-Karte Farbcode
Greifer_P_14												
Greifer_P_15	718366	5939934	12/05/19 01:53:30	Greifer_P_15_005.jpg	Feiner bis mittlerer Sand mit unregelmäßigem Wellenmuster	*Lanice conchilega*, Actinopterygii	13	k.A.	k.A.	k.A.	k.A.	Infralitoraler Feinsand (A5.23)
	718366	5939933	12/05/19 01:55:09									
N5a_1	721585	5954589	11/05/19 01:38:04	N5a_1_014.jpg	Leicht kiesiger Grobsand mit Muschelfragmenten. 'Höhlen', die von *Ensis* gebildet werden, die sich unter die Oberfläche zurückziehen, wenn der Kameraschlitten in Kontakt mit dem Meeresboden kommt	*Lanice conchilega, Ensis* 'burrows', *Leptothecata, Actiniaria, Cancer pagurus, Callionymus lyra,* Paguridae, Actinopterygii, Sepiida, Pleuronectiform, Brachyura, *Sepiola* spp., *Cancer pagurus, Metridium senile, Ensis* sp., *Liocarcinus sp.,* Cerianthidae	29	k.A.	k.A.	k.A.	k.A.	Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und kiesigem Mischsand (A5.137)
	721626	5954710	11/05/19 01:46:42									
N5a_2	721669	5954631	11/05/19 01:16:25	N5a_2_002.jpg	Leicht kiesiger Grobsand mit Muschelfragmenten. 'Höhlen', die von *Ensis* gebildet werden, die sich unter die Oberfläche zurückziehen, wenn der Kameraschlitten in Kontakt mit dem Meeresboden kommt	*Asterias rubens, Lanice conchilega, Cancer pagurus,* Actiniaria, Paguridae, *Ensis sp., Cancer pagurus, Pagurus bernhardus,* Brachyura, *Callionymus lyra, Metridium*	29	k.A.	k.A.	k.A.	k.A.	Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und kiesigem Mischsand (A5.137)
	721555	5954667	11/05/19 01:24:59									

ED50, UTM 31N, CM 3° E												
Station	Ostwert (m)	Nordwert (m)	Datum & Uhrzeit	Beispielfoto (Dateiname)	Sediment-Typ	Auffällige Fauna	Tiefe (m)	Steinige Riffigkeit (nach Irving 2009)			Gesamtstruktur des Riffs	EUNIS Habitat-Klassifizierung mit SBF/Habitat-Karte Farbcode
								Zusammensetzung (% Bedeckung mit Steinen/Geröllen)	Höhe (von Steinen/Geröll in cm)	Riffstruktur Matrix		
	721554	5954667	11/05/19 01:25:00	N5a_2_038.jpg	Großer Felsblock umgeben von Ensis-Muscheln	*senile*, *Liocarcinus sp.*, Cerianthidae		k.A.	k.A.	k.A.	k.A.	Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und kiesigem Mischsand (A5.137)
	721552	5954668	11/05/19 01:25:15									
	721551	5954668	11/05/19 01:25:16	N5a_2_039.jpg	Grobsand-Wellenmuster			k.A.	k.A.	k.A.	k.A.	Infralitorales grobes Sediment (A5.13)
	721544	5954669	11/05/19 01:25:39									
Nord Transekt 1	721487	5954681	11/05/19 00:49:09	N_T_1_002.jpg	Leicht kiesiger Grobsand mit Muschelfragmenten, der unregelmäßige Wellenmuster bildet. 'Höhlen', die von *Ensis* gebildet werden, die sich unter die Oberfläche zurückziehen, wenn der Kameraschlitten in Kontakt mit dem Meeresboden kommt	*Asterias rubens*, *Lanice conchilega*, *Cancer pagurus*, *Pagurus bernhardus*, Actiniaria, Paguridae, *Ensis* sp., Brachyura, Actinopterygii, *Cancer pagurus*, Pleuronectiform, *Limanda*, *Liocarcinus* sp., Cerianthidae	29	k.A.	k.A.	k.A.	k.A.	Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und kiesigem Mischsand (A5.137)
	721425	5954656	11/05/19 00:55:02									
	721425	5954656	11/05/19 00:55:03	N_T_1_021.jpg	Dichte Ansammlungen von *Lanice conchilega*, *Asterias rubens* und *Ensis-Muscheln* auf kiesigem			k.A.	k.A.	k.A.	k.A.	Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und

ED50, UTM 31N, CM 3° E												
Station	Ostwert (m)	Nordwert (m)	Datum & Uhrzeit	Beispielfoto (Dateiname)	Sediment-Typ	Auffällige Fauna	Tiefe (m)	Steinige Riffigkeit (nach Irving 2009)			Gesamtstruktur des Riffs	EUNIS Habitat-Klassifizierung mit SBF/Habitat-Karte Farbcode
								Zusammensetzung (% Bedeckung mit Steinen/Geröllen)	Höhe (von Steinen/Geröll in cm)	Riffstruktur Matrix		
	721392	5954643	11/05/19 00:57:24		Grobsand. 'Höhlen', die von *Ensis* gebildet werden, die sich unter die Oberfläche zurückziehen, wenn der Kameraschlitten in Kontakt mit dem Meeresboden kommt.							kiesigem Mischsand (A5.137)
	721391	5954643	11/05/19 00:57:25	N_T_1_028.jpg	Leicht kiesiger Grobsand mit Muschelfragmenten. 'Höhlen', die von *Ensis* gebildet werden, die sich unter die Oberfläche zurückziehen, wenn der Kameraschlitten in Kontakt mit dem Meeresboden kommt			k.A.	k.A.	k.A.	k.A.	Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und kiesigem Mischsand (A5.137)
	721363	5954633	11/05/19 00:59:20									

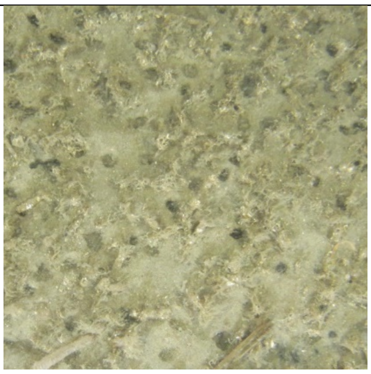
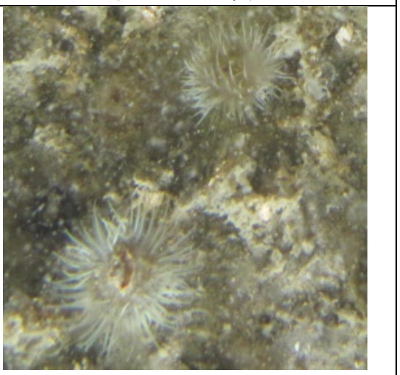
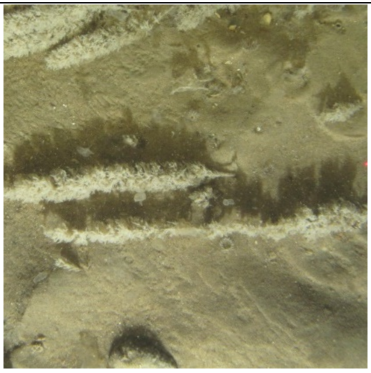
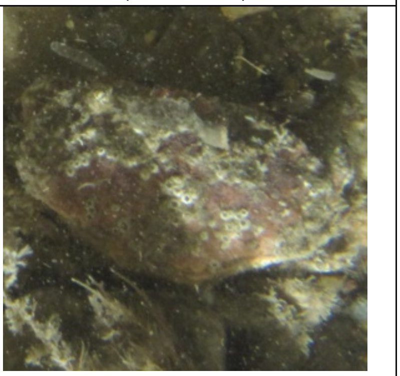
ED50, UTM 31N, CM 3° E												
Station	Ostwert (m)	Nordwert (m)	Datum & Uhrzeit	Beispielfoto (Dateiname)	Sediment-Typ	Auffällige Fauna	Tiefe (m)	Steinige Riffigkeit (nach Irving 2009)			Gesamtstruktur des Riffs	EUNIS Habitat-Klassifizierung mit SBF/Habitat-Karte Farbcode
								Zusammensetzung (% Bedeckung mit Steinen/Geröllen)	Höhe (von Steinen/Geröll in cm)	Riffstruktur Matrix		
Nord Transekt 2	721609	5954992	11/05/19 00:06:16	N_T_2_003.jpg	Leicht kiesiger Grobsand mit Muschelfragmenten, der unregelmäßige Wellenmuster bildet. 'Höhlen', die von *Ensis* gebildet werden, die sich unter die Oberfläche zurückziehen, wenn der Kameraschlitten in Kontakt mit dem Meeresboden kommt	*Asterias rubens, Lanice conchilega, Cancer pagurus, Pagurus bernhardus, Cancer pagurus, Pleuronectiform, Callionymus lyra, Bachyura, Actiniaria, Sepiidae, Liocarcinus sp., Ceriantidae*	29	k.A.	k.A.	k.A.	k.A.	Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und kiesigem Mischsand (A5.137)
	721618	5955031	11/05/19 00:10:55									
	721617	5955032	11/05/19 00:10:56	N_T_2_014.jpg	Kiesiger Grobsand mit Muschelfragmenten, der unregelmäßige Wellenmuster bildet. 'Höhlen', die von *Ensis* gebildet werden, die sich unter die Oberfläche zurückziehen, wenn der Kameraschlitten in Kontakt mit dem Meeresboden kommt			k.A.	k.A.	k.A.	k.A.	Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und kiesigem Mischsand (A5.137)
	721625	5955086	11/05/19 00:14:33									
	721625	5955086	11/05/19 00:14:34	N_T_2_038.jpg	Dichte Ansammlungen von *Lanice conchilega, Asterias rubens* und *Ensis-Muscheln* auf kiesigem			k.A.	k.A.	k.A.	k.A.	Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und

ED50, UTM 31N, CM 3° E												
Station	Ostwert (m)	Nordwert (m)	Datum & Uhrzeit	Beispielfoto (Dateiname)	Sediment-Typ	Auffällige Fauna	Tiefe (m)	Steinige Riffigkeit (nach Irving 2009)			Gesamtstruktur des Riffs	EUNIS Habitat-Klassifizierung mit SBF/Habitat-Karte Farbcode
								Zusammensetzung (% Bedeckung mit Steinen/Geröllen)	Höhe (von Steinen/Geröll in cm)	Riffstruktur Matrix		
	721631	5955141	11/05/19 00:18:28		Grobsand. 'Höhlen', die von *Ensis* gebildet werden, die sich unter die Oberfläche zurückziehen, wenn der Kameraschlitten in Kontakt mit dem Meeresboden kommt.							kiesigem Mischsand (A5.137)
	721631	5955142	11/05/19 00:18:29	N_T_2_041.jpg	Leicht kiesiger Grobsand mit Muschelfragmenten. 'Höhlen', die von *Ensis* gebildet werden, die sich unter die Oberfläche zurückziehen, wenn der Kameraschlitten in Kontakt mit dem Meeresboden kommt			k.A.	k.A.	k.A.	k.A.	Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und kiesigem Mischsand (A5.137)
	721632	5955153	11/05/19 00:19:05									
Nord Transekt 3	721902	5954408	11/05/19 02:04:47	N_T_3_010.jpg	Dichte Ansammlungen von *Lanice conchilega*, *Asterias rubens* und *Ensis-Muscheln* auf kiesigem Grobsand. 'Höhlen', die von *Ensis* gebildet werden, die sich unter die Oberfläche zurückziehen, wenn der Kameraschlitten in Kontakt mit dem Meeresboden kommt.	*Asterias rubens, Lanice conchilega, Cancer pagurus, Pagurus bernhardus, Cancer pagurus, Pleuronectiform, Actiniaria, Gobiidae, Paguridea, Ensis sp., Limanda, Metridium senile, Liocarcinus sp., Eutrigla gurnardus, Cerianthidae*	29	k.A.	k.A.	k.A.	k.A.	Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und kiesigem Mischsand (A5.137)
	721888	5954432	11/05/19 02:07:32									

ED50, UTM 31N, CM 3° E												
Station	Ostwert (m)	Nordwert (m)	Datum & Uhrzeit	Beispielfoto (Dateiname)	Sediment-Typ	Auffällige Fauna	Tiefe (m)	Steinige Riffigkeit (nach Irving 2009)			Gesamtstruktur des Riffs	EUNIS Habitat-Klassifizierung mit SBF/Habitat-Karte Farbcode
								Zusammensetzung (% Bedeckung mit Steinen/Geröllen)	Höhe (von Steinen/Geröll in cm)	Riffstruktur Matrix		
	721887	5954432	11/05/19 02:07:33	N_T_3_018.jpg	Leicht kiesiger Grobsand mit Muschelfragmenten. 'Höhlen', die von *Ensis* gebildet werden, die sich unter die Oberfläche zurückziehen, wenn der Kameraschlitten in Kontakt mit dem Meeresboden kommt			k.A.	k.A.	k.A.	k.A.	Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und kiesigem Mischsand (A5.137)
	721865	5954461	11/05/19 02:09:55									
	721865	5954461	11/05/19 02:09:56	N_T_3_039.jpg	Dichte Ansammlungen von *Lanice conchilega*, *Asterias rubens* und *Ensis-Muscheln* auf kiesigem Grobsand. 'Höhlen', die von *Ensis* gebildet werden, die sich unter die Oberfläche zurückziehen, wenn der Kameraschlitten in Kontakt mit dem Meeresboden kommt.			k.A.	k.A.	k.A.	k.A.	Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und kiesigem Mischsand (A5.137)
	721824	5954518	11/05/19 02:14:38									
	721823	5954519	11/05/19 02:14:39	N_T_3_050.jpg	Leicht kiesiger Grobsand mit Muschelfragmenten. 'Höhlen', die von *Ensis*			k.A.	k.A.	k.A.	k.A.	Dichte *Lanice conchilega* und andere Polychaeten in gezeitenabhängigem Infralitoralsand und

ED50, UTM 31N, CM 3˚ E												
Station	Ostwert (m)	Nordwert (m)	Datum & Uhrzeit	Beispielfoto (Dateiname)	Sediment-Typ	Auffällige Fauna	Tiefe (m)	Steinige Riffigkeit (nach Irving 2009)			Gesamtstruktur des Riffs	EUNIS Habitat-Klassifizierung mit SBF/Habitat-Karte Farbcode
								Zusammensetzung (% Bedeckung mit Steinen/Geröllen)	Höhe (von Steinen/Geröll in cm)	Riffstruktur Matrix		
	721801	5954551	11/05/19 02:17:16		gebildet werden, die sich unter die Oberfläche zurückziehen, wenn der Kameraschlitten in Kontakt mit dem Meeresboden kommt. Gelegentliche Felsbrocken.							kiesigem Mischsand (A5.137)

ANHANG C – BEISPIELE AUFFÄLLIGER ARTEN AUS MEERESBODENFOTOGRAFIE

Beispiele für auffällige Fauna		
 Gemeiner Seestern (*Asterias rubens*)	 Amerikanische Schwertmuschel (*Ensis leei*)	 Schwimmkrabbe (*Liocarcinus* sp.)
 Der Taschenkrebs (*Krebs pagurus*)	 Bäumchenröhrenwurm (*Lanice conchilega*)	 Meerseringelwürmer (Cerianthidae)
 Einsiedlerkrebs (Paguridae)	 Hydroide (*Sertularia*)	 Seepocken auf einem Taschenkrebs (Cirripedia und *Krebs pagurus*)
 Sandaal (*Ammodytes sp.*)	 Eingegrabener Schlangenstern (Ophiuroid)	 gestreifter Leierfisch (*Callionymus lyra*)

ANHANG D – FOTOS DER PROBE UND DES MEERESBODENS

Habitat Summary Information: Grab_P_0

Survey Area: N5a Pipeline

No. of Stills: 27 **Mins of Video: 7** **Track Length: 70m**

Site Selection Criteria

Pipeline Route - Positioned at 1km intervals. Investigating area of mixed reflectivity sediment.

Analogue Interpretation

Variable mixed reflectivity with many raised areas.

Sediment Description

Coarse sand littered with shell fragments and lanice conchilega assemblages.

Conspicuous Fauna

Cnidaria: Actiniaria sp., *Ceriantus* sp., Cerianthidae sp. **Annelida:** *Lanice conchilega* (Sand Mason). **Arthropoda:** Paguridae sp. , Decapoda sp. **Echinodermata:** *Asterias rubens* (Common starfish). **Chordata:** Gobiidae sp.

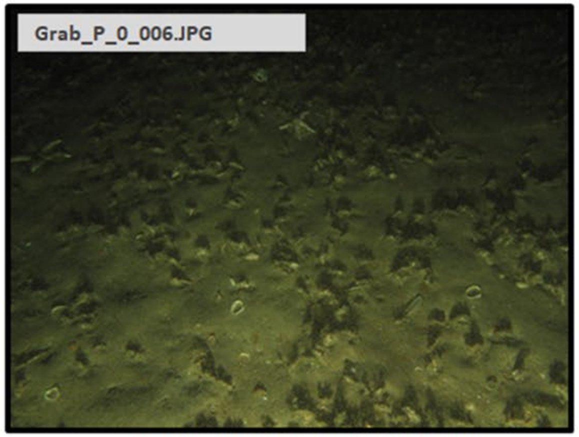


Photo Position: 721647 mE, 5954429 mN

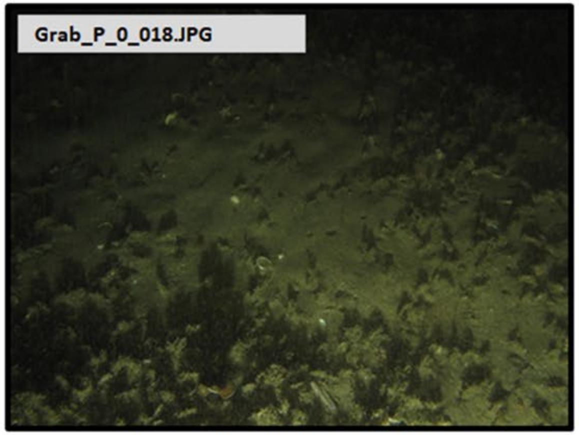


Photo Position: 721620 mE, 5954456 mN

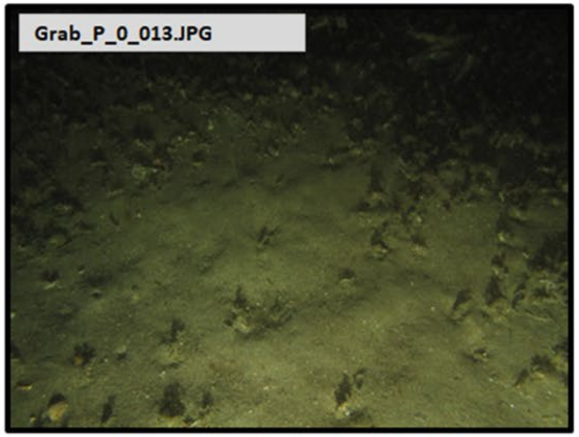


Photo Position: 721634 mE, 5954446 mN

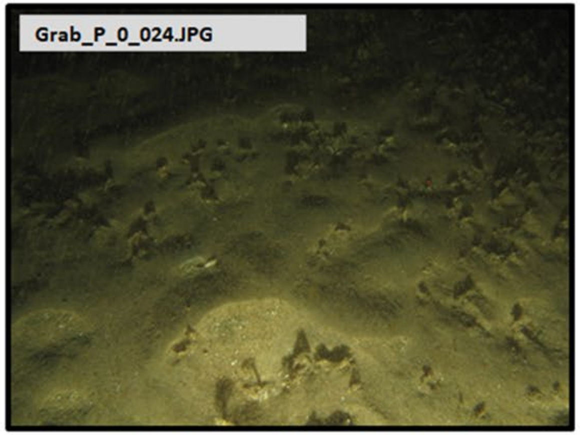
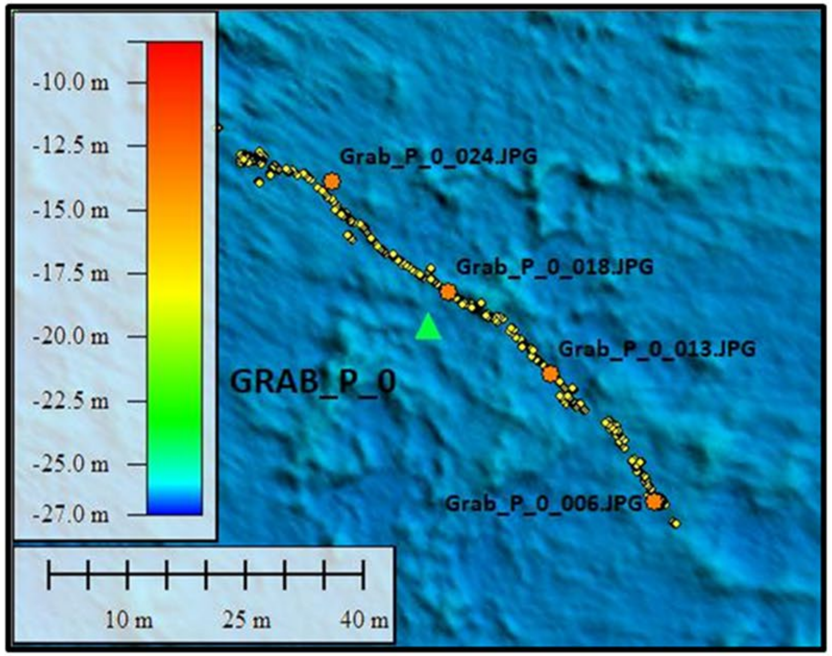


Photo Position: 721606 mE, 5954470 mN



one dyas benthic solutions limited GEO XYZ OFFSHORE

Sediment Example Image

Sieved Sample Image

▲ Grab Location ● Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

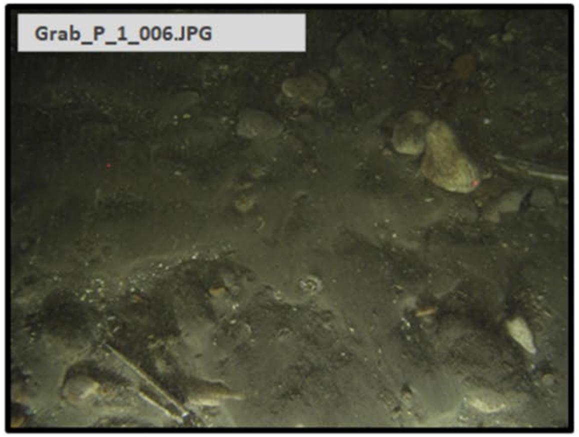


Photo Position: 721325 mE, 5953794 mN

Habitat Summary Information: Grab_P_01

Survey Area: N5a Pipeline

No. of Stills: 1 **Mins of Video: 2** **Track Length: DDV**

Site Selection Criteria

Moved from KP in order to investigate area of high reflectivity sediment.

Analogue Interpretation

Area of mixed high reflectivity.

Sediment Description

Coarse sand with cobbles.

Conspicuous Fauna

Cnidaria: *Cerianthus* sp. **Echinodermata:** *Asterias rubens* (Common starfish). **Bryozoa:** Bryozoa sp.

Only one image taken

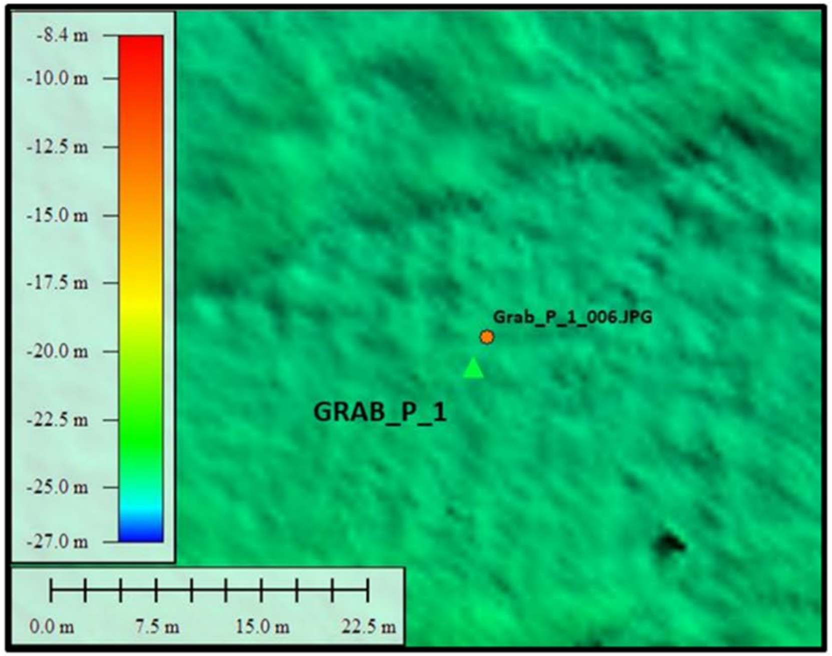
Photo Position: 0 mE, 0 mN

Only one image taken

Photo Position: 0 mE, 0 mN

Only one image taken

Photo Position: 0 mE, 0 mN



Sediment Example Image

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_P_02

Survey Area: N5a Pipeline

No. of Stills: 5 **Mins of Video:** 2 **Track Length:** DDV

Site Selection Criteria

Pipeline Route - Positioned at 1km intervals.

Analogue Interpretation

Low reflectivity.

Sediment Description

Coarse shelly sand with sand ribble bedform.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Arthropoda:** *Corystes cassivelaunus* (Masked crab).

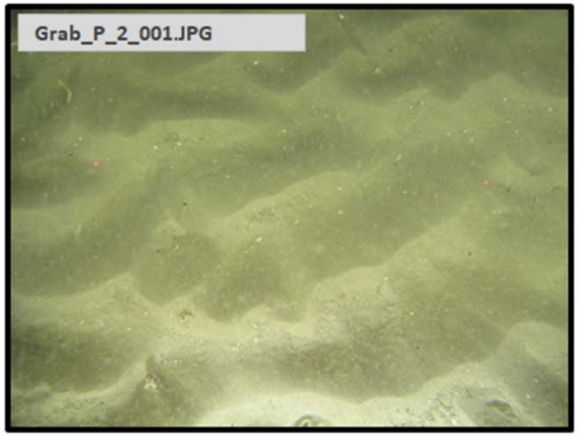


Photo Position: 720980 mE, 5952753 mN

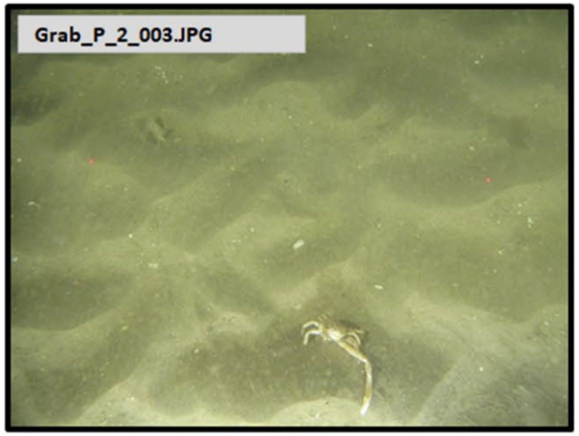
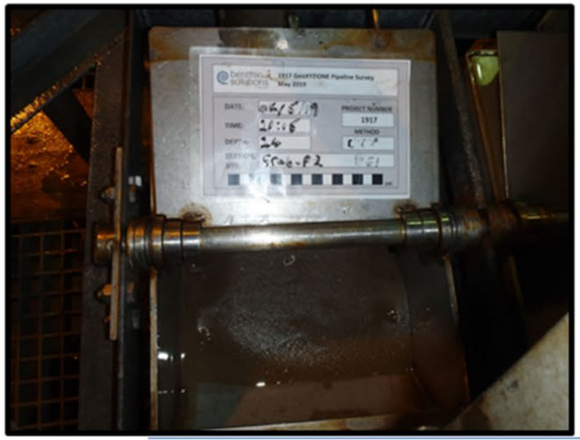
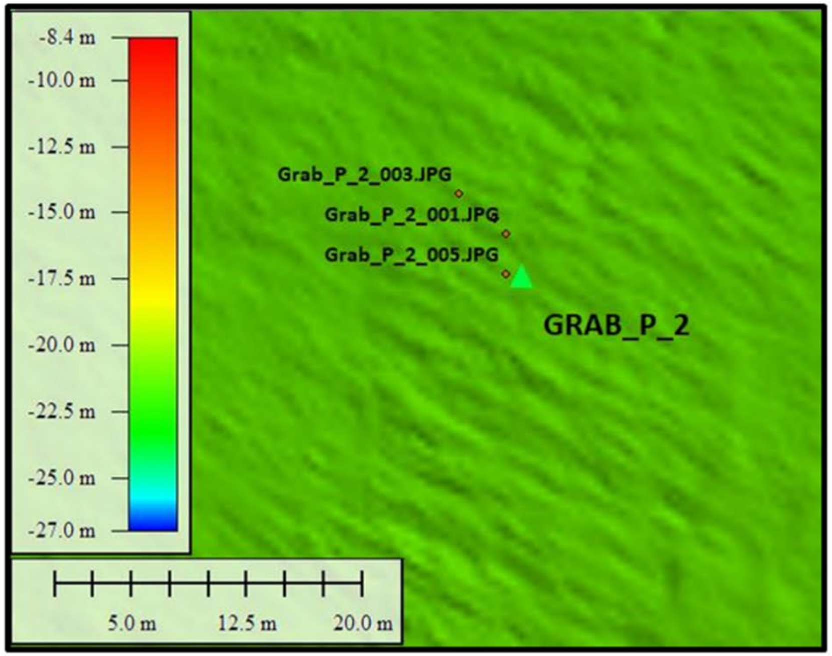


Photo Position: 720977 mE, 5952755 mN



Sediment Example Image



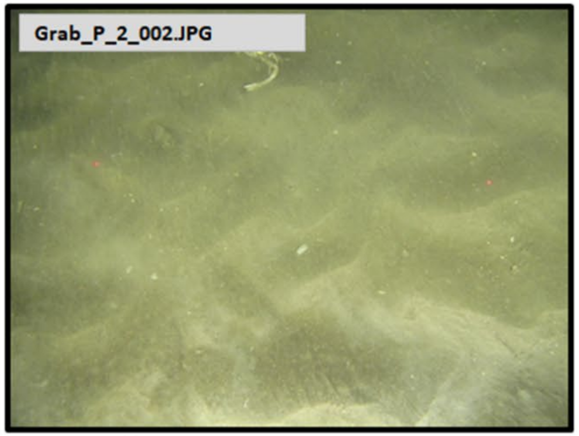


Photo Position: 720979 mE, 5952754 mN

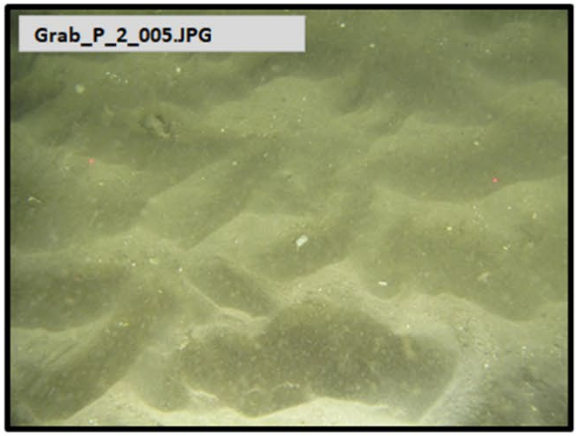


Photo Position: 720980 mE, 5952750 mN

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_P_03

Survey Area: N5a Pipeline

No. of Stills: 10 **Mins of Video: 3** **Track Length: DDV**

Site Selection Criteria

Pipeline Route - Positioned at 1km intervals.

Analogue Interpretation

Low reflectivity.

Sediment Description

Coarse sand forming ripples.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Arthropoda:** *Corystes cassivelaunus* (Masked crab). **Echinodermata:** *Asterias rubens* (Common starfish).

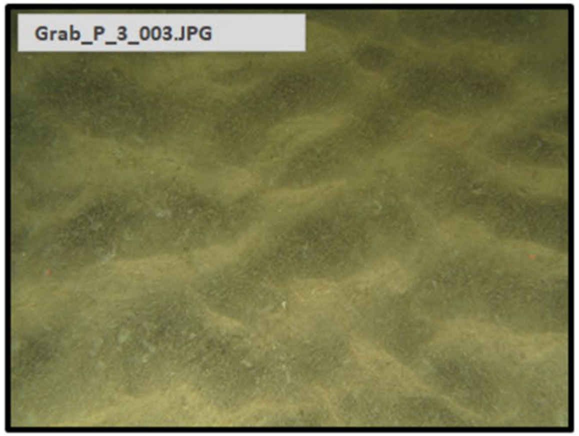


Photo Position: 720668 mE, 5951799 mN

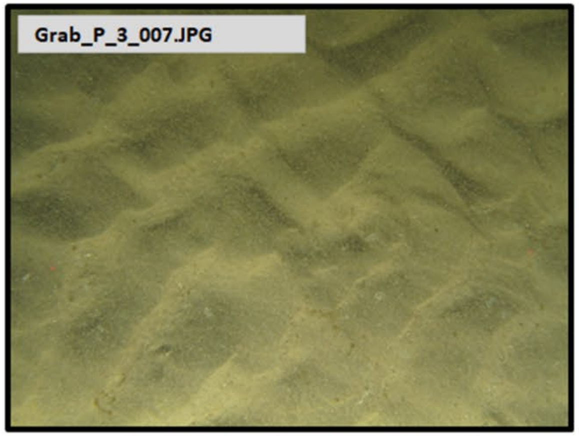
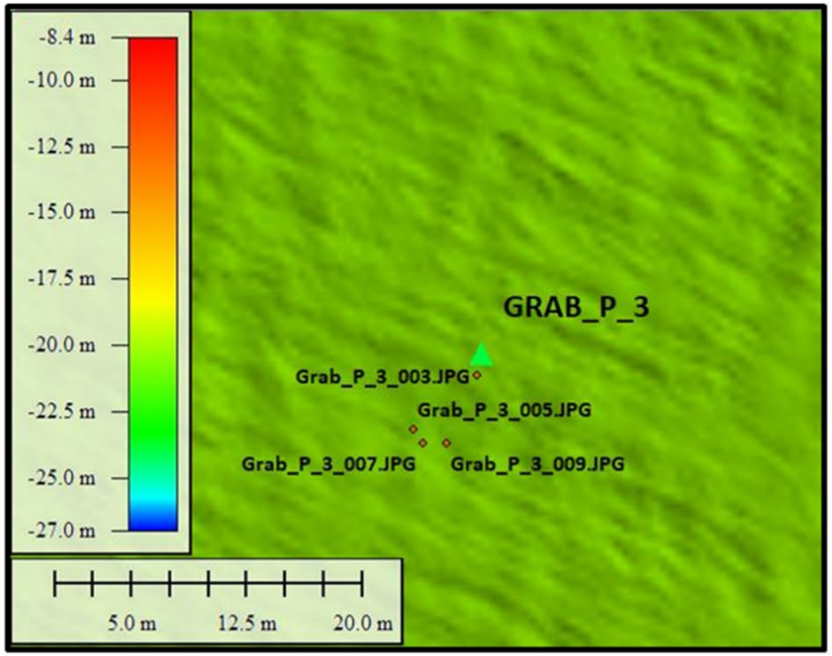


Photo Position: 720664 mE, 5951795 mN

Sediment Example Image



▲ Grab Location ● Camera Track ● Selected Underwater Still

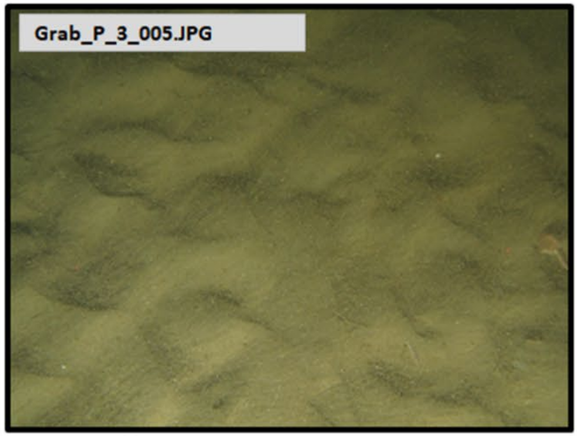


Photo Position: 720664 mE, 5951796 mN

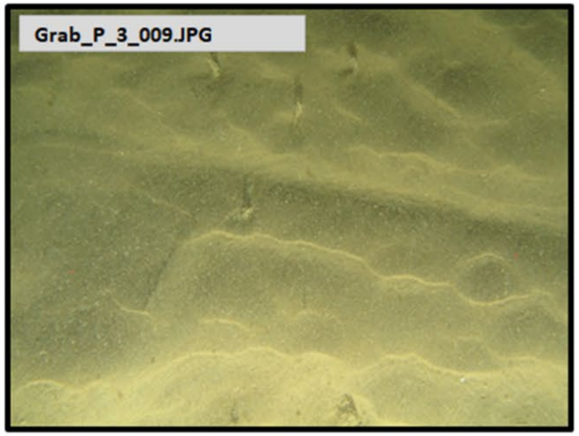


Photo Position: 720666 mE, 5951795 mN

Sieved Sample Image

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_P_04

Survey Area: N5a Pipeline

No. of Stills: 10 **Mins of Video: 3** **Track Length: DDV**

Site Selection Criteria

Pipeline Route - Positioned at 1km intervals.

Analogue Interpretation

Area of variable reflectivity indicating rippling.

Sediment Description

Coarse sand formed into sand ripples.

Conspicuous Fauna

Echinodermata: *Asterias rubens* (Common starfish), Ophiurida sp.

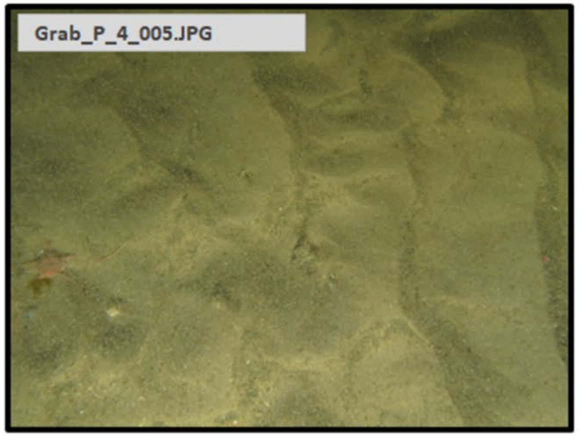


Photo Position: 720356 mE, 5950850 mN

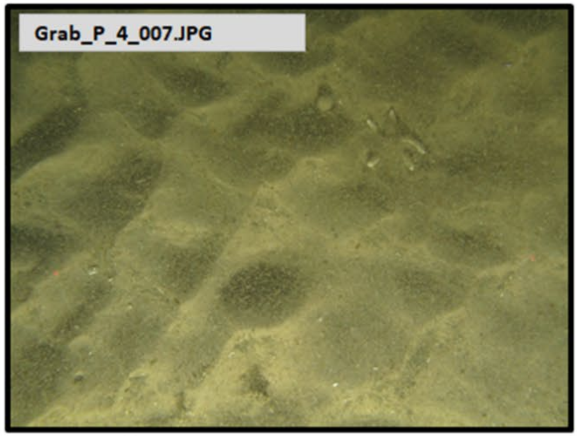


Photo Position: 720355 mE, 5950850 mN

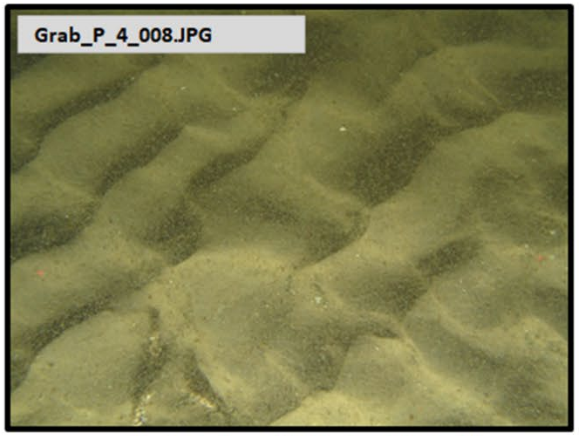
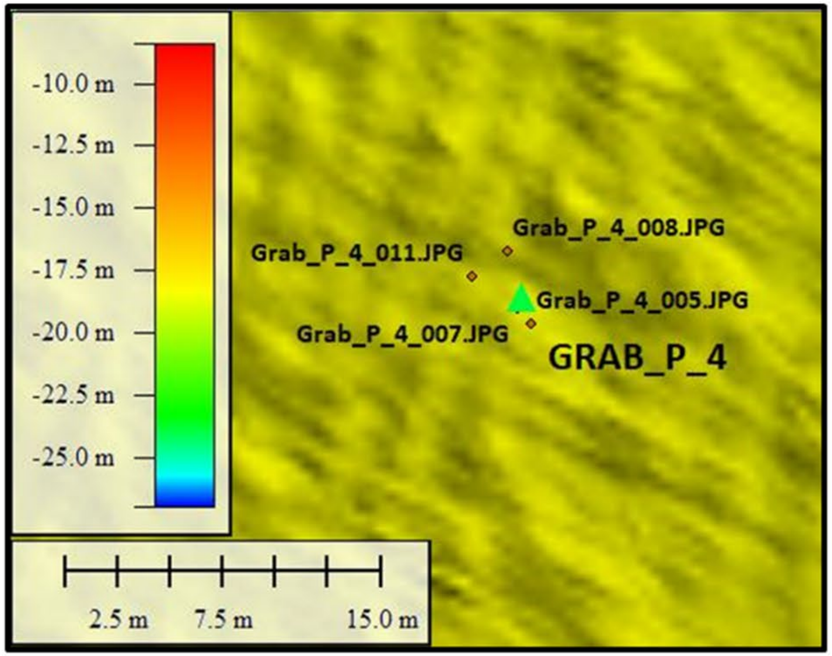


Photo Position: 720355 mE, 5950853 mN



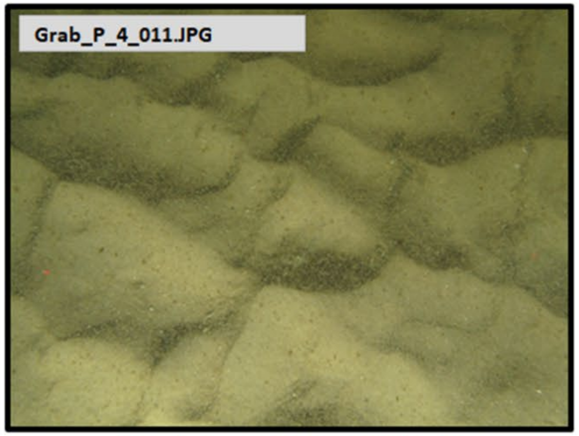


Photo Position: 720353 mE, 5950852 mN

Sediment Example Image

Sieved Sample Image

🟩 Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_P_05

Survey Area: N5a Pipeline

No. of Stills: 16 **Mins of Video: 2** **Track Length: DDV**

Site Selection Criteria

Pipeline Route - Positioned at 1km intervals.

Analogue Interpretation

Area of low, variable reflectivity.

Sediment Description

Coarse shelly sand with rare cobbles.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Arthropoda:** Paguridae sp. **Echinodermata:** *Asterias rubens* (Common starfish).

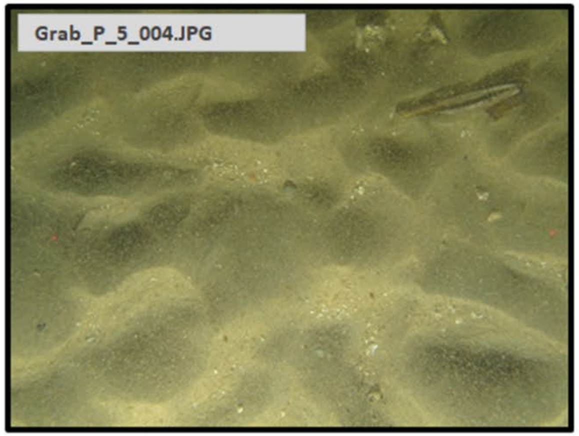


Photo Position: 720039 mE, 5949902 mN

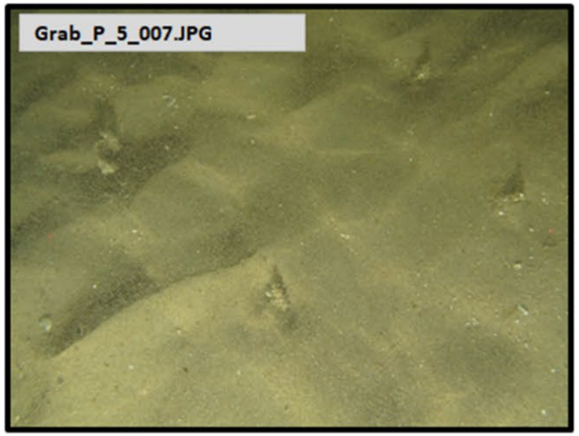


Photo Position: 720044 mE, 5949893 mN

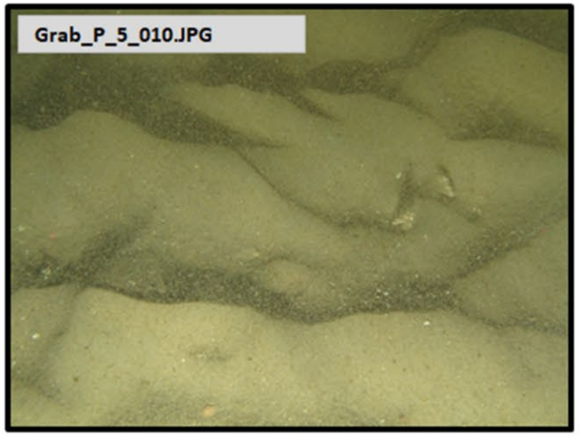
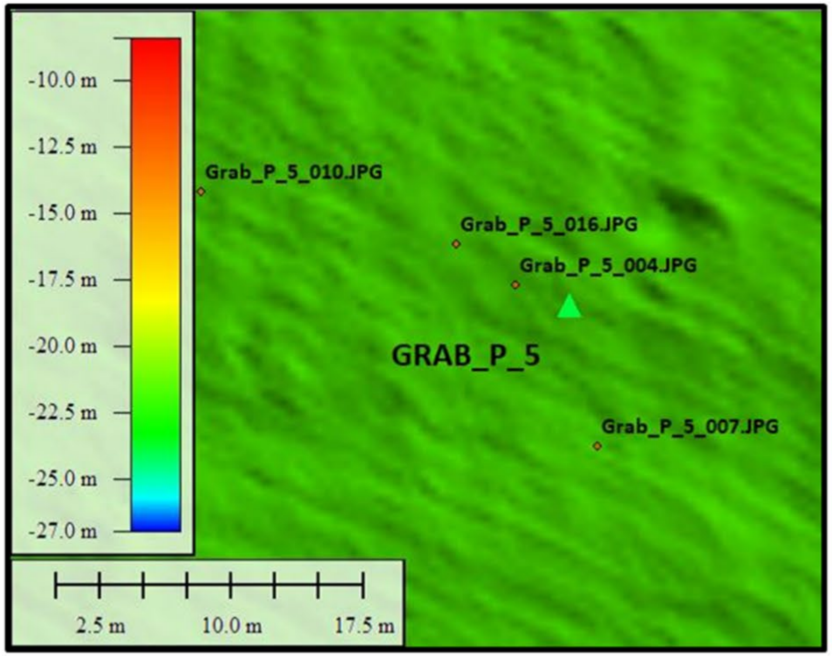


Photo Position: 720021 mE, 5949907 mN



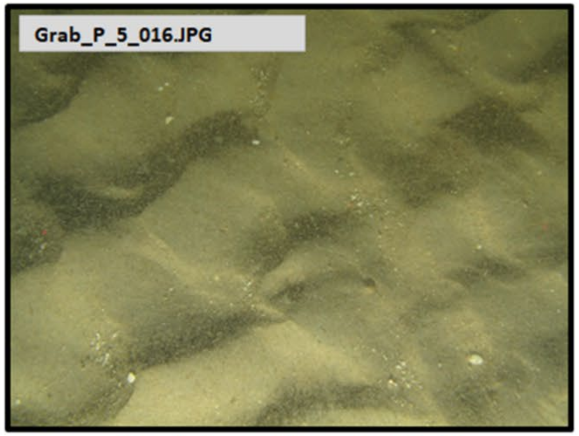


Photo Position: 720036 mE, 5949904 mN

Sediment Example Image

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_P_06

Survey Area: N5a Pipeline

No. of Stills: 12 **Mins of Video: 4** **Track Length: DDV**

Site Selection Criteria

Pipeline Route - Positioned at 1km intervals.

Analogue Interpretation

Area of slightly variable reflectivity.

Sediment Description

Coarse sand with irregular ripples.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Chordata:** Pleuronectiformes sp.

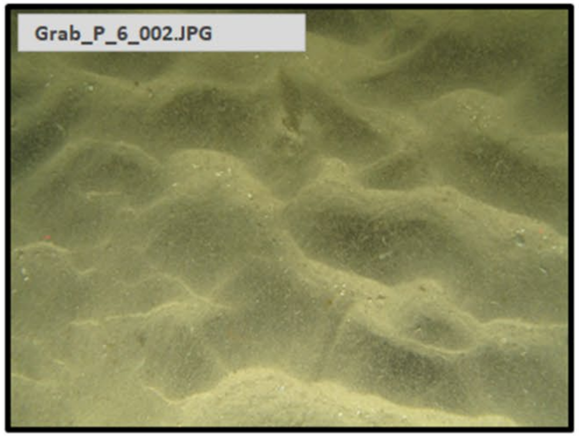

Grab_P_6_002.JPG

Photo Position: 719727 mE, 5948952 mN

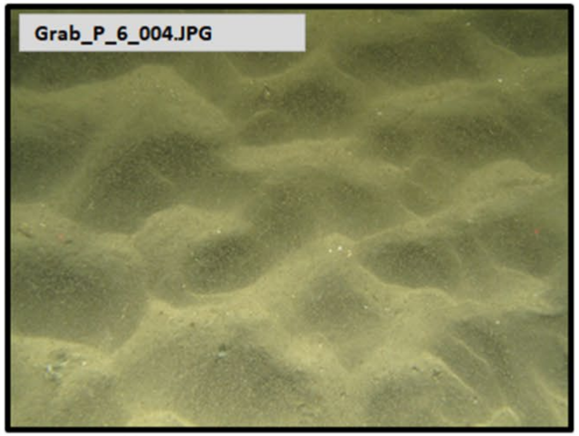

Grab_P_6_004.JPG

Photo Position: 719728 mE, 5948952 mN

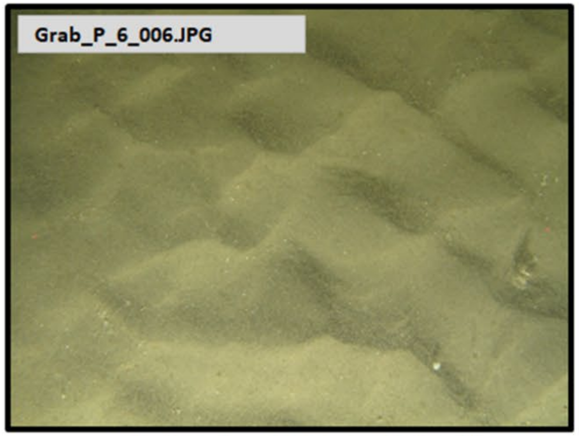

Grab_P_6_006.JPG

Photo Position: 719688 mE, 5948930 mN

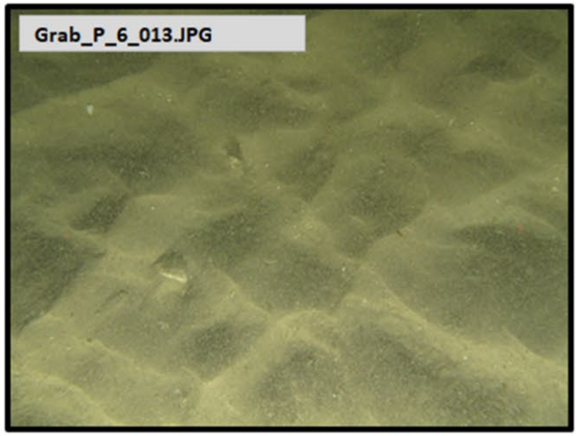
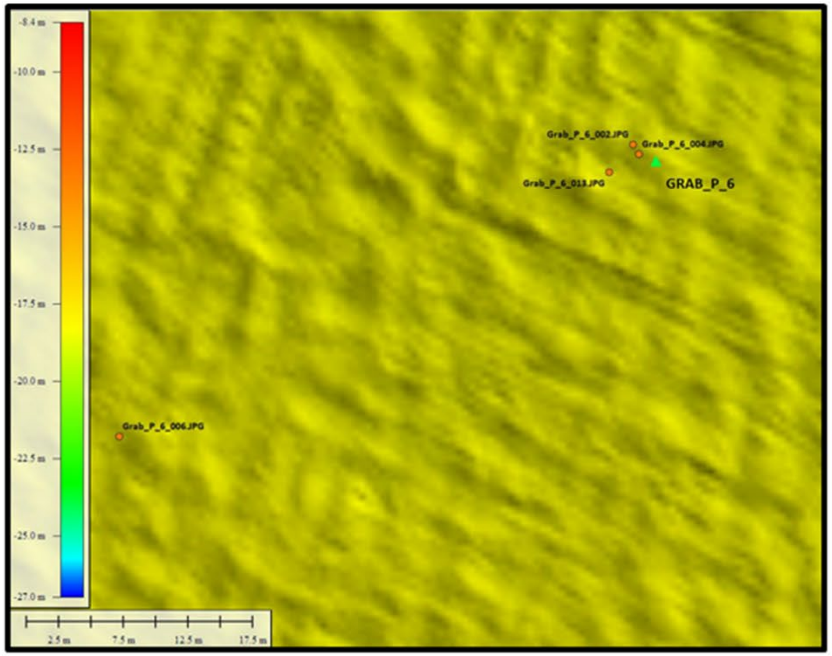
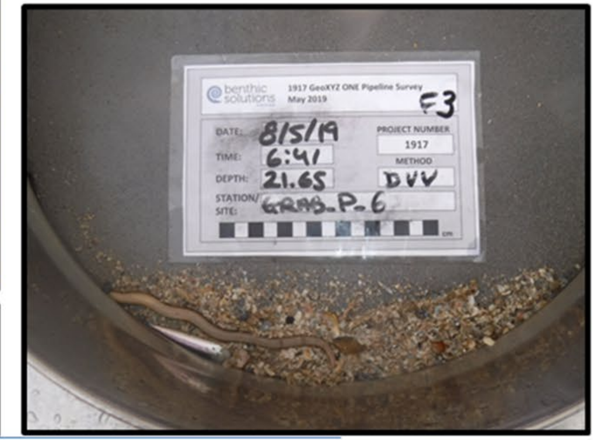

Grab_P_6_013.JPG

Photo Position: 719726 mE, 5948950 mN




F3
DATE: 8/5/19
TIME: 6:41
DEPTH: 21.43
STATION/SITE: GRAB.P.6
PROJECT NUMBER 1917
METHOD DVV

Sediment Example Image


benthic solutions 1917 GeoXYZ ONE Pipeline Survey May 2019
F3
DATE: 8/5/19
TIME: 6:41
DEPTH: 21.65
STATION/SITE: GRAB.P.6
PROJECT NUMBER 1917
METHOD DVV

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_P_07

Survey Area: N5a Pipeline

No. of Stills: 7	Mins of Video: 4	Track Length: DDV

Site Selection Criteria

Moved from KP to investigate mixed reflectivity sediment.

Analogue Interpretation

Area of variable reflectivity with scars in seabed.

Sediment Description

Coarse sand with irregular ripples.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Echinodermata:** Ophiurida sp. **Chordata:** *Callionymus lyra* (Common dragonet).

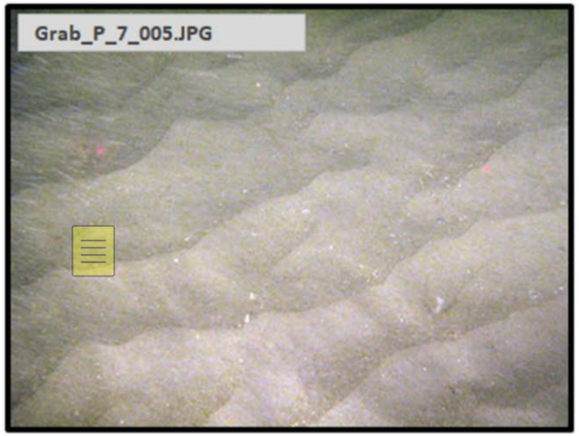


Photo Position: 719408 mE, 5948019 mN

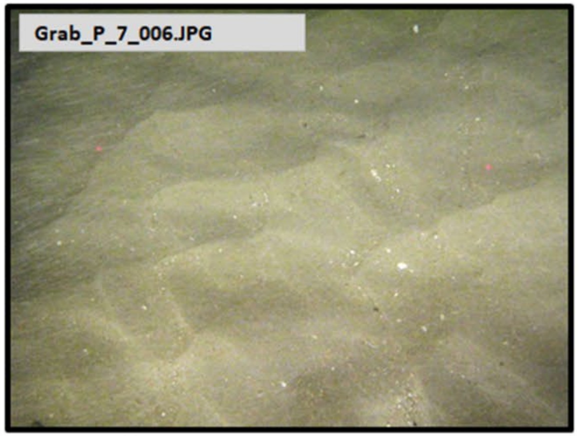


Photo Position: 719411 mE, 5948002 mN

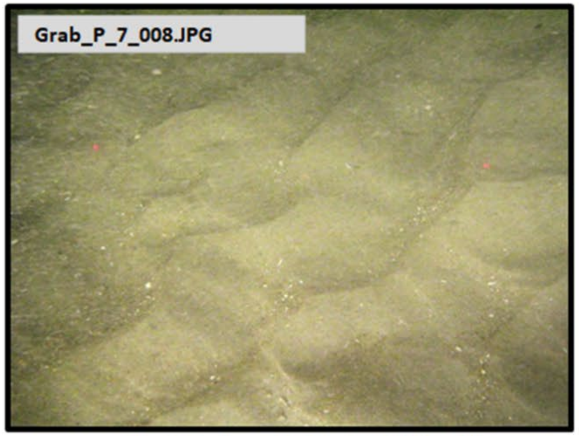
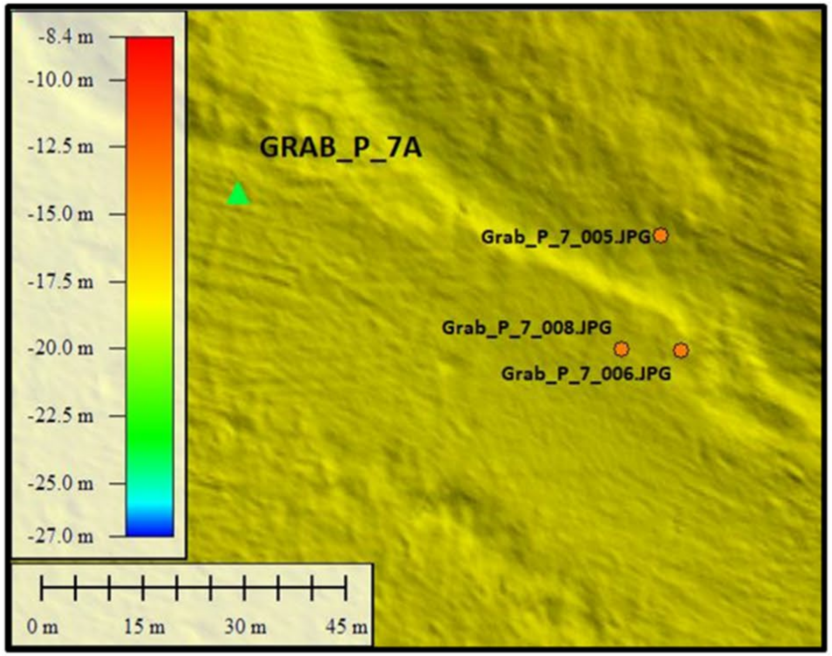
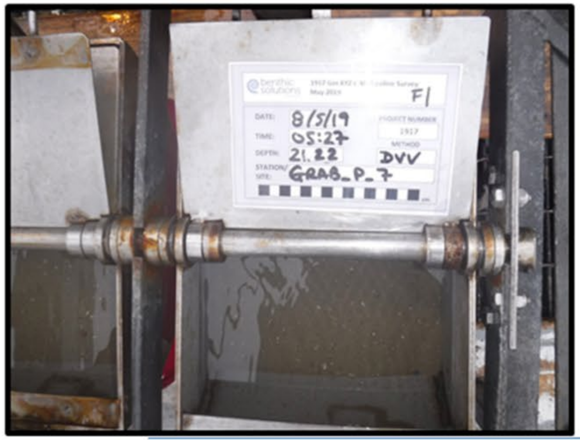


Photo Position: 719403 mE, 5948002 mN

Only 3 good quality seabed images





Sediment Example Image

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_P_08

Survey Area: N5a Pipeline

No. of Stills: 6 **Mins of Video: 2** **Track Length: DDV**

Site Selection Criteria

Pipeline Route - Positioned at 1km intervals.

Analogue Interpretation

Low reflectivity.

Sediment Description

Coarse sand and rare shell debris with irregular ripples

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason).

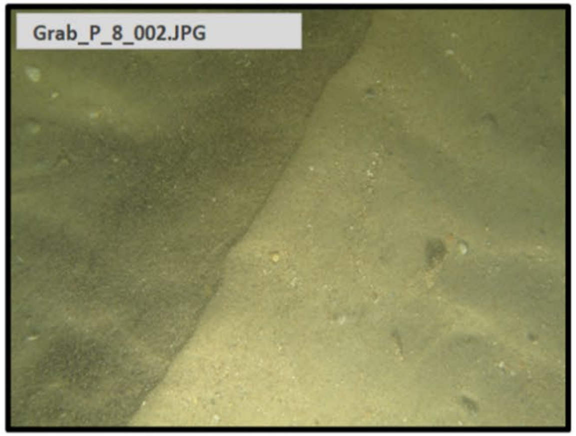


Photo Position: 719097 mE, 5947051 mN

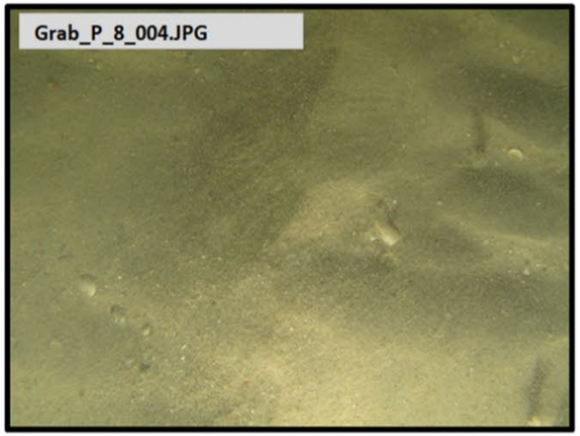


Photo Position: 719076 mE, 5947050 mN

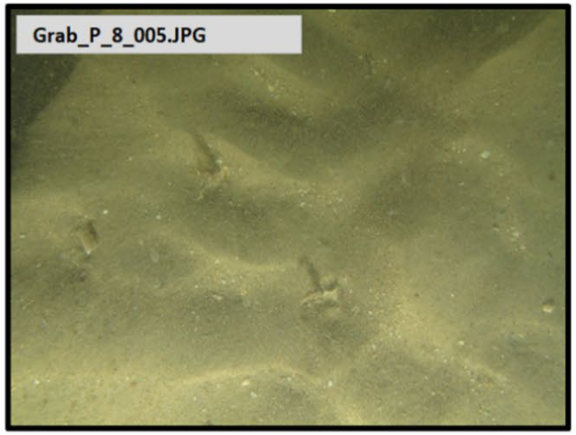


Photo Position: 719125 mE, 5947049 mN

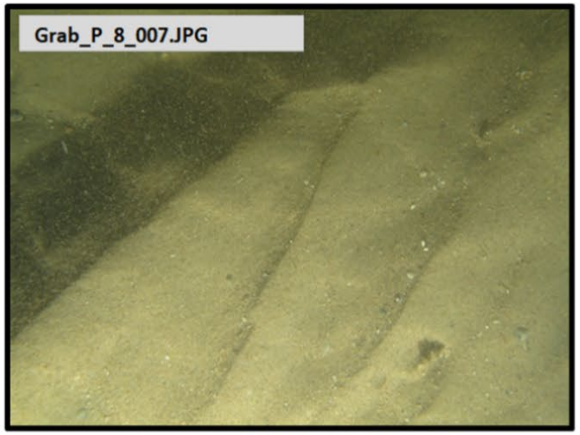
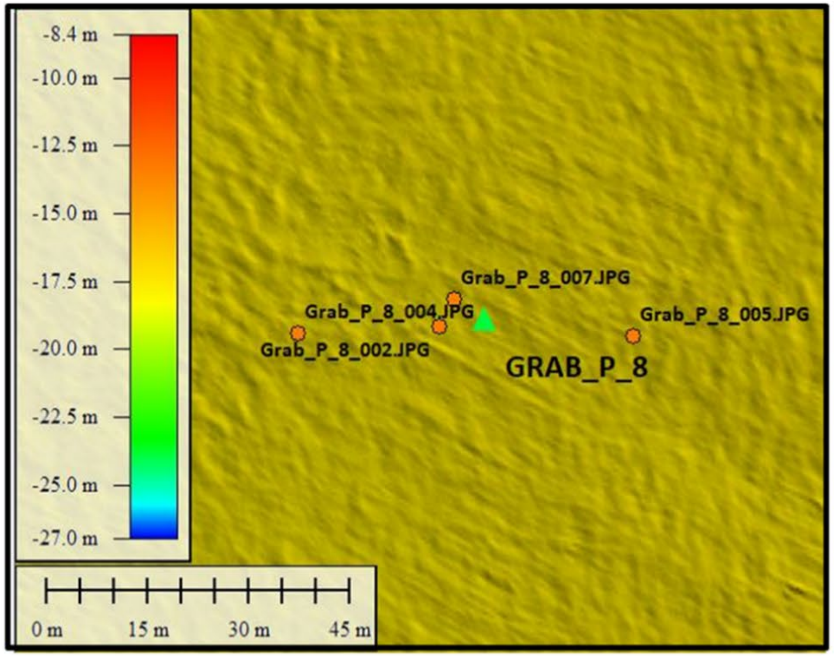
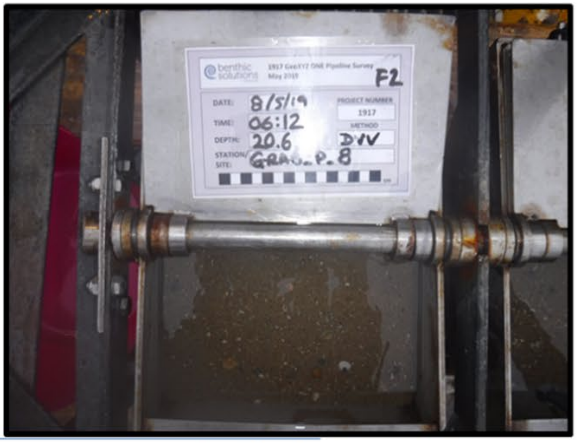


Photo Position: 719099 mE, 5947055 mN



Sediment Example Image



Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_P_09

Survey Area: N5a Pipeline

No. of Stills: 6 Mins of Video: 1 Track Length: DDV

Site Selection Criteria

Pipeline Route - Positioned at 1km intervals.

Analogue Interpretation

Variable reflectivity with scars in seabed.

Sediment Description

Coarse sand and rare shell debris with irregular ripples

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Arthropoda:** *Corystes cassivelaunus* (Masked crab). **Echinodermata:** *Asterias rubens* (Common starfish). **Chordata:** Actinopterygii sp.

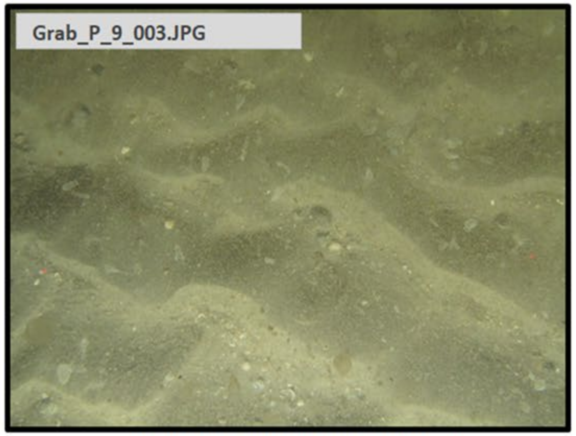


Photo Position: 718861 mE, 5945912 mN

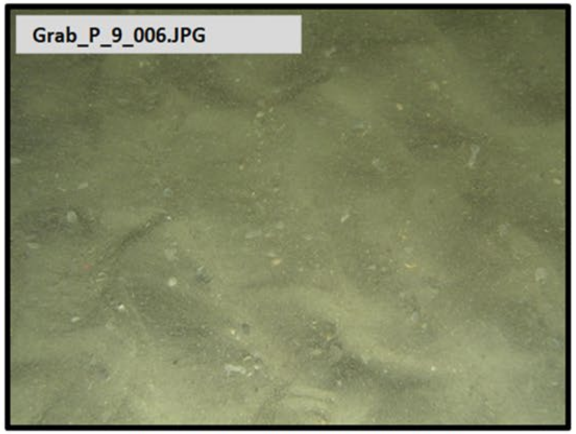
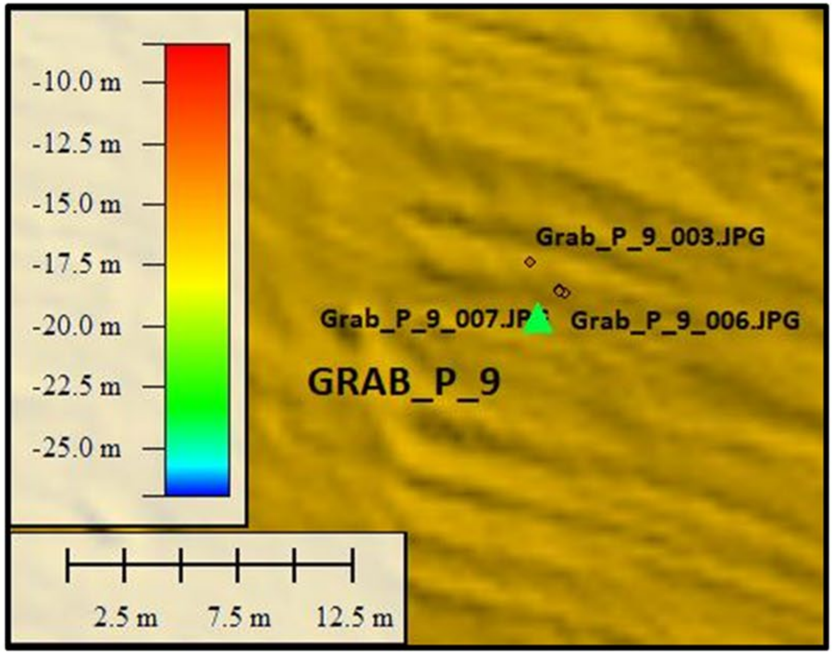


Photo Position: 718863 mE, 5945911 mN

Sediment Example Image



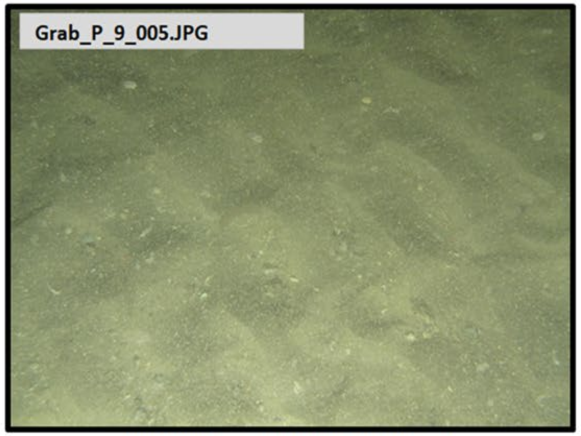


Photo Position: 718862 mE, 5945911 mN

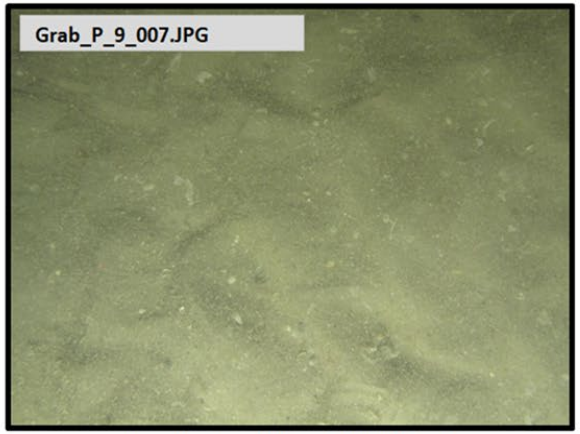


Photo Position: 718862 mE, 5945911 mN

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_P_010

Survey Area: N5a Pipeline

No. of Stills: 8 **Mins of Video:** 2 **Track Length:** DDV

Site Selection Criteria

Pipeline Route - Positioned at 1km intervals.

Analogue Interpretation

Area of variable reflectivity.

Sediment Description

Coarse sand.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Echinodermata:** *Asterias rubens* (Common starfish).

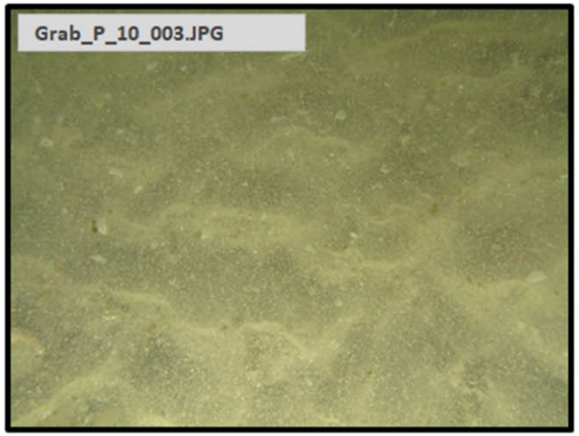


Photo Position: 718778 mE, 5944917 mN

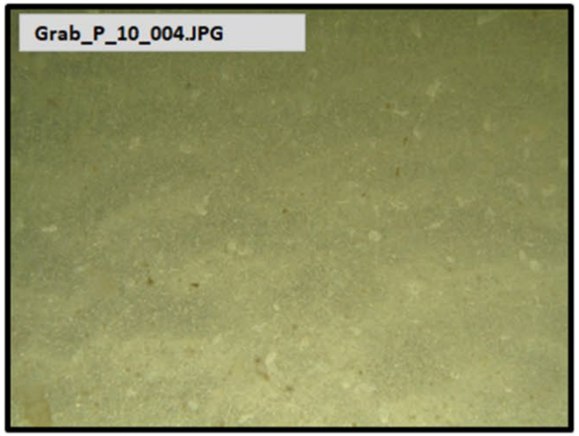


Photo Position: 718778 mE, 5944917 mN

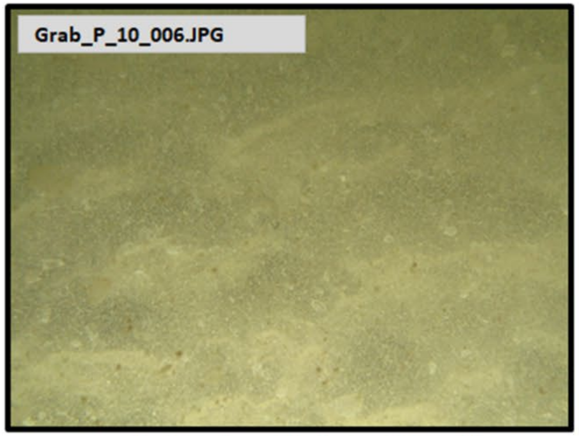


Photo Position: 718778 mE, 5944917 mN

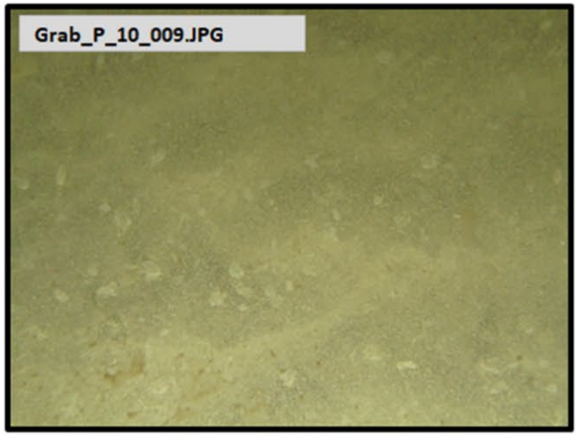
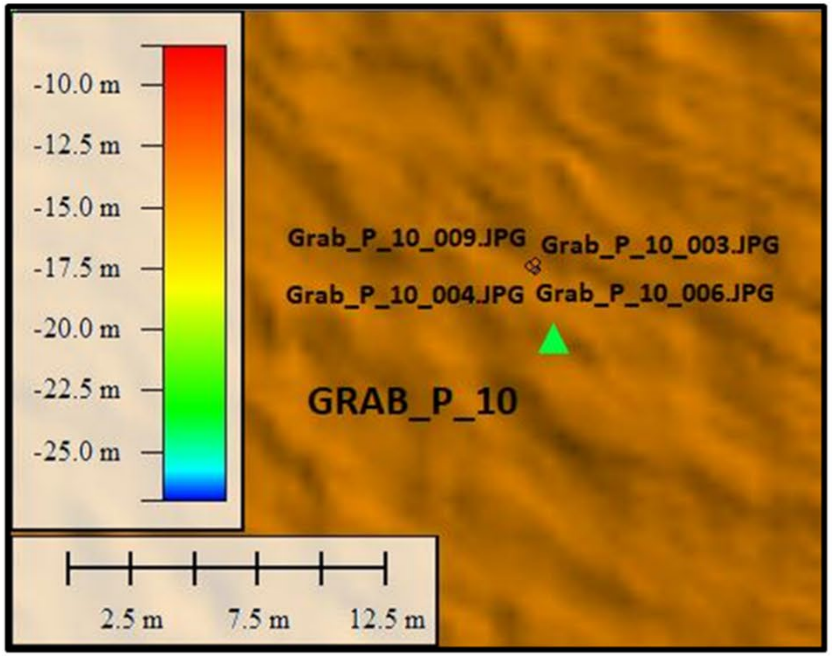


Photo Position: 718778 mE, 5944917 mN




benthic solutions 1917 GeoXYZ ONE Pipeline Survey May 2019 F2

DATE: 12/5/19 PROJECT NUMBER 1917

TIME: 05:44 METHOD

DEPTH: 17.40 DVV

STATION/SITE: GRAB_P_10

Sediment Example Image


benthic solutions 1917 GeoXYZ ONE Pipeline Survey May 2019 F2

DATE: 12/5/19 PROJECT NUMBER 1917

TIME: 05:44 METHOD

DEPTH: 17.40 DVV

STATION/SITE: GRAB_P_10

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_P_011

Survey Area: N5a Pipeline

No. of Stills: 8 **Mins of Video: 2** **Track Length: DDVm**

Site Selection Criteria

Pipeline Route - Positioned at 1km intervals.

Analogue Interpretation

Low reflectivity.

Sediment Description

Coarse sand and rare shell debris with irregular ripples.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Arthropoda:** Brachyura sp.

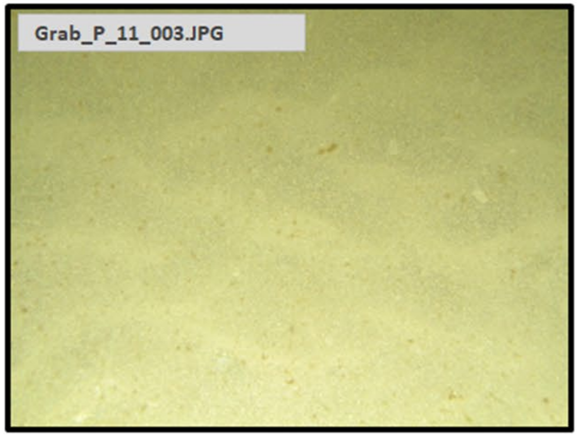


Photo Position: 718696 mE, 5943920 mN

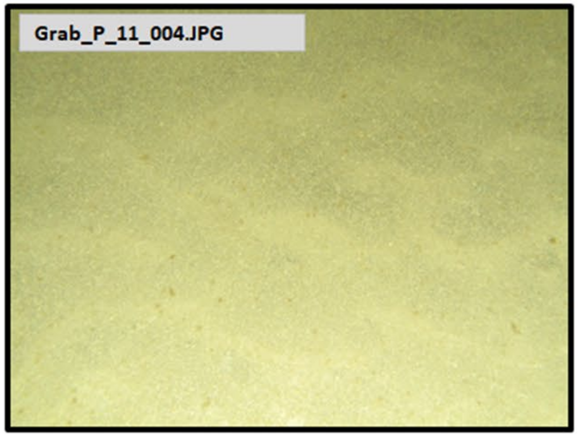


Photo Position: 718696 mE, 5943920 mN

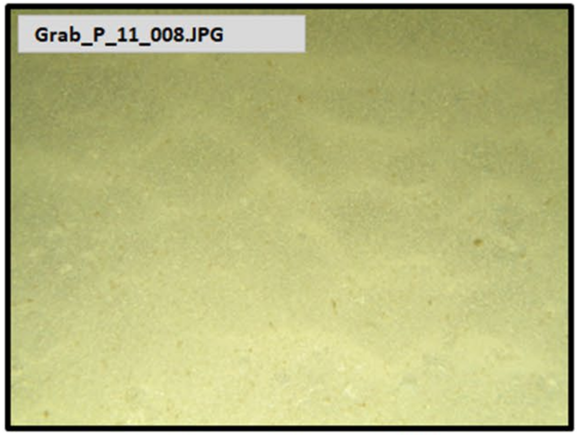


Photo Position: 718697 mE, 5943920 mN

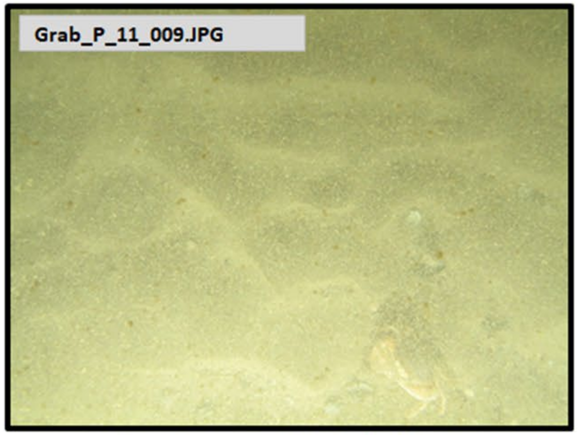
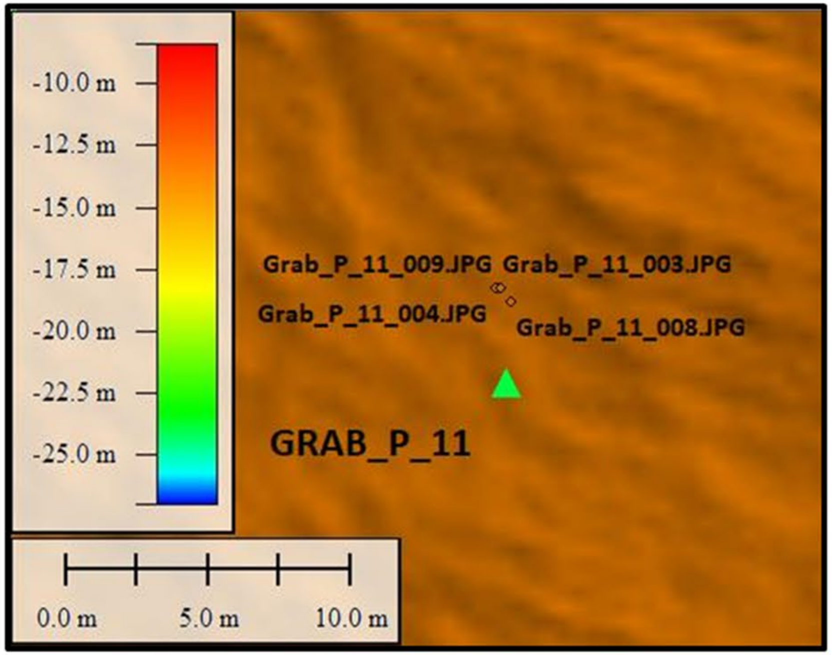


Photo Position: 718697 mE, 5943920 mN



Sediment Example Image

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_P_012

Survey Area: N5a Pipeline

No. of Stills: 8 **Mins of Video: 2** **Track Length: DDV**

Site Selection Criteria

Pipeline Route - Positioned at 1km intervals.

Analogue Interpretation

Area of variable reflectivity with depressions.

Sediment Description

Coarse sand and rare shell debris with irregular ripples.

Conspicuous Fauna

Cnidaria: Actiniaria sp. **Annelida:** *Lanice conchilega* (Sand Mason). **Arthropoda:** *Liocarcinus depurator* (Sandy swimming crab), Brachyura sp, *Cancer maenus* . **Echinodermata:** *Asterias rubens* (Common starfish). **Chordata:** *Callionymus lyra* (Common dragonet), Gobiidae sp.

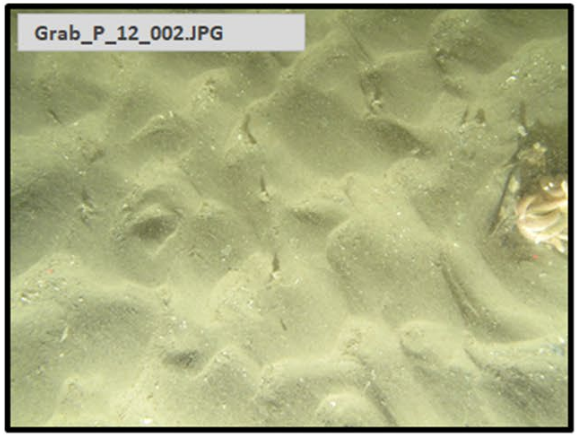


Photo Position: 718613 mE, 5942924 mN

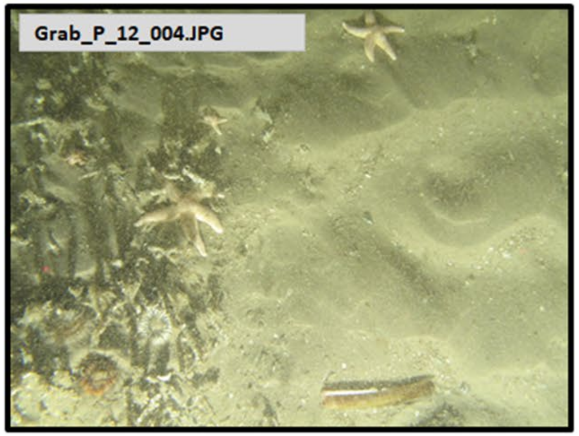


Photo Position: 718614 mE, 5942924 mN

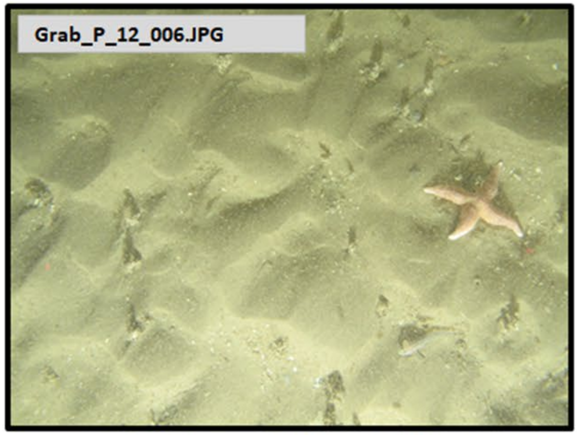


Photo Position: 718614 mE, 5942923 mN

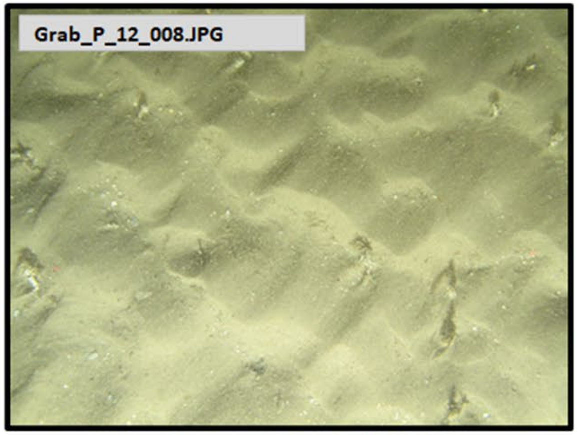
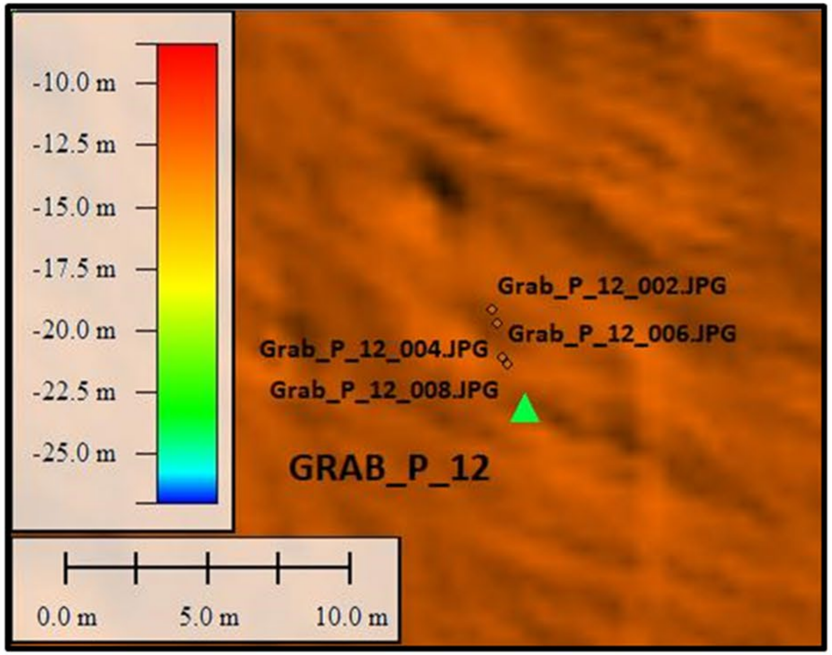


Photo Position: 718614 mE, 5942922 mN



Sediment Example Image

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_P_013

Survey Area: N5a Pipeline

No. of Stills: 7 **Mins of Video: 2** **Track Length: DDV**

Site Selection Criteria

Pipeline Route - Positioned at 1km intervals.

Analogue Interpretation

Area of low reflectivity with some potential scarring.

Sediment Description

Coarse sand with irregular ripples.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Echinodermata:** *Asterias rubens* (Common starfish), Ophiurida sp.

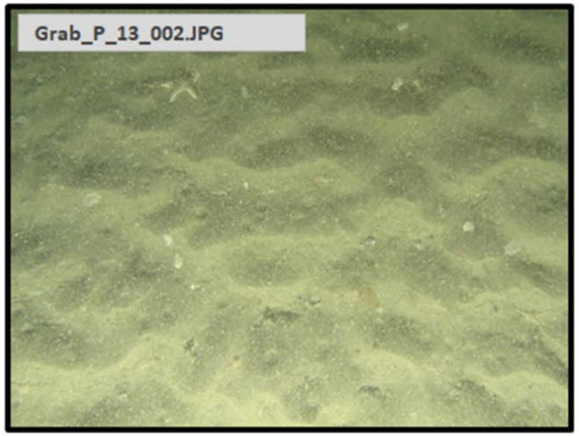


Photo Position: 718531 mE, 5941926 mN

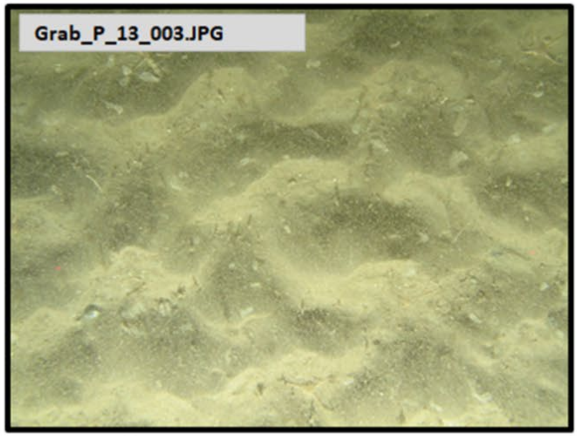


Photo Position: 718531 mE, 5941926 mN

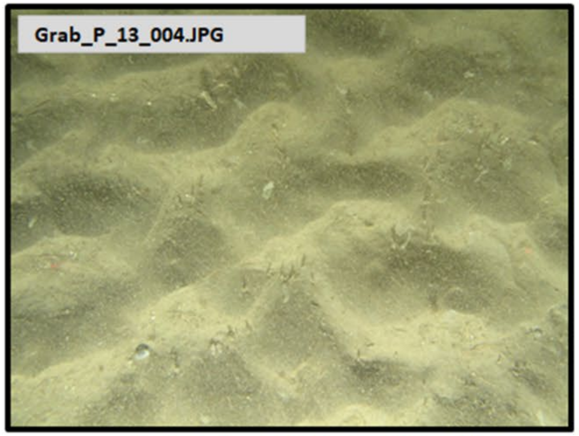


Photo Position: 718531 mE, 5941926 mN

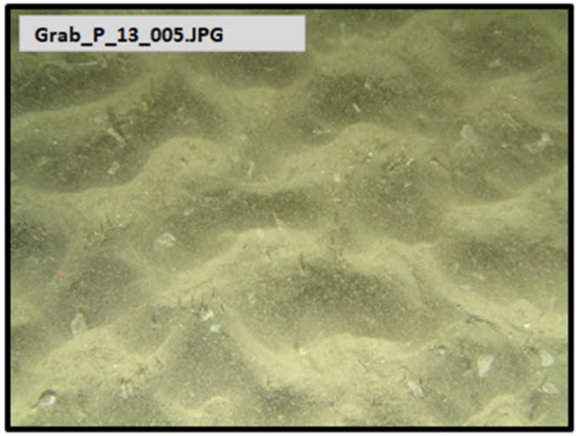
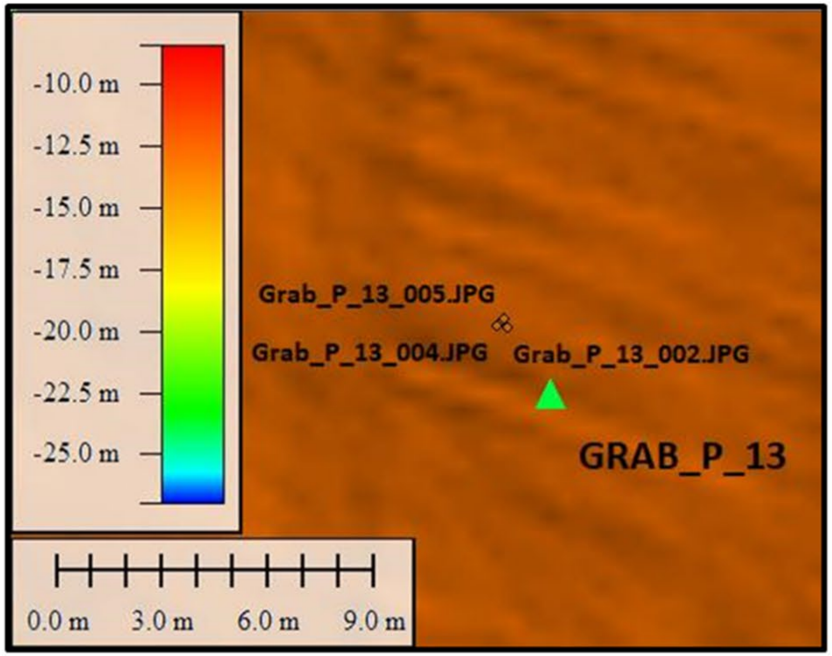
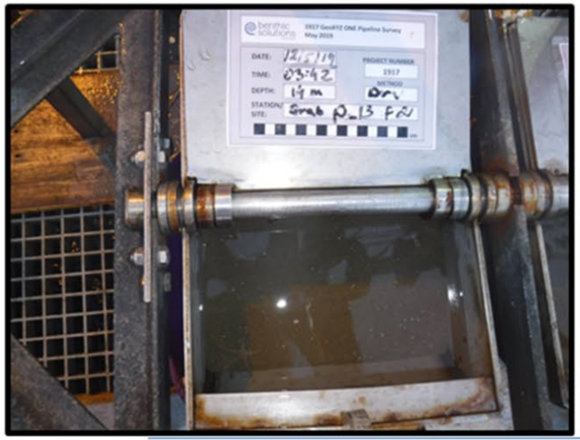


Photo Position: 718531 mE, 5941926 mN





Sediment Example Image

Sieved Sample Image

▲ Grab Location ● Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_P_014

Survey Area: N5a Pipeline

No. of Stills: 5 **Mins of Video:** 1 **Track Length:** DDV

Site Selection Criteria
Pipeline Route - Positioned at 1km intervals.

Analogue Interpretation
Low reflectivity

Sediment Description
No visiblity

Conspicuous Fauna
No visibility

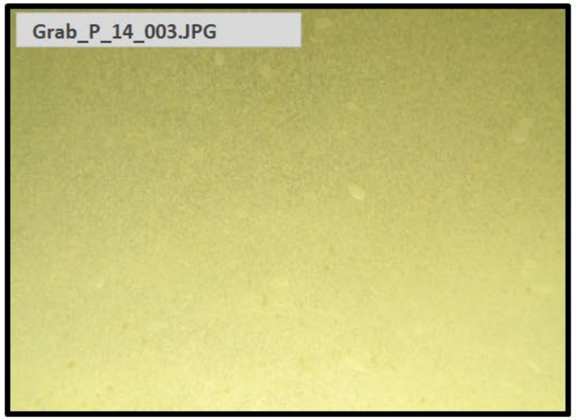

Grab_P_14_003.JPG

Photo Position: 718449 mE, 5940928 mN

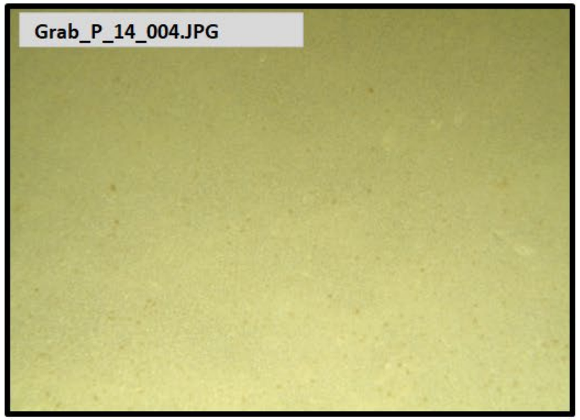

Grab_P_14_004.JPG

Photo Position: 718451 mE, 5940927 mN

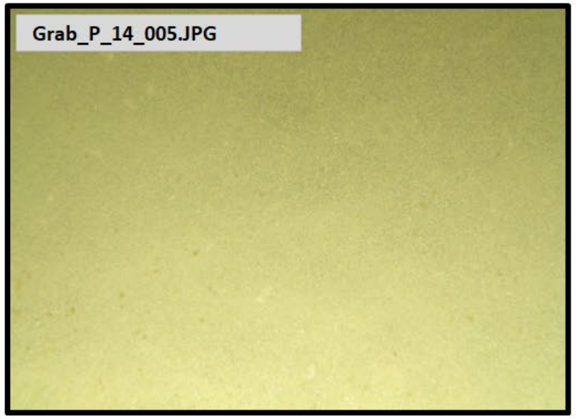

Grab_P_14_005.JPG

Photo Position: 718450 mE, 5940928 mN

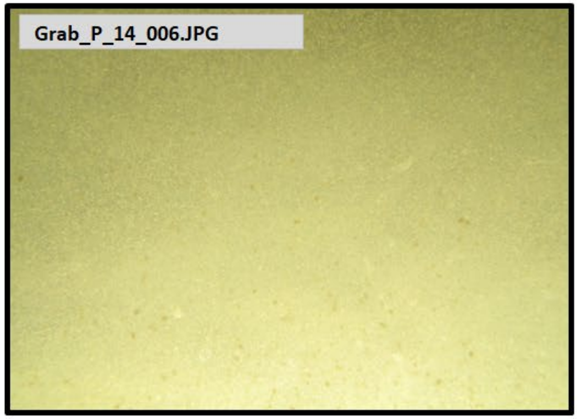
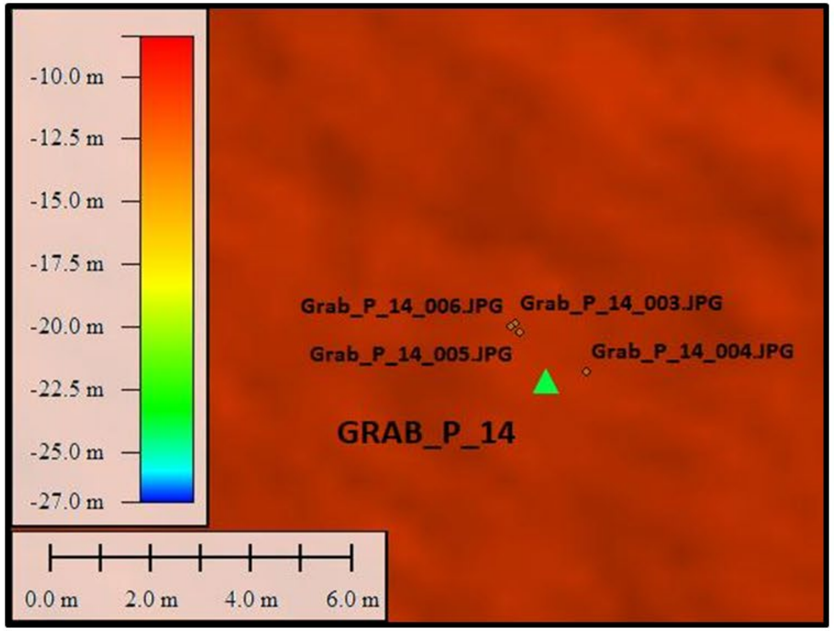
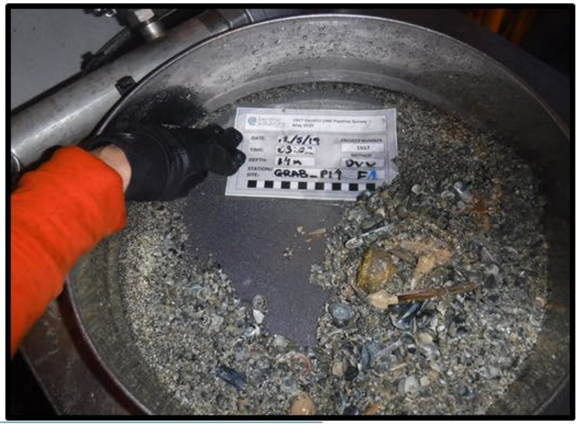

Grab_P_14_006.JPG

Photo Position: 718449 mE, 5940928 mN



Sediment Example Image



Sieved Sample Image

▲ Grab Location ● Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_P_015

Survey Area: N5a Pipeline

No. of Stills: 5 **Mins of Video:** 2 **Track Length:** DDV

Site Selection Criteria

Pipeline Route - Positioned at 1km intervals.

Analogue Interpretation

Low reflectivity.

Sediment Description

Coarse sand with irregular ripples.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Chordata:** Actinopterygii sp.

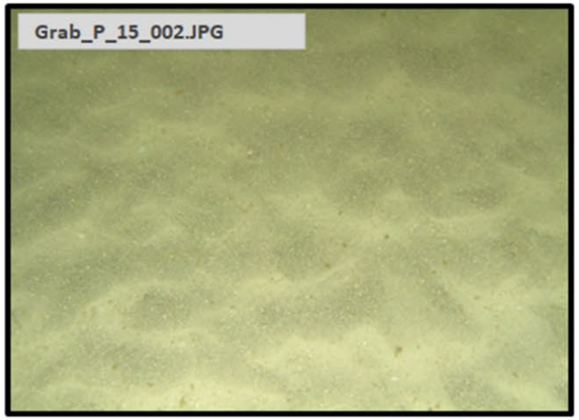


Photo Position: 718366 mE, 5939934 mN

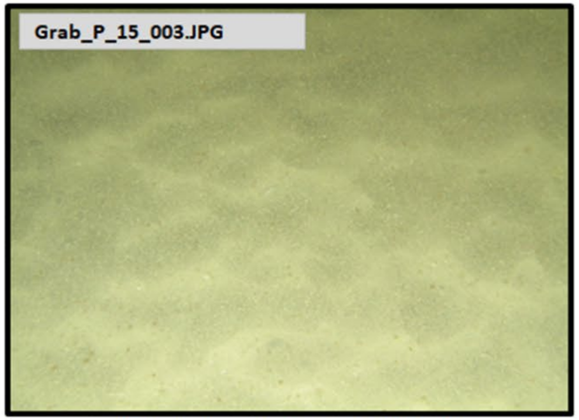


Photo Position: 718366 mE, 5939934 mN

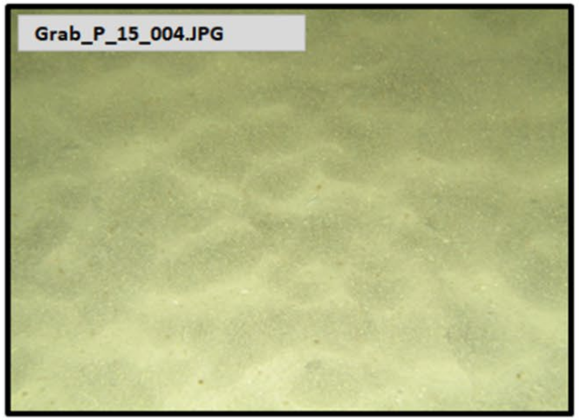


Photo Position: 718366 mE, 5939934 mN

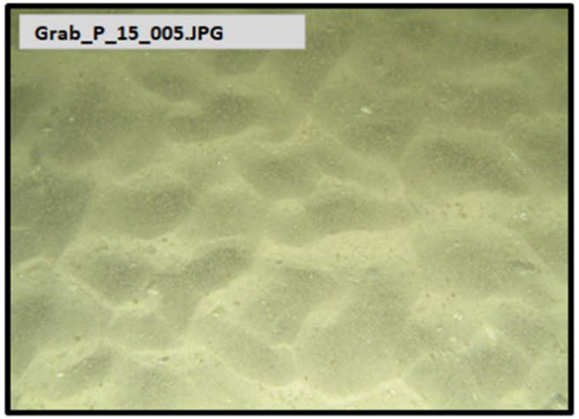
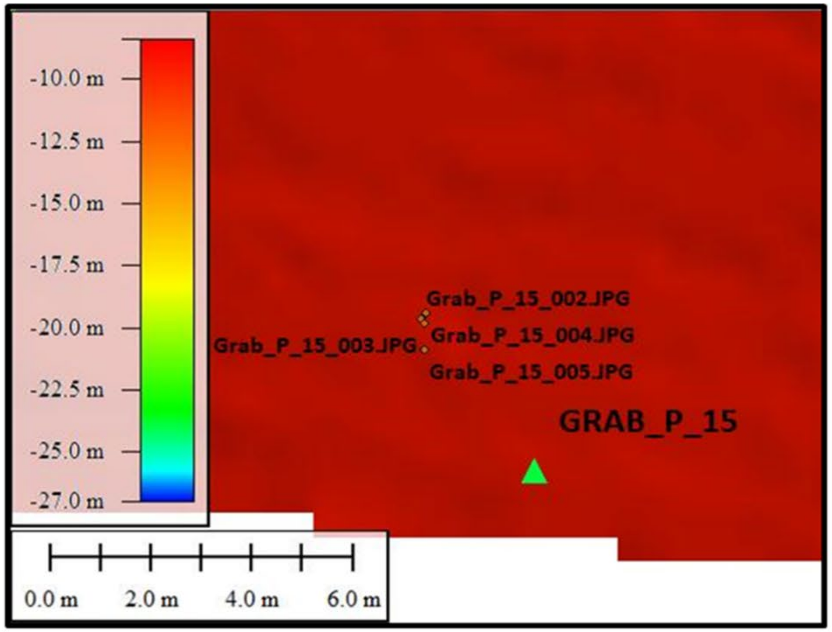


Photo Position: 718366 mE, 5939933 mN



Sediment Example Image

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_C_0

Survey Area: N5a Cable Route

Site Selection Criteria

Original Cable Route and N5a well centre location. Covered using transect N5a_1 and N5a_2.

Analogue Interpretation

Low reflectivity.

Sediment Description

Slightly gravelly/shelly coarse sand.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Echinodermata:** *Asterias rubens* (Common starfish).

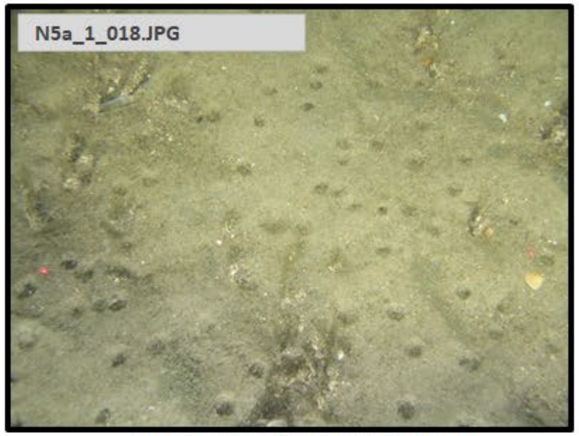

N5a_1_018.JPG

Photo Position: 721606 mE, 5954649 mN

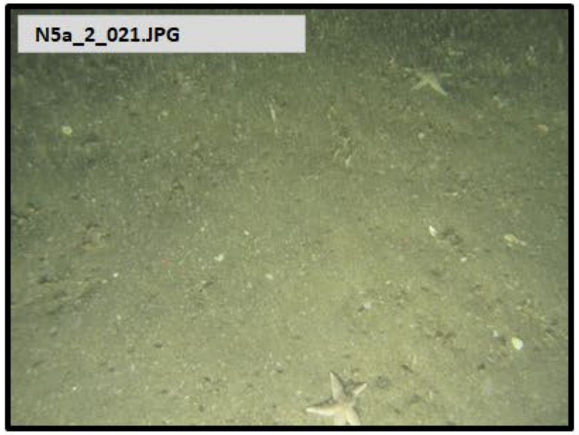
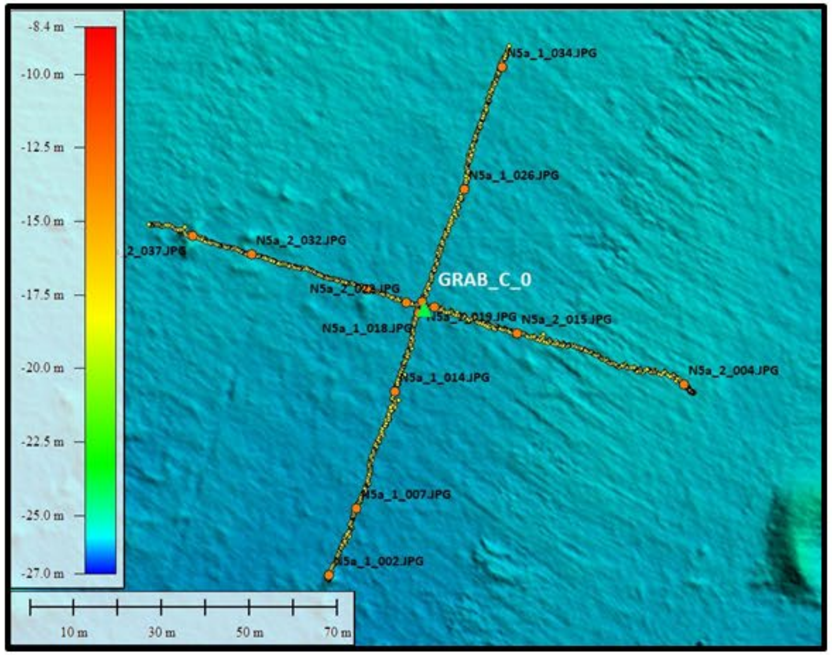

N5a_2_021.JPG

Photo Position: 721610 mE, 5954650 mN

Sediment Example Image



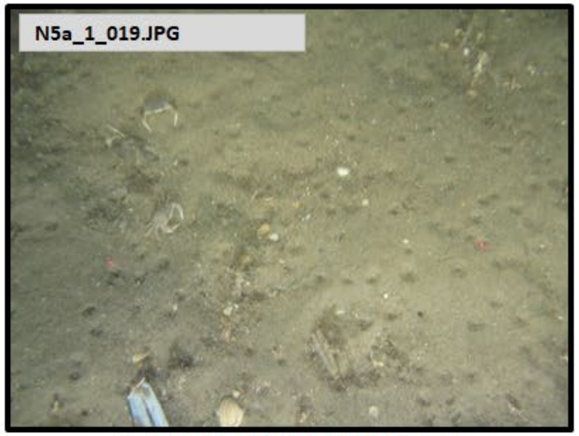

N5a_1_019.JPG

Photo Position: 721607 mE, 5954652 mN

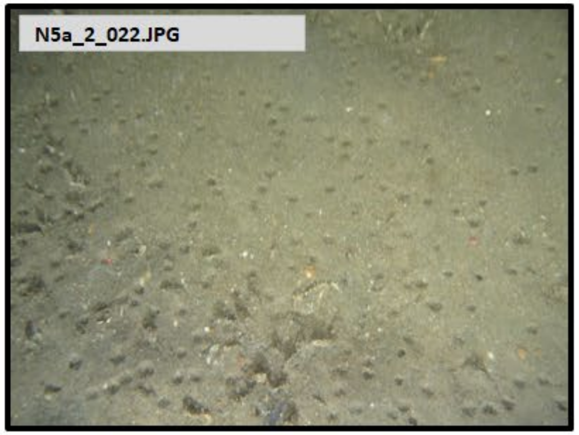

N5a_2_022.JPG

Photo Position: 721603 mE, 5954651 mN

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_C_01

Survey Area: N5a Cable Route

No. of Stills: 2 **Mins of Video:** 1 **Track Length:** DDV

Site Selection Criteria

Original Cable Route – Positioned at 1km intervals.

Analogue Interpretation

Area of variable high reflectivity with raised area near Grab location.

Sediment Description

Coarse sand littered with shell fragments.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Arthropoda:** Decapoda sp, *Liocarcinus* sp. **Echinodermata:** *Asterias rubens* (Common starfish).

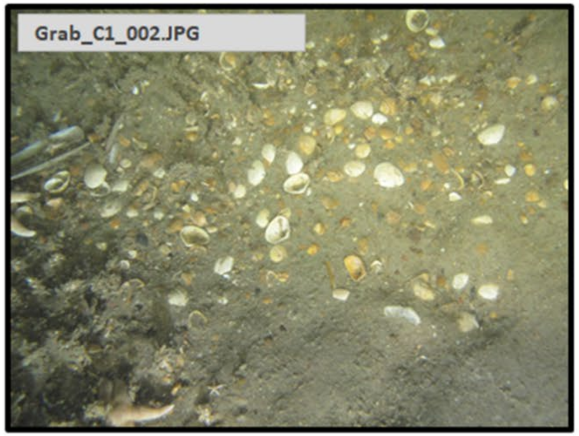


Photo Position: 722598 mE, 5954539 mN

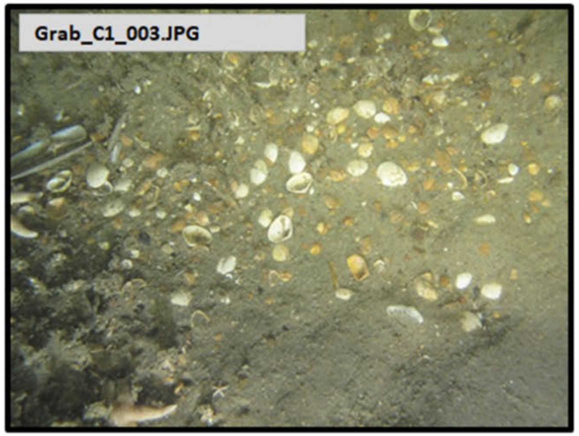


Photo Position: 722598 mE, 5954539 mN

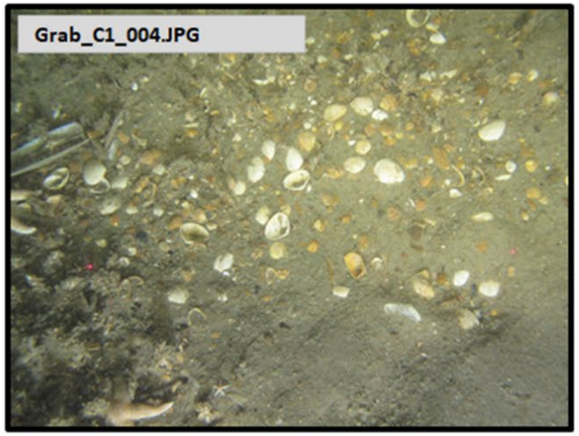


Photo Position: 0 mE, 0 mN

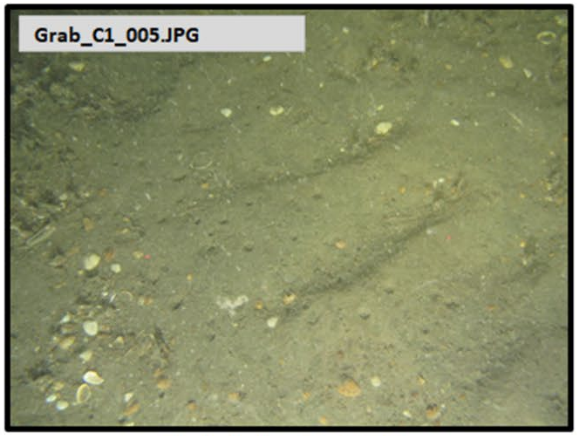
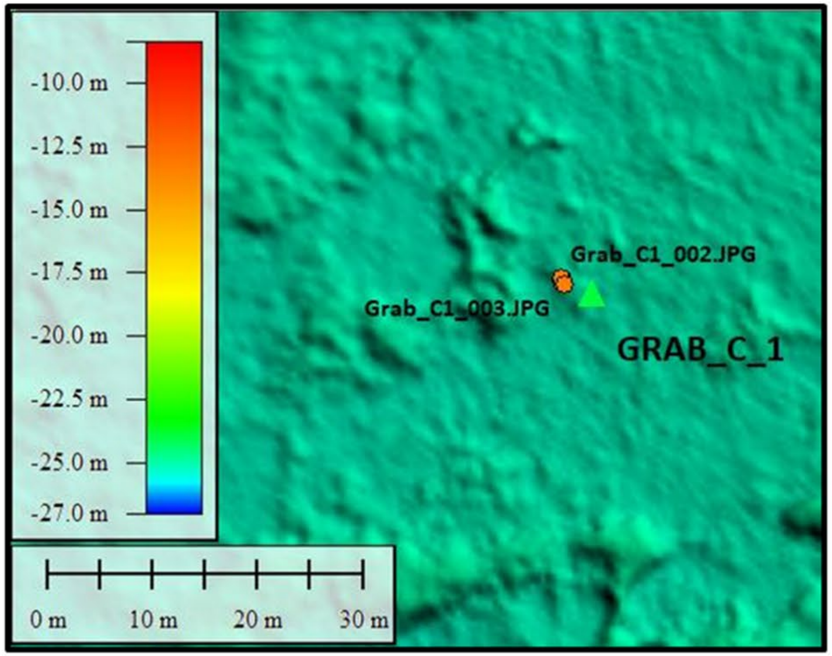


Photo Position: 0 mE, 0 mN



Sediment Example Image

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_C_02

Survey Area: N5a Cable Route

No. of Stills: 5 **Mins of Video: 1** **Track Length: DDV**

Site Selection Criteria

Original Cable Route – Positioned at 1km intervals.

Analogue Interpretation

Area of variable reflectivity.

Sediment Description

Coarse sand.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Arthropoda:** *Liocarcinus* sp. **Mollusca:** *Loligo vulgaris* . **Echinodermata:** *Asterias rubens* (Common starfish).

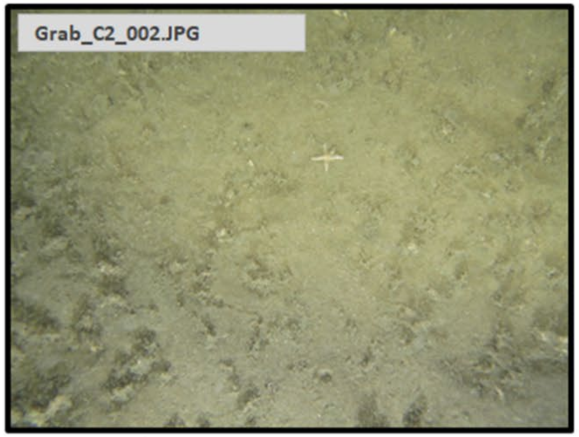


Photo Position: 723594 mE, 5954423 mN

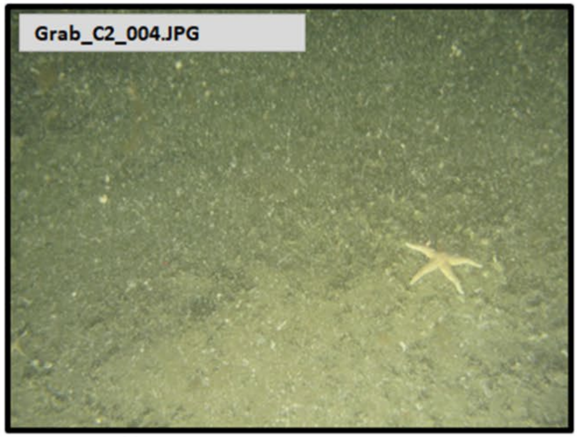


Photo Position: 723594 mE, 5954423 mN

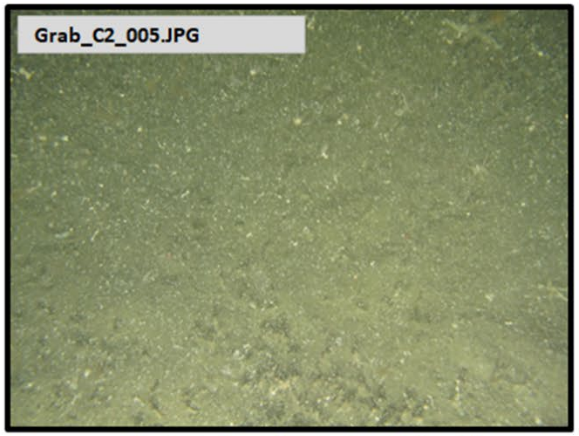


Photo Position: 723596 mE, 5954422 mN

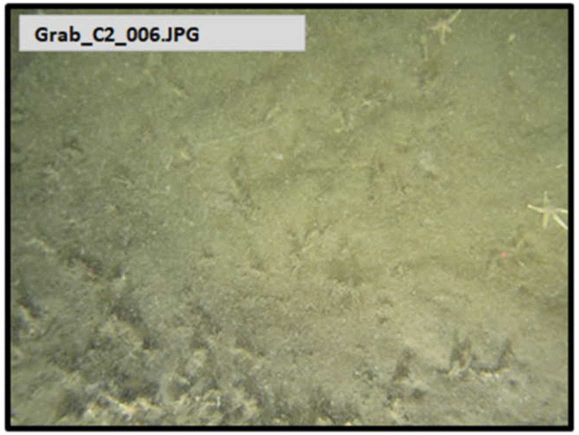
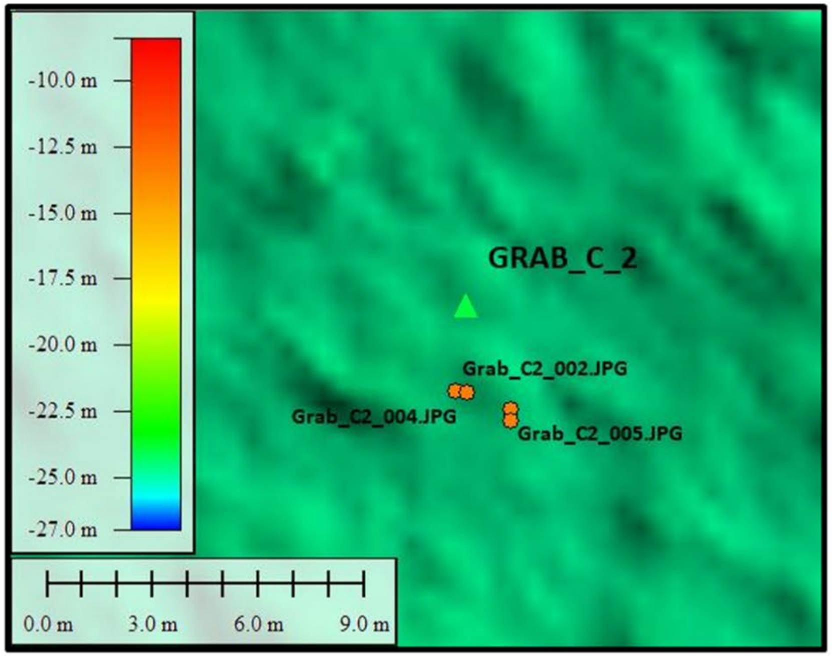


Photo Position: 723596 mE, 5954422 mN



Sediment Example Image

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_C_03

Survey Area: N5a Cable Route

No. of Stills: 8 **Mins of Video:** 3 **Track Length:** DDV

Site Selection Criteria

Original Cable Route – Positioned at 1km intervals.

Analogue Interpretation

Low reflectivity.

Sediment Description

Coarse sand ripples with small shell fragments.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Arthropoda:** *Liocarcinus* sp. **Echinodermata:** *Asterias rubens* (Common starfish).

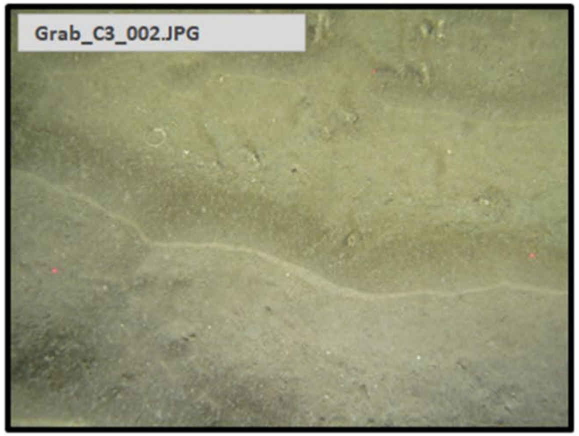


Photo Position: 724589 mE, 5954311 mN

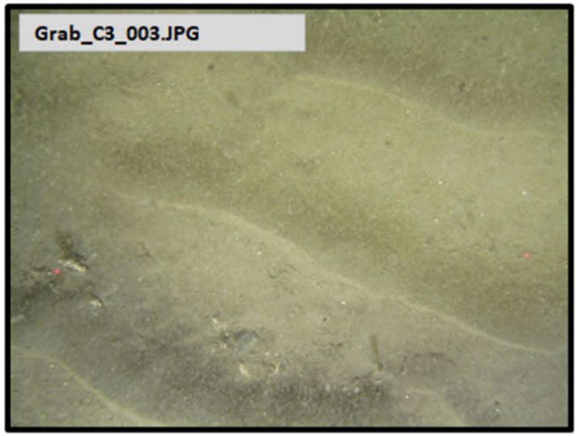


Photo Position: 724589 mE, 5954311 mN

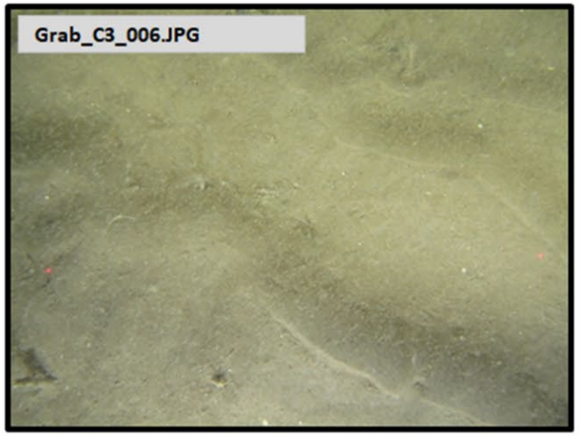


Photo Position: 724589 mE, 5954312 mN

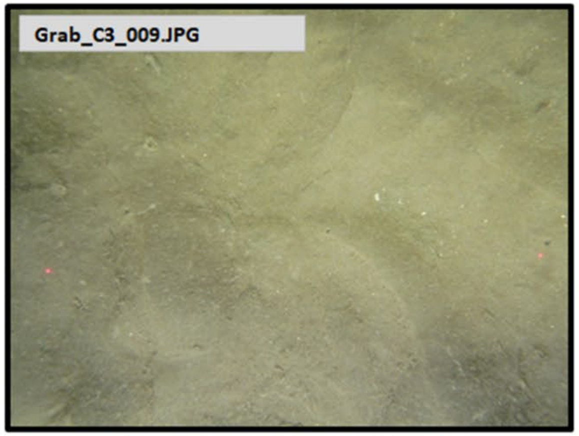
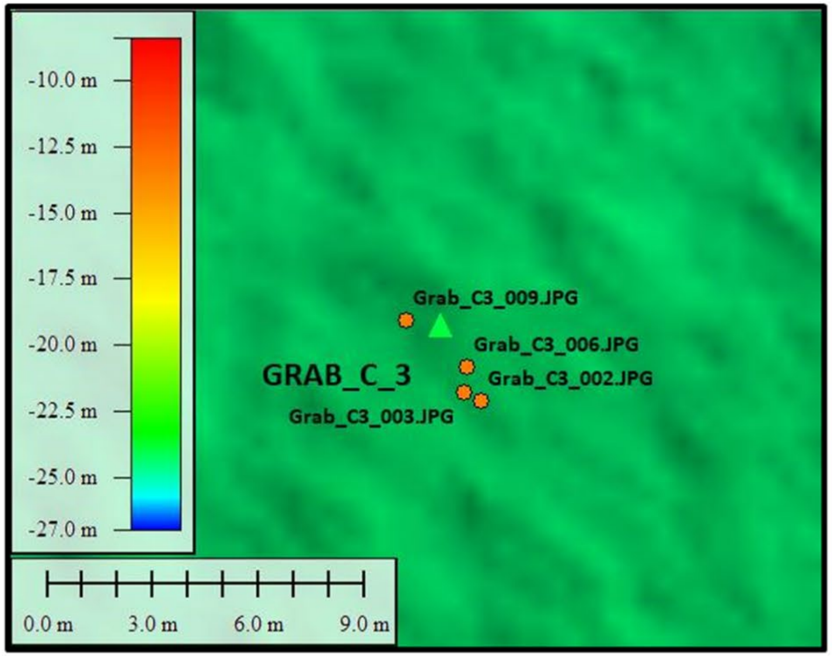


Photo Position: 724587 mE, 5954313 mN



Sediment Example Image

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_C_04

Survey Area: N5a Cable Route

No. of Stills: 9 Mins of Video: 3 Track Length: DDV

Site Selection Criteria

Original Cable Route – Positioned at 1km intervals.

Analogue Interpretation

Low reflectivity.

Sediment Description

Coarse sand ripples with small shell fragments.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Arthropoda:** Decapoda sp. **Echinodermata:** *Asterias rubens* (Common starfish).

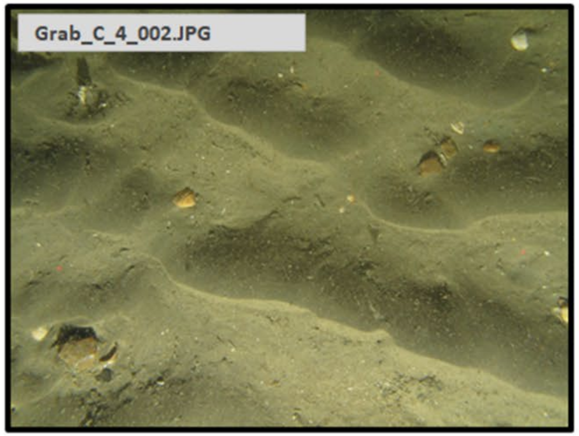


Photo Position: 725582 mE, 5954199 mN

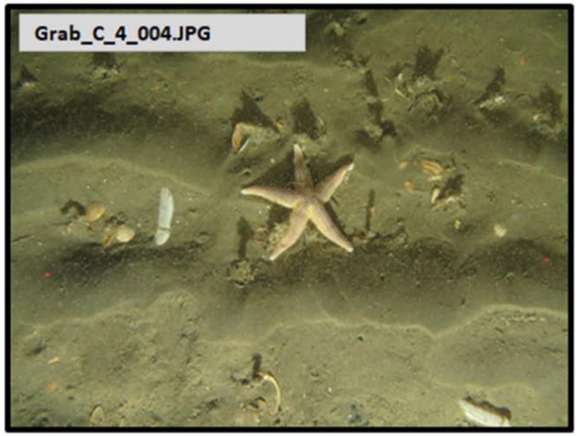


Photo Position: 725583 mE, 5954200 mN

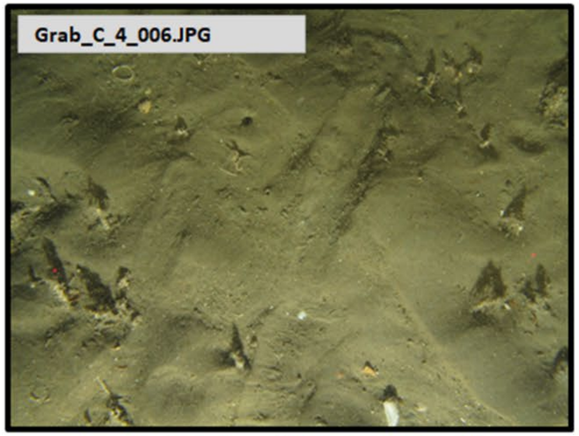


Photo Position: 725582 mE, 5954202 mN

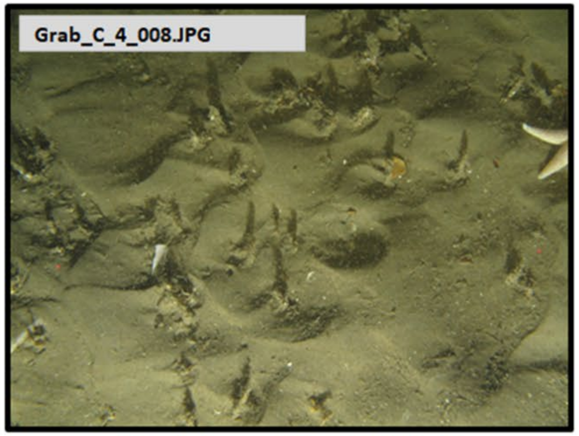
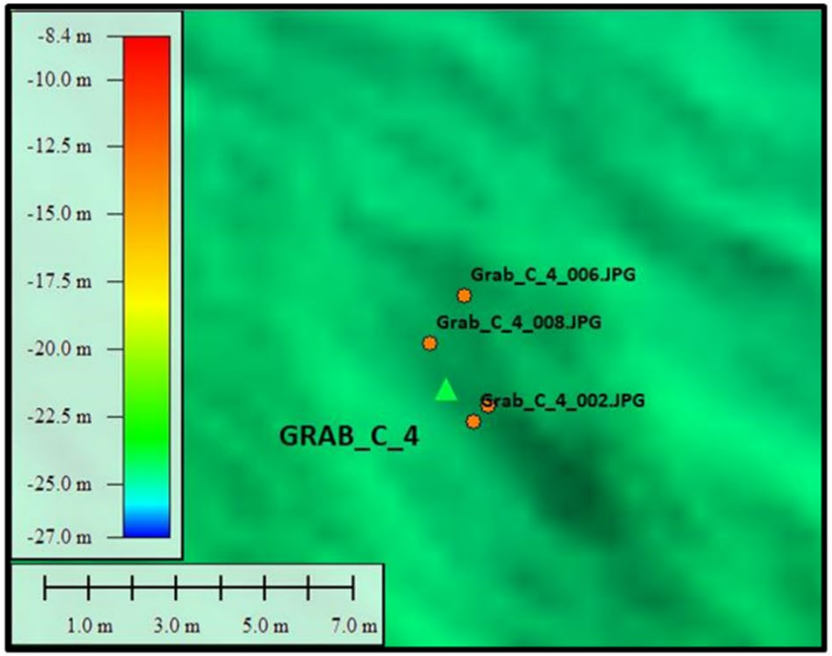


Photo Position: 725581 mE, 5954201 mN



Sediment Example Image

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_C_05

Survey Area: N5a Cable Route

No. of Stills: 9 **Mins of Video:** 3 **Track Length:** DDV

Site Selection Criteria

Original Cable Route – Positioned at 1km intervals.

Analogue Interpretation

Low reflectivity.

Sediment Description

Coarse sand ripples with small shell fragments.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Arthropoda:** *Liocarcinus* sp. **Echinodermata:** *Asterias rubens* (Common starfish). **Chordata:** possibly *Callionymus lyra* (Common dragonet).

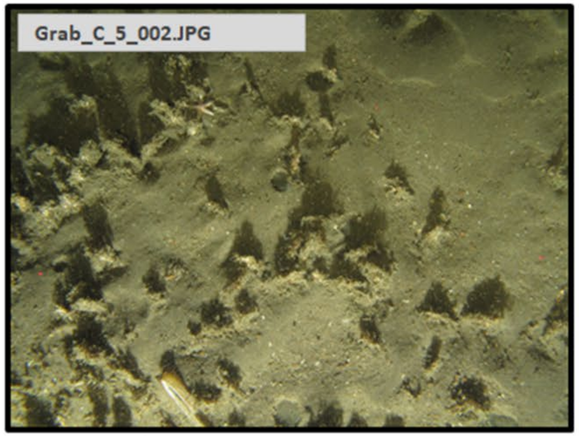


Photo Position: 726576 mE, 5954087 mN

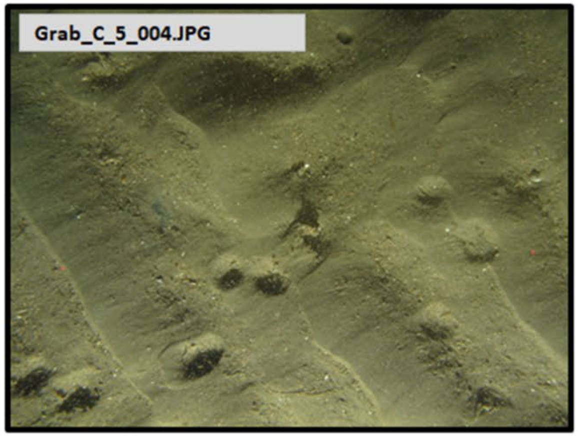


Photo Position: 726578 mE, 5954083 mN

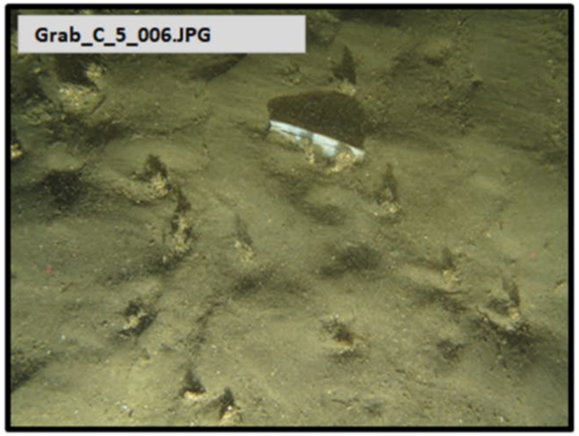


Photo Position: 726575 mE, 5954088 mN

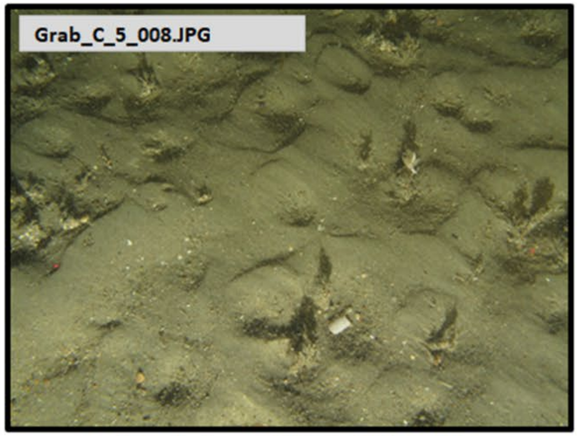
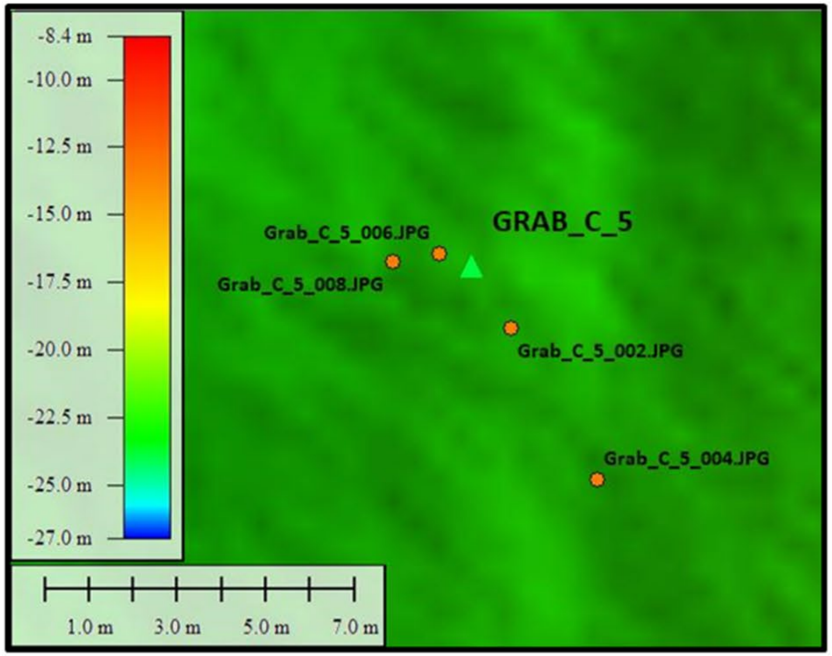


Photo Position: 726574 mE, 5954088 mN



Sediment Example Image

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Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_C_06

Survey Area: N5a Cable Route

No. of Stills: 4 **Mins of Video: 1** **Track Length: DDV**

Site Selection Criteria

Original Cable Route – Positioned at 1km intervals.

Analogue Interpretation

Low reflectivity.

Sediment Description

Coarse sand ripples with small shell fragments that have accumulated within each sand furrow.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason).

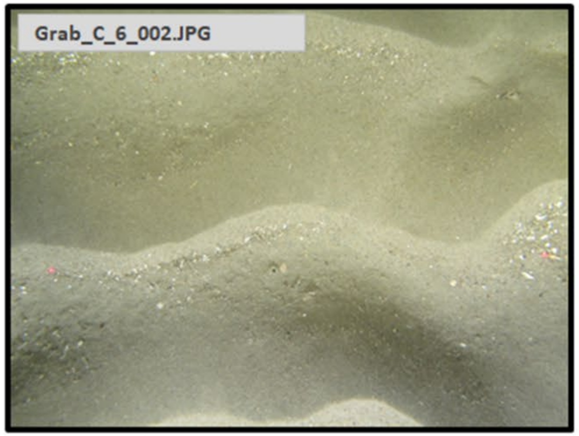


Photo Position: 727352 mE, 5954243 mN

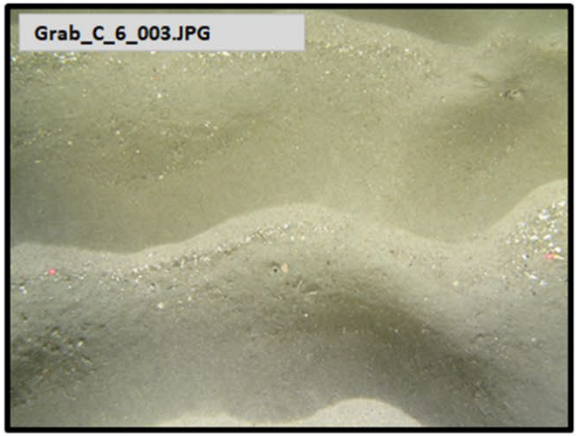


Photo Position: 727352 mE, 5954243 mN

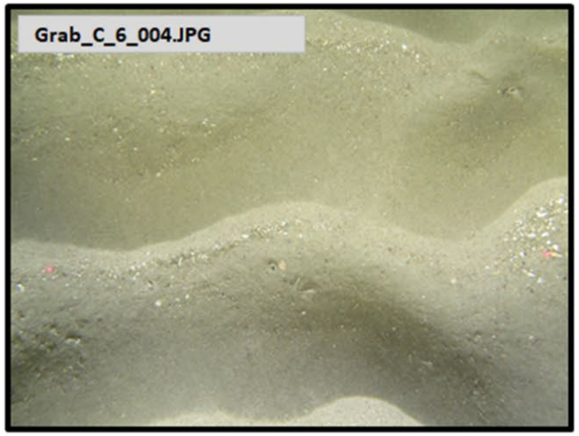


Photo Position: 727352 mE, 5954242 mN

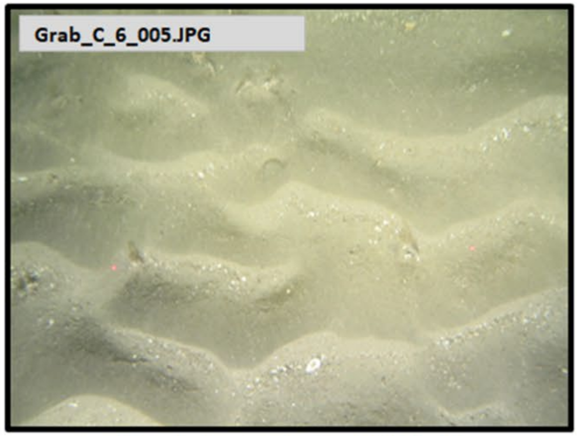
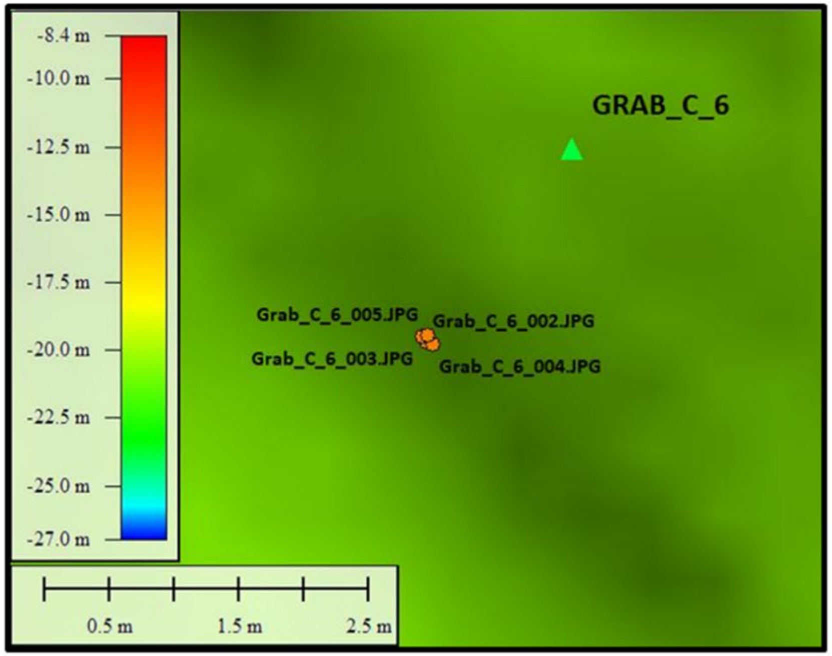


Photo Position: 727352 mE, 5954243 mN



Sediment Example Image

Sieved Sample Image

▲ Grab Location ● Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_C_07

Survey Area: N5a Cable Route

No. of Stills: 5 **Mins of Video: 1** **Track Length: DDV**

Site Selection Criteria

Original Cable Route – Positioned at 1km intervals.

Analogue Interpretation

Low reflectivity.

Sediment Description

Coarse sand ripples with small shell fragments that have accumulated within each sand furrow.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Echinodermata:** *Asterias rubens* (Common starfish).

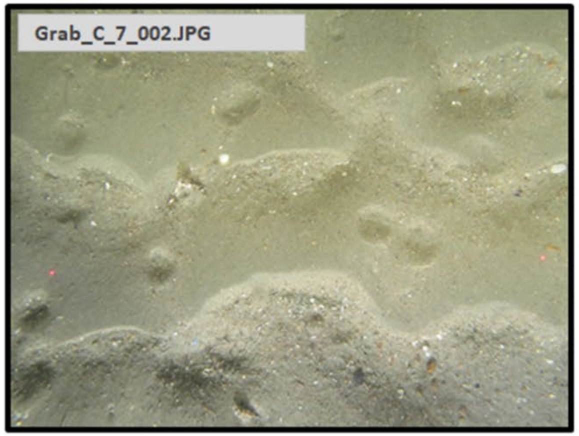


Photo Position: 728147 mE, 5954477 mN

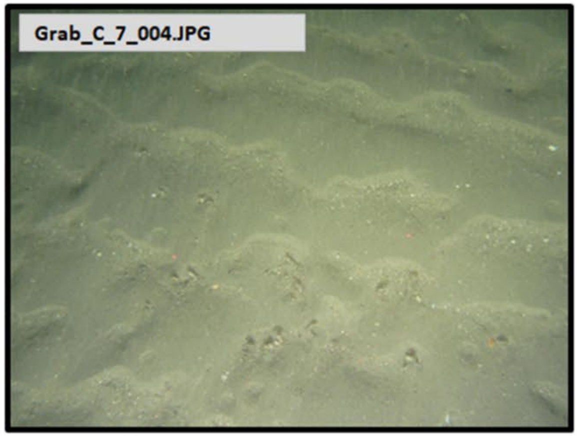


Photo Position: 728147 mE, 5954477 mN

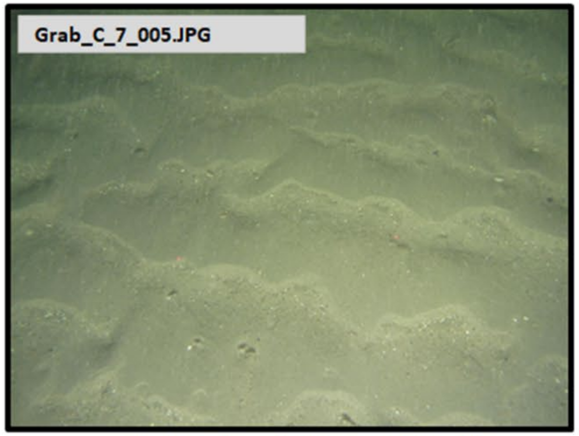


Photo Position: 728147 mE, 5954477 mN

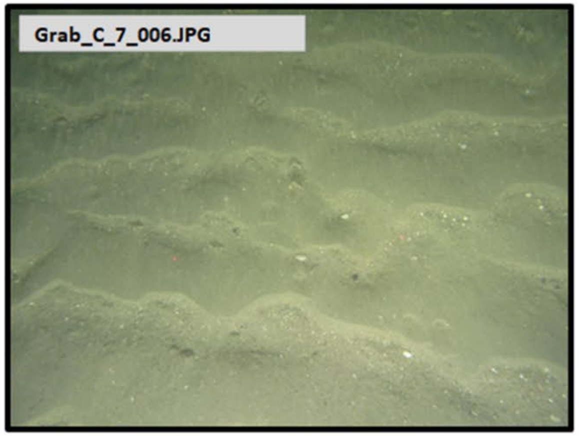
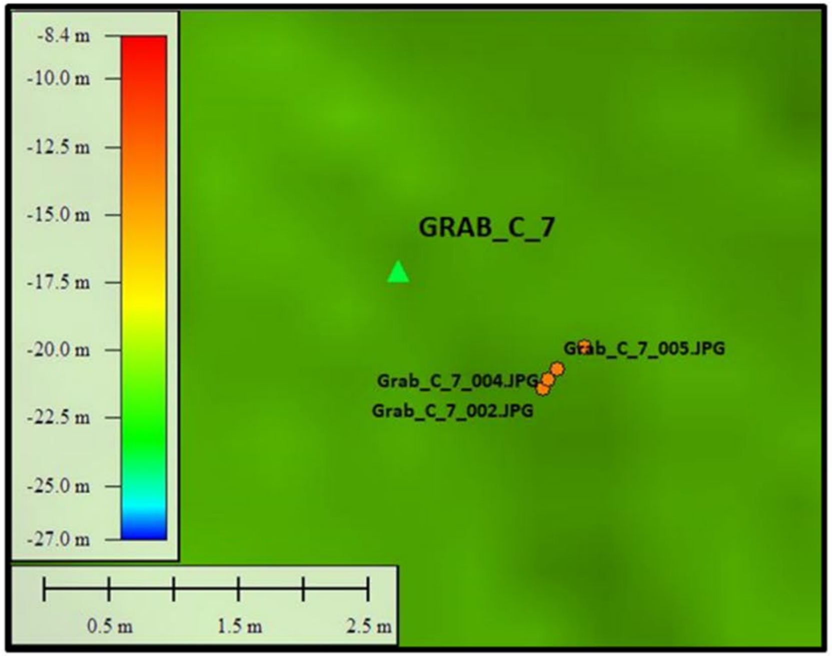


Photo Position: 728148 mE, 5954477 mN



Sediment Example Image

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_C_08

Survey Area: N5a Cable Route

No. of Stills: 5 **Mins of Video: 1** **Track Length: DDV**

Site Selection Criteria

Original Cable Route – Positioned at 1km intervals.

Analogue Interpretation

Low reflectivity.

Sediment Description

Coarse sand ripples with small shell fragments that have accumulated within each sand furrow.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Echinodermata:** *Asterias rubens* (Common starfish). **Chordata:** Gobiidae sp.

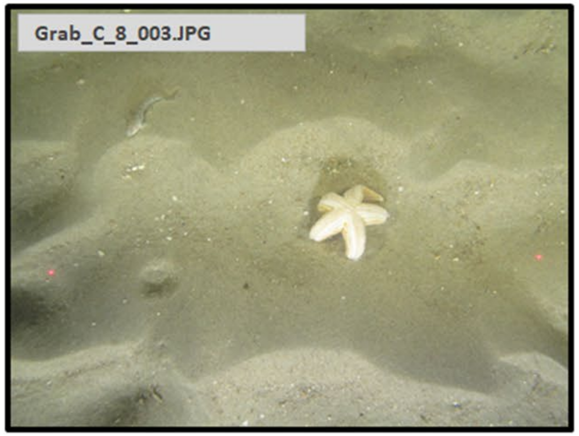


Photo Position: 729107 mE, 5954755 mN

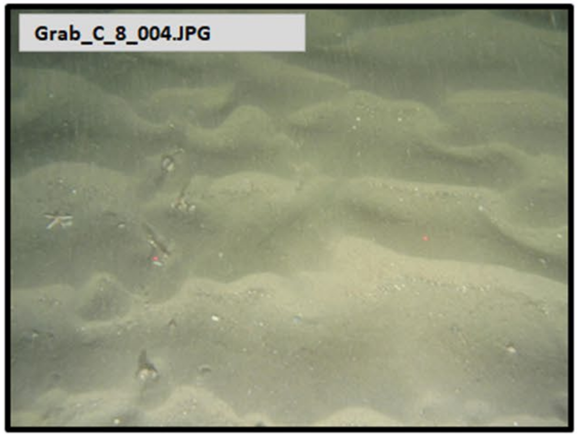


Photo Position: 729107 mE, 5954756 mN

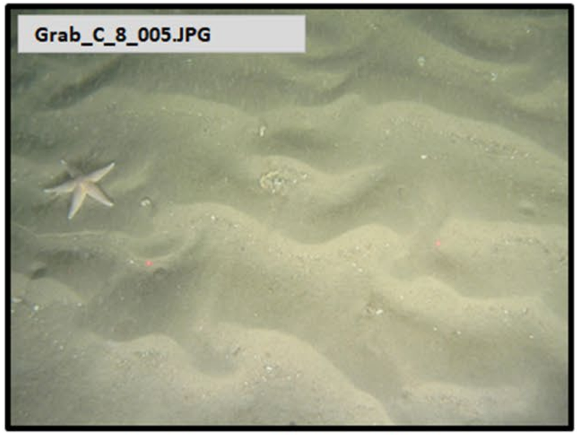
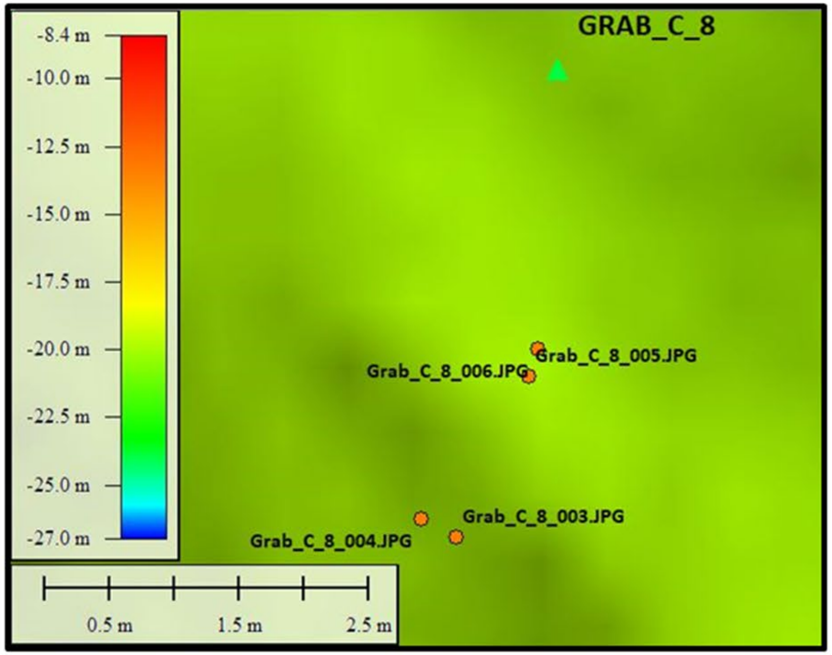


Photo Position: 729108 mE, 5954757 mN

Photo Position: 729108 mE, 5954757 mN



Sediment Example Image

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

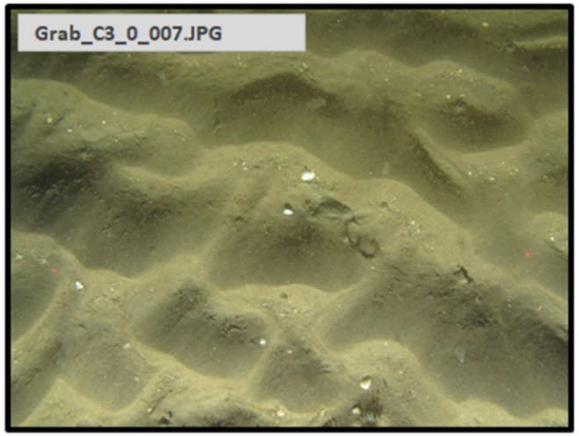


Photo Position: 722245 mE, 5952995 mN

Habitat Summary Information: Grab_C3_0

Survey Area: N5a Cable Route

No. of Stills: 36 **Mins of Video: 9** **Track Length: 125m**

Site Selection Criteria

Secondary Cable Route and N5a second potential well centre location.

Analogue Interpretation

No analogue data.

Sediment Description

Coarse sand ripples with small shell fragments that have accumulated within each sand furrow.

Conspicuous Fauna

Annelida: *Lanice conchilega* (Sand Mason). **Arthropoda:** Decapoda sp., *Corystes cassivelaunus* (Masked crab). **Echinodermata:** *Asterias rubens* (Common starfish), *Ophiura* sp. **Chordata:** Gobiidae sp. , *Ammodytes* sp. (Sand eel).

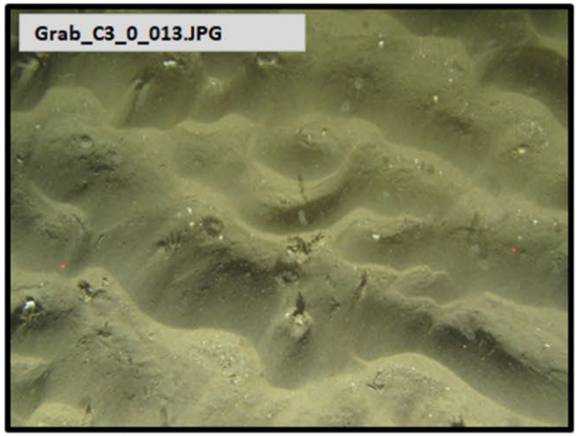


Photo Position: 722260 mE, 5953002 mN

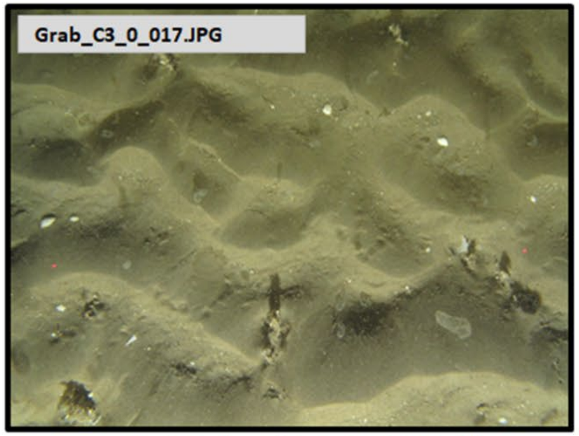
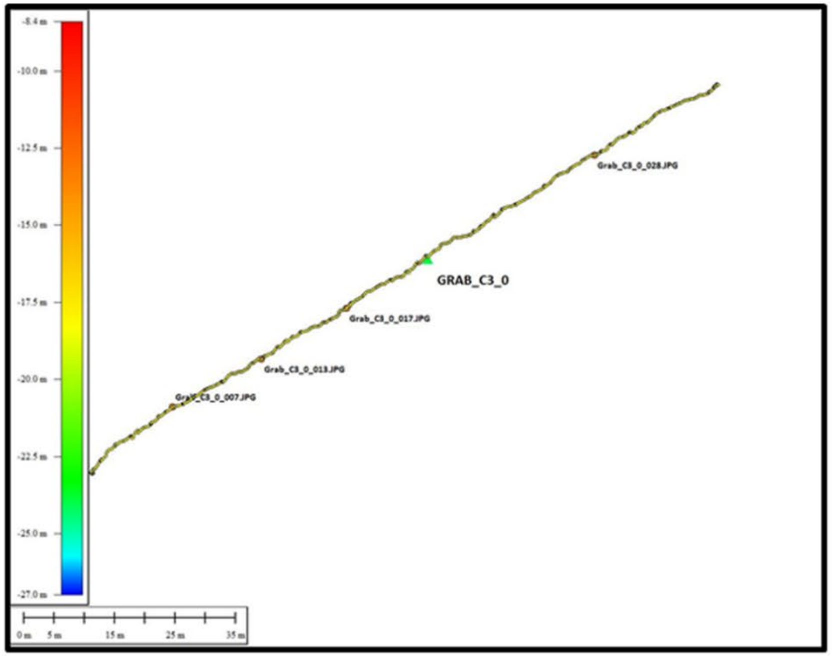


Photo Position: 722274 mE, 5953011 mN



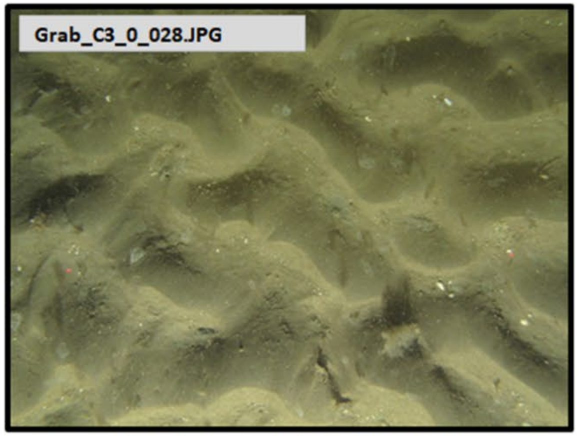
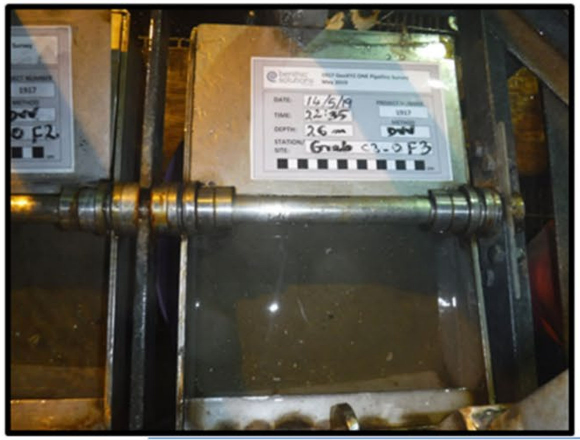


Photo Position: 722315 mE, 5953036 mN



Sediment Example Image

🟩 Grab Location ● Camera Track ● Selected Underwater Still

Sieved Sample Image

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_C3_01

Survey Area: N5a Cable Route

No. of Stills: 7 **Mins of Video: 1** **Track Length: DDV**

Site Selection Criteria

Secondary Cable Route – Positioned to investigate mixed reflectivity sediment.

Analogue Interpretation

No analogue data.

Sediment Description

Coarse shelly sand with partly buried cobbles and slight sand waves.

Conspicuous Fauna

Echinodermata: *Asterias rubens* (Common starfish). **Chordata:** Pleuronectiformes sp.

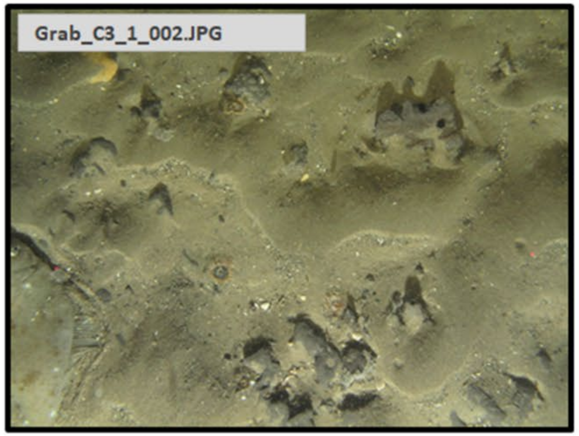


Photo Position: 723807 mE, 5953379 mN

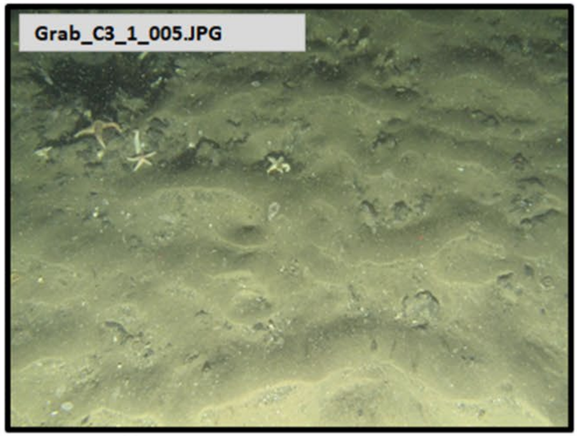


Photo Position: 723807 mE, 5953379 mN

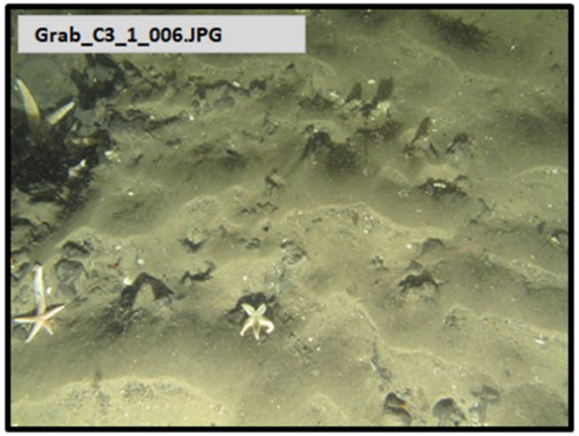


Photo Position: 723808 mE, 5953379 mN

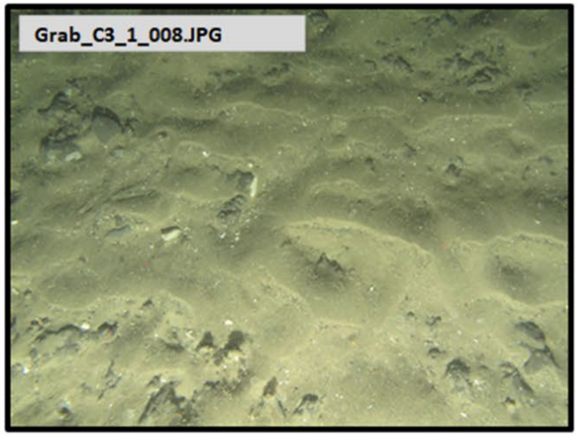
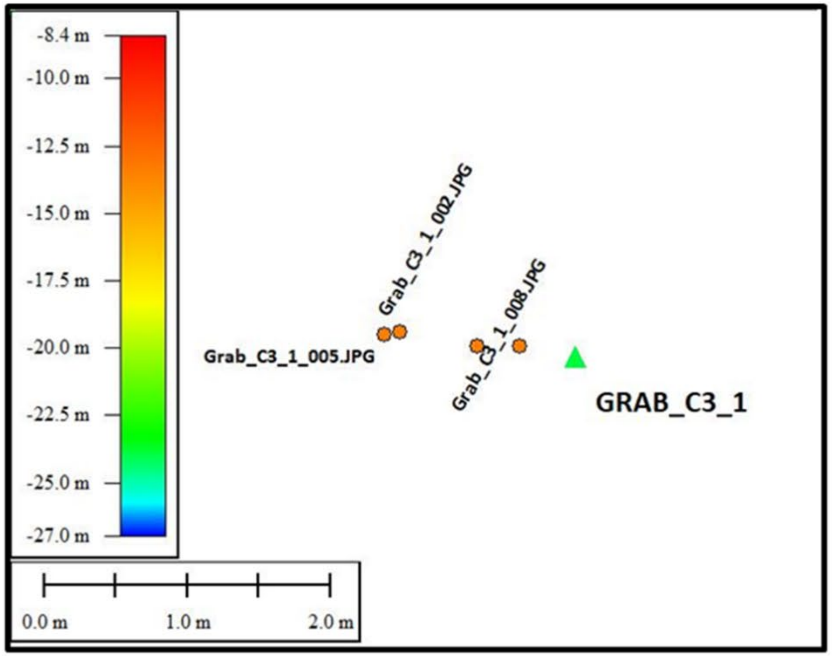


Photo Position: 723808 mE, 5953379 mN



Sediment Example Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Sieved Sample Image

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: Grab_C3_02

Survey Area: N5a Cable Route

No. of Stills: 37 Mins of Video: 13 Track Length: 180m

Site Selection Criteria

Secondary Cable Route – Positioned to investigate high reflectivity sediment.

Analogue Interpretation

Area of variable reflectivity, scarring on seabed (analogue data only available for half of camera line).

Sediment Description

Gravelly and shelly coarse sand.

Conspicuous Fauna

Cnidaria: *Metridium senile* (Plumose Anemone), Actiniaria sp., Cerianthidae sp. **Annelida:** *Lanice conchilega* (Sand Mason). **Arthropoda:** *Cancer pagurus* (Edible crab), Paguridae sp., Decapoda sp., Liocarcinus sp. **Echinodermata:** *Asterias rubens* (Common starfish). **Chordata:** possibly *Callionymus lyra* (Common dragonet), *Ammodytes* sp. (Sand eel), Pleuronectiformes sp.

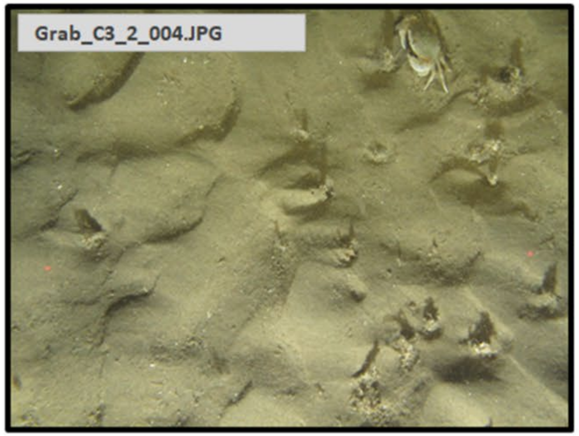


Photo Position: 725364 mE, 5953617 mN

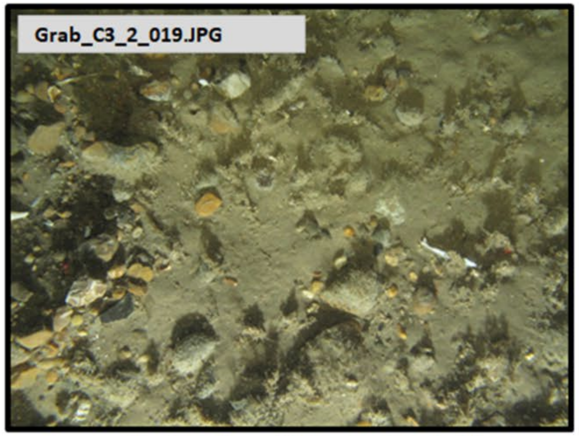


Photo Position: 725352 mE, 5953671 mN

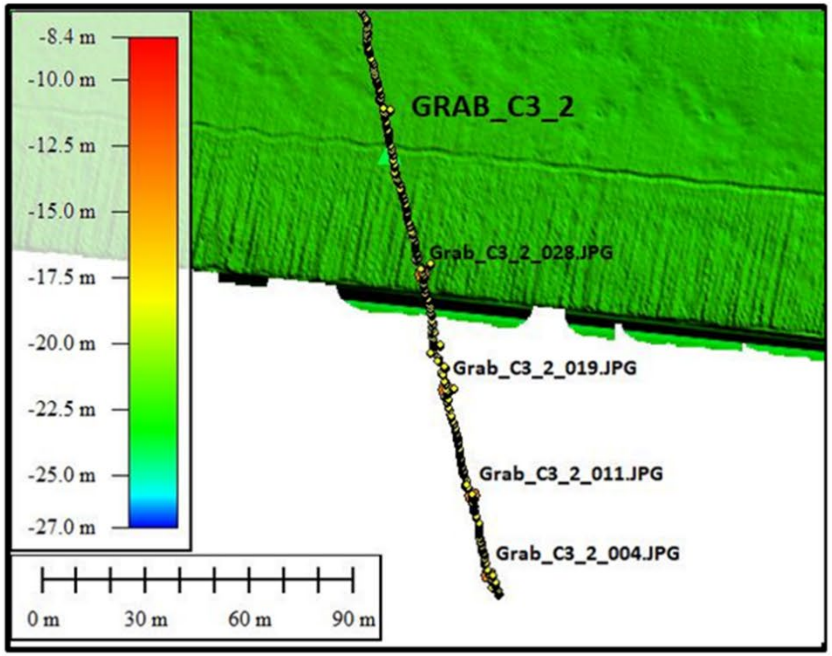


Photo Position: 725359 mE, 5953640 mN

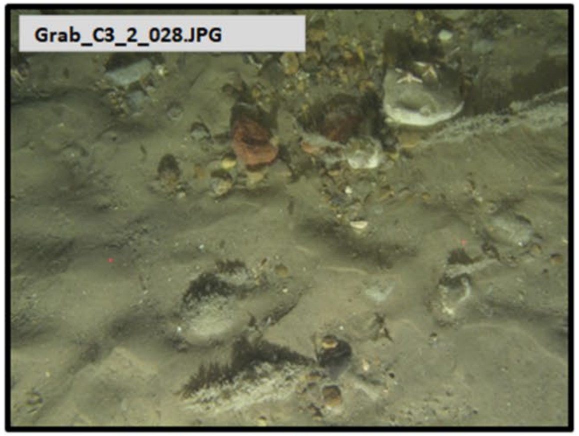


Photo Position: 725345 mE, 5953704 mN

Sediment Example Image

Sieved Sample Image

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: North Transect 1

Survey Area: N5a

No. of Stills: 30 **Mins of Video: 10** **Track Length: 135m**

Site Selection Criteria

Investigating transition from mixed to high reflectivity sediment.

Analogue Interpretation

Area of higher, variable reflectivity with many raised areas.

Sediment Description

Slightly gravelly/shelly coarse sand forming irregular ripples or *Lanice conchilega* aggregations.

Conspicuous Fauna

Cnidaria: Cerianthidae sp. **Annelida:** *Lanice conchilega* (Sand Mason). **Arthropoda:** *Cancer pagurus* (Edible crab), *Pagurus bernhardus* (Common hermit crab), Paguridae sp., *Liocarcinus* sp., Brachyura sp., *Cancer maenus* . **Echinodermata:** *Asterias rubens* (Common starfish). **Chordata:** *Limanda limanda* (Dab), Pleuronectiformes sp., Actinopterygii sp.

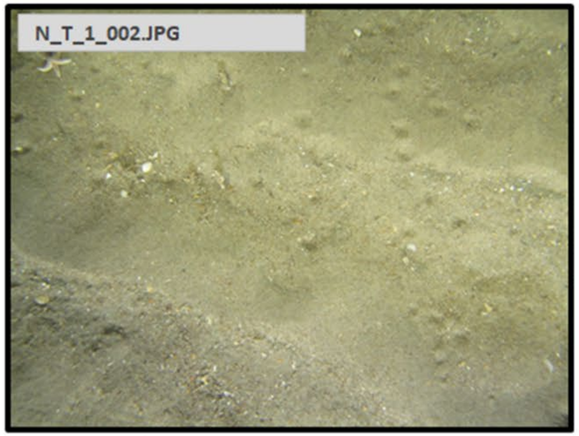

N_T_1_002.JPG

Photo Position: 721487 mE, 5954680 mN

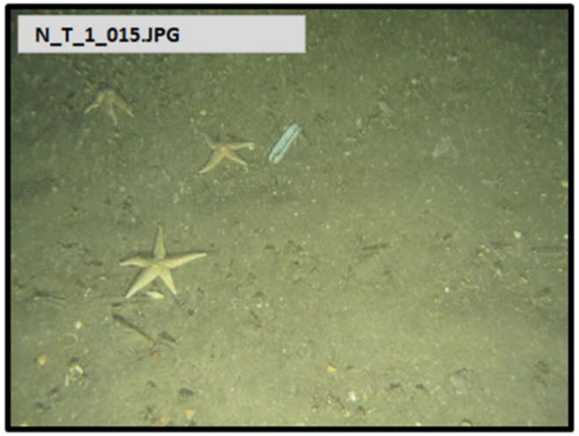

N_T_1_015.JPG

Photo Position: 721432 mE, 5954659 mN

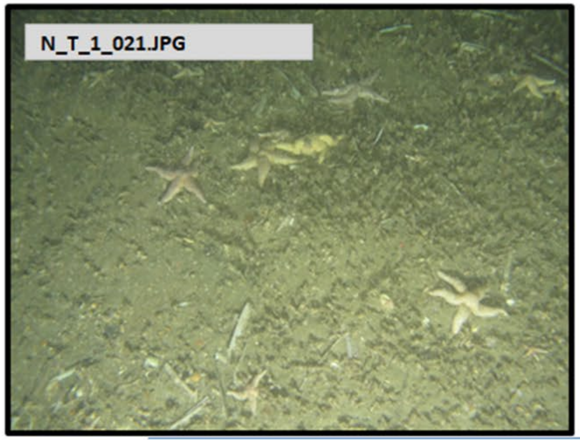
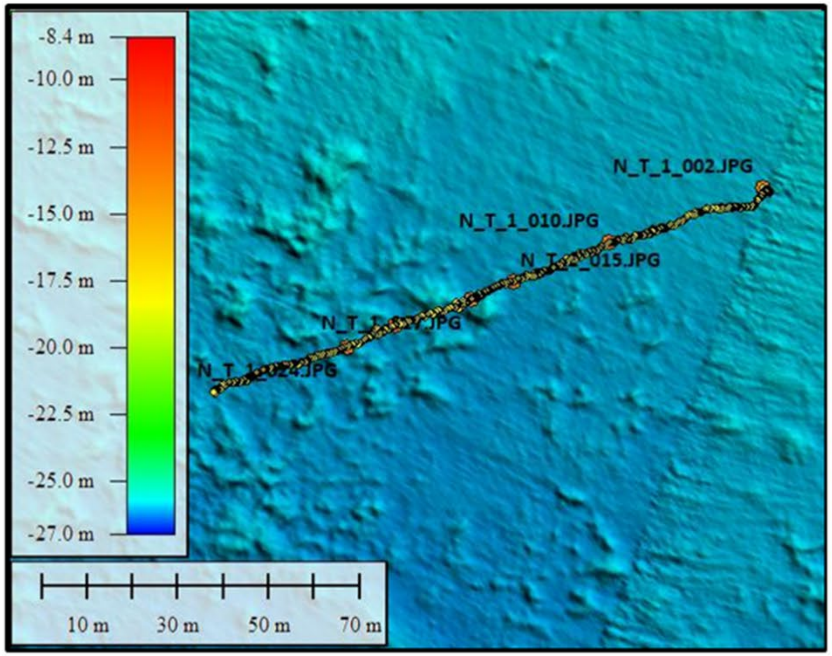

N_T_1_021.JPG

Photo Position: 721406 mE, 5954650 mN



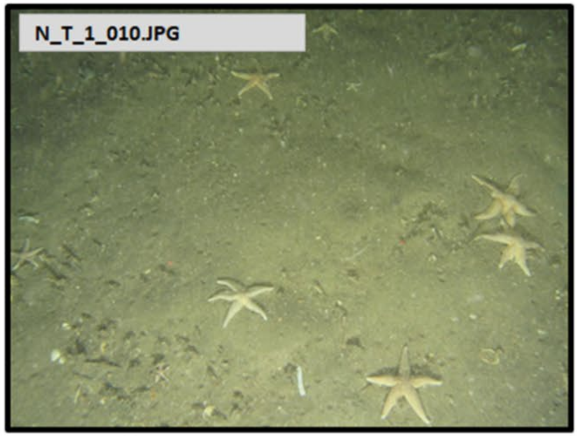

N_T_1_010.JPG

Photo Position: 721453 mE, 5954668 mN

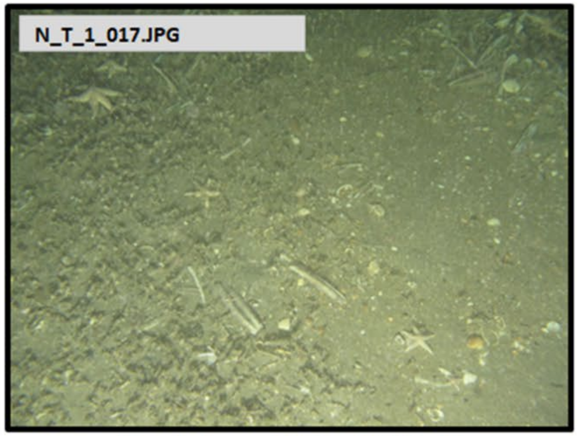

N_T_1_017.JPG

Photo Position: 721423 mE, 5954655 mN

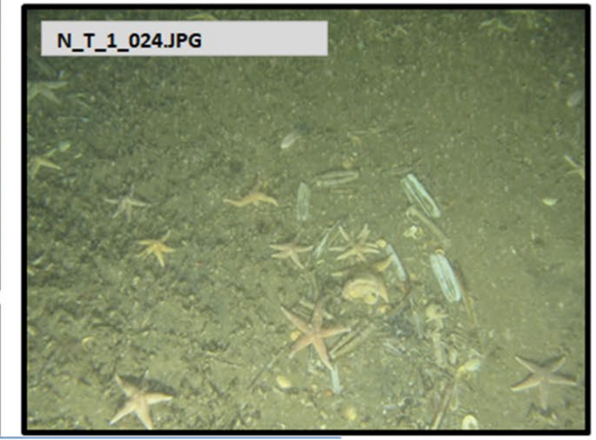

N_T_1_024.JPG

Photo Position: 721395 mE, 5954645 mN

▲ Grab Location ● Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: North Transect 2

Survey Area: N5a

No. of Stills: 41 **Mins of Video: 13** **Track Length: 165m**

Site Selection Criteria

Investigating transition from low to mixed reflectivity sediment.

Analogue Interpretation

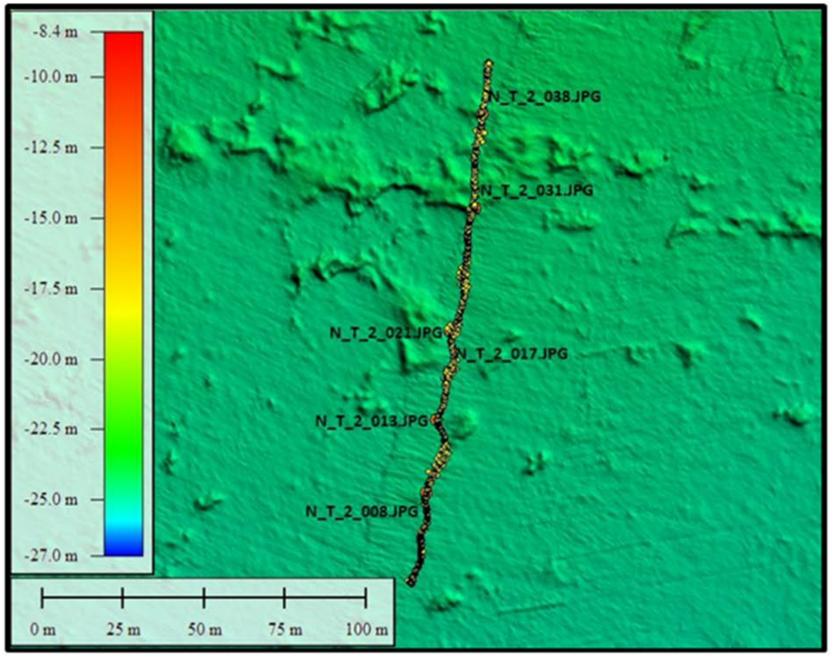
Area of higher, variable reflectivity with raised areas.

Sediment Description

Slightly gravelly/shelly coarse sand forming irregular ripples or *Lanice conchilega* aggregations.

Conspicuous Fauna

Cnidaria: Cerianthidae sp, Cerianthidae sp. **Annelida:** *Lanice conchilega* . **Arthropoda:** *Cancer pagurus* , *Pagurus bernhardus* , Paguridae sp., *Liocarcinus* sp., Brachyura sp., *Cancer maenus* . **Echinodermata:** *Asterias rubens* . **Chordata:** *Callionymus lyra* , Pleuronectiformes sp., Actinopterygii sp.



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▲ Grab Location ○ Camera Track ● Selected Underwater Still

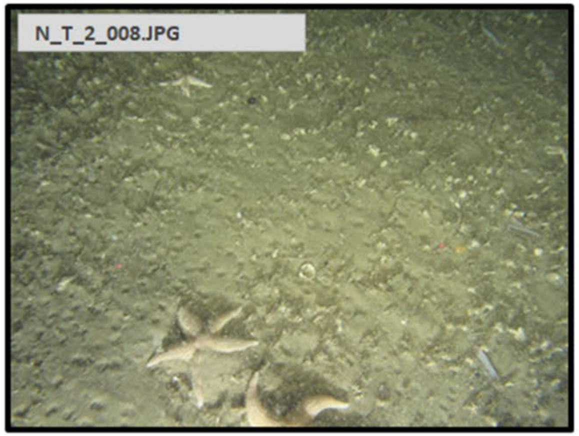


Photo Position: 721613 mE, 5955020 mN

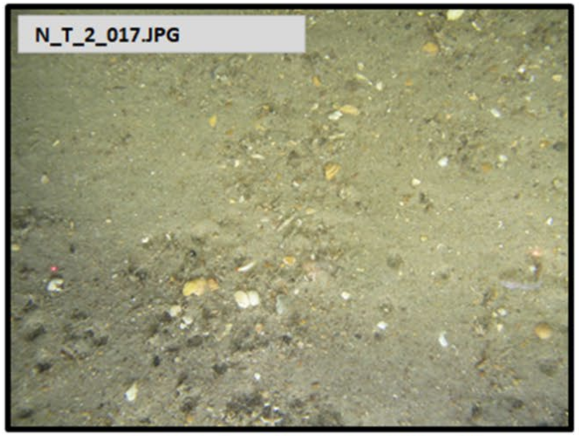


Photo Position: 721620 mE, 5955057 mN

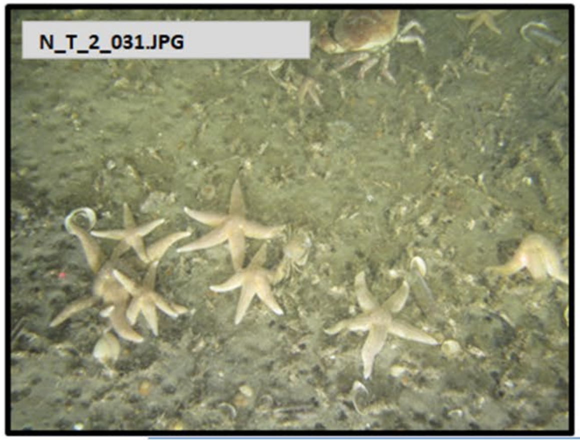


Photo Position: 721628 mE, 5955108 mN

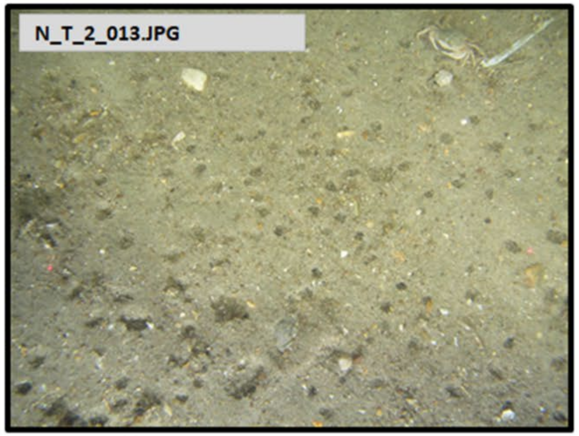


Photo Position: 721616 mE, 5955043 mN

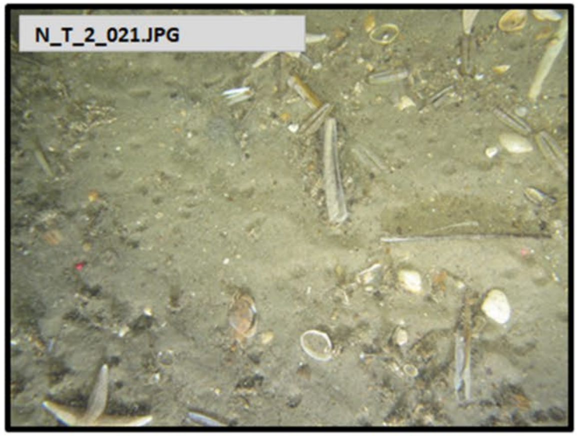


Photo Position: 721621 mE, 5955070 mN

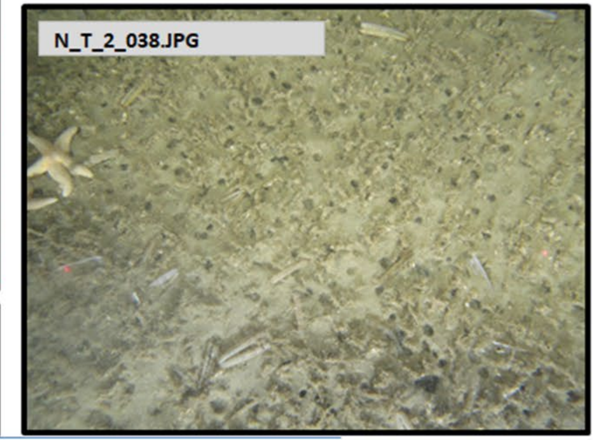


Photo Position: 721630 mE, 5955137 mN

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: North Transect 3

Survey Area: N5a

No. of Stills: 50 **Mins of Video: 13** **Track Length: 175m**

Site Selection Criteria

Investigating transition from mixed to high reflectivity sediment.

Analogue Interpretation

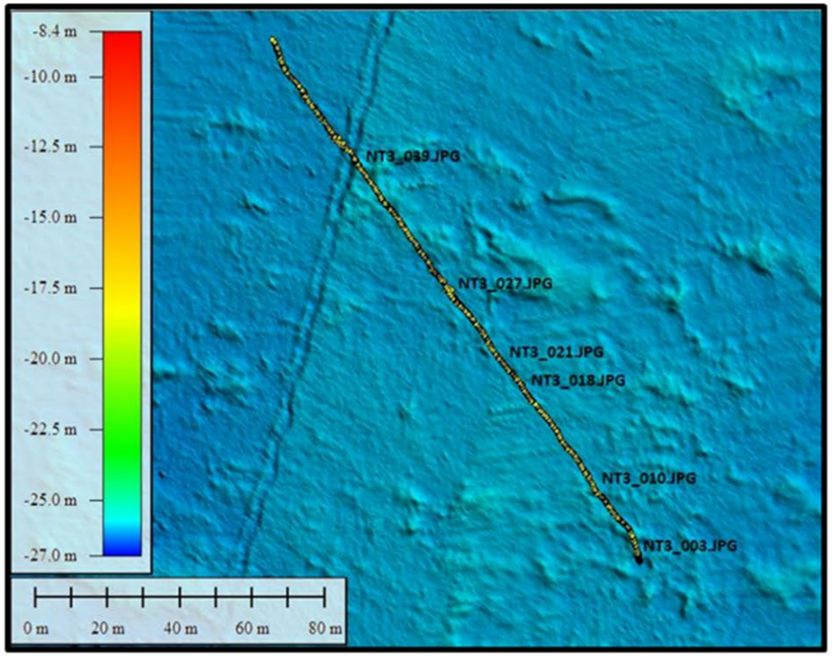
Area of variable reflectivity, some apparent scarring on seabed.

Sediment Description

Slightly gravelly/shelly coarse sand forming irregular ripples or Lanice conchilega aggregations.

Conspicuous Fauna

Cnidaria: *Metridium senile* (Plumose Anemone), Cerianthidae sp. **Annelida:** *Lanice conchilega* (Sand Mason). **Arthropoda:** *Cancer pagurus* (Edible crab), *Pagurus bernhardus* (Common hermit crab), Paguridae sp., *Liocarcinus* sp., Brachyura sp., *Cancer maenus*. **Echinodermata:** *Asterias rubens* (Common starfish). **Chordata:** *Callionymus lyra* (Common dragonet), Gobiidae sp., Pleuronectiformes sp., Actinopterygii sp., *Eutrigla gurnardus* (Grey gurnard).



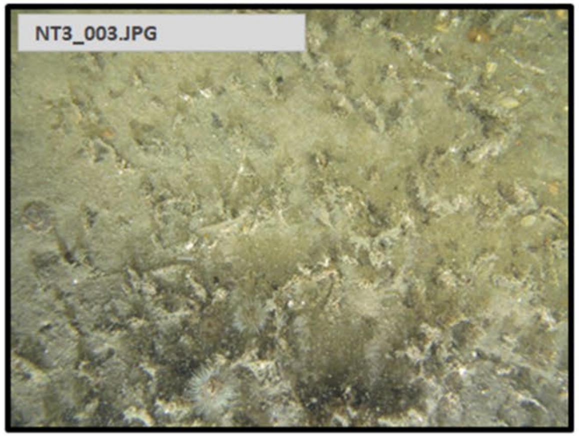
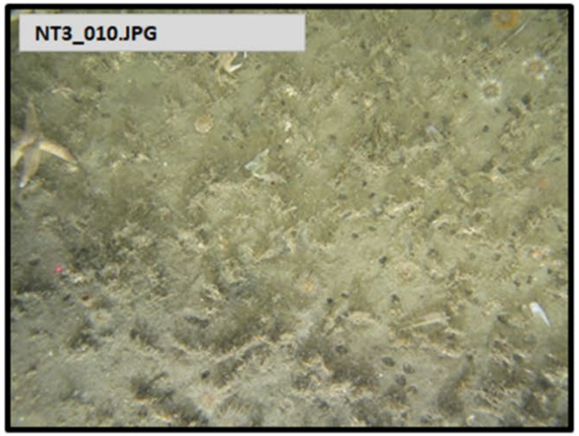


Photo Position: 721903 mE, 5954408 mN



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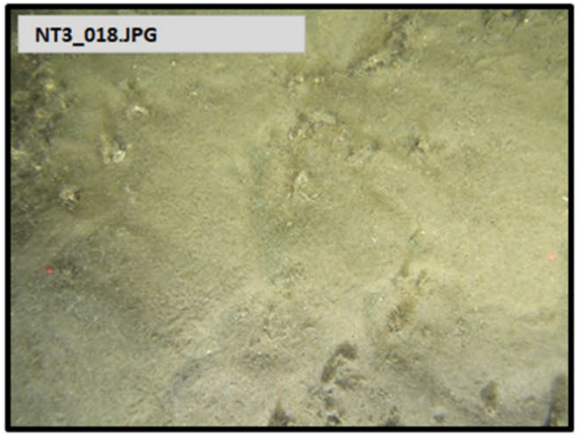

Photo Position: 721872 mE, 5954453 mN

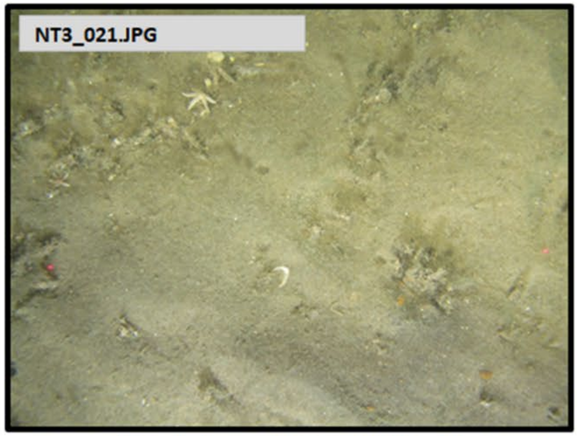

Photo Position: 721866 mE, 5954461 mN

Photo Position: 721852 mE, 5954480 mN

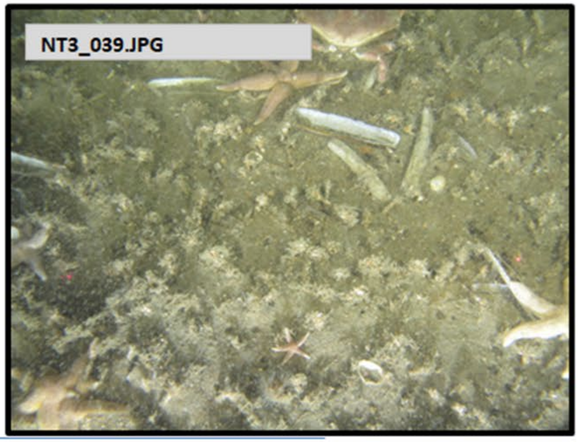

Photo Position: 721852 mE, 5954480 mN

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▲ Grab Location ● Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: N5a Transect 1

Survey Area: N5a

No. of Stills: 35 Mins of Video: 9 Track Length: 130m

Site Selection Criteria

Transect across original N5a well location.

Analogue Interpretation

Area of low reflectivity with some scarring.

Sediment Description

Slightly gravelly/shelly coarse sand.

Conspicuous Fauna

Cnidaria: *Metridium senile* (Plumose Anemone), Cerianthidae sp. **Annelida:** *Lanice conchilega* (Sand Mason). **Arthropoda:** *Cancer pagurus* (Edible crab), Paguridae sp., *Liocarcinus* sp., Brachyura sp., *Cancer maenus* . **Mollusca:** *Sepiola* sp. **Echinodermata:** *Asterias rubens* (Common starfish). **Chordata:** *Callionymus lyra* (Common dragonet), Pleuronectiformes sp., Actinopterygii sp., *Eutrigla gurnardus* (Grey gurnard).

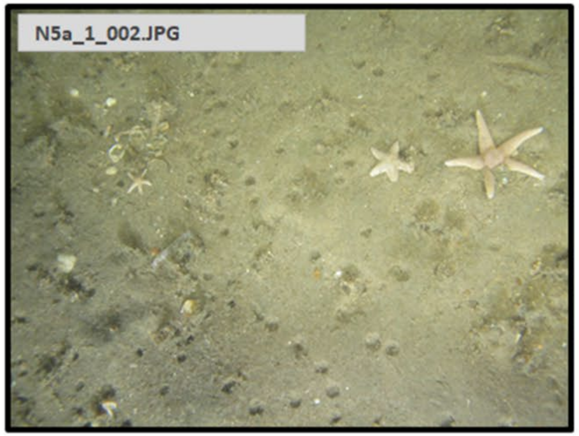


Photo Position: 721585 mE, 5954589 mN

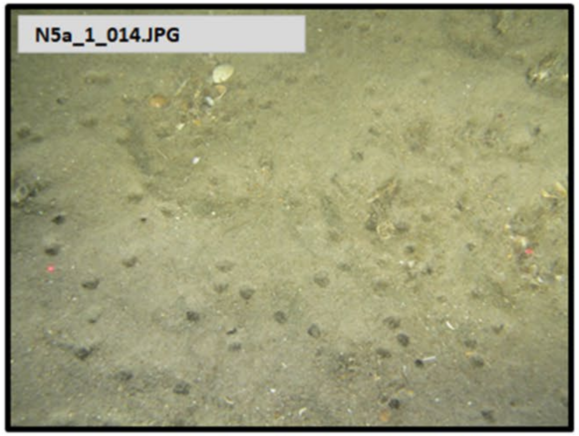


Photo Position: 721600 mE, 5954631 mN

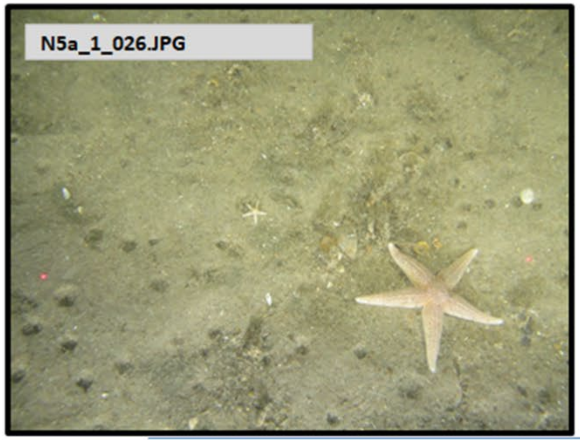
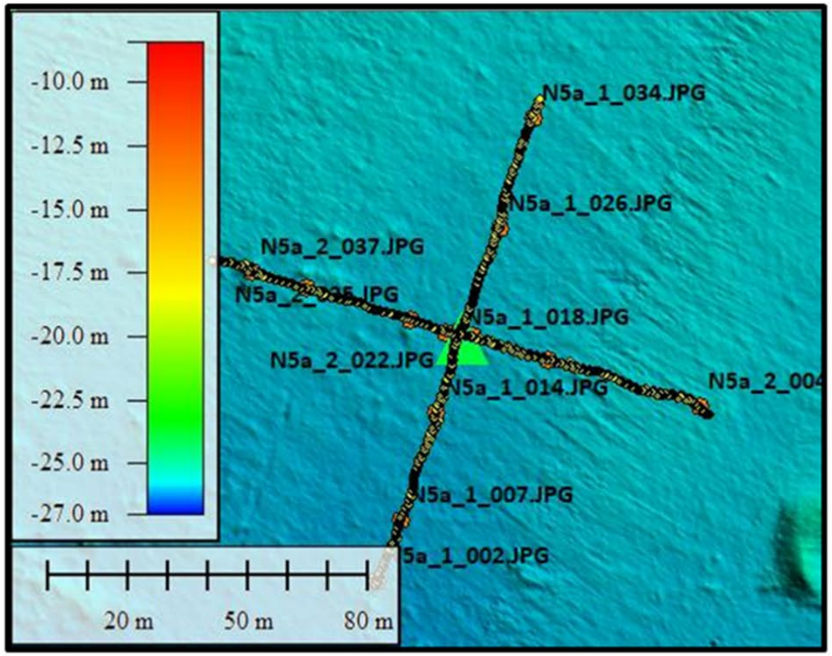


Photo Position: 721616 mE, 5954677 mN



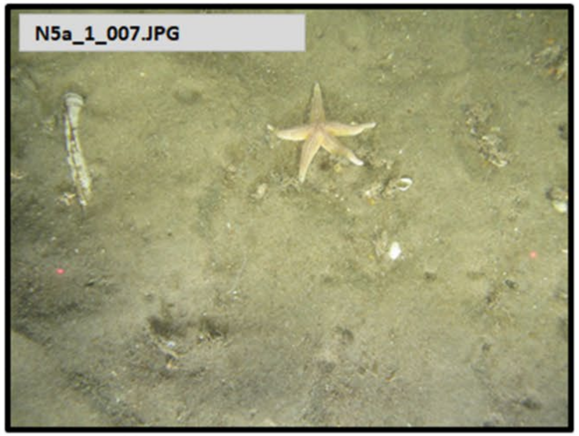


Photo Position: 721592 mE, 5954605 mN

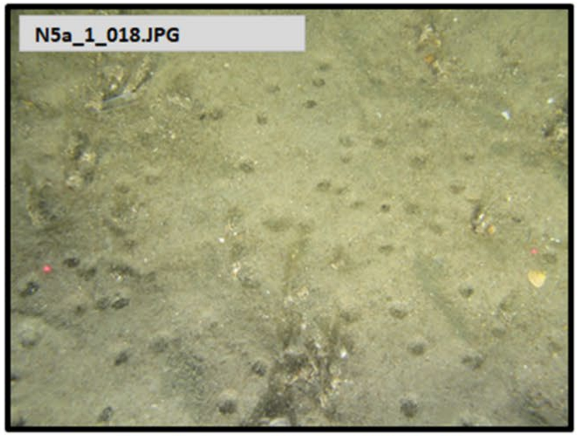


Photo Position: 721606 mE, 5954649 mN

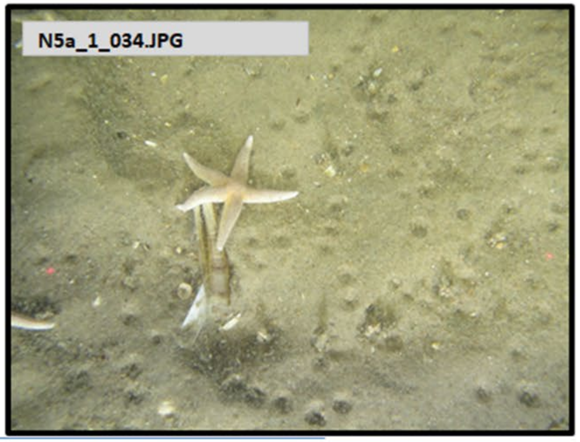


Photo Position: 721625 mE, 5954705 mN

▲ Grab Location ○ Camera Track ● Selected Underwater Still

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

Habitat Summary Information: N5a Transect 2

Survey Area: N5a

No. of Stills: 39 **Mins of Video: 9** **Track Length: 130m**

Site Selection Criteria

Transect across original N5a well location.

Analogue Interpretation

Area of low reflectivity with some scarring.

Sediment Description

Slightly gravelly/shelly coarse sand and aggregations of *Lanice conchilega* .

Conspicuous Fauna

Cnidaria: *Metridium senile* (Plumose Anemone), Cerianthidae sp. **Annelida:** *Lanice conchilega* (Sand Mason). **Arthropoda:** *Cancer pagurus* (Edible crab), Paguridae sp., *Liocarcinus* sp., Brachyura sp., *Cancer maenus* . **Echinodermata:** *Asterias rubens* (Common starfish). **Chordata:** *Callionymus lyra* (Common dragonet), Pleuronectiformes sp., Actinopterygii sp.

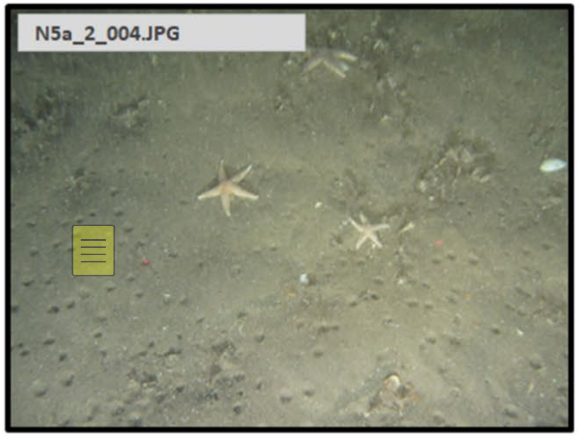


Photo Position: 721613 mE, 5955020 mN

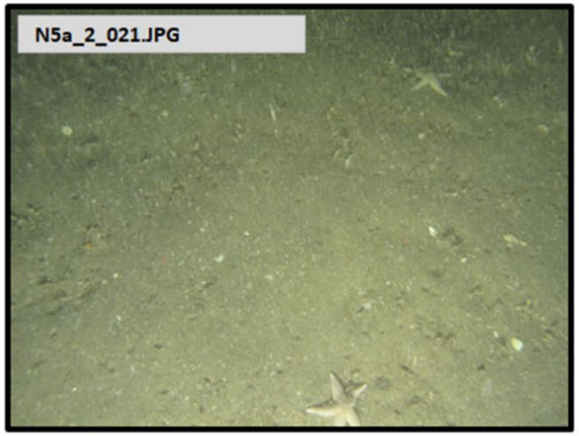


Photo Position: 721620 mE, 5955057 mN

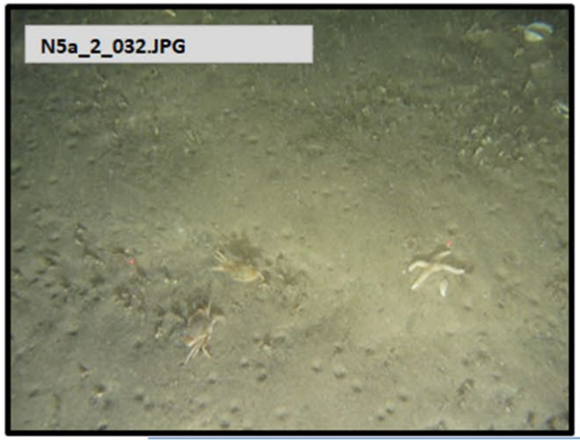
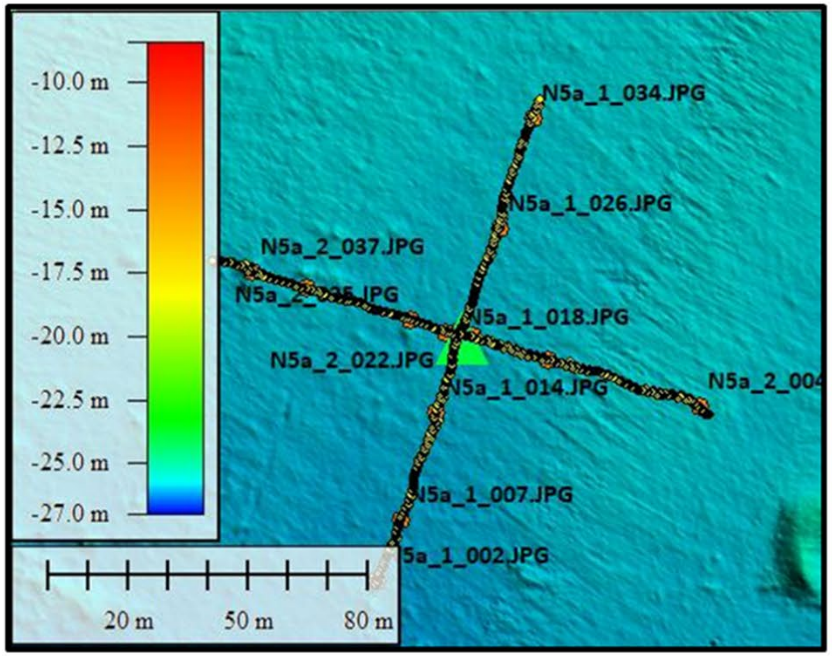


Photo Position: 721628 mE, 5955108 mN



▲ Grab Location ● Camera Track ● Selected Underwater Still

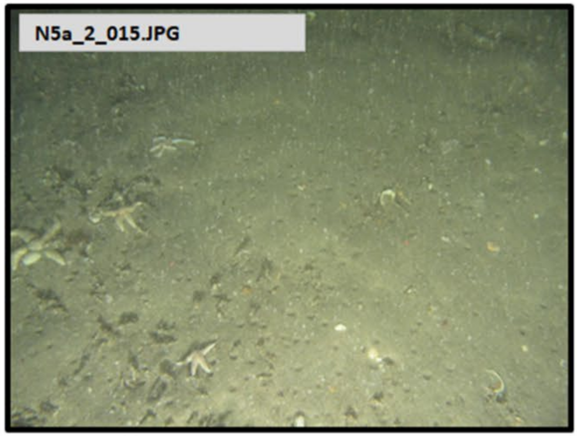


Photo Position: 721616 mE, 5955043 mN

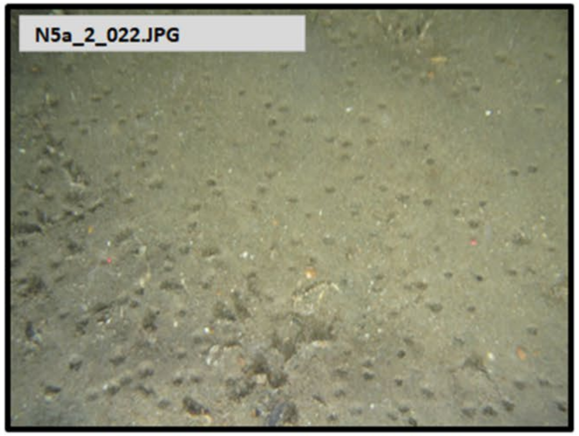


Photo Position: 721621 mE, 5955070 mN

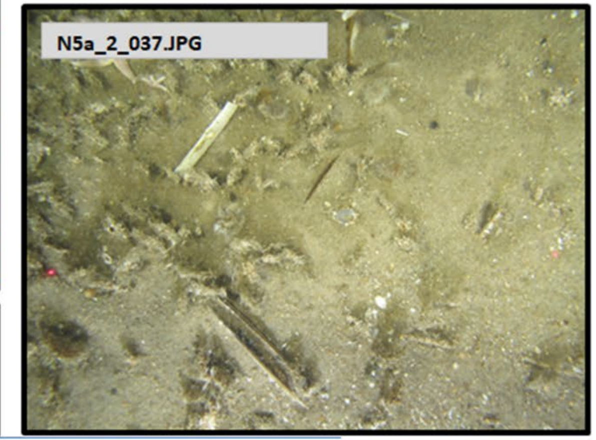


Photo Position: 721630 mE, 5955137 mN

Geodetic Infomation: Datum: ED50 Projection: UTM Zone: 31 North Central Meridian: 3° East

ANHANG E – SERVICE-GARANTIE

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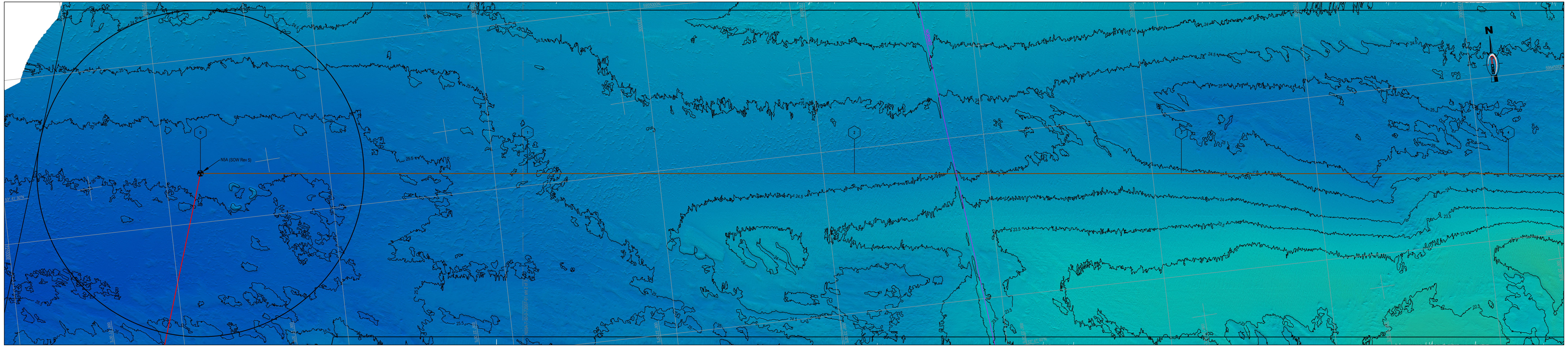
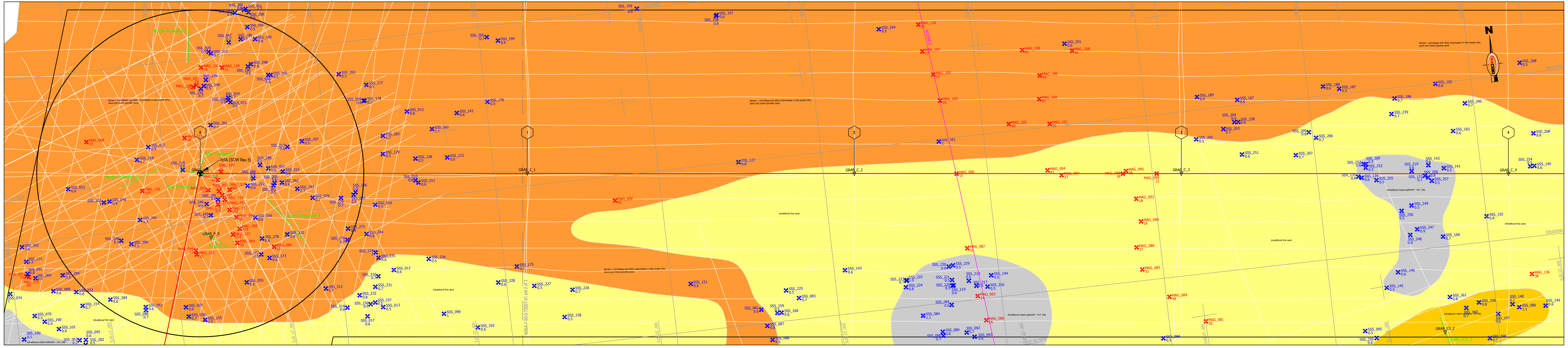
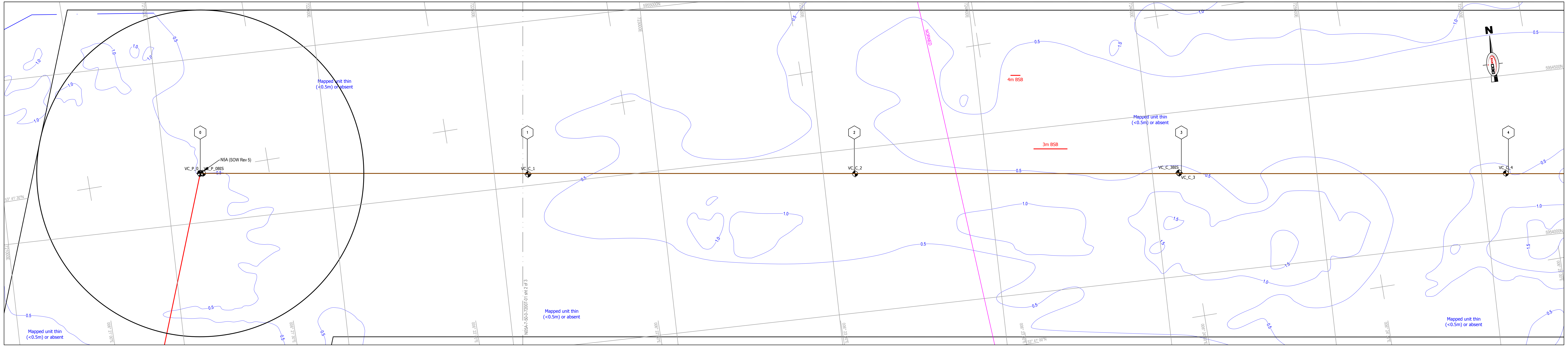
BATHYMETRY



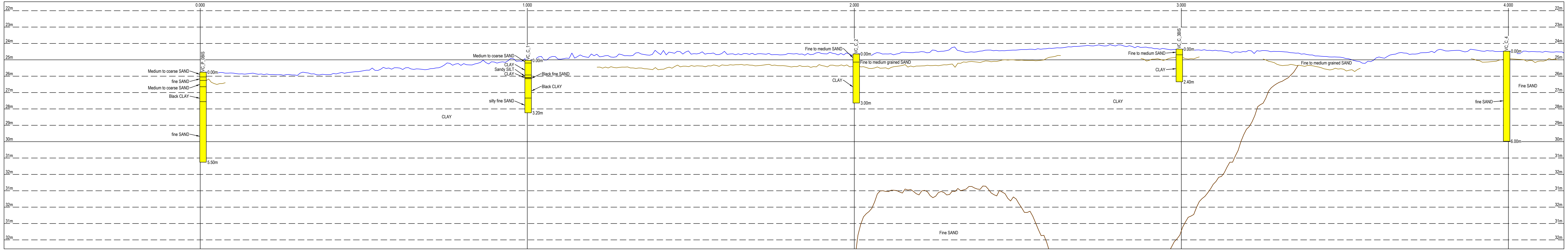
SEABED FEATURES



ISOPACH



LONGITUDINAL PROFILE



LEGEND

Kilometer point

SCALE 1:5000

0 50 100 150 200 250 500 meters

0 200 400 800 1600 feet

Chart match lines
Survey Area (500m at each side of proposed pipeline/cable)
Proposed pipeline route
Proposed cable route
Natura 2000
Cables
Pipelines
500m zone
Proposed new location for N5A platform
Internal cables Riffgat
Monopile location Riffgat
Graticule grid
U.T.M. grid

BATHYMETRY:

All Bathymetry reduced to Lowest Astronomical Tide (LAT)

20 Depth contour at 0.5 meter intervals
Gridsize used for contours: 0.5m

-35m -30 -25 -20 -15 -10 -5m
Gridsize: 0.5m
Height (m)

SEABED FEATERS:

Vessel track
Linear debris
Camera transects
SSS_266 0.8 Object ID
SSS contact/object: Unit value: m
MAG_158 0.6 Object ID
Magnetic contact: Unit value: nT
DEB_023 1.4 x 0.5 x 0.3 Object ID
Debris: Unit value: m (Nmh: No measurable height)
GRAB_P_12 Position of grab sample

Infralittoral fine sand (A5.23)
Infralittoral coarse sediment (A5.13)
Infralittoral mixed sediment (A5.43) - no clay
Dense L. conchilega and other polychaetes in tide-swept infra. Sandand mixed gravelly sand (A5.137)
Infralittoral mixed sediment (A5.43) - Incl. clay

ISOPACH:

1. Time depth conversion carried out using an assumed seismic velocity (ASV) of 1600m/s.
2. The mapped unit is expected to comprise dense SAND

1.0 contour at 0.5 metre intervals
Data extents
Shallow gas
VC_C_4 Position of vibrocore

LONGITUDINAL PROFILE:

Seabed
Base surfical sand
Clay
Kilometer point

VC_C_1 Name of vibrocore
0.00m
4.10m Bottom - depth below seabed

ONE INFORMATION PANEL

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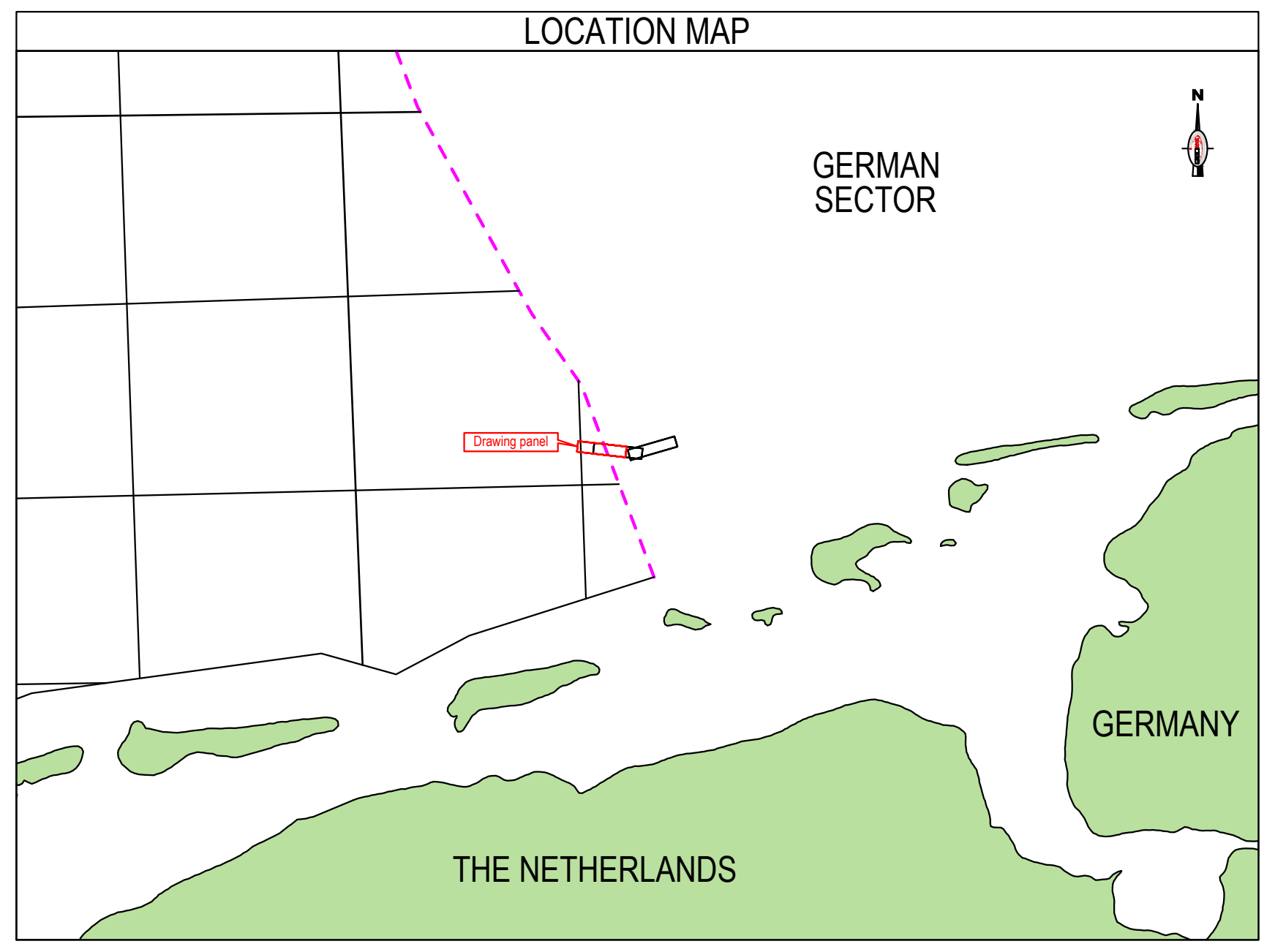
LOCATION MAP



SURVEY EQUIPMENT

Positioning:	Fugro seastar 9205
Multibeam:	R2Sonic 2024
Motion sensor:	POS-MV OceanMaster
Sound velocity probe:	Valeport - Swift
Side scan sonar:	Edgetech - 4200
USBL:	Sonardyne Ranger 2
Magnetometer:	Geometrics - G882
Sub Bottom Profiler	Massa TR1075D
Seismic source:	GSO 180 Sparker

SURVEY SOFTWARE

Online/offline survey suite:	QINSy / Version 8.1
SSS Acquisition:	Edgetech Discover
SSS Processing:	CODA Survey Engine V. 4.3
SBP Acquisition:	Stema SILAS Acquisition
SBP Processing:	Stema SILAS Processing
MAG Acquisition:	QINSy / Version 8.1
MAG Processing:	Oasis Montaj

GEODETIC INFORMATION

Horizontal datum:	European datum 1950 (ED 50)
Spheroid:	International 1924
Semi-major axis:	a = 6378388.00m
Semi-minor axis:	b = 6356911.95m
First eccentricity squared:	e2 = 0.006723
Inverse flattening:	1/f = 297.000
EPSG code:	23031
Projection:	UTM31N
Central meridian:	03° east
Latitude of origin:	0°
False easting:	500000.00m
False northing:	0.00m
Scale factor at central meridian:	0.9996
Units:	Metres
Vertical datum:	Lowest astronomical tide (LAT)

SURVEY DATES

Geophysical acquisition (MBES, MAG, SSS, SBP):

Geo Ocean III: 29/04/2019 untill 15/05/2019

HYDROGRAPHIC SURVEY

N5A development - pipeline route & platform area survey

N5A TO RIFFGAT

Cable route

KP 0.000 to 4.170

Bathymetry - Seabed features - Isopach - Longitudinal profile

Chart: 001/003

Scale: 1/5000

LAT

Drawing made by:

GEOXYZ OFFSHORE
2 Route D'Arlon
Windhof Business center block A
L-8388 WINDHOF
Luxembourg

Client:

Oranje-Nassau Energie B.V.
UNStudio, 7th floor
Parnassusweg 815
1082 LZ Amsterdam (The Netherlands)

Tel: +31 20 535 41 00
Fax: +31 20 535 41 22

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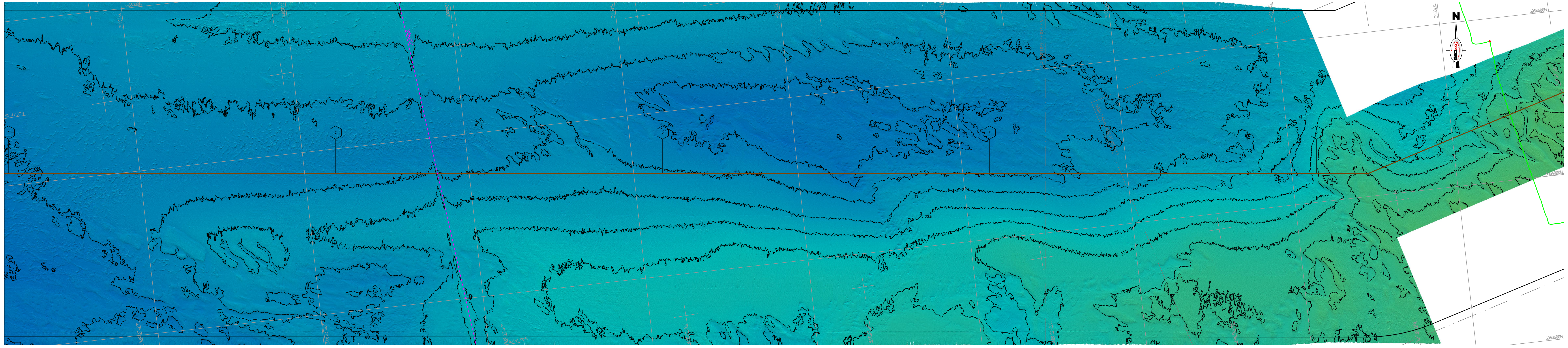
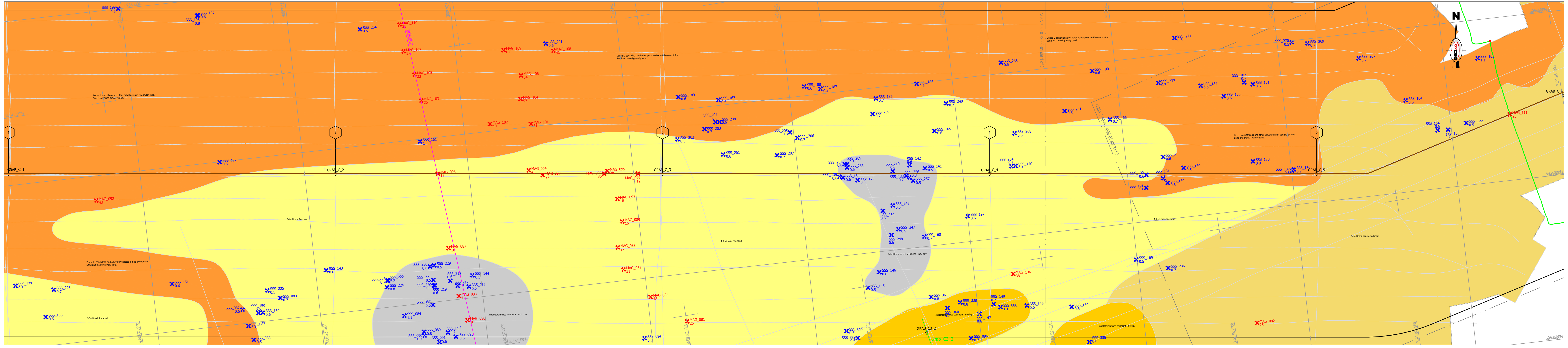
2	15/07/2019	Issued for use	STH	RSP/TDB
3	05/09/2019	Client remarks	STH	RSP/TDB
4	01/10/2019	Client remarks	STH	RSP/TDB

Planname:	LU0022H-553_DR-004_CR_1-3_v4.0	**Project ref:**	N05A-7-50-0-72006-01 sht 1 of 3

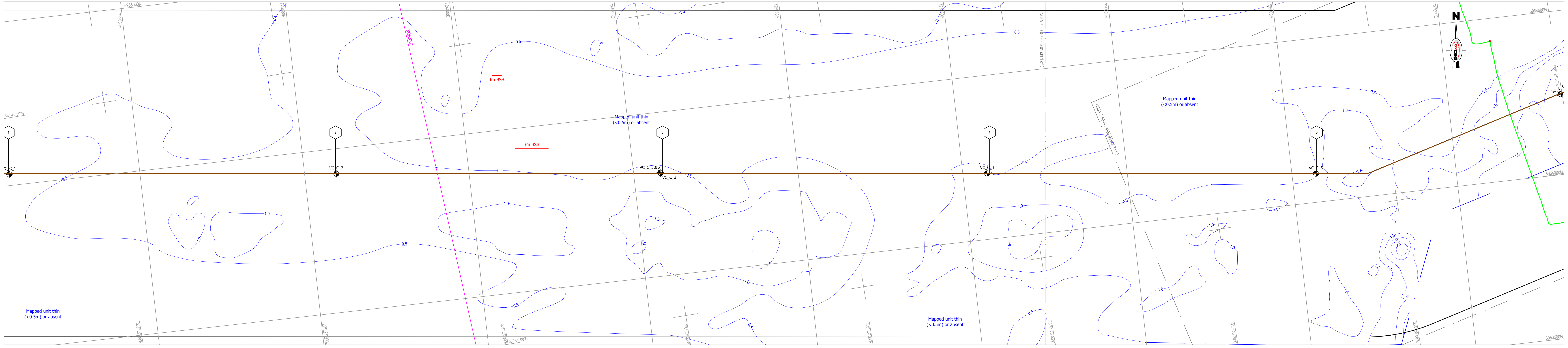
BATHYMETRY



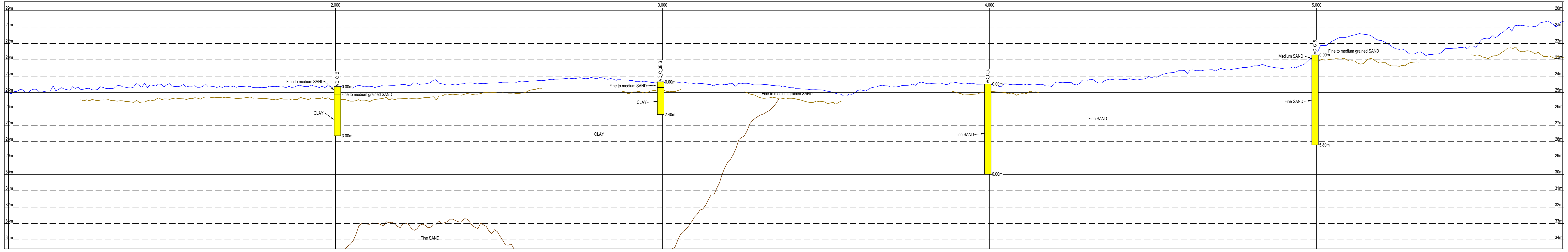
SEABED FEATURES



ISOPACH



LONGITUDINAL PROFILE



LEGEND

SCALE 1:5000

0 50 100 150 200 250 500 meters

0 200 400 800 1600 feet

- Kilometer point
- Chart match lines
- Survey Area (500m at each side of proposed pipeline/cable)
- Proposed pipeline route
- Proposed cable route
- Natura 2000
- Cables
- Pipelines
- 500m zone
- Proposed new location for N5A platform
- Internal cables Riffgat
- Monopile location Riffgat
- Graticule grid
- U.T.M. grid

BATHYMETRY:

All Bathymetry reduced to Lowest Astronomical Tide (LAT)

20 Depth contour at 0.5 meter intervals
Gridsize used for contours: 0.5m

-35m -30 -25 -20 -15 -10 -5m
Gridsize: 0.5m Height (m)

SEABED FEATERS:

- Vessel track
- Linear debris
- Camera transects
- SSS_266 0.8 — Object ID; SSS contact/object: Unit value: m
- MAG_158 0.6 — Object ID; Magnetic contact: Unit value: nT
- DEB_023 1.4 x 0.5 x 0.3 — Object ID; Debris: Unit value: m (Nmh: No measurable height)
- GRAB_P_12 — Position of grab sample

🟨	Infralittoral fine sand (A5.23)
🟨	Infralittoral coarse sediment (A5.13)
🟨	Infralittoral mixed sediment (A5.43) - no clay
🟧	Dense L. conchilega and other polychaetes in tide-swept infra. Sandand mixed gravelly sand (A5.137)
⬜	Infralittoral mixed sediment (A5.43) - Incl. clay

ISOPACH:

1. Time depth conversion carried out using an assumed seismic velocity (ASV) of 1600m/s.
2. The mapped unit is expected to comprise dense SAND

- 1.0 contour at 0.5 metre intervals
- Data extents
- Shallow gas
- VC_C_4 Position of vibrocore

LONGITUDINAL PROFILE:

- Seabed
- Base surfical sand
- Clay
- 4.000 Kilometer point

VC_C_1 Name of vibrocore
0.00m
4.10m Bottom - depth below seabed

ONE INFORMATION PANEL

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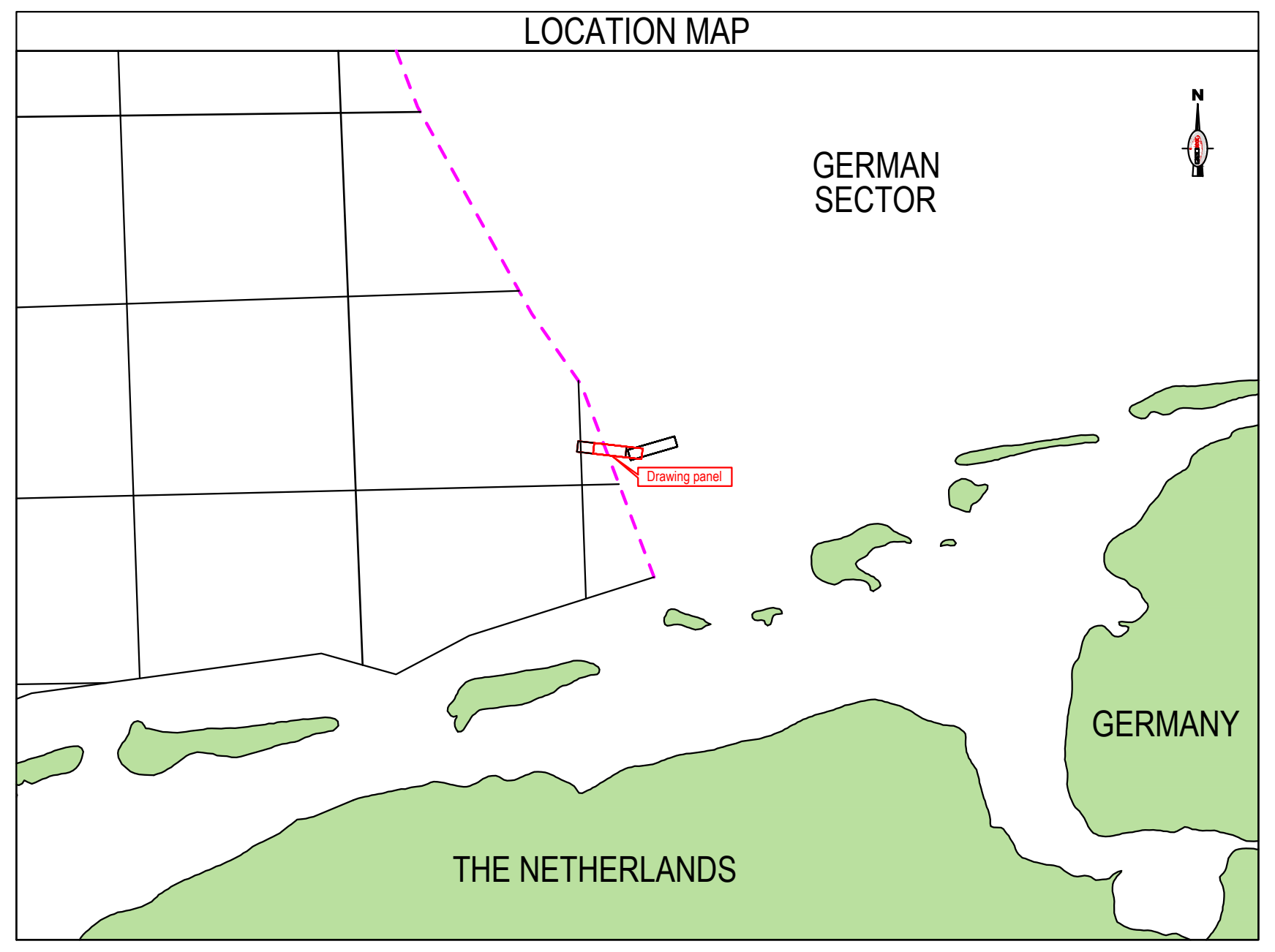
LOCATION MAP



SURVEY EQUIPMENT

Positioning:	Fugro seastar 9205
Multibeam:	R2Sonic 2024
Motion sensor:	POS-MV OceanMaster
Sound velocity probe:	Valeport - Swift
Side scan sonar:	Edgetech - 4200
USBL:	Sonardyne Ranger 2
Magnetometer:	Geometrics - G882
Sub Bottom Profiler	Massa TR1075D
Seismic source:	GSO 180 Sparker

SURVEY SOFTWARE

Online/offline survey suite:	QINSy / Version 8.1
SSS Acquisition:	Edgetech Discover
SSS Processing:	CODA Survey Engine V. 4.3
SBP Acquisition:	Stema SILAS Acquisition
SBP Processing:	Stema SILAS Processing
MAG Acquisition:	QINSy / Version 8.1
MAG Processing:	Oasis Montaj

GEODETIC INFORMATION

Horizontal datum:	European datum 1950 (ED 50)
Spheroid:	International 1924
Semi-major axis:	a = 6378388.00m
Semi-minor axis:	b = 6356911.95m
First eccentricity squared:	e2 = 0.006723
Inverse flattening:	1/f = 297.000
EPSG code:	23031
Projection:	UTM31N
Central meridian:	03° east
Latitude of origin:	0°
False easting:	500000.00m
False northing:	0.00m
Scale factor at central meridian:	0.9996
Units:	Metres
Vertical datum:	Lowest astronomical tide (LAT)

SURVEY DATES

Geophysical acquisition (MBES, MAG, SSS, SBP):

Geo Ocean III: 29/04/2019 untill 15/05/2019

HYDROGRAPHIC SURVEY

N5A development - pipeline route & platform area survey

N5A TO RIFFGAT

Cable route
KP 0.986 to 5.756

Bathymetry - Seabed features - Isopach - Longitudinal profile

Chart: 002/003 | Scale: 1/5000 | LAT

Drawing made by:

GEOXYZ OFFSHORE
2 Route D'Arlon
Windhof Business center block A
L-8388 WINDHOF
Luxembourg

Client:

Oranje-Nassau Energie B.V.
UNStudio, 7th floor
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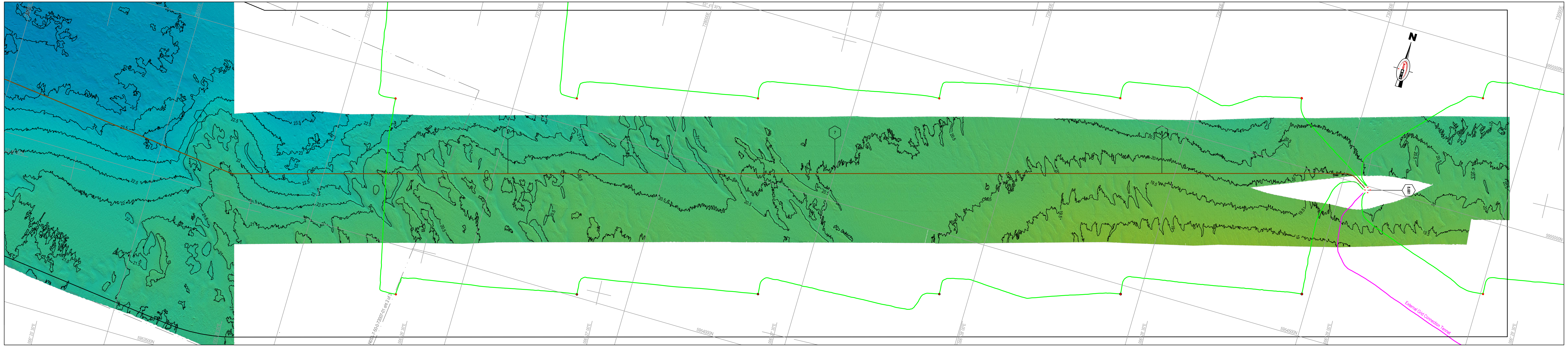
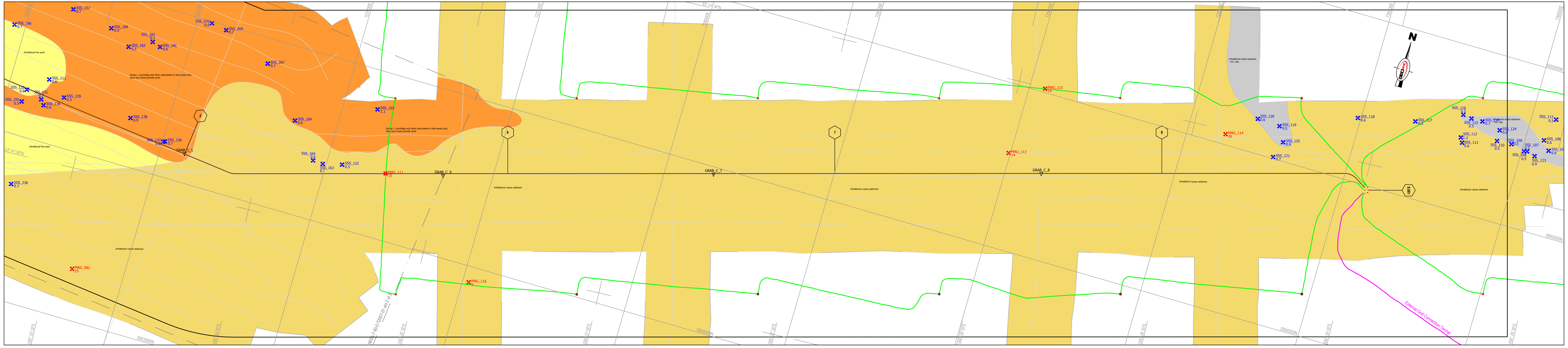
4	01/10/2019	Client remarks	STH	RSP/TDB

Planname:	LU0022H-553_DR-005_CR_2-3_v4.0	Project ref:	N05A-7-50-0-72007-01 sht 2 of 3

BATHYMETRY

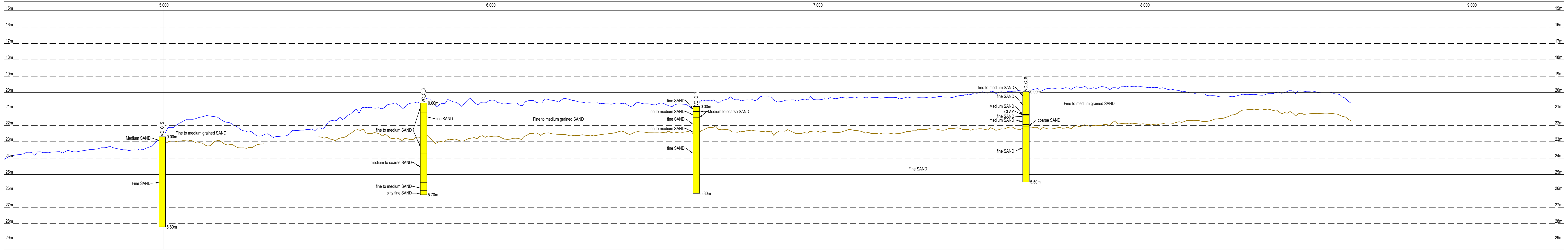


SEABED FEATURES



ISOPACH

LONGITUDINAL PROFILE



LEGEND

Kilometer point

SCALE 1:5000

0 50 100 150 200 250 500 meters

0 200 400 800 1600 feet

Chart match lines

Survey Area (500m at each side of proposed pipeline/cable)

Proposed pipeline route

Proposed cable route

Natura 2000

Cables

Pipelines

○ 500m zone

Proposed new location for N5A platform

Internal cables Riffgat

● Monopile location Riffgat

\+ Graticule grid

U.T.M. grid

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Gridsize: 0.5m

Height (m)

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Vessel track

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SSS_266 0.8 Object ID
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1.0 contour at 0.5 metre intervals

Data extents

Shallow gas

VC_C_4 Position of vibrocore

LONGITUDINAL PROFILE:

Seabed

Base surfical sand

Clay

Kilometer point

VC_C_1 Name of vibrocore

0.00m

4.10m Bottom - depth below seabed

ONE INFORMATION PANEL

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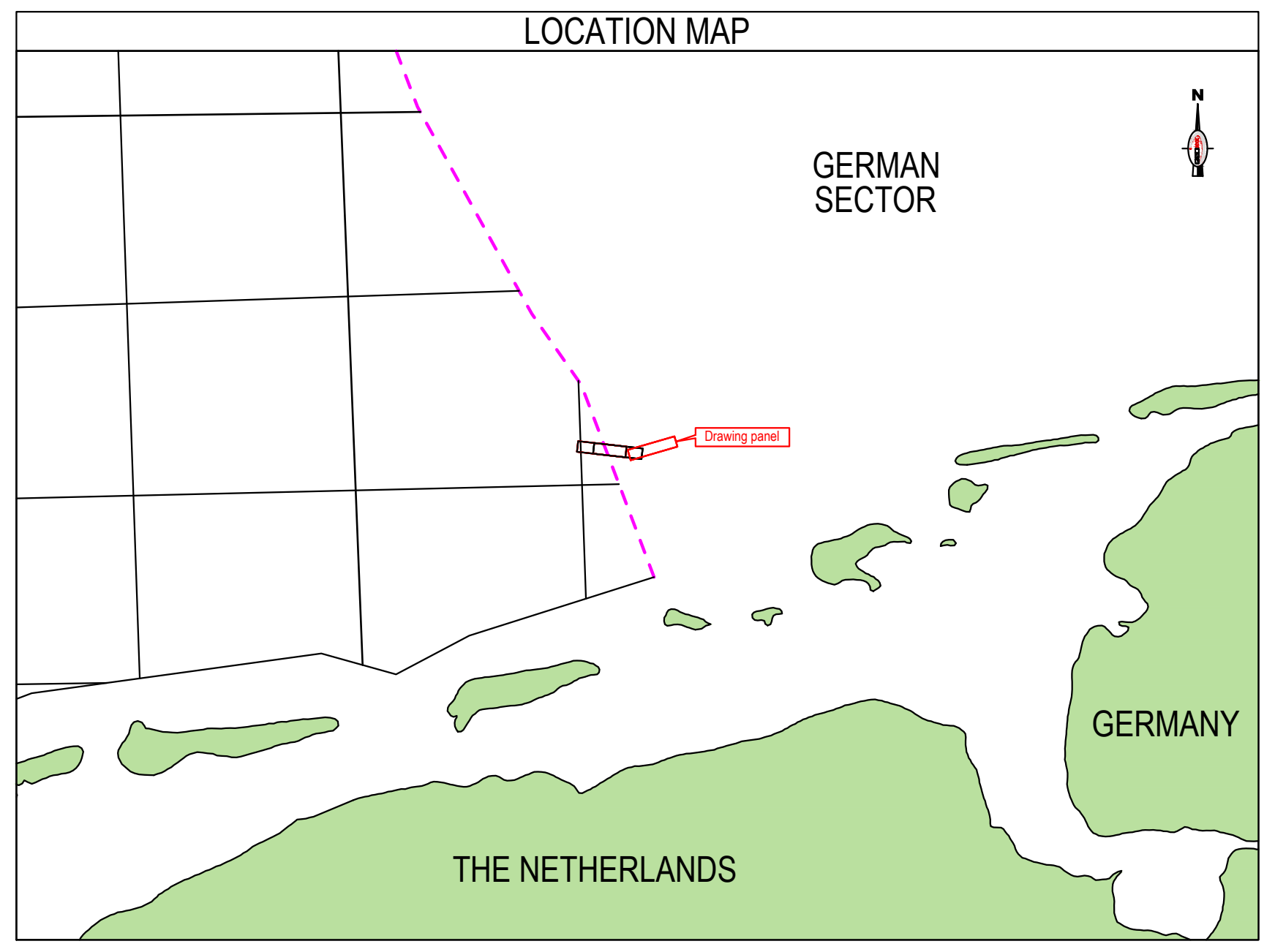
LOCATION MAP



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Side scan sonar:	Edgetech - 4200
USBL:	Sonardyne Ranger 2
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Sub Bottom Profiler	Massa TR1075D
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Scale factor at central meridian:	0.9996
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SBP Processing:	Stema SILAS Processing
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MAG Processing:	Oasis Montaj

SURVEY DATES

Geophysical acquisition (MBES, MAG, SSS, SBP):

Geo Ocean III: 29/04/2019 untill 15/05/2019

HYDROGRAPHIC SURVEY

N5A development - pipeline route & platform area survey

N5A TO RIFFGAT

Cable route

KP 4.511 to 8.681

Bathymetry - Seabed features - Isopach - Longitudinal profile

Chart: 003/003

Scale: 1/5000

LAT

Drawing made by:

GEOXYZ OFFSHORE
2 Route D'Arlon
Windhof Business center block A
L-8388 WINDHOF
Luxembourg

Client:

Oranje-Nassau Energie B.V.
UNStudio, 7th floor
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4	01/10/2019	Client remarks	STH	RSP/TDB

Planname:	LU0022H-553_DR-006_CR_3-3_v4.0	**Project ref:**	N05A-7-50-0-72008-01 sht 3 of 3

N5A Entwicklung

Dieser Text wurde aus dem Englischen übersetzt. Soweit es Widersprüche zum Originaltext gibt, ist der Originaltext führend.

Titel	**Vermessungsbericht - N5A-Plattform zur Riffgat-Kabelstrecke**
GEOxyz Bericht Nr.	LU0022H-553-RR-07
ONE Bericht Nr.	N05A-7-10-0-70023-01
Revision	2.0

2.0	07/08/2019	Ausgegeben zur Verwendung				
1.1	03-07-2019	Rezensionsexemplar				
1.0	14-06-2019	Erster Entwurf				
Revision	Datum	Beschreibung der Revision	Autor	Geprüft	Freigegeben	Freigegeben Kunde

ÄNDERUNGSHISTORIE

Die Bildschirmversion dieses Dokuments ist immer die KONTROLLIERTE KOPIE. Wenn sie ausgedruckt wird, gilt sie als Kopie NUR ZUR INFORMATION, und es liegt in der Verantwortung des Inhabers, dass er die aktuell gültige Fassung besitzt.

Rev.	Grund für die Überarbeitung	Änderungen gegenüber der Vorgängerversion
1.0	Kundenbewertung	N/A
1.1	Kundenkommentare einbeziehen	Zwei Fälle, in denen die verwendete Rohrleitungstrecke in eine Kabelstrecke umgewandelt wurde
2.0	Ausgegeben zur Verwendung	

INHALTSANGABE

ABBILDUNGSVERZEICHNIS

TABELLE DER TABELLEN

REFERENZLISTE

1. Oranje-Nassau Energie, 2019. N5A Development Project Scope of Work. Dokument Ref. N5A-7-10-0- 70000-01.
2. Igeotest, 2019. N5A-Development-Pipeline Route and Platform Area Survey. Geotechnische vorläufige Ergebnisse.
3. Fugro Geoconsulting Limited, 2016. Field operations and Preliminary results Report with Engineering Assessments - Well N5-1 (Ruby) Geotechnical Site Investigation. Project Ref. J11354-R-1(02). Vorbereitet für Hansa Hydrocarbons Limited.

ABKÜRZUNGEN

Die unten aufgeführten Abkürzungen werden in diesem Bericht verwendet. Wenn die in diesem Dokument verwendeten Abkürzungen nicht in dieser Tabelle enthalten sind, kann davon ausgegangen werden, dass es sich entweder um Geräte-Markennamen oder Firmennamen handelt.

	Beschreibung		Beschreibung
2DHR	Zweidimensionale hochauflösende Seismik	PWL	Vorgeschlagener Standort der Plattform
ASV	Angenommene seismische Geschwindigkeit	RWL	Standort der Entlastungsplattform
BSB	Unterhalb des Meeresbodens	SBES	Einstrahl-Echolot
CM	Zentral Meridian	SBP	Unterboden-Profiler
DTU15	Technische Universität Dänemark	SPI	Schusspunkt-Intervall
ED50	Europäisches Datum 1950	SSS	Side-Scan-Sonar
km	Kilometerstand	TWT	Zwei-Wege-Reisezeit
LAT	Niedrigste astronomische Flut	UHR	Ultrahochauflösende Seismik
m	Meter	UKHO	UK Hydrographic Office
MBES	Fächerecholot	USBL	Ultrakurze Basislinie
MODU	Mobile Offshore-Bohreinheit	UTC	Koordinierte Weltzeit
m/s	Meter pro Sekunde	UTM	Universal-Transversal-Mercator
ms	Millisekunden	UXO	Nicht zur Wirkung gelangte Kampfmittel
MSL	Mittlerer Meeresspiegel	WGS84	Weltgeodätisches System 1984

1 KURZFASSUNG

1.1 STANDORTÜBERSICHT

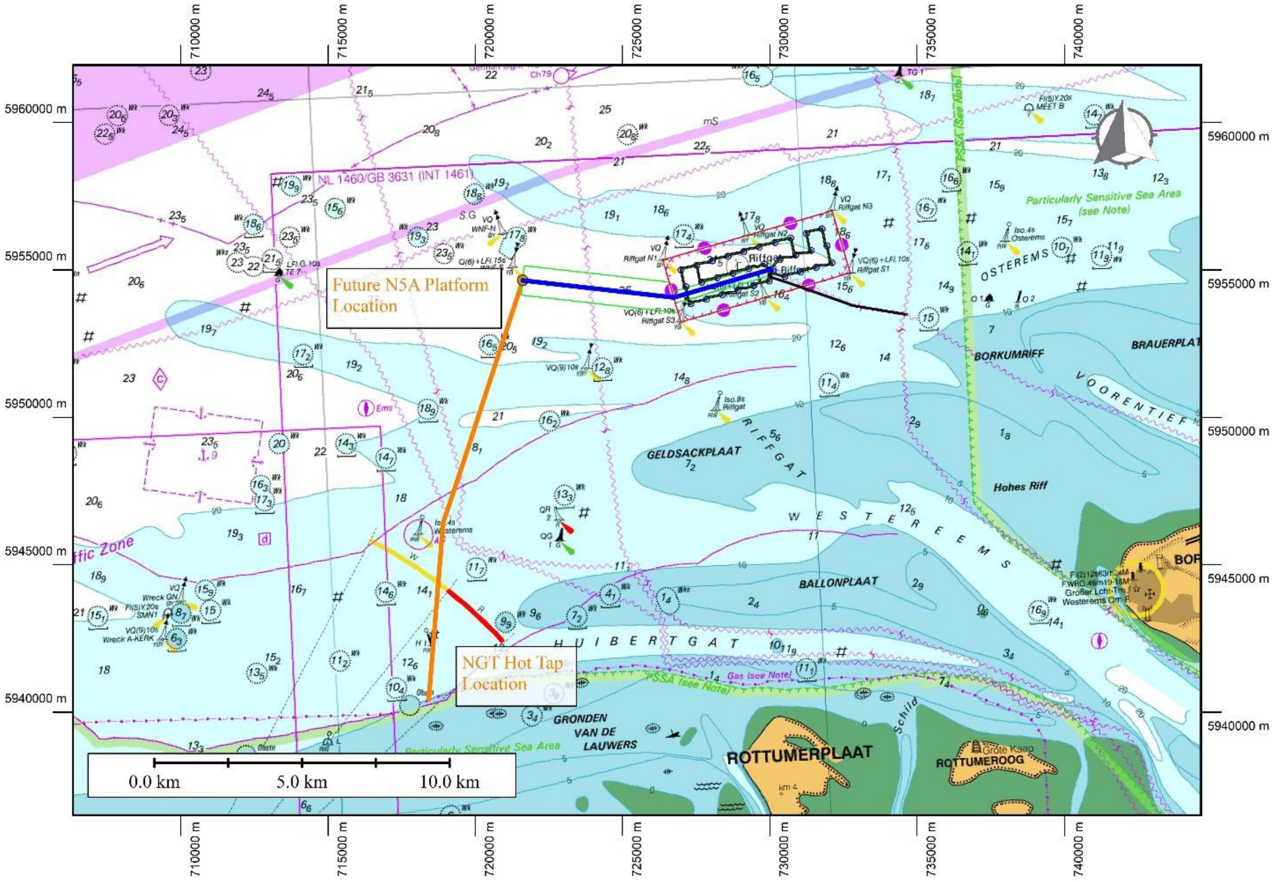


Abbildung 1:
Projektstandortübersicht

BEWERTUNG DER 1.1 KABELSTRECKE VON N5A BIS RIFFGAT

Vorgeschlagene Kabelstrecke Korridor		
Koordinaten des Startorts (N5A Plattform Standort)	721 607,00mE	53° 41' 32.347" N
	5 954 650.00mN	06° 21' 23.281" E
Koordinaten des Endpunkts (Standort Umspannwerk Riffgat Windpark)	730 081.00m E	53° 41' 30.080" N
	5 954 988,00m N	06° 29' 05.312" E
Geodäsie	ED50 : UTM Zone 31N : CM 3° E	
Vertikales Datum	Alle Tiefen sind in Metern unter LAT angegeben, sofern nicht anders angegeben	
Umfragebereich	Streckenlänge - 8681m Route Korridorbreite - 1000m	
Bathymetrie		
Wassertiefe entlang der Route	Maximum: 26.0m LAT; Minimum: 19.6m	

	Die Wassertiefen entlang des vorgeschlagenen Trassenkorridors liegen zwischen 26,4 m auf 26,0 m bei KP0,280 und 19,6 m bei KP7,941.
Wassertiefen innerhalb des Streckenkorridors	Maximal: 26.4m LAT; Minimum: 18.5m LAT Die Wassertiefen entlang des vorgeschlagenen Trassenkorridors liegen zwischen 26,4 m bei etwa KP0,000 und 18,5 m bei KP8,232. Der Meeresboden wird zum ost-nordöstlichen Ende der vorgeschlagene Kabelstrecke graduell untiefer. Etwa bei KP5.133 befindet sich ein kleiner Kamm.
Meeresbodengefälle und Topographie im Streckenkorridor	Bodenformen sind in den Sonar- oder Bathymetrie-Aufzeichnungen nicht abgebildet. Fotos, die während der Umweltuntersuchung aufgenommen wurden, zeigen jedoch deutlich, dass der Großteil des Meeresbodens innerhalb des Untersuchungskorridors von Riffelungen bedeckt ist. Eine Reihe von natürlichen kleineren Trögen, die überwiegend von Nordwest nach Südost verlaufen, treten innerhalb des Untersuchungsgebiets auf. Diese werden als ozeanographische Prozesse interpretiert und scheinen die vorgeschlagene Kabelstrecke von etwa KP5.158 bis zum Ende der vorgeschlagenen Kabelstrecke bei KP8.681 zu kreuzen. Örtliche Wassertiefenschwankungen sind auf das Relief und die Verteilung der Tröge zurückzuführen. Die Wassertiefen entlang der vorgeschlagenen Route liegen zwischen 26,0 m bei KP0.280 und 19,6 m bei KP7.941. Der Meeresboden wird zum ost-nordöstlichen Ende der vorgeschlagenen Kabelstrecke hin leicht seicht. Bei etwa KP5.133 befindet sich eine kleine Erhebung. Das natürliche Gefälle entlang der vorgeschlagenen Trasse beträgt weniger als 1°. Maximale Neigungen von bis zu 7° sind auf die Flanken der markanteren Tröge beschränkt. Drei halbkreisförmige Merkmale mit 1 m positivem Relief, die als mit früheren Bohraktivitäten zusammenhängend interpretiert werden, sind auf den Bathymetriedaten abgebildet. Diese befinden sich am Anfang der vorgeschlagenen Route zwischen KP0.085 und KP0.168; an ihrem minimalen Versatz liegen sie etwa 27 m süd-südwestlich. Sie scheinen in einem Radius von 30 m voneinander entfernt zu sein, mit Abmessungen von 30m x 30m.
Merkmale des Meeresbodens	
Meeresbodensedimente entlang der vorgeschlagenen Route	Es wird erwartet, dass die Sedimente des Meeresbodens entlang der vorgeschlagenen Kabelstrecke bestehen aus feinem bis grobem SAND, mit gelegentlichen Bereichen aus grobem SAND und TON mit Kies und Muschelfragmenten.
Meeresbodensedimente innerhalb des Trassenkorridors	Es wird erwartet, dass die Meeresbodensedimente entlang des vorgeschlagenen Kabelstreckenkorridors aus feinem bis grobem SAND bestehen, mit gelegentlichen Bereichen aus grobem SAND und TON mit Kies und Muschelfragmenten.
Vorhandene Infrastruktur innerhalb dem Untersuchungskorridor	Die Abbildung zeigt das NorNed-Kabel, das die vorgeschlagene Kabelstrecke, die von Nord-Nord-West nach Süd-Süd-Ost verläuft, bei KP2.313 kreuzt. Es wurden mehrere magnetische Kontakte identifiziert,

und entlang der vorgeschlagenen Route	die die Position des Kabels bestätigen.
Trümmer/Hindernisse entlang der vorgeschlagenen Route	Fünf Kontakte befinden sich innerhalb von 10 m von der vorgeschlagenen Trasse, die alle als Felsbrocken interpretiert werden. Der der vorgeschlagenen Kabelstrecke am nächsten liegende Kontakt befindet sich bei KP4.479, 4,7 m süd-südwestlich der vorgeschlagenen Kabelstrecke und ist 0,6 m hoch.

Trümmer/Hindernisse im Streckenkorridor	Innerhalb des vorgeschlagenen Kabelstreckenkorridors kommen zahlreiche Objekte vor, die als Felsblöcke interpretiert werden. Die Mehrzahl der als Findlinge interpretierten Objekte befindet sich im Norden des Untersuchungskorridorbereichs und fällt mit Bereichen mit Lehmaufschlüssen zusammen. Im Bereich der Korridoruntersuchung wurden zahlreiche magnetische Kontakte entdeckt. Mehrere magnetische Anomalien häufen sich in der Nähe des Beginns der vorgeschlagenen Route zwischen KP0.020 und KP0.130. Es wird interpretiert, dass diese mit den drei halbkreisförmigen Merkmalen zusammenhängen, die mit früheren Bohrungen in Verbindung stehen. Andere magnetische Anomalien sind nicht mit einem kartierten Meeresbodenmerkmal verbunden. Diese Kontakte können sich auf vergrabene Trümmerteile beziehen.
Flache Böden	
Erwartete Geologie entlang der Route	Die obere Einheit aus fein- bis mittelkörnigem SAND wird im Allgemeinen nach Osten hin dicker. Westlich der Route AC bei KP 5.156 ist die Einheit etwa 0,5 bis 1 m dick oder fehlt/ist unmerklich dünn, östlich dieses Punktes überschreitet die Einheit lokal eine Dicke von 2 m. Vibrocore-Protokolle zeigen, dass die obere Einheit von KP0 bis KP 3.357 von tonhaltigen Ablagerungen unterlagert ist, die als Füllung eines breiten Kanals interpretiert werden. Von KP 3.357 bis zum Ende der Strecke ist die obere Einheit von feinem SAND unterlagert.
Mögliche Gefährdungen	
Hindernisse entlang der Route	Geröll und Felsbrocken, die in der flachen geologischen Abfolge entlang der vorgeschlagenen Route oder überall im Untersuchungskorridor möglich sind. Oberflächennahen Gas 90 m nördlich der Route von KP2.549 bis KP2.651.

2 EINLEITUNG

2.1 PROJEKTÜBERSICHT

GEOxyz wurde beauftragt, eine geophysikalische Streckenvermessung im niederländischen Sektor, Block N5A, entlang eines vorgeschlagenen Kabelstreckenkorridors zwischen dem Standort der N5A-Plattform und der Riffgat Windpark Transformet Station durchzuführen (siehe separater Bericht Ref LU0022H-553-RR-01). Fächerecholot- (MBES), Seitensichtsonar- (SSS), Magnetometer- und Sub-Bottom-Profiler-Daten wurden entlang eines 9 km mal 1 km großen Vermessungskorridors erfasst.

Elf Umweltproben und fünf Kameratransekte wurden entlang des vorgeschlagenen Trassenkorridors erfasst.

Außerdem wurden neun Rüttelkerne entlang der Trasse entnommen und von Igeotest (Ref.

2) gemeldet. Vorgeschlagene Lage des Kabelstreckenkorridors:

Tabelle 1: Kabelweg N5A nach Riffgat

N5A nach Riffgat Kabelstrecke - ED50, UTM 31N, CM 3° E					
Vorgeschlagenes Kabel Route Standort	KP	Östliche Ausrichtung (m)	Nordwert (m)	Breitengrad	Längengrad
Beginn der Route - N5A Plattform Standort	0.000	721 607.00	5 954 650.00	53° 41' 32.347" N	06° 21' 23.281" E
	5.156	726 730.61	5 954 070.44	53° 41' 05.716" N	06° 26' 00.580" E
	8.630	730 066.69	5 955 037.36	53° 41' 31.697" N	06° 29' 04.664" E
Ende der Route - Umspannwerk Riffgat Windpark Standort	8.681	730 081.00	5 954 988.00	53° 41' 30.080" N	06° 29' 05.312" E

Die Vermessung wurde mit dem Vermessungsschiff Geo-Ocean III zwischen dem $^{1.}$ und $^{15.}$ Mai

2019 durchgeführt. Der Vermessungslinienplan ist in Abbildung 2 dargestellt.

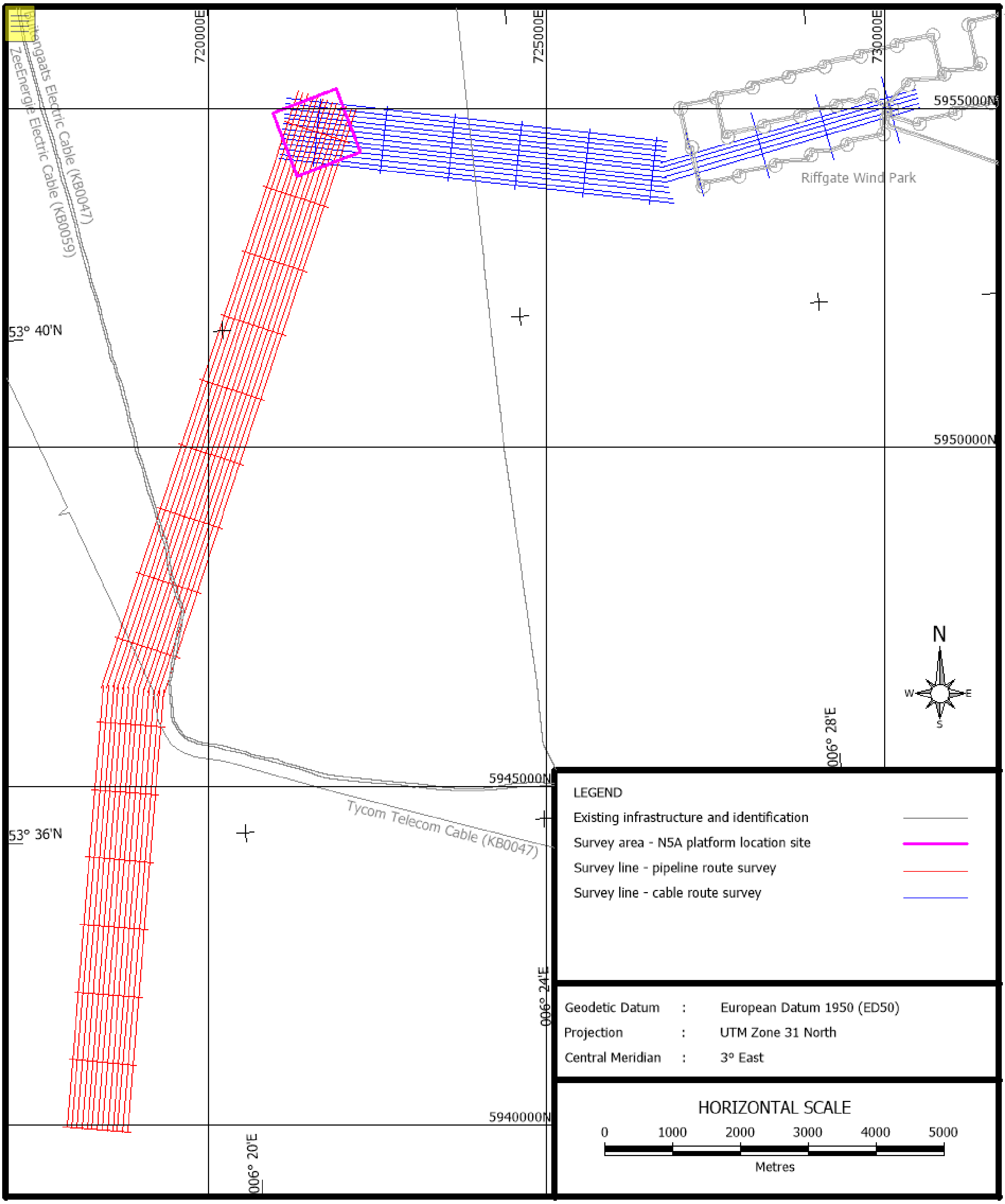


Abbildung 2:
Vermessungslinienplan

2.2 UMFANG DER ARBEIT

Die Ziele für die Streckenuntersuchung sind wie folgt:

- Abschluss aller Vermessungsarbeiten ohne Zwischenfälle in Bezug auf Gesundheit, Sicherheit und Umwelt;
- Identifizierung aller Georisiken und geologischen Bedingungen im Zusammenhang mit der Rohrleitungsinstallation. Dies kann Kanalisierung, Verwerfungen und andere geologische Merkmale und Variationen umfassen, die von Bedeutung sein können;
- Um eventuelle Hindernisse auf dem Meeresboden zu identifizieren;
- Um Wassertiefen und Meeresbodenbedingungen zu ermitteln;
- Untersuchung der geologischen Verhältnisse im Untergrund, um eine detaillierte Klassifizierung der Böden für die Beurteilung der Graben-/Kabelverlegungsbedingungen zu ermöglichen.

2.3 GEODÄTISCHE PARAMETER

2.3.1 Horizontale Referenz

Tabelle 2: Geodätische Parameter

Geodätische Parameter	
Sphäroid	International 1924
Semi-major-Achse	6378388.297
Halb-Minor-Achse	6356911.946
Datum	Europäisches Datum 1950 (ED50)
Projektion	Universal Transverse Mercator (UTM)
Falsche Ostung	500000.00
Falsche Nordrichtung	0.00
Zentraler Meridian	3° Ost
Zentraler Skalenfaktor	0,9996
Breitengrad der Herkunft	0°
Raster Zone	31 Nord
Datumstransformation WGS84 - ED50	
dx	+ 89,5m
dy	+93,8m
dz	+123,1m
Rx	0,0
Ry	0,0
Rz	-0,156
Skala	-1,2ppm

2.3.2 Vertikale Referenz

Alle Wassertiefen wurden mithilfe des DTU15-Modells auf LAT reduziert. Das MSL liegt im Vermessungsbereich 1,6 m über LAT.

3 DATENERFASSUNG, VERARBEITUNG UND EINSCHRÄNKUNGEN

3.1 FÄCHERECHOLOT

Bathymetrische Daten wurden mit einem R2Sonic 2024 Fächerecholot erfasst. Die Gezeitenreduktion wurde mit dem DTU15-Modell durchgeführt. Die Bathymetriedaten wurden auf den niedrigst möglichen Gezeitenwasserstand (LAT) reduziert. LAT liegt innerhalb des Vermessungsgebiets 1,6 m unter MSL.

Die Wassertiefen werden relativ zu den niedrigsten astronomischen Gezeiten (LAT) angegeben und gelten als genau auf
±1 % (ca. 0,3 m). Die Fächerlotdaten wurden auf eine Bin-Größe von 0,5 m x 0,5 m verarbeitet.

Die Datenverarbeitung wurde mit QINSy und QIMERA durchgeführt. Die Daten wurden in QINSy als rohe QPD-Dateien aufgezeichnet. Fächerstrahl-Daten wurden mit einer Kombination aus grundlegenden Filtern bereinigt, die auf den gesamten Datensatz angewendet wurden, und dann wurden einzelne QPDs manuell bereinigt, indem weitere Ausreißer innerhalb der Daten gelöscht wurden. Nach der Bereinigung wurden die QPDs mit den Gezeitenwerten korrigiert und weitere kleinere Anpassungen vorgenommen, um die Daten in QIMERA visuell zu verbessern. Eine endgültige Rasterdatei wurde exportiert und mit einem Konturintervall von 0,5 m konturiert und ein Geo-Tiff für die endgültige Präsentation erstellt.

3.2 SEITENSICHTSONAR

Seitensichtsonardaten wurden mit einem Edgetech 4200 mit einer Frequenz von 100kHz / 400 kHz bei einer Reichweite von 150m/200m erfasst.

Die Daten wurden mit einem Sonardyne Ranger 2 USBL-System positioniert, wobei die Gesamtgenauigkeit der Kontakte durch die Schiffspositionierung, die akustische Positionierung des Schleppfisches relativ zum Schiff und die Position des Kontakts relativ zum Schleppfisch beeinflusst wurde. Bei dieser Untersuchung lag die Positionsgenauigkeit des Seitensichtsonar-Datensatzes im Allgemeinen zwischen ±3-5 m. MBES-Daten wurden verwendet, um die Positionierung von Kontakten aus den SSS-Daten zu verbessern, und Merkmale wie Vertiefungen, Narben usw. wurden generell aus den MBES-Daten ausgewählt, wo immer dies möglich war.

Drei Hauptfaktoren beeinflussen die Auflösung in der Längsrichtung. Dies sind die horizontale Strahlbreite, die Schleppgeschwindigkeit und die Sonarreichweite. Diese Parameter sind in der folgenden Tabelle zusammengefasst. Die Auflösung in Querrichtung wird durch die Sonarfrequenz bestimmt. Die höhere Frequenz ermöglicht zwar die Erkennung kleinerer Objekte, begrenzt aber die Reichweite auf ˜75m.

Sonar-Bereich	150m/200m pro Kanal
Horizontale Strahlbreite	100 kHz 1,5° 400 kHz 0,4°
Vertikale Strahlbreite	100 kHz/400 kHz 50°
Entlang der Spur Auflösung	100 kHz 3,9m bei 150m Reichweite 400 kHz 1,1m bei 150m Reichweite
Auflösung entlang der Strecke	100 kHz 8cm 400 kHz 2cm

Die 100-kHz-Daten wurden zur Erstellung des Mosaiks verwendet. Die Rohdaten wurden in Coda Survey Engine importiert und die Position des Meeresbodens ausgewählt. Die Daten wurden dann skaliert und eine zeitvariable Verstärkung (TVG) sowie eine korrigierte Navigation angewendet. Die Daten wurden dann um die Schräglage korrigiert und übereinander gelegt, um ein möglichst kohärentes Mosaik zu erstellen.

Das Mosaik wurde mit einer Auflösung von 2 Pixeln pro Meter exportiert.

Die Zielerfassung erfolgte in der Regel mit den 400-kHz-Daten. Wenn die Abdeckung mit den 400-kHz-Daten jedoch weniger als 200 % beträgt, wurden die 100-kHz-Daten verwendet. Die gleichen Verarbeitungsschritte - Auswahl des Meeresbodens, Skalierung, TVG und korrigierte Navigation - wurden auch auf die 400-kHz-Daten angewendet. Die Daten wurden dann Zeile für Zeile untersucht und Ziele auf dem Meeresboden wurden ausgewählt - Objekte, lineare Trümmer, Narben, Vertiefungen usw. Die überprüften Kontaktpositionen wurden zwischen den Linien abgeglichen und die Ziellisten exportiert.

3.3 MAGNETOMETER

Magnetometerdaten wurden mit einem Geometrics G882 Magnetometer erfasst, das 10 m hinter dem Seitensichtsonar huckepack angebracht wurde.

Die Daten wurden mit einem Sonardyne Ranger 2 USBL-System positioniert, wobei die Genauigkeit der aus den Magnetometerdaten identifizierten Kontakte durch die Schiffspositionierung und die akustische Positionierung des Schleppfisches beeinflusst wird. Bei dieser Untersuchung lag die Positionsgenauigkeit der Magnetometerdaten im Allgemeinen zwischen ±3-5 m (basierend auf der Positionierung des Seitensichtsonars).

Die Daten wurden als Textdateien in QINSy aufgezeichnet und dann in Oasis Montaj grafisch dargestellt, wobei Kontakte von 10nT oder mehr aufgrund von schiffsbedingtem Rauschen durch kurze Liegezeiten im flachen Wasser ausgewählt wurden und eine Zielliste exportiert wurde. Das Magnetometer wurde in einer Höhe von 10-20 m über dem Meeresboden geflogen, was bedeutet, dass kleine Kontakte möglicherweise übersehen werden könnten. Aufgrund der sehr geringen Datendichte (der minimale Linienabstand betrug 37,5 m) ist die angegebene Position der magnetischen Kontakte die Position der Anomalie entlang der Vermessungslinie und keine Interpretation der genauen Position des potenziellen magnetischen Kontakts. Ein Kontakt kann auf jeder Seite der Vermessungslinie bis zur Hälfte des Abstands zur benachbarten Linie liegen. Wenn also der Linienabstand 50 m beträgt, kann der Kontakt bis zu 25 m auf jeder Seite der Linie liegen. Ein Magnetometer, das auf diese Weise verwendet wird, ist nur von begrenztem Nutzen, aber es ist effektiv, um die Positionen von Infrastruktur am Meeresboden zu bestätigen und die ungefähren Positionen großer magnetischer Kontakte zu markieren.

3.4 UNTERBODEN-PROFILER

Die Bedingungen des flachen Bodens wurden anhand von Pinger-Daten interpretiert, die innerhalb des Untersuchungsgebiets gesammelt wurden. Die Interpretation des Pinger-Datensatzes ist auf ca. 15ms TWT unterhalb des Meeresbodens (12m ASV 1600m/s) begrenzt.

Die geschätzte Auflösung für den Pinger-Datensatz ist

unten aufgeführt.

<u>Pinger</u>

Vertical Auflösung	0,1m (basierend auf einer geschätzten dominanten Frequenz von 4kHz und einer angenommenen konstante Geschwindigkeit von 1600m/s). Die direkte Beobachtung der Aufzeichnungen zeigt, dass eine Auflösung von ca. 0,2m die praktische Grenze sein kann.
Horizontal e Auflösung	0,6m basierend auf einer Triggerrate von 250 Millisekunden. 4m Fresnel-Zone bei 20ms (basierend auf einer geschätzten dominanten Frequenz von 4kHz und einer angenommenen konstanten Geschwindigkeit von 1600m/s).

Die Pinger-Daten wurden in der Erfassungssoftware Coda im Cod-Dateiformat aufgezeichnet. Der Meeresboden wurde ausgewählt, die Daten wurden skaliert, ein TVG angewandt und entweder eine Seegangskompensation oder ein Dünungsfilter angewendet. Die Daten wurden dann als verarbeitete Segydatei exportiert und in die Kingdom 2016 Software importiert, wo die Interpretation durchgeführt wurde.

Die Umrechnung von Zeit in Tiefe wurde mit einer angenommenen konstanten seismischen Geschwindigkeit von 1600m/s durchgeführt. Die lithologischen Beschreibungen werden aus dem seismischen Charakter und den geotechnischen Informationen interpretiert (Refs. 2 und 3).

Die Segy-Daten wurden nach Abschluss der Verarbeitung in eine Kingdom-Workstation geladen und es fand eine grundlegende Qualitätskontrolle der Daten statt. Die Position des Meeresbodens wurde mit den zeitkonvertierten MBES xyz-Daten verglichen. Anschließend wurden Schlüsselhorizonte ausgewählt und alle Daten durch eine iterative visuelle Bewertung auf Anomalien und Abweichungen überprüft.

4 DETAILLIERTE ERGEBNISSE

4.1 BATHYMETRIE

Die Bathymetriedaten wurden mit einem R2Sonic 2024 Mehrstrahl-Echolot erfasst und auf LAT reduziert. LAT ist 1,6 m unter MSL entlang des Streckenkorridors. Die Bathymetriedaten wurden mit einer Zellengröße von 0,5 x 0,5 m gerastert. Ein bathymetrisches Profil durch die vorgeschlagene Vermessungsroute ist in Abbildung3 enthalten.

Eine Reihe natürlicher kleinerer Tröge, die überwiegend von Nordwesten nach Südosten verlaufen, treten innerhalb des Untersuchungsgebiets auf. Diese werden als mit Gezeiten-/Stromprozessen zusammenhängend interpretiert und scheinen die vorgeschlagene Kabelstrecke von etwa KP5.158 bis zum Ende der vorgeschlagenen Kabelstrecke bei KP8.681 zu kreuzen.

Örtliche Wassertiefenschwankungen sind auf das Relief und die Verteilung der identifizierten Tröge zurückzuführen. Die Wassertiefen entlang der vorgeschlagenen Route liegen zwischen 26,0 m bei KP0.280 und 19,6 m bei KP7.941. Der Meeresboden wird zum ost-nordöstlichen Ende der vorgeschlagenen Kabelstrecke hin leicht seicht. Ein kleiner Kamm befindet sich etwa bei KP5.133.

Die natürlichen Steigungen entlang der vorgeschlagenen Route betragen weniger als 1°. Maximale Steigungen von bis zu 7° beschränken sich auf die Flanken der markanteren Tröge.

In den Bathymetriedaten sind drei halbkreisförmige Merkmale mit 1 m positivem Relief abgebildet, die als mit früheren Bohraktivitäten in Zusammenhang stehend interpretiert werden. Diese befinden sich am Anfang der vorgeschlagenen Trasse zwischen KP0.085 und KP0.168; an ihrem minimalen Versatz zur Trasse sind sie ca. 27 m süd-süd-westlich. Sie befinden sich in einem Radius von 30 m und haben eine durchschnittliche Größe von 30 m x 30 m.

Das Norned-Kabel kreuzt die vorgeschlagene Kabelstrecke bei KP 2.313 und verläuft von Nordnordwest nach Südsüdost.

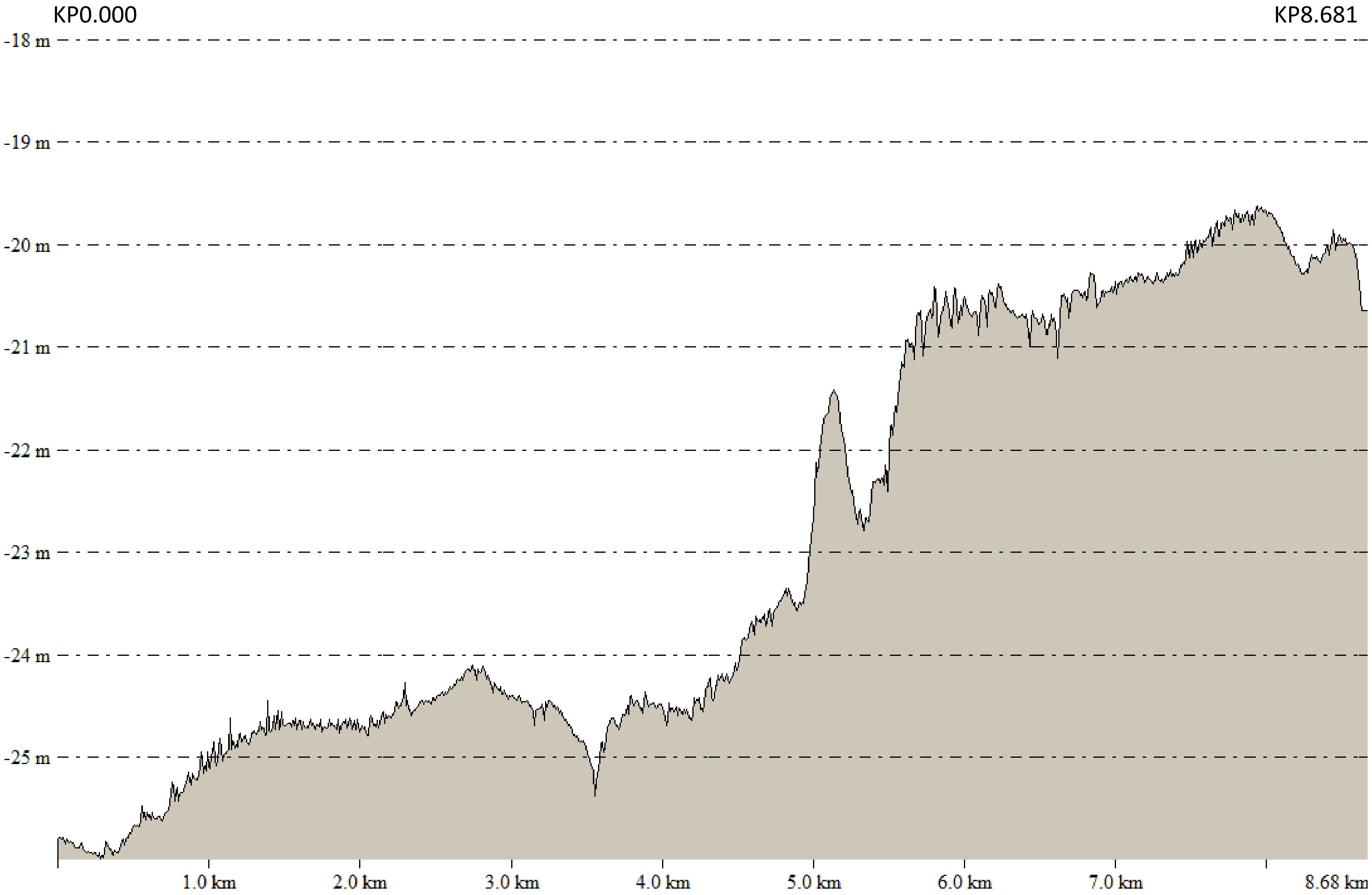


Abbildung 3: Bathymetrisches Profil entlang der vorgeschlagenen Kabelstrecke N5A Plattform nach Riffgat

4.2 MEERESBODENEIGENSCHAFTEN

Seitenscan-Sonardaten wurden mit einem Edgetech 4200-System erfasst, das mit 100kHz/400kHz (150m/200m pro Kanal) arbeitet. Diese Daten wurden durch Bathymetriedaten ergänzt, die auf 0,5 m gerastert waren.

4.2.1 Meeresboden-Sedimente

Es wird erwartet, dass die Meeresbodensedimente entlang des vorgeschlagenen Kabelstreckenkorridors aus feinem bis grobem SAND bestehen, mit gelegentlichen Bereichen aus grobem SAND und TON mit Kies und Muschelfragmenten. Beispiele für Sedimenttypen am Meeresboden sind in den Abbildungen 4 und 5 unten enthalten.

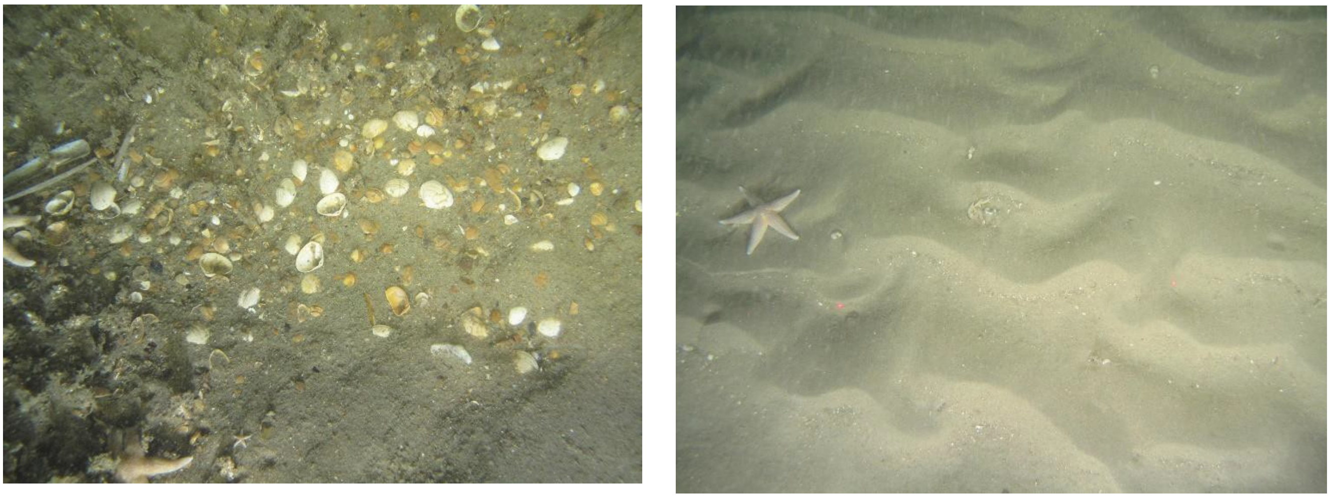


Abbildung 4: Umweltbilder, die die Sedimenttypen des Meeresbodens im Korridor der vorgeschlagenen Kabelstrecke N5A Plattform to Riffgat zeigen. (Linkes Foto - GRAB_C_1. Rechtes Foto - GRAB_C_8)

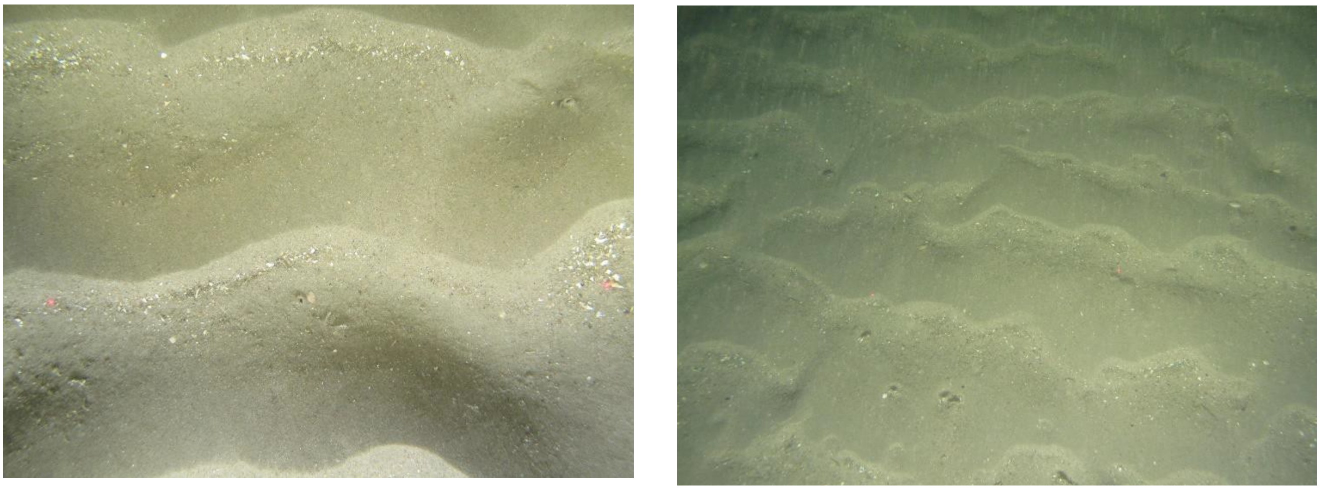


Abbildung 5: Umweltbilder, die den Meeresboden innerhalb des Korridors der Kabelstrecke N5A Plattform to Riffgat bedecken. (Linkes Foto - GRAB_C_6. Rechtes Foto - GRAB_C_7)

4.2.2 Morphologie des Meeresbodens

Die Bodenformen sind in den Sonar- oder Bathymetrie-Aufzeichnungen nicht abgebildet. Fotos, die im Rahmen der Umweltverträglichkeitsprüfung entlang des vorgeschlagenen Trassenkorridors aufgenommen wurden, zeigen jedoch deutlich, dass der Großteil des Meeresbodens im Bereich des Trassenkorridors von Riffelungen bedeckt ist (siehe Abbildung 5).

Der Meeresboden entlang des vorgeschlagenen Rohrleitungskorridors ist zum Ende der Strecke hin sehr leicht untief, mit minimalen und maximalen Wassertiefen entlang der Strecke von 19,6 m LAT bzw. 26,0 m LAT.

4.2.3 Hindernisse auf dem Meeresboden

Innerhalb des vorgeschlagenen Streckenkorridors der Rohrleitung gibt es zahlreiche Objekte, die als Felsbrocken interpretiert werden. Diese wurden eingezeichnet und auf Tafel 2 der Streckenkarten dargestellt. Die meisten Objekte, die als Findlinge interpretiert werden, befinden sich im Norden des Vermessungskorridors in einem Bereich, der mit Bereichen mit Lehmaufschlüssen zusammenfällt.

Fünf Kontakte treten innerhalb von 10 m von der vorgeschlagenen Strecke auf, die alle als Felsbrocken interpretiert werden. Der der vorgeschlagenen Kabelstrecke am nächsten liegende Kontakt befindet sich bei KP4.479, 4,7 m süd-südwestlich der vorgeschlagenen Kabelstrecke und ist 0,6 m hoch. Sonarkontakte innerhalb von 200 m von der vorgeschlagenen Kabelstrecke sind in Tabelle 4 aufgeführt.

Im Bereich der Korridoruntersuchung wurden zahlreiche magnetische Kontakte entdeckt. Mehrere magnetische Anomalien häufen sich in der Nähe des Beginns der vorgeschlagenen Route zwischen KP0.020 und KP0.130. Drei halbkreisförmige Merkmale mit 1 m positivem Relief, die als mit früheren Bohrungen zusammenhängend interpretiert werden, sind in den Bathymetriedaten abgebildet (siehe Abbildung 6).

Innerhalb des Untersuchungskorridorbereichs sind mehrere magnetische Kontakte ausgerichtet, die von Nord-Nordwest nach Süd-Südost verlaufen und die vorgeschlagene Kabelstrecke etwa bei KP2.313 kreuzen. Diese sind mit dem bestehenden Norned-Kabel verbunden. Ein Sonardatenbeispiel, das die Position des Norned-Kabels veranschaulicht, ist in Abbildung 7 enthalten.

Andere aufgezeichnete magnetische Anomalien sind nicht mit einem interpretierten Merkmal des Meeresbodens verbunden. Sie sind möglicherweise mit vergrabenen Objekten verbunden.

Magnetische Kontakte im Umkreis von 200 m um die vorgeschlagene Pipelinetrasse sind in Tabelle 5 aufgeführt.

Tabelle 3: Seitenscansonar Kontaktliste

Seitenscan-Sonar Kontaktliste					
Beschreibung	KP	DCC (m)	Östliche Ausrichtung (m)	Nordwert (m)	Höhe (m)
Objekt	-0.194	-41.1	721 419.2	5 954 712.6	0.7
Objekt	-0.184	142.5	721 408.5	5 954 529.1	1.3
Objekt	-0.159	-80.5	721 458.1	5 954 747.9	0.9
Objekt	-0.054	-10.3	721 555.0	5 954 666.2	0.8
Objekt	0.020	93.9	721 616.0	5 954 554.5	0.6
Objekt	0.032	-148.0	721 655.2	5 954 793.5	0.7
Objekt	0.033	128.0	721 625.0	5 954 519.2	0.7
Objekt	0.054	80.0	721 652.1	5 954 564.4	0.6
Objekt	0.145	38.2	721 746.8	5 954 595.7	0.6
Objekt	0.162	14.9	721 766.6	5 954 616.9	0.8
Objekt	0.169	135.2	721 759.4	5 954 496.7	0.6
Objekt	0.183	-25.5	721 791.4	5 954 654.8	0.5

Objekt	0.189	199.4	721 772.5	5 954 430.6	0.6
Objekt	0.208	-15.3	721 815.4	5 954 641.9	0.6
Objekt	0.224	36.9	721 825.4	5 954 588.2	0.5
Objekt	0.227	29.6	721 829.4	5 954 595.1	0.6
Objekt	0.250	27.9	721 852.0	5 954 594.2	0.6

Objekt	0.252	-5.5	721 858.2	5 954 627.1	0.6
Objekt	0.266	-81.4	721 880.7	5 954 700.9	0.6
Objekt	0.266	186.5	721 850.6	5 954 434.7	0.6
Objekt	0.297	47.3	721 896.8	5 954 569.6	0.7
Objekt	0.311	-98.3	721 927.0	5 954 712.8	0.5
Objekt	0.344	74.7	721 940.2	5 954 537.2	0.7
Objekt	0.430	75.1	722 026.1	5 954 527.0	0.7
Objekt	0.452	168.9	722 037.4	5 954 431.4	0.9
Objekt	0.469	65.0	722 065.6	5 954 532.7	0.5
Objekt	0.475	57.8	722 072.3	5 954 539.2	0.5
Objekt	0.509	185.6	722 091.6	5 954 408.4	0.8
Objekt	0.535	95.9	722 127.9	5 954 494.6	0.5
Objekt	0.558	-59.3	722 168.5	5 954 646.2	0.5
Objekt	0.559	-114.7	722 175.0	5 954 701.1	0.7
Objekt	0.632	-189.2	722 256.4	5 954 767.0	0.8
Objekt	0.658	21.2	722 258.5	5 954 555.0	0.6
Objekt	0.658	-45.2	722 266.1	5 954 620.9	0.5
Objekt	0.667	28.0	722 266.7	5 954 547.2	0.6
Objekt	0.709	-135.5	722 326.4	5 954 705.0	1.1
Objekt	0.755	-48.7	722 362.9	5 954 613.5	0.6
Objekt	0.784	-184.7	722 407.2	5 954 745.4	0.6
Objekt	1.646	-34.4	723 246.4	5 954 499.2	0.8
Objekt	2.258	-97.5	723 862.1	5 954 493.0	1
Objekt	3.046	-104.2	724 644.9	5 954 411.2	0.5
Objekt	3.129	-135.6	724 731.1	5 954 433.1	0.7
Objekt	3.162	-156.9	724 766.8	5 954 450.5	0.6
Objekt	3.174	-157.3	724 778.6	5 954 449.5	0.6
Objekt	3.185	-57.7	724 778.7	5 954 349.3	0.6
Objekt	3.350	-55.7	724 942.4	5 954 328.7	0.7
Objekt	3.390	-125.8	724 989.4	5 954 394.0	0.6
Objekt	3.412	-108.9	725 009.8	5 954 374.7	0.7
Objekt	3.541	10.3	725 124.3	5 954 241.8	0.6
Objekt	3.551	13.4	725 134.4	5 954 237.5	0.6
Objekt	3.557	-28.6	725 144.7	5 954 278.6	0.6
Objekt	3.564	-17.2	725 150.	5 954 266.5	0.5
Objekt	3.565	-28.3	725 152.2	5 954 277.5	0.5
Objekt	3.597	20.7	725 178.6	5 954 225.2	0.5
Objekt	3.643	-181.5	725 246.9	5 954 421.	0.7
Objekt	3.674	114.7	725 244.5	5 954 123.2	0.5
Objekt	3.700	188.4	725 262.4	5 954 046.9	0.6
Objekt	3.704	98.2	725 276.3	5 954 136.2	0.5
Objekt	3.704	-6.7	725 288.5	5 954 240.3	0.6
Objekt	3.721	170.9	725 285.5	5 954 061.9	0.9
Objekt	3.745	7.3	725 327.3	5 954 221.9	0.7
Objekt	3.755	12.4	725 336.5	5 954 215.6	0.8
Objekt	3.755	-25.0	725 341.3	5 954 252.8	0.6
Objekt	3.766	22.7	725 346.4	5 954 204.1	0.5
Objekt	3.800	193.4	725 361.6	5 954 030.7	0.7
Objekt	3.803	-16.0	725 387.3	5 954 238.5	0.5
Objekt	3.831	-129.6	725 428.3	5 954 348.2	0.6
Objekt	3.933	131.0	725 500.7	5 954 077.7	0.6

Objekt	4.067	-21.7	725 650.5	5 954 214.5	0.5
Objekt	4.077	-122.5	725 671.5	5 954 313.5	0.6
Objekt	4.079	-23.1	725 663.1	5 954 214.4	0.6
Objekt	4.230	-190.9	725 831.4	5 954 364.2	0.5
Objekt	4.368	-164.6	725 965.9	5 954 322.6	0.7
Objekt	4.479	44.1	726 052.2	5 954 102.8	0.5
Objekt	4.479	4.7	726 057.4	5 954 141.9	0.6
Objekt	4.531	-50.3	726 114.5	5 954 190.8	0.6
Objekt	4.531	15.2	726 107.6	5 954 125.6	0.7
Objekt	4.545	29.0	726 119.6	5 954 110.4	0.6
Objekt	4.594	-16.9	726 173.3	5 954 150.5	0.5
Objekt	4.805	-36.9	726 385.9	5 954 146.6	0.9
Objekt	4.925	-8.4	726 502.	5 954 104.7	0.8
Objekt	4.930	-11.7	726 506.9	5 954 107.5	0.7
Objekt	5.349	-161.5	726 871.	5 954 279.2	0.6
Objekt	5.405	-39.6	726 958.2	5 954 177.6	0.6
Objekt	5.434	-28.8	726 989.5	5 954 175.5	0.7
Objekt	5.493	-26.6	727 046.9	5 954 189.8	0.5
Objekt	5.602	-195.7	727 104.2	5 954 382.5	1.1
Objekt	8.294	-166.9	729 697.5	5 955 104.1	0.6
Objekt	8.340	-50.0	729 774.8	5 955 004.8	0.7
Objekt	8.360	-144.4	729 767.4	5 955 101.0	0.5
Objekt	8.371	-95.1	729 791.7	5 955 056.7	0.9
Objekt	8.600	-169.5	729 990.5	5 955 191.8	0.6

Tabelle 4: Magnetometer Kontaktauflistung

Magnetometer Kontaktliste						
Beschreibung	KP	DCC (m)	Östliche Ausrichtung (m)	Nordende (m)	Stärke (nT)	Kommentare
Magnetischer Kontakt	-0.177	53.8	721 424.9	5 954 616.5	285	
Magnetischer Kontakt	-0.048	-107.8	721 571.7	5 954 762.5	18	
Magnetischer Kontakt	0.024	51.1	721 625.3	5 954 596.5	53	Korreliert mit halbkreisförmigen Merkmalen, die mit früheren Bohraktivitäten zusammenhängen (siehe Abb. 6)
Magnetischer Kontakt	0.054	20.1	721 658.0	5 954 624.0	45	
Magnetischer Kontakt	0.054	94.5	721 650.5	5 954 550.0	376	
Magnetischer Kontakt	0.057	54.9	721 657.8	5 954 589.0	358	
Magnetischer Kontakt	0.063	-4.7	721 670.5	5 954 647.5	27	
Magnetischer Kontakt	0.068	66.8	721 666.7	5 954 576.0	1100	
Magnetischer Kontakt	0.075	80.1	721 672.2	5 954 562.0	2733	
Magnetischer Kontakt	0.090	111.6	721 683.6	5 954 529.0	252	
Magnetischer Kontakt	0.090	50.2	721 691.2	5 954 590.0	360	
Magnetischer Kontakt	0.100	186.9	721 685.7	5 954 453.0	110	
Magnetischer Kontakt	0.111	134.4	721 702.2	5 954 504.0	58	
Magnetischer Kontakt	0.121	169.5	721 708.2	5 954 468.0	119	
Magnetischer Kontakt	1.268	83.0	722 858.1	5 954 425.0	43	
Magnetischer Kontakt	2.313	1.0	723 905.1	5 954 389.0	15	
Magnetischer Kontakt	2.473	-150.9	724 080.9	5 954 522.0	40	
Magnetischer Kontakt	2.591	-9.3	724 182.6	5 954 368.0	43	
Magnetischer Kontakt	2.597	-151.4	724 205.0	5 954 508.5	31	
Magnetischer Kontakt	2.634	5.5	724 223.6	5 954 348.5	27	
Magnetischer Kontakt	2.821	0.9	724 410.1	5 954 332.0	36	
Magnetischer Kontakt	2.831	-7.3	724 420.9	5 954 339.0	38	
Magnetischer Kontakt	2.862	77.8	724 442.2	5 954 251.0	18	
Magnetischer Kontakt	2.877	147.1	724 449.1	5 954 180.5	16	
Magnetischer Kontakt	2.925	0.8	724 512.9	5 954 320.5	12	
Magnetischer Kontakt	5.627	0.4	727 182.4	5 954 201.0	25	

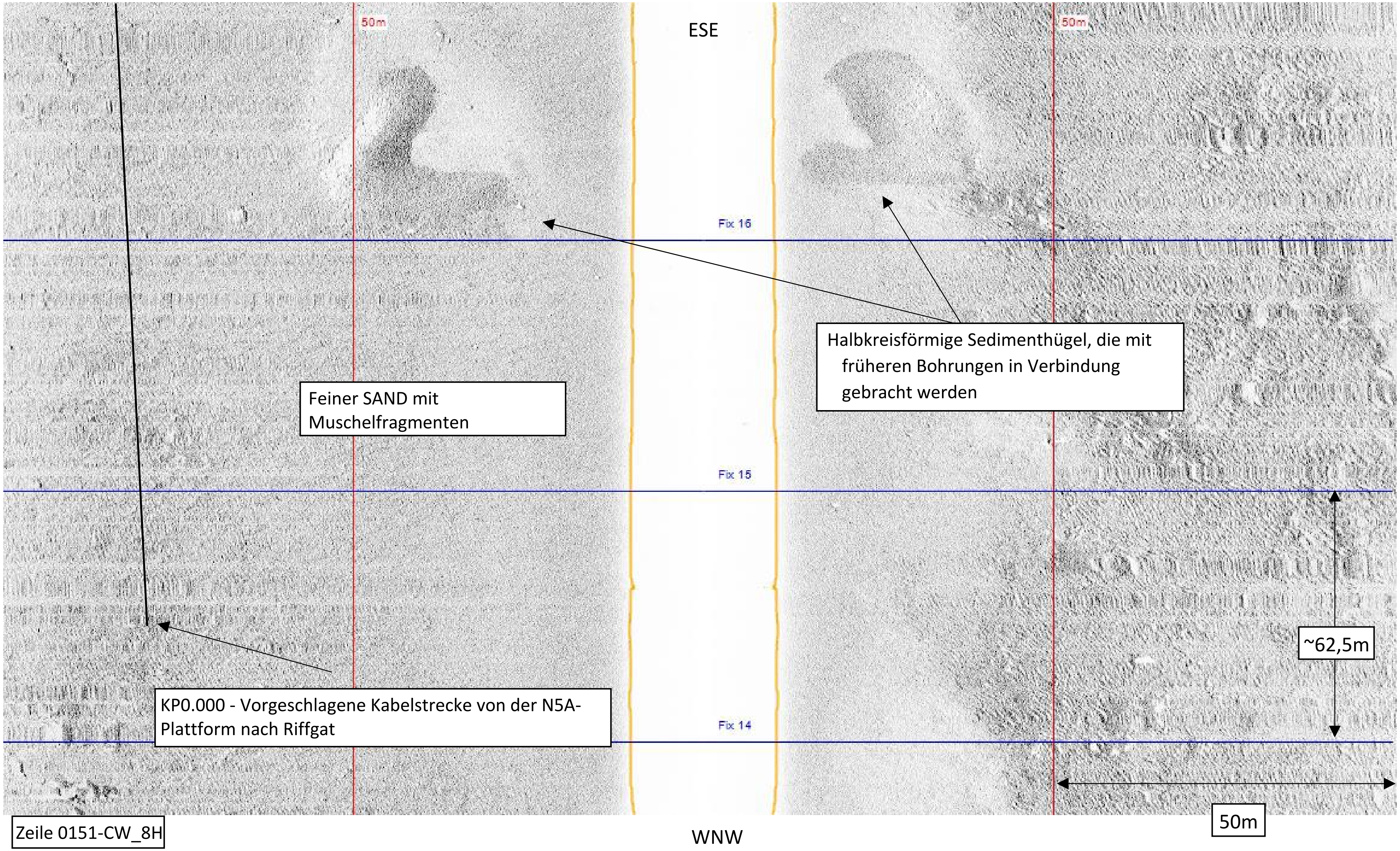
Magnetischer Kontakt	7.532	-62.2	728 994.9	5 954 791.5	14	
Magnetischer Kontakt	8.195	-119.9	729 615.7	5 955 031.5	26	

Tabelle 5 - Zusammenfassung der Schürfproben im Bereich der N5A-Plattform zur Riffgat-Kabelstrecke

Station	Typ	Östliche Ausrichtung	Nordende
GRAB_P_0	EBS/HAS	721 617.9	5 954 452
GRAB_C_0	EBS/HAS	721 607.0	5 954 650
GRAB_C_1	EBS/HAS	722 600.7	5 954 538
GRAB_C_2	EBS/HAS	723 594.3	5 954 425
GRAB_C_3	EBS/HAS	724 588.0	5 954 313
GRAB_C_4	EBS/HAS	725 581.7	5 954 200
GRAB_C_5	EBS/HAS	726 575.3	5 954 088
GRAB_C_6	EBS/HAS	727 353.0	5 954 244
GRAB_C_7	EBS/HAS	728 146.1	5 954 478
GRAB_C_8	EBS/HAS	729 107.9	5 954 759
GRAB_C3_2	EBS/HAS	725 335.2	5 953 740

Tabelle 6 - Zusammenfassung der abgeschlossenen Kameratransekte

Geodäsie: ED50 UTM31N 3°E							
Transekt		**Datum und Uhrzeit**	**Tiefe (m)**	**Östliche Ausrichtung**	**Nordende**	**Nr. Stills**	**Videomaterial (mm:ss)**
P_0 greifen	SOL	02/05/2019 17:15:11	30	721647	5954430	27	07:13
	EOL	02/05/2019 17:22:21	31	721591	5954476		
Nord Transekt 3	SOL	11/05.2019 02:04:48	28.9	721902	5954407	50	12:29
	EOL	11/05/2019 02:17:13	28.8	721802	5954550		
Nord Transekt 3	SOL	11/05.2019 02:04:48	28.9	721902	5954407	50	12:29
	EOL	11/05/2019 02:17:13	28.8	721802	5954550		
N5a Transekt 1	SOL	11/05/2019 01:38:05	28.71	721585	5954588	35	08:37
	EOL	11/05/2019 01:46:38	28.63	721626	5954708		
N5a Transekt 2	SOL	11/05/2019 01:16:28	28.44	721668	5954631	39	09:13
	EOL	11/05/2019 01:25:35	28.64	721544	5954667		
Greifer_C3_2	SOL	14/05/2019 20:46:00	24.97	725366	5953610	37	12:36
	EOL	14/05/2019 20:58:53	24.5	725326	5953785		

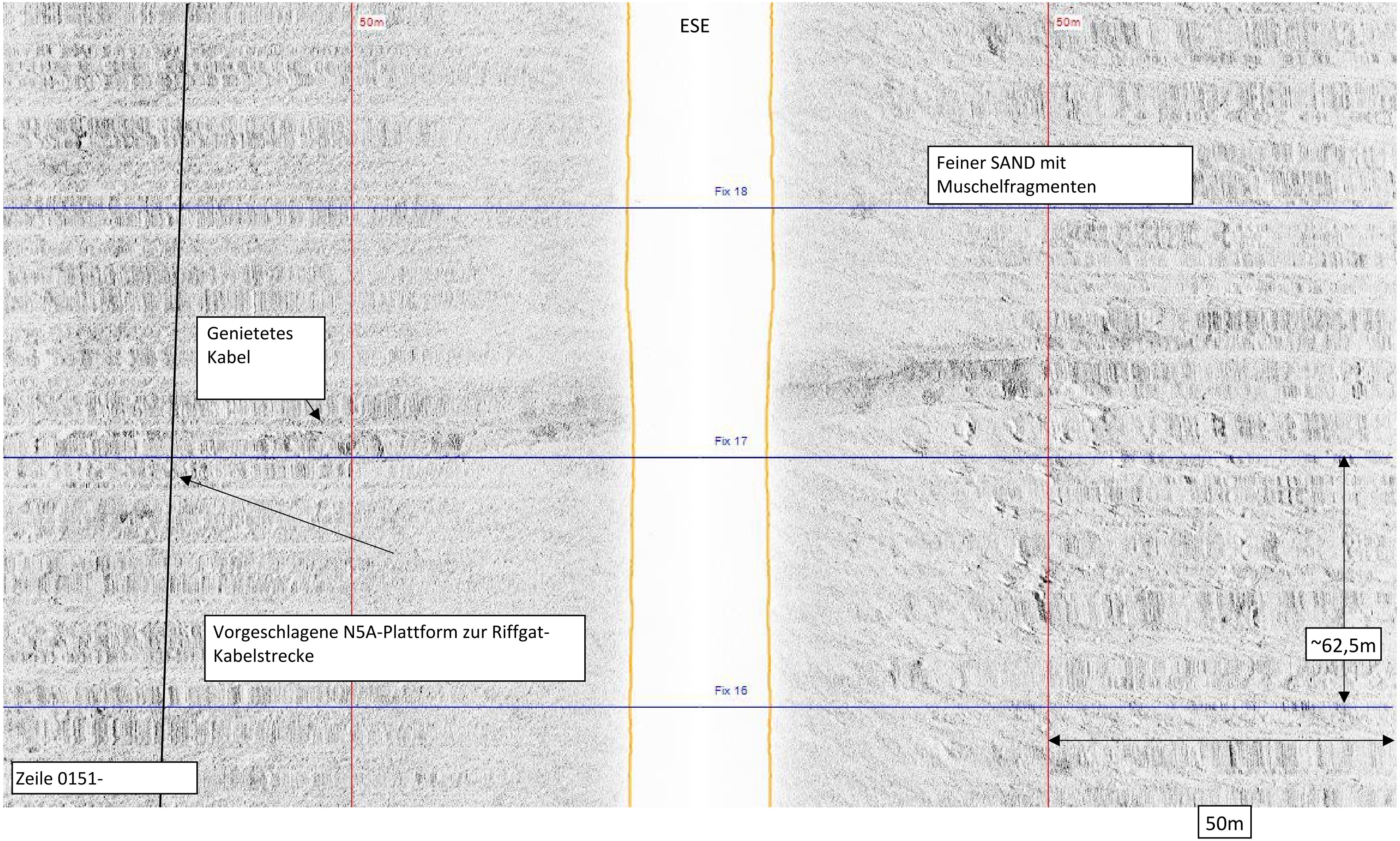


Halbkreisförmige Sedimenthügel, die mit früheren Bohrungen in Verbindung gebracht werden

Feiner SAND mit Muschelfragmenten

KP0.000 - Vorgeschlagene Kabelstrecke von der N5A-Plattform nach Riffgat

Abbildung 6. Beispiel für Seitensichtsonardaten, die die Meeresbodensedimente am KP0.000 (Beginn der Route) der vorgeschlagenen Kabelstrecke von der N5A-Plattform nach Riffgat zeigen


ESE
50m
50m
Fix 18
Fix 17
Fix 16
Feiner SAND mit Muschelfragmenten
Genietetes Kabel
Vorgeschlagene N5A-Plattform zur Riffgat-Kabelstrecke
Zeile 0151-
~62,5m
50m

WNW

Abbildung 7. Beispiel für Seitensichtsonardaten, die die Kreuzung des Norned-Kabels mit der vorgeschlagenen Kabelroute von der N5A-Plattform nach Riffgat zeigen

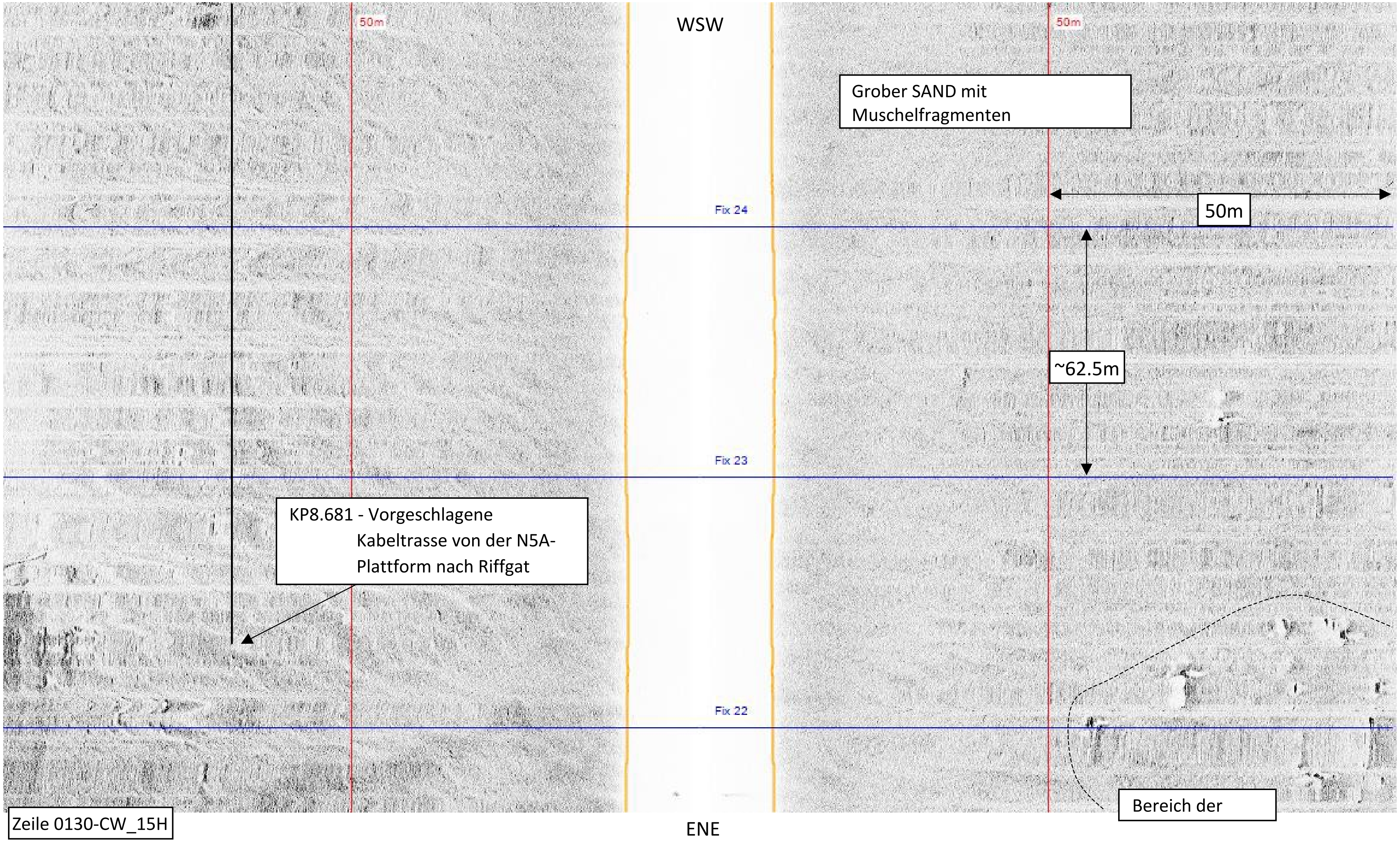

WSW
50m
50m
Grober SAND mit Muschelfragmenten
50m
Fix 24
~62.5m
Fix 23
KP8.681 - Vorgeschlagene Kabeltrasse von der N5A-Plattform nach Riffgat
Fix 22
Bereich der
Zeile 0130-CW_15H
ENE

Abbildung 8. Beispiel für Seitensichtsonardaten zur Darstellung der Meeresbodensedimente bei KP8.681 (Ende der Route) der vorgeschlagenen Kabelstrecke von der N5A-Plattform nach Riffgat

4.3 SCHWARZE BÖDEN

Die Interpretation der oberflächennahen Böden basiert auf dem Sub-Bottom-Profiler-Datensatz in Verbindung mit Bohrloch- und streckenspezifischen Vibrokerndaten (Referenzen 2 und 3). Beispiele für Pinger-Daten, die die oberflächennahen Böden entlang der vorgeschlagenen Route zeigen, sind in den Abbildungen 9 und 10 enthalten.

Anhang A zeigt streckenspezifische Kernprotokolle (Ref. 2).

4.3.1 Oberflächlicher SAND (Meeresboden-H01, fehlend-3m BSB)

Diese Einheit aus fein- bis mittelkörnigem SAND wird im Allgemeinen nach Osten hin dicker. Westlich der Route AC bei KP 5.156 ist die Einheit etwa 0,5 bis 1 m dick oder nicht vorhanden/unmerklich dünn, östlich dieses Punktes überschreitet die Einheit lokal eine Dicke von 2 m. Die folgende Tabelle zeigt, wo die Einheit fehlt (oder zu dünn zum Kartieren ist):

Tabelle 7: Abwesenheiten von oberflächlichem SAND

KP-Startabwesenheit	KP Ende Abwesenheit
0.076	1.203
2.629	2.877
3.062	3.243
3.553	3.883
4.007	4.042
4.156	4.996
5.318	5.464

4.3.2 Sub-Crop (Meeresboden/H01 -, 0->10m BSB)

Vibrocore-Protokolle zeigen, dass die kartierte Einheit von KP0 bis KP 3.357 von tonhaltigen Ablagerungen unterlagert ist, die als Füllung eines breiten Kanals interpretiert werden. Von KP 3.357 bis zum Ende der Route wird die kartierte Einheit von feinem SAND überlagert.

Tabelle 8: Zusammenfassung der Vibrokern-Standorte

Nein.	Vibrokern-ID	Östliche Ausrichtung (m)	Nordwert (m)	Eindringtiefe (m)	Wiederherstellung (m)
1	VC_C_1	722 602.8	5 954 534.4	3.2	3.2
2	VC_C_2	723 596.5	5 954 423.7	3.0	3.0
3	VC_C_3	724 581.3	5 954 314.2	2.8	2.5
4	VC_C_3BIS	724 581.2	5 954 315.8	2.4	2.1
5	VC_C_4	725 574.1	5 954 201.4	6.0	5.5
6	VC_C_5	726 573.0	5 954 087.2	5.8	5.5
7	VC_C_6	727 343.7	5 954 245.0	5.7	5.6
8	VC_C_7	728 143.0	5 954 481.2	5.3	5.3
9	VC_C_8	729 111.9	5 954 761.2	5.6	5.6

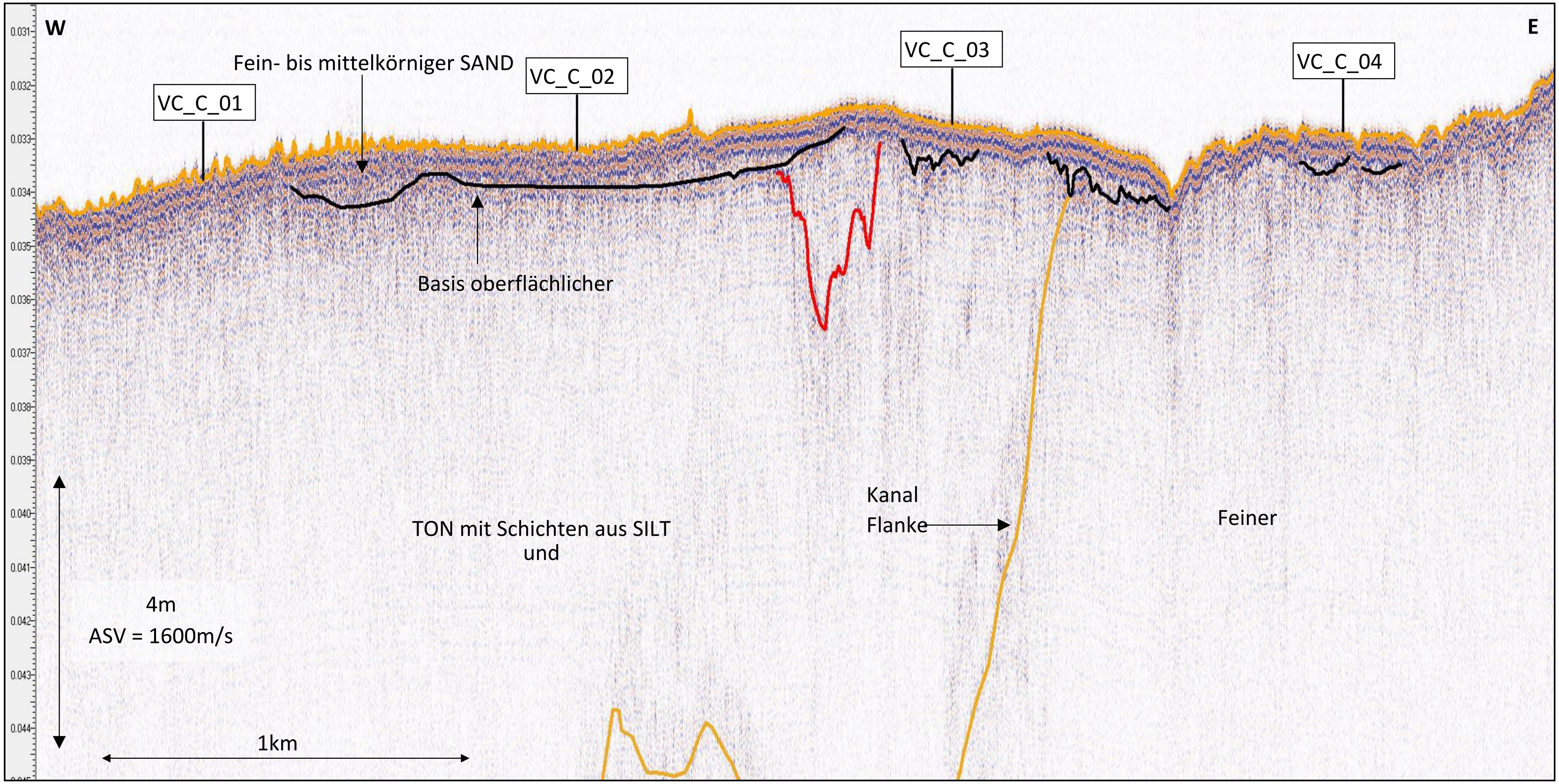


Abbildung 9: SBP-Datenbeispiel am Anfang der Vorgeschlagenen Route, Linie CW_7_PROC

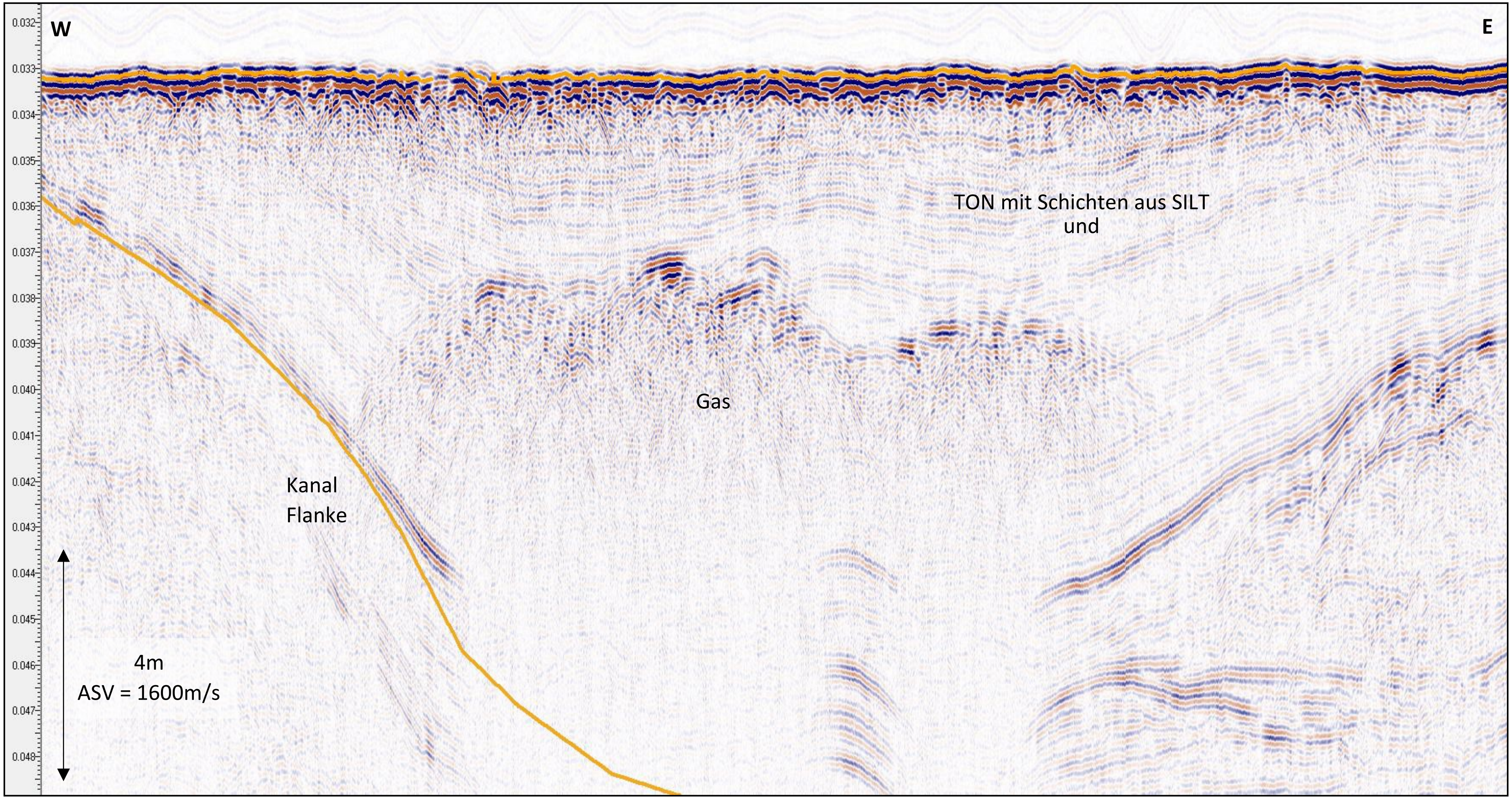


Abbildung 10: SBP-Datenbeispiel, flaches Gas, Linie CW_6_PROC

ANHANG A - VORLÄUFIGE VC-ERGEBNISSE

FELDVERSION

PUNKT: VC_C_1STARTDATUM: 10/5/19

KOORDINATEN (UTM)
N 5954534.42 m
E 722602,76 m
Wassertiefe 27,00 m

ENDTERMIN: 1/10/19
GEOLOGE: MC/AV NORM: BS
EN 5930:2015

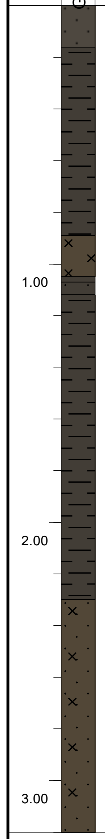
AUSRÜSTUNG: Vibrocore
BOHRER: JC
ASSISTENT: MC

BEMERKUNGEN:

LEGENDE

▨ SAND ▤ CLAY ☒ SILT ☒ SANDST

TIEFE (m BGL)	GRAFISCHES LOG	C.LAUF/C.GRÖẞE (mm)	MATERIALBESCHREIBUNG	PROBEN TYP-	Ausgewählte SAMPLES für	Undrainierte Scherfestigkeit Su (kPa) ⊗ TV Taschen-Torvane □ PP Taschen-Penetrometer	HINWEISE	DETAILLIERTE FOTOS



0,00- 0,16: Sehr dunkelgrauer (2,5Y 3/1) mittel- bis grobkörniger SAND mit seltenem Feinkies und häufigen Muschelfragmenten (einige davon mittelkiesig). Deutliche, aber nicht anhaltende Aufbrausung von HCl.

0.16- 0.89: Sehr dicht zerklüfteter schwarzer (5Y 2.5/1) TON mit gelegentlichen Feinsandeinschlüssen. Kein anhaltendes Aufbrausen von HCl. Die Klüfte sind horizontal und unpoliert mit anhaltendem Aufbrausen von HCl.

0,89- 1,05: Sehr dunkles Graubraun (2,5Y 3/2), leicht sandiger SILT mit gelegentlichen Toneinschlüssen.

1,05- 1,07: Sehr dicht zerklüfteter schwarzer (5Y 2,5/1) TON. Kein anhaltendes Aufbrausen von HCl. Die Klüfte sind horizontal und unpoliert mit anhaltendem Aufbrausen von HCl.

1.07- 1.12: Schwarzer (5Y 2.5/1) feiner SAND. Deutliches, aber nicht anhaltendes Aufbrausen von HCl.

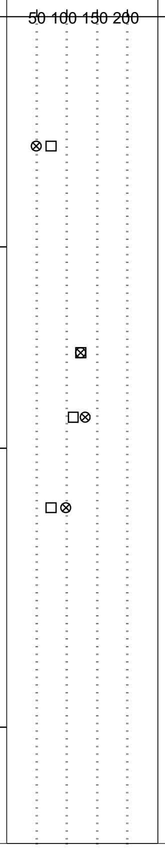
1.12- 2.30: Sehr dicht zerklüfteter schwarzer (5Y 2.5/1) TON mit häufigen Feinsandeinschlüssen. Kein anhaltendes Aufbrausen von HCl. Die Klüfte sind horizontal und unpoliert mit anhaltendem Aufbrausen von HCl.

2.30- 3.20: Sehr dunkelgraubrauner (2.5Y 3/2) schluffiger Feinsand mit häufigen Toneinschlüssen und millimetrischen bis zentimetrischen Tonschichten. Deutliches, aber nicht anhaltendes Aufbrausen von HCl, Ton kein anhaltendes Aufbrausen von HCl.

C.LAUF/C.GRÖẞE: 106

PROBEN TYP-: S-3, S-2, S-1

Ausgewählte SAMPLES für: VC_C_1.3, VC_C_1.2, VC_C_1.1



Unten bei 3,20 m

FELDVERSION

PUNKT: VC_C_2STARTDATUM: 10/5/19

KOORDINATEN (UTM)
N 5954423.75 m
E 723596,51 m
Wassertiefe 27,30 m

ENDTERMIN: 10/5/19
GEOLOGE: MC/AV NORM: BS
EN 5930:2015

AUSRÜSTUNG:
Vibrocore
BOHRER: JC
ASSISTENT: MC

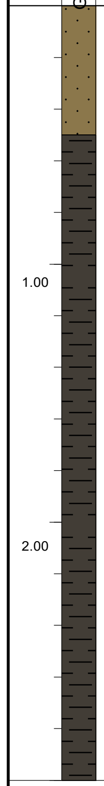
BEMERKUNGEN:

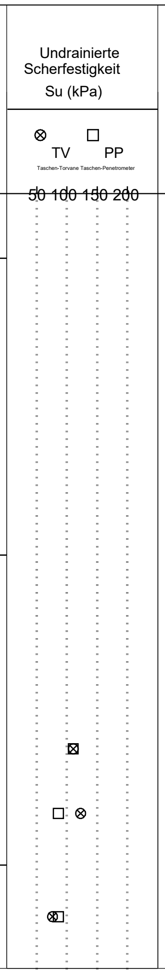
LEGENDE

SAND

TON

TIEFE (m BGL)	GRAFISCHES LOG	LAUF/C.GRÖßE (mm)	MATERIALBESCHREIBUNG	PROBEN TYP-	Ausgewählte SAMPLES für	HINWEISE
		C	0.00- 0.50: Heller olivbrauner (2,5Y 5/4) feiner bis mittlerer SAND mit seltenen amorphen organischen Stoffen schwärzlichen Zonen und gelegentlichen Muschelfragmenten und Polychäten (speziell Lanice Conchilega). Deutliche, aber nicht anhaltende Aufbrausung von HCl. · Von 0,43m bis 0,50m: feiner bis mittlerer SAND mit feinem bis mittlerem Kies mit häufigen Muschelfragmenten		VC_C_2.3	
			0,50- 1,10: Sehr dicht zerklüfteter schwarzer (5Y 2,5/1) TON. Kein anhaltendes Aufbrausen von HCl. Die Klüfte sind horizontal und unpoliert mit anhaltendem Aufbrausen von HCl.			
1.00				S-3		
		106	1.10- 3.00: Sehr dicht zerklüfteter schwarzer (5Y 2.5/1) TON mit seltenen bräunlichen Einschlüssen. Kein anhaltendes Aufbrausen von HCl. Die Klüfte sind horizontal und unpoliert mit anhaltendem Aufbrausen von HCl.		VC_C_2.2	
2.00				S-2		
					VC_C_2..1	
3.00			Boden bei 3,00 m	S-1		




Undrainierte Scherfestigkeit
Su (kPa)

DETAILLIERTE FOTOS

FELDVERSION

PUNKT: VC_C_3STARTDATUM: 10/5/19

KOORDINATEN (UTM)
N 5954314.25 m
E 724581,29 m
Wassertiefe 27,00 m

ENDTERMIN: 10/5/19
GEOLOGE: MC/AV NORM: BS EN 5930:2015

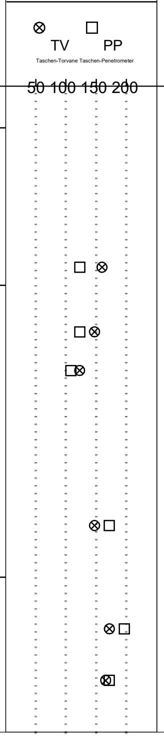
AUSRÜSTUNG: Vibrocore
BOHRER: JC
ASSISTENT: MC

BEMERKUNGEN:

LEGENDE

SAND
TON

TIEFE (m BGL)	GRAFISCHES LOG	C.LAUF/C.GRÖßE(mm)	MATERIALBESCHREIBUNG	PROBEN TYP-	Ausgewählte SAMPLES für	Undrainierte Scherfestigkeit Su (kPa)	HINWEISE
			0,00- 0,38: Olivbrauner (2,5Y 4/3) feiner bis mittlerer SAND mit häufigem amorphem organischem Material und gelegentlichen Muschelfragmenten. Deutliche, aber kein anhaltendes Aufbrausen von HCl.		VC_C_3.3		
1.00 2.00		106	0.38- 2.50: Sehr dicht zerklüfteter schwarzer (5Y 2.5/1) TON. Kein anhaltendes Aufbrausen von HCl. Die Klüfte sind horizontal und unpoliert mit anhaltendem Aufbrausen von HCl.	S-3 S-2 S-1	VC_C_3.2 VC_C_3.1		



Boden bei 2,50 m

DETAILLIERTE FOTOS

FELDVERSION

PUNKT: VC_C_3BisSTARTDATUM: 10/5/19

KOORDINATEN (UTM)
N 5954315.81 m
E 724581,23 m
Wassertiefe 27,00 m

ENDTERMIN: 10/5/19
GEOLOGE: MC/AV NORM: BS
EN 5930:2015

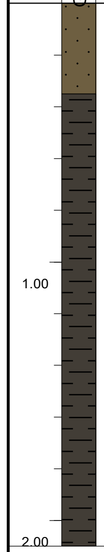
AUSRÜSTUNG:
Vibrocore
BOHRER: JC
ASSISTENT: MC

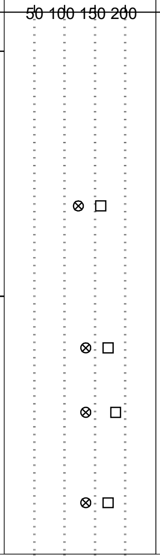
BEMERKUNGEN:

LEGENDE

⬚ SAND
☰ TON

TIEFE (m BGL)	GRAFISCHES LOG	C LAUF/C.GRÖßE (mm)	MATERIALBESCHREIBUNG	PROBEN TYP-	Ausgewählte SAMPLES für	Undrainierte Scherfestigkeit Su (kPa) ⊗ TV Taschen-Torvane □ PP Taschen-Penetrometer	HINWEISE	DETAILLIERTE FOTOS
			0,00- 0,35: Olivbrauner (2,5Y 4/3) feiner bis mittlerer SAND mit häufigem amorphem organischem Material, gelegentlich Muschelfragmenten und Polychäten. (insbesondere Lanice Conchilega). Deutliches, aber nicht anhaltendes Aufbrausen von HCl.		VC_C_3Bis.2			
1.00 2.00		106	0,35- 2,10: Sehr dicht zerklüfteter schwarzer (5Y 2,5/1) TON. Kein anhaltendes Aufbrausen von HCl. Die Klüfte sind horizontal und unpoliert mit anhaltendem Aufbrausen von HCl.	S- 2	VC_C_3Bis.1			





S-1

Unten bei 2,10 m

FELDVERSION

PUNKT: VC_C_4STARTDATUM: 10/5/19

KOORDINATEN (UTM)
N 5954201,36 m
E 725574.08 m
Wassertiefe 27,00 m

ENDTERMIN: 10/5/19
GEOLOGE: MC/AV NORM: BS
EN 5930:2015

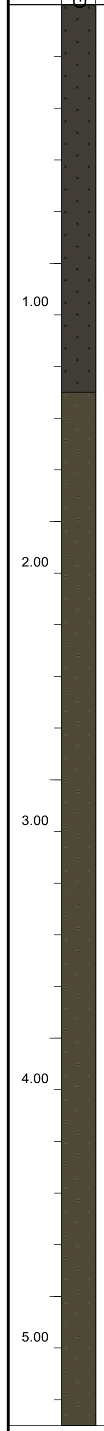
AUSRÜSTUNG: Vibrocore
BOHRER: JC
ASSISTENT: MC

BEMERKUNGEN:

LEGENDE

⬚ SAND

TIEFE (m BGL)	GRAFISCHES LOG	C.LAUF/C.GRÖßE(mm)	MATERIALBESCHREIBUNG	PROBEN TYP-	Ausgewählte SAMPLES für	Undrainierte Scherfestigkeit Su (kPa) ⊗ TV ☐ PP 50 100 150 200	HINWEISE
			0,00- 0,55: Schwarzer (5Y 2,5/1) feiner SAND mit seltenem feinem bis mittlerem Kies und gelegentlichen Muschelfragmenten. Kein anhaltendes Aufbrausen von HCl.		VC_C_4.6		
1.00			0.55- 1.50: Schwarzer (5Y 2.5/1) feiner SAND mit seltenem Feinkies. Kein anhaltendes Aufbrausen von HCl. · Von 1,00 m bis 1,10 m: Dunkelgrauer (5Y 4/1) mittelgrober bis grober SAND.	S-6	VC_C_4.5		
2.00 3.00 4.00 5.00		106	1.50- 5.50: Dunkelolivgrauer (5Y 3/2) feiner SAND mit seltenem Feinkies, seltenen Mittelsandeinschlüssen und gelegentlichen amorphen organischen Stoffen in schwärzlichen Zonen. Kein anhaltendes Aufbrausen von HCl.	S-5 S-4 S-3 S-2	VC_C_4.4 VC_C_4.3 VC_C_4.2 VC_C_4.1		



Boden bei 5,50 m

S-1

DETAILLIERTE FOTOS

FELDVERSION

PUNKT: VC_C_5STARTDATUM: 10/5/19

KOORDINATEN (UTM)
N 5954087,23 m
E 726572.99 m
Wassertiefe 24,50 m

ENDTERMIN: 10/5/19
GEOLOGE: MC/AV NORM: BS
EN 5930:2015

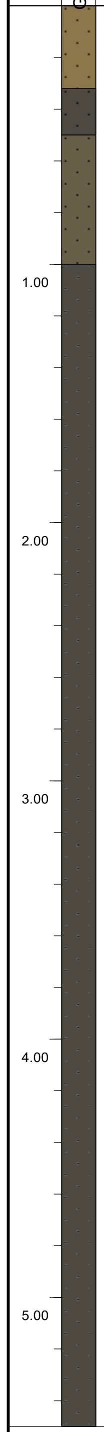
AUSRÜSTUNG:
Vibrocore
BOHRER: JC
ASSISTENT: MC

BEMERKUNGEN:

LEGENDE

SAND

TIEFE (m BGL) | GRAFISCHES LOG | C LAUF/C.GRÖßE (mm) | MATERIALBESCHREIBUNG | PROBEN TYP- | Ausgewählte SAMPLES für | Undrainierte Scherfestigkeit Su (kPa) ⊗ TV ☐ PP Taschen-Torvane Taschen-Penetrometer 50 100 150 200 | HINWEISE | DETAILLIERTE FOTOS



0,00- 0,32: Hellolivbrauner (2,5Y 5/4) mittlerer SAND mit seltenem Feinkies, häufigen schwärzlichen Zonen amorpher organischer Substanz und gelegentlichen Muschelfragmenten. Kein anhaltendes Aufbrausen von HCl.

0.32- 0.50: Sehr dunkelgrauer (5Y 3/1) feiner SAND mit seltenen Toneinschlüssen und millimetrischen Schichten, mit gelegentlicher amorpher organischer Substanz und seltenen Muschelfragmenten. Kein anhaltendes Aufbrausen von HCl.

0.50- 1.00: Olivgrauer (5Y 4/2) feiner SAND mit gelegentlichem feinem bis mittlerem Kies, seltenen Toneinschlüssen und seltenen faserigen Holzfragmenten. Kein anhaltendes Aufbrausen von HCl.

·Von 0,84 m bis 1,00 m: mittlerer SAND.

1.00- 5.50: Sehr dunkelgrauer (5Y 3/1) feiner SAND mit seltenen Toneinschlüssen und gelegentlichen amorphen organischen Stoffen schwärzlichen Zonen. Kein anhaltendes Aufbrausen von HCl.

· Von 2,05 m bis 2,45 m: häufige amorphe organische Substanz in millimetrischen Schichten.

· Von 3,05 m bis 4,16 m: häufige amorphe organische Substanz, millimetrische Schichten und Glimmer.

PROBEN TYP-	Ausgewählte SAMPLES für
S-6	VC_C_5.6
S-5	VC_C_5.5
S-4	VC_C_5.4
S-3	VC_C_5.3
S-2	VC_C_5.2
S-1	VC_C_5.1






Boden bei 5,50 m

FELDVERSION

PUNKT: VC_C_6STARTDATUM: 9/5/19

KOORDINATEN (UTM)
N 5954245.05 m
E 727343,67 m
Wassertiefe 23,30 m

ENDTERMIN: 9/5/19
GEOLOGE: MC/AV NORM: BS
EN 5930:2015

AUSRÜSTUNG:
Vibrocore
BOHRER: JC
ASSISTENT: MC

BEMERKUNGEN:

LEGENDE

SANDSANDCL

TIEFE (m BGL)	GRAFISCHES LOG	LAUF/C.GRÖßE (mm)	MATERIALBESCHREIBUNG	PROBEN TYP-	Ausgewählte SAMPLES für	Undrainierte Scherfestigkeit Su (kPa) ⊗ TV ☐ PP 50 100 150 200	HINWEISE	DETAILLIERTE FOTOS

C

0,00- 0,21: Dunkelgraubrauner (2,5 4/2) feiner bis mittlerer SAND mit seltenen Muschelfragmenten. Deutliche, aber nicht anhaltende

Aufbrausen von HCl. 0.21- 0.60: Dunkelgrauer (2,5Y 4/1) feiner bis mittlerer SAND mit seltenen Toneinschlüssen und seltenen

Muschelfragmenten. Anhaltendes Aufbrausen von HCl.

0.60- 1.04: Olivgrauer (5Y 5/2) feiner SAND, dicht geschichtet mit dunkelolivgrauem (5Y 3/2) schluffigem Ton mit seltenen schwärzlichen amorphen organischen Einschlüssen und seltenen Muschelfragmenten. Anhaltendes Aufbrausen von HCl.

1.00

1,04- 2,06: Graubrauner (2,5Y 5/2) feiner bis mittlerer SAND mit seltenen Toneinschlüssen, seltenen faserigen Holzfragmenten und seltenen Muschelfragmenten. Kein anhaltendes Aufbrausen von HCl.

· Von 1,60 m bis 2,06 m: seltener Feinkies.

2.00

2,06- 2,39: Graubrauner (2,5Y 5/2) feiner bis mittlerer SAND mit gelegentlichem groben Sand und gelegentlichem feinen bis groben Kies. Kein anhaltendes Aufbrausen von HCl.

2,39- 3,10: Graubrauner (2,5Y 5/2) feiner bis mittlerer SAND mit seltener amorpher organischer Substanz. Kein anhaltendes Aufbrausen von HCl.

· Von 2,90 m bis 3,10 m: allmählich zunehmende Größe bis hin zu mittlerem und grobem Sand.

106

3.00

3.10- 4.84: Graubrauner (2,5Y 5/2) mittel- bis grobkörniger SAND mit gelegentlichem Feinsand, seltenem Feinkies und seltenen amorphen organischen Stoffen schwärzlichen Zonen. Kein anhaltendes Aufbrausen von HCl.

· Von 4,00m bis 4,40m: hauptsächlich grober SAND mit seltenem feinen bis mittleren Kies.

4.00

4,84- 5,33: Dunkelolivgrauer (5Y 3/2) feiner bis mittlerer SAND. Kein anhaltendes Aufbrausen von HCl.

5.00

5.33- 5.60: Dick laminierter olivgrauer (5Y 4/2) schluffiger Feinsand und feiner SAND mit gelegentlicher amorpher organischer Substanz in millimetrischen Schichten. Kein anhaltendes Aufbrausen von HCl.

PROBEN TYP-: Unten bei 5,60 m

Ausgewählte SAMPLES für: VC_C_6.6 S-6, S-5, S-4, S-3, S-2, S*1






VC_
C_6.
5

VC_
C_6.
4

VC_
C_6.
3

VC_
C_6.
2

VC_
C_6.
1

FELDVERSION

PUNKT: VC_C_7STARTDATUM: 9/5/19

KOORDINATEN (UTM)
N 5954481,18 m
E 728142,96 m
Wassertiefe 23,10 m

ENDTERMIN: 9/5/19
GEOLOGE: MC/AV NORM: BS EN 5930:2015

AUSRÜSTUNG: Vibrocore
BOHRER: JC
ASSISTENT: MC

BEMERKUNGEN:

LEGENDE

☐ SAND

TIEFE (m BGL) | GRAFISCHES LOG | LAUF/C.GRÖßE (mm) | MATERIALBESCHREIBUNG | PROBEN TYP- | Ausgewählte SAMPLES für | Undrainierte Scherfestigkeit Su (kPa) ⊗ TV ☐ PP Taschen-Torvane Taschen-Penetrometer 50 100 150 200 | HINWEISE | DETAILLIERTE FOTOS

0,00- 0,27: Dunkelolivgrauer (5Y 3/2) feiner SAND mit seltenen amorphen organischen Stoffen, schwärzlichen Einschlüssen und gelegentlichen Muschelfragmenten. Deutliches, aber nicht anhaltendes Aufbrausen von HCl.

0,27- 0,30: Graubrauner (2,5Y 5/2) mittelgrober bis grober SAND mit häufigen Muschelfragmenten. Deutliches, aber nicht anhaltendes Aufbrausen von HCl.

0,30- 0,66: Graubrauner (2,5Y 5/2) feiner bis mittlerer SAND mit gelegentlichen millimetrischen bis zentimetrischen Toneinschlüssen und gelegentlichen Muschelfragmenten. Kein anhaltendes Aufbrausen von HCl (Ton mit deutlichem, aber nicht anhaltendem Aufbrausen von HCl).

0.66- 0.70: Graubrauner (2,5Y 5/2) mittel- bis grobkörniger SAND mit häufigen Muschelfragmenten. Kein anhaltendes Aufbrausen von HCl. 0,70- 0,90: Dunkelgraubrauner (2,5Y 4/2) feiner SAND mit gelegentlichen Muschelfragmenten. Kein anhaltendes Aufbrausen von HCl.

0.90- 1.50: Dunkelgrauer (2,5Y 4/1) feiner SAND mit seltenen Muschelfragmenten. Deutliche, aber nicht anhaltendes Aufbrausen von HCl.

1.50- 1.62: Dunkelgrauer (2,5Y 4/1) feiner bis mittlerer SAND mit häufigem Feinkies und gelegentlichen Muschelfragmenten. Deutliches, aber nicht anhaltendes Aufbrausen von HCl.

1,62- 5,30: Hellbraungrauer (2,5Y 6/2) feiner SAND mit seltenen amorphen organischen Stoffen, schwärzlichen Flecken. Kein anhaltendes Aufbrausen von HCl.

C

106

1.00
2.00
3.00
4.00
5.00

S-6
S-5
S-4
S-3
S-2
S-1

VC_C_7.6
VC_C_7.5
VC_C_7.4
VC_C_7.3
VC_C_7.2
VC_C_7.1

Unten bei 5,30 m

FELDVERSION

PUNKT: VC_C_8STARTDATUM: 9/5/19

KOORDINATEN (UTM)
N 5954761,23 m
E 729111,94 m
Wassertiefe 22,40 m

ENDTERMIN: 9/5/19
GEOLOGE: MC/AV NORM: BS
EN 5930:2015

AUSRÜSTUNG:
Vibrocore
BOHRER: JC
ASSISTENT: MC

BEMERKUNGEN:

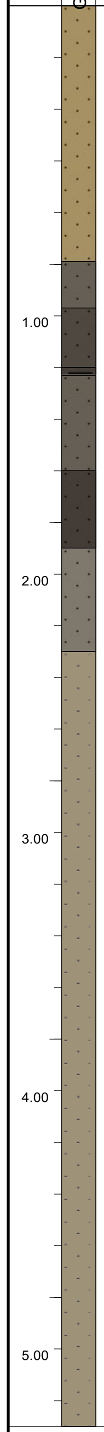
LEGENDE

SAND

TON

TIEFE (m BGL)	GRAFISCHES LOG	LAUF/C.GRÖßE (mm)	MATERIALBESCHREIBUNG	PROBEN TYP-	Ausgewählte SAMPLES für	Undrainierte Scherfestigkeit Su (kPa) ⊗ TV ☐ PP 50 100 150 200	HINWEISE	DETAILLIERTE FOTOS

C



0,00- 0,57: Hell gelbbrauner (2,5Y 6/4) feiner bis mittlerer SAND mit gelegentlichen Muschelfragmenten. Kein anhaltendes Aufbrausen von HCl.

0.57- 0.99: Hell gelbbrauner (2,5Y 6/4) feiner SAND mit gelegentlichen Muschelfragmenten. Kein anhaltendes Aufbrausen von HCl.

0,99- 1,17: Dunkelgrauer (2,5Y 4/1) feiner SAND mit häufigen amorphen organischen Stoffen, schwärzlichen millimetrischen Schichten und Einschlüssen, gelegentlich Muschelfragmenten (mittlere Sand- bis mittlere Kiesgröße). Kein anhaltendes Aufbrausen von HCl.

1.17- 1.40: Sehr dunkelgrauer (2.5Y 3/1) feiner SAND mit häufigen amorphen organischen Stoffen schwärzlichen millimetrischen Schichten und Einschlüssen und seltenen Muschelfragmenten. Deutliches, aber nicht anhaltendes Aufbrausen von HCl.

· Von 1,38 m bis 1,40 m: mittlerer SAND.

1.40- 1.43: Schwarzer (2.5Y 2.5/1) TON. Kein anhaltendes Aufbrausen von HCl.

1.43- 1.80: Dunkelgrauer (2,5Y 4/1) feiner SAND mit gelegentlichem Mittelsand, häufige amorphe organische Substanz schwärzliche Zonen, häufige Muschelfragmente. Deutliches, aber nicht anhaltendes Aufbrausen von HCl.

· Von 1,50 m bis 1,70 m: häufige zentimetrische Lehmtaschen.

· Von 1,60m bis 1,80m: mittlerer SAND mit seltenem Feinkies.

1.80- 2.00: Graubrauner (2,5Y 5/1) mittlerer SAND mit gelegentlichen Muschelfragmenten. Kein anhaltendes Aufbrausen von HCl. 2.00- 2.10: Graubrauner (2.5Y 5/1) grober SAND mit häufigen Muschelfragmenten. Kein anhaltendes Aufbrausen von HCl.

2.10- 2.50: Grauer (2,5Y 5/1) feiner SAND mit gelegentlichem feinen bis groben Kies, seltenen Toneinschlüssen und gelegentlichen Muschelfragmenten. Kein anhaltendes Aufbrausen von HCl.

2.50- 5.50: Hell bräunlich grauer (2,5Y 6/2) feiner SAND. Kein anhaltendes Aufbrausen von HCl.

1.00

2.00

3.00

4.00

5.00

106

S-6

S-5

S-4

S-3

S-2

S-1

VC_C_8.6

VC_C_8.5

VC_C_8.4

VC_C_8.3

VC_C_8.2

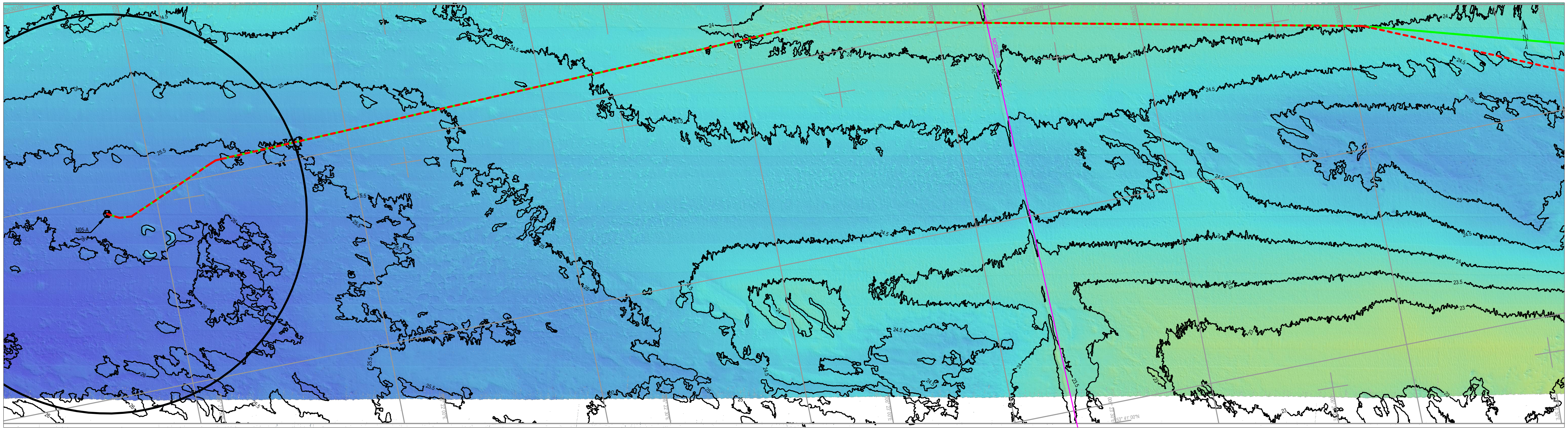
VC_C_8.1

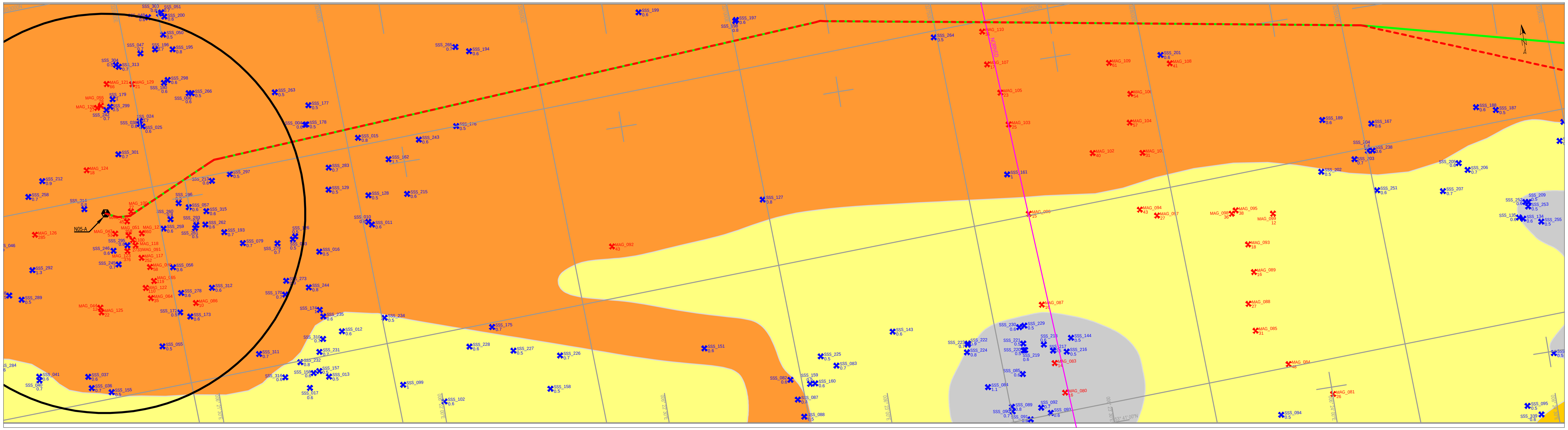
Boden bei 5,50 m

ANHANG B - GRAFIK

Tabelle 9: Liste der Diagramme

Tabelle Nr.	Diagrammtyp	Dateiname
01	Abgleichdiagramm 1 von 3 (ED50)	N05A-7-50-0-72006-01
02	Abgleichdiagramm 2 von 3 (ED50)	N05A-7-50-0-72007-01
03	Abgleichdiagramm 3 von 3 (ED50)	N05A-7-50-0-72008-01
04	Ausrichtungskarte 1 von 3 (WGS84)	N05A-7-50-0-72013-01
05	Ausrichtungskarte 2 von 3 (WGS84)	N05A-7-50-0-72014-01
06	Ausrichtungskarte 3 von 3 (WGS84)	N05A-7-50-0-72015-01





Infrastruktur

Kabeltrasse OPTION 1b	Windparkgebiet
geplante Alternativtrasse	Innerparkkabel Riffgat
500m Sicherheitszone	WEA-Standort Riffgat
N05-A Plattform	NorNed-Kabel

Bathymetrie

-35m -30 -25 -20 -15 -10 -5m

Grid: 0.5m

Tiefe (m)

20 Tiefenlinien Intervall 0,5m

Sedimente

- Feinsedimente
- Grobsedimente
- Mischsedimente
- Sand bis kiesiger Sand
- Mischsedimente inkl. Ton

Objekte

SSS_266 0.8	SSS Kontakt/Objekt
MAG_158 0.6	Magnetometer Kontakt
DEB_023 1.4 x 0.5 x 0.3	Geröll / Findling

Quelle: GEOxyz Offshore / Survey Report - N05A-7-10-0-70023-01.2.0

Revision	DD	MM	YYYY	REVISIONSBESCHREIBUNG	Zeichner	Prüfer	Freigabe
C							
B							
A							
01	19	10	2020	Genehmigungsplanung	HJM	DHE	
	Revisions Datum						

Erstellt	EWE Offshore Service and Solutions GmbH	Maßstab	1:10.000	Papiergröße	A3

ORANJE-NASSAU ENERGIE

Oranje-Nassau Energie B.V.
Amsterdam

TITEL

Kabelverbindung N05–A – OWP RIFFGAT
Bathymetrie und Sedimente
Blatt 01

ASSETCODE	DISC.CDE	DOC.TYPE CDE	PREFIX	DOCUMENT NUMBER	SHEET NR	REVISION
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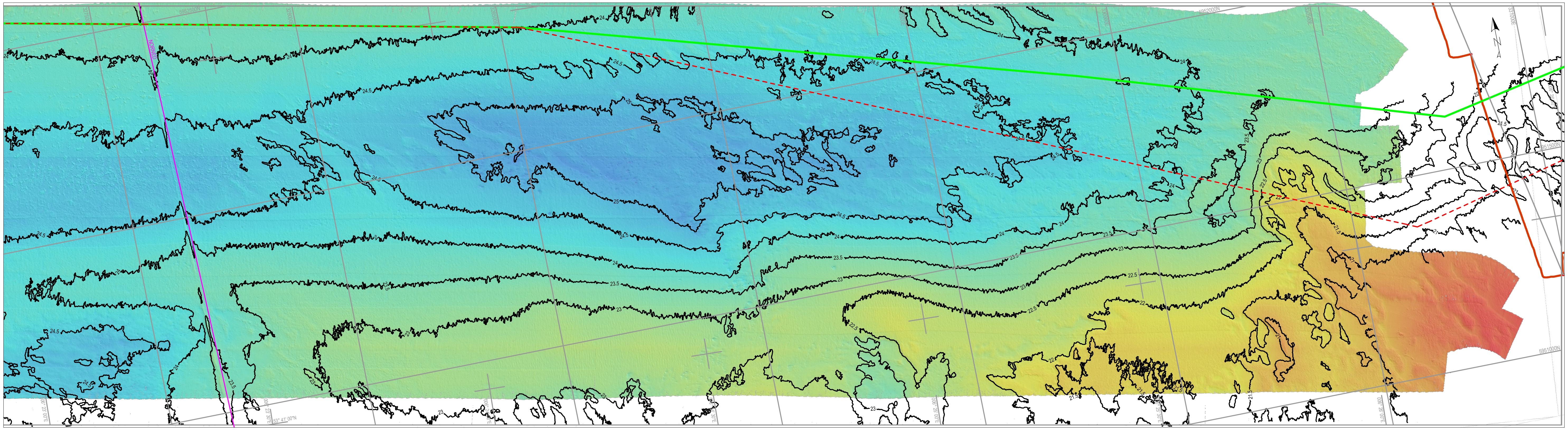

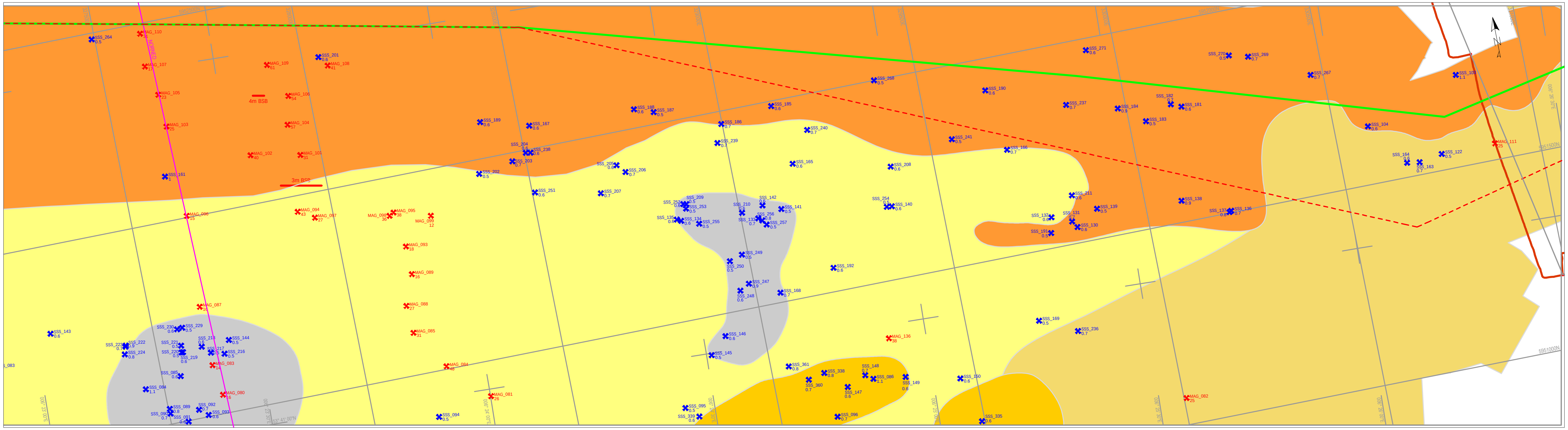

Infrastruktur

Kabeltrasse OPTION 1b	Windparkgebiet
geplante Alternativtrasse	Innerparkkabel Riffgat
○ 500m Sicherheitszone	● WEA-Standort Riffgat
N05-A Plattform	NorNed-Kabel

Bathymetrie

-35m -30 -25 -20 -15 -10 -5m

Grid: 0.5m

Tiefe (m)

20 Tiefenlinien Intervall 0,5m

Sedimente

🟨	Feinsedimente
🟨	Grobsedimente
🟨	Mischsedimente
🟧	Sand bis kiesiger Sand
⬜	Mischsedimente inkl. Ton

Objekte

SSS_266 0.8	SSS Kontakt/Objekt
MAG_158 0.6	Magnetometer Kontakt
DEB_023 1.4 x 0.5 x 0.3	Geröll / Findling

Quelle: GEOxyz Offshore / Survey Report - N05A-7-10-0-70023-01.2.0

Revision	DD	MM	YYYY	REVISIONSBESCHREIBUNG	Zeichner	Prüfer	Freigabe
C							
B							
A							
01	19	10	2020	Genehmigungsplanung	HJM	DHE	
	Revisions Datum						

Erstellt	EWE Offshore Service and Solutions GmbH	Maßstab	1:10.000	Papiergröße	A3

TITEL

Kabelverbindung N05–A – OWP RIFFGAT
Bathymetrie und Sedimente
Blatt 02

ORANJE-NASSAU ENERGIE

Oranje-Nassau Energie B.V.
Amsterdam

ASSETCODE	DISC.CDE	DOC.TYPE CDE	PREFIX	DOCUMENT NUMBER	SHEET NR	REVISION
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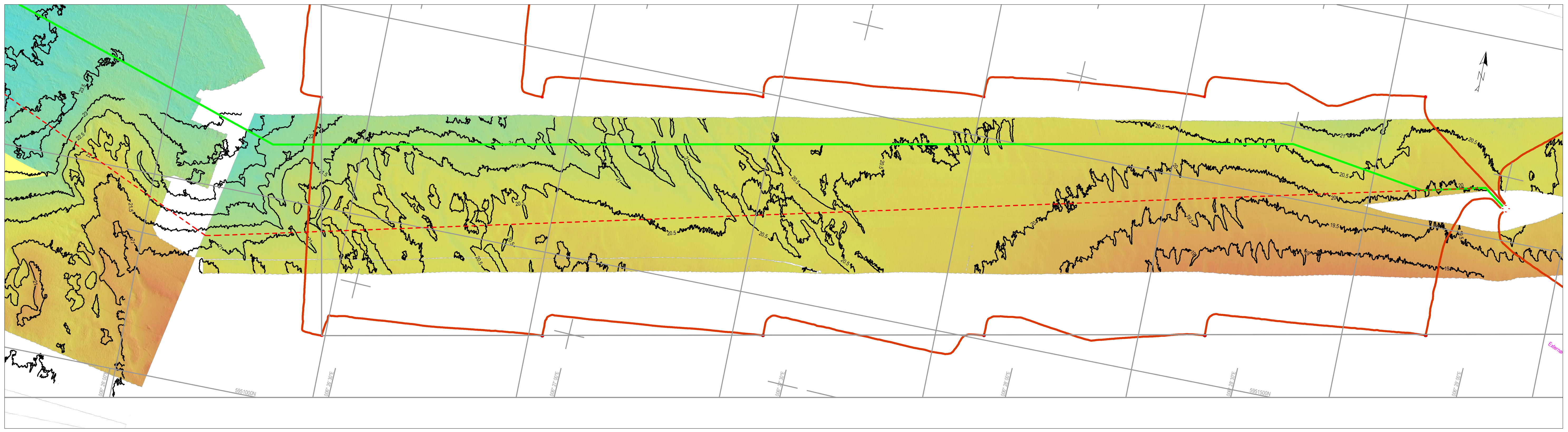
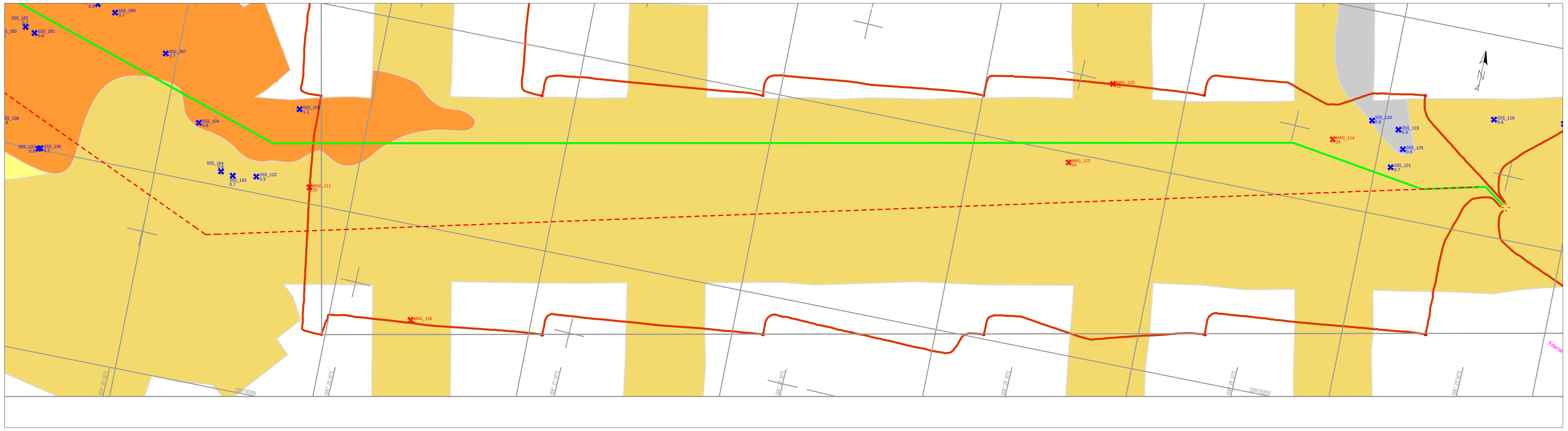




Infrastruktur

- - - -	Kabeltrasse OPTION 1b	▭	Windparkgebiet
—	geplante Alternativtrasse	—	Innerparkkabel Riffgat
○	500m Sicherheitszone	●	WEA-Standort Riffgat
☢	N05-A Plattform	—	NorNed-Kabel

Bathymetrie

-35m -30 -25 -20 -15 -10 -5m

Grid: 0.5m

Tiefe (m)

20 Tiefenlinien Intervall 0,5m

Sedimente

🟨	Feinsedimente
🟨	Grobsedimente
🟨	Mischsedimente
🟧	Sand bis kiesiger Sand
⬜	Mischsedimente inkl. Ton

Objekte

✖ SSS_266 0.8	SSS Kontakt/Objekt
✖ MAG_158 0.6	Magnetometer Kontakt
✖ DEB_023 1.4 x 0.5 x 0.3	Geröll / Findling

Quelle: GEOxyz Offshore / Survey Report - N05A-7-10-0-70023-01.2.0

Revision	DD	MM	YYYY	REVISIONSBESCHREIBUNG	Zeichner	Prüfer	Freigabe
C							
B							
A							
01	19	10	2020	Genehmigungsplanung	HJM	DHE	
	Revisions Datum						

Erstellt	EWE Offshore Service and Solutions GmbH	Maßstab	1:10.000	Papiergröße	A3

TITEL

Kabelverbindung N05–A – OWP RIFFGAT
Bathymetrie und Sedimente
Blatt 03

ORANJE-NASSAU ENERGIE

Oranje-Nassau Energie B.V.
Amsterdam

ASSETCODE	DISC.CDE	DOC.TYPE CDE	PREFIX	DOCUMENT NUMBER	SHEET NR	REVISION
N05A	5	50	0	52003	03	01

32222-TRT-OF0262295

"Technischer Bericht N05-A Elektromagnetisches Feld von Unterseekabeln"

TKF (Twentsche Kabelfabriek)

Technischer Bericht

N05-A

Elektromagnetisches Feld eines Unterseekabels

Details zum Dokument

Datum der Veröffentlichung	02 Jul 20
TKF Revision	C4
Name des Dokuments	32222-TRT-OF0262295
Arbeitgeber	ONE-Dyas B.V.
Kunde	ONE-Dyas B.V.
Kunde Ref.	EIN-006096
Kunde TQ	NA

Dieser Text wurde aus dem Englischen übersetzt. Soweit es Widersprüche zum Originaltext gibt, ist der Originaltext führend.

Dokumentstatus-Historie & Autorisierung

Zustand	Updater	Prüfer	Datum der Änderung	Revision	Kommentar zur Revision
Unter Bearbeitung			11 Jun 20	S3	Dokument mit Simulationsergebnissen bearbeiten
Warten auf interne Zulassung			16 Jun 20	P4	
Intern zugelassen			02 Jul 20	C3	genehmigt
Zur Überprüfung unter Kunde			02 Jul 20	C4	zur Überprüfung an den Kunden senden
Freigegeben			13 Mai 20	02	Intern für die Ausgabe an den Kunden freigegeben
-			-	-	-
-	-	-	-	-	-

Inhaltsverzeichnis

Abkürzungen

Die im Text verwendeten Abkürzungen sind wie definiert zu interpretieren

Querschnittsfläche	
CUSTOMER	ONE-Dyas B.V.
DOB	Tiefe der Grabens
DOC	Tiefe der Abdeckung
FEM	Finales Element Modellierung
PROJECT	N05-A
SUPPLIER	Twentsche Kabelfabriek
TKF	Twentsche Kabelfabriek
Finite-Elemente-Methode	

LIEFERANT verwendet das Internationale Einheitensystem (SI) und damit Einheiten wie z.B.; MW, kA, s et cetera und deren zugehörige Erklärung sind in dieser Liste nicht aufgeführt.

1 Einleitung

Der Zweck dieses Dokuments ist es, den berechneten Wert des elektromagnetischen Feldes von zwei Seekabeln zu berichten, die potenziell für das PROJEKT ausgewählt wurden. In einer früheren Phase wurde eine Reihe von Berechnungen durchgeführt und über einen Teil des Seekabel-Portfolios des LIEFERANTEN berichtet. Die Eingaben für diese Berechnungen sind in Kapitel 3 und die Ergebnisse in Kapitel 4 zusammengefasst. Der KUNDE wählte zwei Szenarien, d.h. CSAs für einen nächsten Schritt der Berechnungen. Dies betrifft den Pegel des elektromagnetischen Feldes in Gauß oder µT, den das Kabel auf der Ebene der Meeresbodenoberfläche abstrahlen wird. In Kapitel 5 wird die gewählte Methode zur Bestimmung des elektromagnetischen Feldes erläutert und in Kapitel 6 werden die Ergebnisse und ggf. Schlussfolgerungen genannt.

2 Eingaben

Die Eingabeparameter werden vom KUNDEN zur Verfügung gestellt, mit Ausnahme der letzten Gruppe von Parametern in diesem Kapitel. Diese elektrischen Parameter des Meeresbodens sind jedoch sinnvolle Annahmen.

Elektrische Parameter:

Betriebsspannungspegel	19/33 (36) kV
Leistung:	23595 kVA
Kosinus Phi:	0,88
Gesamtlänge des Kabels:	9000 Meter
Spannungsabfall:	= < 10%

Umgebungsparameter:

Thermischer Widerstand des Meeresbodens	0,39 K*m/W
DoC	1.5 m
Bodentemperatur am Meeresboden	15 Grad Celsius

Elektrische Parameter des Meeresbodens:

Elektrische Leitfähigkeit des Meeresbodens	1,0 S/m
Relative elektrische Durchlässigkeit des Meeresbodens	1.0
Relative elektrische Permittivität des Meeresbodens	25
Elektrische Leitfähigkeit des Meerwassers	5,0 S/m
Relative elektrische Durchlässigkeit von Meerwasser	1,0
Relative elektrische Permittivität von Meerwasser	81

3 Berechnungen zur Kabelauswahl

Basierend auf den oben genannten Eingangsparametern wird der tatsächliche Strom im Kabel

413 A betragen.

Tabelle 1.

Kabel-konfiguration	**CSA (mm 2)**	**Iscc (kA/1s)**	**Uo Spannungs-abfall (V)**	**Uo Spannungsabfall (%)**	**Temperatur-anstieg auf dem Meeresboden(1)**	**Strombelastbarkeit (A)**	**Kommentar**
149186	400	37.8	547	2,9%	0,9	665	Option 4
149288	300	27.9	647	3,4%	1,1	585	Option 3
149166	240	22.6	757	4,0%	1,4	518	Option 2
(1) 149368	185	17.3	933	4,9%	1,8	447	Option 1
149364	150	13.8	1121	5.9%	2.4	394	Zu geringe Strombelastbarkeit

Temperaturanstieg am Meeresboden bei -200 mm unter der Meeresbodenoberfläche und 413 A

Der KUNDE hat sich für Option 1 und 3 entschieden, um mit der Bestimmung des elektromagnetischen Feldes fortzufahren.

4 Berechnungsmethode für elektromagnetisches Feld

Die Finite-Elemente-Methode (FEM) wird angewendet, um das elektromagnetische Feld in und um ein im Meeresboden verlegtes Seekabel zu berechnen. COMSOL wird als Simulationssoftware gewählt. Ein 2D-FEM-Modell wird in der COMSOL-Software für jedes Kabel generiert (Szenario von Option 1 und Option 3). Die elektrische Leitfähigkeit, die elektrische Durchlässigkeit und die elektrische Permittivität des Meeresbodens werden durch vernünftige Annahmen berücksichtigt. Da es keine existierenden Normen zur Anleitung der FEM-Simulation gibt, werden veröffentlichte wissenschaftliche Arbeiten als Anleitung für die Simulationsarbeit verwendet [1, 2, 3].

4.1 Kabelmodelle

2D-Kabelmodelle, die auf TKF-Kabelabmessungen basieren, werden in COMSOL erstellt. Die Kabelquerschnittsfläche ist so gewählt, dass die Verlegerichtung von Leistungsadern und Lichtwellenleitern (LWL) den ungünstigsten Fall darstellt, bei dem die emittierte magnetische Flussdichte an der Meeresbodenoberfläche direkt über der Kabelachse den höchsten Wert hat.
In den realen TKF-Kabeln für beide Typen sind die Leiter als Al-Litzen ausgeführt, mit quellfähigen Garnen zwischen den Drähten. Um die Simulation zu vereinfachen, wird im Modell der Leiter des Kabels als massiver Al-Leiter mit dem gleichen Durchmesser wie im Kabeldatenblatt angegeben aufgebaut. Die elektrische Leitfähigkeit des Leitermaterials wird stattdessen so eingestellt, dass der elektrische Gesamtwiderstand des Leiters mit den in IEC60228 [4] definierten Werten übereinstimmt.
Diese Vereinfachung hat keinen Einfluss auf die Simulationsergebnisse.
Als Beispiel ist das 3×300mm2 Kabelmodell in Abbildung 1 unten dargestellt. 3×185mm2 Kabel haben die gleiche Struktur, aber nur unterschiedliche Abmessungen im Vergleich zu 3×300mm2 Kabel.

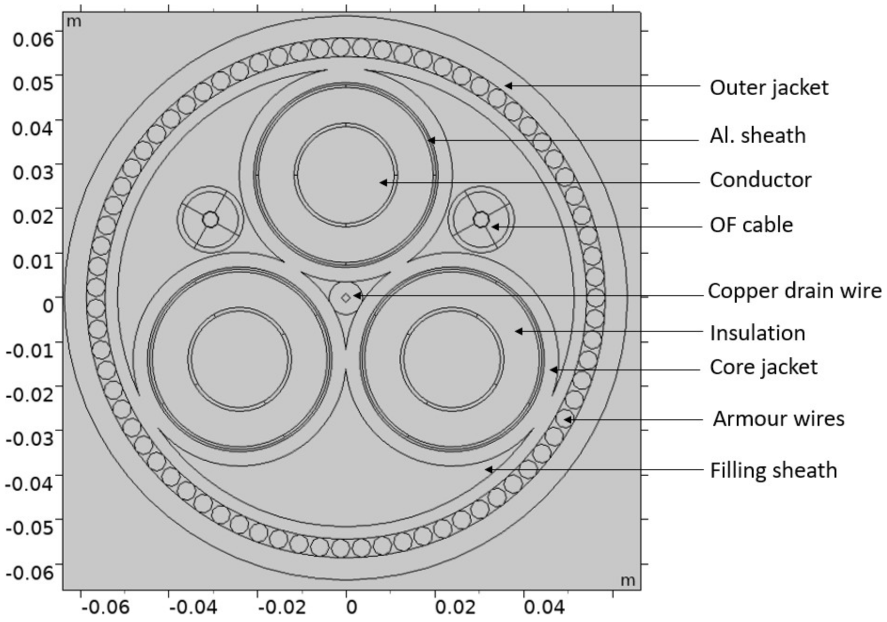


Abbildung 1. 2D-Kabelmodell für 3×300mm2, erstellt in COMSOL.

Das Kabel ist im Meeresboden mit einer Überdeckungstiefe von 1,5 Metern vergraben, wie in einem Beispiel des vollständigen Modells in COMSOL in Abbildung 2 zu sehen ist.

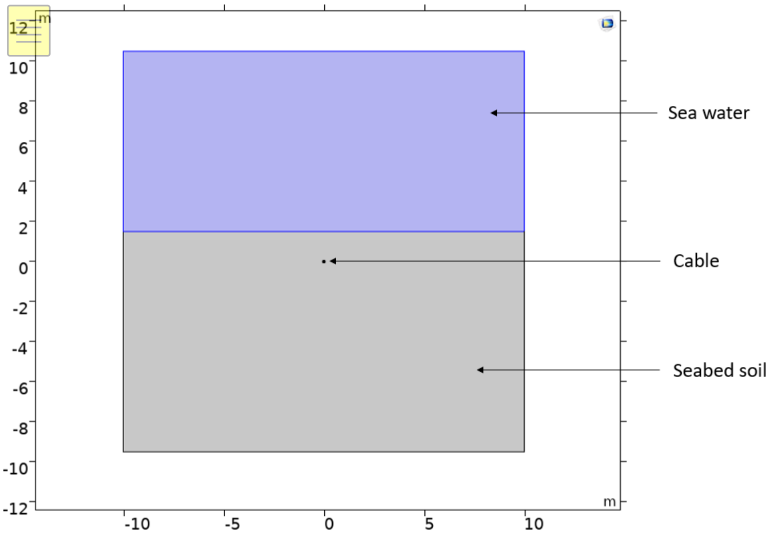


Abbildung 2. Vollständiges Modell für ein im Meeresboden vergrabenes Kabel in COMSOL. Das Rechteck oben, das mit blauer Farbe markiert ist, stellt das Meerwasser dar. Das Rechteck unten repräsentiert den Meeresboden.

4.2 EM-Parameter

Die elektromagnetischen Parameter des Kabels und seiner Umgebung haben Einfluss auf die Simulationsergebnisse. In der folgenden Tabelle 2 sind die elektromagnetischen Parameter für die Komponenten zusammengefasst.

Tabelle 2. Elektrisch-magnetische Eigenschaften des Kabelmaterials und seiner Umgebung. Rc - elektrischer Widerstand des Leiters, definiert nach IEC60228, in der Einheit Ω/m; Ac -Querschnittsfläche des Leitermaterials, in der Einheitm^2.

		Relative elektrische Dielektrizitätskonstante	Relative elektrische Permeabilität	Elektrische (S/m)
Leiter (Al.)		1,0	1,0	$1/(RcAc)$
XLPE-Isolierung		2,5	1,0	$1 \times 10-18$
Isolierendes PE-Material		2,5	1,0	$1 \times 10-14$
Halbleitender Leiter/Isolierschirm		2,3	1,0	1
Semi-leitfähiges PE über Adermantel und LWL-Kabelmantel		2,3	1,0	4
Erdungsschirm (geschweißtes Al. Rohr)		1,0	1,0	$3{,}521 \times 10$
Armiertes Kabel		1,0	600	$7{,}246 \times 10$
Meeresboden		81	1,0	1,0
Meerwasser		25	1,0	5,0

5 Simulationsergebnisse

Das Modell der magnetischen und elektrischen Felder in COMOSL wurde verwendet, um das elektrische Magnetfeld in und um die Kabel zu simulieren. Der in Tabelle 1 definierte PROJEKT-Strom wird während der Simulation in beiden Kabeln angelegt, d.h. 413A für beide 3×185mm2 Kabel und 3×300mm2 Kabel. Zwischen Leiter und Erdungsschirm wurde eine Spannung von 19 kV angelegt. Das Oberflächendiagramm für das elektrische Feld und das Konturdiagramm der magnetischen Flussdichte werden für jeden Kabeltyp unter stationärer Lösung aufgezeichnet.

Zur besseren Veranschaulichung werden die Ergebnisse der magnetischen Flussdichte für jeden Kabeltyp in drei Diagrammen dargestellt.

5.1.1 3×185mm2 Kabel

- **Elektrisches Feld**

Das elektrische Feld existiert nur innerhalb der Kabelisolierung und ist unabhängig von den Umgebungsbedingungen und der angelegten Last. Bei einer angelegten Spannung von 19 kV zwischen Phase und Erde wird die Verteilung des elektrischen Feldes in einem 3×185 mm2 großen Kabel simuliert; das Ergebnis ist in Abbildung 3 dargestellt. Das maximale elektrische Feld erscheint auf dem Leiterschirm: 3,3kV/mm und ein minimales elektrisches Feld tritt auf der Außenseite der Isolierung auf: 1,8 kV/mm.

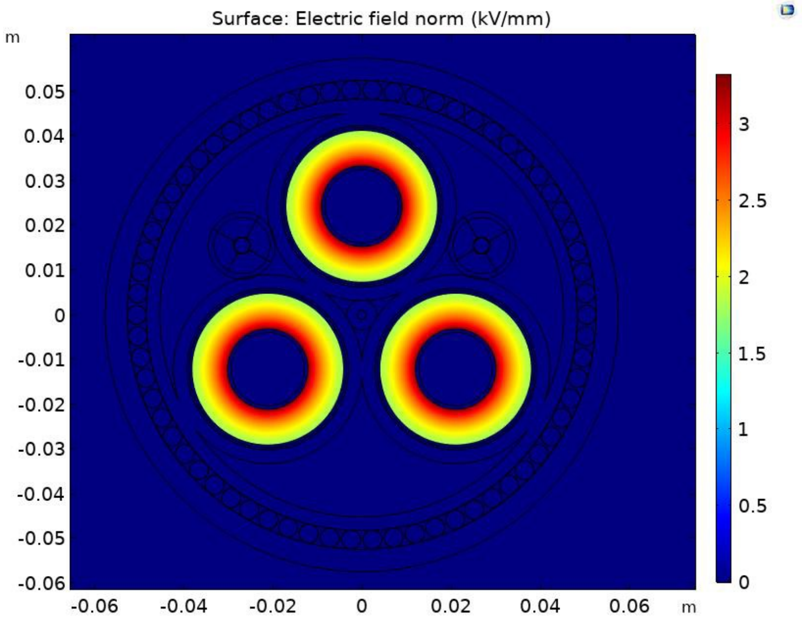
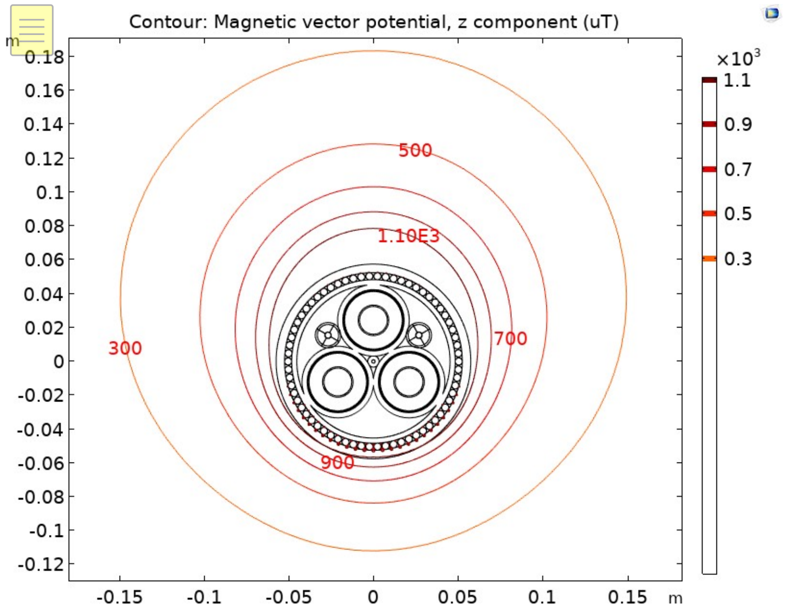
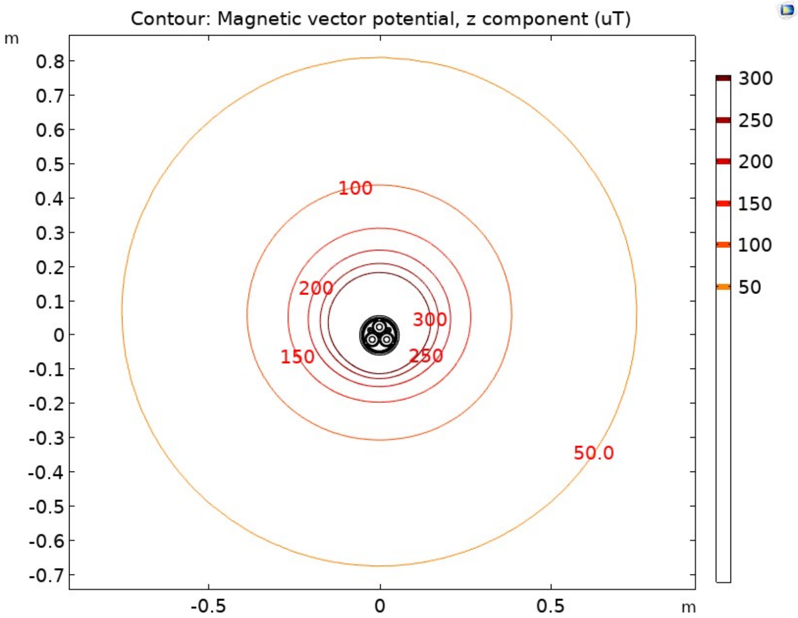


Abb. 3. Elektrische Feldverteilung in einem 3×185mm2 Kabel unter einer Phase-Erde-Spannung von 19kV.

- **Magnetisches Feld**

Die drei Diagramme in Abbildung 4 zeigen die magnetische Flussdichte innerhalb und um das 3×185mm2 -Kabel unter der PROJECT-Spitzenlast. Aus den Ergebnissen geht hervor, dass die magnetische Flussdichte hauptsächlich innerhalb des Kabels begrenzt ist. An einer Stelle, die 0,1 mm neben der Außenfläche des Kabels liegt, beträgt die magnetische Flussdichte 1,9 mT. In einem Abstand von 50cm von der Kabelaußenfläche entfernt, sinkt die höchste magnetische Flussdichte auf 76µT. An der Oberfläche des Meeresbodens direkt über der Kabelachse beträgt die vom Kabel ausgehende magnetische Flussdichte 26µT. In einer Entfernung von 2 m von der Kabelaußenfläche nimmt die höchste magnetische Flussdichte auf 19 µT ab.


Contour: Magnetic vector potential, z component (uT)
m
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
m
×10³
1.1
0.9
0.7
0.5
0.3
500
1.10E3
700
300
900


Contour: Magnetic vector potential, z component (uT)
m
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.5
0
0.5
m
300
250
200
150
100
50
100
200
300
150
250
50.0

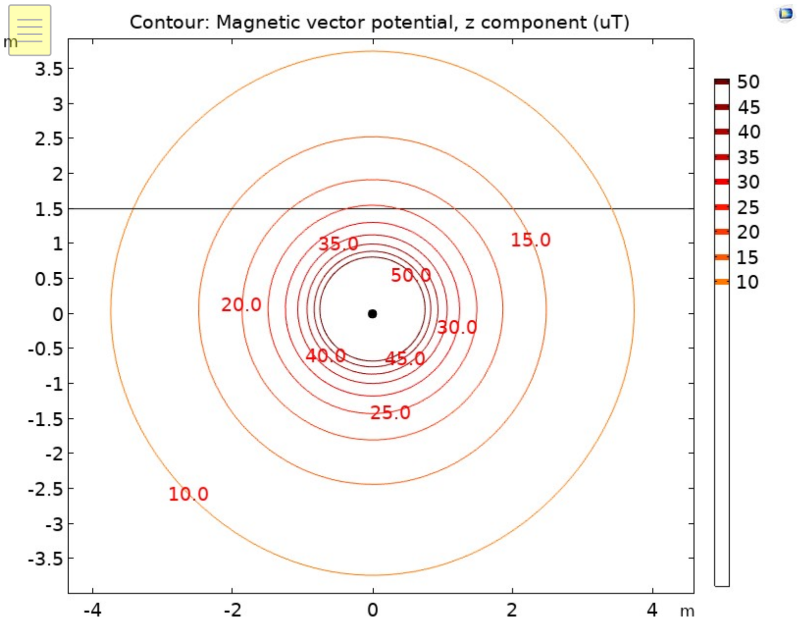


Abbildung 4. Magnetische Flussdichte im und um das 3×185mm2 Kabel, unter PROJECT-Spitzenlast: 413A.

5.1.2 3×300mm2 Kabel

- **Elektrisches Feld**

Das elektrische Feld existiert nur innerhalb der Kabelisolierung und ist unabhängig von den Umgebungsbedingungen und der angelegten Last. Bei einer angelegten Spannung von 19 kV zwischen Phase und Erde wird die Verteilung des elektrischen Feldes in einem 3×300 mm2 großen Kabel simuliert, und das Ergebnis ist in Abbildung 5 dargestellt. Das maximale elektrische Feld erscheint auf dem Leiterschirm: 3,1 kV/mm und ein minimales elektrisches Feld tritt auf der Außenseite der Isolierung auf: 1,9 kV/mm.

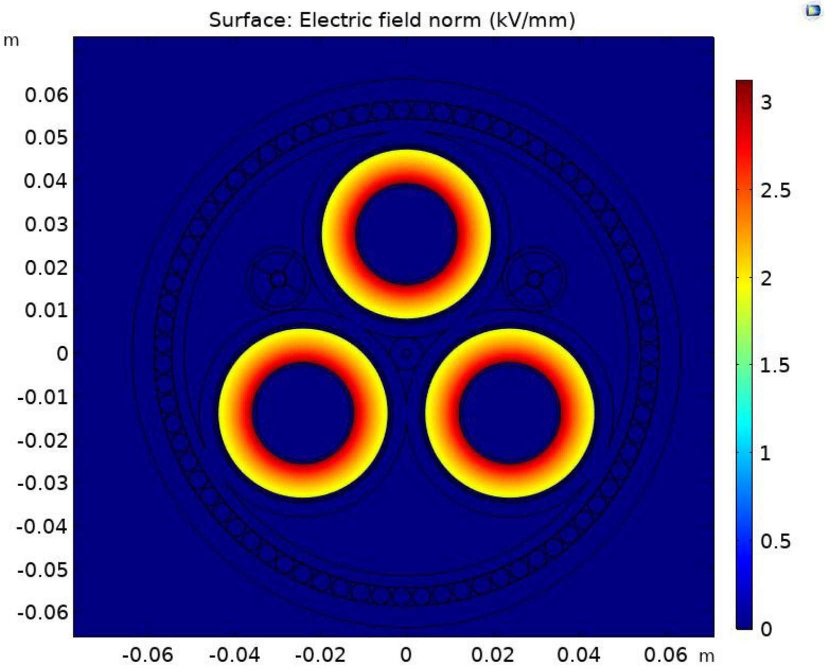
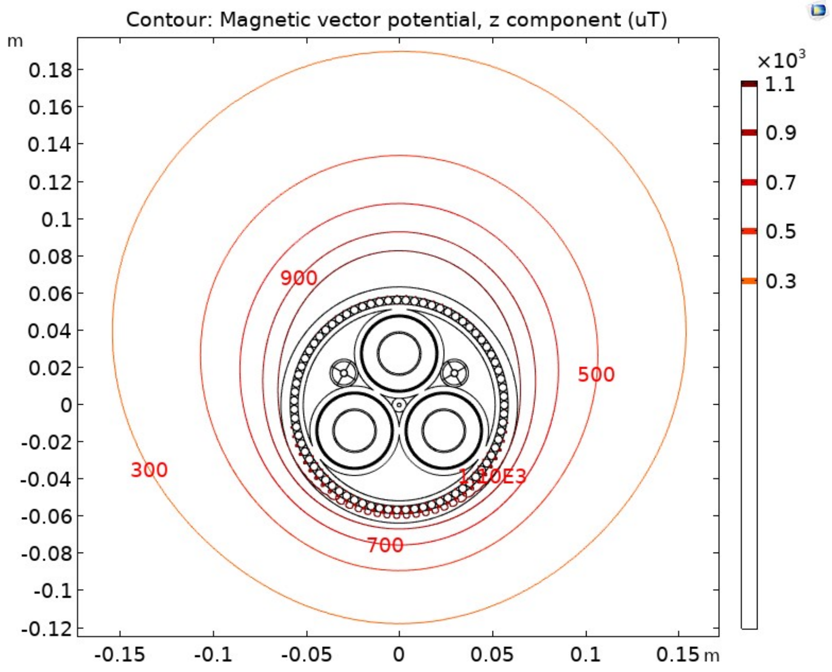
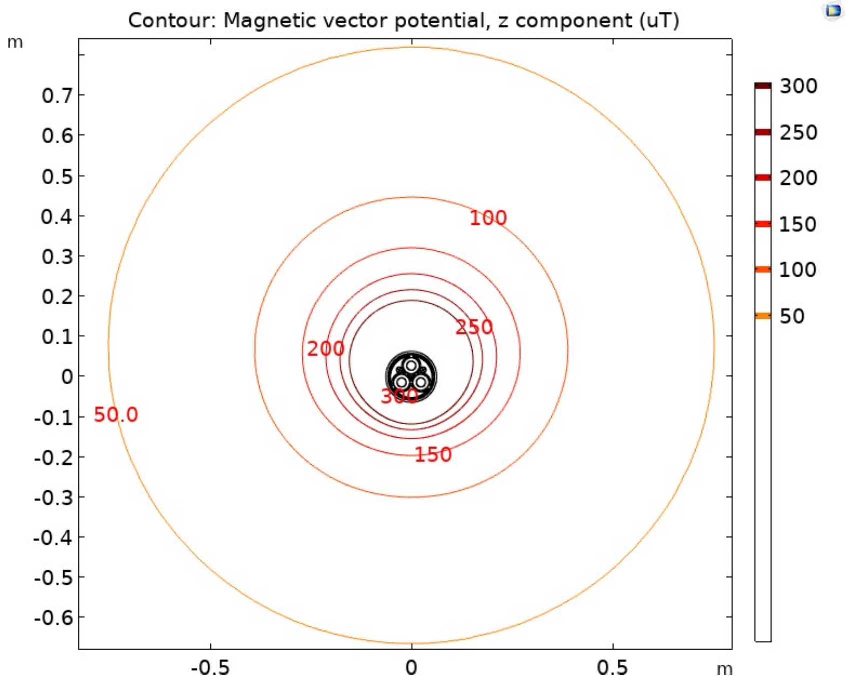


Abb. 5. Elektrische Feldverteilung in einem 3×300mm2 Kabel unter einer Phase-Erde-Spannung von 19kV.

- **Magnetisches Feld**

Die drei Diagramme in Abbildung 6 zeigen die magnetische Flussdichte innerhalb und um das 3×300mm2 -Kabel unter der PROJECT-Spitzenlast. Aus den Ergebnissen ist ersichtlich, dass die magnetische Flussdichte größtenteils innerhalb des Kabels begrenzt ist.
An der Stelle 0,1mm neben der Kabelaußenfläche beträgt die magnetische Flussdichte 1,8mT. In einem Abstand von 50cm von der Kabelaußenfläche entfernt, sinkt die höchste magnetische Flussdichte auf 77µT. An der Oberfläche des Meeresbodens direkt über der Kabelachse beträgt die vom Kabel ausgehende magnetische Flussdichte 26 µT. In einem Abstand von 2 m von der Kabelaußenfläche nimmt die höchste magnetische Flussdichte auf 19 µT ab.





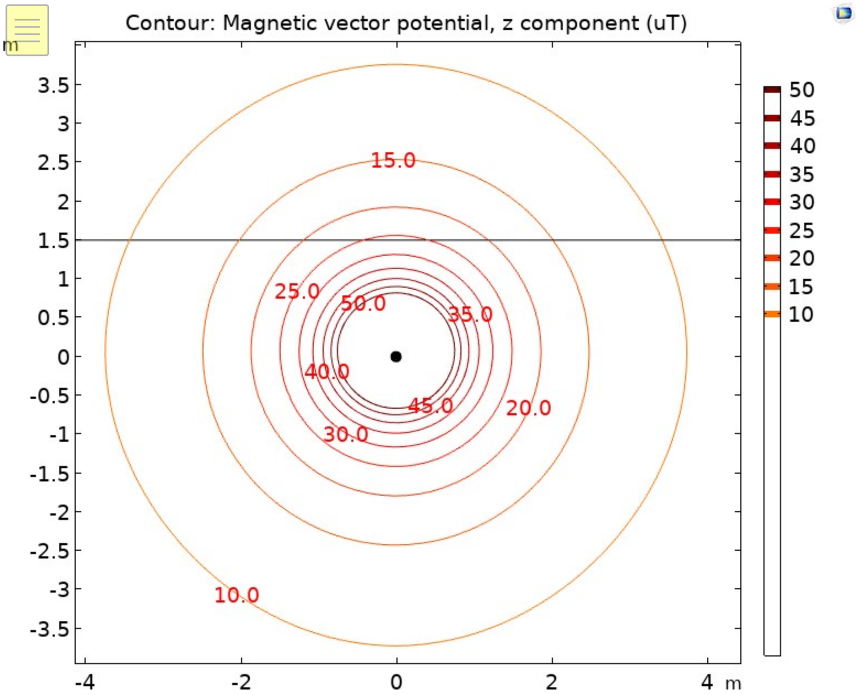


Abbildung 6. Stationäre magnetische Flussdichte im und um das 3×300mm2 Kabel, unter PROJEKT-Spitzenlast: 413A.

6 Fazit

Elektrische und magnetische Felder, die von den beiden PROJEKT-Kabeln 3×185mm2 und 3×300mm2 ausgehen, werden mit Hilfe eines FEM-Modells simuliert. Das elektrische Feld ist aufgrund der Erdungsabschirmung auf jeder Ader innerhalb der Kabelisolierung begrenzt. Die magnetische Flussdichte in und um die Kabel 3×185mm2 und 3×300mm2 unter PROJEKT-Strom wird mit einem 2D-FEM-Modell simuliert. Bei beiden Kabeln beträgt die magnetische Flussdichte an der Kabelaußenfläche weniger als 2 mT, während die magnetische Flussdichte in weniger als 1 m Entfernung von der Kabeloberfläche auf einige zehn Mikrotesla abnimmt, was im gleichen Bereich wie die magnetische Hintergrundflussdichte in der Erde liegt. An der Oberfläche des Meeresbodens beträgt die magnetische Flussdichte, die sowohl von 3×185mm2 als auch von 3×300mm2 Kabeln ausgeht, 26µT.

7 Referenzen

[1] J. C. L. Veloso Silva, A. C. S. Lima, A. P. Cardillo Magalhães und M. T. Correia de Barros, "Modelling seabed buried cables for electromagnetic transient analysis," in IET Generation, Transmission & Distribution, vol. 11, no. 6, pp. 1575-1582, 20 4 2017, doi: 10.1049/iet-gtd.2016.1464.
[2] V. Grinchenko, O. Tkachenko und K. Chunikhin, "Magnetic field calculation of cable line with two-point bonded shields," 2017 IEEE International Young Scientists Forum on Applied Physics and Engineering (YSF), Lviv, 2017, pp. 211-214, doi: 10.1109/YSF.2017.8126621.
[3] Gill, A.; Huang, Y.; Spencer, J.; Gloyne-Philips, I. (2012). Electromagnetic Fields Emitted by High Voltage Alternating Current Offshore Wind Power Cables and Interactions with Marine Organisms, London, UK.
[4] IEC 60228:2004 Conductors of insulated cables.

N05A-5-10-0-50003-01

"Thermischer Einfluss von Seekabeln auf die umgebenden Sedimente und Einhaltung des 2-K-Kriteriums"

FGH e.V.

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Thermischer Einfluss von Seekabeln auf die umgebenden Sedimente und Einhaltung des 2-K-Kriteriums

Bericht

Herausgeber:
FGH e.V.

Adresse:
Besselstraße 20-22
68219 Mannheim
Deutschland

Telefon: +49 621 976807-10
Telefax: +49 621 976807-70
E-Mail: info@fgh-ma.de
Internet: www.fgh-ma.de

Herausgeber:

Mannheim, im Oktober 2020

Inhaltsverzeichnis

1 Umfang der Studie

Eine neue Station von ONE DYAS soll an das 33-kV-Netz des 155-kV-/33- kV-Netzes des Offshore-Windparks (OWF) Riffgat angeschlossen werden [1]. Es ist geplant, ein Seekabel mit einer Länge von ca. 9 km zu verlegen. Der Leistungsbedarf der Station beträgt ca. 20 MW (24 MVA). Der erforderliche Mindestquerschnitt des Seekabels wird mit Hilfe von Leistungsflussberechnungen ermittelt [1]. Es wird ein Mindestquerschnitt von 300 mm^2 empfohlen, um den Strom zu führen. Der maximale Laststrom einer Phase beträgt ca. 460 A. Zusätzlich muss aus naturschutzfachlicher Sicht die Erwärmung des Meeresbodens oberhalb des Kabels begrenzt werden. Es wird eine maximale Erwärmung von 2 Kelvin in 300 mm unterhalb des Meeresbodens (oberhalb des Kabels) gefordert, was als 2-K-Kriterium bezeichnet wird [2]. In diesem Bericht werden die Erwärmungsverluste des Kabelprojekts und die Berechnung des 2-K-Kriteriums dargestellt. Das 2-K-Kriterium wird für drei verschiedene Kabelquerschnitte (300, 400 und 500 mm^2) berechnet.

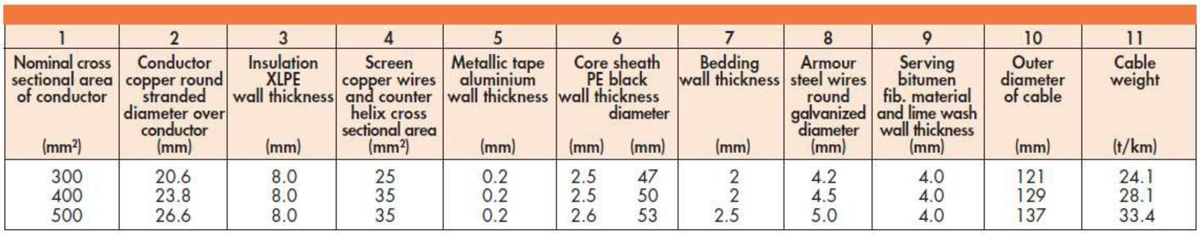
2 Basis der Berechnungen

2.1 Eigenschaften des Meeresbodens

Der spezifische Wärmewiderstand ρT des wassergesättigten Meeresbodens beträgt 0,33 bis 0,50 K-m/W [3]. Die "Geo-Engineering.org GmbH" hat im Jahr 2011 die Wärmeleitfähigkeit des Meeresbodens des Offshore-Windparks Riffgat gemessen [3]. In einer Tiefe zwischen 1,45 und 1,55 m wird ein Wärmewiderstand PT zwischen 0,39 und 0,37 K-m/W gemessen. Als konservativer Ansatz wird das 2-K-Kriterium mit einem Wert von $\rho T = 0{,}39$ K-m/W berechnet. Die Temperatur des Meeresbodens wird mit 10 °C angenommen [2]. Die Berechnung wird für ein Kabel durchgeführt, welches 1,5 m unter dem Meeresboden verlegt ist.

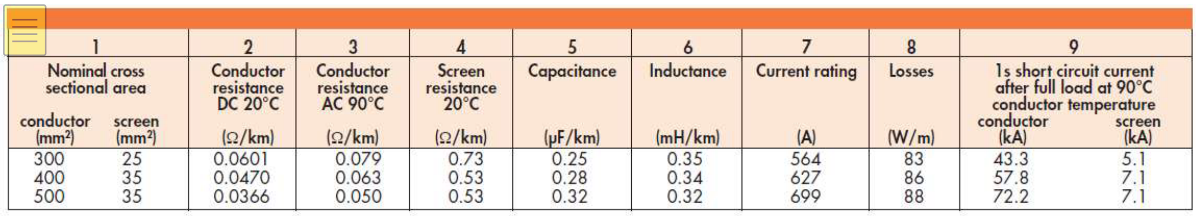
2.2 Kabelsystem

Für die Berechnung wird ein 30 kV-Seekabel verwendet (2XS(FL)2YRAA 18/30(36) kV) [4]. Die thermischen Widerstände und die Leitungsverluste werden mit Hilfe der konstruktiven Daten (Abbildung 1) und der elektrischen Daten (Abbildung 2) des Datenblatts [4] berechnet.



1	2	3	4	5	6		7	8	9	10	11
Nominal cross sectional area of conductor (mm^2)	Conductor copper round stranded diameter over conductor (mm)	Insulation XLPE wall thickness (mm)	Screen copper wires and counter helix cross sectional area (mm^2)	Metallic tape aluminium wall thickness (mm)	Core sheath PE black wall thickness (mm)	diameter (mm)	Bedding wall thickness (mm)	Armour steel wires round galvanized diameter (mm)	Serving bitumen fib. material and lime wash wall thickness (mm)	Outer diameter of cable (mm)	Cable weight (t/km)
300	20.6	8.0	25	0.2	2.5	47	2	4.2	4.0	121	24.1
400	23.8	8.0	35	0.2	2.5	50	2	4.5	4.0	129	28.1
500	26.6	8.0	35	0.2	2.6	53	2.5	5.0	4.0	137	33.4

Abbildung 1 - Konstruktionsdaten [4}



1		2	3	4	5	6	7	8	9	
Nominal cross sectional area		Conductor resistance DC 20°C	Conductor resistance AC 90°C	Screen resistance 20°C	Capacitance	Inductance	Current rating	Losses	1s short circuit current after full load at 90°C conductor temperature	
conductor (mm^2)	screen (mm^2)	(Ω/km)	(Ω/km)	(Ω/km)	(μF/km)	(mH/km)	(A)	(W/m)	conductor (kA)	screen (kA)
300	25	0.0601	0.079	0.73	0.25	0.35	564	83	43.3	5.1
400	35	0.0470	0.063	0.53	0.28	0.34	627	86	57.8	7.1
500	35	0.0366	0.050	0.53	0.32	0.32	699	88	72.2	7.1

Abbildung 2 - Elektrische Daten [4}

2.3 Kabelverluste eines 3-phasigen Unterseekabels

Zur Berechnung der Kabelverluste eines 3-phasigen Seekabels werden verschiedene Verluste und thermische Resistenzen berücksichtigt. Die Hauptverluste sind die I^2 R-Verluste (We) des Leiters.

Mit höherer Temperatur des Kabels steigt der Widerstand des Leiters, der Ummantelung und des Ar mors. Daher steigen die Verluste im gesamten Kabel. Zusätzlich werden der Skin-Effekt und der Proximity-Effekt im Mantel (W_s) und in der Bewehrung (W_c) berücksichtigt. Nach IEC 60287-1-1 werden dielektrische Verluste (W_d) in Spannungsebenen unter 127 kV nicht berücksichtigt [5]. In Abbildung 3 sind das thermische Netzwerk der Verluste und die thermischen Widerstände des Kabelsystems und der Umgebung angegeben.

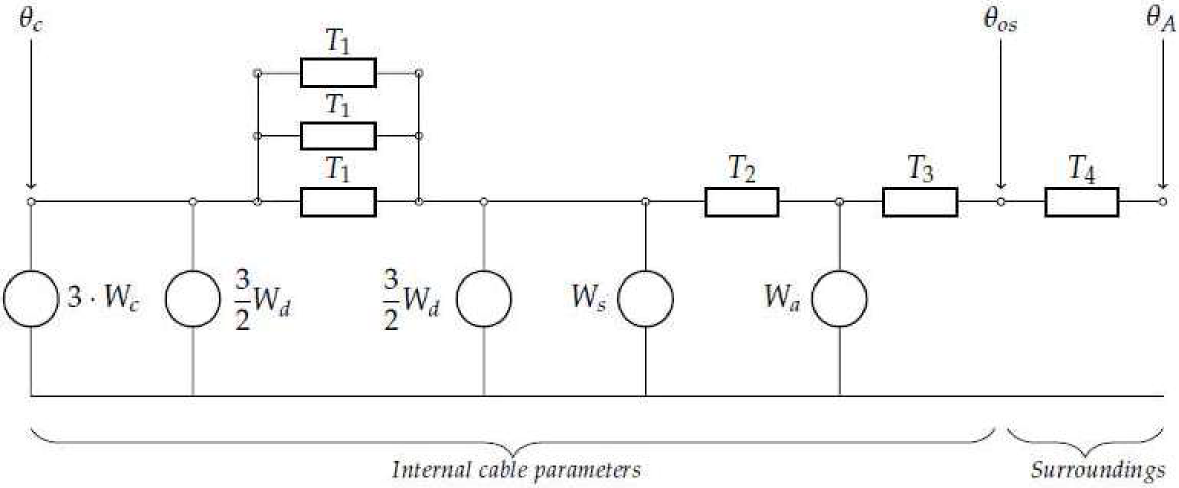


Abbildung 3 - Wärmewiderstände (T), Wärmequellen (W) und Temperaturen (0) in einem dreiadrigen XLPE-Unterseekabel [6}

2.4 Berechnung des 2-K-Kriteriums

Die Erwärmung wird nach der stationären Methode gemäß IEC 60287-2-1 [7] ermittelt. Diese Methode basiert auf dem stationären Zustand des Wärmeflusses. Der Fluss hält konstant den gleichen Maximalwert und der Meeresboden ist bereits erwärmt. Dies ist eine konservative Annahme, da das Erwärmungsverhalten im Meeresboden instationär ist und noch mehr Wärme aufnehmen kann. Das 2-K-Kriterium wird mit Hilfe der Spiegelungsmethode nach IEC 6028-2-1 Abschnitt 2.2.3.1 [7] berechnet. Die Maße für diese Methode sind in Abbildung 4 angegeben.

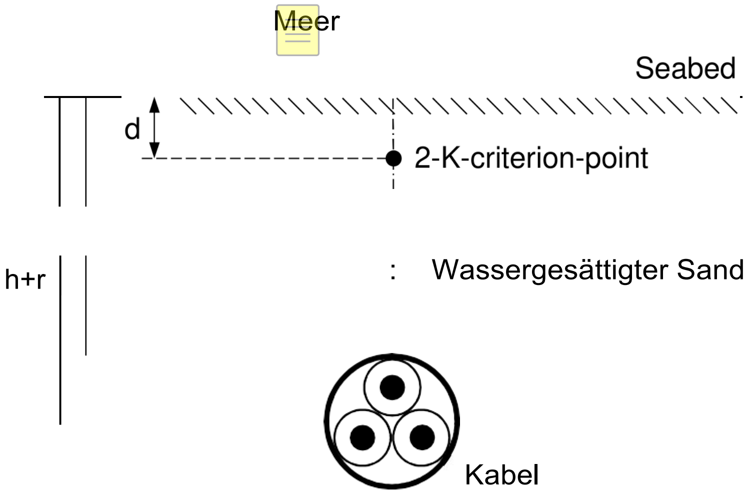


Abbildung 4 - Schematische Darstellung der Verlegung des Kabels und des 2-K-Kriteriumspunktes

Die Temperaturerhöhung $\Delta\theta_{2KP}$ am 2-K-Kriteriumspunkt wird wie folgt berechnet:

$$\Delta\theta_{2KP} = \frac{1}{2\pi} W_{tot} \cdot \rho_T \cdot \ln\left(\frac{h+r+d}{h+r-d}\right)$$

$Wtot$: Gesamtverluste
ρT: spezifischer Wärmewiderstand des Meeresbodens
h: Verlegetiefe des Kabels (1500 mm) d: 2-K-Kriteriumpunkt (300 mm)
r: Radius des Leiters (60 . 5 - 68,5 mm)

3 Ergebnisse

In Tabelle 3-1 sind die unterschiedlichen Verluste für einen maximalen Effektivstrom von I = 460 A von drei verschiedenen Kabelquerschnitten angegeben. Als Ergebnis sind die stationären Werte der Gesamtverluste W_{tot} und die Temperatur des Leiters T_c angegeben.

Tabelle 3-1 - Verluste der berechneten Kabel

	300 mm^2	400 mm^2	500 mm^2
Nennstrom in einem Leiter I (r.m.s)	460 A	460 A	460A
Kabel-Leitungsverluste W_s	42,90 W/m	33,60 W/m	26,71 W/m
Schicht- und Näherungsverluste $W_{s,A}$	15,22 W/m	16,40 W/m	15,85 W/m
Dielektrische Verluste W_d (nicht berücksichtigt)	0,38 W/m	0,38 W/m	0,38 W/m
Gesamtverluste W_{tot}	58,13 W/m	50,00 W/m	42,56 W/m
Temperatur des Leiters T_c	42,27 °C	35,56 °C	30,23 °C

Tabelle 3-2 zeigt die Temperatur am 2-K-Kriteriumspunkt für die drei untersuchten Kabel. Alle drei Querschnitte liegen unter den Maximalwerten von 2 K.

Tabelle 3-2 - Verluste der berechneten Kabel

	300 mm$_2$	400 mm$_2$	500 mm$_2$
Strom in einem Leiter I (r.m.s)	460 A	460 A	460A
Gesamtverluste (W$_{tot}$)	58,13 W/m	50,00 W/m	42,56 W/m
$\Delta\theta_{2KP}$	11,21 K	11,02 K	1,02 K

4 Fazit

Das 2-K-Kriterium in 300 mm unterhalb des Meeresbodens wird mit 1,40 K (300 mm$_2$) , 1,21 K (400 mm$_2$) und 1,02 K (500 mm$_2$) für alle Kabelquerschnitte erfüllt. Die Berechnung ist stark abhängig von den Randbedingungen wie der Verlegetiefe des Kabels, dem spezifischen Wärmewiderstand des Meeresbodens und dem maximalen Laststrom. Die Ergebnisse sind nur für die angegebenen Parameter gültig. Die Berechnung wird mit einem konservativen stationären Verfahren durchgeführt.

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