Danish Offshore Wind 2030 - Kattegat – Grenå Syd - Trige
Location 4A – Landfall, Katholm.
Site Investigations for Horizontal Directional Drilling (HDD)

Geo project no. 208116
Report 51, 2024-12-18

Summary

The electrical infrastructure in Denmark is expanding significantly, which includes connecting underground cables from new wind farms in the North Sea and Inner waters in Denmark to the major transformer stations. Due to cables crossing infrastructure, topographic challenges, protected areas, streams etc. the crossings are planned partly as Horizontal Directional Drilling (HDD).

This particular report concerns cable route 4, from Grenå Syd to Trige at the landfall, Katholm, location 4A.

The field works comprises of one geotechnical borehole with in situ strength testing, soil sampling and groundwater level monitoring, CPTu and a geophysical survey using ERT. Furthermore, geological description and laboratory testing is carried out – including determination of thermal conductivity.

According to Energinet the plan is to carry bout HDD at the beach in the vicinity of the breaking point from the beach to the dunes, and will be drilled towards the sea at 10 - 15 m b.g.l., untill the end of the offshore part of the cable is reached at sea.

In this depth, the HDD will mainly penetrate glacial deposits of clay till with risk of layers of, meltwater sand and meltwater silt with no content of mica. Cobbles end boulders must be expected to be found locally.

As the geology and geotechnical parameters is based on 1 borehole only and extrapolated 3.5 km from the borehole, the likelihood of similar ground conditions is very small.

Geo project no. 208116
Report 51, 2024-12-18
Client ref.: Danish Offshore Wind 2030 -Kattegat – Grenå Syd - Trige

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1 Project

The electrical infrastructure in Denmark is expanding significantly, which includes connecting underground cables from new wind farms in the North Sea and Inner waters in Denmark to the major transformer stations. Due to cables crossing infrastructure, topographic challenges, protected areas, streams etc. the crossings are planned partly as Horizontal Directional Drilling (HDD).

The project contains geotechnical and geophysical investigations for three cable routes from the North Sea (1, 2 and 3), one cable route from Kattegat II (4) and one cable route from Kriegers Flak II (5) as show in Figure 51.1.

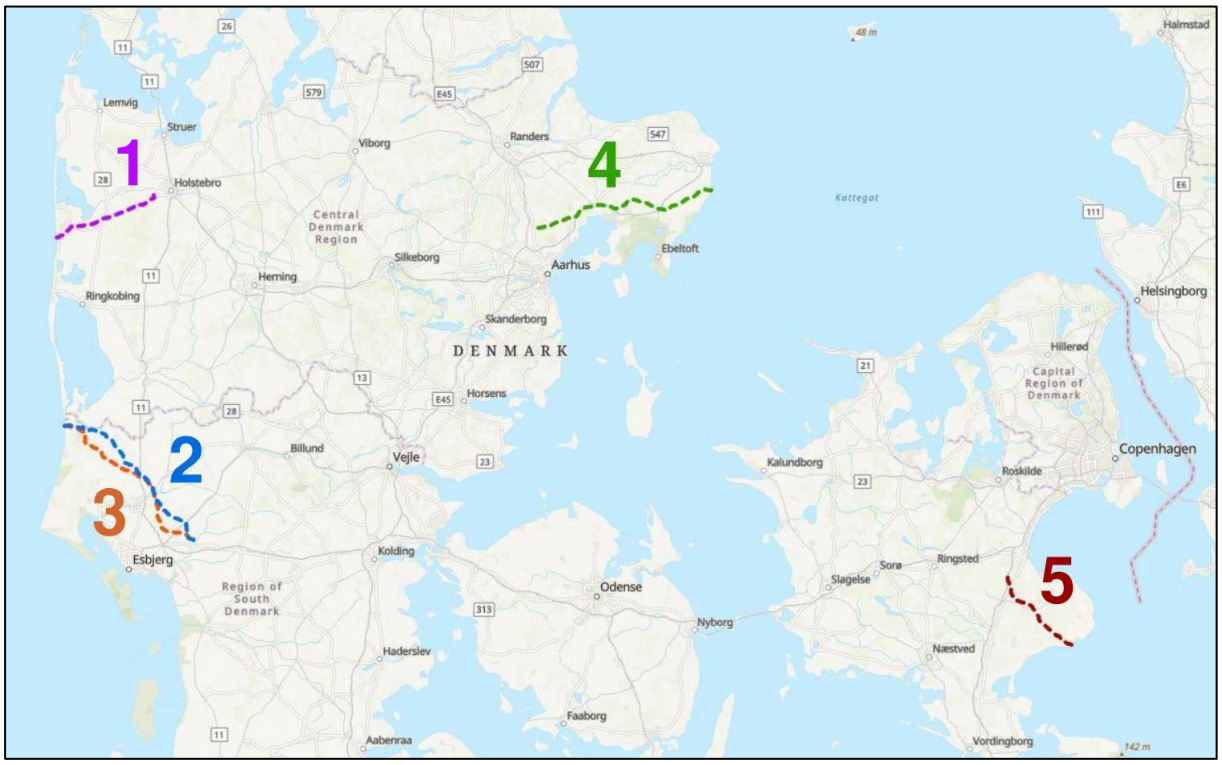


Figure 51.1: Overview map of the five cable routes planned in this project.

This report concerns the cable route from Grenå Syd to Trige (cable route 4) at location 4A as illustrated in Figure 51.2 (and in the overview map cf. enclosure 51.1.1), at landfall Katholm using HDD. Energinet has informed Geo, that the HDD will start at the beach in the vicinity of the breaking point from the beach dunes, and will be drilled towards the sea at 10 - 15 m b.g.l. untill the end of the offshore part of the cable is reached at sea.

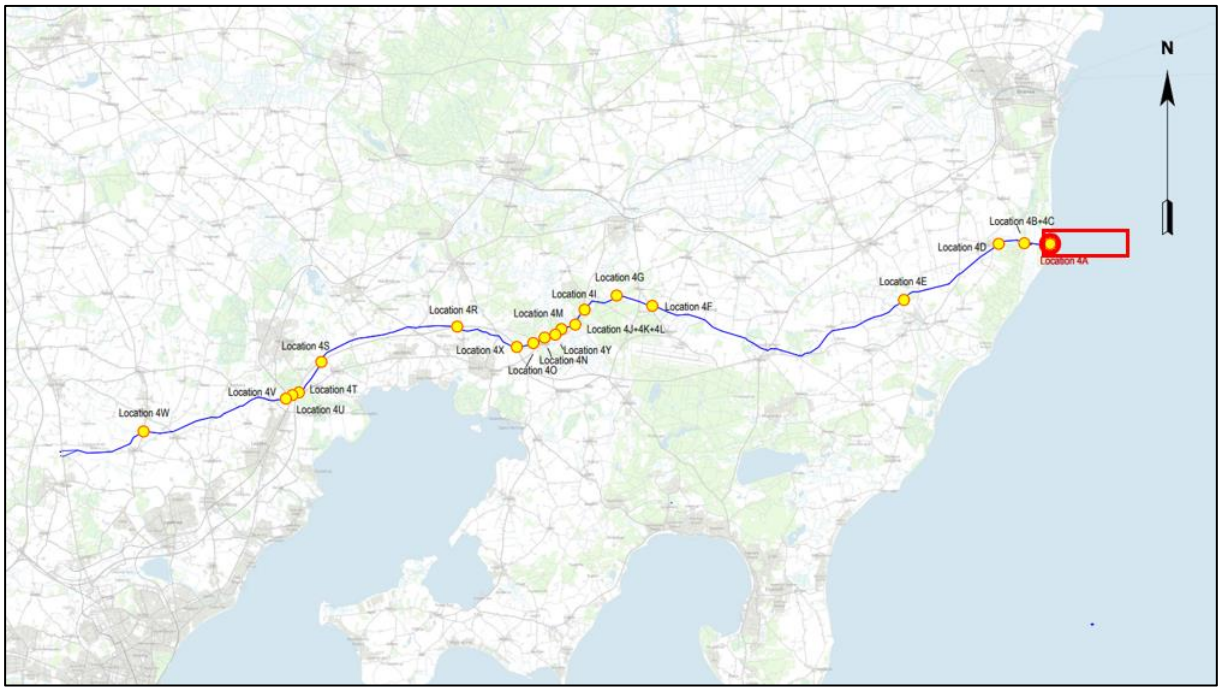


Figure 51.2: Overview map of cable route 4. Location 4A marked with red dot and box.

Geo has been requested to investigate the soil and hydrological conditions prior to execution of the HDD at the landfall, which start at the vicinity to borehole 4A.01. The HDD will terminate at level -10 m approximately 3.5 km from the coastline.

2 Investigations

The investigation contains geotechnical field and laboratory works (carried out by Geo/Geoboringer) and geophysic works (carried out by WSP).

As the geology and geotechnical parameters is based on 1 borehole only and extrapolated 3.5 km from the borehole, the likelihood of similar ground conditions is very small. Therefore, the geology and geotechnical parameters has to be used with great precaution.

2.1 Geophysical investigations

The geophysical survey is performed using the ERT (Electrical Resistivity Tomography) method. ERT determines the variation of the electrical resistivity in the subsurface by transmitting electrical current between two steel electrodes (current electrodes) while simultaneously measuring the voltage difference between two other steel electrodes (potential electrodes).

The instrument used for the ERT survey is the ABEM Terrameter LS 2 (by Guideline Geo AB) and electrode cables with 21 electrode take outs per cable. Along the cable, take outs are positioned for each 2.5 m and at each take out, ground contact is established by a stainless-steel electrode pressed into the ground.

During the data collection process, the electrodes are set up along a profile line with equal distances between the electrodes. Measurements are made in a long range of different electrode combinations (configurations), and the data collection is automatically controlled by the instrument. Through this process, data

containing information about electrical resistivity at different depths along the entire profile is measured in one integrated process.

Lateral resolution along the profile depends on the smallest distance between electrodes, while the investigation depth depends primarily on the largest distance between two electrodes in one measurement.

The resistivity measurements are carried out by a protocol (software setup) assigning electrodes in a large variety of configurations, which secures a dense data coverage with more than 800 measurements for each 50 m profile.

Note, that the depth of investigation is reduced at the ends of the profile and the largest penetration depth appears in the central part of the profile.

2.2 Geotechnical investigations

At the location, one CPTu and one geotechnical borehole have been executed. The target depths of the investigation point has been reached. The CPTu's have been executed approximately 2 m from the corresponding borehole (along or in the opposite direction from the planned HDD line). The terrain level and coordinates of the investigation point has been measured using GPS in system UTM32N/ETRS89 and with DVR90 as vertical reference. The location of the point is shown on the site plan cf. enclosure 51.1.2.

From terrain and to 18,5 m b.g.l. the CPTu has been executed by Geoboringer from a CPT-rig with maximum thrust capacity of 10 tons. During testing a 15 cm^2 piezoelectrical cone is pushed into the ground with a constant speed while measuring the tip resistance (q_c), sleeve friction (f_s) and pore pressure just behind the tip of the cone (u_2).

Between 21 m b.g.l. and 29.2 m b.g.l. the CPTu is carried out at CPT push from the drilling rig.

The borehole has been executed using 6" rotary shell and auger in clay and percussion drilling in sand from a hydraulic drill rig. In the borehole strata are registered, samples taken and in situ tests carried out as required by Energinet.

The sampling at this location consists of:

- Small disturbed samples for geological description and laboratory testing
-

The in situ tests at this location consists of:

- Field vane test[1]

The borehole has been completed with installation of Ø25 mm (diameter) standpipes made of PVC. The filter screening is carried out during simultaneous withdrawal of the casing. To ensure a tight seal between water

[1] Danish Geotechnical Society, dgf-Bulletin 14, 1999, "Referenceblad for Vingeforsøg", version 3

aquifers the annulus above/below the screened pipe is sealed with expanding bentonite pellets in cohesive soils. Level of the screened pipe is chosen in accordance with the soil conditions and proposed depth of the planned HDD. The screened pipe is presented on the borehole profile.

The groundwater level is registered in the standpipe after completing the boreholes and again minimum 5 days hereafter. The results are shown on the borehole profile cf. enclosure 51.2.1.

According to the Danish legislation "Brøndborebekendtgørelse"[2] the boreholes are decommissioned/sealed within a few weeks after the drilling was carried out and the groundwater level is registered. The decommission/sealing is carried out by inserting expanding bentonite bars in the standpipe and thereafter removing the top standpipe approximately 1 m b.g.l.

2.3 Laboratory tests

The geological description of all samples have been carried out in accordance to the Danish dgf-Bulletin 1, 2021 (Danish Geotechnical Society) and standard classification tests required by Energinet have been performed. The standards used for classification tests in Geos laboratory are listed in Table 51.1.

Table 51.1: Standards for classification tests.

Classification test	Standard
Natural water content	DS/EN ISO 17892-1:2014
Grain size distribution	DS/EN ISO 17892-4:2016
Atterberg limits	DS/CEN ISO 17892-12:2018
Thermal conductivity	ASTM D5334-14

Thermal conductivity has been determined using equipment MP2 from Thermtest on selected intact and reconstituted samples. The thermal conductivity tests on reconstituted frictional soils have been carried out by compacting the soil into a mould, where after the soil in the mould is exposed to vibrations and saturated as close to 100 % saturation as possible.

3 Results

3.1 Geophysical results

3.1.1 ERT software and interpretation workflow

Following the data collection process, data is imported and processed in Aarhus Workbench (version 6.9.0.0). Data are inspected and data points, either directly faulty or heavily influenced by noise, are removed. Subsequently, the complete profile is inverted by 2D inversion in two different parameter settings and layer models.

In Aarhus Workbench, the inverted resistivity models are visualised along with geological information from boreholes in the vicinity of the profile. Based on this comparison, a geological interpretation can be performed and visualized along with a geophysical model. Figure 51.3 summarizes this workflow.

[2] BEK nr. 1260 af 28/10/2013 - Bekendtgørelse om udførelse og sløjfning af boringer og brønde på land.

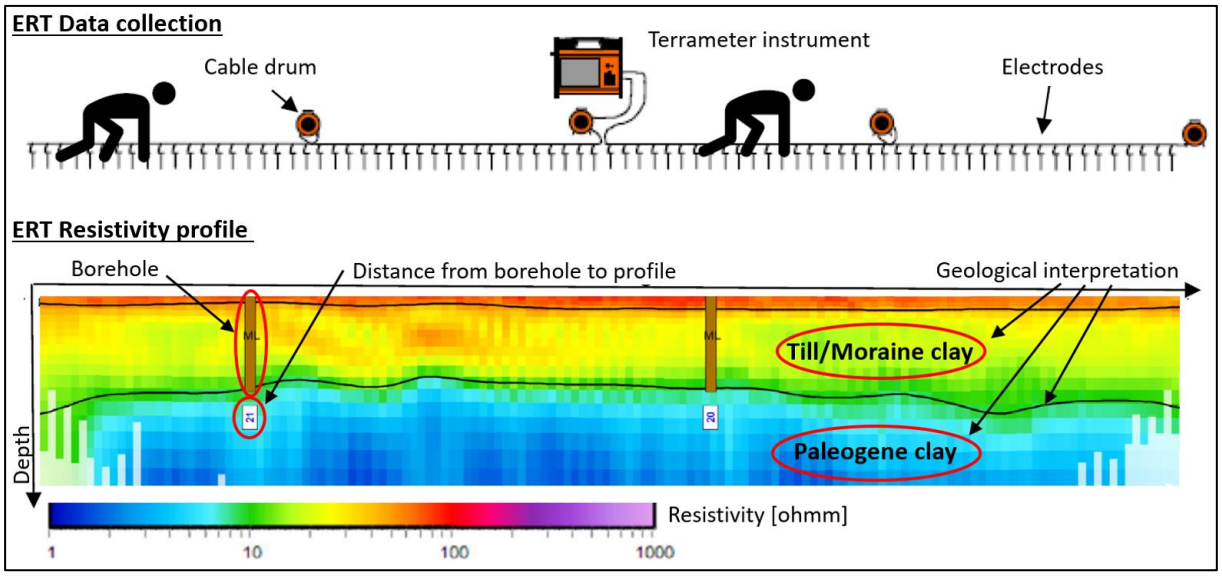


Figure 51.3: An illustration of the ERT workflow from data collection during fieldwork to the resistivity section and finally the geological interpretation.

Enclosure 51.1.3 contains a resistivity section based on inversions of the ERT measurements. The section is based on *smooth inversion*, which is characterized by a smooth variation in the resistivity values. The model is defined by 20-40 layers with fixed layer boundaries and the resistivity values are determined by the inversion process.

Geological layers are illustrated as black and dotted lines on the longitude profile as a cautious interpretation from the ERT, borehole and CPT data. The top soil extent is not marked as the geophysical method is not sufficient to resolve shallow occurrences.

3.1.2 Geological interpretation of resistivity values

Electrical resistivity tomography determines the electrical resistivity properties of the subsoil. The magnitude of the resistivity depends on various geological parameters such as the type of the sediment or rock (clay, sand, limestone, etc.), water saturation and the presence of saline ions.

Generally, the geophysical models can be interpreted to geology according to Figure 51.4.

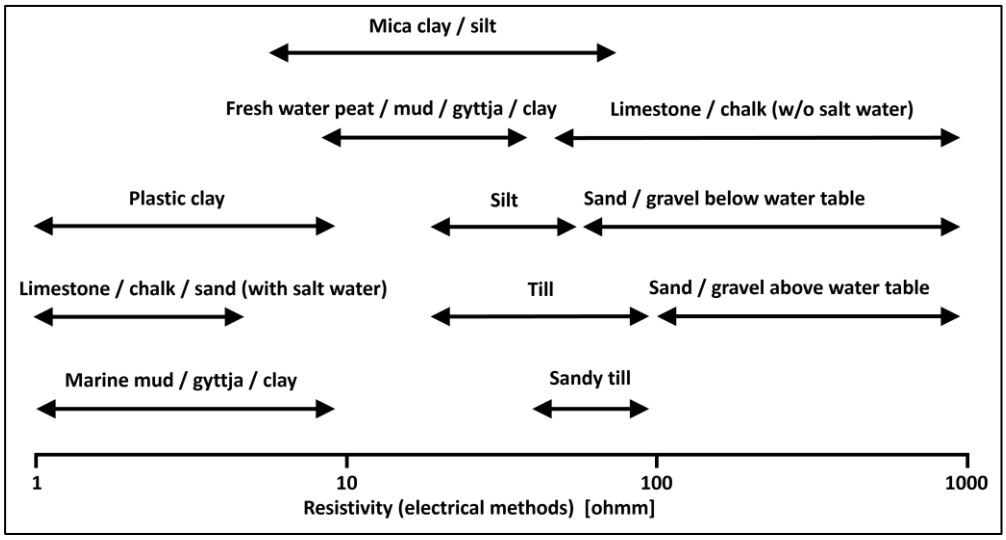


Figure 51.4: Geological interpretations according to resistivity values.

3.1.3 ERT profile 4A-1

ERT profile 4A-1 (see figure 51.5 below) has a length of 207 m. Data were collected with an electrode spacing of 2.5 m. The inverted profile has a data residual of 1.2. A residual close to 1 indicates that the measured data are in good accordance with the determined 2D model and subsurface structures are expected to be well resolved.

During data collection of cable route 4 the weather varied between dry and wet periods, however there was generally good electrode contact while measuring.

In profile 4A-1 generally high resistivities can be seen, with very high resistivities (300-1000+ ohmm) occurring near the surface, especially at distances of 0 to 60 m and 130 to 200 m. Relatively low resistivities (10-50 ohmm) prevail in the interval between elevations of -10 to 6 m at distances of 30 to 200 m. Low resistivities (about 50 ohmm) are also seen in the central and very deepest part of the profile. Throughout the rest of the profile, resistivities of about 100-200 ohmm prevail.

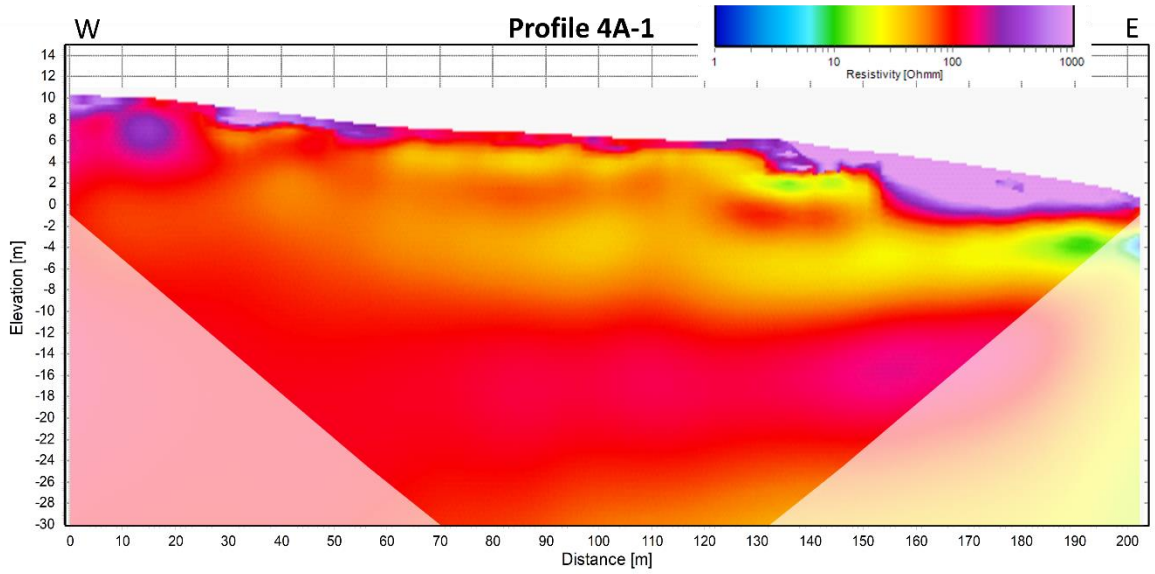


Figure 51.5: ERT Profile 4A-1.

3.2 Geological description of the location

Location 4A is described and interpreted based on the project borehole 4A.01 and CPT 4A.01CPT. Further knowledge is added from the online soil type map and geomorphological maps from GEUS, ref /4/ and /5/, and literature covering the geological history of the area, ref /7/ and /8/. Knowledge of the deeper geological layers is added from nearby boreholes and the FOHM model (2023), ref /9/ and /10/.

The interpretation of the geological conditions is shown in the conceptual geological section along HDD 4A in Figure 51.6.

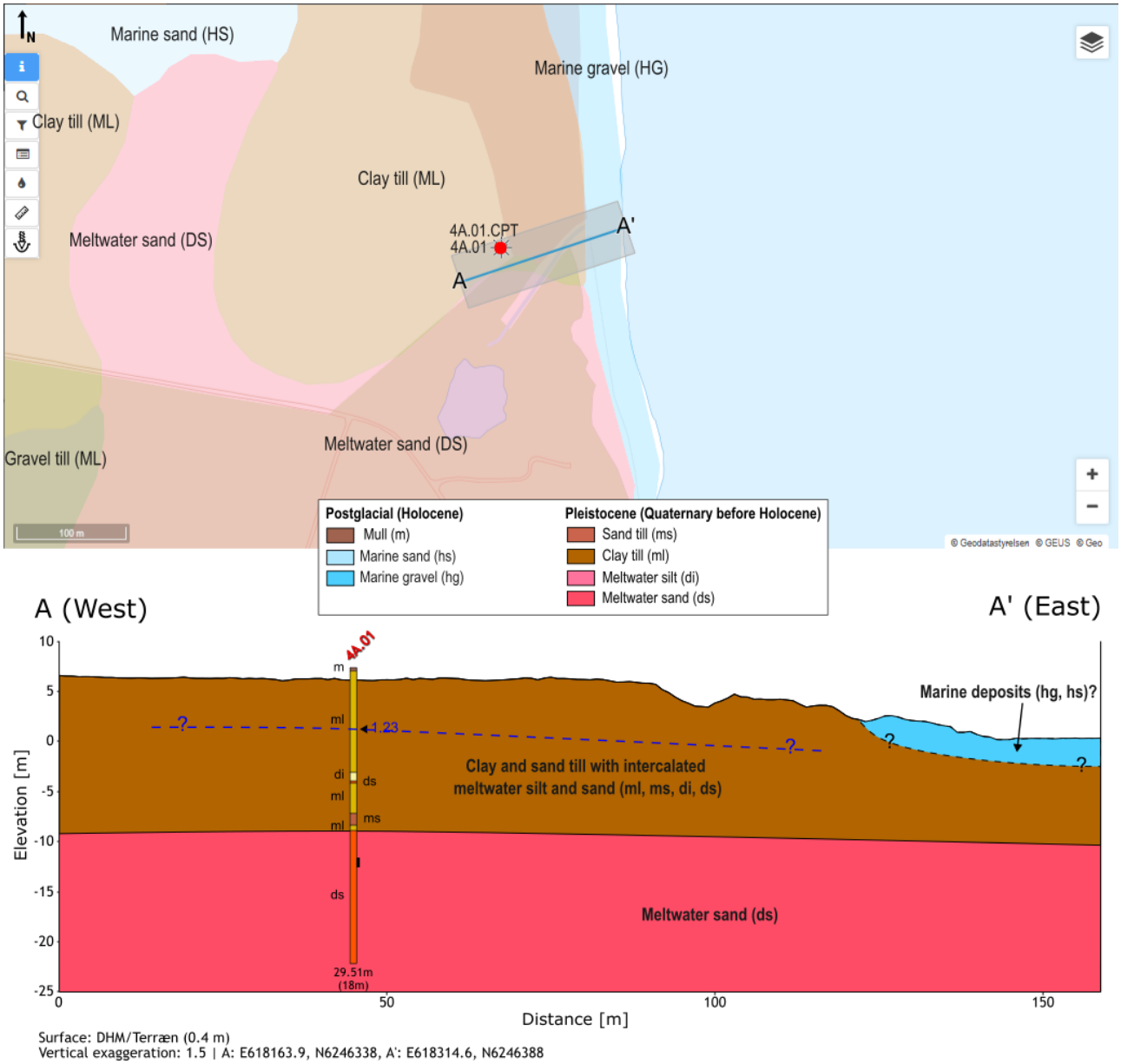


Figure 51.6: The upper panel holds a map view with the location of borehole 4A.01 and CPT 4A.01CPT marked with a red dot. The map view shows the expected soil type one m below terrain, ref /4/, around the planned HDD location. The lower panel shows the conceptual geological section along HDD 4A including borehole logs and interpreted geological units indicated by GEUS symbols. The measured level of groundwater is depicted in the section and represents the potential of the aquifer with filter level marked by a black box attached to the borehole log.

Geological description

In borehole 4A.01 the upper 0.4 m consists of organic topsoil of sand, which superposes clay till interbedded by thick beds of meltwater silt/sand and sand till to around 16.3 m b.g.l. Clay till overlies glacial meltwater sand to the bottom of the borehole at 29.5 m b.g.l.

Detailed borehole information, sample descriptions and other borehole specific data are shown on the borehole log, Enclosure 51.2.1.

Geological interpretation
The HDD is situated on the eastern part of Djursland and is oriented WSW-ENE towards the coast. The terrain level rises from about 0 m DVR90 at the coast to around +6 m DVR90 along the western part of the HDD, where it extends into a till plain.

Postglacial, marine deposits of sand and gravel are to be expected along the coast. These sediments were deposited during the Littorina Transgression, and the coarser sediments represent deposition during storm events.

The glacial till where deposited during the Weichselian glaciation, when ice sheets advanced across the area. The margin of the Young Baltic ice sheet was located close to the HDD. The underlying meltwater sand was deposited during a deglaciation event, and meltwater has probably eroded down into the bedrock. According to previous geological models, and nearby boreholes, the pre-quaternary surface consists of Danien Bryozoan Limestone and is expected below the meltwater sand from around level -11 m a -20 m DVR90. However, limestone has not been recorded in borehole 4A.01, which reaches down to level -22 m DVR90.

3.3 Geotechnical results
The geotechnical investigation carried out for this location is described in section 2.2 and the geological results are described in section 3.2.

No mica is found in the deposits.

3.3.1 Hydrogeology
The groundwater levels have been measured in the standpipe immediately after completing the boreholes and again minimum 5 days hereafter. The groundwater level readings are illustrated on the borehole profiles and furthermore listed in Table 51.2.

Table 51.2: Ground water readings/measurements.

Borehole no.	Ground level (m DVR90)	Date	Depth (m b.g.l.)	Level (m DVR90)	Bottom of filter (m b.g.l.)
4A.01	+7.4	2024-09-05 2024-09-17	6.1 10.3	+1.3 -2.9	20.0

3.3.2 Laboratory tests
Results of the laboratory classification tests are presented either on the borehole profile and/or in enclosure 51.4 (thermal conductivity, plasticity index, grain size distribution etc.).

The results of the thermal conductivity tests are summarized in Table 51.3.

Table 51.3: Results from the thermal conductivity tests.

Borehole no.	Sample no.	Depth (m b.g.l.)	Soil type	Thermal conductivity (W/(m°C))	Thermal resistivity (°C m/W)
4A.01	35+36+37	17-18	Sand	1.31	0.76

4 Derivation of geotechnical parameters

4.1 Strength parameters

4.1.1 Cone penetration test (CPT)

No site specific q_c – φ' correlations are established for derivation of the effective strength parameters for CPTs, which is why international literature and Geos general experience with similar soil has been guiding the recommendations in the following paragraph below.

For sand layers Geo suggest the frictional angle, φ', estimated from the CPT cone resistance, q_c, by the procedure in NGI publication no. 156, cf. ref. /1/.

$$\frac{q_c}{\sigma'_{v0}} = tan^2\left(\frac{\pi}{4}+\frac{\varphi'}{2}\right)exp(\left(\frac{\pi}{3}+4\varphi'\right)tan(\varphi'))$$

where cone resistance q_c is in kPa
σ'_{v0} is effective vertical stress in kPa
frictional angle φ' is in rad (for very silty sand a reduction of 3° should be made)

From the CPT cone resistance, q_c, the undrained shear strength in cohesive soils can be estimated from $c_u = q_c / N_k$, where N_k is a correction factor based on local experience. As default value $N_k = 10$ can be used in many cohesive soils, and $N_k = 10$ is used for late glacial or older clay deposits throughout this project.

4.1.2 Standard penetration test (SPT)

No SPT is carried out at this location

4.1.3 Field vane test

In cohesive soils the undrained shear strength, c_u is derived from the equation $c_u = \mu \cdot c_{fv}$ where c_{fv} is the shear strength from field vane test and μ is a correction factor based on local experience. Based on experience Geo suggest $\mu = 1.0$ in late glacial or older clay deposits.

4.2 Stiffness

4.2.1 Cone penetration test (CPT)

The oedometer stiffness, E_{oed} in sand is stress dependent and can be estimated from q_c using the following algorithm from NGI publication no. 156, cf. ref. /1/.

$$E_{oed} = M_0 \sqrt{\frac{\sigma'_v + \frac{\Delta\sigma'_v}{2}}{\sigma'_v}}$$

where: M_0 = Initial constrained modulus
σ'_v = vertical in situ stress
$\Delta\sigma'_v$ = increase in vertical stress from loading

For normally consolidated sand and silt the initial constrained modulus M_0 is suggested as:

$M_0 = 4 \cdot q_c$ for $q_c < 10$ MN/m^2
$M_0 = 2 \cdot q_c + 20$ for 10 MN/m^2 ≤ q_c ≤ 50 MN/m^2
$M_0 = 120$ for $q_c > 50$ MN/m^2

For over consolidated sand and silt (Over Consolidation Ratio, OCR > 2) the initial constrained modulus M_0 is suggested as:

$M_0 = 5 \cdot q_c$ for $q_c \leq 50$ MN/m^2
$M_0 = 250$ for $q_c > 50$ MN/m^2

As a conservative approach $E_{oed} = M_0$ can be used.

4.2.2 Undrained shear strength

For late glacial and glacial clay deposits the oedometer stiffness, E_{oed}, is estimated from experience as

$$E_{oed} = \frac{4000 \cdot c_u}{w}$$

where: c_u = undrained shear strength derived from the CPT or the field vane test in kPa
w = natural water content in %

4.3 Permeability

For uniform graded sand the permeability, k, is suggested estimated by:

$$k = 0.01 \cdot d_{10}^2$$

where d_{10} is the grain size at 10 % by weight.

5 Evaluation of geotechnical parameters

Recommendations for geotechnical parameters are given in the following paragraphs based on the specific soil type, field tests (CPT and/or field vane test), laboratory tests and Geos general experience with similar soil types.

The values in Table 51.4 are representative values, and both lower and higher values (peak values) must be expected to appear in the actual investigation points as well as in the deposits between the investigation points. Ranges of soil parameters are given and relevant parameters must be selected depending on the situation considered.

The listed geotechnical parameters are:

- q_c Tip resistance (from CPT)
- γ: Weight density above water level
- γ': Effective weight density below water level
- φ': Effective friction angle
- c': Effective cohesion
- c_u: Undrained shear strength
- k: Permeability
- E_{oed}: Oedometer stiffness

Table 51.4: Soil parameters, Location 4A.

Soil description	q_c (MPa)	γ/γ' (kN/m^3)	φ' (°)	c' (kPa)	c_u (kPa)	k (m/s)	E_{oed} (MPa)
Top soil: Sand mull	<0.5-4	18/10	25-35	0	N/A	$1{\cdot}10^{-4}$ - $1{\cdot}10^{-6}$	<1-5
Clay Till, (Gc)	1-15	21/11	30-34	10-20	125->700	$1{\cdot}10^{-7}$ - $1{\cdot}10^{-9}$	40-200
Sand Till, (Gc)	5-15	20/10	36-38	0	N/A	$1{\cdot}10^{-6}$ - $1{\cdot}10^{-8}$	25-75
Silt, (Gc)	4-13	19/10	32-36	0	N/A	$1{\cdot}10^{-6}$ - $1{\cdot}10^{-7}$	20-60
Sand, (Gc)	7-45	19-20/10	36-44	0	N/A	$1{\cdot}10^{-4}$ - $1{\cdot}10^{-5}$	30-240

6 Recommendations

According to Energinet the plan is to carry out HDD from the vicinity of borehole 4A.01 and towards the sea at 10 - 15 m b.g.l., untill the end of the offshore part of the cable is reached at sea.

In this depth, the HDD will mainly penetrate glacial deposits of clay till with risk of layers of, meltwater sand and meltwater silt with no content of mica. Cobbles end boulders must be expected to be found locally.

As the geology and geotechnical parameters is based on only 1 borehole and extrapolated 3.5 km from the borehole, the likelihood of similar ground conditions is very small.

As the location is close to the sea Geo recommend that the risk of high water level is taken into account when establishing drilling pits.

Depending on the drilling method used, minor ground settlements may develop in the vicinity of the HDD centreline as well as close to the drilling pits.

Risks and procedures for execution must be evaluated in detail when a contractor has been assigned and depths, diameter etc. of HDD decided.

Preliminary Risk assessment based on the interpreted geology and the soil conditions met in the boreholes and CPT's is attached in enclosure 51.5.

7 References

/1/ *NGI Publication #156 - Interpretation of Cone Penetrometer Data for Offshore Sands*, T. Lunne and H. P. Christoffersen , NGI, 1985

/2/ DS/EN ISO 22476-3 Geotechnical investigation and testing – Field testing – Part 3: Standard penetration test.

/3/ *In situ testing in Geomechanics*, Fernando Schnaid, 2009

/4/ *Danmarks digitale jordartskort 1:25.000*, version 7, GEUS, 2024

/5/ *Geomorphological map of Denmark 1:200.000*, version 3, GEUS, 2022

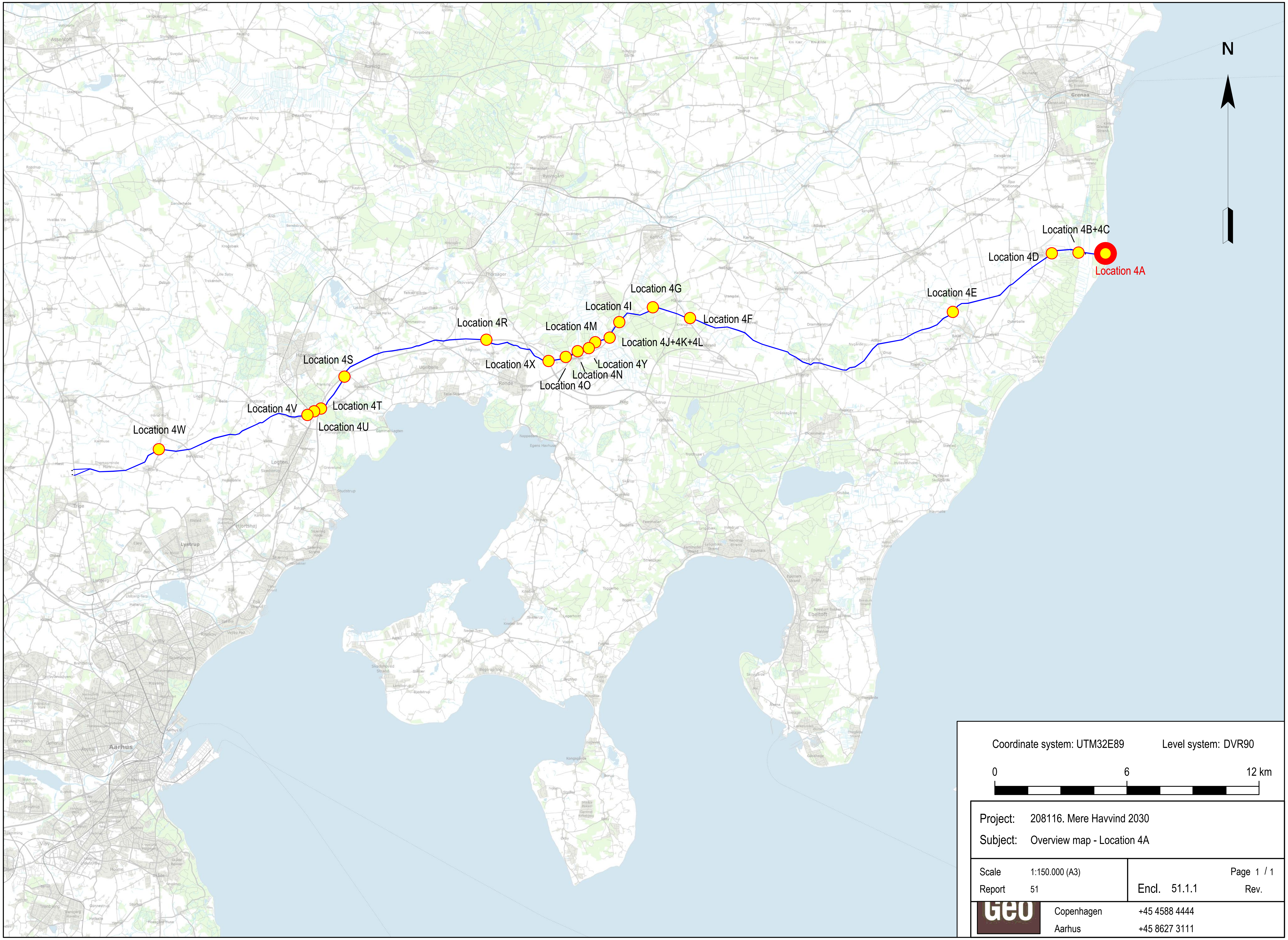
/6/ *Pre-Quaternary surface topography of Denmark 1:250.000*, GEUS, 1994

/7/ *Djurslands Geologi. Pedersen S.A.S & Petersen, K.S, GEUS 1997*

/8/ *Geologisk Set – det mellemste Jylland,* GEUS, Geografforlaget, 1. udgave, 1994

/9/ *Miocæn 3D, opdateret 2015. Den rumlige geologiske model*, Kristensen, M., Vangkilde-Pedersen, T., Skovbjerg Rasmussen, E., Dybkjær, K., Møller, I., Andersen, L. T, Danmarks og Grønlands Geologiske Undersøgelse, Rapport 2015/90, 2015

/10/ *Samling af geologiske modeller i Jylland, FOHM – Fælles offentlig hydrologisk model,* Miljøstyrelsen, Modeludtræk fra LARCOS modeldatabase, 2023



Project: 208116. Mere Havvind 2030

Subject: Overview map - Location 4A

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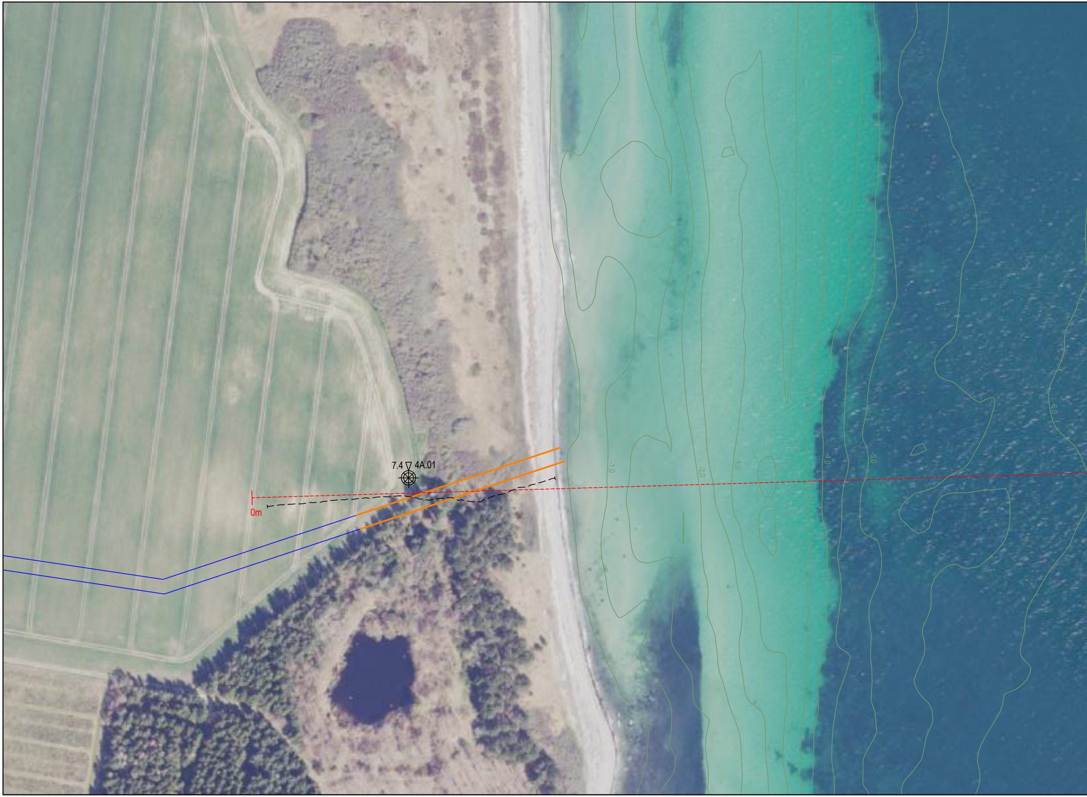
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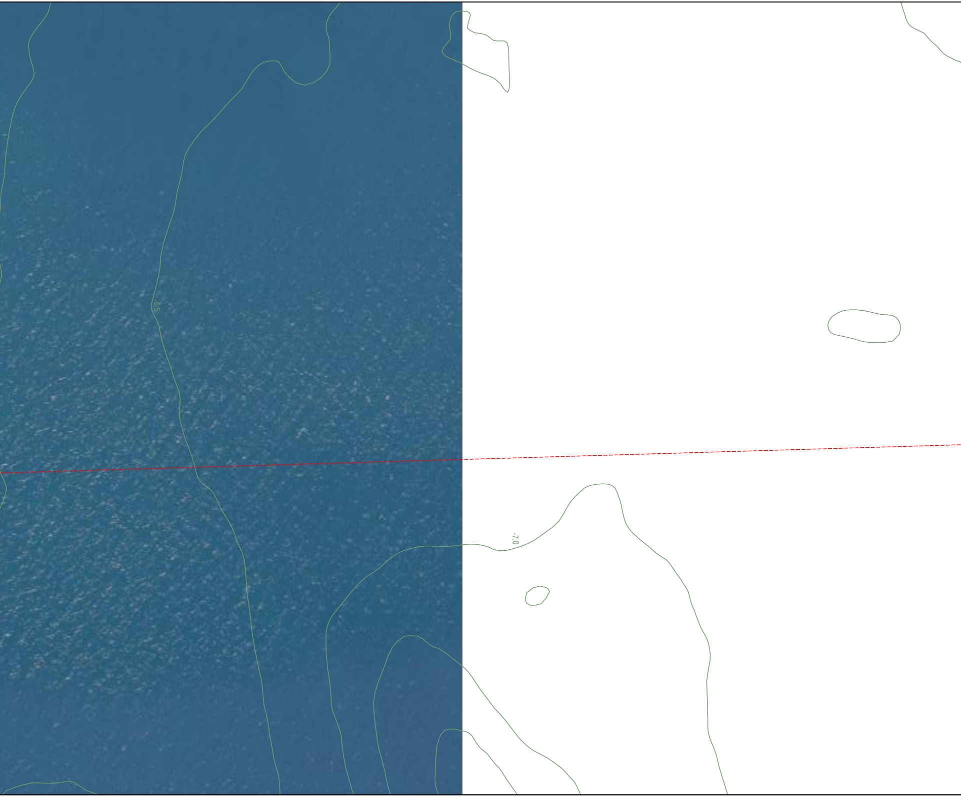

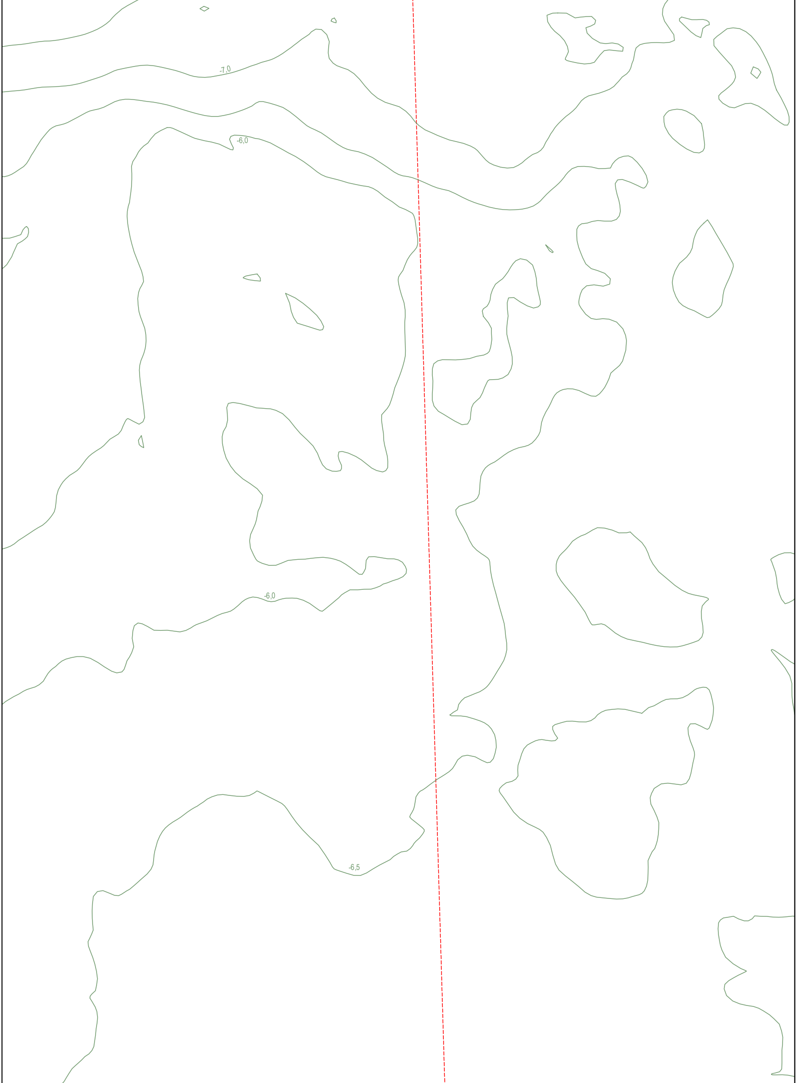

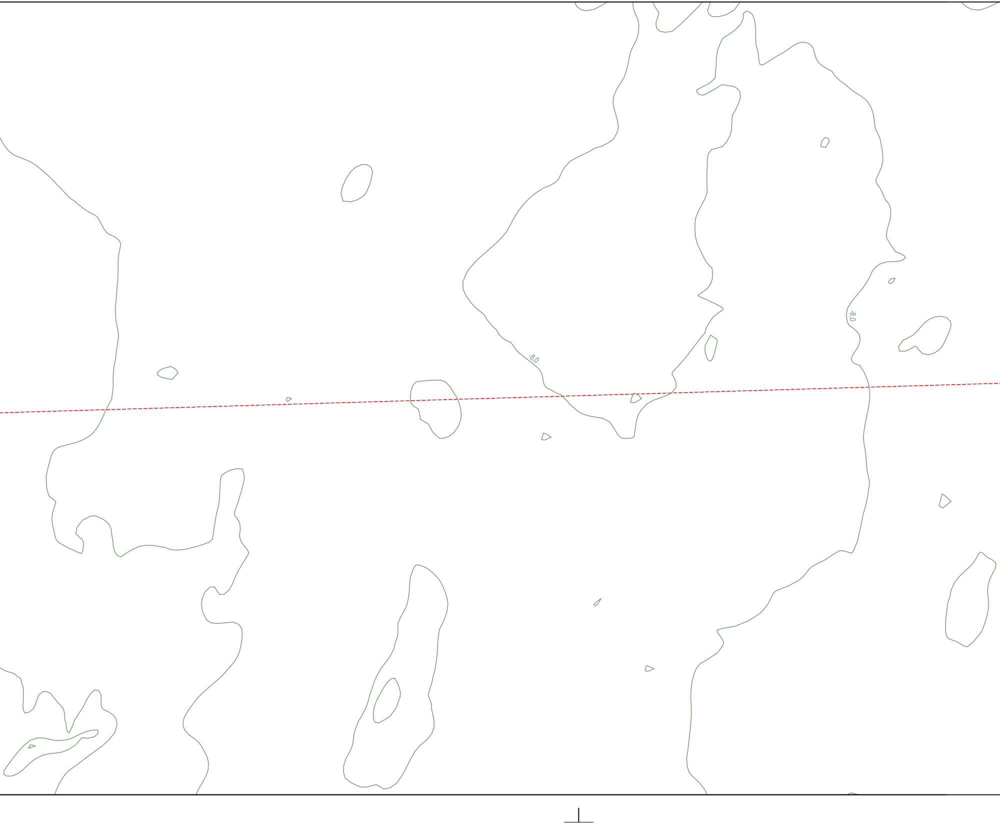

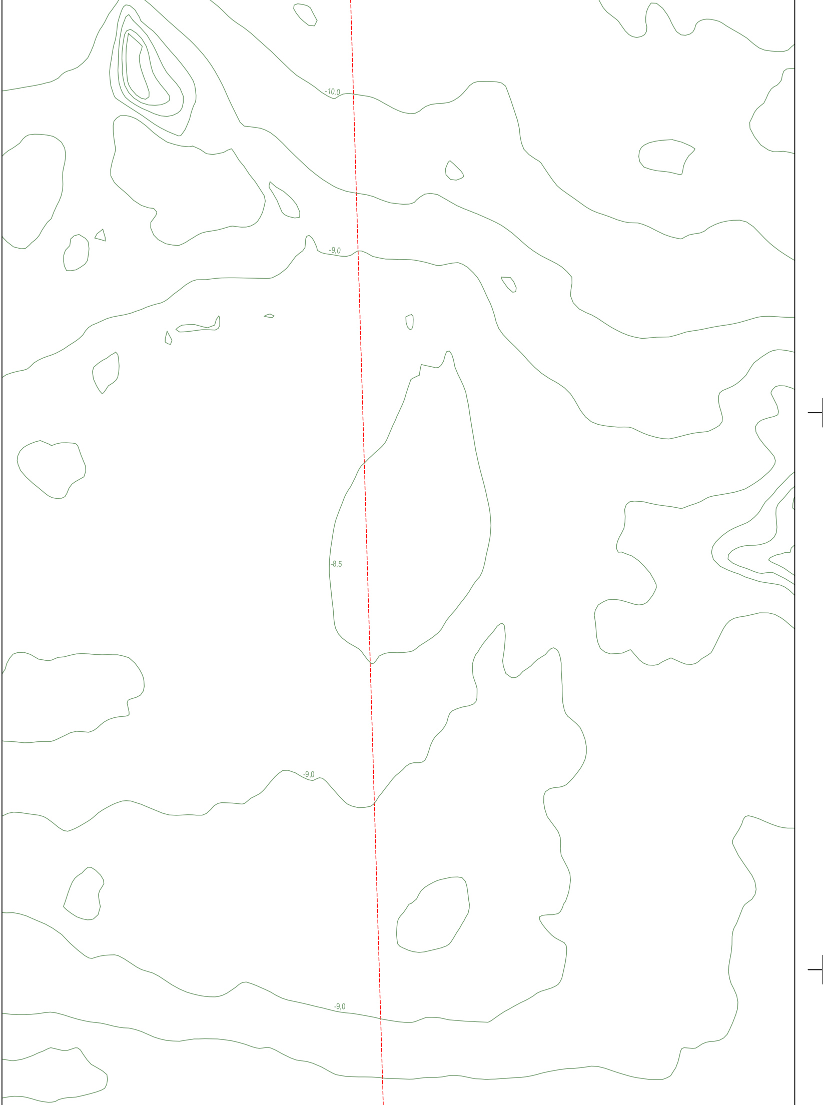
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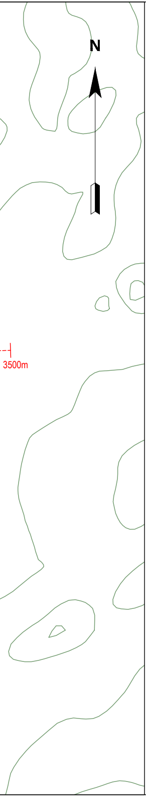
-9,0
-8,5
-9,0
-9,0



Ålsø
Stationsby
Tolstrup
Ålsø
Homå
Høbjerg
Ålsrode
Østerballe
Glatved
N

Legend:

Borehole with CPT

b a
a: Point no.
b: Terrain level

Planned cable route

Planned HDD

Location of longitudinal profile (Encl. 51.1.3)

Seabed level 0,5 m

0 80 160 m

Coordinate system: UTM32E89 Level: DVR90

Project: 208116. Mere Havvind 2030 Subject: Landfall. Katholm 4A	Scale 1:2000 Report 51	Page 1 / 1 Encl. 51.1.2 Rev.

Geo

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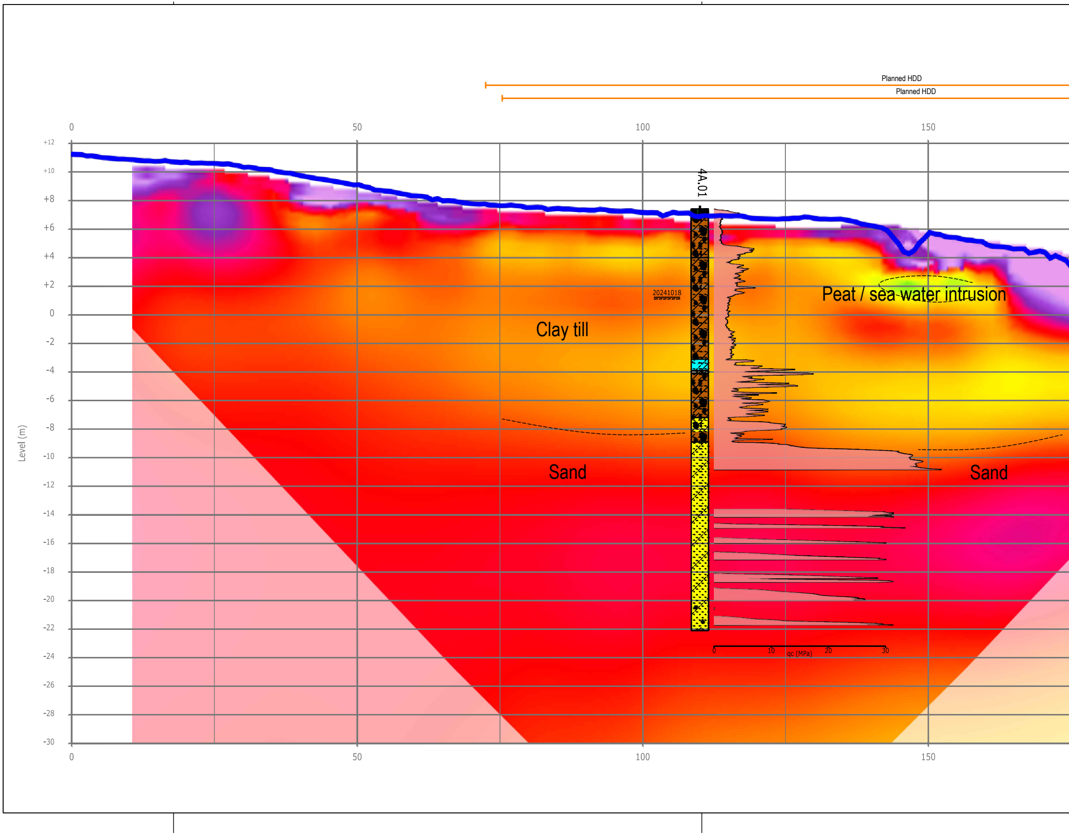
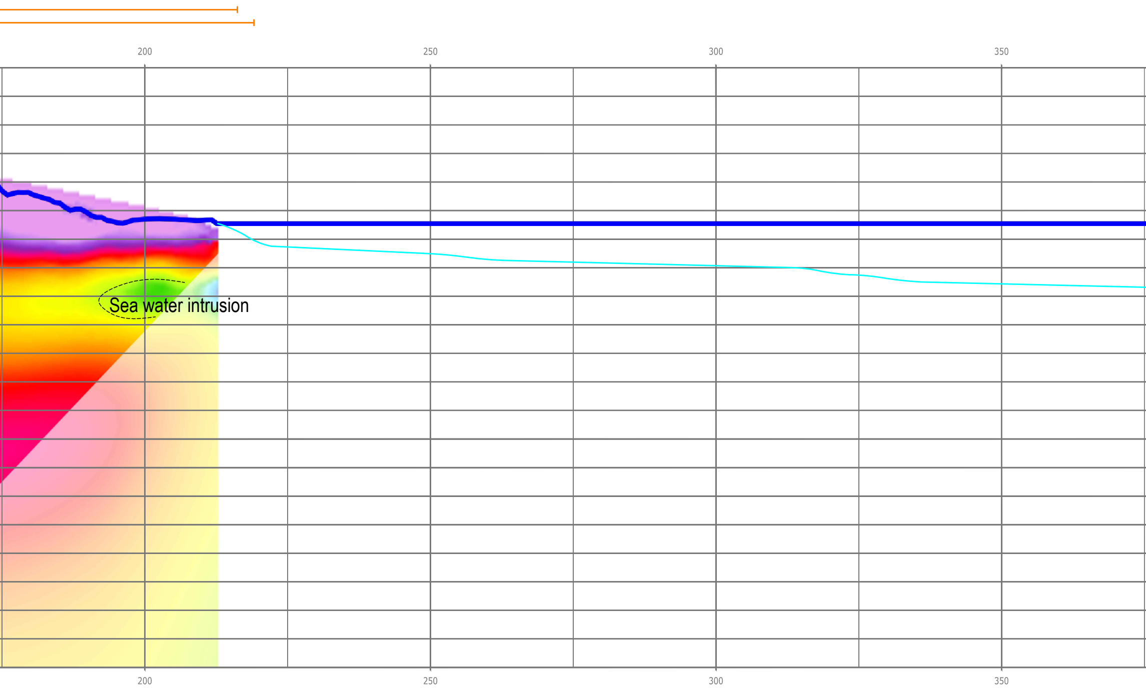
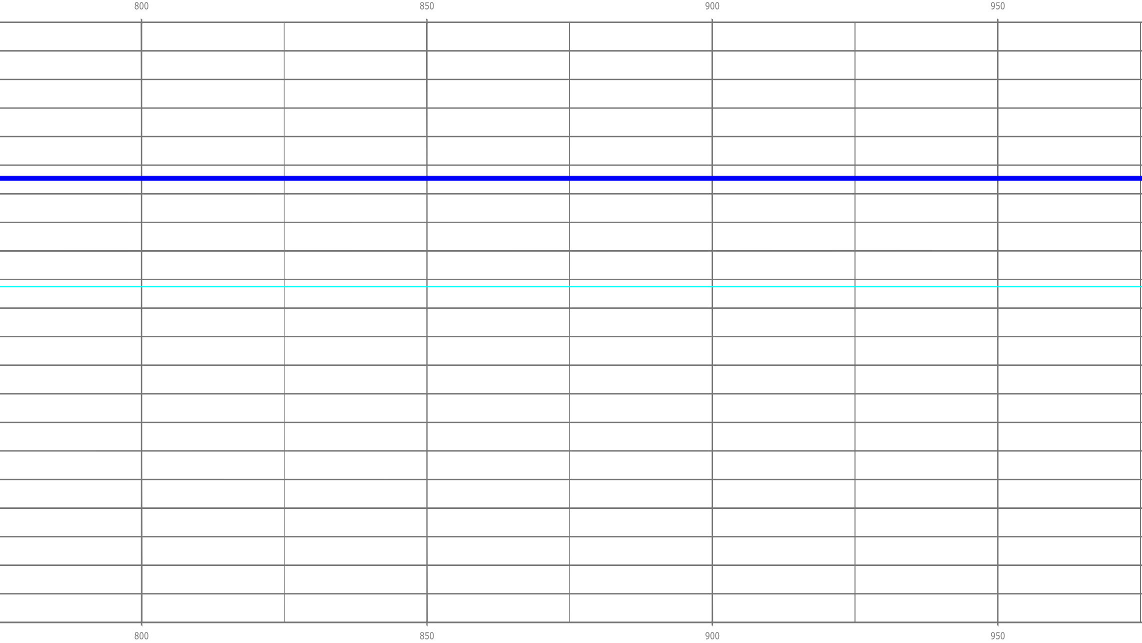
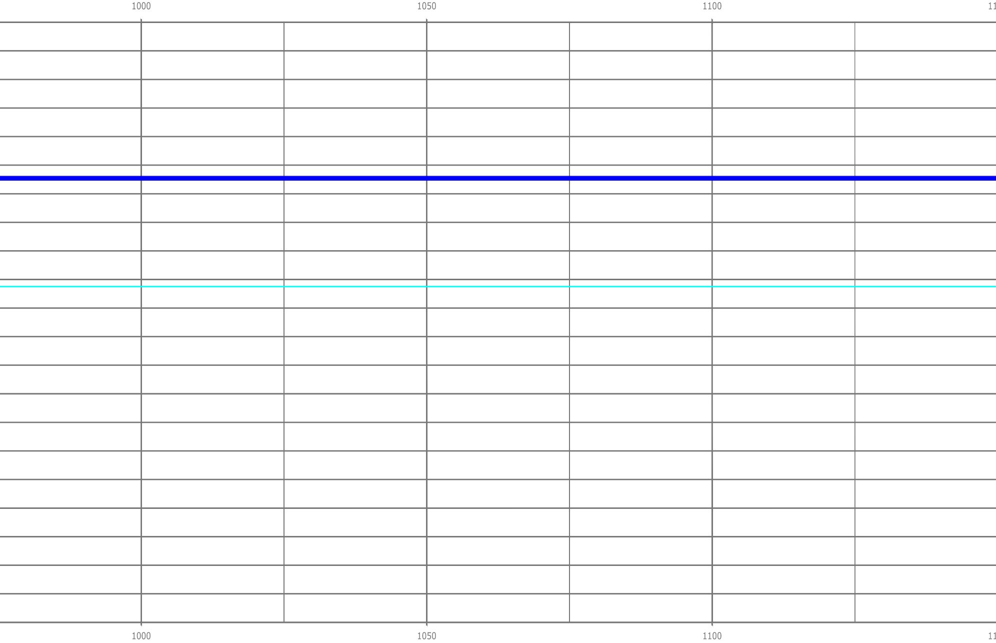
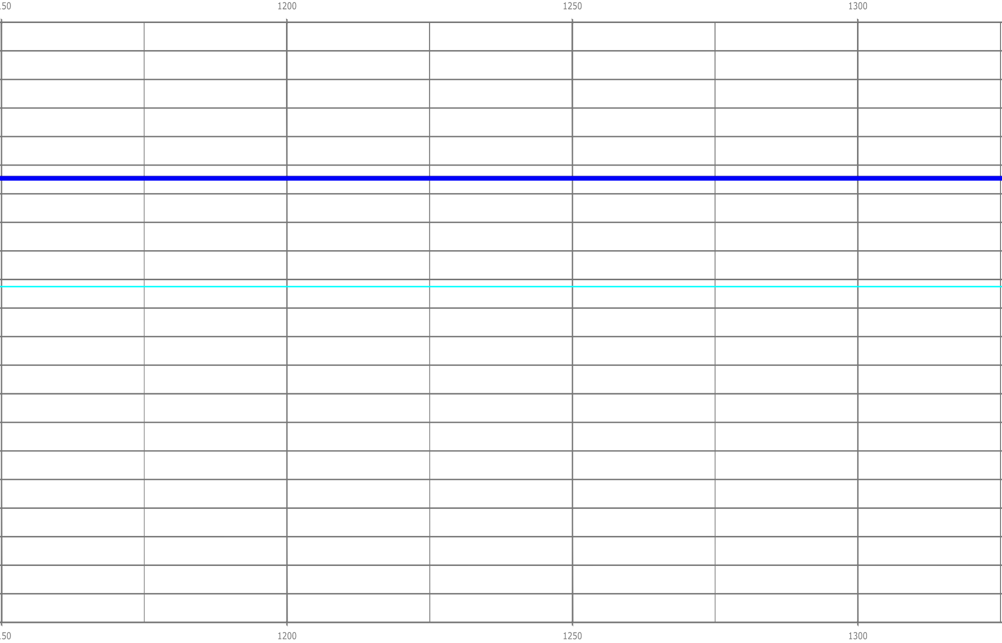

Planned HDD
Planned HDD
0
50
100
150
+12
+10
+8
+6
+4
+2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
Level (m)
4A.01
20241018
Clay till
Peat / sea water intrusion
Sand
Sand
0
10
qc (MPa)
20
30

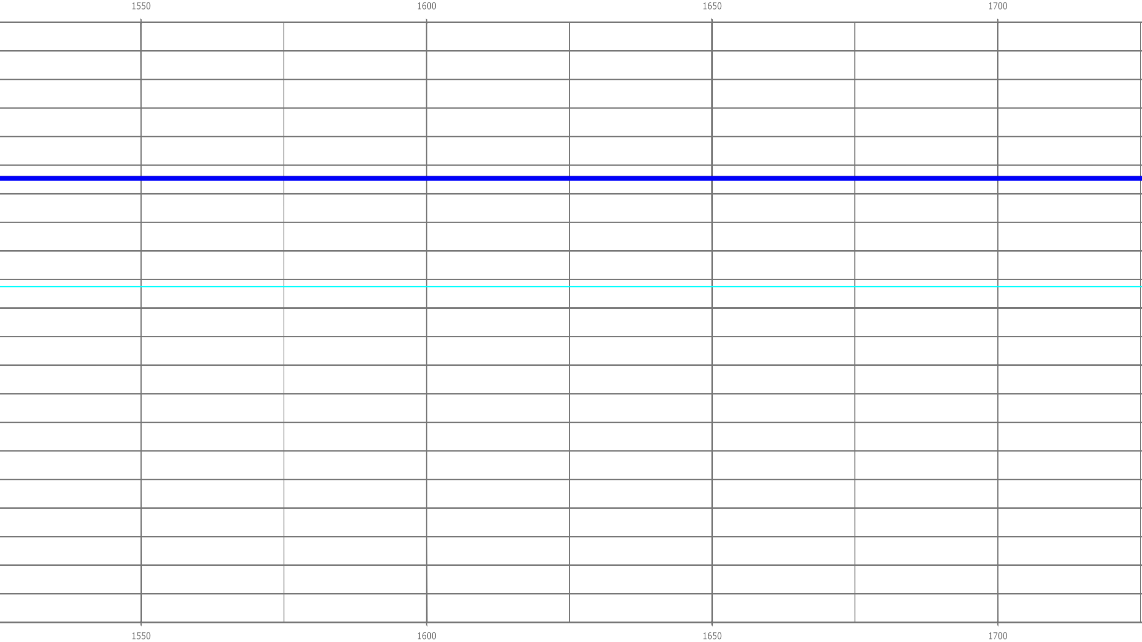
L:\projekter\208001-209000\208116_Energinet_MH2023_SGRI7_Tegninger\AutoCAD filer\208116_længdeprofiler_landfall_v0.dwg 2024-12-12 kdu 3x1

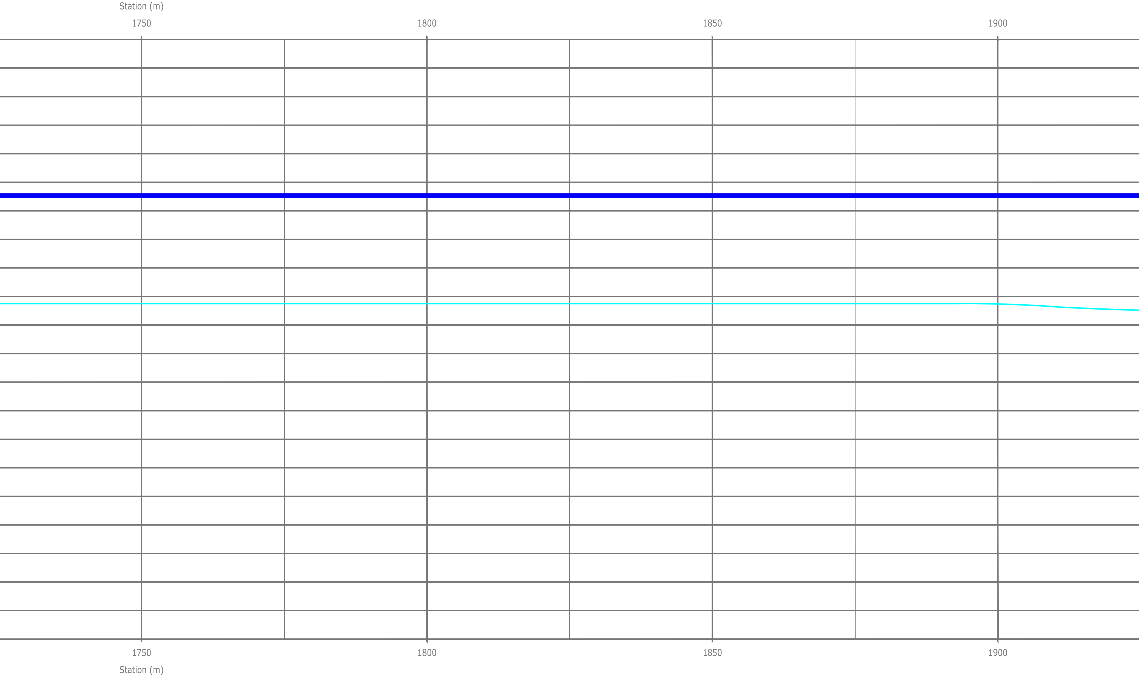


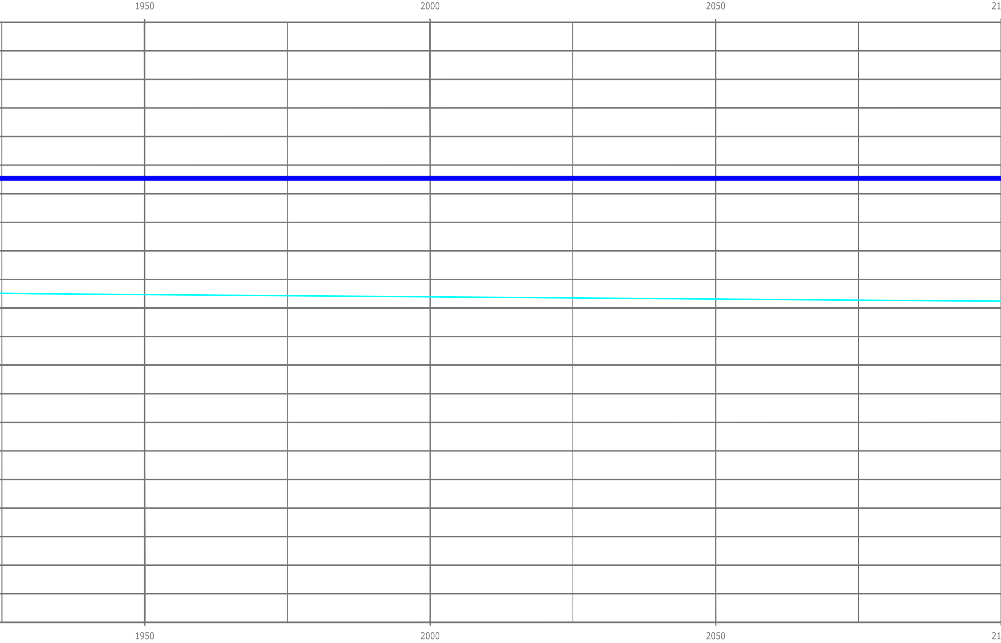


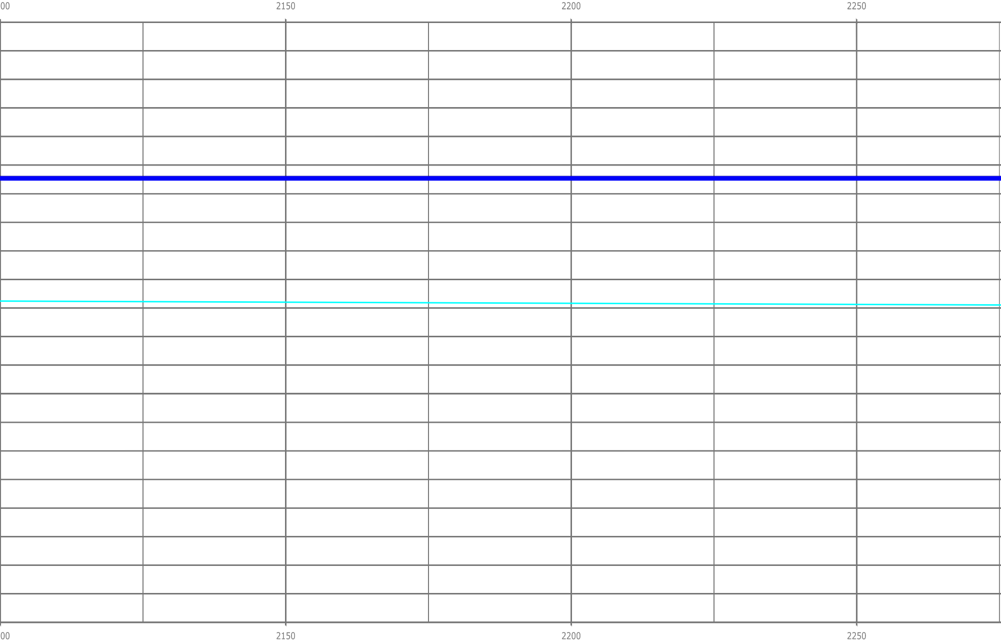


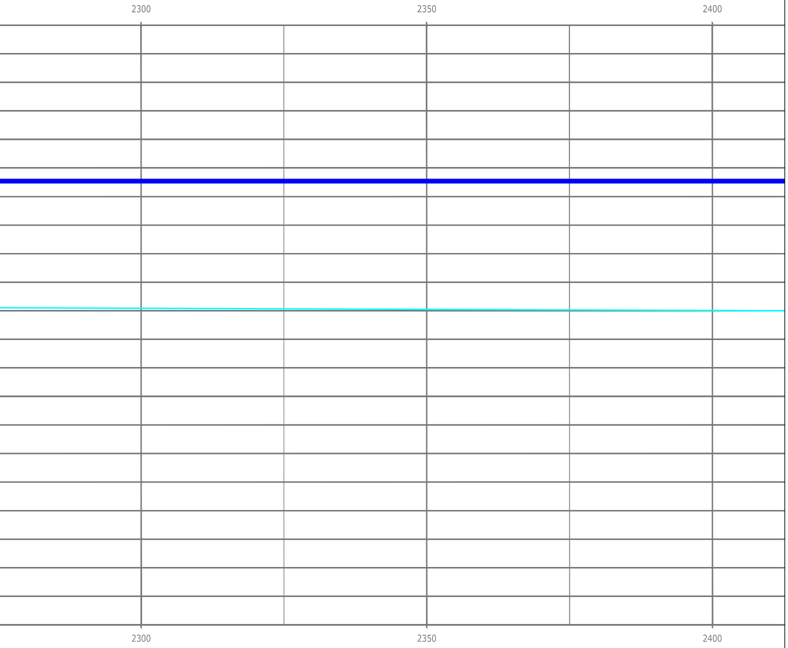


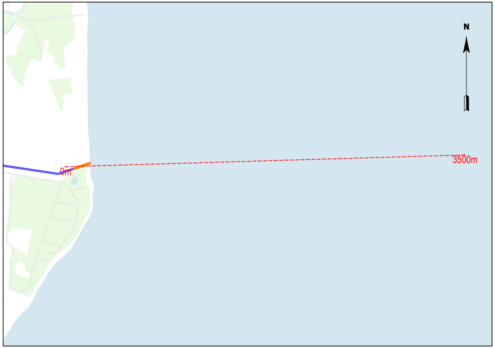






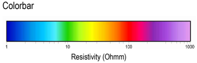






Legend:

🟩	Top soil / Fill
🟨	Sand / Gravel
🟫	Clay till
🟦	Silt
🟦	Clay
🟩	Clay/peat (postglacial)



―	Terrain (Dansk Højde Model)
―	Seabed level
▯	Borehole
▬	Cone penetration test, Tip resistance, q_c
d:XXm	Distance between ERT-line and borehole
―	Planned HDD
------	Interpretation of geological boundaries
═ ═ ═	Highest measured groundwater level

x 1:500 — 0 20 40 m

y 1:200 — 0 8 16 m

Project: 208116. Mere Havvind 2030	Scale x 1:500 y 1:200	Page 1 / 2
Subject: Longitudinal profile - Landfall. Katholm 4A	Report 51	Encl. 51.1.3 Rev.

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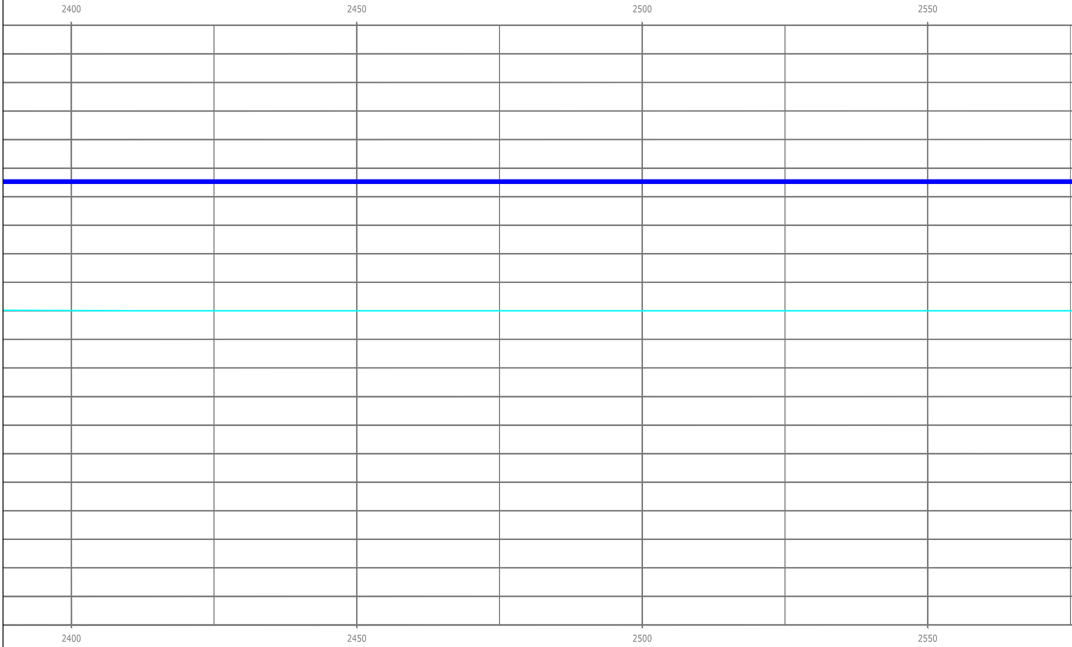
Aarhus +45 8627 3111


2400
2450
2500
2550
2400
2450
2500
2550

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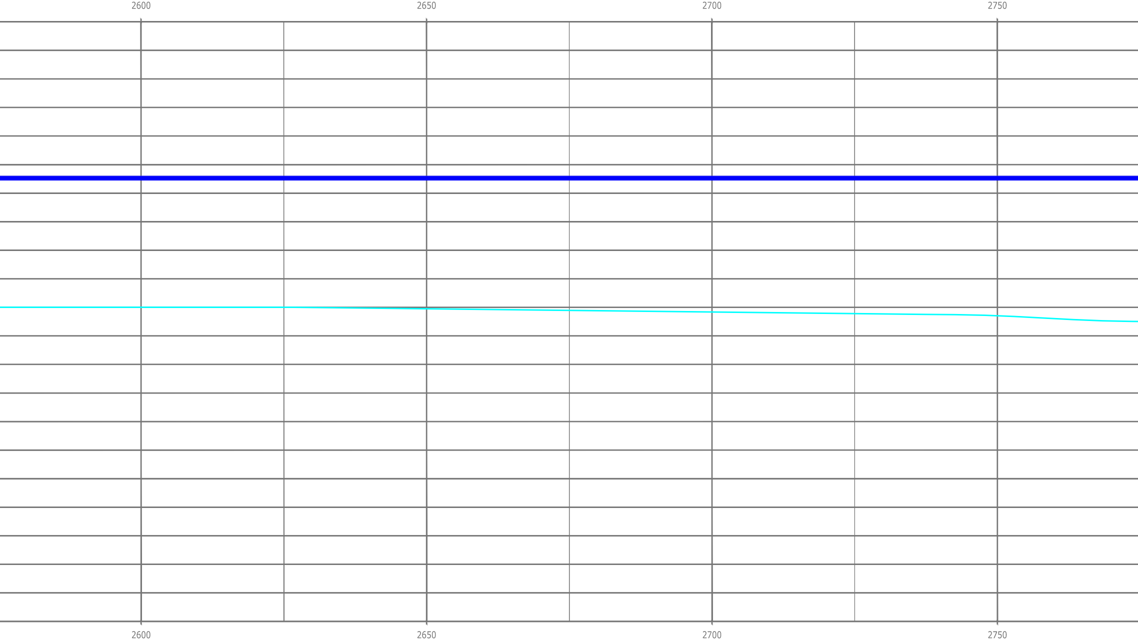
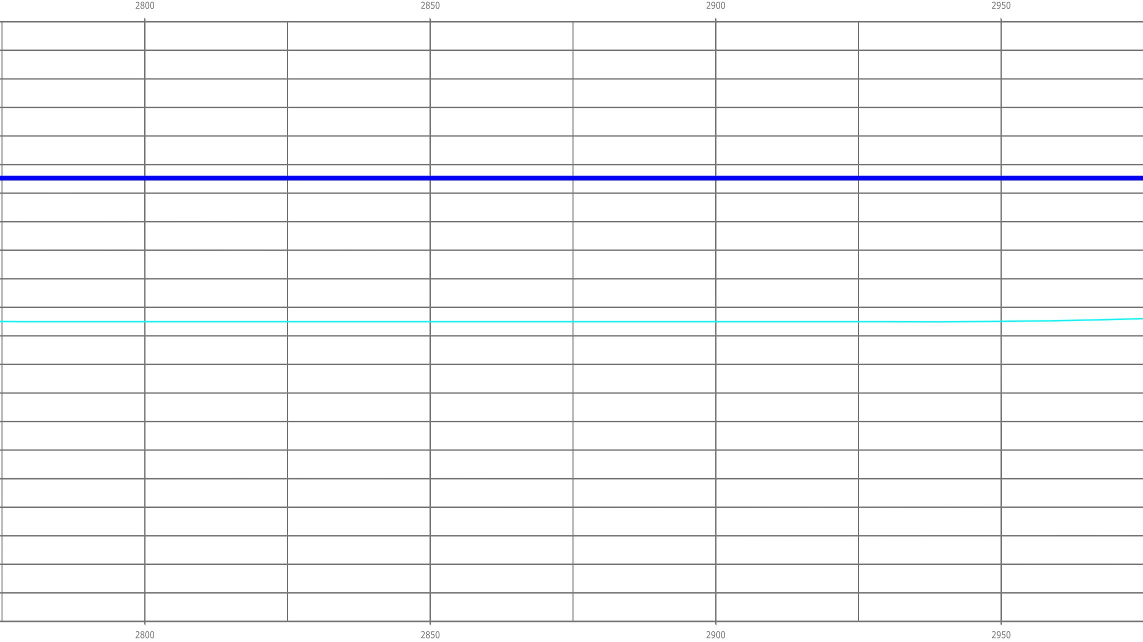
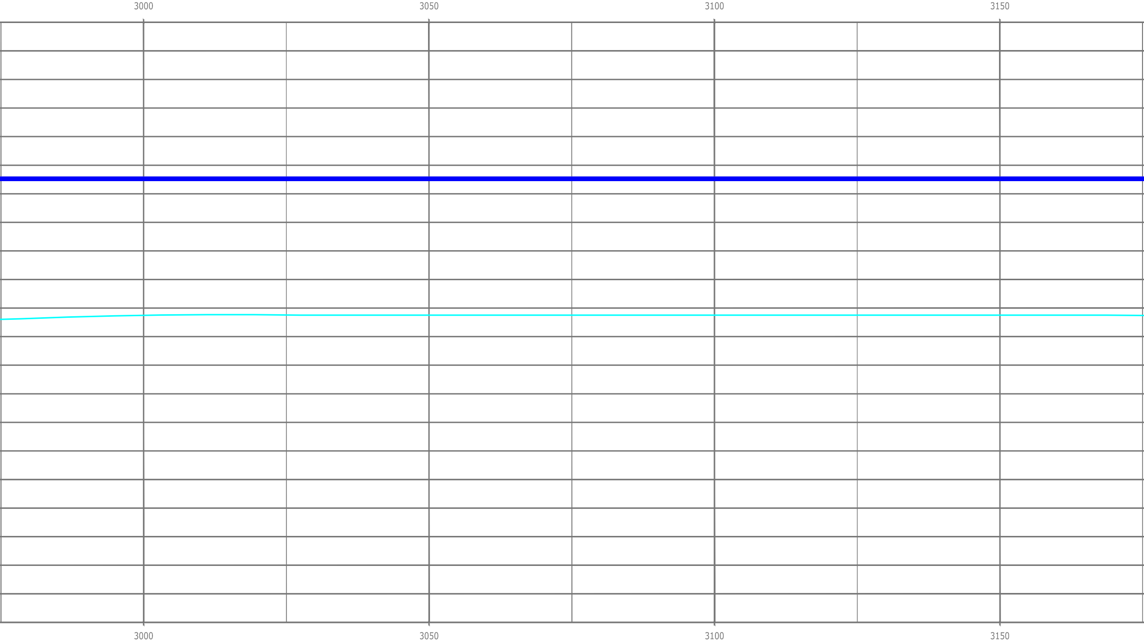
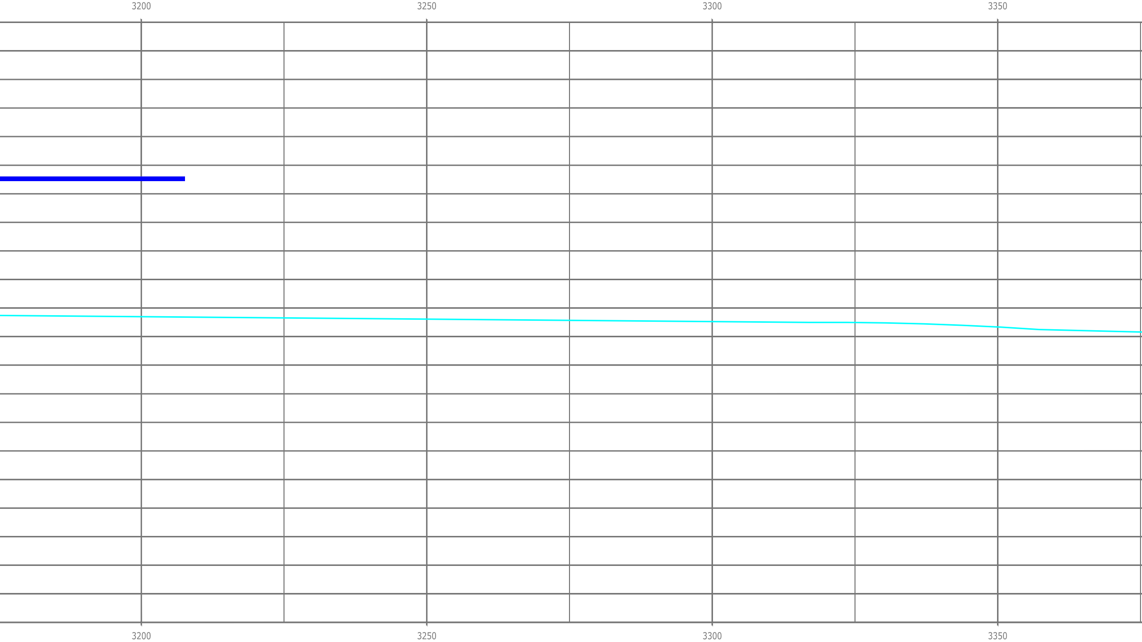
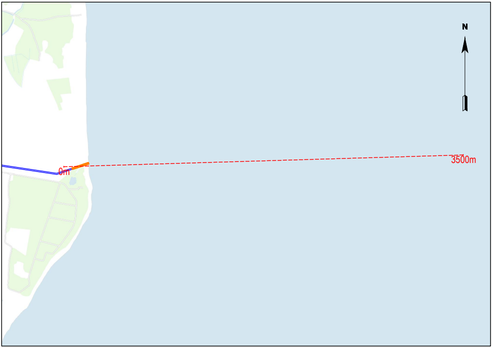






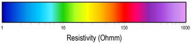




Legend:

🟩 Top soil / Fill
🟨 Sand / Gravel
🟫 Clay till
🟦 Silt
🟦 Clay
🟩 Clay/peat (postglacial)

Colorbar



— Terrain (Dansk Højde Model)

- - - - - - Interpretation of geological boundaries

— Seabed level

═ ═ ═ Highest measured groundwater level

▯ Borehole

Cone penetration test, Tip resistance, q_c

d:XXm Distance between ERT-line and borehole

— Planned HDD

0
20
40 m
x 1:500
0
8
16 m
y 1:200

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Subject: Longitudinal profile - Landfall. Katholm 4A	Report 51	Encl. 51.1.3 Rev.

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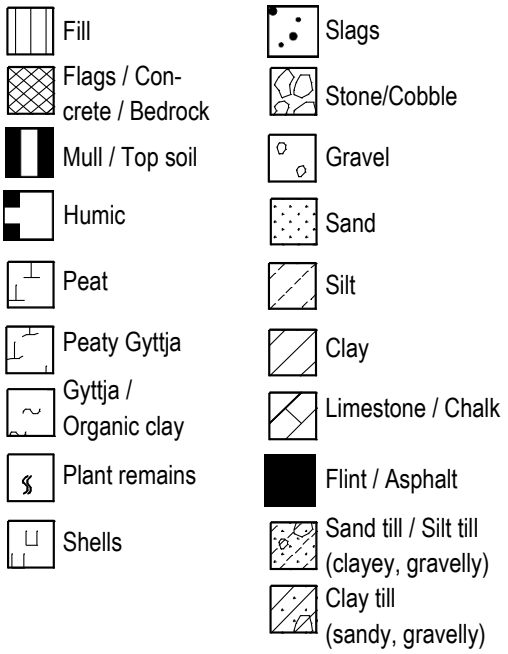
Geo-Standard: Legend and Abbreviations

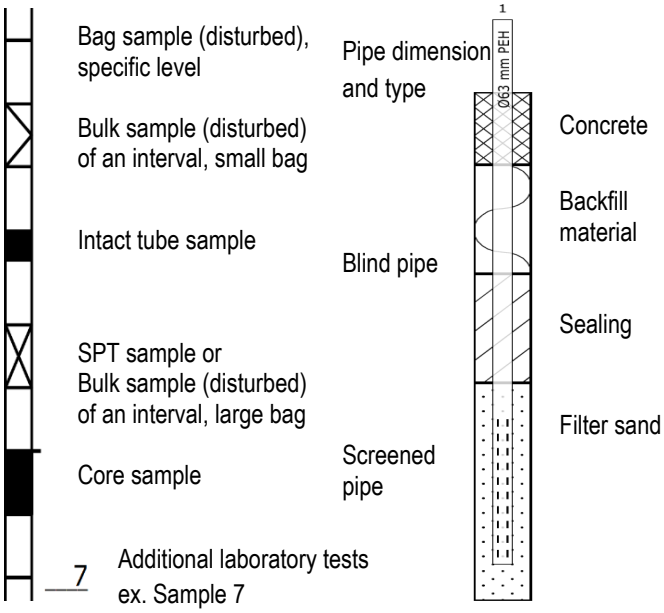
Borehole Profiles. Geotechnical, core and environmental

Description according to dgf-Bulletin 1, rev. 2, December 2021

Soil types



Samples



Pipe dimension and -type

Deposit

Ae	Aeolian (wind)
Br	Brackish
Fi	Fill
Fw	Freshwater
Gl	Glacier
Gr	Igneous/Bedrock
Ls	Landslide
Ma	Marine
Me	Metamorphic
Mw	Meltwater
Ss	Solifluction
Ts	Top soil
Vo	Volcanic
Wd	Wash down

Geological age

Re	Recent
Pg	Postglacial
Lg	Late glacial
Gc	Glacial
Ig	Interglacial
Is	Interstadial
Ng	Neogene
Pn	Paleogene
Mi	Miocene
Ol	Oligocene
Eo	Eocene
Pl	Paleocene
Sl	Selandian
Da	Danian
Ct	Cretaceous
Ju	Jurassic
Tr	Triassic
Si	Silurian
Ca	Cambrian
Pc	Precambrian

General abbreviations

sl.	slightly
v.	very
w.	with
lam.	lamina(e)
fragm.	fragments
biot.	bioturbation
bryo.	bryozoans
calc.	calcareous
noncalc.	non-calcareous
glauc.	glauconite
T	top of sample
B	bottom of sample

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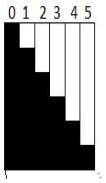
CVR-nr.: 59781812

Core samples

Recovery: Ratio in percentage between sample length and length of core run (Total Core Recovery, TCR). Value appears at top of core run.

RQD: Rock Quality Designation. Ratio in percentage between total length of core pieces with length more than 100 mm, and length of core run. Value appears at top of core run.

Fractures



0 = S0	Unfractured	No fractures
1 = S1	Very slightly fractured	20 - 60
2 = S2	Slightly fractured	10 - 20
3 = S3	Fractured	6 - 10
4 = S4	Very fractured	2 - 6
5 = S5	Crushed, blocky	< 2 cm

Induration

1 = H1	Unlithified	Can easily be shaped with fingers
2 = H2	Slightly indurated	Can easily be worked with knife
3 = H3	Indurated	Can be worked with knife
4 = H4	Strongly indurated	Can be scratched with knife
5 = H5	Very strongly indurated	Cannot be scratched with knife

Tests

c_{fv}	Field vane shear strength	(kN/m²)	Measured by vane test in undisturbed soil
c_{rv}	Field vane shear strength	(kN/m²)	Measured by vane test in remoulded soil
N	Standard penetrations test (SPT)		Number of blows per 0.3 m penetration of Ø51 mm SPT probe by use of the energy h · G = 0,76 m · 0,635 kN
w	Water content	(%)	Ratio between weight of water and weight of grains
w_p	Plastic limit	(%)	Water content at the boundary between semisolid and plastic state (NP: Non plastic)
w_L	Liquid limit	(%)	Water content at the boundary between plastic and liquid state
I_P	Plasticity index	(%)	$w_L - w_P$
γ	Unit weight	(kN/m³)	Ratio between total weight and total volume
e	Void ratio		Ratio between pore volume and grain volume
e_{max}	Void ratio, loosest state		Void ratio of very loose standard state
e_{min}	Void ratio, densest state		Void ratio of very dense standard state
I_D	Relative density		$(e_{max} - e)/ (e_{max} - e_{min})$
ka	Carbonate content	(%)	Ratio between weight of carbonate and total grain weight
gl	Loss on ignition	(%)	Weight loss by prolonged and high heating, % of total grain weight

Additional tests

In situ tests:

PR	Pressuremeter
FH	Falling Head
PP	Pumping
EL	Elastometer
GA	Gammalog

Laboratory tests:

B	Brazil	S	Simple shear
C	Consolidation	T	Triaxial
D	Specific gravity	U	Unconfined compression
E	e_{max} and e_{min}	V	Shear box
F	Photo	W	Vibration compaction
G	Grain size analysis	SP	Standard proctor test
P	Point load	MP	Modified proctor test

References

Danish Standard:

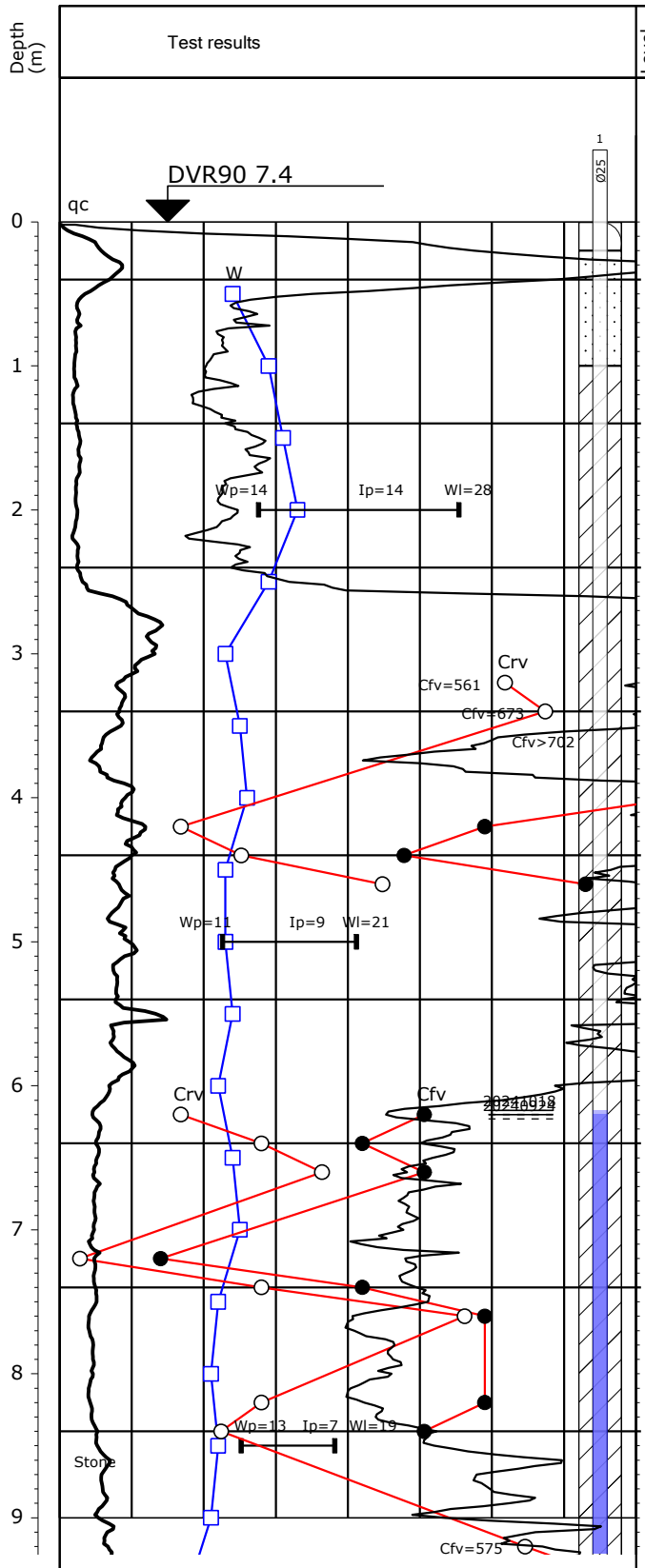
DS/EN 1997-1:2007 – Geoteknik-Del 1

Danish Geotechnical Society:

- ”A guide to engineering geological soil description” (dgf-Bulletin 1, rev. 2, December 2021)
- ”Felthåndbogen” (dgf-Bulletin 14)

Danish Geotechnical Society:

- ”Laboratoriehåndbogen” (dgf-Bulletin 15)
- ”Referenceblad for vingeforsøg”
- ”Referenceblad for SPT-forsøg”



No.	Geological Description	Env.	Age
1	MULL: SAND, sl. clayey, sl. gravelly, noncalcareous, dark greyish brown	Ts	Re
2	CLAY TILL, very sandy, sl. gravelly, noncalcareous, yellowish brown	Gl	Gc
3	CLAY TILL, sandy, sl. gravelly, noncalcareous, w. a few sand parts, yellowish brown	Gl	Gc
4	CLAY TILL, medium plasticity, sandy, sl. gravelly, noncalcareous, yellowish brown	Gl	Gc
5	CLAY TILL, medium plasticity, sandy, sl. gravelly, noncalcareous, greyish brown	Gl	Gc
6	CLAY TILL, low plasticity, sandy, sl. gravelly, sl. calcareous, greyish brown	Gl	Gc
7	CLAY TILL, low plasticity, sandy, sl. gravelly, calcareous, greyish brown	Gl	Gc
8	CLAY TILL - -	Gl	Gc
9	CLAY TILL, low plasticity, sandy, sl. gravelly, calcareous, grey	Gl	Gc
10	CLAY TILL - -	Gl	Gc
11	CLAY TILL - -	Gl	Gc
12	CLAY TILL - -	Gl	Gc
13	CLAY TILL - -	Gl	Gc
14	CLAY TILL - -	Gl	Gc
15	CLAY TILL - -	Gl	Gc
16	CLAY TILL, very low plasticity, very sandy, sl. gravelly, calcareous, grey	Gl	Gc
17	CLAY TILL - -	Gl	Gc
18	CLAY TILL - -	Gl	Gc
19	CLAY TILL - -	Gl	Gc

Continues

□	10	20	30	W (%)
○ ●	100	200	300	Crv, Cfv (kN/m²)
→	1	2	3	qc (MPa)
→	10	20	30	qc (MPa)

Soil description acc. to dgf-Bulletin 1, Revision 2, December 2021.

Coordinate system: UTM32E89
X : 618201 (m) Y : 6246369 (m)

Job: 208116 Energinet. Mere Havvind 2030

Drilled by: Geo BSM/JEP Date: 2024-09-05 Geology by: NIO Borehole: 4A.01

Method: Cased Shell & Auger 6" DGU no: Encl. No.: 51.2.1 Rev.: 0 P. 1/4

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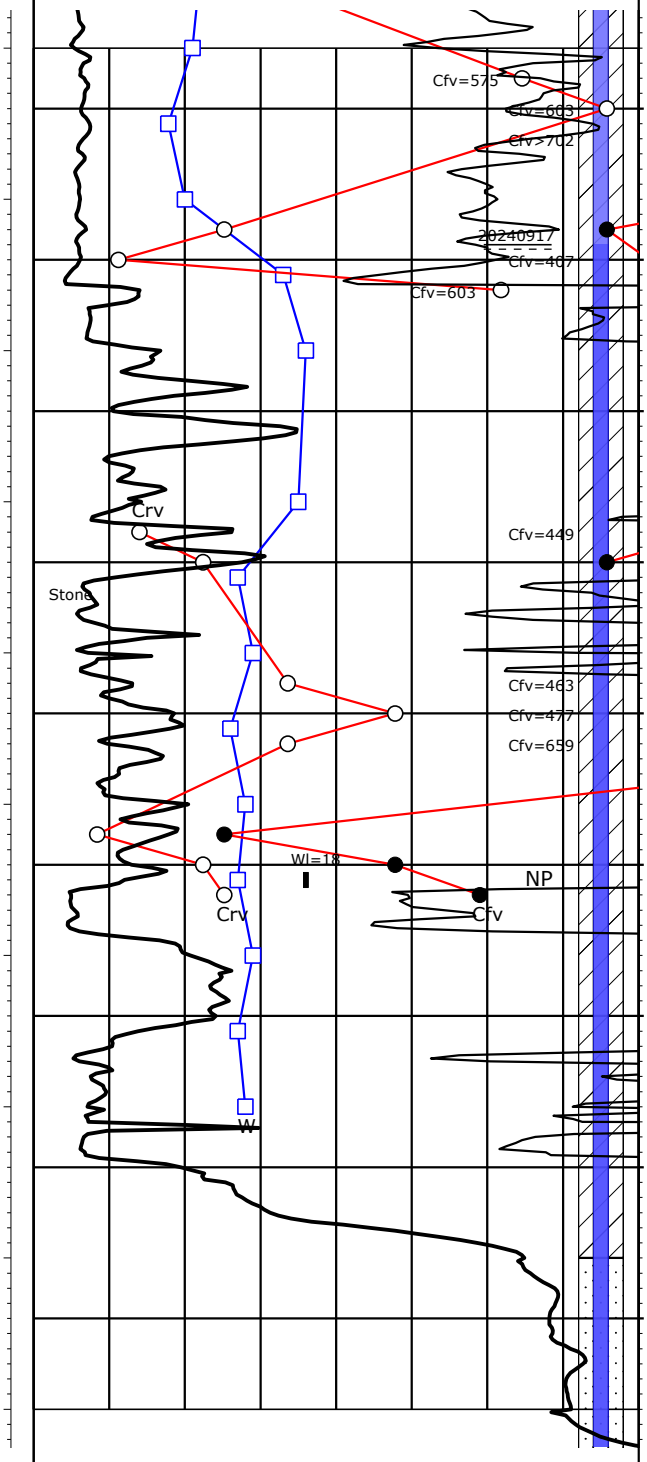
Profile



Depth (m)	Level (m)	No.	Geological Description	Env.	Age
			Continued		
9	-2	19	CLAY TILL - -	Gl	Gc
		20	CLAY TILL - -	Gl	Gc
10		21	CLAY TILL - -	Gl	Gc
	-3	22	CLAY TILL, very low plasticity, very sandy, sl. gravelly, calcareous, w. silty layers, grey	Gl	Gc
11		23	SILT, very sandy, clayey, calcareous, grey	Mw	Gc
	-4	24	SAND, medium, graded, sl. clayey, very silty, with redeposited lignite, w. clay layers, dark greyish brown	Mw	Gc
12		25	CLAY TILL, low plasticity, sandy, sl. gravelly, calcareous, grey	Gl	Gc
	-5	26	CLAY TILL - -	Gl	Gc
13		27	CLAY TILL - -	Gl	Gc
	-6	28	CLAY TILL, very low plasticity, very sandy, sl. gravelly, sl. calcareous, grey	Gl	Gc
14		29	CLAY TILL, low plasticity, sandy, sl. gravelly, w. a few sand parts, calcareous, grey	Gl	Gc
	-7	30	SAND TILL, very clayey, sl. gravelly, sl. calcareous, grey	Gl	Gc
15		31	SAND TILL - -	Gl	Gc
	-8	32	SAND TILL - -	Gl	Gc
16		33	CLAY TILL, very low plasticity, very sandy, sl. gravelly, sl. calcareous, grey	Gl	Gc
	-9	34	SAND, fine, graded, very silty, sl. calcareous, grey	Mw	Gc
17		35	SAND, fine, poorly graded, silty, sl. calcareous, grey	Mw	Gc
	-10	36	SAND, fine, uniformly graded, silty, sl. calcareous, grey	Mw	Gc
18		37	SAND, fine, poorly graded, silty, sl. calcareous, grey	Mw	Gc
			Continues		

□ 10 20 30	W (%)
○ ● 100 200 300	Crv, Cfv (kN/m²)
→ 1 2 3	qc (MPa)
➔ 10 20 30	qc (MPa)

Soil description acc. to dgf-Bulletin 1, Revision 2, December 2021.

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Job: 208116 Energinet. Mere Havvind 2030

Drilled by: Geo BSM/JEP Date: 2024-09-05 Geology by: NIO Borehole: 4A.01

Method: Cased Shell & Auger 6'' DGU no: Encl. No.: 51.2.1 Rev.: 0 P. 2/4

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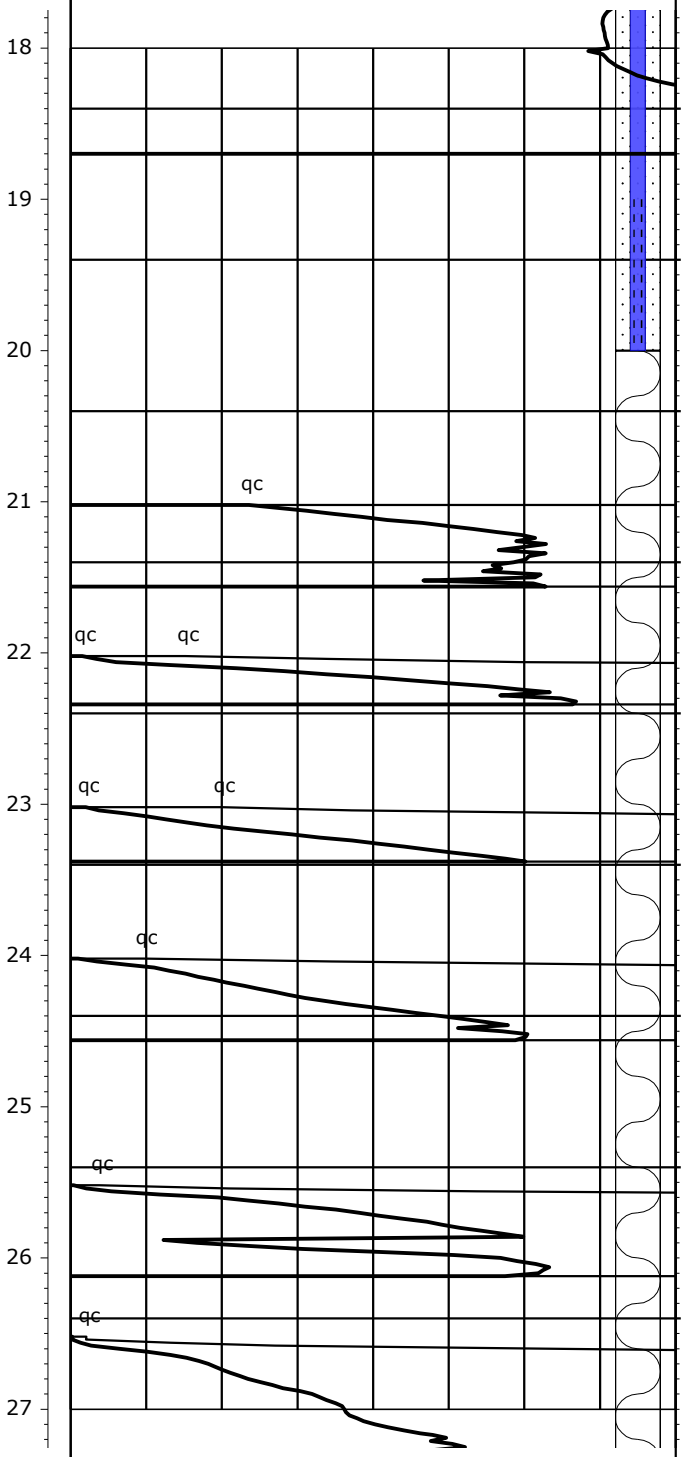
Profile



Level (m)	Geology	Sample	No.	Geological Description	Env.	Age
				Continued		
			37	SAND, fine, poorly graded, silty, sl. calcareous, grey	Mw	Gc
-11			38	SAND - -	Mw	Gc
			39	SAND, fine, uniformly graded, silty, sl. calcareous, grey	Mw	Gc
-12			40	SAND, fine, uniformly graded, sl. silty, sl. calcareous, grey	Mw	Gc
			41	SAND - -	Mw	Gc
-13			42	SAND - -	Mw	Gc
			43	SAND - -	Mw	Gc
-14			44	SAND, fine, uniformly graded, silty, sl. calcareous, grey	Mw	Gc
			45	SAND - -	Mw	Gc
-15			46	SAND - -	Mw	Gc
			47	SAND - -	Mw	Gc
-16			48	SAND - -	Mw	Gc
			49	SAND - -	Mw	Gc
-17			50	SAND - -	Mw	Gc
			51	SAND - -	Mw	Gc
-18			52	SAND - -	Mw	Gc
			53	SAND - -	Mw	Gc
-19			54	SAND - -	Mw	Gc
			55	SAND - -	Mw	Gc
				Continues		

□	10	20	30	W (%)
○ ●	100	200	300	Crv, Cfv (kN/m²)
→	1	2	3	qc (MPa)
→	10	20	30	qc (MPa)

Soil description acc. to dgf-Bulletin 1, Revision 2, December 2021.

Coordinate system: UTM32E89
X : 618201 (m) Y : 6246369 (m)

Job: 208116 Energinet. Mere Havvind 2030

Drilled by: Geo BSM/JEP Date: 2024-09-05 Geology by: NIO Borehole: 4A.01

Method: Cased Shell & Auger 6'' DGU no: Encl. No.: 51.2.1 Rev.: 0 P. 3/4

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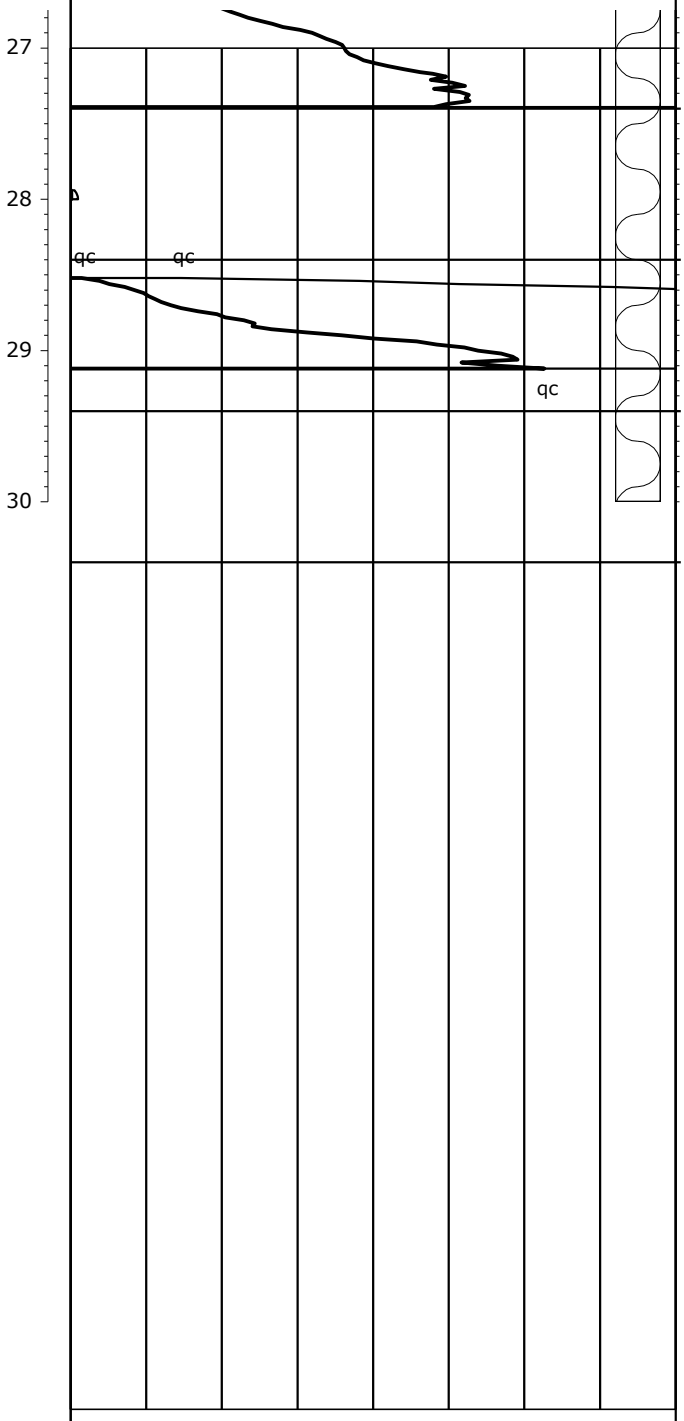
Profile



Test results | Level (m) | Geology | Sample | No. | Geological Description | Env. | Age

Continued

No.	Geological Description	Env.	Age
55	SAND - -	Mw	Gc
56	SAND, fine, uniformly graded, sl. silty, sl. calcareous, grey	Mw	Gc
57	SAND, fine, poorly graded, silty, sl. gravelly, sl. calcareous, grey	Mw	Gc
58	SAND, medium, poorly graded, silty, gravelly, sl. calcareous, grey	Mw	Gc
59	SAND, coarse, uniformly graded, gravelly, sl. calcareous, grey	Mw	Gc
60	SAND, fine, poorly graded, silty, sl. gravelly, sl. calcareous, grey	Mw	Gc

□	10	20	30	W (%)
○ ●	100	200	300	Crv, Cfv (kN/m²)
→	1	2	3	qc (MPa)
→	10	20	30	qc (MPa)

Soil description acc. to dgf-Bulletin 1, Revision 2, December 2021.

Coordinate system: UTM32E89
X : 618201 (m) Y : 6246369 (m)

Job: 208116 Energinet. Mere Havvind 2030

Drilled by: Geo BSM/JEP Date: 2024-09-05 Geology by: NIO Borehole: 4A.01

Method: Cased Shell & Auger 6'' DGU no: Encl. No.: 51.2.1 Rev.: 0 P. 4/4

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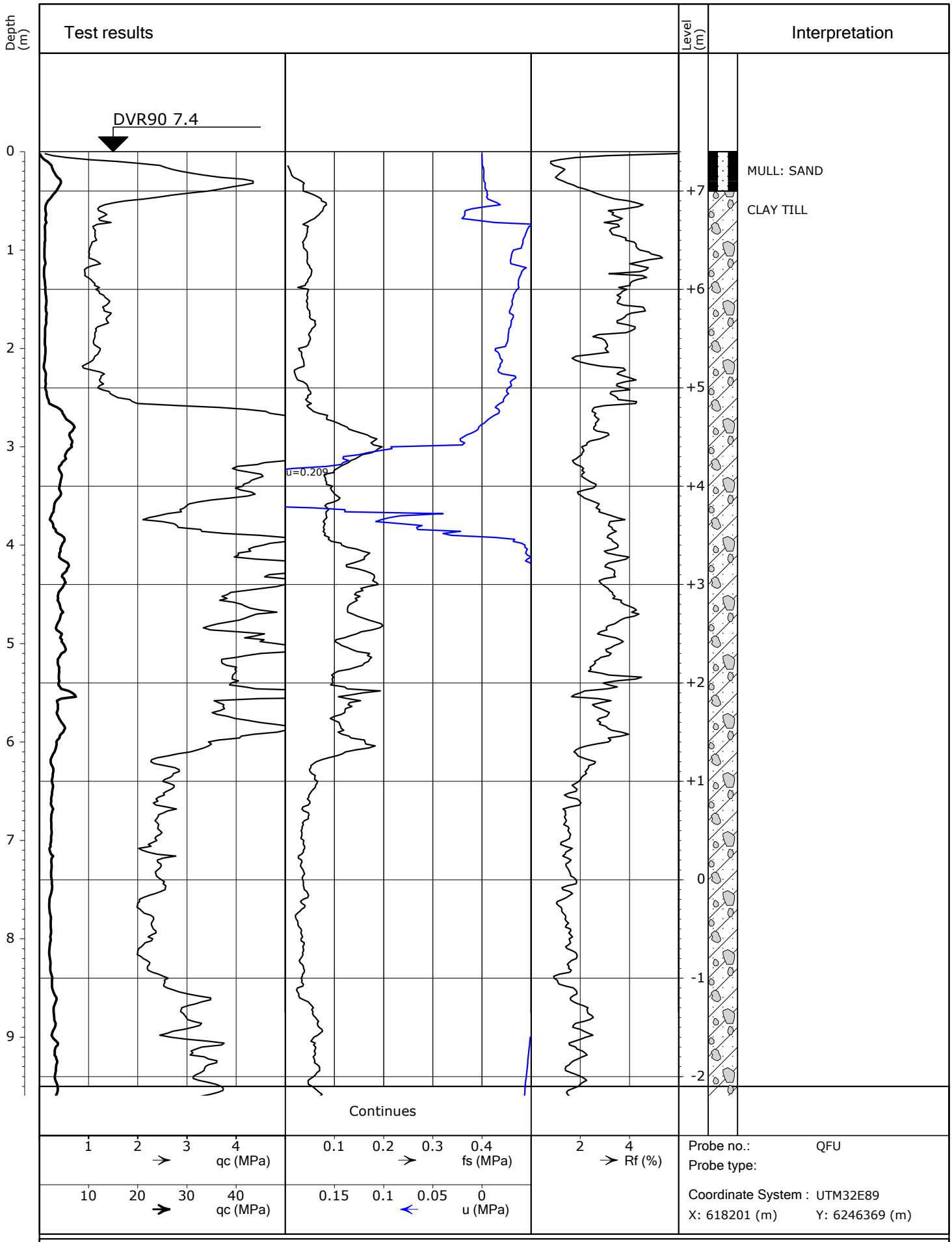
Profile



Probe no.: QFU
Probe type:
Coordinate System : UTM32E89
X: 618201 (m) Y: 6246369 (m)

Project: 208116 Energinet. Mere Havvind 2030

CPT by: Geoboringer Date: 2024-08-25 Interpretation: JDO Point no. : 4A.01.CPT

Profile by: JDO Control: NIO Approved: Date: Encl.: 51.3.1 Rev.: 0 S. 1/4

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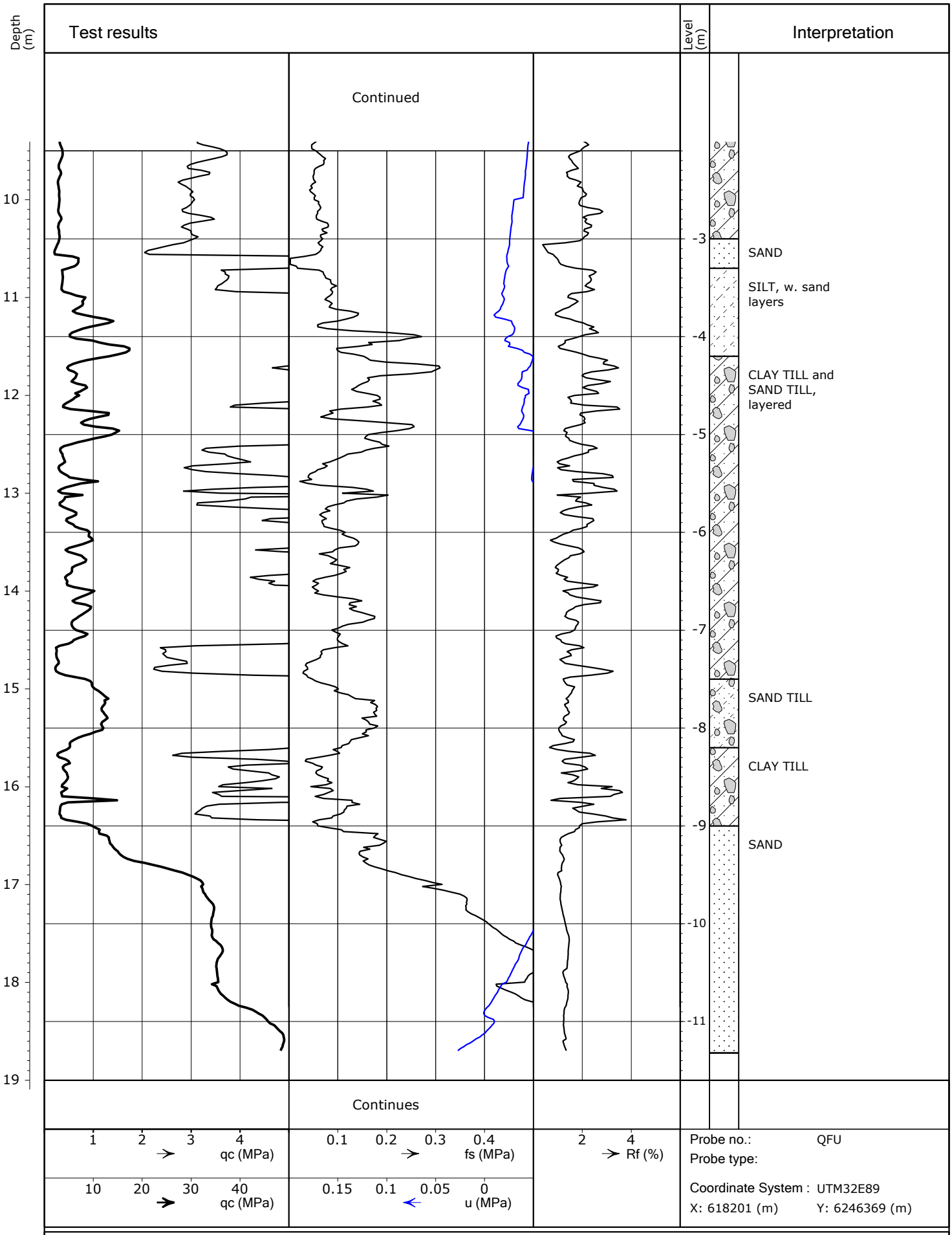
CPT profile



Probe no.: QFU
Probe type:

Coordinate System : UTM32E89
X: 618201 (m) Y: 6246369 (m)

Project: 208116 Energinet. Mere Havvind 2030

CPT by: Geoboringer Date: 2024-08-25 Interpretation: JDO Point no. : 4A.01.CPT

Profile by: JDO Control: NIO Approved: Date: Encl.: 51.3.1 Rev.: 0 S. 2/4

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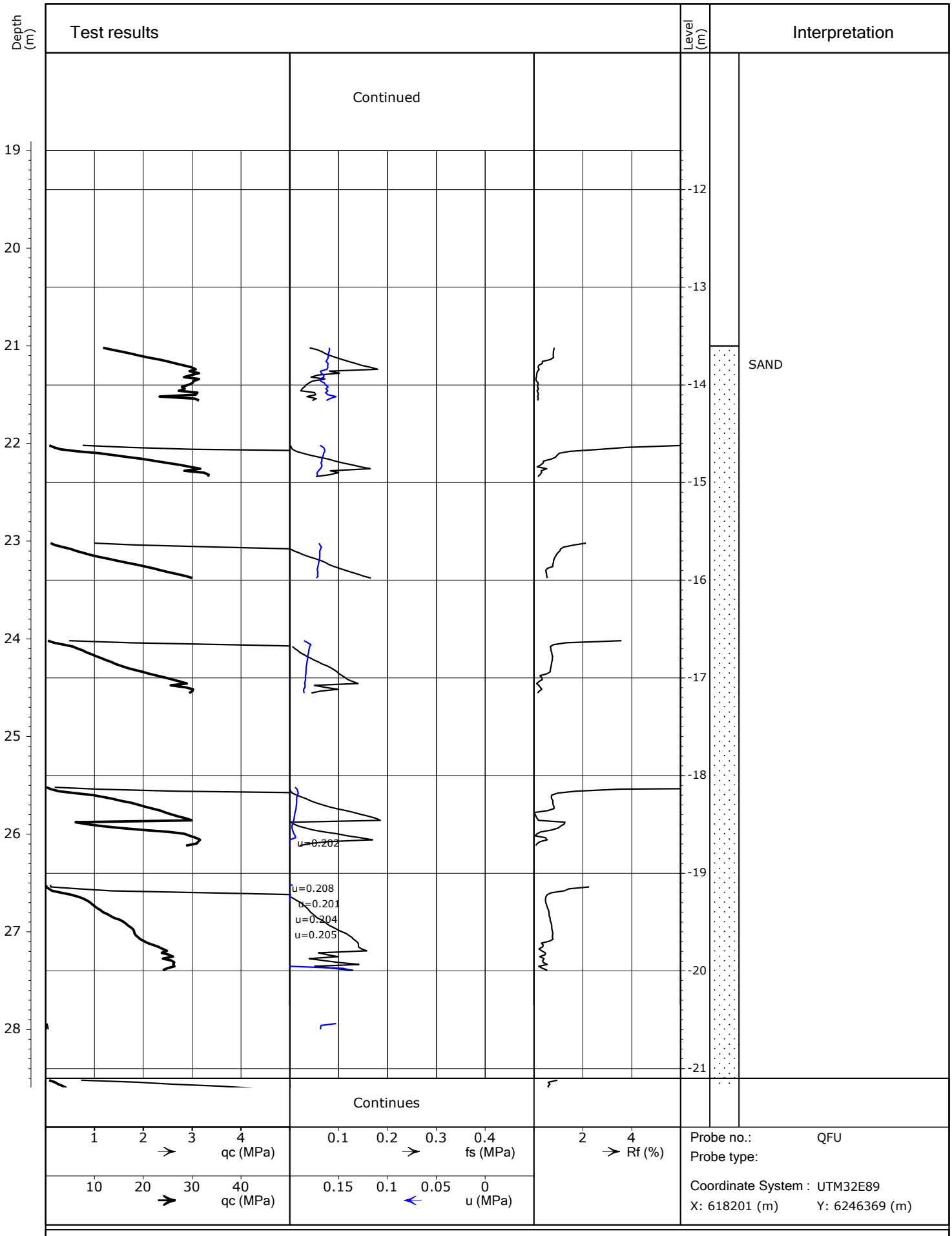
CPT profile



Project: 208116 Energinet. Mere Havvind 2030

CPT by: Geoboringer Date: 2024-08-25 Interpretation: JDO Point no. : 4A.01.CPT

Profile by: JDO Control: NIO Approved: Date: Encl.: 51.3.1 Rev.: 0 S. 3/4

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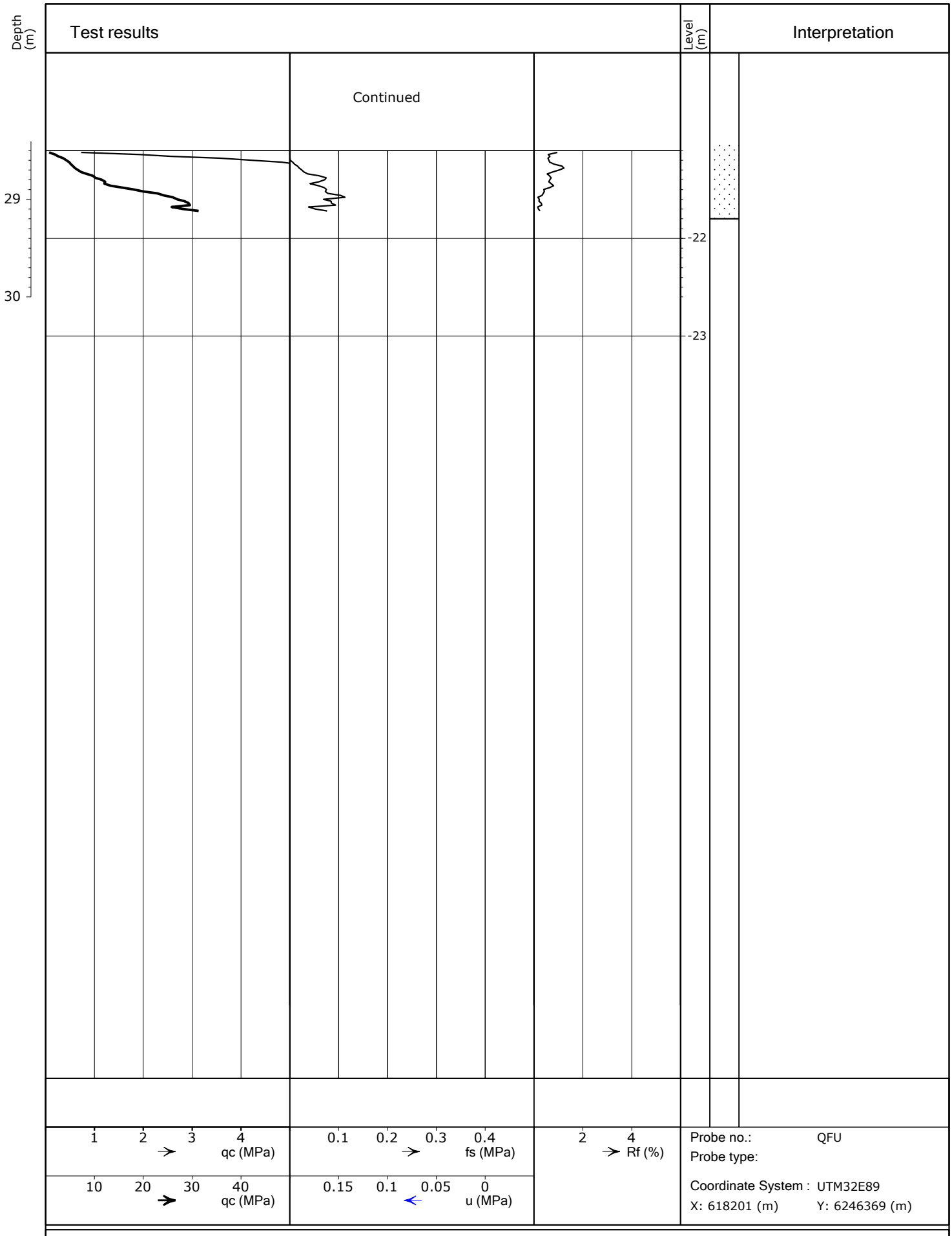
CPT profile



Project: 208116 Energinet. Mere Havvind 2030

CPT by: Geoboringer Date: 2024-08-25 Interpretation: JDO Point no. : 4A.01.CPT

Profile by: JDO Control: NIO Approved: Date: Encl.: 51.3.1 Rev.: 0 S. 4/4

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CPT profile

Performed : NJO Date : 2024-10-28
Controlled : NJO Date : 2024-10-30
Approved : JDO Date : 2024-11-07

Job : 208116 Energinet. Mere Havvind 2030

Enc. No : 51.4.1.1 Pg. 1 / 1

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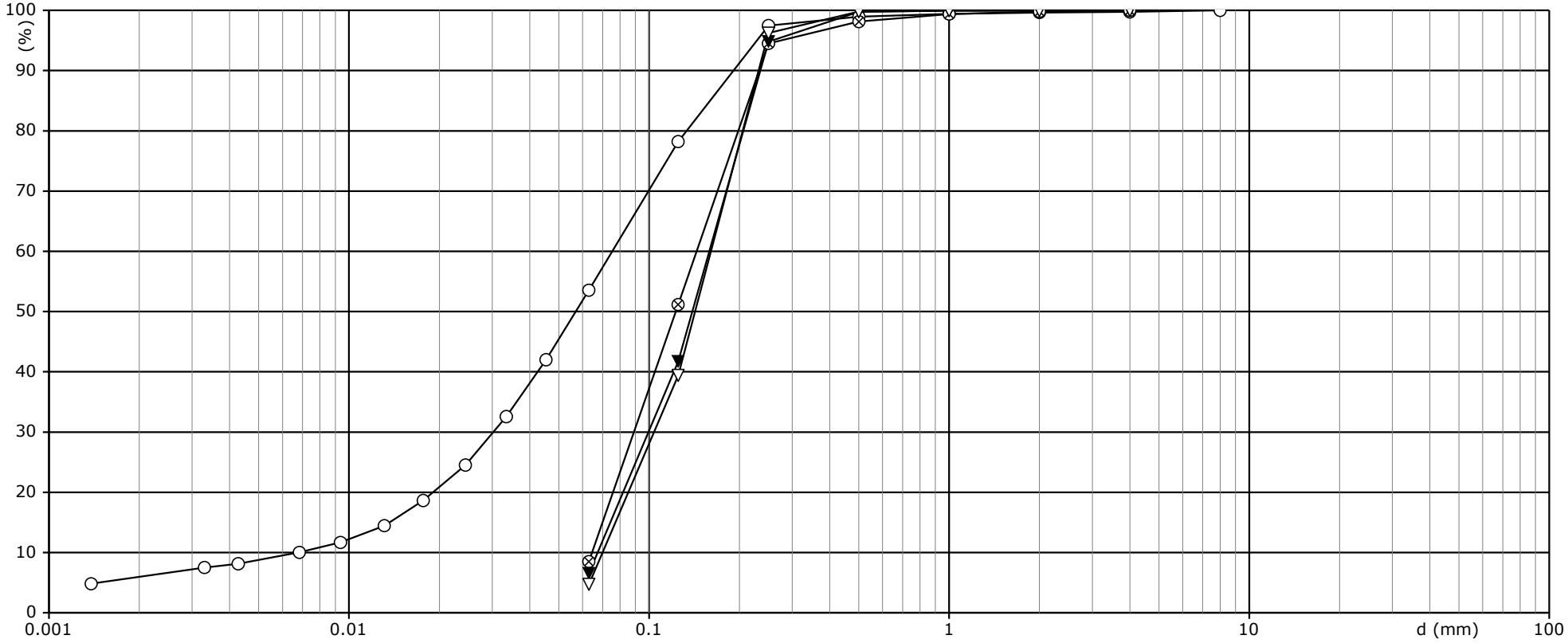
Grain Size Distribution

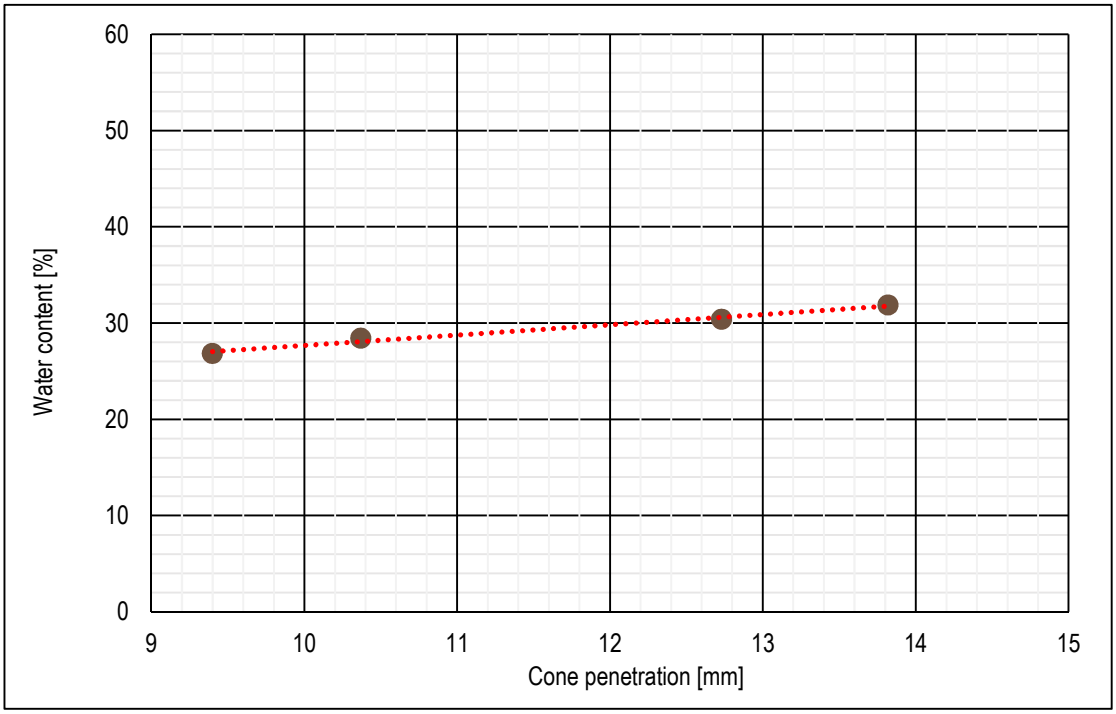


	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	
CLAY	SILT			SAND			GRAVEL			STONE

Boring/Sample No. :	4A.01 / 23	4A.01 / 36	4A.01 / 44	4A.01 / 54	/
Curve	○	⊗	▼	▽	
Geology	SILT	SAND	SAND	SAND	
Medium grain size d_{50}[mm]	0,0569	0,123	0,139	0,142	
Uniformity coeff. d_{60}[mm] / d_{10}[mm]	0,0754 / 0,0068= 11,137	0,144 / 0,0645= 2,233	0,159 / 0,0674= 2,359	0,161 / 0,0699= 2,303	/ =
Plasticity index W_L- W_P= I_P[%]	- =	- =	- =	- =	- =
Activity I_P[%] / Clay [%] = I_A	/ 6,0 =	/ =	/ =	/ =	/ =
$CaCO_3$[%]					
Specific gravity d_S					
Note					

Liquid Limit, Plastic Limit and Plasticity Index of Soils - Fall-Cone Method

Identification		Geological description
Borehole	4A.01	CLAY TILL, medium plasticity
Specimen no.	5	
Depth [m]	2	



Results

Initial water content	$w_{initial}$	[%]	16,3
Liquid limit	w_L	[%]	27,7
Plastic limit	w_P	[%]	13,8
Plasticity Index	I_P	[%]	13,8
Particles >0.425 mm	-	[%]	10,1

Notes

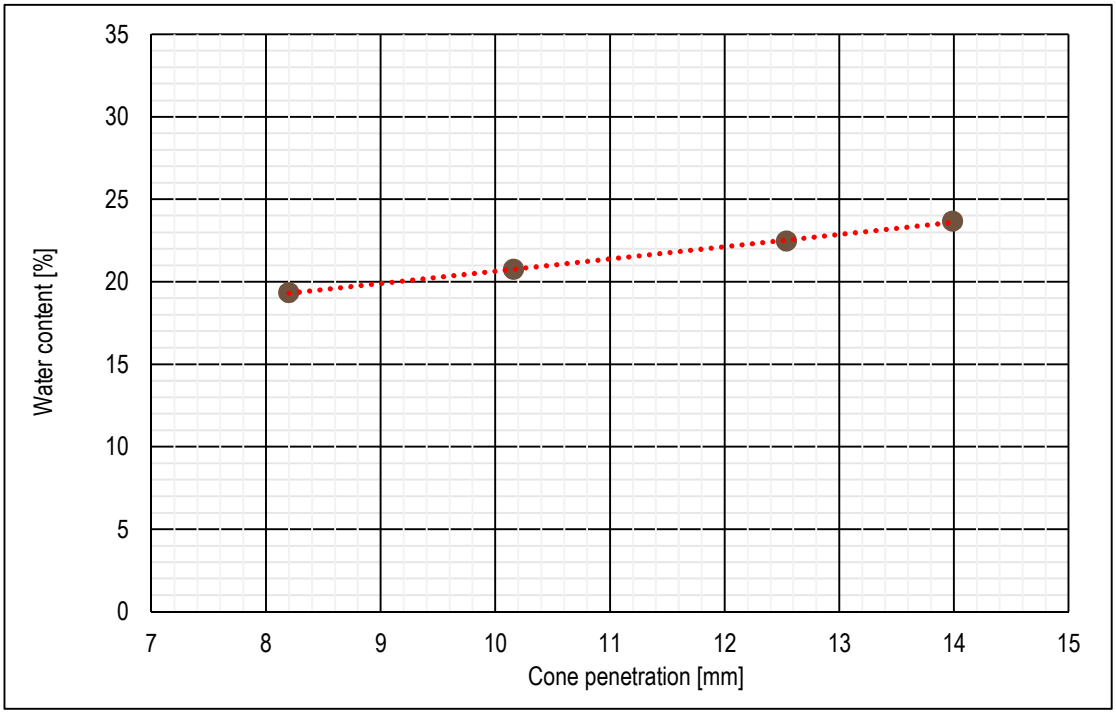
Standard

Testing is carried out in accordance with DS/CEN ISO 17892-12:2018 - Fall-Cone Method.

Prepared :	NJO	Date :	2024-11-07	Project :	208116 Energinet. Mere Havvind 2030
Checked :	NJO	Date :	2024-11-08	Report :	51 Encl. no.: 51.4.2.1
Approved :	JDO	Date :	2024-11-12	Subject :	Plasticity Index

Liquid Limit, Plastic Limit and Plasticity Index of Soils - Fall-Cone Method

Identification		Geological description
Borehole	4A.01	CLAY TILL, low plasticity
Specimen no.	11	
Depth [m]	5	



Results

Initial water content	$w_{initial}$	[%]	11,6
Liquid limit	w_L	[%]	20,6
Plastic limit	w_P	[%]	11,3
Plasticity Index	I_P	[%]	9,3
Particles >0.425 mm	-	[%]	7,5

Notes

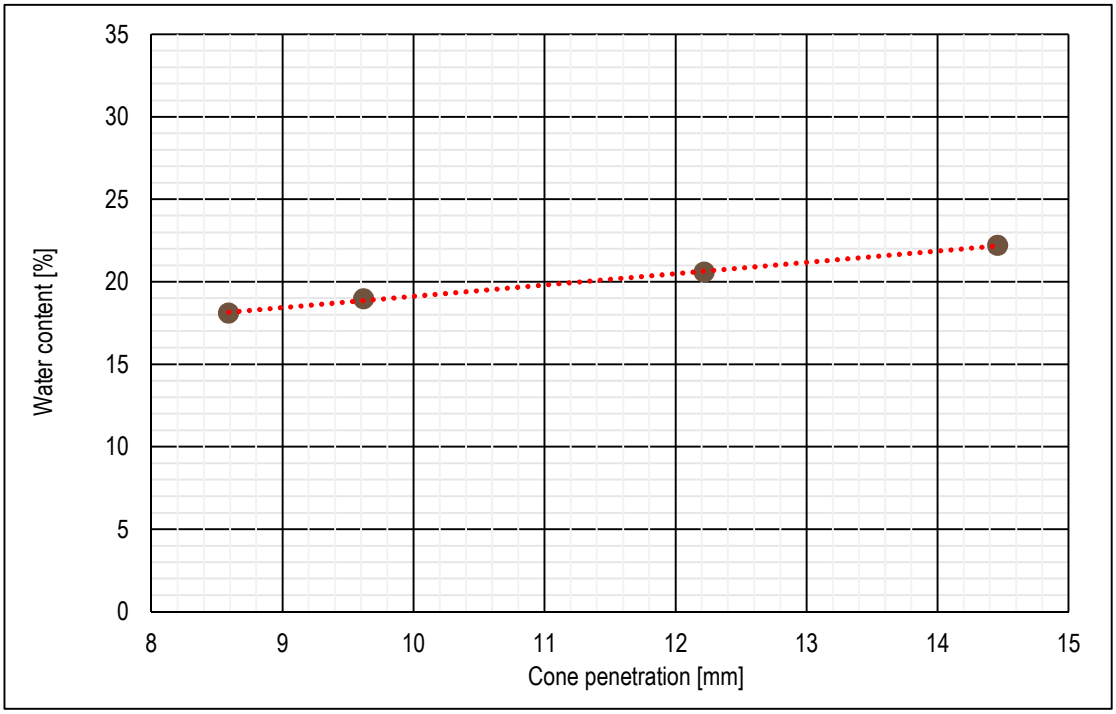
Standard

Testing is carried out in accordance with DS/CEN ISO 17892-12:2018 - Fall-Cone Method.

Prepared :	NJO	Date :	2024-11-07	Project :	208116 Energinet. Mere Havvind 2030
Checked :	NJO	Date :	2024-11-08	Report :	51 Encl. no.: 51.4.2.2
Approved :	JDO	Date :	2024-11-12	Subject :	Plasticity Index

Liquid Limit, Plastic Limit and Plasticity Index of Soils - Fall-Cone Method

Identification		Geological description
Borehole	4A.01	CLAY TILL, very low plasticity
Specimen no.	18	
Depth [m]	8,5	



Results

Initial water content	$w_{initial}$	[%]	11,2
Liquid limit	w_L	[%]	19,1
Plastic limit	w_P	[%]	12,6
Plasticity Index	I_P	[%]	6,5
Particles >0.425 mm	-	[%]	5,8

Notes

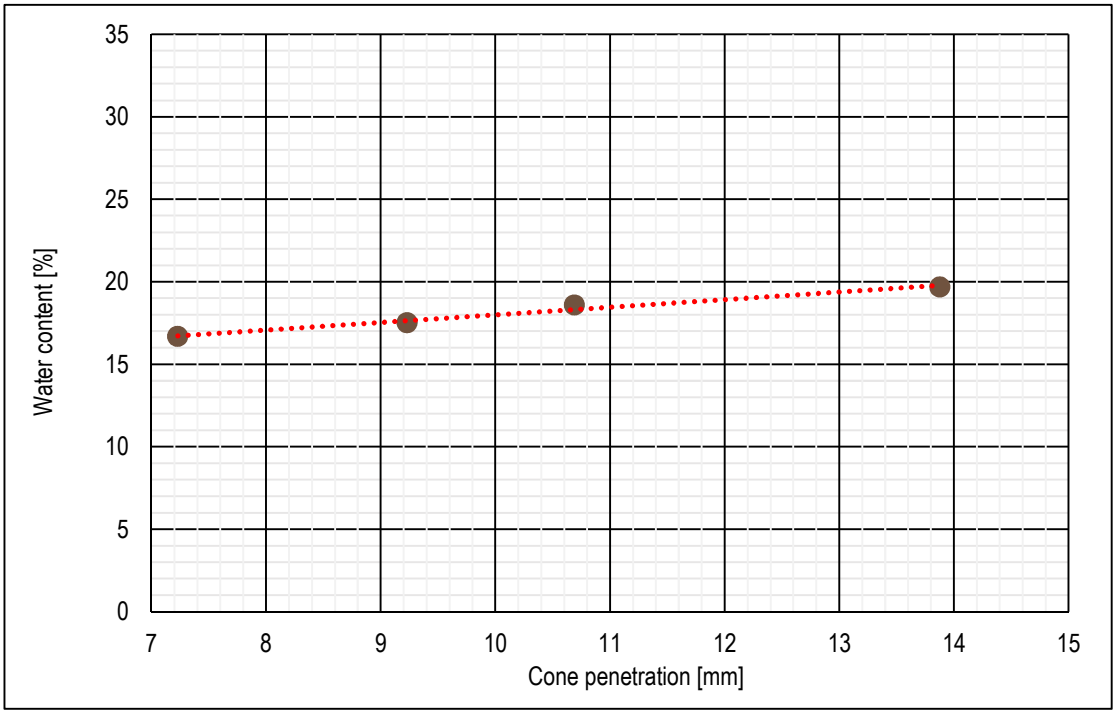
Standard

Testing is carried out in accordance with DS/CEN ISO 17892-12:2018 - Fall-Cone Method.

Prepared :	NJO	Date :	2024-11-07	Project :	208116 Energinet. Mere Havvind 2030
Checked :	NJO	Date :	2024-11-08	Report :	51 Encl. no.: 51.4.2.3
Approved :	JDO	Date :	2024-11-12	Subject :	Plasticity Index

Liquid Limit, Plastic Limit and Plasticity Index of Soils - Fall-Cone Method

Identification		Geological description
Borehole	4A.01	SAND TILL
Specimen no.	30	
Depth [m]	14,5	



Results

Initial water content	$w_{initial}$	[%]	13,7
Liquid limit	w_L	[%]	18,0
Plastic limit	w_P	[%]	-
Plasticity Index	I_P	[%]	NP
Particles >0.425 mm	-	[%]	11,1

Notes

Standard

Testing is carried out in accordance with DS/CEN ISO 17892-12:2018 - Fall-Cone Method.

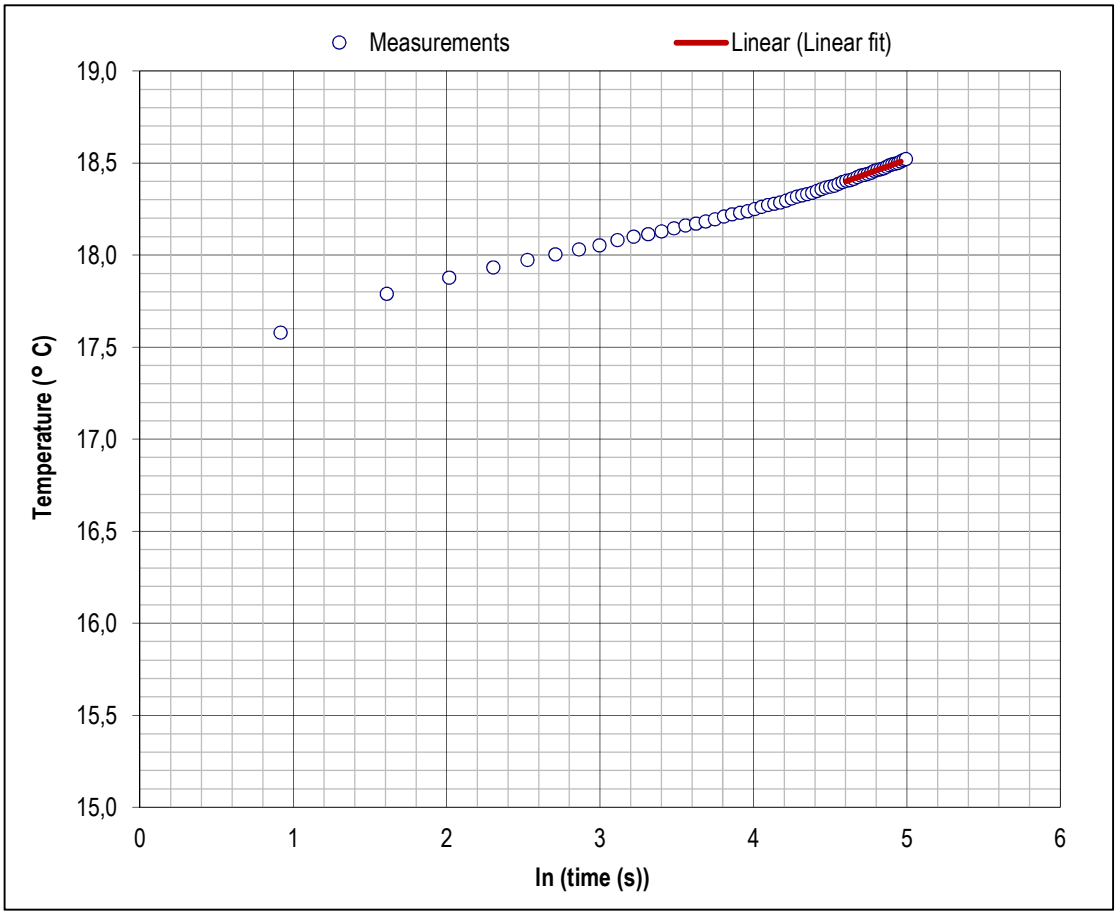
Prepared :	NJO	Date :	2024-11-07	Project :	208116 Energinet. Mere Havvind 2030
Checked :	NJO	Date :	2024-11-08	Report :	51 Encl. no.: 51.4.2.4
Approved :	JDO	Date :	2024-11-12	Subject :	Plasticity Index

Determination of Thermal Conductivity of Soil by Thermal Needle Probe Procedure

Identification		Geological description
Borehole	4A.01	SAND
Specimen no.	35+36+37	
Depth [m]	17,0-18,0	

Specimen dimensions, classification parameters and results

Height	175	mm	ρ_{bulk}	2,04	g/cm^3	λ	1,31	W/(m°C)
Diameter	75,4	mm	ρ_{dry}	1,68	g/cm^3	1/λ	0,76	°C m/W
w	21,7	%	$\rho_{s, est.}$	2,65	g/cm^3	r^2	1,00	-
e	0,578	-	S_r	99,6	%	Q	5,19	W/m



Configuration of set-up

Controler	MP2-BL		Calibration factor	0,956	-	Current	0,250	A
Needle type:	TLS150		Needle inserted	150	mm	Measuring time	150	s
Needle length	150	mm	Needle diameter	2,00	mm	Installation	Pushed	

Standard

Testing is carried out in accordance with ASTM D5334 - 14

Notes

Prepared :	NJO	Date :	2024-11-03	Project :	208116 Mere Havvind 2030
Checked :	NJO	Date :	2024-11-04	Report :	51
Approved :	JDO	Date :	2024-11-12	Subject :	Thermal Conductivity

Encl. no.: 51.4.3.1

Risk Assessment - Horizontal Directional Drilling

Risk	Consequence (s)	Category	Degree of Risk		Countermeasure (s)	Residual Risk	
			C	L		C	L
Horizontal Directional Drilling							
Difficult/challenging access to the drilling pits due to soft terrain / slippery surface. Especially in depressions combined with high precipitation periods.	Drilling supplier / equipment getting stuck in the field	I/T/F	1	D	Steel plates can be used to secure access.	1	A
Drilling equipment hitting large boulders, bigger than 20 cm in diameter Very likely at this location	Drilling stops	T/F	3	B	Drilling supplier must have a procedure of action in place if this occurs.	3	B
Unstable borehole (especially in frictional soils under the groundwater table) *Less likelihood at this location.*	Drilling borehole collapse and causes minor settlements of surface Drilling speed decreases / stops	F/T	3	D	Drilling supplier must use a suitable drilling mud to prevent collapse of the borehole. The drilling mud can have additive suitable to the soil conditions.	3	A
Very permeable soils (with and without groundwater pressure) causing loss of drill mud / dilution of drilling mud *Less likelihood at this location.*	Reduce lubricating effect (additives) Drilling mud leaks out in the formation and can cause unstable borehole	T/E	2	C	Drilling supplier has to be prepared for an increased consumption of drilling mud and handling of excess mud/water. Use a thick drilling mud if necessary.	2	A
Use of additive in the drilling mud	Additive (chemicals) and can cause pollution of the surrounding soil and water environment.	E	3	B	Drilling supplier must only use additive suitable for the specific soil formation and has to make sure that the additive are approved/documented for the project.	3	A
Blowout	Unintended loss of drilling mud to terrain or water environment.	T/F/E	4	C	Drilling supplier has to monitor/observe/detect if there is a sudden pressure drop during the drilling works and have a procedure of in action if blowout happens (ex. small decompression holes). Reduce the length of the cable route, because long cable routes have higher risk of blowout due to the higher pressure in the drilling mud. Investigation points (boreholes/CPT) are placed in a secure distance from the planned HDD line. Ensure sufficient depth of HDD, especially when crossing beneath a stream.	3	B

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Risk	Consequence (s)	Category	Degree of Risk		Countermeasure (s)	Residual Risk	
			C	L		C	L
HDD is too close to the surface *Probably not relevant at this location*	Settlements of surrounding terrain, construc-tions/roads/railway etc. Blowout	F/E	4	C	Carefully planning location of the drilling pits, length and depth of the HDD below terrain, existing constructions, roads, streams, railway etc.	4	B
Flooding of drilling pit due to heavy precipi-tation, insufficient lowering/draining of the groundwater table etc.	Drilling stops until pit is drained Loss/damaged of equipment	I/T/F	4	C	Establishing a water lowering/draining system prior to start of drilling. Execution of drilling from terrain if possible.	4	B

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Severity of Consequence (C)					Increasing Likelihood (L)→				
Rating	**Injury /illness** abbreviation (I)	**Property/ Financial** abbreviation (F)	**Time/Quality** abbreviation (T)	**Environment** abbreviation (E)	**Rare** May occur but only in exceptional circumstances (ie. Never heard of in the Industry)	**Unlikely** Could occur in some circumstances (ie. Heard of in the Industry)	**Possible** Might occur in some circumstances (ie. Has happened in the Organisation or more than once per year in the Industry	**Likely** Will probably occur in most circumstances (happened at a Location or more than once per year in the Organisation)	**Almost Certain** Is expected to happen in most circumstances (ie. Has happened more than once per year in the Location)
					A	**B**	**C**	**D**	**E**
5	Multiple fatalities	Extensive damage Incurred significant financial loss	Serious Breach	Massive effect	Medium	**High**	**High**	**High**	**High**
4	Permanent total disability or 1 fatality	Major damage Substantial financial loss incurred	Major Breach	Major effect	Low	Medium	**High**	**High**	**High**
3	Major health effect / injury	Localised damage. Moderate financial loss incurred	Considerable impact	Localised effect	Low	Medium	Medium	Medium	**High**
2	Minor health effect / injury	Minor damage. Minor financial loss incurred	Limited impact	Minor effect	Low	Low	Medium	Medium	**High**
1	Slight health effect / injury	Slight damage Low financial loss incurred	Slight impact	Slight effect	Low	Low	Low	Low	Medium

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Rating	Injury/illness	Property – Premises, and 3rd party	Time/Quality	Environment
5	**Multiple fatalities** - From an accident or occupational illness	**Extensive damage** - Substantial or total loss of operation. Incurred significant financial loss		**Massive effect** - Persistent severe environmental damage or severe nuisance over a large area. Loss of commercial, recreational use or nature conservancy, resulting in major financial consequences for the company. Ongoing breaches well above statutory or prescribed limits.
4	**One to three fatalities or permanent total disability** - From an accident or occupational illness. Irreversible health damage with serious disability or death	**Major damage** - Partial operation loss, 2 weeks shutdown, Substantial financial loss incurred	**Major impact –** Partial operation loss, 2 weeks shutdown, Extensive adverse effect on quality. Potentially restrictive measures and/or impact on grant of licences. Mobilisation of action groups	**Major effect** - Severe environmental damage. The company is required to take extensive measures to restore the contaminated environment. Extended breaches of statutory or prescribed limits, or widespread nuisance.
3	**Major injury or health effects** (including Permanent Partial Disability) - Affecting work performance in the longer term, such as a prolonged absence from work. Irreversible health damage without loss of life, e.g. noise induced hearing loss, chronic back injuries	**Moderate damage** - Partial shutdown Moderate financial loss incurred	**Considerable impact –** Partial shutdown Extensive adverse effect on quality. Mobilisation of action groups	**Localised effect** - Limited discharges affecting the neighbourhood and damaging the environment. Repeated breaches of statutory or prescribed limit, or many complaints.
2	**Minor injury or health effects** - Affecting work performance, such as restriction to activities (Restricted Work Case) or a Lost Time Injury. Limited health effects which are reversible, e.g. skin irritation, food poisoning	**Minor damage** - Brief disruption, Minor financial loss incurred	**Limited impact –** Brief disruption Multiple Stakeholder upset	**Minor effect** - Sufficiently large contamination or discharge to damage the environment, but no lasting effect. Single breach of statutory or prescribed criterion, or single complaint.
1	**Slight injury or health effects** (including first aid case and medical treatment case and occupational illness) - Not affecting work performance or causing disability	**Slight damage** - No disruption to operations, Low financial loss incurred	**Slight impact** – No disruption to operations Individual Stakeholder upset	**Slight effect** – Slight environmental damage, within the fence and within systems. Negligible financial consequences

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