Danish Offshore Wind 2030 - North Sea I (A3) - Vedersø Klit - Idomlund

Location 1AA – Landfall Vedersø Klit (Natura 2000 and protected area)

Site Investigations for Horizontal Directional Drilling (HDD)

Geo project no. 208116
Report 94, 2024-11-27

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 the landfall 1AA at cable route 1, close to Vedersø Klit (Natura 2000 and protected area).

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

Energinet has informed Geo, that the HDD will start at the beach in the vicinity of the breaking poin from the beach dunes, and will be drilled towards the sea at 5-10 m b.g.l. untill the end of the off shore part of the cable is reached at sea.

In this depth, the HDD may penetrate saturated deposits of postglacial sand with layers of gyttja and peat mud. No Mica is found in the deposits, but may be found along the 1 km long stretch.

This report has to be read in correlation with report no. 1, which contain the general geological description, results of the geophysical survey and laboratory results from the nearby location 1.A.

Geo project no. 208116
Report 94, 2024-11-27
Client ref.: Danish Offshore Wind 2030 - North Sea I (A3) – Landfall Vedersø Klit

Prepared for:
Energinet Eltransmission A/S
Tonne Kjærsvej 65
DK-7000 Fredericia
Att.: Frits Christiansen

Prepared by
Janni Dolby, jdo@geo.dk, +45 3174 0346
Lars Christiansen, lch@geo.dk, +45 3174 0272

Controlled by
Susanne Granhøj

Content

Enclosures

Drawings
1.1.1: Overview map
94.1.2: Site plan
94.1.3: Longitudinal profile

Geo standard   Legends and Abbreviations

Borehole profiles
1.2.1: Borehole 1A.01

CPT profiles
1.3.1: 1A.01.CPT

Laboratory tests
Reference is made to report no. 1.

1.5: Risk Assessment

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 including landfalls 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 94.1.

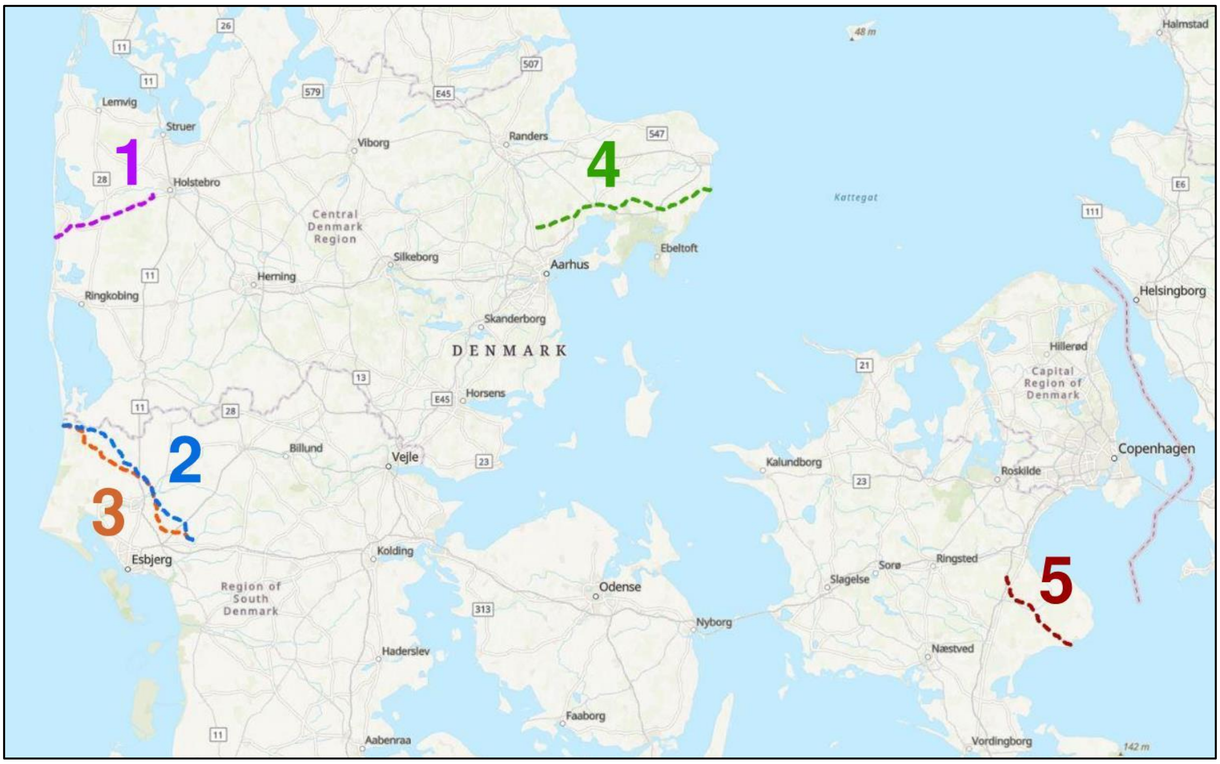


Figure 94.1: Overview map of the five cable routes planned in this project.

This report concerns the landfall part at cable route 1, (Vedersø Klit to Idomlund) at location 1AA as illustrated in Figure 94.2 (and in the overview map cf. enclosure 1.1.1), at landfall Vedersø Klit - a Natura 2000 area[1] - 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 5-10 m b.g.l. untill the end of the offshore part of the cable is reached at sea.

---

[1] Natura 2000 is a term for the EU network for protected areas

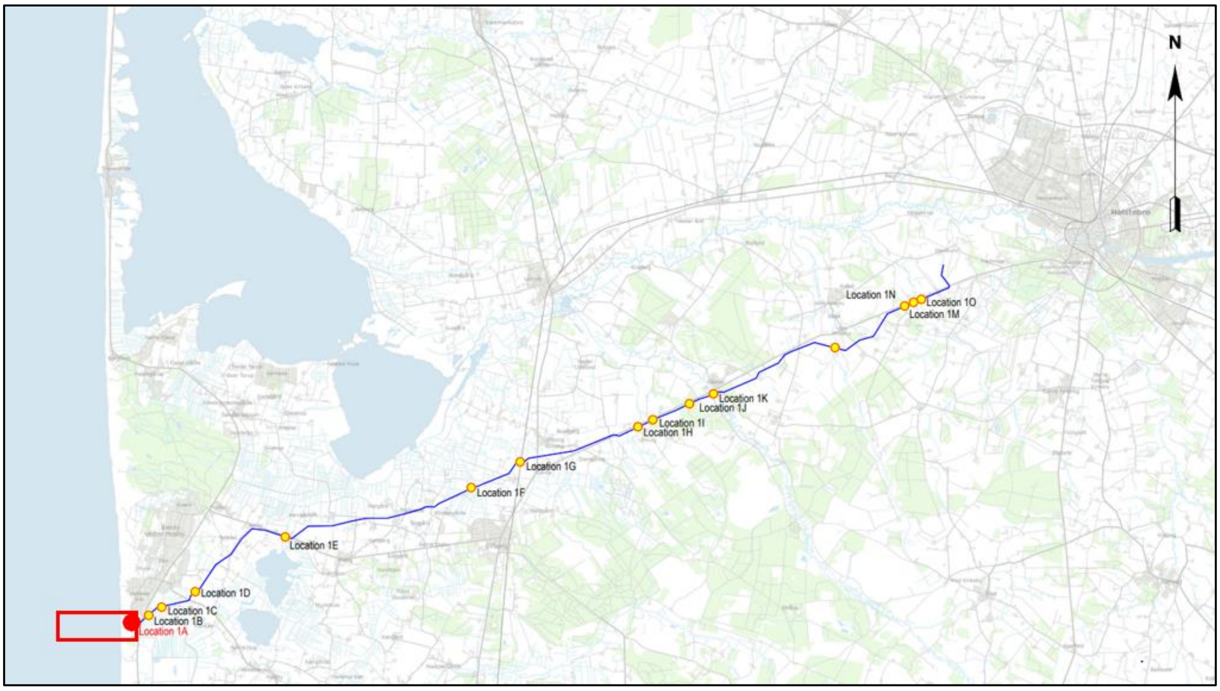


Figure 94.2: Overview map of cable route 1. Location 1A is marked with a red dot. Landsfall (1AA) is marked with a red box.

Geo has been requested to investigate the soil and hydrological conditions prior to execution of the HDD at the landfall, which start at the seaside of the dunes, and end at level -10 m approximately 1 km from the coastline.

This report has to be read in correlation with report no. 1, which contain the general geological description, results of the geophysical survey and laboratory results from the nearby location 1.A. As the geology and geotechnical parameters is based on 1 borehole and extrapolated 1 km from the borehole, the likelihood of similar ground conditions is very small. Therefore, the geology and geotechnical parameters has to be used with the great precaution.

2 Investigations

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

2.1 Geophysical investigations

For the geophysical survey in the area using ERT (Electrical Resistivity Tomography) method reference is made to Report No. 1.

2.2 Geotechnical investigations

At the location 1AA, one CPTu and one geotechnical boreholes have been executed. The target depths of the investigation point have been reached. The CPTu has 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 94.1.2.

The CPTu have 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 at constant speed measuring the tip resistance (q_c), sleeve friction (f_s) and pore pressure just behind the tip of the cone (u_2).

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 boreholes strata are registered, samples taken and in situ tests carried out as required by Energinet.

The sampling consists of:

- Small disturbed samples for geological description and laboratory testing

The in situ tests consists of:

- Field vane test[2]

The borehole has been completed with installation Ø25 mm (diameter) standpipe and the material consists of PVC. The filter screening is carried out during simultaneous withdrawal of the casing. To ensure a tight seal between water 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 borehole and again minimum 5 days hereafter. All results are shown on the borehole profile cf. enclosure 1.2.1.

According to the Danish legislation “Brøndborebekendtgørelse”[3] the borehole is 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 94.1.

---

[2] Danish Geotechnical Society, dgf-Bulletin 14, 1999, “Referenceblad for Vingeforsøg”, version 3

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

Table 94.1: 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
Loss on ignition	DS/EN 15935:2021

3 Results

3.1 Geophysical results

For the geophysical results reference is made to report No. 1.

3.2 Geotechnical results

The geotechnical investigation carried out for this location is described in section 2.2.

At borehole 1A.01 postglacial deposits of sand is found from terrain to 6.7 m b.g.l. Below postglacial deposits of gyttja and peat mud is found down to 8.2 m b.g.l. underlain by 1.5 m of postglacial sand. From 9.7 m b.g.l late glacial deposits of meltwater clay is found to approx. 14 m b.g.l. where glacial deposits of gravel till and clay till is encountered down to the bottom of the borehole.

No Mica is found in the deposits.

The late glacial clay is high in plasticity.

3.2.1 Hydrogeology

The groundwater levels have been measured in the standpipe immediately after completing the borehole and again minimum 5 days hereafter. The groundwater level readings are illustrated on the borehole profile, and furthermore listed in Table 94.2.

Table 94.2: 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.)**
1A.01	+3.2	2024-04-16 2024-04-24 2024-05-07	1.7 2.5 1.7	+1.5 +0.7 +1.5	9.5

3.2.2 Laboratory tests

Results of the laboratory classification tests are presented either on the borehole profile and/or in report 1.

For results of thermal conductivity tests carried out on samples taken in nearby borehole 1A.02 reference is made to report No. 1.

3.3 Geological description of the location

For general geological description of the area, reference is made to Report No. 1.

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[4].

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

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 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 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. In interglacial peat and diatomite gyttja Geo suggest $\mu \approx 1.0$ depending on the considered limit state and in postglacial, organic soils (peat, gyttja etc.) $\mu = 0.5 – 0.8$.

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.

---

[4] NGI Publication #156 "Interpretation of Cone Penetrometer Data for Offshore Sands", NGI 1985, T. Lunne and H. P. Christoffersen

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

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 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$^2 \leq q_c \leq 50$ MN/m^2

$M_0 = 120$ for $q_c > 50$ MN/m^2

For over consolidated sand (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 Field vane test

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

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

where: c_{fv} = field vane strength 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 94.3 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 94.3: Soil parameters, Location 1AA.

Soil description	**q_c (MPa)**	**γ/γ' (kN/m^3)**	**φ' (°)**	**c' (kPa)**	**c_u (kPa)**	**k (m/s)**	**E_{oed} (MPa)**
Sand, (Pg)	1-25	18-20/10	32-40	0	N/A	$5 \cdot 10^{-4}$ - $5 \cdot 10^{-6}$	5-100
Gyttja, (Pg)	2-6	12-15/2-5	20-30	0	100-200	$1 \cdot 10^{-8}$ - $1 \cdot 10^{-10}$	<1
Peat mud, (Pg)	2-3	11-13/1-3	20-30	0	125-150	$1 \cdot 10^{-4}$ - $1 \cdot 10^{-6}$	<1
Clay, (Lg)	2-15	18-20/10	25-30	5-10	50-175	$1 \cdot 10^{-8}$ - $1 \cdot 10^{-10}$	8-25
Clay Till, (Gl)	2-3	20-21/11	30-32	10-15	125-175	$1 \cdot 10^{-7}$ - $1 \cdot 10^{-9}$	20-40

6 Recommendations

At location 1AA, the plan is to carry out HDD at the beach in the vicinity of the breaking point from the beach dunes, and will be drilled towards the sea at 5-10 m b.g.l. untill the end of the offshore part of the cable is reached at sea.

In this depth, the HDD may penetrate deposits of postglacial sand with layers of gyttja and peat mud. No Mica is found in the deposits in borehole 1A.01, but may be found along the 1 km long stretch.

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 borehole and CPT, is attached in enclosure 94.5.

Coordinate system: UTM32E89   Level system: DVR90

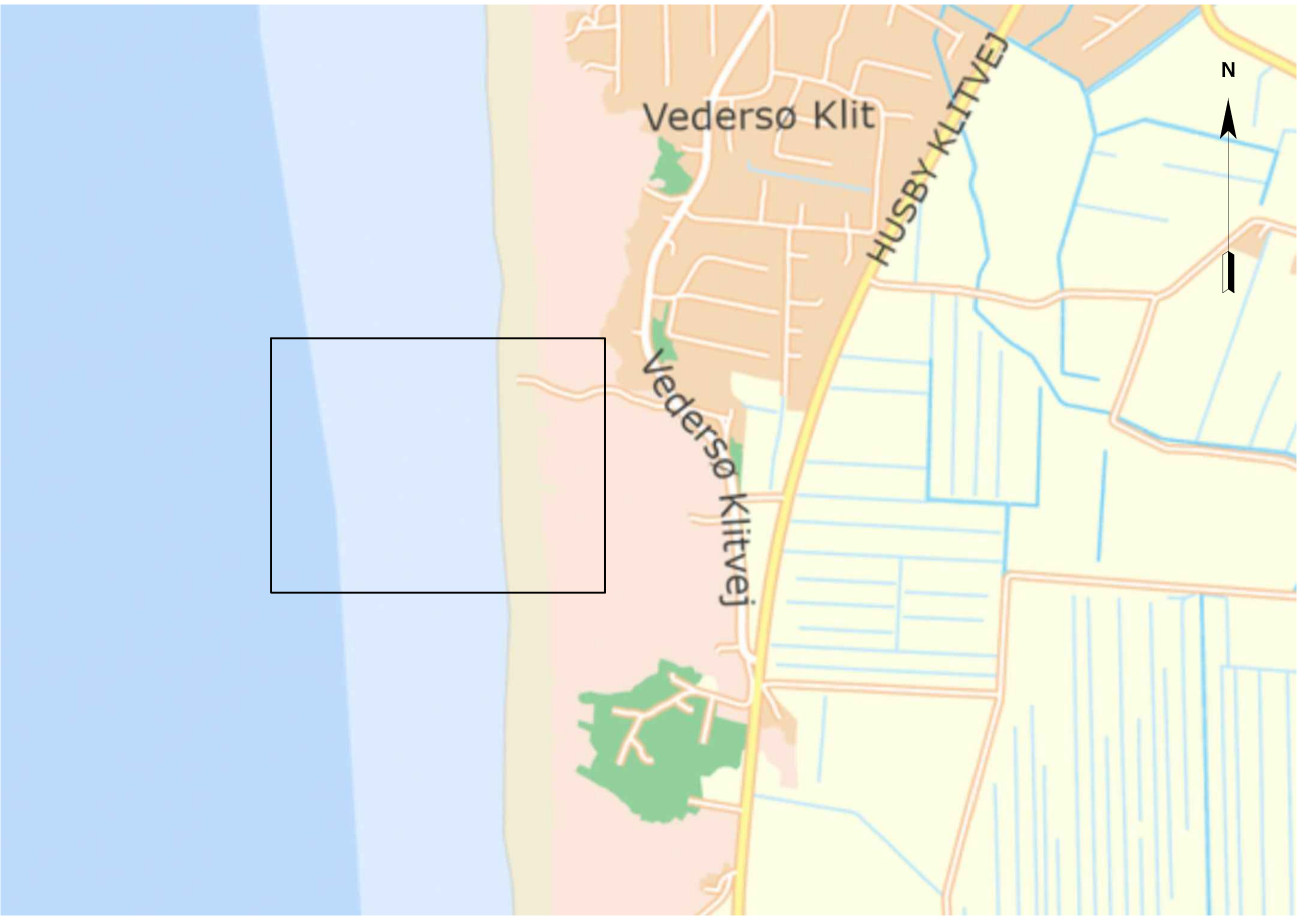
0   4   8 km

Project:	208116. Mere Havvind 2030
Subject:	Overview map - Location 1A

Scale	1:100.000 (A3)		Page 1 / 1
Report	1	Encl. 1.1.1	Rev.

Geo
Copenhagen +45 4588 4444
Aarhus +45 8627 3111

\\geo.local\GEODATA\projekter\208001-209000\208116_Energinet_MH2023_SGR7_Tegninger\208116_situationsplan_v0.dwg   2024-06-18   cbp   1A(1.1.1)



Legend:

Borehole with CPT

b ▽ a
a: Point no.
b: Terrain level

— Planned cable route

— Planned HDD

⊢ — ⊣ Location of longitudinal profile (Encl. 94.1.2)

— Seabed level 0,5 m

Coordinate system: UTM32E89
Level: DVR90

0 80 160 m

Project: 208116. Mere Havvind 2030
Subject: Landfall. Vedersø Klit 1AA

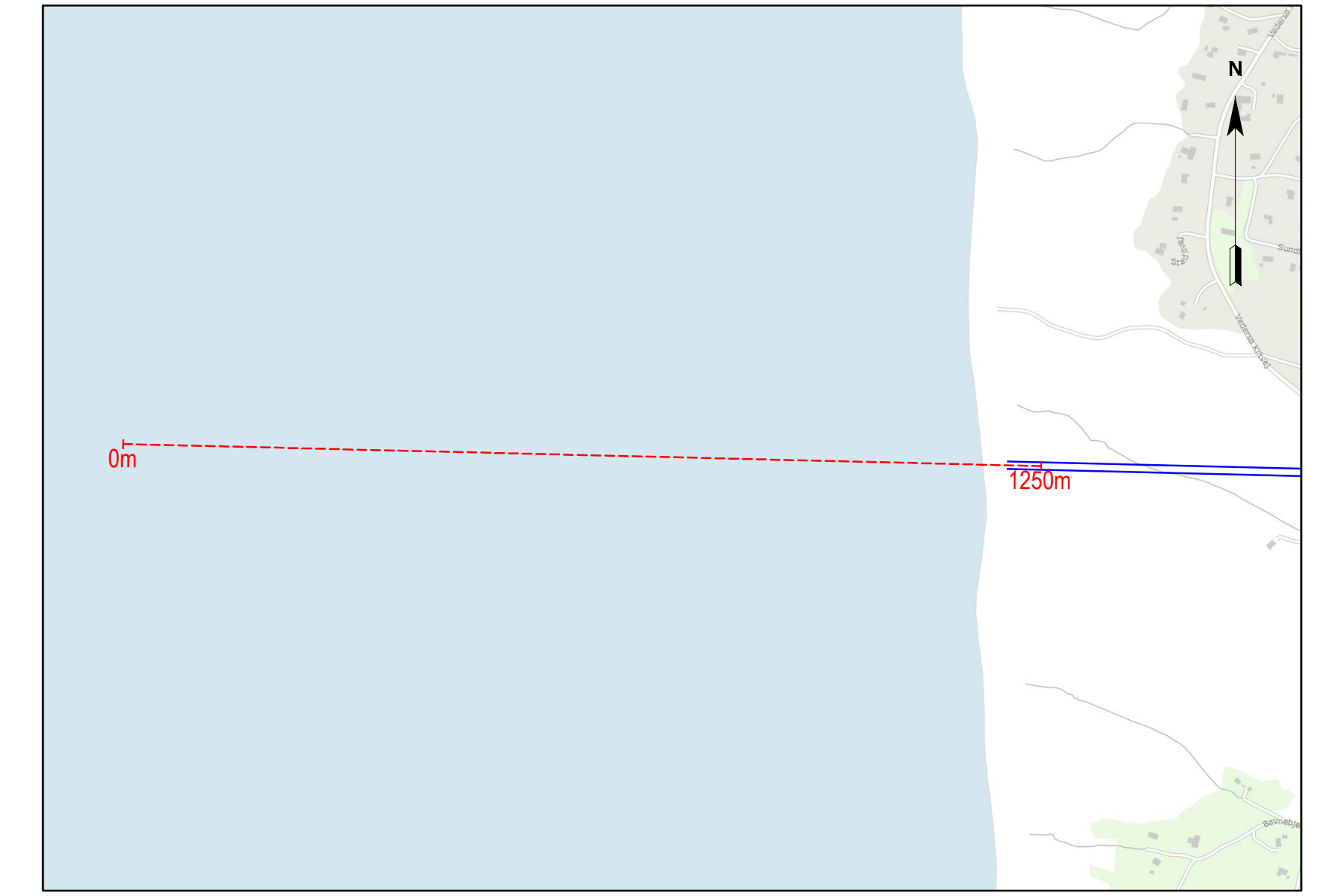
Scale 1:2000
Report 94

Page 1 / 1
Encl. 94.1.1
Rev.

Geo
Copenhagen +45 4588 4444
Aarhus +45 8627 3111

L:\projekter\208001-209000\208116_Energinet_MH2023_SGR\7_Tegninger\208116_situationsplan_v0.dwg 2024-11-21 kdu 3x1

L:\projekter\208001-209000\208116_Energinet_MH2023_SGR\7_Tegninger\AutoCAD filer\208116_længdeprofiler_landfall_v0.dwg 2024-11-26 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

Colorbar

1 10 100 1000

Resistivity (Ohmm)

------ 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 / 1
Subject: Longitudinal profile - Landfall Klit 1AA	Report 94	Encl. 94.1.2 Rev.

Geo
Copenhagen +45 4588 4444
Aarhus +45 8627 3111

Geo-Standard: Legend and Abbreviations

Borehole Profiles. Geotechnical, core and environmental

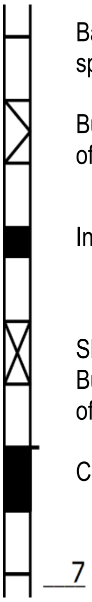
Description according to dgf-Bulletin 1, rev. 2, December 2021

Soil types

- Fill
- Flags / Concrete / Bedrock
- Mull / Top soil
- Humic
- Peat
- Peaty Gyttja
- Gyttja / Organic clay
- Plant remains
- Shells

- Slags
- Stone/Cobble
- Gravel
- Sand
- Silt
- Clay
- Limestone / Chalk
- Flint / Asphalt
- Sand till / Silt till (clayey, gravelly)
- Clay till (sandy, gravelly)

Samples



Bag sample (disturbed), specific level

Bulk sample (disturbed) of an interval, small bag

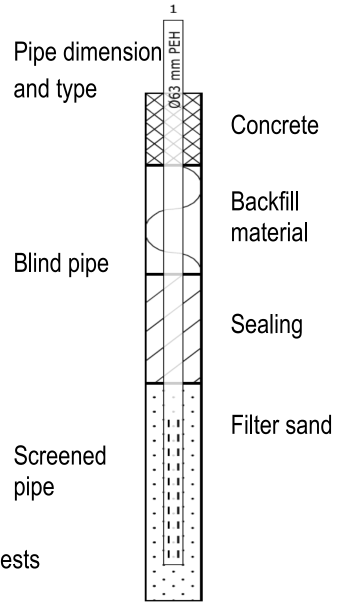
Intact tube sample

SPT sample or Bulk sample (disturbed) of an interval, large bag

Core sample

Additional laboratory tests ex. Sample 7

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

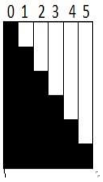
General abbreviations

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

Core samples

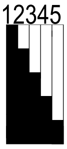
Recovery:	Ratio in percentage between sample length and length of core run (Total Core Recovery, TCR). Value appears at top of core run.
RQD:	Rock Quality Designation. Ratio in percentage between total length of core pieces with length more than 100 mm, and length of core run. Value appears at top of 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:

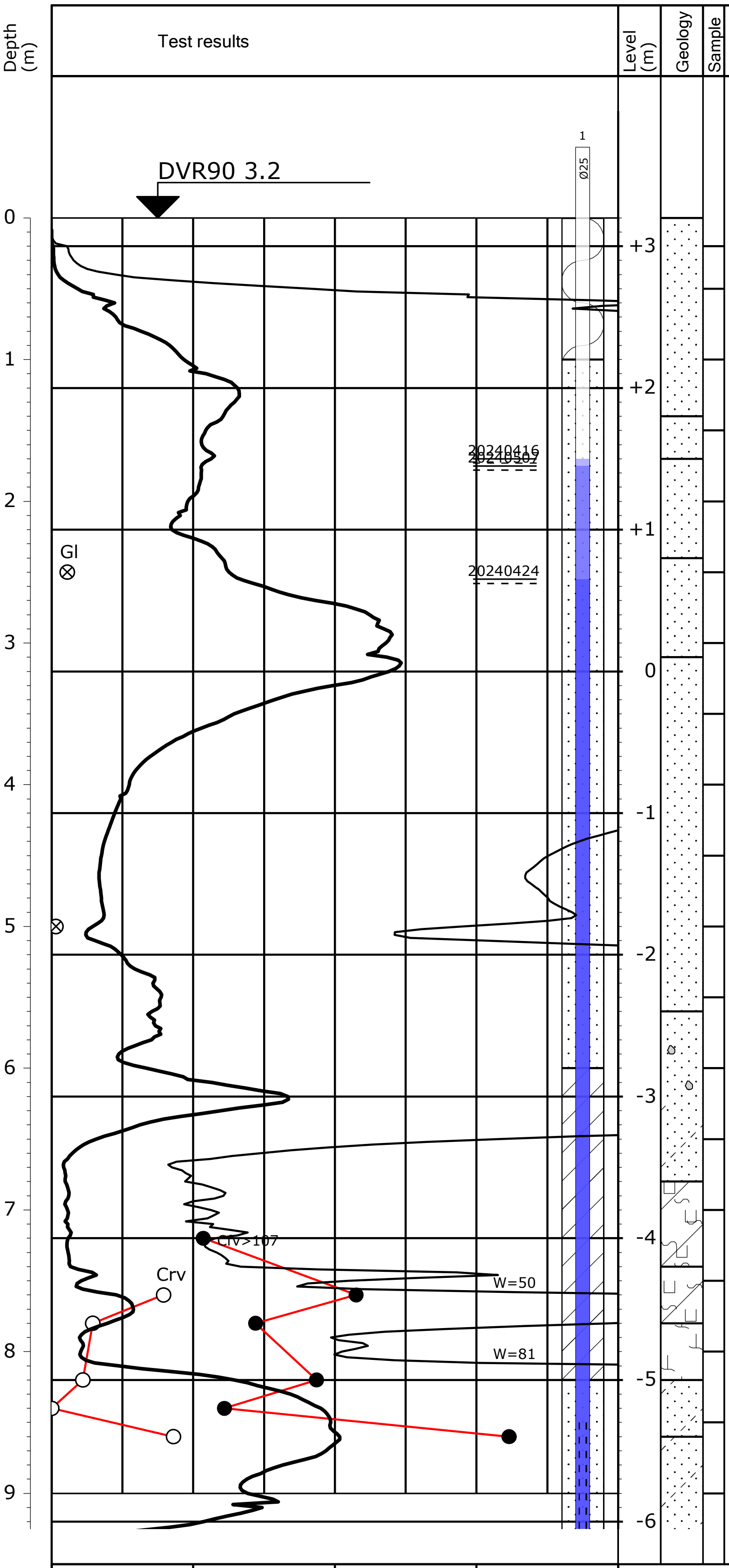
DS/EN 1997-1:2007 – Geoteknik-Del 1

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	SAND, medium, uniformly graded, noncalcareous, light grey	Ae	Pg
2	SAND - -	Ae	Pg
3	SAND, medium, uniformly graded, noncalcareous, light grey	Ma	Pg
4	SAND, medium, uniformly graded, noncalcareous, grey	Ma	Pg
5	SAND, medium, uniformly graded, noncalcareous, with discolerede specks, grey	Ma	Pg
6	SAND, medium, uniformly graded, noncalcareous, w. few organic parts, grey	Ma	Pg
7	SAND, medium, uniformly graded, noncalcareous, grey	Ma	Pg
8	SAND - -	Ma	Pg
9	SAND, medium, uniformly graded, noncalcareous, with discolored specks, grey	Ma	Pg
10	SAND, medium, uniformly graded, noncalcareous, grey	Ma	Pg
11	SAND - -	Ma	Pg
12	SAND - -	Ma	Pg
13	SAND, medium, uniformly graded, sl. gravelly, noncalcareous, grey	Ma	Pg
14	SAND, medium, poorly graded, silty, noncalcareous, w. few gyttja parts, w. few shell fragments, grey	Ma	Pg
15	GYTTJA, medium, uniformly graded, medium plasticity, very clayey, sl. calcareous, w. shell fragments, dark olive grey	Ma	Pg
16	GYTTJA, medium plasticity, clayey, sl. calcareous, w. shell fragments, dark olive grey	Ma	Pg
17	PEAT MUD, noncalcareous, w. few sand laminae, brownish black	Ma/ Fw	Pg
18	SAND, fine, graded, very silty, noncalcareous, w. few organic specks, grey	Ma/ Fw	Pg
19	SAND, medium, poorly graded, silty, noncalcareous, grey	Ma/ Fw	Pg

Continues

□	10	20	30	W (%)
⊗	2	4	6	Gl. (%)
○ ●	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 : 446168 (m) Y : 6233930 (m)

Job: 208116 Mere Havvind 2030

Drilled by: Geoboringer Date: 2024-04-16 Geology by: tan Borehole: 1A.01

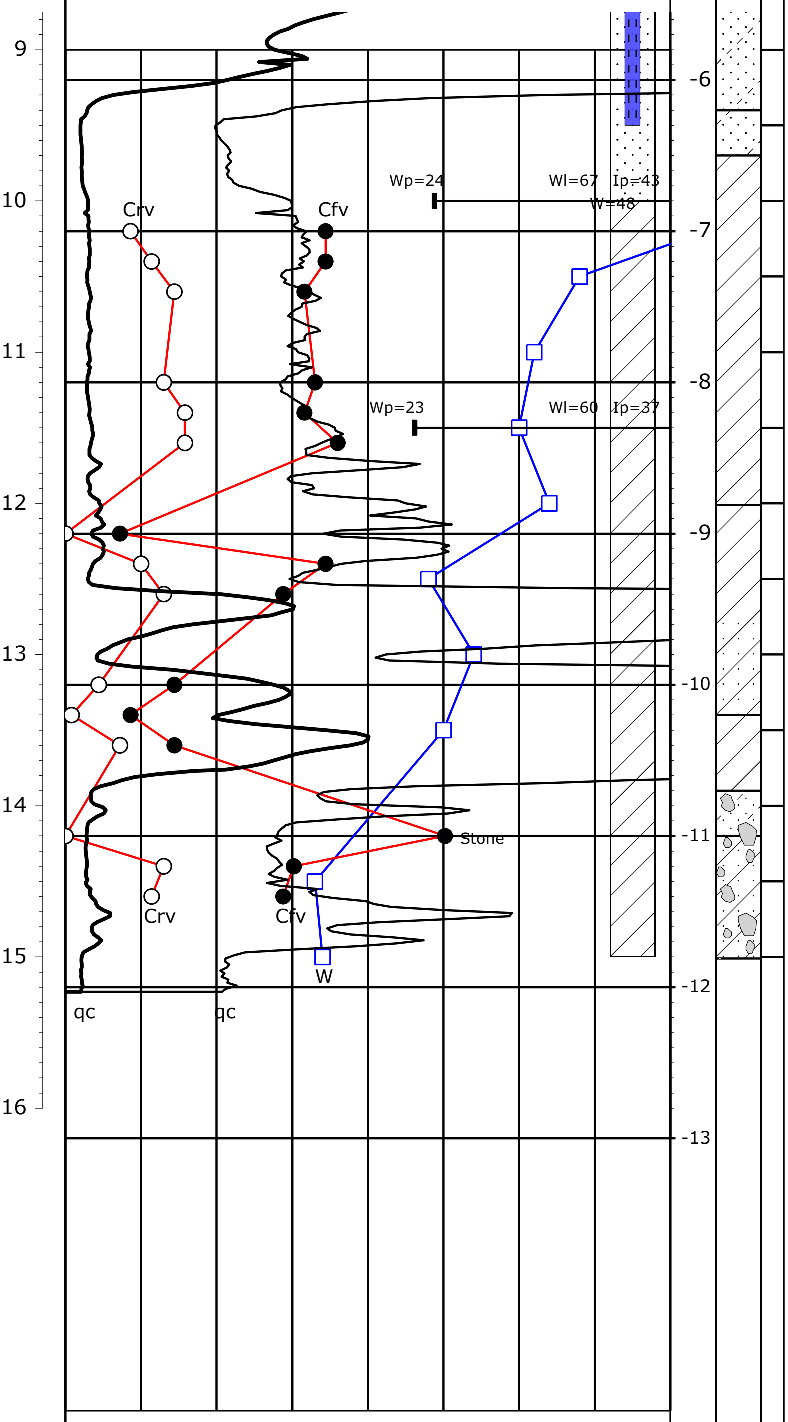
Method: Cased Shell & Auger 6'' DGU no: Encl. No.: 1.2.1 Rev.: 0 P. 1/2

Geo Copenhagen + 45 4588 4444
Geo Aarhus + 45 8627 3111

Profile

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

Continued



No.	Geological Description	Env.	Age
19	SAND, medium, poorly graded, silty, noncalcareous, grey	Ma/ Fw	Pg
20	SAND, fine - medium, graded, very silty, noncalcareous, w. few organic parts, w. few iron sulphide stains, brownish grey	Ma/ Fw	Pg
21	CLAY, high plasticity, noncalcareous, w. few sand specks, brownish grey	Mw	Lg
22	CLAY, high plasticity, calcareous, w. few sand specks, grey	Mw	Lg
23	CLAY, high plasticity, calcareous, w. few sand laminae, grey	Mw	Lg
24	CLAY, high plasticity, calcareous, w. sand specks, grey	Mw	Lg
25	CLAY, high plasticity, calcareous, grey	Mw	Lg
26	CLAY, medium plasticity, calcareous, grey	Mw	Lg
27	CLAY, medium plasticity, calcareous, w. sand parts, grey	Mw	Lg
28	CLAY, medium plasticity, sl. calcareous, w. sand laminae, dark grey	Mw	Lg
29	GRAVEL TILL, clayey, silty, sandy, sl. calcareous, dark grey	Gl	Gc
30	CLAY TILL, medium plasticity, sandy, sl. gravelly, calcareous, w. few sand parts, dark grey	Gl	Gc
31	CLAY TILL, medium plasticity, sandy, sl. gravelly, sl. calcareous, dark grey	Gl	Gc

□	10	20	30	W (%)
⊗	2	4	6	Gl. (%)
○ ●	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 : 446168 (m) Y : 6233930 (m)

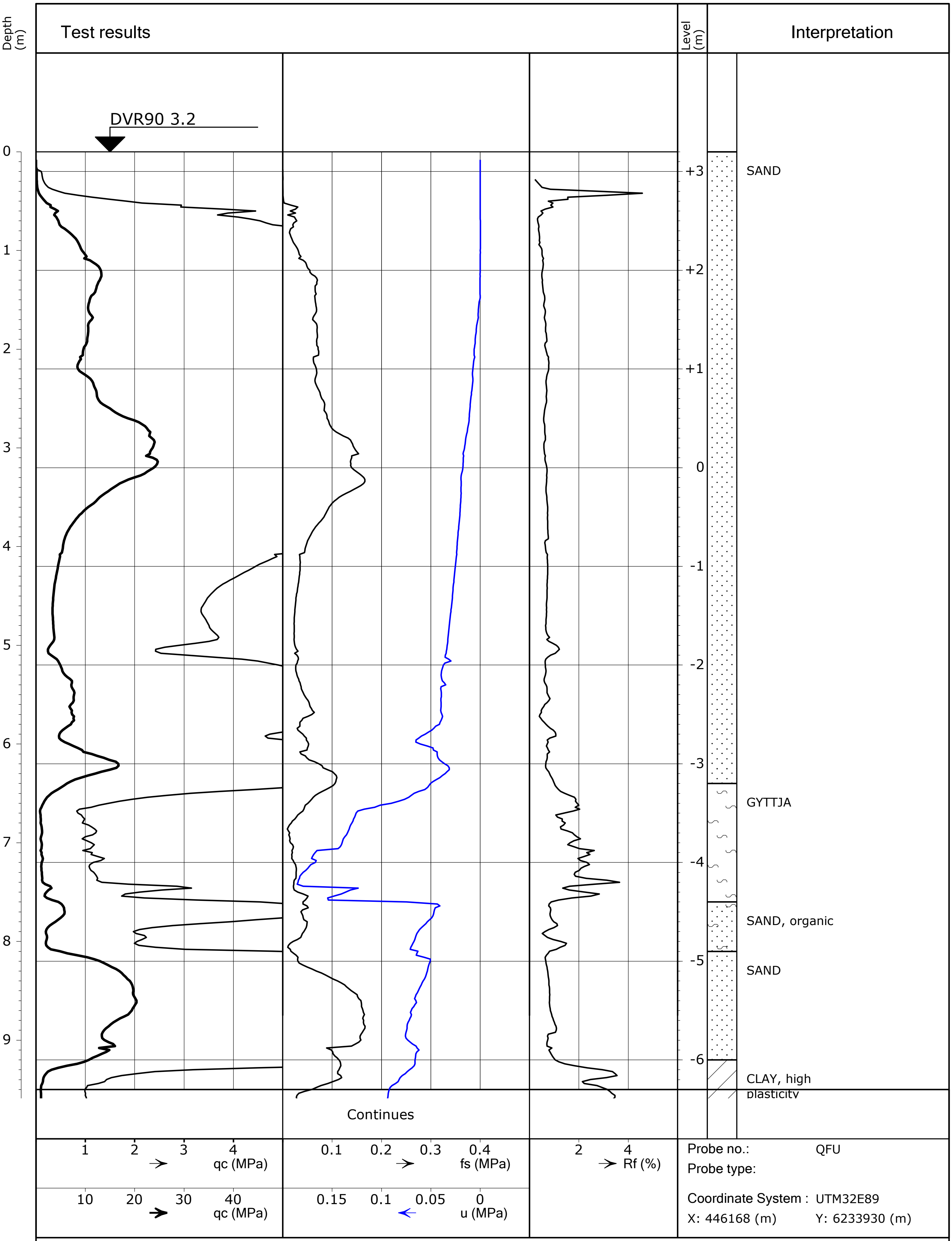
Job: 208116 Mere Havvind 2030

Drilled by: Geoboringer Date: 2024-04-16 Geology by: tan Borehole: 1A.01

Method: Cased Shell & Auger 6'' DGU no: Encl. No.: 1.2.1 Rev.: 0 P. 2/2

Geo Copenhagen + 45 4588 4444
Geo Aarhus + 45 8627 3111

Profile



Probe no.: QFU
Probe type:

Coordinate System : UTM32E89
X: 446168 (m) Y: 6233930 (m)

Project: 208116 Mere Havvind 2030

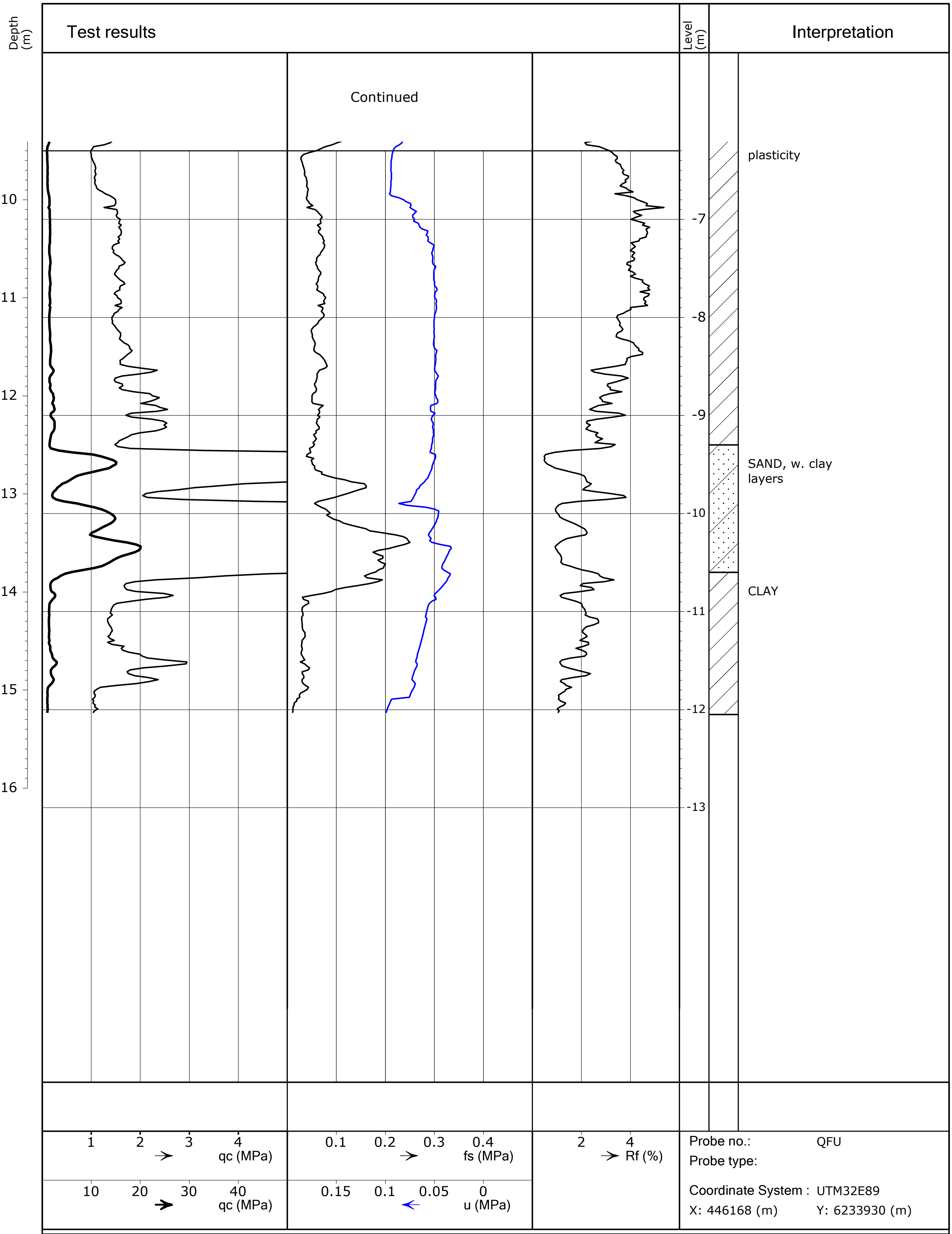
CPT by: Geoboringer Date: 2024-04-08 Interpretation: JDO Point no. : 1A.01.CPT

Profile by: JDO Control: NIO Approved: SGR Date: 2024-07-12 Encl.: 1.3.1 Rev.: 0 S. 1/2

Geo

Geo Copenhagen + 45 4588 4444
Geo Aarhus + 45 8627 3111

CPT profile



Probe no.: QFU

Probe type:

Coordinate System : UTM32E89

X: 446168 (m) Y: 6233930 (m)

Project: 208116 Mere Havvind 2030

CPT by: Geoboringer Date: 2024-04-08 Interpretation: JDO Point no. : 1A.01.CPT

Profile by: JDO Control: NIO Approved: SGR Date: 2024-07-12 Encl.: 1.3.1 Rev.: 0 S. 2/2

Geo

Geo Copenhagen + 45 4588 4444

Geo Aarhus + 45 8627 3111

CPT profile

GeoGIS2005 2.4.7 - GEOSQL08 - PSTCUK_Geo - 12-07-2024 11:30:41

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 loose sand, soft terrain / slippery surface at the beach. 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
Clay causing high friction on drilling rod (may be relevant)	Drilling speed decreases or drillings stops	T/F	3	B	Drilling supplier must use a suitable drilling mud to reduce friction. The drilling mud can have additive suitable to the soil conditions.	3	A
Unstable borehole (especially in frictional soils under the groundwater table)	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	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
HDD penetrating soft soil deposits like peat, gyttja, mull, etc.	Difficulty in maintaining the alignment of the HDD. Risk of blowout.	F/T	3	C	Changing the drilling alignment to higher/lower altitude (during the project planning process)	2	B
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.	3	B

					Ensure sufficient depth of HDD.		
Flooding of drilling pit due to heavy precipitation, 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

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

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