NorthConnect

Cable Burial Risk Assessment

CA Report No.: C831R01 - 04

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SUMMARY

NorthConnect is a project set up to develop, consent, build, own and operate an HVDC electrical interconnector between Peterhead in Scotland and Simadalen in Norway. The 665km long, 1400MW interconnector will provide an electricity transmission link allowing the two nations to exchange power and increase use of renewable energy. The intention is for the HVDC interconnector to be operational by 2023.

Under instruction from the Client, Cathie Associates has undertaken a Cable Burial Risk Assessment (CBRA) for the subsea cable route corridor from Boddam, Peterhead to Simadalen at the head of Hardangerfjord. This report presents the results of the CBRA for the complete subsea cable route corridor based upon the best industry practice as documented by the Carbon Trust CBRA Guidance and DNV guidelines.

The shallow geology of the survey corridor varies considerably across the entire route length: from loose to dense sands and extremely low to high strength clays; through to gravels, glacial Tills, boulder areas and outcropping bedrock.

The North Sea section mainly comprises of sands and lower strength clays. However, glacial Tills are expected to be subcropping at varying depth within the surveyed corridor between KP 1.35 and KP 5.1 in the UK nearshore, with some localised bedrock outcrops. High strength clays are also found within the first 5km of the UK landfall, generally overlying the Till, and in localised areas of the eastern slope of the Norwegian Trench (KP 447.5 to KP 456.2). Boulders are common within the first 62.5km of the route and within the Fjord.

Localised bedrock outcrops are noted on the approach to the Norwegian coastline, in particular between KP 470 and KP 474, and within the Hardangerfjord. Bedrock/Till is interpreted periodically in raised areas across the width of the Hardangerfjord. These may represent terminal moraine features; however the presence of bedrock has not been ruled out by the survey contractor. In the bottom of the Fjord, the sides of which are steep and rocky, clays of very low to extremely low strength are found. In many areas, these sediments are interpreted as being mass-transport deposits. Historic slip-scarp features occur regularly perpendicular to the Fjord length.

A HAZID workshop was conducted between Cathie Associates and NorthConnect KS. The outcome of this workshop was a set of hazard considerations to progress forward into this CBRA. Through the undertaking of the risk assessment, the most onerous hazards to the cables were identified as;

- Anchors from transiting vessels (Dropped in emergency circumstances)
- Fishing gear seabed interaction (Trawling, potting)
- Rock fall / Landslides (Fjord section)
- Submarine Slope Failures (Fjord section)

As agreed with NorthConnect KS a quantitative approach has been undertaken to understand the level of protection offered against anchoring by a range of burial depths as presented in Appendix B and discussed in detail in Appendix D. Maximum threatline depths

have also been determined for the other main hazards identified, and recommended minimum depths of lowering are proposed to mitigate these hazards as detailed in the CBRA table in Appendix B.

It should be noted that the Cable Burial Risk Assessment only considers hazards anticipated during the operational lifespan of the cable (and not during installation). The findings of this assessment have been used to inform a separate Cable Protection Analysis Report, which covers installation risks to the subsea cables.

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1. Introduction

1.1 Background

NorthConnect is a project set up to develop, consent, build, own and operate an HVDC electrical interconnector between Peterhead in Scotland and Simadalen in Norway. The 665km long, 1400MW interconnector will provide an electricity transmission link allowing the two nations to exchange power and increase use of renewable energy. The intention is for the HVDC interconnector to be operational by 2023.

NorthConnect KS is a Joint Venture (JV) project company owned by four community and state-owned partners from Norway and Sweden: Agder Energi AS, E-CO Energi AS, Lyse Produksjon AS, and Vattenfall AB. The partnership was established on 1st February 2011.

A 550m corridor has been surveyed by MMT and the cable routes will be optimised within this corridor based on the results of the survey. Within the UK 12NM limit, a 60m wide "Conceptual Installation Corridor" will be defined for the purposes of environmental consenting.

Under instruction from the Client, Cathie Associates has undertaken a Cable Burial Risk Assessment (CBRA) for the complete route from Long Haven Bay, Peterhead to Simadalen, Handangerfjord. The findings of this assessment (cable risk threatlines and other seabed features) will be used to inform protection levels and a separate Cable Protection Analysis Report. The Cable Protection Analysis Report (CPAR, C831R02) will comprise a burial assessment of the cable corridor for different tool types and a review of burial tools currently available in the market along with consideration of alternative forms of cable protection where these may be required.

1.2 Objectives and Purpose of Document

The objectives of this study are to summarise all available data pertaining to the seabed conditions along the length and width of the cable route corridor and identify potential hazards to the NorthConnect Interconnector cables. This report is focussed on hazards which pose a threat during the operational lifetime of the cables, whilst the CPAR focusses on risks associated with installation.

Based upon the threatlines identified, minimum recommended depths of lowering (depth from mean seabed level to top of product) have been derived based upon the fishing threatline depth and mobile sediment amplitude (of large ripple class and smaller) to protect the cable from fishing as a minimum (residual risk from shipping is discussed separately within the report). Separately, NorthConnect have developed front-end engineering design (FEED) protection levels (A, B, C, D) that are to apply to each section. These use the threatlines, probabilistic anchor risk and seabed conditions as presented in this report to produce two burial depths for both "Hard" and "Soft" sediment conditions, with the definitions of being those as-used for anchor assessment (namely soft soils comprising clays of <40kPa shear strength, and hard soils comprising higher strength clays and/or sands).

The purpose of this document is to assess risk along the NorthConnect route corridor in order to assist with deriving risk-informed protection levels, and to inform the CPAR.

Figure 1: Overview of the NorthConnect survey corridor and original survey sections (Ref. 1)

1.3 Aim and Scope of Work

The aim of this work scope is to inform the route engineering and cable protection strategy. The scope of work is as follows:

- Review of all available data to establish ground conditions and establish any data gaps
- Review of existing hazard and risk assessments and update as necessary based upon latest available information
- HAZID workshop and establishment of Risk Register
- Characterisation of areas of mobile bedforms
- Shipping assessment based on third party AIS dataset
- Derivation of threatline depths below the seabed for the identified hazards
- Anchor penetration study including probabilistic assessment to inform risk-based target burial depths
- Production of a CBRA Report including Alignment Charts to document the findings of the study and inform the next phase of the engineering i.e. the CPAR

1.4 Abbreviations

A list of the abbreviations used in this report is provided in Table 1.

Table 1: List of abbreviations

Abbreviation	Description
AIS	Automatic Identification System
ALARP	As Low As Reasonably Practicable
BAS	Burial Assessment
bsbl	Below Sea bed level
CBRA	Cable Burial Risk Assessment
Client	NorthConnect KS
CPAR	Cable Protection Analysis Report
DOL	Depth of Lowering (to top of product)
DTS	Desk Top Study

Abbreviation	Description
FEED	Front End Engineering Design
IMR	Inspection Maintenance Repair
KP	Kilometre Post
LAT	Lowest Astronomical Tide
MAG	Magnetometer
MBES	Multi-beam Echo Sounder
mbsbl	Metres Below Sea Bed Level
MSL	Mean Sea Level
N/A	Not Available
NM	Nautical Mile
CPT	Cone Penetration Test
RSBL	Reference Sea Bed Level
SBP	Sub Bottom Profiler
SCL	Survey Centre Line
SSS	Side Scan Sonar
UXO	Unexploded Ordnance
VC	Vibrocore
OOS	Out of Service (infrastructure)

2. Data Adequacy Review

2.1 Data Sources

Several Front-End Engineering Design reports have been undertaken for the project including a Desk Top Study (DTS), incorporating a preliminary hazard assessment and cable route engineering; and an initial Cable Protection Study comprising risk assessment and trenchability assessment by the Client. In addition, a geophysical, benthic and geotechnical investigation of the cable route has been performed: the results of which have been used to inform both this CBRA report and the CPAR.

The Client supplied the following documents for use in the assessment:

1. MMT, Geotechnical Report: 102273-NOC-MMT-SUR-REP-GEOTECH (Feb 18)
2. MMT, Geophysical, Benthic and Geotechnical Route Survey: Final Survey Report, Ref: 102273-NOC-MMT-SUR-REP-SURVEYRE (May 18)
3. MMT, Geophysical, Benthic and Geotechnical Route Survey: Field Operations Report, Crossing and Inspection Survey, Ref: 102273-NOC-MMT-SUR-REP-CIFREPLB (Nov 17)
4. MMT, Geophysical, Benthic and Geotechnical Route Survey: Field Archaeological Report, Ref: 102273-NOC-MMT-SUR-REP-FIELDALB (Apr 17)
5. MMT, Geophysical, Benthic and Geotechnical Route Survey: Geophysical and Geotechnical Alignment Chart(s), RPL-R09, Route B (Mar 18)
6. NorthConnect, RPL-RouteB-R09 (Nov 17)
7. MMT, Contact and Anomaly lists, UK Nearshore and North Sea, project 102273 (Survey Report Appendix)
8. NorthConnect, Attachment E01.10 - Requirements to Submarine Cable Protection (16/04/18)
9. Xodus, Desk Top Survey and Route Engineering Study: Route Option Analysis Report, Ref: A-30722-S04-REPT-002 (Sep 12)
10. MMT, GIS data, WebGIS portal data
11. Riggall & Associates, Conceptual HDD Design Norther / Southern Alignment, Drawing No. 20160401RA-C/01 and 04 (May 16)
12. 6 Alpha, UXO desk top study (May 17)
13. NGI, Hardangerfjord Geohazard Assessment, Document number 20180094-01-R (Mar 18)
14. NorthConnect, Attachment E02.02.01 Annex 1: List of Crossings (25/04/18)

The following additional non-project specific references have been used:

15. BGS, 1994. Geology of the central North Sea. London: HMSO
16. BGS 1:250000 UTM series of the United Kingdom and continental shelf, sheet 57N-02W, Peterhead, 1986.
17. Carbon Trust, Cable Burial Risk Assessment Methodology, Guidance for the Preparation of Cable Burial Depth of Lowering Specification, CTC835, February 2015
18. Carbon Trust, Application Guide for the Specification of the Depth of Lowering using the Cable Burial Risk Assessment (CBRA) methodology, Dec 2015
19. DNV-RP-F107, Recommended Practice, Risk Assessment of Pipeline Protection, October 2010
20. Deltares, 2013. Anchor Tests German Bight. Document Number 1207052-002-GEO-0003
21. Eigaard, O.R. et al, 2015. Estimating seabed pressure from demersal trawls, seines and dredges based on gear design and dimensions. *ICES Journal of Marine Science*.
22. Marine Management Organisation, UK Sea Fisheries Statistics 2015, 2015.
23. Marine Traffic, AIS Traffic Data, whole NSL route – two full calendar years 10/2015 to 09/2017 © marinetraffic.com 2015/2017
24. Shapiro S., Murray J., Gleason R., Barnes S., Eales B., and Woodward P., (1997) Threats to Submarine Cable, SubOptic '07, San Francisco.
25. DNV, Subsea Power Cables in Shallow Water, DNV-RP-J301, 2014.
26. Vryhof Anchors, Anchor Manual 2010 – The Guide to Anchoring, 2010
27. MAIB, 1997. Report of the Inspector's Inquiry into the loss of the Fishing Vessel Westhaven AH 190 with four lives on 10 March 1997 in the North Sea.
28. Marine Scotland web GIS portal: https://marinescotland.atkinsgeospatial.com/nmpi/
29. Norwegian fisheries map data: https://kart.fiskeridir.no/
30. Postglacial mass movements and depositional environments in a high-latitude fjord system – Hardangerfjorden, Western Norway (Benjamin Bellwald, Berit Oline Hjelstuen, Hans Petter Sejrup, Haflidi Haflidason)

Under instruction from NorthConnect KS, Cathie Associates has also completed the following separate studies:

31. Cathie Associates, Cable Protection Analysis Report, C831 R02
32. Cathie Associates, UK 12 NM Detailed Burial Assessment, C831 R03

2.2 Data Adequacies and Gaps

An appraisal of the available information is presented in Table 2.

Table 2: Data appraisal

Data Requirement	Data Adequacy	Comments
Geophysical Data	✓	
Bathymetry	✓	
Seabed Features	✓	
Shallow Geology	✓	Seismic interpretation has been combined with geotechnical sampling to inform shallow geology characteristics
Geotechnical Data	✓	
GIS	✓	
Metocean Data	✓	
Sediment Mobility	✓	Characteristics of mobile bedforms identified during the geophysical surveys have been recorded in the survey report, however a dedicated sediment mobility study has not yet been undertaken.
UXO	✓	UXO data is discussed in the CPAR, as this is an installation rather than lifetime risk. Preferred strategy is avoidance rather than removal following detailed survey.
Wrecks	✓	
Exclusion Zones	✓	
Fishing	✓	
Shipping	✓	
Dredging and Dumping	✓	
Existing Infrastructure	✓	

Data Requirement	Data Adequacy	Comments
Cable Specification	×	Not yet available
RPL	✓	References to KPs are based on the Survey Centre Line. KPs are correct for RPL09.
Slope stability	✓	NGI report has assessed slopes identified as most critical

The available data supplied by the Client and gathered by Cathie Associates during the assessment from third party sources has been deemed generally acceptable to undertake this cable burial risk assessment.

2.2.1 A note on Route Positioning Lists (RPL's)

KP distances are given according to RPL09, however sample localities and the start and end of each assessed section are also referenced in Easting/Northing co-ordinates in the event that the RPL is updated further.

This report (C831R01), as well as the CPAR (Ref. 31) has been carried out using the survey centre-line of RPL09 as the basis of the KP system and recording of seabed features. According to RPL09, the HDD exit is located at KP 0.1. A separate report (Ref. 32) covers the UK 12 Nautical Mile area (to KP 27.7) in greater detail and presents an amended RPL/KP system to account for some minor re-routing.

3. Assessment of Seabed Conditions

3.1 Bathymetry and Seabed Features

The bathymetry and seabed features have been summarised from the latest survey data (Ref. 1) and alignment charts (Ref. 5) in the CBRA table in Appendix B. The main seabed features observed are:

- Surface boulders: Surface boulders of varying density are found mostly within the first 50km from the UK landfall, and in parts of the Fjord. The implications of boulders on cable installation are discussed in detail in the CPAR (C831R02) and 12NM BAS (C831R03).
- Mobile sediments: Found mostly within the first 62.5km of the UK landfall (see section 5.3.1 for discussion on mobile sediments)
- Iceberg plough marks: The base of icebergs during the previous ice age have carved marks into the seabed between KP 415 and KP 456. Clay strength is variable in parts of this area depending upon the level of reworking and soft clay infill.
- Trawl marks: Evidence of demersal fishing, found across most of the North Sea. See section 5.2.3 for discussion of fishing.
- Pockmarks: Naturally occurring depressions in the seabed found regularly between KP 80 and KP 415, noted in the CBRA table, Appendix B. These should be avoided by the final route as they are generally steep-sided their formation is associated with potentially corrosive gas.
- Potential slip scarps across the cable route and landslides from the Fjord sides. See sections 5.2.6 and 5.2.7 for further discussion.
- Outcropping / thinly covered bedrock: In the UK nearshore c. KP 4, outcropping bedrock is noted (avoided though later routing). Within the Fjord, Bedrock/Till and Bedrock areas are common. In the latter case, many of these areas may be avoided by routing (See CPAR Appendix Table, Ref. 31) to allow the cable to be buried in soft sediment, however between KP 470 and KP 474, shallow bedrock is generally unavoidable.

A bathymetric profile of the route is given in Figure 3, section 3.4.1. This shows the rapid deepening from the UK end of the route into the North sea , the deep Norwegian Trench (maximum 280m on route), and the very deep water found within Handangerfjord (maximum c. 850m). Water depth holds implications for anchor strike risk and the probabilities of successful anchor deployment. This is discussed in Appendix D. Discussed in section 3.4.1 are the potential moraine Till or bedrock ridges that can be seen on the profile between KP 450 and KP 600.

3.2 Existing Infrastructure

A large number of cables and pipelines (both in service and decommissioned) are indicated to cross the cable route. A comprehensive list is provided in Ref. 14, and crossing locations, infrastructure type and burial status (North Sea only) are also detailed in Appendix B (note this includes some repeat crossings). Not all of this infrastructure will be crossed using a designed crossing, e.g. disused cables will be cut and cleared from the route.

It should also be noted that the presence of some of this infrastructure could not be confirmed during the survey e.g. the disused Aberdeen-Bergen telegraph cable, where nothing was found at the expected location, however a cable was detected c. 4km closer to the UK. The telegraph cable could either have been cut and subsequently moved from its original position, or the as-found location could represent an unrecorded cable, leaving the Aberdeen-Bergen cable unfound.

At the time of the subsea inspection, the Hywind export cable at KP 10.964 (RPL09) was located in a partially covered, very shallow trench. At the time of writing, the cable has been protected using placed rock berms. This has required almost 60,000 tons of rock placed along the majority of the length of the 24km export cable. The example of the Hywind export cable and how any lessons-learned may impact the cable installation strategy of NorthConnect is discussed in detail in the detailed 12NM burial assessment (Ref. 32).

Consultation with the relevant stakeholders and appropriate crossing agreements should ensure that the risk associated with these assets is safely mitigated. Once the specific requirements of the Crossing Owners are understood, a suitable cable protection strategy for these areas can be developed to ensure the residual risk is ALARP. Crossing protection e.g. mattressing/rock placement will be discussed in the CPAR.

3.3 Regional Geology Summary

Publicly available information from the BGS (Ref. 15, 16) and the DTS (Ref. 9) has been consulted to provide an initial assessment of the of regional geology in the North Sea. The principal formations within the uppermost 3m of the seabed are listed in the following tables for information purposes, although detailed information is taken from the more recent MMT survey.

Table 3: Shallow soil formations expected in the UK Sector (upper 3m)

Soil Formation	**General Description**
Holocene	Veneer of surficial SANDS
Forth Formation Upper	Medium dense to very dense fine SAND, locally gravelly
Forth Formation Lower	Very soft to stiff slightly sandy CLAY, partings and layers of sand. Near the Scottish coast, includes the St Andrew's Bay member, soft to stiff laminated plastic CLAY with gravel
Wee Bankie Formation	Till interbedded with thin layers of sand and silty clay, coarse sand and gravel deposits, resting on bedrock or pre-Quaternary Sediments
Witch Ground Formation	Very soft to soft slightly sandy CLAY with fine to coarse gravel, can grade to SILT or to SAND soils at the margins of the Witch Ground Basin
Coal Pit Formation	Firm to very stiff CLAY and dense to very dense SAND

Table 4: Shallow soils expected in the Norwegian Sector (upper 3m)

Soil Formation	General Description
Flags Formation	Correlates with Witch Ground Formation in UK sector. Very soft to soft CLAY
Viking Bank Formation	Generally well-sorted sands, forming topographic rises, clays at base can form channel-fill deposits
Kleppe Senior Formation	Very soft to soft CLAY, correlates with Witch Ground in time and soil character
Norwegian Trench Formation	Gravelly stiff to hard CLAY
Tampen Formation	Firm to very stiff sandy silty CLAY, sand partings and local gravel lenses
Sperus Formation	Mainly firm to very stiff, sandy silty CLAY with shells and pebbles
Cape Shore Formation	Reworked soil, predominantly sandy with pebbles. Grades to more clay-dominated soil further north
Ferder Formation	Mainly firm to hard sandy gravelly CLAY, some sections more laminated with silt and sand layers
Bedrock (Pre-Quaternary)	May outcrop (depending on interpretation) locally at seabed approaching the coast, crystalline.

Table 5: Approximate Distribution of Geological Formations

Approx. KP from	Approx. KP to	Formation(s)
0	45	Forth Upper/Lower Formations Wee Bankie Formation (sub-cropping, outcropping on Port survey line) between KP 1.35 and KP 5.1
45	60	Coal Pit Formation
60	224	Witch Ground Formation
224	360	Flags, Viking, Sperus, Cape Shore, Ferder Formations
360	370	Tampen, Viking Bank, Sperus Formations
370	380	Kleppe Snr., Norwegian Trench Formations
380	460	Kleppe Snr. Formation
460	480	Tills, Bedrock
480	664	Fjord. Soft sediments punctuated by Till (possibly glacial moraine) or bedrock ridges across Fjord.

Note that these KP distances (For the range 0 - 480) are approximate and obtained from geological map information, with the exception of the Wee Bankie Formation, which is likely to be correlated with the sub-cropping Till observed on the MMT alignment charts 4000 and 4001 (Ref. 5).

The bedrock at the UK coastline (which the HDD will pass through) is granite. Consultation with BGS maps suggests that the bedrock encountered in the vicinity of KP 4 is conglomeritic sandstone, although this is to be avoided (See C831R03 detailed BAS)

Any bedrock encountered approaching the Norwegian coast or within the Fjord is expected to be granitic or metamorphic in nature, such as between KP 470 and KP 474.

3.4 Shallow Geology

The shallow geology has been assessed based upon the findings of the detailed geophysical survey and the geotechnical sampling undertaken by MMT and presented on their charts (Ref. 1, Ref. 2, Ref. 6). Where further interpretation has been undertaken by Cathie Associates this has been indicated.

The shallow geology of the survey corridor varies considerably across the entire route length: from loose to dense sands and extremely low to high strength clays; through to gravels, glacial Tills, boulder areas and outcropping bedrock.

The North Sea section mainly comprises of sands and lower strength clays. However, glacial Tills are expected to be subcropping at varying depth within the surveyed corridor between KP 1.35 and KP 5.1 in the UK nearshore (Possibly the Wee Bankie Formation), with some localised bedrock outcrops. High strength clays are also found within the first 5km of the UK landfall, generally overlying the Till, and in localised areas of the eastern slope of the Norwegian Trench (KP 447.5 to KP 456.2). Boulders are common within the first 62.5km of the route and within the Fjord.

Localised bedrock outcrops are noted on the approach to the Norwegian coastline, in particular between KP 470 and KP 474, and within the Hardangerfjord. Bedrock/Till is interpreted periodically in raised areas across the width of the Hardangerfjord, with a veneer of soft sediment. These may represent terminal moraine features; however the presence of bedrock has not been ruled out by the survey contractor. In the bottom of the Fjord, the sides of which are steep and rocky, clays of very low to extremely low strength are found. In many areas, these sediments are interpreted as being mass-transport deposits. Historic slip-scarp features occur regularly perpendicular to the Fjord length.

Geological conditions are summarised on a section by section basis in Table 6 of section 3.4.2. Further discussion of the expected geology is also included in the CPAR, (C831R02, Ref. 31) and 12NM Detailed BAS (C831R03, Ref.32) where it is discussed in relation to anticipated burial tool performance.

3.4.1 Inner Fjord Ridges

Relatively steep, pronounced, bathymetric ridges periodically cross the Fjord perpendicular to the cable. MMT sub-bottom profile sections interpret these features as Till or Bedrock/Till in different locations. The example shown in Figure 2 below (Peak KP 521.75) is interpreted as Till. The scale of these features is best seen on an overview profile of route bathymetry (Right hand side of Figure 2). This profile between KP 400 and KP 600 suggests these features could be interpreted as terminal or push moraines, left behind after pulses of re-advancement during overall glacial retreat following the last glacial maximum (LGM), although where Bedrock/Till is interpreted, shallow rock should not be ruled out. Only one sample (VC 15-SS-01, KP 592.698) appears to possibly encounter the top of this Till, recording fine to medium sand below 0.7m.

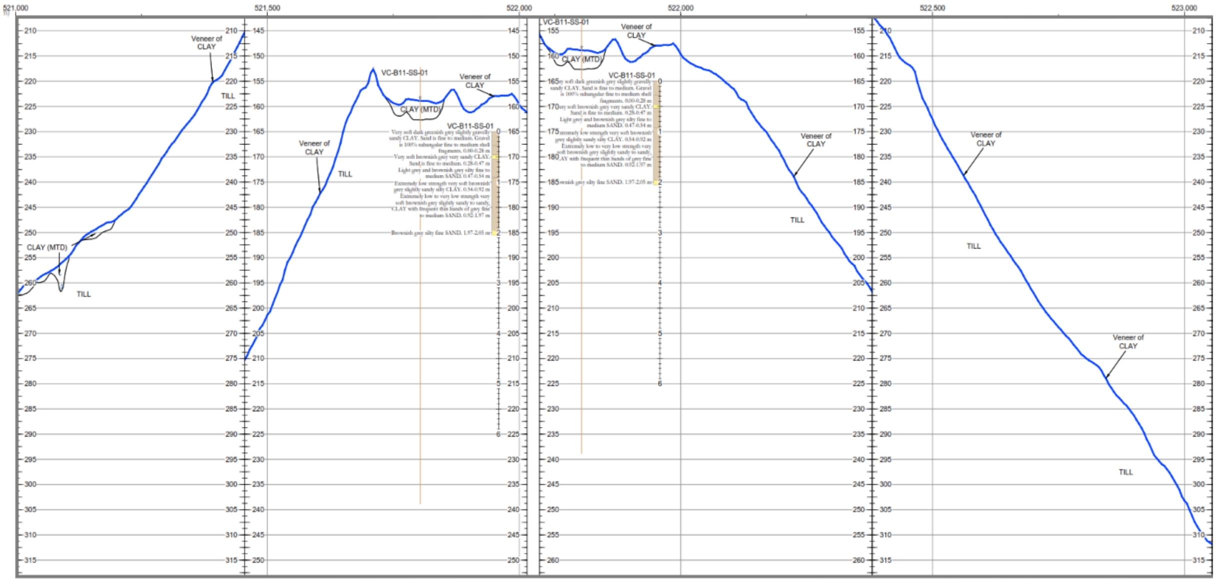

Figure 2: Bathymetry and interpretation of a Fjord ridge (MMT Chart 4114)

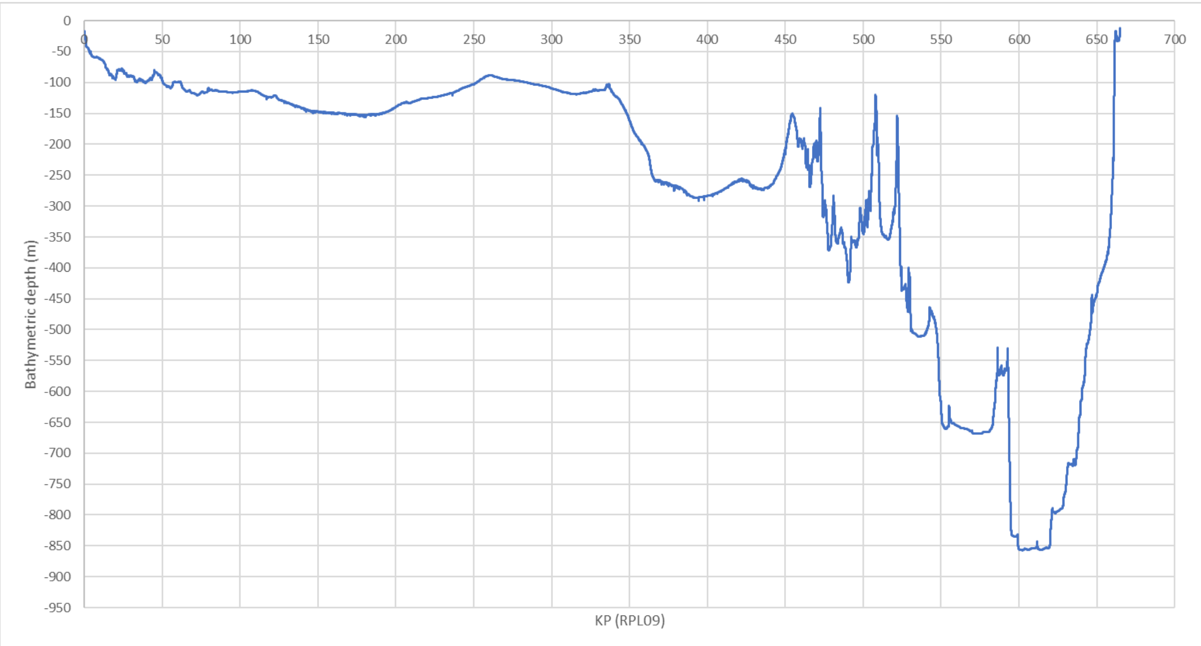

Figure 3: Route Bathymetry (Ref. 2)

Significant seabed gradients are associated with the area. The issue of seabed gradients, slope stability hazards and how they will impact the installation is covered in more detail in the CPAR (Ref. 31), although if burial tools cannot be used due to gradient, external protection may be provided.

If and where bedrock is exposed or covered by very thin sediments (insufficient for burial), stabilisation and protection of the cable will be achieved by means other than burial, most likely using rock placement. It is often possible to route the cable away from interpreted outcropping/sub-cropping bedrock and allow burial into the seabed. Steep seabed gradients that are impassable by burial equipment may also see the cable surface-laid and protected by external protection. Another solution could be to operate a jet trencher in free-flying mode, as discussed in the CPAR report (Ref. 31).

3.4.2 Geological and Geotechnical conditions along the route

Assessment of the geology using CPT and Vibrocore samples in addition to sub-bottom interpretation allowed the route to be divided according to expected geological/geotechnical conditions. Clay strengths are outlined in Table 7. The CBRA table provides an assessment of the geology on a section-by section basis, and the description of each section is reproduced below in Table 6. These expected conditions were used to define the dominant sediment type in the shipping zones for anchor penetration calculation purposes, see section 5.2.1. The KP extents of the shipping zones were derived based upon both geology and traffic density, see Appendix D.

Table 6: Route Section Geology

KP From	KP To	Brief Description of Geology expected in section
0	0.1	BEDROCK (HDD)
0.1	1.35	SAND over dense SAND
1.35	3.7	Veneer of SAND/GRAVEL over 0.5-4m CLAY over TILL. SAND present under clay in some areas. (Clay medium to high strength)
3.7	4.47	Veneer of SAND/GRAVEL over 1-2m CLAY over TILL, BEDROCK outcrops. (Expect Clay medium to high strength)
4.47	4.60	Veneer of SAND/GRAVEL over 0.5-1m CLAY over TILL (Expect clay of medium to high strength)
4.60	5.10	Veneer of SAND/GRAVEL over TILL (Expect Till/Clay to be medium to high strength)
5.1	5.75	0.4-0.7m GRAVEL or very gravelly SAND, over CLAY (Clay low-medium strength)
5.75	14.20	0.4-0.7m GRAVEL or very gravelly SAND, over CLAY (Clay low-medium strength)
14.20	15.00	0.4-0.7m GRAVEL or very gravelly SAND, over CLAY (Clay low-medium strength)
15.00	20.00	0.5m gravelly SAND over CLAY (Clay borderline medium/low strength)
20.00	24.00	Areas of CLAY and areas of SAND to depth
24.00	27.70	0.2-0.6m SAND over CLAY (Low Strength)
27.70	32.50	0.2-0.6m SAND over CLAY (Low Strength)
32.50	40.00	0.2-0.6m SAND over CLAY (Low Strength)
40.00	44.50	2m SAND over CLAY (Low strength)
44.50	49.75	CLAY (Very low strength) Variable thickness of loose SAND cover, up to 1.2m
49.75	60	CLAY (Very low strength) Variable thickness of loose SAND cover, up to 1.2m
60.00	72.75	CLAY (Very low strength) Variable thickness of SAND cover (Samples suggest 0.75-2m)

72.75	79.50	CLAY (Extremely low strength) Variable thickness of SAND / SILT cover (Sample suggest 0.8-2m.
79.50	102.00	0.6-1m SAND/SILT over extremely/very low strength CLAY
102.00	107.50	CLAY (Extremely low strength)
107.50	119.60	CLAY (Extremely / very low strength)
119.60	126.00	CLAY (Extremely low strength)
126.00	200.00	CLAY (Extremely low strength)
200.00	224.00	CLAY (Extremely low strength)
224.00	240.50	SAND and CLAY (Extremely low strength)
240.50	276.00	SAND to depth
276.00	290.50	SAND to depth
290.50	341.50	Areas of SAND and CLAY (Extremely/Very Low Strength)
341.50	348.50	CLAY (Extremely/Very Low Strength)
348.50	363.50	CLAY (Extremely Low Strength)
363.50	390	CLAY (Extremely/Very Low Strength)
390	409.50	CLAY (Extremely Low Strength)
409.50	413.00	CLAY (Extremely Low Strength)
413.00	415.00	CLAY (Extremely Low Strength)
415.00	427.75	CLAY (Extremely Low Strength)
427.75	430.00	CLAY (Extremely Low Strength)
430.00	447.50	CLAY (Extremely Low Strength)
447.50	456.25	CLAY (Very low to high strength)
456.25	460.75	CLAY (Extremely low strength)
460.75	470.00	CLAY (Extremely low strength), highly localised sub-cropping BEDROCK/TILL
470.00	480.65	Sub-cropping/exposed BEDROCK, BEDROCK/TILL interspersed with areas of CLAY and SAND BEDROCK outcrops are particularly prevalent between KP 470 and KP 474, although found locally across the section
480.65	482.25	BEDROCK/TILL
482.25	502.30	CLAY (Extremely/Very Low Strength)
502.30	505.75	CLAY (Extremely/Very Low Strength), some areas of BEDROCK/TILL with veneer of CLAY
505.75	508.75	BEDROCK/TILL with veneer of CLAY, and CLAY (Extremely/Very Low Strength)
508.75	509.80	BEDROCK/TILL with veneer of CLAY, and CLAY (Extremely/Very Low Strength)
509.8	520.6	CLAY (Extremely/Very Low Strength)
520.60	524.65	TILL with veneer of CLAY (Veneer thickness unknown, TILL not sampled)
524.65	531.50	CLAY (Extremely/Very Low Strength)

531.50	548.25	CLAY (Extremely/Very Low Strength)
548.25	549.00	BEDROCK or TILL with veneer of CLAY
549.00	557.50	CLAY (Extremely/Very Low Strength)
557.50	592.60	CLAY (Extremely/Very Low Strength)
592.60	594.60	BEDROCK or TILL with veneer of CLAY or SAND/GRAVEL
594.60	610.00	CLAY (Extremely/Very Low Strength)
610.00	634.75	CLAY (Extremely/Very Low Strength)
634.75	658.70	CLAY (Extremely/Very Low Strength)
658.70	661.40	CLAY (Extremely/Very Low Strength). Outcrops of BEDROCK KP 660.5 - 661.3
661.40	664.66	CLAY (Very Low Strength)

For reference, strength descriptions are defined as follows:

Table 7: Undrained Shear Strength Definitions

Description	Undrained Shear strength (kPa)
Extremely Low	<10
Very Low	10-20
Low	20-40
Medium	40-75
High	75-150

In the MMT geotechnical report (Ref. 1), complete descriptions of CPT and VC samples at each location are provided. A further level of description is provided by applying a "Seabed Index" classification to each complete sample, reproduced from the MMT report in Table 8 below. This classification is applied across the whole depth of the sample, and thus may not be representative of the upper 1-3m of sediment. It should thus only be used as guide to general conditions along the route. Many of the Fjord ridges are not covered by samples, and are thus not represented in the list of seabed indices. Nevertheless, for completeness the route classification according to this index is included in Appendix B.

Table 8: MMT seabed index

SI	Typical Seabed Sediment
1	Shallow Bedrock (<1.00m)
2	Bedrock / Obstruction (>1.00m)
3	Very dense granular, very to extremely high strength cohesive
4	Medium to high strength cohesive
5	Dense granular
6	Medium dense granular
7	Loose granular, low to medium strength cohesive
8	Very loose granular
9	Very low to low strength sandy cohesive
10	Extremely low strength cohesive

4. Burial Risk Assessment Methodology

4.1 Introduction

The basis of a risk assessment for a submarine cable relies on identifying the potential hazards, associated risks and evaluating the level of protection that may be afforded to the cable by its armouring (internal and/or external), cable burial beneath the seabed and any other means, such as rock placement or concrete mattressing.

The most reliable and cost-effective form of cable protection is generally recognised to be ensuring no interaction between the cable and the identified hazards. This is most easily achieved by routing the cable away from such hazards or, where this is not practical, by burial below the seabed. Armouring of the cable provides protection against some external threats and impact resistance of the cable will be documented in the Cable Contractor documentation. However, damage to the cable due to fishing gear impact still represents a significant threat therefore it is recommended to protect the cable by burial as a primary choice or by other means where this is impractical.

The Cable Burial Risk Assessment only considers hazards anticipated during the operational lifespan of the cable. Installation risks will be discussed separately in the CPAR.

4.2 Methodology

The methodology followed in this report is adopted in accordance with the industry guidance documents: the Carbon Trust Cable Burial Risk Assessment (CBRA) Methodology (Ref. 17), CBRA Application Guide (Ref. 18), and DNV Subsea Power Cables in Shallow Water (Ref. 25).

The principles of the methodology are that following the identification of the initial cable routes (in this case the cable routes have been provided by the Client) the following steps are taken:

1. Seabed conditions are assessed.
2. Threat/hazard identification assessment.
3. Identified risks to the cable are assessed in more detail – either through a probabilistic approach, where applicable and/or data quality permits, or through a more qualitative approach.
4. Minimum Depths of Lowering are recommended to mitigate the risks identified to an appropriate level.

4.3 Hazard Classification

There are a wide range of obstacles and seabed users which present a hazard to subsea cables. Many of these can be avoided by considered routing; however, activities such as fishing and accidental anchoring generally cannot be avoided through routing alone.

Hazards can typically be classified as primary or secondary. A primary hazard has a direct impact upon the cable and can cause damage. Such hazards include ship anchors with associated anchor penetration into the seabed and fishing, where bottom trawling gear can snag and damage cables.

A secondary hazard is one which does not directly damage a cable but can result in an increased risk of damage from primary hazards. Such hazards include sediment mobility/mobile bedforms where shifting surface sediments can reduce burial cover or expose a previously buried cable.

For each hazard, whether primary or secondary, there are specific associated risks which are discussed below.

Table 9: Primary hazards

Hazard	Risks
Fishing	Impact, pull over damage or hooking of cable.
Vessel Anchoring	Impact, hooking or pull over damage from dragged or dropped anchors.
Offshore Construction/ Maintenance	Contact from jack up legs, impact from dropped objects.
Marine Survey Operations	Dropped / deployed objects.
Military Activity	Impact damage from live ordnance.
Dredging	Impact and damage during dredging activity.
Spoil Dumping	Impact damage / deep burial causing overheating.
Cable on-bottom stability (fatigue and/or abrasion)	Excessive movement on the seabed causing abrasion / fatigue issues.
Submarine Slope Failure (natural or potentially induced by installation)	Impact damage / deep burial causing overheating, excessive cable bending.
Rock Fall / Landslides	Impact damage and excessive cable bending.

The common secondary hazards are detailed in the table below.

Table 10: Typical secondary hazards

Hazard	Necessary Conditions
Sediment Mobility / Coastal processes	Suitable sediment Energetic wave / current regime
Excessive Seabed Slope	Ledges, sand waves, steep outcrops, slide back-scars.
Hard Substrates	Bedrock/hard sediment exposure

Dredging	Dredging activity over cable reducing cover/increased exposure to other hazards
Historic slides and rockfalls	Earthquakes may trigger new movement of potentially unstable features (from previous events).

5. Threat/Hazard Identification and Assessment

5.1 Geotechnical Risk Register

Based upon the supplied data set and data acquired by Cathie Associates from third parties a geotechnical risk register was compiled to outline the threats to the cables across the route for the *operational lifetime* of the project. The risk register was reviewed during the HAZID workshop held with the Client on 5th October 2017 and updated accordingly.

The purpose of this exercise was to ensure that all hazards were identified and assessed and the risk to cables appropriately acknowledged. The geotechnical risk register is presented in Appendix A and the main hazards are discussed in more detail below. It should be noted that not all hazards detailed in Section 4.3 are present along the proposed route, therefore several hazards were discounted during the initial risk assessment. Installation risks will be presented and assessed separately in the CPAR, with its own dedicated risk register covering risks associated with the installation process.

5.2 Primary Hazards

5.2.1 Shipping

Vessel traffic is discussed in detail in Appendix C. The probabilistic anchoring assessment methodology is discussed in more detail in Appendix D and briefly summarised in this section. The risk from shipping arises from the accidental or emergency dragging of an anchor across the cable resulting in damage or even complete severance, resulting in lost capacity and necessitating repair. For the purposes of anchor analysis, the shallow geology has been classified into "soft" and "hard" seabed. Anchor penetration is c. 3 times as deep in low strength clay due to a combination of the low resistance to shear and the angle at which the anchor fluke penetrates this type of substrate. Thus, in our classification of the seabed for the CBRA, "Soft" substrates are considered to be low strength CLAY <40kPa, with "Hard" substrate including everything else (SAND or CLAY ≥ 40kPa).

For the purposes of anchor analysis calculations, the top 3m is assessed. Of course, there is often likely to be significant soil type and strength variation within this depth, therefore each sampled soil profile has been individually appraised in order to place it into a classification. This approach differs from the CPAR where the anticipated target trench depth is used to focus the assessment of soil conditions.

Table 11: Summary of findings of probabilistic assessment (return period, years)

KP	Accidental/Emergency Scenario Anchor Strike Return period [years] at burial depths indicated [mbsl] (route cumulative – rounded to the nearest 1000)									
	0	0.25	0.5	0.75	1.0	1.5	2	3	4	5
0 – 664.66	4000	4000	4000	4000	6000	7000	7000	7000	40000	59000

As can be seen from Table 11, the most significant increases in protection (through lower probability of anchor strike) occur between 0.75m and 1m burial and between 3m and 4m burial. This is a product of the DWT (dead weight tonnage) distribution of ships that are recorded crossing the route and the different penetration models for "soft" versus "hard" soils. See Appendix C for more discussion about the methodology and results of the shipping assessment, and Appendix D which discusses the anchor strike risk methodology use to produce the results in Table 11.

Minimum recommended depths of lowering have been derived using the fishing threatline (section 5.2.2) and consideration for mobile sediments (section 5.3.1). Anchor strike probability for these depths (see CBRA table) was calculated in each section, with the route-total calculated anchor-strike return-period being 4000 years. As discussed in section Appendix D.1.3, this provides a level of protection such that the residual risk from accidental/emergency anchoring is deemed to be low compared to the potential lifetime of the project.

5.2.2 Anchorages and Fish-Farms

There are no dedicated anchorages on the survey centre line, however an anchorage is noted to exist near Simadalen landfall for quarry vessel traffic. Increased burial has been stipulated by the Client in this area (ref. Appendix B). Anchoring behaviour is also noted at the UK end of the route (See C831R01 D09) and increased burial is to be applied here also.

A risk has also been identified in areas near fish-farms, where a vessel collision, bad weather or careless placement could result in a static anchor (which secures the floating structure) being dragged cross the HVDC cables. Enhanced protection is similarly stipulated by Client in these areas as detailed in Appendix B.

5.2.3 Fishing

Commercial fishing is a hazard to subsea cables (even armoured cables) where fishing gear interacts with the seafloor: potentially resulting in damage due to impact or snagging. It should also be noted that a cable can pose a risk to the fishing vessels themselves if left on the seabed, as small vessels can founder if snagged on a significant obstruction (Ref. 27).

The depths of penetration of the fishing gear govern the potential interaction risks to the proposed cable. It should be noted that excessive seabed penetration increases risk to loss of equipment and increases towing forces required, increasing fuel costs, so fisherman generally look to limit penetration where possible.

Information regarding intensity of fishing, based on the assessment of AIS data is presented in drawing C831R01 D03 in Appendix E. It can be seen from this information that trawling is prevalent across most of the route. The CBRA table in Appendix B details the presence and location of trawl marks which occur along large sections of route.

Marine Scotland (Ref. 28) provides information concerning fishing types in the North Sea and the following broad observations are noted:

- Intense potting and scallop trawling activity from UK coast out to approximately KP 20, year-round
- Demersal fishing along the majority of the route, year-round
- Trawling for Nephrops prevalent for much of the route (~KP 40 to ~KP 290) during spring/summer months
- Trawling for Herring for most of the route (~KP 105 to ~KP 480) during summer months

Additional fishing intensity information has been supplied to the project by the Norwegian Fishing Authority (see Figure 4), although exact details of the fishing types are not included. Activity appears particularly intense along the length of the Norwegian Trench, intersected by North connect c.KP 300 to KP 400. Demersal fishing activity is evidenced by trawl marks, which are commonly found by the survey, even in water depths approaching 300m.

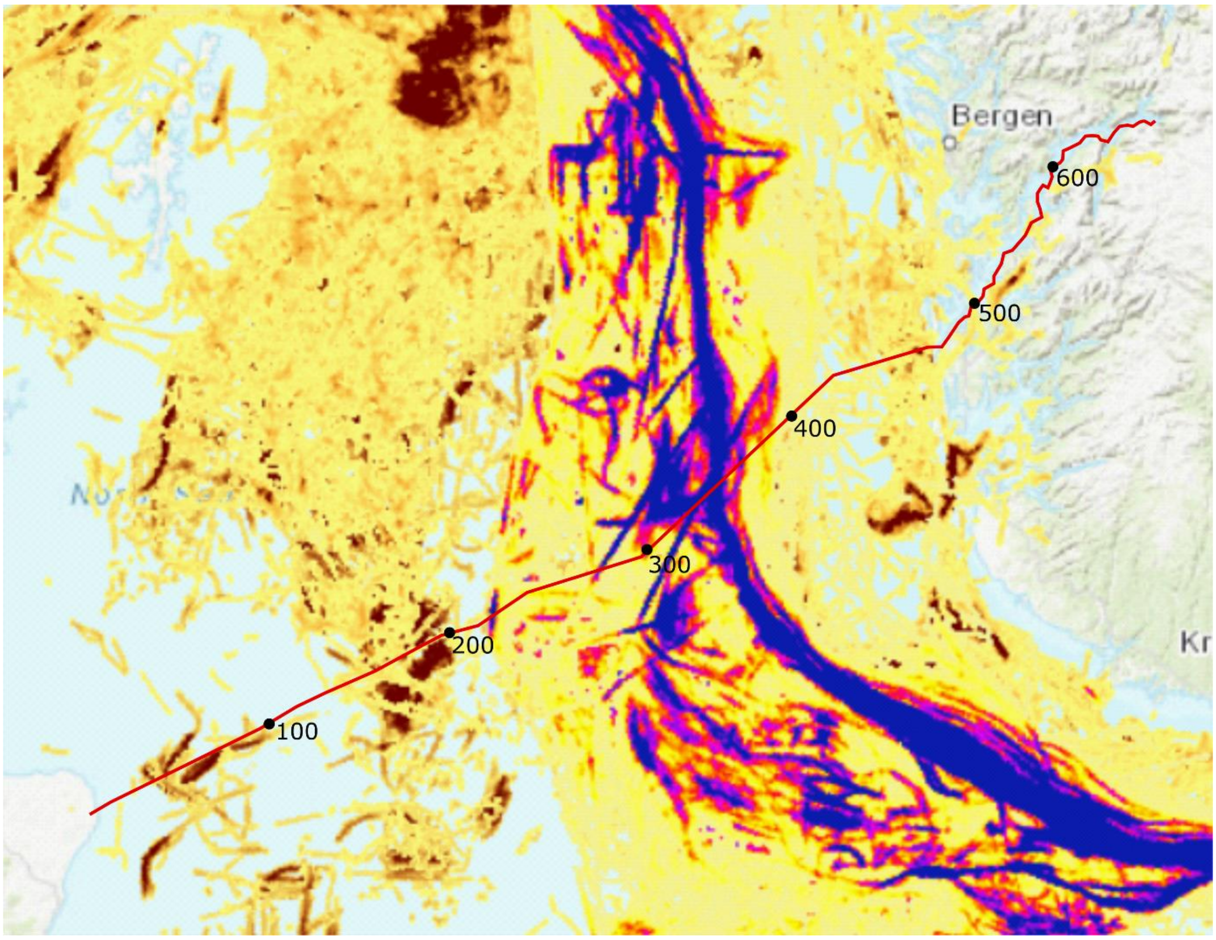

Figure 4: Norwegian Fishing Authority Fishing Intensity Data

(Areas of greatest activity signified by darker colours)

Norwegian fisheries data maps (Ref. 29) show that there is active fishing taking place in many parts of Hardangerfjord, usually confined to areas near to the shore, although the map data does not show the type and method of fishing, and whether this may impact the seabed. Although fishing is noted in the deeper parts of the Fjord, it is not thought to reach the seabed (see 600m cut-off, below). Discussions with the client suggested that fishing is not expected to occur in the furthest upper reaches of the Fjord (where water depth is <600m, KP 634.75 – KP 664.66)

In the case of the identified fishing methods currently employed along the route the following threatline depths are considered reasonable based upon previous experience and available references (Ref. 17):

- Fishing gear penetration in surficial sand ~0.2m
- Fishing gear penetration in low strength clay ~0.3m

The application of this risk is presented in the CBRA table in Appendix B. A 600m bathymetric depth cut-off has been applied to the fishing threatline in agreement with the Client, as below this depth fishing activity is not considered a genuine risk to the cable, however, if further information regarding fishing activity in these areas becomes available, this threatline should be re-assessed.

5.2.4 On-bottom Stability

Surface laid cables are subject to loading from waves and currents and this could result in cable movement and migration across the seabed. Relatively high tidal/storm currents are observed in UK waters, and excessive movement on the seabed could cause abrasion and/or fatigue issues. It is recommended that the cable should be buried or externally protected as soon as possible following cable lay, to avoid any damage.

Cable migration is also likely to increase the shipping risk profile, as the cable position will no longer be accurately identified on marine charts and this is likely to result in an increased risk from other primary hazards such as vessel anchors, fishing and construction activities.

In this case it is understood that cable burial/protection is planned therefore on-bottom stability and cable fatigue are not considered as threats as long as the cable remains buried or protection (i.e. rock placement) remains in place.

5.2.5 Dredging/Soil Dumping

Spoil grounds have been identified near Peterhead landfall (Ref. 9), however no known dredging/dumping sites have been identified within or close to the survey corridor.

5.2.6 Rockfall

Along the length of the Fjord, rockfall is highlighted as a risk originating from the steep, sheer sides of the Fjord. Rockfall poses a risk of cable impact damage or lateral displacement. Boulders falling at high velocity may be expected to penetrate the very soft Fjord-bottom sediments beyond reasonable burial depths. Areas interpreted as past rockfall and mass-transport deposits originating from the Fjord sides have been identified within the survey corridor and avoiding these areas through routing is likely to offer the best protection for the cable.

The risk of future events is still present in areas where rockfall/boulders are not observed and routing the cable in the centre of the Fjord where possible could reduce its exposure to future rockfalls from either side.

5.2.7 Submarine Slopes

Significant slip-scarps are found periodically along the length of the Fjord, generally perpendicular to the Fjord and survey centre line. The implications for cable installation across these features are discussed in the CPAR (Ref. 31). Transverse slopes are not expected to be encountered if the cable is routed on the base of the Fjord, however any detailed routing should consider the difficulties transverse slopes pose to cable installation.

5.2.7.1 Slope Failure

In terms of lifetime risks to the cable, ground movements beneath the cable could result in free-span and strain, also movement of material originating from upslope could displace and strain a cable. Further burial by mass-transport deposits could also result in excess thermal insulation and overheating of the cable. The effect of loading the crest of these slopes with further material (rock placement) may potentially destabilise the material, although loading of the toe of the slope could also be expected to increase the stability. This scenario has not been assessed in the NGI scope of work (see below).

Further detailed assessment of submarine slope failures in the fjords has been performed by the Norwegian Geotechnical Institute (NGI) (Ref. 13). Previous research is summarised below in section 5.2.7.2, and the conclusions of the NGI report are summarised in section 5.2.7.3.

5.2.7.2 Bergen University research

Seismic profiles in the upper regions of Hardangerfjorden (Inner Samlafjorden and Utnefjorden/Eidfjorden) combined with a 15.7m core sample from Inner Samlafjorden, (at c.KP 614 on the NorthConnect survey centre line) have been used by Bellwald et al of the University of Bergen to investigate mass-transport deposits in the area.

To summarise the paper (Ref. 30), the work suggests that at the particular sample location, above rockhead lies 160m of glaciomarine deposits which in turn are overlain by 55m of stacked mass-transport deposits, comprising 19 identified separate movement events depositing up to 13m of turbidite deposits.

The chronostratigraphic record suggests high movement activity 11100 – 8200 years BP and 4100 years BP to present. 14 mass-transport deposit (MTD) events are dated early Holocene with a return period of 200 years, during a period of high sedimentation. Low sedimentation in the mid-Holocene marks a quiet period. Activity in the late Holocene has a return period of 1000 years and is hypothesised to be triggered by glaciotectonic induced earthquakes (related to ice unloading) or large rockfalls.

The slide-scars themselves (from where the material originates) are found in areas of steeper seabed, the gradients of which appear to be controlled by the underlying rock profile.

It is noteworthy that in the 15.7m core raised from the depths (857m) of Inner Samlafjorden, the last mass-transport deposit was dated as occurring 2400 years BP (before present). Mass transport deposits of the same age have been identified in many fjords in western Norway and a seismic trigger is suggested.

A magnitude 4.5 quake at the mouth of the Fjord in the year 2000 was not noted to result in any mass-movement. A decline in the magnitude of post-glacial tectonic activity could be a reason for the decrease in the frequency of mass-transport events, however a large decrease in background sedimentation rate from 0.8 to 0.1 mm/yr. over the last 3000 years is another explanation with a lower supply of new material lengthening the period for which the seabed slopes remain in a stable equilibrium state. This is similar to the mid-Holocene period where low sediment supply is suggested to be the reason for lower mass-movement activity.

Accounting for the points discussed above, risks of a slide that impact the cable may be interpreted to be low given the interlude since the previous events. However, sediment is still accreting, albeit at a slower rate, so the risk of a cable-damaging event must still be considered. Slope stability of seabed slip scarps is discussed in the NGI report (Ref.13), summarised below.

5.2.7.3 NGI study

5.2.7.3.1 Stability Conclusions

The NGI study undertook stability analyses of four scarps identified as being potentially the most critical using a 1D screening process. For all of these four slopes, 2D finite-element (FE) analysis was performed for static and pseudo-static conditions to model earthquake scenarios. The latter models used seismic behaviour expected for 475-year and 2475-year return period magnitude events. A further 3D FE analysis was performed on the most critical of the four slopes.

Segments of the four slopes analysed were coded according to their nearest sample locations (for use of soil parameters). In terms of RPL09 these are:

- 17-SS-01 (segments a-f) -Scarp c.KP 620
- 18-SS-01 (segments a,b) -Scarp c.KP 638.1
- 18-SS-04 (segments a-c) -Scarp c.KP 642.2
- 18-SS-08 (segment a) -Scarp c.KP 661.5

The latter feature is the largest observed on the route, near the head of the Fjord.

The NGI report states that Eurocode 8 requires static factors of safety of 1.4 and pseudo-static factors of safety of 1.1 in clay. Of all of the slopes, 17-SS-01, 18-SS-01 and 18-SS-04 pass this level of safety under 2D static and pseudo static conditions for both return periods. Slope 18-SS-08 under 2D analysis had a static FOS = 1 and pseudo-static FOS <1, thus did not pass Eurocode 8 under any conditions. Under 3D analysis, it passed under pseudo-static conditions with FOS of 1.2 and 1.1 for 475 and 2475 year events respectively. However, it did not pass Eurocode 8 under static conditions (FOS =1.2)

This slope, the final slip-scarp before landfall, is thus identified as being most critical regarding danger to the cable.

It should be noted that the NGI study did not assess the risk of slides/falls from the sides of the Fjord, and also did not analyse any potential impacts of installation or placement of material on these slopes which should be considered prior to construction.

5.2.7.3.2 Clay Strength

NGI has suggested that the lab testing performed by MMT may have underestimated the shear strength of the clay in the Fjords due to unavoidable disturbance to the soil during vibrocore sampling. These lab results are fed back into the calibration of CPT correlation (N_{kt}). Consequently, NGI reduced N_{kt} from 17.5 (MMT) to 13 based upon their experience of Fjord sediments. As an example, a clay previously interpreted as 10kPa shear strength would have a small increase to 13.5kPa. It is acknowledged that further reinterpretation of the survey results would be merited at the detailed design stage.

5.3 Secondary Hazards

5.3.1 Mobile Sediments

The presence of bedforms of potentially mobile sediments were identified during the survey work (Ref. 2). Bedforms of varying size identified and have been summarised in the CBRA table in Appendix B, and the majority of these are found between KP 0 and KP 62.5. The maximum observed bedform size reported by MMT on the survey centre line is 0.7m (large ripples, see Table 12) and these are found between KP 24 and KP 45. Some larger bedforms were identified in the survey report as lying to the north or south of the SCL, and it is possible that these may have migrated onto the cable alignment prior to installation. This possibility should be considered following further surveys by the installation contractor.

The MMT bedform size classification as supplied in the survey data is given below for information:

Table 12: MMT mobile bedform size classification

Bedform Type	Length (m)	Height (m)
Ripples	< 5	0.01-0.1
Large Ripples	5 – 15	0.1-1
Megaripples	15 - 50	1- 3
Sandwaves	50 – 200	> 3

In the absence of repeat surveys to analyse mobility, it is recommended that an allowance for sediment mobility is included in the cable protection strategy where bedforms have been identified, equivalent to the bedform height.

6. Conclusions and Recommendations

Through the undertaking of the risk assessment, the most onerous lifetime hazards to the cables were identified as;

- Anchors from transiting vessels
- Fishing gear seabed interaction
- Rock fall / Landslides
- Submarine Slope Failures

As agreed with the Client, a quantitative approach has been undertaken to understand the level of protection offered against anchoring by a range of burial depths as presented in Appendix B and discussed in detail in Appendix D.

The outcome of the shipping and probabilistic analyses suggest that accidental or emergency anchor-strike risk is considered to be low. At the minimum recommended depths of lowering (defined in Appendix B), the average annual anchor strike return period is 4000 years for the complete route, meaning that an anchor drag across the cable, at sufficient depth to cause damage would only be expected to occur once every 4000 years. This equates to a probability of an anchor strike of 0.026% in any given year of operation. For a planned infrastructure lifespan of 25 years (0.64% chance), 50 years (1.28% chance), or even 100 years (2.56% chance), this represents a low risk (equivalent to DNV Category 3). This assessment should be revisited in the future if significant changes in shipping traffic or levels of vessel redundancy are observed.

Maximum threatline depths have also been determined for the other main hazards identified, notably fishing, as detailed in the CBRA table in Appendix B. Burial to mitigate the threat from fishing (0.2m to 0.3m) is deemed a minimum requirement, except where (in agreement with the Client) the risk from fishing activity has been deemed to be low.

In addition to the above, the hazard assessment has identified the presence of potentially mobile bedforms in localised areas along the cable route, mostly located within the first 62.5km of the route, having a maximum size of 0.7m. Currently no repeat bathymetric data set is available, therefore, it was not possible to confirm the full extent of sediment mobility. In the absence of more detailed analysis it is recommended that an additional allowance for sediment mobility is included in the cable protection strategy where bedforms have been identified. However, there is not expected to be any requirement for pre-sweeping operations prior to installation operations.

The primary method of protection for the cable will be burial, accounting for efficiency and cost effectiveness. Rock placement will be used for cable crossings. It is anticipated that rock placement will also be used where adequate burial cannot be achieved due to the presence high strength material at shallow depth. Assessment of burial methods as well as additional protection options is provided in the CPAR report (31) and Detailed BAS for the UK 12NM (Ref. 32) which build upon the findings of this report.

Appendix A – Risk Register

GEOTECHNICAL RISK REGISTER

Front Sheet

CA Client : NorthConnect KS
Project : NorthConnect
Project No : C831R01

Revision History

Revision	Purpose	Author(s)	Reviewed:	Approved:	Date
1	Draft	EJO	EJO	JIR	06/11/2017
2	Issued	PTH	EJO	EJO	15/03/2018
3	Final	PTH	EJO	EJO	03/05/2018

Risk Rating

Probability	Definition
1	Never heard of in Industry
2	Heard of in Industry
3	Incident has occurred near the project area
4	Happens several times a year in Industry
5	Happens several times a year at project location

Consequence	Definition
1	Negligible Damage
2	Minor Damage / Exposure to other hazards
3	Localised Damage / No unplanned loss of capacity
4	Major Damage - replacement of small section / Unplanned loss of capacity
5	Extensive Damage - replacement of significant section of cable/ Unplanned loss of capacity

Geotechnical Risk Matrix		Consequence				
		1	2	3	4	5
Probability	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

CA Client : NorthConnect KS
Project : NorthConnect
Project No : C831R01

GEOTECHNICAL RISK REGISTER

GEOTECHNICAL RISK (LIFETIME RISKS)	Data Sources / Data Adequacy	Risks to Installed Cable							
			Initial Risk				Residual Risk		
		Hazard Details	Freq	Cons	Rank	Quantification / Mitigation	Freq	Cons	Rank
Primary Hazards									
Shipping - current	WebGIS, AIS Dataset 10/2015 to 09/2017, DTS	Ships can cause direct damage to exposed or insufficiently buried cables by deploying anchors either deliberately (in case of anchorages) or accidentally over / next to a cable. Direct cable strike or more likely snagging of cable can cause damage to cable (and vessel). The cable corridor is subject to shipping traffic of various natures, and will be assessed in detail based on the AIS dataset. The presence of designated anchorages to be assessed based on available charting/AIS data.	2	4	8	Probabilistic assessment of shipping and estimation of likely anchor penetration depth relative to seabed geology and shipping activity. Conservative approach to be taken with regard to unknown factors. Determination of appropriate cable burial depths to afford adequate protection. Protection against dropped objects from construction/ maintenance vessels Identification of new cables on nautical charts / anchorage exclusion zones.	1	4	4
Shipping - future variations	WebGIS, AIS Dataset 10/2015 to 09/2017, DTS	Shipping traffic could vary over time for various reasons including: - Activity relating to construction/decommissioning of nearby offshore assets such as oil & gas structures or offshore wind farms - Exclusion zones surrounding work sites or new assets may cause shipping to cross the cable at different points	2	4	8	Determination of appropriate cable burial depths to afford adequate protection for existing traffic levels. Regular monitoring of vessel traffic as part of IMR regime. The risk to the cables should be continually reassessed in line with any significant changes in shipping that are identified, allowing better quantification of the risk and if necessary the planning of potential mitigation actions (such as AIS monitoring services, guard vessels, deeper burial, etc.).	1	4	4
Fishing	WebGIS, AIS Dataset 10/2015 to 09/2017, DTS, UK fishing reports	Fishing activities can result in direct damage to exposed or insufficiently buried cables by fishing gear snagging on the cable. Also (greater) risk to the fishing vessel in the event of a snagging incident. Multiple types of fishing have been observed including: - Trawling - Dredging - Potting	2	4	8	Assessment of likely fishing gear penetration based on identified fishing types relative to seabed geology and recommendation of burial to sufficient depth to afford adequate protection. A recommended minimum level of burial has been given to protect from this threatline. Ongoing monitoring of fishing activity and methods as part of IMR regime. Identification of new cables on nautical charts / fishermen awareness initiatives.	1	4	4
Fishing - future variations in equipment	WebGIS, AIS Dataset 10/2015 to 09/2017, DTS	Fishing methods and equipment could vary with time resulting in increased risk to the cables.	2	4	8	Ongoing monitoring of fishing activity and methods as part of IMR regime. The risk to the cables should be reassessed if there is a significant change in fishing activities which results in greater penetration of fishing equipment into the seabed. If necessary, mitigation actions to be taken (deeper burial, rock placement, fishing exclusion zones, etc.). Given the increased vessel running costs of deeper penetrating fishing gear (higher towing force), increase in this factor is considered unlikely, however it is possible that the locations of fishing grounds will change in future.	1	4	4
Bathymetry and Metocean Conditions (On-bottom Stability)	WebGIS, Block Reports, MetOcean Report, DTS	Water depth and metocean conditions influence cable on bottom stability (abrasion / fatigue effects on surface laid cables). Both variables are also key factors in sediment mobility (considered separately) and water depth is a consideration in the probabilistic assessment of anchor strike (considered separately). Water depths vary from c.23m at UK HDD exit to maximum of >850m in the Fjord. Shallow water wave effects anticipated in the approach to landfall. North Sea tidal currents in the area have been observed to exceed 2 knots.	3	2	6	Provided offshore cables are to be buried, surface laid sections should be minimal. Potential movement / fatigue of any residual sections of exposed cable should be monitored with appropriate IMR regime e.g. regular survey to monitor bathymetry changes, using a risk-based approach to prioritise surveys, continual assessment of the risks to the cable and the need for remedial works should the cable be exposed. Stability of remedial rock berms under metocean loadings has been assessed as part of a technical note (C831T01).	2	2	4
Dredging / Dumping	WebGIS, Block Reports, DTS	Dredging activity can result in direct damage to cables as well as exposure of buried cables or reduction in burial, increasing risk to primary hazards such as shipping or fishing. Over-burial by dumping, can result in exceeding cable thermal / physical design parameters. Spoil grounds noted within corridor at UK end, but not within the survey corridor.	2	4	8	TCE no dredging zone 235m either side of 30m cable corridor within 12NM (500m buffer). RPL developed according to constraints. Consultation with dredging licence holders, as required. Identification of new cables on nautical charts / implementation of exclusion zones for dredging / dumping activity.	1	4	4
Rock Fall	WebGIS, Survey Report, Academic Papers	Rockfall or other mass movement from the Fjord sides may cause impact damage to the cable, or lateral displacement inducing tensions or kinks. Rockfall is recorded all the way along the Fjord, and the survey provides evidence of these deposits on the Fjord bottom.	3	2	6	Softness of sediment in the majority of the Fjord area means that protection from rockfall is unlikely to be gained by burial. The simplest way to reduce the risk will be to use routeing to avoid areas of historic mass transport deposition originating from the side of the Fjord, as recorded by the survey. Keeping the cable route central to the Fjord where possible should reduce the likelihood that material will strike the cable from either side.	1	2	3

CA Client : NorthConnect KS
Project : NorthConnect
Project No : C831R01

GEOTECHNICAL RISK REGISTER

GEOTECHNICAL RISK (LIFETIME RISKS)	Data Sources / Data Adequacy	Risks to Installed Cable							
			Initial Risk				Residual Risk		
		Hazard Details	Freq	Cons	Rank	Quantification / Mitigation	Freq	Cons	Rank
Submarine Slope Failures	WebGIS, Survey Report, Academic Papers	Numerous slip-scarp features cross the width of the Fjord, generally perpendicular to the survey centre line. The installed cable will have to traverse these features. Failure of the ground underneath the cable at the scarp-slope crest or impact by mass-movement material originating upslope could cause cable damage by inducing cable tension, creating freespans or causing slack areas of cable to become kinked. NGI research suggests that only one scarp (Major feature c. KP 661.5) is naturally unstable under static and seismic conditions, however this modelling does not include disturbances or loadings as a consequence of cable installation.	3	4	12	Avoid slopes where possible, transition of cable across existing slip-scarps or potential future scarps is in many cases unavoidable. Triggering of failure may be seismic, with a suggested return period of 1000 years (based upon dating mass-flow deposit sequences), which may be considered ALARP. Further investigation into the risks of loading the slope with rock placement etc during installation (as many scarps are too steep for burial tools). The use of a burial tool with a free-flying mode of operation and skids may allow steep areas to be traversed and the cable buried.	2	4	8
Anchorages and static fish-farm anchors	WebGIS, Block Reports, DTS	A quarry vessel anchorage exists near the route at Simadalen, this has been identified by NorthConnect to be justifying extra protection from possible anchor-strike damage. No other anchorages have been noted in the survey corridor, and once the cable is marked on admiralty charts, no future anchorages would be expected to appear on the cable alignment. A risk has also been highlighted near fish-farms, where bad weather or third-party collision could cause a (usually) static anchor to be dragged across the cable and cause damage. A shipyard at Stoord (Kvaerner) and mobilisation area raised some concerns about the proximity of the cable route to their operations. Ships have been noted anchoring in proximity to the cable route at the UK Landfall	2	4	8	Increased protection through burial (FEED level D) has been specified near fish farm anchoring points, the Kvaerner yards, the Simadalen quarry cargo vessel anchorage and the first c.850m of the route from the HDD exit at UK landfall. Identification of new cables on nautical charts / anchorage exclusion zones.	1	4	4
Secondary Hazards									
Mobile Sediment / Seabed Mobility	WebGIS, Block Reports, DTS	Sediment movement following cable installation can result in exposed or over-buried cables, increasing the risk to the cables from external and internal threats.	3	2	6	Sympathetic routing. Adequate burial mitigating mobile sediment layer. Monitoring of residual risk from external threats. Appropriate cable design to withstand possible over-burial; thermal effects etc. Survey prior to the cable lay to confirm assessment of site / RPL(s). Regular survey of cables as part of IMR regime - with emphasis on areas anticipated to be mobile. Reassessment of cable risks and mitigation works as required if cable becomes over-buried or exposed.	2	1	2
Coastal Processes / Landfall	WebGIS, Block Reports, DTS, HDD outline design	Exposure of near shore cables may result from coastal processes; increasing risk to cables from external threats.	3	2	6	Cables in intertidal zone will be protected via HDD UK end. Regular survey of cable as part of IMR regime, particularly the inshore area, to monitor residual risk.	2	2	4

Appendix B – Cable Burial Risk Assessment Table

Project name:	**NorthConnect**
Project number:	**C831**
Client name:	**NorthConnect KS**
Location:	**Northern North Sea**

Cable Burial Risk Assessment

FOR INFORMATION ONLY

KP (RPL09 Corridor) From	KP To	Co-ordinates ETRS 1989 UTM Zone 31N From	Co-ordinates To	Length (km)	Seabed Geology and Samples: Summary of geology in upper 3m in section [14]	Additional notes on shallow geology	Relevant CPT/VC tests / samples in section	MMT Seabed Index at sample locations (1-10)	Geotech test / sample location: KP	Easting	Northing	Bathymetry range within section [m below MSL]	Seabed Features: Seabed features[2] (Survey Centre Line)	Crossings (KP as-found by MMT) Status (**B** - Buried, **S** - Surface laid) -North sea survey, as-found location given *Fjord section as-found location	Slide-scarp and mass transport areas	Slides and rockfalls from Fjord side
0	0.1 [1]	212349, 6377615	212447, 6377634	0.1	**BEDROCK (HDD)**							18 to 24.5	HDD			
0.1	0.85	212447, 6377634	213135, 6377906	0.75	**SAND over dense SAND**		CPT/VC_A_001	SI not applied	0.193	212508	6377506	24.5 to 28.5	Ripples KP: 0.1 - 0.222			
0.85	1.35	213135, 6377906	213564, 6378161	0.5			CPT/VC_A_003	SI not applied	1.277	213503	6378129	28.5 to 40	Large Ripples KP: 1.338 - 1.368			
1.35	3.7	213564, 6378161	215583, 6379364	2.35	Veneer of **SAND/GRAVEL** over **0.5-4m CLAY** over **TILL**. **SAND** present under clay in some areas. (Clay medium to high strength)		CPT/VC_A_004/A	SI not applied	3.376	215308	6379193	40 to 51.5	High density boulders <50% are >0.75m in size Ripples KP: 1.685 - 2.180 2.518 - 2.603 3.169 - 3.652			
3.7	4.47	215583, 6379364	216245, 6379758	0.77	Veneer of **SAND/GRAVEL over 1-2m CLAY** over **TILL, BEDROCK** outcrops. (Expect Clay medium to high strength)							50 to 55	Mix of high density and numerous boulders. <50% are >0.75m in size. Ripples KP: 4.270 - 4.521 Megaripples KP: 4.096 - 4.169 Rock outcrops			
4.47	4.60	216245, 6379758	216348, 6379835	0.13	**Veneer of SAND/GRAVEL** over **0.5-1m CLAY** over **TILL** (Expect clay of medium to high strength)	Shallow bedrock KP 4.5						54 to 55	Numerous boulders <50% are >0.75m in size. Ripples and large ripples KP: 4.467 - 4.878			
4.60	5.10	216348, 6379835	216697, 6380193	0.50	Veneer of **SAND/GRAVEL** over **TILL**(Expect Till/Clay to be medium to high strength)							55 to 57	Numerous boulders <50% are >0.75m in size. Ripples and large ripples KP: 4.467 - 4.878			
5.1	5.75	216697, 6380193	217151, 6380658	0.65	0.4-0.7m **GRAVEL** or very gravelly **SAND, over CLAY** (Clay low-medium strength)							57 to 59	Numerous boulders <50% are >0.75m in size.			
5.75	14.20	217151, 6380658	223191, 6386521	8.45	0.4-0.7m **GRAVEL** or very gravelly **SAND, over CLAY** (Clay low-medium strength)		CPT/VC 01-SS-02 CPT/VC 01-SS-03	7 4	8.570 12.850	219119 222108	6382680 6385750	59 to 73	Numerous boulders (patchy from KP 9.5) <50% are >0.75m in size. Ripples & Large Ripples KP: 6.634 - 7.413 Ripples KP: 7.162 - 8.891 9.925 - 10.852 11.212 - 11.940 12.556 - 16.571	10.964 Active cable (B in progress)		
14.20	15.00	223191, 6386521	223896, 6386898	0.80	0.4-0.7m **GRAVEL** or very gravelly **SAND, over CLAY** (Clay low-medium strength)							73 to 79	Occasional boulders <50% are >0.75m in size. Ripples KP: 12.556 - 16.571			
15.00	20.00	223896, 6386898	228191, 6389279	5.00	**0.5m** gravelly **SAND** over **CLAY** (Clay borderline medium/low strength)		CPT/VC 01-SS-04/4A	7	17.232	225902	6387974	78 to 95	Occasional boulders <50% are >0.75m in size. Ripples KP: 12.556 - 16.571 16.951 - 19.141 18.009 -19.2 (start alt-course) See next section for alt-course	16.597 Disused cable B (MMT not found) 18.558 Active pipeline S		
20.00	24.00	228191, 6389279	231952, 6390641	4.00	Areas of **CLAY** and areas of **SAND** to depth		CPT/VC 02-SS-01	6	23.872	231832	6390595	78 to 96	Occasional boulder patches on alt course KP 0 - KP 0.75 Alt-course to be used avoiding sandwave / ridge. Alt-course mobile sediments: Occasional ripple patches, area of megaripples on SCL KP 2.097 - KP 2.251 Alt course end c.KP 23.5 c.KP 4.6 on Alt) Ripple patches continue beyond end of section.			
24.00	27.70	231952, 6390641	235431, 6391900	3.70	**0.2-0.6m SAND** over **CLAY** (Low Strength)							78 to 91	Numerous boulders KP 27.25-27.7 <50% are >0.75m in size. Large Ripples KP: 24.590 - 41.440			
27.70	32.50	235431, 6391900	239944, 6393535	4.80	**0.2-0.6m SAND** over **CLAY** (Low Strength)		CPT/VC 02-SS-02/A	7	28.300	235991	6392098	89 to 96	Numerous boulders KP 31.5-32.5 <50% are >0.75m in size. Large Ripples KP: 24.590-41.440			
32.50	40.00	239944, 6393535	246996, 6396089	7.50	**0.2-0.6m SAND** over **CLAY** (Low Strength)		CPT/VC 02-SS-03/A/B	8-9	39.08	246124	6395776	94 to 99	Numerous boulders KP 32.5-34, KP 35.9-40 <50% are >0.75m in size. Large Ripples KP: 24.590-41.440			
40.00	44.50	246996, 6396089	251227, 6397621	4.50	**2m SAND** over **CLAY** (Low strength)		CPT 02-SS-04/A	8	40.610	247575	6396299	90 to 99	Numerous boulders KP 40-41.6 <50% are >0.75m in size. Large Ripples KP: 24.590-41.440 43.076 - 45.111 Megaripples KP 40.727 - 43.967 Sandwaves (see note)* KP: 44.183 - 45.389			
44.50	49.75	251227, 6397621	256163, 6399408	5.25	**CLAY** (Very low strength) (Variable thickness of loose **SAND** cover, up to 1.2m	Occurrence of sand not well constrained, section considered low strength for anchoring. SAND is very loose and silty.						80 to 93	Mix of occasional, numerous and high density boulders KP 44.5 - 48.3 <50% are >0.75m in size. Large Ripples KP: 44.557 - 45.546 45.564 - 50.345			
49.75	60	256163, 6399408	265035, 6404168	10.25	**CLAY** (Very low strength) (Variable thickness of loose **SAND** cover, up to 1.2m		CPT/VC 02-SS-05 CPT 02-SS-06 CPT/VC 03-SS-01	8-9 8 7	50.609 51.918 57.830	256969 258163 263120	6399704 6400243 6403157	93 to 109	Large Ripples KP: 52.889 - 58.792 59.717 - 62.423	53.403 S Active pipeline		
60.00	72.75	265035, 6404168	276319, 6410105	12.75	**CLAY** (Very low strength) (Variable thickness of **SAND** cover (Samples suggest 0.75-2m)	Occurrence. Thickness of sand not well constrained, section considered low strength for anchoring. SAND is very loose and silty.	CPT/VC 03-SS-02/A/B CPT/VC 03-SS-03	8 9	64.105 67.976	268668 272094	6406077 6407883	99 to 121	Large Ripples KP: 59.717 - 62.423 Trawl marks KP 64.6 - 72.75	60.326 B Active pipeline		
72.75	79.50	276319, 6410105	282292, 6413248	6.75	**CLAY** (Extremely low strength) (Variable thickness of **SAND / SILT** cover (Sample suggest 0.8-2m.	Occurrence. Thickness of sand not well constrained, section considered low strength for anchoring. VC records 0.84m SILT over CLAY, CPT suggests 1.6m very silty SAND.	CPT/VC 03-SS-04	8-9	73.950	277389	6410665	112 to 120	Trawl marks across whole section.			
79.50	102.00	282292, 6413248	301920, 6424244	22.50	**0.6-1m SAND/SILT** over extremely/very low strength **CLAY**		CPT/VC 03-SS-05 CPT 03-SS-06 CPT/VC 03-SS-07	8-9 9 9	80.655 86.549 98.243	283317 288497 298666	6413786 6416591 6422374	108 to 117	Trawl marks across whole section. Occasional pockmarks on or near centreline.			
102.00	107.50	301920, 6424244	306670, 6427016	5.50	**CLAY** (Extremely low strength)		CPT/VC 03-SS-08/A1/A2	9	107.039	306267	6426782	113 to 114	Trawl marks across whole section. Pockmark nearby at KP 105			
107.50	119.60	306670, 6427016	317149, 6433064	12.10	**CLAY** (Extremely / very low strength)		CPT/VC 03-SS-09 CPT/VC 03-SS-10	9-10 9	108.500 117.990	307533 315735	6427518 6432299	113 to 124	Trawl marks across whole section. Occasional pockmarks from KP 114 onward, c.4m deep.	115.131 B Disused cable (Found in unexpected position)		
119.60	126.00	317149, 6433064	322757, 6436147	6.40	**CLAY** (Extremely low strength)		CPT/VC 03-SS-11	9	122.005	319272	6434199	124 to 128	Frequent pockmarks.			
126.00	200.00	322757, 6436147	389837, 6467085	74.00	**CLAY** (Extremely low strength)		CPT/VC 03-SS-12 CPT 04-SS-01 CPT 04-SS-02	9 9 10	126.99 150.270 179.100	323621 344489 370410	6436633 6446916 6459492	128 to 154	Frequent pockmarks. Trawl marks KP 145.4 - 200	137.347 B Group 4 x Active pipelines 137.391 B - 137.391 B - 137.449 B - 140.250 B Group 2 x Active pipelines 140.288 B - 142.830 B Group 5 x Disused pipelines 142.861 B - 142.895 B - 142.926 B - 142.926 B - 156.395 S Active pipeline		
200.00	224.00	389837, 6467085	411413, 6477119	24.00	**CLAY** (Extremely low strength)		CPT 04-SS-03 CPT 04-SS-04 CPT/VC 04-SS-05	9 9 9	203.280 215.985 222.454	392987 404653 410106	6468008 6472813 6476287	139 to 124	Trawlmarks across c.50% of section. Frequent possible gas seeps. MMT suggest that signal in water column unlikely to be caused by fish.	205.053 S Active pipeline 219.410 S Active pipeline		

KP From	KP To	Hazard Interaction Depth [m]: Maximum potentially mobile bedform height in section on SCL	Fishing	Deepest observed anchor threat	Shipping Zone	Zone Length (km)	Dominant Sediment Type in Shipping Zone (for anchoring assessment)	Accidental/Emergency Anchor Strike Annual Failure Frequency (Return Period in Years, nearest 1000)[4]: 0[5]	0.25[5]	0.50	0.75	1.00	1.50	2.00	3	4	5	Burial Recommendations: Recommended minimum Depth of Lowering (DOL)[15] to protect from fishing+mobile sediments	Additional Notes	Representative DOL across shipping zone for anchor risk calculation	Probability of anchor strike at recommended minimum DOL	Return Period (years, nearest 1000)	FEED Protection Level[13]
0	0.1 [1]	HDD																					
0.1	0.85	<0.2 (limited area)	0.2	1.2	**1**	4.60	SAND or CLAY ≥ 40kPa	48000	48000	49000	52000	>100000	>100000	>100000	>100000	>100000	>100000	0.2[7]	See Note 7	0.2	2.08107E-05	48000	D
0.85	1.35	0.7 (limited area)																0.2[7]	See Note 7				C
1.35	3.7	<0.2																0.2[7]	See Note 7				C
3.7	4.47	0.5 (limited area)																0.2[7]	See Note 7				C
4.47	4.60	0.3																0.2[7]	See Note 7				C
4.60	5.10	0.3	0.2	1.2	**2**	0.50	SAND or CLAY ≥ 40kPa	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	0.2[7]	See Note 7	0.2	7.99059E-06	125000	C
5.1	5.75	0	0.2	1.8	**3**	14.90	SAND or CLAY ≥ 40kPa	19000	19000	19000	19000	>100000	>100000	>100000	>100000	>100000	>100000	0.2		0.3	5.28428E-05	19000	C
5.75	14.20	0.5																0.3[7] (0.1m accounts for ripples, more advised for megaripples)	See Note 7				C
14.20	15.00	<0.2																0.3 (0.1m accounts for ripples)					C
15.00	20.00	<0.2																0.3 (0.1m accounts for ripples)					C
20.00	24.00	0.2 (0.5 Limited area)	0.2	2.0	**4**	4.00	SAND or CLAY ≥ 40kPa	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	0.3[7] (0.1m accounts for ripples, more advised for megaripples)	See Note 7	0.3	6.69711E-06	149000	C
24.00	27.70	0.7	0.3	6.0	**5**	3.70	LOW STRENGTH CLAY (<40kPa)	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	1 (0.7m accounts for large ripples)		1	5.63865E-06	177000	C
27.70	32.50	0.7	0.3	6.6	**6**	12.30	LOW STRENGTH CLAY (<40kPa)	87000	87000	87000	87000	87000	87000	90000	90000	>100000	>100000	1 (0.7m accounts for large ripples)		1	1.15021E-05	87000	C
32.50	40.00	0.7																1 (0.7m accounts for large ripples)					C
40.00	44.50	0.7 (*Interpreted sandwave 4.5m, limited area). Potentially immobile relict feature.	0.2	2.0	**7**	4.50	SAND or CLAY ≥ 40kPa	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	0.9 (0.7m accounts for large ripples)		0.9	1.56E-06	642000	C
44.50	49.75	0.4	0.3	6.0	**8**	15.50	LOW STRENGTH CLAY (<40kPa)	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	0.7 (0.4m accounts for large ripples)		0.75	8.26674E-06	121000	C
49.75	60	0.5																0.8 (0.5m accounts for large ripples)					C
60.00	72.75	0.5	0.3	6.6	**9**	140.00	LOW STRENGTH CLAY (<40kPa)	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	0.3[7]	See Note 7	0.3	6.04929E-06	165000	C
72.75	79.50	0																0.3					C
79.50	102.00	0																0.3					C
102.00	107.50	0																0.3					C
107.50	119.60	0																0.3					C
119.60	126.00	0																0.3					C
126.00	200.00	0																0.3					C
200.00	224.00	0	0.3	6.6	**10**	24.00	LOW STRENGTH CLAY (<40kPa)	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	0.3		0.3	4.54341E-06	220000	C

KP (RPL09 Corridor) From	KP To	Co-ordinates ETRS 1989 UTM Zone 31N From	Co-ordinates To	Length (km)	Seabed Geology and Samples: Summary of geology in upper 3m in section [14]	Additional notes on shallow geology	Relevant CPT/VC tests / samples in section	MMT Seabed Index at sample locations (1-10)	Geotech test / sample location: KP	Easting	Northing	Bathymetry range within section [m below MSL]	Seabed Features: Seabed features[2] (Survey Centre Line)	Crossings (KP as-found by MMT) Status (**B** - Buried, **S** - Surface laid) -North sea survey, as-found location given *Fjord section as-found location	Slide-scarp and mass transport areas	Slides and rockfalls from Fjord side
224.00	240.50	411413, 6477119	425382, 6485874	16.50	**SAND** and **CLAY** (Extremely low strength)	Clay/Sand boundary located in this section (Loose sand sampled at very end of section. Charts suggest change at c. KP 233, however reflectors don't show clear change. Consider section as low strength clay.	CPT/VC 05-SS-01	7	239.305	424324	6485339	112 to 124	Trawlmarks across c.50% of section. Frequent possible gas seeps. MMT suggest that signal in water column unlikely to be caused fish.	235.929 B Active cable		
240.50	276.00	425382, 6485874	459805, 6492945	35.50	**SAND** to depth		CPT/VC 05-SS-02 CPT/VC 05-SS-03 CPT/VC 06-SS-01	5 3 3	247.138 261.600 275.730	431674 445792 459549	6487988 6490447 6492852	88 to 111	Occasional Trawl marks. Rare pockmarks	244.610 S Active pipeline 246.750 S Active pipeline 248.384 B Active cable 248.414 S 2 x Active pipelines 248.445 S - 259.413 B Active cable 264.888 S Active pipeline 268.635 S Active pipeline 280.857 S Active pipeline 287.657 B Active cable		
276.00	290.50	459805, 6492945	472700, 6499251	14.50	**SAND** to depth							96 to 103	Featureless	298.564 B Disused cable		
290.50	341.50	472700, 6499251	513994, 6528958	51.00	Areas of **SAND** and **CLAY** (Extremely/Very Low Strength)	*Loose clayey silty sand interpreted in vicinity of 06-SS-02 and 07-SS-01 not well defined by reflectors, section considered low strength clay for anchoring to remain conservative.	CPT 06-SS-02* CPT/VC 06-SS-03 CPT/VC 06-SS-04 CPT/VC 07-SS-01*	7 9 9 8	293.196 303.800 319.900 331.600	474850 483355 496197 505777	6500877 6507264 6516926 6523407	103 to 119	Trawl marks KP 294.5-324.1 Ripples KP: 309.048 - 309.882 Ripples & Large Ripples KP: 328.480 - 345.408	304.477 B Active cable 326.208 S Active pipeline 338.965 Planned cable		
341.50	348.50	513994, 6528958	519794, 6532877	7.00	**CLAY** (Extremely/Very Low Strength)		CPT/VC 07-SS-02	9	345.43	517253	6531157	123 to 152	Ripples KP: 328.480 - 345.408			
348.50	363.50	519794, 6532877	532223, 6541275	15.00	**CLAY** (Extremely Low Strength)		CPT 07-SS-03	10	357.300	527033	6537758	152 to 238	Frequent small pockmarks. Trawl marks KP 348.5-351.5, 359.5-361.8	351.365 Planned cable		
363.50	390	532223, 6541275	554181, 6556111	26.50	**CLAY** (Extremely/Very Low Strength)		CPT/VC 07-SS-04 CPT 08-SS-01	9 10	363.620 387.600	532308 552194	6541337 6554771	103 to 285	Very frequent pockmarks up to 8m deep, c.100m across. Trawl marks across whole section.	374.606 Planned pipeline		
390	409.50	554181, 6556111	570338, 6567028	19.50	**CLAY** (Extremely Low Strength)		CPT/VC 08-SS-02	10	405.880	567341	6565008	274 to 290	Very frequent pockmarks up to 8m deep, c.100m across. Trawl marks across whole section.	390.661 B Active cable 397.186 B Active cable		
409.50	413.00	570338, 6567028	573239, 6568987	3.50	**CLAY** (Extremely Low Strength)							269 to 274	Trawl marks across whole section.			
413.00	415.00	573239, 6568987	574896, 6570107	2.00	**CLAY** (Extremely Low Strength)							267 to 271	Iceberg plough marks throughout section. Pockmark on centre line at KP 413.			
415.00	427.75	574896, 6570107	585460, 6577245	12.75	**CLAY** (Extremely Low Strength)		CPT/VC 08-SS-03	10	419.800	578862	6572791	256 to 267	Iceberg plough marks throughout section. Pockmark on centre line at KP 413.			
427.75	430.00	585460, 6577245	587325, 6578505	2.25	**CLAY** (Extremely Low Strength)							266 to 272	Iceberg plough marks throughout section. Occasional boulders, <50% are >0.75m in size			
430.00	447.50	587325, 6578505	601825, 6588302	17.50	**CLAY** (Extremely Low Strength)		CPT/VC 09-SS-01 CPT 09-SS-02 CPT 09-SS-03	9 10 10	431.800 442.720 444.490	588811 597860 599317	6579503 6585619 6586602	231 to 274	Iceberg plough marks throughout section. Occasional boulders, <50% are >0.75m in size	446.595 S Active pipeline		
447.50	456.25	601825, 6588302	609264, 6592719	8.75	**CLAY** (Very low to high strength*)	(*Variable degrees of iceberg reworking and soft sediment fill)	CPT/VC 09-SS-04 CPT/VC 09-SS-05 CPT/VC 09-SS-06	7 7 9	449.707 449.783 452.660	603656 603718 606052	6589531 6589579 6591259	165 to 235	Iceberg plough marks throughout section. Numerous boulders, <50% are >0.75m in size			
456.25	460.75	609264, 6592719	613607, 6593354	4.50	**CLAY** (Extremely low strength)		CPT/VC 09-SS-07	9	457.363	610355	6592493	165 to 205	Featureless	456.816 S Active pipeline		
460.75	470.00	613607, 6593354	621415, 6596941	9.25	**CLAY** (Extremely low strength), highly localised subcropping **BEDROCK/TILL**		CPT/VC 09-SS-08 CPT/VC 09-SS-09 CPT/VC 09-SS-10 CPT/VC 09-SS-11	9 7 10 9	461.949 464.259 465.232 465.805	614686 616769 617395 617913	6593862 6594370 6595014 6595256	190 to 270	Numerous boulders, <50% are >0.75m in size: KP 460.75 - 462.25 KP 464.1 - 466 Occasional boulders, <50% are >0.75m in size: KP 462.25 - 463.65		Interpreted mass-transport deposit: KP 467.55 - 467.65	
470.00	480.65	621415, 6596941	625174 ,6601722	10.65	Subcropping/exposed **BEDROCK, BEDROCK/TILL** interspersed with areas of **CLAY** and **SAND** **BEDROCK** outcrops are particularly prevalent between KP 470 and KP474, although found across the section.	Appears particularly rocky between KP 471.1 - KP472.8 Considered LOW STRENGTH CLAY for shipping assessment as this comprises the majority of this section.	VC 09-SS-12A VC 09-SS-13 VC 09-SS-15 CPT/VC 09-SS-14 VC 09-SS-16	8 9 9 9 7	471.417 472.274 475.505 477.137	622313 623075 625365 625228	6596333 6596621 6596679 6598293	142 to 372	Frequent areas of numerous/high density boulders <50% ore >0.75m in size, Diamicton Till, Reefs. Where sampled, ,Till appears to comprise gravelly sand. Ripples KP: 473.393 - 473.4498 Extreme gradients, thin sediment cover over bedrock.			
480.65	482.25	625174 ,6601722	624204 ,6602969	1.60	**BEDROCK/TILL**		Unsampled					282.5 to 352	High density boulders <50% are > 0.75m in size			
482.25	502.30	624204 ,6602969	634429 ,6618436	20.05	**CLAY** (Extremely/Very Low Strength)		VC-B10-SS-01 CPT/VC-B10-SS-02	9 9	489.723 499.138	627790 631809	6608737 6616669	290 to 424	Occasional pinnacles of bedrock at seabed c.KP 487.5 -488.5, (avoidable) Occasional boulders KP 488.3-489.1 <50% are >0.75m in size Trawl marks KP 488.3 - 501.0		Patches interpreted mass transport deposits KP 483.25-484	
502.30	505.75	634429 ,6618436	637330, 6621058	3.45	**CLAY** (Extremely/Very Low Strength), some areas of **BEDROCK/TILL** with veneer of **CLAY**		VC 10-SS-03A	9	502.328	634454	6618450	217 to 334	Routeing should be able to avoid rock/hard sediment and bury the cable in soft clay . Thus considered soft clay for anchoring assessment. Patches occasional/numerous boulders KP 502.5-505.6,	505.435 Active cable	Mass transport deposits across section (contains disturbed reflectors indicative of mass transport deposits.)	
505.75	508.75	637330, 6621058	638422, 6623764	3.00	**BEDROCK/TILL** with veneer of **CLAY**, and **CLAY** (Extremely/Very Low Strength)							217 to 120	Route consistently on "bedrock" (MMT interpretation), KP 507.75 - 508.75 (unavoidable, clay veneer thickness unknown. "Bedrock" may be Till). Other 2km in section may be possible to route on soft material. High density boulders KP 505.75-507.75, <50% are >0.75m in size. Reef on or near centreline KP 506.5 - 508.0. Relict bedforms on centre-line KP 507.555 - 507.743			
508.75	509.80	638422, 6623764	638211, 6623745	1.05	**BEDROCK/TILL** with veneer of **CLAY**, and **CLAY** (Extremely/Very Low Strength)							187 to 225	Numerous boulders ,<50% are >0.75m in size. KP 508.75-509.8		Mass transport deposits across section	
509.8	520.6	638211, 6623745	644395 ,6631769	10.80	**CLAY** (Extremely/Very Low Strength)		CPT/VC-B10-SS-04 CPT/VC 10-SS-05	9 9	509.983 514.708	638407 641978	6623841 6626604	290 to 354	Rock pinnacle at KP 519.5 (avoidable) Numerous boulders KP 509.8- 510.25, Mix of numerous and occasional boulders KP 516.4 - 516.75 KP 517.4 -520.4 <50% are >0.75m in size.	510.916 Active cable 511.116 Active cable 511.249 Active cable 511.307 Active cable 511.548 Active cable	Mass transport deposits outcrop KP 510-520.6. Possible historic slip-scarp at KP 510.6	
520.60	524.65	644395 ,6631769	647271 ,6634614	4.05	**TILL** with veneer of **CLAY** (Veneer thickness unknown, TILL not sampled)	11-SS-01 samples pocket of thicker clay (not representative of surrounding geophysical interpretation of Till with veneer) 11-SS-01 samples CLAY veneer, TILL not reached after 1.6m	VC-B11-SS-01 VC-B11-SS-02A	9 9	521.803 523.993	645197 646790	6632666 6634169	152 to 430	Raised area is interpreted as Till with a clay veneer. This (and later) features may have been formed as terminal moraines by periods of glacial re-advancement during the overall final retreat. High density boulders KP 521.1 - 524.4 <50% are >0.75m in size Routing may be able to avoid exposed till/bedrock KP 524.25-524.6 Reef patch at KP 521.7	523.223 Active cable		
524.65	531.50	647271 ,6634614	650232 ,6640121	6.85	**CLAY** (Extremely/Very Low Strength)	*Assuming cable is routed through low strength clay areas, avoiding bedrock	Unsampled					400 to 503	Large very steep "islands" of bedrock in Fjord bottom. Port/Starboard survey lines suggest these areas are easily avoidable to allow the cable to be installed in soft sediment. Occasional boulders, <50% are >0.75m in size. KP 526.3 - 526.4 KP 528.2 - 528.6	525.92 Active cable	Section consists mostly of mass transport deposits outcrop unless bedrock/till is found.	

KP From	KP To	Hazard Interaction Depth [m]: Maximum potentially mobile bedform height in section on SCL	Fishing	Deepest observed anchor threat	Shipping Zone	Zone Length (km)	Dominant Sediment Type in Shipping Zone (for anchoring assessment)	Accidental/Emergency Anchor Strike Annual Failure Frequency (Return Period in Years, nearest 1000)[4]: 0[5]	0.25[5]	0.50	0.75	1.00	1.50	2.00	3	4	5	Burial Recommendations: Recommended minimum Depth of Lowering (DOL)[12] to protect from fishing+mobile sediments	Additional Notes	Representative DOL across shipping zone for anchor risk calculation	Probability of anchor strike at recommended minimum DOL	Return Period (years, nearest 1000)	FEED Protection Level[13]
224.00	240.50	0	0.3	6.0	**11**	16.50	LOW STRENGTH CLAY (<40kPa)	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	0.3		0.3	8.47326E-07	118000	C
240.50	276.00	0	0.2	1.8	**12**	50.00	SAND or CLAY ≥ 40kPa	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	0.2		0.2	2.53627E-06	394000	C
276.00	290.50	0																0.2					C
290.50	341.50	<0.2, some 0.6	0.3	7.3	**13**	99.50	LOW STRENGTH CLAY (<40kPa)	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	0.3[7]	See Note 7	0.3	9.41706E-06	106000	C
341.50	348.50	<0.2, some 0.6																0.4 (0.1m accounts for ripples)					C
348.50	363.50	0																0.3					C
363.50	390	0																0.3					C
390	409.50	0	0.3	7.3	**14**	25.00	LOW STRENGTH CLAY (<40kPa)	78000	78000	78000	78000	78000	78000	78000	78000	>100000	>100000	0.3		0.3	1.28367E-05	78000	C
409.50	413.00	0																0.3					C
413.00	415.00	0																0.3					C
415.00	427.75	0	0.3	6.0	**15**	15.00	LOW STRENGTH CLAY (<40kPa)	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	0.3		0.3	3.5501E-06	282000	C
427.75	430.00	0																0.3					C
430.00	447.50	0	0.3	6.0	**16**	40.00	LOW STRENGTH CLAY (<40kPa) (Dominant type)	80000	80000	80000	80000	80000	80000	82000	82000	>100000	>100000	0.3		0.3	1.24718E-05	80000	C
447.50	456.25	0																0.3					C
456.25	460.75	0																0.3					C
460.75	470.00	0																0.3					C
470.00	480.65	<0.2 (limited area)	0.3	6.0	**17**	10.65	Consider as LOW STRENGTH CLAY (<40kPa) (Overall)	53000	53000	53000	53000	53000	53000	58000	58000	>100000	>100000	0.3[7]	See Note 7 See Note 8	0.3	1.89196E-05	53000	C
480.65	482.25	0	0.2	1.8	**18**	1.60	Bedrock/Till (Consider as SAND or CLAY ≥ 40kPa)	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	0.2	See Note 8	0.2	6.29986E-06	159000	C
482.25	502.30	0	0.3	6.0	**19**	20.05	LOW STRENGTH CLAY (<40kPa)	50000	50000	50000	50000	51000	51000	58000	58000	>100000	>100000	0.3		0.3	1.98063E-05	50000	C
502.30	505.75	0	0.3	6.0	**20**	7.50	LOW STRENGTH CLAY (<40kPa) (*Detailed routing should be able to avoid bedrock i in which case cable installation will be on/in soft clay)	58000	58000	58000	58000	58000	59000	65000	65000	>100000	>100000	0.3	See Note 8	0.3	1.73527E-05	58000	C
505.75	508.75	Bedforms are Relict <0.2, 3 (Megaripples)					Bedrock/Till, Consider as SAND or CLAY ≥ 40kPa (Shipping zone 20 uses soft sediment for anchor calculations risks to be conservative)											0.3	See Note 8				C
508.75	509.80	0					LOW STRENGTH CLAY (<40kPa) (*Detailed routing may be able to avoid bedrock/till in which case cable installation will be in soft clay)											0.3	See Note 8				C (D 509-509.8)
509.8	520.6	0	0.3	6.0	**21**	10.8	LOW STRENGTH CLAY (<40kPa)	53000	53000	53000	53000	53000	56000	65000	65000	>100000	>100000	0.3		0.3	1.87684E-05	53000	D (B KP 520-520.8)
520.60	524.65	0	0.2	1.8	**22**	4.05	Consider as SAND or CLAY ≥ 40kPa	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	>100000	0.2		0.2	2.58901E-06	386000	B
524.65	531.50	0	0.3	(0)	**23**	6.85	LOW STRENGTH CLAY (<40kPa)*	ANCHORING NOT CONSIDERED TO POSE A RISK BEYOND ZONE 22 DUE TO WATER DEPTH BEING >400m										0.3		-	0	-	B

KP (RPL09 Corridor)		Co-ordinates ETRS 1989 UTM Zone 31N		Length (km)	Seabed Geology and Samples						
From	To	From	To		Summary of geology in upper 3m in section [14]	Additional notes on shallow geology	Relevant CPT/VC tests / samples in section	MMT Seabed Index at sample locations (1-10)	Geotech test / sample location: KP	Easting	Northing
531.50	548.25	650232 ,6640121	659120 ,6652619	16.75	**CLAY** (Extremely/Very Low Strength)		CPT/VC 11-SS-03 CPT/VC 11-SS-04 CPT/VC 12-SS-01 CPT/VC 12-SS-02	9 9 9 9	539.651 542.718 543.438 547.61	653856 654541 655111 658692	6646994 6649993 6650532 6652147
548.25	549.00	659120 ,6652619	659619 ,6653179	0.75	**BEDROCK** or **TILL** with veneer of **CLAY**		Unsampled				
549.00	557.50	659619 ,6653179	665014 ,6659116	8.50	**CLAY** (Extremely/Very Low Strength)		VC B12-SS-03	9	555.018	663766	6657473
557.50	592.60	665014 ,6659116	676238 ,6684411	35.10	**CLAY** (Extremely/Very Low Strength)		VC B12-SS-04 VC B13-SS-01A VC B14-SS-01	9 9 9	572.419 586.194 590.893	671601 673305 675629	6671067 6681516 6682836
592.60	594.60	676238 ,6684411	677261 ,6686119	2.00	**BEDROCK** or **TILL** with veneer of **CLAY** or **SAND/GRAVEL**	Sample records clay (0.7m) over SAND to 0.7-2m (end of sample)	VC B15-SS-01A	9	592.698	676289	6684498
594.60	610.00	677261 ,6686119	682547 ,6698306	15.40	**CLAY** (Extremely/Very Low Strength)		CPT/VC B16-SS-01 VC B16-SS-02	9 9	598.768 609.308	676934 682546	6690101 6697615
610.00	634.75	682547 ,6698306	702765 ,6703392	24.75	**CLAY** (Extremely/Very Low Strength)		CPT/VC B17-SS-01 CPT/VC B17-SS-02	9 9	620.377 630.507	690357 699382	6703185 6706051
634.75	658.70	702765 ,6703392	721786 ,6712367	23.95	**CLAY** (Extremely/Very Low Strength)		CPT/VC B18-SS-01 VC B18-SS-02 CPT/VC B18-SS-03 CPT/VC B18-SS-04 CPT/VC B18-SS-05 CPT/VC B18-SS-06 CPT/VC B18-SS-07	9 9 9 9 9 9 9	638.405 639.678 640.688 642.449 646.638 650.663 655.334	704936 705442 706161 707330 710206 714281 718610	6704601 6705780 6706496 6707787 6710922 6711097 6712745
658.70	661.40	721786 ,6712367	724305 ,6712302	2.70	**CLAY** (Extremely/Very Low Strength). Outcrops of **BEDROCK** KP 660.5 - 661.3	*Bedrock outcrops appear to be avoidable	Unsampled				
661.40	664.66	724305 ,6712302	727248 ,6713622	3.26	**CLAY** (Very Low Strength)		CPT/VC B18-SS-08	9	661.687	724538	6712493

KP From	KP To	Bathymetry range within section [m below MSL]	Seabed Features: Seabed features[2] (Survey Centre Line)	Crossings (KP as-found by MMT) Status (**B** - Buried, **S** - Surface laid) -North sea survey, as-found location given *Fjord section as-found location	Slide-scarp and mass transport areas	Slides and rockfalls from Fjord side
531.50	548.25	464 to 547	Occasional boulders, <50% are >0.75m in size: KP 534.25 - 534.5 Occasional boulders, >50% are >0.75m in size: KP 540.55 - 540.6 KP 544.9 - 545.1 Numerous boulders, >50% are >0.75m in size: KP 535.7 - 535.8	533.666 Active cable 533.758 Active cable 533.873 Active cable 533.96 Active cable 534.077 Active cable 534.191 Active cable 534.357 Active cable 534.376 Active cable 534.742 Active cable 538.650 Out of use cable 539.229 Out of use cable 539.24 Out of use cable	Slip-scarp at KP 542.45 Possible historic slip-scarp at KP 547.7 Interpreted mass-transport deposits: KP 534.8 - 535.1 KP 539.4 - 540.6 KP 541.3 - 542.45 KP 543 - 543.8	KP 539.4 to 539.94 -Interpreted from MBES and SBP; from east, rather gentle side slopes, could be from sliding during decreasing sea level KP 540.13 to 540.67 -Interpreted from MBES and SBP; across, rather gentle side slopes, could be from sliding during decreasing sea level KP 543.43 to 543.77 -Interpreted from MBES and SBP; from south, rather gentle side slopes, could be from sliding during decreasing sea level
548.25	549.00	547 to 605	Bedrock or Till interpreted, with a veneer of clay.			
549.00	557.50	605 to 660	Raised area across Fjord: KP 554.9 - 555.3 interpreted as Bedrock/Till with overlying clay mass-transport deposit.		Slip-scarps: KP 549.75 KP 549.9 Interpreted mass-transport deposits: KP 549.75 - 550.6 KP 555.25 - 556	
557.50	592.60	528 to 668	Raised area across Fjord: KP 586 - 588.95 interpreted as Bedrock/Till with veneer/cover of clay. Occasional boulders, <50% are >0.75m in size: KP 585.9 - 586.65	563.317 Active cable 566.707 Active cable 573.047 Active cable 577.246 Active cable 578.652 Active cable 582.517 Out of use cable 583.406 Active cable 584.179 Active cable 584.681 Active cable 584.707 Active cable 584.933 Active cable 585.063 Out of use cable	Slip-scarp: KP 585.25 Mass transport deposits outcrop: 592.1 - 592.7 Interpreted mass-transport deposits: KP 585.3 - 585.7	
592.60	594.60	530 to 800	Raised area across Fjord interpreted as Bedrock/Till with clay or sand/gravel veneer. Very rapid deepening, from -530m to -800m from KP 592.7- 595.5 Occasional boulders, >50% are >0.75m in size: KP 594 - 594.5, although found on port and starboard survey lines throughout section.			
594.60	610.00	805 to 857	Route in proximity of explosive dumping ground KP 609.5 - 611.5	596.216 Active cable 596.306 Active cable 598.021 Out of use cable 598.39 Active cable 600.323 DCC 142 Active cable 601.067 Out of use cable	Slip-scarp: KP 599.1 - 599.15 Mass transport deposits outcrops: KP 594.60 - 595.7 KP 599.15 - 599.8 Interpreted mass-transport deposits: KP 599.25 - 599.75 KP 603.5 - 603.9	KP 595.81 to 595.96 -Interpreted from MBES and SBP; from east, steep side slope, could be old rockfall KP 597.48 to 597.59 -Interpreted from MBES, small lobes from east and west KP 603.54 to 603.91 -Interpreted from MBES and SBP; from southeast, steep, high side slope[10]
610.00	634.75	716 to 857	Numerous boulders, <50% are >0.75m in size: KP 612.8 - 613.4 Occasional boulders, >50% are >0.75m in size: KP 630.5 - 631 High-density boulders, >50% are >0.75m in size: KP 632.95 - 633.25	610.622 Active cable 612.582 Active cable 618.476 Active cable 619.307 Active cable 633.396 Active cable 634.611 Active cable 634.647 Active cable	Slip-scarps: Multiple small scarps KP 620 - 620.5 Possible older scarp KP 621.2 Scarp KP 630.7 Mass transport deposits outcrop: KP 611.4 - 611.75 KP 619.2 - 621.2 KP 627.9 - 630.9 Interpreted mass-transport deposits: KP 611.4 - 611.65 KP 619.9 - 620.25 630.35 - 630.7	
634.75	658.70	330 to 720	Raised section across Fjord interpreted as Bedrock/Till, covered by soft mass-transport clay deposit. KP 646.4 - 647.0 Occasional boulders, <50% are >0.75m in size: KP 636.6 - 637.1 Occasional boulders, >50% are >0.75m in size: KP 657.9 - 658.2	636.228 Active cable 637.338 Active cable 637.556 Active cable 637.887 Active cable 641.7 Active cable 642.007 Out of use cable 642.044 Active cable 647.387 Active cable 654.534 Active cable	Slip-scarps: KP 638.1 - 638.25 KP 642.25 KP 650.45 KP 657.1 Mass transport deposits outcropping throughout. Interpreted mass-transport deposits occur regularly from KP 637.4 onwards, from scarps on centre and sides of Fjord.	KP 644.1 to 644.9 -Interpreted from MBES and SBP; from north west, covers 1/3 of corridor, steep, high side slope[10] KP 645.88 to 646.32 -Interpreted from MBES and SBP; from north northeast , crosses the corridor, steep, high side slope (looks fresh) [11] KP 654.86 to 655.2 -Interpreted from MBES and SBP; from north, steep, covers more than half of the corridor, steep side slope (looks fresh) [11]
658.70	661.40	330 to 76	Complex section. Mix of soft sediment and Bedrock. Incidence of soft/harder material is patchy across all 3 survey lines. Considered as LOW STRENGTH CLAY for shipping assessment to remain risk-conservative and due to the very low levels of traffic. Exposed/subcropping bedrock KP 660.5 - 661.3 Numerous / occasional boulder patches across section, <50% are >0.75m in size. Exposed bedrock may be avoidable.	661.244 Out of use cable	Extreme gradients Patches of interpreted mass-transport deposits KP 659.9 - 661.3. Mass transport deposits (Where not interpreted as Till/bedrock)	^Begins in above section KP 658.64 to 658.88 -Interpreted from MBES and SBP; from north, steep, covers more than half of the corridor, steep side slope (looks fresh). Correlates with gully onshore?[11] KP 659.9 to 660.18 -Interpreted from MBES and SBP; from north, steep, covers more than half of the corridor, steep side slope (looks fresh). Correlates with gully onshore?[11]
661.40	664.66	76 to 13	High density boulders, >50% are >0.75m in size, KP 663.65 - 663.8.	662.89 Active cable 664.018 Active cable 664.273 Active cable	Extreme gradients Very large slip-scarp KP 661.4 - 661.6, likely source of mass transport deposits in previous sections.	KP 663.72 to 663.82 -Lobe from south, covering 1/3 of corridor, steep mountain side with gully above.[11]

KP From	KP To	Hazard Interaction Depth [m]: Maximum potentially mobile bedform height in section on SCL	Fishing	Deepest observed anchor threat	Shipping Zone	Zone Length (km)	Dominant Sediment Type in Shipping Zone (for anchoring assessment)	Accidental/Emergency Anchor Strike Annual Failure Frequency (Return Period in Years, nearest 1000)[4]: 0[5]	0.25[5]	0.50	0.75	1.00	1.50	2.00	3	4	5
531.50	548.25	0	0.3	(0)	**24**	16.75	LOW STRENGTH CLAY (<40kPa)	-	-	-	-	-	-	-	-	-	-
548.25	549.00	0	0.2	(0)	**25**	0.75	Consider as SAND or CLAY ≥ 40kPa	-	-	-	-	-	-	-	-	-	-
549.00	557.50	0	Fishing not considered a risk at these depths	(0)	**26**	8.50	LOW STRENGTH CLAY (<40kPa)	-	-	-	-	-	-	-	-	-	-
557.50	592.60	0	0.3	(0)	**27**	35.10	LOW STRENGTH CLAY (<40kPa)	-	-	-	-	-	-	-	-	-	-
592.60	594.60	0	0.2	(0)	**28**	2.00	Consider as SAND or CLAY ≥ 40kPa	-	-	-	-	-	-	-	-	-	-
594.60	610.00	0	Fishing not considered a risk at these depths	(0)	**29**	15.40	LOW STRENGTH CLAY (<40kPa)	-	-	-	-	-	-	-	-	-	-
610.00	634.75	0	Fishing not considered a risk at these depths	(0)	**30**	24.75	LOW STRENGTH CLAY (<40kPa)	-	-	-	-	-	-	-	-	-	-
634.75	658.70	0	Fishing not considered to pose a risk this far up the Fjord (as agreed with client)	(0) Anchor risk not considered due to extremely low vessel count. Protection level D protects against quarry anchorage KP 661.4 - KP 664.66)	**31**	29.91	LOW STRENGTH CLAY (<40kPa)	-	-	-	-	-	-	-	-	-	-
658.70	661.40	0															
661.40	664.66	0															
Cumulative return period if full route at this depth								4000	4000	4000	4000	6000	7000	7000	7000	40000	59000

KP From	KP To	Burial Recommendations: Recommended minimum Depth of Lowering (DOL)[12] to protect from fishing+mobile sediments	Additional Notes	Representative DOL across shipping zone for anchor risk calculation	Probability of anchor strike at recommended minimum DOL	Return Period (years, nearest 1000)	FEED Protection Level[13]
531.50	548.25	0.3		-	0	-	B (D KP 543.2 -544.8)
548.25	549.00	0.2	See Note 8	-	0	-	B
549.00	557.50	0		-	0	-	A
557.50	592.60	0.3	See Note 10	-	0	-	B (D KP 586.7 - 588.7, KP 591 - 592.6)
592.60	594.60	0.2		-	0	-	D
594.60	610.00	0	See Note 10	-	0	-	A (D KP 594.6 - 596, KP 598.5, 599.5)
610.00	634.75	0	See Note 10	-	0	-	A (D KP 616.5 - 619.3, KP 621 - 625)
634.75	658.70	0	See Note 10	-	0	-	A
658.70	661.40	0	See Note 10				A
661.40	664.66	0*	See Note 10				D
				Total	0.000251293	4000	

MMT Seabed Index

SI	Typical Seabed Sediment
1	Shallow Bedrock (<1.00m)
2	Bedrock / Obstruction (>1.00m)
3	Very dense granular, very to extremely high strength cohesive
4	Medium to high strength cohesive
5	Dense granular
6	Medium dense granular
7	Loose granular, low to medium strength cohesive
8	Very loose granular
9	Very low to low strength sandy cohesive
10	Extremely low strength cohesive

Notes on Burial Risk Assessment Parameters:
1. HDD exit at 170 degrees from North, 170m away from and perpendicular to RPL09 survey centre line at KP 0.1
2. Patches of mobile sediments are recorded to their full KP extent if they lie in part or fully within a zone.
3. Intra-zone KP ranges of potential mobile sediments are given in the "**Seabed features**" column. The mobile sediments column gives the largest thickness of potential mobile sediment observed within the zone. Bedform size classification is given in the report.
4. Probabilistic assessment has been undertaken using a yearly average from the two year dataset. Return periods are large in some cases for individual route sections - however the cumulative risk to the entire route should be considered when considering target burial depths.
5. The cable may be at significant risk from fishing and/or instability at this depth
6. All references to KP's and coordinates are based on RPL09.
7. Avoid, remove or increase burial where significant bedforms are encountered in order to bury cable below mobile sediment level to prevent subsequent exposure to threat lines. Note that the maximum bedform size is based upon MMT bedform size classification.
8. Rock placement may be required (due to unavoidable slopes etc)
9. Increase burial to protection level D in vicinity of fish farms (buffer c.200m suggested, varied case-by-case)
10. Further assessment / routeing avoidance of potentially unstable slopes should be conducted.
11. Landslide/rockfall from Fjord side is identified as being potentially critical in this area
12. Recommended minimum (short section) DOL based upon mobile sediments and fishing threat line. Actual burial targets will be driven by NorthConnect FEED document. Burial to be refined based upon precise location of mobile bedforms immediately before installation. These recommendations provide no extra factor of safety for the fishing threatline. Probabilistic assessment results should also be considered with regard to residual risk from anchoring.
13. Protection levels are defined in the NorthConnect FEED document

DNV Cat 1	>100000
DNV Cat 2	10000 to 100000
DNV Cat 3	1000 to 10000

Appendix C – Shipping Assessment

Appendix C.1.1 Shipping Data

The hazard to subsea cables from shipping is associated with the deployment of anchors either in designated anchorage zones (which should be avoided through routing) or in emergency situations that result in anchor deployment through mechanical failure or deployment without due care. The potential impact on the seabed and/or the resultant snagging of a deployed anchor can result in damage to a buried cable.

An Automatic Identification System (AIS) dataset covering the NorthConnect RPL for a 2-year period (01/09/15 to 31/08/17) was acquired (Ref. 23).

Appendix C.1.2 Data Processing

The AIS data generally includes the following:

- Vessel MMSI identification no.
- Vessel type
- Position
- Time
- Length
- Deadweight

The data was provided as point data, therefore, it required processing to convert into tracks for each vessel. The vessel tracks were then broken down in GIS such that in the event of multiple crossings by the same vessel they would all be counted.

Figures showing the track plots for each type of vessel are presented in Appendix E.

Appendix C.1.3 Data assessment / data gaps

The data is considered fit for purpose; however, it does have some limitations. The following was noted:

A deadweight tonnage (DWT) value was not recorded in the dataset for some vessels detailed in the shipping assessment. These vessels' DWT values were determined by conducting an online search of ship tracking websites using the unique MMSI numbers of the most frequently reoccurring vessels. Where the precise DWT values were found, these were added. Where not, the ship was assigned to the most appropriate category depending on its size and purpose as determined by the information available.

Due to project time constraints, it has not been possible to individually look up DWT values for all vessels, and for some vessels no online data was available, consequently a number of "unknown" vessels remain. In the probabilistic assessment, the distribution of known vessels was scaled up by the number of unknown vessels. For example, if the AIS dataset for a particular route section contained DWT values for 90% of vessels and 10% were unknown, the number of known vessels in each DWT bin would be multiplied by 1.11* such that the shape of the distribution remained the same and the total number of vessels equalled 100% of vessel crossings.

There are several harbours towards the western end of the RPL that are home to a considerable number of small pleasure craft. Small vessels are not required to carry AIS equipment. Therefore, values in the AIS dataset may underestimate of the volume of pleasure craft. Given the relatively small size and low power of these vessels, their anchors are not anticipated to penetrate far into the seabed and may not pose a significant threat to the cable however an impact/snagging assessment would be required to confirm this. It should also be noted that, the cable may pose a hazard to the craft themselves.

Vessel tracks were broken down in GIS such that in the event of multiple crossings by the same vessel they would all be counted.

Appendix C.1.4 Traffic Patterns and Trends

The density of traffic (for the period 01/09/2015 to 31/08/2017) on the cable route along the full route is shown in accompanying drawing C831R01 D01. The main points are briefly described here.

- Traffic is very dense near the UK end of the route from KP 0-50, with declines beyond KP 25 and then KP 50
- Traffic is comparatively lighter from KP 70 to KP 390 except for a moderately busy shipping lane KP 200 – 225.
- Traffic is dense on the approach to the Norwegian coast, KP 390 -470.
- Traffic is very dense around the Fjord entrance and the lower reaches of the Fjord, KP 470 to KP 530, From there to the end of the route at KP 664.66, where traffic is very light.
- A monthly breakdown of cable route crossings (Figure C.1, C.2) shows a clear seasonal pattern with significantly lower traffic during the winter months, although the baseline level shows significant traffic in all seasons. Data is consistent for the two-year period with no obvious anomalous skews to the dataset, although Summer 2017 appeared to show a higher level of traffic compared to the previous year, both in the Fjord (C.2) and the North Sea (C.1).

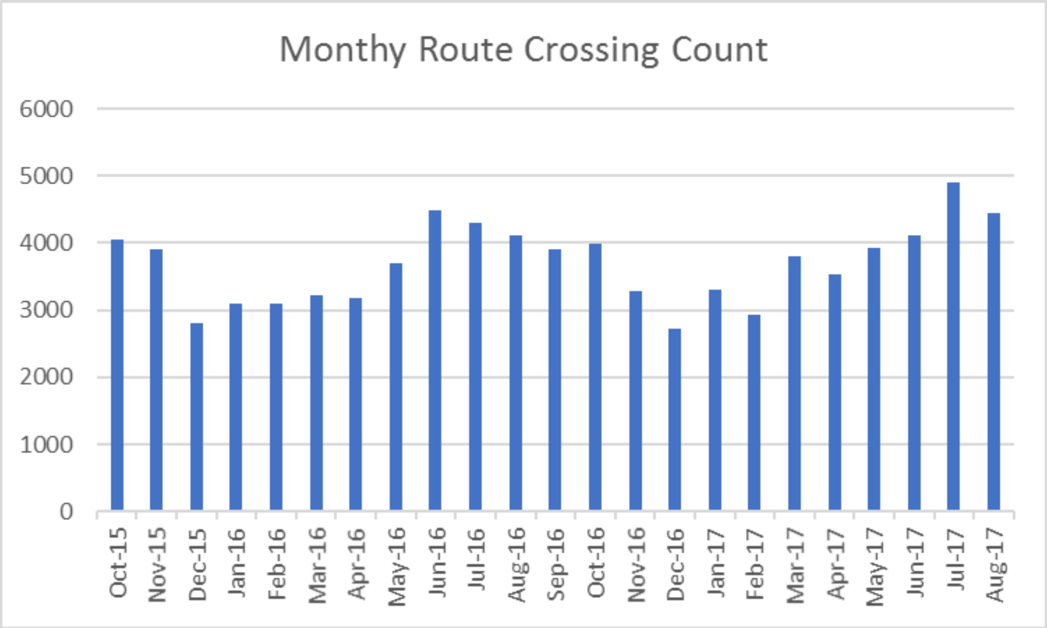

Figure C.1. Crossing counts by month, KP 0.1 – 480.65.

Note: Incomplete months from the beginning and end of the dataset were discarded.

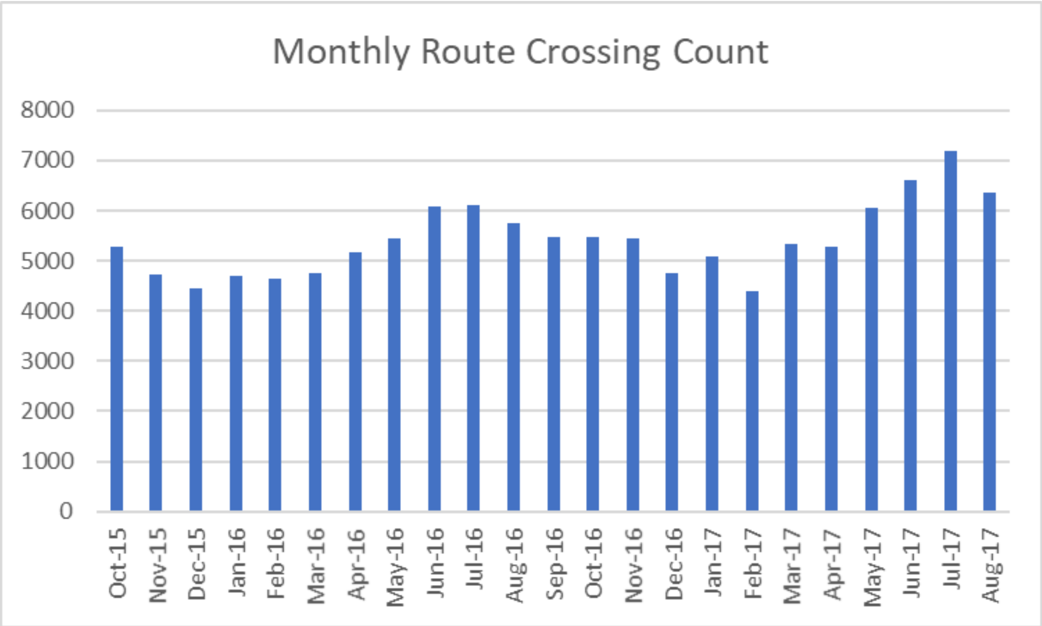

Figure C.2. Crossing counts by month, KP 480.65 – 664.66.

Note: Incomplete months from the beginning and end of the dataset were discarded.

Appendix C.1.5 Vessel Type

The AIS dataset included a diverse range of vessel types. For the purpose of the assessment these were divided into the eight categories shown in Table C.1 and are presented in Appendix E. The "government" group includes police, search and rescue and military vessels.

In addition to the vessels logged in the pleasure craft group, the values shown in the tables and appendix of this section may underestimate the volume of pleasure craft as small vessels such as these are not required to carry AIS equipment and so they would not be represented in the AIS dataset. Given the relatively small size and low power of these vessels, their anchors are not anticipated to penetrate far into the seabed and may not pose a significant threat to the cable however an impact/snagging assessment would be required to confirm this. It should also be noted that, the cable may pose a hazard to the craft themselves.

Table C.1: Number of crossings per vessel type (1-year average)

Type	Number of crossings
Cargo/Tanker	56424
Offshore Industry	14067
Passenger/pleasure	15777
Survey	560
Port/Dredging	2959
Government	907
Tug	4994
Fishing	9512
Unknown / Other	4359
TOTAL	109558

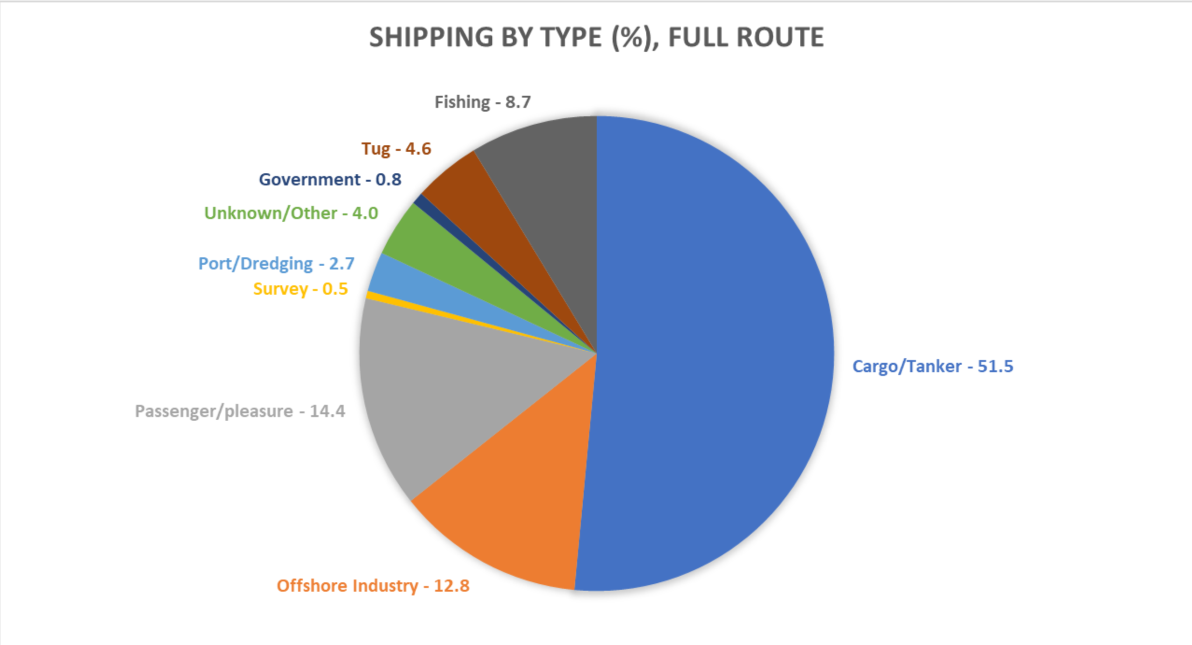

Figure C.3: Percentage of cable-route crossings in two-year period by vessel category

Figure C.3 shows that the majority of the 89040 crossings of the route over the two years comprise the Cargo/Tanker vessels (51.5%), Passenger/pleasure vessels (14.4%), shipping related to the offshore industry (12.8%) and fishing vessels (8.7%).

Individual vessel tracks according to vessel category are presented in drawings C831R01 D02 to D09.

Appendix C.1.6 Vessel Size

Figure C.4 below show the distribution of deadweight tonnage (DWT) of vessels which crossed the proposed cable route (KP 0.1 to 480.65) during the period covered by the AIS dataset. These proportions include a significant percentage of unknowns which remain even after the most commonly crossing vessels of unknown DWT were looked up. Figure C.5 shows the distribution of known DWT vessels only, which also represents the size distribution after the DWT unknowns had been reallocated proportionally among the known size ranges, according to their proportion)

The majority of vessels fall into the 1000 to 10000 Te category (71% of vessels for which DWT is known). Vessels of unknown DWT comprise 37% of vessel cable route crossings. For undertaking the probabilistic analysis, each class is scaled-up as discussed. Thus 45% of known vessel crossing DWT's in the 1000-10000 category scales to 71% of the upscaled probabilistic data. This scaling may represent an element of conservatism, as the unknown vessels appear to generally be smaller ships (fishing vessels etc) when looked up. However, there are also often large vessels, which for whatever reason, do not have their DWT information inputted to the AIS record, as received for processing. At present, no research has been conducted as to an average size distribution of vessels of unknown DWT, thus the directly proportional scaling has been applied. A much larger proportion of vessels in the Fjord are of unknown DWT. This may reflect their size, or the fact that many will be used as inshore vessels only and not deem it necessary to report statistics such as DWT on their AIS transmissions.

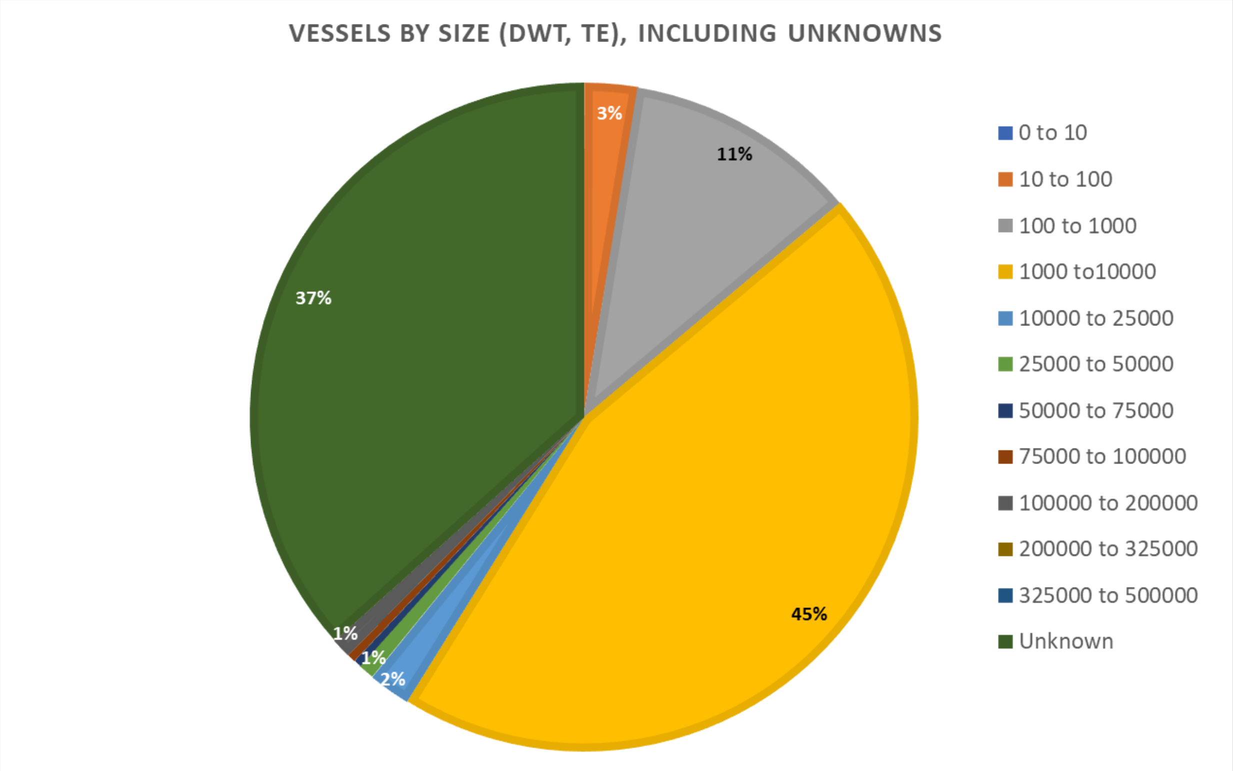

Figure C.4: Vessel sizes (Nearest %, including unknowns)

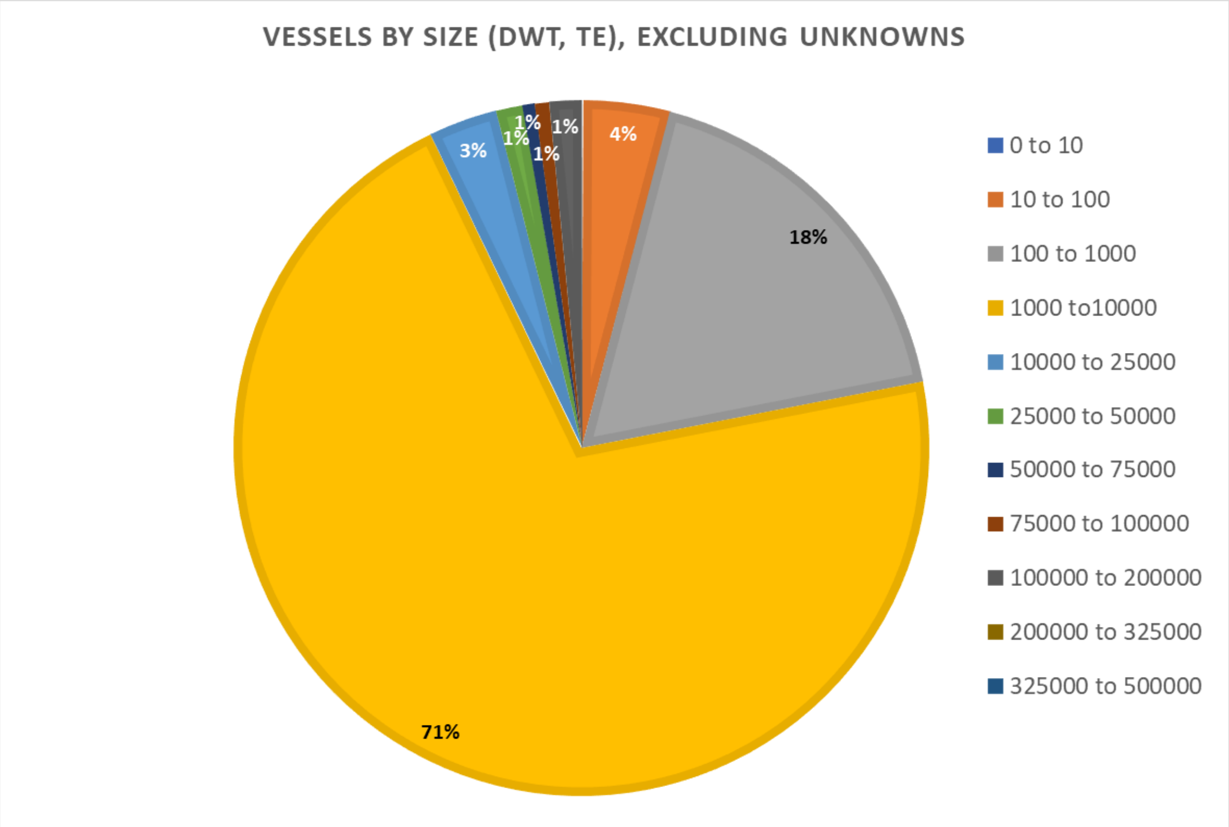

Figure C.5 Vessel sizes (Nearest %, excluding unknowns)

Table C.2: Vessel size categories

DWT (Te)	Average annual* number of crossings for the full route
Unknown**	40118
0 to 10	63
10 to 100	2775
100 to 1000	12395
1000 to 10000	49243
10000 to 25000	2208
25000 to 50000	859
50000 to 75000	402
75000 to 100000	458
100000 to 200000	1024
200000 to 325000	15
325000 to 500000	1
TOTAL	109558

*Averaged from the 2-year AIS dataset running 1/09/15 to 31/08/17.

**For the probabilistic assessment, each category in each zone is scaled up proportionally to account for unknown DWT values.

This methodology is inherently conservative, as, as is explained in Appendix D, anchor sizes are assumed for vessels in each DWT classification based upon the upper bound DWT for each bin.

Appendix C.1.7 Anchorages

No designated anchorages were noted on the SCL, although discussions with NorthConnect have highlighted an anchorage near Simadalen landfall, for quarry freight vessels. Enhanced burial is planned for this area (FEED Level D).

Enhanced burial (D) is also proposed in the vicinity of the Kvaerner Stord yards and mobilisation area in Hardangerfjord.

Vessels with their AIS status set to anchored in the area during the year of data are shown in Drawing C831R01D09. The shipping assessment indicates that anchoring occurs in the vicinity of the oil and gas installations; these activities are assumed to be carefully planned and undertaken with caution due to the difficulties and dangers anchoring in deep water and with sensitive subsea infrastructure nearby. Therefore, this is not considered in the emergency anchoring assessment.

FEED protection level D is planned for the first c. 850m of route following the HDD exit at UK landfall, as vessels have been visually observed anchoring in this area by members of the NorthConnect project team, as well as recorded by the AIS data. Post installation, once the cable is marked on marine charts it is expected that vessels will anchor elsewhere and not present a threat to the cables.

Anchorages in the form of static fish-farm anchors are noted in multiple locations crossing over the route. Extra protection has been agreed with the Client in these areas to mitigate against the risk of an anchor being dragged across the cable, possibly due to bad weather or a third-party collision with the floating farm.

Appendix D – Anchor Risk Probabilistic Methodology

Appendix D.1.1 Anchor Frequency Assessment

The probabilistic method evaluates the exposure of the cable to external threats by considering the amount of time vessels spend within a critical distance of the cable and the probability that a vessel might have an incident that requires the deployment of an anchor. The effect of water depth and bathymetric profile is considered very important and is included as a qualitative factor.

The calculation for the probability of an anchor striking a cable is given by:

$$P_{strike} = P_{traffic} * P_{wd} \sum_{1}^{No.ships\ in\ section} t * P_{incident}$$

Where:

$P_{traffic}$: Traffic probability modifier based on the tolerable level of risk

P_{wd} : Probability modifier for nature and depth of seabed

t : Vessel time in 'critical zone', $t = \frac{D_{ship}}{V_{ship} x\ 8760 hrs\ per\ year}$

V_{ship} : Ship speed (metre/hr)

D_{ship} : Distance travelled by a ship in area under consideration (in metres)

$P_{incident}$: Probability of an incident occurring for that vessel size and type

8670 hrs : Factor to annualise the results

The derivation and application of each of the terms in the formula for P_{strike} is discussed below:

$P_{traffic}$: is intended to be modified iteratively based on an agreed tolerable level of risk, this assessment has been undertaken taking into account all vessels recorded during the survey period i.e. $P_{traffic}$ = 1. The assessment is therefore conservative in this regard.

P_{wd}: accounts for changes in water depth, and proximity to anchorages varies along the route and is discussed in detail later.

V_{ship}: Has been assumed to be 2 knots based on previous Cathie Associates consultations with industry

D_{ship}: is a key item and can vary significantly depending upon the vessel size and speed. The CBRA method suggests either assessing every AIS track or using the 90th percentile vessel to conservatively estimate the critical anchor drag length. In this assessment, D_{ship} has been calculated according to the vessel categories listed in Table C.2 using the following formula:

$$D_{ship} = \frac{m \times V^2{}_{ship}}{4 \times UHC}$$

Where:

m = vessel mass (taken as displacement, in tons)

UHC = Ultimate Holding Capacity of anchor

$P_{incident}$: A conservative value for frequency of machinery breakdown of 2.0 x 10^{-5} per hour of operation per vessel has been assumed for this assessment based on industry guidance

Table D.1: Water depth modifier, P_{wd}

Water depth / Profile	Carbon Trust P_{wd}	Utilised P_{wd}
Water depth >400m	0	0
Water depth greater than 100m	0	**0.01**
Water depth 50 to100m	0	**0.05**
Water depth 30 to 50m	0.1	0.1
Water depth 10 to 30m	0.5	0.5

In areas of water 100-400m deep we have decided to use a P_{wd} of 0.01 to reflect the minimal but not impossible probability of an anchor penetrating the seabed in deep water. The workshop held with NorthConnect KS resulted in an agreed cut off for anchor risk at 400m bathymetric depth, below which the probability of anchor will be considered to be zero given the limitations on maximum chain length. This is in addition to the fishing threatline being capped at 600m water depth.

Appendix D.1.2 Anchor Threatline Assessment

To assess the shipping density in the study area, the number and type of AIS tracks entering the study area were mapped. The output was then factored to an annual basis. This data was then used to represent the number and type of vessels anticipated to cross the subsea cables over the course of a year. With the range of vessel sizes and deadweight established, the displacement of a vessel can be estimated and this used to derive the indicative anchor size of the vessel. From the anchor size, it is possible to estimate the fluke length from standard anchor geometries. For this assessment, stockless anchors were used as defined by Vryhof in their publication 'Anchor Manual 2010 – The Guide to Anchoring', 2010 (Ref. 26).

Having defined the indicative fluke lengths for the anchor, it is possible to define the potential anchor penetration depths into the seabed based on the following approach:

- Sands and high strength clays = 1 x fluke length x sin 45°
- Low strength clays* = 3 x fluke length x sin 45°

**For this assessment anchor penetrating in clay units described as "low strength" (corresponding to "Soft" in the NorthConnect FEED document) or below (i.e. less than 40 kPa) followed the low strength clay method.*

Several of the MMT units describe medium strength clay and for these zones the sands and high strength clays anchor penetration method has been followed. If, in some parts *of these zones, the clay is towards the lower bound of this bracket the depth of anchor penetration may be underestimated however as other conservatisms are built in to the probabilistic method the overall risk should still be captured. As an example: the largest anchor size for each bin is assumed for the calculations – i.e. all vessels in the 100 to 1000 DWT category are assumed to be 1000DWT.*

This approach is based on the work completed by Shapiro et al (Ref. 24). It is recognised that anchor penetrations may vary significantly in mixed ground conditions; however, there is limited published literature or field trials available to allow an accurate prediction of drag anchor penetrations for each anchor size and soil type and detailed numerical modelling or field trials would be required to estimate anchor penetrations in mixed ground conditions. As a consequence, a significant simplification of the ground conditions had to be made on the basis of ground investigation data available to provide a realistic estimate of the penetrations likely to be achieved by dragged anchors for each relevant cable zone.

The anticipated anchor penetration depths for each vessel size in sand or low strength clay are summarised Table D.2.

Table D.2: Estimated anchor penetration depth

DWT (Te)	Estimated Displacement (Tons)	Estimated Anchor Size (kg)*	Estimated Fluke Length (m)*	Estimated Anchor Penetration Depth (m)*	
				Sands	Low strength Clay
0 to 10	17	36	0.33	0.24	0.77
10 to 100	170	123	0.50	0.35	1.15
100 to 1000	1700	524	0.81	0.57	1.86
1000 to 10000	17000	2388	1.34	0.95	3.08
10000 to 25000	42500	4388	1.64	1.16	3.77
25000 to 50000	85000	6959	1.91	1.35	4.39
50000 to 75000	127500	9114	2.09	1.48	4.80
75000 to 100000	170000	11039	2.23	1.58	5.12
100000 to 150000	255000	14461	2.44	1.72	5.60
150000 to 200000	340000	17516	2.60	1.84	5.97
200000 to 325000	552500	24206	2.89	2.04	6.64
325000 to 500000	850000	32255	3.18	2.25	7.31

*Note: Precision of numbers reflects formula outputs rather than an indicator of confidence. Final output probabilities (Table D.3) have been rounded to reflect this.

To enable better utilisation of the data and accurately assess the potential hazards presented by shipping to the cables, each zone has been considered separately according to the geology and annual shipping density from the AIS shipping data (Ref. 23). The maximum anchor penetration depths for the proposed zones are detailed in the burial assessment table in Appendix B.

Appendix D.1.3 Probabilistic Assessment Results

Cumulative frequency of a vessel anchor strike across each cable was calculated and the return period determined. It should be noted that an acceptable level of risk has not yet been agreed between all stakeholders hence hazard return periods have been detailed in the table below in relation to increased burial depth. The cable route has been split into encountered shallow geology and expected type of vessel. The most onerous types of vessel to cross the cable route are those of high DWT e.g. the section of the cable where the shipping lane with frequent Cargo/ Bulk Carrier traffic or the areas with large oil tankers crossing. The return periods need to be considered differently for sand and low strength clay for the following reasons:

- Anchor drag length in low strength clay is greater resulting in a larger area of influence around the cable.
- Anchors can penetrate deeper into low strength clay and so are more likely to be able to reach and damage the cable at a given depth.

The return periods for each individual cable section are detailed in the CBRA table in Appendix B, an example of one zone (zone 21) is shown in Table D.3. During the workshop with NorthConnect KS in Oslo, protection levels were preliminarily outlined for the route, drawn from the outcomes of the threatline assessments. These provide a framework that specifies a minimum acceptable burial depth from the chosen contractor (short sections only, case by case basis), as well as a target burial depth. Independent of this, in the CBRA recommendations are made for the absolute minimum depth of lowering to protect from the threatline posed by fishing alone, accounting for an allowance mobile sediments where encountered (large ripples or smaller in size, a different strategy is advised for larger bedforms). As discussed earlier in this report, this provides a level of protection such that the residual risk from accidental/emergency anchoring is deemed to be low.

In the example given in Table D.3 below, the change in anchor strike return period with increased burial is relatively small until between 3 and 4m depth. This is because the most common vessel size is the 1000 to 10 000Te DWT range. An accidental anchor deployment with an estimated weight of 2400kg for a 10 000Te vessel would be expected to penetrate 3.08m into the soft clay. A degree of conservatism is incorporated, as, for the purposes of the calculation all vessels within the 1000 to 10 000Te class are assumed to be carrying anchors of a size suitable for the upper-bound of the class (10 000Te vessel), whereas an estimated anchor for a 1000Te DWT vessel (524kg) would be estimated to penetrate 1.86m into the seabed. The risks in this section are considered low according to the probabilistic assessment, and to completely protect against the most common class of vessel would require burial >3m.

Table D.3: Probabilistic Assessment Return Period Summary: Example shipping zone 21

Cable Burial Depth (m)	Hazard Return Period (years, nearest 1000)
0	53000
0.25	53000
0.5	53000
0.75	53000
1	53000
1.5	56000
2	65000
3	65000
4	>100000
5	>100000

Appendix E – Shipping Drawings

Appendix F – Alignment Charts

Alignment charts are supplied in a separate file.