Beatrice Offshore Wind Farm Consent Plan

Cable Plan (OfTW)

December 2016

Beatrice Offshore Windfarm Ltd

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Project Title/ Location	Beatrice Offshore Wind Farm
Project Reference Number	LF000005-PLN-214
Date:	December 2016

Beatrice Offshore Wind Farm

Cable Plan

(Offshore Transmission Works)

Pursuant to the OfTW Marine Licence Condition 3.2.2.10

For the approval of the Scottish Ministers

Rev	Prepared By	Sign Off	Checked By	Sign Off	Approved By	Sign Off	Date of Issue
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Cable Plan (OfTW) Overview

Purpose and Objectives of the Plan

This Offshore Transmission Works (OfTW) Cable Plan (CaP) has been prepared to address the specific requirements of condition 3.2.2.10 attached to the OfTW Marine Licence issued to Beatrice Offshore Windfarm Limited (BOWL).

The overall aim of the OfTW CaP is to set out the procedures for the installation of the subsea Export Cables and the OTM Interconnector Cable between the Offshore Transformer Modules (OTMs), noting that a separate Wind Farm CaP has been prepared for the offshore inter-array cables.

This OfTW CaP confirms that the construction procedures described are in accordance with those considered in the original Application, and that construction-related mitigation measures detailed in the Application will be applied during installation.

All relevant method statements developed by contractors involved in the Beatrice Project must comply with the procedures set out in this OfTW CaP

Scope of the Plan

This OfTW CaP covers, in line with the requirements of the OfTW Marine Licence condition, the following:

- Details of the location and cable laying techniques for the subsea Export Cables and OTM Interconnector Cable, including the method of burial and protection;
- The results of survey work including geophysical, geotechnical and benthic surveys which will help inform cable routing, and methodologies for future survey work during the operational life of the cables;
- The technical specification of both the Export Cables and OTM Interconnector Cable, a burial risk assessment and measures to address exposure of cables; and
- Confirmation that the construction methods described within the OfTW CaP align with those considered in the original Application.

Structure of the Plan

The OfTW CaP is structured as follows:

Sections 1 to 3 set out the scope and objectives of the OfTW CaP, provide an overview of the Project and set out statements of compliance.

Section 4 sets out the process for making updates and amendments to this document.

Section 5 provides detail on the Export Cable and OTM Interconnector Cable routes and key constraints considered. It also provides detail on the geophysical, geotechnical and benthic surveys conducted to inform cable routing.

Section 6 details the location and layout of Export Cables and the OTM Interconnector Cable and the micro-siting tolerances.

Section 7 provides the technical specification of the Export Cables and OTM Interconnector Cable and their components. The results of electromagnetic field assessments are also detailed.

Section 8 details the results of the Cable Burial Risk Assessment and the Near Shore Erosion Risk Assessment.

Section 9 provides detail of the installation procedures and cable laying methodology.

Section 10 describes the inspection procedures and maintenance surveys to be carried out after installation and during operation.

Section 11 provides information to demonstrate compliance with the Application, and how the mitigation proposed in the Application will be delivered.

Appendix A details the ES and SEIS commitments relevant to this OfTW CaP and Appendix B demonstrates compliance with the original Application and mitigation set out in the ES and SEIS; Appendix C provides the detailed Near Shore Erosion Risk Assessment

Plan Audience

This OfTW CaP is intended to be referred to by relevant personnel involved in the construction of the Beatrice Project, including BOWL personnel, Key Contractors and Subcontractors. Compliance with this OfTW CaP will be monitored by BOWL (Consents and Licencing Team), the BOWL Ecological Clerk of Works (ECoW) and reported to the Marine Scotland Licensing and Operations Team.

Plan Locations

Copies of this OfTW CaP are to be held in the following locations:

- BOWL Head Office;

- At the premises of any agent, Key Contractor or Subcontractor (as appropriate) acting on behalf of BOWL;

- The BOWL Marine Coordination Centre at Wick;

- With the Ecological Clerk of Works (ECoW(s)).

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List of Abbreviations and Definitions

Term	Definition / Description
AC	Alternating Current.
AEZ	Archaeological Exclusion Zone.
Annex I cobble reef	The Joint Nature Conservation Committee has identified Special Areas of Conservation (SACs) within UK offshore waters for three habitat types listed in Annex I of the Habitats Directive. One of these habitat types is reefs, which may be variously comprised of bedrock, boulders and/or cobbles, or may be biogenic.
Application	The application letters and Environmental Statement submitted to the Scottish Ministers by BOWL on 23 April 2012 and Supplementary Environmental Information Statement submitted to the Scottish Ministers by BOWL on 29 May 2013.
BOWL	Beatrice Offshore Windfarm Limited (Company Number SC350248) and having its registered office at Inveralmond House, 200 Dunkeld Road, Perth, PH1 3AQ.
CBRA	Cable Burial Risk Assessment.
CLV	Cable Lay Vessel.
Consent Plans	Other plans, schemes or programmes referred to in this OFTW CMS as are required by the conditions of the OfTW Marine Licence, Wind Farm Marine Licence and/or the Section 36 Consent as the case may be.
CoP	Construction Programme as required for approval under Condition 10 of the S36 Consent and Condition 3.2.2.3 of the OfTW Marine Licence (Ref: LF000005-PLN-138).
CPS	Cable Protection System, a protective articulated cable casing installed between the OTM J-tube bellmouth and the seabed. It is designed to protect the cable from J-tube to seabed by providing increased: cable stability, abrasion protection, corrosion resistance, protection from dropped objects and weighted anchorage to the seabed.
Development	The Wind Farm and the OfTW.
Development Area	The marine area associated with the Wind Farm and OfTW corridor.
Depth of Closure	The depth of water beyond which annually significant wave events will cease to contribute to beach sediment supply and morphological processes.
Direct Pipe	DIRECT PIPE® is a pipeline installation methodology

Term	Definition / Description
	pioneered by Herrenknecht, a form of HDD which has the advantages of micro tunnelling technology. This technique excavates the borehole using a micro tunnelling machine, pushed by the prefabricated final pipeline in one single step.
DoL	Minimum Depth of Lowering (of buried cables) where possible.
DS	Design Statement as required for approval under Condition 14 of the S36 Consent and Condition 3.2.2.7 of the OfTW Marine Licence.
DSLP	Development Specification and Layout Plan as required for approval under Condition 13 of the S36 Consent and Condition 3.2.2.6 of the OfTW Marine Licence (Ref: LF000005-PLN-152).
ECoW	Ecological Clerk of Works as required for approval under Condition 30 of the S36 Consent and Condition 3.2.2.12 of the OfTW Marine Licence.
EC1	Beatrice Transmission subsea Export Cable 1 (Easterly cable).
EC2	Beatrice Transmission subsea Export Cable 2 (Westerly cable).
EMP	Environmental Management Plan as required for approval under Condition 15 of the S36 Consent and Condition 3.2.1.2 of the OfTW Marine Licence (Ref: LF000005-PLN-144).
EPCI	Engineering, Procurement, Construction and Installation.
Erosion Edge	This is edge of the hinterland vegetation where it meets the marine influenced beach topography. It is typically where shingle storm washover fans meet the vegetation edge of the hinterland. It is otherwise referred to as the ‘vegetation edge’ or ‘back of berm’.
ES	The Environmental Statement submitted to the Scottish Ministers by the Company on 23 April 2012 as part of the Application.
Entry Point	The onshore entry point for the pipe on completion of the Direct Pipe installation activities and after the pipeline has been cut to the required length. Typically, the final pipe entry point corresponds to the front wall of the Pipe Thrust Pit.
Export Cables	The High Voltage (HV) Alternating Current (AC) 220kV electrical transmission cable required to connect the Windfarm to the OnTW.

Term	Definition / Description
Final Exit Point	The offshore seabed end of pipe position, once the pipeline has been pulled back in to the seabed to achieve the required depth of burial. It is also the point at which the Polypipe attaches the pipe end flange.
Habitats Directive	Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora.
HDD	Horizontal Directional Drilling. A steerable, trenchless, method of installing an underground pipe, conduit or cable in a shallow arc along a prescribed bore path by using surface-launched drilling equipment, with minimal impact on the surrounding area.
HVAC	High Voltage Alternating Current
Inter-array cables/cabling	The Medium Voltage (HV) Alternating Current (AC) 33kV electrical cables that connect the WTGs to the OTMs.
OTM Interconnector Cable	High Voltage (HV) Alternating Current (AC) 220kV electrical cable that connects the OTMs to one another.
ISV	Installation Support Vessel
J-tube	Steel tubes that allow the installation of cables by providing a safe and secure conduit through which the cables can be pulled. The tubes run from the cable termination points on the WTG or OTM top deck down the support structure and bend outwards in a ‘J’ shape terminating in a wide bell mouth approximately 2-3m above the seabed. The J-tube provides long term protection for the cable routed from subsea to the upper deck.
Key Contractors	The contractors appointed for the individual work steams of Marine Installation; Transmission; and WTGs.
km	Kilometre
kV	Kilovolt
LAT	Lowest Astronomical Tide
Licensing Authority	The Scottish Ministers
Marine Co-ordination	The management and surveillance of people, vessels and offshore structures and progress of the construction works to ensure the safe preparation and execution of offshore activities, in order to minimise the probability of an incident, and to provide effective response if an incident does occur.
Marine Licences	The OfTW Marine Licence and the Wind Farm Marine Licence.
MCA	Maritime and Coastguard Agency
MHWS	Mean High Water Springs.

Term	Definition / Description
MS - LOT	Marine Scotland Licensing Operations Team.
NSERA	Near-shore Erosion Risk Assessment.
NSP	Navigational Safety Plan as required for approval under Condition 18 of the S36 Consent and Condition 3.2.2.9 of the OfTW Marine Licence (Ref: LF000005-PLN-128).
OfTW	This Offshore Transmission Works. The OfTW includes the transmission cables required to connect the Wind Farm to the OnTW. This covers the Export Cables from the OTMs to the Mean High Water Springs (MHWS) at the landfall west of Portgordon on the Moray coast. It also includes the two OTMs and the OTM interconnector cable.
OfTW CaP	The Offshore Transmission Works Cable Plan as required for approval under Condition 3.2.2.10 of the OfTW Marine Licence (Ref: LF000005-PLN-214).
OfTW CMS	The Offshore Transmission Works Construction Method Statement in respect of the export cable installations and OTM commissioning to be submitted for approval under Condition 3.2.2.4 of the OfTW Marine Licence (Ref: LF000005-PLN-184).
OfTW Marine Licence	The written consent for the OfTW granted by the Scottish Ministers under Section 20(1) of the Marine (Scotland) Act 2010 and Section 65 of the Marine and Coastal Access Act 2009, issued on 2 September 2014, as amended by the revised licence issued on 27 April 2016.
OnTW	Onshore Transmission Works (OnTW) from Mean High Water Springs (MHWS) at the landfall west of Portgordon on the Moray coast to the onshore substation and connection to the National Grid network. It consists of two onshore buried Export Cables (2x20km), the onshore BOWL 220kV/400kV substation and two 400kV (2x0.5km) Export Cables to the Scottish and Southern Electricity Networks substation at Blackhillock.
OSP	Offshore Substation Platform.
OTM	Offshore Transformer Module means an alternating current (AC) OSP which is a standalone modular unit that utilises the same substructure and foundation design as a wind turbine generator. Each transformer module is the collection point for half the Wind Farm's WTG generated power at 33kV and converts it to the 220kV onshore transmission voltage to minimise electrical losses
Pipe Thruster	The unit which is used to provide up to 750 tonnes of thrust or pull force to the pipeline string being installed.
Pipe Thruster Pit	The onshore location of the Pipe Thruster. The Pipe

Term	Definition / Description
	Thruster Pit (sometimes known as the launch pit) is a temporary pit structure which provides the necessary structural anchorage for the Pipe Thruster Unit and is configured to allow the required ground entry angle for the pipe. The Pipe Thruster Pit is usually constructed from sheet piles and concrete which is fully removed on completion of the pipeline installation.
PLGR	Pre-lay grapnel run is a route clearance activity to remove longitudinal debris (fishing nets, ropes, wire etc.) which may impede cable lay or its subsequent burial.
Polypipe	The Polypipe is a medium or high density 20-30m long plastic pipe conduit which facilitates the cable entry and pull-in into the offshore pipe Final Exit Point situated beneath the seabed. The Polypipe is attached to the pipe end flange. On completion of the cable pull-in both the Polypipe and cable are buried beneath the seabed for long term protection.
ROV	Remotely operated vehicle
Seabed push-out point	The offshore seabed exit point for the direct pipe and micro tunnelling machine. The pipeline is "over" pushed out onto the seabed to allow recovery of micro tunnelling machine, before the pipe is sealed and pulled back in to the seabed to achieve the required depth of seabed burial at the end of the pipe.
Section 36 Consent	Consent granted by the Scottish Ministers under Section 36 of The Electricity Act 1989 to construct and operate the Wind Farm, dated 19th March 2014.
SEIS	The Supplementary Environmental Information Statement submitted to the Scottish Ministers by the Company on 29 May 2013 as part of the Application.
Site	The areas outlined in red and black on Figure 1 attached to the S36 Consent and the figure contained in Part 4 of the OfTW Marine Licence respectively.
SNH	Scottish Natural Heritage
SSS	Side Scan Sonar.
SSSI	Site of Special Scientific Interest.
Subcontractor	Subcontractors to the Key EPCI Contractors
Transition Joint Bay	The transition joint bay (TJB) is where the 220 kV Subsea cable is jointed to the 220 kV Land cable. The TJBs are part of the permanent cable infrastructure and are set some distance back from the Entry Points.
UXO	Unexploded Ordnance.

Term	Definition / Description
VMP	Vessel Management Plan as required for approval under Condition 16 of the S36 Consent and Condition 3.2.2.8 of the OfTW Marine Licence (Ref: LF000005-PLN-168).
WGS84	World Geodetic System 1984; the reference coordinate system used by the Global Positioning System.
Wind Farm	The offshore wind turbine array development as assessed in the ES including wind turbines, their foundations, and inter-array cabling.
Wind Farm CaP	Wind Farm Cable Plan as required for approval under Condition 19 of the S36 Consent.
Wind Farm Marine Licence	The written consent for the Wind Farm granted by the Scottish Ministers under Section 20(1) of the Marine (Scotland) Act 2010, issued on 2 September 2014, as amended by the revised licence issued on 27 April 2016.
WTG	Wind Turbine Generator.

1 Introduction

1.1 Background

1.1.1 BOWL received consent for the Wind farm under Section 36 of the Electricity Act 1989 from the Scottish Ministers on 19th March 2014 (the Section 36 Consent) and was granted two Marine Licences from the Scottish Ministers for the Wind Farm and associated Offshore Transmission Works (OfTW), on 2nd September 2014 and subsequently superseded on 27 April 2016 (reference: [04461/16/0]/[04462/16/0]).

1.2 Objectives of this Document

1.2.1 The OfTW Marine Licence contains a variety of conditions that must be discharged through approval by the Scottish Ministers prior to the commencement of offshore construction.

1.2.2 One such requirement of the OfTW Marine Licence is the approval of a Cable Plan (CaP), as required by condition 3.4.4.10 (the Consent Condition).

1.2.3 The relevant condition setting out the requirement for an OfTW CaP for approval, and which are to be discharged by this OfTW CaP, is set out in full in Table 1.1.

1.2.4 For the purposes of the Consent Condition, this OfTW CaP relates to the 220kV Export Cables and 220kV OTM Interconnector Cable. A separate Wind Farm CaP has been prepared for the inter-array cables.

Table 1.1 - Consent Condition to be discharged by this OfTW CaP

Consent Document	Condition Reference	Condition Text	Reference to relevant Section of this CaP
Marine Licence (OfTW)	3.2.2.10	The Licensee must, no later than 6 months prior to the Commencement of the Works, submit a CaP in writing, to the Licensing Authority for their written approval.	This document sets out the OfTW CaP for approval by the Scottish Ministers
		Such approval may only be granted following consultation by the Licensing Authority with the JNCC, SNH, MCA, and the SFF and any other advisor or organisations as may be required at the discretion of the Licensing Authority.	Consultation to be undertaken by the Scottish Ministers
		The CaP must be in accordance with the Application	Sections 11 and Appendices A and B
		The CaP must include the following: a) Details of the location and cable laying techniques for the cables;	Section 6 and 9

Consent Document	Condition Reference	Condition Text	Reference to relevant Section of this CaP
		b) The results of survey work (including geophysical, geotechnical and benthic surveys) which will help inform cable routing;	Section 5
		c) Technical specification of all cables, including a desk based assessment of attenuation of electro-magnetic field strengths and shielding;	Section 7
		d) A burial risk assessment to ascertain if burial depths can be achieved. In locations where this is not possible then suitable protection measures must be provided;	Section 8 and Section 9
		e) Methodologies for over trawl surveys of cables through the operational life of the Works where mechanical protection of cables laid on the sea bed is deployed; and	Section 10
		f) Measures to address exposure of any cables.	Section 10

1.2.5 In addition to the specific requirements of Condition 3.2.2.10 of the OfTW marine Licence for an OfTW CaP (as set out in Table 1.1), this OfTW CaP also includes information in respect to near-shore cable installation works which will comprise a form of HDD, known as Direct Pipe installation (see Section 9), and therefore includes information in respect of Condition 3.2.3.8 of the OfTW Marine Licence, as set out in Table 1.2.

Table 1.2 - Other consent conditions relevant to this OfTW CaP

Consent Document	Condition Reference	Condition Text	Reference to relevant section of this CaP
Marine Licence (OfTW)	3.2.3.8	The Licensee must ensure the seaward end point of the HDD will be located as far as practicable towards the depth of closure; the landward exit point of the HDD will be located onshore of the high-water mark, which may move landward due to coastal retreat; and the cables will be suitably buried between the seaward exit of the HDD and the depth of closure (the depth of water beyond which annually significant wave events will cease to contribute to beach sediment supply and	Section 9

		morphological processes).	

1.3 Linkages with Other Consent Plans

1.3.1 This OfTW CaP sets out the layout of the Export Cables and OTM Interconnector Cable and the methods for their installation. However, ultimately it will form part of a suite of approved documents that will provide the framework for the construction process – namely the other Consent Plans required under the Section 36 Consent and Marine Licences.

1.3.2 Condition 3.2.2.10 of the OfTW Marine Licence (see Table 1.1) does not explicitly identify linkages between this OfTW CaP and other Consent Plans. However, other conditions require that several other Consent Plans be consistent with the OfTW CaP; these plans are identified in Table 1.2.

Table 1.2 – OfTW CaP linkages with other Consent Plans

Other Consent Plan	Consistency with and linkage to CaP
The OfTW Construction Method Statement (CMS) (OfTW Marine Licence Condition 3.2.2.4)	The purpose of the OfTW CMS is to detail the methods that will be implemented during the construction of the OfTW. The CaP is, so far as is reasonably practicable, consistent with the OfTW CMS.
The OfTW Operation and Maintenance Programme (OMP) (required under OfTW Marine Licence Condition 3.2.3.2)	The OfTW OMP will set out the procedures and good working practices for the operational and maintenance (O&M) phase of the OfTW. The OMP will be, so far as is reasonably practicable, consistent with the CaP

1.4 Structure of this OfTW CaP

1.4.1 In response to the specific requirements of condition 3.2.2.10 of the OfTW Marine Licence, this OfTW CaP has been structured so as to be clear that each specific requirement of the condition has been met and that the relevant information to demonstrate that the requirements of the consent Condition are met by this OfTW CaP. The document structure is set out in Table 1.3.

Table 1.3 – OfTW CaP document structure

Section	Title	Overview
1	Introduction	Background to consent requirements and overview of the OfTW CaP scope and structure; and Identifies those other Consent Plans relevant to the construction/installation process and provides a statement of consistency between this OfTW CaP and those plans.
2	BOWL Statements of Compliance	Sets out the BOWL statements of compliance in relation to the OfTW CaP Consent Condition and the broader construction process.
3	Project Overview	Provides an overview of the project and key construction

Section	Title	Overview
		programme milestones. Identifies the Key Contractor.
4	Updates and Amendments to this OfTW CaP	Sets out the procedures for any required updating to or amending of the approved OfTW CaP and subsequent further approval by the Scottish Ministers
5	Cable Route and Installation Considerations	Provides information on the Export Cable and OTM Interconnector Cable routes and key constraints considered. It also provides detail on the geophysical, geotechnical and benthic surveys conducted to inform cable routing.
6	Location and Layout of Export Cables and OTM Interconnector Cable	Provides detail on the location of the Export Cable and OTM Interconnector Cables and micro-siting.
7	Technical Specification of Export Cables and OTM Interconnector Cable	Details the cable specifications and the results of an electromagnetic field assessment.
8	Cable Burial Risk Assessment	Provides details of the cable burial risk assessment conducted to determine installation procedures.
9	Export Cables and OTM Interconnector Cable Installation Methodology	Summarises the installation procedures associated with the Export and OTM interconnector cabling.
10	Export Cable Operation and Maintenance	Sets out the operation and maintenance programme and remedial procedures in the event that the cables become exposed.
11	Compliance with the Application, ES and SEIS	Sets out how the details in this OfTW CaP are in accordance with those assessed in the ES and SEIA; and how the mitigation measures related to construction identified in the ES and SEIS are to be delivered.

2 BOWL Statements of Compliance

2.1 Introduction

2.1.1 The following sections are intended to re-affirm the BOWL commitment to ensuring that the Development is constructed in such a manner as to meet the relevant legislative requirements set out by the OfTW Marine Licence.

2.2 Statements of Compliance

2.2.1 BOWL in undertaking the construction of the project will require compliance with this OfTW CaP as approved by the Scottish Ministers (and as updated or amended from time to time following the procedure set out in Section 4 of this OfTW CaP).

2.2.2 Where updates or amendments are required to this OfTW CaP, BOWL will require that the Scottish Ministers are informed as soon as reasonably practicable and where necessary the OfTW CaP will be updated or amended (see Section 4 below).

2.2.3 BOWL in undertaking the construction of the OfTW will require compliance with other, relevant Consent Plans as approved by the Scottish Ministers as set out in Section 1.3 above.

2.2.4 BOWL in undertaking the construction of the OfTW will require compliance with the limits defined by the original application and the project description defined in the Environmental Statement (ES) and Supplementary Environmental Information Statement (SEIS) and referred to in Part 2 and 4 of the OfTW Marine Licence in so far as they apply to the OfTW CaP (unless otherwise approved in advance by the Scottish Ministers) (see Section 11 and Appendix A (Compliance with ES/SEIS Commitments) and Appendix B (Compliance with ES/SEIS Rochdale Envelope Parameters)).

2.2.5 BOWL will, in undertaking the construction of the OfTW, require compliance with all other relevant legislation and require that all necessary licences and permissions are obtained by the Key Contractors and Sub-contractors through conditions of contract and by an appropriate auditing process.

3 Development Overview

3.1 Introduction

3.1.1 This section of this OfTW CaP provides an overview of the BOWL Development and summarises the timing of the offshore construction work.

3.1.2 The specific detail on the cable specification and installation procedures associated with both the OTM inter-connector cable and the Export Cables is provided in Section 7 and 9 of this OfTW CaP respectively.

3.2 Development Overview

3.2.1 The Development will consist of the following main components:

- A total generating capacity of not less than 588MW;
- Up to 84 wind turbines of 7MW rated generating capacity;
- Jacket substructures each installed on four pile foundations driven into the seabed;
- Two AC 220 / 33 kV substation platforms, referred to as Offshore Transformer Modules (OTMs) to collect the generated electricity and transform the electricity from 33kV to 220kV for transmission to shore;
- A network of circa 140km of inter-array cables, buried or (if burying is not possible) mechanically protected, subsea cables to connect strings of turbines together and to connect the turbines to the OTMs;
- Two buried or mechanically protected, subsea Export Cables, totalling circa 140km in length, to transmit the electricity from the two OTMs to the landfall at Portgordon and connect to the two onshore buried Export Cables for transmission at the transition joint pit. The onshore Export Cables further transmit the electricity to the BOWL onshore substation at Blackhillock. After which further 400 kV cabling connect the BOWL substation to the National Grid network via the neighbouring Scottish Hydro Electric Blackhillock substation;
- One OTM Interconnector Cable of circa 1.2km in length that links the OTMs to one another; and
- Minor ancillary works such as the deployment of metocean buoys and aids to navigation as defined in the Lighting and Marking Plan (LMP) (Ref: LF000005-PLN-136).

3.2.2 The Development is located approximately 13.5 km offshore from its nearest point to the east Caithness coastline in the Moray Firth (Figure 3.1). The Export Cables are located within the corridor outlined in black on Figure 3.1 and the OTM Interconnector Cable is located within the Wind Farm area, outlined in red on the same figure.

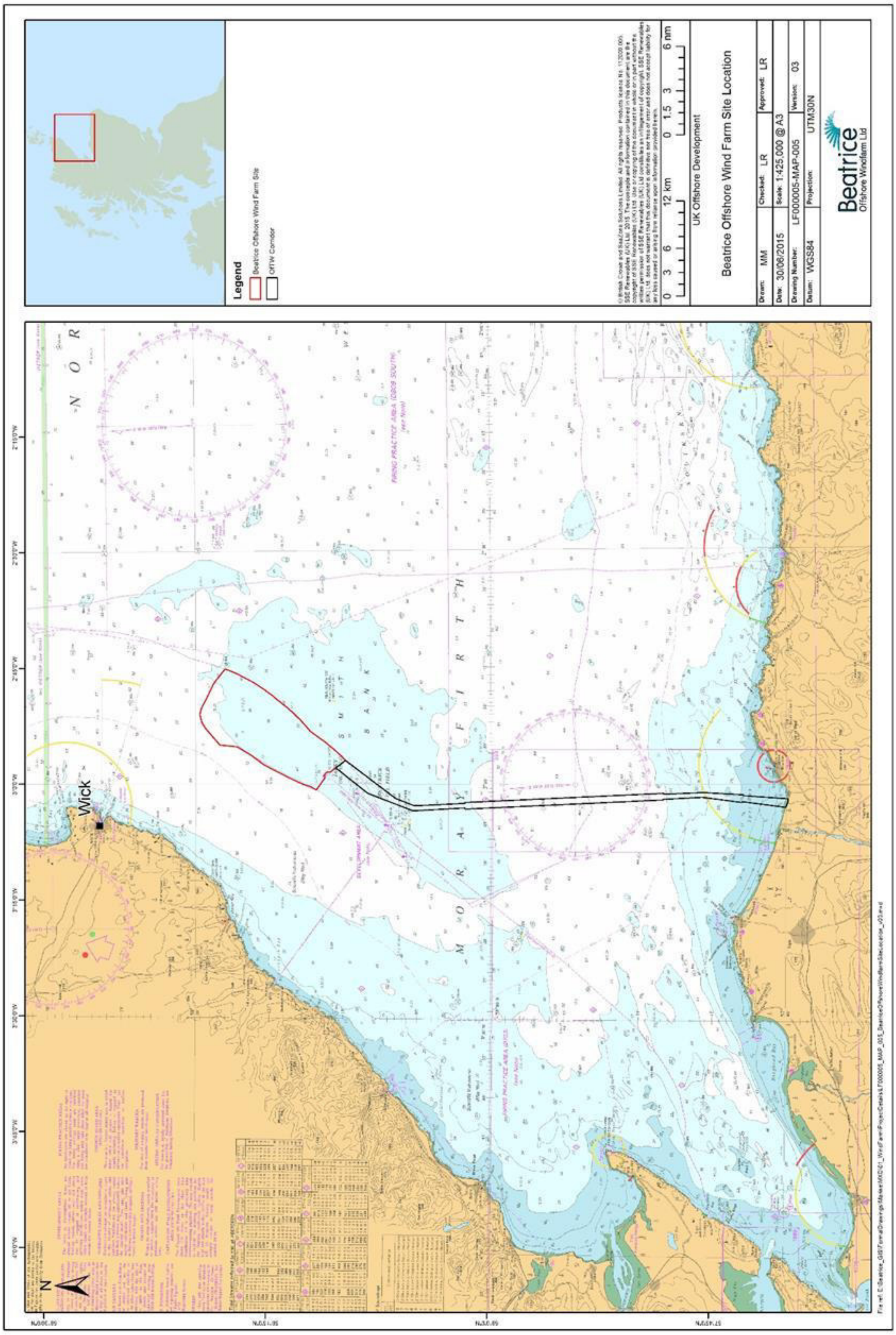


Figure 3.1 – Development general location map

3.3 Timing of Construction Works

3.3.1 Details of the construction programme are provided in the approved Construction Programme (CoP) (required under Condition 10 of the S36 Consent and Condition 3.2.2.3 of the OfTW Marine Licence) (BOWL Document Ref: LF000005-PLN-143). It is currently anticipated that the offshore construction works will be carried out around the clock (i.e. 24 hour working 7 days a week unless noted otherwise).

3.4 Key Contractors

3.4.1 BOWL have contracted Siemens Transmission and Distribution Limited (STDL) and Nexans Norway (part of the wider Nexans group) who have formed a Joint Venture, to design, manufacture, supply and install the offshore and onshore transmission infrastructure. Nexans Norway will design, supply and install the offshore Export Cables and the OTM Interconnector Cable.

3.4.2 Nexans Norway is part of the Nexans group, a world leading cable manufacturer, with industrial facilities in 40 countries and commercial activities worldwide. Nexans Norway produce and install submarine power cables and advanced umbilicals to transmit and connect renewables projects to national transmission systems around the globe.

3.4.3 Siemens Transmission and Distribution Ltd (STDL) is the UK's largest transmission substation contractor, employing around 700 employees in the UK. STDL designs and constructs AC and DC substations for UK generation, transmission and distribution companies and industrial customers. The business is currently working on design and build contracts for three offshore wind farm connections.

3.5 Subcontractors

3.5.1 Nexans Norway will be responsible for identifying and contracting Subcontractors such as may be required to provide services for the completion of the construction works. The installation of the horizontal pipes (or ducts) through which the cables will be installed where they reach landfall will be subcontracted to Stockton Drilling Limited.

3.5.2 Examples of additional services that may need to be sub-contracted include nearshore works, seabed preparation, boulder clearance, rock dump protection, support vessels, guard vessels, survey services, transport services, supply of minor components, waste services, vessel provisioning and bunkering services and provision of equipment to be used in the construction works.

4 Updates and Amendments to this OfTW CaP

4.1.1 This OfTW CaP sets out the proposed methods for installation of the Export Cables and the OTM Interconnector Cable.

4.1.2 Consent Condition 3.2.4.4 of the OfTW Marine Licence recognises that updates or amendments to this OfTW CaP may be required, stating that:

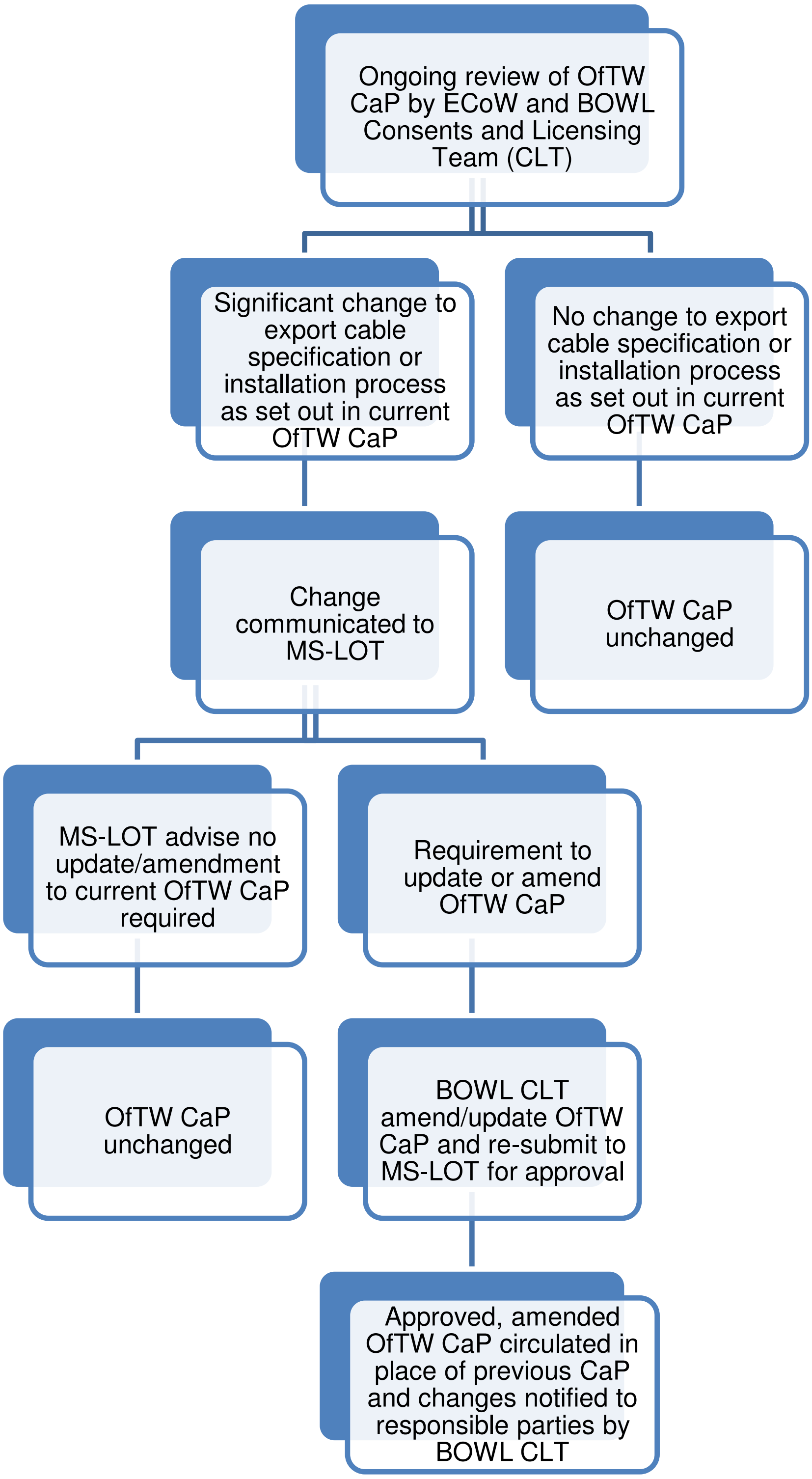
Any updates or amendments made to the …CaP… by the Licensee, must be submitted, in writing, by the Licensee to the Licensing Authority for their written approval.

4.1.3 The main approach to the installation process is described in this OfTW CaP including:

- Location, number and specification of cables (including constraints and data used to inform Export Cable and the OTM Interconnector Cable location and installation);
- Export and OTM Interconnector Cable Burial Risk Assessment; and
- Cable Installation and protection procedures.

4.1.4 Where it is necessary to update this OfTW CaP in the light of any significant new information related to the cables, BOWL propose to use the change management process set out in Figure 4.1 in identifying such information, communicating such change to the Scottish Ministers, re-drafting the OfTW CaP if required, seeking further approval for the necessary amendments or updates and disseminating the approved changes/amendments to responsible parties.

Figure 4.1 OfTW CaP Change Management Procedure



5 Cable Route and Installation Considerations

5.1 Introduction

5.1.1 The Consent Condition requires that this OfTW CaP includes the following:

The results of survey work (including geophysical, geotechnical and benthic surveys) which will help inform cable routing

5.1.2 This section provides information on the key constraints, including those identified through surveys, that have determined cable routing (as set out in Section 6).

5.2 Key Constraints Identified in the OfTW Development Specification and Layout Plan

5.2.1 The routing of the Export Cables has been driven fundamentally by the location of the point of electrical connection to the National Grid at Blackhillock substation.

5.2.2 There are a small number of physical spatial constraints within the Wind Farm 'developable area' and along the OfTW corridor. These are defined in the OfTW Development Specification and Layout Plan (DSLP) (BOWL Document Ref: LF000005-PLN-181). The following constraints have been taken into account in defining the Export Cables and OTM Interconnector Cable routes, and are shown in Figures 5.2 to 5.5:

- A 500m buffer around the Beatrice Alpha, Bravo, Charlie and Jacky oil platforms to preclude the installation of any cables (as required by Condition 3.2.3.12 of the OfTW Marine Licence);
- A 770m buffer from the Moray Firth Round 3 Zone boundary (as required under the terms of The Crown Estate Agreement for Lease) applies to all cables within the Wind Farm boundary. Cables within the OfTW corridor are not subject to this limitation;
- Plugged or abandoned wellheads have been avoided;
- A small number of magnetic anomalies that could represent unexploded ordnance (UXO) were identified by survey. The Export Cables have been routed to avoid these;
- Several features of potential archaeological interest identified by geophysical surveys and their associated Archaeological Exclusion Zones (AEZs) have been avoided; and
- The locations of previously laid cables or pipelines have been avoided.

5.2.3 In addition to the constraints listed above, the OfTW Marine Licence includes a provision for horizontal directional drilling (HDD) to install the Export Cables beneath the Spey Bay Site of Special Scientific Interest (SSSI) where the cable makes landfall in order to minimise potential effects on features of conservation interest (see Table

1.2). To avoid impacting designated features of the Spey Bay SSSI the Export Cables will be installed via pre-installed horizontal pipes, beneath the SSSI.

5.2.4 Scottish Hydro Electric Transmission (SHE-T) have been awarded a licence by The Crown Estate to lay sub-sea transmission cables as part of the Caithness to Moray HV DC transmission project. The SHE-T cable landfall will be west of Portgordon and lies just within the BOWL OfTW export cable corridor. Under a proximity agreement BOWL and SHE-T have agreed cable routings within the BOWL corridor, with the BOWL Export Cables now constrained to the western side of the BOWL OfTW corridor at landfall as shown on Figure 5.3.

5.2.5 Potential constraints (or 'risks') that have been considered in defining cable installation methods and intended depths of cable burial are fully described in Section 8.

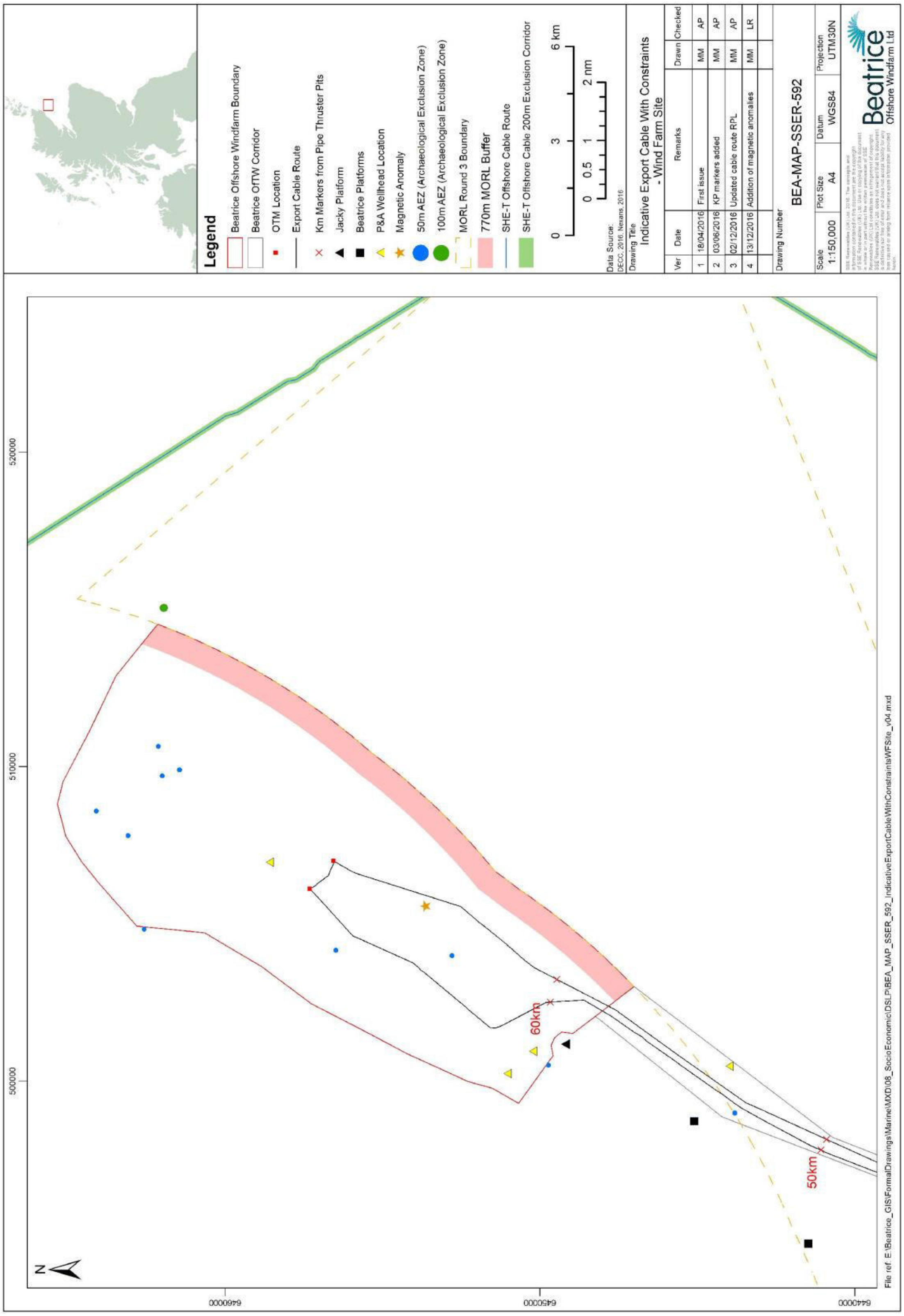


Figure 5.1 – Key constraints within the ‘developable area’ relevant to the Export Cables and OTM Interconnector Cable

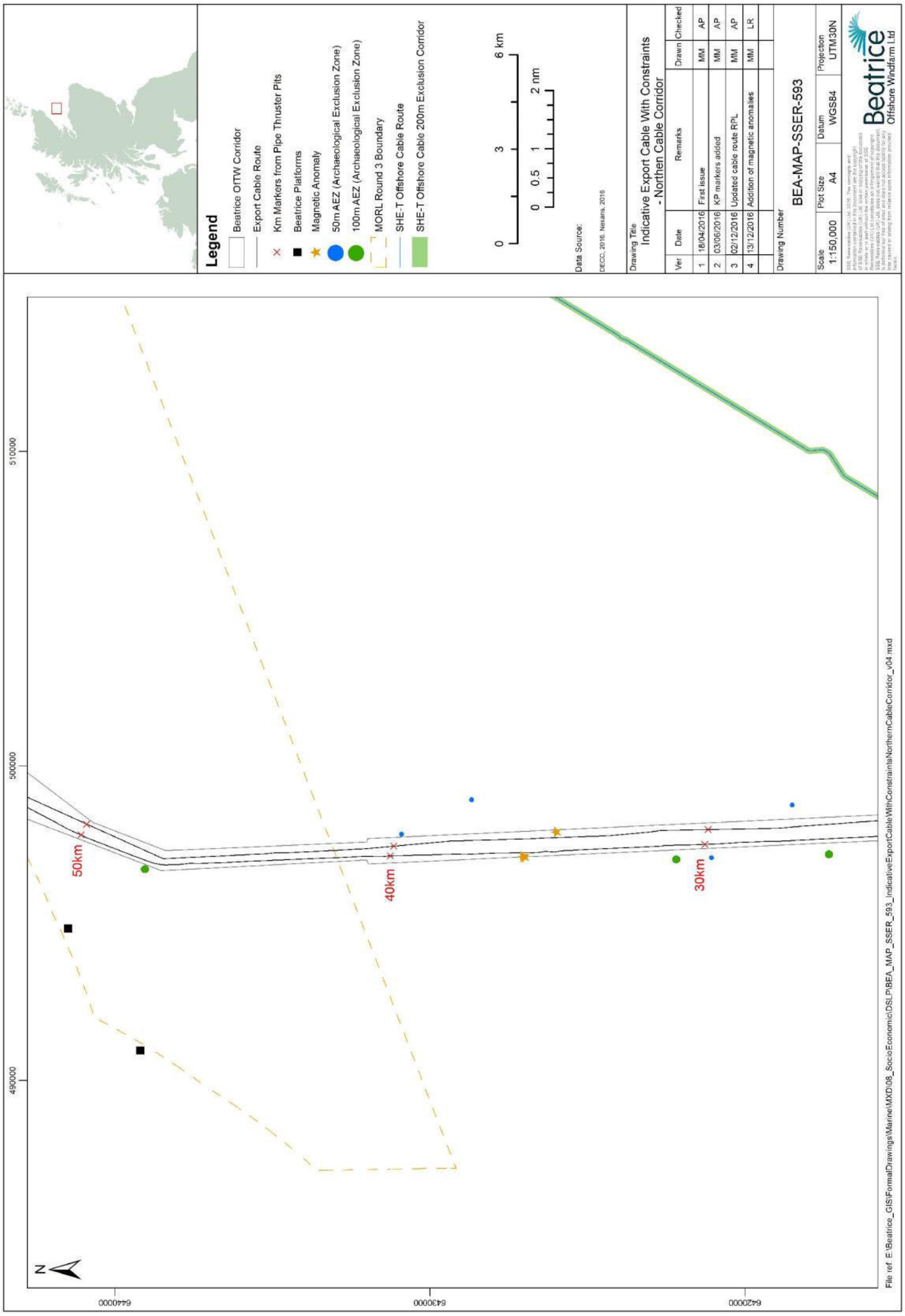


Figure 5.2 – Key constraints relevant to the Export Cables (northern section of OfTW corridor)

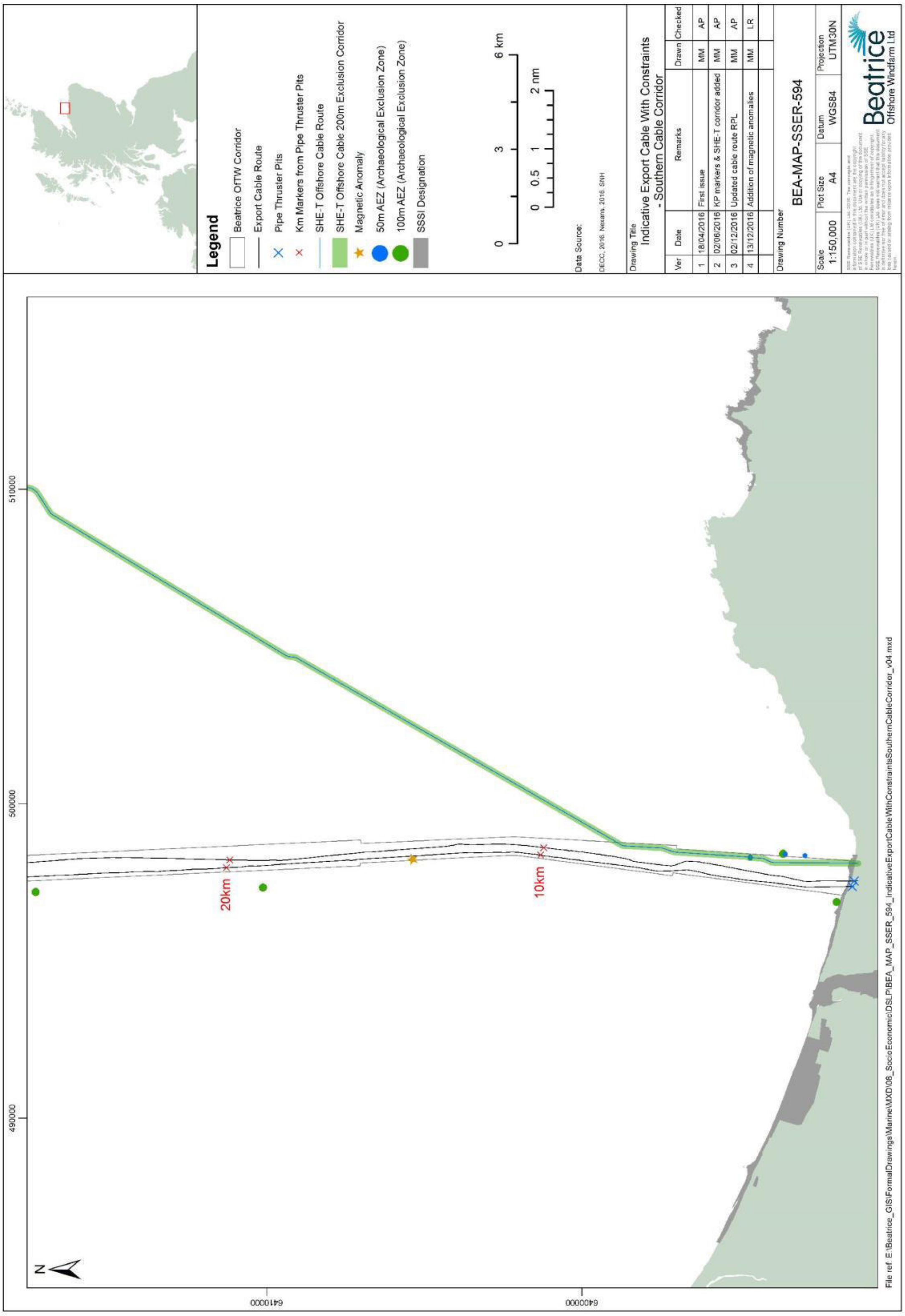


Figure 5.3 – Key constraints relevant to the Export Cables (southern section of OfTW corridor)

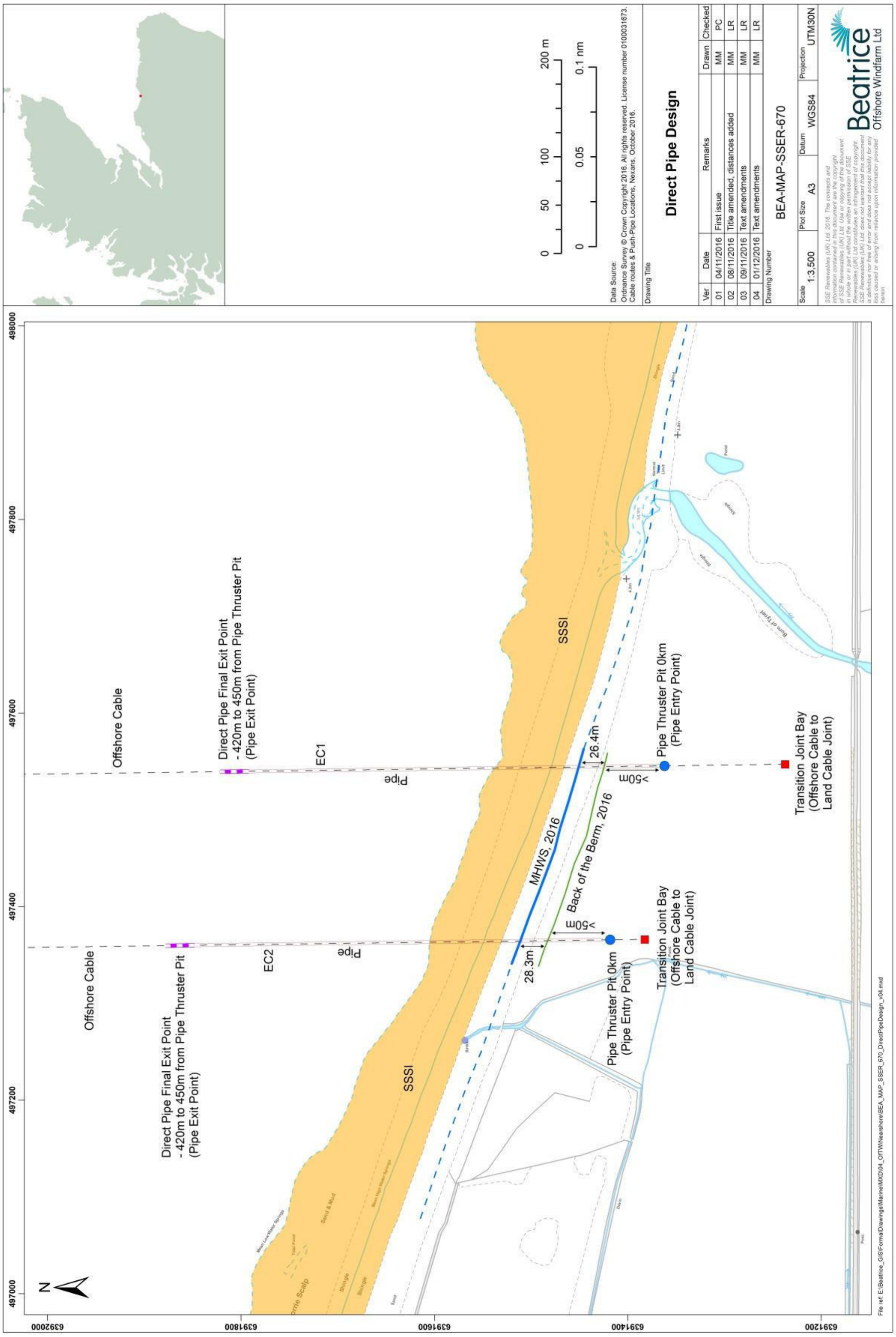


Figure 5.4 – Key constraints relevant to the Export Cables (near-shore and landfall section of OfTW corridor)

5.3 Constraints to Cable Routing and Installation Identified by Surveys

5.3.1 A series of geotechnical, geophysical and benthic surveys have been commissioned by BOWL to understand seabed conditions along the OfTW corridor. The results of these surveys have been considered in defining the routing and installation of the Export Cables. A summary of relevant pre-construction surveys conducted is provided in Table 5.1 below.

Table 5.1 - Summary of pre-construction baseline surveys conducted in the OfTW corridor

Date	Contractor	Survey Type and Spatial Coverage	Comments
2010	**CMACS** (Benthic)	Hamon grab samples Drop Down Video (DDV) samples Epibenthic beam trawls	Benthic survey works completed in 2010 across the Beatrice Offshore OfTW corridor. The survey was undertaken to characterise benthic communities along the export cable route, to inform the original Beatrice Environmental Statement (ES) and Supplementary Environmental Information Statement (SEIS).
2011	**Gardline** (Benthic, Geophysical and Geotechnical)	Single and Multi-beam echo sounder, side scan sonar, magnetometer and sub-bottom profiler Geotechnical: Sampling boreholes and cone penetrations test (CPT) boreholes	Geophysical survey works was undertaken in 2011 to inform OfTW cable route options. Survey was undertaken to characterise sediment types, geological features, bathymetry and to identify the presence of reef structures. Focus on the 10km landward section of the corridor to identify particular geophysical features. Geotechnical surveys comprised 40 CPTs and 31 vibrocores. Locations were spaced along the route at 400 to 3800m intervals.
2011	**Osiris** (Geophysical and Geotechnical)	Multi-beam echo sounder, side scan sonar, sub-bottom profiler	Osiris completed a geophysical site survey along the Beatrice OfTW area during April and May 2010. The objectives were to assess detailed bathymetry, seabed features and shallow soil conditions. The survey was undertaken to characterise seabed conditions along the potential export cable corridor, to inform the original ES and SEIS.
2015	**MMT** (Geophysical and Geotechnical)	Geophysical: Multi-beam echo sounder, side scan sonar, transverse gradiometer, sub-bottom profiler, remotely operated vehicle (ROV) imagery over 74km of export cable corridor. Geotechnical: Sampling boreholes and cone penetrations test (CPT) boreholes	MMT completed a survey over approximately 74km of export cable route corridor during August and September 2015. The geophysical survey comprised multibeam echo sounding, side scan sonar, transverse gradiometer, sub-bottom profiler, and ROV data acquisition techniques. The geotechnical survey comprised 74 vibrocores and 74 CPTs were completed along the export cable corridor to a minimum depth of 5m below seabed. The survey was undertaken to inform export cable detailed engineering design.
2015	**APEM** (Benthic)	Drop Down Video (DDV) samples	APEM completed a survey along the landward 10km of the export cable corridor to determine the distribution and extent of potential cobble reef habitat which constitutes potential Annex I habitat under the EC Habitats Directive.
2016	**Fugro** (Shore based	Sub-bottom profilers	Fugro completed a survey along transects from the onshore working area (near the planned Pipe

	and near-shore geophysical survey)		Thruster Pit locations) to 1.4 and 1.6 km offshore. The survey provided details of the sub-geological layers to inform the most suitable method of installing the horizontal pipes beneath the SSSI.
2016	**Nexans, Clinton and Ordtek** (UXO survey)	Magnetometers, side scan sonar, multi beam echo sounders (ROV)	Survey of Export Cable route installation corridors to identify any magnetic anomalies that could indicate presence of UXO.

5.3.2 The text below summarises the findings of these surveys as relevant to Export Cable corridor routing (as set out in Section 6 this OfTW CaP) or installation methods (as set out in Section 9 of this OfTW CaP) as appropriate.

Geophysical Surveys of the OfTW Corridor

5.3.3 The general bathymetry of the OfTW corridor is characterised by flat seabed with gentle slopes though there are a number of depressions and surface channels along the route (see Figure 5.5).

5.3.4 Bathymetry along the Export Cable corridor routes ranges from approximately 1m below Lowest Astronomical Tide (LAT) at the Direct Pipe final exit point (see Figure 5.4), to a maximum depth of 99m in the central part of the routes.

5.3.5 Surface geology identified from geophysical surveys determined that the northern and middle part of the OfTW corridor are generally dominated by gravelly sand and sandy gravel. In the deeper central areas of the route, there are deposits of laminated clay with silt. Diamicton was detected in the southern region of the corridor with occasional pockets containing clay (see Figure 5.6).

5.3.6 Boulders were observed along the entire corridor, with the highest density of boulders greater than 0.2m diameter occurring within 10km of the shoreline (see Figure 5.7). There is the potential for subsurface boulders to also be present.

5.3.7 Surveys of the OfTW corridor conducted by MMT in 2015 (Table 5.1) detected a total of 983 magnetic anomalies, of which 245 were interpreted as possibly anthropogenic. After progression of export cable engineering routing, a further detailed UXO survey was completed by Nexans Norway in August 2016. Various magnetic anomalies within the export corridor were identified; the export cables were re-routed around the more significant targets. With successful re-routing achieved, no UXO detonations were required.

5.3.8 Additional ground investigation surveys, utilising seismic refraction techniques, on the shoreline and in the near-shore area of the OfTW corridor were completed in 2016 (see Table 5.1). These surveys were used to determine the rock bed level beneath the overlying gravelly sediment and describe the stratigraphy and bed rock conditions between 0m and 20m below ground level. The results have been used to inform refinement of the approach to the pipe profile and the installation by the Direct Pipe methodology beneath the coastal area of the SSSI.

Geotechnical Surveys of the OfTW Corridor

5.3.9 Geotechnical surveys confirm seabed sediments along the southern portion of the OfTW corridor are characterised by diamicton with occasional pockets of clay. The deeper central areas of the OfTW corridor are overlain by thick deposits of laminated clay and silt. Along most of the corridor, a thin sand layer forms the top layer classified as sand and gravel.

5.3.10 Geotechnical bore sampling on the shoreline has confirmed that sediments around the landfall consist of a thick unconsolidated gravelly sediment of varying depths. The presence of these sediments was considered in determining the most suitable method of installing horizontal pipes.

Benthic Surveys of the OfTW Corridor

5.3.11 Benthic surveys were conducted in 2010 and 2015 (Table 5.1). Recorded features of interest included the ocean quahog (*Arctica islandica*); a bivalve listed as a Scottish Priority Marine Feature (PMF) and listed as an OSPAR threatened / declining species, and the biotope SS.SCS.ICS.MoeVen: *Moerella* spp. with venerid bivalves in infralittoral gravelly sand biotope, also a PMF. The former was encountered in very low numbers and the second was considered by the ES to be likely to recover rapidly from construction-related disturbance.

5.3.12 Surveys identified four main habitat types associated with different sediment types were recorded along the OfTW corridor; burrowed mud and fine to medium sand with shell fragments dominated survey area. Little epifauna was observed in the sediments furthest offshore in the OfTW corridor. However, it is assumed these sediments will support benthic faunal communities associated with gravelly seabed. Along the central part of the OfTW corridor, sediments were classed as muds with evidence of high levels of bioturbation. The habitat was identified as biotope SS.SMu.CFiMu.SpnMeg including sea pens and burrowing megafauna. This habitat is listed as a PMF on the draft list for Scottish Territorial Waters. In the shallower waters of Spey Bay within 10km of the shore, hard substratum overlying sand sediment supported encrusting epifauna and an area of cobble reef representative of the biotope SS.SCS.CCS.Pomb and potential Annex I reef habitat was recorded.

5.3.13 A follow up pre-construction survey of portions of the OfTW corridor was undertaken in 2015 to confirm the presence and extent of potential Annex I habitats in the near-shore portion of the OfTW corridor and to inform cable routing (BOWL Document Ref: LF000005-REP-584). The survey report was accepted by Marine Scotland Science on the 25th January 2016 and explains that a low to medium resemblance to Annex I cobble reef habitat was identified within the near-shore 10km of the OfTW corridor. On the basis that no areas of high resemblance to Annex I cobble reef were identified within the OfTW corridor, the highly localised extent of temporary disturbance from cable installation works, the high recoverability of these habitats and the widespread distribution of similar habitats in the area, Marine Scotland agreed that the results should not have implications for the cable routing within the OfTW corridor (BOWL Document Ref: LF000005-LET-290).

Summary of Surveys of the Offshore Wind Farm

5.3.14 The following information is intended to provide a brief summary of the results of surveys within the Wind Farm relevant to routing and installation of the OTM Interconnector Cable.

5.3.15 The seabed across the Wind Farm has water depths varying between 34.2m and 60.4m. The seabed gradient across the site is irregular with gentle slopes.

5.3.16 Evidence of seabed mobility was minimal; however, areas of ripples within the survey area were identified.

5.3.17 Surveys have identified the presence of boulders across the Wind Farm. A significant number of boulders with a dimension greater than 0.2m were identified across the site, with boulders of up to 1.0m diameter recorded. There is the potential for subsurface boulders to also be present.

5.3.18 A survey for UXO across the Wind Farm identified 102 magnetic anomalies that were deemed to be of potentially anthropogenic origin. Visual inspections using ROV found that only 2 of these were anthropogenic in nature and none were observed to be UXO.

5.3.19 The geology of the Wind Farm generally comprises a surface Holocene sediment of up to 2m thickness comprising loose to medium dense fine to medium gravelly sand to sandy gravel. Soil conditions across the majority of the survey area consist of Holocene very loose to dense sand over loose to medium dense to very dense fine to medium silty gravelly sand and sandy gravel in the top 2.0m below seabed level.

5.3.20 Benthic surveys identified some features of conservation interest within the Wind Farm, including a PMF species and habitat (as reported above).

5.4 Summary of Key Constraints Identified by Survey

5.4.1 Ground investigation surveys have identified potential constraints to the installation of the Export Cables. Boulders are present on the seabed along the entire length of the OfTW corridor, but are particularly dense in the near-shore portion of the OfTW corridor from 4 to 10km of the shoreline. In this near-shore area, boulders will be displaced a short distance from the intended route of the Export Cables during seabed preparation works prior to installation (see Section 9 for more detail).

5.4.2 Geophysical and geotechnical surveys have also indicated that in some areas of the OfTW corridor stiff or dense sediments are present which may limit the depth to which the Export Cables can be buried. Where cables cannot be installed to a target depth, cable protection will be installed; further information on the installation of additional protective measures is set out under Section 9.

5.4.3 These surveys additionally identified unconsolidated gravelly sediments in the vicinity of the landfall location which have to be considered in assessing the feasibility of different installation methodologies for the horizontal pipes, through which the Export Cables will be installed underneath the SSSI. The results from the additional seismic refraction ground investigation surveys, completed in 2016, have been used to inform the refinement of the design of the pipe profiles and their installation by the Direct Pipe methodology beneath the coastal area of SSSI. This technique is a hybrid between micro tunnelling and traditional HDD and has distinct advantages in unconsolidated ground conditions likely to be encountered.

5.4.4 The results detail the stratigraphy and bed rock conditions between 0m and 20m below ground level. The results of these surveys have been used to determine a final method for installing the horizontal pipes.

5.4.5 The UXO survey identified a small number of magnetic anomalies that have the potential to be UXO targets. The anomalies have been avoided by routing of the Export Cables around them.

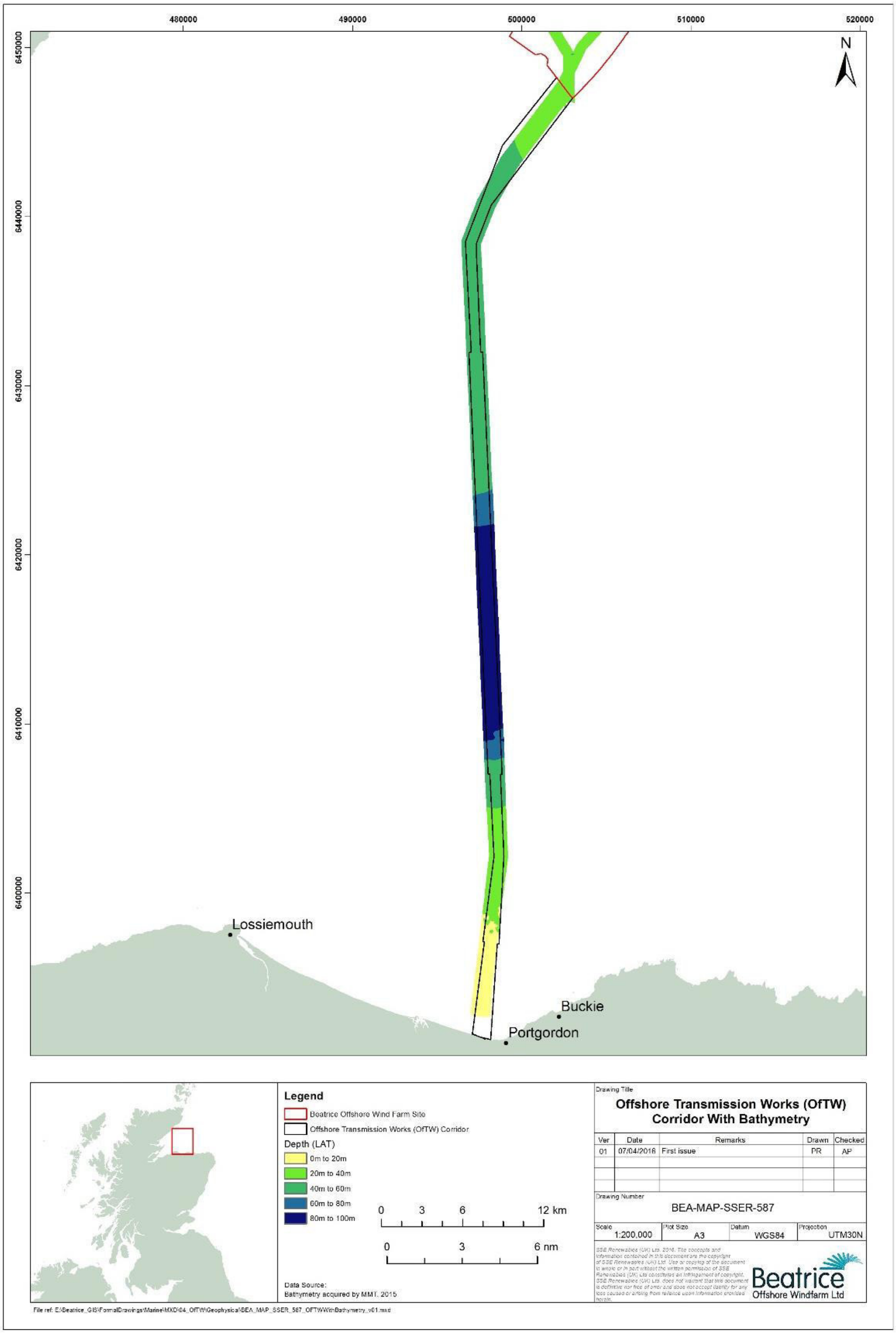


Figure 5.5– Bathymetry along the OfTW corridor

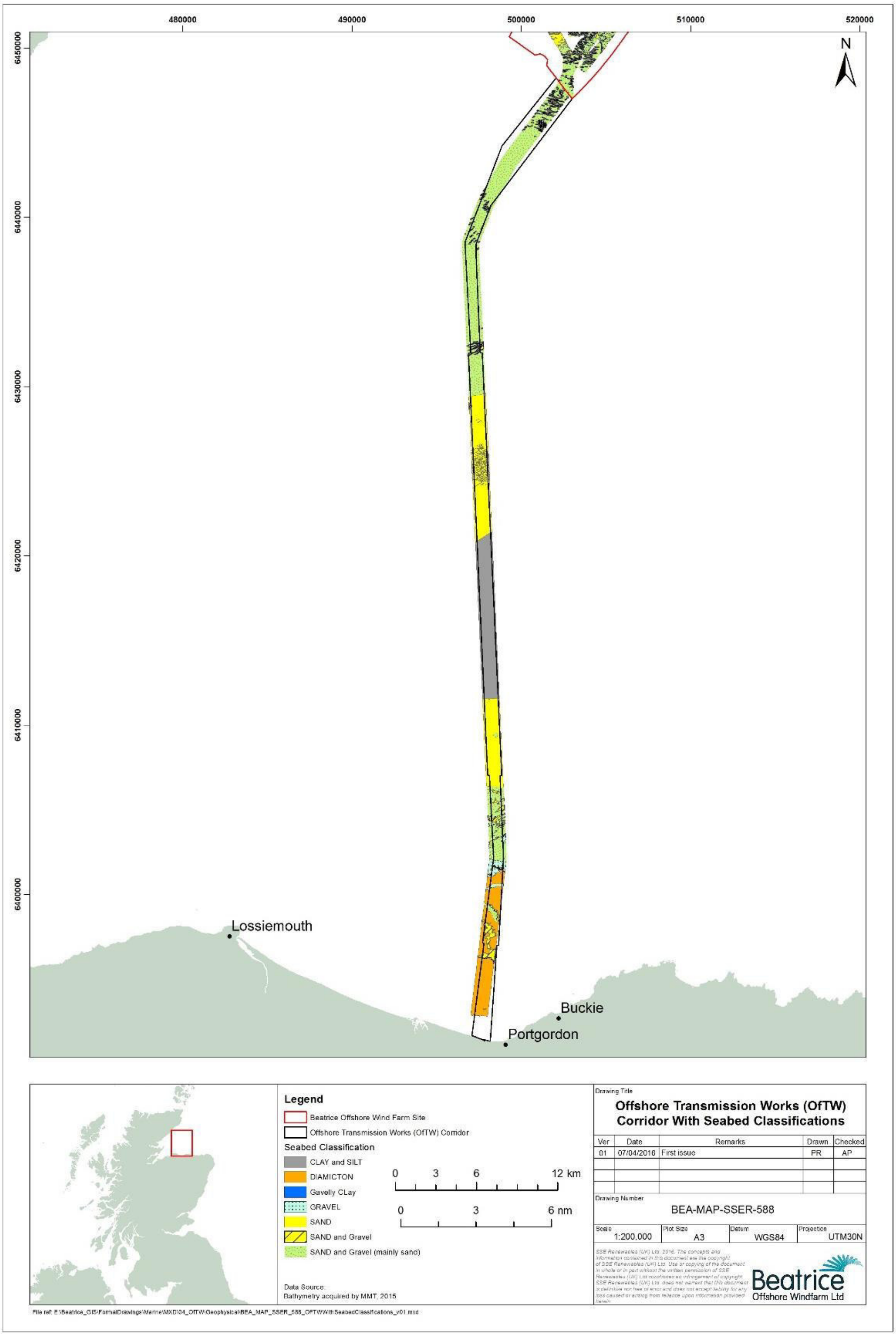


Figure 5.6 – Seabed classification and sediment type along the OfTW corridor

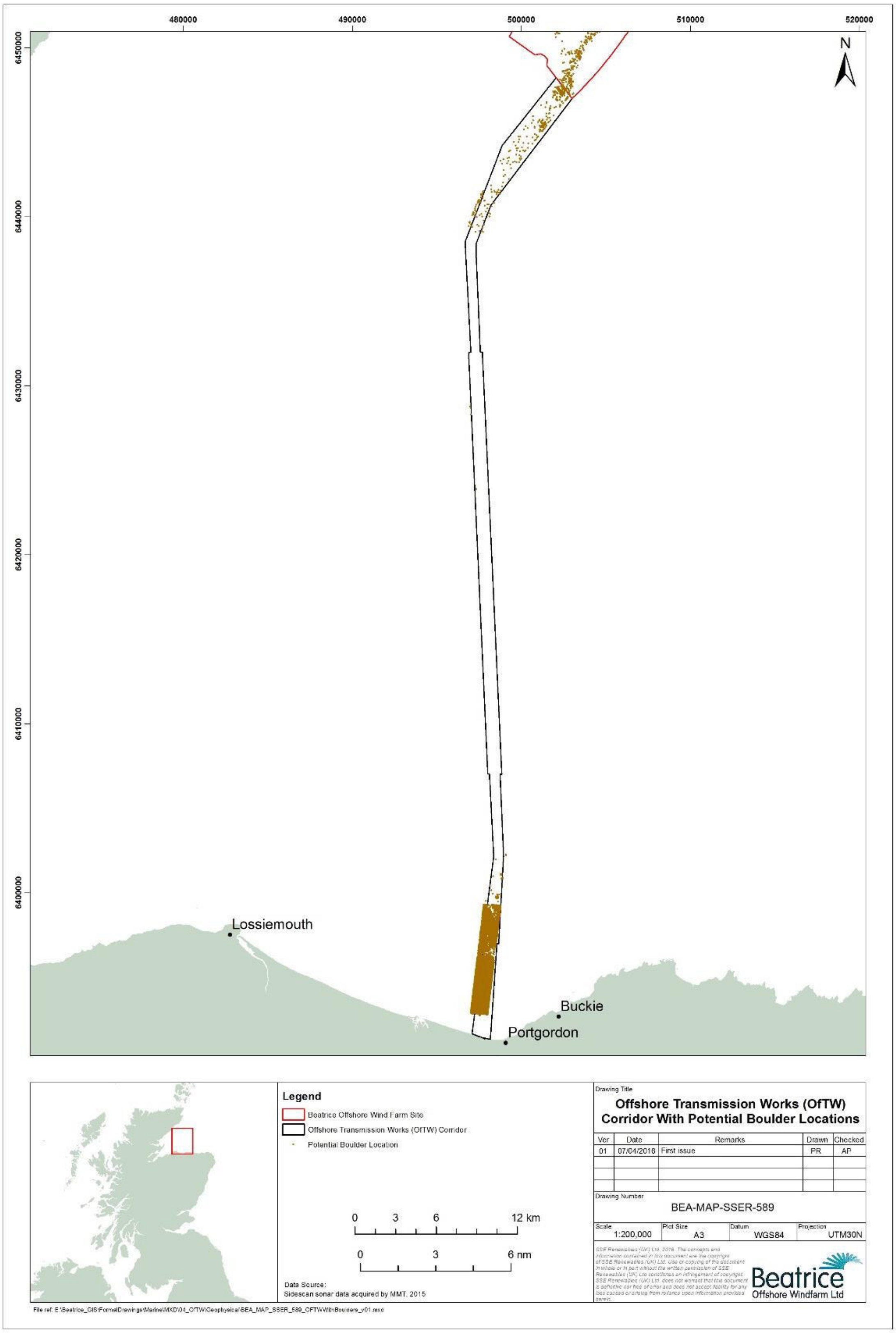


Figure 5.7 – Boulder locations along the OfTW corridor

6 Location and Layout of Export Cables and OTM Interconnector Cable

6.1 Introduction

6.1.1 The Consent Condition requires that this OfTW CaP includes the following:

Details of the ***location*** *and cable laying techniques for the cables*

6.1.2 This section describes the layout and location of the Export Cables and OTM Interconnector Cable, taking into account the layout as presented in the OfTW DSLP, and any constraints identified in Section 5. Cable laying techniques are described in section 9 of this OfTW CaP.

6.2 Location and Layout

6.2.1 Two buried or mechanically protected 220kV subsea Export Cables will be installed and protected, meeting the 25-year design life requirement, to transmit the electricity from the OTMs to the landfall west of Portgordon where they are then connected to 220kV HVAC onshore cables. The onshore cables then run underground for approximately 19km from landfall at Portgordon to the substation site at Blackhillock where they are connected to the National Grid network.

6.2.2 Where the Export Cables approach the shoreline, they will travel beneath the seabed and shore via pre-installed horizontal pipes in order to avoid impacts on the SSSI (Figure 5.4). The Export Cables will emerge from the pipes, remaining buried below the seabed, between 420 and 450m offshore from the Pipe Thruster Pit at the final exit point.

6.2.3 The total route length of each Export Cable from the onshore Pipe Thruster Pit at landfall to the OTM J-tube cable conduit is approximately 70km, with two cable lengths jointed at a mid-point 35km offshore. An approximately 1.2km long 220kV OTM Interconnector Cable will connect the OTMs located within the centre of the Wind Farm. The layout of OfTW cables is presented in sections in Figures 5.1 to 5.3 and an overview is shown in Figure 6.1.

6.2.4 The Export Cables and OTM Interconnector Cable configuration coordinates are presented in Table 6.1 below.

Table 6.1 – OfTW cable arrangements and cable lengths

Layout		Start Point		End Point		Approximate Length (m)
Start	**End**	**Latitude (ddm) WGS84**	**Longitude (ddm) WGS84**	**Latitude (ddm) WGS84**	**Longitude (ddm) WGS84**	
Export Cable 1						
OTM1	Landfall	50 70.10'E	64 56.558'N	49 74.30'E	63 91.575'N	68,400
Export Cable 2						
OTM2	Landfall	50 61.13'E	64 57.311'N	49 73.64'E	63 91.607'N	69,900
OTM Interconnector cable						
OTM1	OTM2	50 70.10'E	64 56.558'N	50 61.13'E	64 57.311'N	1,200

6.3 Route Refinement and Micro-siting

6.3.1 The final location and layout of Export Cables within the OfTW corridor, and of the OTM Interconnector Cable, remains subject to possible minor route refinement.

6.3.2 Immediately prior to cable installation the Key Contractor may undertake a visual survey of the intended cable routes using an ROV and after the cable lay vessel (CLV) has arrived on site in order to verify that the route is clear and the cables can be safely laid in the intended location and as a check that no changes that might affect the cable installation have occurred since the previous surveys. Where obstacles are present, the cables may be micro-sited around them by means of minor modifications to the proposed route. The on-board surveyor will make a record of any minor modifications to the route where necessary.

6.3.3 Along the majority of the OTM Interconnector Cable and Export Cable routes, micro-siting is unlikely to exceed a deviation of 50m from the planned route centre line. For safety reasons, cables will not be laid outwith the UXO-surveyed areas.

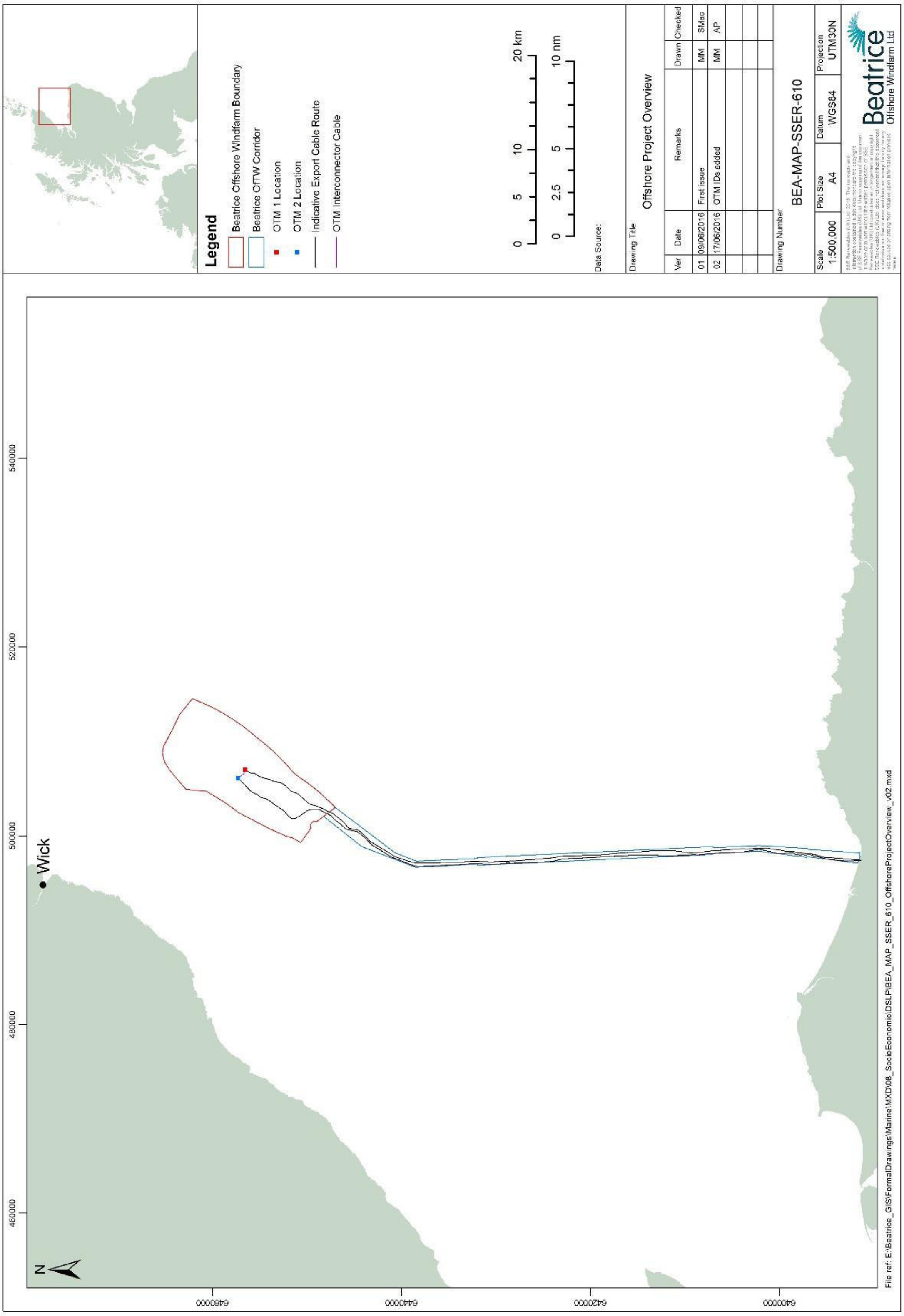


Figure 6.1 – Wind farm OTM locations and OfTW and Interconnector cable routes

7 Technical Specification of Export Cables and OTM Interconnector Cables

7.1 Introduction

7.1.1 The OfTW Marine Licence Condition 3.2.2.10 requires that this OfTW CaP includes the following:

> *Technical specification of all cables, including a desk based assessment of attenuation of electro-magnetic field strengths and shielding*.

7.1.2 The OfTW cable system consists of two separate Export Cables and one OTM Interconnector Cable.

7.1.3 The Export Cables and OTM Interconnector Cable will be 3 core 220kV lead sheathed, armoured submarine power cables.

7.1.4 Two types of export cable are required, as follows:

- Where the Export Cables are installed beneath the SSSI, via pre-installed horizontal ducts, the cable is specified to maximise heat dispersion. Here the cable will be made up of a 3 x 1600m^2 copper-core conductor. The copper-cored cable has an outside diameter of 267mm; and
- The remainder of the Export Cables and the OTM Interconnector Cable will be made up of 3 x 1200mm^2 aluminium cores, having an outside diameter of 245m.

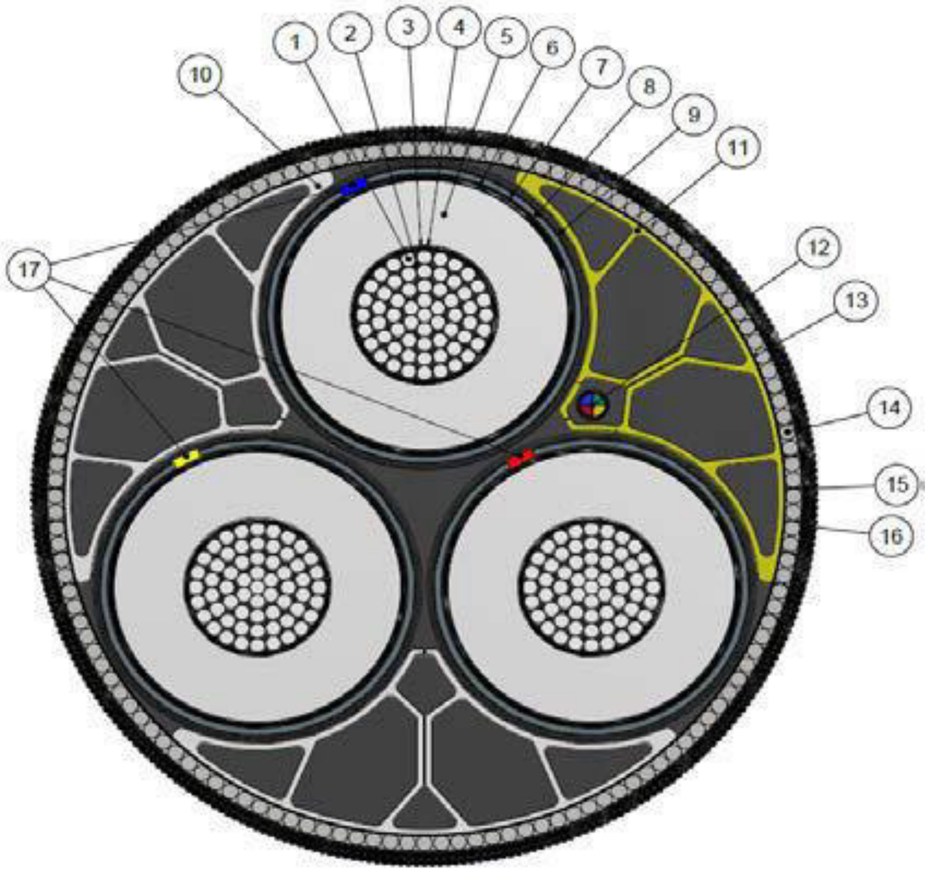
7.1.5 The two types of export cables will be jointed during the manufacturing process. The length of the 1600mm^2 core cable will be approximately 1km and the transition from the 1600 mm^2 cable to 1200 mm^2 cable will be within the Depth of Closure (and buried to 1.5m – 1.7m below the seabed surface).

7.2 Cable Components

7.2.1 Technical cable requirements have been determined by BOWL. Figure 7.1 shows the key components of the cable used for the offshore section of the Export Cables and the OTM Interconnector Cable.

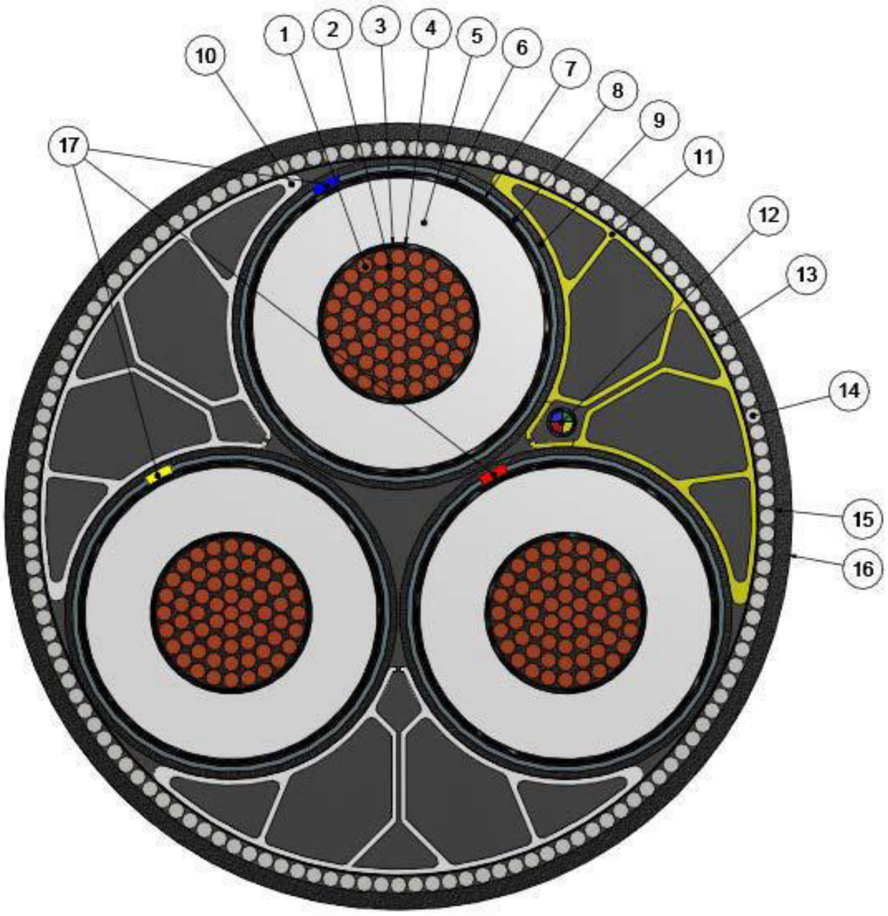
7.2.2 Figure 7.2 shows the key components of the cable that will be used for the near-shore section of the Export Cables.

Figure 7.1 - Cross section of the OTM Interconnector Cable and main section of Export Cables (3 x 1200mm^2 Aluminium core subsea cable)



Item	Description	Item	Description
1	Conductor	10	Filler Element
2	Conductor Filling Compound	11	Filler Element for Fibre Optic
3	Swellable Tape	12	Fibre Optic Element
4	Inner Semi-conductor	13	Armour Bedding
5	Insulation	14	Armour Wires
6	Outer Semi-conductor	15	Polypropylene Serving
7	Swellable Tape	16	Polypropylene Serving
8	Lead Sheath	17	Power Core ID – Plastic strand
9	Polyethylene (PE) Sheath		

Figure 7.2 - Cross section of the Near-shore Export Cable (3 x 1600mm^2 Copper core subsea cable)



Item	Description	Item	Description
1	Conductor	10	Filler Element
2	Conductor Filling Compound	11	Filler Element for Fibre Optic
3	Swellable Tape	12	Fibre Optic Element
4	Inner Semi-conductor	13	Armour Bedding
5	Insulation	14	Armour Wires
6	Outer Semi-conductor	15	Polyethylene Sheath Bedding
7	Swellable Tape	16	Polyethylene Sheath
8	Lead Sheath	17	Power Core ID – Plastic strand
9	Polyethylene Sheath		

7.2.3 The main components of the Export Cables and OTM Interconnector Cable are described briefly below.

Power Cores

7.2.4 The cables will be comprised of three power cores of copper or aluminium. The cross-sectional area of each core will be indicatively 1600mm^2 or 1200mm^2. The cores will be insulated with cross-linked polyethylene (XLPE) or ethylene propylene rubber (EPR). For waterproofing each core will have an outer lead sheath.

Fibre Optic Element

7.2.5 The Export Cables will be fitted with a fibre optic core, within cable interstices, to provide the necessary functionality for wind turbine control and instrumentation systems.

Assembly

7.2.6 Appropriate filler materials (e.g. ropes or extruded polymeric profiles) will be included within the cable interstices to provide a robust and stable base for the application of armouring.

7.2.7 The Export Cables will have a galvanised steel wire outer armour layer protected from corrosion using a bitumen based compound. The armour layer encloses the cores, the fibre optic cable and any fillers. A serving wrapped over the armour layer will be comprised of polypropylene yarns (anti-friction) appropriately specified and sized to meet installation and operational requirements.

7.3 Electromagnetic Fields

7.3.1 This section summarises the results of a desk based assessment carried out by Siemens (2016) on behalf of BOWL on the attenuation of electromagnetic fields associated with the Export Cables.

7.3.2 The study calculated the magnetic field magnitudes at a given distance from both the 1200mm^2 and 1600mm^2 220kV AC Export Cables at a burial depth of 0.6 (1200mm^2 cable only), 1 and 2 metres. The insulation and sheathing of the cable power cores, and the burial of the cables, encourage shielding of EMF.

7.3.3 The magnetic field generated by a single conductor at a given point was calculated using the Biot-Savart Law. When there are 3 conductors (a 3 core cable) such as the Export Cables being used for the OfTW, the magnetic field can be calculated using the superposition of fields of a single conductor.

7.3.4 The predicted EMF attenuation from the Export Cables are shown in figures 7.3 to 7.7 below. The x axis indicates distance from the cable centre (metres) and the y axis indicates the magnetic field strength (µTesla). The plots also show the magnitude of magnetic field at multiple heights from the seabed (0m, 5m and 10m).

7.3.5 The magnetic fields generated from a 1600mm^2 AC 220kV Export Cable, at a trench depth of 1m are expected to reach a maximum value of ~25uT. The magnetic fields generated from a 1200mm^2 AC 220kV Export Cable and OTM Interconnector Cable at a trench depth of 0.6m is expected to reach a maximum value of ~50 uT. It was observed that the magnetic field decreases rapidly with burial depth, vertical distance from the seabed and horizontal distance from the cable.

7.3.6 In all cases, the predicted maximum magnetic field strength of the export cable at the seabed is expected to be equal to or lower than the earth's magnetic field (~50uT).

Figure 7.3 – The magnetic field expected from 1600mm^2 copper AC 220kV export cable assuming 1m burial depth

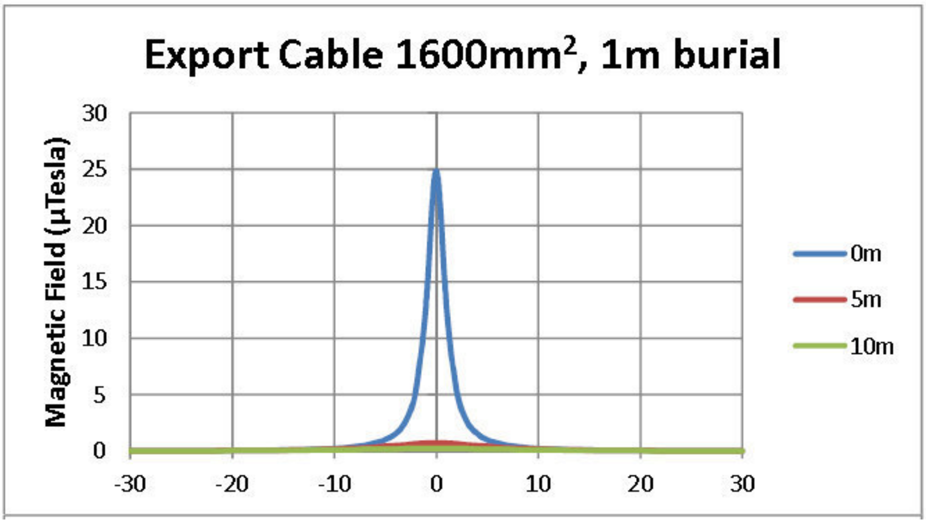


Figure 7.4 – The magnetic field expected from 1600mm^2 copper AC 220kV export cable assuming 2m burial depth

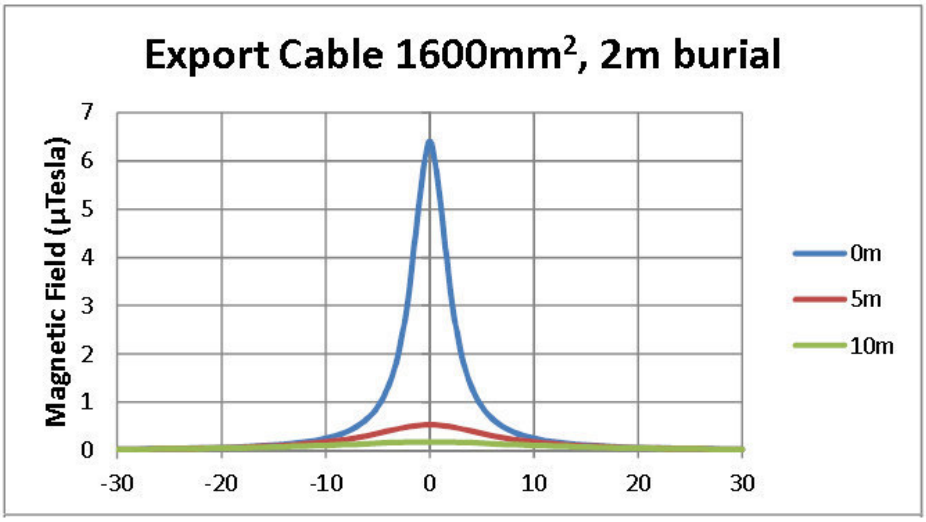


Figure 7.5 – The magnetic field expected from 1200mm^2 aluminium AC 220kV export cable assuming 0.6m burial depth

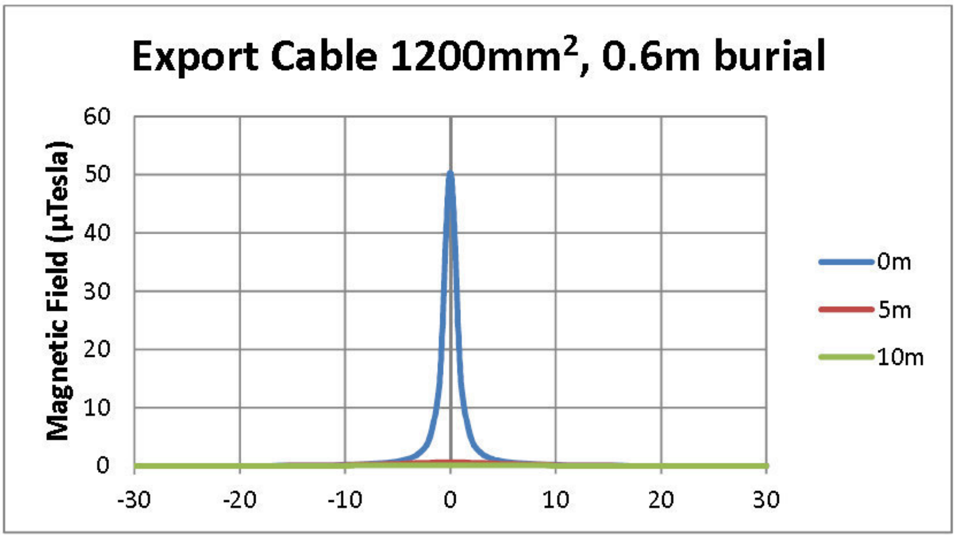
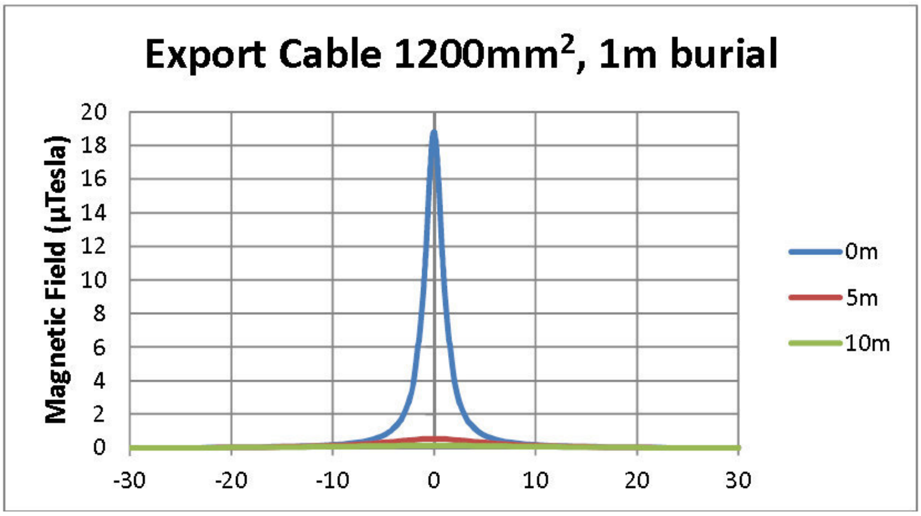


Figure 7.6 – The magnetic field expected from 1200mm^2 aluminium AC 220kV export cable assuming 1m burial depth



8 Cable Burial Risk Assessment

8.1 Introduction

8.1.1 The Marine Licence (OfTW) Condition 3.2.2.10 requires that this OfTW CaP includes the following:

> *A **burial risk assessment** to ascertain if burial depths can be achieved. In locations where this is not possible then suitable protection measures must be provided*

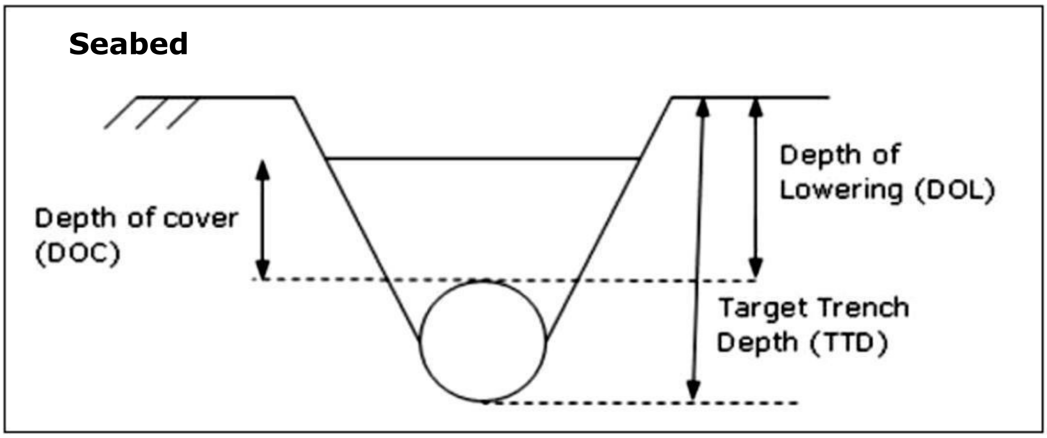
8.1.2 This section provides a summary of the results of the Cable Burial Risk Assessment (CBRA) for the offshore export cables and OTM Interconnector Cable, conducted by Geomarine (2016) and the Near Shore Erosion Risk Assessment (NSERA) for the near-shore section of the Export Cables undertaken by Royal Haskoning DHV(2016).

8.1.3 BOWL intends to bury the OTM Interconnector Cable and the Export Cables as much as reasonably practicable. Where adequate burial cannot be achieved mechanical protection will be applied to the cables. The outcomes of the CBRA and NSERA have been used by BOWL to define appropriate cable burial depths that will ensure adequate cable protection over the lifetime of the Development and along the entire length of the cables.

8.1.4 A number of technical terms may be used when describing cable burial depths. For the purpose of this OfTW CaP, only the recommended minimum Depth of Lowering (DoL) is described. The DoL is the depth at which the top of the cable is below the surface of the seabed. An adequate DoL is required to ensure minimal interference with potential hazards such as vessel anchors or fishing gear that may cause damage to cables, or to ensure cables do not become exposed as a result of physical processes. Note that the DoL is often set deeper than the minimum cable burial protection requirements to mitigate against operational or burial tool deficiencies. Where it is not possible to reach the minimum DoL, cable protection measures will be employed.

8.1.5 Terms used when describing cable burial are presented in Figure 8.1 below.

Figure 8.1 - Cable burial terminology



8.2 Offshore Cable Burial Risk Assessment

8.2.1 Geomarine were commissioned by BOWL to undertake the offshore CBRA with the aim of determining the suitable minimum DoL required to provide an acceptable level of protection for the cables along their respective routes. It focused on risks to the buried Export Cables from: (i) commercial shipping activity; (ii) commercial fishing activity; (iii) anchor penetration; and (iv) natural changes in seabed bathymetry (BOWL, 2016).

8.2.2 The CBRA considered as far as practicable all identifiable potential threats to the cable routes, with regard to the full length of the cable routes. A threat assessment was then used to fully assess the potential occurrence and consequences of the threats identified. The assessment considered, with regard to the full length of the cable routes, the following:

- Analysis of shipping data including distribution of vessels, their type and dead weight tonnage;
- Analysis of shipping data to determine vessel courses across the cable corridors;
- An assessment of the anchor types and sizes likely to be found on the vessels identified;
- The depth of penetration of the identified anchors;
- Analysis of fishing data, including the extent of different fishing methods and the distribution of vessel sizes;
- An assessment of the types and size of fishing gear in use;
- The depth of penetration of the identified gear; and
- An assessment of the change in seabed profiles between bathymetric surveys in order to estimate the rate of change.

8.2.3 Key considerations include the potential for interaction with fishing gear and vessel anchors, as summarised below.

Commercial Shipping Activity

8.2.4 The CBRA analysed AIS data for the Moray Firth for the period between August 2014 and July 2015 to gain an understanding of seasonal shipping frequencies (noting that monthly and yearly variation in shipping traffic is likely).

8.2.5 The data indicated that the Moray Firth is transited by a variety of vessels. The two main shipping channels cross the export cable route between approximately 6km and 27km, and between 39km and 50km along the Export Cable route from the Pipe Thruster Pits. Vessels following this route are generally in transit to and from the ports of the Inner Moray Firth. In addition, a high frequency of passenger vessels leave Portessie and travel to the Beatrice and Jacky Fields in the Moray Firth.

8.2.6 The vessel statistics indicate that the vast majority of vessels traversing the OfTW corridor are fishing vessels, with the remainder made up of cargo, passenger, tanker and supply vessels.

Commercial fishing activity

8.2.7 Of the fishing methods currently in use in the vicinity of the OfTW corridor, scallop dredging represents the greatest threat to subsea cables with trawling and bottom set fixed fishing gear also posing a significant risk

8.2.8 Publicly available information indicates that fishing gear such as that used in the Moray Firth (scallop dredgers, demersal trawl nets, pelagic trawl, beam trawls, pots and traps) do not normally penetrate into the seabed beyond 0.3m where the seabed is composed of very soft clays (Shapiro *et al.,* 1997). On this basis the CBRA recommended a DoL of 0.6m.

Anchor Penetration

8.2.9 Being designed to penetrate the seabed to achieve a holding capacity, anchors can be particularly damaging to subsea cables. Known or designated vessel anchoring sites are located outwith the OfTW corridor. The principal risk from anchoring therefore lies in the occasions where a vessel is forced to anchor due to mechanical failure or when needed to prevent collision.

8.2.10 The CBRA, taking account of shipping activity in the region, the likelihood of anchoring being required, and a variety of anchor types, recommended a DoL between 0.3m and 1.7m depending upon location along the OfTW corridor. The recommended DoL for the OTM Interconnector Cable is between 0.3m to 1.7m below the seabed, subject to BOWL's preferred risk profile.

8.2.11 The probability of an anchor coming into contact with each cable buried to protection from 90%, 75% and 50% of vessels as well as an unburied cable is considered extremely low. The probability of an anchor strike will be further lower than that predicted in the CBRA as the cables will be marked on navigational charts once installed and the Wind Farm established. Therefore, the maximum DoL identified in the CBRA is considered likely to be overly conservative; time and cost constraints determine that the likely DoL should be less than the maximum recommended.

8.3 Near Shore Erosion Risk Assessment

8.3.1 The NSERA assesses the risks to the near-shore sections of the Export Cables from coastal erosion, including both vertical (downward) lowering of the seabed and horizontal (landward) recession of the shore. The NSERA is provided in Appendix C.

8.3.2 With reference to the requirements of OfTW Marine Licence Condition 3.2.3.8, the NSERA demonstrates that:

- The seaward exit point of the Direct Pipe will be located as far offshore as practicable towards the depth of closure, given the physical limitations imposed by the direct pipe and cable installation methods being utilised and consideration of landward recession rates to enable a suitable 'set-back' location for the landward entry point of the pipe.
- The landward entry point of the Direct Pipe will be located onshore of the high-water mark, and is set back a suitable distance to allow for a conservative projection of coastal recession over the 25-year operational life of the Development.
- The Export Cables will be suitably buried between the seaward exit point of the Direct Pipe and the Depth of Closure (the depth of water beyond which annually significant wave events will cease to contribute to beach sediment supply and morphological processes).

8.3.3 The NSERA demonstrates that, at a DoL of 1.3m where the Export Cables exit the Direct Pipe, progressively deepening to a minimum DoL of 1.5m along approximately 20m, with the Export Cables remaining at this burial depth until they reach the Depth of Closure, the offshore cables are assessed to remain suitably buried between the seaward Direct Pipe Final Exit Point and the Depth of Closure over the 25-year operational life of the Development.

8.4 Depth of Lowering

8.4.1 An assessment of minimum DoL in terms of engineering constraints was performed concurrently with the CBRA and NSERA, which considered the following:

- Bathymetry;
- Seabed morphology;
- Shallow geology; and
- Additional or alternative protection strategies.

8.4.2 On the basis of this and the findings of the CBRA and NSERA, BOWL have determined a minimum DoL. Where cable burial depths recommended within the CBRA were technically prohibitive the residual risk left by reducing the burial depth has been considered and the protection measures described in section 9 applied.

8.4.3 Offshore from the Depth of Closure, BOWL have determined a minimum DoL for the OTM Interconnector Cable and Export Cables of 0.6m below the surface of the seabed (see Figure 8.1). Where the minimum DoL cannot be achieved, then appropriate means of additional protection will be employed. Likely protection measures are described in Section 9.6 below.

8.4.4 Near-shore, where the Export Cables pass under the SSSI via horizontal pipes, the pipe burial profiles will be suitably engineered to maintain pipe burial for the 25-year design life based on projected coastal erosion rates, taking account of both horizontal and vertical components. The pipe final exit points have a minimum DoL of 1m below the surface of the seabed to the top of pipe. The Export Cables within those pipes have a minimum DoL of 1.3m. As the Export Cables exit the horizontal pipes and extend seawards to the Depth of Closure, the cables will descend over the first 20-30m from a depth of 1.3m to a minimum DoL of 1.5m below the surface of the seabed.

8.4.5 Further detail on cable burial is provided in Section 9.4.

9 Export Cable and OTM Interconnector Cable Installation Methodology and Process

9.1 Introduction

9.1.1 The OfTW Marine License Condition 3.2.2.10 requires that this OfTW CaP includes the following:

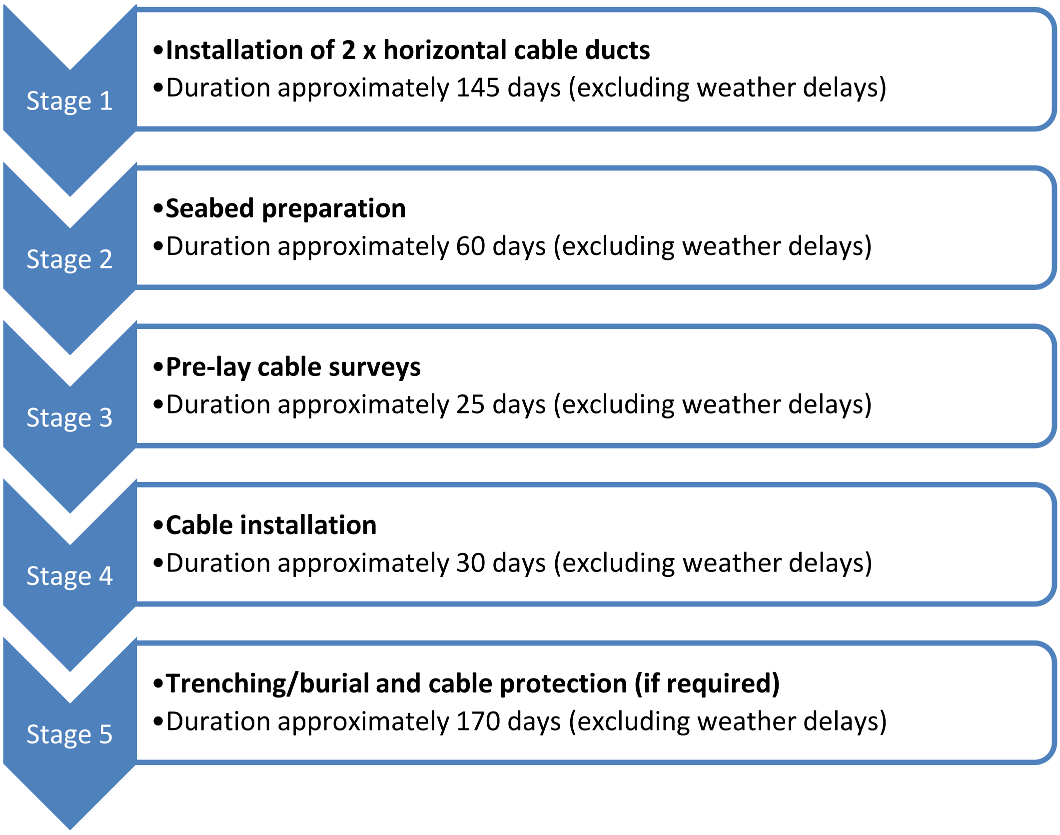
*Details of the location and **cable laying techniques** for the cables*

9.1.2 This section sets out the cable laying techniques for the subsea Export Cables and OTM Interconnector Cable.

9.1.3 An indicative installation sequence for both Export Cables and the OTM Interconnector Cable is presented in Figure 9.1, including approximate durations for each activity.

9.1.4 Greater detail on each of the stages in the installation process (Stages 1 – 5) is then provided in the subsequent sections. Total duration for the installation and protection of both Export Cables and the OTM Interconnector Cable is estimated to be circa 455 days excluding any weather delays. Installation of all cables will be completed in multiple campaigns across two construction seasons.

Figure 9.1: Export cable and OTM Interconnector Cable installation sequence



9.1.5 All the subsea cables will be transported to site direct from the point of manufacture at Halden, Norway by sea on the CLV.

9.1.6 Details of the proposed construction vessels are set out in the Vessel Management Plan (VMP) (required under Condition 16 of the s36 consent and Condition 3.2.2.8 of the OfTW Marine Licence) (BOWL Document Ref: LF000005-PLN-168).

9.2 Export Cable Installation Stage 1 – Installation of horizontal cable pipes

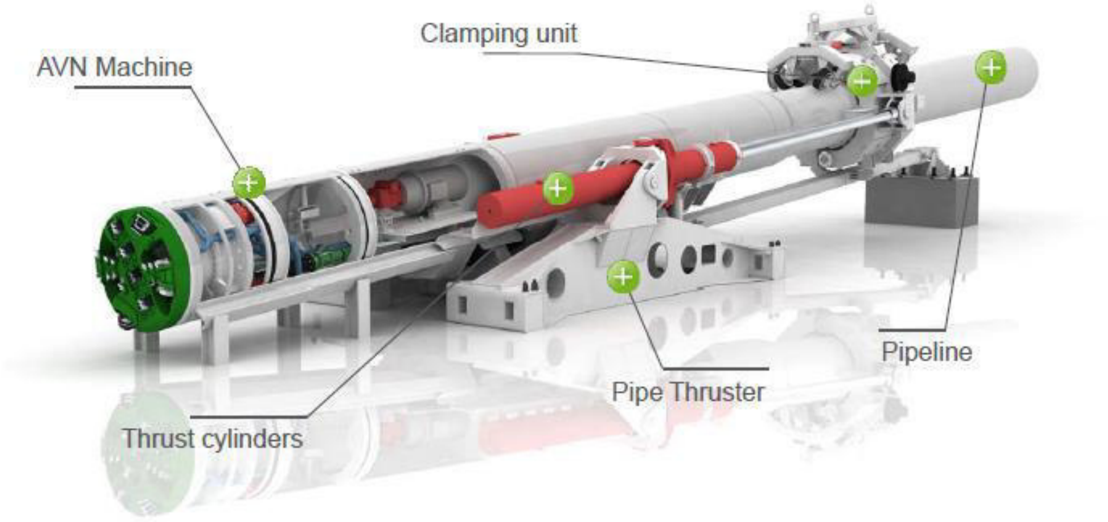
9.2.1 Due to the existence of the SSSI at Spey Bay (and in accordance with OfTW Marine Licence Condition 3.2.3.8) BOWL intends to install the Export Cables beneath the SSSI. In this location the Export Cables will be installed into pre-installed horizontal pipes running below the shoreline. Pre-installed horizontal cable pipes will be used for each of the two Export Cables from the onshore Pipe Thruster Pit locations, under the SSSI area and out to an offshore exit point.

9.2.2 The design of the horizontal pipes and the means of installing them has been influenced by the results of a ground risk assessment, based on the geotechnical properties and morphology of the seabed, and an engineering assessment of the maximum pull-in loads that the Export Cables can withstand.

9.2.3 The horizontal pipes will be installed using a 'Direct Push Pipe' HDD method (referred to as 'direct pipe' below). The direct pipe method involves use of a micro-tunnelling machine pushed through the ground with a prefabricated pipe from an onshore Pipe Thruster Pit to the final exit point offshore. This methodology allows the pipe to be installed in a single step and removes the requirement for pilot drilling, reaming and final pipe pull-in otherwise required under a 'traditional' HDD approach. It also removes the risk of drill bore collapse in unconsolidated sediments, thus minimising the risk of effects on sediment transport patterns.

9.2.4 During direct pipe installation, the micro-tunnelling machine and pipe behind it will be pushed into the ground from the onshore Pipe Thruster Pit. Seabed sediments will be excavated by the tunnelling machines cutting wheel and broken down into suitable sized material, which will then be pumped to shore via the pipe. The tunnelling system will be lubricated with bentonite solution at the cutting head and as a pipe anti-friction agent.

Figure 9.2. Main system components of the Direct Pipe drill method



9.2.5 At the seabed push out point the micro-tunnelling machine will be disconnected from the installed pipe by divers activating a hydraulic release once it completes the profile and exits at the seabed. The divers will then recover the tunnelling machine from the seabed using airbags.

9.2.6 Once the tunnelling machine is disconnected the pipe will be flooded and the end sealed by divers to prevent sediment entering the pipe. Once this is complete, the pipe will be pulled back approximately 30m to the final exit point where the top of the pipe is buried 1m below the surface of the seabed. The total length of each pipe will be between 420m and 450m (from the Pipe Thruster Pits to the final exit points). Once this is complete, backhoe trenching can commence (see section 9.3).

9.2.7 If any difficulties are encountered during the tunnelling process, the pipe thruster can pull back the pipe together with the micro-tunnelling machine to begin the process again, or steer a deviation around a problematic ground area.

Figure 9.3. Example direct pipe installation setup

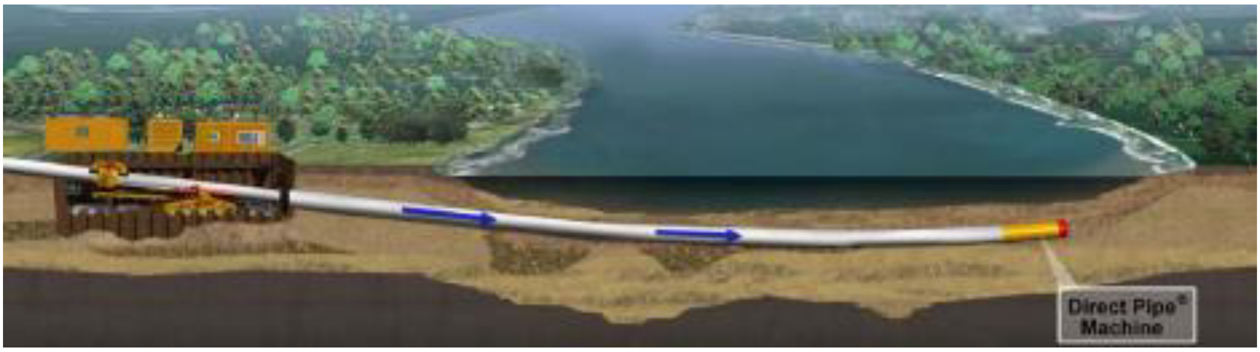
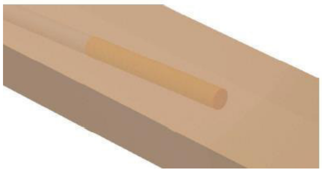
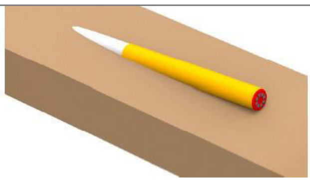
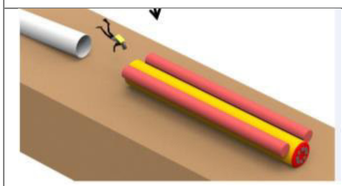
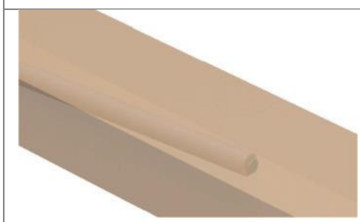
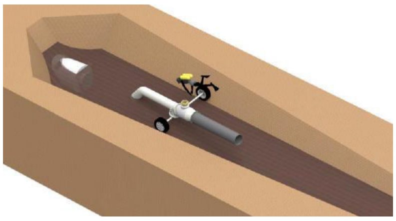
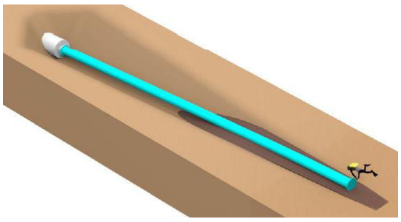


Figure 9.4. Direct pipe installation sequence

	1. The micro-tunnelling machine and pipe behind it will be pushed into the ground from onshore by a pipe thruster from a launch pit.
	2. The pipe will travel beneath the seabed until the micro-tunnelling machine is pushed-out between 420-450m offshore
	3. Divers detach the micro-tunneling machine and recover to the surface
	4. Once the micro-tunneling machine has been removed, divers seal the end to ensure no sediment enters the pipe.
	5. The pipe is pulled back approximately 30m, until the top of the pipe end is 1m below the seabed.

9.2.8 Prior to cable installation, divers will excavate the seabed in the area of the pipe exit. On exposing the pipe end, the divers will unseal it and install a polypipe and messenger wire, which will remain flush with the seabed for cable pull-in and which will later be buried. The pull-in wire is connected to a cable pull-in winch located within the onshore construction compound.

Figure 9.5. Direct Pipe installation sequence (continued)

	6. Backhoe trenching commences to remove boulders along the cable route infront of the installed pipe. The trench is then left to refill naturally.
	7. Divers re-open the trench close to the Direct Pipe to expose the pipe exit and seal.
	8. Divers install a Polypipe and messenger wire in preparation for cable installation that will take place later.

9.3 Export Cable Installation Stage 2 – Seabed preparation

9.3.1 There is a high density of boulders of up to 1.5m diameter along the near-shore Export Cable routes that would prohibit standard cable burial.

9.3.2 A backhoe trencher will be used to prepare the seabed in the near-shore area from a point as close to the offshore pipe exit point as possible to 4.5km offshore from the Pipe Thruster Pits. To ensure trenching activity does not impact the installed horizontal pipes, backhoe trenching operations will commence approximately 5m from the pipe exit. Backhoe trenching will allow for the cable routes to be excavated and will allow the removal of both surface and sub-surface boulders, which will be placed on the seabed a short distance away from the cable routes. The interface between the pipe exit and start of backhoe trenching will be trenched by divers.

9.3.3 Following trenching works, which will be completed within 45 days, the trench that is now clear of boulders will be allowed to naturally refill with seabed sediments. This will enable subsequent installation of the cable using standard burial methods (Section 9.60).

9.3.4 Seabed debris such as fishing gear and abandoned wires or chains can be detrimental to cable lay and cable burial operations and there is a risk that the seabed jetting tool that is intended to be used to bury pre-laid cables could become entangled or stuck. Therefore, approximately one month prior to the start of cable laying operations, all OTM Interconnector Cable and Export Cable routes will be cleared of any surface debris crossing the cable routes by the use of a Pre-Lay Grapnel Run (PLGR).

9.3.5 A specialised vessel will be mobilised together with any required survey and positioning equipment, and a grapnel assembly. A variety of grapnel types are available, and suitable grapnels (which will accommodate changing sediment conditions along the cable routes) will be selected prior to PLGR.

9.3.6 The PLGR vessel will tow a seabed deployed grapnel rig along the centreline of the cable route (re-runs will be conducted where the grapnel has not stayed within the target corridor). The grapnel tow winch will be fitted with a strain gauge which will detect the rise in tension when it encounters debris. Any debris encountered will be recovered to the deck of the vessel for appropriate licensed disposal ashore.

9.3.7 PLGR works will take approximately 15 days to complete.

9.4 OTM Interconnector Cable and Export Cable Installation Stage 3 – Pre lay surveys

9.4.1 Immediately prior to laying the OTM Interconnector Cable and Export Cables the CLV may perform a specific pre-lay survey along the routes if required. This will be done after the vessel is loaded with the cable and has arrived at site. The pre-lay survey is designed to ensure no changes to the seabed have occurred that will affect the cable installation since the previous surveys. A remotely operated vehicle (ROV) will be used to carry out any pre-lay survey requirement.

9.5 OTM Interconnector Cable and Export Cable Installation Stage 4 – Cable installation

9.5.1 Once the direct pipes are pre-installed under the Spey Bay SSSI shoreline, and the pre-lay surveys have been completed, installation of the Export Cables and the OTM Interconnector Cable will commence.

9.5.2 Cable installation will be undertaken by the CLV loaded with the export cable and interconnector cable lengths which are loaded on a dedicated cable carousel carried by the vessel.

9.5.3 Cable installation will take place in four campaigns. Due to the length of the Export Cables, each cable will be laid in two parts and then connected and joined at the mid-point approximately 35 km from the Pipe Thruster Pits and OTMs. A brief outline of the installation stages is as follows:

- Offshore Campaign 1: Load and lay Export Cable 1 – Shore to midpoint,
- Offshore Campaign 2a: Load and lay Export Cable 1 – OTM to midpoint and joint;
- Offshore Campaign 2b: Lay OTM Interconnector Cable – 1st End OTM 1 to 2nd

End OTM;

- Offshore Campaign 3: Load and Lay Export Cable 2 – OTM to mid-point; and
- Offshore Campaign 4: Load and Lay Export Cable 2 – Shore to mid-point and joint second section of the second Export Cable from the near-shore ducted pipeline to the hairpin joint location at the mid-point offshore.

Offshore Campaign 1 (2017)

9.5.4 The first element of installation is pull-in of Export Cable 1 into the pre-installed pipe from the offshore end of the direct pipe Polypipe to the landfall site.

9.5.5 The CLV will set up at the offshore end, approximately 300m from the end of the pre-installed pipe.

9.5.6 A workboat will be anchored or jacked up above the offshore end of the direct pipe Polypipe and will retrieve the pull-in wire from the Polypipe (which is connected back to the onshore pull-in winch at the landfall site) and pass the pull-in wire to the CLV. The CLV will then connect the pull-in wire to the cable end. The cable is then paid out from the CLV and floated towards the workboat.

9.5.7 The cable is then pulled into the Polypipe from the onshore pull-in winch and the floats are removed from the offshore end of the cable simultaneously. When the required cable length is pulled onshore, the workboat will move towards the CLV, lowering the cable behind it as it goes. Care will be taken to ensure the cable is laid on the route which has been back-hoed previously to enable subsequent seabed burial.

9.5.8 When the first end pull-in and laydown of the cable is completed the CLV will start laying the cable along the planned route to the mid-point approximately 35km offshore from the Pipe Thruster Pits and at a typical laying speed of between 10 and 25m per minute depending on surface and seabed conditions. At the mid-point the cable end will be sealed and the end laid to a ground rope and clump weight for ease of recovery.

Offshore Campaign 2a (2017)

9.5.9 The second section of Export Cable 1 (see Table 6.1 and Figure 6.1) will be installed at OTM1 in the following process.

9.5.10 A CLV with the second section of the Export Cable 1 will position itself near OTM1 to install the cable through the OTM J-tubes. The J-tubes are steel tubes that allow the installation of cables by providing a conduit through which the cables can be pulled. A remotely operated vehicle (ROV) will then detach the cover of the J-tube, and attach a wire from the vessel to a pre-installed J-tube messenger wire. The messenger wire will then be recovered onto the deck of the CLV.

9.5.11 The export cable will then be connected to the messenger wire, and the Cable Protection System (CPS) will be mounted on the cable during cable pay out to the OTM. The cable will be protected with approximately 10-15m of CPS from the outside of the J-tube into the seabed. The cable will be pulled onto the OTM and secured.

9.5.12 The CLV will then install the cable moving south along the route towards landfall and the point at approximately 35km, where the first section of Export Cable 1 was installed in the previous campaign. The first cable sealed end will then be recovered using the ground rope, from the seabed onto the CLV. Both cable ends will be tested and then jointed. Once complete the joint will be lowered to the seabed. Care will be taken so as not to twist or loop the cable during deployment of the joint to the seabed.

9.5.13 The joint lay down will be surveyed using an ROV to ensure cable integrity and that the lay down configuration is suitable for ROV jet burial. Once complete cable burial can commence.

Offshore Campaign 2b (2017)

9.5.14 During Offshore Campaign 2b the OTM interconnector cable will also be installed. First end pull-in as described above for Export Cable 1 will be carried out to install the first end of the Interconnector Cable to OTM1. The cable will then be laid out over approximately 1.2km.

9.5.15 Once the cable reaches OTM2, second end pull-in will take place. The cable will be measured, cut and prepared for the pull-in operation; prior to cutting and final deployment to the seabed the Cable Protection System (CPS) will be installed on the cable end.

9.5.16 An ROV will then connect the pull-in wire to a messenger wire and the messenger wire and pull-in wire are pulled onto the CLV. The pull in wire is then lowered to the seabed and attached to the cable by an ROV. The cable is then pulled in to OTM2. Once completed and secured on the OTM, cable burial will commence.

Offshore Campaign 3 (2018)

9.5.17 The first section of Export Cable 2 will be installed on OTM2 via the method of first end pull-in as described above for Export Cable 1. The cable will be laid along the cable route to the mid-point approximately 35km offshore. The cable end will be sealed, and laid to a ground rope and clump weight.

Offshore Campaign 4 (2018)

9.5.18 First end pull-in of the second section of Export Cable 2 into the pre-installed pipe will be conducted via the same method as described above for Export Cable 1. The cable will then be laid up to 35km where the first section of Export Cable 2 was installed in the previous campaign. The first cable sealed end will be recovered from the seabed onto the CLV using the ground rope. Both cable ends will be tested and then jointed. Once complete the joint will be lowered to the seabed. Care will be taken so as not to twist the cable during deployment of the joint to the seabed. The joint lay down will be surveyed using an ROV to ensure cable integrity and that the lay down configuration is suitable for ROV jet burial. Once complete cable burial will commence.

Figure 9.6. Example of a cable laying operation (cables first end being over-boarded from the CLV)

9.6 OTM Interconnector Cable and Export Cable Installation Stage 5 – Cable trenching and burial

9.6.1 Subsea cables are exposed to a range of threats from both natural and anthropogenic sources. Cables can be protected by armouring and by seabed burial. The most reliable form of cable protection is generally recognised as being burial into the seabed. The level of protection required for a cable is a function of the nature of the external threat, the strength of the seabed soils and the depth of burial. During installation, the surface laid Export Cables and OTM Interconnector Cable will be either trenched into the seabed to the Depth of Lowering (DoL) by a dedicated trenching vessel, or will remain surface laid and be suitably protected, most likely by the addition of rock placement.

9.6.2 Exposed surface laid cable prior to burial or application of mechanical protection will be protected by guard vessel(s), strategically placed along the cable route to ward off any vessels whose activity is a threat to the cables (e.g. trawling, scallop dredging etc.) or whose safety could be compromised by snagging on cables.

9.6.3 During cable trenching operations, a seabed trenching tool will be launched from the cable trenching vessel. The surface laid cable will be straddled by the trencher to engage the water jetting swords. The seabed trenching tool will then complete a first trenching run to bury the cable. Progress of the burial operation will be dependent on target trench depth and the nature of the seabed sediments.

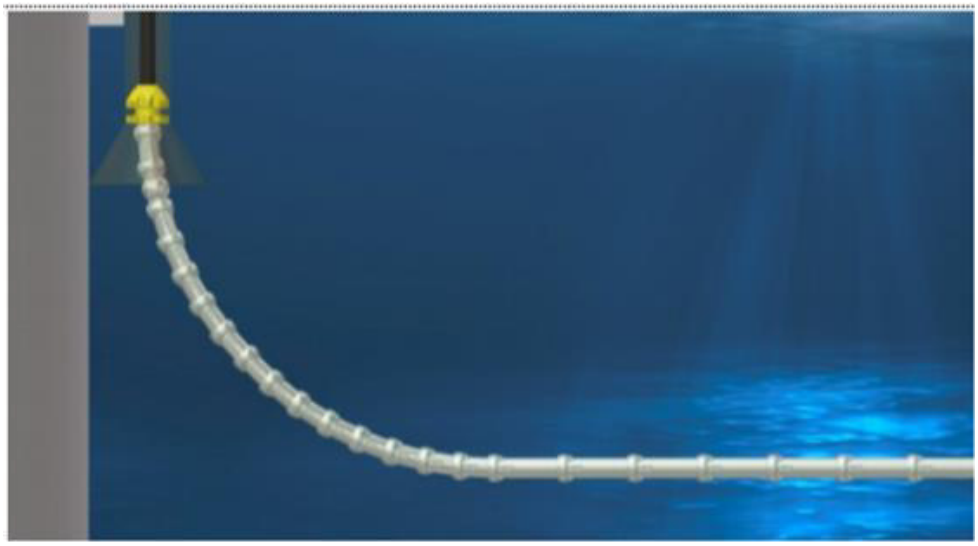
9.6.4 It is anticipated that cable burial will be primarily achieved by the use of a water jetting seabed trenching vehicle capable of performing jet trenching in softer sediments (Figure 9.7). Such jet trenching vehicles will use nozzles mounted on jet swords to inject water at high pressure into the soil surrounding the cable which fluidises the seabed in the immediate vicinity allowing the cable to sink under its own weight, before the soil re-settles over the top. To maximise post-trenching cable cover and to minimise the disturbance of sediment away from the trench, site specific trencher settings will be derived based on the soil conditions to ensure disturbed sediment is monitored and managed efficiently throughout operations.

Figure 9.7. Examples of seabed cable trenching tools and cable plough

9.6.5 Where dense sand and stiff clay sediments prevent the use of a standard jetting tool, a hybrid jet trencher that combines both jet trenching and chain cutting may be used.

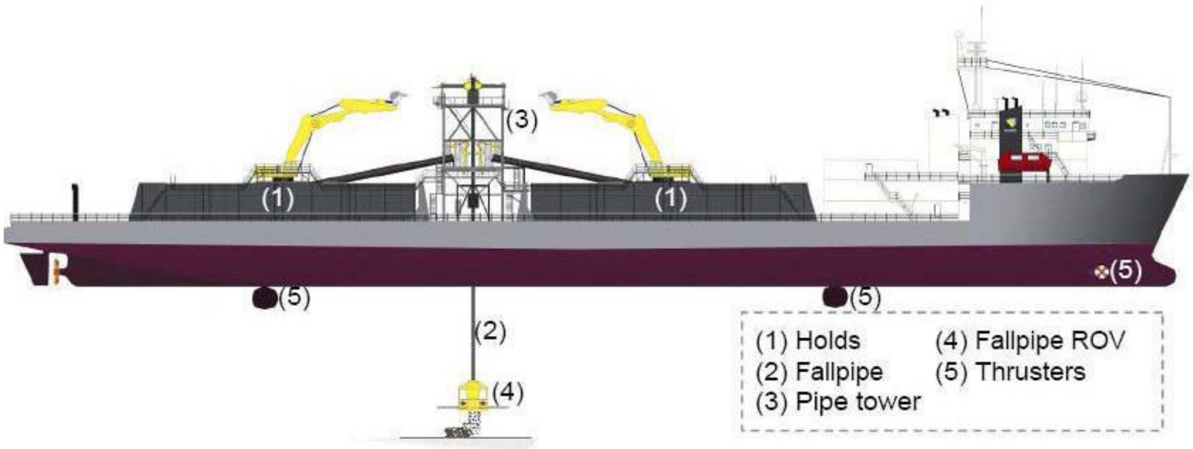
9.6.6 A close fitting cable protection system (CPS) will be installed on the Export and OTM Interconnector Cables between the seabed and the J-tube interface to protect and stabilise the cable (Figure 9.8). The CPS will consist of articulated split pipes and bend restrictors to protect the cables from dropped objects, current induced fatigue, dynamic wave action, vibration and other local hazards at this interface.

Figure 9.8 - Example of cable protection system at OTM J-tube



9.6.7 Where ground conditions are such that the trenching tool is ineffective it may be necessary to install rock protection. Rock protection will be installed from a rock placement vessel using a dynamic positioning system (See Figure 9.9). In this case specialised rock placement equipment will be used to deploy the graded rock through a flexible fall pipe to the seabed. Positioning of the fall pipe exit will be controlled by a fall pipe ROV to ensure accurate placement and adequate protection of surface laid cables.

Figure 9.9 - Example of rock placement vessel



9.6.8 The anticipated approach to Export Cable burial and protection is as follows, with cable protection strategies varying along the route of the Export Cables:

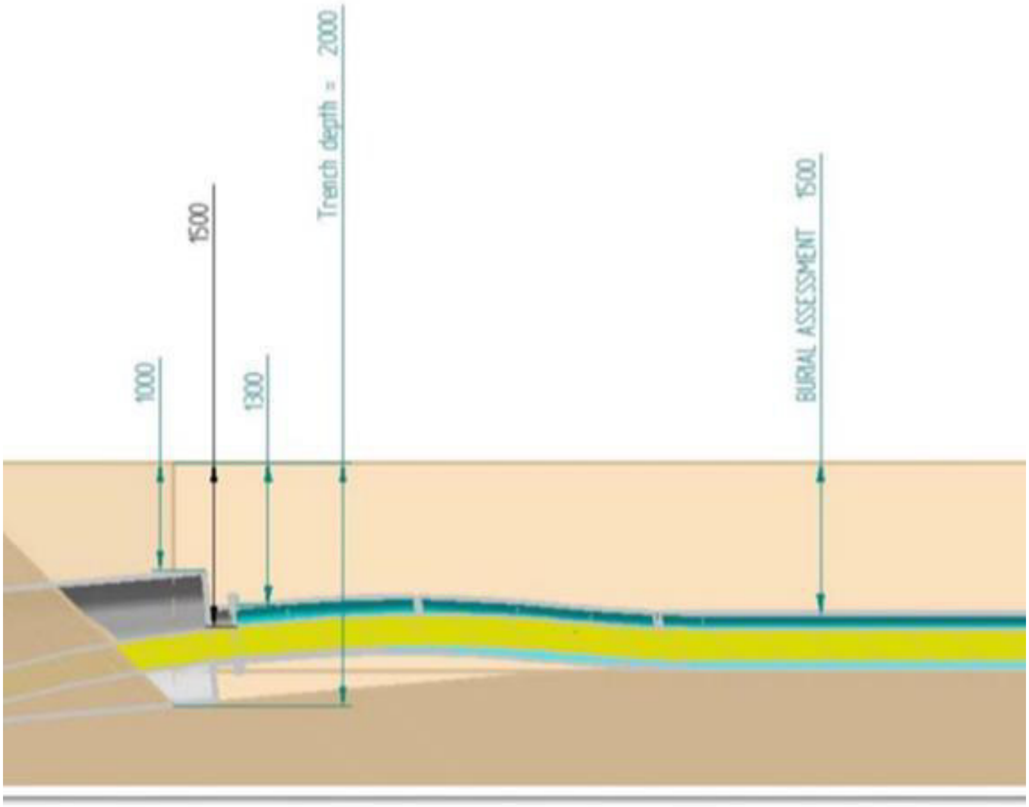
Pipe Thruster Pits (0km) to the final exit point of the pipes

- Cables will be protected within the pre-installed horizontal pipes from the onshore Pipe Thruster Pits, underneath the designated SSSI beach area, out to the seaward final exit point at 420m – 450m from the Pipe Thruster Pits. At the final exit points of the pipes, they will be buried 1m below the seabed (Figure 9.10), with the Export Cables buried 1.3m below the surface of the seabed within the pipes.

From the final exit points of the pipes to 4.5 km

- Due to the high density of boulders along this section of the route, a backhoe trencher will be used to prepare the seabed prior to cable lay. This will allow for the removal of both surface and sub-surface boulders, which will be placed on the seabed away from the cable routes. The trenches will then be allowed to refill naturally;
- The water jetting trenching tool will bury the cables along the previously trenched and cleared routes out to 4.5km from the Pipe Thruster Pits. For the first 20m – 30m from the pipe final exit points the cables will be buried to a DoL of between 1.3m and 1.5m until they reach the minimum DoL (see 8.4.4) of 1.5m below the surface of the seabed (Figure 9.10). No additional protection is anticipated to be required.

Figure 9.10 - Example of cable burial at the ducted pipe exit



4.5 km to 10.5 km

- Conditions are expected to be unsuitable for cable burial; instead cables are likely to be surface laid and protected by rock placement;
- Due to the high frequency and size of surface boulders and the high probability of sub-surface boulders, the ground conditions are assessed as potentially unsuitable for cable burial. In this area cable burial using jet trenching will be attempted and where this is unworkable the cable will likely be protected by rock placement.
- Where rock placement is required rock berms will, as far as reasonably practicable, be profiled to minimise the risk of snagging by fishing gear.

10.5 km to 19 km

- For this section of the cable route, the jetting tool will be used to achieve a minimum DoL of 0.6m. This area is identified as a shipping channel, so all operations will be conducted with support from guard vessels.

19 km to 68.5 km

- For the final section of the Export Cable route cables will be buried using a water jetting tool to achieve a minimum DoL 0.6m.

9.6.9 It is anticipated that the OTM Interconnector Cable will be buried along the entire route, to a DoL of 0.6m.

10 Export Cable Operation and Maintenance

10.1 Over Trawl Surveys

10.1.1 The OfTW Marine License Condition 3.2.2.10 requires that this OfTW CaP includes the following:

Methodologies for over trawl surveys of cables through the operational life of the Works where mechanical protection of cables laid on the sea bed is deployed.

10.1.2 The Subsea Export Cables and OTM Interconnector Cable will be subject to periodic inspection. In the Operation Phase, further cable and/or seabed surveys will be undertaken to confirm that cables remain buried to the required depths or the existing seabed remains unchanged. These surveys will address requirements set out in Chapters 9/21 and 10/22 of the ES in relation to the need for post lay cable burial surveys.

10.1.3 Currently, as noted under Section 9 above, it is anticipated that the full length of the OTM Interconnector Cable will be buried to the DoL determined with due regard to the CBRA process set out in Section 8, to provide protection to both the cables and to other marine users (with the exception of short lengths where the cables approach the OTMs). In this event no over trawl surveys will be conducted.

10.1.4 As noted in Section 9, however, in the event that the DoL is not achieved, additional protection for some sections of the export and OTM Interconnector Cables, in the form of rock placement may be required.

10.1.5 Where additional cable protection measures are applied in an area of known fishing activity, BOWL propose to conduct further discussions with Marine Scotland with regard to the need for over trawl surveys, taking account of:

- The extent and location of the cable protection material;
- The design of the cable protection material (noting that these can be designed to minimize effects on towed fishing gear); and
- The amount and type of fishing activity observed along the export cable corridor.

10.1.6 Where rock placement is required rock berms will, as far as reasonably practicable, be profiled to minimise the risk of snagging by fishing gear.

10.1.7 A survey will be undertaken approximately 1-year post-installation to confirm the cables remain as installed. The frequency and scope of further monitoring will be proportional to the risk of future cable exposure and determined based on the outcome of the above.

10.1.8 Where considered necessary, over trawl surveys are likely to involve the charter of a suitable fishing vessel with standard demersal trawl gear which has experience of fishing in the area to undertake tows and replicate the usual fishing activity at the location of interest. The purpose of this is to ensure the cable protection utilised allows bottom towed gear to pass over the surface of the cable protection without snagging or damage. The final methodology for over trawl surveys will be determined in consultation with MS-LOT and with the involvement of local fishermen.

10.2 Cable Inspection Procedures

10.2.1 The OfTW Marine License Condition 3.2.2.10 requires that this OfTW CaP includes the following:

Measures to address exposure of any cables.

10.2.2 Following installation, an assessment will be completed identifying areas of cable at potential risk of exposure in the future. Monitoring will focus on any 'at-risk' areas identified. Subject to the findings of the surveys, the frequency of these will be adapted to the appropriate level of risk exposure.

10.3 Remedial Actions

10.3.1 In the event of cable failure or exposure, cable sections will be replaced and/or re-buried or cable protection will be applied.

10.3.2 In the near shore area, the NSERA concludes that exposure of the pipe and/ or cable is unlikely. However, in the event that they do become exposed the preference would be to rebury the infrastructure using similar methods to those described in Section 9 of this CaP. In the event that the pipe becomes exposed at the final exit location there could also be an option to excavate it, and cut it to allow reburial of the pipe, and cable within it, to the desired depth below the seabed. The details of remedial actions will be developed once the pipes and cables have been installed, and will be described in the Operation and Maintenance Programme for the Offshore Transmission Works, which under OfTW Marine Licence Condition 3.2.3.2 is required to be submitted to the Licensing Authority no later than 3 months prior to the commissioning of the first OTM.

11 Compliance with the Application, ES and SEIS

11.1 Introduction

11.1.1 Condition 3.2.2.10 of the OfTW Marine License states:

The CaP must be in accordance with the Application

11.1.2 Sections 11.2 and 11.3 set out information from the ES/SEIS and original Application with regard to:

- Compliance with the Export Cable and OTM interconnector cable installation details as assessed in the ES/SEIS; and
- Export Cable and OTM interconnector cable installation related mitigation measures detailed in the ES/SEIS.

11.2 Compliance with Export Cable and OTM Interconnector Cable Installation Details Assessed in the ES/SEIS

11.2.1 The ES and SEIS described a range of specification and layout options that could be applied during the construction of the Development.

11.2.2 Since the Section 36 Consent and Marine Licences were awarded, the design of the Development and approach to installation has been substantially refined to that described in this OfTW CaP (and in other relevant Consent Plans). In order to demonstrate compliance of this refined design, installation methods and cable specifications described in the ES and SEIS are compared to the installation methods and specifications detailed within this OfTW CaP (see Appendix A).

11.3 Delivery of Export Cable and OTM Interconnector Cable Installation Related Mitigation Proposed in the ES/SEIS

11.3.1 The ES and SEIS detailed a number of mitigation commitments relevant to the export cable installation activities. Appendix B sets out where each commitment has been addressed within this OfTW CaP.

12 References

BOWL (2016) Beatrice Offshore Wind Farm Employers Requirements Offshore Export Cable. Doc. Reference no. LF000005-SPF-175

BOWL (2015) Determination of the Capacity of the Export Cables at the HDD. Doc. Reference no. LF000005-TNC-080

Geomarine (2015) Beatrice Cable Burial Risk and Protection Assessment

MMT (2015) Beatrice Offshore Wind Export Cable Geophysical and Geotechnical Report. Doc. Reference no. LF000005-REP-605

MMT (2015) Export Cable Site Investigation – Field Report. Doc. Reference no. LF000005-REP-604

Nexans (2015) Offshore Export Cable Shore Landing / HDD Design Report. Doc. Reference no. LF000005-REP-615

Nexans (2016) FEED Offshore Export Cable. Cable Design Report Subsea Cable. Doc. Reference no. LF000005-REP-613

Nexans (2015) FEED Offshore Export Cable. Cable Route and Installation Engineering. Doc. Reference no. LF00000-REP-616

Osiris (2011) Geophysical Report Volumes 2a-2c

Shapiro, S. Murray, J, Gleason, R, Barnes, S. Eales, B and Woodward, P.(1997); Threats to Submarine Cables; Suboptic 1997

Siemens (2016) Electromagnetic Field Study – Cables. Doc. Reference no. LF000005-REP-1336

Appendix A - Compliance with ES/SEIS Rochdale Envelope Parameters

Table A1 presents a comparison of consented project parameters relevant to the OfTW installation and construction process, against the details set out in this OfTW CaP.

Table A1 – Comparison of ES/SEIS Rochdale Envelope and OfTW CaP construction and installation parameters

Offshore Transmission Works	Rochdale envelope parameters	OfTW CaP
Number of cable trenches	Up to 3 trenches required on the seabed	2
Seabed preparation	No specific methods described, though potential for seabed preparation acknowledged.	Grapnel Run Backhoe trenching from the final exit point of the pipe to 4.5km offshore (from the Pipe Thruster Pits).
Means of cable installation beneath the SSSI	HDD methodology, with the end of HDD located as far offshore as practicable	Direct Pipe methodology (a form of HDD incorporating micro-tunnelling), with the end of the Direct Pipe located as far offshore as practicable
Maximum width of cable trench	3m (total maximum area of seabed disturbance from cabling of 2.34km^2)	Maximum width 4 – 5m (for the area of backhoe trenching) (but noting that the maximum area of disturbance for the export cable route will be circa 0.78km^2)
Depth of cable trench	0m to 2.5m	Minimum DoL of 0.6m
Maximum number of cables per trench	3	1
Installation method	Ploughing Trenching Jetting	Trenching Jetting
Protection method	Concrete blanket / mattressing Rock net / gabion Rock placement	CPS at OTMs (footprint less than rock placement alternative considered in ES/SEIS) Most likely rock placement
Maximum length of cable	45% of total cable length	6km per cable (~9% of cable

protection (i.e. Maximum length of surface laid cable)		length) + contingency for non-burial performance
Maximum extent of cable protection	0.26km ^{2}	0.036km^2

Appendix B - Compliance with ES/SEIS Mitigation Measures

Table B1 presents the commitments made by BOWL in the ES and SEIS to mitigation measures relevant to this CaP.

Table B1 - ES and SEIS Construction-related Mitigation relevant to this OfTW CaP

Source	Reference (ES or SEIS chapter)	Details of Commitment	Implementation
ES	Project Description	Horizontal Directional Drilling will be used to allow the cables to be installed under the Spey Bay SSSI.	Section 9 of this OfTW CaP
ES	Site Selection and Consideration of Alternatives	Cable landfall will be between NGR: NJ 38614 64277 and NJ 37525 64629)	Section 6 of this OfTW CaP
ES	Site Selection and Consideration of Alternatives	Directional drilling will likely be undertaken under the landfall location, to avoid disturbing the Spey Bay SSSI. ...the directional drilling is likely to start at this location or beyond so that the cable does not interfere with offshore/onshore/along shore sediment movement. The cable will then exit onshore sufficiently far enough back so that the coastline retreat would not expose the cable on the beach in its expected operational lifetime.	Sections 5 and 9 of this OfTW CaP
ES	Physical Processes OfTW	The offshore end of the HDD will aim to exit as far offshore as is practicable, up to the 6 m LAT contour. If the full distance cannot be achieved due to geological or technological limitations, an alternative method of protecting the cable between the HDD exit and the depth of closure will be verified with Marine Scotland. The design of any alternative protection (pending further detailed engineering design works) will aim to minimise effects on sediment transport patterns and ultimately ensure that the protected features of the SSSI will not be adversely affected by the works	Sections 5 and 9 of this OfTW CaP and Appendix C
ES	Marine Mammals OfTW	The use of cable sheathing to reduce the strength of magnetic fields arising	Section 7 of this OfTW CaP

Source	Reference (ES or SEIS chapter)	Details of Commitment	Implementation
		from the subsea cable route will be investigated	
ES	Commercial Fisheries OfTW	BOWL is committed to cable burial where feasible (minimum 55% of the export cable route)	Sections 8 and 9 of this OfTW CaP
ES	Commercial Fisheries OfTW	BOWL is committed to protection of cable where burial is not feasible (up to 45% of the export cable route)	Section 9 of this OfTW CaP
ES	Shipping and Navigation OfTW	Cables will be buried or protected where feasible	Sections 8 and 9 of this OfTW CaP
ES	Shipping and Navigation OfTW	Periodic and planned surveys of cable routes to monitor burial depths and sea bed mobility	Section 10 of this OfTW CaP
SEIS	Introduction	The subsea cable will be a minimum of 1.5 km from the Beatrice Bravo Oil Platform	Section 5 of this OfTW CaP (noting that the required buffer has been reduced)
SEIS	Project Description	In higher voltage cables the metallic sheath will be designed to provide a shield against the main electric field (E) as per the design specification standard IEC 60502.	Section 7 of this OfTW CaP
SEIS	Shipping and Navigation	An Anchoring Impact Assessment and a Burial Protection Study will be carried out to address CoS comments once detailed design of the OfTW has been completed.	Section 8 of this OfTW CaP (noting that the CBRA provides the information referred to in the SEIS commitment)

Appendix C – Near Shore Erosion Risk Assessment

Project Title	Beatrice Offshore Wind Farm
Date:	December 2016

Beatrice Offshore Wind Farm

Near-Shore Erosion Risk Assessment

Rev	Prepared By	Signed	Checked By	Signed	Approved By	Signed	Date of Issue
2.0	Nick Cooper, RHDHV	[signature]	Phil Cowlishaw, BOWL	[signature]	Steven Wilson, BOWL	[signature]	13/12/2016

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1 Glossary

Cable	Beatrice Offshore Wind Farm's transmission high voltage (HV) alternating current (AC) 220 kV subsea export cable.
Back of the berm	Landward edge of the shingle berm, where the limit of the storm shingle washover fans meet the vegetation edge of the hinterland, as measured by BOWL's 2016 topographic survey
Depth of Closure	The depth of water beyond which annually significant wave events will cease to contribute to beach sediment supply and morphological processes.
Direct Pipe	DIRECT PIPE® is a pipeline installation methodology pioneered by Herrenknecht, a form of HDD which has the advantages of micro tunnelling technology. This technique excavates the borehole using a micro tunnelling machine, pushed by the prefabricated final pipeline in one single step. The necessary thrust force is provided by the Pipe Thruster which pushes the micro tunnelling machine forward (or pulls it backward) together with the pipe – with a thrust force of up to 750 tonnes in increments of 5 metres. The push force is transferred to the Direct Pipe through the Pipe Thruster's clamping unit and then to the tunnelling machine's cutterhead.
EC1	Beatrice Offshore Wind Farm's transmission subsea Export Cable 1 (Easterly cable).
EC2	Beatrice Offshore Wind Farm's transmission subsea Export Cable 2 (Westerly cable).
Entry point	The onshore entry point for the pipe on completion of the Direct Pipe installation activities and after the pipeline has been cut to the required length. Typically the final pipe entry point corresponds to the front wall of the Pipe Thruster Pit.
Final Exit Point	The offshore seabed pipe exit point, once the pipeline has been pulled back in to the seabed to achieve the required depth of burial. It is also the point at which the Polypipe attaches to the Direct Pipe.
Horizontal Directional Drilling (HDD)	A steerable, trenchless, method of installing an underground pipe, conduit or cable in a shallow area along a prescribed bore path by using surface-launched drilling equipment, with minimal impact on the surrounding area.
Landward transgression	A term used to describe the geomorphological behaviour of a landform under processes which lead to its landward movement over time.
Landward translation	A term used to describe an analytical process whereby a survey transect is displaced in the horizontal plane by a defined distance (in this case the 'set back distance')

MHWS	Mean high water spring tide mark is located part-way along the seaward face of the shingle berm. BOWL's 2016 topographical survey established the distance from MHWS to 'back of berm' was variable but approximately 25m.
Pipe Thruster	The unit which is used to provide up to 750 tonnes of thrust or pull force to the pipeline string being installed.
Pipe Thruster Pit	The onshore location of the Pipe Thruster. The Pipe Thruster Pit (sometimes known as the launch pit) is a temporary pit structure which provides the necessary structural anchorage for the Pipe Thruster Unit and is configured to allow the required ground entry angle for the pipe. The Pipe Thruster Pit it is usually constructed from sheet piles and concrete which is fully removed on completion of the pipeline installation.
Polypipe	The Polypipe is a medium or high density 20 – 30m long plastic pipe conduit which facilitates the cable entry and pull-in into the offshore pipe Final Exit Point situated beneath the seabed. The Polypipe is attached to the pipe end flange. On completion of the cable pull-in both the Polypipe and cable are buried beneath the seabed for long term protection.
Seabed push-out point	The offshore seabed push-out point for the direct pipe and micro tunnelling machine is the location where the pipe is "over" pushed out onto the seabed to allow recovery of micro tunnelling machine, before the pipe is sealed and pulled back in to the seabed to achieve the required depth of seabed burial at the end of the pipe at the final position
Set back distance	The distance by which landfall infrastructure will be set back from the shore so that projected future coastal erosion over the next 25 years can be accommodated without compromising the infrastructure. The set back distance is measured from the back of the berm. It has been established as a distance of 50m.
Shingle Berm	The wave-built, gently sloping, often sizable shingle or gravel barrier, between the seaward foreshore and landward backshore plane or hinterland. The barrier is usually characterised with a series of storm ridges on its seaward face and shingle wash over fans landward of its ridge
Transition Joint Bay (TJB)	The transition joint bay (TJB) is where the 220 kV Subsea cable is jointed to the 220 kV Land cable. The TJBs are part of the permanent cable infrastructure and are set some distance back from the Entry Points.
Vegetation edge	This is edge of the hinterland vegetation where it meets the marine influenced beach topography. It is typically where shingle storm washover fans meet the vegetation edge of the hinterland. It is otherwise referred to as the "erosion edge" or "back of the berm".

2 Introduction

Royal Haskoning DHV (RHDHV) has been appointed by Beatrice Offshore Windfarm Limited (BOWL) to undertake a Near-Shore Erosion Risk Assessment (NSERA). This covers the inshore section of the two AC HV 220 kV offshore transmission cables which extend from the Beatrice Offshore Wind Farm (OWF), located in the outer Moray Firth, to the consented landfall to the west of Portgordon on the Moray coast (Figure 1). The two offshore transmission cables are named EC1 and EC2.

A Cable Burial Risk Assessment (CBRA) has previously been undertaken as an integral part of the Cable Plan (CaP) for the Offshore Transmission Works (OfTW), focusing on risks to the buried offshore transmission cables from: (i) commercial shipping activity; (ii) commercial fishing activity; (iii) anchor penetration; and (iv) natural changes in seabed bathymetry (BOWL, 2016).

This NSERA supports the CaP by providing supporting evidence of risks to the near-shore sections of the offshore transmission cables and the onshore permanent infrastructure (Transition Joint Bays) from coastal erosion, including both vertical (downward) lowering of the seabed and horizontal (landward) recession of the shore.

This NSERA is presented within the context of Discharge Condition 3.2.2.10 Cable Plan ("CaP") and Condition 3.2.3.8 Horizontal Directional Drilling ("HDD") of the Offshore Transmission Works Marine License.

Condition 3.2.3.8 states:

The Licensee must ensure:

1. *The seaward exit point of the HDD will be located as far offshore as practicable towards the depth of closure;*
2. *The landward entry point of the HDD will be located onshore of the high-water mark, which may move landward due to coastal retreat; and*
3. *The cables will be suitably buried between the seaward exit point of the HDD and the depth of closure (the depth of water beyond which annually significant wave events will cease to contribute to beach sediment supply and morphological processes).*

Each of the items listed under Condition 3.2.3.8 are discussed in turn in following sections.

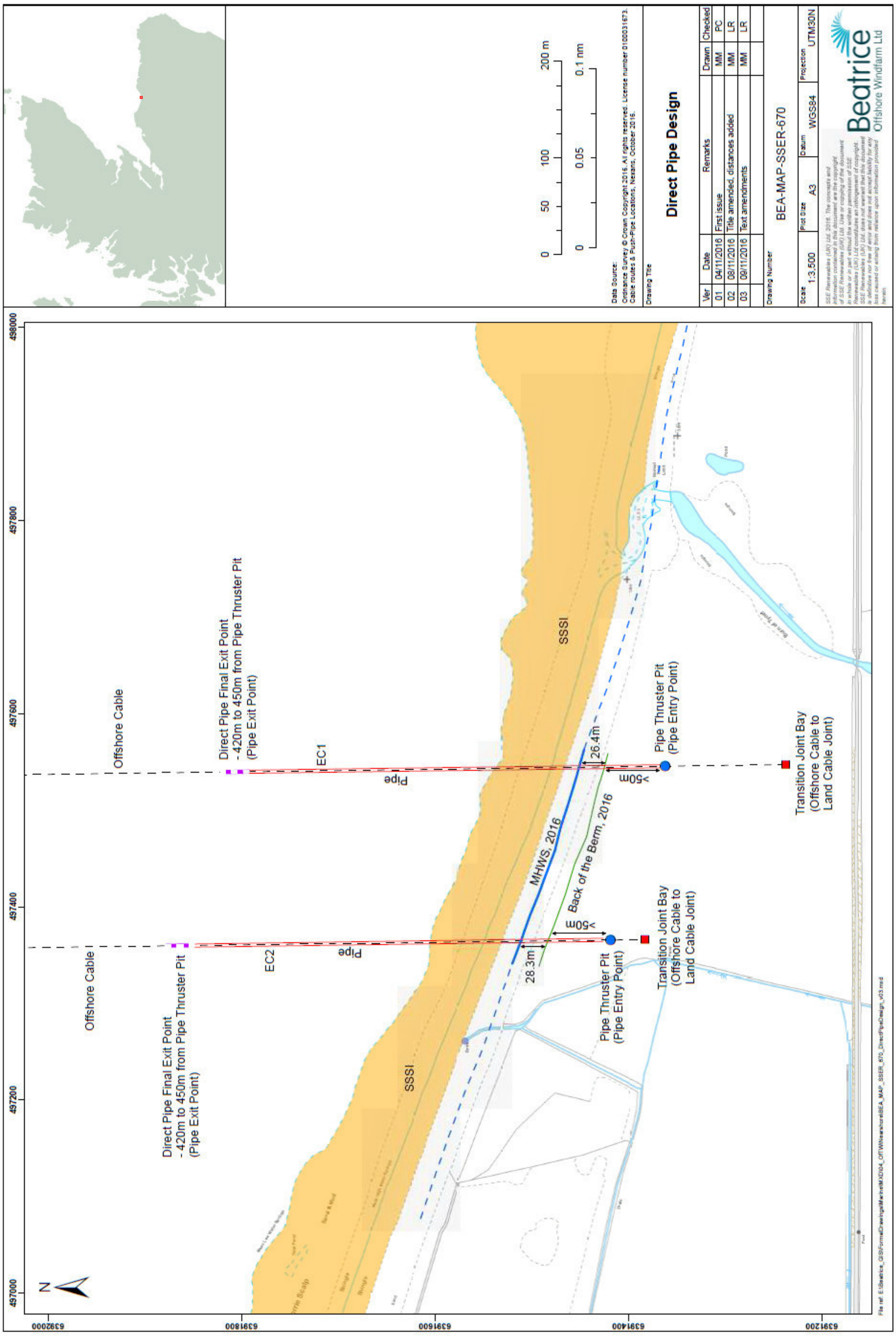

Figure 1 Pipe and Cable Layout at Landfall

3 Seaward Exit Point of Landfall Installation Works

Marine Licence Discharge Condition 3.2.3.8 point 1 states:

- *The seaward exit point of the HDD will be located as far offshore as practicable towards the depth of closure.*

The 'depth of closure' referred to in Condition 3.2.3.8 is the seaward limit of the active beach profile in terms of cross-shore sediment transport. It is considered that any activities within the active beach profile (i.e. from the upper beach extending seawards to the depth of closure) have the potential to affect the sediment transport processes within the littoral zone, which ultimately could affect the volumes of sediment observed on the beaches. The depth of closure is typically defined based upon empirical theory and is governed primarily by the wave parameters (especially wave height) attained at particular locations (and associated water depths) perpendicular to the shore (Hallermeier, 1981). Within Spey Bay, the depth of closure is achieved in water depths of ~6m (BOWL, 2013).

The final end position of the HDD has been located as far offshore as practicable towards the depth of closure. The design of the landfall installation works has been strongly influenced by:

- ground risk assessment, based on the geotechnical properties and morphology of the seabed (as defined by various geotechnical and geophysical surveys); and
- engineering assessment of the maximum pull-in loads that the HV AC 220 kV export cables can withstand when being installed through the Direct Pipe.

Due to the extensive presence in the nearshore and inter-tidal zones of non-cohesive sands and gravels, a 'Direct Pipe' HDD installation method is a more suitable methodology than the more 'traditional' HDD method.

The Direct Pipe method involves use of a micro-tunnelling machine pushed through the ground by a 48" steel pipe from its entry point within a Pipe Thruster Pit to an offshore exit point. This methodology allows the duct to be installed in a single step and removes the requirement for pilot drilling, reaming and final duct pull-in otherwise required under the traditional HDD approach. It also removes the use of bentonite drill muds to maintain the drill bore and therefore avoids the risk of bore collapse in porous unconsolidated sediments.

It should be noted that during Direct Pipe installation the micro-tunnelling machine continues past the Final Exit Point location of the pipe to reach a seabed push-out point (where it emerges from below the seabed). Thus the tunnelling machine can be released from the pipe end and recovered by divers. The sealed pipe end is then pulled-back (landwards) along its bore to its Final Exit Point location below the seabed. With respect to Condition 3.2.3.8 this Final Exit Point location is defined as the 'seaward exit point' of the HDD in this NSERA.

The length of the pipe installation that can be achieved using a Direct Pipe method is limited to the maximum allowable pull-in loads on the cable to be installed through it. For the Beatrice AC HV 220 kV export cables this equates to approximately 30 tonnes which represents a maximum pipe length in the region of 420 – 450m for EC1 and EC2 as measured from the onshore Pipe Thruster Pits.

In addition to this engineering limitation on the practicably achievable length of pipe installation, a suitable onshore set back distance needs to be incorporated at the landward end of the pipe (entry point) to allow for future coastal recession over the 25 year design lifetime of the Development. This has been defined as a 50m set back distance, measured from the landward edge of the shingle berm, where the limit of the storm shingle washover fans meet the vegetation edge of the hinterland (referred to as the “back of the berm” as measured by BOWL’s 2016 topographic survey) and is further discussed in Section 4.

The two principal constraints or limitations on the design are therefore:

(i) practicable maximum pipe installation lengths using Direct Pipe method (420 - 450m for EC1 and EC2); and

(ii) suitable set back distance for future coastal recession (50m, measured from the back of the berm, as measured by BOWL’s 2016 topographic survey).

These two physical constraints on the pipe installations equate to the following maximum water depths at the pipe Final Exit Point locations:

- approximately 1.1m depth of water relative to LAT for EC1; and
- approximately 1.0m depth of water relative to LAT for EC2.

At the Final Exit Points, the Direct Pipe (into which an offshore transmission cable will be installed) will have been pulled back into the seabed to a minimum depth of -1m below the seabed surface to top of the pipe (see Section 5 for further details).

Whilst the Final Exit Points of the Direct Pipe installations will be located as far offshore as practicable towards the depth of closure they remain within the active beach profile. As such, further assessment has been carried out with respect to the risk of pipe and cable re-exposure from both storm events (short term) and coastal recession and sea level rise (longer term) to demonstrate that the cables will be suitably buried between the seaward Final Exit Point of the Direct Pipe and the depth of closure (as required by Condition 3.2.3.8). These assessments are provided in Section 5.

4 Landward Entry Point of Landfall Installation Works

Marine Licence Condition 3.2.3.8 point 2 states:

- *The landward entry point of the HDD will be located onshore of the high-water mark, which may move landward due to coastal retreat.*

This section provides a discussion of how a suitable set back distance has been defined to ensure that the landward entry point of the Direct Pipe (defined by the position of the Pipe Thruster Pit) is located sufficiently far onshore to allow for landward recession due to coastal retreat over the 25 year operational lifetime of the Development. As discussed in Section 3 of the NSERA, this issue is also one of the two critical limiting factors in determining the length of the Direct Pipe installation that can be achieved for the offshore transmission cables, and thus this is inter-related to an extent with Marine Licence Condition 3.2.3.8 point 1.

Previous assessment of a suitable set back distance (derived from the BOWL Environmental Statement) is summarised in Section 4.1. This sets out the historic erosion rates and basis upon which initial assessments of a suitable set back distance were made.

As new information on erosion rates has emerged from the Scottish Government's National Coastal Change Assessment for Scotland (*Rennie et al. 2016*) the original assessments of a suitable set back distance have been re-evaluated. This process is described in Section 4.2.

4.1 BOWL Environmental Statement

Extensive work has previously been undertaken to characterise the baseline physical processes and coastal geomorphology at the landfall area as part of the Beatrice OWF Environmental Statement (ABPmer, 2012a & 2012b; BOWL, 2013).

This previous work drew fully from all known available published and 'grey' literature sources available at the time (e.g. Ritchie *et al.*, 1978; Ritchie, 1983; Dobbie & Partners, 1990; Comber, 1993; Hansom & Black, 1994; Riddell & Fuller, 1995; HR Wallingford, 1997; Ramsay & Brampton, 2000; Gemmell, 2000; Gemmell *et al.*, 2001).

As part of this previous work, historic shoreline evolution was mapped from historic Ordnance Survey maps by means of changes in the mean high water and mean low water marks. This shows that the coastline to the east of the Spey has experienced net recession over the past century. This is consistent with anecdotal evidence of changes at Spey Bay Golf Club, but is in contrast to the coastline west of the Spey which has experienced accretion over the same time period.

Based on analysis of historic maps and charts, a long term average annual erosion rate of 0.64m per year was calculated at the landfall site (ABPmer, 2012b). For the purposes of construction works, this has been translated into a highly conservative set back distance (measured from the back of the berm where the landward limit of shingle washover fans meets the vegetation edge of the hinterland in the present day (2016). The back of the berm is shown as a yellow line in Plate 1. Assuming 50m recession over 25 years, the following approach was used to identify the suitable set back distance:

- Long term erosion rate = 0.64m/year, rounded up to 0.7m/year for conservatism
- 25 years x 0.7m/year = 17.5m erosion

- Factor of safety = 2.0
- 2.0 x 17.5m = 35m
- Additional contingency = 15m
- Total set back distance = 35m + 15m = 50m (measured from the back of berm)

Plate 1 – Present day photograph 2016 showing a westerly cross view of the shingle berm. The yellow line marks the back of the berm.

Consequently, BOWL has worked on the basis of a 50m set back distance (measured from the 'back of the berm') for the landfall infrastructure within its engineering design process.

4.2 National Coastal Change Assessment for Scotland

The Scottish Government (SG) is currently undertaking a *National Coastal Change Assessment for Scotland* (Rennie *et al.* 2016). Between August and October 2016, Scottish Natural Heritage (SNH) provided BOWL with interim outputs from this study which were intended to inform BOWL about past and future projections of coastal change at the landfall site.

This information enabled BOWL to re-assess its previous engineering considerations of suitable set back distance, based upon both the new information available from the *National Coastal Change Assessment*, and BOWL's risk appetite for the 25 year project lifetime.

The dialogue between BOWL and SNH on the topic of erosion projections took place on several occasions and concluded with a telephone meeting between Dr. Alistair Rennie (SG/SNH) and Dr. Nick Cooper (technical adviser to BOWL) on 4th October 2016. A record of the dialogue on the erosion projections is presented in a sequential manner in Technical Appendix A. A synopsis of the principal findings arising from interpreting the outputs from the *National Coastal Change Assessment* project is provided below:

- The long term erosion rate for the landfall site is around 0.6m/year (1903 – 2014), measured as the change in Mean High Water Springs (MHWS). This matched well with a rate of 0.64m/year used to inform the engineering design considerations.

- The past epoch which is likely to provide the most appropriate analogue for the likely future changes over the next 25 years is the most recent 25 years. This is because the rates of recent past sea level rise, sediment supply and ground conditions are likely to be most similar to those projected for the next quarter-century.
- The average erosion rate in MHWS over the past 25 years (actually 24 years based on available data between 1990 and 2014) is around 1.24m/year. If this rate is projected over the next 25 years, then the erosion will affect 31m of land. Setting the infrastructure back 50m from the 'back of berm' provides a total buffer of great than 70m landward of MHWS (50m set back from the back of the berm or plus ~25m distance between the back of the berm and the MHWS 2016) leaving a distance of around 44m unaffected by recession.
- As emerging information from the *National Coastal Change Assessment* project was refined between the first and second outputs, the erosion rate appears to have been altered (increased). Even when sensitivity analysis was applied to the updated rates to determine the effect of 25% and 50% increases in the worst case observed values, however, the infrastructure remained unaffected during its 25 year operational life.
- When SNH were further updated with the most recent survey data provided by BOWL from 2016, the rates of erosion (between 2003 and 2016) were recalculated by SNH to be 0.9m/year at the western cable (EC1) and 0.6m/year at the eastern cable (EC2).
- If these most recent data are combined with data from 1990 to 2003, the average rates over the past quarter-century (actually 26 years) are 1.35m/year at EC1 and 1.05m/year at EC2.
- Recognising that there could be errors within the calculation of the erosion rates as an inherent consequence of inaccuracies in mapping the position of MHWS from historic data, a further sensitivity test was undertaken to consider the worst case of potential errors acting upon the worst case erosion rate established for any one given epoch. Whilst the resulting value is considered unrealistically high (2.99 m/year) (see Technical Appendix A) even this scenario only impinges upon the Pipe Thruster Pit locations after a full 25 year period. The Pipe Thruster pits are temporary works, present during construction only and fully removed upon pipe and cable installation and not the permanent infrastructure at the landfall such as the Transition Joint Bays which are set back further.

Based on the above points, BOWL has re-assessed its considerations of suitable set back distance for design and construction of the landfall works, taking due account of a range of different projected erosion rates, and sensitivities on those rates associated with uncertainties and errors in data mapping. After this re-assessment BOWL remains confident that its use of a minimum 50m set back distance measured from the back of berm for the onshore pipe entry point is a suitably conservative approach.

It should also be noted that there is a further approximately 25m between MHWS and the back of the berm adding further contingency the design.

BOWL has also further set back the more sensitive permanent landfall infrastructure that will be present throughout the operational life of the Development, namely the Transition Joint Bays) which are located some 36m (for EC1) and 125m (for EC2) landward of the (temporary) Pipe Thruster Pits, offering a considerable additional buffer against coastal erosion. As part of the onshore design the cables across the hinterland, from the Pipe Thruster Pits (Pipe Entry Point) to the Transition Joint Bays will be buried to a sufficient depth to ensure that it does not become exposed.

The design of each Direct Pipe profile will be to sufficient depth to ensure that the pipe will not become exposed by the ongoing landward coastal recession or storm-induced erosion events. This issue is addressed in Section 6.

5 Cable Burial Within Depth of Closure

Marine Licence Condition 3.2.3.8 point 3 states:

- *The cables will be suitably buried between the seaward exit point of the HDD and the depth of closure (the depth of water beyond which annually significant wave events will cease to contribute to beach sediment supply and morphological processes).*

Under the Direct Pipe installation method, the offshore transmission cables will be pulled into the pre-installed pipe, extending under the hinterland, shingle berm, inter-tidal shore and shallow near-shore. Due to the arc of the Direct Pipe installation between its entry and Final Exit Point (See Figure 5), the shallowest depth of burial in the seabed along the near-shore section of the cable is located at the Final Exit Point of the Direct Pipe. The Final Exit Point is defined as the seaward point where the Direct Pipe stops and the cable (within a Polypipe for protection) then is buried directly into the seabed.

For a Direct Pipe length of between 420 – 450m the pipe offshore Final Exit Point is likely to be within 1.1m depth of water (relative to LAT) for EC1 and within 1.0m depth of water (relative to LAT) for EC2. In both cases, this is within the zone defined by Marine Licence Condition 3.2.3.8 as requiring assessment with respect to the risk of cable re-exposure. This could result as a consequence of changes in seabed level, arising from both storm events (short term) and coastal recession and sea level rise (longer term).

The Direct Pipe and cable burial details at the Final Exit Point are presented in Figure 6. It can be seen that the top of the Direct Pipe, once pulled back into its Final Exit Point is at a minimum depth below the seabed of 1.0m to top of pipe.

Upon exiting the Direct Pipe at the Final Exit Point, the cable is protected by a Polypipe. The top of the Polypipe is at an initial minimum depth of 1.3m below the seabed and, along a distance of approximately 20m from the pipe Final Exit Point, progressively deepens to achieve a minimum target burial depth of 1.5 – 1.7m below the seabed which it retains to the depth of closure and beyond. When the Polypipe is at a minimum target depth of 1.5m below the seabed, the top of the cable itself is at a minimum depth of 1.7m below the seabed.

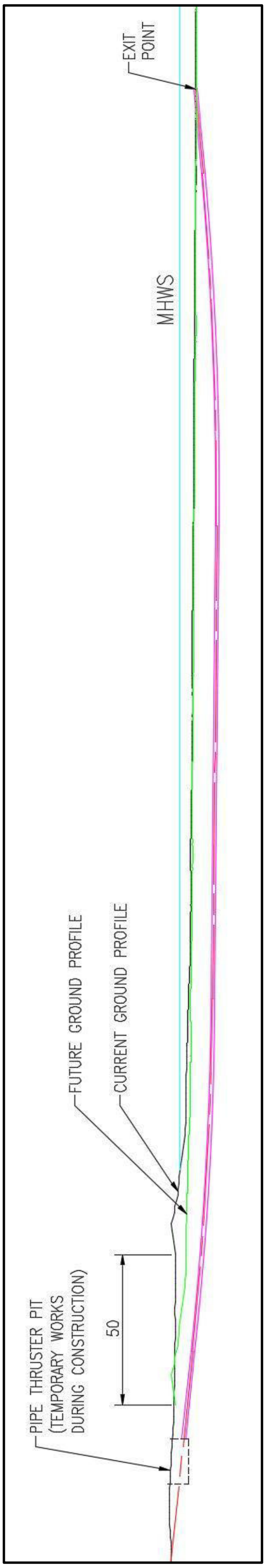

Figure 5 – Schematic Representation of the Direct Pipe Installation between Pipe Thruster Pit (Entry Point) and Final Exit Point (the arc of the installation results in shallowest burial depth at exit point), showing current and projected ground profiles.

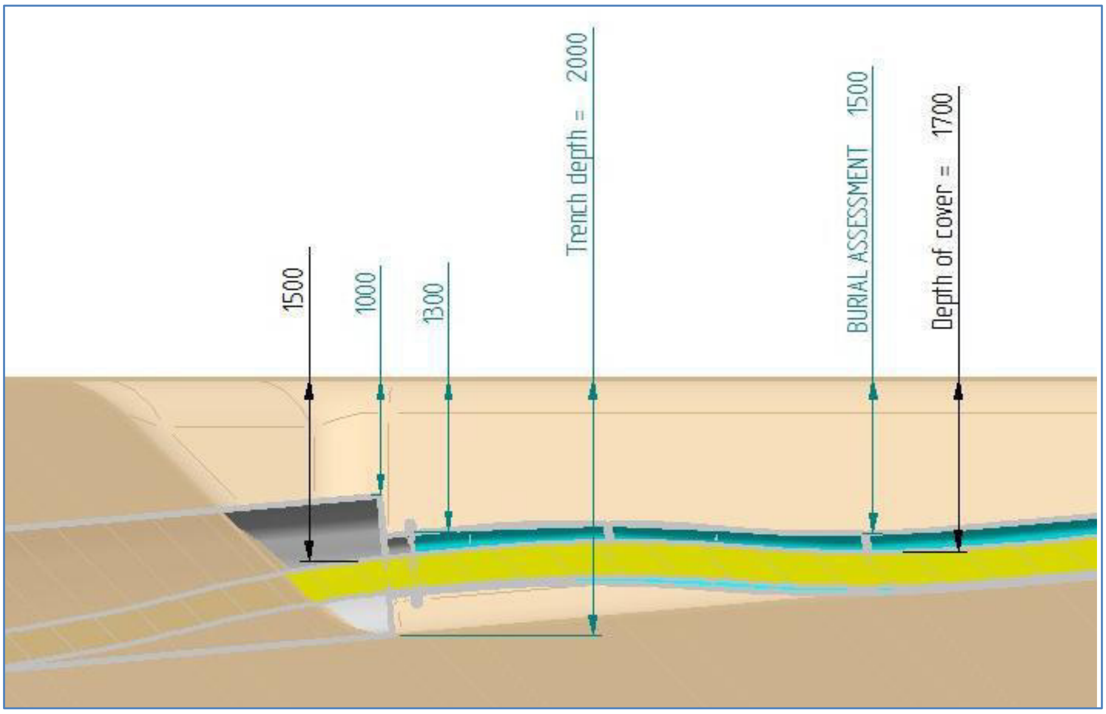

Figure 6 – Schematic Representation of Direct Pipe (grey), Polypipe (turquoise) and Cable (yellow) Burial at the Direct Pipe Final Exit Point

Following a review of available peer-reviewed published scientific literature, industry 'good practice' guidance and existing codes of practice, it is apparent that there is no readily available method for assessing the depth of seabed lowering under individual storm events. Rather, recommended approaches typically use risk-based assessment methods to inform engineering judgements of suitable burial depths.

The first widely published methodology for selecting appropriate cable burial depths (Allan, 1998) recognised the need to consider 'natural threats' (including submarine landslides, sediment mobility, seismic activity and iceberg scour) alongside 'human threats' (including trawling, shell fishing, anchoring and dredging) within the context of a semi-quantitative (i.e. 'relative ranking' based) Burial Protection Index (BPI). The BPI has since been widely used in practice and remains cited as good working practice in more recent industry-wide guidance relating to offshore wind farms (BERR, 2008).

The BPI approach recommends, amongst other factors, engineering considerations of soil strength (in terms of broad parameterisation as 'very soft clay', 'firm clay', coarse sand' and 'fine sand'), although this was in the context of potential cable damage from anchor penetration through the different soil types rather than different soil types being potentially subject to different rates of erosion (seabed lowering) which is the issue under consideration in this section. The BPI also recommends consideration of bedforms and sediment mobility, although again the context of these issues is different to the issues presently under consideration here, being more related to large scale sandwaves and meggaripples where cable exposure due to bedform mobility could lead to cable free-spanning between bedform crests.

In developing its Cable Plan (CaP), BOWL has taken into consideration an assessment of bathymetry, seabed morphology and shallow geology (alongside assessment of risks to the installed cable arising from commercial shipping activity, commercial fishing activity and anchor penetration) in a manner similar to the methods described above. This work, alongside engineering assessments of the Direct Pipe installation method, resulted in the recommendation for the top of the Direct Pipe to be buried to a minimum depth of 1m below the seabed at its Final Exit Point.

More recently, the Carbon Trust has published guidance specifically on the preparation of cable burial 'depth of lowering' specification (Carbon Trust, 2015) as part of its Offshore Wind Accelerator Research & Development programme. This re-iterates the need to consider seabed conditions (bathymetry, seabed features and geology) and both natural hazards (including seabed mobility) and anthropogenic hazards as underlying principles of a Cable Burial Risk Assessment (CBRA), but the guidance is categorical in its statement that detailed rules are not provided. Rather the content of the guidance is to be used as a tool to help decision-making.

The nearshore seabed between the Direct Pipe Final Exit Point and the depth of closure does not contain large scale bedforms such as mega ripples, sand waves or sand banks. therefore the risk of cable re-exposure is deemed low. There are, however, occasional low-amplitude bars identified on the bathymetric survey between MLWS and just below LAT and, through discussion with SNH, it is considered that the formation of such features in close proximity to the Direct Pipe Final Exit Point cannot from available evidence be categorically discounted. This issue has therefore been considered in further detail later in this section.

The most recent publication on the topic of cable burial in nearshore waters is a Recommended Practice code that was published in March 2016 (DNV GL, 2016). This identifies a number of methods that may be useful in determining the burial depth, including:

- Qualitative review of long-term experience with similar infrastructure in the area;
- Semi-quantitative Burial Protection Index (BPI) (Allan, 1998);
- Quantitative 'threat-line' assessment (which relates to the depth of penetration of a specific hazardous activity (e.g. trawling, anchoring) into the seabed and does not relate to general seabed lowering or accretion due to natural erosion processes; and
- Cable Burial Risk Assessment (CBRA) methodology (Carbon Trust, 2015).

The code also recommends that in areas of "unstable seabed" (e.g. mudslides, megaripples, sandwaves or subject to erosion due to storms) data should be obtained or collected covering long periods (commonly several years, also distinguishing seasons) to assess the situation along the planned cable route.

To assess a suitable cable burial depth between the Final Exit Point of the Direct Pipe and the depth of closure of the active beach profile, it would be ideal to have bathymetric data covering the seabed over at least two (and ideally more) successive surveys separated by a suitable gap in time to capture seasonal, annual or decadal scale changes. However, in the absence of such data an alternative is to estimate the seabed level changes over a 25 year period based upon landward translation of the active beach profile.

To enable this assessment, a digital ground model has been developed using the recently available 2016 topographic, bathymetric and geological data of the hinterland, shingle berm, inter-tidal area and near-shore seabed along a transect for each offshore transmission cable, extending from the Pipe Thruster Pit (Entry Point) on land offshore to the Direct Pipe Final Exit Point and beyond to the depth of closure.

A translation approach has then been undertaken to relocate the whole transect, from back of the berm to the depth of closure, landwards by a distance of 50m. This translation distance was determined using the methods previously described in Section 4.1 and re-assessed in light of emerging evidence from the Scottish Government's *National Coastal Change Assessment* project in the manner described previously in Section 4.2.

This approach represents a pragmatic means of assessing the profile response to landward transgression, adopting the principles of conservation of mass and continuity of form and function. The fact that the approach does not incorporate longshore sediment transport is not considered a fundamental constraint on its applicability to Spey Bay because the longshore transport rates are relatively low, estimated at approximately 3,000m^3 (ABPmer, 2012b).

The landward translation model does simplify the processes which control the migration of the profile, and especially the shingle berm but it is considered that these processes are inherently incorporated within the determination of long-term erosion rates. For example, the 'roll-back' of the shingle berm will not likely be associated with an ongoing, progressive change, but is more likely to be governed by episodic storm events that force gravels and cobbles to wash over the crest of the shingle berm and form wash-over fans on the landward side (Orford & Anthony, 2011). However, these processes will have occurred in response to storms in the past and therefore are inherently incorporated within a net average long term rate of recession.

Furthermore, the landward translation model is deemed conservative because only a horizontal component has been incorporated. The 'Bruun Rule' for coastal retreat under rising sea levels (Bruun, 1954; 1962; 1988), which forms the underlying basis of the landward translation model, assumes that as the recession occurs, material eroded from the upper shore will become deposited on the lower shore and near-shore and thus the whole profile will experience a vertical shift upwards in its position as the landward translation occurs. This vertical component has been omitted from the landward translation model considered here, partly because the shingle berm will not necessarily behave in this manner (it is more likely to roll-back under storm wave action) and partly because the 'uplift' component in the Bruun Rule is due primarily to sea level rise. At Spey Bay the rates of sea level rise over the next quarter-century are projected to be relatively low and there is a good level of confidence in projections over such timescales. Confidence in climate change projections decreases with progression into the future, say 50 years and especially 100 years.

With the above in mind, the landward translation model represents the most pragmatic (and arguably only technical feasible) means of assessing whether future changes in the seabed over a 25 year operation life will impact upon cable exposure. The important point is to recognise the uncertainties associated with the projections and ensure that a sufficient factor of safety is built into the design.

Reflecting this approach, it is possible to determine the change in seabed level between the present and future projected active beach profile after landward translation of the profile by a conservative distance of 50m. Along both EC1 and EC2 the change in sea bed level due to the landward translation is < 0.2m at any point between the pipe Final Exit Point and further seawards across the active beach profile over the 25 year operation life of the Development.

Specifically at the Final Exit Point of EC1, the change in seabed level is 0.12m and at the Final Exit Point of EC2 the change is 0.17m. Under such changes, the shallowest point of burial along either cable (namely the top of the Direct Push Pipe at the Final Exit Point) remains unaffected by these estimated seabed changes.

As previously in this section, whilst the entirety of the seabed between the Direct Pipe Final Exit Point and the depth of closure is very flat and featureless, the 2016 bathymetric survey showed that there are occasional low-amplitude bars present (presumably ephemerally) between MLWS and just below LAT. Through discussion with SNH, it is considered that the formation of such features in closer proximity to the Direct Pipe Final Exit Point cannot, from available evidence, be categorically discounted. These low-amplitude bars cover a cross-sectional profile width of less than 100m and the bars typically are of the order of 0.1 – 0.3m in height and up to 14.5m in length. Across the width of this 'field' of bars, a series of successive crests and troughs is present, which cause the seabed topography to locally deviate from the otherwise characteristic level of adjacent general areas. If, after the landward translation process of the active profile, the resultant seabed is more characterised by the flatter seabed levels, then changes of up to 0.3m can be observed by simply the effective 'removal' of the crest of a bar. When combined with the general background seabed lowering (<0.2m but taken as a worst case value here of 0.2m), there could be a change in bed level at any particular point of up to 0.5m.

Under a worst case scenario, it may be that the difference in sea bed level after the translation process is associated with the maximum distance between a crest of a bar and a trough (rather than 'general' background seabed levels), which can be a total distance of up to 0.7m in isolated areas. If the general seabed lowering (up to 0.2m) is superimposed upon this then a value of up to 0.9m is theoretically feasible.

It should be noted that the nature of the bars is such that changes of this maximum 'worst case' potential order will only occur at isolated points, rather than along extensive sections of cable. Furthermore, at present, such features have only been observed between MLWS and just below LAT, where the Direct Pipe is actually buried several metres below the present day seabed (the actual distance varies along this length due to the arc of the Direct Pipe). To date, these features have not been observed further offshore (including at the Direct Pipe Final Exit Point), where the seabed has been categorised as flat and featureless.

Nonetheless, if these worst case conditions were to combine in this manner <u>and</u> if they did so at the location of the Direct Pipe Final Exit Point, then up to 0.9m lowering would result in 0.1m of residual sediment cover above the top of the Direct Pipe.

Given the findings of the above assessments, it is deemed that under reasonably expected conditions the proposed minimum burial depths of the Direct Pipe Final Exit Point (1.0m), the Polypipe (1.3m) and cable (progressively deepening to 1.5 - 1.7m along approximately 20m, with cable burial remaining at 1.5 - 1.7m thereafter) represent suitable burial depths to maintain seabed coverage and protection within the active beach profile of the seabed for the 25 year operation life of the Development.

Even under an unlikely scenario of a worst case combination of events occurring and such occurrences being directly experienced at the shallowest point of burial (namely the Direct

Pipe Final Exit Point) it is envisaged that burial will still be attained. However, acknowledging the low risk that exists of re-exposure at this single point location, the mitigation stated in the CaP will be adopted. This will involve cutting the exposed section of Direct Pipe back to re-establish a desired depth of burial and re-burying the cable using the same post-lay techniques that would have been used for the initial installation process. This approach is possible because the Direct Pipe is only needed as an installation conduit for the cable installation and serves no function during the operation and maintenance phase.

6 Other Cable Burial Depth Considerations

In addition to the requirement to ensure the cable remains buried between the Direct Pipe Final Exit Point and the depth of closure of the active beach profile, it is also important to ensure that the Direct Pipe itself remains buried between the Pipe Thruster Pit (Pipe Entry Point) and its Final Exit Point within the upper levels of the active beach profile.

Given that over much of its length, the Direct Pipe is bored to depths of around 7m below the seabed and only grades out shallower at the onshore Pipe Thruster Pit entry point and the offshore Final Exit Point, the principal concern in this respect is not the anticipated vertical lowering of the seabed (as either storm-driven or longer term changes), but rather the depth of the burial landward of the existing shingle berm when future projected landward recession is taken into consideration.

Figure 7 shows detail of the 50m landward translation of the active profile in the vicinity of the shingle berm. For purposes of geographical referencing, this figure also shows the location of the Pipe Thruster Pit, although this would only be present as temporary works during construction. Note that the permanent infrastructure (namely the Transition Joint Bay) is located some 36m landward of the Pipe Thruster Pit along EC1 and some 125m landward of the Pipe Thruster Pit along EC2.

Due to the projected (conservative) landward recession of the current active beach profile, the minimum depth of sediment cover on EC1 at any single point between the present and projected future berm crest reduces to a residual 4.1m for cable EC1. For cable EC2, the corresponding minimum depth of sediment cover reduces to a residual 4.7m at any single point on the profile.

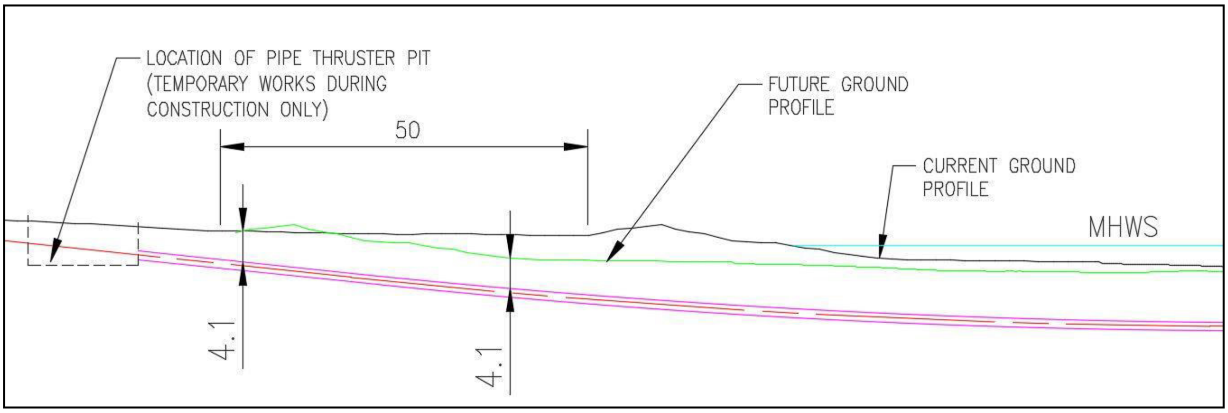

Figure 7 – Schematic Representation of Landward Translation (50m) of the Shingle Berm over 25 years

The above assessment demonstrates that the Direct Pipe bore profile is designed sufficiently to withstand any vertical lowering of the seabed during storms or longer term trends, but can also accommodate the longer term landward transgression of the profile in the vicinity of the shingle berm and landwards to the location of the Pipe Thruster Pits, which will be present as temporary works during construction only.

7 Conclusion

This Near-Shore Erosion Risk Assessment (NSERA) sets out a review of the available site data and coastal assessments to provide supporting evidence to the Cable Plan (CaP) for the Offshore Transmission Works (OfTW), specifically in relation to risks to the near-shore sections of the offshore transmission cables and infrastructure from coastal erosion. This has included an assessment of erosion due to both vertical (downward) lowering of the seabed and horizontal (landward) recession of the shore.

In relation to the Marine Licence Condition 3.2.3.8 point 1, it has been demonstrated that the seaward Direct Pipe Final Exit Point will be located as far offshore as practicable towards the depth of closure. The proposed design considers the physical limitations imposed by the Direct Pipe and the subsequent cable pull-in installation limitations, as well as consideration of landward recession rates to enable a suitable set distance for the entry point of the Direct Pipe.

In relation to the Marine Licence Condition 3.2.3.8 point 2, it has been demonstrated that the designed landward entry point of the HDD (Direct Pipe Entry point at the Pipe Thruster Pit) will be located sufficiently onshore of the high-water mark, and set back to a suitable distance to accommodate a conservative landward projection of coastal recession over the 25 year operation life of the Development.

In relation to the Marine Licence Condition 3.2.3.8 point 3, it has been demonstrated that the offshore cables are assessed to remain suitably buried between the seaward Direct Pipe Final Exit Point and the depth of closure (the depth of water beyond which annually significant wave events will cease to contribute to beach sediment supply and morphological processes) over the 25 year operation life of the Development. In the unlikely event of cable re-exposure due to erosion, appropriate mitigation has been proposed with the cut back of the Direct Pipe and re-burial of the cable to suitable depths.

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Technical Appendix A: BOWL & SNH Discussions Regarding Erosion Projections

A1 Background

The Scottish Government (SG) is currently undertaking a *National Coastal Change Assessment* for Scotland (Rennie *et al.* 2016). Between August and October 2016, Scottish Natural Heritage (SNH) provided BOWL with interim outputs from this study which were intended to inform BOWL about past and projected future projections of coastal change.

This information enabled BOWL to re-assess its previous engineering considerations of suitable set back distance, based upon both the new information and BOWL's risk appetite through the 25 year lifetime of the project.

The dialogue between BOWL and SNH on the topic of erosion projections took place on several occasions and concluded with a telephone meeting between Dr. Alistair Rennie (SNH) and Dr. Nick Cooper (technical adviser to BOWL) on 4th October 2016.

Both parties agreed that it would be useful to present the development of the thinking on the issue in a sequential manner, reflecting the evolving nature of the outputs. However, it was felt most appropriate that this information would be best presented in this manner in the form of a Technical Appendix to any submitted reports, with a brief synopsis of the approach and conclusion summarised in the main report.

This Technical Appendix presents the dialogue on the erosion projections in a sequential manner and each sub-section concludes with a re-appraisal of the set back distances used in BOWL's design of the infrastructure at the cable landfall based upon the information presented at that stage.

A2 National Coastal Change Assessment for Scotland (first outputs)

In August 2016, SNH provided an image to BOWL showing that project's interim historic erosion assessments from its *National Coastal Change Assessment* superimposed upon an aerial image of the cable landfall area taken from the onshore planning application (reproduced here as Figure A1). It is noticeable that SNH very usefully broke down the historic rates of change in position of Mean High Water Springs (MHWS) under different epochs, as shown in Table A1, rather than solely providing a long term average between the earliest and most recent dates.

Table A1 – SNH's Assessment of Historic Erosion Rates of MHWS at Landfall Location

Start Date	End Date	Retreat distance (m)	Average annual rate (m/yr)
1903 (historic maps)	1990 (OS map)	37	0.43
1990 (OS map)	2003 (Lidar)	20	1.54

2003 (Lidar)	2014 (aerial photo)	9.7	0.88
Additional calculations			
1990 (OS map)	2014 (aerial photo)	29.7	1.24 most recent 25 year period
1903 (historic maps)	2014 (aerial photo)	66.7	0.60 long term (century scale) average

*** Note that all data have spatial errors (see figure for details)**

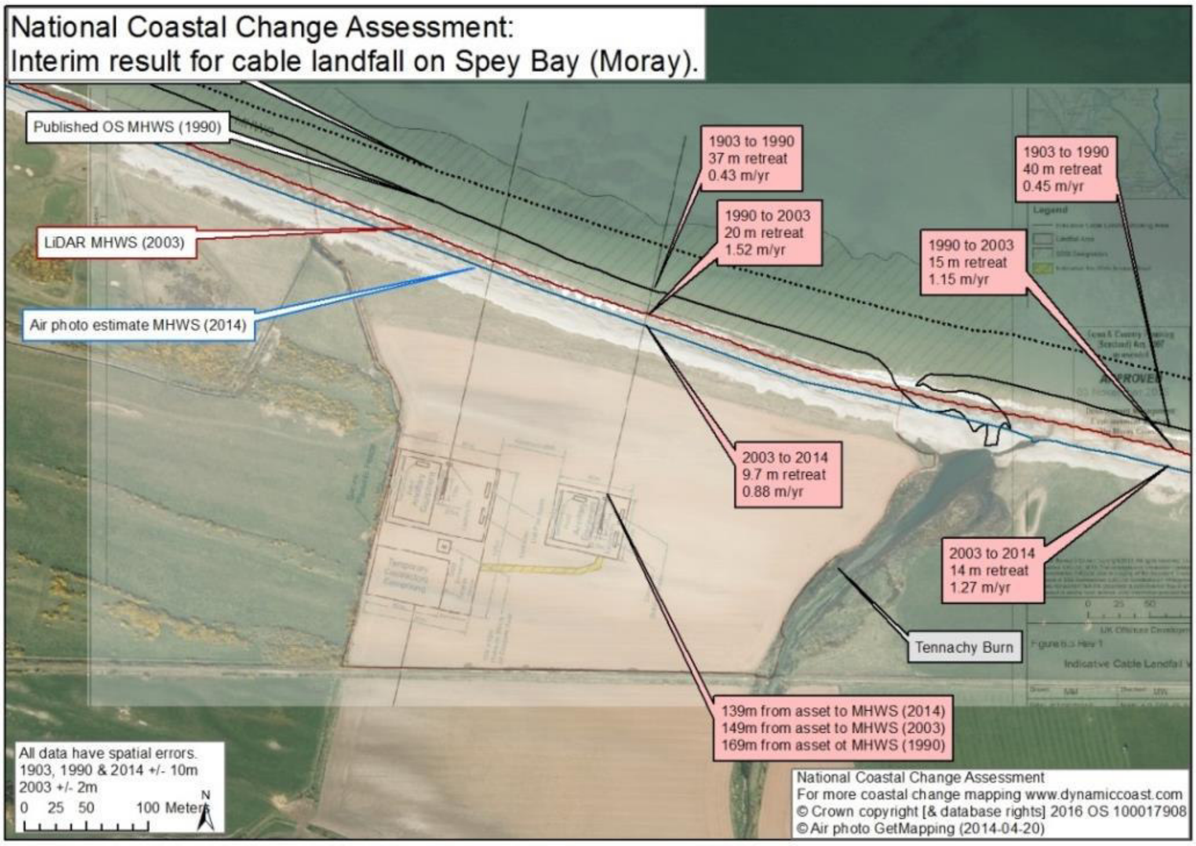

Figure A1 – A reproduction of SNH's First Assessment of Historic Erosion Rates of MHWS at the Landfall Location

In addition to the data provided by SNH, the long term recession rate of MHWS over the period 1903 to 2014 has also been calculated and presented in this table, together with a rate for the most recent quarter-century period, namely 1990 to 2014. The latter may be the most representative of the likely rates over the next quarter of a century, since the sea level, sediment supply and ground conditions will be most similar to those experienced during that period.

Whilst noting the inherent uncertainties and inaccuracies in the analysis, the resulting long term average value of 0.60m/year between 1903 and 2014 is highly consistent with a value of 0.64m/year determined form analysis of historic OS maps and bathymetric charts during assessments in relation to the Shetland HVDC Link project (ABPmer, 2009), which in formed the BOWL Environmental Impact Assessment. It is also broadly comparable to slightly higher level estimates by Hansom and Black (1994) of 0.74m/year loss between 1960 and 1994 at Spey Bay Golf Club.

Even using the average rates from the most recent quarter century, which are higher than the long term average by a factor of approximately 2, the erosion of MHWS would be 31m over the next 25 years, with a sufficient remaining 'buffer' of over 30m between the landfall works (set back 50m from where the landward limit of shingle washover fans meets the vegetation edge of the hinterland in the present day) and the projected position of MHWS in 25 years' time, taking a width between this vegetation edge and MHWS of approx. 10m as a minimum (conservative) value.

Using the maximum average annual erosion rate calculated by SNH for any one time period, namely 1.54m/year between 1990 and 2003, the recession of MHWS over 25 years would be 38.5m, with a remaining buffer of over 20m between the landfall works (set back 50m from where the landward limit of shingle washover fans meets the vegetation edge of the hinterland in the present day) and the projected position of MHWS, taking a similar width between this vegetation edge and MHWS as above.

Based upon the above analysis, a landward set back distance of 50m for the landfall works is deemed suitably conservative by BOWL for the 25 year operational life of the Beatrice OWF even under the worst case recession over the short-term presented in Table 1 of 1.54m/year.

A3 National Coastal Change Assessment for Scotland (second outputs)

At a meeting in early September 2016, SNH presented to BOWL further outputs from its *National Coastal Change Assessment* (reproduced as Figure A2). In providing these outputs, SNH was clear to point out that it was provided as information and that BOWL should:

1. use this information to inform its own assessments of suitable set back distance, based on BOWL's risk appetite through the 25 years lifetime of the project; and
2. note that whilst the measurements imply precision, there is considerable uncertainty in future assessments and therefore all values are presented to aid discussions and should not be considered definitely as predictions.

BOWL acknowledges both of these points and accepts that the outputs are 'projections' to aid assessment on future erosion and help explore uncertainties and are not definitive predictions.

The historic changes in MHWS show an annual recession rate of ~0.3 – 0.4m/yr in the vicinity of the cables between 1905 and 1990, increasing measurably to ~1.5 – 1.8m/yr between 1990 and 2003. These rates are broadly consistent with the interim results presented in Table 1, although the upper envelope is slightly greater in magnitude. It should be noted that the 2003 data are derived from Lidar survey and such technology from over a decade ago was known to have lower accuracies than contemporary Lidar systems.

It is also noticeable that whilst the interim results updated the analysis to 2014, using aerial photography, the further analysis omits these data and bases its projections on the "worst case" rates from 1990 – 2003. Given potential concerns over the accuracy of Lidar data from 2003, it could be argued that the (lower) rates observed between 1990 and 2014 would be more representative of the likely future projections over the next quarter-century since they perhaps use more reliable datasets and they represent well the recent-past, contemporary and near-future sediment supply, ground conditions and rates of sea level rise.

It is also noted that data is presented to show up to 10m landward movement in the edge of vegetation on the hinterland, which marks the landward limit of the washover fans from the shingle ridge, between 2009 and 2014. This is then averaged to suggest an average annual recession rate of up to 2m/year. Whilst acknowledging that the datasets do show such a change in places, there are two points worth noting:

1. The dataset is short term and would be expected to capture morphological changes due to storm-driven wash-over processes. The occurrence, magnitude and sequencing of storms over the period under consideration may play an important part in the observed changes and these may not necessarily be representative of storm-driven changes within a longer period of time, nor of longer term rollback of the ridge. For example, the winters of 2010 and 2013 were particularly noted for the severity of storms which affected large parts of the eastern UK coast.
2. There are some locations where there was no measurable change in position of the vegetation edge.

Notwithstanding these matters, BOWL acknowledges that the long term prognosis is for the shingle barrier to transgress landwards over the lifetime of the Development. Due to this, the projections provided by SNH of future changes in MHWS (based on extrapolation of historic rates between 1990 and 2003) are extremely useful to inform considerations of set back distances for landfall infrastructure. Recognising the aforementioned limitations and uncertainties of the data, such projections are inherently conservative.

Results show that if past rates from between 1990 and 2003 are projected to the years 2025 and 2050, the landfall infrastructure is unaffected. In fact, at these rates the infrastructure would remain unaffected for between 91 years (EC1) and 99 years (EC2).

Using the same approach, if the erosion rate was lower, at say the 1.24m/year shown by the interim SNH outputs between 2003 and 2014, the infrastructure would remain unaffected for between 132 years (EC1) and 119 years (EC2).

SNH also presented a sensitivity analysis to aid discussions, whereby the past rates from between 1990 and 2003 were increased in the future projections by factors of 25% and 50%. This showed that under these scenarios the projected '2050 erosion line' would actually be reached by 2041 (25 years) and 2034 (18 years) respectively.

A back-calculation approach along the same lines as before shows that under a 25% increase in past rates from between 1990 and 2003, the infrastructure would remain unaffected for between 73 years (EC1) and 79 years (EC2). Even with a 50% increase in past rates from between 1990 and 2003, the infrastructure would remain unaffected for between 61 years (EC1) and 66 years (EC2).

BOWL concludes therefore that even under the highest observed past historic rates (with all the inaccuracies and uncertainties noted) and with a highly conservative approach of a 50% increase in these, the infrastructure would remain unaffected through its operational lifetime of 25 years.

It is envisaged that sea level rise changes over the next 25 years would only have a minor influence on coastal rollback of the shingle ridge and therefore remains confident in the 50m set back (measured from where the landward limit of shingle washover fans meets the vegetation edge of the hinterland in the present day) used in its design.

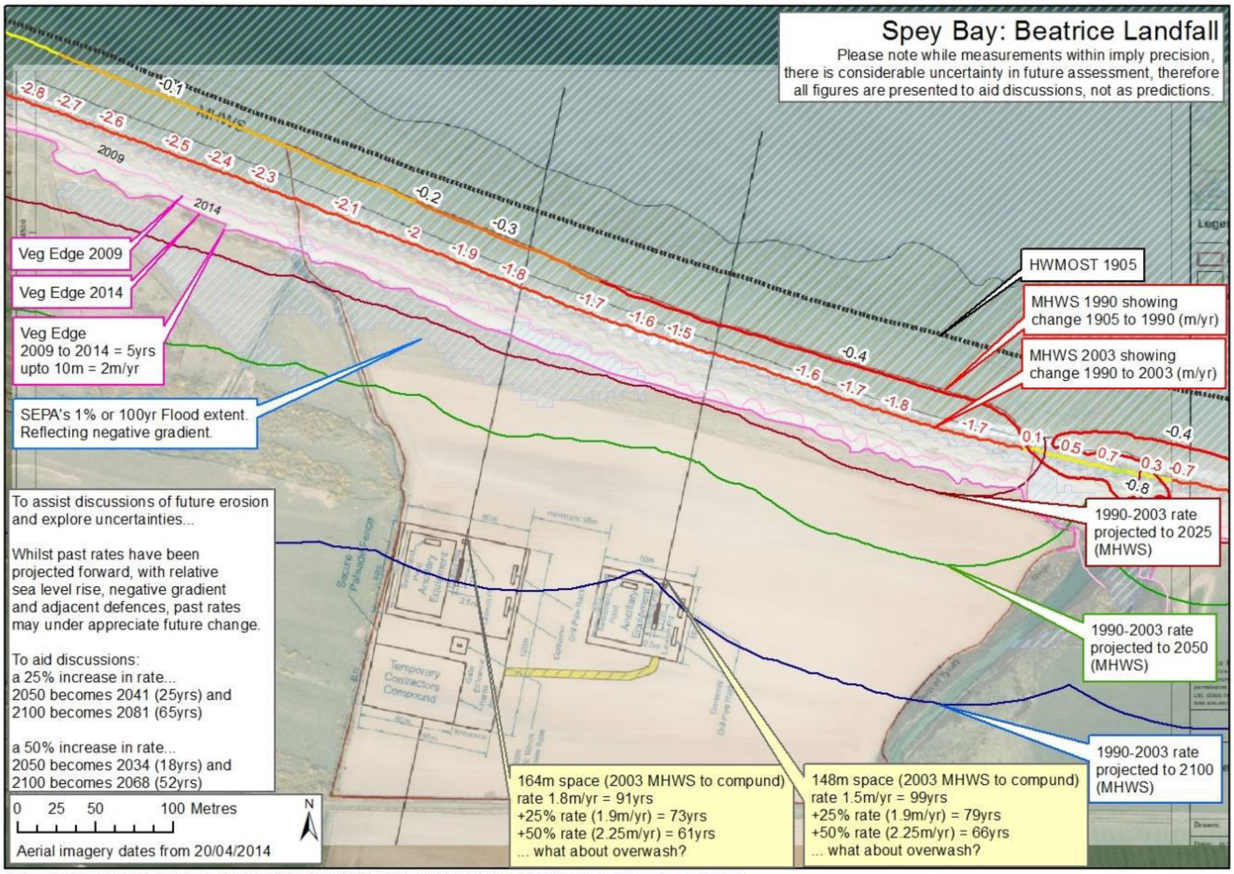

Figure A2 – A reproduction of SNH's Second Assessment of Historic Erosion Rates of MHWS' at the Landfall Location

A4 National Coastal Change Assessment for Scotland (third outputs)

Following BOWLs interpretation of the first and second outputs from the *National Coastal*

Change Assessment, SNH provided a third set of outputs on 12th September 2016 (reproduced as Figure A3). This updated the second outputs with beach topographic survey data provided to SNH by BOWL from 2016.

SNH's analysis showed that between its 2003 survey (using Lidar) and BOWL's 2016 survey (topographic) some 11.6m and 8.4m retreat of MHWS was recorded at EC1 and EC2 respectively. These erosion distances equate to average annual rates over the period 2003 to 2016 of 0.9m/year and 0.6m/year respectively. This shows that the most recent observed changes are within the bounds of the previous conservative assessments and, in fact, are nearer to the long term average value of 0.60m/year observed between 1903 and 2014 than some of the higher values considered in the sensitivity tests described previously.

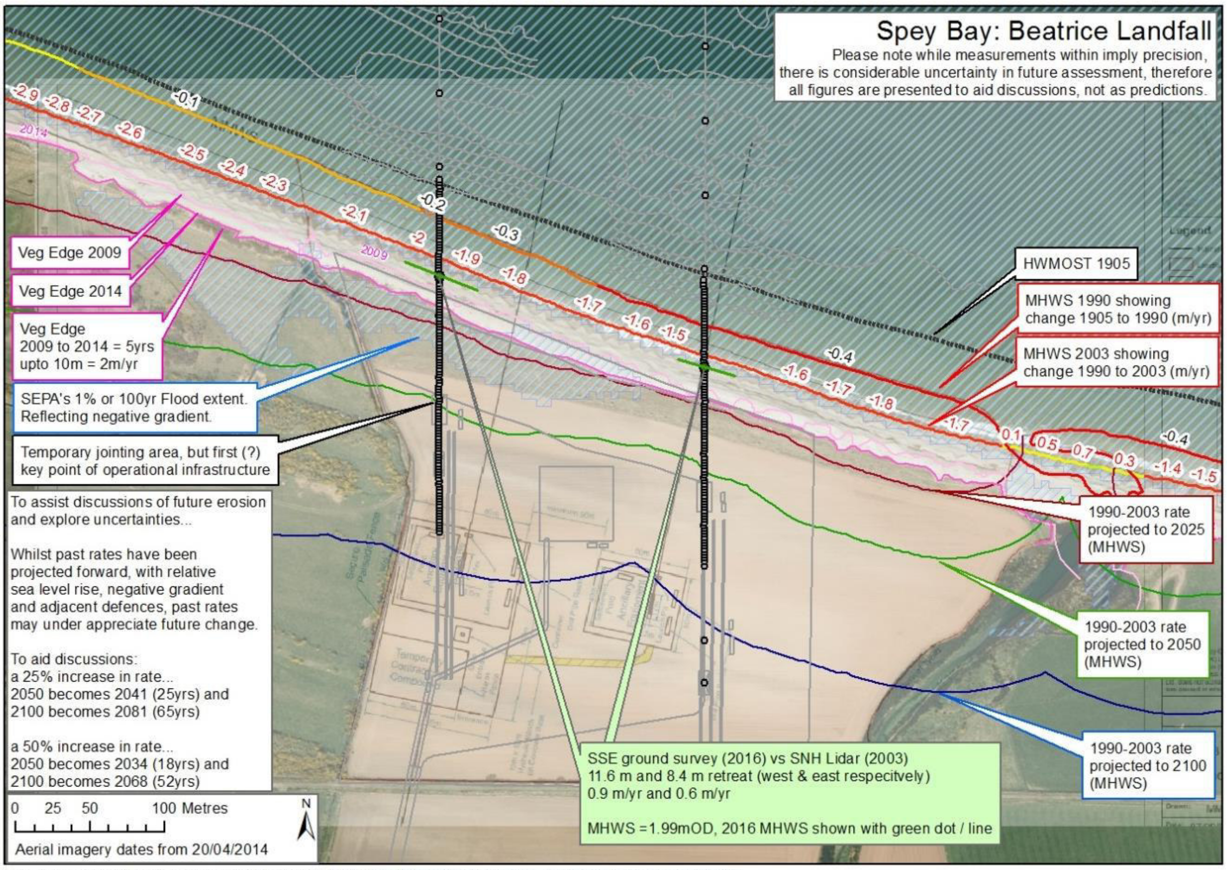

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Figure A3 – A reproduction of SNH's Third Assessment of Historic Erosion Rates of MHWS' at the Landfall Location

Figure A3 does infer that the projected erosion of MHWS by 2050 will begin to impinge on some areas of 'operational infrastructure' at the landfall, but these locations are actually where Pipe Thruster Pits will temporary be sunk during the construction phase to enable cable laying rather than being more permanent operational infrastructure (such as Transition Joint Bays). Assessment of suitable depths for these Pipe Thruster Pits and the associated burial depths for the export transmission cable at its landfall has taken into consideration the landward transgression of the cross-shore profile, assuming it maintains it present morphology (form, function and level), to ensure is remains buried over the 25 year operational life.

Given that these most recent data between 2003 and 2016 show annual average erosion rates that are well within the conservative estimates used in determining a suitable set back distance, BOWL remains confident that a 50m set back (measured from where the landward limit of shingle washover fans meets the vegetation edge of the hinterland in the present day) of the landfall infrastructure is a conservative engineering decision.

Furthermore, if one was to consider the observed annual average erosion over the past 26 years (1990 to 2016) as a valid indicator of the likely projected rates over the next 25 years, the rate would be 1.35m/year at EC1 (1.8m/year between 1990 and 2003 and 0.9m/year between 2003 and 2016) and 1.05m/year at EC2 (1.5m/year between 1990 and 2003 and 0.6m/year between 2003 and 2016). Again, under this sensitivity test the 50m set back distance (measured from where the landward limit of shingle washover fans meets the vegetation edge of the hinterland in the present day) remains conservative.

A5 National Coastal Change Assessment for Scotland (fourth outputs)

Dr. Alistair Rennie (SNH) and Dr. Nick Cooper (technical adviser to BOWL) held a telephone meeting on 4th October 2016 to discuss the methods used to assess past and projected future coastal recession at the landfall location in producing the SNH outputs. There was common understanding on the science and discussion particularly focused on the associated inherent uncertainties in mapping erosion rates from historic datasets given the mapping scales used.

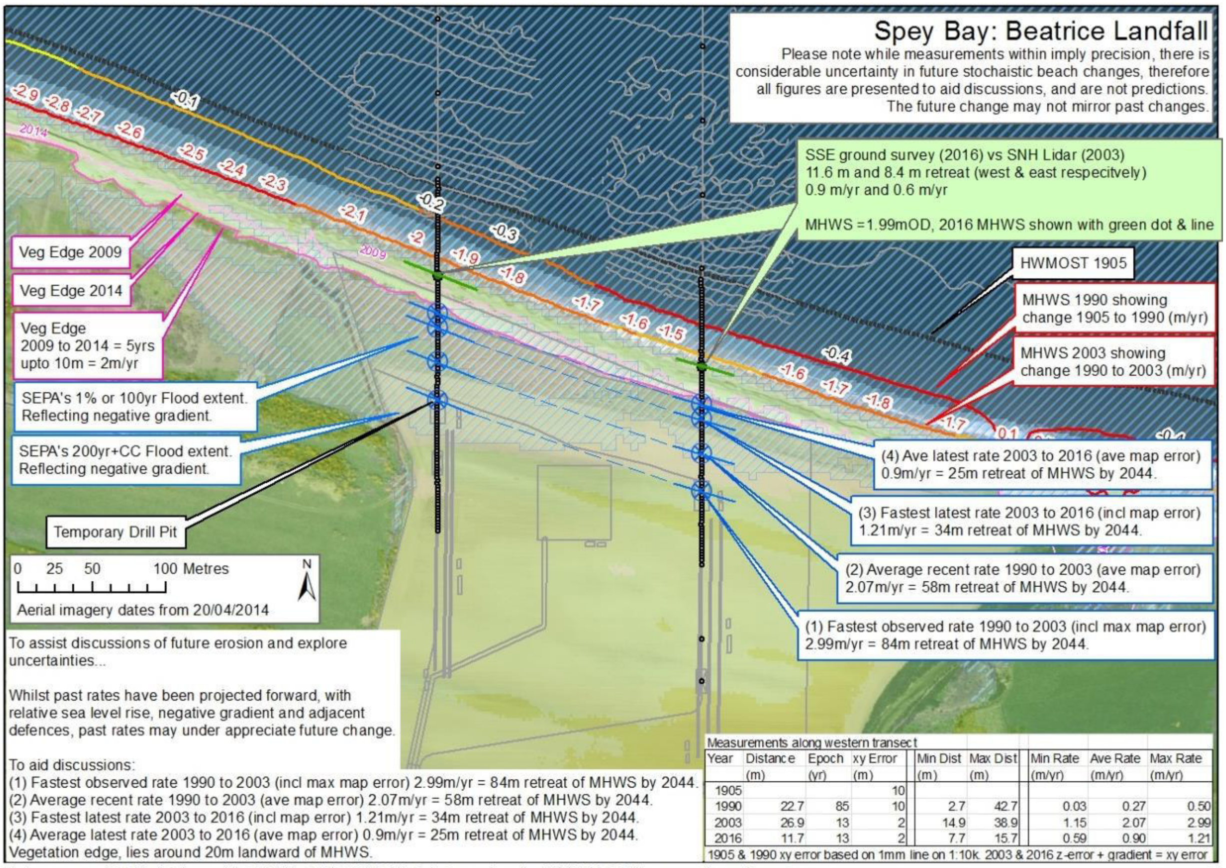
Using the erosion rates observed at the western cable (which are higher than those at the eastern cable), Dr. Rennie presented an envelope of potential erosion rates around the average (or 'central') estimates previously provided. This envelope was based on maximum negative error and maximum positive error in mapping. Negative error would result in lower than central estimates, and positive error would result in greater than central estimates.

To explore the sensitivities of the potential positive errors, an updated figure was produced (reproduced as Figure A4). This took a base date for construction of 2019, and considered erosion projections after the planned operational life of 25 years from this date (i.e. by 2044) under four erosion rate scenarios at the western cable, namely:

- Average erosion rate 2003 to 2016 (central estimate) = 0.9 m/year
- Above plus maximum positive error in mapping = 1.21 m/year

- Average erosion rate 1990 to 2003 (central estimate) = 2.07 m/year*
- Above plus maximum positive error in mapping = 2.99 m/year

* This is higher than the rate presented by SNH in the project's second outputs for the western cable.



Year	Distance (m)	Epoch (yr)	xy Error (m)	Min Dist (m)	Max Dist (m)	Min Rate (m/yr)	Ave Rate (m/yr)	Max Rate (m/yr)
1905			10					
1990	22.7	85	10	2.7	42.7	0.03	0.27	0.50
2003	26.9	13	2	14.9	38.9	1.15	2.07	2.99
2016	11.7	13	2	7.7	15.7	0.59	0.90	1.21

Figure A4 – A reproduction of SNH's Fourth Assessment of Historic Erosion Rates of MHWS' at the Landfall Location

Based on these outputs, under all but one scenario the infrastructure shown in the figure at the landfall is unaffected by the projected coastal erosion over the 25 year operational life.

The one scenario which does show some impingement on the infrastructure shown in the figure is the one which takes the following:

- Cable location with the highest past erosion rates of the two cables;
- Worst case erosion rate (1990 – 2003) for that location; and
- Worst case maximum positive error.

However, even under this scenario it is only the temporary Pipe Thruster Pits which become affected by erosion by 2044. The permanent infrastructure (such as Transition Joint Bays) remains considerably further landward. Furthermore, the landfall infrastructure has been further refined since the above image was produced and the updated details are provided in Figure 1 of the main NSERA report.

Acknowledging that the cable needs to be buried to a sufficient depth across the hinterland to ensure that it does not become exposed by the coastal erosion, BOWL remains confident in its use of a 50m set back distance (measured from where the landward limit of shingle washover fans meets the vegetation edge of the hinterland in the present day) as used in its engineering design for the permanent landfall works.