moray offshore renewables ltd

Environmental Statement

Technical Appendix 2.1 B - Concept Engineering Study (JP Kenny, 2011)

Telford, Stevenson, MacColl Wind Farms and associated Transmission Infrastructure Environmental Statement

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Report

Experience that Delivers

Prepared for: MORL

Work Package 7 - Concept Report

March / 2011

APPENDIX 2.1 B

Experience that Delivers

Client:

MORL

Project Name:

CONCEPT ENGINEERING STUDY

Document Title:

WORK PACKAGE 7 - CONCEPT REPORT

Document Number:	Document Type:
06-3336-01-G-3-006	Report
Client Document Number:	**Number of pages:**
n/a	56

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01	11/03/11	ISSUED FOR COMMENT	DD	CS/TOS	NJR		
Rev	Date	Reason for Issue	Prep. By	Chk. By	App. By	QA	Client Approval

2.1B2

COMMENTS SHEET		
REVISION	DATE	COMMENTS
01	11/03/11	ISSUED FOR COMMENT

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1.0 INTRODUCTION

1.1 Background

In January 2010, EDP Renováveis (EDPR) and SeaEnergy Renewables Limited (SERL) were awarded a Zone Development Agreement by The Crown Estate to develop wind farm sites within the Moray Firth zone, one of the nine zones comprised in Round 3 of the UK offshore wind competitive leases. EDPR and SERL have formed Moray Offshore Renewables Limited (MORL) to develop 1.5GW of offshore wind by 2020 within the zone.

The site is located 12nm (22.2km) from the coast on the Smith Bank in the Moray Firth and covers an area of 522.15km². Two development areas within the zone have been identified by MORL: the Eastern Development Area and the Western Development Area. The Eastern Development Area has fewer constraints to offshore wind development, and therefore MORL has proposed developing this section first. The future development of the Western Development Area will be the subject of a separate Environmental Impact Assessment (EIA), held at a later date.

MORL has stated its commitment to the delivery of the Target Zone Capacity (TZC) of 1.5GW within Zone 1 by 2020. It is proposed that the offshore capacity of 1.5GW will be installed in two phases with the first phase of 1,140MW connecting in 2018, and the second phase of 360MW connecting in 2020.

1.2 Objectives

The objective of this desk-top study is to develop, evaluate, compare, and rank cable route options from the offshore substation to the onshore connection point at Peterhead, taking into consideration all aspects of routing issues including seabed and ground conditions, engineering constraints, third party interactions, environmental and physical constraints, and restricted zones. Additional ranking criteria for the routes comprise socio-economic considerations, risk, and through-life cost. Up to four routes will be recommended and ranked, each comprising offshore and onshore corridors, and proposed locations for the landfall and the onshore substations.

This report accounts for work related to Stage 1 of Work Package 7 – Cable Routing Concept Engineering. In this initial phase of the study, the following objectives were followed:

- Generation of a comprehensive GIS geo-database and associated constraint maps;
- Study of the bathymetry and slopes;
- Appraisal of the proposed landfalls;
- Development of cable routes options through a comprehensive desk-top route selection process.

A cable routing assessment to examine the proposed options in detail, and compare and rank them will be carried out at Stage 2 of this study.

This report also presents the Stage 1 studies of cable installation methodologies, construction vessel types, and decommissioning requirements, which are part of Work Package 9.

1.3 Definitions and Abbreviations

For the purposes of this document, the following definitions, abbreviations and acronyms have been used:

BGS	British Geological Survey
BOWL	Beatrice Offshore Winds Limited
CLV	Cable Lay Vessel
CPT	Cone Penetration Testing
EDPR	EDP Renováveis
FEED	Front End Engineering Design
FPSO	Floating Production Storage and Offloading
HDD	Horizontal Directional Drilling
KP	Kilometre Post
MBL	Minimum Breaking Load
MOD	Ministry Of Defence
MORL	Moray Offshore Renewables Ltd
MPSV	Multi-Purpose Supply Vessel
NNR	National Nature Reserve
OSP	Offshore Substation Platform
ROV	Remotely Operated Vehicle
ROW	Right Of Way
SAC	Special Areas of Conservation
SERL	SeaEnergy Renewables Limited
SHETL	Scottish Hydro Electric Transmission
SPA	Special Protection Areas
SSE	Scottish and Southern Energy
SSSI	Site of Special Scientific Interest
UKHO	United Kingdom Hydrographic Office
UTM	Universal Transverse Mercator
WGS	World Geodetic System
WTG	Wind Turbine Generator

2.0 SUMMARY AND CONCLUSIONS

2.1 Stage 1 Routes Summary

Four routes are proposed at this stage. They are designated by the name of their landfall. The route coordinates are listed in Table 2 below.

Table 1 Stage 1 Route lengths

Sandend	Inverboyndie	Fraserburgh Beach	Rattray South	Rattray North
Offshore length: 53.0km Onshore length: 62.9km	Offshore length: 57.1km Onshore length: 53.2km	Offshore length: 80.7km Onshore length: 28.3km	Offshore length: 103.0km Onshore length: 15.5km	Offshore length: 100.3km Onshore length: 15.5km

Table 2 Stage 1 Route coordinates

Sandend		Inverboyndie		Fraserburgh Beach		Rattray South		Rattray North	
Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing
Offshore									
515008.2	6393428	526404.3	6392135	559591.5	6393839	569697.8	6383891	569697.8	6383891
515465.4	6393912	526721.5	6393512	560819.4	6394988	573112.5	6384911	573112.5	6384911
515574.6	6394281	527245.1	6398216	561037.3	6396128	574176.1	6385868	574176.1	6385868
516804.7	6402523	526543.9	6412860	560417.0	6397637	574373.6	6387266	574373.6	6387266
515262.9	6424622	517360.8	6432077	558120.4	6399196	571903.6	6394891	567685.8	6407946
513111.5	6438952	513084.3	6438998	554516.1	6399196	570145.7	6396702	565874.3	6412030
510325.0	6445321	510351.2	6445247	550777.7	6398609	567545.7	6398157	563239.5	6413561
				546083.8	6398039	558120.4	6399196	553727.4	6415665
				541037.8	6398575	554516.1	6399196	517360.8	6432077
				536892.1	6402122	550777.7	6398609	513123.8	6438949
				534510.8	6407678	546083.8	6398039	510351.2	6445272
				529549.9	6415814	541037.8	6398575		
						536892.1	6402122		
						534510.8	6407678		
						529549.9	6415814		
						517360.8	6432077		
						513123.8	6438949		
						510351.2	6445272		
Onshore									
Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing
515008.2	6393428	526404.3	6392135	559591.5	6393839	569697.8	6383891	569697.8	6383891
515532.2	6392886	526740.8	6392021	559667.0	6393305	568178.6	6382449	568178.6	6382449

Sandend		Inverboyndie		Fraserburgh Beach		Rattray South		Rattray North	
Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing
515555.8	6392306	527104.6	6391469	560431.0	6392294	568268.3	6381183	568268.3	6381183
516432.2	6392055	527414.5	6390549	560218.9	6391391	568593.8	6380180	568593.8	6380180
517372.7	6391470	527067.2	6389924	560298.4	6390324	568858.8	6377656	568858.8	6377656
519475.0	6391042	527228.8	6388857	560632.5	6387276	569087.0	6376980	569087.0	6376980
520370.0	6389862	527703.4	6387828	560655.3	6385421	568928.3	6376605	568928.3	6376605
521054.2	6389668	528298.1	6387332	561070.8	6381486	568829.8	6374699	568829.8	6374699
523439.9	6389455	529233.1	6386142	561602.1	6380507	568748.8	6373405	568748.8	6373405
525869.8	6388030	531085.3	6385142	562096.3	6379554	568748.8	6373405	568748.8	6373405
526777.1	6387587	531552.0	6384678	563643.2	6378122	569775.1	6372984	569775.1	6372984
528298.1	6387332	533819.3	6383937	564707.1	6377454	570420.4	6372432	570420.4	6372432
529233.1	6386142	535434.7	6383258	565963.4	6376419	570839.5	6371570	570839.5	6371570
531085.3	6385142	535773.7	6383436	566215.5	6375583	571763.7	6371089	571763.7	6371089
531552.0	6384678	537009.1	6383321	568391.8	6373551	571972.3	6371104	571972.3	6371104
533819.3	6383937	541944.9	6380493	569775.1	6372984				
535434.7	6383258	543322.3	6379951	570420.4	6372432				
535773.7	6383436	545682.2	6378333	570839.5	6371570				
537009.1	6383321	547480.0	6377839	571763.7	6371089				
541944.9	6380493	548622.5	6377349	571972.3	6371104				
543322.3	6379951	550549.0	6376834	559591.5	6393839				
545682.2	6378333	551809.7	6376759						
547480.0	6377839	554535.0	6375998						
548622.5	6377349	555760.4	6375811						
550549.0	6376834	560012.5	6374576						
551809.7	6376759	561302.3	6374421						
554535.0	6375998	563523.1	6373596						
555760.4	6375811	568807.4	6371929						
560012.5	6374576	570496.9	6371489						
561302.3	6374421	571352.1	6371058						
563523.1	6373596	571972.3	6371104						
568807.4	6371929	526404.3	6392135						
570496.9	6371489								
571352.1	6371058								
571972.3	6371104								

2.2 Conclusions

Stage 1 of the routing engineering study has been completed. The GIS geo-database and associated constraint maps have been generated and used to conduct the desk-top route selection process. Five offshore and four onshore route options have been developed on the basis of four landfall location which were chosen after a comprehensive landfall review.

Stage 2 of this study will examine the Stage 1 routing options in detail, and compare and rank them.

3.0 DATA

3.1 General

The principal source of information used for this concept routing study is the chart data listed in Section 3.2 below. All data was compiled into a GIS database used for preliminary routing and then Multi-Criteria Optimisation.

The information compiled by METOC in the Export Cable Route Feasibility Study (Ref. 1) was used to gain a better understanding of the routing constraints shown in the charts, and as a basis for the initial screening of routing options.

The information gathered during landfall site visits on 28th February 2011 is included in this report and clearly highlighted.

3.2 Data sources

The following datasets provided by MORL have been used in this concept routing study:

- SeaZone data:
  - Environmental data (e.g. protected areas, fauna & flora, wrecks, oil & gas infrastructures, cables and pipes, aviation, geology, navigation, tides and currents);
  - Gridded bathymetry data;
  - Chartered basemap;
- RYA data – yachting routes;
- UKHO detailed bathymetry data;
- BGS data – seabed sediment and bathymetry (large area covering the all Moray Firth and beyond);
- Technical data: MORL site boundary, eastern development area, wind farm boundaries (eastern dev area), Beatrice Demonstrator turbines, Beatrice Offshore Wind Limited site boundary, Moray Firth ports & harbours.

A detailed list of the data layers included in the SeaZone data is presented in Ref. 1.

Due to its increased resolution, the 'UKHO detailed bathymetry data' was used in preference to the 'SeaZone gridded bathymetry data'.

Additionally, the following data sources were used:

- METOC Export Cable Route Feasibility Study (Ref. 1);
- Google aerial imagery;
- Bing aerial imagery;
- Site visit of preferred landfall locations as per initial screening.

3.3 Grid and Coordinate System

The internal project GIS database was developed in the Universal Transverse Mercator coordinate system, within zone 30V. The datum system used is WGS 84. Coordinates are given in Eastings and Northings in metres.

3.4 Kilometre Point Definition

Positions along the cable are identified by their Kilometre Point (KP) which is defined as the length of cable measured from the offshore substation towards shore.

3.5 Key Locations

An overview of the Moray Firth Area is shown in Figure 3.1. The offshore connection point of the export cable is the principal wind farm substation. Its location has not been finalised at this stage, but it is assumed for this study to be near the geometric centre of the array (see Figure 3.2), to the East of the East/West zone divide; this assumed location offers significant advantages for inter-array cable routing. It should be noted that the relocation of the offshore substation within the zone would not have a significant impact on the routing options presented here.

The onshore connection point is the Peterhead Power Station owned and operated by Scottish and Southern Energy (SSE), located just south of Peterhead and shown in Figure 3.2.

The coordinates of the export cable endpoints are listed in Table 3.

Table 3 Export cable endpoint locations

Location	Easting [m]	Northing [m]
Offshore substation	510270	6445310
Peterhead connection point	572000	6370750

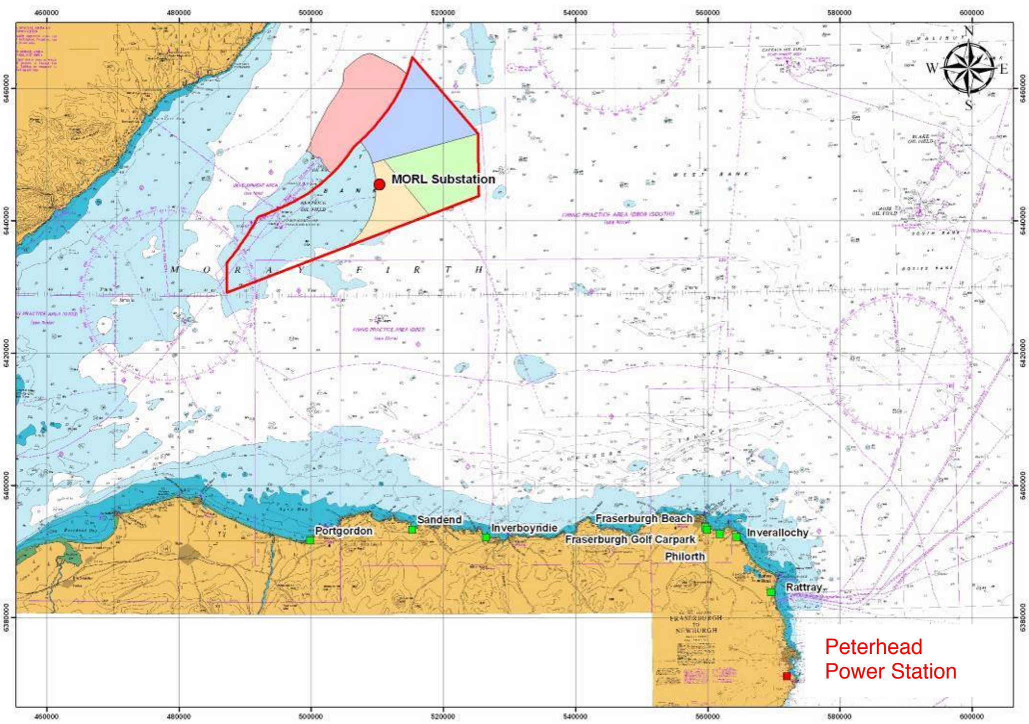

Figure 3.1 Overview of the Moray area.

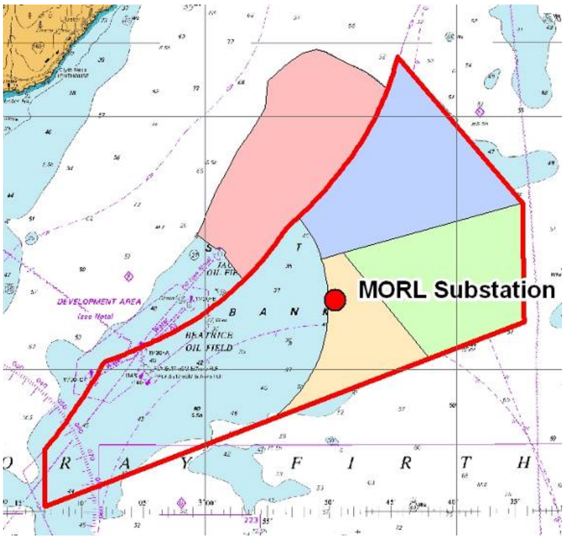

Figure 3.2 Offshore substation (left). Connection point in Peterhead (right).

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4.0 LANDFALL SELECTION

4.1 General

As part of the Export Cable Route Feasibility Study (Ref. 1), METOC identified eleven potential landfall locations on the southern coast of the Moray Firth to link the wind turbine array to the envisaged connection point at Peterhead. Three of those locations were discarded during a workshop with MORL on 19th November 2010. The remaining eight locations were used by METOC as waypoints for the preliminary routes, and evaluated to aid the ranking of said routes.

For completeness, all of the eight landfalls retained during the workshop were initially considered in this study. They are then ranked and the best 3-5 are chosen, taking into account their intrinsic suitability for cable landing, as well as the intention to offer a variety of routing options to retain flexibility in route selection.

The following information was used in this appraisal:

- offshore GIS data (see Section 3.2);
- Google aerial imagery;
- preliminary site visit reports from METOC;
- site visits of five locations organised on 28th February and 01st March.

The locations examined during the site visit were selected by preliminary screening of landfall options.

4.2 Landfall Locations

The eight landfall considered in this study are shown in Figure 4.1 and are listed in Table 4 together with their coordinates. The three locations discarded during the workshop on 19th November 2010 are Lossiemouth Forest, Cullen, and St Fergus.

Table 4 Potential landfall location coordinates

Location	Easting [m]	Northing [m]
Portgordon	499783	6391611
Sandend	515242	6393259
Inverboyndie	526437	6392091
Fraserburgh Beach	559627	6393615
Fraserburgh Golf Car Park	559901	6393279
Philorth	561810	6392579
Inverallochy	564338	6392184
Rattray	569567	6383846

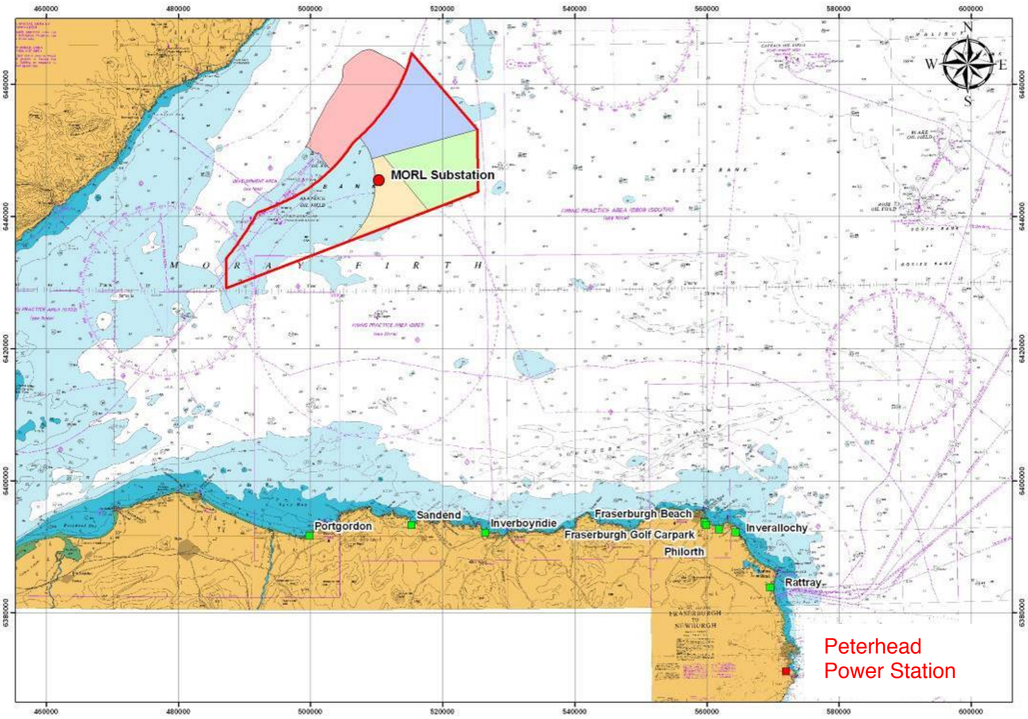

Figure 4.1 Potential landfall locations

4.3 Installation technique

To minimise the environmental impact at the landfall site, it is desirable for the cable to be buried continuously below the existing ground and seabed levels. For this, appraisal of the landfalls has considered three types of proven landfall designs:

- **Open cut trenching**
  This method consists of the excavation of a trench across the landing area, which is then back-filled following installation of the cable. For landfalls, the trench can be divided into two sections; the inshore section, which can be undertaken by land-based equipment; and the offshore section which has to be undertaken by specialist dredging/trenching equipment.

- **Horizontal Directional Drilling (HDD) across the landfall area**
  HDD has become an accepted method of installing cables in areas that cannot be open cut. HDD involves the drilling of a hole at depth through the ground, in which the cable is installed. The conduit is normally installed first and the cable pulled in afterwards. Where possible, the conduit is installed from shore, some distance back from the coastline, to a point nearshore. The maximum length of conduit through which a standard cable can be pulled is typically around 500m, due to the maximum cable allowable pulling force. However, the first section of the cable can be specially manufactured to have a high tensile resistance to allow pulling through a duct in excess of 1000m. This manufacturing technology is proven and has already been used by ABB.

- **Horizontal Directional Drilling (HDD) with a beach jointing pit**
  When full open cut trenching is ruled out and the length of the HDD conduit is effectively limited by the maximum cable pulling load, the installation of a junction pit on the back beach should be considered. The HDD then only extends to the back of the beach above the high water mark or in the intertidal zone. Open cut

trenching is used across the beach from the jointing pit to nearshore, below the low water mark. This reduces the length of cable pull required but also necessitates additional onshore construction works.
Another motivation to use a beach jointing pit is to avoid the de-rating of the offshore cable along its whole length associated with pulling its shore end through the landfall conduit. With this method, it is the onshore cable which is pulled through the conduit and thus requires a rating increase, which comes at a much lower cost than for the offshore cable due to its lower cost per metre and shorter length (typically only a few kilometres per section).

Site conditions determine which are possible, as well as their associated cost and environmental impact. In all those designs, the cable is typically deployed from a CLV offshore and floated / pulled towards shore to be installed in the trench and / or the HDD conduit.

4.4 Landfall Appraisal

Appraisal of the potential landfall sites is centred on the coastal area but also takes into account the offshore approach and the onshore exit path. The offshore / onshore transition point is typically located onshore above the high-water mark, some distance back from the coastline. How far inland this point is located can be influenced by a number of factors such as:

- Beach topography / profile;
- The extent of dunes;
- Submarine and onshore cables Minimum Breaking Load (MBL);
- Third party constraints and protected areas.

Consideration is given to constructability, environmental, and socio-economical factors. Notably, access by construction vehicles (both onshore and offshore) is taken into account for all types of landfall designs. The principal criteria used for landfall appraisal are presented hereafter.

Route length
The length of the offshore route will have a direct impact on the material and installation cost. However, in the present case, the shortest offshore routes come at the cost of longer onshore routes and vice versa. For that reason, consideration has been given to selecting landfall locations offering a wide range of route lengths.

Nearshore trenchability
The feasibility of trenching the export cable depends on the seabed sediment type. Numerous burial methods exist but they are all limited by soil stiffness which can be estimated through knowledge of the sediment type. The whole coast of the region of interest is characterised by a rocky seabed. The thickness of the overlying veneer is therefore critical to the trenchability of the cable. Two to three metres of sediments is typically required for cable burial.

Nearshore water depth
Large cable lay vessels require a minimum draft to operate. At this stage, the criterion under evaluation is the distance from the coast of the 10 m water depth isoline.

Nearshore 3rd party limitations
Access to the landfall site may be limited by the nearshore presence of sensitive or protected areas (e.g. SSSI, flora / fauna conservation sites) or 3rd party activity which may present a risk to the cable (e.g. fishing, yachting routes).

Feasibility of open cut trenching
The prime factors affecting the feasibility of open cut trenching are the coastal topography and the soil type, which have to be suitable for excavation. Access to the beach area is required for construction but is often possible through the cable Right Of Way. The presence of third party activity and / or protected areas in the vicinity of the cable landfall might preclude open cut trenching, or hinder construction activities which typically generate noise, vibrations, and road traffic disturbance, and require working areas for spoil, access, and storage.

Feasibility of HDD across the landfall area
Besides potential environmental and third party limitations regarding HDD (including surface disturbance at the entry and exit points), the main constraint for the installation of an underground conduit across the landfall area is the maximum conduit length which is limited by the maximum pulling load of the cable. Although modern drilling equipment is highly versatile, the soil type must also be examined to evaluate the difficulty of the drilling operation (for example, gravel in a sparse sand matrix is challenging). Onshore, a suitable location must be found for the deployment of the HDD rig.

Feasibility of HDD with a beach jointing pit
Such design is typically adopted when an important natural barrier (e.g. cliffs or large sand dunes) or a sensitive area stands between the beach and the onshore transition point; this can be a hindrance to beach access which is required for construction vehicles. The length of HDD must not exceed the pulling limitations of the cable and the beach must be suitable for open cut trenching from the pit to nearshore. Environmental and third party limitations also have to be taken into account.

Onshore jointing
The onshore jointing location is typically situated at one end of the HDD conduit. Space is required for construction works and vehicle access must be possible.

Onshore exit path
From the jointing pit, the cable must have a clear exit pathway into the onshore cable corridors. The number of obstacle crossings (e.g. waterways, roads, railways, pipelines, cables) should be minimised.

Exposure to the environment
Sheltering from the environment is an advantage to maximise the operating window of construction works. Furthermore, sheltering typically minimises the risk of the cable becoming exposed and coastal erosion.

4.4.1 Preferred Landfall Sites

Based on the criteria discussed above as well as a general appraisal of the particulars of each site, the recommended landfall sites are:

- Sandend;
- Inverboyndie;
- Fraserburgh Beach;
- Rattray.

All four are suitable for cable landfall and for the use of standard installation methods. Together, they provide a wide range of routing options in terms of cable corridors, and offshore / onshore route length proportions.

Overall, Fraserburgh Beach is considered the preferred option as open cut trenching seems feasible, with minimal impact on 3rd parties and the environment. Furthermore, a route passing through this landfall would be one of the shortest, with a greater proportion of offshore cable compared to other selected routes (e.g. through Inverboyndie).

A summary of the salient positive and negative features of each site is given in the following sections. A comparison matrix encompassing more aspects of landfall construction is included in Appendix 1.

It should be noted that the exact landing point of the cable at each potential landfall site may differ from the one presented in the feasibility study (Ref. 1) as only the general cable landing areas were carried forward from that study.

4.4.2 Portgordon

The proposed landfall location is located to the East of Portgordon and shown in Figure 4.2. It is located to the South-West of the development zone, hence causes the offshore and onshore routes to be longer compared to the other proposed landfalls.

Aerial imagery suggests a rocky seabed which makes the landfall approach unsuitable for cable burial. Cable protection would therefore probably require rock dumping or mattressing. Furthermore, the stony reef is a potential Annex I Habitat (pAIH) area which the cable would have to cross.

Good access from the nearby road makes open cut trenching a possibility, depending on the depth of the beach sediment. The installation of a drilled conduit is also a possibility: the envisaged entry and exit point would then be the nearby fields and a position below the low water mark respectively.

Portgordon is the proposed landing site of the SHETL export cable as well as the BOWL export cable. This could potentially create conflicts regarding minimum cable separation requirements, crossings, and timing of construction works.

Figure 4.2 Potential landfall at Portgordon

4.4.3 Sandend

The Sandend landfall is located straight to the South of the wind farm development zone. It is therefore associated with the shortest offshore route. The shape of the bay provides good sheltering for cable installation and protects against coastal erosion. The beach is accessible to construction vehicles off a nearby two-lane road.

Aerial photography indicates that nearshore sand coverage is best on the West side of the bay, although this would have to be confirmed by surveying. High sand dunes are uniformly located at the back of the beach except in front of the caravan park, on the West side of the beach (see Figure 4.3). A site visit confirmed that this would be the most favourable cable landing point at Sandend. Open cut trenching would be possible there, across the beach and though the caravan park, where the onshore jointing pit would be located. From there, the cable route would follow *Seaview Rd*. towards the South. The use of HDD is also possible here to avoid disrupting the caravan park. Starting onshore in the field to the South of the caravan park, the conduit could end on the back beach or offshore below the low water mark to minimise disruption to the ground surface.

Cooperation from the caravan park owners is not expected to be a barrier as construction works could be organised during the low season and the area could benefit from improvements performed after reinstatement.

Overall, this landfall location is recommended due to the ease of installation and expected cooperation from the local owners. However, Sandend is associated with the one of the longest onshore routes, which increases the onshore routing risk.

Figure 4.3 Potential landfall at Sandend

4.4.4 Inverboyndie

The proposed cable landing site at Inverboyndie is also situated straight to the South of the development zone, 11 km to the East of Sandend. The offshore route landing at Inverboyndie is only marginally longer than the one to Sandend and is therefore also one of the shortest. Inverboyndie is the landfall location of the SHEFA-2 telecommunication cable which indicates that the soil conditions are suitable for cable burial. No rock outcrops are visible on the beach or nearshore, as confirmed during the site visit.

Although the area immediately behind the beach is flat, high hills surround the bay, except behind the caravan park. To observe a safe separation from the SHEFA-2 cable and avoid crossing it, the envisaged location for landfall installation is on the Western end of the caravan park, as shown in Figure 4.4. Separation from the SHEFA-2 cable is then in excess of 250 m at all points. Open cut trenching is possible on the beach and in the grazing field that would accommodate the onshore jointing pit. A short HDD is likely to be required to cross the stream behind the caravan park. The HDD would come out on the beach or offshore (with a conduit length of 60 m and 100 m respectively), thus avoiding disruption to the caravan park.

Figure 4.4 Potential landfall at Inverboyndie

4.4.5 Fraserburgh Beach

The proposed location for a landfall at Fraserburgh Beach is situated at the West end of the Fraserburgh bay. The potential cable corridor is delimited by rocky seabed to the West and the Fraserburgh Golf Club to the East. The nearshore approach shows a few rocky outcrops, but appears suitable to cable burial, pending survey of the sediment depth.

The patch of land immediately to the South of the children's playground (see Figure 4.5) is ideally located for installing an onshore jointing pit: open cut trenching to the beach is possible; the site is directly accessible (via *South Harbour Rd*); a stretch of unused grass fields allows routing to the South (between the cemetery and the golf club). Furthermore, the site visit showed that the area is in relatively poor condition due to an apparent lack of maintenance and the presence of decrepit WW2 structures: this is an opportunity to offer improvements to the landowners after reinstatement. The nearby buildings with a view on the patch of land are factories (owned by *Power Jacks Ltd*), hence objection to construction works from the owners is unlikely. Disruption to the beach would only be temporary and alternative walkways could be established to allow crossing of the works area. HDD is again also a possible alternative to open cut trenching to minimise disruption to the beach; the conduit would then extend from onshore to the back beach (50 m) or to offshore (300 m).

Maritime traffic is unlikely to be hindered by cable installation as the offshore route would remain at a distance in excess of 500 m from the mouth of the harbour at its closest point. Approval from the harbour authority would nevertheless by required.

Figure 4.5 Potential landfall at Fraserburgh Beach

4.4.6 Fraserburgh Golf Car Park

This location is situated to the East of the Fraserburgh Beach landfall site. The cable would land on the beach at the top end of the Fraserburgh Golf Club as shown in shown in Figure 4.6. The extensive sand dunes and the golf course behind it make HDD a requirement. The patch of land behind the golf club car park would be suitable for a drilling rig. To keep the conduit length below 500 m, a beach jointing pit would have to be installed. Construction vehicles would access the beach jointing pit from the North along the beach. A minimum drilling depth of 8 to 10 metres would be required to avoid disturbing the golf course.

Although this landfall is technically feasible, the landfall at Fraserburgh Beach is preferred due to its increased simplicity in terms of construction works and 3rd party consents. This landfall was therefore not retained in the list of preferred landfalls. It should be noted, however, that a route going through Fraserburgh Beach would be virtually identical to a route going through Fraserburgh Car Park.

Figure 4.6 Potential landfall at Fraserburgh Golf Car Park

4.4.7 Philorth

A third landfall option was identified by METOC at the eastern end of the bay at Fraserburgh (see Figure 4.7). After landing on the beach, the cable would have to cross high sand dunes and a stream, and be routed through a protected zone. A conduit of important length (400+ m) built by HDD would be necessary. These onshore challenges rule out this location without further consideration, especially compared to other locations much more suitable for landfall construction.

Figure 4.7 Potential landfall at Pilorth

4.4.8 Inverallochy

Aerial imagery indicates that the seabed at circa 250 m from the coast is predominantly rock, suggesting that extra cable protection would be needed. However, cable burial at shore approach (including the intertidal zone) may still be possible, depending on the sediment depth.

Cable installation is only possible through the golf course and would require finding an agreement with the owners which are likely to oppose the construction proposal. Open cut trenching seems to be possible on the beach, through the dunes (only approx. 50m deep), and through the golf course. Alternatively, the use of HDD would minimise disruption to the golf course but the conduit would have to be installed at a minimum depth of 8 to 10 metres depth to avoid disrupting the ground above it. It is envisaged that the drilling rig would be deployed in the patch of land used for sheep grazing behind the golf.

A visit of the site revealed that the properties behind the road at the back of the golf are of high value, which makes resistance of land owners in the area probable.

Although technically feasible, this landfall presents significant land leasing problems and does not have any tangible advantage compared to Fraserburgh beach which is the favoured landfall location in that area of the coast.

Figure 4.8 Potential landfall at Inverallochy

4.4.9 Rattray

Amongst the landfall locations considered in this study, Rattray is the closest to the connection point at Peterhead, and is therefore associated with the shortest onshore route. It is proposed to install the landfall immediately to the North of the swathe of pipelines connecting to the pipeline terminals at St Fergus (see figure Figure 4.9). The sand dunes that would be traversed are not part of the SSSI zone which protects the dune system to the North.

The high (approx. 10 m) and deep (approx. 250 m) sand dunes in that location make open cut trenching difficult although possible as evidenced by the reinstated nearby pipeline ROWs visible via aerial photography. Installation via HDD is preferred here. The length of the conduit would be minimum 300 m with a beach jointing pit on the back beach. Construction vehicles could access the beach via the pipeline terminal; extra care would have to be taken when driving over pipeline ROWs on the beach. Access to the onshore HDD conduit start would be through grazing fields, along the cable ROW.

Trenching on the beach and in the intertidal zone seams feasible but rocky outcrops visible via aerial photography again indicate that it may not be possible to bury the cable continuously in the nearshore area.

A sandy potential Annex I Habitat (pAIH) is located off the coast of Rattray but the presence of numerous pipelines suggests that its crossing would not be a problem.

Figure 4.9 Potential landfall at Rattray

5.0 OFFSHORE ROUTING

5.1 Methodology

At a high level, offshore cable routing is a minimisation exercise to find the shortest route from the offshore substation to the landfall site under constraints dictated by engineering, physical and environmental limitations, and third parties. All constraints are associated with a “weight” and are input into the GIS database. A global weighted constraints map is then created for the Multi-Criteria Evaluation to find the optimum route outside of the no-go areas. Multi-Criteria Evaluation is a process comprising automated tools as well as appraisal by engineers with specialist expertise in different fields (e.g. power cables, cable laying, ploughing, landfall installation).

The constraints effectively define the envelope which will guarantee the long term integrity of the cable as well as its safe installation. The main sets of constraints which have been used in this study are presented in the following sections. Other parameters taken into account by the Multi-Criteria Evaluation are as follows:

- Cable stability;
- Cable protection;
- Cable separation requirements;
- Ability to utilise existing cable lay construction methods;
- Minimisation of seabed pre-lay intervention requirements;
- Minimisation of seabed and cable post-lay intervention requirements;
- Minimisation of the number of cable and pipeline crossings;
- Minimisation of the environmental impact;
- Minimisation of interference of all types.

Following existing cable / pipeline corridors is an option which minimises installation risks and is often preferred by stakeholders as it minimises disturbance to the environment. However, this is not an option here as no existing corridors would suit the requirements of this exercise.

It should be noted that the chosen routes described in Section 7.0 are shown on the figures of this section to illustrate the application of routing methodology and the respect of the constraints.

5.2 Route length

The route length minimisation exercise described above is bound by the route end points, namely the location of the offshore substation and the landfall. When comparing routes to different landfalls, the overall route length from the offshore substation to the connection point should be taken into account. Furthermore it can be preferable to increase the offshore route length to decrease the onshore route length, depending on onshore routing constraints which can be complex regarding ROW negotiations.

5.3 Engineering Constraints

5.3.1 Bathymetry and Slopes

Figure 5.1 shows the bathymetry of the Moray Firth region sourced from the United Kingdom Hydrographic Office (UKHO). Its mesh size of 250 m is adequate for this study, but a detailed survey of the final route will be required for detailed routing. The maximum local slope over the whole area has been derived from the UKHO data and is shown in Figure 5.2.

Away from the coast, the seabed in the Moray Firth area features relief at water depths varying generally between 40 and 80 m. Despite this variation, the slopes are generally gentle at less 1 degree and rarely exceed 3 degrees. However, the seabed is marked in the South-East of the Moray Firth by the Southern Trench, a scar of approx. 4.7 km in length, with water depths reaching more than 200 m and local slopes in excess of 15 degrees.

The MORL site boundary defines a region characterised by very gentle slopes below 1 degree, with a water depth ranging from 30 to 57 m. The export cable route will start at the offshore substation situated within that zone, and head to the South towards the coast.

Away from the coast, the water depth in the Moray Firth area is not considered to be a problem for the installation of large power cables of typical design for such application. Supposing that two pairs of HVDC cables are installed, each circuit carrying 750 MW, the cable weight in water is likely to be in the vicinity of 35 kg per metre. At 200 m water depth, the maximum tension in the cable due to its own weight during installation is estimated at 8.4 tonnes which is comfortably below the maximum allowable tension of a typical 750 MW HVDC cable. This will have to be confirmed once the electrical infrastructure and the cable type have been finalised. The transmission properties of the cables are unlikely to be affected by pressure at such depth.

Close to the coast, the nearshore approach is characterised by very gentle slopes, and water depths below 10 m extending to more than 1 km from the coast. Floating the cable ashore over such distance is possible in suitable weather conditions. However, in more adverse weather conditions, a shallow draft Cable Lay Vessel (CLV) may be required to come closer to the coast to reduce cable stress.

Generally speaking, it is preferable for routes to traverse areas with a smooth seabed and benign gradients. Cable laying across slopes is conducted at 90° to the direction of the greatest slope to avoid asymmetrical loads on the plough which would destabilise it. The maximum slope angle in which a cable can be safely ploughed is typically 10 to 15 degrees depending on the plough and the experience of the cable installer. At high angles, cable plough operations become unstable: the plough tends to come out of the ground or bury itself in, or can topple over. Slope reversals can cause the tension at the back of the plough to unbury the cable in the downward slope as the plough is going uphill. Moreover, the sediment in high slopes is more likely to move and possibly lead to the cable becoming unstable or becoming exposed. In the Moray Firth area, only the Southern Trench has slopes which could be a hindrance to cable laying. It should also be noted that the relatively low resolution of the bathymetric survey is likely to smooth the contours, hence higher slopes are expected to be found locally in the area. Validation of a route across the Southern Trench would require a detailed seabed survey of the area.

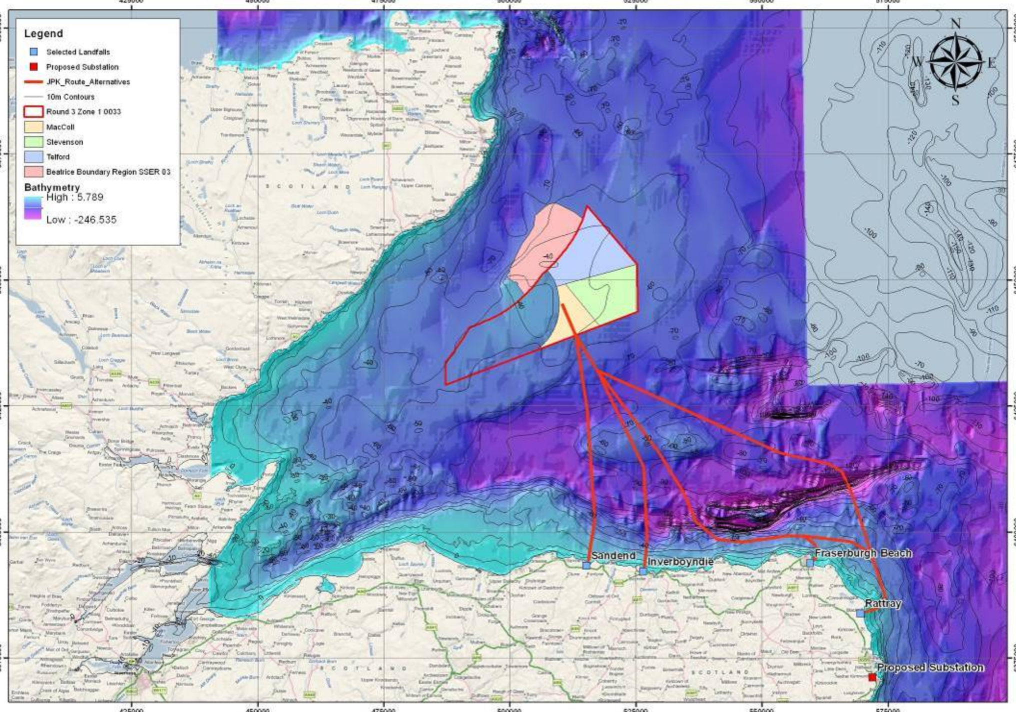

Figure 5.1 Bathymetry / hillshade in the Moray Firth. Water depth is measured in metres.

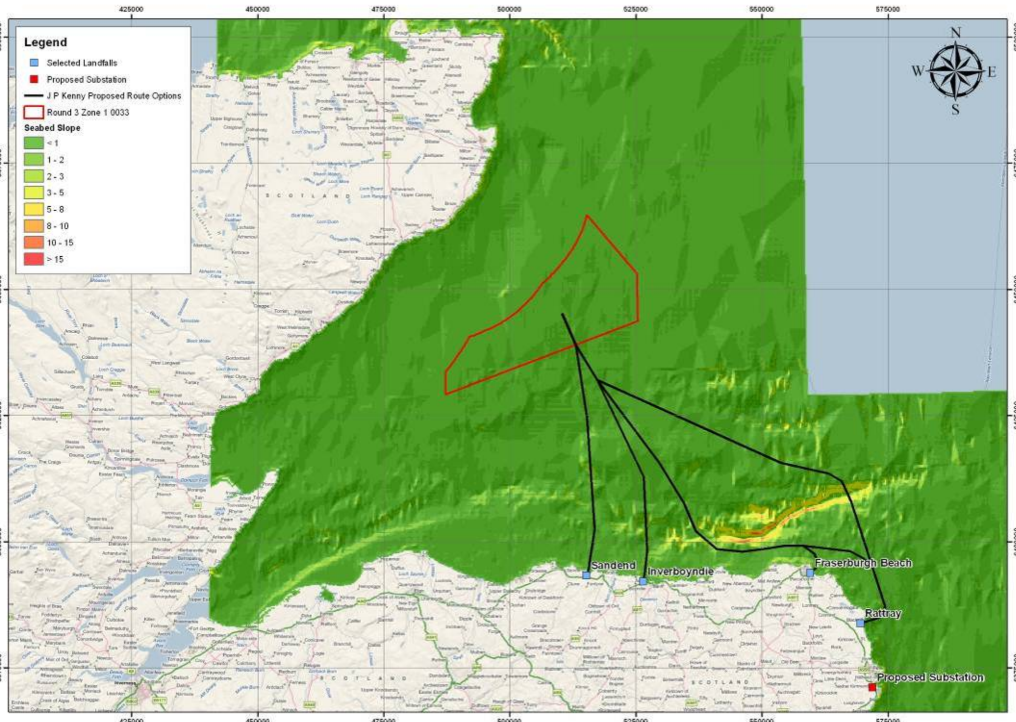

Figure 5.2 Seabed slopes (measured in degrees from horizontal) in the Moray Firth.

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5.3.2 Geology

For stability and protection purposes, it is envisaged that the cable will be buried over its whole length if possible. The required burial depth will be defined at a later phase in the project, but a depth circa two metres is likely to be recommended for protection. The top layer of seabed sediments is therefore critical to the design and installation of the cables.

The type and shear strength of the top soil will determine the suitability of different burial techniques, and in particular ploughing which is the preferred burial method for such application. The type and strength of the soil also affects the stability of the cable in slopes. Areas with mobile sediments (e.g. sand waves) are avoided to mitigate the risk on cable stability and unburial over time. In shallow waters, the potential for soil liquefaction should also examined when more information on sediments is available.

Determination of the shear strength of the soil will require surveying using intrusive techniques such as Cone Penetration Testing (CPT) or coring. The topsoil sediment type is estimated from BGS charts but its depth is unknown. Again, surveying will be necessary to determine this depth, either through intrusive techniques (e.g. CPT), with a sub-bottom profiler (sparker / boomer), or a combination of the two. Areas which are not suitable for ploughing may require extra cable protection such as rock dumping.

Table 5 shows the seabed sediment types found in the Moray Firth using the project classification system, together with the modified Folk equivalent classification used by BGS illustrated in Figure 5.3.

Table 5 Classification of seabed materials

Classification in supplied GIS data	Description	Folk classification (Ref. 2)
MUD	Mud	M
SDMD	Sandy mud	sM
-	Slightly gravelly mud	(g)M
-	Slightly gravelly sandy mud	(g)sM
GVMD	Gravelly mud	gM
SND	Sand	S
MUSD	Muddy sand	mS
SGSA	Slightly gravelly sand	(g)S
SGMS	Slightly gravelly muddy sand	(g)mS
GMSD	Gravelly muddy sand	gmS
GVSD	Gravelly sand	gS
GV	Gravel	G
MDGV	Muddy gravel	mG
MSGR	Muddy sandy gravel	msG
SDGV	Sandy gravel	sG
ROCK	Undifferentiated bedrock lithology	-

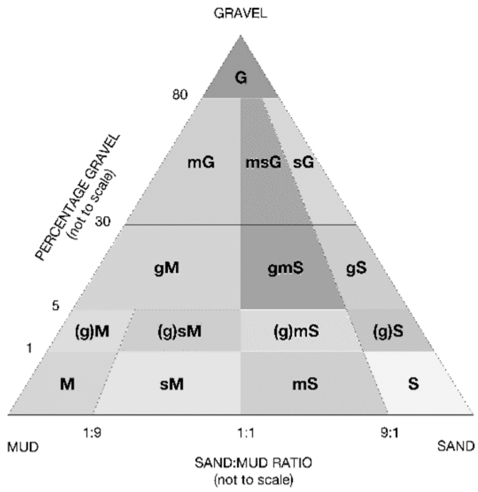

Figure 5.3 Modified Folk triangle classification used by BGS

The Moray Firth region is shown in Figure 5.4. A wide range of topsoil sediments is present in the area of interest located south of the wind farm development zone. The cable routes will predominantly encounter sand (SND) and muddy sand (MUSD), as well as sections of sandy gravel (SDGV), gravelly sand (GVSD), slightly gravelly sand (SGSA), and sandy mud (SDMD). Assuming that the top sediment layer has a depth of at least two to three metres, a range of burial methods is possible, including ploughing which is typically preferred to minimise disturbance to the environment.

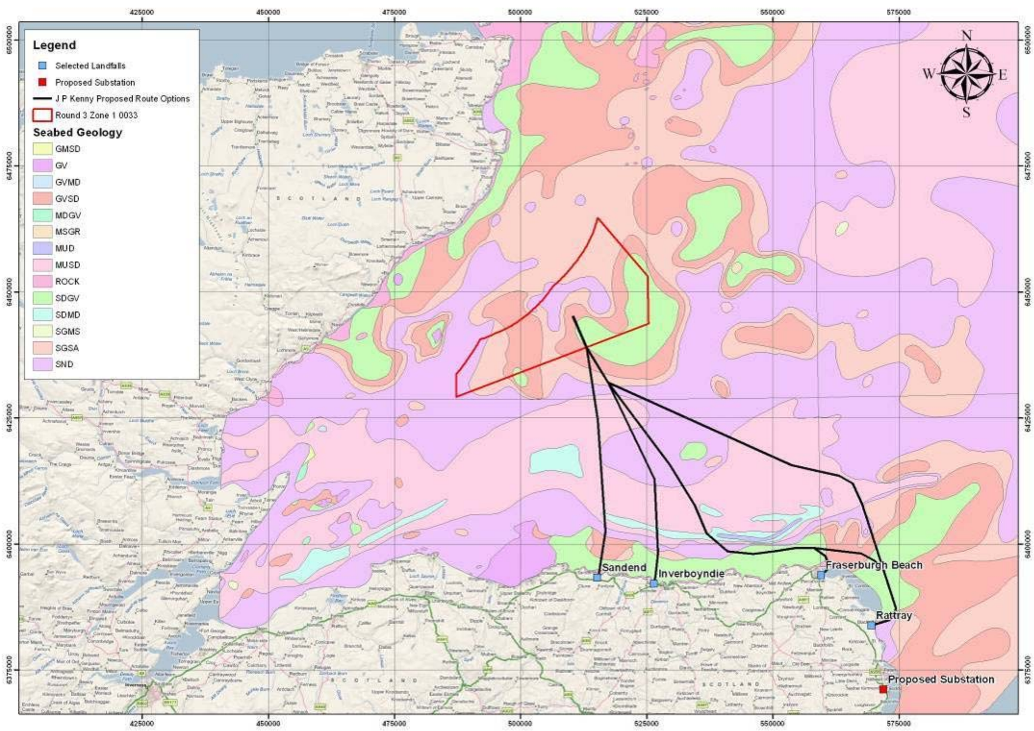

Figure 5.4 Seabed geology in the Moray Firth

5.3.3 Turns and Lay Radii

The number of turn points in the offshore route is minimised to simplify the installation and minimise the risk of ploughing operations.

Although the minimum allowable bending radius of power cables under tension is typically of the order of a few metres, it is desirable to observe a minimum lay radius to suit the plough limitations and to avoid the unburial of the cable behind the apex of a turn due to tension in the cable behind the plough. In this study, a minimum lay radius of 1 km was used.

5.3.4 Landfall approach

To minimise the complexity of cable installation at the landfall, the angle of the cable at shore approach is chosen to find a compromise between the following parameters:

- Minimisation of the shore pull length across the landing area to minimise the maximum pull load on the cable;
- Minimisation of the distance between the cable landing point and the 10 m water depth isoline to allow the CLV to come as close as possible to shore and minimise the length of nearshore trenching required;
- Maximise the distance from the coast of the first turn to simplify marine operations nearshore;
- Be as parallel as possible to nearshore wave effects to ease installation and minimise the loads on any exposed part of the cable.

5.4 Physical and Third Party Constraints

5.4.1 General

One of the key constraints of offshore routing in highly developed / utilised areas is to minimise interference of the cable with obstacles and hazards, which exist in the Moray Firth area (see Figure 5.5). The offshore route completely avoids obstacles which cannot be crossed and is optimised to minimise the number of obstacle crossings which require special works (pre or post-lay). A minimum safe distance is observed around obstacles which may increase the risk to cable integrity in their vicinity (e.g. dropped objects at offshore platforms), or which may be sensitive (e.g. other cables / pipelines).

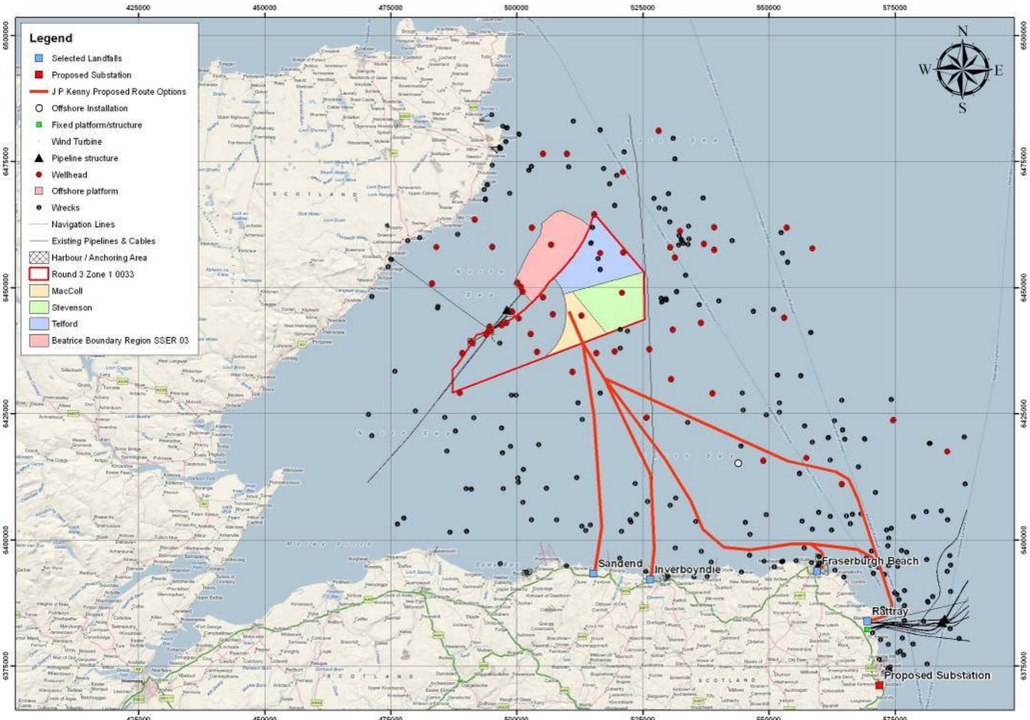

Figure 5.5 Physical and third party constraints in the Moray Firth

5.4.2 Obstructions

Obstructions which cannot be crossed are avoided altogether with a minimum clearance of 100 m for disused / natural obstacles and 500 m for offshore structures in operation. Numerous obstacles are found in the Moray Firth as shown in Figure 5.5. Such obstacles include:

- Wrecks;
- Subsea structures;
- Wellheads (active or not);
- Platforms and FPSOs;
- Rock outcrops;
- Spoil ground;
- Coastal structures (buildings, pontoons, harbours).

5.4.3 Crossings

Some obstacles can / must be crossed but extra works (pre or post-lay) are required, which is non desirable to minimise cost, risk, and potential conflicts with the owners. The following structures which may require crossing works are found in the Moray Firth:

- Telecoms cables;
- Pipelines;
- Power cables (planned route).

Notable structures are the SHEFA-2 cable landing near Inverboyndie which would have to be crossed for all landfalls to the East of Inverboyndie. The pipelines landing in St. Fergus

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are also noteworthy: the cable must stay to the North of the swathe if the Rattray route is chosen. To the West, the planned route of the SHETL and BOWL cables does not impact the routing of the MORL export cable.

Furthermore, areas envisaged for future developments (e.g. other wind farm sites) should be avoided to safeguard the cable and avoid potential future conflicts. In particular, pinch points (e.g. landfalls or corridors between sensitive areas) should not be sterilised by the installation of the cable.

5.4.4 Hazards

Other features which can be crossed but are avoided to minimise the risk to the cable due to dropped objects are:

- Navigation routes;
- Yachting routes near ports;
- Anchoring areas.

Also, the length of cable traversing harbour authority areas is minimised to avoid potential conflicts arising from the hindrance to port access caused by the CLV, which must stay stationary close to the coast potentially for days during landfall installation.

5.5 Environmental and Seabed Use Constraints

5.5.1 General

Routing through environmentally sensitive areas is a barrier to environmental consenting and is therefore avoided (see Figure 5.6). Seabed zones which are exploited by human activities increase the risk to the cable during operation and can be the source of conflicts during installation of the cable; they should therefore be avoided wherever possible.

5.5.2 Protected Areas

The protected areas in the Moray Firth are located along the coast (see Figure 5.6) and include the following types of sites which are discussed in detail in Ref. 1:

- Flora / fauna conservation areas;
- Special Protection Areas (SPA);
- Special Areas of Conservation (SAC);
- Sites of Special Scientific Interest (SSSI).

Potential Annex I Habitats are not included in the available datasets, hence are not shown in the constraint maps. However, only the route to Rattray is impacted: the nearshore approach is a Potential Annex I Habitat with sandy sediment. The numerous pipelines landing in St Fergus also cross this area, hence this is not considered a hindrance to routing.

5.5.3 Seabed Use

The provided dataset does not appear to include any fishing data, hence the fishing zones are not represented in the constraints maps. However, the METOC feasibility report (Ref. 1) shows that said zones (for trawling, creeling, and "bottom towed gear") cover most of the area of interest and cannot therefore be realistically be avoided. The risk due to cable routing through fishing grounds will be mitigated by providing adequate protection to the cable.

Similarly, the MOD firing danger area is not included in the available datasets but does not impact cable routing.

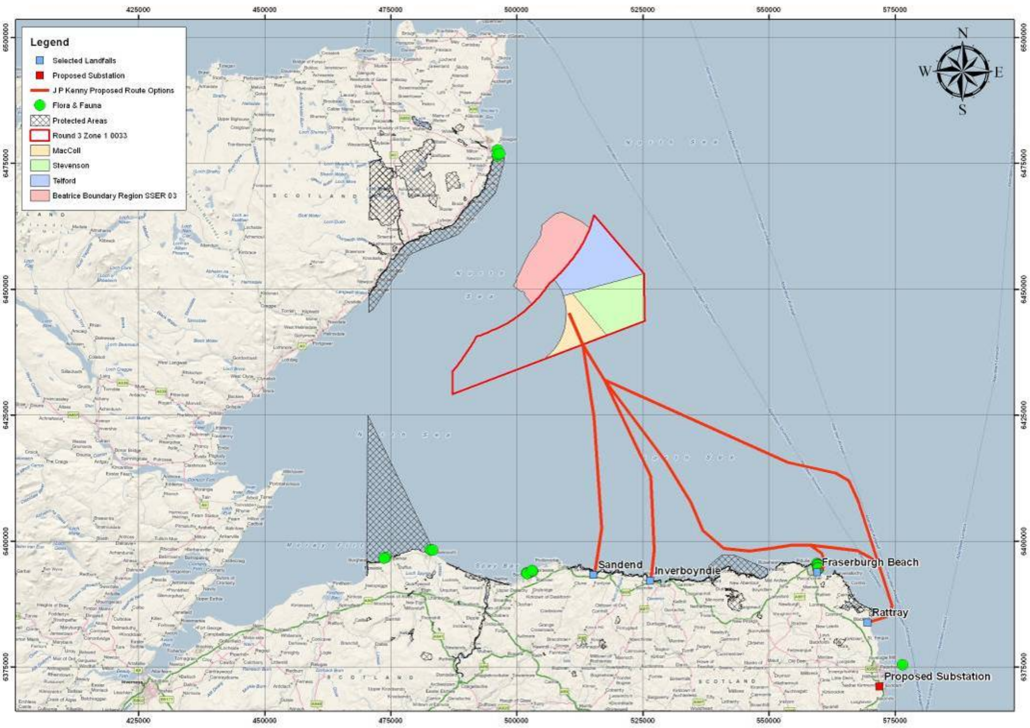

Figure 5.6 Environmental constraints in the Moray Firth

5.6 Go and no-go zones

The constraints presented in the previous sections are overlaid in Figure 5.7, which shows the proposed routes in the context of all the offshore routing constraints used in this study.

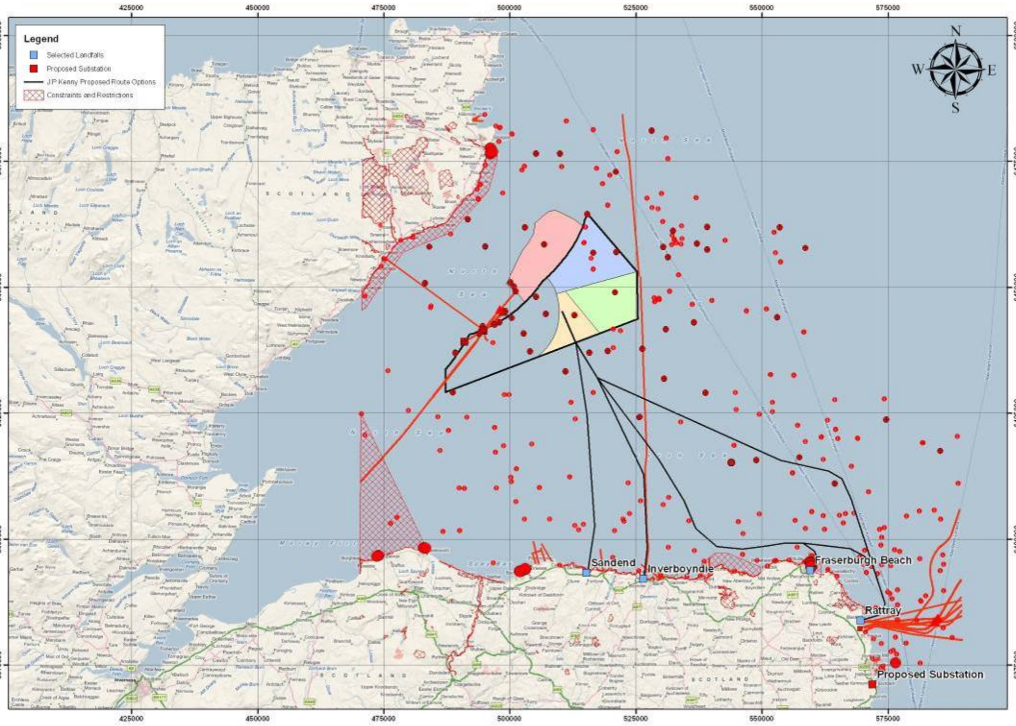

Figure 5.7 Global offshore constraints map

6.0 ONSHORE ROUTING

6.1 Methodology

Similarly to offshore routing, the aim of onshore routing is to find the shortest route from the landfall to the onshore connection point, under constraints dictated by engineering, physical and environmental limitations, and third parties. All constraints are associated with a "weight" and are input into the GIS database. A global weighted constraints map is then created for the Multi-Criteria Evaluation to find the optimum route outside of the no-go areas. Multi-Criteria Evaluation is a process comprising automated tools as well as appraisal by engineers with specialist expertise in different fields (e.g. power cables, cable laying, ploughing, landfall installation).

The constraints effectively define the envelope which will guarantee the long term integrity of the cable as well as its safe installation. The main sets of constraints which have been used in this study are presented in the following sections. Other parameters taken into account by the Multi-Criteria Evaluation are as follows:

- Cable protection;
- Cable separation requirements;
- Ability to utilise existing cable lay construction methods;
- Minimisation of ground pre-lay intervention requirements;
- Minimisation of ground and cable post-lay intervention requirements;
- Minimisation of the number of crossings;
- Minimisation of the environmental impact;
- Minimisation of interference of all types;
- High level cost minimisation (e.g. preference for open cut trenching, avoidance of high value terrain).

Routing across fields is favoured as following roads is likely to increase the density of features encountered, disrupt local traffic, and increase the number of landowners whose consent would be required. Access to the ROW is not considered a problem as the cable route never strays far from roads.

The outcome of the onshore routing exercise is ultimately a 200 m corridor for which concept solutions for cable installation exist at all points along the route.

6.2 Route length

The onshore route length minimisation exercise is bound by the route end points, namely the location of the landfall and the connection point at Peterhead. When comparing routes to different landfalls, the overall route length from the offshore substation to the connection point should be taken into account. Because of the typical complexity of the negotiation with third parties for ROW leasing, shorter onshore routes are considered to present a significant advantage, despite the longer associated offshore route.

6.3 Engineering Constraints

6.3.1 Topography and Slopes

Onshore cable installation is typically carried out with standard excavators and cable lay vehicles. Easy vehicle access to the route is therefore critical and routing thus avoids important ground slopes. Furthermore, cable jointing must be carried out at regular intervals along the route; this activity requires a flat patch of land.

The topography of the onshore routing area is shown in Figure 6.1. The area is generally characterised by gentle rolling hills which are suitable for typical onshore installation techniques. However, some areas feature small mounts and cliff systems which should be avoided wherever possible to circumvent the need to use special construction techniques. Of particular note, the area South of Inverboyndie features arduous terrain which requires special consideration during the routing exercise.

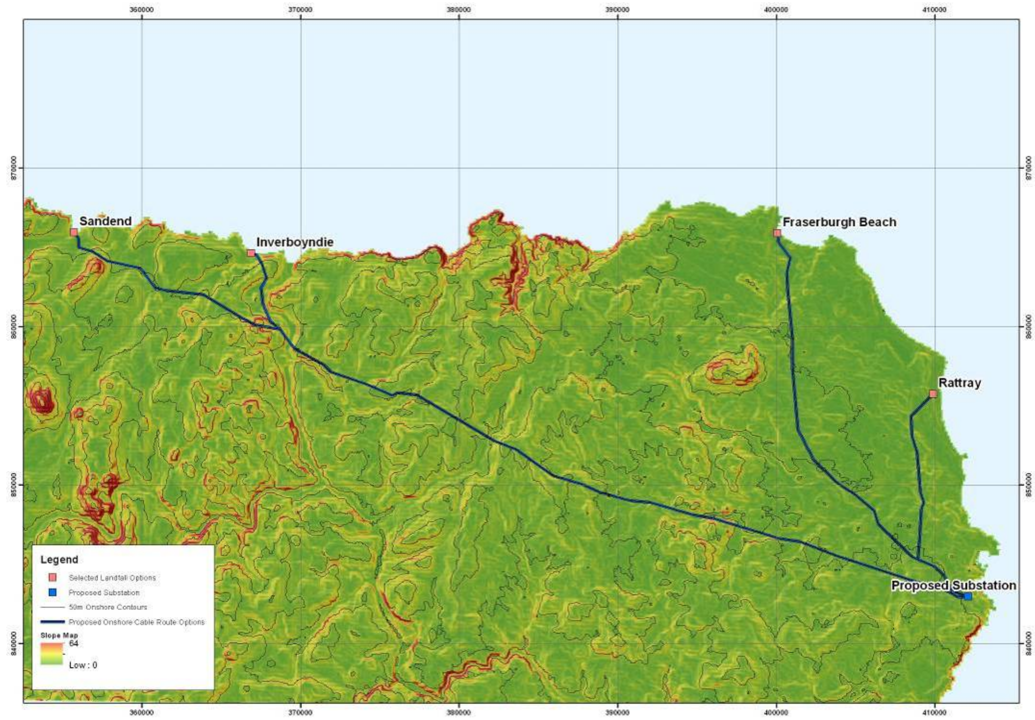

Figure 6.1 Topography of the onshore routing area: map of the slopes. Slopes are measured in degrees.

6.3.2 Turns and Lay Radii

The number of turn points in the onshore route is minimised to simplify the installation and minimise the risk of cable manipulation. The minimum allowable bending radius of power cables under tension is typically of the order of a few metres which is comfortable for onshore cable laying and therefore virtually does not impact cable routing.

6.4 Physical and Third Party Constraints

6.4.1 General

The installation of buried power cables onshore requires the avoidance or the crossing of numerous features. The cost of onshore installation can be relatively low in areas with a low density of features such as farm land, or grass fields. However, costs can quickly go up when traversing obstacles, areas of high activity, or high value terrain. The avoidance of such features is therefore desirable. The following sections highlight the key physical and third party constraints in the onshore area of interest. Those constraints are shown in Figure 6.2.

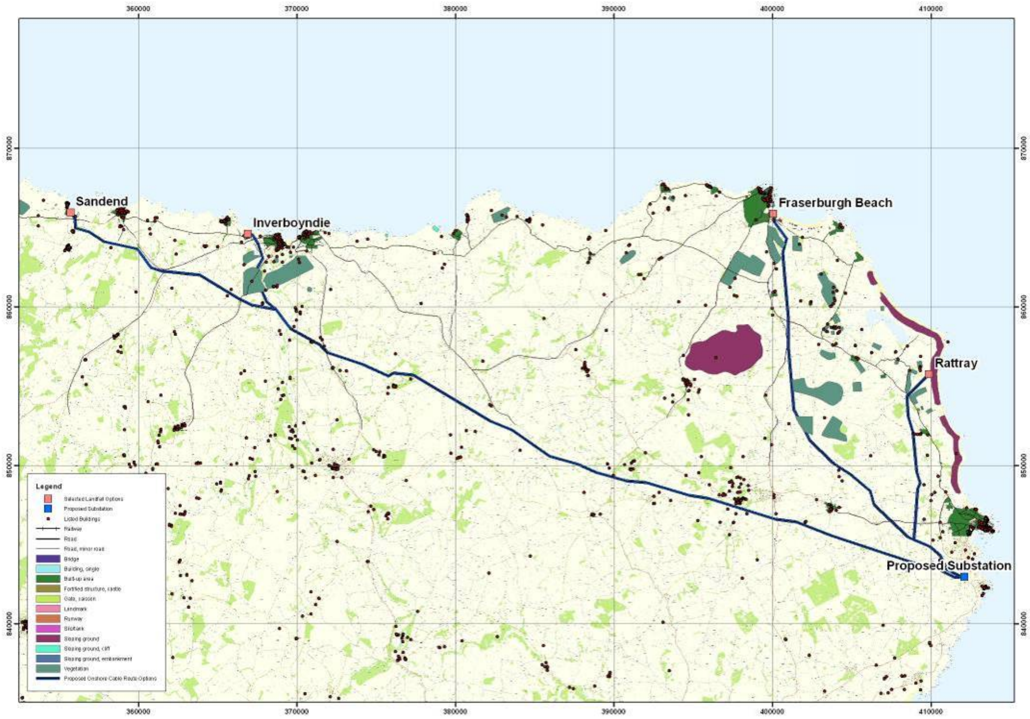

Figure 6.2 Physical and third party constraints in the onshore routing area

6.4.2 Crossings

Onshore routing in developed areas typically requires crossing numerous features. Readily available crossing solutions exist for virtually all types of crossings but they require extra work (e.g. HDD) which is undesirable. The number of crossings should be therefore minimised. Typical features found in the area of interest are:

- Roads / railroads;
- Cables / pipelines;
- Streams / rivers;
- Cliffs.

When avoidance is not possible, a crossing is preferably located at a point which minimises the complexity of the solution, disturbance to the environment, and disruption to human activities. The topography, vehicle access, and local characteristics of the feature (e.g. river width, number of lanes for roads) are also taken into account.

6.4.3 Obstructions

To avoid interference with existing infrastructures and disruption to existing service and human activities, the following areas are avoided:

- Urban areas;
- Gas / water / electricity supply infrastructure;
- Buildings (including factories, silos, tanks, bridges, wind turbines…);
- Cemeteries.

Other areas avoided to facilitate the detailed engineering of the route, minimise the impact on the environment, and ultimately minimise cost include:

- Forests;
- Rocky areas.

6.4.4 Land use

Although it is typically only examined in detail during detailed design, land use has been given attention in this concept study, to improve the quality of the routing and the subsequent route comparison. It should be noted that the available GIS routing information does not include land use data, so aerial imagery has been used for that purpose in this study.

6.4.5 Third party consent

Onshore routing is typically challenging in terms of third party consenting. The detailed review of third party consent requirements for a given route will be performed during detailed design. However, several good practices are already applied at the present conceptual stage using aerial photography and ordnance survey maps. Generally speaking, the following areas are avoided:

- Built-up areas;
- Private properties / residential areas;
- Listed buildings.

Following the edge of properties is desirable to minimise the number of parties involved. However, this will require ownership maps to be created during detailed design.

6.5 Environmental Constraints

For onshore routing at the concept stage, only no-go areas are taken into account to create the corridors. Protected areas are completely avoided, but environmentally sensitive areas which can be crossed are not taken into account: the level of granularity required to take sensitive areas into account is outside of the scope of this concept study and will be addressed in the detailed routing study. It should be noted that sensitive areas which can be crossed are not available in the provided datasets.

Protected areas are shown in Figure 6.3 and include the following types of sites:

- Flora / fauna conservation areas;
- Special Protection Areas (SPA);
- Special Areas of Conservation (SAC);
- Sites of Special Scientific Interest (SSSI);
- National Nature Reserve (NNR);
- Ramsar Sites.

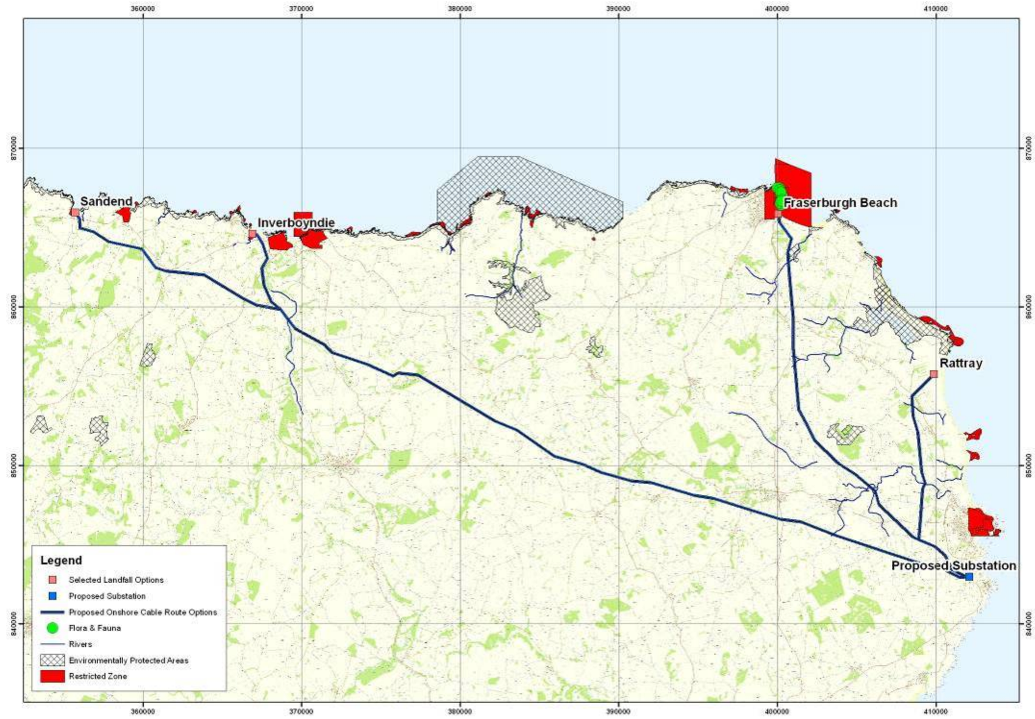

Figure 6.3 Environmental constraints in the onshore routing area

6.6 Substation Location

It is envisaged to install the two substations in the vicinity of the connection point in Peterhead as highlighted in the METOC feasibility study (Ref. 1). The constraints on the choice of a suitable onshore substation location are identical to the onshore routing constraints, with the following additional criteria:

- Location within 1 km of connection point in Peterhead;
- Required area of 100 m x 100 m for the erection of two adjacent substations;
- Minimal landscape impact;
- Minimal site preparation works;
- Good road access for workers access during operations.

Aerial imagery, GIS data, and in-situ appraisal during the site visit on 28 February 2011 were used to propose the substation location shown in Figure 6.4. Of particular note, the site visit was instrumental in choosing a location which will minimise the impact on the landscape.

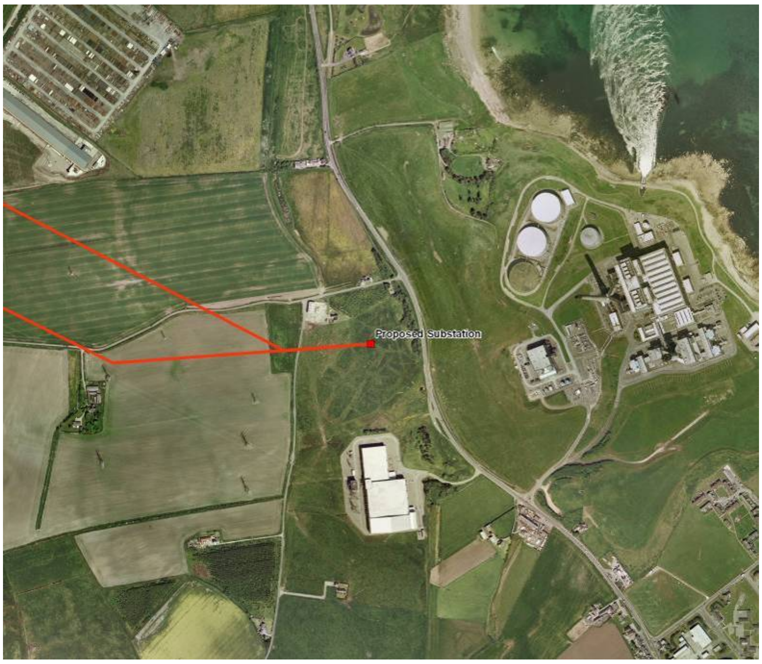

Figure 6.4 Proposed onshore substation location

7.0 CABLE ROUTE OPTIONS

7.1 Methodology

The starting point of combined offshore / onshore cable routing is to choose suitable landfall locations to be used as endpoints for the offshore and the onshore routing which are effectively separate exercises. The intrinsic suitability for cable landing of the potential landfall locations is taken into account, as well as the intention to propose a variety of routing options to retain flexibility in route selection.

The feasibility study (Ref. 1) identified eight landfalls suitable for cable routing. Those were reviewed and four were retained with the aim of creating four routes from the offshore substation to the connection point in Peterhead. A Multi-Criteria Evaluation was then conducted offshore and onshore to produce four conceptual routes defined by corridors with a width of 200 m. The methodology used in the Multi-Criteria Evaluation is described in Sections 5.1 and 6.1 for offshore and onshore routing respectively.

Stage 1 results are shown below. All routes are considered feasible and concept solutions for design and installation exist at all points of the routes using proven designs and construction methods.

The appraisal of the routes and their comparison will be presented in the next revision of this report which will cover Stage 2 of the study.

7.2 Offshore Routes

The concept offshore cable route options are shown in Figure 7.1. The lines represent corridors with a width of 200 m. They satisfy all routing constraints and have been engineered to meet operational and construction requirements.

Of particular note, two routes lead to Rattray; the northern branch requires the crossing of the Southern Trench and the confirmation of its viability will require a detailed survey. The southern route requires cable laying parallel to the coast gradient and in shallower waters which increases the lay risk. Stage-2 of this study will compare those two options and evaluate the trade-off between the cost of surveying an extra route and the potential cost saving associated with said route.

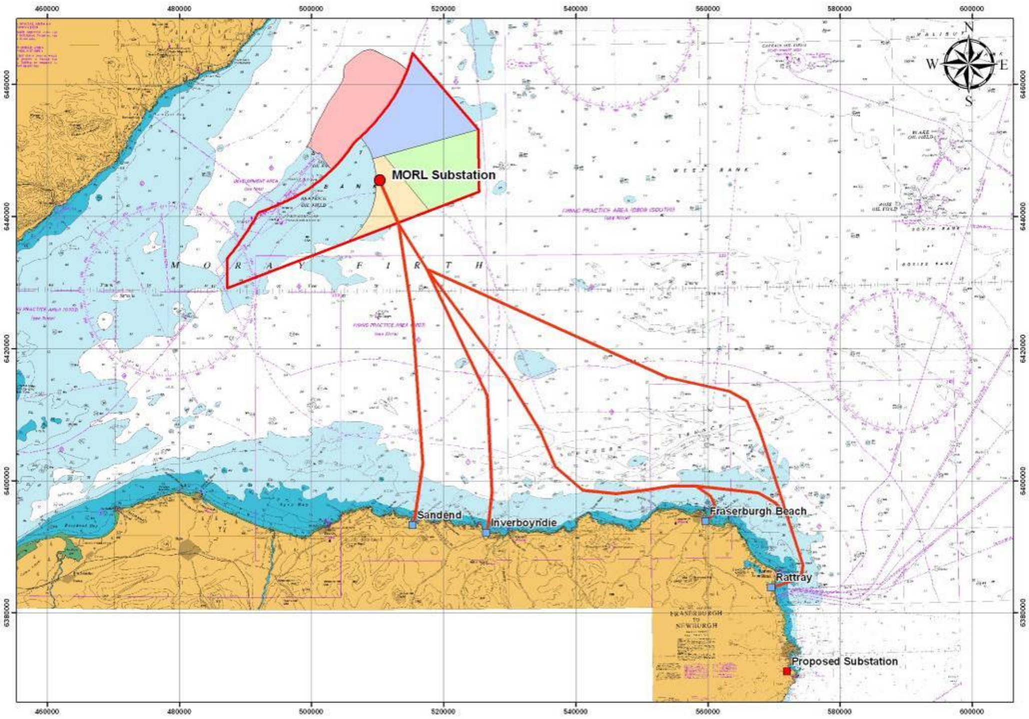

Figure 7.1 Offshore route options

Table 6 Offshore route lengths

Sandend	Inverboyndie	Fraserburgh Beach	Rattray South	Rattray North
Offshore length: 53.0km	Offshore length: 57.1km	Offshore length: 80.7km	Offshore length: 103.0km	Offshore length: 100.3km

Table 7 Offshore route coordinates

Sandend		Inverboyndie		Fraserburgh Beach		Rattray South		Rattray North	
Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing
515008.2	6393428	526404.3	6392135	559591.5	6393839	569697.8	6383891	569697.8	6383891
515465.4	6393912	526721.5	6393512	560819.4	6394988	573112.5	6384911	573112.5	6384911
515574.6	6394281	527245.1	6398216	561037.3	6396128	574176.1	6385868	574176.1	6385868
516804.7	6402523	526543.9	6412860	560417.0	6397637	574373.6	6387266	574373.6	6387266
515262.9	6424622	517360.8	6432077	558120.4	6399196	571903.6	6394891	567685.8	6407946
513111.5	6438952	513084.3	6438998	554516.1	6399196	570145.7	6396702	565874.3	6412030
510325.0	6445321	510351.2	6445247	550777.7	6398609	567545.7	6398157	563239.5	6413561
				546083.8	6398039	558120.4	6399196	553727.4	6415665
				541037.8	6398575	554516.1	6399196	517360.8	6432077
				536892.1	6402122	550777.7	6398609	513123.8	6438949
				534510.8	6407678	546083.8	6398039	510351.2	6445272

Sandend		Inverboyndie		Fraserburgh Beach		Rattray South		Rattray North	
Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing
				529549.9	6415814	541037.8	6398575		
						536892.1	6402122		
						534510.8	6407678		
						529549.9	6415814		
						517360.8	6432077		
						513123.8	6438949		
						510351.2	6445272		

7.3 Onshore Routes

The concept onshore cable route options are shown in Figure 7.2. The lines represent corridors with a width of 200 m. They satisfy all routing constraints and have been engineered to meet operational and construction requirements.

Figure 7.2 Onshore route options

Table 8 Onshore route lengths

Sandend	Inverboyndie	Fraserburgh Beach	Rattray South	Rattray North
Onshore length: 62.9km	Onshore length: 53.2km	Onshore length: 28.3km	Onshore length: 15.5km	Onshore length: 15.5km

Table 9 Onshore route coordinates

Sandend		Inverboyndie		Fraserburgh Beach		Rattray South		Rattray North	
Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing
515008.2	6393428	526404.3	6392135	559591.5	6393839	569697.8	6383891	569697.8	6383891
515532.2	6392886	526740.8	6392021	559667.0	6393305	568178.6	6382449	568178.6	6382449
515555.8	6392306	527104.6	6391469	560431.0	6392294	568268.3	6381183	568268.3	6381183
516432.2	6392055	527414.5	6390549	560218.9	6391391	568593.8	6380180	568593.8	6380180
517372.7	6391470	527067.2	6389924	560298.4	6390324	568858.8	6377656	568858.8	6377656
519475.0	6391042	527228.8	6388857	560632.5	6387276	569087.0	6376980	569087.0	6376980
520370.0	6389862	527703.4	6387828	560655.3	6385421	568928.3	6376605	568928.3	6376605
521054.2	6389668	528298.1	6387332	561070.8	6381486	568829.8	6374699	568829.8	6374699
523439.9	6389455	529233.1	6386142	561602.1	6380507	568748.8	6373405	568748.8	6373405
525869.8	6388030	531085.3	6385142	562096.3	6379554	568748.8	6373405	568748.8	6373405
526777.1	6387587	531552.0	6384678	563643.2	6378122	569775.1	6372984	569775.1	6372984
528298.1	6387332	533819.3	6383937	564707.1	6377454	570420.4	6372432	570420.4	6372432
529233.1	6386142	535434.7	6383258	565963.4	6376419	570839.5	6371570	570839.5	6371570
531085.3	6385142	535773.7	6383436	566215.5	6375583	571763.7	6371089	571763.7	6371089
531552.0	6384678	537009.1	6383321	568391.8	6373551	571972.3	6371104	571972.3	6371104
533819.3	6383937	541944.9	6380493	569775.1	6372984				
535434.7	6383258	543322.3	6379951	570420.4	6372432				
535773.7	6383436	545682.2	6378333	570839.5	6371570				
537009.1	6383321	547480.0	6377839	571763.7	6371089				
541944.9	6380493	548622.5	6377349	571972.3	6371104				
543322.3	6379951	550549.0	6376834	559591.5	6393839				
545682.2	6378333	551809.7	6376759						
547480.0	6377839	554535.0	6375998						
548622.5	6377349	555760.4	6375811						
550549.0	6376834	560012.5	6374576						
551809.7	6376759	561302.3	6374421						
554535.0	6375998	563523.1	6373596						
555760.4	6375811	568807.4	6371929						
560012.5	6374576	570496.9	6371489						
561302.3	6374421	571352.1	6371058						
563523.1	6373596	571972.3	6371104						
568807.4	6371929	526404.3	6392135						
570496.9	6371489								
571352.1	6371058								

Sandend		Inverboyndie		Fraserburgh Beach		Rattray South		Rattray North	
Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing
571972.3	6371104								

7.4 Consenting Parameters

The results of this study will be used to define the consenting parameters to be included in the Rochdale Envelope. As the outcome of Stage 1 of this study, the master Consenting Parameters sheet will be updated with the following information regarding the export cable:

- Footprint:
  - The maximum offshore route length is 103.0km.
  - The export cable may traverse a potential Annex I Habitat (pAIH) close to its landfall (in Sandend and in Rattray).
- Installation technique:
  - It is expected the export cable will be ploughed over its whole length except nearshore and close to the substation.
  - Nearshore and at the substation, the cable may be buried by jetting.
  - The temporary increase in suspended sediments (plumes), the extent of sediment deposition, and the release of contaminants bound in seabed sediments due to cable installation are expected to be minimal overall, as ploughing causes minimal disturbance to the seabed and jetting may be used only over short lengths.
- Protection
  - Nearshore and at the substation, the cable may be protected by rock dumping or mattressing.
  - Protection of the cable is not expected to impact fishing activities.
- Crossings
  - The export cable may have to cross the SHEFA-2 telecommunication cable (for the Fraserburgh Beach and Rattray routes).

8.0 CONSTRUCTION METHODOLOGY AND DECOMMISSIONING

8.1 Offshore

8.1.1 Cable Laying Methodology

Cable laying of the export cable and of the inter array cables will be undertaken from a dedicated Cable Lay Vessel (CLV) and will generally be laid from shore to the offshore site.

The export cable will be delivered directly from the manufacturing facility onboard the cable lay vessel. On completion of the shore pull, the installation vessel will commence normal lay by paying out the cable and moving the vessel along the lay route. An ROV will be located at the cable touch-down point to monitor the position and the catenary of the cable. All lay parameters, including tension and lay-back distance, will be monitored to ensure they are within the design limits. Cable integrity will be monitored during lay operation according to the cable manufacturer specifications. On completion of laying, the cable lay vessel will come to a stop and will be positioned in a suitable configuration to allow the cable to be pulled into the bellmouth of the J-tube at the offshore platform.

The inter array cables will be pre-cut, terminated, and loaded onto the cable lay vessel. The vessel will initially stand off from the first wind turbine structure. The messenger line will be retrieved and the cable pulled into the J-tube from the turbine structure. The cable lay vessel will then pay out the cable whilst moving towards the destination wind turbine. At this location, the second messenger line will be retrieved and the cable pulled into the second wind turbine structure.

8.1.2 Cable Burial Method

The seabed at the proposed wind farm site is composed of sand, gravel, and mud, in varying proportions. A number of methods could be used to bury the cable:

- Pre-lay dredging (particularly in non-cohesive soil types): this produces a wide trench where mechanical backfilling may be necessary to provide complete cover over the cable following installation.
- Cable ploughs: they are designed to minimise of soil disturbance and may be operated simultaneously during cable lay, or from a separate vessel following completion of the laying operation. A picture of a typical cable plough is shown in Figure 8.1. If necessary, trenching may be facilitated by the use of a jetting system to loosen / liquefy the soil directly in front of the blade. Ploughing is the most efficient burial method, but stability may be compromised by seabed slopes and the suitability of any equipment proposed should be evaluated in the event that steep slopes are encountered. Ploughs are less attractive should second-pass / remedial burial be needed due to the intrinsic limitations in plough manoeuvrability and the associated risk of contact with and damage to the cable.

Figure 8.1 Typical Cable Plough

- Jetting trenchers: these are capable of achieving burial depths in excess of 2m in soft clays (mud) and sands. A picture of a typical jetting trencher is shown in Figure 8.2. These are most commonly mounted on a self-propelling ROV to post-lay bury the cable. In certain conditions, this method may require two to three passes to achieve an adequate burial depth and relies on natural backfill through the sediment settling. Jetting is effective on sand and clay seabeds where the density of the material is sufficiently high to keep the trench clear. Burial depths in material which cannot hold a clear furrow will be significantly reduced.

Figure 8.2 Typical Jetting Trencher

Ploughing during cable lay and post-lay jetting could both be considered at the proposed wind farm site due to the sea bed sediment encountered. As a single-pass, a ploughing operation is normally the most efficient and economical approach and will most likely be the preferred option. This is due to the speed of the operation in both creating and backfilling the trench. Moreover, ploughing can be completed without additional equipment common in jetting operations, which thereby reducing costs. A plough is an effective burial tool as it pushes the cable directly into the trench before it can collapse.

It is anticipated that a separate system may be required to cover the inter-tidal and shallow water sections of the route. A typical system designed for such an application is the DPT5; a high pressure shallow water jetting system (see Figure 8.3), powered and controlled from a shallow water pumping barge. It is fitted with 2.5m jet swords and can trench in sand, silts and gravels.

Figure 8.3 DPT5 high pressure shallow water jetting system

8.1.3 Cable Protection

Cable protection is typically required at each end of the inter-array cables close to offshore structures between the burial point and the transition to the vertical. It is expected that the length of exposed cable will be up to 50m at each end.

Typical cable protection solutions include covering the cable with mattresses. Standard mattress dimensions typically measure 6m length by 3m width. Accordingly, up to approximately 7 mattresses would be required per cable end. In sandy areas, the mattresses may require fronds, which will attract sediment and create sediment build-up. The fronds are manufactured from buoyant fibrillated polypropylene which is connected to the concrete mattress. A picture of a typical concrete mattress with fronds is shown in Figure 8.4.

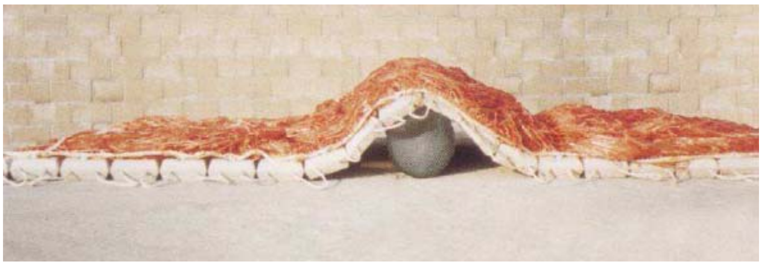

Figure 8.4 Typical Concrete Mattress with Fronds

More novel solutions such as the use of wire mesh nets filled with rocks could also be considered. These typically comprise plastic coated galvanized steel mesh ‘baskets’ into which cobble sized rock is placed. These ‘baskets’ can be stacked together to form a protective layer. A picture of a typical rock filled wire mesh baskets is shown below in Figure 8.5.

Cable protection with mattresses or rock nets may also be required to remediate insufficient burial depth.

Figure 8.5 Typical Gabion Basket / Reno Mattress

8.1.4 Landfall Installation

There are two basic techniques for constructing a cable landfall: open cut trenching or Horizontal Directional Drilling (HDD); the choice will depend on the conditions of the chosen site. HDD can be carried out across the whole landfall area or only over a shorter length, from shore some distance back from the coast to a beach jointing pit. More details on the specifics of those installation techniques are found in Section 4.3.

From the lay vessel, the export cable is brought to the landfall by a combination of floating and pulling ashore. Depending on the type of CLV and the stand-off distance from shore, the cable is usually floated ashore by attaching buoyancy aids and pulling it with a shore based winch using a pulling head (see Figure 8.6). Careful consideration of all the hydrodynamic and environmental forces should be evaluated to ensure that the cable does not become overstressed during the pull. Once the cable pull has been completed and buoyancy attachments removed the cable lay vessel will continue laying the cable offshore along the designated route.

Figure 8.6 Cable floated / pulled ashore from a DP Cable Lay Vessel

8.2 Construction Vessel

A wide range of vessels are suitable to cable laying / ploughing. The choice of vessel will depend on capability, cost, availability, cable characteristics, and the versatility required from the vessel to perform other tasks. During the selection process, vessels categorized in both the Cable Lay Vessel (CLV) and Multi-Purpose Supply Vessel (MPSV) categories should be considered. Using a barge with carousel may be required to lay the export cable in the shallow waters close to shore. However, the use of a shallow draft CLV to carry out the whole cable installation may be more cost effective as vessel mobilisation costs are significant. Examples of suitable vessels for cable laying are as follows:

- Cable Lay Vessels (CLV) e.g.
  - CTC *Volantis.*
  - GMSL *CS Sovereign.*
  - VSMC *Stemat Spirit.*
- Multi-Purpose Supply Vessel (MPSV), e.g.
  - Reef *Polar Prince*
  - Solstad *Normand Mermaid*
- Barge with carousel, e.g.
  - VSMC *Stemat 82.*
  - GMSL *AMT Explorer.*
  - TPG *AMT Discoverer.*

Some of the new Cable Lay Vessels coming onto the market prior to the start of construction claim to be of a new type. However, any potential advantage will have to be examined on a case-by-case basis. Examples of such new vessels are as follows:

  - GMSL *Global Spirit.*
  - Beluga Hochtief Beluga Connection.

8.3 Decommissioning

The Department of Energy and Climate Change (DECC) requires the development of a decommissioning plan at the outset of a project. This plan must meet the requirements of the comprehensive statutory scheme set out in the Energy Act 2004 (Ref. 3) for the decommissioning of offshore installations in the Renewable Energy sector.

At decommissioning, removing the whole of all disused structures is generally desirable. However, where the cable is buried at depth and is deemed unlikely to become exposed in the future, it may be preferable to leave the cable in-situ, to avoid the impact of removal on the marine environment and the high cost of removal. It should be noted that the cost of removal could be mitigated by the high value of the salvaged copper at decommissioning, which may be significant given the trend the price of copper has followed over the last 10 years. If it is decided to leave the cables in-situ, the decommissioning plan should include a contingency plan in case the cable does become exposed by natural seabed movement and poses a risk to maritime activities (e.g. fishing, anchoring).

9.0 REFERENCES

1. METOC, Export Cable Route Feasibility Study, P1461_RN2456_Rev2, 13 Jan 2011.
2. Robert L. Folk, The Distinction between Grain Size and Mineral Composition in Sedimentary-Rock Nomenclature, The Journal of Geology, Vol. 62, pp 344–359, Jul 1954.
3. Energy Act 2004 – Chapter 3 – Decommissioning of offshore installations.

Appendix 1

LANDFALL COMPARISON MATRIX

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Landfall Site	Lossiemouth Forest	Portgordon	Cullen	Sandend	Inverboyndie	Fraserburgh Beach	Fraserburgh Golf Car Park	Philorth	Inverallochy	Rattray	St Fergus
Appraised in-situ during site visit	NO	NO	NO	YES	YES	YES	NO	NO	YES	YES	NO
JPK Landfall Ranking	- Long / Indirect Route - discarded during November meeting		- Long / Indirect Route - discarded during November meeting	1 Good potential landfall - short offshore route	1 Good potential landfall - short offshore route				2 Short onshore route	3 Shortest onshore route	- 11 offshore pipeline crossings - discarded during November meeting
METOC Landfall Ranking	3	2	2	1	2	3	2	4	1	4	2
METOC Route Ranking	4+	4+	4+	2	3	4+	4+	4+	1	4+	4+
ROUTE LENGTH											
METOC Offshore Route Length		60.5 km		48.6 / 54.84 km	51.7 km	78.9 km	78.9 km	78.7 km	84.7 km	94.7 km	
NEARSHORE											
seabed trenchability		Gravel / satellite imagery indicates a rocky seabed		Gravely sand / possible rock	Sandy gravel	Sandy gravel / gravely sand	Sandy gravel / gravely sand	Sandy gravel / gravely sand	Sandy gravel / gravely sand. Possible rock outcrops.	Sand. Possible rock outcrops.	
cable length with water depth < 10m		1.8 km		1.6 km	1.2 km	1.2 km	1.2 km	1.2 km	1.0 km	1.4 km	
environmental / 3rd party limitations		Protected area / SHETL consented route		None	SHEFA cable	None	None	None	None	Existing pipelines to the South	
BEACH LANDING											
exposure to environment				Sheltered East and West							
coast erosion potential					Low (looking at SHEFA beach jointing pit)						
Open cut trenching across beach											
open cut trenchability		Apparent rock on beach		Possible	Stream	Possible but difficult in areas due to high dunes	Possible but difficult due to high dunes	Possible but difficult due to high dunes	Through golf course behind beach	Possible but difficult in areas due to high dunes	
construction vehicle access		Nearby roads and grass fields		Nearby roads and grass fields	Nearby roads and grass fields	2 way coastal road nearby	From the North on the beach	Difficult across sand dunes / from the North on the beach	Coastal road	Via the cable Right Of Way	
environmental / 3rd party limitations		Roads close to coast		Removable concrete blocks.	Stream / SHEFA cable landing nearby / small caravan park	Moderate dunes	High dunes / golf course behind beach	High dunes / river crossing / protected area onshore	Golf course behind beach	Existing pipelines to the South	
Beach joining pit - short HDD											
open cut beach trenchability		Difficult due to small beach depth. Possible rock.		Possible	Possible	Possible	Possible	Possible	Possible	Possible	
construction vehicle access		Nearby roads and grass fields		Nearby roads and grass fields	Nearby roads and grass fields	2 way coastal road nearby	From the North on the beach	Difficult across sand dunes / from the North on the beach	Through golf course / from North or South on beach	From the South via the terminal	
HDD length		100 m		200 m (under caravan park)	60 m	50 m	400 m	400 m	200 m	300 m	
beach jointing pit construction		Difficult due to small beach depth. Sand / pebbles / rocks. Pit would be on patch of		Sand	Sand / gravel	Sand	Sand	Sand	Sand	Sand	
environmental / 3rd party limitations		Narrow land strip available behind beach		None	SHEFA cable landing nearby / small caravan park	None	Golf course behind beach	River crossing / protected area onshore	Golf course behind beach	Existing pipelines to the South	
Long HDD under beach											
HDD Length		150 m		350 m (under caravan park)	100 m	300 m	600 m	700 m	350 m	500 m	
environmental / 3rd party limitations		Roads / Farmland		None	SHEFA cable landing nearby / small caravan park	None	Golf course behind beach	River crossing / protected area onshore	Golf course behind beach	Existing pipelines to the South	
ONSHORE											
jointing site construction		Possible in grass fields		Possible in grass fields	Possible in grass fields	Possible in grass fields	Possible in grass fields	Possible in grass fields	Possible in grass fields	Possible in grass fields	
exit path to onshore route		SHETL consented route		No notable hindrance	SHEFA cable nearby	No notable hindrance	No notable hindrance	No notable hindrance	No notable hindrance	Possible conflicts with existing pipelines