



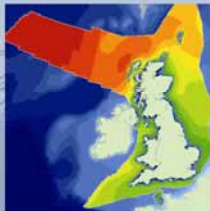
Beatrice Offshore Windfarm Ltd

Beatrice Offshore Wind Farm: Transmission Cable Landfall Impact Assessment

Report R.1886

January 2012

Creating sustainable solutions for the marine environment



Beatrice Offshore Windfarm Ltd

Beatrice Offshore Wind Farm: Transmission Cable Landfall Impact Assessment

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Summary

ABP Marine Environmental Research Ltd (ABPmer) has been appointed by Beatrice Offshore Windfarm Limited (BOWL) to consider the physical processes aspect of the Environmental Impact Assessment (EIA) for the proposed Beatrice Offshore Wind Farm.

This report follows the baseline assessment report (ABPmer, 2011) and provides an assessment of the potential impacts of the proposed offshore transmission cable upon physical processes in the marine environment. These potential effects have been assessed using the realistic 'worst-case' characteristics of the proposed development as advised by BOWL and/or as presented within the Project Design Statement (PDS) (BOWL, 2011).

The principle factors controlling the magnitude of potential impacts to the designated morphological features present at the landfall site are considered. Further quantitative information is provided to inform the planning of the landfall operation, minimising or mitigating the risk of any effect.

Abbreviations

| | |
|----------------|---|
| ABPmer | ABP Marine Environmental Research Ltd |
| BOWL | Beatrice Offshore Windfarm Limited |
| EIA | Environmental Impact Assessment |
| H _c | Beach closure depth |
| HDD | Horizontal Directional Drill |
| H _e | Annual extreme wave height (10 in 1 year condition) |
| HVDC | High-voltage Direct Current |
| km | kilometre(s) |
| LAT | Lowest Astronomical Tide |
| m | metre(s) |
| MHWS | Mean High Water Springs |
| OftW | Offshore Transmission Works |
| PDS | Project Design Statement |
| SSSI | Sites of Special Scientific Interest |
| T _e | Wave period corresponding to the annual extreme wave height |

Beatrice Offshore Wind Farm: Transmission Cable Landfall Impact Assessment

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1. Introduction

1.1 Overview

ABP Marine Environmental Research Ltd (ABPmer) has been appointed by Beatrice Offshore Windfarm Limited (BOWL) to consider the physical processes aspect of the Environmental Impact Assessment (EIA) for the proposed Beatrice Offshore Wind Farm.

The BOWL application site is located in the north of the Outer Moray Firth, approximately 15 km south east of the Caithness coast, as detailed in the Project Design Statement (PDS) (BOWL, 2011).

An integral part in the determination of the potential impact of the proposed wind farm and OfTW (Offshore Transmission Works) infrastructure upon the environment is the assessment of its interaction with physical processes and regimes. The purpose of this study is to demonstrate a sufficiently robust understanding of the potential interaction of the transmission cable and coastal sediment regimes at the landfall site and to provide suggestions for mitigation and monitoring requirements. This report follows the baseline assessment (ABPmer, 2011).

2. Description of the Proposed Landfall Options

The proposed BOWL transmission cable landfall options A & B are located to the west of Portgordon (see Figure 1), a small village some 2 km from Buckie on the southern Moray Firth coastline.

The coastline at this general location is orientated west north west to east south east. There is a fishing harbour and concrete slipway at the eastern end of Portgordon. The harbour wall and slipway intercepts the westerly littoral drift of shingle as indicated by the significant accumulation of cobbles on the updrift (east) side of the eastern most harbour wall. West and adjacent to the harbour, there is a wide cobble beach that is heavily vegetated to the rear. Moving further eastwards, the beach width decreases rapidly to the extent that rock armour has been installed to protect properties and the coast road up to some 500 m from the harbour.

Immediately to the west of the harbour the village is fronted by a 3 m high concrete seawall, a 12-15 m wide apron that slopes around 15° and a concrete splash wall. The seawall is further protected by rock armour. Seawards of this, the intertidal area is composed of medium sized, sandy sediments. The rock armour extends some 50 m beyond the seawall to provide protection to the eroding shingle beach.

Westwards of the village but prior to the section containing the landfall sites, the beach is characterised by a relatively wide intertidal area named the Tannachy Sands. This is composed of patchy sand, overlying a conglomerate rock base. The active shingle storm ridge begins as a low angled feature at Porttannachy. The shingle beach at this point is approximately 20 m wide and is backed by a steep, 1 m high grassed bank, which shows evidence of erosion and

overtopping. A track runs along the top of the ridge as far as the outfall pipe for the Portgordon maltings works.

The first proposed landfall point A is located between the Portgordon maltings outfall pipe and the Tynet Burn, which intersects the beach some 500 m from the end of the seawall at Portgordon. The Tynet Burn is described in more detail in the following section (B.1.2). On this section of beach, cusps and ridges of different wavelengths are apparent and the shingle ridge is clearly present but variable in height (approximately 1-2 m).

The second proposed landfall point B is located to the west of the burn. Here the shingle ridge increases in height (to around 4 m) and steepens. Suites of well developed cusps and ridges of different wavelengths occur in the beach face.

From Portgordon towards the landfall locations, the sandy foreshore progressively lowers and is gradually replaced by shingle from east to west, towards the mouth of the Spey. Richie (1983) describes this stretch of coast as being transitional from a sand dominated beach at Porttannachy to the 5 m high shingle berm and ridges at Tugnet.

Overtopping of the ridge crest is evident and large shingle overwash 'fans' have been deposited at the back of the beach, which slopes gently then onto agricultural land (and further westwards a golf course). Fans are more obviously apparent to the west of the Tynet Burn.

2.1 Tynet Burn

As described above, the Spey Bay beach is intersected by the Tynet Burn approximately 500 m to the east of Portgordon. At first sight, the opening across the beach appears to be relatively recent with an older, more direct drainage route to the east. However, based on the geomorphology map produced by Ritchie *et al* (1978), the stream has maintained its present course since at least 1977. Evidence of undercutting and recession of the river bend can clearly be seen at the site. This is most likely due to a combination of high fluvial discharges during periods of heavy rainfall and storm wave activity within the drainage outlet across the beach.

3. Sediment Transport

3.1 Sediment Sources

There are generally considered to be three main sources of sediment to the Spey Bay frontage:

- Glaciofluvial sand and gravel reserves deposited offshore during the last ice age, which are transported onshore by rising sea levels;
- Fluvial gravels carried downstream by the River Spey and deposited in the nearshore zone;
- Reworking of relict sediment deposits by contemporary hydrodynamic processes.

The cliffs to the east of Portgordon may now be discounted as a sediment source given that they are now fronted by hard defences. However, based on visual evidence and previous studies, some sediment is still transported westwards along the coast.

3.2 Longshore Transport

The sediment transport processes in the Moray Firth have been classified by Ramsay and Brampton in their Coastal Cells in Scotland report (HR Wallingford, 1997). The Moray Firth forms Cell 3 whose boundaries are the drift divides at Cairnbulg Point in the south and Duncansby Head. Spey Bay is located in Subcell 3b (Portknockie to Branderburgh). According to this assessment, the net longshore transport direction along the south coast of the Moray Firth including Spey Bay is westerly.

The visual evidence collected during a visit to the site also shows that the dominant longshore transport direction is westerly. Additionally, the orientation of the coastal features between the Tynet Burn and Tugnet is indicative of a net westerly drift caused by swell and long fetch wind waves approaching the shore obliquely from the north and north east.

Wave refraction analysis has been used to simulate potential longshore transport, (Dobbie and Partners, 1990). The results of this study predicted a potential annual transport rate of approximately 3,000 m³ (Figure 2). However, on a year on year basis, the magnitude and direction of transport were found to vary considerably providing further evidence of the sensitivity of the coastal system to the wave climate.

Further evidence for a long term westerly drift can be seen by observing the difference in size and abundance of the ridges to the east and west of the Spey Mouth. However, Ritchie (1983) points out that at certain times fluvial sediment from the Spey must have moved eastwards as there is in fact little evidence that significant volumes of material eroded from the till cliffs to the east of Portgordon fed the Spey Bay coastline even before the construction of the harbour and sea defences.

It is also suggested that incident waves from the north and north-west have, in the past (and continue to do so) generated temporary eastward transport of fluvial sediment from the Spey, which has contributed to the creation of the shingle ridges to the east of the river mouth. This theory is supported by the narrowing of the shingle ridges eastwards from Tugnet and the transition from a shingle beach to a sand dominated system and it would seem that episodically, at least, the River Spey was formerly the dominant source of sediment to the eastern part of Spey Bay.

3.3 Sediment Budget

A sediment budget is a balance of the sediment volume entering and exiting any given section of the coast or an estuary. Sediment budget analysis consists of the evaluation of sediment fluxes, sources and sinks from different processes that result in additions and subtractions within a control volume (e.g. a section of coast or an estuary) in order to gain a better understanding of the estuary system. Gemmell (2000) and Gemmell *et al.* (2001) used a

combination of map and field evidence coupled with computer modelling to produced a sediment budget for Spey Bay, presented schematically in Figure 2.

Input of sediment to Spey Bay originates from both updrift erosion of beach material and from the River Spey. River modelling studies suggest the Spey annually contributes 8000 m³ of sediment to the coastal system (Riddell and Fuller, 1995) whilst the amount of sediment contributed by recession of the adjacent shoreline is estimated at 12,570 m³. These input sediments contain approximately 80 % gravel and 20 % sand which means c. 15,900 m³ of gravel is input to the Spey system each year.

However, it appears that each year there is a loss of both sand and gravel from the Spey Bay coastal system with losses of sand amounting to approximately 8860 m³/year whilst losses of gravel are around 10,300 m³. It is unclear where this volume of gravel is transported to although it may be the case that methodological errors in the estimation of sediment volume have resulted in an over estimate of sediment loss. The final destination of the sand is likely to be the sand dunes (which are accreting behind the beach) along with the Lossie saltings whilst a certain amount will be transported offshore, bypassing the local sediment cell boundary (Ramsay and Brampton, 2000) at Lossiemouth.

4. Historic Shoreline Evolution

Analysis of historic shoreline variability along the Spey Bay coastline has previously been undertaken by Gemmell *et al.*, (2001). Consideration of the changes in the position of mean high-water and low water springs between the first Ordnance Survey (which was carried out in 1870) and a later survey (1970) shows that to the east of the Spey Delta, the coast has experienced erosion over the past 100 years. This is in contrast with the western side of Spey Bay which has experienced accretion over the same time period. Beach gradient and volumetric changes for east Spey Bay are recorded in Table 1.

Table 1. Beach gradient and volume change (1870-1970)

| Profile Location (km East of Tugnet) | 1870 Beach Gradient (° from vertical) | 1970 Beach Gradient (° from vertical) | Beach Volume Change (m ³) |
|---|--|--|--|
| 4(Porttannachy) | 47 | 28 | -128 000 |
| 3.5 | 40 | 28 | -126 000 |
| 3 | 45 | 13 | -104 000 |
| 2.5 | 50 | 29 | -60 000 |
| 2 | 53 | 23 | -45 000 |
| 1.5 | 45 | 20 | -43 000 |
| 1 | 43 | 15 | -79 000 |
| 0.5 | 32 | 18 | -145 000 |
| (Tugnet) | 20 | 8 | - |

(Source: Gemmell *et al.* 2001)

From Table 1, it is evident that over the past 100 years there has been an increase in beach gradient at all locations along the eastern Spey Bay coastline¹. It is also apparent that the highest values of sediment loss are encountered at the eastern end of the frontage, near to the proposed landfall. According to Hansom and Black (1994), the Spey Bay golf club lost over 25 m of land between 1960 and 1994. This equates to an erosion rate of 0.7 m per year. However, during severe storms, the seaward face of the narrow shingle ridge between Porttannachy and Tugnet has been observed to temporarily recede at a rate of 0.5 m per day. Comparison of historic Ordnance Survey charts for a previous study (ABPmer, 2009) indicated that at the proposed landfall the high water mark receded by 62 m between 1905 and 2001 (Figure 3). This equates to an average annual recession rate of 0.64 m per year, which is comparable with the values quoted by Hansom and Black (1994).

In summary, based on the assessment of historic OS maps, it is clear that the proposed landfall site has been subject to long term coastal erosion and that the findings of a previous study carried out by ABPmer (ABPmer, 2009) are in broad agreement with previous authors. It is recommended that annual beach profiles should be taken at the landfall site to monitor short term profile response to storm events and medium to long term response to sea level rise.

5. Calculation of Beach Closure Depth

The beach profile at a given site is subject to sometimes quite extreme variations (in addition to long term evolutionary trends) in response to wave action as sediment from the upper shore is 'drawn down' the face of the beach. Vertical variations are greatest in the nearshore zone with the envelope of change narrowing in an offshore direction. This zonation has been related to the annual wave climate by Hallermeier (1981), who described the so called 'beach closure depth' as the seaward limit of extreme bottom changes for sandy beaches. The closure depth is defined as:

$$H_c = 2.28H_e - 68.5 (H_e^2/gT_e^2)$$

Where

H_e = Annual extreme wave height (10 in 1 year condition) (m)

T_e = Corresponding wave period (s)

Given the wide, sandy intertidal and offshore morphology of the BOWL landfall locations, the Hallermeier (1981) method was considered appropriate for estimating beach closure depth.

H_e and T_e have been derived as 2.9 m and 8.5 s respectively for a location immediately offshore of the cable landfalls using the numerical wave model. Using these values in the above equation gives a beach closure depth of 5.8 m, which is in broad agreement with the value for a location to the west of the mouth of the Spey quoted by Gemmell *et al* (2001) (6 m) calculated using an alternative method.

¹ Note that a decrease in degrees as shown in Table 1 indicates an increase in gradient i.e. the beach becomes steeper.

The vertical datum for the beach closure depth is assumed to be the Lowest Astronomical Tide (LAT).

6. Summary of Conceptual Processes Understanding

From the assessment of contemporary hydrodynamic and sedimentary processes, it is clear that the Spey Bay coastline represents a highly dynamic environment that is subject to complex forcing mechanisms.

In terms of hydrodynamic controls, waves appear to dominate in driving sediment transport processes as tidal currents are generally too weak to exert much influence. In particular, waves from the north and north west have been shown to reverse the longshore transport of sediment, resulting in the accumulation of fluvial sediments to the east of the Spey mouth. The mouth of the River Spey is an extremely complex area which regularly experiences rapid and significant changes in its morphology as a result of the complex interactions between fluvial and coastal processes. The river is highly dynamic, often with high discharge levels, which combined with the extreme dynamism of the coast creates an extremely complex and dynamic interface between the fluvial and coastal zone.

Under normal conditions, the net longshore transport is westerly. However, the drift is intercepted by the harbour and sea defences at Portgordon, by the outflow from the Tynet Burn. It is doubtful whether sediments transported from the east of Portgordon ever constituted the primary source of sediment to the coast to the west of the Tynet Burn. However, the wide expanse of shingle that has accumulated on the updrift side of the harbour indicates that historically, at least, significant volumes of shingle were moved westwards along the shore.

The whole coastline from Portgordon to Tugnet is erosional. Evidence of this can be seen at the mouth of the Tynet Burn, where the back berm deposits from the troughs of relict ridge systems are exposed. This indicates that the older, progradational ridges are being reworked by the present, active storm ridge and that the coast is retreating. Both Ritchie (1983), and Hansom and Black (1996) state that whilst the eastern part of Spey Bay is eroded and rotates landwards, it fuels a seawards rotation of the west Spey Bay gravel ridges.

The main threats to the land use and infrastructure along the Spey Bay coastline and, in particular the proposed landfall site are rising sea levels and accelerated erosion due to more frequent attack by large waves.

7. Potential Impacts of Cable Installation

Horizontal Directional Drilling (HDD) permits the installation of a cable underneath the beach without disturbing the surface sediments. Considerable control is possible over the drilled route allowing the avoidance of sensitive areas.

7.1 Potential Impacts of the Cable Landfall on Coastal Processes

The potential impacts of this cable installation method on coastal processes are limited. There will be no anticipated changes to waves, currents, seabed mobility or sediment transport, other than slightly elevated levels of suspended sediment at the drill exit site. Any sediments released into the water column will be of a small volume and quickly redistributed to trace levels across the intertidal area. In order to ensure the least amount of disturbance, the HDD will be started on land and carried out seawards of the beach closure depth as active beach processes cease beyond this point. There will be no impacts on the local hydrodynamic or sedimentary regime associated with the operational lifespan of the cabling method.

7.2 Potential Impacts of the Cable Landfall on the Beach and the SSSI Features

To avoid any direct effects, and to minimise the risk of indirect effects, 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 would be required (e.g. burial or encasement of the cable). The design of any alternative protection (pending further detailed engineering design works) would 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. The final design will be verified with Marine Scotland.

Other potential direct impacts that may arise relate to the onshore and offshore HDD entry/exit points and to the movements of plant/equipment. These operations will be planned and designed with due regard for the designated features and will benefit from the embedded mitigation in the relevant engineering best practice. Localised effects onshore can be repaired following construction and as such, any impacts arising from the construction will be both temporary and highly localised as the drilling operation will be completed within a very short time.

7.3 Potential Damage to the Cable Landfall as a Result of Coastal Erosion and Seabed Mobility

In addition to the potential impacts of the cable installation on the natural environment and on the designated features, it is also necessary to consider whether the evolving coast could cause damage to the cable either in the short term or during the 25 year operational period. This assessment will also provide information as to a suitable location for any onshore infrastructure that will not necessitate the construction of hard defences at any point in the future.

Based on the assessments of coastal processes and historic shoreline evolution, it is clear that the proposed landfall site is an eroding coastline with an average shoreline recession rate of approximately 0.6 m per year. The main risks to the landfall site are:

- Reduced sediment supply;
- Accelerated sea level rise;

- Increased wave attack.

Assuming that the shingle beach will continue to roll back in response to storm events and sea level rise at a similar average rate to that observed previously (-0.7 m/year), the total landward recession over the proposed 25 year scheme lifetime will be around 18 m. However, this does not take into account the effects of extreme waves or changes to longshore transport processes and assumes that the frontage continues to remain undefended. Consequently, when selecting a suitable location for the jointing bay, an appropriate degree of conservatism should be added to the predictions of profile retreat. It is suggested that any onshore infrastructure should be sited at least 50 m landwards of the high water mark to allow for any increases in the current recession rate.

8. Conclusions and Recommendations

The assessments carried out are based on the best information available at the time of the study. It is recognised that the data history for the specific proposed landfall site is limited (e.g. in relation to wave records, number of beach profiles, etc.). However all interpretations have adopted a conservative stance and have been correlated to other available information (site observations etc) to ensure that the results and conclusions are valid and that these inherent uncertainties do not compromise any subsequent recommendations.

From the assessment of historic coastal evolution and contemporary hydrodynamic and sedimentary processes, it is clear that Spey Bay is a highly complex and dynamic system that has resulted over time in the formation of valued geomorphological features. The SSSI is highly sensitive to a range of forcing mechanisms and faces increasing pressure in the future from rising sea levels, depleted sediment sources and more frequent attack from larger storm waves. The current status of the coastline from Portgordon to Tugnet and in particular the proposed landfall site is erosional. With this in mind, the following recommendations should be applied to the cable landfall at this site.

- The offshore exit point for the directional drill should aim for a location as far seawards as possible up to the beach closure depth at 6 m (below LAT);
- 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 would be required (e.g. burial or encasement of the cable);
- Any onshore infrastructure should be sited at least 50 m back from the present MHWS mark;
- A suitable programme of pre and post installation monitoring is recommended. This monitoring might include:
 - (i) A pre- and post-installation survey to ensure that the beach has remained undisturbed or can be reprofiled correctly following any disturbance;
 - (ii) Summer and winter profiles at the landfall site;
 - (iii) Biannual site visit to undertake a visual assessment of beach levels;
 - (iv) Seabed assessment in the nearshore zone to monitor potential scour around the cable entry/exit point.

In conclusion, provided that the mitigation and monitoring presented above are implemented, the transmission cables and associated onshore infrastructure can be installed without damage to the designated features and remain throughout the proposed operating period without necessitating any remedial coastal defence works.

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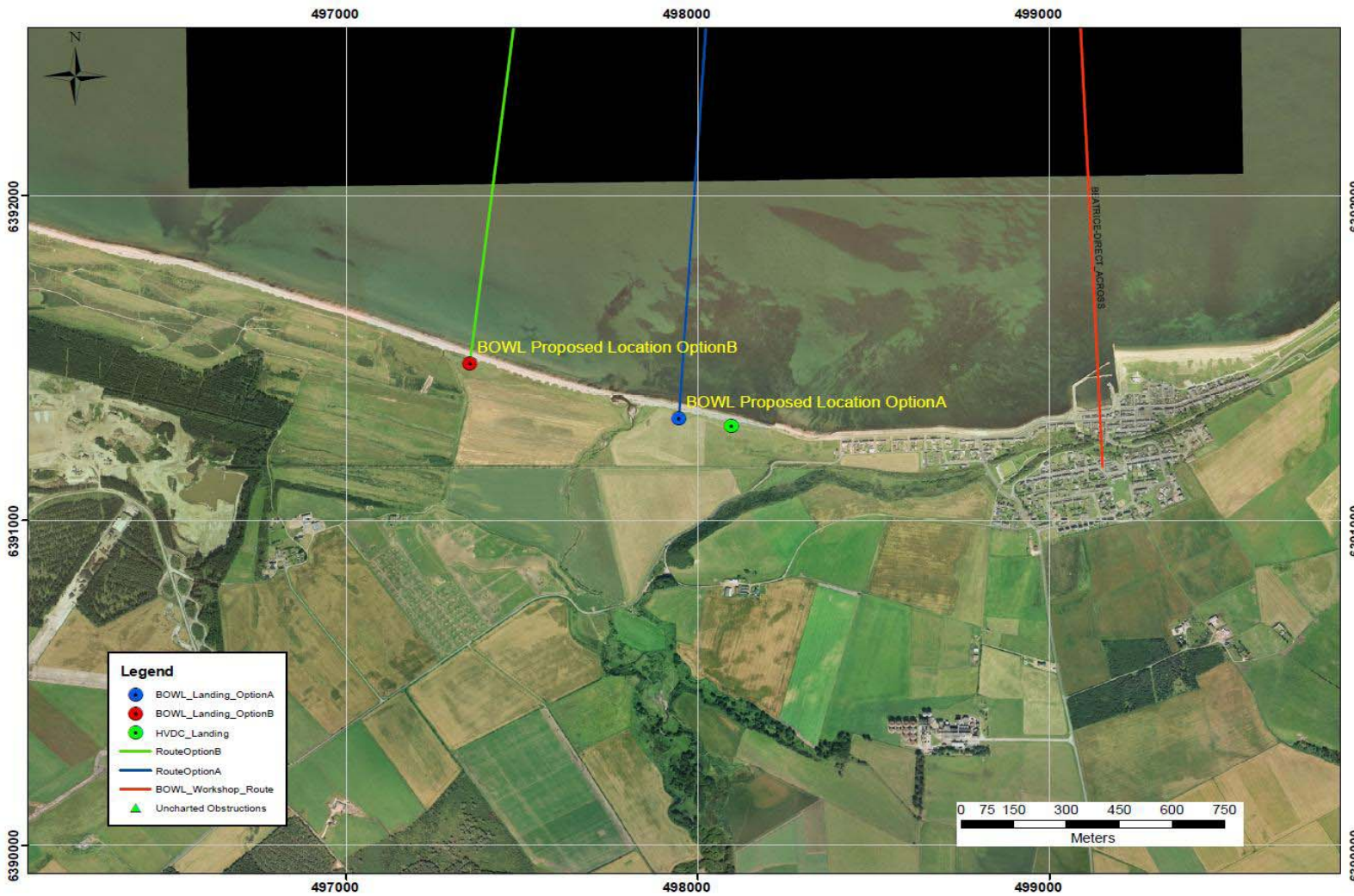
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Figures





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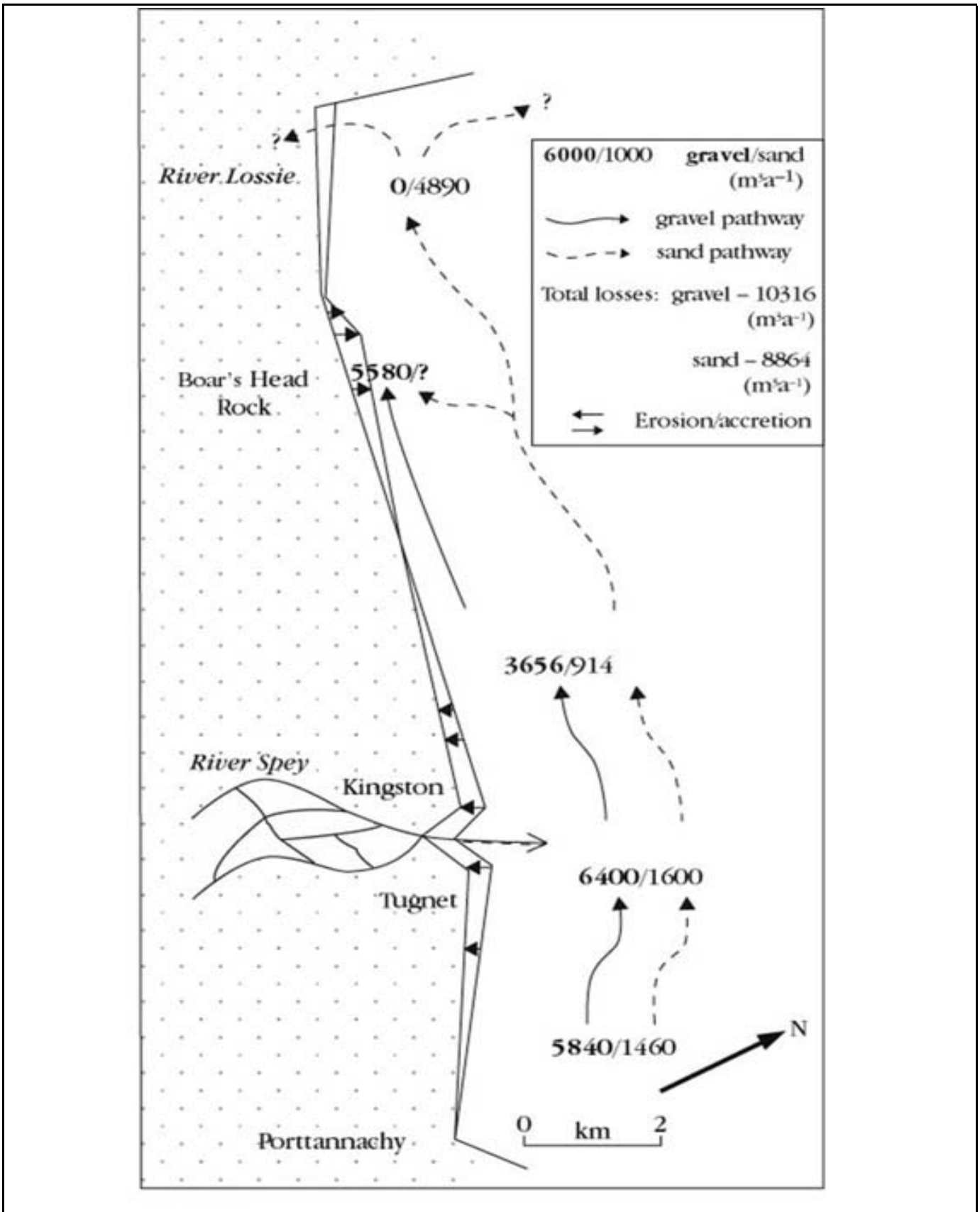


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Approximate Locations of the Proposed Landfall Locations A and B

Figure 1



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(From Dobbie and Partners, 1990)



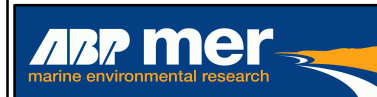
Sediment Transport Rates in the Vicinity of the Landfall

Figure 2



- 1905 MLWS
- 1905 MHWS
- 2001 MHWS

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Coastal Retreat Between 1905 and 2001

Figure 3



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