21 OFFSHORE TRANSMISSION WORKS PHYSICAL PROCESSES AND GEOMORPHOLOGY

21.1 INTRODUCTION

1. This Section describes the likely significant effects of the OfTW on physical processes and includes effects on marine sedimentary and coastal geomorphological environments. The assessment has been undertaken by ABP Marine Environmental Research Ltd (ABPmer).

2. Cumulative, in-combination and inter-relating effects of cable burial with other similar operations in the vicinity of the Wind Farm site are considered in Section 9: Wind Farm Physical Processes and Geomorphology. There are no other potential sources of additional cumulative effect along the cable route and so no further cumulative effect assessment is provided in this Section.

3. This Section of the ES is supported by the following documents:

- Annex 9A: Physical Processes Baseline Assessment;
- Annex 9B: Numerical Model Calibration and Validation Report;
- Annex 9C: Scour Assessment; and
- Annex 9D: Landfall Assessment.

4. This Section includes the following elements:

- Assessment Methodology and Significance Criteria;
- Baseline Description;
- Development Design Mitigation;
- Assessment of Potential Effects;
- Mitigation Measures and Residual Effects;
- Summary of Effects;
- Assessment of Cumulative Effects;
- Statement of Significance; and
- References.

21.1.1 POLICY AND PLANS

5. The following policy, guidance and best practice documents have been considered in the preparation of this physical processes baseline and assessment:

- Offshore wind farms: guidance note for Environmental Impact Assessment in respect of Food and Environmental Protection Act (FEPA) and Coast Protection Act (CPA) requirements (DEFRA, CEFAS and DfT, 2004) (current at the time of reporting, to be updated by the following reference when finalised);
- Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects (CEFAS, 2011);
- Guidance on Environmental Impact Assessment in Relation to Dredging Applications (Office of the Deputy Prime Minister, 2001);
- Nature Conservation Guidance on Offshore Wind Farm Development (DEFRA, 2005);

- Marine Renewable Energy and the Natural Heritage: An Overview and Policy Statement (Scottish Natural Heritage, 2003);
- Coastal Process Modelling for Offshore Wind Farm Environmental Impact Assessment: Best Practice Guidance (COWRIE, 2009);
- Consenting, EIA and HRA Guidance for Marine Renewable Energy Deployments in Scotland (EMEC & Xodus AURORA, 2010); and
- Overarching National Policy Statement for Energy (EN-1) (Department of Energy and Climate Change, 2011).

21.2 ASSESSMENT METHODOLOGY AND SIGNIFICANCE CRITERIA

21.2.1 CONSULTATION

6. Consultations were undertaken through the EIA scoping process. In addition, ABPmer has recently contributed to a similar study in relation to another cable landfall in the Spey Bay area for SHETL. Advice and opinions were provided by MS and SNH during the development of this previous study and have been incorporated into the present one.

Table 21.1 Summary of Consultation Undertaken

Consultee	Summary of Consultation Response	Project Response
MS, SNH, JNCC, RSPB	The effect of the OfTW infrastructure on the extent, distribution, function or structure of designated marine and coastal habitats (SACs and SPAs).	Effects on designated coastal sites are set out in section 21.5.
Maritime and Coastguard Agency (MCA)	Depth of cable burial.	The depth of cable burial will be chosen as part of the cable route design. This Section provides an assessment of the impacts of cable burial and describes the resulting effects if it should become exposed.

21.2.2 SCOPE OF ASSESSMENT

7. Issues relating to the construction, operation and decommissioning of the OfTW were previously considered in the Scoping Report and relevant Scoping Opinion response. The following potential issues were identified through the consultation process.

21.2.2.1 Cable Burial

8. Issues raised included:

- Concern from SNH, JNCC and the RSPB regarding direct or indirect impacts on habitats. However, the temporary and localised nature of any effect is acknowledged; and
- Concerns from the MCA regarding depth of cable burial in relation to navigation and anchoring safety.

21.2.2.2 *Cable Landfall*

9. Issues raised included:

- Concern from SNH, JNCC and the RSPB regarding impacts on the geomorphological features of the Spey Bay SSSI; and
- Onshore jointing bay to be situated sufficiently far landward to avoid the need for coastal defence over the operational lifetime.

21.2.3 GEOGRAPHICAL SCOPE

10. This study considers both local and regional effects of the OfTW. In the context of physical processes, near-field refers to the area adjacent to the cable route where exposed sections of cable or other burial operations may interact directly with the marine environment and cause the greatest magnitude of effect. Far-field refers to areas distant from the cable route where pathways exist for an effect to be translated to a distant sensitive receptor.

11. The geographical scope of the modelling tools used in the present study was also chosen to encompass a sufficiently large area that the baseline environment affecting or interacting with the OfTW route is fully contained within the model domain.

12. The geographical scope of the wider study therefore includes both the Inner and Outer Moray Firth and a large area of the northern North Sea (including the Pentland Firth for tides and the largest open fetches for waves) but is focussed in this section upon the OfTW corridor.

21.2.4 BASELINE SURVEY METHODOLOGY

13. A detailed baseline assessment of the Moray Firth offshore region has been undertaken and is reported in Annex 9A: Physical Processes Baseline Assessment. Further details regarding the particular baseline characteristics of the Spey Bay and landfall may be found in Annex 9A: Physical Processes Baseline Assessment.

21.2.4.1 *Metocean Surveys*

14. A gap analysis of existing data was undertaken to consider the requirements for additional metocean survey. The results of the analysis demonstrated that a sufficient quantity, quality and distribution of previously collected data are available to calibrate and validate regional scale numerical models that were used to further quantify temporal and spatial variability in key metocean parameters. As a result, no new metocean surveys were commissioned along the OfTW route. New metocean survey data have been collected within the footprint of the Wind Farm and Moray Firth Round 3 Zone and are described in Section 9: Wind Farm Physical Processes and Geomorphology.

21.2.4.2 *Geophysical and Geotechnical Surveys*

15. High-resolution multi-beam echo sounder and side-scan-sonar data were collected in June 2011. These data are used to identify surficial bathymetric features and seabed type distribution along the submerged part of the cable route.

21.2.4.3 *Sediment Grab Sample Surveys*

16. Surveys of the seabed comprised 26 grab samples from the cable route and its surroundings. Particle Size Analysis (PSA) of the sediments recovered, in conjunction with the geophysical survey data, informs a quantitative understanding of the distribution of surficial sediment.

21.2.4.4 *Drop-Down Camera Surveys*

17. Drop-down camera images were also collected at 50 locations as part of the seabed survey. These images provide additional qualitative information about fine scale (less than 1 m length scale) sediment type and bedforms along the cable route not resolved by the geophysical survey.

21.2.4.5 *Landfall Site Visit*

18. Photographs and observations collected during various visits over the last three years to the Spey Bay area by members of the ABPmer and BOWL project teams were used to qualitatively inform elements of the baseline understanding and assessment.

21.2.4.6 *Previously Collected or Created Data*

19. Previously collected primary data and other created secondary data were obtained from external sources to inform the wider regional understanding of physical processes in the Moray Firth. In addition to sources referred to in the previous sections, these include the following:

- Regional scale bathymetry data from various sources (UK Hydrographic Office, bathymetry by TCarta, and the General Bathymetric Chart of the Oceans (GEBCO));
- Surge water level and current statistics (from the Proudman Oceanographic Laboratory);
- Statistics of near-surface suspended sediment concentration interpreted from MODIS satellite data archives (Dolphin et al, 2011);
- Assessments of the geological character and history of Smith Bank and the Moray Firth, including inferred patterns of sediment transport (Holmes et al, 2004);
- Seabed PSA data (British Geological Survey (BGS) archives, dates not reported with all samples); and
- Maps of broad surficial sediment type distribution (BGS, 2011).

20. Additional information was also obtained from the following previously undertaken studies and incorporated in to the assessment; more information regarding these may be found in Annex 9A: Physical Processes Baseline Assessment.

- River Spey: Coastal and Estuarial Management, Detailed Investigations (Dobbie and Partners, 1990);
- The geomorphology, conservation and management of the River Spey and Spey Bay SSSIs, Moray (Gemmell et al, 2001);

- Sediment transfer from gravel-bed rivers to beaches (Gemmell, 2000);
- Scottish Natural Heritage Focus on Firths: Coastal Landford, Processes and Management Options 2: Estuaries of the Outer Moray Firth (Hansom and Black, 1994);
- Coastal Cells in Scotland (HR Wallingford, 1997);
- Coastal Cells in Scotland: Cell 3 - Cairnbulg Point to Duncansby Head (Ramsay and Brampton, 2000);
- The Spey Bay Geomorphological Study (Riddell and Fuller, 1995);
- Northeast Scotland Coastal Field Guide and Geographical Essays (Ritchie, 1983); and
- The Beaches of Northeast Scotland (Ritchie et al, 1978).

21.2.5 EFFECT ASSESSMENT METHODOLOGY

21.2.5.1 Worst Case

21. The complete range of options being considered for the OfTW in relation to the Wind Farm development is provided in Section 7: Project Description. In relation to physical processes, the worst cases will vary depending upon the effect in question as listed in Table 21.2.

Table 21.2 Worst Case Scenarios Assessed

Potential Effect	**Worst Case Scenarios Assessed**
OfTW: Construction and Decommissioning Phases	
Increase in suspended sediment concentrations as a result of OfTW installation activities	Trenching by energetic means (e.g. jetting). Single trench with cross-section of disturbance 3 m wide by 2.5 m deep in a 'V' shaped profile. All material is resuspended. Three cable trenches but not simultaneously laid.
Disturbance of coastal morphology at the landfall site	Horizontal Directional Drilling (the only realistic case).
OfTW: Operational Phase	
Scour effects due to the exposure of OfTW and cable protection measures	Exposure of the OfTW cable or the presence of cable protection measures.

21.2.5.2 Numerical Modelling

22. A number of calibrated regional scale numerical modelling tools were created to inform the understanding of the baseline environment in the present study and are described in more detail in a separate report (Annex 9B: Numerical Model Calibration and Validation Report). The modelling tool types developed for use include:

- MIKE 21 HD – tidal model (water level, current speed and direction); and
- MIKE 21 SW – spectral wave model (wave height, period and direction).

23. In relation to the OfTW these models were only used to provide additional information about the spatial variation in tidal current speed, general patterns of

inferred sediment mobility, and to provide a time series of wave data (to obtain typical annual values) representative of the cable landfall.

24. The tidal and wave models utilise a flexible mesh approach (the model domain is divided into a field of interlocking triangles of variable size) so that the near-field is resolved in much higher spatial detail (order 300 m), gradually decreasing with distance from the areas of most interest.

25. These models were developed and applied in accordance with the best practice guidance provided in COWRIE (2009). The design of the models and the levels of calibration and validation achieved are reported in Annex 9B: Numerical Model Calibration and Validation Report. The tidal and wave models achieved a good level of calibration and were validated satisfactorily against the available measured data. These models are therefore considered to be fit for purpose of describing spatial and temporal variability of the parameters of interest within the study area.

26. The tidal and wave model domains both include a large area of the northern North Sea. In the tidal model, this is needed to correctly resolve the progression of the tidal wave, especially through the Pentland Firth which has an important control on the tidal regime near to Smith Bank. In the wave model this is needed to adequately account for the longest fetch lengths, over which the largest waves to affect the cable route are developed.

27. The ability of the numerical models to provide a completely accurate simulation of the hydrodynamic regimes is inherently limited by the quantity and quality of the input data, and the necessary simplifications and assumptions made by the model in comparison to the complete range of real-world complexity and detail. Uncertainty in estimating the baseline water levels, waves and currents is reduced by calibrating, and quantified by validating the model. Best practice guidance in this respect is provided in COWRIE (2009) and has been followed in the present study.

28. A number of other numerical tools (spreadsheet based models) have also been applied in the present study to provide a conservative estimate of the thickness of sediment accumulation or levels of SSC where the effects are localised to a scale smaller than the resolution of the regional models (order 1 to 10s of metres and order of seconds to minutes of effect). The methods and assumptions relating to these analyses are presented where used.

21.2.5.3 Assessment Limitations

29. General limitations of the methods and numerical models used to inform the present study were discussed in Section 9: Wind Farm Physical Processes and Geomorphology.

30. The actual rate and pattern of dispersion of sediments during cable burial is likely to be variable and dependent upon the actual machine used and the local soil properties. However, review documents (e.g. Royal Haskoning and BOMEL, 2008) consistently find that the effect of cable burial (considering a wide variety of situations) is only a localised and temporary effect.

31. Reasonable limitations in the absolute accuracy of the models used to quantify the baseline environment are discussed in Section 21.2.5.2.

21.2.5.4 Significance Criteria

32. The assessment of significance has been made in accordance with the terminology, methods and criteria presented in Section 4: EIA Process and Methodology.

33. The magnitude of any potential effects is assessed on a quantitative basis:

- Relative to the range of baseline natural variability; and
- In terms of its spatial and temporal scales.

34. Where the magnitude of an effect is not predicted to cause the baseline range of natural variability to be exceeded, the effect is considered to be of a low small magnitude and therefore negligible, irrespective of the nature of the receptor. The sensitivity of a receptor to an effect may be determined on the basis of its physical sensitivity to change, but may be modified upwards on the basis of any special designations that may apply.

35. Where the magnitude of an effect is predicted to exceed the baseline range of natural variability, the value, sensitivity or importance of each receptor within the spatial and temporal extent of the effect is also objectively considered, to obtain the corresponding level of significance.

36. Effects which are of moderate or major significance are considered to be significant in terms of the EIA Regulations, whilst effects of minor significance are considered to be not significant in relation to the EIA Regulations.

21.3 BASELINE DESCRIPTION

21.3.1 SMITH BANK

37. The start of the OfTW cable route is located at the exit to the Wind Farm on Smith Bank, a bathymetric high in the Outer Moray Firth, see Figure 1.2.

38. The main body of the bank is relict and stable, comprising bedrock overlain by poorly sorted stiff clay till sediments, with a variably thick veneer of (occasionally shelly) marine sands and gravels. Smith Bank is therefore not a true sand bank and its overall shape is relatively insensitive to changes in sediment transport pathways.

39. Side-scan sonar data indicate a predominance of granular surface sediments across Smith Bank, except in the shallowest parts near the crest, where the underlying till is largely exposed with little sediment veneer. PSA data indicate that surface sediments are typically medium sands (250 to 500 µm diameter) with little (i.e. less than 5%) or no measurable content of fines (less than 63 µm). Typically, less than 3% of sediment volume is classed as gravel (greater than 2 mm). However, in 10% of locations, 10 to 20% of the sediment volume, and in a further 10% of locations, 20 to 30% of the sediment volume, may comprise gravels.

40. Smith Bank is exposed to semi-diurnal tidal forcing. The mean neap tidal range is 1.4 m, the mean spring tidal range is 2.8 m, and the maximum (astronomical) tidal range is 4 m. The tidal current axis is aligned approximately north by north east

(ebb) and south by south west (flood). Peak tidal current speeds over Smith Bank are generally 0.25 ms^{-1} during mean neap tides and 0.50 ms^{-1} during mean spring tides. Instantaneous current speeds are generally slightly higher than average (by order of 5 to 10%) at the northern end of the Wind Farm due to the influence of the Pentland Firth and deeper water, and correspondingly less than average at the southern end. Spatial gradients in tidal current speed result in a weak residual transport directed south-west or south, into the Moray Firth.

41. Non-tidal surges are known to occur in the Moray Firth, caused by the influence of strong winds and atmospheric pressure gradients associated with storms over the North Sea. Non-tidal surges can cause instantaneous water levels to be up to 1 m above or below the predicted value. Tidal surges also induce a surge current, which will be directed into the Moray Firth. The magnitude of this current will vary depending upon the scale and timing of the surge, but an extreme event may modify normal tidal currents by the order of 1 ms^{-1}. In this area the magnitude of surge currents is predicted to decrease rapidly with distance into the Moray Firth and so the north eastern end of the Wind Farm will experience the greatest effects.

42. Other non-tidal effects over the lifetime of the Wind Farm and associated OfTW infrastructure will include the potential for mean sea level rise as a result of climate change, over a nominal 25 year period this is estimated to be 0.08 to 0.14 m, based on a medium emissions scenario as reported by UKCIP (2009).

43. Smith Bank is also exposed to wave action on a regular basis. Winds blowing from directions from south by south east, clockwise through to north, are only able to act upon the water surface over a relatively limited distance (termed the fetch) within the confines of the Moray Firth. Hence waves from these directions are typically limited in height and period, in proportion to the distance from the coastline to the location of interest. Winds and hence waves (but of a limited height) most frequently occur from the south west.

44. Much larger waves are observed to come from other directions that have much longer fetches into the North Sea. Over such long distances, distant storms can also drive long period swell waves into the Moray Firth that do not necessarily rely on further local wind input. Key extreme significant wave height (Hs) statistics are provided in Table 21.3.

Table 21.3 Extreme Significant Wave Heights (Hs) for Location 58.25° N 2.86° W

Sector	Coming Direction (°N)	Return Period – Hs (m)			
		1 in 1 yr	1 in 10 yr	1 in 50 yr	1 in 100 yr
N	337.5 to 22.5	6.3	7.2	7.6	7.9
NE	22.5 to 67.5	6.7	8.0	8.9	9.2
E	67.5 to 112.5	6.7	7.5	8.0	8.2
SE	112.5 to 157.5	6.3	7.1	7.6	7.9
S	157.5 to 202.5	4.6	6.0	6.7	7.0
SW	202.5 to 247.5	4.9	5.8	6.4	6.6
W	247.5 to 292.5	4.7	5.6	6.2	6.4
NW	292.5 to 337.5	4.1	5.0	5.5	5.6
Maximum Hs (m)		6.7	8.0	8.9	9.2

45. Based on a theoretical assessment of sediment transport potential using relationships described in Soulsby (1997), tidal currents alone are largely insufficient to mobilise the main body of the marine (medium) sands, except around peak current periods on mean spring range tides or larger (current speeds greater than 0.45 to 0.5 ms^{-1}). The predicted transport rates due to currents alone are in the order of 10^{-7} to 10^{-6} m^{3}m^{-1}s^{-1}. A small proportion of finer sands present may be relatively more mobile; gravels will however remain immobile under the full normal range of tidal currents. Evidence of weakly mobile (poorly defined), current induced (asymmetrically crested) bedforms was observed in some of the drop-down camera images; however, no consistent modulation in the measured Suspended Sediment Concentration (SSC), which would be indicative of more energetic sand transport or resuspension of fines, was observed in correlation with semi-diurnal or spring-neap tidal cycles.

46. Evidence of wave induced (symmetrical and long crested) bedforms was also observed in some of the drop-down camera images. Modulation in measured SSC (indicative of more energetic sand transport or resuspension of fines) was observed to correlate with frequently occurring storm events (approximately greater than 4 m Hs, i.e. more frequent that a 10 in 1 year event). In the absence of currents, waves do not result in significant net sediment transport. In conjunction with the typical range of currents present, commonly occurring and extreme waves can theoretically increase the rate of potential sediment transport by one to three orders of magnitude (order of 10^{-6} to 10^{-4} m^{3}m^{-1}s^{-1}).

47. A conceptual model of sediment transport through the region is that sediments (mostly shelly carbonates) are generally moving from the Pentland Firth into the Moray Firth, parallel to the Caithness coastline and along the coastal margins (Reid and McManus, 1987; Ramsey and Brampton, 2000). Most sediment transport likely occurs in pulses associated with (relatively frequent) storm events, although a very weak background transport rate may be associated with stronger (e.g. peak spring) tidal currents. In the absence of surge effects, the resulting direction of sediment transport is determined by the direction of the tidal current at the time (bi-

directional and aligned to the tidal axis but with a weak residual directed into the Moray Firth). During larger storms, surge effects will both increase the transport rate and cause the transport to be more consistently directed into the Moray Firth.

48. Levels of SSC are typically low (less than 4 mgl^{-1}) both nearbed and in the upper water column during periods of calm weather (i.e. due to tidal currents alone). However, more energetic resuspension of sediments during storms, as described above, is observed to increase levels of SSC up to the order of 100s to low 1000s of mgl^{-1} at approximately 1 m above the bed. This is in agreement with theoretical relationships predicting profiles of SSC, which also indicate levels in the order of 1000s of mgl^{-1} near to the bed and order 10s of mgl^{-1} higher in the water column (more likely associated with finer sediment fractions).

21.3.2 OUTER MORAY FIRTH

49. From the Wind Farm, the middle section of the OfTW cable route will also pass through central parts of the Outer Moray Firth, see Figure 1.2.

50. Water depths in this region vary from 50 m CD at the edge of Smith Bank to 100 m CD in a deepwater channel that runs parallel to the southern Moray Firth coastline. Water depths shoal then gradually to the shoreline and cable landfall in Spey Bay.

51. Seabed sediments in this area are broadly characterised as sandy or gravelly sandy material. The grain size of the sand fractions is generally finer than on Smith Bank (63 to 125 µm diameter). The proportion of fines (less than 63 µm diameter) is also elevated (up to 50%) in the deeper parts of the cable route and in the central Outer Moray Firth where current speeds are lower and water depths are greater, preventing wave action from penetrating to the bed so energetically or frequently.

52. The tidal water level regime is similar to that described for Smith Bank (see Section 21.3.1). The progression of the tidal wave through the Moray Firth causes central parts to experience a relatively high degree of tidal rotation through the tidal cycle (i.e. the tidal axis is not well defined). Some areas towards the southern margins of the route will experience extended periods of very low current speed or slack water. Divergent patterns of tidal flow on the south coast in the vicinity of Spey Bay also result in asymmetry of current speed and flood/ebb duration. Flow is asymmetrically biased towards the east (out of the Moray Firth) in the vicinity of Spey Bay. Peak mean spring current speeds in these areas are in the region of 0.2 to 0.35 ms^{-1}. Peak mean neap current speeds will be approximately half the corresponding spring value.

53. The wave regime in central parts of the Moray Firth will vary with distance along the route, in proportion to the fetch length available for wave development from each direction. The largest waves to affect the route will come from offshore sectors and will be similar to or perhaps slightly smaller than that described previously for Smith Bank.

54. The relatively low current speeds are not sufficient to frequently transport significant quantities of the sediment types present in many central parts of the route. Wave action is also less likely to penetrate to the seabed in deeper parts of the route; however, some wave induced (symmetrically crested) bedforms were

observed in the drop-down camera images at shallower sites. On the basis of estimates of theoretical sediment mobility, the seabed in parts of the route less than 60 to 70 m deep is considered largely immobile except perhaps during exceptional storm events.

55. In the shallower waters near to the southern end of the route, wave action will contribute to higher rates of sediment transport, which will be directed east, out of the Moray Firth, due to the underlying tidal asymmetry.

56. The relatively low mobility of sediments in the central part of the route also suggests that nearbed SSC will not be particularly variable in response to the tidal or wave regimes. In this case, background values of the order 1 to 10 mgl^{-1} might be expected throughout the water column. Deeper areas within one tidal excursion of areas sufficiently shallow to experience sediment resuspension due to waves may experience a general increase in SSC (order 10s of mgl^{-1}) due to advection of sediment resuspended elsewhere. Shallower areas (e.g. close to Spey Bay) may experience levels of SSC equivalent to that described for Smith Bank (100s to 1000s mgl^{-1} nearbed during storms, decreasing to 10s mgl^{-1} in the upper water column).

21.3.3 SPEY BAY SSSI

57. The end of the OfTW cable route is located in Spey Bay on the central southern coastline of the Outer Moray Firth.

58. The proposed BOWL OfTW landfall (see Section 7: Project Description) is located to the west of Portgordon, a small village some 2 km from Buckie on the southern Moray Firth coastline, see Figure 1.2.

59. The coastline at this general location is orientated west by north west to east by south east. 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.

60. Immediately to the west of the harbour the village is fronted by a 3 m high concrete seawall, a 12 to 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.

61. 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 (the geomorphological feature covered by the SSSI designation) 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.

62. 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. Ritchie (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.

63. 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, cusps and ridges of different wavelengths are apparent and the shingle ridge is clearly present but variable in height (approximately 1 to 2 m).

64. West of the Tynet burn 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.

65. 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 to a golf course). Fans are more obviously apparent to the west of the Tynet Burn.

21.4 DEVELOPMENT DESIGN MITIGATION

66. Mitigation of effects on the physical environment has been embedded into the design of the cable landfall operation by excluding the possibility of open trenching through the intertidal zone, in favour of a subterranean directional drilling process.

21.5 ASSESSMENT OF POTENTIAL EFFECTS

67. This Section considers the effect of the OfTW on the identified physical process receptors during the construction, operation and decommissioning phases of development.

21.5.1 CONSTRUCTION PHASE: INCREASE IN SUSPENDED SEDIMENT CONCENTRATIONS AND DEPOSITION OF SEDIMENTS

21.5.1.1 Smith Bank and other Coastal Habitats in the Outer Moray Firth

68. An increase in SSC may affect the form and function of Smith Bank or other identified coastal habitats if the modified condition falls outside of the baseline range of natural variability. The feature of the physical receptor at risk of modification is the level of SSC.

69. An accumulation of sediment may also affect the form and function of Smith Bank if the modified condition falls outside of the baseline range of natural variability. The features of the physical receptors at risk of modification are the short term rate of sediment deposition, the nature of sediment deposits and net changes in total water depth.

70. The effects of the expected increase in SSC and sediment accumulation have been assessed separately by other EIA topics in relation to other sensitive receptors e.g. Section 22: OfTW Benthic Ecology, Section 26: OfTW Marine Archaeology and Cultural Heritage and Section 28: OfTW Shipping and Navigation.

71. The following assessment presents worst case scenarios for energetic sediment release, expressed per metre of trench length.

72. The maximum subsurface trench dimensions for all proposed burial methods are 3 m wide by 2.5 m deep in a 'V' shaped profile, resulting in 3.75 m^3m^{-1} sediment disturbance. It is assumed that 100% of the wet material disturbed will be ejected from the trench. The porosity of the material is conservatively estimated as 20% void resulting in 3 m^3m^{-1} sediment release. The sediment is likely to be quartz mineral with a density of 2,650 kgm - 3 resulting in 7950 kgm - 1 sediment release.

73. The resulting levels of SSC depend upon the volume of water into which this sediment volume is mixed (which is in turn dependent upon the height of sediment ejection, the settling rate of the sediment and the ambient current speed). A range of possible outcomes are given in Tables 21.4 to Table 21.6.

74. The resulting thickness of sediment deposition depends upon the area of seabed over which this sediment volume is deposited (also dependent upon the height of sediment ejection, the settling rate of the sediment and the ambient current speed). A range of possible outcomes are given in Table 21.4 to Table 21.6.

75. The elevation to which the sediment might be ejected is not known with certainty and may vary between burial methodologies, sediment types and the nature of the hydrodynamic regime at the time of the release. A lower height of ejection will result in a higher level of SSC and thickness of deposition but with a smaller footprint of effect, and vice versa.

76. Along the OfTW route the dominant grain sizes present that are susceptible to resuspension through cable installation include gravels, medium sands and finer material in variable proportions. The representative settling velocities of these grain sizes are approximated as 0.5, 0.05 and 0.0001 ms^{-1}, respectively. The typical peak tidal current speed is 0.5 ms^{-1} on mean spring tides and 0.25 ms^{-1} on mean neap tides. Current speeds are less than the peak value for most of the tidal cycle. With regards to resulting levels of SSC, a lower flow speed will disperse sediment at a lower rate, providing a more conservative estimate of effects. The value 0.25 ms^{-1} is used here as a condition conservatively representative of most normal states of flow during individual tides and over the spring-neap cycle.

77. These values are applied in Table 21.4 to Table 21.6 to quantify the total effect adjacent to the trench for gravels, sands and fine sediments. The tables assume that the total mass of sediment (7,950 kg from the one metre long trench section) is resuspended evenly up to a variable ejection height. The time required for sediment to settle at the specified rate through the total height of ejection is calculated to yield the duration of the effect. The length scale of the effect is the furthest distance travelled by the plume (downstream), found as the product of the ambient current speed (0.25 ms^{-1}) and the duration of the effect. The estimate of mean SSC is found by dividing the total mass of sediment by the volume of the triangular wedge of water through which the sediment will settle ([ejection height x downstream distance] ÷ 2). The average thickness of any resulting seabed deposit

is found by dividing the total volume of sediment (3 m^3) by the footprint (length scale of the effect x 1 m).

78. The calculated effect shown in the tables is representative of the conditions expected downstream of the nominal one metre trench section. As the trenching machine moves forward along the route, so also will the effect arising from subsequent sections of the trench. It is noted that the tidal axis is perpendicular or very oblique to the cable route along most of its length, most of the time. The speed of cable burial along the route may vary depending on soil conditions and the machine used. Differences in rate will determine the area of seabed affected at any given time, but the predicted duration and length scales of effect, levels of SSC and thicknesses of deposit will remain unchanged.

Table 21.4 Extent and Magnitude of Effect of OfTW Trenching in Gravels (settling velocity 0.5 ms-1)

Ejection Height (m)	Duration of Effect (s)	Length Scale of Effect (m)	Indicative Mean SSC (mgl^{-1})	Average Thickness of Deposit (m)
1	2	1	31,800,000	2.7*
5	10	3	1,272,000	1.2
10	20	5	318,000	0.6
25	50	13	50,880	0.24

* Maximum thickness – constrained by stable slope angle

Table 21.5 Extent and Magnitude of Effect of OfTW Trenching in Medium Sands (settling velocity 0.05 ms-1)

Ejection Height (m)	Duration of Effect (s)	Length Scale of Effect (m)	Indicative Mean SSC (mgl^{-1})	Average Thickness of Deposit (m)
1	20	5	3,180,000	0.600
5	100	25	127,200	0.120
10	200	50	31,800	0.060
25	500	125	5,088	0.024

Table 21.6 Extent and Magnitude of Effect of OfTW Trenching in Fine Sediments (settling velocity 0.0001 ms-1)

Ejection Height (m)	Duration of Effect (s)	Length Scale of Effect (m)	Indicative Mean SSC (mgl^{-1})	Average Thickness of Deposit (m)*
1	10,000	2,500	6,360	0.001
5	50,000	12,500	254	<0.001
10	100,000	25,000	64	<0.001
25	250,000	62,500	10	<0.001

79. Cable installation in gravels or generally coarser sediments will have only very localised effects as material will be almost instantly deposited and therefore any

effect will be confined to within a very small distance of the cable route (order of metres).

80. Cable installation in sandy material will have a relatively high magnitude effect on suspended sediment concentration (elevated to order 1000s to 100,000s mgl^{-1}). The effect will however be short term (order seconds to minutes) and will be largely localised to the cable installation location (main effect within 10s of meters). Once redeposited, resuspended sediment will join the natural sedimentary environment and ceases to present any further effect. The resulting local thickness of accumulation in the area of effect is estimated to be of the order 0.05 to 0.5 m (depending up on the height of ejection and the current speed).

81. Cable installation in finer materials will also have a generally relatively high magnitude effect on suspended sediment concentration once the effects are initially dispersed (elevated to order 10s to 1,000s mgl^{-1}). The effect will persist for longer than for sands but are still short term (order of minutes to a few hours) and will be more disperse (main effect within 100s to 1000s of meters, up to one tidal excursion distance). Once redeposited, resuspended sediment will join the natural sedimentary environment and ceases to present any further effect. The resulting local thickness of accumulation is estimated to be less than 0.001 m under most circumstances.

82. A lower height of ejection will result in a relatively higher level of SSC and thickness of deposition, especially in conjunction with lower current speeds. However, the effect will also be contained within a smaller footprint and last for a shorter time.

83. Conversely, a greater height of ejection will result in relatively greater dispersion and a lower level of SSC and a smaller thickness of deposition, especially in conjunction with higher current speeds. However, the effect will also then be spread over a larger footprint and last for a longer time.

84. The purpose of cable burial is to achieve a certain depth of burial and thickness of sediment cover over the cable. The machines employed for this task are therefore designed to retain as much sediment in the trench profile as possible. The volume of sediment resuspension (and hence the effects on SSC and subsequent deposition thickness) will therefore be inherently minimised by these machines and further by application of best practice in their usage.

85. The effects of cable burial on SSC are of a magnitude potentially in excess of the natural range of variability. However, the effect will be localised and temporary. The findings in this assessment are consistent with the evidence base of guidance and observations relating to such activities (e.g. Royal Haskoning and BOMEL, 2008; COWRIE, 2010).

86. A small to medium magnitude of change that may locally and temporarily exceed the range of natural variability is therefore assessed to arise in an area of low sensitivity, resulting in a negative effect of minor significance which is therefore not significant in terms of the EIA Regulations.

21.5.2 CONSTRUCTION PHASE: DISTURBANCE OF COASTAL MORPHOLOGY AT THE LANDFALL SITE

87. Once the cables reach landfall, HDD works will be used to create an underground conduit for each cable between the offshore and onshore parts of the route (see Section 7: Project Description). This method has historically shown to cause minimal direct disturbance to the existing coastline and, if correctly designed, will also not leave any infrastructure exposed in the active parts of the beach (onshore or offshore) and so will not affect littoral processes.

88. Further details regarding the physical baseline environment of the landfall site and the assessment of the depth of closure and rate of coastal retreat are provided in Annex 9A: Physical Processes Baseline Assessment.

89. A quantitative assessment, using the method of Hallermeier (1981) and based on the sediment types present and the typical intra-annual wave regime at the landfall location (derived from the wave model), indicates that the beach closure depth is in the order of 6 m. It is conservatively assumed that this depth is relative to the Lowest Astronomical Tidal (LAT) water level. This value is also in agreement with the value for a location to the west of the mouth of the Spey quoted by Gemmell *et al* (2001), calculated using an alternative method for the purposes of general coastal processes understanding.

90. 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 will be verified with MS. The design of any alternative protection (pending further detailed engineering design works) will aim to minimise effects on sediment transport patterns and ultimately ensure that the protected features of the SSSI will not be adversely affected by the works.

91. Climate change will lead to mean sea level rise and so will not affect the location chosen on the basis of present day bathymetry and water depths.

92. Previous studies also indicate that the body of gravel comprising the beach is naturally reducing in volume and retreating slowly over relatively long time scales (Gemmell et al, 2001). The present average rate of coastal retreat in the vicinity of the landfall has been estimated as 0.64 m per year on the basis of a comparison of Mean Low Water Spring boundaries between successive historical shoreline maps. This equates to a projected total rollback of 16 m over a 25 year period. To take account of uncertainty in the actual potential lifetime of the installation and future rates (including the potential additional effects of climate change) it is therefore conservatively recommended that the onshore end of the HDD should be located at least 50 m behind the present MWHS mark.

93. The HDD will not have any effect on water quality in the vicinity of the receptor as drill arisings will be captured at the onshore end of the HDD route.

94. A negligible magnitude of change is therefore assessed to arise in an area of high sensitivity. The resulting effect is therefore not significant in terms of the EIA Regulations.

21.5.3 OPERATION PHASE: INTRODUCTION OF SCOUR EFFECTS DUE TO EXPOSURE OF OFTW AND CABLE PROTECTION MEASURES

21.5.3.1 Scour Effects

95. Structures introduced into the marine environment and located near to the seabed will interact with the naturally present hydrodynamic and sedimentary regimes, resulting in the potential for sediment scour to occur. The removal of sediment from underneath a section of cable exposed on the seabed can lead to free-spanning (an engineering risk) and further sediment erosion (an environmental effect) due to flow contraction under the exposed section. Exposed cables are also at greater risk of physical damage and will require further intervention to rebury or protect them. Exposure and scour is primarily an engineering risk, often mitigated using cable burial and scour protection.

96. The aim is that cables will be buried where seabed conditions allow. Where seabed conditions do not allow for adequate burial, cables will be surface laid and protected with other means.

97. According to generic information provided in Royal Haskoning and BOMEL (2008), the OfTW cable diameter is likely to be in the order of 0.1 to 0.3 m and the weight of the cable in excess of 30 kgm^{-1}.

98. Whitehouse (1998) summarises various studies that provide empirical estimates of equilibrium scour depth underneath pipelines (similar in principle to cables). The predicted scour depth in all cases is primarily dependent upon the diameter of the cable. It is also noted that the cable must be significantly exposed for scour to occur and that an oblique orientation of the cable to the ambient tidal or wave forcing will also reduce the predicted effect.

99. Should the cable be or become exposed, it may cause scouring of the underlying sediments. If the cable is taut or stiff, sections of the cable might become elevated relative to the lowered bed level. If the cable is not taut or stiff, then it will sag to remain in contact with the seabed, irrespective of how much scour occurs. This has been previously observed to lead to self burial of pipelines due to sediment migration into the depression created that partially buries the obstruction, causing further scour to cease and allowing ambient sediment transport to refill the scour depression. Given the weight of the cable, if exposed it will not be moved on the seabed by either the naturally present tidal or wave regimes.

100. From Whitehouse (1997), a conservative estimate for all cases (current, wave or combined scour) is that the maximum depth of scour will be between one and three times the cable diameter (i.e. 0.1 to 0.9 m) and the maximum horizontal extent of any scour effect will be up to fifty times the cable diameter (i.e. 5 to 15 m). As such, any depression created will not necessarily be steeply sided. In predominantly sandy areas, the surface of the scour pit will be of similar character to the ambient bed. In more gravelly areas, a gravel lag veneer may initially form as finer sands

are preferentially winnowed, but may then become buried by predominantly sandy material following recovery of the seabed if self burial of the cable occurs.

101. The effects of scour potentially resulting from the exposure of cables are considered to be of a small magnitude relative to the range of naturally occurring variability. Effects will also be localised to the cable route. The findings in this assessment are consistent with the evidence base of guidance and observations relating to such activities (e.g. Royal Haskoning and BOMEL, 2008; COWRIE, 2010).

102. A small magnitude of change that does not exceed the range of natural variability is therefore assessed to arise in an area of low sensitivity, resulting in a negative effect of negligible significance which is therefore not significant in terms of the EIA Regulations.

21.5.3.2 Effect of Cable Protection Measures

103. Protection measures that might be deployed onto unburied sections of cable may take various forms including combinations of:

- Rock placement;
- Geo-textile or frond matting;
- Concrete mattresses; and
- Gabions.

104. Although the effects of scouring are assessed as not significant, scour protection measures are used to mitigate the engineering risk posed by scour and exposure of the cable to external causes of damage. Where used, the measures will prevent scour from developing around the cable; however, the area occupied by the scour protection might also be similarly considered as a modification to the sedimentary environment and may cause a more limited depth and area of secondary scour to develop.

105. There is insufficient information available to accurately quantify the effect of all possible designs of protection measure, which may vary greatly in detail and scale even amongst the four general types named here. On the basis of information contained in Section 7: Project Description it is unlikely that the thickness of the protection will be significantly greater than 0.5m. Therefore, the combined elevation of the cable and protection may be in the order of 1 m. The extent of the protection material will be in the order of 3 m from the cable route.

106. Following installation and where sediment transport is likely to occur, an initial period of sediment accumulation (order of 0.1 to 0.2 m^3m^{-1}) might occur to create a smooth slope. Such sediment transport is more likely to occur in areas of non-cohesive sediment (i.e. sands) in shallower water depths along the route, i.e. near to Wind Farm and near to the landfall.

107. Based on the typical rates of sediment transport in these areas (10^{-6} to 10^{-5} $m^3m^{-1}s^{-1}$) estimated on the basis of the regional wave and tidal regimes, this process may take place in the order of 3 to 50 hours of storm activity, i.e. a few months or less) in water depths up to 50 m. However, in other deeper parts of the route where wave

action penetrates to the bed both less frequently and to a lower magnitude, transport rates will be lower and such accumulation will take considerably longer.

108. The slope angle presented by sections of protected cable would be in the order of 18˚ (a 1:3 slope) which is within the natural range of bed slope angles associated with bed forms and so will not affect patterns of sediment transport following the initial period of accumulation.

109. Where the local sediments are either generally immobile or more cohesive in nature, conditions may not be favourable for sediment accumulation. Where this is due to very low transport rates (e.g. in the central part of the Outer Moray Firth), the presence or absence of an obstacle will therefore not cause any further effect.

110. Where scour protection materials are used, depending on the design, the materials may create turbulence and secondary scour (already considered elsewhere in this Section). The action of scour on the upstream side of the cable will be to actively resuspend and transport sediment over the obstacle, again therefore not causing any effect on sediment transport.

111. The effects of cable protection measures are considered to be of a small magnitude relative to the range of naturally occurring variability and will not have a measurable effect on sediment transport beyond a short to medium term period of initial adjustment. Effects on morphology or sediment surface texture will be localised to the cable route.

112. A small magnitude of change that does not exceed the range of natural variability is therefore assessed to arise in an area of low sensitivity, resulting in a negative effect of negligible significance which is therefore not significant in terms of the EIA Regulations.

21.5.4 DECOMMISSIONING PHASE

113. Effects during the decommissioning phase are predicted to be similar in nature, although no greater in magnitude than those arising during the construction phase.

21.6 MITIGATION MEASURES AND RESIDUAL EFFECTS

21.6.1 SCOUR EFFECTS

114. The assessment in relation to scour around exposed cables is based on a 'worst-case' scenario that no scour protection is provided, at least for a sufficiently long time that maximum scour will develop. As a matter of standard engineering practice, the project's detailed engineering design will consider whether scour protection should be applied as part of the initial installation. The development of any scour will also be monitored post construction and scour protection will be installed if required.

115. Section 7: Project Description describes a variety of types and dimensions of scour protection that will likely be installed in conjunction with cables either as they exit substations or where they are otherwise exposed along their route. Scour protection may be considered an engineering necessity to ensure long-term stability of the structures. Where scour protection is adequately designed and applied,

scour associated with the object being protected will be absent. However, secondary scour (associated with the scour protection materials themselves) may occur at a smaller scale (in proportion to the dimensions of the protection material).

116. The extent of the protection must be sufficiently large to afford the desired protection (of a similar length scale to the extent of scour reported). The design of the scour protection will take into account the transition from the scour protection to the natural seabed to minimise secondary scouring.

117. The dimensions of secondary scour will be highly variable depending upon the type and design of scour protection chosen, but will be much smaller in volume and extent (in proportion to the much smaller dimensions of the obstacle presented to the flow) than that described in relation to scour around an unprotected structure.

118. The effect of scour prior to the installation of scour protection material was found to be not significant in Section 21.5.3. The residual effect of scour following the installation of scour protection material remains negligible and therefore not significant in terms of the EIA Regulations.

21.7 MONITORING AND ENHANCEMENTS

21.7.1 SCOUR EFFECTS

119. Visual and/or bathymetric surveys will be undertaken pre- and post-construction along part or all of the OfTW route and these surveys compared to assess the success of cable burial or the degree (area, depth and volume of sediment displaced) of scour around exposed or protected sections. Subsequent surveys may then be planned depending on the results of this initial monitoring schedule. In terms of timescales, selected areas will be surveyed prior to and post construction

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120. Visual and/or bathymetric surveys will be undertaken pre- and post-construction at the offshore exit point of the HDD and these surveys compared to assess the success of cable burial or the degree (area, depth and volume of sediment displaced) of scour around exposed or protected sections. Subsequent surveys may then be planned depending on the results of this initial monitoring schedule. In terms of timescales, selected areas will be surveyed prior to and post construction.

121. Visual and/or topographic surveys will be undertaken pre- and post-construction between the onshore jointing bay and an adjacent point on the beach around or below MLWS. These surveys will be compared to monitor the actual (naturally occurring) rates of beach morphological change and retreat. Provided that the offshore surveys demonstrate that the cable is not exposed and causing an interruption of sediment transport onshore of the 6 m CD contour, any changes observed will be due to natural processes and not attributable to the presence of the cable. In terms of timescales, selected areas will be surveyed prior to and post construction.

Table 21.7 Summary of Effects

Residual Effect	**Sensitivity of Receptor**	**Magnitude of Effect**	**Nature**	**Effect**
OfTW: Construction and Decommissioning Phases				
Smith Bank and other Designated Coastal Habitats – Increase in suspended sediment concentrations and deposition of sediments as a result of OfTW installation activities	Low	Small to medium	Negative	Minor (not significant)
Disturbance of coastal morphology at the landfall site	High	Negligible	Negative	Negligible (not significant)
OfTW: Operational Phase				
Smith Bank and other Designated Coastal Habitats – Scour effects due to the exposure of OfTW and cable protection measures	Low	Small	Negative	Negligible (not significant)

21.8 ASSESSMENT OF CUMULATIVE EFFECTS

122. Cumulative, in-combination and inter-relating effects are considered in the Wind Farm Section 9: Wind Farm Physical Processes and Geomorphology. No further consideration of such effects is required here.

21.9 STATEMENT OF SIGNIFICANCE

21.9.1 SMITH BANK AND THE OUTER MORAY FIRTH

123. Smith Bank and parts of the central Outer Moray Firth along the cable route may experience localised and temporary modification to levels of SSC in the lower water column during construction and decommissioning, which may exceed the normal range of natural variability.

124. Sandy or coarser sediments released during cable burial activities may accumulate locally to the cable route to a thickness (order of millimetres to a few centimetres) that may exceed the normal (short term) range of natural variability in seabed level but will not change the surficial sediment character.

125. Fine sediments resuspended will likely be more widely dispersed resulting in a more extensive but low level effect on SSC, but will not accumulate in any measurable thickness (i.e. less than 0.001 m).

126. In the unexpected event of cable exposure at the seabed surface, localised scouring might occur (order of tens of centimetres to one metre) with a mild slope to the ambient seabed. Due to its weight, the cable is unlikely to be moved if exposed.

Cable protection measures if and where used will not pose an obstruction to sediment transport, once established in the early stages of the operational phase.

127. On the basis of the assessment provided in this Section and as detailed in Table 21.7, the effects described above are not significant in terms of the EIA Regulations.

21.9.2 SPEY BAY SSSI

128. No measurable effect on the Spey Bay SSSI features are predicted, provided that the HDD is initiated further than 50 m landward of the MWHS mark (see paragraph 90) and the cable is suitably buried to avoid direct effects. In doing so, the cable will have no physical presence in the active part of the beach system during its operational lifetime, thus also avoiding the potential for the development of any scour.

129. On the basis of the assessment provided in this Section and as detailed in Table 21.7, the effects described above and any effects on the SSSI are not significant in terms of the EIA Regulations.

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