3 Physical Environment (Offshore)

3.1 Bathymetry

3.1.1 Introduction

3.1.1.1 This chapter provides a summary characterisation of the bathymetry of the three proposed wind farm sites and offshore transmission infrastructure (OfTI) and its regional setting. A more detailed description may be found in the supporting technical appendix: Metocean and Coastal Processes (Technical Appendix 3.4 A, ABPmer, 2011a).

3.1.1.2 This baseline is used to inform the following impact assessments:

- Chapter 6.1 (Hydrodynamics);
- Chapter 6.2 (Sedimentary and Coastal Processes);
- Chapter 9.1 (Hydrodynamics);
- Chapter 9.2 (Sedimentary and Coastal Processes);
- Chapter 13.1 (Hydrodynamics); and
- Chapter 13.2 (Sedimentary and Coastal Processes).

3.1.1.3 This baseline and the associated impact assessments, described above, are also used to inform the following assessments:

- Chapter 7.1 (Benthic Ecology);
- Chapter 7.2 (Fish and Shellfish Ecology);
- Chapter 8.5 (Archaeology and Visual Receptors);
- Chapter 10.1 (Benthic Ecology);
- Chapter 10.2 (Fish and Shellfish Ecology);
- Chapter 11.5 (Archaeology and Visual Receptors);
- Chapter 14.1 (Benthic Ecology);
- Chapter 14.2 (Fish and Shellfish Ecology); and
- Chapter 15.5 (Archaeology and Visual Receptors).

3.1.1.4 This chapter comprises the following:

- Consultation with relevant statutory bodies;
- Detailed desk study and accompanying field survey to establish baseline conditions; and
- Consideration of the relevant key legislative and planning information.

3.1.2 Consultations

3.1.2.1 During the scoping consultations (described in more detail in Chapter 1.3: Environmental Impact Assessment), methodologies and data sources were proposed to inform the baseline understanding of the hydrodynamic and sedimentary environments. The suggested methods included the use of previously collected and new field data, numerical modelling, desktop assessments and reference to previous studies. Table 3.1-1 below summarises specific comments made during the scoping process. No specific comments were made regarding the development of a physical environmental baseline.

Table 3.1-1 Consultation Undertaken and Responses

Organisation	Consultation Response	MORL Approach
Marine Scotland	Concern regarding impacts of offshore export cable burial on local (inc. intertidal mudflat) habitats. However, temporary and localised nature of any effect is acknowledged. Cumulative / in-combination effects should be considered.	Assessed in Chapter 6.2, Chapter 9.2 and 13.2. A methodology statement for assessment of cumulative and in-combination impacts in relation to physical processes was submitted to Marine Scotland. The methodology was found to be suitable for the intended purpose and is reflected in the work presented in this Environmental Statement (ES).
SNH / JNCC / RSPB.	Impacts upon hydrodynamic and sedimentary regimes affecting the extent, distribution, function or structure of marine and coastal habitats (Special Areas of Conservation (SACs) and Special Protection Areas (SPAs), especially the East Caithness Cliffs SPA. Cumulative / in-combination effects should be considered.	Assessed in Chapter 6.1 and 6.2, Chapter 9.1 and 9.2 and Chapter 13.1 and 13.2. Chapter 12.2 also provides a Habitat Regulations Appraisal Summary.
Historic Scotland.	Impacts upon sedimentary regimes affecting sites of potential archaeological interest.	Effects on Archaeological and Visual Receptors assessed in Chapter 8.5, Chapter 11.5 and Chapter 15.5.
MCA / RYA / Ports and Harbours	Changes in the set and rate of the tidal stream and for changes in sediment mobility that might affect navigable water depth. Ref MCA guidance MGN371 (MCA, 2008). Concerns regarding depth of cable burial. Cumulative / in-combination effects should be considered.	Assessed in Chapter 6.1 and 6.2, Chapter 9.1 and 9.2 and Chapter 13.1 and 13.2.

3.1.3 Offshore Generating Station and Transmission Infrastructure Baseline Characteristics

Desktop Studies

3.1.3.1 In order to characterise the site specific and regional bathymetry of the study area (see Figure 3.1-1, Volume 6 a) various data sources were used, namely:

- Navigational charts;
- Digital bathymetry data sets, including:
  - Coarse resolution large scale data sets (e.g. digital charts or General Bathymetric Chart of the Oceans (GEBCO) data);
  - Medium resolution digital survey bathymetry (available from the UK Hydrographic Office, UKHO); and
  - High resolution swath bathymetry (available from the UKHO).
- Previous publications describing gross and fine scale bathymetric features (e.g. Andrews *et al.,* (1990), Holmes *et al.,* (2004)); and
- Statistics of mean sea level rise as a result of climate change (UKCIP09).

3.1.3.2 These data show that the three proposed wind farm sites encompass part of the summit and the eastern flank of Smith Bank, a morphological high point in the Outer Moray Firth measuring, approximately, 35 km long from south-west to northeast, and 20 km wide (295 km^2). Water depths in this area range from approximately 35 to 55 mCD (below Chart Datum), with the greatest depths found along the south-eastern margin of the site. Smith Bank is separated from the Caithness coast to the north by a relatively deep channel (up to approximately 75 mCD).

3.1.3.3 Other sedimentary features smaller than Smith Bank are also present in the central parts of the Outer Moray Firth. The southern part of the Outer Moray Firth is characterised by a long deep channel feature (the Southern Trench) which is up to approximately 220 mCD.

3.1.3.4 Official estimates of the effects of global climate change suggest that by 2050, relative sea level in the Moray Firth will have risen between 0.22 and 0.35 m above 1990 levels. This will be apparent as an increase in water depth (bathymetric depth) below the relevant vertical datums (e.g. lowest astronomical tide).

Bathymetric Survey of the Zone

3.1.3.5 A high resolution swath bathymetry survey of the three proposed wind farm sites was undertaken between May and September 2010 and is shown in Figure 3.1-2, Volume 6 a. The survey provides 100 % data coverage within the EDA, including the three proposed wind farm sites and a small (less than 100 m) buffer area outside of the EDA. The WDA was also surveyed at approximately 20 % coverage in a coarse but regular grid.

3.1.3.6 The gross scale morphology of the part of Smith Bank surveyed is consistent with the desktop study data sources listed above.

3.1.3.7 This survey additionally reveals the presence of relict sand wave features to the north of the wind farm sites and sharp edged sand patch features near to the crest of Smith Bank.

Bathymetric Survey of the Offshore Export Cable Route

3.1.3.8 A high resolution swath bathymetry survey of the offshore export cable route was undertaken in July to September 2011. The survey area includes a broad corridor (varying in width with the water depth) along the whole of the proposed export cable route.

3.1.3.9 The gross scale morphology of the part of the Moray Firth surveyed is consistent with the desktop study data sources listed above.

3.1.4 Individual Site Baseline Characteristics

3.1.4.1 Table 3.1-2 below provides further site specific information for each of the wind farms. In each case, local crests and ridges are also present as shown in the figures of the accompanying appendix (Technical Appendix 3.4 A).

Table 3.1-2 Bathymetric Characteristics of the Individual Sites

Individual Wind Farm Sites	Summary of Baseline Characteristics	Relevant Figures for Each Site
Telford	Maximum water depth 57 mCD, minimum water depth 39 mCD. Generally shoaling from northeast to southwest towards the crest of Smith Bank.	Figure 3.2-1, Volume 6 a
Stevenson	Maximum water depth 53 mCD, minimum water depth 37 mCD. Generally shoaling from northeast to southwest towards the crest of Smith Bank.	Figure 3.2-1, Volume 6 a
MacColl	Maximum water depth 57 mCD, minimum water depth 39 mCD. Generally shoaling from east to west towards the crest of Smith Bank.	Figure 3.2-1, Volume 6 a

3.1.5 Legislative and Planning Framework

3.1.5.1 Legislative and planning frameworks do not specify any requirements in relation to the baseline understanding of wave and tidal regimes.

3.1.6 References

ABPmer, 2011a. Moray Firth Round 3 Zone: Physical Processes Baseline Assessment. ABPmer Report R1869.

Andrews, I.J., Long, D., Richards, P.C., Thomson, A.R., Brown, S., Chesher, J.A. & McCormac, M., 1990. United Kingdom offshore regional report: The Geology of the Moray Firth. London: HMSO for the British Geological Survey.

Holmes R., Bulat J., Henni P., Holt J., James C., Kenyon N., Leslie A., Long D., Musson R., Pearson S., Stewart H., 2004. DTI Strategic Environmental Assessment Area 5 (SEA5): Seabed and superficial geology and processes. British Geological Survey Report CR / 04 / 064N.

3.2 Geology

3.2.1 Introduction

3.2.1.1 This chapter provides a summary characterisation of the geological setting of the three proposed wind farm sites and OfTI. A more detailed description may be found in the supporting technical appendix: Metocean and Coastal processes (Technical Appendix 3.4 A, ABPmer (2011a)).

3.2.1.2 This baseline is used to inform the following impact assessments:

- Chapter 6.1 (Hydrodynamics);
- Chapter 6.2 (Sedimentary and Coastal Processes);
- Chapter 9.1 (Hydrodynamics);
- Chapter 9.2 (Sedimentary and Coastal Processes);
- Chapter 13.1 (Hydrodynamics); and
- Chapter 13.2 (Sedimentary and Coastal Processes).

3.2.1.3 This baseline and the associated impact assessments, described above, are also used to inform the following assessments:

- Chapter 7.1 (Benthic Ecology);
- Chapter 7.2 (Fish and Shellfish Ecology);
- Chapter 8.5 (Archaeology and Visual Receptors);
- Chapter 10.1 (Benthic Ecology);
- Chapter 10.2 (Fish and Shellfish Ecology);
- Chapter 11.5 (Archaeology and Visual Receptors);
- Chapter 14.1 (Benthic Ecology);
- Chapter 14.2 (Fish and Shellfish Ecology); and
- Chapter 15.5 (Archaeology and Visual Receptors).

3.2.1.4 This chapter comprises the following:

- Consultation with relevant statutory bodies;
- Detailed desk study and accompanying field survey to establish baseline conditions; and
- Consideration of the relevant key legislative and planning information.

3.2.2 Consultations

3.2.2.1 During the scoping consultations (described in more detail in Chapter 1.3: Environmental Impact Assessment), methodologies and data sources were proposed to inform the baseline understanding of the hydrodynamic, geological and sedimentary environments. The suggested methods included the use of previously collected and new field data, numerical modelling, desktop assessments and reference to previous studies. Specific comments made during the scoping were summarised in Table 3.1-1 above. No specific comments were made regarding the development of a physical environmental baseline.

3.2.3 Offshore Generating Station and Transmission Infrastructure Baseline Characteristics

Desktop Studies

3.2.3.1 In order to characterise the site specific and regional geology of the study area various data sources were used, including:

- Charted data from the British Geological Survey (BGS 1984, 1987); and
- Previous publications describing regional and fine scale geological features (e.g. Andrews *et al*. (1990), Holmes *et al.,* (2004)).

3.2.3.2 The offshore near-surface geology in the Outer Moray Firth is comprised predominantly of Cretaceous rocks, whilst both Jurassic and Permo-Triassic rocks are encountered along the southern / inner margins of the Firth. An extensive blanket of Quaternary deposits is present across almost the entire Firth with sediment thicknesses of around 70 m commonly observed.

3.2.3.3 Smith Bank is a geologically constrained feature (i.e. it is a raised hard rock feature) overlain by a relatively thin veneer of more recently deposited marine sediments. The nature of these surficial marine sediments is described in Chapter 3.5 (Sedimentary and Coastal Processes).

Geophysical Seismic Survey of the MORL Zone

3.2.3.4 A seismic survey of sub-bottom geology in the three proposed wind farm sites was undertaken between May and September 2010. The survey provides 100 % data coverage within the EDA, including the three proposed wind farm areas and a small buffer outside of the EDA. The WDA was also surveyed at approximately 20 % coverage in a coarse but regular grid.

3.2.3.5 The more detailed results show that over Smith Bank and within the three proposed wind farms, the thickness of (sandy) marine sediments is highly variable, typically between 1 and 5 m, tending to become thinner or absent near to the crest of Smith Bank, and thicker (order of tens of metres) in some locations associated with the infill of paleo-valley features.

3.2.3.6 The marine deposits overlay glacial tills (compacted poorly sorted mixtures of fine and coarse material). Where the surface veneer is sufficiently thin, glacial till is exposed at the seabed surface.

Geophysical Seismic Survey of the Offshore Export Cable Route

3.2.3.7 A seismic survey of sub-bottom geology in the offshore export cable route was undertaken in July – September 2011. The survey area includes a broad corridor (varying in width with the water depth) along the whole of (what at the time of the survey were) the two proposed transmission cable route options. Only the Fraserburgh cable route was taken forward for the purposes of this ES.

3.2.3.8 Given the shallow nature of operations along the offshore export cable route, it is the thickness of the surficial sediment layers that is of key interest to the baseline understanding. The survey indicates that surficial sediment layers are typically greater than 3 to 5 m thick.

3.2.4 Individual Site Baseline Characteristics

Table 3.2-1 below summarises the geophysical characteristics for each wind farm site.

Table 3.2-1 Geophysical Characteristics of the Individual Sites

Individual Wind Farm Sites	Summary of Baseline Characteristics
Telford	Marine sediment veneer (typically 1 to 3 m thick, increasing to 10 to 30 m in the central southern part of the site, very thin or absent over the bathymetric high in the western part of the site) overlying glacial till.
Stevenson	Marine sediment veneer (typically 1 to 3 m thick, very thin or absent over the bathymetric highs in central and eastern parts of the site) overlying glacial till.
MacColl	Marine sediment veneer (typically 1 to 3 m thick, increasing to 5 m in the western part and 10 to 30 m at the north eastern edge of the site) overlying glacial till.

3.2.5 Legislative and Planning Framework

Legislative and planning frameworks do not specify any requirements in relation to the baseline understanding of geology.

3.2.6 References

ABPmer, 2011a. Moray Firth Round 3 Zone: Physical Processes Baseline Assessment. ABPmer Report R1869.

Andrews, I.J., Long, D., Richards, P.C., Thomson, A.R., Brown, S., Chesher, J.A. & McCormac, M., 1990. United Kingdom offshore regional report: The Geology of the Moray Firth. London: HMSO for the British Geological Survey.

British Geological Survey (BGS) (1984). Moray-Buchan 57N 04W sea bed sediments and Quaternary, 1:250,000 geological map.

British Geological Survey (BGS) (1987). Caithness 58N 04W sea bed sediments and Quaternary, 1:250,000 geological map.

Gardline 2011. Moray Firth Round 3 Zone OFTO cable route geophysical survey - various reports.

Holmes R., Bulat J., Henni P., Holt J., James C., Kenyon N., Leslie A., Long D., Musson R., Pearson S., Stewart H., 2004. DTI Strategic Environmental Assessment Area 5 (SEA5): Seabed and superficial geology and processes. British Geological Survey Report CR / 04 / 064N.

Osiris Projects, 2011. Moray Firth Round 3 Zone geophysical survey - various reports.

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3.3 Wind Climate

3.3.1 Introduction

3.3.1.1 This chapter provides a summary characterisation of the wind climate within the three proposed wind farm sites and offshore transmission infrastructure (OfTI) and the regional setting. A more detailed description may be found in the supporting technical appendix: Metocean and Coastal Processes (Technical Appendix 3.4 A) ABPmer (2011a).

3.3.1.2 This baseline is used to inform the following impact assessments:

- Chapter 6.1 (Hydrodynamics);
- Chapter 6.2 (Sedimentary and Coastal Processes);
- Chapter 9.1 (Hydrodynamics);
- Chapter 9.2 (Sedimentary and Coastal Processes);
- Chapter 13.1 (Hydrodynamics); and
- Chapter 13.2 (Sedimentary and Coastal Processes).

3.3.1.3 This baseline and the associated impact assessments, described above, are also used to inform the following assessments:

- Chapter 7.1 (Benthic Ecology);
- Chapter 7.2 (Fish and Shellfish Ecology);
- Chapter 8.5 (Archaeology and Visual Receptors);
- Chapter 10.1 (Benthic Ecology);
- Chapter 10.2 (Fish and Shellfish Ecology);
- Chapter 11.5 (Archaeology and Visual Receptors);
- Chapter 14.1 (Benthic Ecology);
- Chapter 14.2 (Fish and Shellfish Ecology); and
- Chapter 15.5 (Archaeology and Visual Receptors).

3.3.1.4 This chapter comprises the following:

- Consultation with relevant statutory bodies;
- Detailed desk study and accompanying field survey to establish baseline conditions; and
- Consideration of the relevant key legislative and planning information

3.3.2 Consultations

3.3.2.1 During the scoping consultations (described in more detail in Chapter 1.3: Environmental Impact Assessment), methodologies and data sources were proposed to inform the baseline understanding of the hydrodynamic and sedimentary environments. The suggested methods included the use of previously collected and new field data, numerical modelling, desktop assessments and reference to previous studies. Specific comments made during Table 3.1-1 abovethe scoping were summarised in. No specific comments were made regarding the development of a physical environmental baseline.

3.3.3 Offshore Generating Station and Transmission Infrastructure Baseline Characteristics

Desktop Studies

3.3.3.1 In order to characterise the wind climate of the three proposed wind farm sites and offshore transmission infrastructure (OfTI) for the purposes of EIA, various existing data sources were used, including:

- Observations from Wick Airport (14 years) (see Figure 3.3-1, Volume 6 a);
- Hindcast wind from the Met Office (20 years); and
- A summary of 11 months of observations from the Beatrice Alpha Oil Platform.

3.3.3.2 Frequency analysis of these data shows that the most frequent wind directions are from the west (247.5 to 292.5 ˚N), accounting for almost 20 % of the record, and from the south (157.5 to 202.5 ˚N) and south-east (112.5 to 157.5 ˚N), together accounting for around 35 % of the total record. Over 70 % of the record contains wind speeds in the range 2 to 8 m / s and observed wind speeds only infrequently (< 1 % of time) exceed 16 m / s. During extreme events (return period of one in ten years or more), wind speeds might peak as high as 25 or 30 m / s. This summary is broadly consistent with the short period of observations made offshore at the Beatrice Alpha Platform (see Technical Appendix 3.4 A).

3.3.3.3 No additional site specific surveys of wind have been undertaken.

3.3.4 Individual Site Baseline Characteristics

3.3.4.1 For the purposes of the environmental impact assessment, there is no significant difference in wind climate (as described above) between the individual sites and along the export cable route.

3.3.5 Legislative and Planning Framework

3.3.5.1 Legislative and planning frameworks do not specify any requirements in relation to the baseline understanding of wind climate.

3.3.6 References

ABPmer, 2011a. Moray Firth Round 3 Zone: Physical Processes Baseline Assessment. ABPmer Report R1869.

3.4 Hydrodynamics (Wave Climate and Tidal Regime)

3.4.1 Introduction

3.4.1.1 This chapter provides a summary characterisation of the wave and tidal regimes active within the Project and its regional setting. A more detailed description may be found in the supporting technical appendix: Metocean and Coastal processes (Technical Appendix 3.4 A, ABPmer (2011a)).

3.4.1.2 This baseline is used to inform the following impact assessments:

- Chapter 6.1 (Hydrodynamics: Wave Climate and Tidal Regime);
- Chapter 6.2 (Sedimentary and Coastal Processes);
- Chapter 9.1 (Hydrodynamics: Wave Climate and Tidal Regime);
- Chapter 9.2 (Sedimentary and Coastal Processes);
- Chapter 13.1 (Hydrodynamics: Wave Climate and Tidal Regime); and
- Chapter 13.2 (Sedimentary and Coastal Processes).

3.4.1.3 This baseline and the associated impact assessments, described above, are also used to inform the following assessments:

- Chapter 7.1 (Benthic Ecology);
- Chapter 7.2 (Fish and Shellfish Ecology);
- Chapter 8.5 (Archaeology and Visual Receptors);
- Chapter 10.1 (Benthic Ecology);
- Chapter 10.2 (Fish and Shellfish Ecology);
- Chapter 11.5 (Archaeology and Visual Receptors);
- Chapter 14.1 (Benthic Ecology);
- Chapter 14.2 (Fish and Shellfish Ecology); and
- Chapter 15.5 (Archaeology and Visual Receptors).

3.4.1.4 This chapter comprises the following:

- Consultation with relevant statutory bodies;
- Detailed desk study and accompanying field survey to establish baseline conditions; and
- Consideration of the relevant key legislative and planning information.

3.4.2 Consultations

3.4.2.1 During the scoping consultations (described in more detail in Chapter 1.3: Environmental Impact Assessment), methodologies and data sources were proposed to inform the baseline understanding of the hydrodynamic environment. The suggested methods included the use of previously collected and new field data, numerical modelling, desktop assessments and reference to previous studies. Specific comments made during the scoping were summarised in Table 3.1-1 above. No specific comments were made regarding the development of a physical environmental baseline.

3.4.3 Offshore Generating Station and Transmission Infrastructure Baseline Characteristics

Desktop Studies

3.4.3.1 In order to characterise the tidal water level regime of the study area (see Figure 3.1-1, Volume 6 a) for the purposes of the environmental impact assessment, various data sources were used (see Figure 3.4-1, Volume 6 a), including:

- Primary tide gauge at Wick;
- Admiralty tide tables for Wick;
- Previously published hindcast surge statistics for the MORL Zone location and based on a statistically representative set of surge data;
- Field survey of tidal water levels (see paragraph 3.4.3.23 below); and
- Numerical modelling tools (see paragraph 3.4.3.27 below).

3.4.3.2 The three proposed wind farms are situated within a meso-tidal setting and is characterised by a mean spring tidal range of just under 3 m and a maximum astronomic range (HAT to LAT) of approximately 4 m.

3.4.3.3 There is some variation in tidal range along the offshore export cable route, with the larger tidal ranges experienced towards the landward end. Near the export cable landfall, the mean spring range is 3.7 m.

3.4.3.4 Storm surges may cause short term modification to predicted water levels and under an extreme (1 in 50-year return period) storm surge, water levels may be up to 1.25 m above predicted levels.

3.4.3.5 It is probable that relative sea levels will rise in this region during the course of the 21st Century and by 2100 (beyond the lifetime of the proposal) is likely to be approximately 0.5 to 0.8 m higher across the study area.

3.4.3.6 Climate change may be expected to slightly increase the mean water level over the lifetime of the proposed development; however, the tidal range about the new mean level is not likely to be measurably affected.

3.4.3.7 In order to characterise the tidal current regime of the study area for the purposes of environmental impact assessment, various data sources were used, including:

- Previously collected current meter observations (see Technical Appendix 3.4 A);
- Previously published hindcast surge statistics (see paragraph 3.4.3.1 above);
- Field survey of tidal water levels (see paragraph 3.4.3.23 below); and
- Numerical modelling tools (see paragraph 3.4.3.27 below).

3.4.3.8 Information available on the strength of tidal currents in this region shows that recorded (depth-averaged) peak spring current speeds are around 0.45 to 0.5 m / s, with the fastest speeds recorded in the north of the three proposed wind farms (see Figure 3.4-2, Volume 6 a).

3.4.3.9 Current speeds decrease with distance into the Moray Firth (see Figure 3.4-3, Volume 6 a). Peak mean spring current speeds in the Western Development Area are around 0.3 m / s.

3.4.3.10 Along most of the offshore export cable route, peak current speeds are typically less than 0.4 m / s. However, they increase markedly off Kinnairds Head, in a region extending approximately 10 km offshore of the export cable landfall and extending beyond Rattray Head. Here, peak spring tidal current speeds are more typically 1.0 m / s (maximum 1.15 m / s) due to acceleration around the headland.

3.4.3.11 Both storm waves and storm surges may cause short term modification of astronomically-driven tidal currents. During a 1:1 year storm event, orbital currents are likely to approach 1 m / s in the south of the three proposed wind farm sites, in the relatively shallow water over the crest of Smith Bank. Currents of this magnitude are considerably greater than that observed during peak spring tidal flows. Similarly, under an extreme (1 in 50 year return period) storm surge, current speeds may be more than twice that encountered under normal peak spring tide conditions.

3.4.3.12 Residual tidal currents (over a period of days to weeks) are directed generally into the Moray Firth (to the south-south west).

3.4.3.13 Climate change is not expected to have any effect on the local tidal current regime (currents are largely controlled by the corresponding tidal range) over the lifetime of the proposed development.

3.4.3.14 In order to characterise the wave climate of the study area for the purposes of environmental impact assessment, various existing data sources were used, including:

- Field survey of waves (see paragraph 3.4.3.23 below); and
- Numerical modelling tools (see paragraph 3.4.3.27 below).

3.4.3.15 The wave regime in the Outer Moray Firth includes both swell waves generated elsewhere in the North Sea and locally generated wind waves. The wave regime in the Outer Moray Firth is typically characterised by wind waves although longer period swell waves can be identified within the observational wave records collected from within and near to the application site. Wave roses from the available observational data are shown in Figure 3.4-4, Volume 6 a.

3.4.3.16 The largest waves come from the more exposed offshore sectors (from north through south-east) and wave heights during extreme events may be 6 to 7 m during relatively frequent (annual) events or as much as 9 m for the 50 year return period condition. Waves coming from other directions within the Moray Firth are generally smaller during extreme events (4 to 5 m or up to 7 m, respectively) due to the relatively shorter distances available for wave growth. The effect of different wind directions (affecting the distance available for wave growth) (wave fetch) has on the distribution of wave height is shown in Figure 3.4-5, Volume 6 a.

3.4.3.17 The offshore export cable route is likely to be exposed to waves of equal or larger size than the wind farms themselves from exposed offshore sectors; the size of waves from other directions will vary along the route depending upon the wind direction and corresponding distance of open water. The variable and on average greater water depths along the route mean that the ability of a given wave condition to penetrate to the seabed may also be variable.

3.4.3.18 Even though water depths across the wind farm sites are no less than 35 m, storm waves sufficiently large to cause water motion at the seabed are not uncommon.

3.4.3.19 Climate change is predicted to cause variability in the inter-annual wave climate over the lifetime of the proposed development; however, historical trends have shown that this variability may include (order of ±10 %) in mean storminess on decadal timescales.

3.4.3.20 Naturally occurring stratification (measurable gradients in water density over relatively short distances) occurs in the study area due to seasonal heating of the water and vertical fronts (the oceanographic features formed by stratification in a vertical plane) are also observed between regions of slight freshwater influence coming from the Moray Firth. Previously published papers (e.g. Adams and Martin, 1986; Connor *et al.,* 2006) were used to characterise stratification and fronts in the Moray Firth (e.g. the Buchan front) including their general location and characteristics in relation to primary productivity.

3.4.3.21 Applying general oceanographic theory, it is likely that the (weak) strength and natural position of the Buchan front in the outer Moray Firth is governed by the relative magnitude of tidal current flows in the adjacent inshore areas and of seasonal stratification in adjacent offshore areas.

3.4.3.22 Climate change is not expected to have any effect on the range of natural variability in the location or strength of stratification and fronts over the lifetime of the proposed development.

Field Survey of Wave and Tidal Regimes

3.4.3.23 One wave buoy and three seabed frames were deployed at strategic locations within the three proposed wind farm sites by Partrac (Technical Appendix 3.4 A). Locations (shown in Figure 3.4-1, Volume 6 a) were deliberately selected to best inform an understanding of spatial variation in key hydrodynamic parameters within the MORL Zone, in accordance with best practice guidance for offshore wind farm EIA (Cefas, 2004, 2009) and related numerical modelling (COWRIE, 2009). All devices collected measurements of wave parameters (height, period and direction). The seabed frames also collected measurements of tidal water levels and profiles of current speed and direction throughout the water column.

3.4.3.24 Seabed frame data was collected for between 100 and 120 days (in July 2010 to January 2011) the majority of data collection was coincident between all devices. As such, these data provide a robust measure of underlying tidal processes in the area.

3.4.3.25 The wave buoy has been collecting data from June 2010 to present, although with a few short periods of downtime. Wave data collected by the seabed frames overlaps with the wave buoy deployment.

3.4.3.26 Similar additional data are available from the adjacent proposed Beatrice Offshore Wind Farm by means of a data sharing agreement. This provides a further two seabed frames, located at the eastern and western ends of that site, and one wave buoy (providing a longer continuous period of wave data). The locations of these devices are shown in Figure 3.4-1, Volume 6 a.

Numerical Modelling Studies

3.4.3.27 Observed data are inherently limited either in temporal or spatial resolution and extent. To reduce any residual uncertainties, a tidal and a wave numerical model were created to provide additional data for the study. Full details of the numerical modelling tools used may be found in Technical Appendix 3.4 A (ABPmer 2011b).

3.4.3.28 The tidal model was built using the 'MIKE by DHI' Hydrodynamic module. The model encompasses the whole of the Moray Firth, north to the Pentland Firth and south to the Firth of Forth to properly develop flows into and out of the study area. The model is shaped by the best available bathymetry data (see Chapter 3.1: Bathymetry) and utilises realistic water level boundaries that permit simulation of specific periods of real time, either in the past or in the future. The model performance in simulating both water levels and currents was calibrated and validated using the various observed data available.

3.4.3.29 The wave model is built using the 'MIKE by DHI' Spectral Wave module. The model encompasses the whole of the Moray Firth, north to Iceland and south and east to incorporate all long fetches within the North Sea. The model is shaped by the best available bathymetry data (see Chapter 3.1: Bathymetry) and utilises realistic spatially varying maps of wind speed and direction that permit simulation of specific periods of real time in the past. The model performance in simulating waves in the Moray Firth was also calibrated and validated using the various observed data available.

3.4.3.30 The findings of these models have been incorporated into this baseline characterisation and are also presented in Technical Appendix 3.4 A, ABPmer (2011a).

3.4.4 Individual Site Baseline Characteristics

3.4.4.1 For the purposes of the environmental impact assessment, there is no significant difference in astronomical tidal range, residual flow direction, storm surges, extreme wave heights from offshore sectors and the effects of climate change (as described above) between the individual sites. Table 3.4-1 below summarises the hydrodynamic characteristics for each site.

Table 3.4-1 Hydrodynamic Characteristics of the Individual Sites

Individual Wind Farm Sites	Summary of Baseline Characteristics
Telford	Peak mean spring tidal current speeds 0.5 to 0.4 m / s, decreasing from north to south; tidal axis approximately north -south. Relatively more sheltered from (short fetch) waves coming from the north east.
Stevenson	Peak mean spring tidal current speeds 0.45 to 0.35 m / s, decreasing from north to south; tidal axis approximately NNE to SSW.
MacColl	Peak mean spring tidal current speeds 0.4 to 0.3 m / s, decreasing from north to south; tidal axis approximately NNE to SSW. Relatively less sheltered from (short fetch) waves coming from the north east.

3.4.4.2 There is some variation in tidal range and patterns of currents along the offshore export cable route. Tidal range becomes relatively larger towards the landward end (mean spring range is 3.7 m at the landfall site). Peak current speeds along most of the cable route are typically less than 0.4 m / s; however they increase markedly off Kinnairds Head (to approximately 1.0 m / s on mean spring tides), in a region extending approximately 10 km offshore of the landfall site.

3.4.5 Legislative and Planning Framework

3.4.5.1 Legislative and planning frameworks do not specify any requirements in relation to the baseline understanding of wave climate and tidal regimes.

3.4.5.2 The methods used are however consistent with the guidelines for data collection in support of offshore wind farm environmental impact assessment provided by Cefas (2004, 2011), EMEC & Xodus AURORA (2010) and COWRIE (2009).

3.4.6 References

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3.5 Sedimentary and Coastal Processes

3.5.1 Introduction

3.5.1.1 The following sub-sections provide a summary characterisation of the sedimentary environment and coastal (physical) processes active within the study area (see Figure 3.1-1, Volume 6 a). A more detailed description may be found in the supporting technical appendix: Metocean and Coastal processes (Technical Appendix 3.4 A, ABPmer, 2011a).

3.5.1.2 This baseline is used to inform the following impact assessments:

- Chapter 6.1 (Hydrodynamics: Wave Climate and Tidal Regime);
- Chapter 6.2 (Sedimentary and Coastal Processes);
- Chapter 9.1 (Hydrodynamics: Wave Climate and Tidal Regime);
- Chapter 9.2 (Sedimentary and Coastal Processes);
- Chapter 13.1 (Hydrodynamics: Wave Climate and Tidal Regime); and
- Chapter 13.2 (Sedimentary and Coastal Processes).

3.5.1.3 This baseline and the associated impact assessments, described above, are also used to inform the following assessments:

- Chapter 7.1 (Benthic Ecology);
- Chapter 7.2 (Fish and Shellfish Ecology);
- Chapter 8.5 (Archaeology and Visual Receptors);
- Chapter 10.1 (Benthic Ecology);
- Chapter 10.2 (Fish and Shellfish Ecology);
- Chapter 11.5 (Archaeology and Visual Receptors);
- Chapter 14.1 (Benthic Ecology);
- Chapter 14.2 (Fish and Shellfish Ecology); and
- Chapter 15.5 (Archaeology and Visual Receptors).

3.5.1.4 This chapter comprises the following:

- Consultation with relevant statutory bodies;
- Detailed desk study and accompanying field survey to establish baseline conditions; and
- Consideration of the relevant key legislative and planning information.

3.5.2 Consultations

3.5.2.1 During the scoping consultations (described in more detail in Chapter 1.3: Environmental Impact Assessment), methodologies and data sources were proposed to inform the baseline understanding of the hydrodynamic and sedimentary environments. The suggested methods included the use of previously collected and new field data, numerical modelling, desktop assessments and reference to previous studies. Specific comments made during the environmental impact assessment scoping were summarised in Table 3.1-1 above. No specific comments were made regarding the development of a physical environmental baseline.

3.5.3 Offshore Generating Station and Transmission Infrastructure Baseline Characteristics

Desktop Studies

3.5.3.1 In order to characterise the sedimentary environment of the study area for the purposes of environmental impact assessment, various data sources were used, including:

- Previously collected seabed grab data (British Geological Survey, BGS);
- Previously developed maps of surficial seabed sediment type (BGS);
- Previous publications describing regional and fine scale geological features (e.g. Andrews *et al.,* (1990), Holmes *et al.,* (2004), as detailed in Technical Appendix 3.4 A);
- Field survey and grab sampling of surficial sediment type (see paragraph 3.5.3.10 below);
- Field survey of suspended sediment concentration (see paragraph 3.5.3.12 below); and
- The quantitative information and data developed with regards to the hydrodynamic regime (see Chapter 3.3: Wind Climate).

3.5.3.2 As shown in Figure 3.5-1 and Figure 3.5-2 in Volume 6 a, seabed sediments across the three proposed wind farm sites and OfTI generally consist of Holocene gravelly sand and sand; fine (silt and clay sized) particles are largely absent. A modal peak grain size at 185 µm (fine sand) was found in over half of the grab samples collected from the area of the three proposed wind farms. Other modal peak grain sizes were also variably observed across the three proposed wind farm sites and OfTI, ranging from 24,000 µm (pebble gravel) to 150 µm (fine sand). The proportion of shell in sediment samples from and nearby to the study area are frequently in excess of 50 % (Partrac, 2010; BGS, 1987).

3.5.3.3 Seabed sampling was attempted at 20 locations (Figure 4.2-2, Volume 6 a) along the offshore export cable route (see Chapter 4.2: Benthic Ecology). Near to the wind farm sites, in intermediate water depths, the offshore export cable route will transit areas of mixed sands and gravels, with initially small and variable fines content. Seabed sediments become progressively finer in deeper water along the route, becoming relatively muddy in the deepest parts, at the eastern end of the Southern Trench. The sediment character and distribution in these offshore sections is the result of the relatively benign tidal regime and the spatially variable effect of wave action at the seabed, depending upon the local water depth.

3.5.3.4 Within much of the area of the three proposed wind farms, surficial marine sediments are generally thin (1 to 3 m) with the underlying glacial till very close to the surface.

3.5.3.5 Across almost the entire Moray Firth an extensive blanket of Quaternary deposits (glacial tills) are present below the marine sand veneer. The thicknesses of this layer are commonly observed to be in excess of 100 m. Within the three proposed wind farm sites and OfTI the Quaternary units are of variable thickness, ranging from < 10 m to c. 150 m. These sediments are underlain by a thick unit of firm to very hard Lower Cretaceous clay.

3.5.3.6 The available evidence suggests that (bedload) material is travelling into the Firth from the north, passing along the Caithness coast and towards the Inner Moray Firth (see Figure 3.4-2, Volume 6 a). Tidal currents are largely incapable of mobilising anything larger than fine sand-sized material within the three proposed wind farm sites and OfTI and as a result, there is only limited net bedload transport of sediment due to tidal currents alone.

3.5.3.7 However, the combination of tidal and non-tidal currents and wave induced currents during storms results in considerably higher current speeds at the bed. As a result, it is likely that the commonly present medium-sized sand is regularly mobilised across the three proposed wind farm sites and OfTI during storms. Owing to the combination of higher tidal current speeds and moderate water depths, the northern areas of the three proposed wind farms are most active in this way.

3.5.3.8 During calm conditions, suspended sediment concentrations are typically very low (approximately < 5 mg / l as shown in Figure 3.5-1, Volume 6 a). However, during storm events, near bed current speeds can be significantly increased due to the influence of waves stirring of the seabed, causing a short-term increase in suspended sediment concentration, theoretically in the order of 1,000s to 10,000s of mg / l very close to the seabed, 100s or 1,000s of mg / l in the lower water column but only 10s of mg / l in the upper water column. Coarser sediments may be transported a short distance in the direction of ambient flow or down-slope under gravity before being re-deposited. Finer material that persists in suspension will eventually be transported in the direction of net tidal residual flow (i.e. to the south west) into the Firth.

3.5.3.9 Climate change is not expected to have any effect on the type or distribution of sediments within the extent of and over the lifetime of the proposed development.

Field Survey of Surficial Seabed Sediment Type

3.5.3.10 Eighty grab samples of surficial seabed sediments were collected within the study area (concentrated in the Eastern Development Area) as part of the benthic ecology survey and reported in EMU (2011a). A further twenty grab samples of surficial seabed sediments were collected along the export cable route as part of the benthic ecology survey and reported in EMU (2011b).

3.5.3.11 The samples were analysed to obtain the detailed particle size distribution. The results of the analysis are in agreement with the more generalised distribution shown in the BGS surficial sediments map publications. The results do however provide more detailed information regarding the relative proportions of different grains sizes and material types within the sediments present.

Field Survey of Suspended Sediment Concentration

3.5.3.12 A turbidity sensor was also mounted on each of the seabed frames described in paragraph 3.4.3.23. These sensors provide coincident measurements of turbidity (mainly related to suspended sediment concentration). The results show that nearbed levels are typically low (order of 1 to 5 mg / l) but can be much higher (order tens or hundreds of mg / l) during large storm events.

3.5.4 Individual Site Baseline Characteristics

3.5.4.1 All sites comprise a veneer of marine sediments overlying a glacial till deposit. Table 3.5-1 below provides further site specific information on the basis of the combined available data.

Table 3.5-1 Sedimentary and Coastal Process Characteristics of the Individual Sites

Individual Wind Farm Sites	Summary of Baseline Characteristics
Telford	Veneer of slightly gravelly sand in most areas, becoming progressively coarser (gravelly sand to sandy gravel) towards the eastern edge of the site.
Stevenson	Thin veneer of sandy sediments overlying coarse gravels in the shallowest parts of the site (the crest of Smith Bank). Sediment veneer becoming thicker but progressively coarser (slightly gravelly sand to gravelly sand to sandy gravel) with increasing water depth to the north east and east.
MacColl	Gravelly sands and sandy gravels, becoming coarser with increasing water depth to the south-east.

3.5.5 Legislative and Planning Framework

3.5.5.1 Legislative and planning frameworks do not specify any requirements in relation to the baseline understanding of sedimentary and coastal processes.

3.5.5.2 The methods used are however consistent with the guidelines for data collection in support of offshore wind farm EIA provided by Cefas (2004, 2011), EMEC & Xodus AURORA (2010) and COWRIE (2009).

3.5.6 References

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3.6 Underwater Noise

3.6.1 Summary

3.6.1.1 A number of species of marine mammals, fish and shellfish use sound for prey detection, communication and navigation. Anthropogenic noise, which falls within the audible range of these species and exceeds natural background levels, has the potential to disturb and, in extreme cases, cause auditory injury. In recent years, the study of underwater noise associated with the construction of offshore wind farms has been a topic of substantial research (e.g. Tougaard *et al.*, 2003a and 2003b; Nedwell *et al.*, 2004; Bailey *et al.*, 2006; Thomsen *et al.*, 2006; and Nedwell *et al.*, 2007a and 2007b). In the context of offshore wind farm development, it is widely accepted that impact piling operations are likely to be the principal source of noise that has the potential to affect marine life.

3.6.1.2 This chapter describes the approach taken to the modelling of underwater noise generated during construction of the Telford, Stevenson and MacColl wind farm sites, including the construction of a met mast, and associated offshore transmission infrastructure, and the means by which likely significant effects on marine mammals and fish are assessed.

3.6.1.3 The available information on the nature of the background noise in the seas around the UK is then presented. Following this, the desk–top studies which have been undertaken to inform marine mammal and fish impacts assessments are described. The application of modelling techniques are outlined to identify which activities will generate the most significant noise levels during wind farm and offshore transmission infrastructure construction, and to determine the levels of noise generated. Finally, model outputs are presented which describe the levels of noise generated during particular construction activities. In addition, the noise associated with the adjacent Beatrice Offshore Wind Farm Limited (BOWL) wind farm site has been taken into account in the modelling of cumulative noise levels. The model outputs presented in this chapter are representative of those generated by the modelling exercise.

3.6.1.4 The full and detailed model outputs are provided in the following technical appendix:

- Technical Appendix 3.6 A (Underwater Noise Technical Report).

3.6.1.5 The likely significant effects of underwater noise on marine biological receptors are assessed in the following chapters (and relevant technical appendices):

- Chapters 7.2, 10.2 and 14.2 (Fish and Shellfish Ecology);
- Chapters 7.3, 10.3 and 14.3 (Marine Mammals); and
- Chapter 12.1 (Whole Project Assessment).

3.6.2 Consultations

3.6.2.1 Table 3.6-1 below summarises consultation responses received by MORL with regards to underwater noise. These responses have been taken into account in the following assessments.

Table 3.6-1 Summary of Consultation Responses Relating to Underwater Noise

Organisation	Consultation Response	MORL Approach
Marine Scotland Science (MSS)	**Offshore Generating Station Scoping Response:** Construction: Details of noise pollution resulting from any construction activity and any associated potential effects on cetaceans / pinnipeds / fish will be required. Noise assessments should take into consideration background noise. The particular cause of concern with regards to cetaceans is the cumulative impact from all additional wind farm sites on the NE of Scotland. The proposed development will need to consider potential impacts on migratory fish, including salmon, sea trout, sea lamprey and river lamprey during all phases of the Project. Potential impacts may include physical or avoidance reactions at both the individual and population level. **Comments on draft ES:** MSS highlighted that the following points need consideration: • Maintenance noise; and • Due to the possibility that herrings dive for reproduction override its avoidance to noise may result in fish entering areas of noise which may be harmful.	The effect of underwater noise propagation has been modelled from a single and multiple simultaneous pile installations. The underwater background noise levels have been taken into account in the assessment in the baseline chapters (Section 2). dB_{ht}(Species) modelling with respect to behavioural avoidance ranges has been undertaken. The assessment of likely significant effects on fish is presented in Chapters 7.2, 10.2, 12.1 and 14.2. The assessment of likely significant effects on marine mammals is presented in Chapters 7.3, 10.3, 12.1 and 14.3.
Joint Nature Conservation Committee (JNCC) & Scottish Natural Heritage (SNH)	**Offshore Generating Station Scoping Response:** • An important aspect of the EIA will be modelling of noise during the installation of jacket structures in order to assess which is the best foundation option. Data from the Beatrice Demonstrator jacket installation and monitoring during construction was highlighted as a possible source of information; • JNCC & SNH recommend that the applicant considers and discusses the full range of mitigation techniques for noise impacts during construction. The choice of mitigation should be determined by review of the zone of potential impacts. In case of insufficient evidence being gathered then it is necessary to use appropriate precaution. MORL & BOWL should collaborate on this issue; and • Construction / decommissioning impacts: the EIA should include discussion of the impacts of underwater noise on fish, especially during spawning. Expected levels of noise production should be set out and the impact this will have on fish life stages, movements and behaviour should be considered. **Transmission Infrastructure Scoping Response:** • JNCC & SNH recommends that underwater noise modelling work includes cable laying and associated vessel activity as potentially noisy activities. **Comments on draft ES:** • The ES will need to emphasise that models are absolute worst case scenarios and not the most likely, therefore	Underwater noise modelling for construction operations has been undertaken, with the model calibrated using data measured at similar installations, including the Beatrice Demonstrator turbines. A variety of potential mitigation measures have been considered in the noise modelling. The assessment of likely significant effects of underwater noise on fish, including spawning, are presented in Chapters 7.2, 10.2, 12.1, and 14.2. The potential effect from various noise sources, including cable laying and vessel activity, have been taken into account. A discussion on the chosen modelled piling locations is provided in paragraphs 3.6.5.130 to 3.6.5.40 below and in Technical Appendix 3.6 A.

Organisation	Consultation Response	MORL Approach
Joint Nature Conservation Committee (JNCC) & Scottish Natural Heritage (SNH) **(continued)**	very precautionary. Some discussion around the representativeness of any chosen piling location would be very useful; and • JNCC & SNH are happy with the use of humpback whale audiogram as a proxy for minke whales.	
Scottish Natural Heritage (SNH)	**Comments on draft ES:** • It is important to know the expected timing and duration of activities that will generate noise, and for noise impacts to be considered in respect of key periods of sensitivity for each fish species; • Possible impact on salmonid species outside of the areas 'immediately' offshore should also be considered; • While much of the noise is likely to be absorbed by land or dissipate to the surface in shallow water, it is not clear how noise waves behave when being 'funnelled' into shallow water (e.g. into the narrower part of the firth) or to what extent noise is reflected back into open water. The ES would benefit from discussion of this; • Further detail on the noise modelling for simultaneous piling events should be provided; and • A review of the best source of information for salmon and noise should be undertaken.	Substantial modelling for simultaneous piling has been undertaken, showing the ranges as the noise approaches the narrower part of the firth. There will be little "funnelling" due to the acoustically "soft" nature of much of the seabed and no significant increase in noise as a consequence. Paragraphs 3.6.5.30 to 3.6.5.40 below provide a summary of the piling scenarios modelled and Technical Appendix 3.6 A provides further detail on the modelling assumptions and outputs of noise modelling.
Moray Firth Inshore Fisheries Group (MFIFG)	**Offshore Generating Station coping Response:** The impact on sediment loading and noise associated with construction and sub–sea cabling systems on general fish ecology, and squid population in particular, needs to be evaluated. The unique ecology of the squid populations will require specialised sampling equipment and an understanding of spatial and temporal distributions.	The noise impact of significant construction activities has been modelled (paragraphs 3.6.5.18 to 3.6.5.22 below).
Whale and Dolphin Conservation Society (WDCS)	**Offshore Generating Station Scoping Response:** • WDCS anticipates that the most likely negative impacts of wind [farm] developments could result from noise generated during pile driving. Quieter and more benign alternatives to pile driving should be considered and methods that can be used to limit noise to the greatest extent possible should be employed; and • Mitigation measures should be demonstrated as being effective given the considerable sensitivities of a number of marine mammal species in the region. Priority should be given to those techniques that prevent impacts. The use of soft start is not likely to be adequate and shut down is likely to be required as well as operational restrictions at night and in poor visibility. Should pile driving be required then effort should be made to reduce noise propagation as far as possible. **Transmission Infrastructure Scoping Response:** • WDCS agrees that disturbance and injury as a result of noise should be included as potential impacts. Where modelling is proposed, ground–truthing should be	A comparison of underwater noise associated with a variety of construction activities has confirmed that piling has the largest impact ranges (see paragraphs 3.6.5.18 to 3.6.5.22 below). MORL is proposing to undertake a series of studies associated with the installation of a met mast, including underwater noise data collection with the aim of propagation model (see Chapter 7.3 for details). MORL is working with The Crown Estate and other offshore wind developers with regards to investigating and developing further best

Organisation	Consultation Response	MORL Approach
Whale and Dolphin Conservation Society (WDCS) **(continued)**	considered. **Comments on draft ES:** • Noise levels during construction remains a key concern and as a minimum should be monitored; • Given the development size and considerable time–span for construction of the whole development, long term population impacts are considered an issue; and • Appropriate and effective mitigation measures should be considered.	practice for mitigation measures that may be implemented to reduce either the level of noise at the source or noise propagation. Detailed assessments on likely significant effects (short and long term) on marine mammal populations are provided in Chapters 7.3, 10.3, 12.1 and 14.3.

3.6.3 Baseline

3.6.3.1 A large database, containing measurements of underwater noise taken during offshore construction projects in UK territorial waters, has been used to provide information on the background noise in the Moray Firth. The measurements were taken in a large range of different geographical locations and sea states, cover a broad frequency range from 1 Hz to over 100 kHz and have a dynamic range in excess of 70 dB.

3.6.3.2 Recordings of underwater noise taken at 10 different sites, all of which are between 1 km and 20 km from the UK coast, have been analysed to yield typical spectra for underwater coastal background sound. The sites are shown on a map of the UK in Figure 3.6-1, Volume 6 a.

3.6.3.3 Background noise levels underwater often arise from distant shipping, industrial activities and other anthropogenic noise, ocean turbulence, wind, rain, biological sources, such as snapping shrimp, as well as other marine life. The measurements were analysed over the frequency range from 1 Hz to 120 kHz. All of the measurements used were taken in the absence of precipitation, with no other noticeable sources of underwater noise, such as nearby shipping, present and at Sea States from 1 to 3, with the hydrophone at half water depth (typically 10 m to 15 m below the surface).

3.6.3.4 Plate 3.6-1 and Plate 3.6-2 below present summaries of the Power Spectral Density levels, describing how the power of the measured sound level is distributed across the frequency range, of underwater noise measured at the various sites, with the data from the Moray Firth highlighted and an average of all the data also shown. Plate 3.6-1 below presents data for measurements during Sea State 1 conditions and Plate 3.6-2 below presents data for slightly rougher Sea State 3 conditions.

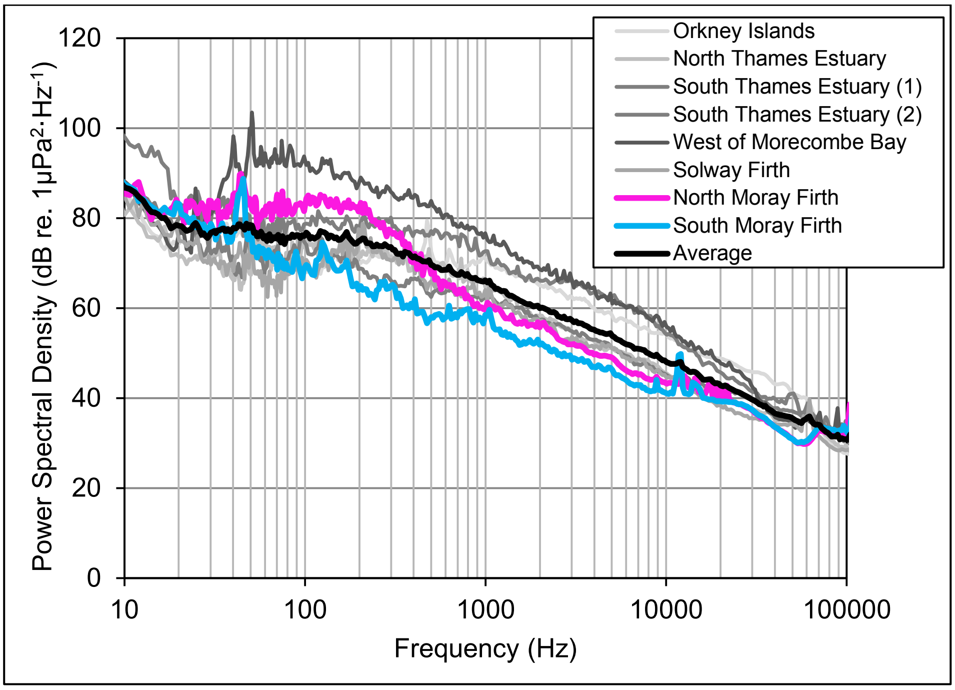

Plate 3.6-1 Summary of Power Spectral Density Levels of Background Underwater Noise at Sea State 1 at Sites Around the UK Coast

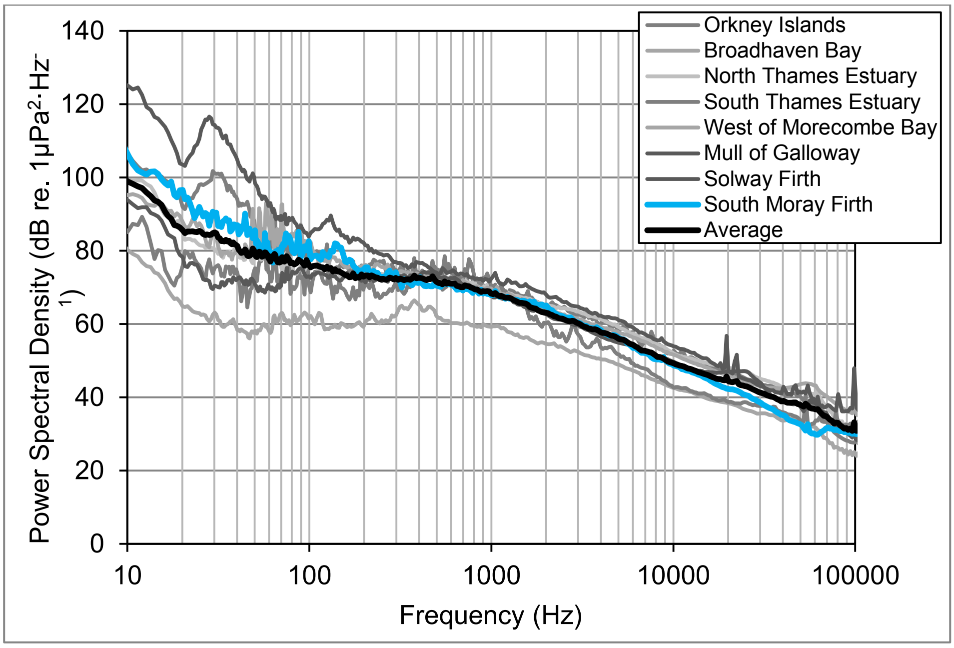

Plate 3.6-2 Summary of Power Spectral Density Levels of Background Underwater Noise at Sea State 3 at Sites Around the UK Coast

3.6.3.5 It can be seen from Plate 3.6-1 and Plate 3.6-2Plate 3.6-2 above that the typical levels of background underwater noise in the Moray Firth region are very close to the overall average for the UK coast. In order to provide an estimate of the typical levels of background noise that may occur in the Moray Firth, taking into account natural variation, it is therefore appropriate to use the averages presented in Table 3.6-2 and Table 3.6-3 below, in terms of sound levels weighted (dB_{ht}(Species) explained in Section 4 of Technical Appendix 3.6 A) to account for species perception and unweighted for Sea State 1 and Sea State 3 respectively.

Table 3.6-2 Summary of Average Background Levels of Noise Around the UK Coast and in the Moray Firth at Sea State 1

	Unweighted dB re. 1 μPa	Bass dB$_{ht}$- (*Micropterus salmoides*)	Cod dB$_{ht}$(*Gadus morhua*)	Dab dB$_{ht}$- (*Limanda limanda*)	Herring dB$_{ht}$- (*Clupea harengus*)	Salmon dB$_{ht}$- (*Salmo salar*)	Bottlenose dolphin dB$_{ht}$- (*Tursiops*)	Harbour porpoise dB$_{ht}$- (*Phocoen phocoena*)	Harbour seal dB.$_{ht}$(*Phoca vitulina*)	Killer whale dB$_{ht}$- (*Orcinus orca*)
Overall Average Background Noise Levels – Sea State 1										
Max	126	15	39	26	42	17	66	74	43	66
Min	92	0	1	0	9	0	36	44	21	37
Mean	111	5	23	10	28	5	44	54	31	47
South Moray Firth Averages – Sea State 1										
Max	115	5	30	20	36	8	40	53	27	44
Min	103	1.5	23	7	27	2	38	53	24	41
Mean	106	3.5	26	11	29	5	39	53	25	42
North Moray Firth Averages – Sea State 1										
Max	111	3	27	17	33	6	42	54	31	47
Min	92	0	5	0	10	0	39	53	21	41
Mean	99	0	15	2	20	0	40	53	24	42

Table 3.6-3 Summary of Average Background Levels of Noise Around the UK Coast and in the Moray Firth at Sea State 3

	Unweighted dB re. 1 μPa	Bass dB$_{ht}$- (*Micropterus salmoides*)	Cod dB$_{ht}$- (*Gadus morhua*)	Dab dB$_{ht}$- (*Limanda limanda*)	Herring dB$_{ht}$- (*Clupea harengus*)	Salmon dB$_{ht}$- (*Salmo salar*)	Bottlenose dolphin dB$_{ht}$- (*Tursiops*)	Harbour porpoise dB$_{ht}$- (*Phocoen phocoena*)	Harbour seal dB$_{ht}$(*Phoca vitulina*)	Killer whale dB$_{ht}$(*Orcinus orca*)
Overall Average Background Noise Levels – Sea State 3										
Max	132	15	42	31	47	19	50	60	38	53
Min	94	0	3	0	11	0	30	42	7	29
Mean	112	4	22	11	28	5	41	52	27	43
South Moray Firth Averages – Sea State 3										
Max	120	15	42	30	45	19	44	54	38	50
Min	101	0	15	0	21	0	40	53	29	46
Mean	109	4	26	11	30	4	42	53	32	47

3.6.4 Underwater Noise Modelling Methodology

3.6.4.1 The estimation of the levels of underwater noise from the three proposed wind farms and offshore transmission infrastructure development has been undertaken in two phases.

3.6.4.2 In the first, a broad–brush modelling approach has been used to rank order amongst a wide range of offshore wind farm–related sources of underwater noise. This was done using the Simple Propagation Estimator And Ranking (SPEAR) model developed specifically for the Moray Firth developers. The information used to validate this model has come from a very substantial database of recordings of various noise sources, that has been compiled over the last 20 years. The model uses estimates from this database of the typical frequency content, source level and transmission losses associated with each type of noise source, to calculate the variation of noise level with range from the source. This estimated noise level, and a suitable criterion for a level above which it will have an effect, is used to estimate the area which is affected by the noise source for each class or species of marine species.

3.6.4.3 The rank ordering showed that most of the activities had a negligible adverse effect, so they could be eliminated from further consideration in the second phase of the assessment, where the focus was on sources of noise that have the capacity to cause a significant adverse effect. The activity that generated the highest noise levels (impact piling) was modelled in detail using the Impulse Noise Sound Propagation and Impact Range Estimator (INSPIRE) model to provide an assessment of the levels of noise at various ranges from the piling operations. The results of this detailed modelling were then used to inform the assessment of effects on marine mammals and fish. A summary of results from the SPEAR and INSPIRE models is shown in 3.6.6 of this chapter and paragraphs 3.6.5.18 to 3.6.5.22 below. Technical Appendix 3.6 A provides more details on the methodology followed.

Modelling of Sound Propagation

3.6.4.4 Sound levels underwater are usually described in terms of the Source Level (SL), which is a measure of the radiated sound at the noise source, and the Transmission Loss (TL), which describes the way in which the radiated sound decays. The Sound Pressure Level at a specific range from the source is found from the difference between the SL and TL. For a constant depth and frequency the calculation of TL is relatively simple. In relatively shallow coastal waters, where wind farms are typically situated, the depth may rapidly fluctuate between water of a few metres and deeper water of tens of metres. In these circumstances the Transmission Loss becomes a more complex function of depth that depends heavily on the local bathymetry and hence must be calculated using a more sophisticated model. Section 5.2 of Technical Appendix 3.6 A gives a more detailed explanation of how sound propagation is modelled.

3.6.4.5 The INSPIRE model has been developed specifically to model the propagation of impulsive broadband underwater noise in shallow waters. It uses a combined geometric and energy flow / hysteresis loss model to conservatively predict propagation in relatively shallow coastal water environments, and has been tested against measurements from a large number of other offshore wind farm piling operations (Nedwell *et al.,* 2011). Transmission losses are calculated by the model on a fully range and depth dependent basis. The model imports bathymetry data as a primary input to allow it to calculate the transmission losses along transects extending from the pile location. Other simple physical data are also supplied as input to the model. The model is able to provide a wide range of outputs, including the peak pressure, dB_{ht} and Sound Exposure Level (SEL) of the noise. These quantities are fully described in Section 4 of Technical Appendix 3.6 A. For the purposes of estimating noise impacts, it is the dB_{ht} and M–Weighted SEL values which are of interest, which have been presented in the results, and they are described in 3.6.5 of this chapter.

3.6.4.6 As well as calculating the SEL variation with range, the model incorporates a "fleeing animal receptor" extension which enables the noise dose an animal receives as it moves away from a piling operation to be calculated. This feature permits the calculation of the nearest distance from a pile, from which an animal must start fleeing, such that its noise dose just reaches the criterion value at the cessation of the piling operation. In the work reported here a typical 'cruising speed' of 1.5 m / s was assigned to the mammals under consideration. Stationary animal receptors have also been considered in the model. It should be noted that the M–Weighted SEL criteria is designed for species of marine mammal and hence no assumptions for fleeing fish have had to be made for this assessment.

3.6.4.7 In Phase 2, the INSPIRE model was used to assess in detail the ranges at which fatality, physical injury, auditory injury and behavioural avoidance were likely to occur for a range of animal species. The Seal Framework Document (Technical Appendix 7.3 B) gives further details.

3.6.5 Effects of Underwater Noise on Marine Species

3.6.5.1 The effect of sound on underwater life can have a variety of effects depending on the level of the noise, in the same way as it has on humans in air. At one extreme, the loudest noise can generate a substantial pressure that is sufficient to injure or kill an animal in the same way as an explosion. Noise at a lower level can have less extreme effects: damage to an animal's auditory sense will occur before any physical injury occurs. At the other end of the scale, a quieter noise will not cause any harm to an animal but may trigger a behavioural response which, at sufficient volume, will cause the animal to flee the area to escape the high noise levels.

3.6.5.2 Over the past 20 years it has become increasingly evident that noise from human activities in and around underwater environments may have an impact on the marine species in the area. The extent to which intense underwater sound might cause an adverse environmental impact on a particular species is dependent upon the level of the incident sound, its frequency content, its duration and / or its repetition rate (for example: see Hastings and Popper (2005)). As a result scientific interest in the hearing abilities of aquatic animal species has increased.

3.6.5.3 The sound pressures required for physical injury or mortality are universal across species. However, other effects noted above (for example: the noise level required to elicit a behavioural response) are species dependent. Paragraphs 3.6.5.4 to 3.6.5.15 below describe the criteria which will be used to assess the likelihood of an adverse effect on marine mammals and fish fauna.

Lethality and Physical Injury

3.6.5.4 The following criteria have been applied in this study for levels of noise likely to cause physical effects to marine mammals and fish:

- Lethal effect may occur where peak–to–peak levels exceed 240 db re 1 μpa, or an impulse of 100 Pa.s; and
- Physical injury may occur where peak–to–peak levels exceed 220 db re 1 μpa, or an impulse of 35 Pa.s.

3.6.5.5 The measures of sound quoted here (peak–to–peak level and impulse) are fully described in Technical Appendix 3.6 A (Underwater Noise). It should be noted that impact ranges and areas for which the above levels could potentially occur are extremely small and mitigation measures to be used should ensure that no fatality or physical injury will occur.

Audiological Injury

3.6.5.6 At a high enough level of sound traumatic hearing injury may occur even where the duration of exposure is short. Injury also occurs at lower levels of noise where the duration of exposure is long. In this case the degree of hearing damage depends on both the level of the noise and the duration of exposure to it. These effects can be classed as either Temporary Threshold Shifts (TTS), where a temporary loss of hearing ability occurs but no permanent damage is done, or Permanent Threshold Shift (PTS), where there is a permanent adverse effect to the threshold of hearing.

3.6.5.7 A set of criteria to assess auditory damage has been proposed by Southall *et al.*, (2007). That study, however, considers the likelihood of hearing damage (PTS) caused by accumulated noise exposure, rather than occurring as a result of a single event. Their auditory injury criteria, for various groups of marine mammals, are based on Peak Pressure Levels and M–weighted Sound Exposure Levels (dB re 1 μPa^2.s (M)). The M–weighting weighs the incident sound according to the audiological sensitivity of the species under consideration. The criteria are given in Table 3.6-4 below. No such criteria exist for fish and as such cannot be considered further.

3.6.5.8 The measures of sound quoted here (peak pressure level, Sound Exposure Level, and the M–weighting concept) are fully described in Section 2 of the Underwater Noise Technical Appendix 3.6 A.

Table 3.6-4 Proposed Injury Criteria for Various Cetacean Groups

Marine Mammal Group	Sound Type
	Single and Multiple Pulses
Low Frequency Cetaceans (e.g. Minke Whale)	
Peak Pressure Level	230 dB re 1 μPa
Sound Exposure Level	198 dB re 1 μPa^2.s (M_{lf})
Mid Frequency Cetaceans (e.g. Bottlenose Dolphin)	
Peak Pressure Level	230 dB re 1 μPa
Sound Exposure Level	198 dB re 1 μPa^2.s (M_{mf})

Marine Mammal Group	Sound Type
High Frequency Cetaceans (e.g. Harbour Porpoise)	
Peak Pressure Level	230 dB re 1 μPa
Sound Exposure Level	198 dB re 1 μPa^2.s (M_{hf})
Source: Southall *et al.,* (2007)	

3.6.5.9 Southall also notes suggested criteria for pinnipeds, given in Table 3.6-5 below.

Table 3.6-5 Proposed Injury Criteria for Various Pinniped Groups

Marine Mammal Group	Sound Type
	Single and Multiple Pulses
Pinnipeds (in water) (e.g. Harbour Seal)	
Peak Pressure Level	218 dB re 1 μPa
Sound Exposure Level	186 dB re 1 μPa^2.s (M_{pw})
Source: Southall *et al.,* (2007)	

3.6.5.10 These figures suggest that pinnipeds are significantly more sensitive than cetaceans, with an adverse effect occurring at much lower noise levels. However, recent research by Thompson and Hastie (2011) has demonstrated evidence that pinnipeds actually respond much more like the cetaceans, and that the same sound exposure level, 198 dB re 1 μPa^2.s (M_{pw}), would be just as appropriate for the pinnipeds. This approach has been taken and 198 dB SEL has been used in the modelling for all cetaceans and pinnipeds. More detail on this is provided within the Marine Mammal Technical Appendix 7.3 B.

Behavioural Impacts

3.6.5.11 At levels lower than those that cause physical injury, PTS or TTS, noise may nevertheless have important behavioural effects on a species, of which the most significant is avoidance of the insonified area (the region within which noise from the source of interest is above ambient underwater noise levels). The significance of the effect requires an understanding of its consequences. For instance, avoidance may be significant if it impedes the migration of a species. However, in other cases the movement of species from one area to another may be of no consequence.

3.6.5.12 The dB_{ht}(*Species*) metric (Nedwell *et al.,* (2007b)) has been developed as a means for quantifying the potential for a behavioural impact of a sound on a species in the underwater environment. It is similar in concept to the dB (A) in humans in that it uses a species' audiogram in its calculation.

3.6.5.13 As any given sound will be perceived differently by different species (since they have differing hearing abilities) an absolute noise level will produce a different dB_{ht} value depending on what species is under consideration. Consequently the species name must be appended when specifying a level using this metric.

3.6.5.14 If the level of sound is sufficiently high on the dB_{ht}(*Species*) scale, it is likely that an avoidance reaction will occur. The response from a species will be probabilistic in nature (e.g. at 75 dB_{ht}(*Species*) one individual from a species may react, whereas another individual may not: the metric indicates the probability of an individual reacting and may also vary depending upon the type of signal. A level of 0 dB_{ht}(*Species*) represents a sound that is at the hearing threshold for that species and is, therefore, at a level at which sound will start to be 'heard'. At this and lower perceived sound levels no response occurs as the receptor cannot hear the sound.

3.6.5.15 The appropriate dB_{ht} levels used in the modelling are described in Table 3.6-6 below.

Table 3.6-6 Assessment Criteria Used to Assess the Potential Impact of Underwater Noise on Marine Species

Level in dB_{ht}(*Species*)	Effect
75 and above	Mild avoidance reaction by the majority of individuals (see Technical Appendix 7.3 B: Seal Framework Document).
90 and above	Strong avoidance reaction by virtually all individuals.
Source: Nedwell *et al.*, (2007)	

Species Considered in the Assessment

3.6.5.16 Table 3.6-7 below presents a summary of the species of interest to this study, along with some information regarding the availability of data concerning their sensitivity to underwater sound. Full references are given in Section 4 Technical Appendix 3.6 A.

Table 3.6-7 Summary of Marine Species Included in the Assessment with Audiological Data Available

Species Common to Area	Audiogram Available?	Surrogate Used	Comments	Reference
Cod	Yes	–	–	Chapman and Hawkins (1973)
Herring	Yes	–	–	Enger (1967)
Salmon	Yes	–	–	Hawkins and Johnstone (1978)
Bottlenose Dolphin	Yes	–	–	Johnson (1967)
Harbour Porpoise	Yes	–	–	Kastelein (2002)
Common (Harbour) Seal	Yes	–	No single audiogram dataset covering full audiometric range available. Data from two studies used.	Kastak and Schusterman (1998) Mohl (1968)

Species Common to Area	Audiogram Available?	Surrogate Used	Comments	Reference
Grey Seal	Partial – only upper frequencies	Harbour seal	No single audiogram dataset covering full audiometric range available. Data from two studies used.	Kastak and Schusterman (1998); Mohl (1968)
Killer Whale	Yes	–	–	Szymanski *et al.*, (1999)

3.6.5.17 Table 3.6-8 below includes species that were also considered, but for which no specific audiological data exists. In order to include these species, a surrogate species for which audiogram data is available was selected. These surrogate species are considered representative of the species of interest and were selected based on their family and hearing morphology.

Table 3.6-8 Summary of Marine Species Included in the Assessment with Hearing Sensitivity Based on Surrogate Audiological Data

Species Common to Area	Audiogram Available?	Surrogate Used	Comments	Reference
Plaice	No	Dab	–	Chapman and Sand (1974)
Minke Whale	No	Humpback whale	No surrogate data available for large mysticetes	Erbe (2002)
Risso's Dolphin	Yes	Striped dolphin	Existing audiogram data indicates higher threshold than other dolphin species but high background noise levels during audiogram tests	Risso's dolphin – Nachtigall *et al.*, (1995) Striped dolphin – Kastelein (2003)
White–Sided Dolphin	No	Bottlenose dolphin	Audiogram data suggest bottlenose dolphins are the most sensitive dolphin species to sound, so may provide conservative indication of impacts	Johnson (1967)
White Beaked Dolphin	Partial – only upper frequencies	Striped dolphin	Partial audiogram data for white–beaked dolphins indicates close match to striped dolphin data	White beaked dolphin – Nachtigall *et al.*, (2008) Striped dolphin – Kastelein (2003)

Engineering Parameters Assessed

3.6.5.18 The SPEAR model has been used to make prediction runs for a number of representative development scenarios for the various activities related to offshore wind farms; a summary is provided in Table 3.6-9 below.

3.6.5.19 Detailed information relating to the exact amount of time that activities will require to be carried out (for example, duration of time a vessel will be on site, the type of vessel or how long dredging may take) is not available at this stage. It has therefore been necessary to take a worst case estimation in terms of noise generation which considers all the activities to be carried out continuously for a 24 hour period, except impact piling.

Table 3.6-9 Summary of Parameters Taken Into Account in the SPEAR Modelling

Activity	Parameters Used for SPEAR Modelling
Impact Piling	4.4 hours driving per pile. 2,500 mm (for the jacket pin–piles) and 4,500 mm (for the met mast) diameter piles. Two piles installed per day.
Vessel Noise	DP jack up barges for piling, substructure and wind turbine installation. Other large and medium sized vessels will be on site to carry out other construction jobs, diving support and anchor handling. Other small vessels for crew transport and survey work on site.
Trenching	Required for the inter–array cables (offshore generating station) and offshore export cable installation (offshore transmission infrastructure).
Cable Laying	Required for the inter–array cables (offshore generating station) and offshore export cable installation (offshore transmission infrastructure).
Rock Placing	Required if Gravity Base Structures are to be used.
Dredging	Trailer Suction Hopper Dredger required on site for offshore transmission installation.
Operational Noise	Assume 24 hours a day for operational wind turbines.

3.6.5.20 The results of the SPEAR modelling for herring and the harbour seal as a typical sensitive fish and mammal species are given in Plate 3.6-3 and Plate 3.6-4 below respectively, where a 2.5 m pile is modelled for the impact piling. Results for other species are given in Section 8.3 of Technical Appendix 3.6 A – they are similar to the two results given here.

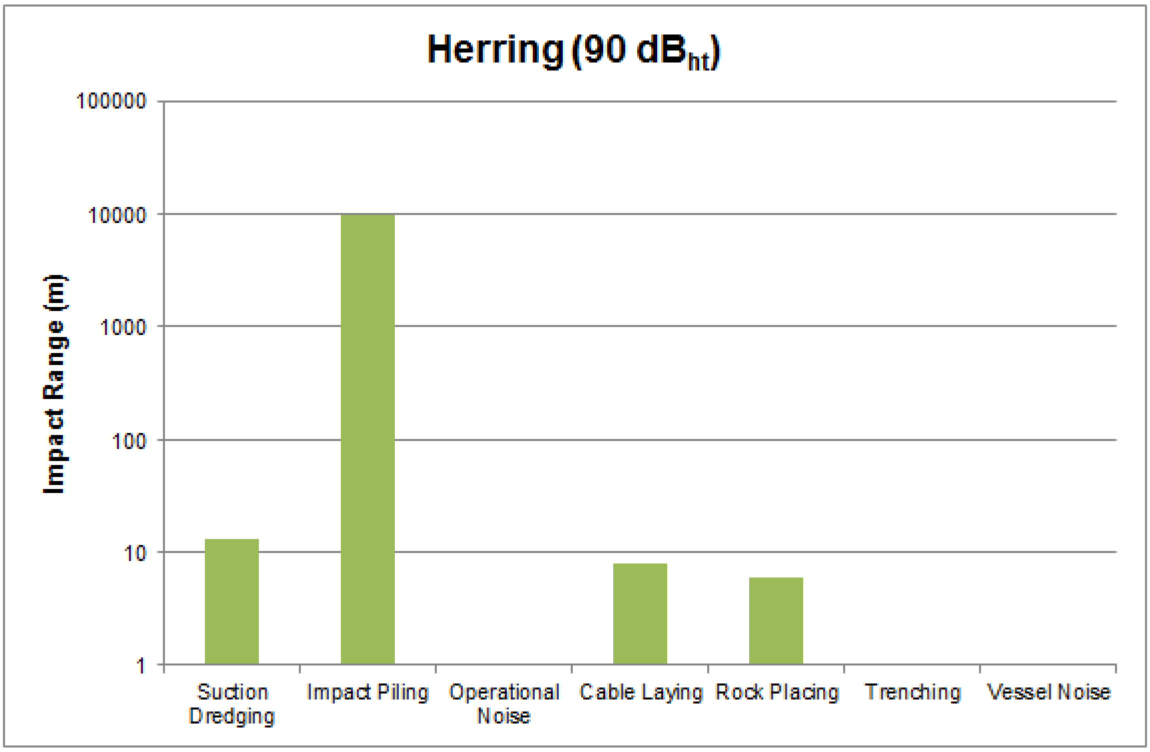

Plate 3.6–3 Spatial Extent of Impact of Various Activities (90 dB$_{ht}$) on Herring (2.5 m pile)

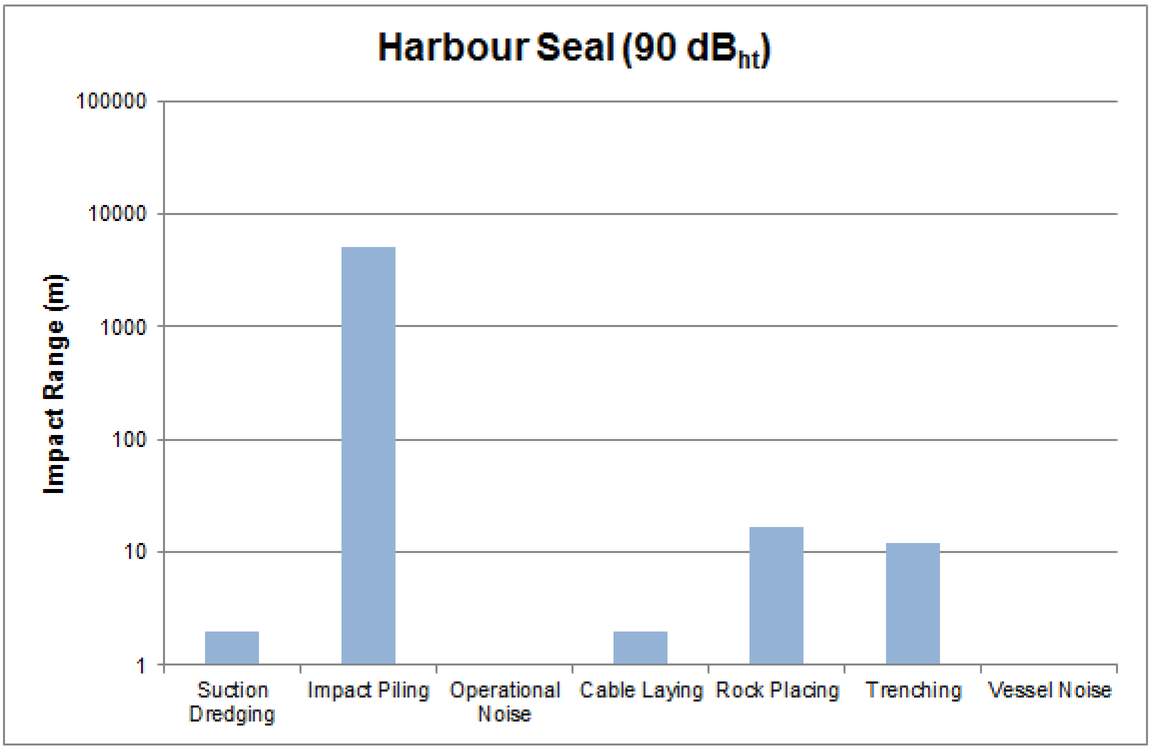

Plate 3.6–4 Spatial Extent of Impact of Various Activities (90 dB_{ht}) on Harbour Seal (2.5 m pile)

3.6.5.21 Plate 3.6-5 below shows the estimated impact ranges that will result from impact piling.

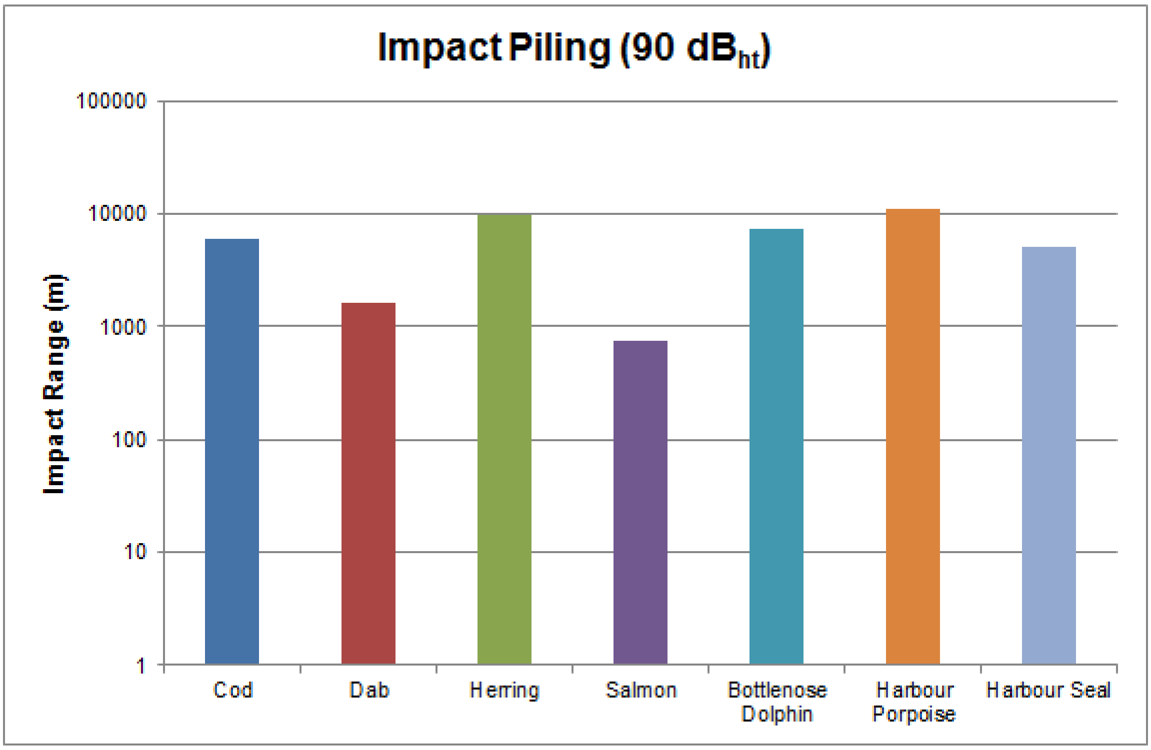

Plate 3.6–5 Estimated Impact Ranges for Various Species Resulting from Impact Piling (90 dB_{ht}), Using a 2.5 m Diameter Pile

3.6.5.22 The impact range values produced by the SPEAR programme are indicative of the area of ocean which is rendered potentially unusable by a species as a result of a particular activity. It is clear from the figures that impact piling is the dominant noise source and hence the activity that will have the greatest impact. This activity has therefore been studied in greater detail using the INSPIRE model.

Modelling Requirements of the Rochdale Envelope

3.6.5.23 As described in Chapter 2.2 (Project Description) the wind turbine foundation designs included within the Rochdale Envelope for the Telford, Stevenson and MacColl wind farms include gravity base structures and jackets with pin piles. For the offshore substation platforms, OSPs (offshore transmission infrastructure) jack–ups with pin piles or suction caissons are also considered. Plate 3.6-3 and Plate 3.6-4 above show that the noise associated with piling is greater than that of with rock placing for gravity foundations. It can also be assumed that, due to the methods involved, suction caissons would also be quieter than impact piling. However, as using suction caissons is a relatively new construction technique, insufficient data is available to reasonably assess performance.

3.6.5.24 With regards to predicting noise impacts, the noise levels associated with driving the pin piles is proportional to the blow energies required for their installation. A preliminary pile design study was undertaken to understand the sensitivity of pile length and the required driving energy in relation to pile diameter, soil type, soil strength, substructure type, wind turbine size and design method and to estimate the most credible worst case pile driving scenario. The study concluded that required pile length and therefore driving energy varies with turbine size, with larger turbines requiring longer piles and greater piling energy. The blow energies required to drive pin piles into the substrate also vary with soil strength, with stiffer / denser soils generally requiring greater blow energies.

3.6.5.25 Analysis of the geophysical and geotechnical survey data indicated that the soil type across the three proposed wind farm sites falls into three geological provinces of differing soil profiles. The geotechnical parameters were derived based on the data from 19 boreholes across the three proposed wind farm sites (Figure 3.6-2, Volume 6 a). Therefore, the parameters used in the noise modelling studies represent an indication of the likely soil conditions across the site. Within each geological province there will be some level of variation in the soil composition which may affect the required pile driving energy (impact energy) and therefore pile hammer size. Further detail on soil provinces is given in Technical Appendix 3.6 A.

3.6.5.26 Stiffer, denser soils generally require greater blow energies. This will have an impact upon the predicted dB_{ht} levels for each species considered. However, it should be noted that softer / looser soils are likely to require slightly longer pin piles to securely tie the foundations into the sea floor, possibly resulting in a greater duration of piling but at lower energy to drive the piles to depth. This will have an impact upon the predicted SEL levels. Province 3 soil is the stiffest soil type found across the three proposed wind farm sites, and driving piles into it will require the highest blow energy.

3.6.5.27 A workshop was held with MORL engineers, marine mammal specialists and the noise modellers in order to investigate the noise implications associated with changes in both soil type and turbine size, with regards to pin pile requirements. During the workshop predictions of the noise levels arising from driving different diameter pins into the same location (same soil type), and the same diameter pin pile into the three different soil types, were modelled to determine the most credible worst case scenario.

3.6.5.28 The modelling showed that, for piles of 2, 2.5 and 3 m diameter driven in province 3 soil at a location close to a seal haul–out site, the 75 dB_{ht} contours for the 2 m and 2.5 m diameter piles were very similar, and that the 75 dB_{ht} contour for the 3 m diameter pile was at most 6 km larger than that for the 2.5 m diameter pile. The conclusion was that SELs were more closely correlated with the blow energy than the length of the piles.

3.6.5.29 The workshop demonstrated that the most credible worst case operation selected was representative of driving a large diameter pile into upper bound hard clays using high energies, and was more onerous than driving piles into lower bound soils for longer duration using lower energies. The study showed that certain soil / pile diameter / design methods gave significantly greater piling energies, however, these combinations are not considered viable due to high foundation costs, potential installation difficulties and ease of mitigation (by use of alternative design methods and / or increasing pile diameter). Therefore the driving of a 2.5 m diameter pin pile into province 3 soil was considered the most credible worst case operation. Table 3.6-10 below details the blow energy profile employed for the noise modelling, assuming maximum impact energy of 1,200 kJ for 100 % hammer efficiency.

Table 3.6-10 Assumed Blow Energy Profile Required to Drive a 2.5 m Diameter Pin Pile to a Depth of 26 m into Province 3 Soils

Penetration Depth	Hammer Efficiency	Impact Energy (kJ)	No of blows	Time
0 to 4 m	15 %	170	260	15 mins
4 to 14 m	40 %	450	2,400	45 mins
14 to 16 m	80 %	890	1,000	15 mins
16 to 26 m	95 %	1,080	7,000	2 hrs

Scenarios Modelled

3.6.5.30 As described in Chapter 2.2 (Project Description), the size and capacity (and so number) of turbines within each of the three proposed wind farm sites have yet to be defined. The Rochdale Envelope allows for between 189 and 339 turbines, of between 3.6 and 8 MW rating. Each turbine foundation would require up to four pin piles of either 2 m or 2.5 m diameter. The Rochdale Envelope also includes up to eight OSPs (up to six AC substations plus two AC / DC converter stations) that would require up to 163 m diameter pin piles each. These piles could be driven into each of the three soil provinces.

3.6.5.31 Whilst recognising that the EIA process should use credible worst case scenarios, it was determined that the complexity arising from modelling a larger number of small turbines compared to a smaller number of large turbines, in addition to the piling requirements of the offshore substation platforms, would not be warranted. Instead, the impact assessments presented for pile driving activity centred around the worst credible case of driving a 2.5 m diameter pile for the turbines and a 3 m diameter pile for OSPs, both into province 3 soil (see Technical Appendix 3.6 A for details on blow energies to drive 3 m piles into province 3). It is recognised that this represents a conservative impact assessment for the turbine foundations and

OSPs. For the purposes of calculating SELs the modelling will assume that two piles would be driven in any 24 hr period.

3.6.5.32 The foundation installation programme modelled represents three scenarios as shown in Table 3.6-11 below. Each scenario assumes a maximum of 339 turbines plus eight OSPs, for a total of 1,484 pin piles (Four pin piles per turbine and 16 per platform) at 260 minutes per pile (conservative estimate based on longest estimated piling duration).

Table 3.6-11 Modelled Scenarios

Scenario	Build Programme (years)	Max. No. of Years with Piling Activities	Max. No. of Vessels (piling activities)
1	5	4	1
2	4	3	2
3	3	2	6

3.6.5.33 An average of 13 % of piling days for the wind turbines and 1 % for the OSPs are estimated for scenario 1, assuming maximum piling duration (approximately15 % of overall piling days over five years).

3.6.5.34 Each site may ultimately be constructed independently of the other two, and as such it is necessary for the impact assessment to include the scenario of construction of all three at the same time so as to account for any coordination issues between the projects. Scenario 3 would only occur to mitigate delays in the building schedule or result from supply chain constraints. It is recognised therefore that the probability of six simultaneous piling events (scenario 3) is very low and, if occurring, would be of very short duration.

3.6.5.35 All of the above scenarios are therefore extremely conservative, assuming maximum number of turbines and offshore platforms (339 turbines and eight platforms), longest estimated piling duration (per pin pile), weather constraints and mobilisation and demobilisation activities. Further refinement of these parameters (engineering information, build programmes) will be undertaken during determination / post consent as the engineering studies progress and preferred contractors are identified in order to provide a more 'realistic' worst case.

3.6.5.36 The locations chosen to represent the spread of piling activities associated with each scenario are shown in Figure 3.6-3, Volume 6 a.

3.6.5.37 The worst case for a single vessel being used is location 1, chosen as the location with the greatest proximity to sensitive receptors in the Moray Firth. Additional modelling has also been carried out for each of the three proposed wind farm sites individually, MacColl, Stevenson, and Telford, as well as the offshore transmission infrastructure (offshore platforms) independently.

3.6.5.38 For two vessels being used, the worst case for the marine mammals is when locations 1 and 5 are modelled. Additional modelling has also been carried out for two vessels on each of the three sites (MacColl, Stevenson, and Telford) independently.

3.6.5.39 For six vessels being used, piling is modelled at locations 1 to 6.

3.6.5.40 In addition to the up to six vessels operating within the three proposed wind farm sites described above, BOWL may also be piling foundations within the Moray Firth during the expected construction phase. Information from BOWL indicates that the developer is considering up to two construction vessels to be in operation at any one time on their site. The two locations at which piling might take place are labelled A and B in Figure 3.6-3, Volume 6 a. BOWL has provided the blow energy profile given below in Table 3.6-12 as being indicative for the driving of a 2.4 m diameter pile into the soils within their site boundary.

Table 3.6-12 Predicted Blow Energy Profile Provided by BOWL as Being Required to Drive a 2.4 m Diameter Pile into the Soils of the Beatrice Site

Impact Energy (kJ)	No of Blows	Time
280	1,200	15 mins
920	3,700	1 hr
1,380	3,700	1 hr
1,840	3,700	1 hr
2,300	3,700	1 hr

3.6.6 Details of INSPIRE Modelling of Impact Piling

3.6.6.1 The following tables give an overview of the modelling and the results presented for the various scenarios. All the outputs of the scenarios modelled for each of the receptors can be found within Section 4 of Technical Appendix 3.6 A (Underwater Noise).

Table 3.6-13 Scenario 1 – Piling Activity at Location 1

Pile Diameter (m)	Number of Piles / Pile Location	Hammer Capacity (kJ)	Species	Results Shown
2.5 **(3 for OSP modelling)**	Piling on MacColl, Stevenson and Telford sites	1,200 (for 2.5 m) 1,800 (for 3 m)	Cod, Herring, Plaice, Salmon, Bottlenose dolphin, Harbour porpoise, Harbour seal, Minke whale	90 dB_{ht} and 75 dB_{ht} contours
2.5 **(3 for OSP modelling)**	Two pin piles installed sequentially on MacColl, Stevenson and Telford sites.	1,200 (for 2.5 m) 1,800 (for 3 m)	Low, mid, high frequency cetacean and pinnipeds	Contours between 200 and 186 dB re 1 $\mu Pa^2.s$ (M) in 2 dB increments for fleeing and stationary animals

Table 3.6-14 Scenario 2 – Piling Activity at Two Locations

Pile Diameter (m)	Number of Piles / Pile Location	Hammer Capacity (kJ)	Species	Results Shown
2.5	Simultaneous piling at two locations on the three proposed wind farm sites, including each individual site	1,200	Cod, Herring, Plaice, Salmon, Bottlenose dolphin, Harbour porpoise, Harbour seal, Minke whale	90 dB_{ht} and 75 dB_{ht} contours
2.5	Two pin piles installed sequentially at two locations on the three proposed wind farm sites simultaneously, including each individual site	1,200	Low, mid, high frequency cetacean and pinnipeds	Contours between 200 and 186 dB re 1 μPa^2.s (M) in 2 dB increments for fleeing and stationary animals

Table 3.6-15 Scenario 3 – Piling Activity at Six Locations

Pile Diameter (m)	Number of Piles / Pile Location	Hammer Capacity (kJ)	Species	Results Shown
2.5	Simultaneous piling at six locations on the MORL site	1,200	Cod, Herring, Plaice, Salmon, Bottlenose dolphin, Harbour porpoise, Harbour seal, Minke whale	90 dB_{ht} and 75 dB_{ht} contours
2.5	Two pin piles installed sequentially at six locations on the MORL site simultaneously	1,200	Low, mid, high frequency cetacean and pinnipeds	Contours between 200 and 186 dB re 1 μPa^2.s (M) in 2 dB increments for fleeing and stationary animals

Table 3.6-16 Additional Cumulative Scenarios – Piling on the Three Proposed Wind Farm Sites and on the BOWL Site Concurrently

Pile Diameter (m)	Number of Piles / Pile Location	Hammer Capacity (kJ)	Species	Results Shown
2.5 (at locations on MORL); 2.4 (at locations on BOWL)	Simultaneous piling at one location on the MORL site and one location on the BOWL site	1,200 (2.5 m pile, MORL) and 2,300 (2.4 m pile, BOWL)	Cod, Herring, Plaice, Salmon, Bottlenose dolphin, Harbour porpoise, Harbour seal, Minke whale	90 dB_{ht} and 75 dB_{ht} contours
2.5 (at locations on MORL); 2.4 (at locations on BOWL)	Two pin piles installed sequentially at one location on the MORL site and one location on the BOWL site simultaneously	1,200 (2.5 m pile, MORL) and 2,300 (2.4 m pile, BOWL)	Low, mid, high frequency cetacean and pinnipeds	Contours between 200 and 186 dB re 1 μPa^2.s (M) in 2 dB increments for fleeing and stationary animals
2.5 (at locations on MORL); 2.4 (at locations on BOWL)	Simultaneous piling at two locations on the MORL site and two locations on the BOWL site	1,200 (2.5 m pile, MORL) and 2,300 (2.4 m pile, BOWL)	Cod, Herring, Plaice, Salmon, Bottlenose dolphin, Harbour porpoise, Harbour seal, Minke whale	90 dB_{ht} and 75 dB_{ht} contours

Pile Diameter (m)	Number of Piles / Pile Location	Hammer Capacity (kJ)	Species	Results Shown
2.5 (at locations on MORL); 2.4 (at locations on BOWL)	Two pin piles installed sequentially at two locations on the MORL site and two locations on the BOWL site simultaneously	1,200 (2.5 m pile, MORL) and 2,300 (2.4 m pile, BOWL)	Low, mid, high frequency cetacean and pinnipeds	Contours between 200 and 186 dB re 1 μPa².s (M) in 2 dB increments for fleeing and stationary animals
2.5 (at locations on MORL); 2.4 (at locations on BOWL)	Simultaneous piling at six locations on the MORL site and two locations on the BOWL site	1,200 (2.5 m pile, MORL) and 2,300 (2.4 m pile, BOWL)	Cod, Herring, Plaice, Salmon, Bottlenose dolphin, Harbour porpoise, Harbour seal, Minke whale	90 dB_{ht} and 75 dB_{ht} contours
2.5 (at locations on MORL); 2.4 (at locations on BOWL)	Two pin piles installed sequentially at six locations on the MORL site and two locations on the BOWL site simultaneously	1,200 (2.5 m pile, MORL) and 2,300 (2.4 m pile, BOWL)	Low, mid, high frequency cetacean and pinnipeds	Contours between 200 and 186 dB re 1 μPa².s (M) in 2 dB increments for fleeing and stationary animals

Summary of Modelling of Piling Activity

3.6.6.2 Underwater noise generated by pile driving at several locations during construction of the three proposed wind farm sites has been calculated using the INSPIRE noise modelling software. Detailed outputs are given in Section 9 of Technical Appendix 3.6 A.

3.6.6.3 The range of noise emissions with reference to the different species has been calculated in respect of dB_{ht}(Species) and M–weighted dB SEL to assess the potential impact of the piling on marine species. This is both in terms of injury and behavioural response. Unweighted levels of 240 dB re. 1 μPa and 220 dB re. 1 μPa for lethality and physical injury are also considered, and are of the order of 2 m and 38 m respectively from the pile.

3.6.6.4 These calculated levels have been used to inform the fish and marine mammal assessments and detailed biological interpretation of the data can be found in Chapters 7.2 (Fish and Shellfish Ecology) and Chapter 7.3 (Marine Mammals).

3.6.6.5 General comments with respect to cumulative noise exposure can be made. The area of sea affected by noise from simultaneous piling generally is not much greater than if the piling was undertaken at separate times. Indeed, the total area is often less due to the overlap of the insonified areas. In this respect, the overall sound exposure during piling simultaneously at multiple locations is sometimes lower than if the piling was undertaken at separate times.

3.6.7 Noise Generated During Offshore Construction Activities other than Piling

3.6.7.1 Noise modelling has been undertaken to determine the effect of underwater noise on marine species of interest in the Moray Firth during the installation of the three proposed wind farms and offshore transmission infrastructure (OfTI) other than piling (discussed in previous sections).

3.6.7.2 The various activities that will take place during the installation of the 3 wind farms and OfTI have been analysed and their effect assessed using a large database of underwater noise measurements and the SPEAR model (see paragraphs 3.6.5.18

to 3.6.5.22 for a description of the SPEAR program). The noise sources that have been considered in this case are trenching, cable laying, rock placing, dredging and vessel noise from the construction vessels and the support vessels. All of these activities have been modelled for continuous operation.

Noise Metrics

3.6.7.3 The modelling has been undertaken using two noise metrics, the dB_{ht}(Species) and M–weighted SELs. These metrics are described in detail in Section 2 of Technical Appendix 3.6 A (Underwater Noise).

Modelling Results

3.6.7.4 Table 3.6-17 to Table 3.6-21 below give the maximum impact ranges and areas of sea affected for a variety of underwater noise sources associated with the wind farms and OfTI construction activities (not including piling). These are calculated using the SPEAR model, for the key species of fish and marine mammals using the dB_{ht}(Species) metric. From these results it can be seen that the largest impact is estimated for the harbour porpoise, with a 90 dB_{ht} impact range of 140 m for trenching activities (Table 3.6-20). This equates to an area of sea excluded of 1 km^2-hrs, which gives an indication of the area that an animal will be excluded from over a period of time. It should also be noted that the estimated impact ranges are greater for species of marine mammal than they are for fish. This is most likely to be because of the substantial high frequency component of the noise. Marine mammals can perceive higher frequencies of noise than fish, and the noise sources involved for these operations are primarily in the higher frequencies. A more detailed analysis of the results from the modelling, using the SPEAR model, is given in Section 8 of Technical Appendix 3.6 A (Underwater Noise).

Table 3.6-17 Maximum Impacts from Suction Dredging Using the dB_{ht}(Species) Metric

Activity: Suction Dredging	90 dB_{ht}(*Species*)		75 dB_{ht}(*Species*)	
	Impact Range (m)	Area of Sea Affected (km^2–hours)	Impact Range (m)	Area of Sea Affected (km^2–hours)
Cod	7	< 1	39	< 1
Dab	1	< 1	7	< 1
Herring	13	< 1	65	< 1
Salmon	1	< 1	5	< 1
Bottlenose Dolphin	21	< 1	72	< 1
Harbour Porpoise	21	< 1	200	3
Harbour Seal	2	< 1	26	< 1

Table 3.6-18 Maximum Impacts from Cable Laying Using the dB_{ht}(Species) Metric

Activity: Cable laying	90 dB_{ht}(*Species*)		75 dB_{ht}(*Species*)	
	Impact Range (m)	Area of Sea Affected (km^2–hours)	Impact Range (m)	Area of Sea Affected (km^2–hours)
Cod	1	< 1	20	< 1
Dab	< 1	< 1	1	< 1
Herring	8	< 1	66	< 1
Salmon	< 1	< 1	1	< 1
Bottlenose Dolphin	9	< 1	75	< 1
Harbour Porpoise	29	< 1	220	4
Harbour Seal	2	< 1	29	< 1

Table 3.6-19 Maximum Impacts from Rock Placing for Gravity Base Installations Using the dB_{ht}(Species) Metric

Activity: Rock Placing	90 dB_{ht}(*Species*)		75 dB_{ht}(*Species*)	
	Impact Range (m)	Area of Sea Affected (km^2–hours)	Impact Range (m)	Area of Sea Affected (km^2–hours)
Cod	2	< 1	25	< 1
Dab	< 1	< 1	4	< 1
Herring	6	< 1	62	< 1
Salmon	< 1	< 1	4	< 1
Bottlenose Dolphin	31	< 1	170	2
Harbour Porpoise	99	1	550	23
Harbour Seal	17	< 1	99	1

Table 3.6-20 Maximum Impacts from Trenching Using the dB_{ht}(Species) Metric

Activity: Trenching	90 dB_{ht}(*Species*)		75 dB_{ht}(*Species*)	
	Impact Range (m)	Area of Sea Affected (km^2–hours)	Impact Range (m)	Area of Sea Affected (km^2–hours)
Cod	1	< 1	16	< 1
Dab	< 1	< 1	< 1	< 1
Herring	< 1	< 1	27	< 1
Salmon	< 1	< 1	2	< 1
Bottlenose Dolphin	81	< 1	350	9

Activity: Trenching	**90 dB_{ht}(*Species*)**		**75 dB_{ht}(*Species*)**	
	Impact Range (m)	**Area of Sea Affected (km²–hours)**	**Impact Range (m)**	**Area of Sea Affected (km²–hours)**
Harbour Porpoise	140	1	640	31
Harbour Seal	12	< 1	87	1

Table 3.6-21 Maximum Impacts from Vessel Noise Using the dB_{ht}(Species) Metric

Activity: Vessel Noise	**90 dB_{ht}(*Species*)**		**75 dB_{ht}(*Species*)**	
	Impact Range (m)	**Area of Sea Affected (km²–hours)**	**Impact Range (m)**	**Area of Sea Affected (km²–hours)**
Cod	< 1	< 1	8	< 1
Dab	< 1	< 1	< 1	< 1
Herring	1	< 1	10	< 1
Salmon	< 1	< 1	< 1	< 1
Bottlenose Dolphin	12	< 1	110	1
Harbour Porpoise	22	< 1	200	3
Harbour Seal	< 1	< 1	11	< 1

3.6.7.5 Table 3.6-22 below summarises the results of the SPEAR modelling in terms of M–weighted SELs for assessing the impact of underwater noise on marine mammals. Assuming an animal fleeing from the noise source at a rate of 1.5 m / s (considered to be a typical cruising speed for a marine mammal) it is unlikely that a marine mammal will receive a level of noise at which auditory injury is expected to occur for any of the activities associated with the construction of the wind farms and OfTI (not including piling). This is based on the criteria proposed by Southall *et al.,* (2007).

3.6.7.6 Using a stationary animal model, where it is assumed that the receptor stays in the same location relative to the vessel for a 24 hour period, the largest ranges out to which auditory injury is expected to occur are predicted to be 100 m. It should be noted that not only are these thought to be highly precautionary levels, it is highly unlikely that an animal will stay in the same position near a noise source for a 24 hour period.

Table 3.6-22 Summary of the Maximum Impacts from Non Piling Construction Activities Using the M–Weighted SEL Metric

	Fleeing Animal (1.5 m / s) Auditory Injury Range (m)	Stationary Animal Auditory Injury Range (m)
Low Frequency Cetaceans (198 dB re. 1 µPa².s (M_{lf})	< 1	< 100 m
Mid Frequency Cetaceans (198 dB re. 1 µPa².s (M_{mf})	< 1	< 100 m
High Frequency Cetaceans (198 dB re. 1 µPa².s (M_{hf})	< 1	< 100 m
Pinniped (in water) (198 dB re. 1 µPa².s (M_{pw})	< 1	< 100 m

3.6.8 References

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3.6.9 *Technical Glossary*

Acoustic particle velocity – The time rate of change of the displacement of fluid particles created by the forces exerted on the fluid by acoustic pressure in the presence of a sound wave. The units of velocity are metres per second (m / s).

Acoustic Pressure – The force per unit area exerted by a sound wave above and below the ambient or static equilibrium pressure is called the acoustic pressure or sound pressure. The units of pressure are pounds per square inch (psi) or, in the SI system of units, Pascals (Pa). In underwater acoustics the standard reference is one–millionth of a Pascal, called a micro–Pascal (1 µPa).

Ambient sound – Normal background noise in the environment, which has no distinguishable sources.

Area of sea excluded (km²–hours) – The area of sea excluded with each activity; this gives an idea of the area expected to be excluded to an animal, based on a given dB_{ht}(*Species*) criteria over a period of time. This means direct comparisons can be made against the area of sea excluded during a short piling operation or a dredging operation lasting all day. These results have been given as kilometres squared excluded times hours (km²–hours). For example: if 10 km²–hours of sea are excluded, this could mean that 1 km² of sea is excluded for 10 hours or that 10 km² of sea is excluded for 1 hour.

Bandwidth – The range of frequencies over which a sound is produced or received.

Decibel (dB) – A customary scale most commonly used (in various ways) for reporting levels of sound. A difference of 10 dB corresponds to a factor of 10 in sound power. The actual sound measurement is compared to a fixed reference level and the "decibel" value is defined to be 10 log10, (actual / reference), where (actual / reference) is a power ratio. Because sound power is usually proportional to sound pressure squared, the decibel value for sound pressure is 20 log10 (actual pressure / reference pressure). As noted above, the standard reference for underwater sound pressure is 1 micro–Pascal (µPa). The dB symbol is followed by a second symbol identifying the specific reference value (i.e. re 1 µPa).

Far field – A region far enough away from a source that the sound pressure behaves in a predictable way, and the particle velocity is related to only the fluid properties and exists only because of the propagation sound wave (see Near field).

Hertz – The units of frequency where 1 hertz = 1 cycle per second. The abbreviation for hertz is "Hz."

Impulse sound – Transient sound produced by a rapid release of energy, usually electrical or chemical such as circuit breakers or explosives. Impulse sound has extremely short duration and extremely high peak sound pressure.

Near field – A region close to a sound source that, depending on the size of the source relative to the wavelength of the sound, has either irregular sound pressure or exponentially increasing sound pressure towards the source, and a high level of acoustic particle velocity because of kinetic energy added directly to the fluid by motion of the source. This additional kinetic energy does not propagate with the sound wave. The extent of the near field depends on the wavelength of the sound and/or the size of the source.

Peak pressure – The highest pressure above or below ambient that is associated with a sound wave.

Permanent threshold shift (PTS) – A permanent loss of hearing caused by some kind of acoustic or drug trauma. PTS results in irreversible damage to the sensory hair cells of the ear, and thus a permanent loss of hearing.

Pulse – A transient sound wave having finite time duration. A pulse may consist of one to many sinusoidal cycles at a single frequency, or it may contain many frequencies and have an irregular waveform.

Resonance frequency – The frequency at which a system or structure will have maximum motion when excited by sound or an oscillatory force.

Sea State – the general condition of the free surface on a large body of water – with respect to wind waves and swell – at a certain location.

Beaufort Wind Scale	Mean Wind Speed		Limits of Wind Speed		Wind Descriptive Terms	Probable Wave Height (m)	Probable Max. Wave Height (m)	Seastate	Sea Descriptive Terms
	Knots	ms^{-1}	Knots	ms^{-1}					
0	0	0	< 1	< 1	Calm	–	–	**0**	Calm (glassy)
1	2	1	1–3	1–2	Light air	0.1	0.1	**1**	Calm (rippled)
2	5	3	4–6	2–3	Light breeze	0.2	0.3	**2**	Smooth (wavelets)
3	9	5	7–10	4–5	Gentle breeze	0.6	1.0	**3**	Slight
4	13	7	11–16	6–8	Moderate breeze	1.0	1.5	**3–4**	Slight–Moderate
5	19	10	17–21	9–11	Fresh breeze	2.0	2.5	**4**	Moderate
6	24	12	22–27	11–14	Strong breeze	3.0	4.0	**5**	Rough
7	30	15	28–33	14–17	Near gale	4.0	5.5	**5–6**	Rough–Very rough
8	37	19	34–40	17–21	Gale	5.5	7.5	**6–7**	Very rough–High
9	44	23	41–47	21–24	Severe gale	7.0	10.0	**7**	High
10	52	27	48–55	25–28	Storm	9.0	12.5	**8**	Very High
11	60	31	56–63	29–32	Violent storm	11.5	16.0	**8**	Very High
12	–	–	64+	33+	Hurricane	14+	–	**9**	Phenomenal

Source: Met Office

Shock wave – A propagating sound wave that contains a discontinuity in pressure, density, or particle velocity.

Sound attenuation – Reduction of the level of sound pressure. Sound attenuation occurs naturally as a wave travels in a fluid or solid through dissipative processes (e.g. friction) that convert mechanical energy into thermal energy and chemical energy.

Sound exposure – The integral over all time of the square of the sound pressure of a transient waveform.

Sound exposure level (SEL) – The constant sound level acting for one second, which has the same amount of acoustic energy, as indicated by the square of the sound pressure, as the original sound. It is the time–integrated, sound–pressure–squared level. SEL is typically used to compare transient sound events having different time durations, pressure levels and temporal characteristics.

Sound exposure spectral density – The relative energy in each narrow band of frequency that results from the Fast Fourier Transform (FFT – a mathematical operation that is used to express data recorded in the time domain as a function of frequency) of a transient waveform. It is a measure of the frequency distribution of a transient signal.

Sound pressure level (SPL) – The sound pressure level or SPL is an expression of the sound pressure using the decibel (dB) scale and the standard reference pressures of 1 µPa for water and biological tissues, and 20 µPa for air and other gases.

Spectrum – A graphical display of the contribution of each frequency component contained in a sound.

Temporary threshold shift (TTS) – Temporary loss of hearing as a result of exposure to sound over time. Exposure to high levels of sound over relatively short time periods will cause the same amount of TTS as exposure to lower levels of sound over longer time periods. The mechanisms underlying TTS are not well understood, but there may be some temporary damage to the sensory cells. The duration of TTS varies depending on the nature of the stimulus, but there is generally recovery of full hearing over time.

Threshold – The threshold generally represents the lowest signal level an animal will detect in some statistically predetermined percent of presentations of a signal. Most often, the threshold is the level at which an animal will indicate detection 50 % of the time. Auditory thresholds are the lowest sound levels detected by an animal at the 50 % level.

Total energy dose – The total cumulative energy received by an organism or object over time in a sound field.

Unweighted sound levels – Sound levels which are 'raw' or have not been adjusted in any way. For example: to account for the hearing ability of a species.

Weighted sound levels – A sound level which has been adjusted with respect to a 'weighting envelope' in the frequency domain, typically to make an unweighted level relevant to a particular species. Examples of this are the dB(A), where the overall sound level has been adjusted to account for the hearing ability of humans, or dB_{ht}(*Species*) for fish and marine mammals.

3.7 Hydrology, Geology and Hydrogeology

3.7.1 Introduction

3.7.1.1 This chapter details the existing hydrological, hydrogeological and geological baseline conditions present within and adjacent to the proposed development. It also provides details of potential existing land contamination identified within the study area. The onshore study area is defined in Figure 1.1-4, Volume 6 a. The study area was defined by assessing an onshore cable route ranging from 1 to 3 km wide, divided into sections along the route. The study area is comprised of a number of environments, including urban, rural, agricultural, industrial and coastal land.

3.7.1.2 The study consisted of the following aspects:

- Field surveys consisting of comprehensive site walkovers to inform the baseline assessment;
- Detailed desk study to establish the baseline conditions within the study area;
- Consideration of the relevant key legislative and planning information; and
- Consultation with relevant statutory and non-statutory bodies, including Aberdeenshire Council, Scottish Water, Scottish Environmental Protection Agency (SEPA) and RIGS Group (Regionally Important Geological Sites).

3.7.1.3 A detailed account of this information is provided in:

- Technical Appendix 3.7 A (Hydrology, Geology and Hydrogeology Technical Report).

3.7.1.4 This baseline is used to inform the Hydrology, Geology and Hydrogeology Impact Assessment described in:

- Chapter 9.3 (Hydrology, Geology and Hydrogeology); and
- Chapter 13.3 (Cumulative Impact Assessment).

3.7.1.5 Effects on hydrology, hydrogeology and geology may result in secondary ecological effects on habitats or species. Effects on ecological receptors, including fish, are considered in the following chapters:

- Fish and Shellfish Ecology (Chapters 4.3, 7.2, 10.2 and 14.2);
- Intertidal Ecology (Chapters 4.6, 10.5 and 14.5); and
- Terrestrial Ecology (Chapters 4.7, 10.6 and 14.6).

3.7.2 Consultations

3.7.2.1 A summary of consultation responses are shown in Table 3.7-1 below.

Table 3.7-1 Summary of Consultations

Organisation	Consultation Response	MORL Approach
Aberdeenshire Council (response to baseline enquiries)	Detailed information provided in relation to: • Potentially contaminated land; • Private water supplies; • Landfill records;	Accommodated information in consideration of the baseline conditions

Organisation	Consultation Response	MORL Approach
Aberdeenshire Council (response to baseline enquiries) (continued)	• Geodiversity sites; and • Petroleum records. Infrastructure Services advised that when a planning application is submitted for the route of the cable and associated infrastructure, it would assess the proposed route and request either investigation or place a formal note on the planning decision, expecting that any potentially contaminated land found along the route be investigated and this Service informed of the results accordingly. (Peter Exon – Aberdeenshire Council).	Accommodated information in consideration of the baseline conditions
Scottish Water (response to baseline enquiries)	The location of water supply, sewerage and drainage infrastructure has been requested. No data has been supplied to date.	This information can be followed up once the specific route is finalised.
SEPA (response to baseline enquires)	Information provided in relation to: • Licensed water abstractions; • Historic flooding; • Extreme tidal levels; and • Coastal erosion issues. SEPA recommended that contact be made with Aberdeenshire Council as a flood prevention authority to discuss coastline erosion near Fraserburgh.	Accommodated information in consideration of the baseline conditions.
SEPA (comments on draft ES chapters)	• Watercourse crossing details are required once the final cabling route is defined.	MORL will develop watercourse crossing design as detailed in the mitigation measures.
	• SEPA highlight that the cable route crosses the Burn of Savoch and Ellie Burn which are part of the Loch of Strathbeg Catchment. Sediment transport from the catchment has contributed to the enriched state of the Loch which is in turn effecting the survival of species of interest. Avoidance of these tributaries is advised but if not possible strict sediment controls are required during construction.	MORL will consider this as far as possible in the Cable Route Detailed Alignment Development and where it is not possible the mitigation measures relating to sediment control will be employed.
	• SEPA highlight that the River Ugie is affected by phosphorous which is in part due to sediment particles. The cable route currently follows a long length of the North Ugie Water. Trenching along a considerable length could increase the risk of excessive sedimentation and / or alter the hydrology compared to where perpendicular crossings are used. The Ugie Catchment is one of the first catchments in Scotland to be part of a Priority Catchment Initiative and as such, extensive ground works adjacent to this watercourse could increase sediment load which requires careful consideration.	MORL will consider this as far as possible in the Cable Route Detailed Alignment Development and where it is not possible the mitigation measures relating to sediment control will be employed.
	• The Loch of Strathbeg RBMP classification should be included.	This is now detailed in the baseline.
	• The onshore infrastructure proposals have the potential to create morphological and diffuse pollution impacts on water bodies. It will be important to follow best practice to prevent deterioration in the ecological status of water bodies.	This impact is assessed and migration proposed to control possible impacts on water quality and catchments.

Organisation	Consultation Response	MORL Approach
SEPA (comments on draft ES chapters) **(continued)**	• Flood risk: avoid flood plains where possible. Where they cannot be avoided, storage of excavated material is recommended outwith the flood plain where possible. If not, a site specific risk assessment would be required. • Flood risk: Post the construction and completion of the trench, pre-construction ground levels must be reinstated in the flood plain in order to avoid impacts on flood plain storage and flood flows.	• MORL will consider this as far as possible in the Cable Route Detailed Alignment Development and where it is not possible the mitigation measures relating to crossing design will be employed. • MORL will develop watercourse crossing design as detailed in the mitigation measures.
RIGS group (Regionally Important Geological Sites)	Enquires with the Scottish RIGS Coordinator have established that there is not a RIGS group for the Aberdeenshire area and as such there are no RIGS sites.	None required

3.7.3 Baseline Characteristics

3.7.3.1 A summary of the information that has been collated during desk-based studies and walkover surveys is provided below. Supporting details and reference data are contained in Technical Appendix 3.7 A.

3.7.4 Climate

3.7.4.1 The climate conditions, in terms of precipitation are relatively uniform throughout the study area. The average annual rainfall, as estimated using Flood Estimation Handbook data (Centre for Ecology and Hydrology, 2009), varies between approximately 720 to 840 mm. The largest rainfall depth is associated with the western areas near Mormond Hill.

3.7.4.2 In Scotland the annual average rainfall varies between 600 to 3,000 mm. This suggests that rainfall in the study area is relatively low which is largely related to the low altitude and location near the east coast of Scotland.

3.7.4.3 Extreme rainfall depths within the study area could reach up to 67 mm per day for a 3.3 % (1 / 30) annual probability storm event and 97.1 mm for a 0.5 % (1 / 200) annual probability storm event.

3.7.5 Catchments

3.7.5.1 The study area is situated with a maximum distance to the coastline of some 12 km and contains a number of catchments with drainage areas ranging from very small (minor streams discharging directly to the North Sea) to 340 km^2.

3.7.5.2 The largest catchments are:

- River Ugie catchment: 340 km^2;
- Water of Philorth catchment: 64 km^2; and
- Burn of Savoch catchment: 44 km^2.

3.7.5.3 Indicative catchment outlines are shown in Figure 3.7-1, Volume 6 a.

3.7.5.4 The highest elevation within the River Ugie and Water of Philorth catchments is approximately 234 m above ordnance datum (AOD) (Waughton Hill/Mormond Hill). Note that the most upstream parts of the River Ugie catchment area are of a similar altitude.

3.7.5.5 Within the study area, elevations vary between sea level and 93 mAOD. The topography is relatively flat or gently undulating. Elevations gradually reduce from the Mormond Hill area towards the coastline. A dune system is present along large stretches of the coastline between Fraserburgh and Peterhead.

3.7.5.6 Land elevations remain higher near the proposed substation location near Peterhead. Here the coastline drops more steeply from 20 mAOD to sea level.

3.7.5.7 The natural drainage regimes within the key catchments are characterised as having a relatively high baseflow, with low direct runoff volumes. This indicates relatively slow catchment response, with a large proportion of runoff through groundwater. See Table 3.7-2 below for details.

Table 3.7-2 Drainage Characteristics Based on Flood Estimation Handbook Data (Centre for Ecology and Hydrology 2009)

Catchment	Baseflow Index (%)	Standard Percentage Runoff (%)
River Ugie	52	33
Water of Philorth	60	29
Burn of Savoch	47	34

3.7.5.8 Land use is predominantly agriculture / rural with some industrial and urban areas throughout the study area and coastal land use at the landfall point.

3.7.6 Watercourses

3.7.6.1 The main watercourses within or flowing through the study area are shown in Figure 3.7-1, Volume 6 a.

3.7.6.2 The largest river is the River Ugie with two major tributaries, the North Ugie Water and the South Ugie Water. The North Ugie Water flows through the study area over a length of 4.5 km, approximately. Other rivers generally cross the onshore cable route perpendicularly over the shortest possible distance.

3.7.6.3 All rivers near the onshore cable route are classified as lowland rivers and have a relatively low longitudinal gradient. The larger rivers, including the River Ugie, meander through relatively wide floodplains. River beds predominantly consist of gravel and sand or clay.

3.7.6.4 River channel and floodplain characteristics for the main rivers are shown in Plate 3.7-1 below.

Water of Philorth

North Ugie Water

South Ugie Water

River Ugie

Plate 3.7-1 Typical Views of Key Rivers and their Floodplains

3.7.6.5 Beside the main rivers shown in Figure 3.7-1, Volume 6 a, there are numerous minor watercourses within the study area as shown in Figure 3.7-2 Volume 6 a. This includes both natural streams and man-made drainage ditches and channels. The drainage ditches are thought to be related to the relatively flat topography and the need for improved drainage for agricultural purposes.

Flow Regime

3.7.6.6 The only river for which water levels and flow rates are monitored, is the River Ugie. The gauging station at Inverugie is approximately 7 km downstream of the onshore cable route. Key flow parameters at this location are shown in Table 3.7-3 below.

Table 3.7-3 Flow Regime River Ugie at Inverugie (Centre for Ecology and Hydrology, n.d.; Wallingford HydroSolutions Limited, 2009)

Magnitude	**Flow Rate (m³/s)**
Low flow (95 percentile)	11
Average flow	48
Median annual maximum flood (QMED) / approximate bank-full flow	45
Extreme flood (0.5 % annual probability)	200

Flooding

3.7.6.7 The rivers within the study area have associated floodplains which may be prone to flooding during storm events where flow rates exceed the channel capacity.

3.7.6.8 The potential extent of these natural floodplains up to a 0.5 % annual probability is shown on the Indicative River & Coastal Flood Map, available online (Scottish Environment Protection Agency, 2010). This map cannot be reproduced within this ES due to intellectual property right restrictions.

3.7.6.9 Those locations where the potential inundation zone extends beyond areas directly adjacent to the river banks have been included in Figure 3.7-2, Volume 6 a. These areas include, for example, low lying land near the confluence of the North and South Ugie Water with the River Ugie. Other areas at risk of river flooding include low lying areas near the Kessock Burn and the Water of Philorth, south of Fraserburgh.

3.7.6.10 SEPA supplied further details on locations of known historic flooding records in and near the study area. These highlight the history of surface water flooding throughout Fraserburgh due to undersized drainage infrastructure. Additionally, flooding occurred in 2006 at Fraserburgh beach where a (partially) blocked culvert caused flooding of a public road and car park.

3.7.6.11 The supplied locations of historic flooding are shown in Figure 3.7-2, Volume 6 a.

Water Quality

3.7.6.12 Water quality along all main rivers flowing through the study area is monitored by SEPA under the EU Water Framework Directive. This data has been analysed and its findings are summarised in Table 3.7-4 below.

Table 3.7-4 Water Quality Classification (Scottish Environment Protection Agency)

River	Overall Status (in 2008)	Current Pressures
Kessock Burn	Moderate	Morphological alterations due to agriculture
Water of Philorth	Moderate	Morphological alterations due to agriculture
Burn of Savoch	Moderate	Diffuse source pollution due to agriculture Morphological alterations due to agriculture
River Ugie and tributaries	Moderate	Abstractions for public water supplies Diffuse source pollution due to agriculture Diffuse and point source pollution due to sewage

3.7.6.13 SEPA have advised that the River Ugie and the Ugie Catchment is part of a Priority Catchment Initiative which aims to eradicate agricultural practices which prevent the River Ugie meeting 'Good' status for the Water Framework Directive.

3.7.7 Lochs and Other Water Bodies

3.7.7.1 There are no significant open water bodies within the study area. However, there are a number of smaller ponds, flooded quarries and a small reservoir present.

3.7.7.2 There is one water body downstream of the cable route, the Loch of Strathbeg. This loch is designated as a Site of Special Scientific Interest (SSSI), Special Protection Area (SPA) and a RAMSAR site .

3.7.7.3 The Green Burn and the Burn of Logie flow through the cable route and discharge into the Loch of Strathbeg via the Burn of Savoch.

Coastline

3.7.7.4 The coastline near the proposed landfall point at Fraserburgh consists of a dune system with a sand beach which ranges between 100 to 200 m in width during low tide. The most northern section of the study area boundary includes the docks at Fraserburgh and a public esplanade.

3.7.7.5 Typical characteristics of the coastline at the landfall point are shown in Plate 3.7-2 below.

Plate 3.7-2 Coastline at Proposed Landfall Point near Fraserburgh (looking north)

3.7.7.6 The risk of flooding from the North Sea is shown on SEPA's River & Coastal Flood Map (Scottish Environment Protection Agency, 2010). The only part of the study area affected by coastal flooding risk is situated near Fraserburgh harbour.

3.7.7.7 Extreme tidal level estimates at Fraserburgh have been supplied by SEPA and are based on a study by the Environment Agency (2011). The tidal level with an annual exceedance probability (AEP) of 0.5 % is approximately 2.85 mAOD and the 0.1 % AEP level is approximately 2.98 mAOD.

3.7.7.8 Likely significant effects on the coastline and foreshore, related to the offshore cable route, are discussed in Chapter 9.3 (Hydrology, Geology and Hydrogeology). For example: this includes wave and current conditions and coastal erosion.

3.7.8 Water Supplies and Abstractions

3.7.8.1 The locations of private water supplies were supplied by Aberdeenshire Council and are shown in Figure 8 (Abstractions and water supplies) in Technical Appendix 3.7 A. Private water supplies can be split between Type A (more than 10 m^3 per day, serving more than 50 persons or for commercial activities) and Type B (all other) supplies (Scottish Government, 2006). The source of most of the private drinking water supplies is not recorded. However, this is likely to include groundwater abstractions via wells due to the sand and gravel geology.

3.7.8.2 SEPA supplied information on the licensed groundwater and surface water abstractions under the Controlled Activities Regulations (Scottish Government, 2011). These abstractions are typically more than 50 m^3 per day (Scottish Environment Protection Agency, 2011) and are shown in Figure 8 (Abstractions and water supplies) in Technical Appendix 3.7 A. Within the study area there are only three licensed abstractions, two of which are for agricultural purposes and one for mining and quarrying. There are no surface water abstractions within or downstream of the study area for public drinking water supplies.

3.7.9 Hydrogeology

3.7.9.1 Information regarding the hydrogeological environment underlying the cable route was taken from the following sources:

- Scottish Environment Protection Agency, 2004. Bedrock Aquifer Map of Scotland;
- Scottish Environment Protection Agency, 2004. Superficial Aquifer Map of Scotland;
- Scottish Environment Protection Agency, River Basin Management Plan Interactive Map. Available at: http://gis.sepa.org.uk/rbmp/; and
- Scottish Environment Protection Agency, 2004. Groundwater Vulnerability of the Uppermost Aquifer Map of Scotland.

3.7.9.2 Excerpts from the above sources are provided in Figures 5 to 7 in Technical Appendix 3.7 A where available digitally. A summary of information provided in the above references is provided below. Further details of the hydrogeological environment can be found in Technical Appendix 3.7 A.

Groundwater Bodies

3.7.9.3 The River Basement Management Plan (RBMP) GIS (Scottish Environment Protection Agency, n.d.) was undertaken to provide information on groundwater bodies beneath the study area and these were all classified as 'Good'.

3.7.9.4 The RBMP GIS shows that the whole study area is within a Drinking Water Protection Area, referring to a body of water which may be used for the abstraction of drinking water. It is noted that most of Scotland is classified as a protection area in this regard.

Hydrogeological Classification

3.7.9.5 The Bedrock Aquifer Map of Scotland (Scottish Environment Protection Agency, 2004a) indicates that the study area is underlain by aquifers of very low productivity (F VL) or low productivity (F L) where flow is dominated by fracture flow.

3.7.9.6 The bedrock aquifers underlying the southern parts of the study area are shown to be of very low productivity (F VL) where groundwater flow is by fracture flow. This generally accords with the felsic bedrock geology shown in the geological map.

3.7.9.7 The northern part of the study area is shown to be underlain by a bedrock aquifer of low productivity (F L) where groundwater flow is also by fracture flow.

3.7.9.8 The Superficial Aquifer Map of Scotland (Scottish Environment Protection Agency, 2004b) indicates that the study area is underlain by aquifers of low, medium and high productivity where flow is by intergranular fracture flow. The southern parts of the study area have not been classified.

Groundwater Vulnerability

3.7.9.9 The Groundwater Vulnerability of the Uppermost Aquifer (Scottish Environment Protection Agency, 2004c) indicates that the site is underlain by vulnerability classes 2, 3, 4b, 4c and 4d. Under the classification scheme 1 is the least vulnerable and 5 is the most vulnerable (Table 3.7-5 below).

Table 3.7-5 Summary of SEPA's Groundwater Vulnerability Class Definitions (Scotland & Northern Ireland Forum for Environmental Research, 2004)

Classification			Definition
High	5		Vulnerable to most water pollutants with rapid effect in many scenarios.
	4	4a	Vulnerable to those pollutants not readily adsorbed or transformed. Divided into four subclasses according to the depth and permeability rate of the superficial deposits.
		4b	
		4c	
		4d	
	3		Vulnerable to some pollutants with many significantly attenuated.
	2		Vulnerable to some pollutants but only when continuously discharged/leached.
Low	1		Only vulnerable to conservative pollutants in the long term when continuously and widely discarded and leached.

3.7.9.10 The south of the study area is underlain largely by vulnerability classes 2, 3 and 4b. The remainder of the area is underlain almost exclusively by vulnerability class 4b with smaller areas of 4c and 4d shown crossing the centre of the area close to New Leeds and Longmay (Figure 7, Technical Appendix 3.7 A).

3.7.10 Soils

3.7.10.1 Soils data has been collated from the Soil Survey of Scotland maps, Sheet 5 (The Macaulay Institute, 1982).

3.7.10.2 The distribution of soils within the study area is dependent on the geology, topography and drainage regime of the area. Table 3.7-6 below summarises the soil types found within the study area from north to south.

Table 3.7-6 Summary of Soils in Study Area (The Macaulay Institute, 1982)

Map Unit	Soil Association	Component Soils	Parent Material	Landforms
380	Links	Regosols; some gleys	Windblown Sands	Beaches and Dunes with gentle and strong slopes
98	Corby/Boyndie/ Dinnet	Humus iron podzols, alluvial soils	Fluvioglacial and raised beach sands and gravels derived from acid rocks	Valley floors, terraces and mounds with gentle and strong slopes
1	Alluvial Soils	Alluvial Soils	Recent riverine and lacustrine	Flood plains, river terraces and former lake beds
97	Corby/Boyndie/ Dinnet	Humus-iron podzols; some gleys	Fluvioglacial and raised beach sands and gravels derived from acid rocks	Undulating lowlands, mounds and terraces with gentle slopes
498	Strichen	Humus-iron podzols; some brown forest soils and gleys	Drifts derived from arenaceous schists and strongly metamorphosed argillaceous schists of the Dalradian Series	Undulating lowlands and hills with strong and steep slopes; non-rocky
423	North Mormond/Orton	Brown Forest soils: some humus-iron podzols	Drifts derived from Old Sandstone Sediments and acid metamorphic rocks	Undulating lowlands and foothills with strong slopes
497	Strichen	Noncalcareous gleys, humic gleys, some peaty gleys and humus-iron podzols	Drifts derived from arenaceous schists and strongly metamorphosed argillaceous schists of the Dalradian Series	Undulating lowland and valley sides with gentle and strong slopes; non rocky
3	Organic Soils	Basin and Valley Peats	e-eroded peat Organic deposits	Basins and Valleys
115	Countesswells/ Dalbeattie/Priestlaw	Humus-iron podzols; some brown forest soils and gleys	Drifts derived from granites and granitic rock	Undulating lowlands and hills with gentle and strong slopes; non and slightly rocky
518	Tarves	Noncalcareous gleys, peaty gleys; some brown forest soils with gleying	Drifts derived from intermediate rocks or mixed acid and basic rocks, both metamorphic and igneous	Undulating lowlands with gentle slopes; non rocky
429	Peterhead	Brown forest soils with gleying; some gleys	Drifts derived from Old Red Sandstone Sediments with igneous and metamorphic rocks and conglomerate cobbles	Undulating lowlands with gentle and strong slopes
430	Peterhead	Noncalacareous gleys; some peaty gleys and brown forest soils with gleying	Drifts derived from Old Red Sandstone Sediments with igneous and metamorphic rocks and conglomerate cobbles	Undulating lowlands with gentle slopes

3.7.10.3 The study area is predominantly of agricultural land use and therefore the quality of the underlying soils and protection of these may be of local importance.

3.7.11 Superficial Geology

3.7.11.1 A superficial geology map for the study area based on the BGS 1:650,000 scale GIS map is provided as Figure 6 in Technical Appendix 3.7 A.

3.7.11.2 This details that the superficial geology for the study area comprises:

- Alluvium;
- Till;
- Blown sand;
- Glacial sand and gravel; and
- Localised areas of peat.

3.7.11.3 The superficial geology is dominated by glacial till which is crossed in places by alluvium, glacial sand and gravel and peat. In the south of the study area there are three areas of glacial sand and gravel close to Longside. In the north of the onshore cable route, glacial sand and gravel is shown to extend from Rathen (adjacent to the west of the route) northward to Fraserburgh. Alluvium deposits of clay, silt and sand are also identified along the course of the River Ugie and South Ugie Water.

3.7.11.4 Peat is identified within the study area near New Leeds. The area of peat is shown to trend northwest southeast through the onshore cable route. Two smaller areas of peat are also shown to underlie the onshore cable route to the east associated with the St Fergus Moss, and southeast associated with Rora Moss.

3.7.11.5 Initial peat probing was undertaken on the area of peat in the New Leeds area during the site walkover on 10 October 2011, which recorded peat depths ranging from 0.1 to 1.9 m. Further detailed information of the peat probing undertaken are included in Technical Appendix 3.7 A.

3.7.12 Solid Geology

3.7.12.1 A bedrock geology map for the study area based on the BGS 1:650,000 scale GIS map is provided as Figure 5 in Technical Appendix 3.7 A.

3.7.12.2 The solid geology for the study area comprises:

- Felsic igneous intrusive rocks;
- Psammite, semipelite and pelite of the Argyll group; and
- Quartzite of the Argyll Group.

3.7.12.3 The south of the study area is shown to be underlain almost exclusively by felsic rocks of Ordovician to Devonian age. This is likely to comprise rock types such as granite and other coarse grained igneous intrusions.

3.7.12.4 The remainder of the study area is dominated by bedrock comprising the Argyll Group of metamorphic rocks including psammite, semipelite, pelite and quartzite. These are metamorphic rock types likely to include crystalline rock types such schist and gneiss.

3.7.12.5 In addition to the overall bedrock geology two dykes are shown to cross the study area. These are shown to be comprised of dolerite and basalt of Carboniferous to Permian age that are located close to the Forehill Treatment Works and Hythie.

3.7.12.6 There are no geological faults shown within the study area.

3.7.13 Minerals

3.7.13.1 Given the geological strata identified along the cable route, no coal reserves are evident within the region.

3.7.13.2 Sand and gravel deposits and hard rock are present which have the potential to be economically viable and the land uses in the study area show a history of hard rock quarries and more so sand and gravel pits.

3.7.14 Potential for Existing Land Contamination

3.7.14.1 Technical Appendix 3.7 A provides the detailed research completed on identifying sites of potential concern in relation to land contamination. This was completed by a combination of review of historical map records and enquires with Aberdeenshire Council.

3.7.14.2 Enquires with Aberdeenshire Council confirmed that there are no designated statutory Part IIA Contaminated Land sites within the study area.

3.7.14.3 A large number of sites with historical land uses which could result in the presence of contamination of the subsurface in the form of solids / liquids / gases have been identified in the study area:

- In the urban area of Fraserburgh, close to the landfall area, there are numerous potential land uses of concern in relation to contamination (e.g. railway land, industrial land, harbour area, tanks, substations, depots and garages);
- In the south of the study area there are several features of interest including Peterhead Power Station, associated substations, railway land, RAF Buchan, harbour land and petrol filling stations;
- There are 30 historical extraction sites identified mostly further south along the cable route, including sand and gravel pits, pits (unspecified type) and granite quarries;
- There are seven known landfills identified from data provided by SEPA and Aberdeenshire Council;
- A disused railway line (Great North of Scotland Railway) is located trending roughly north-south in the northern half of the study area;
- Longside Airfield is located partly in the south of the study area;
- A gasometer (i.e. gas storage tank) was noted at Philroth House (NK001644) which could indicate the presence of a small country house gasworks;
- A large quarry is shown on historical maps (1924) at NK109444 which is not shown on present day mapping and has presumably been infilled. A small gravel pit is also present (NK105434); and
- Other features of interest include various works including corn mills, smithies, sheep washes, substations, depots, tanks, infilled ponds, an infilled canal and a poultry farm.

3.7.15 Designated Areas

3.7.15.1 Information on biological designated sites is provided in Chapter 4.1. The following summarises the details of the geological designated sites.

3.7.15.2 The Kirkhill geological SSSI is identified at NK012526 close to Leys. This site is designated because it represents the most complete record of Middle to Late Quaternary deposits in Scotland that are considered to be of high importance for Quaternary studies.

3.7.15.3 The Philorth Valley geological SSSI is identified at NK010634 in the north. This site is designated due to its importance for the study of relative sea-level changes in Scotland during the Holocene.

3.7.15.4 The Loch Strathbeg SSSI (NK073589) is situated to the east of the study area. This site is designated due to its importance for migratory birds and wildfowl in addition to the flora and fauna of the dune slacks. The site also provides interest by a variety of raised shoreline features and is considered outstanding for coastal geomorphology studies.

3.7.15.5 The Waters of Philorth is a designated Local Nature Reserve containing saltmarshes, dunes and grasslands.

3.7.15.6 The Sinclair Hills Site of Environmentally Sensitive Areas (SESA) geomorphology site extends just into the north-western edge of the study area close to the Water of Philorth. This site is noted to be designated due to its importance for ice movement studies.

3.7.16 Legislative and Planning Framework

3.7.16.1 This study takes account of the following key legislative and planning information:

- Water Environment and Water Services (Scotland) Act 2003 (2003 asp 3);
- Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2011 (SSI 2011 No. 139);
- The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (SSI 2011 No. 209);
- Scottish Executive, 2000. *Planning Advice Note 33: Development on Contaminated Land;*
- Scottish Executive, 2006. Environmental Protection Act 1990: Part IIA Contaminated Land Statutory Guidance: Edition 2, Scottish Executive, Paper SE/2006/44; and
- Scottish Government, 2010. *Scottish Planning Policy.*

3.7.17 References

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3.8 Noise (Onshore)

3.8.1 Introduction

3.8.1.1 This chapter provides a description of the baseline against which the construction and decommissioning noise effects, associated with the Onshore Transmission Infrastructure (OnTI), have been compared to assess their magnitude and significance. For simplicity, assessment of this topic may be considered in two parts:

- Installation and decommissioning of cabling elements in the onshore export cable route, from landfall at Fraserburgh Beach to the preferred locations for the substation(s) in the location of Peterhead Power Station; and
- Construction and decommissioning of the substation(s).

3.8.1.2 The study consisted of the following aspects:

- Consultation with relevant statutory bodies;
- Detailed desk study to establish the baseline conditions; and
- Consideration of the relevant key legislation and guidance.

3.8.1.3 This baseline is used to inform the noise impact assessment described in:

- Chapter 9.4 (Noise: Onshore);
- Chapter 12.1 (Whole Project Assessment); and
- Chapter 13.4 (Cumulative Impact Assessment).

3.8.2 Consultations

3.8.2.1 The Department of Environmental Health (DEH) at Aberdeenshire Council has been consulted to determine their approach to the management of noise during construction / decommissioning activities.

3.8.2.2 Aberdeenshire Council has confirmed that it is satisfied with the approach proposed for the assessment of construction noise for the OnTI, Table 3.8-1 below.

Table 3.8-1 Consultation Responses

Organisation	Consultation Response	MORL Approach
Aberdeenshire Council	EHO satisfied with proposed approach to assessment.	Assessment of onshore noise to include cabling and substation elements of OnTI. Noise associated with operation of the substation to be addressed as the subject of a technical report in support of a separate planning application.

Consultation

3.8.2.3 The DEH at Aberdeenshire Council has been consulted to determine their approach to the management of noise during construction / decommissioning activities.

3.8.2.4 Aberdeenshire Council has confirmed that it is satisfied with the approach proposed for the assessment of construction noise for MORL's OnTI.

3.8.2.5 In terms of core hours for construction, Aberdeenshire Council has confirmed that their standard hours are as per Table 3.8-2 below:

Table 3.8-2 Aberdeenshire Council Standard Hours for Construction

Monday – Friday	0700 to 1900 h
Saturday	0700 to 1200 h
Sundays and Bank Holidays	No noisy equipment should operate

3.8.2.6 These core hours will be the subject of a planning condition with the additional direction that any application to vary these hours should be lodged with the Council in writing for their consideration.

3.8.3 Onshore Transmission Infrastructure Baseline Characteristics

Desktop Studies

3.8.3.1 A desktop study of the onshore export cable route from Fraserburgh beach (where the export cable landfall is located) to the preferred locations for the substation(s) in the vicinity of Peterhead Power Station, has been undertaken to inform the baseline assessment. Figure 1.1-5, Volume 6 a, illustrates the cable route and preferred substation locations used to inform the assessment.

3.8.3.2 The area indicated for export cable landfall incorporates an urban section of south east Fraserburgh. From here, the onshore export cable route within which the finalised cabling route will lie heads due south, roughly following the line of the A952. This rural route takes in many small hamlets, individual farms and dwellings.

3.8.3.3 Around the settlement of Fetterangus, the route extends south east towards Peterhead and Boddam to where the preferred substation(s) locations lie. This end of the route does not extend into urban areas, remaining in rural settings, although the A90 passes through the final section.

3.8.3.4 It is likely that ambient noise levels throughout the majority of this area will be relatively low, especially during night time periods. Where dwellings are adjacent to the roads identified, road traffic noise is likely to be dominant at all times, although it is likely that road traffic flows will dip at night, reducing the contribution of road traffic noise. The acoustic environment at dwellings in the urban area identified in south east Fraserburgh is likely to be influenced by mixed urban sources, resulting in perhaps higher ambient levels than those experienced at more rural locations.

3.8.3.5 It is also observed that there are a number of existing industrial installations at the Peterhead end of the route, which are likely to contribute noise from fixed plant to the surrounding environment; this may also influence ambient noise levels at the closest noise sensitive dwellings within the route.

Survey

3.8.3.6 A technical appendix will be prepared in support of a separate planning application for the OnTI, which will address the likely operational effects of this element of the proposals.

3.8.3.7 Typical levels of day (0700 to 2300 h) and night time (2300 to 0700 h) ambient noise will be established at locations representative of the closest noise sensitive receptors. Noise surveys will predominantly be unattended and will encompass weekday and weekend periods to ensure any discrepancies in ambient noise sources or levels are considered.

3.8.3.8 Representative manufacturers' data for noise emitting elements of the substation(s) will be used to predict levels of operational noise at the closest identified sensitive receptors. Where appropriate, cumulative levels of noise from fixed plant will also be considered; these calculations will consider the levels of operational plant noise already contributing to the ambient noise environment at nearby sensitive dwellings, and will predict any changes these levels as a result of introducing additional sources associated with the substation(s) once the location is finalised. Where required, mitigation measures will be suggested and the likely residual effects calculated.

3.8.4 Legislation and Guidance

3.8.4.1 No specific all-encompassing legislation exists in order to assess the overall effects of current and future noise and vibration sources affecting any given sensitive receptor, for a development of this kind. Relevant standards and guidelines have therefore been referred to throughout this assessment in addition to guidance from the Environmental Health Department of the presiding local authority, Aberdeenshire Council. The following documents have been used for guidance:

- The Control of Pollution Act (1974);
- BS 5228: 2009 Code of Practice for Noise and Vibration Control on Construction and Open Sites: Part 1: Noise;
- Planning Advice Note (PAN) 1/2011: Planning and Noise and associated Technical Advice Note (TAN); and
- Department of the Environment Advice Leaflet (AL) 72: Noise control on Building Sites.

3.8.5 References

Control of Pollution Act (1974)

British Standard (BS) 5228 (2009) Code of practice for noise and vibration control on construction and open sites. Part 1: Noise;

Department of the Environment Advisory Leaflet (AL) 72: Noise control on Building Sites; and

The Institute of Acoustics/Institute of Environmental Management Assessment Working Party: Draft Guidelines for Environmental Noise Impact Assessment.

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