Inch Cape Offshore Wind Farm

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Offshore Environmental Statement:

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Appendix 10A: Metocean and Coastal Processes Assessment

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INCH CAPE OFFSHORE LIMITED (ICOL)

APPENDIX 10A METOCEAN AND COASTAL PROCESSES ASSESSMENT

TECHNICAL REPORT

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SUMMARY

Inch Cape Offshore Limited (ICOL) are developing a Wind Farm and associated Offshore Transmission Works (OfTW). The project location can be seen in Figure 10A.1 and for assessment purposes is considered as two discrete locations, the Development Area and the Offshore Export Cable Corridor. A description of the Project can also be found in the Environmental Statement (ES) Chapter 7 Description of Development.

The Neart na Gaoithe (NnG) wind farm developed by Mainstream Renewable Power Limited (Mainstream) is located in proximity to the ICOL Project as can be seen in the ES Chapter 4 Process and Methodology Figure 4.1. ICOL have worked with the NnG project to collect and share information where appropriate, and have jointly commissioned a series of studies to inform their respective Environmental Impact Assessments (EIA). In addition to these developments, the Firth of Forth (FoF) wind farm which will be developed by Seagreen Wind Energy Limited (Seagreen), is also proximate to the sites, and has been included in this assessment. ICOL, Mainstream and Seagreen are all part of the Forth and Tay Offshore Wind Developers Group (FTOWDG).

In support of the ICOL EIA, Intertek has been commissioned to undertake assessments of meteorological/oceanographic (metocean) and coastal processes relating tothe Project as well as a regional study area. Intertek has been supported in these assessments, in particular with the description of the baseline conditions and the sediment-related components, by Partrac Consulting Limited (Partrac). The conclusions of the assessments can be found in the ES Chapter 10; Metocean and Coastal Processes, which has been supported by the findings in this report.

The Project and other NnG and FoF projects will potentially affect the metocean and coastal processes regimes in and around the development areas. Effects may range from short to long term and from temporary to permanent, and the assessment has considered long-term timescales up to 50 years, in line with The Crown Estate's lease term. ICOL requires an understanding of the magnitude and significance of these effects, with a view to implementing, where necessary, appropriate mitigation measures in order to minimise impacts.

This study required the delivery of a calibrated and validated hydrodynamic, spectral wave and particle tracking model of the Forth and Tay area, and the delivery of a metocean and coastal processes assessment using the models and other available information. The modelling system and the associated assessments provided ICOL and other stakeholders with the regional and site-specific characterisation of the metocean and physical geomarine

environment. This allowed the baseline environmental conditions to be determined, against which the effects of each individual development, and any cumulative effects due to all developments, have been assessed.

This document is the Technical Report for the ICOL Project, and provides the results of the study with specific reference to the Project. This report addresses the effects of the Project in both the near field (NF) (the study area lying within Development Area and Offshore Export Cable Corridor)- in addition to the far-field (FF) (i.e. out with the near field including the coastal zone), and also any cumulative effects with the NnG and FoF projects. Consideration of cumulative effects from other projects is considered in the ES Chapter 10 section 10.7.

The key conclusions from the study are as follows:

1) The presence of installation equipment, such as jack-up rigs and cable laying vessels, during the construction phase of the Project may cause very small, localised and temporary effects to the NF hydrodynamics and wave climate.

2) Construction processes, such as the installation of foundations in the Development Area and the burial of the Offshore Export Cable and inter-array cables, will result in the displacement of seabed sediment into the water column. The impacts from these activities will be small and localised to the NF, with peak elevated concentrations of suspended sediment up to 4000 mg/l above background (depending on the activity), and a maximum deposition thickness of 1.9 m in the immediate vicinity of the wind turbine generator (WTG) foundations. Impacts due to the installation of offshore substation platform (OSP) foundations will be similarly localised, although with probably slightly greater deposition thickness given their larger scale. No impacts are predicted beyond about 3 km of the activity in all cases.

3) The presence of the WTGs and OSPs, including their foundations, in the ICOL Development Area will cause only small effects to the metocean and sediment regimes.

4) The predicted changes to water level due to the ICOL Project are very small (<0.03 per cent of the mean spring tidal range), and generally localised to the NF, with the exception of a very small impact (<0.02 per cent of the mean spring tidal range) in the upper reaches of the Firth of Forth. These predicted changes will not be measureable.

5) The predicted changes to tidal currents due to the ICOL Project are small (approximately 7 per cent of peak spring tidal velocities), and restricted to the vicinity of the Development Area. These predicted changes are low compared with the natural variability of current flows in the area.

6) The predicted changes to the wave climate due to the ICOL Project are also small (less than 2 per cent of average wave heights), and restricted to the vicinity of the

Development Area. These predicted changes are small compared with the natural variability of wave heights.

7) The consequent changes to the sediment transport processes due to the ICOL Project are considered to be small, with the frequency of the exceedance of the critical shear stress changing typically by 1 to 2 per cent (with a maximum difference of 5 per cent). These changes are also restricted to the vicinity of the Development Area.

8) Localised changes to flow around the structures have the potential to lead to scouring of material.

9) If gravity base structures (GBS) are used, scour protection will be used. This protection will in turn minimise environmental impacts due to scour. Scour protection will be designed appropriately in order to ensure any secondary scour around the protection is itself minimised.

10) It is predicted that there will be scour around the jacket structures which will be localised within the NF. Scour pits around each leg of the jacket structure will not overlap, regardless of WTG or OSP size. Therefore, the scour will be local, rather than global. The resulting plume of suspended sediment concentrations (SSC) due to the scoured material will be small in extent, with peak concentrations between 30 and 100 mg/l above background levels, and concentrations beyond the structures reducing to <10 mg/l above background levels in a short distance. The resulting deposition footprints will be localised around the foundation base, with a maximum thickness of 1.1 m and deposition depths of more than 1 mm extending no more than 200 m from the structure.

11) The predicted cumulative impacts to water level due to the ICOL Project and the NnG and FoF projects are fairly widespread, but very small in size (<0.07 per cent of the mean spring tidal range).

12) The predicted cumulative changes to tidal currents due to the ICOL Project and the NnG and FoF projects are small in size (between 3 and 6 per cent of peak spring tidal velocities), and localised to the NF of each development. No cumulative far-field (FF) impacts are predicted on the tidal current regime.

13) The predicted cumulative changes to the wave climate due to the ICOL Project and other nearby OWF developments are considered to be small in size (<3 per cent of average wave heights), although the affected areas are approximately three to four times larger than the impacts from the ICOL Project on its own.

14) The predicted cumulative changes to sediment transport processes due to the ICOL Project and other nearby developments are considered to be small in size, with the predicted frequency of exceedance of the critical shear stress changing typically by 1 to 3 per cent (with a maximum difference of 6 per cent). These changes are restricted to the vicinity of the development sites.

The ICOL Project will not cause net changes to general coastal processes (the regional sediment transport regime or sediment dynamics along the nearby coastline), even when the cumulative impacts from the NnG and FoF projects are considered.

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TABLES

FIGURES

LIST OF ABBREVIATIONS

α	Total scour footprint (m^2)
BERR	Department for Business, Enterprise and Regulatory Reform
BGS	British Geological Survey
BODC	British Oceanographic Data Centre
CD	Chart Datum
Cefas	Centre for Environment, Fisheries, and Aquaculture Sciences
CFD	Computational Fluid Dynamics
COWRIE	Collaborative Offshore Wind Research Into the Environment
d_{50}	Median grain size
D_B	Base diameter (of GBS)
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
D_T	Tower diameter (of GBS)
DTI	Department of Trade and Industry
EIA	Environmental Impact Assessment
EMU	EMU Limited
ES	Environmental Statement
FF	Far-field
FTMS	Forth and Tay Modelling System
FTOWDG	Forth and Tay Offshore Wind Developers Group
FWR	Foundation for Water Research
GBS	Gravity Base Structure
H	Height of conical section (of GBS)
HD	Hydrodynamic
H_s	Significant wave height

HW	High water
ICOL	Inch Cape Offshore Limited
Intertek	Intertek Energy and Water Consultancy Services (formerly Intertek METOC)
JNCC	Joint Nature Conservation Committee
LAT	Lowest Astronomical Tide
LW	Low water
Mainstream	Mainstream Renewable Power Limited
Metocean	Meteorological/oceanographic
MSL	Mean Sea Level
MW	Megawatts
NF	Near-field
OSP	Offshore Substation Platform
OWF	Offshore Wind Farm
Partrac	Partrac Consulting Limited
POL	Proudman Oceanographic Laboratory
PSD	Particle Size Distribution
PT	Particle Tracking
REPSOL	Repsol Nuevas Energias UK Limited
S_e	Equilibrium scour depth (m)
SEA	Strategic Environmental Assessment
Seagreen	Seagreen Wind Energy Limited
SEPA	Scottish Environment Protection Agency
SERL	SeaEnergy Renewables Limited
SMP	Shoreline Management Plan
SNH	Scottish Natural Heritage
SSC	Suspended Sediment Concentration
STW	Scottish Territorial Waters

SW	Spectral Wave
T_p	Peak wave period
T_z	Mean zero-crossing wave period
UKCIP	UK Climate Impacts Programme
UKHO	UK Hydrographic Office
UKMO	UK Meteorological Office
V_s	Volume of scoured material per leg (m^3)
V_{TOT}	Volume of scoured material per foundation (m^3)
WTG	Wind Turbine Generator
X_s	Lateral extent of scour (m)

10A.1 INTRODUCTION

Inch Cape Offshore Limited (ICOL) are developing a Wind Farm and associated Offshore Transmission Works (OfTW). The project location can be seen in Figure 10A.1 and for assessment purposes is considered as two discrete locations, the Development Area and the Offshore Export Cable Corridor. A description of the Project can also be found in the Environmental Statement (ES) Chapter 7 Description of Development.

The Neart na Gaoithe (NnG) wind farm developed by Mainstream Renewable Power Limited (Mainstream) is located in proximity to the ICOL Project as can be seen in the ES Chapter 4 Process and Methodology Figure 4.1. ICOL have worked with the NnG project to collect and share information where appropriate, and have jointly commissioned a series of studies to inform their respective Environmental Impact Assessments (EIA). In addition to these developments, the Firth of Forth (FoF) wind farm which will be developed by Seagreen Wind Energy Limited (Seagreen), is also proximate to the sites, and has been included in this assessment. ICOL, Mainstream and Seagreen are all part of the Forth and Tay Offshore Wind Developers Group (FTOWDG).

ICOL and NnG jointly commissioned Intertek Energy and Water Consultancy Services (Intertek; formerly Intertek METOC) to undertake the metocean and coastal processes assessments for the ICOL and NnG EIAs. Seagreen has opted to use an independent approach for its EIA.

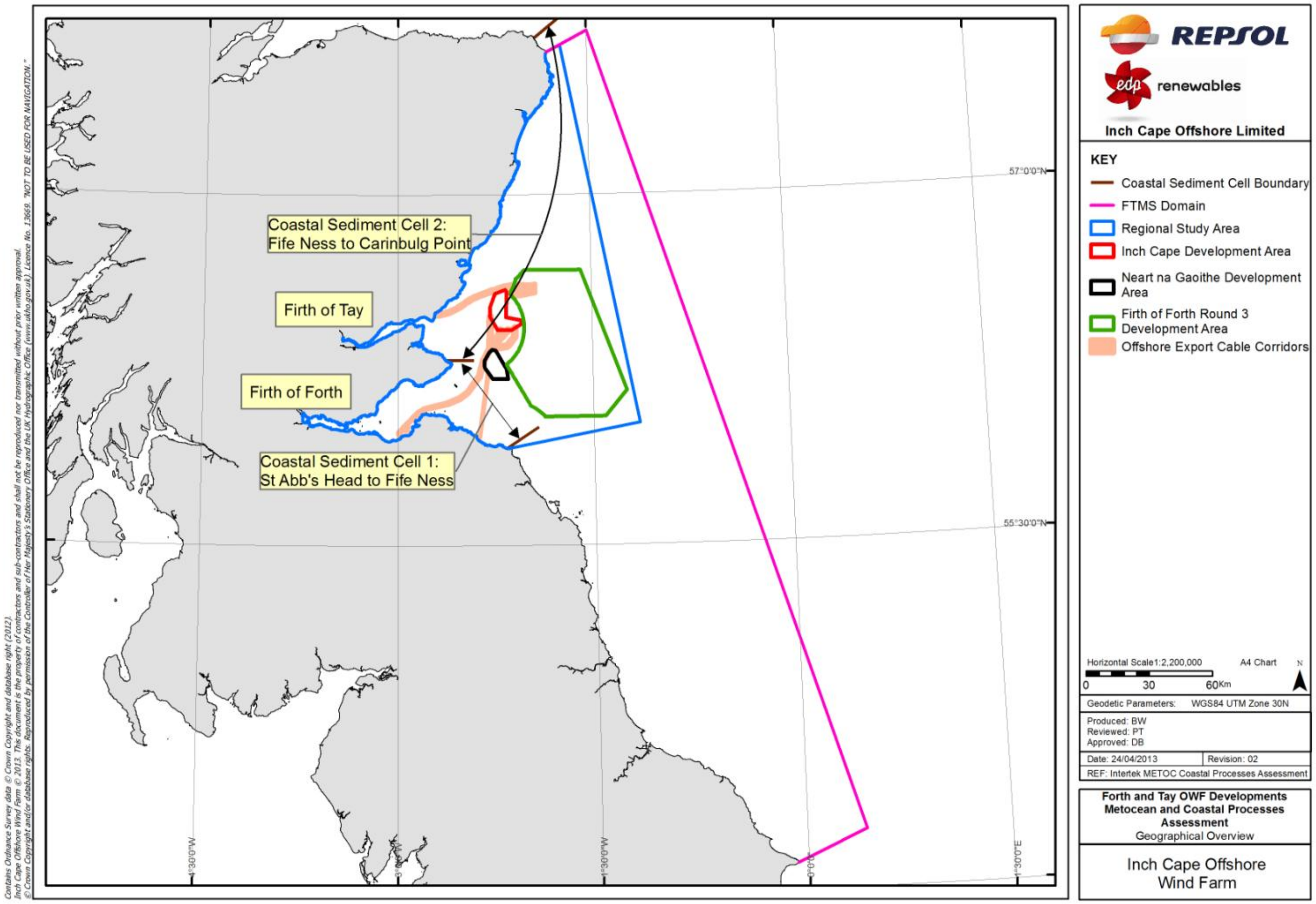
Figure 10A.1 provides a geographic overview of the region, including the ICOL Project and NnG and FoF projects.

In support of the ICOL EIA, Intertek has been commissioned to undertake assessments of meteorological/oceanographic (metocean) and coastal processes relating the Project as well as a regional study area. Intertek has been supported in these assessments, in particular with the description of the baseline conditions and the sediment-related components, by Partrac Consulting Limited (Partrac). The conclusions of the assessments can be found in the ES Chapter 10; Metocean and Coastal Processes, which has been supported by the findings in this report. The Project and the other NnG and FoF projects will potentially affect the metocean and coastal processes regimes in and around the development areas. Effects may range from short to long term and from temporary to permanent, and the assessment has considered long-term timescales up to 50 years, in line with The Crown Estate's lease term. ICOL requires an understanding of the magnitude and significance of these effects, with a view to implementing, where necessary, appropriate mitigation measures in order to minimise impacts.

The study required the delivery of a Forth and Tay Modelling System (FTMS), and the delivery of a metocean and coastal processes assessment using the FTMS and other available information. The FTMS comprised calibrated and validated models of hydrodynamic (HD) and spectral wave (SW) processes, and a Particle Tracking (PT) model for investigating sediment transport and deposition. The FTMS and the associated assessments provide ICOL and other stakeholders with the regional and site-specific characterisation of the metocean and physical geo-marine environment. This has allowed the baseline environmental conditions to be determined, against which the effects of the Project, and any cumulative effects due to other projects, have been assessed.

This document is the Technical Report for the ICOL Project (comprising the Wind Farm and the Offshore Transmission Works), and forms Appendix 10A to Chapter 10: Metocean and Coastal Processes of the ES. It provides the results of the metocean and coastal processes study with specific reference to the ICOL Project. This report considers the effects of the Project in both the near and far-field, and also any cumulative effects of other projects, including the NnG and FoF projects. Consideration of cumulative effects from other projects is considered in the ES Chapter 10 Section 10.7.

Figure 10A 1: Geographic Overview



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10A.1.1 SCOPE OF WORK

The following scope of work was agreed between Intertek and ICOL:

- Prepare a **Methodology Statement**. This outlined the proposed methodology for the assessment, including the procedures for the baseline study, the FTMS construction, and the analysis of impacts from the developments. This document was circulated to all relevant stakeholders via Marine Scotland, for comment and approval.
- Undertake a **Data Gap Analysis and Data Review**. This included the collation and review of all relevant data (hydrodynamic, bathymetric, geological, bed morphology and sediment information) available from existing sources at the time of the review (May 2011). This specifically included the data collected as part of the metocean, geotechnical, geophysical and benthic survey campaigns commissioned by ICOL and relevant NnG data..
- Undertake a **Regional Baseline Assessment**. This was prepared in partnership with Partrac, and provides a detailed description of the existing metocean and sediment regime conditions on a region-wide basis. This includes an area from St Abbs Head (England) to Cairnbulg Point (NE Scotland) and extends eastwards to the eastern boundary of FoF, thereby incorporating the Project and NnG and FoF projects.
- Construct, calibrate and validate a suitable modelling system. The **FTMS** was built using an unstructured flexible mesh dynamic modelling system. This is a sophisticated two-dimensional modular based modelling system, and has the capacity to run HD, SW and PT models. It can be used to predict the physical properties of tidal currents and waves, and the interactions between these, for any specified area. It can also be configured with structures representing existing or proposed marine developments, such as wind farms, in order to quantify the effects such developments may have on the metocean regime.
- Undertake an **Assessment** of the ICOL Project by considering the changes or impacts to the metocean and sediment regimes, and thereby to coastal processes, due to each development. Near- and far-field, and short- and long-term impacts have been considered, as well as any cumulative effects from all developments. The potential effects of changing climatic conditions in the future (i.e. sea-level rise and increased ‘storminess’) have also been considered.
- Provide a **Technical Report** (this document) for ICOL, to provide a detailed description of the work undertaken.
- Prepare a relevant **Metocean and Coastal Processes ES chapter**, summarising the work undertaken, for inclusion in the ES (Chapter 10).

The key documents produced as part of this study are therefore:

- The Methodology Statement (ES Chapter 10 – Appendix 10D – Intertek METOC Report No: RN2550[1]).
- Comments on the Methodology Statement from Marine Scotland, and the formal response from the developers to these comments (ES Chapter 10 – Appendix 10E[8,9]).

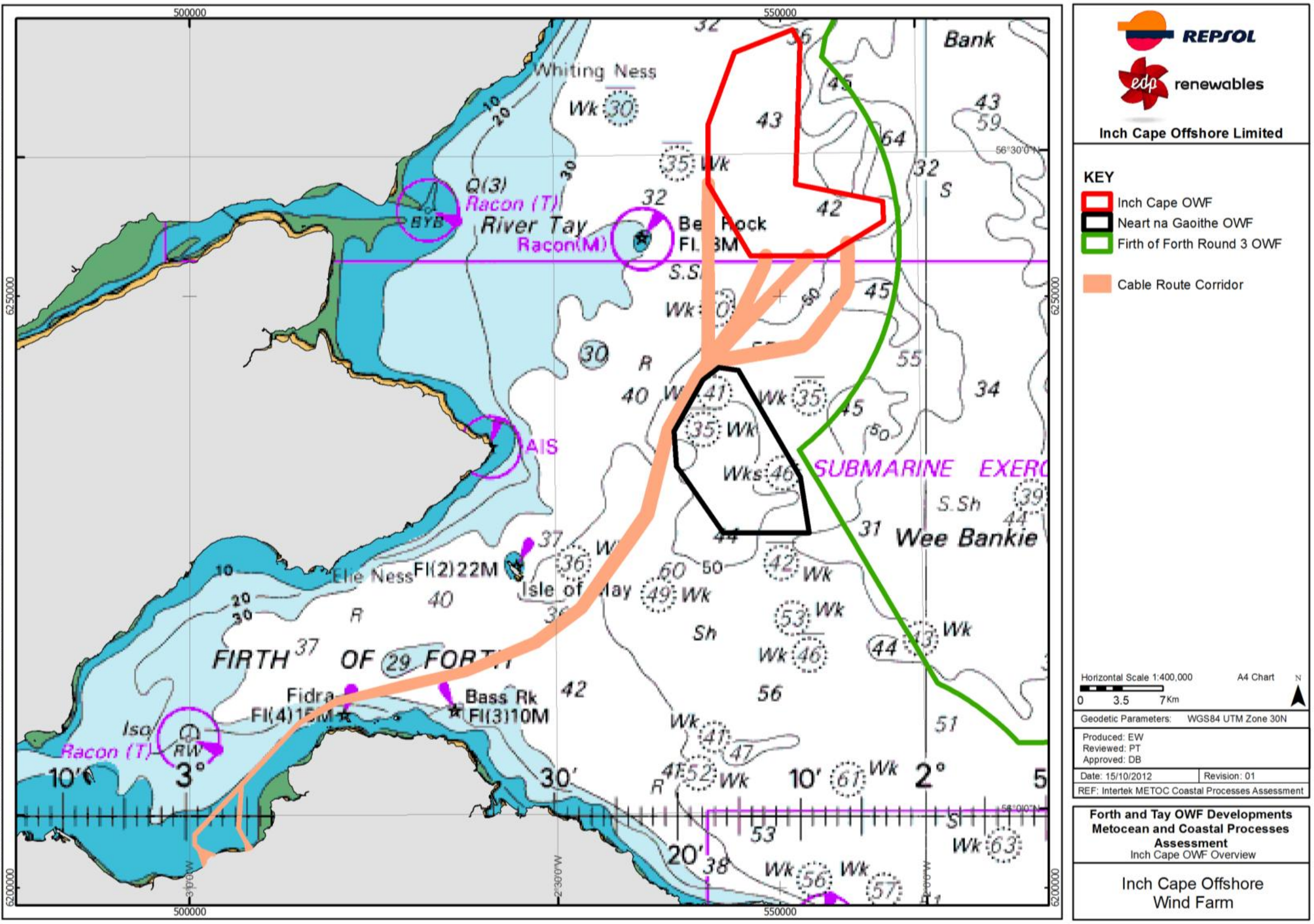
- The Data Gap Analysis and Data Review (ES Chapter 10 – Appendix 10B – Intertek METOC Report No: RN2597[2]).
- The FTMS Hydrodynamic and Spectral Wave Model Calibration and Validation Report (ES Chapter 10 – Appendix 10C – Intertek METOC Report No: RN2636[3]).
- The Regional Coastal Processes Baseline Description Report (ES Chapter 10 – Appendix 10F – Intertek METOC Report No: RN2728[4]).
- The Technical Report for the NnG development (Intertek METOC Report No: RN2709[5]).
- The Coastal Processes Chapter for the NnG development Environmental Statement (Intertek METOC Report No: RN2762[6]).
- In addition, a more detailed description of the baseline conditions relevant to the ICOL Development Area, and an assessment of potential scour within the Development Area, have been prepared together with Partrac. These are included in Annex 10A.1 (Development Area Baseline Description) and Annex 10A.6 (Development Area Scour Potential Assessment) of this report.

10A.1.2 DEVELOPMENT OVERVIEW

The ICOL Development Area is located approximately 15-22 km to the east of the Angus coastline in Scotland. The Development Area covers an area of approximately 150 km², in water depths of between 35.5 m and 63.3 m to Lowest Astronomical Tide (LAT). The project is anticipated to consist of a maximum of 213 wind turbine generators (WTGs).

The construction of the ICOL Project is due to commence by 2016, and completion of the development is anticipated by 2020. The Crown Estate lease term is for 50 years. Figure 10A.2 provides an overview of the Forth and Tay area together with the boundaries of the ICOL Development Area and Offshore Export Cable Corridor.

Figure 10A.2: Geographic overview of the ICOL OWF site and surrounding area



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10A.1.2.1 Design Envelope

The potential development parameters and scenarios are defined as a Design Envelope and presented in the ES Chapter 7: Description of Development. The assessment of potential impacts on metocean and coastal processes is based upon the worst case scenario as identified from this Design Envelope, and is specific to the potential impacts considered in this technical assessment.

For the WTGs, OSPs and met masts, Gravity Base Structures (GBS) represent a worse case than jacket foundations for:

- Impacts on water levels, currents and waves, and thus on the wider sediment transport regime. This is because GBS offer the greatest total blocking effect to the passage of currents and waves (i.e. they have the greatest cross-sectional area within the water column).
- Pre-installation dredging, and consequent impacts on suspended sediment concentration (SSC) and seabed features. This is because the dredged sediment volumes are significantly larger than would be produced by drilling for jacket foundations.
- Jackets represent a worse case for sediment scour and associated impacts, since scour protection will be built into any GBS foundation concept.

For cable installation (both Offshore Export Cables and inter-array cables) a variety of cable installation methodologies are considered. For the purposes of this assessment it is assumed that the entire trench volume is suspended. This is a conservative assumption which provides a consideration of all potential cable installation methodologies. For the purposes of this assessment any installation methodology which results in suspension of the entire trench volume is known as installation by energetic means.

More detail is provided in Section 10A.4 but the following section provides a summary of the Design Envelope parameters considered in the assessment.

10A.1.2.2 Wind Turbine Generators (WTG)

In order to agree a consistent modelling approach with NnG and the ICOL Project, modelling was carried out in early 2011 which supported the earlier application timescales of the NnG project. At the commencement of the metocean and coastal processes assessment many details of the development were at an early stage of development. ICOL provided Intertek with design information which was used to define the ‘worst case’ scenarios for use in the assessment. These were agreed with both ICOL and Mainstream in February 2011, prior to undertaking the majority of the modelling.

At that time, it was considered that the Wind Farm would comprise of a maximum of 328 WTGs on either steel jacket or GBS foundations (see Section 10A.1.2.3). The worst case applied in the assessment assumed there would be the maximum number of WTGs (328) on the maximum dimensions of GBS. This would lead to the greatest impact on metocean and coastal processes in terms of effects on water levels, currents and waves and thus the wider sediment regime. This was considered to be conservative as the largest WTGs would be fewer in number with a larger spacing between each WTG (than that modelled).

Following preliminary design and a refinement of the Design Envelope it was concluded that a maximum of 213 WTGs would be installed in the Development Area. The originally modelled worst case, modelled for effects on water levels, currents and waves therefore represents a greater potential impact scenario than the Design Envelope worst case scenario. However, as impacts relating to water levels, currents and waves were small (Section 10A.4) this was considered not to be an overly conservative modelling scenario. WTGs will be set out in a regular array, with lines running approximately northwest to southeast – aligned perpendicular to the predominant wind direction. Minimum spacing between each WTG were originally modelled based on a range from 850 m (cross wind) and to 530 m (downwind) which represented the worst case in terms of project density. The closest spacing in the Design Envelope between WTGs will be 820 m, in both the crosswind and downwind directions. Therefore the worst case scenario modelled is considered to be slightly more conservative than the worst case presented in the Design Envelope, and appropriate for the assessment.

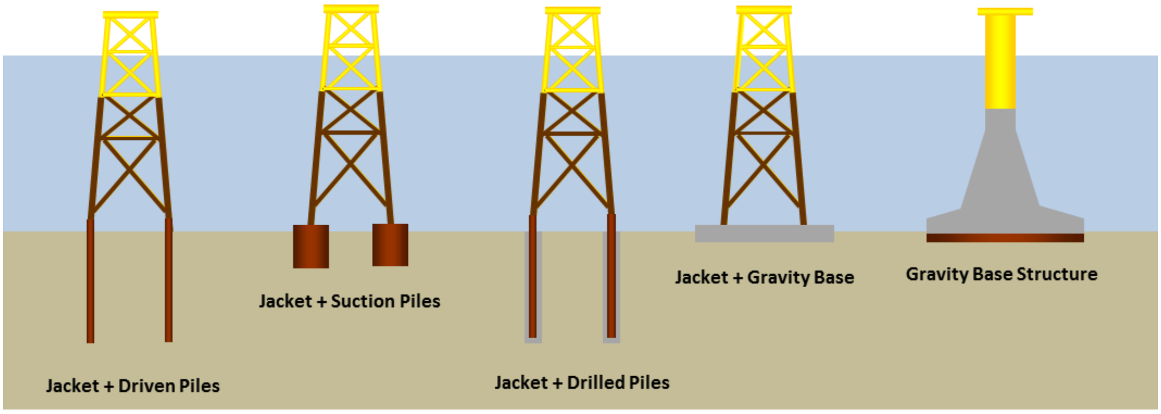
When considering impacts on suspended sediments, deposition, and scour, the modelling was carried out considering effects at a small number of individual WTG locations. This allowed a consideration of any overlap of effects using the minimum possible spacing. These individual WTG effects were then extrapolated to present data for the maximum number of WTGs in the Design Envelope (213). Finally plots were presented which showed the larger number of WTGs with the minimum spacing across the entire Development Area. This relates to a higher number of WTGs than would actually be deployed. Although this scenario will not occur in practice, it allows a visualisation of the interactions at individual foundation locations to be shown across the entire Development Area.

It was therefore concluded that the original modelled scenarios for WTGs numbers and spacings were appropriate to represent the Project Design Envelope.

10A.1.2.3 Foundation Types

The foundation type for the WTGs are detailed in Chapter 7 Section 7.6 and will either be a GBS or steel framed jacket (also known as jacket) or a hybrid solution that will incorporate elements of both GBS and jackets as can be seen in Figure 10A.3.

Figure 10A.3: Schematic of foundation types



GBS effects on waves, tides and currents

As stated in 10A.1.2.1 for effects on water levels, currents and waves and thus the wider sediment regime, GBS have been recognised as representing the worst case.

The GBS is a mainly concrete and steel reinforced structure which uses the weight of the structure and internal ballast to maintain position. In terms of effects on metocean and coastal processes, it is the overall cross-sectional area and total volume of the structure within the water column which is important for this assessment, rather than the exact shape, or the materials used. Since a worst case scenario has been applied, the modelled impacts presented are therefore not sensitive to the final design.

The dimensions of the GBS will be dependent on the WTG used and final GBS detailed design. The original modelled design dimensions for the GBSs are provided in Table 10A.1. In the original scenario, a base diameter of 50 m was used in conjunction with the original maximum number of WTGs (328). As per the Design Envelope the actual maximum diameter will be 65 m and maximum number of WTGs (213). It is considered that the original model represents an appropriately conservative worst case scenario. This is because even with a smaller base diameter the overall blocking area with the original number of WTGs is still larger than the Design Envelope smaller maximum WTG numbers and larger base diameter.

In addition to this, as impacts relating to water levels, currents and waves were small (Section 10A.4) this was considered not to be an overly conservative modelling scenario.

Table 10A 1: Anticipated GBS dimensions

Parameter	Original Modelled Scenario	Design Envelope		Final Model
		WTG	OSP	
Base Diameter, DB (m)	50	65	130	50
Spacing between WTGs along row (aligned NW to SE – cross-wind) (m)	856	820	n/a	856
Spacing between WTG rows (downwind) (m)	535	820	n/a	535
Maximum number of WTGs	328	213	5	328

GBS effects on suspended sediment and associated deposition

Seabed preparation (excavation, placement of gravel and backfill using a dredging vessel) is often required for GBS.

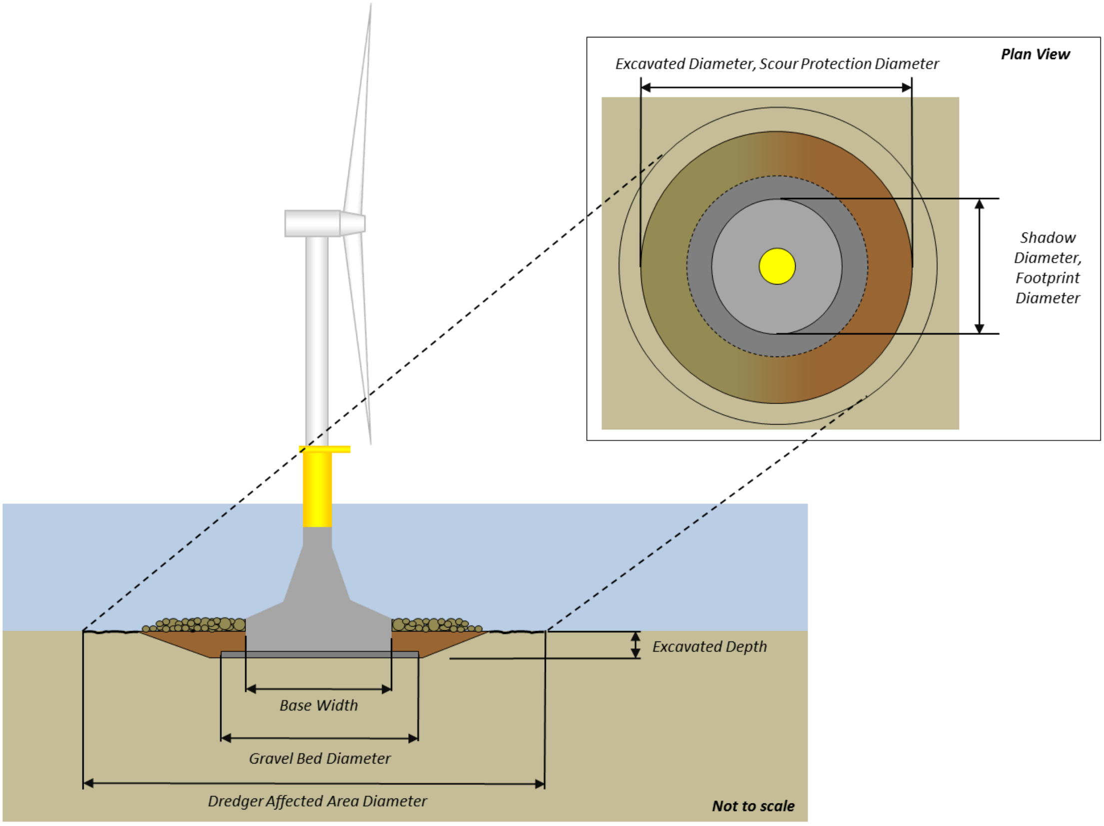
In the event that seabed preparation is required, the a number of options are possible for the excavated volume of seabed material. The following options could be used individually or in combination depending on ground condition and construction techniques and are listed below in order of preference:

- Use as backfill material around WTG foundations.
- Deposit within the foundation/substructure as ballast.
- Re-use of material for other unrelated activities if commercially viable.
- Deposit to the seabed at an off-site offshore licensed location.

In the event that the material is used as backfill or ballast, it has been assumed that this material can be deposited by a controlled fall pipe arrangement. It is possible that all of the excavated volume will be used as backfill following installation of the foundation.

The associated volume of dredged material per GBS was assumed as 28,503 m3. This was based on an inverted truncated conical pit with depth 5 m, top (sea bed surface) diameter 95 m, and base diameter 75 m) (see Figure 10A-4 below).

Figure 10A.4: Illustration of the Design Parameter Definitions for GBS



When considering impacts on suspended sediments, and deposition the modelling was carried out considering the volumes of sediment associated with the Design Envelope parameters per GBS. The effects at a small number of individual WTG locations were then modelled to allow a consideration of any overlap of effects using the minimum possible spacing. These individual WTG effects were then scaled up to present data for the maximum number of WTGs in the Design Envelope (213). Finally plots were presented which showed the larger number of WTGs (328) with the minimum spacing across the entire Development Area. This relates to a higher number of WTGs than would actually be deployed. Although this scenario will not occur in practice, it allows a visualisation of the interactions at individual foundation locations to be shown across the entire Development Area.

This is an inherently conservative assessment which allows for consideration of a worst case at an individual WTG location. As a result, when considered across the entire Development Area the extrapolated values will be higher than is expected.

Jacket effects on scour

A steel framed jacket substructure is a construction of tubular steel formed of cylindrical legs and a lattice of cross-bracing. Again the final size and design of the jacket substructure will be dependent on the size of the WTG. There are various steel framed jacket substructures under consideration for the Project; in this case a four-legged jacket has been assessed as a representative arrangement for the purpose of identifying the worst case. Based on the Design Envelope, the maximum leg diameter expected, if jacket foundations are used, is 3 m. Figure 10A.5 provides an indication of the type of jacket structure that may well be used.

As for SSC relating to GBS dredging, the effects of scour at a small number of individual WTG locations were modelled to allow a consideration of any overlap of effects using the minimum possible spacing. These individual WTG effects were then scaled up to present data for the maximum number of WTGs in the Design Envelope (213). Finally plots were presented which showed the larger number of WTGs (328) with the minimum spacing across the entire Development Area. This relates to a higher number of WTGs than would actually be deployed. Although this scenario will not occur in practice, it allows a visualisation of the interactions at individual foundation locations to be shown across the entire Development Area.

Figure 10A.5: Photo of the jacket foundation used at the Beatrice Demonstrator Project

Jackets represent a worse case for sediment scour and associated impacts, since scour protection will be built into any GBS foundation concept.

10A.1.2.4 Offshore Substation Platforms (OSP) and Metmasts

Within the Development Area, up to five offshore substation platforms (OSP) and three met masts will be installed, in addition to the WTGs. The scale of OSPs and their foundations will be larger than a WTG (up to 130 m diameter base). The location and design of the OSPs is not yet defined as it is subject to detailed layout and electrical design. Therefore locations have not been explicitly modelled.

OSP effects on waves, tides and currents

Given that the modelled worst case for the Wind Farm represents a significantly greater potential impact scenario with a larger blocking area than the Design Envelope worst case scenario including the OSPs, it is considered that the potential impact from the OSPs is represented within the impacts assessed.

OSP effects on suspended sediment and associated deposition and scour

OSPs were represented as being the equivalent of four WTGs in terms of dredged sediment and met masts as one WTGs. These were included in the calculations for SSC and deposition across the development area.

10A.1.2.5 Inter-array and Offshore Export Cables

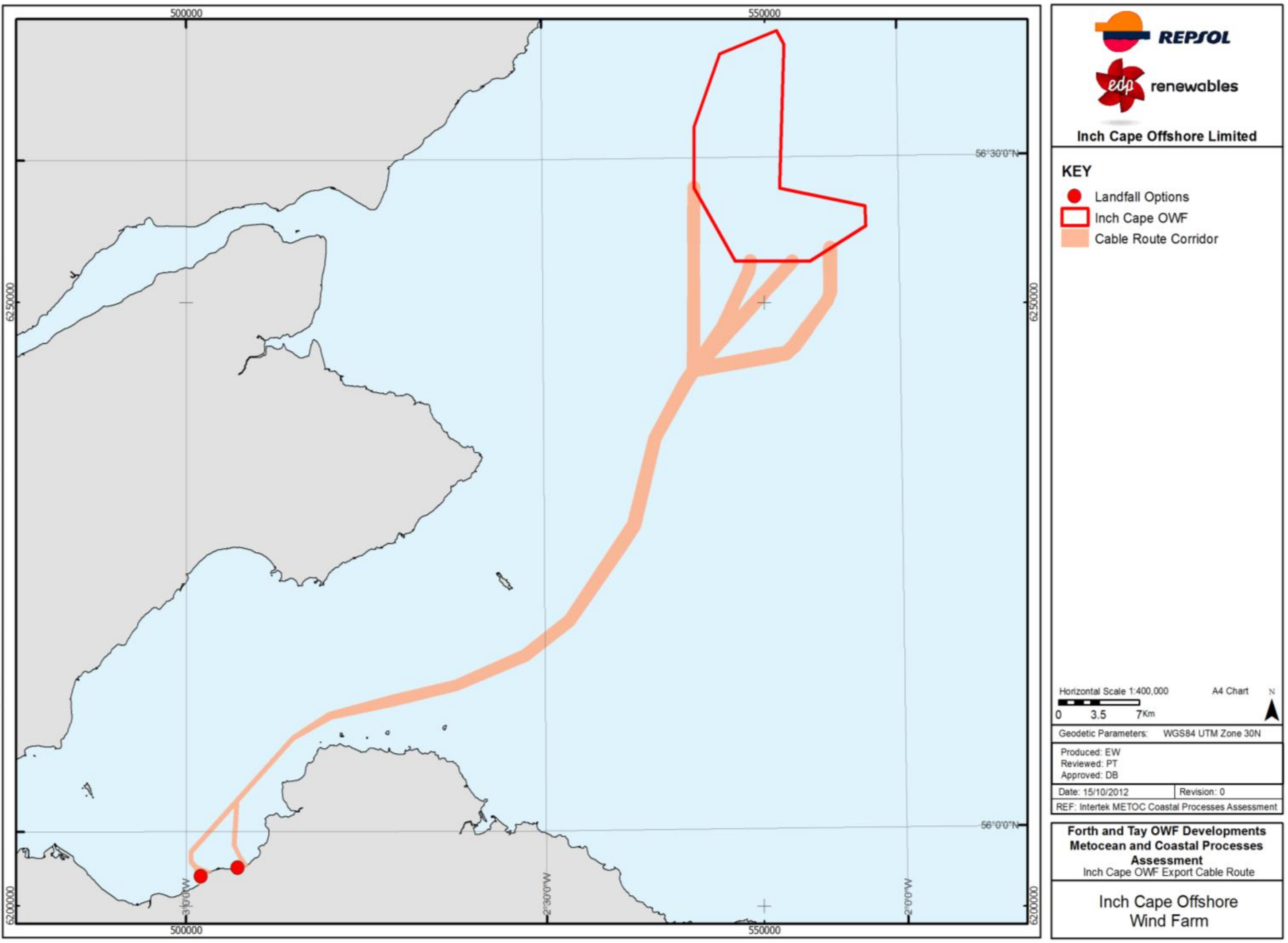
The WTGs will be connected via inter-array cables, and power from the Wind Farm will be exported to a landfall location using an Export Cable. All Cables will be suitably buried or will be protected by other means when burial is not practicable. The burial depth will vary depending on the burial technique employed and the local seabed conditions, but the target burial depth is 1 m with an expected range of 0 – 3 m, and a maximum trench width of 1 m. 2 m was chosen as being sufficiently conservative to represent the macro impacts of SSC from burial across the Offshore Export Cable Corridor.

Cable burial will be by either jetting trenchersor ploughing installation techniques. In addition to these techniques horizontal directional drilling, rock wheel cutters and open cut trenchers may be required at the landfall sites.

For the purposes of this assessment it is assumed that the entire trench volume is suspended. This is a conservative assumption which provides a consideration of all potential cable installation methodologies. For the purposes of this assessment any installation methodology which results in suspension of the entire trench volume is known as installation by energetic means.

The Offshore Export Cable Corridor exits the Development Area at its southern boundary and follows an approximately south-western bearing to one of the two potential landfall sites located at Cockenzie and Port Seton, East Lothian. The route is shown in Figure 10A.6 and is approximately 83 km long.

Figure 10A.6: Offshore Export Cable Corridor from the ICOL OWF



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Inch Cape Offshore Wind Farm © 2012. This document is the property of contractors and sub-contractors and shall not be reproduced nor transmitted without prior written approval.

10A.1.2.5 Other Developments

The wind farm developments of NnG and FoF Phase 1 are relatively close to the Development Area (see Figure 10A.1), and their construction programmes may also overlap with that of the Project. This means that cumulative impacts may arise. Therefore, the Project assessment included a modelling and impact assessment to determine the magnitude and significance of any cumulative impacts.

The NnG wind farm site lies approximately 10 km south of the southern boundary of the Development Area, and the FoF sites lie immediately to the east of the Development Area (encompassing a large area that extends to the north and south of the Development Area). The NnG and the FoF projects are at a similar stage of planning as the ICOL development (although slightly more advanced as consent applications have been submitted for both developments). Construction of these developments is likely to occur between 2014 and 2019 and the OWFs are likely to have life spans similar to that of the Project. FoF is likely to be developed in three different Phases, with Phase 1 in the northern area of the Zone (nearest to the Development Area) being developed first and Phases 2 and 3 in the centre and southern areas following.

With respect to the assessment of cumulative impacts of the Project with other projects, a number of developments and activities were identified with the potential to interact with the Project. These are detailed in the ES Chapter 4: Process and Methodology Section 4.7.

The Cockenzie Power Station decommissioning and subsequent potential redevelopment lies close to the Offshore Export Cable Corridor. It was not considered that any aspects of this development would cause cumulative impacts with the Project since it has only very minor marine elements. In addition to this it is not anticipated that there will be major overlap in programme of activities that occur in proximity i.e. near shore cabling works and any shoreline works, due to the short duration of these elements of the works, and the known programme durations.

All other identified developments and activities were scoped out on the basis of distance from the Project; the predicted changes in metocean conditions due to the Wind Farm and OfTW were negligible at these sites (change in water level <0.5 cm; change in current speed <0.5 cm/s; change in wave height <1 cm).

10A.1.2.6 Decommissioning

The potential effects of decommissioning are considered to be equivalent to and potentially lower than the worst case effects assessed for the construction phase. The approach to decommissioning is described in the ES Chapter 7. A decommissioning plan will be prepared in accordance with the requirements of the Energy Act 2004 (see the ES Chapter 3: Regulatory Requirements, Section 3.3.2) and will be subject to approval from the Department of Energy and Climate Change prior to implementation.

10A.1.3 METHODOLOGY

A Methodology Statement was prepared by Intertek and agreed with both ICOL and Mainstream. This Statement (see ES Chapter 10 – Appendix 10D) describes in detail the methodology for the metocean and coastal processes assessment. This Statement was issued as a stand-alone report to ICOL and Mainstream in February 2011, and was then forwarded to Marine Scotland (as representative of all stakeholders) for review.

The agreed methodology is fully aligned with the best practice guidance provided in the Collaborative Offshore Wind Research Into the Environment (COWRIE) report[7].

The agreed approach is summarised as follows:

- Bespoke hydrodynamic, spectral wave and sediment models covering the Project and the surrounding region would be developed, calibrated and validated. These models comprise the FTMS. The FTMS would be constructed using industry standard software that uses a sophisticated, two-dimensional modular-based modelling system.
- Both the FTMS and the subsequent impact assessments would be developed and implemented according to industry best practice.
- The FTMS, together with the available field data, would be used to assess the following:
- baseline conditions (an understanding of the metocean and sedimentological regimes as they are now);
- post-construction impacts from each individual wind farm (focusing on how metocean and sedimentological conditions are modified relative to the baseline);
- post-construction long-term (50 year) cumulative impacts from the Project and the NnG and FoF projects;
- post-construction long-term (50 year) cumulative impacts to include the three wind farms and any other industries or developments that may be identified in the area;
- scour potential around individual structures and the need/justification for scour protection;
- short-term impacts on suspended sediment concentrations (SSC) during the construction phase (such as from laying foundations or dredging cables); and
- the possible implications of climate change to the impacts predicted by the metocean and coastal processes assessment.

Following the submission of the Methodology Statement, and the subsequent response from Marine Scotland, the project team, which included ICOL, Mainstream, and Intertek discussed and agreed in more detail the different scenarios to be included in the modelling and impact assessment. In particular, it was agreed to adopt a worst case scenario for each of the developments, on the basis that the final detailed design and layout of the developments will not be known prior to consent application. This led to the adoption of an 'assessment scheme' which is based on the type and number of foundations, the layout of WTGs, and the construction techniques, that would all lead to the greatest impacts on metocean and coastal processes. In reality, the final development scheme is likely to be different to the 'assessment scheme' used in this study, but as long as the final scheme is comparable with, or within the modelled (worst case) scheme, then predicted impacts as reported in the assessment will be indicative of the worst case actual impacts that might result.

In addition, it was agreed that cumulative impacts due to the three projects in the region would be investigated, but that no additional cumulative effects needed to be considered. Details of the assessment scheme, and the different scenarios assessed, are provided in more detail in Section 10A.4.

10A.1.4 CONSULTATION

The modelling and assessment approach, as detailed in the Methodology Statement (ES Chapter 10 – Appendix 10D), was provided to Marine Scotland, the regulatory consultee and contact point for all interested stakeholders, for its review.

Marine Scotland collated comments from all relevant stakeholders, and provided a response to the Methodology, in a letter to SeaEnergy Renewables Limited (SERL – now REPSOL)[8]. This letter is included in ES Chapter 10 – Appendix 10E. In general the stakeholders accepted the proposed methodology, and stated that:

"The proposed methodology is rigorous and well thought out. The proposed modelling methodology is particularly impressive."

However, a number of specific clarifications were requested, and these were addressed in a letter of response sent by Mainstream and SERL to Marine Scotland[9]. This letter is also included in ES Chapter 10 – Appendix 10E.

The main comments on the methodology raised by Marine Scotland and the other stakeholders were responded to as follows:

- Identification of sensitive receptors. Sensitive receptors (e.g. benthic habitats, fish and shellfish spawning and nursery grounds) within and around the Development Area, and the potential impacts on these due to changes in the metocean or coastal processes regimes, are considered as part of the broader EIA.
- Survey campaign. The targeted survey campaign obtained sufficient information to enable construction, calibration and validation of the FTMS, and parameterisation of the baseline and inputs for the metocean and coastal processes assessment. See, for example, the FTMS calibration and validation report (ES Chapter 10 – Appendix 10C), and Annex 10A.1 – ICOL Development Area Baseline Description.
- Sediment regime. The study has fully considered the potential impact of the development on different aspects of the sediment regime. This includes: sediment transport pathways, sources and sinks; bed forms and features (including sandbanks and sandbank stability); erosion; deposition; suspended load and SSC; and bed load. See, for example, Annex 10A.1 – Development Area Baseline Description; Section A10.5.3 – Changes to the Sediment Regime; and Section A10.5.4.3 – Changes to the Sediment Regime (Cumulative Impacts).

Definition of “cumulative” and “in-combination”. This has been addressed, and is clarified in Chapter 4: Process and Methodology, Section 4.7.10A.1.5 Data Sources.

Intertek undertook an extensive review of all available data, including a gap analysis to identify any additional information that would be required to inform assessment. Full details of this data gap analysis and data review and are provided in the ES Chapter 10 – Appendix 10B (Data Gap Analysis and Data Review). The final version, which incorporated all client comments received, was submitted to ICOL and Mainstream in May 2011.

The principal data sources used in the assessment were the field data collected during the dedicated geophysical and benthic surveys commissioned by ICOL, together with the metocean survey campaigns commissioned by the both Mainstream and ICOL, and the model outputs derived from the FTMS developed specifically by Intertek for the purpose of this assessment. These were supplemented by: other existing field data (held by third party organisations, such as the British Oceanographic Data Centre (BODC), the Proudman Oceanographic Laboratory (POL), the British Geological Survey (BGS) and the Centre for Environment, Fisheries, and Aquaculture Sciences (Cefas)); the existing scoping reports for the developments previously commissioned; and other third party information and reports, such as Shoreline Management Plans (SMP). It should be noted however, that a number of other surveys commissioned by ICOL (such as geotechnical surveys and additional benthic surveys) have been completed since May 2011. These were therefore not included in the earlier data review, but were planned surveys that were known about, and were therefore taken into consideration in the gap analysis.

Table 10A.2 provides a summary of the data and their sources used in the assessment.

Table 10A.2: Summary of major data sources used

Data Source	Study/Data Name	Data Theme(s)	Data Location
ICOL/Mainstream	Scoping Studies	Environmental baseline	Development Area
HR Wallingford reports	Review of existing information (2010[10]) Various background reports (engineering and survey design)	Water quality (turbidity) Environmental baseline	East coast of Scotland/ Development Area
ICOL/Mainstream (collected by Partrac)	Metocean survey (2010[11])	Metocean monitoring data (waves, tides, wind, SSC, particle size data)	In and around Development Area
ICOL (collected by iXSurvey and Osiris Projects)	Geophysical surveys – Development Area (2011[12]) and Offshore Export Cable Corridor (2012[13,14])	Bathymetry and geophysical	Development Area and Offshore Export Cable Corridor
ICOL (collected by AMEC)	Benthic surveys (see ES Appendix 12C – Benthic Ecology Baseline Development Area)	Particle size data	Development Area
ICOL (collected by EMU Ltd)	Benthic surveys (see ES Appendix 12C – Benthic Ecology Baseline Offshore Export Cable Corridor)	Particle size data	Offshore Export Cable Corridor
ICOL (collected by Fugro)	Geotechnical survey (2011[15], 2012[16])	Geotechnical data	Development Area
Joint Nature Conservation Committee (JNCC)	UK SeaMap 2010[17]	Seabed habitats/landscapes	East coast of Scotland

Data Source	Study/Data Name	Data Theme(s)	Data Location
Scottish Natural Heritage (SNH)	Coastal Cells in Scotland[31] Cell 1 St Abb's Head to Fife Ness Cell 2 Fife Ness to Cairnbulg Point	Shoreline processes	East coast of Scotland
BGS	Tay and Forth seabed sediments (1986[18]) Tay and Forth solid geology (1986[19]) Tay and Forth quaternary geology (1987[20]) General geology and sediment maps[21,22,23,24,25] BGS online core and surface grab sample archives	Geology, sedimentology, sediment features, sediment thickness and sediment transport	Tay and Forth
UK Hydrographic Office (UKHO)	Various contemporary charts (Admiralty Charts 175 and 190) Tide Tables, Co-tidal Charts	Bathymetry, tidal streams, water levels	East coast of Scotland
C-MAP	Electronic chart database (2007[26])	Bathymetry	East coast of Scotland
BODC, POL	Data inventories and data holdings	Current measurements Wave measurements Surge data	Various port and offshore sites
Scottish Environment Protection Agency (SEPA)	River inflows	Freshwater/sediment inputs	Major rivers
Cefas	WaveNet data inventory and data holding (2011[27])	Wave measurements	Firth of Forth
UK Meteorological Office (UKMO)	Data summary	Meteorological data	Eastern Scotland
Coastal Councils	SMPs	Shoreline processes, coastal processes	Tayside; Fife; East Lothian; Angus
Department of Trade and Industry (DTI) – Department for Business, Enterprise and Regulatory Reform (BERR)	Strategic Environmental Assessment (SEA) 3, SEA 5; 2007/07 Atlas of Renewable Energy	Regional geomarine assessment; synoptic oceanographic parameters	Regional
Department of Energy and Climate Change (DECC)	UK Offshore Energy SEA (2009[28])	Regional geomarine assessment	Regional
Scottish Executive (report by Faber Maunsell and Metoc)	Scottish Marine Renewables SEA (2007[29])	Regional geomarine assessment	Regional
The Tay Estuary Forum	The Tay Estuary Coastal References Database[30] (covering literature, reports and academic dissertations/theses)	Geology; sedimentology; fluvial flows	Tay and Forth
Intertek (for ICOL)	The Forth and Tay Modelling System (developed specifically for this assessment)	Metocean (hydrodynamic and waves); sediments	Regional study area, Development Area, Offshore Export Cable Corridor

10A.2 PHYSICAL ENVIRONMENT (BASELINE)

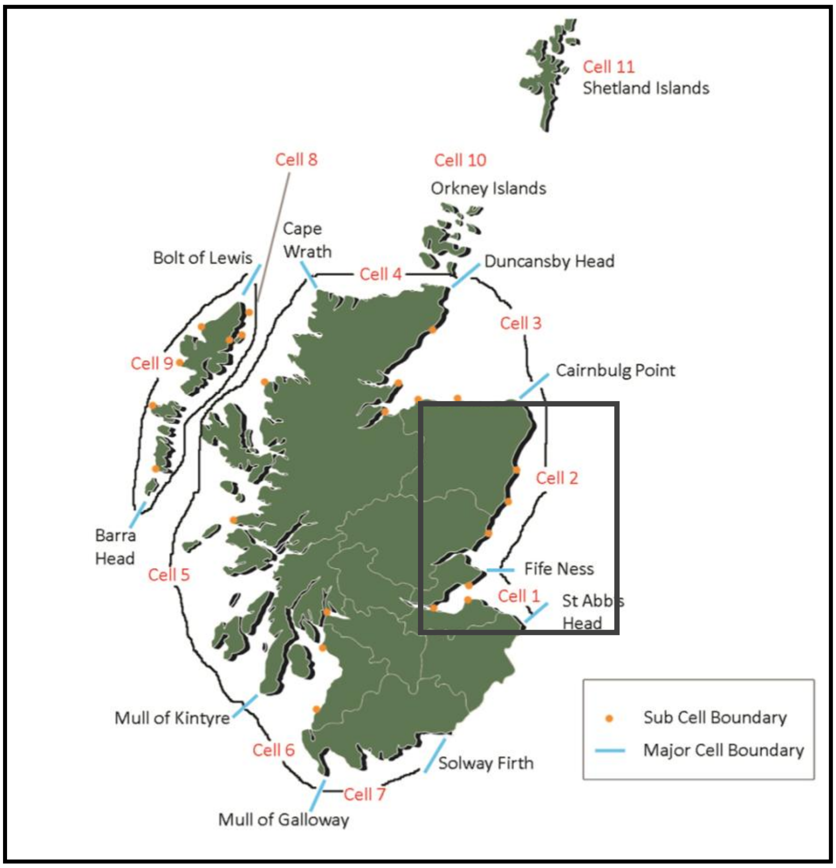
10A.2.1 REGIONAL AREA

The existing physical environment, or baseline conditions, have been assessed by Intertek in consultation with Partrac, based on a range of field data, existing literature and model outputs (as outlined in Table 10A.2). The baseline metocean and sediment regimes on a regional basis are described in full in ES Chapter 10 – Appendix 10F Regional Coastal Processes Baseline Description.

The regional extent for the purposes of the assessment is defined as the marine offshore region extending from St Abb's Head (Berwickshire) to Cairnbulg Point (Aberdeenshire) and extending eastwards to the eastern boundary of theFoF project. This area spatially embraces the Project and NnG project on a scale which encompasses the potential for cumulative effects of construction in the FoF project area, and is defined at the shoreline by coastal cell boundaries. On occasion in the Appendix 10F Regional Baseline Report, the sub-cell boundary at Deil's Head (near Arbroath, Angus) has been used to delimit the description of shoreline processes. The western limit for consideration was the Forth Road Bridge.

Figure 10A.7 shows the extent of the regional assessment in the context of the coastal cells, as defined by Ramsay and Brampton[31].

Figure: 10A.7: Definition of the extent for the regional baseline description



10A.2.2 INCH CAPE PROJECT

In addition to the regional scale assessment of baseline conditions, the study has included a more detailed analysis of the existing physical environment of the Development Area, using site-specific data provided by ICOL.

This analysis considered the bathymetry and sediment cover of the area, physical oceanographic processes (tides, waves and storm events), fluvial inputs and the sediment transport regime, by both suspended sediment and bedload pathways. The full details of this analysis are provided in Annex 10A.1.

The following provides a general summary of the metocean and coastal processes regimes for the Development Area.

1) The seabed forms a broad oval plain with a shallower region in the centre of the Development Area and deeper regions in pockets across the area, especially in the south-eastern region. General water depths within the Development Area boundary (encompassing about 150 km^2) range between 35.5 and 63.3 m Chart Datum (CD), with a mean water depth of 49.3 m CD.

2) Mean spring tidal range is approximately 4.6 m.

3) The seabed is characterised by no dramatic geomorphological features other than two sandbank areas, one in the northwest and a shallower bank in the centre of the Development Area. These sandbank areas have a relief of ~12-17 m above the surrounding seabed.

4) Surficial sediments form a relatively thin veneer (0-0.5 m thick) and are characterised dominantly by medium sand (distributed across the site, including in deeper areas), with generally a minor mud fraction and a variable gravel component. Where gravel is present in minor amounts it is generally 'very fine' to 'fine' (2-8 mm), whereas in areas of richer gravel deposits particle sizes can range up to ~20-30 mm, or even greater in isolated pockets.

5) The vertical profile of Quaternary sediments comprises contemporary sands/gravels, over inter-bedded sand and silt overlying stiff, hard (boulder) clay.

6) Across the Development Area there is an almost complete absence of bedform features. Megaripples are faintly discernible on open plain areas and in most cases associated with shallower, gravel-rich areas. This suggests the site is not highly dynamic.

7) The ambient tidal current regime is not sufficiently powerful to generate significant sediment transport on either the spring or neap tidal phases. Fine and medium sand are transported by the tidal currents but only during spring tides and only higher in the tidal range. Therefore the Development Area can be classified as 'slightly mobile' during the summer months.

8) The Development Area can be classified as 'moderately mobile' during the winter months, when sands are mobile for 15-20 per cent of the time within any year. Storm conditions with waves in excess of 5.5 m significant wave height, and a mean wave period of >8-8.5 s are predicted to mobilise sediments across the site, and such conditions have a return period of greater than one in ten years.

9) The Development Area receives waves most frequently from a north-northeasterly direction (22.5 degrees); mean wave periods range between two and nine seconds; and significant wave heights up to ~6.24 m were recorded by *in situ* instrumentation. Waves also arrive from both the south-eastern and south-western quadrants but these form only a minor component of the wave direction spectrum. Wave breaking rarely occurs at the Development Area, only under extreme marine conditions.

10) Fair-weather SSC, nominally due to tidal resuspension, is very low (<15 mg/l).

11) No SSC measurements were obtained during winter storm conditions, but using the largest winter wave measured, coincident with the storm surge peak spring tide, the winter SSC has been estimated to be 81 mg/l (using the method of Soulsby[32]).

12) A net directional suspended sediment transport in the direction of the flood tidal axis (S – SSW) exists, but residual tidal transport of suspended fine sediments is not judged to be significant on an annual basis.

13) Large-scale (vertical) changes to general seabed level are not anticipated.

14) A net directional suspended sediment transport in the direction of the flood tidal axis (S – SSW) exists, but residual tidal transport of suspended fine sediments is not judged to be significant on an annual basis.

15) Tidal excursion during spring tides has the potential to transport very low settling velocity material outwith the site to 7.2 km (north) and 8.7 km (south).

16) Fluvial inputs of freshwater from the Rivers Forth, Tay and Eden are small in relation to the tidal (marine) volume. Concentrations of suspended sediment in fluvial discharges are low and therefore input of fluvial sediments is negligible.

17) Shoreline sediment transport is dominantly due to wave action, by waves from the southeast. Information is available on shoreline sediment transport processes via regional SMPs[33].

10A.2.3 FUTURE CONDITIONS (CLIMATE CHANGE)

Over relatively short time periods (e.g. months) the mean sea level (MSL) can be regarded as being stationary (non-changing). However, over longer time periods (e.g. several years) MSL varies in response to sea level rise and long period tidal trends (e.g. the 18.6 year lunar nodal cycle). Hence, the baseline definition is non-stationary in situations when MSL also varies. The combination of an increasing MSL (as a function of sea level rise) and potentially increased storminess is an important issue for future coastal change within the outer Forth and Tay estuaries. Research for the Department for Environment, Food and Rural Affairs (DEFRA) by the UK Climate Impacts Programme (UKCIP) suggests increases of up to 10 per cent in the speeds of extreme winds and heights of extreme waves on the coasts. The consequences in terms of coastal processes is likely to be most evident along the shorelines where much of the wave energy is finally dissipated leading to modified rates of littoral drift. The advancing position of mean high water on beaches will also lead to wave energy dissipation higher up on the foreshore with anticipated beach loss and scour in front of sea walls, or increased frequency of overtopping of coastal dunes or structures. Effects would also apply to offshore areas where the profile of sandbanks may reduce relative to local water depths introducing greater exposure to offshore waves (i.e. there is less wave shoaling and larger waves therefore can run up the shore). The impact of increased wave energy may have consequences for the sediment transport within the area.

Future sea level rise results from the net effect of global change in sea level and the local change in land levels due to post-glacial rebound and subsidence. Based on DEFRA guidance[34] the land in Scotland (which is rising) is assumed to have a rate of change of +0.8 mm per year. The recommended value of relative sea level rise for flood and coastal defence planning for Scotland is 2.5 mm per year in sea level rise to 2025, 7.0 mm per year from 2025 to 2055 and then 10 mm per year from 2055 to 2085.

10A.3 BASELINE ASSESSMENT USING THE FORTH AND TAY MODELLING SYSTEM

A key requirement of the coastal processes assessment was the development of a dedicated hydrodynamic and spectral wave model. Intertek METOC has constructed, calibrated and validated the FTMS for the purpose of modelling the baseline metocean conditions, and the subsequent change or effect on the metocean and sediment regimes in both the near and far-field due to the developments. Near-field (NF) studies consider the interaction between structures and the effect of the Project within the Development Area and Offshore Export Cable Corridor. Far-field (FF) studies consider the general effect of the Project across the surrounding area.

The FTMS has been constructed using an unstructured flexible mesh dynamic modelling system. This is a sophisticated two-dimensional modular based modelling system, and has the capacity to run hydrodynamic (HD), spectral wave (SW) and particle tracking (PT) models. It may be used to predict the physical properties of tidal currents and waves, and the interactions between these, for any specified area. The FTMS can also be configured to represent the effect of structures, such as WTGs and their foundations, on the hydrodynamic conditions and wave climate.

A flexible mesh model has the advantage of using a spatially varying resolution, so that the complex bathymetries and coastal topographic features can be sufficiently resolved by the model. It also allows fine resolution to be configured in the key areas of interest (for instance around the Development Area), whilst a coarser resolution can be employed in areas that do not require or warrant such fine detail (such as in the deeper waters closer to the open water boundaries).

The FTMS was built with a spatial resolution varying from approximately 60 m in the area of interest to approximately 2500 m in the offshore part of the model domain. This allows adequate representation of the physical processes in both the NF and the FF. A total of 131,582 triangular elements are used in the model. The FTMS covers an area of 33,462 km^2.

Figure 10A.8 shows the model domain of the FTMS as a whole, and Figure 10A.9 shows the model in more detail around the ICOL Development Area. The depths shown are in metres relative to MSL (the vertical datum used in the FTMS).

Figure 10A.8: FTMS model domain and mesh resolution

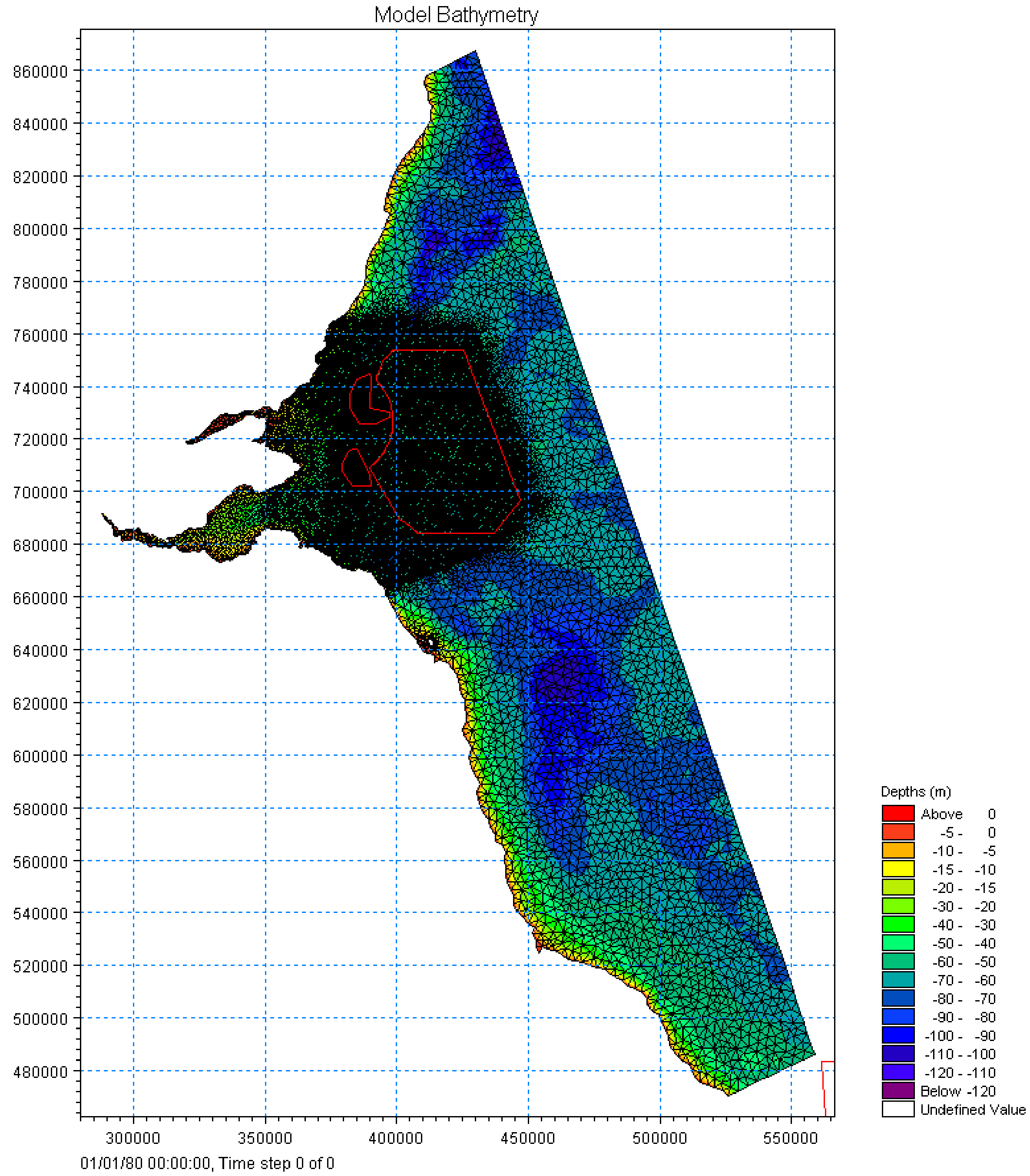
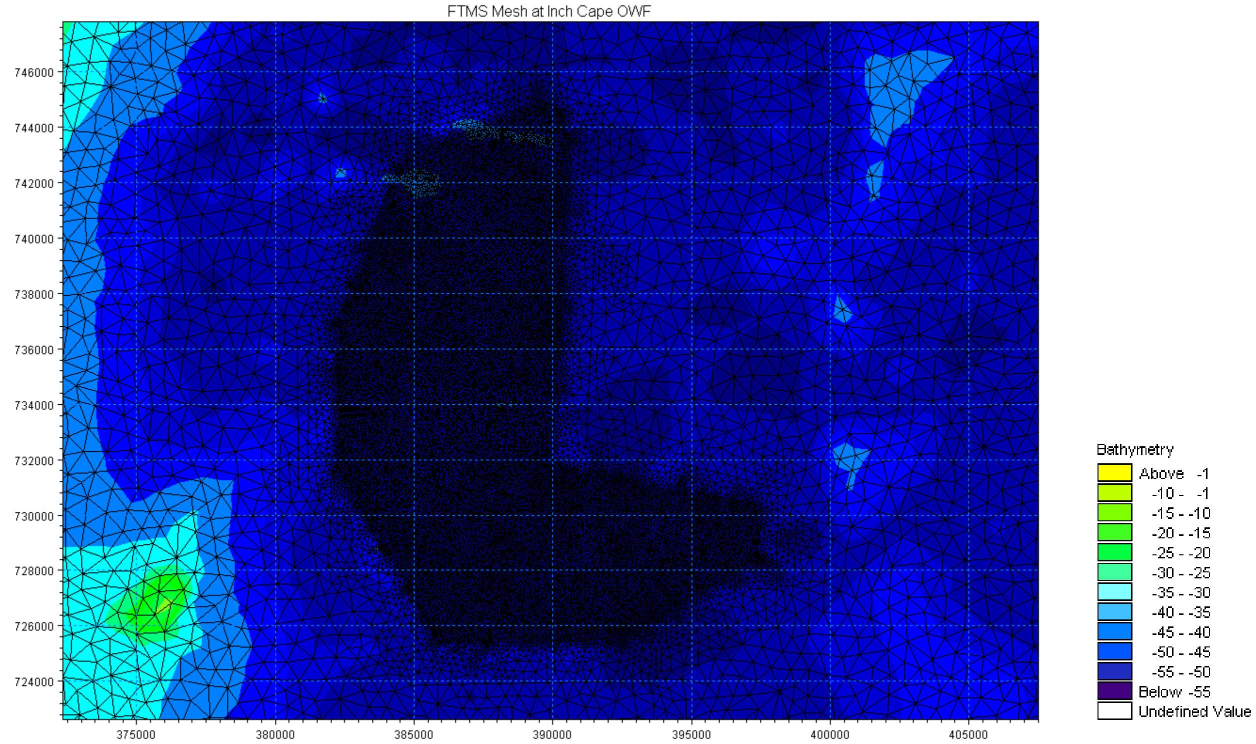


Figure 10A.9: FTMS resolution around the ICOL Development Area



Full details of the construction, calibration and validation of the FTMS HD and SW models are provided in ES Chapter 10 – Appendix 10C.

The calibration and validation report concluded that:

The FTMS HD and SW models have been well calibrated and validated against appropriate field data, and have been demonstrated to be performing very well across the model domain. The FTMS is therefore fit for the purpose of undertaking the metocean and coastal processes assessment for the ICOL Project.

The validated FTMS was used to determine the baseline metocean conditions (water levels, current flows and wave climate), and the resulting baseline sediment regime, against which any modelled changes due to the Project were compared.

10A.3.1 HYDRODYNAMIC REGIME

The HD component of the validated FTMS was used to model the typical tidal conditions experienced across the ICOL Development Area and the region as a whole. A long-term time series of water level was analysed in order to produce tidal harmonic constituents applicable to the general study area. These tidal constituents were used to re-predict a time series of tidal elevations for a full year. From this time series, and the tidal harmonic constituents, it was possible to determine representative mean spring and mean neap tidal conditions. The HD model was then run for a period during which these mean spring and mean neap conditions occurred. In this way, the FTMS was used to model typical conditions of water level and current velocity.

The typical hydrodynamic conditions across the region were extracted from the model outputs. Figures showing water levels and current speeds are given in Annex 10A.2 – Section 1. High water (HW) and low water (LW) levels on both spring and neap tides, and peak speeds on the flooding and ebbing tides are shown. In addition, percentile (%ile) speeds (calculated over the modelled mean spring and neap tides which are representative of typical tidal conditions) are presented. The selected percentiles represent the percentage of current speeds (through the tidal cycle) that are less than the speed presented. For example, if the 90-percentile current speed is 0.5 m/s, then currents will be less than this value (0.5 m/s) for 90 per cent of the time (or conversely speeds only exceed 0.5 m/s for 10 per cent of the time).

The 50, 90, 95 and 99-percentiles provide a sufficient set of results to represent the general hydrodynamic regime, with a focus on the more extreme (energetic) end of the distribution. The 50-percentile represents the average conditions, and the 90, 95 and 99-percentiles capture the lower frequency but more energetic tidal conditions, which are those more likely to cause sediment mobilisation. The equally infrequent quiescent conditions (i.e. the 10, 5, and 1-percentile conditions) are considered to be of lower relevance to the metocean and coastal process assessment, and have therefore not been included in this study.

Regional (FF) scale plots and more detailed plots around the development (NF) are shown in Annex 10A.2 – Section 1.

These plots show that hydrodynamic conditions do not vary much across the Development Area and its surrounding environment, with water levels and current flows being spatially very uniform at each state of the tide. Water levels range between about 2.0 m (HW) to -2.4 m (LW) – relative to MSL – during spring tides, and between about 1.0 m (HW) to -1.2 m (LW) during neap tides. Current speeds reach up to about 0.6 m/s on both the flooding and ebbing spring tides, and up to about 0.4 m/s on both the flooding and ebbing neap tides.

The tidal cycle has a slight asymmetry, with the flood tide slightly dominating the ebb tide during both spring and neap tides (see Annex 10A.1 for more details). This will influence the net sediment transport pathways.

These modelled data are consistent with the observed data collected during the metocean campaign, and with other general information about the tidal regime within the area (see Annex 10A.1). Table 10A.3 provides a summary of modelled tidal ranges and currents in the ICOL Development Area.

The semi-diurnal tide is the dominant cause of current flow throughout the study area. Non-tidal components of the total current are of relatively smaller significance. This is because they are either low in magnitude (such as general circulation currents) or infrequent in nature (such as storm surge currents). For example, the 50-year return storm surge current, as determined through analysis undertaken by Partrac and PhysE (see Annex 10A.1), is similar in magnitude to the peak current on a mean spring tide (about 0.6 m/s). More frequent storm surges will have correspondingly lower associated current speeds. Surface wind drift currents can reach speeds of a few tens of centimetres per second in any direction, but these will be confined to the upper layer (top few metres) of the water column and will therefore have no effect on seabed sediment mobility. However, it should be noted that non-tidal flows, such as storm surges and wind-driven currents, would be in addition to the tidal currents experienced at the time.

10A.3.2 WAVE CLIMATE

The SW component of the FTMS was used to model the baseline wave climate. Long duration time series of wave and wind data at two locations on the offshore (eastern) boundary of the FTMS were acquired from the UKMO. These data covered an 11-year period (2000 to 2011) and were derived from the UKMO UK Waters wave model. The data were analysed in order to determine the frequency of occurrence of waves with different heights, periods and directions. The analysed wave and wind data were then used to drive the SW model under a large number of different wave conditions (with different wave heights, periods and directions) in order to represent the long-term wave climate across the model domain. Both onshore waves propagating into the model domain from the North Sea, and offshore wind-generated wave conditions were included.

Annex 10A.3 provides details of the wave climate analysis.

The frequencies of occurrence for each of the different modelled wave conditions were used to undertake a statistical analysis of the modelled wave climate, from which different percentiles of the key wave parameters (significant wave height, mean and peak wave period) were derived. The selected percentiles represent the percentage of wave conditions which are less than the presented value. For example, the 90-percentile significant wave height is the wave height that 90 per cent of all waves are less than (or conversely, the wave height which only 10 per cent of waves exceed).

Figures showing the modelled baseline wave climate are included in Annex 10A.2 – Section 2. These include plots of significant wave height (H_s), mean zero-crossing (mean) wave period (T_z), and peak wave period (T_p), which are shown as 50, 90, 95 and 99-percentiles. Annex 10A.2 Section 2.1 includes the regional (FF) scale plots, and Annex 10A.2 Section 2.2 provides more detail around the Development Area (NF).

These figures indicate that the wave climate across the Development Area is very uniform, with little spatial variation in either significant wave height or mean/peak wave period. The significant wave height varies between 1.2-1.4 m (50-percentile) to 5.6-5.8 m (99-percentile), with mean wave period varying between 4.5-5.0 s (50-percentile) to 8.0-8.5 s (99-percentile), and peak wave period varying between 6.5-7.0 s (50-percentile) to 14.5-15.0 s (99-percentile). These modelled results are consistent with all other previous analyses of the wave climate in the area. Table 10A.3 provides a summary of the modelled wave conditions in the Development Area.

Table 10A.3: Summary of modelled parameters in the Development Area

Parameter	Modelled
Mean spring tidal range (m)	4.4 m
Mean neap tidal range (m)	2.4 m
Mean peak spring tidal current (m/s)	0.6 m/s
Mean peak neap tidal current (m/s)	0.4 m/s
50%ile Significant wave height (m)	1.2 – 1.4 m
50%ile Mean wave period (s)	4.5 – 5.0 s
50%ile Peak wave period (s)	6.5 – 7.0 s

10A.3.3 SEDIMENT REGIME

The sediment regime is fundamentally driven by the tidal currents and wave climate and is a function of the type and amount of sediment available for erosion, transport, and subsequent deposition (or accretion).

In order to assess any impact of the Project on the local and regional sediment regime (and thereby on coastal processes), the existing (baseline) bed shear stress due to the tidal currents, the wave climate, and ultimately the combination of both tidal currents and wave processes, was determined.

The bed shear stress is the force exerted at the seabed due to the combination of currents and waves (wave orbital velocity). The bed shear stress is also a function of the grain size of the seabed sediment. If the bed shear stress exceeds the critical shear stress required for entrainment, then mobilisation of the seabed material will occur, and this material will be transported either along the seabed (as bedload), or in the water column (as suspended load), depending on the material type and the magnitude of the bed shear stress. Both the bed shear stress and the critical entrainment stress are dependent on the median grain size (d_{50}). For this reason, a spatially varying seabed d_{50} map was developed, based on the data available from the BGS for the region as a whole, and supplemented with the site-specific sediment samples within and around the Development Area (from the geophysical and benthic sampling survey).

Figures 10A.10 and 10A.11 show contour plots of the critical shear stress for entrainment. A full description of the analysis of the bed shear stress and critical shear stress for entrainment is provided in Annex 10A.4.

Figures showing the baseline sediment regime are shown in Annex 10A.2 – Section 3. These include contours of the 50, 90, 95 and 99-percentile bed shear stress due to currents, waves, and combined (currents and waves). Annex 10A.2 Section 3.1 includes the regional scale plots, and Annex 10A.2 Section 3.2 shows these in more detail around the Development Area.

The baseline sediment regime has been summarised in four key plots (Figures 10A.12 to 10A.15). These show the spatial variation in the percentage of time that the critical shear stress for entrainment is exceeded due to the combined bed shear stress. Because bed shear stress varies continually due to the orbital wave motion, the mean and maximum bed shear stress throughout a wave cycle, together with the percentage of time these exceed the critical shear stress, have been determined.

Figures 10A.12 and 10A.13 show contours on the regional (FF) scale, for the mean and maximum combined bed shear stress respectively. Figures 10A.14 and 10A.15 show the same, but in more detail around the Development Area.

These are based on the combined effects of currents and waves, and indicate how often seabed sediment will be mobilised due to the baseline hydrodynamic regime and wave climate. These results are discussed in more detail in Annex 10A.1.

The plots indicate that while the exceedance of critical shear stress ranges from 5–40 per cent across the regional study area, over most of the Development Area the exceedance of critical shear stress due to mean combined wave and current forcing is 15 to 25 per cent (i.e. seabed sediment will be mobilised between 15 and 25 per cent of the time). There is no distinct spatial distribution in the variability in the amount of seabed mobilisation, except for a slight increase in exceedance in the very northern extent of the Development Area. Owing to the depth of water in the Development Area, only the very largest (highest and longest period) waves cause small orbital motions at the bed. The dominant cause of critical entrainment stress exceedance is the tidal current.

Though there are spatial differences in the percentage exceedance of critical shear stress across the Development Area, these are not large. Therefore, based upon this evidence the site can be classified as slightly mobile under waves and currents combined.

Figure 10A.10: Critical shear stress (for entrainment) – Regional area

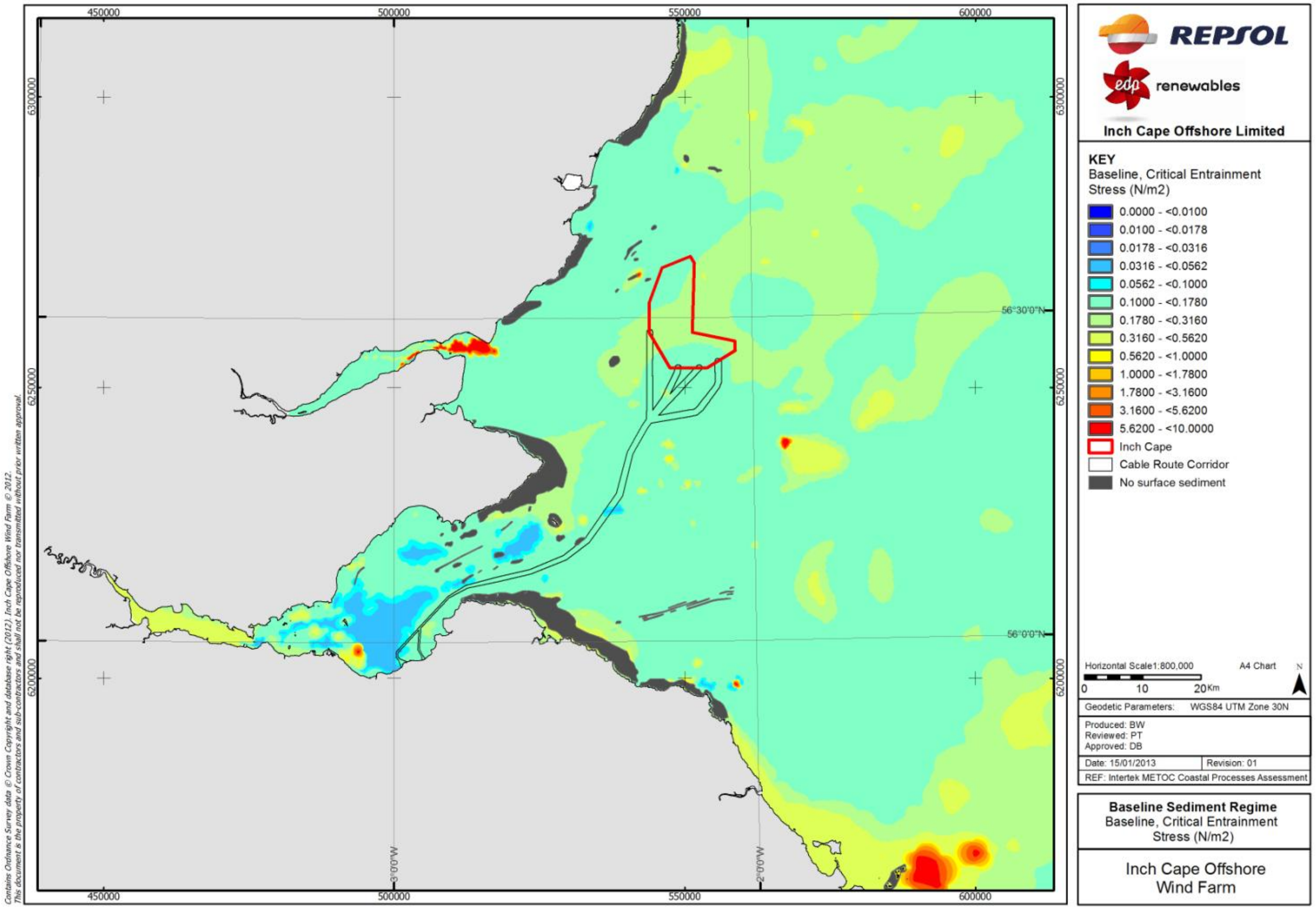


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Figure 10A.11: Critical shear stress (for entrainment) – ICOL Development Area

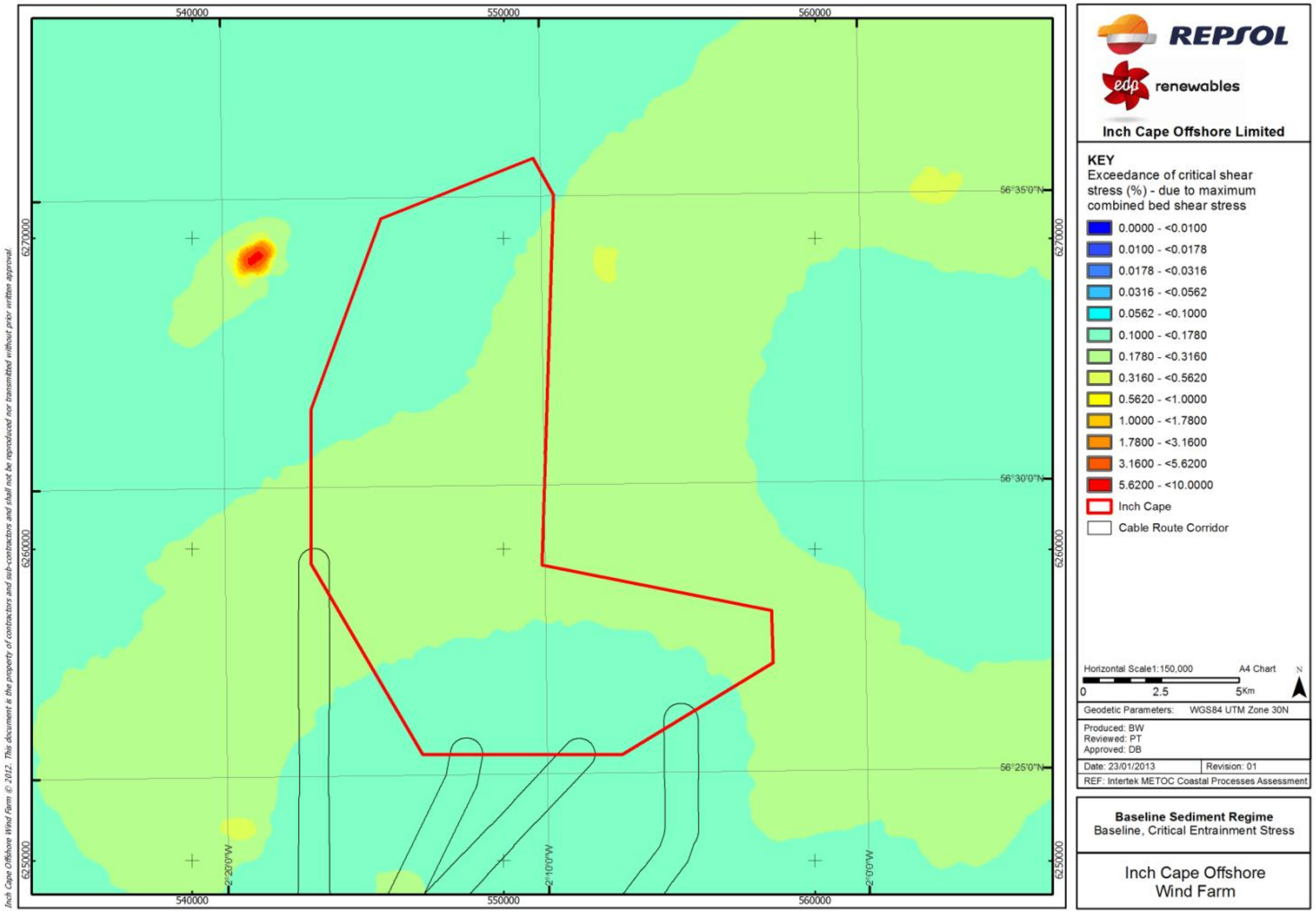


Figure 10A.12: Exceedance of critical shear stress (for entrainment) due to mean combined bed shear stress – Regional Area

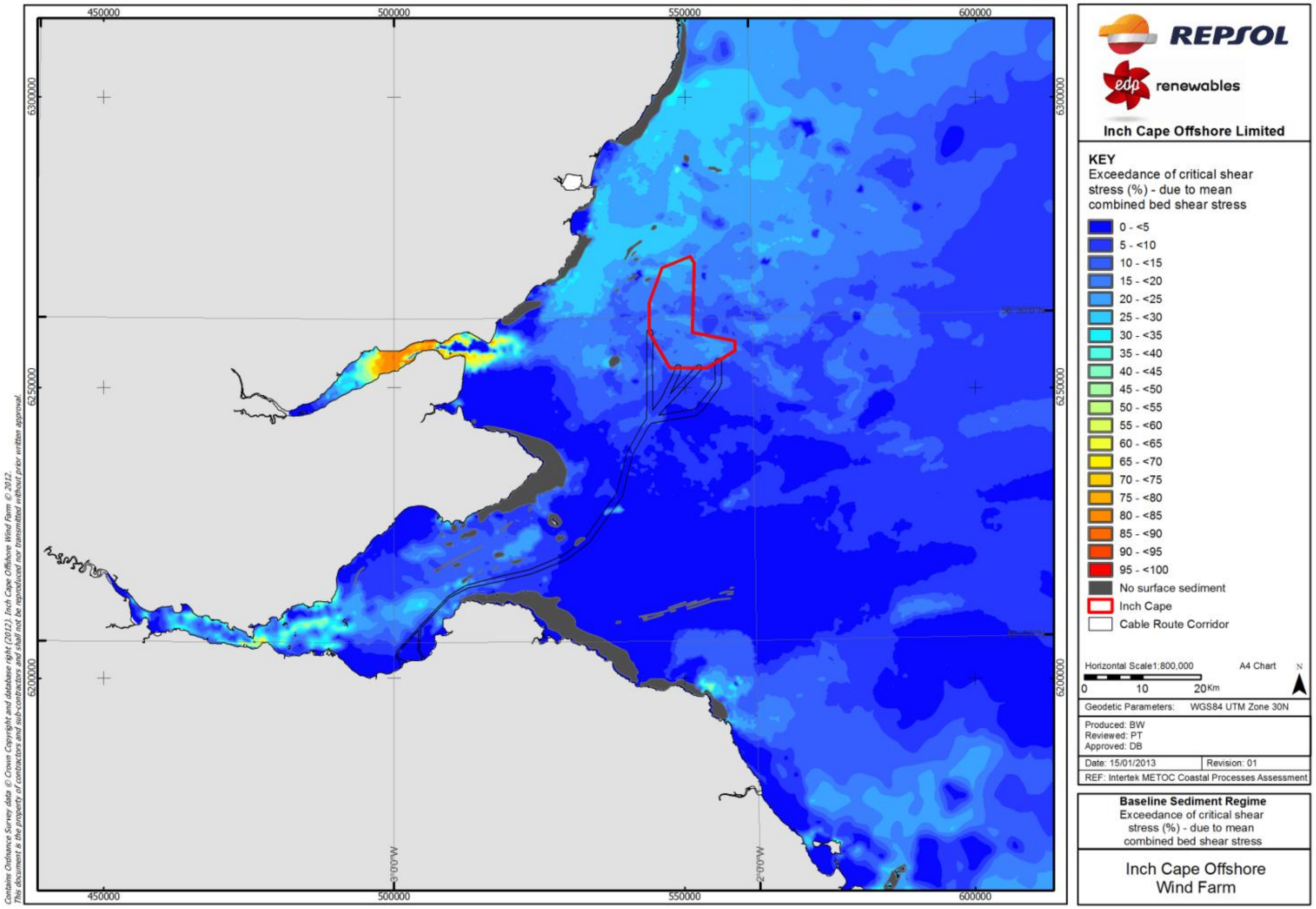


Figure 10A.13: Exceedance of critical shear stress (for entrainment) due to maximum combined bed shear stress – Regional Area

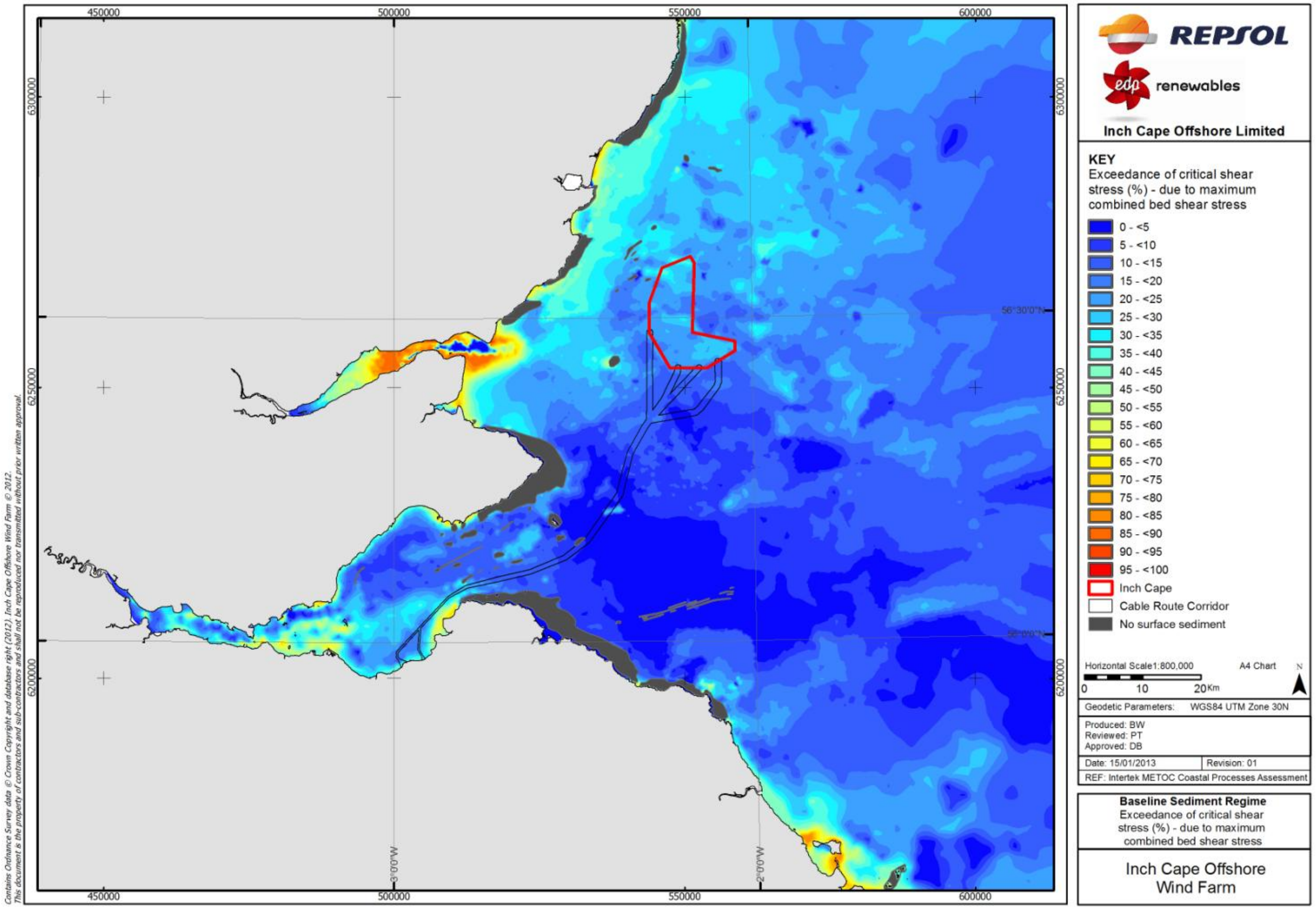


Figure 10A.14: Exceedance of critical shear stress (for entrainment) due to mean combined bed shear stress – ICOL Development Area

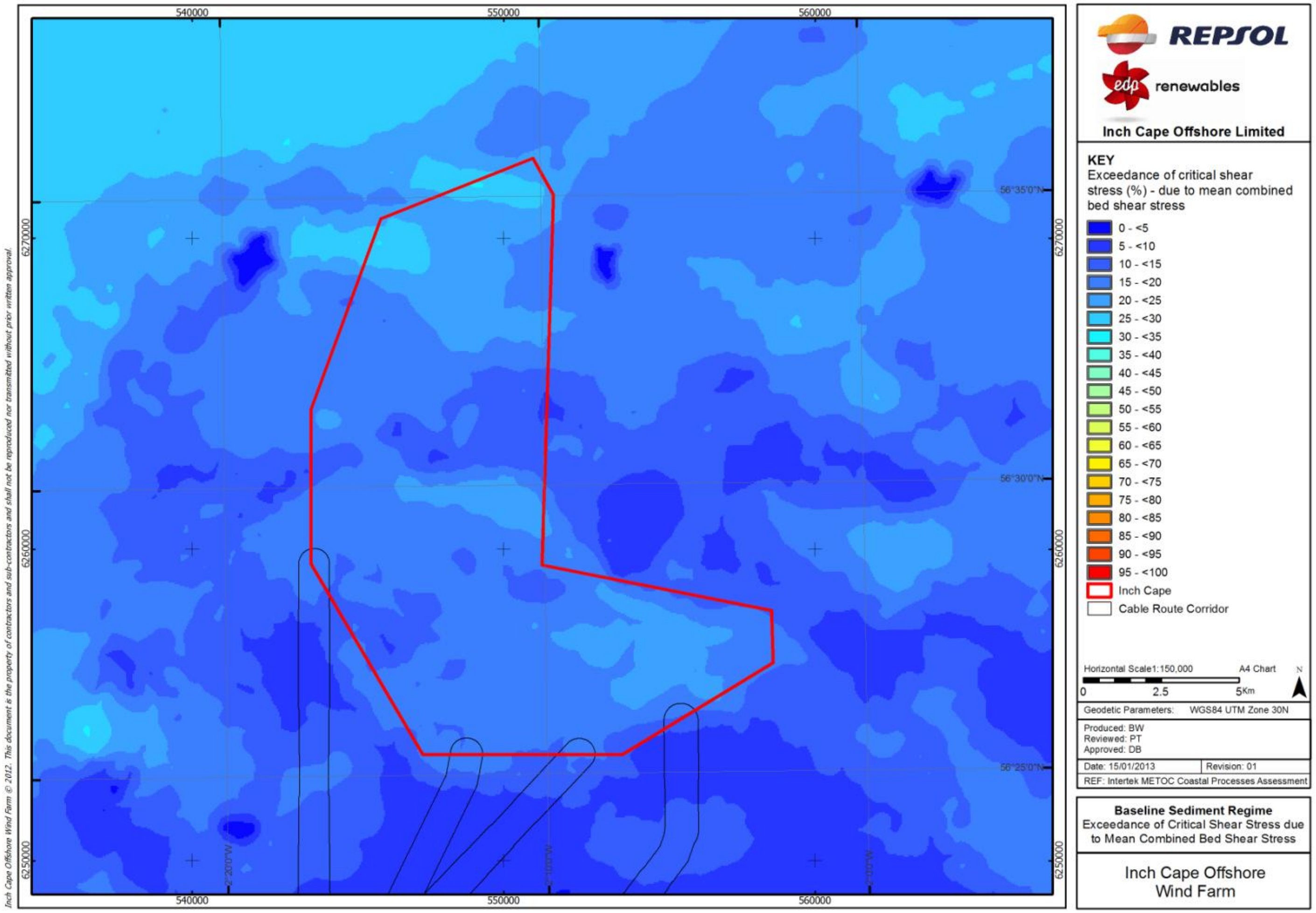
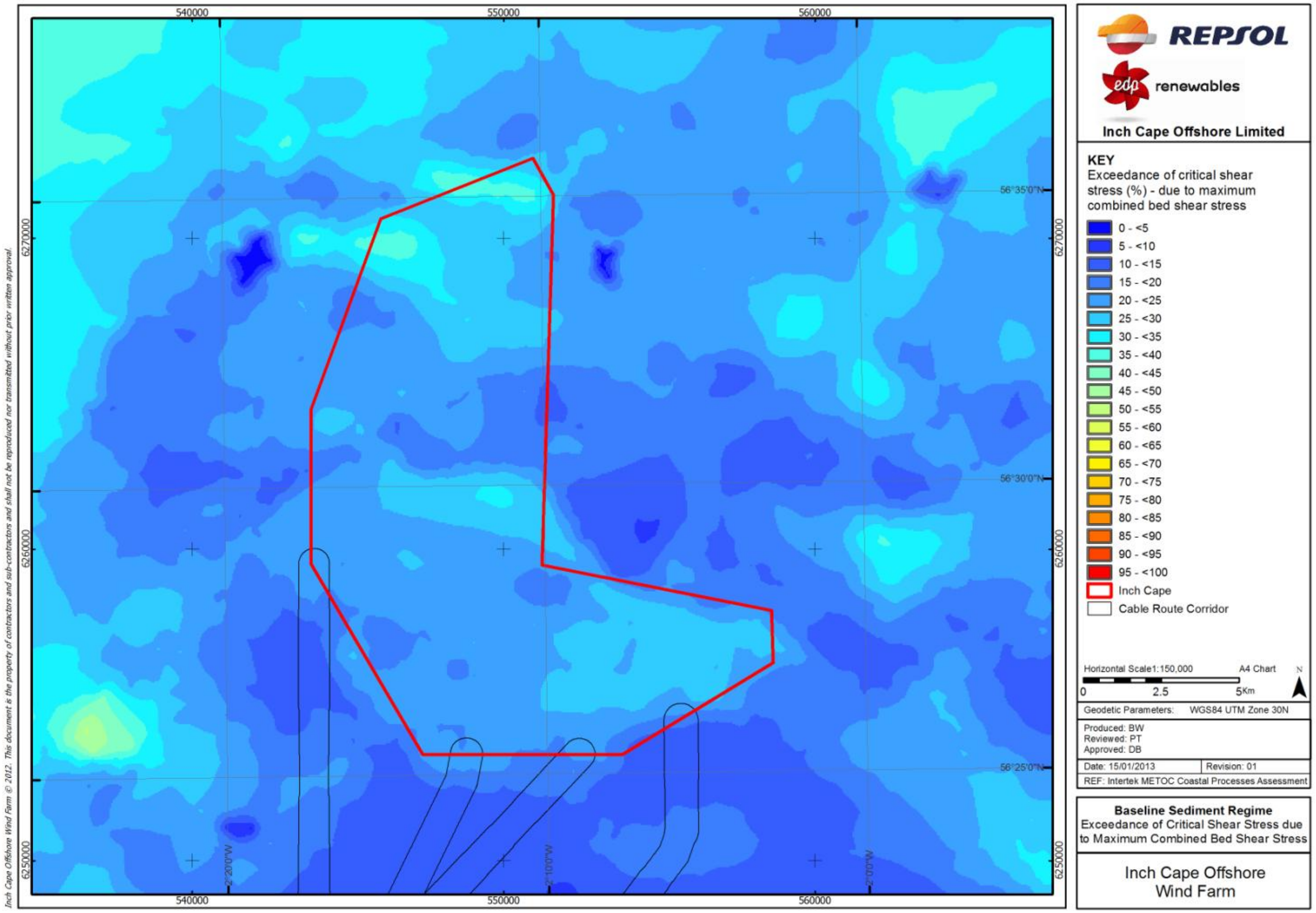


Figure 10A.15: Exceedance of critical shear stress (for entrainment) due to maximum combined bed shear stress – ICOL Development Area



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10A.3.3.1 Far-field Suspended Sediment Transport

The typical FF net transport of suspended sediment from the development site was modelled using the FTMS particle tracking module. A dummy continuous discharge of a very large number of neutrally-buoyant particles over a spring-neap cycle was modelled using the FTMS, driven by the baseline (pre-development) HD model. The dummy discharge was released at the centre of the Development Area, in order to represent the net movement of suspended sediment from the Development Area. A similar run was undertaken with the developments in place, in order to identify any change in the net movement due to the developments (see Section A10.5). However, it should be noted that the modelled particles represent only the background, or ambient suspended sediment, and do not represent any specific discharge resulting from the development.

10A.4 ASSESSMENT OF IMPACTS

In order to assess and quantify the potential impacts on metocean and coastal processes due to the development, changes to the baseline (existing) metocean and sediment regimes have been determined using the FTMS. Any changes to these existing regimes might result in a change to the metocean and coastal processes in the study area, and a consequential impact on the geomarine environment.

The methodology applied has been outlined in Section A10.1.3, and is provided in more detail in ES Chapter 10 – Appendix 10D. This approach has been agreed with Marine Scotland (and all other relevant stakeholders), and is also in line with the best practice guidance provided in the COWRIE report.

The applied approach can be summarised as follows:

1) The baseline (existing) conditions were determined based on the best available information, including field data collected specifically by the developers, and supported by output from the FTMS. This is reported for the regional study area in ES Chapter 10 – Appendix 10F, and in more detail for the Development Area in Annex 10A.1.

2) The FTMS numerical modelling system was developed, calibrated and validated. This has been configured so that it is suitable for modelling the metocean and sediment regimes in both the near- and far-field, and is capable of incorporating the effects of the development on these regimes. The FTMS construction is described in full in ES Chapter 10 – Appendix 10C.

3) The FTMS was used to model a range of metocean (tide and wave) conditions under the baseline scenario (no OWF developments). These model outputs were used to determine the baseline sediment regime (in terms of bed shear stress and exceedance of critical shear stress for entrainment). This baseline study is described in Section A10.3 and presented in Annex 10A.2.

4) The FTMS was then used to model the same range of conditions under the ‘with-development’ scenarios, (including the cumulative and future climate scenarios) and to compare the resulting metocean and sediment regimes with the baseline regimes.

5) The magnitude of the changes to these regimes were quantified, and the significance of the resulting effects on the metocean regime and sedimentary / coastal processes were assessed. The significance of indirect effects on other receptors, such as the impact of elevated SSC on fish, are not assessed within the metocean and coastal processes assessment, but have been considered in the relevant chapters of the ES.

A range of temporal and spatial scales, as well as a number of different scenarios, were incorporated in the assessment, which are detailed in this Section.

10A.4.1 EIA METHODOLOGY

The Project has the potential to impact a variety of identified receptors through the changes it causes to metocean and coastal processes. These impacts can be:

- Direct – there are direct impacts on sedimentary features such as sand banks or other seabed features; or
- Indirect – whereby changes to the metocean or sedimentary regimes cause knock-on effects on other receptors such as fish, marine mammals or benthic ecology.

The significance of any impacts on identified receptors is quantified using an established EIA methodology. This process involves: calculating the magnitude of the impact on an identified receptor; determining the sensitivity of that receptor to change; and combining these magnitude and sensitivity measures in order to determine the significance of the impact on the receptor. The significance lies on a scale from Negligible/Minor to Major. If the significance of impact is towards the upper end of this scale, this indicates a potential need for mitigation.

The generic ICOL EIA methodology is described in ES Chapter 4 Section 4.4.3. The EIA methodology adopted for specific receptors is outlined in the individual topic chapters of the ES; for metocean and coastal processes, the EIA methodology is fully described in ES Chapter 10 Section 10.4.1.

This technical report does not aim to undertake the EIA for all of the identified receptors. Instead, it quantifies the size of effect that the Project will have on different metocean and sedimentary **processes**. The size of these effects on processes are in turn used within the ES to define the magnitude of impact for different identified receptors.

It should be noted that a predicted change in the metocean regime, or sedimentary and coastal processes, does not necessarily imply an impact if there are no receptors present that are sensitive to the change. This approach is in line with COWRIE guidelines[7].

Changes to the following processes have been considered within this report:

- Water level;
- Tidal currents;
- Wave heights;
- SSC;
- Sediment transport regime.

10A.4.2 TEMPORAL SCALES OF ASSESSMENT

As agreed with the clients and stakeholders, the potential changes to the metocean and coastal processes have been assessed over the following temporal scales:

- Construction phase;
- Operational phase, including:

- Short-term post-construction effects;
- Long-term post-construction effects; and
- Decommissioning phase.

10A.4.2.1 Construction Phase

This included the analysis of any effect on the metocean and sediment regimes due to the construction processes (rather than from the presence of the development itself). The activity of large installation equipment, such as jack-up rigs, and the process of laying foundations and burying cables, all have the potential to affect the environment, and these effects were considered as part of the assessment.

10A.4.2.2 Short-term Post-Construction Phase

This included the assessment of any short-term effects from the Project following completion (over timescales of days to weeks). The presence of the WTGs, OSPs and met masts and their associated foundations will cause a change to both the flow of water and the characteristics of waves as they pass through the development site and are modified by the structures. Current speeds will increase locally as the flow accelerates around the structures, and waves may be partially blocked or otherwise modified by the structures. Such changes will also lead to an increase in the potential for sediment entrainment and erosion around the structures, resulting in scour around the foundations.

Therefore, as well as the short-term changes to the baseline regimes, an estimate of the potential scour around the foundations, and the subsequent fate of scoured material was included in the study.

10A.4.2.3 Long-term Post-Construction Phase

This included the assessment of the long-term effects over the lifetime of the Project (up to 50 years), and included the cumulative impacts from the otherprojects in the area. It also included an assessment of the effects of a changing climate, and the resulting changes to the metocean and sediment regime due to sea-level rise and increased ‘storminess’. These potential changes were compared with the predicted changes (to the present baseline) due to the development.

10A.4.2.4 Decommissioning Phase

Impacts from the decommissioning phase have not been explicitly modelled. The potential effects of decommissioning are considered to be equivalent to and potentially lower than the worst case effects assessed for the construction phase. For example, the effects of WTG foundation removal are considered to cause similar or lower impacts to the construction processes (such as pre-installation dredging, or scour around jacket leg structures).

10A.4.3 SPATIAL SCALES OF ASSESSMENT

In accordance with best practice, and as agreed with the clients and stakeholders, the potential changes to metocean and coastal processes have been assessed over the following spatial scales:

- Near-field; and
- Far-field.

Owing to the unstructured and flexible resolution of the modelling system developed, it was possible to analyse both the NF and FF effects using the FTMS. In addition, the NF assessment was supported by the empirically-based analysis of the potential scour around individual structures.

10A.4.3.1 Near-field Scale

The NF study included the assessment of effects from the Project on a local scale (i.e. within the Development Area and Offshore Export Cable Corridor). This included the effect on the local environment from individual WTGs, met masts and OSPs, and a determination of any localised cumulative or overlapping impacts between adjacent WTGs. The NF study included the assessment of effects from the entire Project on environmental processes in the immediate vicinity of the development.

The spatial resolution of the FTMS throughout the Development Area and immediately surrounding it is approximately 60 m. The model therefore incorporated at least ten model elements (cells) between WTG structures, and this resolution was considered appropriate for the NF assessment of the Development Area.

It should be noted that the NF processes and effects (such as small scale turbulence around structures) are not resolved explicitly in the FTMS, and such processes are parameterised in the model to account for the overall effect. Very fine resolution Computational Fluid Dynamics (CFD) modelling would be required to fully resolve such processes, and it is generally considered that such costly analysis is not appropriate for an EIA.

The parameterisation of the relevant processes was undertaken using the specific mechanisms as provided and recommended by the developers of the industry-standard modelling software[35,36,37]. These included determining the current-induced drag force and a decay term around each individual structure, so that the currents, water levels and wave energy are appropriately modified. The parameterisations applied, and the subsequent representation of the individual structures within the model, is explained in more detail in Annex 10A.5.

In addition, the assessment of the potential for scour around the individual structures has not been undertaken directly using the FTMS, which is not suitable for such small scale analysis. An empirically-based assessment, using well-known engineering equations, has been undertaken (see Annex 10A.6). This assessment used the modelled currents and waves from the FTMS, along with seabed sediment characteristics obtained from the benthic survey samples, and the dimensions of the foundation structures, as inputs to the equations. The fate of the estimated volume of scoured material was then modelled using the FTMS to determine the excursion of any resulting plume of suspended sediment, in-water SSC, and the resulting footprint and thickness of the deposited material.

It should be noted that although the ICOL Project and NnG project was resolved in the FTMS in sufficient detail to assess the NF scale effects (i.e. those from individual turbines), the spatial resolution around the FoF development site was coarser, and therefore not sufficient to assess the NF scale impacts around each structure within that site. However, the model is sufficiently resolved to allow the individual structures to be included in the model, and to assess any total, FF impact from the development as a whole. Therefore, cumulative impacts from this site have been accounted for.

10A.4.3.2 Far-field Scale

The FF study included the assessment of the effects from the Wind Farm and OfTW on a regional scale. This included the effect from the Project on coastal processes beyond the Development Area and Offshore Export Cable Corridor, and in particular extending to the shoreline. The FF assessment also included the cumulative impacts from the otherprojects. Fundamentally, the FTMS accounts for overall acceleration and deflection of current flows, and the loss of wave energy due to the developments as a whole, and models the gradual return to ambient metocean conditions with increasing distance from the developments.

The resolution of the FTMS in the FF varied from about 150 m close to theWind Farm, to 2500 m in the most distant areas near the model boundaries. Within the FoF development site the model resolution was approximately 500 m, and within coastal areas, including the Forth and Tay estuaries, the model resolution was about 800-1200 m. The FTMS was therefore considered to be suitable for assessing the processes in the FF. This is in line with the COWRIE best practice guidelines[7]. The FF tidal fluctuations (in current speeds and water levels) and the general wave climate, as well as the overall effect on these from the wind farm developments as a whole, are considered to be adequately represented in the FTMS.

10A.4.4 ASSESSING THE EFFECTS OF STRUCTURES

Any structures placed within the marine environment, such as the foundations for the WTGs and OSPs, may lead to changes to the metocean regime. NF effects on currents will include the bifurcation and deflection of flow, and the resulting acceleration and deceleration of current speeds, and small scale turbulence around structures. Structures will interact with the wave field potentially causing scattering/diffraction, reflection and shoaling of waves.

As discussed previously, such processes were not explicitly resolved in the FTMS, but were parameterised in order to model the overall effect of such processes, in both the near and far-field. The FTMS provides different options for the parameterisation of structures, and these were investigated to determine the most appropriate method.

The details of how theWind Farm and OfTW were incorporated in the FTMS are provided in Annex 10A.5.

10A.4.5 SUMMARY OF ASSESSMENT SCENARIOS

The study used different assessment techniques and tools in order to account for all of the various temporal and spatial scales, and the different types of effect that needed to be investigated. These are summarised in Table 10A.4.

Table 10A.4: Summary of assessment topics and modelling tools/methods applied

Potential Effect	Near-field (NF) Modelling Tools	Far-field (FF) Modelling Tools	Processes included
Changes to hydrodynamics (water levels and current flows)	FTMS HD module (utilising the fine model resolution around the development site).	FTMS HD module (utilising the variable resolution of the model mesh).	Bifurcation of flow around structures (NF) Localised acceleration of currents (NF) Change in general circulation (FF) Change in tidal symmetry, orientation (FF) General change in energy of hydrodynamic regime (NF/FF)
Changes to the wave climate	FTMS SW module (utilising the fine model resolution around the development site).	FTMS SW module (utilising the variable resolution of the model mesh).	Refraction Shoaling Bottom dissipation Wave breaking White capping Wind-wave generation Directional spreading Frequency spreading Wave-current interaction General change in energy of the wave regime
Changes to sediment regime	FTMS HD and SW modules FTMS PT module Site-specific (and regional) sediment grain size data Standard equations to determine the locations and frequency of occurrence of sediment mobilisation (based on bed shear stress).		Near bed tidal currents Near bed wave orbital velocities Seabed sediment size distributions Bed shear stress Critical shear stress for entrainment
Fate of scoured material around foundations	Empirical scour equations FTMS PT module	FTMS PT module	Equilibrium scour depth and scour pit dimensions SSC Deposited sediment thickness and extent
Fate of dredged material from GBS preparations	FTMS PT module	FTMS PT module	Estimate of dredged material SSC Deposited sediment thickness and extent
Fate of disturbed material during cable burial	FTMS PT module	FTMS PT module	Estimate of disturbed material SSC Deposited sediment thickness and extent
Impacts on seabed during installation due to jack-up legs and large anchors	Not Modelled	Not Modelled	Estimate of indentations on seabed

10A.4.6 PHYSICAL PROCESSES ASSESSED

To determine the significance of an impact, the magnitude of the effect needs to be understood and taken into account. The magnitude of an effect is the physical change in the environment from baseline (background) conditions as a result of the development.

The magnitude of an effect is a function of:

- spatial extent;
- duration;
- frequency;
- severity.

The exact definition and application of these parameters, and more importantly the vulnerability to the effect, will vary according to each topic and receptor group. The metocean and coastal processes assessment has determined the direct impact on the physical processes in question, but has not assessed any indirect or secondary effects on other receptors, such as benthic ecology or fish.

In order to allow the magnitude of change and the significance of the effect to be determined for identified receptors, changes to the following physical processes have been quantified:

- Water level;
- Tidal currents;
- Wave heights;
- SSC;
- Sediment transport regime.

It is the purpose of this metocean and coastal processes study to quantify the physical changes to the metocean and sediment regimes, so that the significance of any impacts on different receptors can be assessed as part of the EIA. The significance of the impacts from these effects on any receptors is therefore not included in this report.

10A.4.7 MODELLED WORST CASE SCENARIO

As discussed in Section A10.1.2, the design of the Wind Farm and OfTW cannot be finalised at this stage. This is primarily due to procurement and supply chain considerations, the requirement for further site investigation and continued design, and the timing of investment decisions. The EIA process presented in the ES has therefore been completed using a Design Envelope. This approach is recognised within the draft *Marine Scotland Licensing and Consents Manual Covering Marine Renewables and Offshore Wind Energy Development* (Marine Scotland, 2012) as being appropriate for developments of this nature.

The Design Envelope includes a number of components and all permanent and temporary works required to generate or transmit electricity to the national grid. The assessments within each technical chapter are based upon the design parameters which represent the worst case for the receptor under consideration; this is presented in Chapter 10 Section 10.1.3 and summarised in 10A.1.2. As each individual impact assessment is based on the worst case parameters specific to their topics, the overall impact assessment represents the worst case scenarios for the Project.

10A.4.7.1 Metocean Impacts Scenario

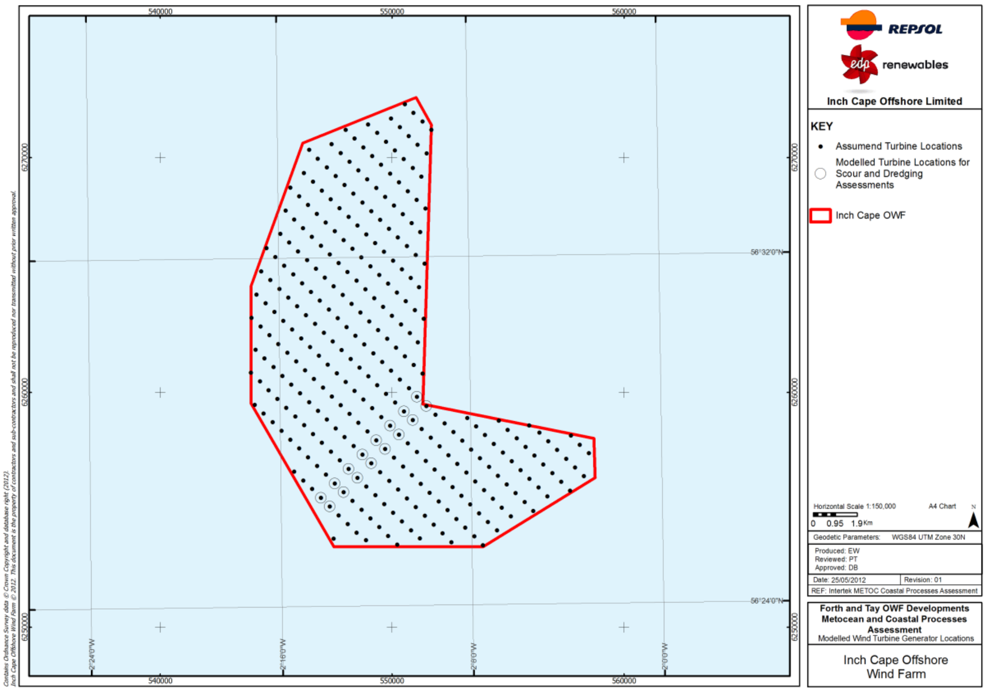
Following discussion with ICOL and Mainstream's development project teams, and based on the experience of Intertek and Partrac, it was determined that a GBS foundation type, rather than a jacket structure, would lead to the greatest change to the metocean regime, due to the greater cross-sectional area which would lead to the impedance of currents and waves within the water column. Through calculation and discussion with the clients, it was also agreed that the larger foundation (for the large WTG) would lead to greater overall impact than the smaller foundation base required for the small WTG. Although the spacing between WTGs would be slightly greater for the large WTGs (1200 m compared with 856 m – see Section A10.1.2), the significantly greater cross-sectional area of each of the larger bases would lead to greater impacts overall.

To ensure the assessment was conservative, the layout used in the assessment assumed complete coverage of large WTGs over the entire site. The WTG spacing for the smallest WTG was applied, combined with the cross-sectional area of the largest WTG. A crosswind spacing of 856 m along the line of WTGs, and a downwind spacing of 535 m between lines was applied across the whole site, resulting in a total number of modelled WTGs of 328. This exceeds the maximum number of WTGs (213) as indicated in the later Design Envelope, and is therefore a highly conservative development layout. Figure 10A.16 shows the layout of the modelled ICOL Development Area.

It should be noted that for study of the effects of blocking on the current and wave regimes, all 328 assumed WTGs were included in the modelling. However, for study of the effects of sediment dispersion resulting from dredging or scour, two representative rows of eight WTGs (i.e. 16 in total) were modelled, and the resulting impacts were extrapolated across the site to assess the overall impacts, as necessary. In extrapolating these impacts, results were scaled to the number of structures given in the Design Envelope (213 WTGs, five OSPs and three met masts).

This is discussed in more detail in the relevant sections below.

Figure 10A.16: Location of modelled WTGs within the Development Area



10A.4.7.2 Construction Phase Disturbed Sediment Scenarios

There are a number of construction phase activities which may lead to impacts on the environment, and which were therefore considered in the assessment. These were as follows:

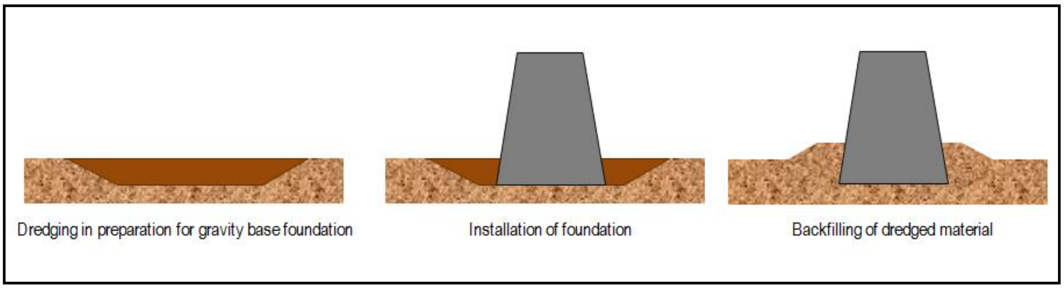
- Dredging of seabed to prepare/level bed for GBS foundations;
- Burial of Offshore Export Cable and inter-array cables; and
- Indentations on the seabed due to jack-up rig legs and anchoring during the installation of foundations/WTGs.

The main effect from any sediment disturbed during the construction phase will be an increase in SSC, and the potential redistribution of seabed sediments. The size and extent of these effects will be dependent on the volume, particle size and type of disturbed sediment, the local hydrodynamic regime, and the water depth.

10A.4.7.2.1 Gravity base foundation preparation

Seabed preparation for the installation of GBS foundations will result in sediment disturbance and elevated SSC. The worst case assessment assumes that all dredged material is deposited at the foundation bases in order to complete a balanced backfill. Any removal of material from the Development Area will be of lesser impact than this scenario. In preparation for GBS foundations, the seabed will be dredged and the removed seabed sediment taken up to the dredger vessel at the surface for temporary storage while the gravity foundation is installed. This dredged material will then be returned to the seabed via a fall-pipe arrangement and deposited in a controlled manner around the base of the foundation. Some of the dredged material will be reinstated in the pit after the foundation is installed, and the remaining material will be built up around the foundation in layers – see Figure 10A.17.

Figure 10A.17: Process of dredging and backfilling of the GBS foundations



The technique applied, the volume of material removed, and the depth and rate of discharge will be dependent on the type and size of foundations, the seabed sediment composition, and the vessel used. The worst case scenario modelled assumes the following:

- The largest dredged area will be circular, with a diameter of 95 m around each WTG. An inner circle (75 m diameter) will be dredged to five metres depth, with sloping sides in an outer circle – 10 m around the inner circle. A sediment porosity of 60 per cent was assumed (i.e. 60 per cent of the volume dredged will be sediment, and 40 per cent will be water, which is a typical split for near-surface seabed sediments). The volume of each dredged pit will be 28,500 m^3. This is an inherently conservative assessment which allows for consideration of a worst case at an individual WTG location. As a result, when considered across the entire Development Area the extrapolated values will be higher than is expected.
- It was assumed that all of this material will be discharged to the water column, close to the seabed at each WTG location. Since 100 per cent of the dredged material is released, this assumption also allows for the overspill that might occur during the initial dredging of the sediment which will be a lesser impact than the modelled worst case.
- It was assumed that the dredged material will be released five metres above the seabed, and will be subject to advection and dispersion by the ambient currents while falling through the water column toward the seabed. The expected height of the fall-pipe will be between one metre and five metres from the seabed. The greater the release height, the greater the size of the resulting deposition footprint.
- It was assumed the dredging and backfilling process will be on a continual basis, with the backfilling around each foundation base taking 24 hours to complete, and the commencement of backfilling the next excavation pit starting immediately after the previous one. In reality, it is likely to take several days to complete the preparation of each base, which may be undertaken in several phases, and there will be periods between the completion of one base, and the commencement of backfilling the next. However, this assessment is not sensitive to the precise duration of backfilling, since most of the sediment settles quickly and it is this which primarily influences the deposition footprint.
- It should be noted that in the plots that show the impacts (Annex 10A.7), a daily snapshot of the evolving plume has been extracted from the model – the time selected for each day is the point at which the discharge from one foundation pit has ceased, and the discharge from the next one has just commenced. The plots therefore show the plume from the previous

day's discharge, and a very small amount of discharged sediment from the next foundation location.

- It was assumed that the material was discharged at a constant rate; in reality the material is likely to be discharged in controlled phases. As before, the assessment is not sensitive to this assumption since the rate of settling is the key consideration. The deposition footprint will be similar whether discharged rapidly or slowly, and constantly or in phases.
- Momentum of the release via the fall-pipe was not modelled. Therefore, sediment was introduced into the model at five metres above the bed, at a constant rate, but was not given any downward momentum. This will lead to a larger deposition footprint than might actually occur as the released sediment will in fact have a downward momentum and will settle more quickly, leading to a smaller, but thicker deposition footprint. The larger footprint is considered to be conservative since deposition depths close to the foundation will be large under any feasible scenario.
- Since the spatial variation in conditions across the Development Area, in terms of the hydrodynamic regime, the sediment type and the particle size distribution (PSD), are very small, it was assumed that the actual modelled locations selected (16 representative WTGs near the middle of the Development Area) will not lead to any noticeable variation in the resulting impacts of SSC or deposition footprint.
- It should be noted that the scale of the other assumptions that would affect the resulting impacts, such as the volume, rate and discharge depth of the discharged material, far exceeds the very small potential variation that might result if a different WTG location within the development site were to be modelled.

In order to determine the indicative worst case impacts (in terms of disruption to the seabed, elevated SSC and changes to sediment processes) that might occur at the site due to GBS foundation preparation, two neighbouring lines of WTGs (each with eight WTGs) through the middle of the Development Area were selected for modelling. The modelled deposition footprints from these 16 WTG locations were then extrapolated across the rest of the Development Area.

A representative average PSD for the dredged sediment was applied. This was based on the sediment samples taken throughout the Development Area, which showed reasonable uniformity. The modelled PSD is shown in Table 10A.5, and a summary of the modelling inputs is shown in Table 10A.6.

The results from the 16 representative WTGs modelled were extrapolated in order to estimate sediment settling depths across the entire Development Area. This technique allowed for dredged sediment impacts from 213 WTGs, five OSPs and three met masts. Met masts area equivalent to WTGs in terms of the volume of dredged sediment, while each OSP was treated as being equivalent to the sediment disturbance of four WTGs due to their greater size.

Table 10A.5: Representative particle size distribution applied

Sediment Category	Mean Grain Size (mm)*	Settling Velocity (m/s)	%
Very Coarse Gravel	47.75	1.4171	0.000
Coarse Gravel	24.00	1.0560	0.000
Medium Gravel	11.94	0.7968	0.000
Fine Gravel	5.93	0.5548	0.000
Very Coarse Gravel	3.00	0.3494	0.000
Very Coarse Sand	1.50	0.2030	0.191
Coarse Sand	0.75	0.1031	12.084
Medium Sand	0.38	0.0471	52.108
Fine Sand	0.19	0.0179	32.664
Very Fine Sand	0.09	0.0054	1.066
Silt (Mud)	0.03	0.0007	1.887

*mean grain size has been estimated based on the range of grain sizes for each sediment category, as per the Wentworth scale

Table 10A.6: Summary of inputs for the GBS preparation impact assessment

Location	Discharge volume (per GBS) m^3	Discharge rate (kg/s)	Discharge duration (per GBS)	Start of dredging/release	
				Tide	Tidal Phase (approx)
Turbine 1 (row 1)	17102*	524.54*	24 hours	Spring	HW
Turbine 2 (row 2)	17102*	524.54*	24 hours	Spring	HW-50mins
Turbine 3 (row 1)	17102*	524.54*	24 hours	Spring	HW-1h40mins
Turbine 4 (row 2)	17102*	524.54*	24 hours	Intermediate	HW-2h30mins
Turbine 5 (row 1)	17102*	524.54*	24 hours	Intermediate	HW+3h20mins
Turbine 6 (row 2)	17102*	524.54*	24 hours	Neap	LW+2h
Turbine 7 (row 1)	17102*	524.54*	24 hours	Neap	LW+1h15mins
Turbine 8 (row 2)	17102*	524.54*	24 hours	Neap	LW+20mins
Turbine 9 (row 1)	17102*	524.54*	24 hours	Intermediate	LW-30mins
Turbine 10 (row 2)	17102*	524.54*	24 hours	Intermediate	LW-1h15mins
Turbine 11 (row 1)	17102*	524.54*	24 hours	Spring	LW-2h
Turbine 12 (row 2)	17102*	524.54*	24 hours	Spring	LW-3h
Turbine 13 (row 1)	17102*	524.54*	24 hours	Spring	HW+2h25mins
Turbine 14 (row 2)	17102*	524.54*	24 hours	Intermediate	HW+1h35mins
Turbine 15 (row 1)	17102*	524.54*	24 hours	Intermediate	HW+45mins
Turbine 16 (row 2)	17102*	524.54*	24 hours	Neap	HW

*based on a circular area with a diameter of 95 m, the inner circular area (with a diameter of 75 m) to be dredged at a depth of 5 m and the outer circle (surrounding 10 m) sloping from 5 m to 0 m depth. A density of 2650 kg/m^3, and a sediment porosity of 60%, were assumed.

The fate of the dredged material was modelled using the FTMS PT module.

The discharge of material from the first foundation pit began at HW on a spring tide and therefore the modelling covered a period of sixteen days, which incorporated a spring-neap tidal cycle. The modelling is considered to be representative of the likely impacts, regardless of when in the tidal cycle the operation actually takes place, or where within the site the material is discharged.

10A.4.7.2.2 Cable burial

The Offshore Export Cable and inter-array cables are likely to be buried wherever possible.

Cable burial will be by either jetting trenchers or ploughing installation techniques. In addition to these techniques horizontal directional drilling, rock wheel cutters and open cut trenchers may be required at the landfall sites.

Modern technologies are now developed to the point where loss of sediment is substantially minimised; however, some material is unavoidably and permanently disturbed both through sediment removal and direct trenching vehicle impact. For the purposes of the modelled worst case scenario for the burial of the Offshore Export Cable and inter-array cables, a burial depth of 2 m and a trench width of 1 m were assumed. The Design Envelope states that trench depths are likely to very between 0 and 3 m, with a target depth of 1 m. The greatest trench depth (3 m) is unlikely to be used extensively for the inter-array and Offshore Export cables, so the modelled depth of 2 m represents a reasonable and conservative estimate when averaged across the Development Area and Offshore Export Cable Corridor. The rate of cable burial depends on a number of factors, such as the vessel used, the water depth, the technique employed and the sediment type. The Design Envelope details the cable lay rate which will be between 300 – 500 m per hour. For the purposes of assessment the average burial rate of 400 m per hour was used. In practice the scale of the other assumptions that would affect the resulting impacts, such as the volume of the discharged material, far exceeds the very small potential variation that might result if a different lay rate was modelled. As such this is considered an appropriate assessment to represent a worse case.

For a trench depth of 2 m and width of 1 m, and based on a square, or U-shaped profile (as assumed for this assessment), this equates to a maximum volume of displaced material of 800 m^3 per hour (conservatively assuming 100 per cent liberated sediment during trenching). This is conservative, since smaller volumes would result if a V-shaped profile is used and not all sediment were to be released to the water column.

For the Offshore Export Cable Corridor, to assess the potential changes to the physical environment from the cable burial activities, the FTMS Particle Tracking module was used to model a moving discharge (at a rate of 400 m per hour). Three representative locations were modelled: one close to the Development Area; one approximately mid-way along the Offshore Export Cable Corridor; and one close to landfall.

Specific PSD data were available near the Development Area, with a modal average for three PSD sample sites calculated. PSD data for the remaining two sites on the Offshore Export Cable Corridor were modelled based on available BGS data, since survey data were not available at the time of modelling. It was assumed the sediment consisted of equal parts of very fine sand and mud at these locations. Later PSD survey data within the Offshore Export Cable Corridor indicate that the PSDs applied for the nearshore and midpoint assessments (50 per cent sand, 50 per cent mud) are in good agreement with the measured values (approximately 60 per cent sand, 40 per cent mud), and the modelled scenario is therefore valid. The PSD data applied at the selected modelling locations are shown in Table 10A.7, and the surveyed PSD samples nearest to the locations assessed during the cable burial study are shown in Table 10A.8.

For impacts from the inter-array cable burial activities in the Development Area, the results from the Offshore Export Cable Corridor (modelled location closest to the Development Area) are considered to be representative. This is based on the fact that the trench width and depth, and the trenching techniques anticipated, are equivalent, and the sediment characteristics and hydrodynamic conditions at the offshore location along the Offshore Export Cable Corridor are similar to conditions within the Development Area.

A summary of the modelling inputs for the cable burial assessment is shown in Table 10A.9, and the results are presented in Annex 10A.7.

Table 10A.7: Particle size distribution data applied in the cable burial assessment

Sediment Category	Mean Grain Size (mm)	Nearshore % (BGS data)	Midpoint % (BGS data)	Offshore % (Sample ID T5)
Very Coarse Gravel	47.75	0.00	0.00	0.00
Coarse Gravel	24.00	0.00	0.00	0.00
Medium Gravel	11.94	0.00	0.00	0.34
Fine Gravel	5.93	0.00	0.00	1.05
Very Fine Gravel	3.00	0.00	0.00	0.81
Very Coarse Sand	1.50	0.00	0.00	1.76
Coarse Sand	0.75	0.00	0.00	4.12
Medium Sand	0.38	0.00	0.00	26.00
Fine Sand	0.19	0.00	0.00	42.76
Very Fine Sand	0.09	50.00	50.00	11.50
Silt / Mud	0.03	50.00	50.00	11.54

Table 10A.8: Additional particle size distribution data collected for Offshore Export Cable

Release Location	Sample ID	Gravel (%)	Sand (%)	Silt Clay (%)	Gravel Average (%)	Sand Average (%)	Silt/Clay (Mud) Average (%)
Nearshore	20	0.35	96.78	2.87	**0.62**	**62.14**	**37.24**
	17	0.90	27.50	71.60			
Midpoint	8	0.07	61.47	38.46	**0.07**	**61.47**	**38.46**
Offshore	3	0.14	96.61	3.25	**0.13**	**97.17**	**2.70**
	24	0.09	97.31	2.60			
	25	0.15	97.61	2.24			

Table 10A.9: Summary of cable burial modelling inputs

Release location	Discharge Volume per hour (m^3)	Discharge rate (kg/s)	Discharge duration	PSD sample ID
Nearshore	480*	353**	12.5 hours (mean spring tide)	N/A
Midpoint	480*	353**	12.5 hours (mean spring tide)	N/A
Offshore	480*	353**	12.5 hours (mean spring tide)	T5A, T5B and T5C average

* based on depth of 2 m, width of 1 m, trenching rate of 400 m per hour, and a porosity of 60% (as determined from the sediment material collected at the site and provided by Partrac)

** this equates to a mass of 1,272,000 kg per hour based on a volume of disturbed sediment of 480 m^3 per hour and a solid density for sand of 2,650 kg/m^3

10A.4.7.2.3 Jack-up rig anchoring

Although there may be some sediment disturbed during the installation by jack-up rigs (through anchoring and spud cans), it was considered that any impacts would be small, temporary and localised. The potential volume of disturbed material will be very small in comparison with the dredged material likely to be removed and discharged during the GBS preparations. Any impacts due to the use of jack-up rigs during installation will therefore be much smaller than those estimated from the GBS preparation modelling.

10A.4.7.3 Scour Assessment Scenario

For the purposes of the scour assessment, it was determined that if GBSs were employed as the foundation type, scour protection would certainly be required, and that adequate scour protection and mitigation options would be included in the engineering design of the bases. Any impact due to scour around GBSs will therefore be minimised as a matter of course. As such, the worst case scenario in terms of impacts on the environment due to potential scour will be from jacket structures, and the scour assessment therefore assumed jacket structures would form the foundation type. The empirically-based study of scour around the jacket structures is detailed in full in Annex 10A.6.

This study determined that the maximum volume of scoured material from a single jacket structure (for the largest WTG) will be 4,990 m^3, and that it would take at least 12 days for the equilibrium depth scour pits to develop. The fate of the potential scoured material was modelled using the FTMS PT module. In order to be conservative, the maximum volume of scoured material (4,990 m^3 per WTG), which was based on peak spring tide rates, was released at 16 WTGs in the middle of the Development Area over a 16-day period (i.e. roughly one spring-neap cycle). This is a conservative estimate as it is unlikely that this WTG installation rate will be achieved in practice. However, as the results were not particularly sensitive to the installation rate, this was considered not to be overly conservative. The same 16 WTG locations, and the same representative PSD, were used as in the GBS foundation preparation scenario, and the material was discharged two metres above the seabed (which is considered to be a realistic height for sediment disturbance based on the size fractions present).

As with the GBS dredging assessment, the results from the 16 representative WTGs modelled were extrapolated in order to estimate sediment settling depths across the entire Development Area. This technique allowed for scoured sediment impacts from 213 WTGs, five OSPs and three met masts. Met masts were treated as being equivalent to WTGs in terms of the volume of scoured sediment, while each OSP was treated as being equivalent to four WTGs due to their greater size and number of piles.

10A.4.7.4 Cumulative Impacts Scenario

For the cumulative impact scenario, the NnG and FoF projects were also included in the model. The same worst case scenario approach was used for the layout of the NnG project as for the ICOL Project, with the modelled turbine array having complete coverage over the entire Development Area. This resulted in 126 turbines being included in the assessment, which is many more than the maximum number (75), based on the consent application capacity. For the FoF wind farm, the largest GBS was used, but the number of WTGs for the entire zone was limited to 1000, which was the anticipated maximum number expected for the whole development (Phases 1, 2 and 3). This was based on a maximum of 725 turbines expected for Phases 2 and 3, as outlined in the FoF Scoping Report[38], and an estimated maximum of 275 turbines for Phase 1 (based on the proportional areas of each phase). Modelling complete coverage of the entire FoF Wind Farm area with a minimum turbine spacing (as was modelled for ICOL and NnG) would have resulted in the inclusion of more than 3000 turbines, which was considered too extreme and unrepresentative of worst case conditions.

It should be noted that as no other information regarding the FoF project was available at the time, other than the Scoping Report, the 1000 modelled turbines were positioned as close to the ICOL Project and NnG projects as possible, in order that the worst case cumulative impacts would be assessed. The final array layout for the FoF Wind Farm will not be as modelled, and the WTGs are likely to be more evenly spread between the three phases, and further from the Project and NnG project. In the recently submitted ES for the FoF Phase 1 development, the site boundaries are further from the Development Area than were modelled, and the maximum number of turbines expected in Phase 1 is 150 (rather than 275 as modelled for this Phase). Actual cumulative impacts due to this development are therefore very likely to be less than those reported here, and so it is concluded that an appropriately conservative worst case scenario was presented.

Table 10A.10 summarises the modelled worst case scenario details for the three OWFs. Figure 10A.18 shows the layout of the three modelled OWFs for the cumulative scenario.

Table 10A.10: Modelled worst case scenario details

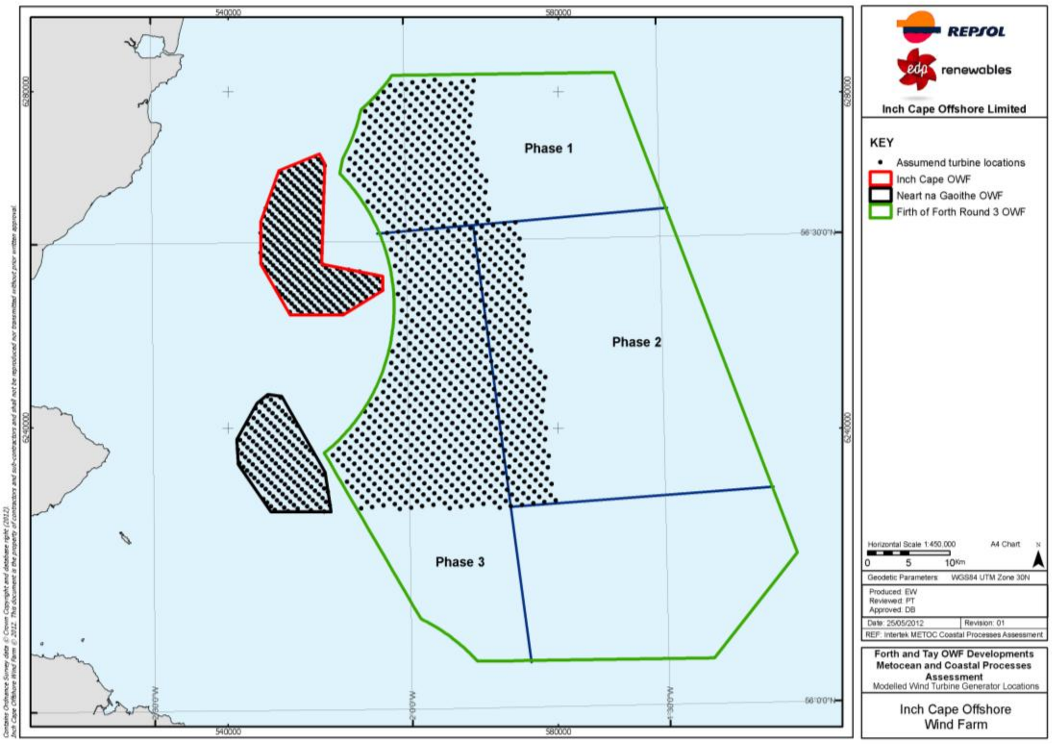
Parameter	Inch Cape	Neart na Gaoithe	Firth of Forth (all Phases)
Cross sectional area per structure (m^2)	1345	859	1345
Spacing between WTGs (along line) (m)	856‡	1008	856‡
Spacing between WTG lines (m)	535‡	630	535‡
Modelled number of WTGs**	328†	126†	1000*
Gravity base dredged material per turbine (m^3)	28,503	5,000	Not modelled
Cable burial depth (m)	2	2	Not modelled

*Based on awarded capacity of development

†Based on the complete coverage of the entire site

‡Spacings based on the smaller turbine, but note that GBS dimensions are based on the larger turbine. This leads to greater overall impact.

Figure 10A.18: Outline of modelled worst case layouts for the three wind farms for the cumulative impact scenario



10A.4.7.5 Cumulative Changes to Far-field Suspended Sediment Transport

In order to assess any changes to the general hydrodynamic regime, and consequently the net movement of any naturally occurring suspended sediment from the Development Area, a continuous discharge of suspended sediment released over a spring-neap cycle was modelled using the FTMS PT module. The release was modelled from 16 selected locations in the middle of the Development Area. These are representative of the situation throughout the Development Area, since the hydrodynamic regime and surface sediment composition are both fairly homogenous.

The same release was modelled with and without the three wind farms in place. The outputs were visually compared in order to identify any changes to the net sediment transport pathway due to the developments. It should be noted that this scenario does not represent any specific discharge of sediment resulting from the Project, but instead aims to identify any significant changes to the net far-field transport of suspended sediment.

10A.4.7.6 Future (Changing) Climate Scenario

The quantified changes to metocean and coastal processes due to the Project have been assessed under present climatic conditions (i.e. with no sea level rise or increased storminess). Under a future climate scenario, the quantified changes due to the Project infrastructure are likely be marginally different to the changes predicted under present climatic conditions as described in the following section.

However, it is considered that the modelling results for present climatic conditions are representative of impacts due to the Project under future climatic conditions. This is because predicted impacts are only very small outwith the Development Area, and within the Development Area, the modelled effects of climate change are likely to cause only small changes to the predicted quantified changes. In addition to this, there is a high level of uncertainty in assessing future baseline under climate change. As such, it is considered appropriate that the impact assessment has been carried out using the current baseline.

For the assessment of changes to metocean and coastal processes under a different climate in the future, the UKCIP projections of sea-level rise and increased storminess, as outlined in Section A10.2.3, were applied to the Baseline scenario. A time horizon of 50 years from 2016 was used in order to determine the level of increases to sea level, extreme wave heights and wind speeds. The climate changes applied are summarised in Table 10A.11.

Table 10A.11: Future (changing) climate projections used

Parameter	UKCIP projection	Baseline Condition (2016)	Future Condition (2066)
Sea-Level Rise (m)	2.5 mm/yr (to 2025) 7 mm/yr (2025 – 2055) 10 mm/yr (2055 – 2085)	0	0.355 m
Wind Speed (m/s)	+5% (to 2055) +10% (2055 – 2115)	*x*	1.1*x*
Wave Height (m)	+5% (to 2055) +10% (2055 – 2115)	*x*	1.1*x*

10A.5 RESULTS OF IMPACT MODELLING

This section provides details of the quantified effects of the Project on metocean and coastal processes. The discussion is divided into changes to the hydrodynamic regime, changes to the wave climate, and then the resulting changes to the sediment regime. In addition, the cumulative impacts are summarised, and finally the analysis of potential changes due to the future (or changing) climate are discussed.

The FTMS HD and SW models were configured with the GBS foundations and WTG structures at the assumed WTG locations for the Development Area (for the ICOL-only impacts – see Figure 10A.15), and for all three wind farm developments (for the cumulative impacts – see Figure 10A.17). The same scenarios as were used for the baseline assessment (see Section 3) were modelled under the 'with development' configurations, and the results compared with the baseline to identify any differences to baseline conditions. The baseline results were subtracted from the 'with-development' results, so that positive changes indicate an increase (say in current speed) due to the development, and negative changes show a decrease.

Annex 10A.7 provides all of the impact assessment plots.

It should be noted that the absolute accuracy of the FTMS in predicting water levels, tidal currents and wave parameters is limited, due to a number of sources of error and uncertainty, including in the field data itself, and in the inherent limitations of the numerical approximations to real world physical processes. The model has been demonstrated to perform well when compared to field data, based on the coastal model guidelines from the Foundation for Water Research[39] (FWR) which were applied in the model calibration and validation process. An indication of the level of accuracy of the model is provided by the FWR guidelines, which aim for modelled levels to be within 0.1 m, and for modelled speeds to be within 0.1 m/s of measured values for 90 per cent of time and space combinations

However, for the impact assessment undertaken here, the difference or change due to the Project has been determined by modelling two different scenarios using the same fundamental model. The accuracy of the relative differences predicted is much greater than the accuracy of the absolute predictions, and very small predicted changes (less than the absolute accuracy of the model) would be considered to be valid.

10A.5.1 CHANGES TO THE HYDRODYNAMIC REGIME

10A.5.1.1 Construction Phase

The effects on the hydrodynamic regime due to the construction phase will be caused by the presence of the engineering and installation equipment, such as jack-up rigs and cable-laying barges. Such equipment will be located at one location (i.e. a turbine foundation) at a time, and for relatively short durations. The effect of the construction phase has not been explicitly modelled.

The effects on the hydrodynamic regime due to such equipment will be very low, localised and temporary.

It is also considered that no cumulative impacts would result, even if several installation operations (i.e. cable burial and foundation preparation) were to occur simultaneously.

10A.5.1.2 Operational Phase

The effects on the hydrodynamic regime due to the operational phase of the Project have been modelled using the FTMS HD model (as discussed in Section 4). The results of the modelling show the predicted changes to water level and current speed on both the local scale (NF) and regional scale (FF).

Analysis of these plots indicates that the effects on the hydrodynamic regime due to the ICOL Project are small and generally localised to the Development Area.

10A.5.1.2.1 Changes to water levels

Near-field

There is an area (approximately 14 km x 10 km) around the southwest boundary of the Development Area where the mean spring HW level is predicted to be typically between 0.5 and 1 mm (~0.02 per cent of the spring tidal range) lower than the baseline. Within this area there are a number of smaller areas, localised around individual WTGs, where water levels are predicted to decrease by between 1 and 1.5 mm. In contrast there is an area to the northeast of the Development Area (approximately 12 km x 5 km) where mean spring HW level is predicted to increase by between 0.5 and 1 mm (~0.02 per cent of the spring tidal range) compared to the baseline.

During mean spring LW the area of water level increase is larger and extends out of the NF area. Within this area there are a number of much smaller areas, localised around individual WTGs and overlapping WTGs, where water levels are predicted to increase by up to 1.5 mm. In contrast there is an area (approximately 10 km x 5 km) at the northeast boundary of the Development Area where the mean spring LW level is predicted to be up to 1 mm lower than the baseline.

The tide floods in a south-southwesterly direction and ebbs in a north-northeasterly direction; therefore, these areas of greatest change are aligned with the general orientation of the tidal ellipse (the path traced out by the tidal current vector during a tidal cycle) in the Development Area. As a result, on the flooding tide the WTGs in the north and east of the Development Area cause a very localised build up or increase in water level, with a corresponding reduction in water level ‘downstream’ of the flooding tide. The opposite happens on the ebbing tide.

No noticeable changes (i.e. >0.5 mm) to water level during mean neap tides are predicted.

The predicted NF changes of (up to) ±1.5 mm are approximately 0.003 per cent of the total water depth, and about 0.03 per cent of the mean spring tidal range at the site. The predicted changes are well within natural variability and would not be measurable in the field.

Far-field

FF changes to water level are predicted to be generally unnoticeable over most of the regional study area during mean neap tides and at mean spring HW. However, during mean spring LW an area of increase in water level extends from the Development Area south-westwards and into the upper reaches of Firth of Forth. Across this area water level is predicted to increase by 0.5-1.0 mm. In addition to this there is an area within the upper reaches of the Firth of Forth where the mean spring HW level is predicted to be between 0.5 and 1.0 mm lower than the baseline. During mean neap HW this decrease is also present but the area affected is smaller.

These changes to water level in the Firth of Forth are not necessarily unexpected, since the Firth shows resonant tidal characteristics. One of the consequences of this is that the tidal range increases with distance up the Firth. For example, the range at Alloa (far western end) is about 25 per cent greater than at the entrance to the Firth (near Dunbar), and nearly 35 per cent greater than at the Development Area. So, for example, a one per cent change in range will show up as a bigger absolute difference at the western end of the Firth.

In addition, a small change in the tidal phase (e.g. if it travels slower through the Development Area) could be amplified as the wave propagates up the Firth, which could affect the timing of high and low water. There is also a pronounced funnelling effect towards the west.

However, the size of the change in water level in the Firth is less than 0.02 per cent of the mean spring tidal range, which is 5 m in this part of the Firth, and this change will therefore not be measurable.

No noticeable changes (i.e. >0.5 mm) to water levels during mean neap LW are predicted in the FF.

The predicted changes to water level due to the Project are therefore very small (<0.03 per cent of tidal range), and generally localised to the NF, with the exception of a small change (<0.02 per cent of tidal range) in mean spring LW across the regional study area and upper reaches of the Firth of Forth.

10A.5.1.2.2 Changes to tidal currents

Near-field

In the NF, localised changes to current speeds due to the Project are predicted. The western part of the Development Area experiences slightly larger areas of change, with speeds increasing by up to 0.02 m/s (approximately three per cent of baseline) and decreasing by up to 0.04 m/s (approximately seven per cent of baseline) on the mean spring peak ebb and mean spring peak flood tide respectively. The affected areas are aligned with the general tidal orientation, as is expected. Areas of change are very small in extent and centred around individual turbines. Generally, current flow will be reduced 'upstream' and 'downstream' of the structure, and increased around the sides, as the flow is first retarded in front of the GBS, then bifurcates and accelerates around the structure, and then slows and re-joins the ambient flow behind.

Differences during neap tides are much less marked, and most of the Development Area does not experience any noticeable change (i.e. there is <0.01 m/s change).

Analysis of the differences seen in the percentile speeds shows that only very low and localised changes to the average (50-percentile) conditions are seen, but for the higher percentile conditions (90, 95 and 99-percentile), there is a general pattern of increased flow around the western boundary of the Development Area (up to 0.012 m/s or approximately two per cent of baseline), with a corresponding reduction in flows in the central parts of the Development Area (up to 0.024 m/s or approximately four per cent of baseline). It should be noted that the mean peak ebb/flood spring tide will occur for approximately four per cent of the time, and so is approximately equal to the 95-percentile speed.

The maximum predicted changes (+0.02 m/s and -0.04 m/s) are between approximately three per cent and seven per cent of the peak spring tidal currents (0.6 m/s). These changes are relatively small and localised, and are comparable with the natural variability in currents likely to be experienced at the site.

However, it should be noted that the predicted changes in current speeds do have the potential to lead to scour around the foundation bases if scour protection is not employed. The potential for scour has been assessed separately, and is summarised in Section 5.3.2.2, and reported in full in Annex 10A.6.

Far-field

No noticeable changes to tidal currents are seen in the FF, beyond the immediate vicinity of the Development Area.

The predicted changes to tidal currents due to the Project are small (up to a maximum of seven per cent of peak tidal flows), and restricted to the immediate vicinity of the Development Area.

10A.5.1.3 Decommissioning Phase

It is possible that all buried equipment (cables and foundations) would be left *in situ*. However, it is also possible that all equipment associated with the development might need to be removed, including the buried cables. The decommissioning activities, if required, will be of a similar nature to the construction activities, but in reverse, although there will be no need for any dredging or GBS foundation preparation. For this reason, the likely impacts on the hydrodynamic regime during the decommissioning phase are considered to be similar to those predicted during the construction phase, and will be small, localised and temporary.

10A.5.2 CHANGES TO THE WAVE CLIMATE

10A.5.2.1 Construction Phase

As with the effect on the hydrodynamic regime, the impact of the construction phase on the wave climate will be due to the presence of the associated engineering and installation equipment, such as jack-up rigs and cable laying vessels. This equipment will be located for short periods of time (several hours to several days, depending on the activity) at one location at a time, and therefore any impacts on the wave climate will be low, localised and temporary. In addition, it is very likely that the installation of the Project will need to take place during more quiescent wave conditions, as some operations will not be possible when more extreme waves are present. Effects on the wave climate due to the presence of installation equipment are lower for smaller waves.

10A.5.2.2 Operational Phase

The effect of the operational phase of the Wind Farm on the wave climate will be primarily associated with the blocking of the passage of waves through the Development Area by the WTGs/met masts/OSPs and their foundations.

The effects on the wave climate due to the operational phase of the development have been modelled using the FTMS SW model (as discussed in Section A10.4). The results of the modelling show the predicted changes to significant wave height due to the Project on both the local scale (NF) and regional scale (FF).

Analysis of these plots indicates that the effects on the wave climate due to the Development Area are very small and generally localised to the Development Area and the immediate vicinity.

10A.5.2.2.1 Changes to significant wave height

Near-field

In the NF, changes to significant wave height due to the development are seen across the majority of the Development Area, and in the immediate vicinity (up to 10 km) surrounding the Development Area boundary. Significant wave heights are reduced compared with baseline conditions, by between 0.01 and 0.03 m (up to two per cent of the 50-percentile baseline). Regardless of the percentile wave height, the predicted effect of the Project is a general reduction in wave height. The greatest differences are seen for the 99-percentile wave heights, with almost the entire Development Area experiencing a reduced wave height, and some small areas in the immediate surrounding vicinity of the Development Area also experiencing slightly lower (between 0.01 and 0.02 m) wave heights.

These predicted changes (up to 0.03 m) are between 2 per cent and 0.5 per cent of the 50-percentile and 99-percentile wave heights (respectively) experienced at the site.

This general reduction in wave heights is expected since the Project will remove some wave energy as waves pass through the Development Area. There are no increased wave heights predicted.

It is noted that the percentage change to the 50-percentile condition is greater than the percentage change to the less frequent (90 to 99-percentile) conditions. This is expected given that wave energy removed by the structures will be proportionally less for more extreme conditions of higher wave energy.

Far-field

The Project is seen to affect the wave climate (by reducing significant wave heights by up to 0.03 m) in the immediate area surrounding the Development Area, up to a maximum distance of 10 km. Beyond this localised impact, there are no noticeable changes (i.e. >0.01 m) predicted in the FF. These predicted changes are well within the natural variability of wave conditions experienced throughout the regional study area.

The predicted changes to the wave climate due to the Project are considered to be small (less than two per cent of average waves), and restricted to the immediate vicinity of the Development Area.

10A.5.2.3 Decommissioning Phase

As with the effect of the construction phase on the wave climate, it is anticipated that any equipment required on site for the decommissioning of the development would have only a very limited, localised and temporary impact on the wave climate. Equipment on site would be located at one place at a time, so cumulative impacts would not result.

10A.5.3 CHANGES TO THE SEDIMENT REGIME

10A.5.3.1 Construction Phase

The use of jack-up vessels to provide stable or fixed working platforms will lead to indentations left on the seabed by the barge legs and large anchors. On completion of the operation, these may leave an impression when removed from the seabed. The exact nature of the initial disturbance will vary depending upon the design and dimensions of the leg or anchor, and the geotechnical properties of the seabed sediment in the area. The effects from jack-up vessels are considered to be small, localised, and short-term.

The impact of the construction phase on the sediment regime will primarily be due to the release of disturbed seabed sediment into the water column through the various installation processes. In particular the impacts from the preparation of the bed for the GBS foundations (if used) and from the process of cable burial have been modelled using the PT module within the FTMS.

The results of the modelling show the predicted extent and concentrations of suspended sediment plumes (above background levels), and the resulting deposition footprint due to settling of the disturbed sediment. It should be noted that although only the middle two turbine rows have been modelled, since conditions across the site are relatively uniform, the results are indicative of impacts that would result from any turbine location within the Development Area. There will be small variations, due to small differences in the PSD and current flows across the site, but these will be of little importance.

10A.5.3.1.1 Impacts due to preparation of GBS foundations

Analysis of the results shows that impacts are localised around the area of the operation. Concentrations of suspended sediment due to this activity have a peak of up to 4000 mg/l above background very close to the release location. Within approximately 1 km of the release location, concentrations are predicted to be between 30 and 100 mg/l above background during most states of the tide. The farthest extent of the suspended sediment plume (with a concentration of >1 mg/l above background) is up to approximately 10 km from the release location. Analysis of the model outputs indicates that >98 per cent of suspended sediment will settle out of the water column within 10-20 minutes of release. The remaining fractions settle out within 1-2 hours and travel a maximum of 10 km from the release location, although only a small volume of the finest sediment travels more than 3.5 km from the release point.

The resulting suspended sediment plume therefore is high compared with the background concentrations (typically ~15 mg/l), although this peak is localised and very short-lived, with concentrations returning to background very quickly.

The deposition footprints will be elliptical and aligned with the tidal ellipse. The resulting deposition footprints will be localised around each WTG base with a maximum average thickness (in the model cell containing the WTG) of 1.9 m. The extent of the footprint with a thickness >10 cm will reach up to 150 m away from the WTG. Beyond this distance, the deposition thickness rapidly reduces, and is typically <1 mm within ~1.5 km and <0.1 mm within approximately three kilometres of the WTG.

The deposition footprints from the smaller fractions of material from each excavation pit will therefore overlap with the neighbouring footprints, to form a more or less continuous layer of deposited dredged material of varying thickness across the Development Area. However, the majority of the dredged material will be layered around the base of each WTG in a controlled manner and will be within the dimensions of the excavated area.

If the dredged material were to be released closer to the seabed than 5 m, the impacts on SSC are predicted to be less than the results presented due to the fact the sediment will settle more quickly. This is because the material settles out much more quickly, leading to a smaller but thicker deposition footprint.

The discharge of dredged sediments during the preparation of GBS foundations will lead to elevated concentrations of suspended sediment (with very localised peaks up to 4000 mg/l above background), but the resulting plumes will not be advected beyond the near vicinity of the Development Area (10 km for the finest fractions only), and they will settle out within 1-2 hours of discharge. The resulting deposition footprint is likely to cover the Development Area with varying thickness, ranging from ~1.9 m around the immediate vicinity of each WTG, where material is layered up around the foundation base, to <0.1 mm three kilometres away from the WTGs.

10A.5.3.1.2 Impacts due to the cable burial process

Analysis of the FTMS PT model predictions indicates that impacts due to Offshore Export Cable burial will be much lower than those predicted from the GBS preparations. This is as expected given the lower quantities of disturbed sediment. Regardless of the location along the cable route, the elevated SSCs are typically between 3 and 100 mg/l above background, with some localised peaks in some small areas reaching 100–300 mg/l (averaged across a model grid cell; greater depths may occur very close to the cable). The associated suspended sediment plumes will generally travel less than three kilometres from the Offshore Export Cable Corridor. The bulk of the material (>98 per cent) will settle out within five to ten minutes, and the remaining fine material will settle out within one hour.

The resulting deposition footprints are equally localised, with peaks of 3-5 mm (averaged across a model grid cell; greater depths may occur very close to the cable). The maximum predicted deposition thickness is <5 mm. The extent of the deposition footprint (with thickness >1 mm) is up to about one kilometre either side of the cable trench. The deposition footprint is smaller than the extents of the suspended sediment plume due to the fact that very fine material will effectively remain in suspension indefinitely, or will slowly settle out beyond three kilometres from the release location but will not form a noticeable deposited layer.

These predicted impacts conservatively assume that the entire volume of the trench will be suspended into the water column.

Impacts from the burial of inter-array cables are similar to those determined for the Offshore Export Cable at the offshore modelled location (see Section A10.4.7.2.2). The impacts presented for the worst case Offshore Export Cable burial are therefore considered to be representative of potential impacts that might occur from the inter-array cable burial.

The process of Offshore Export Cable or inter-array cable burial might lead to very localised impacts (elevated concentrations) of suspended sediment (with peaks up to 300 mg/l above background, averaged across a model grid cell), but the resulting plumes will not be advected beyond the NF vicinity of the cable, and will settle out within a day of disturbance. The resulting deposition footprint is likely to be thin (typically <1 mm within one kilometre) with peaks up to 5 mm averaged across a model grid cell.

10A.5.3.2 Operational Phase

The impact of the operational phase of the OWF on the sediment regime will be primarily associated with changes to sediment entrainment, by reducing or increasing the amount of bed shear stress (by altering the wave and/or current regime). If bed shear stress is increased, for example due to the acceleration of currents around the structures, then more sediment could become entrained and transported, either as bedload or suspended sediment. Conversely, a reduction in bed shear stress (e.g. due to reduced wave heights) might lead to greater rates of deposition.

In particular, the effects of the OWF on the sediment regime might be associated with scouring of sediment around the foundations of the WTGs or OSPs, with the scoured material being transported elsewhere.

The effects on sediment transport processes have been modelled using the HD and SW modules of the FTMS, in combination with analysis of the seabed sediment characteristics. An estimate of the volume of scoured material was made using empirically-derived equations (see Annex 10A.6), and the fate of the scoured material was modelled using the FTMS PT module.

The results of the analyses show the predicted changes to exceedance of the critical shear stress (both the maximum and mean bed shear stress across a wave cycle due to combined currents and waves are depicted).

10A.5.3.2.1 Changes to the sediment transport processes

In this Section, we report changes in the percentage of time for which the critical entrainment stress is exceeded. In all cases, the predicted changes are reported as an absolute percentage, not a relative percentage. So, for example, if a particular location experiences exceedance of the critical entrainment stress for five per cent of the time at present, and this is predicted to increase to six per cent of the time once the Wind Farm is fully installed, this will be reported as a one per cent increase in critical entrainment stress exceedance, not 20 per cent.

Near-field

Analysis of Figures 10A.19 and 10A.20 (NF) indicates that the overall effect of the Project on sediment transport processes is low in magnitude, and limited to the NF area. There are a small number of areas surrounding the Development Area where the critical shear stress is predicted to be exceeded more frequently (typically for 1-2 per cent of the time, with some very small peaks of up to three per cent increase in the frequency of exceedance). Conversely, there are slightly larger areas across the Development Area, where the critical shear stress is predicted to be exceeded less often (typically for one to two per cent of the time, with a maximum reduction in frequency of exceedance of five per cent). The majority of the NF area is not predicted to change by more than ±1 per cent. This is considered to be well within the natural variability that would be experienced within the Development Area (i.e. due to spatial and temporal changes in currents, waves and sediments).

The differences in the exceedance due to maximum bed shear stress (the peak stress that occurs during a wave cycle) are not as marked as for mean bed shear stress (the average across a wave cycle).

The areas of increased and decreased frequency of exceedance of the critical shear stress coincide with the areas of increased and decreased current speeds (due to the Project), as would be expected. Owing to the nature of the tidal conditions, as described in Annex 10A.1, currents are generally increased by the OWF in one area, and decreased in another during the flood tide, and *vice-versa* for the ebb tide.

The bed shear stress is related to both the current speed and wave conditions (height and period). Generally the wave climate in the Development Area has slightly less energy (lower wave heights) due to the presence of the Project, which would result in a lower bed shear stress. However, where current speeds are generally increased due to the Project, the combined bed shear stress (due to currents and waves) is predicted to increase. This is because, under normal conditions, currents cause significantly greater bed shear stress than waves across the ICOL Development Area.

Some changes to the amounts of erosion and deposition would occur in these areas of (respectively) increased or decreased exceedance of the critical shear stress, but these changes are likely to be small and localised.

Far-field

Analysis of Figures 10A.21 and 10A.22 shows that no noticeable change to the percentage exceedance of the critical shear stress (i.e. ±1 per cent) is predicted in the FF.

The predicted changes to sediment transport processes due to the Project are considered to be small, with the predicted frequency of exceedance of the critical shear stress changing typically by one to two per cent (with a maximum difference of five per cent). These changes are restricted to the immediate vicinity of the Development Area.

Figure 10A.19: Difference in the exceedance of critical shear stress (N/m²) – based on the combined (currents plus waves) maximum bed shear stress – near-field

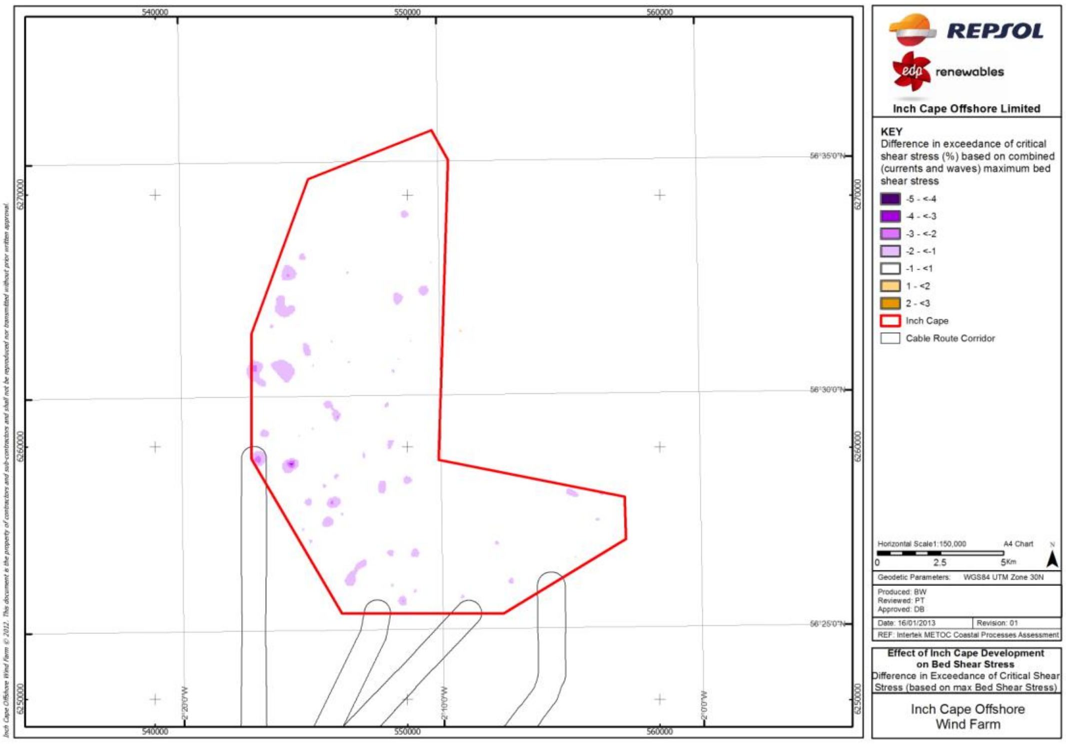


Figure 10A.20: Difference in the exceedance of critical shear stress (N/m²) – based on the combined (currents plus waves) mean bed shear stress – near-field

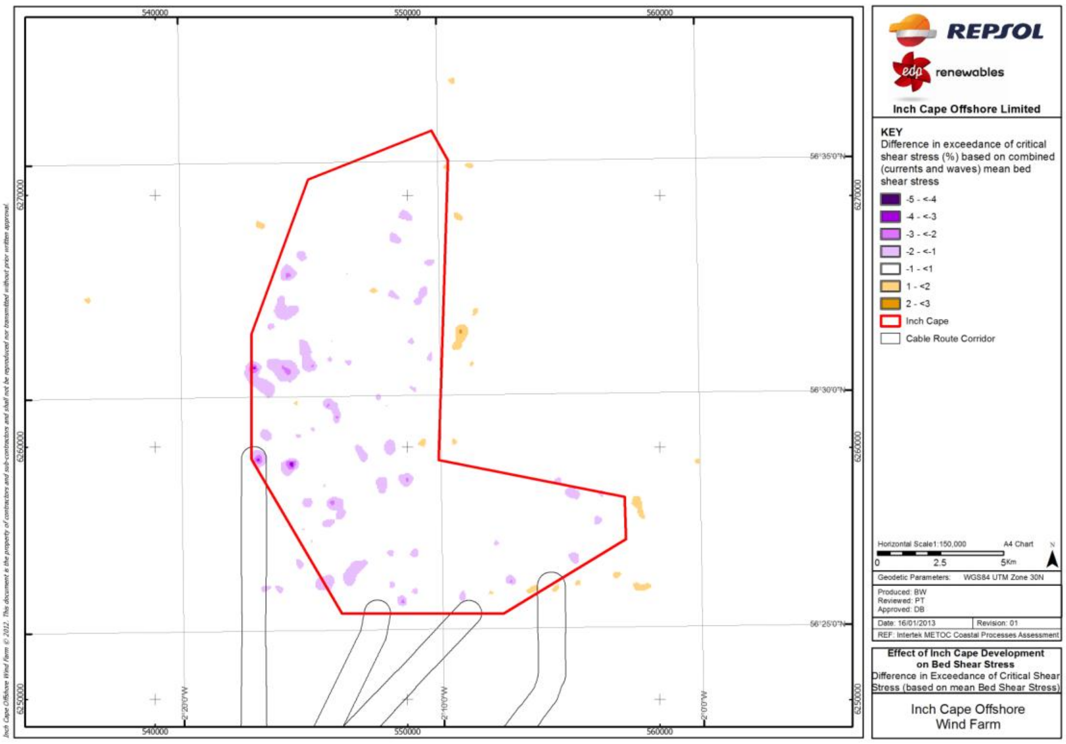


Figure 10A.21: Difference in the exceedance of critical shear stress (N/m²) – based on the combined (currents plus waves) maximum bed shear stress – far-field

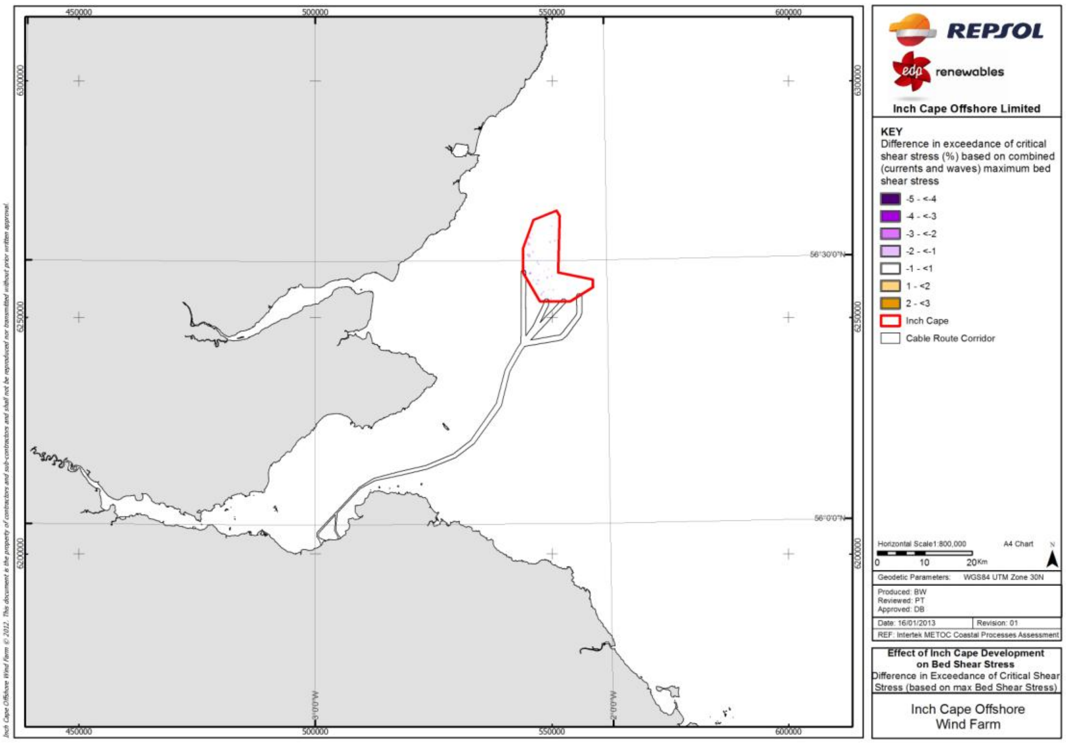
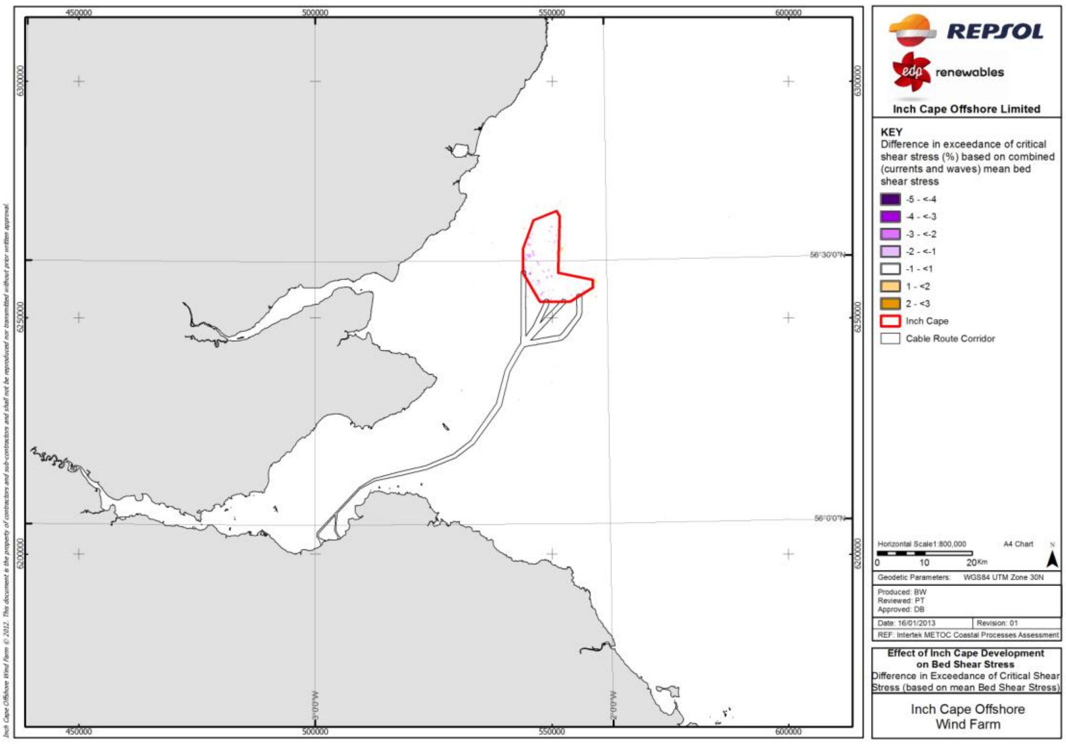


Figure 10A.22: Difference in the exceedance of critical shear stress (N/m²) – based on the combined (currents plus waves) mean bed shear stress – far-field



10A.5.3.2.2 Impacts due to scour

The assessment of the potential for scour is provided in full in Annex 10A.6, and the results are summarised in Table 10A.12. For conservatism, the scour assessment considered jacket structures since these represent a worse case than GBSs (which would be scour-protected).

Table 10A.12: Summary of predicted equilibrium scour depth, lateral extent, volume of sediment per leg and per foundation, and the total scour footprint

Forcing	Scour Depth S_e (m)	Lateral extent X_s (m)	Volume of Scoured Sediment Per Leg, V_s (m^3)	Volume of Scoured Sediment Per Foundation, V_{TOT} (m^3)	Total Scour Footprint, α (m^2)
Peak Spring Tide	6.7	12	1,230	4,992	2,261
Peak Neap Tide	2.0	3.6	40	161	298
Return Period Total Currents (Yrs)					
1:1	10.5	18.8	4,454	17,817	5,148
1:10	11.6	20.8	5,955	23,820	6,218
1:50	12.4	22.3	7,263	29,053	7,086
1:100	12.7	22.9	7,823	31,292	7,449

The estimated scour pit dimensions are around each leg of the jacket structure. Since the jacket legs are expected to be at least 20 m apart (and up to 60 m for WTGs, depending on the size of the foundations) the scour pits from neighbouring legs are not predicted to interact. The scour pits from neighbouring WTGs, which will be more than 800 m apart, will definitely not interact. The likely scour would therefore be considered as local rather than global scour.

The fate of the scoured material has been modelled using the FTMS PT module, and a typical volume per turbine of 4992 m^3 was applied (the volume that would be scoured under regularly-occurring spring tide conditions). This was released into the water column close to the bed continuously over a spring-neap cycle.

Two rows of WTGs in the middle of the site were modelled, with eight WTGs in each row. The results from this modelling are indicative of the potential impacts from scour around a WTG located anywhere within the Development Area. This is due to the fact that currents and sediment type and size are more or less uniform across the Development Area. The small variations that would result due to any small differences in currents or PSD are well within the conservatisms and assumptions inherent in the assessment. The resulting deposition footprint from the scour around all WTGs has therefore been determined by extrapolating the modelled deposition across the whole Development Area, and accumulating any overlapping footprints.

The results of the modelling show that the elevated SSC would be low and localised. Peak concentrations very close to the scour pit are predicted to lie typically between 30 and 100 mg/l above background, with a maximum of 116 mg/l (averaged across a model grid cell). Beyond approximately 100 m from the structures, SSC will typically be less than 10 mg/l above background. The effects will be temporary and the majority of suspended sediment will settle out very soon after release. The majority of sediment (>98 per cent) is predicted to settle out within 5-10 minutes, with most of the remaining fractions settling within one hour. The finer fractions of mud have the ability to travel further as they remain in suspension for longer before settling on the seabed.

It should be noted that, in the impact plots, the visual difference in modelled contours beyond the Development Area is due to the larger FTMS model elements and therefore a coarser resolution away from the Development Area.

The resulting deposition footprints will be localised around the WTG base with a maximum thickness of 1.1 m, and the extent of the footprint with a thickness >10 cm will reach up to 150 m away from the WTG. Beyond this distance, the deposition thickness rapidly reduces, and is typically <1 mm within ~200 m and <0.1 mm within ~700 m of the WTG.

10A.5.3.3 Decommissioning Phase

It is possible that all equipment, including cables and foundations, may need to be removed, in which case a similar level of impact as predicted by the construction phase modelling would result, although it is noted that impacts are likely to be less due to the fact that no bed-levelling through dredging would be required.

10A.5.4 CUMULATIVE IMPACTS

Two levels of cumulative impact have been considered:

- Cumulative impacts between the Wind Farm and the OfTW; and
- Cumulative impacts due to interactions between the Project (the Wind Farm and OfTW) and other developments and activities.

The former is detailed in the ES Chapter 10 Section 10.7.1 – 10.7.3. The latter is considered in the ES Chapter 10 Section 10.7.4 - 10.7.6 and in more detail below.

With respect to the assessment of cumulative impacts of the Project with other projects, a number of developments and activities were identified with the potential to interact with the Project. These are detailed in Chapter 4 Section 4.7.

The requirement to assess cumulative impacts with other developments and activities was assessed using the FTMS, by considering changes to the hydrodynamic regime with the Project in place. The NnG and FoF wind farms were taken forward to a full cumulative impact assessment, due to their proximity to the Project and the high likelihood of interaction.

The Cockenzie Power Station decommissioning and subsequent potential redevelopment lies close to the Offshore Export Cable Corridor. It was not considered that any aspects of this development would cause cumulative impacts with the Project since it has only very minor marine elements. In addition to this it is not anticipated that there will be major overlap in programme of activities that occur in proximity i.e. near shore cabling works and any shoreline works, due to the short duration of these elements of the works, and the known programme durations.

All other identified developments and activities were scoped out on the basis of distance from the Project; the predicted changes in metocean conditions due to the Wind Farm and OfTW were negligible at these sites (change in water level <0.5 cm; change in current speed <0.5 cm/s; change in wave height <1 cm).

Therefore, the metocean and coastal processes cumulative impact assessment has considered the Project being developed in conjunction with:

- The proposed NnG offshore wind farm and associated offshore transmission infrastructure; and
- The proposed FoF offshore wind farm and associated offshore transmission infrastructure.

10A.5.4.1 Changes to the Hydrodynamic Regime

The effect on the hydrodynamic regime due to the cumulative impacts from the Project and NnG and FoF projects has been modelled using the FTMS HD model (as discussed in Section 10A.4). The results of the modelling show the predicted changes to water level and current speeds on the regional scale (FF).

Analysis of these plots indicates that the effects on the hydrodynamic regime due to the ICOL, NnG and FoF projects are low and generally localised to the sites. Changes to water levels are seen across a wider area but these are very small.

10A.5.4.1.1 Changes to water levels

There is an area (approximately 4 km x 8 km) around the southwest boundary of the NnG development site where the mean spring HW level is predicted to be up to 2.5 mm lower than the baseline. Surrounding this, covering a much larger area (from the wind farms to the coast), the mean spring HW level is predicted to be up to 1.5 mm lower than the baseline.

Mean spring HW level is predicted to be further reduced within the Firth of Forth, reaching a peak change at the upper end of the estuary of 3.5 mm (lower than baseline).

There is also an area further offshore, within the FoF project, but east of the modelled WTG locations, where the mean spring HW level is up to 1.5 mm higher than the baseline.

These changes are due to the retardation of the flooding tide by the OWF developments which causes a build up or increase in water level, with a corresponding reduction in water level ‘downstream’ of the developments on a flooding tide. The opposite happens on the ebbing tide, with a large area showing a slight increase in water level at mean spring LW (up to 1.5 mm), and a smaller area, further offshore (i.e. ‘downstream’ of the developments on the ebbing tidal wave) experiencing a reduction in water level at mean spring LW (up to 1.5 mm).

Similar, but smaller changes are predicted at mean neap HW, although no noticeable change (i.e. >0.5 mm change) to water level at mean neap LW is predicted.

The predicted general FF changes of (up to) 2.5 mm are approximately 0.05 per cent of the mean spring tidal range, and the maximum change (3.5 mm) in the Firth of Forth is about 0.07 per cent of the mean spring tidal range in that area. These predicted changes are very small in comparison to natural variability, and would not be measurable.

The predicted cumulative impacts to water level due to ICOL Project and other nearby OWF developments are fairly widespread, but very small in size (<0.07 per cent of mean spring tidal range).

10A.5.4.1.2 Changes to tidal currents

The cumulative impacts on current speeds are very localised to the OWF development sites. Similar sized areas and magnitudes of change are predicted as for the scenario with the ICOL Project alone, with no noticeable cumulative effect from one OWF on another.

Current speeds are predicted to increase by up to 0.02 m/s, and decrease by up to 0.04 m/s on the mean spring peak ebb and mean spring peak flood tide respectively. The affected areas are aligned with the general tidal orientation, as is expected, with areas of change being very localised and centred around individual WTGs. No noticeable changes are seen in FoF project area. This is due to the resolution of the model in this area, which is too coarse to show the localised (NF) effects of the individual WTGs. However, the general FF effect of the FoF project is fully accounted for in the modelling, and if these were to overlap with any effects from the ICOL Project or NnG project, then the cumulative impact would be demonstrated.

Differences during mean neap tides are much less marked, and most of the OWF sites do not show any noticeable (i.e. >0.01 m/s) change.

As with the effect of the ICOL Project on its own, there are no noticeable predicted changes to the tidal current regime in the FF.

The predicted cumulative changes to tidal currents due to the ICOL Project and other nearby OWF developments are small (up to a maximum of six per cent), and very localised to the NF. No cumulative FF impacts are predicted on the tidal current regime.

10A.5.4.2 Changes to the Wave Climate

The cumulative effects on the wave climate due to the ICOL Project and , NnG and FoF projects have been modelled using the FTMS SW model (as discussed in Section 10A.4). The results of the modelling show the predicted changes to significant wave height due to the developments on the regional scale (FF).

10A.5.4.2.1 Changes to significant wave height

Changes to significant wave height due to the developments are seen across the majority of the sites, with wave heights typically reduced by between 0.01 and 0.03 m, with maximum differences of up to 0.04 m predicted. The cumulative effect of the three developments is to increase the area affected, but not to increase the size of the change (i.e. the increase or decrease in wave height). The developments take energy out of the passing wave climate, and therefore the resulting wave heights are always reduced (waves are never bigger as a result of the developments).

The maximum predicted changes to wave heights (up to 0.04 m) equate to 2.8 per cent and 0.8 per cent of the 50-percentile and 99-percentile wave heights respectively.

The predicted cumulative changes to the wave climate due to the ICOL Project and other OWF developments are considered to be small (less than three per cent of average wave heights), although the affected areas are considerably larger than the effects from the Project on its own.

10A.5.4.3 Changes to the Sediment Regime

The cumulative effects of the ICOL Project, NnG and FoF projects on the sediment regime have been modelled using the HD and SW modules of the FTMS, in combination with analysis of the seabed sediment characteristics.

The results of the analysis are shown in Figures 10A.23 to 10A.24 (and also for completeness in Annex 10A.7). These show the predicted changes to exceedance of the critical shear stress. As discussed in Section A10.5.3.2, the exceedance of the critical shear stress is a function of the combined currents and waves experienced at a location, and changes to the percentage of time this measure is exceeded can indicate a change to the sediment regime. In the plots shown, the predicted changes are reported as an absolute percentage, not a relative percentage. So, for example, if a particular location experiences exceedance of the critical entrainment stress for five per cent of the time at present, and this is predicted to increase to six per cent of the time once due to cumulative impacts from the developments, this will be reported as a one per cent increase in critical entrainment stress exceedance, not 20 per cent.

10A.5.4.3.1 Changes to the sediment transport processes

Analysis of Figures 10A.23 and 10A.24 indicates that the overall cumulative effect of the OWFs on sediment transport processes is very similar to the effect from just the ICOL development. The cumulative differences in the exceedance of the critical shear stress are small, and limited to the local areas of the development sites.

This is as expected given that the combined bed shear stress is dominated by tidal currents, rather than waves, and the cumulative differences to currents are very similar to those predicted when considering the ICOL Project development on its own.

The cumulative impact from other projects (as with that from ICOL on its own) produces no change greater than one per cent to the percentage exceedance of the critical shear stress in the FF. The predicted changes are within the natural variability expected at the site.

The predicted cumulative changes to sediment transport processes due to the ICOL Project and other surrounding developments are considered to be very small, with the predicted effects restricted to the immediate vicinity of each OWF development site.

Figure 10A.23: Cumulative difference in the exceedance of critical shear stress (%) – based on the combined (currents plus waves) maximum bed shear stress – far-field

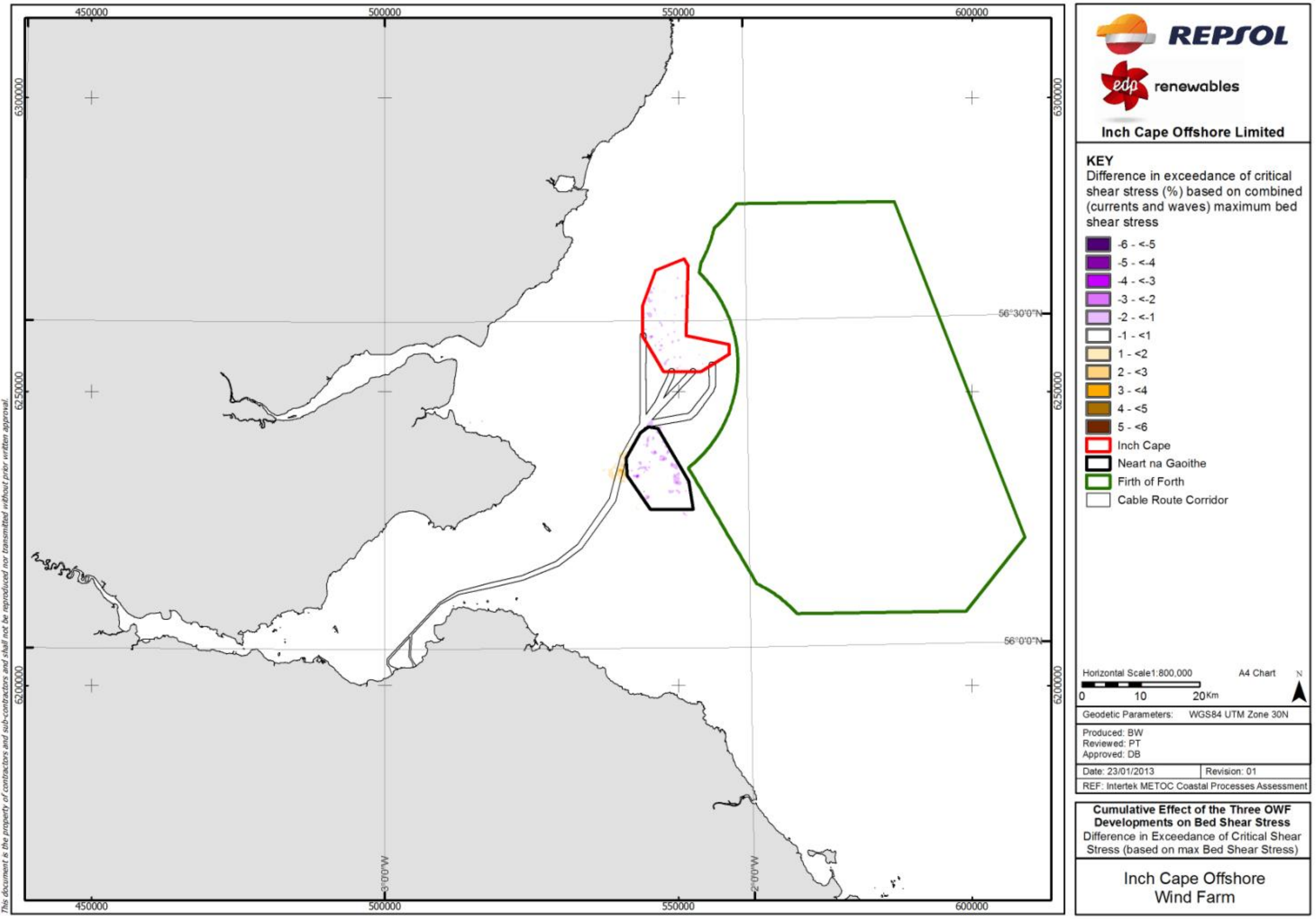


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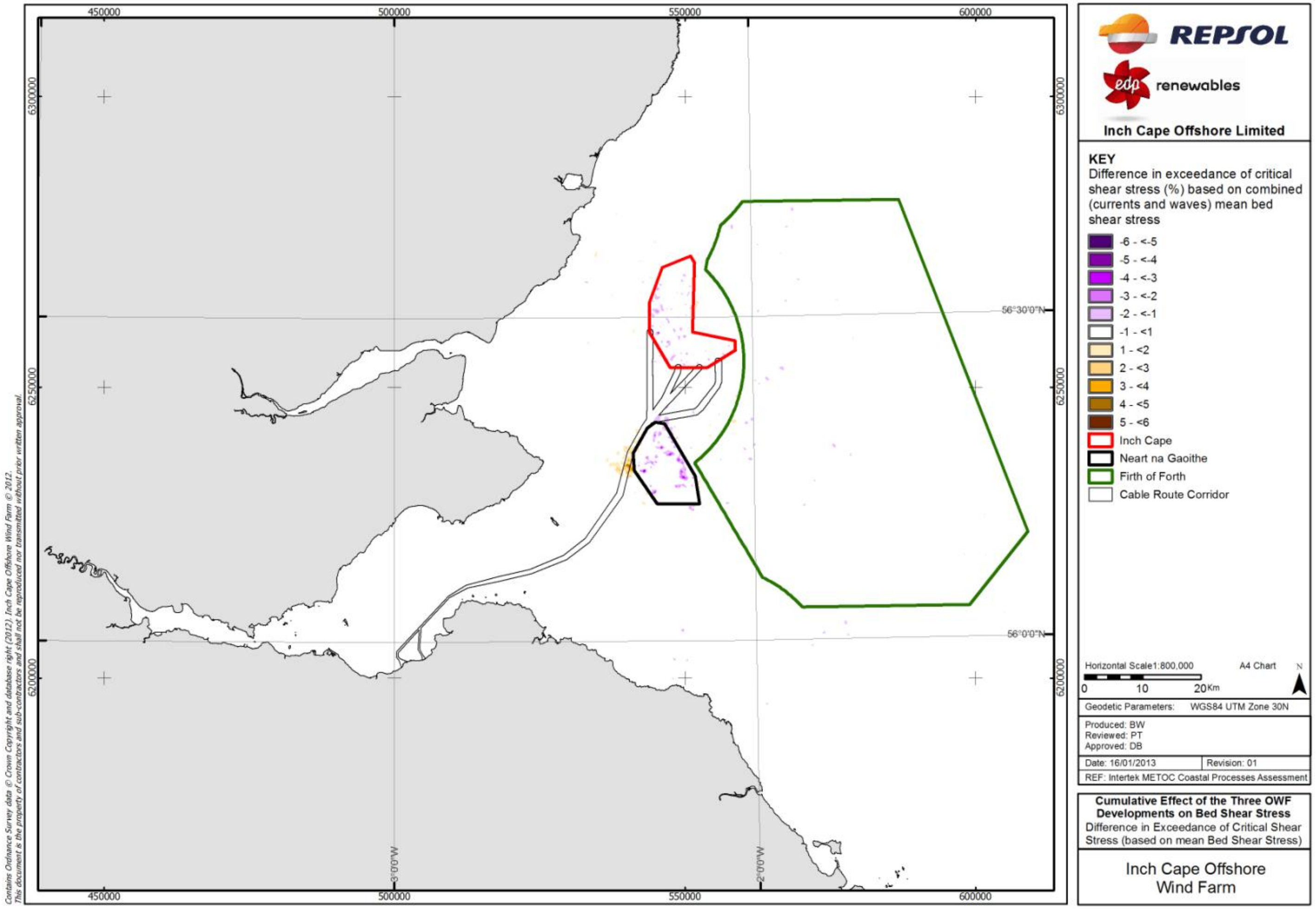
Figure 10A.24: Cumulative difference in the exceedance of critical shear stress (%) – based on the combined (currents plus waves) mean bed shear stress – far-field

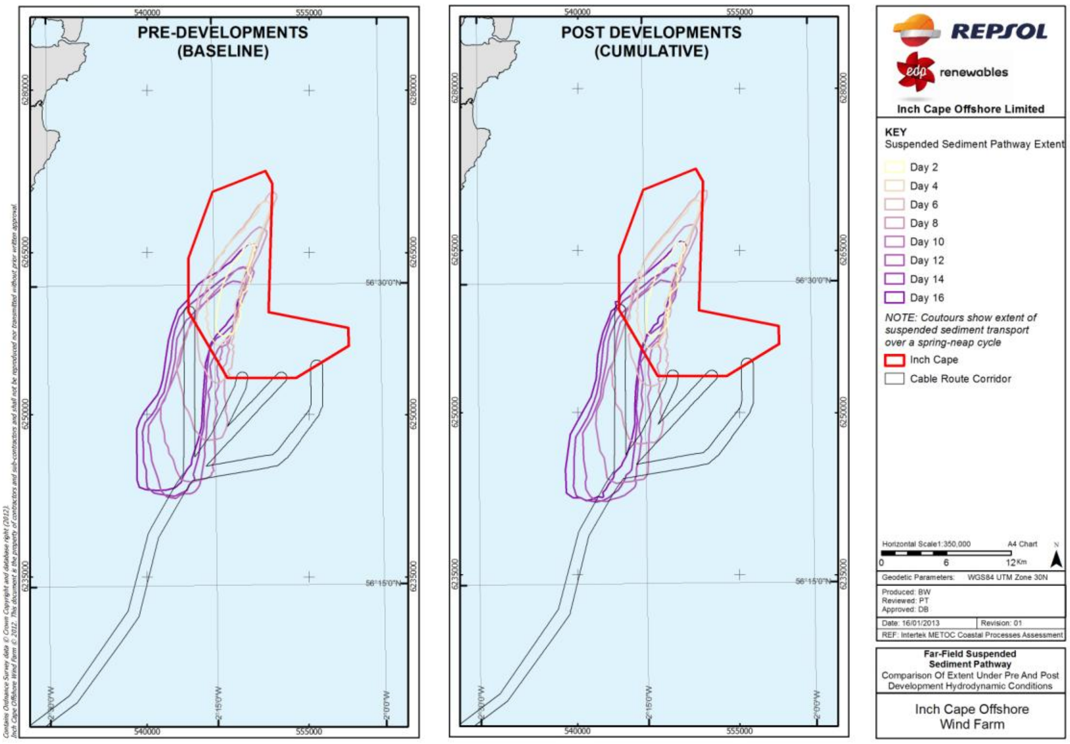


10A.5.4.3.2 Far-field suspended sediment transport

An indication of any cumulative changes to the FF suspended sediment transport due to the ICOL Project and NnG and FoF projects was investigated using the FTMS PT module. A continuous release of a large number of neutrally-buoyant particles over a spring-neap cycle was modelled using the 'with all developments' scenario HD model. The results were then compared with the same results generated using the baseline HD model. It should be noted that this modelled scenario is not representative of any discharge or release of sediment due to the Project, but simply represents the net movement of naturally occurring ambient suspended sediment in the area. The results indicate that net transport is to the south of the site. This is caused by the flood-dominated tidal regime experienced in the area.

Figure 10A.25 shows a comparison of the extent of the resulting FF suspended sediment plume under pre-developments (baseline model run with no developments in place) and post-developments (model configuration with all three OWF developments) hydrodynamic conditions. A visual comparison of the two extents shows that no significant differences are apparent. The plot indicates that the OWF developments will not cause net changes to the regional sediment transport regime, even when the three sites are considered cumulatively.

Figure 10A.25: Far-field suspended sediment pathway – comparison of transport extent under pre- and post-developments hydrodynamic conditions



10A.5.5 CHANGES DUE TO THE FUTURE (CHANGING) CLIMATE

10A.5.5.1 Changes to the Hydrodynamic Regime

The effect on the hydrodynamic regime due to potential climate change has been modelled using the FTMS HD model (as discussed in Sections A10.2.3 and A10.4.7.6). The results of the modelling show the predicted changes to water level and current speeds on the regional scale (FF).

10A.5.5.1.1 Changes to water levels

As expected, the change to water level due to climate change is seen more or less uniformly across the model domain, and throughout the tidal cycle. There is a predicted increase in high and low water levels during both the spring and neap tide equivalent to the projected sea-level rise of 0.355 m. Slightly higher or lower changes are predicted near the head of the Firths of Forth and Tay, which is due to amplification of the tidal wave in these locations coupled with a more general modification to the hydrodynamic regime caused by the increased water depths associated with climate change.

Water level changes due to climate change are very much greater in magnitude than water level changes due to the ICOL Project and other projects. However, the projected sea-level rise is relatively small in comparison to typical water depths in the Forth and Tay offshore region. Therefore, although both water levels and current velocities may be modified under future climatic conditions, the modelling demonstrates that the overall tidal regime (tidal ranges, phases, tidal wave propagation etc.) is broadly similar to that for the present day.

Under a future climate scenario, the size of the effect due to the developments might be marginally different to the size assessed under present climatic conditions. It is, however, considered likely that the modelling results give a good indication of the effects due to the developments under future sea level conditions.

The predicted change in water level due to potential climate change is significantly greater, in both magnitude and extent, than the predicted change due to the ICOL Project and other projects.

10A.5.5.1.2 Changes to tidal currents

The predicted change to tidal currents due to potential climate change is very varied, with both positive and negative changes to current speeds predicted in different locations. There is no clear pattern to the predicted changes, but typically current speeds are seen to vary by no more than 0.01 m/s across the model domain, with a decrease in speed generally more likely than an increase. Peak changes of up to +0.1 m/s and -0.3 m/s are seen in some isolated locations within the Firths of Forth and Tay, where the increase in water depth due to climate change is proportionately greater compared to the total water depth.

The predicted changes indicate that generally the effect of sea-level rise on tidal currents will be minimal, with tidal currents typically being very similar in most areas to the baseline conditions, but with possibly a bias towards a small reduction in current speeds. Greater differences are likely in isolated shallower areas close to the coast, and in particular within the Firths of Forth and Tay.

Under a future climate scenario, the size of the effect due to the ICOL Project and other projects might be marginally different to the size assessed under present climatic conditions. It is, however, considered likely that the modelling results give a good indication of the effects due to the developments under future sea level conditions (see the argument in Section A10.5.5.1.1).

The predicted change in tidal currents due to potential climate change is generally small, but spatially varied. The predicted change is similar in size to, but considerably more widespread than, the maximum predicted change due to the ICOL Project and other projects.

10A.5.5.2 Changes to the Wave Climate

The effect on the wave climate due to potential climate change has been modelled using the FTMS SW model (as discussed in Sections A10.2.3 and A10.4.7.6). The results of the modelling show the predicted changes to significant wave height on the regional scale (FF).

10A.5.5.2.1 Changes to significant wave height

The potential increase in storminess in the future gives predicted wave heights that are all greater than the baseline conditions. Modelled wave heights and wind speeds at the boundaries were increased by 10 per cent to represent future climate change, resulting in an increase in significant wave height of between about 0.2-0.4 m (50-percentile), to more than 1.0 m (99-percentile).

It is considered likely that the size of the effect due to the ICOL Project and other projects will be similar under the future climate scenario (increased wave height) as under the present wave regime.

The predicted change in significant wave height due to potential climate change is significantly greater than the predicted change due to the ICOL Project and other projects..

10A.5.5.3 Changes to the Sediment Regime

The effects of potential climate change on the sediment regime have been modelled using the HD and SW modules of the FTMS, in combination with analysis of the seabed sediment characteristics.

The results of the analysis are shown in Figures 10A.26 to 10A.27 (and also for completeness in Annex 10A.7). These show the predicted changes to exceedance of the critical shear stress (both the maximum and mean bed shear stress across a wave cycle due to combined currents and waves are depicted).

The Figures indicate that exceedance of the critical shear stress under conditions of maximum bed shear stress is predicted to increase, typically by between two and four per cent. Peak changes are predicted to be between six and 12 per cent, and these are located close to the coast. These values refer to the increased percentage of the total time for which the critical shear stress is exceeded, rather than a relative change compared to the baseline.

Under the climate change scenario, exceedance of the critical shear stress under conditions of mean bed shear stress is predicted to result in a much less marked difference (than for the maximum bed shear stress). A much smaller portion of the model domain shows changes of greater than one per cent in the exceedance time. Generally, where changes are predicted, these indicate a reduction in the exceedance of critical shear stress, with a maximum reduction of between five and ten per cent in the upper Firth of Forth. As before, these values refer to the increased percentage of the total time for which the critical shear stress is exceeded, rather than a relative change compared to the baseline.

The predicted changes are consistent with the predicted changes to the hydrodynamic and wave climates. The general increase in wave heights results in a widespread general increase in the maximum bed shear stress (which is dominated by the peak orbital wave velocity under the more extreme wave conditions). However, although the mean bed shear stress is influenced by the mean wave energy, it is not dominated as much by waves, and therefore the influence of the currents (which do not generally increase) is greater. These competing factors result in the much smaller changes in exceedance of critical shear stress under conditions of mean bed shear stress than is seen for the maximum bed shear stress.

The predicted change in the maximum bed shear stress (and therefore in the exceedance of the critical shear stress) due to potential climate change is significantly greater, in both size and extent, than the predicted change due to the ICOL Project and other projects.

Figure 10A.26: Difference due to potential climate change in the exceedance of critical shear stress (% of time) – based on the combined (currents plus waves) maximum bed shear stress – far-field

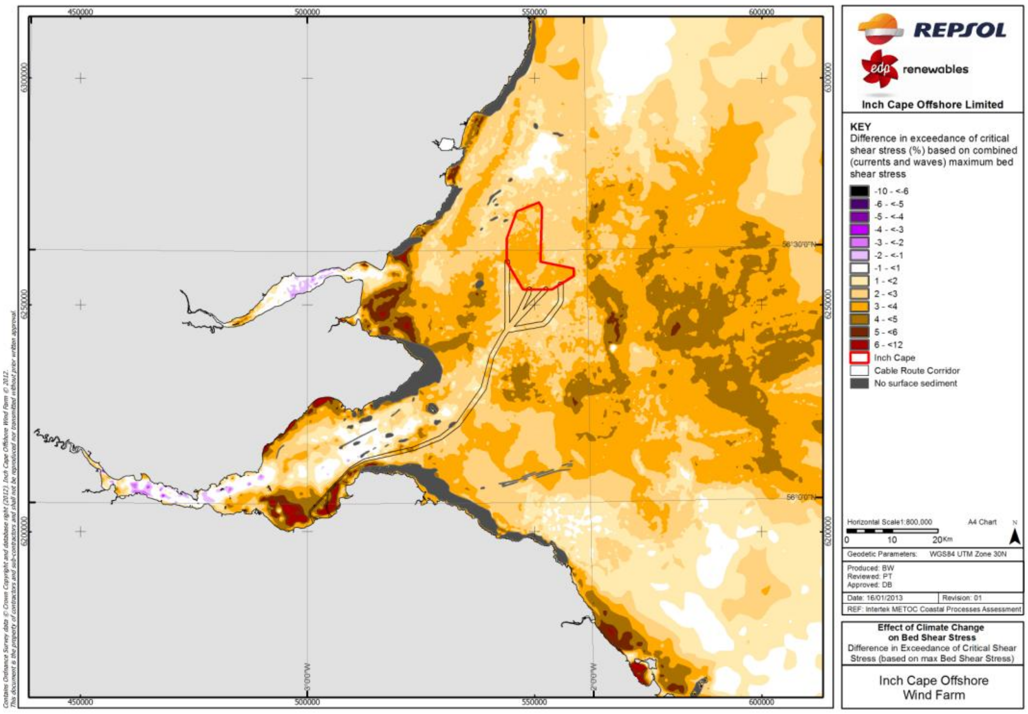
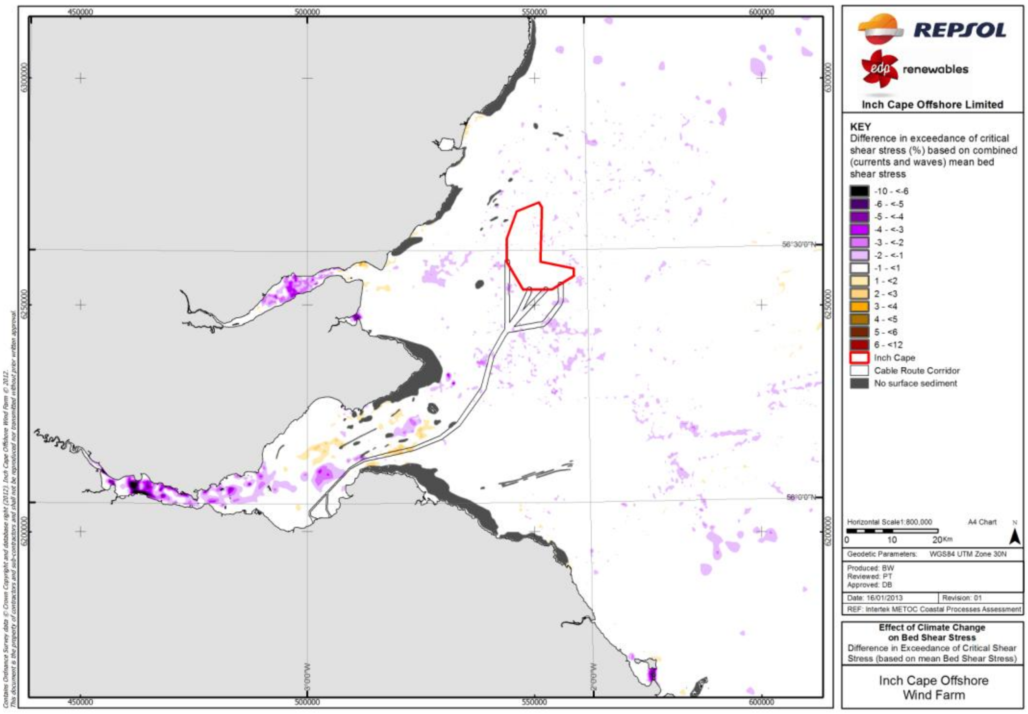


Figure 10A.27: Difference due to potential climate change in the exceedance of critical shear stress (% of time) – based on the combined (currents plus waves) mean bed shear stress – far-field



10A.6 CONCLUSIONS AND LIMITATIONS

10A.6.1 CONCLUSIONS

This study has considered the impacts on the metocean and sediment regimes, and consequently the effect on coastal processes, due to the ICOL Project.

Both NF and FF impacts due to the Project have been assessed over the short and long term. In addition, cumulative impacts from the ICOL Project and other projects (the NnG FoF projects) have been accounted for. Finally, the effects on the metocean and coastal processes that might result due to the potential changes to the climate in the future have also been considered.

The key conclusions from this assessment are presented below, and a summary of the predicted impacts and significance is provided in Table 10A.13 (for impacts due to the Development Area) and Table 10A.14 (for impacts due to the Offshore Export Cable).

10A.6.1.1 Construction Phase

The presence of installation equipment, such as jack-up rigs and cable laying vessels, during the construction phase of the Project may cause very small, localised and temporary effects to the NF hydrodynamics and wave climate.

Construction processes, such as the preparation of foundations and the burial of the Offshore Export Cable and inter-array cables, will result in the displacement of seabed sediment into the water column, and in the elevation of concentrations of suspended sediment.

The worst case increase in SSC due to foundation preparations might be up to 4000 mg/l above background (due to the foundation preparation for GBSs), but these peaks will be localised around the discharge location, and very temporary. The resulting plumes may be advected by up to 10 km from the release location for the finest sediment fractions, but over 97 per cent of the sediment will settle out within 5-10 minutes of discharge and much closer to the release point. The resulting deposition footprint is likely to cover the Development Area with varying thickness, ranging from about 1.9 m in the immediate vicinity around each WTG foundation, where material will be layered up around the base, to less than 1 mm approximately three kilometres away from each WTG location.

The worst case increase in SSC impacts from the cable burial process will be up to 300 mg/l above background (averaged across a model grid cell), but these will be localised. The resulting plumes will not be advected beyond the NF vicinity of the cable route and almost all sediment will settle out within one hour of disturbance. The resulting deposition footprint is likely to be very thin (typically <1 mm averaged across a model grid cell) with worst case peaks up to 5 mm.

10A.6.1.2 Operational Phase

The presence of the WTGs and their foundations in the Development Area will modify the metocean and sediment regimes. Localised changes to flow around the structures also has the potential to lead to scouring of material.

The predicted changes to water level due to the Project are very small (<0.03 per cent of tidal range), and generally localised to the NF, with the exception of a small change (<0.02 per cent of spring tidal range) in the upper reaches of the Firth of Forth.

The predicted changes to tidal currents due to the Project are small (approximately seven per cent of peak spring tidal velocities), and restricted to the vicinity of the Development Area.

The predicted changes to the wave climate due to the Project are considered to be small (less than two per cent of average wave heights), and restricted to the vicinity of the Development Area.

The predicted changes to the sediment transport processes due to the Project are considered to be small, with the frequency of exceedance of the critical shear stress changing typically by one to two per cent (with a maximum difference of five per cent). These changes are also restricted to the vicinity of the Development Area.

10A.6.1.2.1 Impacts of scour

If GBS structures are used, it is assumed that scour protection will be put in place. The scour protection will be suitably designed in order to minimise any secondary scour. On this basis it is assumed that scour will be significantly mitigated if GBSs are used.

If jacket structures are employed, the estimated worst case equilibrium scour depth will be between 2 and 6.7 m; the lateral extent of the scour pit will be between 3.6 and 12 m; and the scoured area will between 298 and 2261 m^2. The actual dimensions of the scour pits around each leg of the structure will depend on the size and location of WTG/OSP installed. However, scour pits will not overlap regardless of WTG/OSP size, and therefore the scour will be local, rather than general. It should be noted that the extent of scouring reported here is worst case, especially since there is a layer of stiff clay, which may limit the amount of scour, underlying the Development Area at varying depth.

The volume of scoured material will be between 161 and 4992 m^3, again depending on the size and location of the WTGs/OSPs. The resulting worst case elevated SSC would be low and localised, with peak concentrations between 30 and 100 mg/l above background levels. Beyond the structures, SSC will be quickly drop to less than 10 mg/l above background levels.

The resulting deposition footprints will be very localised around the WTG/OSP base, with a maximum thickness of 1.1 m and the extent of the footprint with a thickness >10 cm reaching up to 150 m away from the turbine. Beyond this distance, the deposition thickness will rapidly reduce, and will be typically <1mm within ~200 m and <0.1 mm within ~700 m of the WTG/OSP location.

10A.6.1.3 Decommissioning Phase

The approach to decommissioning is described in the ES Chapter 7. A decommissioning plan will be prepared in accordance with the requirements of the Energy Act 2004 (see Chapter 3: Regulatory Requirements, Section 3.3.2) and will be subject to approval from Department of Energy and Climate Change prior to implementation. The potential effects of decommissioning are considered to be equivalent to and potentially lower than the worst case effects assessed for the construction phase.

It is possible that all buried equipment (cables and foundations) would be left *in situ*. However, it is also possible that all equipment associated with the development might need to be removed, including the buried cables. In either case, the likely impacts on the hydrodynamic regime, wave climate and consequently the sediment transport processes will be very small, localised and temporary.

The impacts due to disturbed sediments during the process of decommissioning will be similar to those predicted due to the installation processes during the construction phase, although it is noted that impacts are likely to be less, due to the fact that no bed-levelling through dredging would be required.

10A.6.1.4 Cumulative Impacts

Two levels of cumulative impact have been considered:

- Cumulative impacts between the Wind Farm and the OfTW; and
- Cumulative impacts due to interactions between the Project (the Wind Farm and OfTW) and other developments and activities.

The former is detailed in the ES Chapter 10 Section 10.7.1 – 10.7.3. The latter is considered in the ES Chapter 10 Section 10.7.4 - 10.7.6 and in Section 10A.5.4 in more detail and summarised below. The Cockenzie Power Station decommissioning and subsequent potential redevelopment lies close to the Offshore Export Cable Corridor. It was not considered that any aspects of this development would cause cumulative impacts with the Project since it has only very minor marine elements. In addition to this it is not anticipated that there will be major overlap in programme of activities that occur in proximity i.e. near shore cabling works and any shoreline works, due to the short duration of these elements of the works, and the known programme durations.

All other identified developments and activities were scoped out on the basis of distance from the Project; the predicted changes in metocean conditions due to the Wind Farm and OfTW were negligible at these sites (change in water level <0.5 cm; change in current speed <0.5 cm/s; change in wave height <1 cm).

Therefore, the metocean and coastal processes cumulative impact assessment has considered the ICOL Project being developed in conjunction with:

- The proposed NnG offshore wind farm and associated offshore transmission infrastructure; and
- The proposed FoF offshore wind farm and associated offshore transmission infrastructure.

The predicted cumulative impacts to water level due to the ICOL Project and other nearby projects are fairly widespread, but very small in size (<0.07 per cent of spring tidal range).

The predicted cumulative changes to tidal currents due to the ICOL Project and other nearby projects are low (between three and six per cent of peak spring tidal velocities), and very localised to the NF of each development. No cumulative FF impacts are predicted on the tidal current regime.

The predicted cumulative changes to the wave climate due to the ICOL Project and other nearby projects are of a similarly small size to those from on its own (less than three per cent of average wave heights), but the affected areas are considerably larger.

The predicted cumulative changes to sediment transport processes due to the ICOL Project and other nearby projects are considered to be small, with the predicted frequency of exceedance of the critical shear stress changing typically by one to three per cent (with a maximum difference of six per cent). These changes are restricted to the immediate vicinity of the development sites.

The ICOL Project and other projects will not cause net changes to the regional sediment transport regime or sediment dynamics along the nearby coastline, even when the three sites are considered cumulatively.

10A.6.1.5 Climate Change Impacts

The predicted change in water level due to potential climate change is significantly greater, in both size and extent, than the predicted change due to the OWF developments.

The predicted change in tidal currents due to potential climate change is generally small, but spatially varied. The predicted change is similar in size to, but considerably more widespread than, the maximum predicted change due to the OWF developments. However, the predicted change in significant wave height due to potential climate change is predicted to be significantly greater than the expected change due to the OWF developments.

The predicted change in the maximum bed shear stress (and therefore in the exceedance of the critical shear stress) due to potential climate change is significantly greater, in both size and extent, than the predicted change due to the OWF developments.

It is therefore considered that the effects on the hydrodynamic regime, wave climate and consequently the sediment transport processes due to the changing climate in the future are likely to be generally greater in both size and extent than the predicted changes due to the OWF developments.

10A.6.2 LIMITATIONS

The work undertaken within this study has quantified the effects of the development on the metocean regime and coastal processes. For any other elements of the EIA, this study shall be considered together with the results of other environmental studies from the ICOL Project team. This will allow a full analysis of engineering and environmental implications to ensure that all impacts are assessed in terms of their significance.

This study has made use of numerical modelling techniques, using calibrated and validated HD, SW and PT models, in combination with relevant field data and empirically-derived equations. As such, there are a number of sources of error and uncertainty, both in the underlying field data and in the inherent limitations of the numerical approximations to real world physical processes.

The evaluation of baseline conditions is based on validated models and is consistent with the field data and other relevant sources, such as previous studies, but will obviously include some inaccuracies. However, the numerical models used are very good at identifying relative differences between scenarios. The results and conclusions presented here are therefore valid and fit for the purpose of assessing the potential effects on the metocean and coastal processes. They also form a good basis for further analysis, but should not be used in isolation for any detailed engineering design.

In addition to the limitations in the numerical analyses, there are also a number of unknowns about the Project itself (such as the number and size of WTGs, or what foundation types will be used). Therefore the assessment has applied assumptions that result in the worst case for the assessment of each topic or issue. The final design of the scheme will be within the worst case scenario modelled, and actual impacts are therefore likely to be less than those presented here.

Table 10A.13: Summary of predicted measurable change due to the Wind Farm

Phase	Source	Physical Process	Near-Field		Far-field		Cumulative, Far-field	
			Size of Change	Duration of Change	Size of Change	Duration of Change	Size of Change	Duration of Change
Construction	Installation Equipment	Water Level	No impact	No impact	No impact	No impact	No impact	No impact
		Tidal Currents	No impact	No impact	No impact	No impact	No impact	No impact
		Wave Heights	No impact	No impact	No impact	No impact	No impact	No impact
		SSC	No impact	No impact	No impact	No impact	No impact	No impact
		Sediment Regime	No impact	No impact	No impact	No impact	No impact	No impact
	Bed preparation for GBSs (dredging)	Water Level	No impact	No impact	No impact	No impact	No impact	No impact
		Tidal Currents	No impact	No impact	No impact	No impact	No impact	No impact
		Wave Heights	No impact	No impact	No impact	No impact	No impact	No impact
		SSC	Up to 4000 mg/l above background	Short-term during dredging period only	No impact	No impact	No impact	No impact
		Sediment Regime	No impact	No impact	No impact	No impact	No impact	No impact
Operational and Maintenance	Presence of GBS and turbines	Water Level	Up to 0.03% of mean spring tidal range	Effectively permanent, but dependent on tidal conditions	Up to 0.02% of spring tidal range	Effectively permanent, but dependent on tidal conditions	Up to 0.07% of mean spring tidal range.	Effectively permanent, but dependent on tidal conditions
		Tidal Currents	Up to 7% of peak spring speeds	Effectively permanent, but dependent on tidal conditions	No impact	No impact	No impact	No impact
		Wave Heights	Reduced by up to 2% (dependent on wave conditions)	Effectively permanent, but dependent on wave conditions	No impact	No impact	Reduced by up to 3% (dependent on wave conditions)	Effectively permanent, but dependent on wave conditions
		SSC	No impact	No impact	No impact	No impact	No impact	No impact
		Sediment Regime	Up to 5% absolute increase in exceedance of critical shear stress (typically 1-2%)	Effectively permanent, but dependent on tidal and wave conditions	No impact	No impact	No impact	No impact

Phase	Source	Physical Process	Near-Field		Far-field		Cumulative, Far-field	
			Size of Change	Duration of Change	Size of Change	Duration of Change	Size of Change	Duration of Change
	Scour around jacket structures	Water Level	No impact	No impact	No impact	No impact	No impact	No impact
		Tidal Currents	No impact	No impact	No impact	No impact	No impact	No impact
		Wave Heights	No impact	No impact	No impact	No impact	No impact	No impact
		SSC	Maximum >100 mg/l above background (typically <30 mg/l)	During formation of equilibrium scour pits – dependent on tides but typically up to about 1 month	No impact	No impact	No impact	No impact
		Sediment Regime	No impact	No impact	No impact	No impact	No impact	No impact
Decommissioning		Water Level	No impact	No impact	No impact	No impact	No impact	No impact
		Tidal Currents	No impact	No impact	No impact	No impact	No impact	No impact
		Wave Heights	No impact	No impact	No impact	No impact	No impact	No impact
		SSC	Up to 4000 mg/l above background	Short-term during GBS removal period only	No impact	No impact	No impact	No impact
		Sediment Regime	Negligible	Temporary	No impact	No impact	No impact	No impact

Table 10A.14: Summary of predicted impacts due to the Offshore Export Cable

Phase	Source	Physical Process	Near-Field		Far-field		Cumulative, Far-field	
			Size of Change	Duration of Change	Size of Change	Duration of Change	Size of Change	Duration of Change
Construction	Offshore Export Cable burial	Water Level	No impact	No impact	No impact	No impact	No impact	No impact
		Tidal Currents	No impact	No impact	No impact	No impact	No impact	No impact
		Wave Heights	No impact	No impact	No impact	No impact	No impact	No impact
		SSC	Up to 300 mg/l above background	Short-term during cable burial period only	No impact	No impact	No impact	No impact
		Sediment Regime	No impact	No impact	No impact	No impact	No impact	No impact
Operational and Maintenance		Water Level	No impact	No impact	No impact	No impact	No impact	No impact
		Tidal Currents	No impact	No impact	No impact	No impact	No impact	No impact
		Wave Heights	No impact	No impact	No impact	No impact	No impact	No impact
		SSC	No impact	No impact	No impact	No impact	No impact	No impact
		Sediment Regime	No impact	No impact	No impact	No impact	No impact	No impact
Decommissioning	Removal of Offshore Export Cable	Water Level	No impact	No impact	No impact	No impact	No impact	No impact
		Tidal Currents	No impact	No impact	No impact	No impact	No impact	No impact
		Wave Heights	No impact	No impact	No impact	No impact	No impact	No impact
		SSC	Up to 300 mg/l above background	Short-term during cable removal period only	No impact	No impact	No impact	No impact
		Sediment Regime	No impact	No impact	No impact	No impact	No impact	No impact

10A.7 REFERENCES

1) Intertek METOC, February 2011. Inch Cape and Neart na Gaoithe Offshore Wind Farms – Proposed Methodology for Metocean and Coastal Processes Assessments. Report No: P1476_RN2550_Rev1.

2) Intertek METOC, May 2011. Inch Cape and Neart na Gaoithe Offshore Wind Farms – Data Gap Analysis and Data Review. Report No: P1476_RN2597_Rev2.

3) Intertek METOC, September 2011. Inch Cape and Neart na Gaoithe Offshore Wind Farms Coastal Processes Assessment – Hydrodynamic and Spectral Wave Model Calibration and Validation. Report No: P1476_RN2636_Rev0.

4) Intertek METOC, September 2011. Regional Coastal Processes Baseline Description – Inch Cape and Neart na Gaoithe Offshore Wind Farms. Report No: P1476_RN2728_Rev0.

5) Intertek METOC, November 2011. Coastal Processes Assessment for Neart na Gaoithe Offshore Wind Farm. Report No: P1476_RN2709_Rev2.

6) Intertek METOC, October 2011. Neart na Gaoithe Coastal Processes Assessment. Environmental Statement, Chapter 4. Report No: P1476_RN2762_Rev2.

7) Email from Esther Villoria (REPSOL) to Paul Taylor (Intertek METOC), 22 June 2012. Containing “INC-ENG-MGMT-RNE-REF-002r3 Design Envelope 22 06 12 FINAL.xlsx”.

8) COWRIE Ltd, ABPMer and HR Wallingford, September 2009. Coastal Process Modelling for Offshore Wind Farm Environmental Impact Assessment: Best Practice Guide.

9) Forth and Tay Offshore Wind Developers Group, 2010. Scottish Offshore Wind Farms – East Coast – Discussion Document (2) – Approach to Cumulative Effects Assessment. November 2010. Final Report: 9V9341.

10) Letter from Marine Scotland to SeaEnergy Renewables Ltd, 18 April 2011. Response to proposed methodology for metocean and coastal processes assessments. Marine Scotland Ref: 005/OW/SER-10 and 008/OW/MainS-10.

11) Letter from SeaEnergy Renewables Ltd and Mainstream Renewable Power Ltd to Marine Scotland. Response to Marine Scotland’s comments on the STW regional metocean and coastal processes Methodology Statement.

12) HR Wallingford, 2010. Firth of Forth and Tay Developers Group, Collaborative Oceanographic Survey, Specification and Design. Work Package 1: Review of Existing Information. Technical Note DER4539/01. 17 September 2010.

13) Partrac, 2010. Forth and Tay Metocean Survey, Draft Summary Data Report. P1127.05.D008s04.

14) iXSurvey Ltd, 2011. Report of Survey for Senergy S&G on behalf of SeaEnergy Renewables. Site Survey – Inchcape, Volume 1 – Survey Results. JN3508.

15) Osiris Projects, 2012. Export cable route survey. Volume 1 – Operations report; Volume 2 – Results report; Volume 3 – Geotechnical report. Ref. C12027. November 2012.

16) Osiris Projects, 2012. Export cable route landfall survey. Volume 1 – Operations report; Volume 2 – Results report; Volume 3 – Geotechnical report. Ref. C11043. July 2012.

17) Fugro, 2011. Geotechnical Survey. J11099 – 1 September 2011, Geotechnical Report – Field Data.

18) Fugro, 2012. Geotechnical Survey. J11129 – 2 March 2012, Site Characterisation Campaign Complete Report.

19) McBreen, F., Askew, N., Cameron, A., Connor, D., Ellwood, H., Carter, A., 2011. UK SeaMap 2010 Predictive mapping of seabed habitats in UK waters. JNCC Report 446, ISBN 0963 8091.

20) British Geological Survey, 1986. Tay Forth Sheet 56°N – 04°W, Seabed Sediments, 1:250,000 series.

21) British Geological Survey, 1986. Tay Forth Sheet 56°N – 04°W, Solid Geology, 1:250,000 series.

22) British Geological Survey, 1987. Tay Forth Sheet 56°N – 04°W, Quaternary Geology, 1:250,000 series.

23) Gatliff, R.W., Richards, P.C., Smith, K., Graham, C.C., McCormac, M., Smith, N.J.P., Long, L., Cameron, T.D.J., Evans, D., Stevenson, A.G., Bulat, J. and Ritchie, J.D., 1994. The geology of the Central North Sea. British Geological Survey offshore regional report, HMSO, London. ISBN 0118845047.

24) Holmes, R., 1977. Quaternary deposits of the Central North Sea. 5 – The Quaternary geology of the UK sector of the North Sea between 56 and 55° N. Report of the Institute of Geological Sciences, No.77/1.4.

25) Holmes, R., Jeffrey, D. H., Ruckley, N. A., Wingfield, R. T. R., 1993. Quaternary geology around the United Kingdom (North Sheet). 1:1 000 000. Edinburgh: British Geological Survey.

26) Holmes, R., Bulat, J., Henni, P., Holt, J., James, C., Kenyon, N., Leslie, A., Long, D., Musson, R., Pearson, S. and Stewart, H., 2004. DTI Strategic Environmental Assessment Area.

27) Pantin, H., 1991. The seabed sediments around the UK. BGS Research Report SB/90/1. 47pp.

28) C-MAP, 2007. CM-93/3 Global Chart Database. Version 283.

29) Centre for Environment, Fisheries and Aquaculture WAVENET, 2011. QA/QC procedure. Available at: http://www.cefas.defra.gov.uk/our-science/observing-and-modelling/monitoring-programmes/wavenet/qaqc-procedure.aspx [Accessed 12 October 2012].

30) Department of Energy and Climate Change, 2009. Offshore Energy SEA Environmental Report. January 2009.

31) Scottish Executive, 2007. Scottish Marine Renewables SEA – Environmental Report.

32) Tay Estuary Forum, 2013. The Tay Estuary Coastal References Database. Available at: http://www.dundee.ac.uk/crsem/TEF/review.htm [Accessed 7 May 2013].

33) Ramsay, D.L., and Brampton, A.H., 2000. RSM 143 Coastal Cells in Scotland Cell 1; RSM 144 Coastal Cells in Scotland Cell 2.

34) Soulsby, R.L. 1995. Bed shear stresses due to combined waves and currents. In Advances in Coastal Morphodynamics, Ed. Stive, M.J.F., et al., pp4-20 – 4-23. Delft Hydraulics, Netherlands.

35) Angus Council, 2004. Angus Shoreline Management Plan, First Edition. Available at: http://www.angus.gov.uk/ac/documents/roads/SMP/default.html [accessed 4 April 2011].

36) DEFRA, October 2006. Flood and Coastal Defence Appraisal Guidance – FCDPAG3 Economic Appraisal – Supplementary Note to Operating Authorities – Climate Change Impacts.

37) DHI, 2009. Mike 21 Flow Model FM – Hydrodynamic Model, User Guide. January 2009.

38) DHI, 2009. Mike 21 SW – Spectral Waves FM Module, User Guide. January 2009.

39) DHI, 2009. Mike 21 Flow Model FM – Particle Tracking Module, User Guide. January 2009.

40) The Planning Inspectorate, April 2012. Advice note nine: Using the ‘Rochdale Envelope’. Version 2. Available at: http://infrastructure.planningportal.gov.uk/wp-content/uploads/2012/03/Advice-note-9.pdf [accessed April 2012].

41) Seagreen Wind Energy, June 2011. Seagreen Phases 2 and 3 Scoping Report – Round 3 Firth of Forth. Document No: A4MR/SEAG-Z-DEC230-SRP-072.

42) Foundation for Water Research, March 1993. A Framework for Marine and Estuarine Model Specification in the UK.