Chapter 9 Physical Processes

9.1 Introduction

1 Coastal processes consider the natural cycle of tides, the movement of currents, the wave climate, and the resulting sediment regime. The presence of structures on the seabed has the potential to influence and affect the flow of water (increasing and decreasing current speeds and water levels) and the characteristics of waves (removing wave energy and modifying wave direction), thus potentially altering the sediment regime.

2 The term 'metocean' comes from the abbreviation of the words 'meteorology' and 'oceanography', and is used to describe the marine and coastal physical environment, which in this case incorporates wind, waves and currents. The metocean regime influences the sediment regime, and together these regimes influence coastal processes, thereby shaping the coastal physical environment.

3 This chapter describes the following:

- The baseline (existing) metocean conditions based on a desk study, collected field data and modelling, using a dedicated hydrodynamic and spectral wave modelling system developed for this study;
- The determination of the magnitude and extent of predicted changes to the metocean conditions (water levels, currents and waves), and any resultant changes to the sediment regime, using the dedicated numerical modelling system; and
- The assessment of the importance of the predicted changes to the physical environment, with specific reference to seabed forms (such as sandbanks) and coastal processes.

4 The study area includes the local environment around the Neart na Gaoithe development site, and the more regional environment, which incorporates the nearby coastline of east Scotland, and the areas around the Inch Cape and Firth of Forth Round 3 Zone 2 offshore wind farm sites. The regional area of interest is shown in Figure 9.1.

5 This chapter includes effects the developments may have on the physical environment in both the near-field and far-field. The near-field encompasses the effect on the local environment from individual turbines, and any localised cumulative or overlapping impacts between adjacent turbines within the immediate vicinity of the development site). The far-field considers the effect from the proposed developments beyond the development site, and in particular extending to the shoreline. As well as near-field and far-field changes, effects may range from short to long term, and the assessment has considered timescales up to 50 years, based on the maximum duration of the seabed lease.

6 Due to the regional nature of the coastal processes assessment, the developers of Inch Cape (REPSOL) and Neart na Gaoithe (Mainstream) jointly commissioned the modelling study. This was to ensure all relevant and up to date data could be incorporated within the regional model to inform the site-specific assessments.

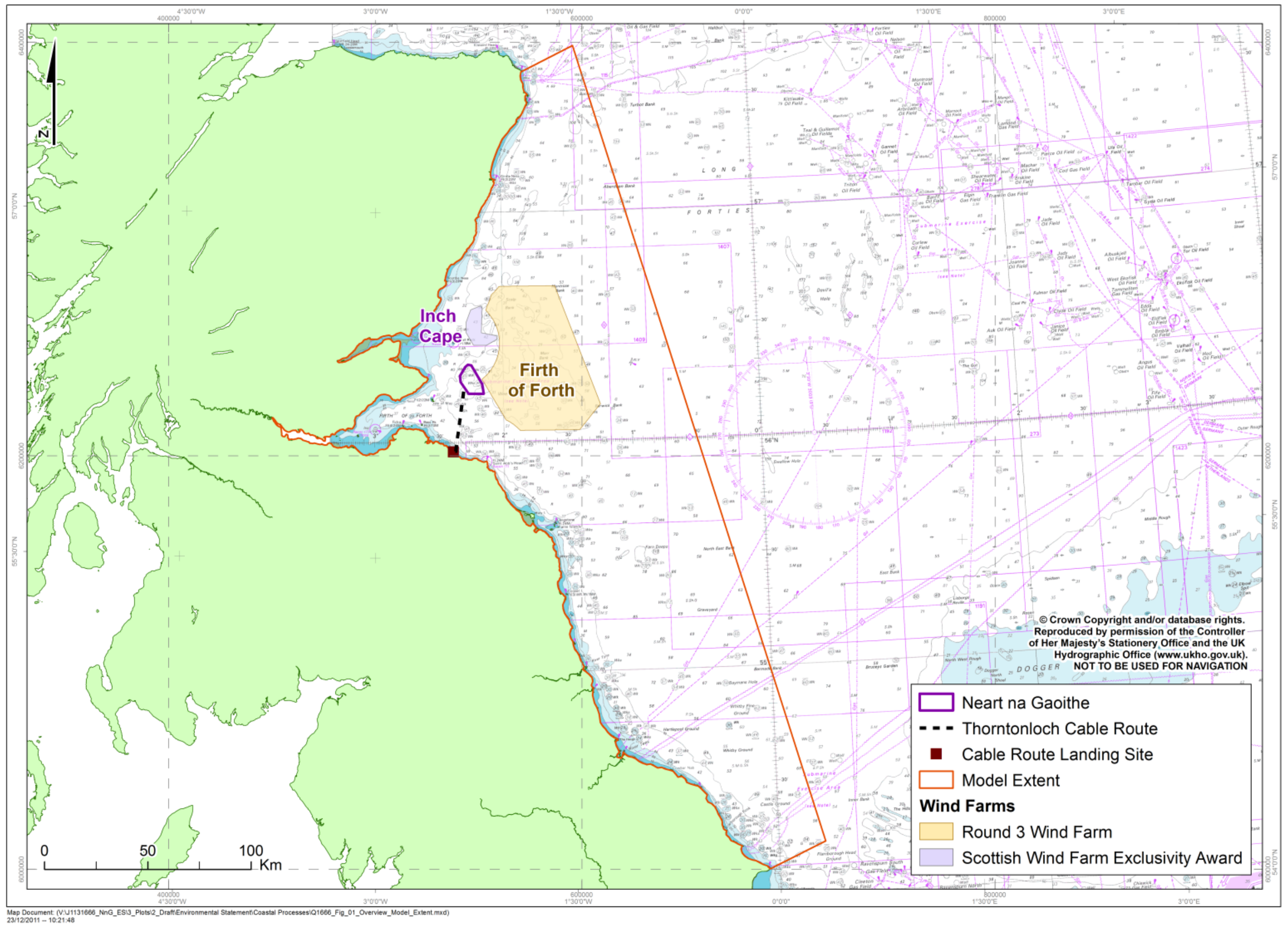

Figure 9.1: Geographic overview of the regional area of interest and model extents

9.2 Guidance and Legislation

7 The best practice guidance for the assessment of impact of offshore wind farms on metocean and coastal processes has been followed. This is provided by:

- Collaborative Offshore Wind Energy Research into the Environment (COWRIE) - Coastal Process Modelling for Offshore Wind Farm Environmental Impact Assessment (Lambkin *et al*., 2009); and
- Centre for Environment, Fisheries and Aquaculture Science (Cefas) - Offshore Wind Farms: Guidance Note for Environmental Impact Assessment in Respect of FEPA and CPA Requirements (Cefas, 2004).

9.3 Data Sources

8 An extensive review of all available data was undertaken, including a gap analysis to identify any additional information that would be required. Full details of this data review and gap analysis are provided in Appendix 9.1: Data Gap Analysis and Data Review.

9 The principal data sources used in the assessment were as follows:

- The field data collected during the dedicated geophysical, ecological and metocean survey campaigns (Partrac, 2010; EMU Limited (EMU), 2010a; EMU, 2010b; Gardline, 2011). The model outputs derived from the Forth and Tay Modelling System (FTMS), developed specifically for the purpose of this assessment using the MIKE21 modelling software (DHI, 2011);
- Other existing field data, such as those held by third party organisations, including the British Oceanographic Data Centre (BODC), the Proudman Oceanographic Laboratory (POL), the British Geological Survey (BGS) and Cefas;
- The project specific scoping reports; and
- Other third party information and reports, such as Shoreline Management Plans (SMPs).

10 These data are outlined in Table 9.1.

9.3.1 Survey Methodology

11 In order to inform the baseline description of the site the following number of surveys were undertaken.

9.3.1.1 Baseline Survey

12 The baseline surveys relevant to the assessment of impacts on the metocean and coastal processes are as follows:

- Metocean monitoring survey (Partrac, 2010);
- Bathymetric, geophysical and benthic surveys (EMU, 2010a; EMU, 2010b); and
- Geotechnical survey (Gardline, 2011).

13 The geophysical and benthic ecology surveys are discussed in Chapter 8: Geology and Water Quality, and Chapter 14: Benthic Ecology.

14 The metocean campaign consisted of oceanographic monitoring equipment at four locations in the area offshore of the Firths of Forth and Tay. The campaign was commissioned as a collaboration between the Inch Cape, Forth Array and Neart na Gaoithe developers to ensure sufficient good quality data were collected to inform the studies for each development.

15 The instruments were deployed in early December 2009 at the locations shown in Figure 9.2 and detailed in Table 9.2. An additional instrument (an Acoustic Wave and Current meter) was deployed in May 2010 to provide further data. Data were collected for the following parameters:

- Current speed and direction (vertical profile);
- Wave parameters (e.g., height, period, direction);
- Meteorological parameters (e.g., wind speed, direction, humidity, temperature);
- Intermittent turbidity data; and
- *Ad hoc* water samples (subjected to total suspended solids concentration and particle size analysis) – collected at the Neart na Gaoithe location.

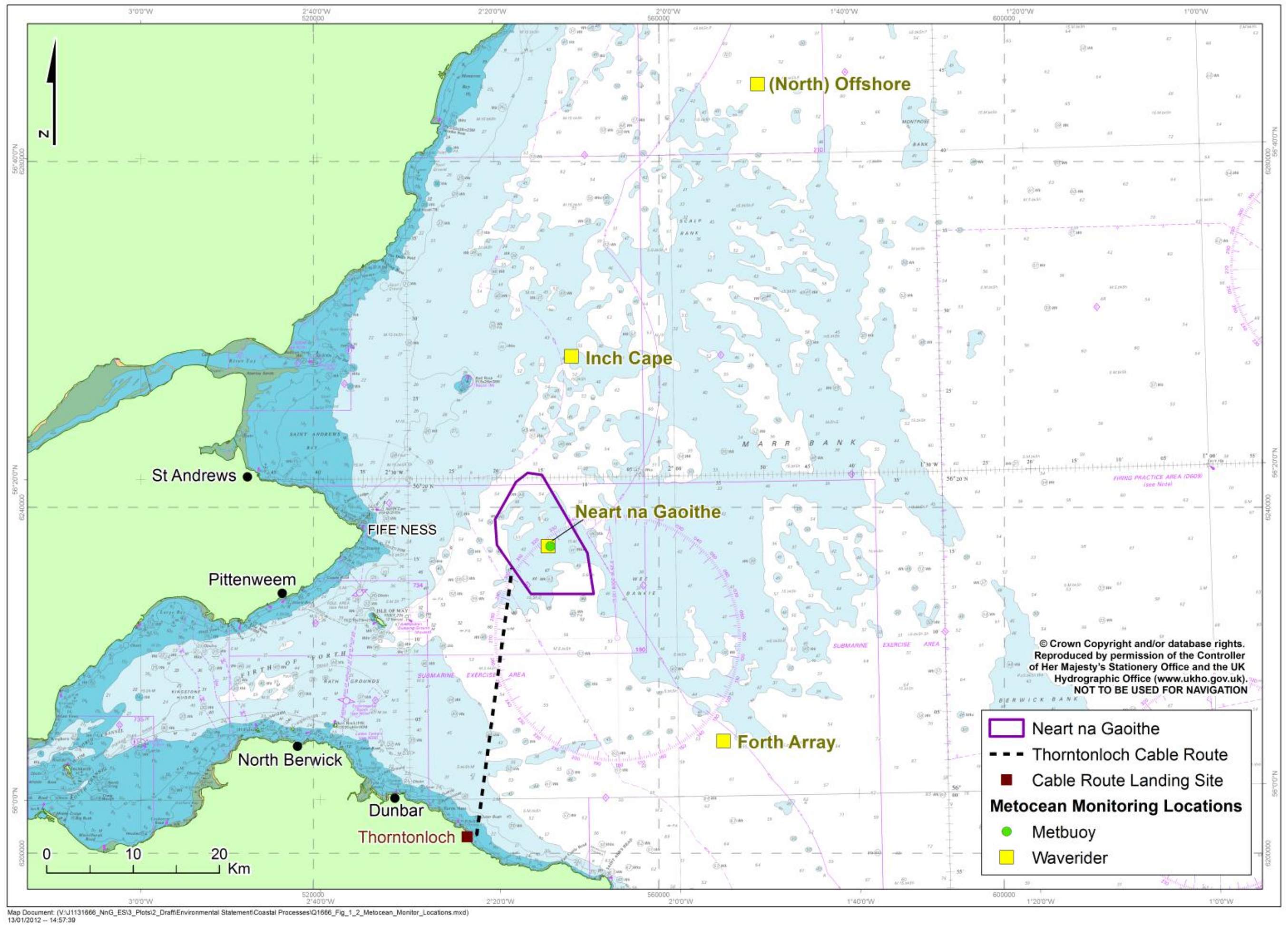

Figure 9.2: Metocean (oceanographic) monitoring locations

16 Quality control information was also collected for the Acoustic Wave and Current meter (AWAC) and Acoustic Doppler Current Profilers (ADCP) to ensure the data were robust.

Data source	Study / data name	Data theme(s)	Data location
Mainstream / REPSOL	Scoping studies.	Environmental baseline.	Offshore site and cable route.
HR Wallingford reports	Firth of Forth Water Quality Model Assessment of Field Data; Scoping Support (2009); and Various background reports (engineering and survey design).	Water quality (turbidity). Baseline description.	East coast of Scotland and at offshore site and cable route.
Mainstream / REPSOL (collected by Partrac)	Metocean monitoring survey (Partrac, 2010)	Metocean monitoring data (waves, tides, wind).	Offshore site and cable route.
Mainstream (collected by EMU)	Neart na Gaoithe Proposed Offshore Wind Farm and Cable Route Geophysical Survey (EMU, 2010b); and Neart na Gaoithe Proposed Offshore Wind Farm Benthic Ecology Characterisation Survey (EMU, 2010a).	Bathymetry, geophysical and particle size data.	Offshore site and cable route.
Mainstream (collected by Gardline)	Geotechnical survey (Gardline, 2011).	Geotechnical data.	Offshore site and cable route.
Joint Nature Conservation Council (JNCC) UK SeaMap (McBreen *et al.*, 2011)	UK SeaMap 2010 Predictive mapping of seabed habitats in UK waters (McBreen *et al.*, 2011).	Seabed habitats/landscapes.	East coast of Scotland.
Scottish Natural Heritage (SNH)	Coastal Cells in Scotland: Cell 1 St Abb's Head to Fife Ness; and Cell 2 Fife Ness to Cairnbulg Point.	Shoreline processes.	East coast of Scotland.
British Geological Survey (BGS)	Seabed Sediments, 1:250,000 series, Tay Forth, Sheet 56°N-04°W, (Graham, 1986); Quaternary Geology, 1:250,000 series. Tay Forth, Sheet 56°N-04°W, (Stoker, 1987); Solid Geology, 1:250,000 series, Tay Forth, Sheet 56°N-04°W, (Cheshire, *et al.*, 1986 and BGS, 1986); General – geology and sediment maps: Holmes *et al.* (1993); Pantin (1991); Gatliff *et al.* (1994); and Core archive; and Surface grab sample archive (www.bgs.ac.uk).	Geology, sedimentology; Sediment features; Sediment thickness; and Sediment transport.	Forth and Tay area.
UK Hydrographic Office (UKHO)	Admiralty Chart 1407; Tide Tables; and Co-tidal Charts.	Bathymetry and tidal streams; and Water levels.	East coast of Scotland.
C-MAP	Electronic chart database (C-MAP, 2007).	Bathymetry.	East coast of Scotland.
British Oceanographic Data Centre (BODC)	Data Inventory Deployments.	Current measurements; Wave measurements; and Surge data.	Various port sites.
Centre for Ecology and Hydrology (CEH)	River Statistics, UK Hydrometric Register (Marsh and Hannaford, 2008)	Freshwater Inputs.	Major rivers.
Cefas WaveNet	Data inventory.	Wave measurements.	Directional waverider information from WaveNet from 19 August 2008 at 56^{0} 11.33'N. 2^{0} 30'W.
UK Met Office (UKMO)	Data summary.	Meteorological data.	Eastern Scotland.
Coastal Councils	SMPs for Angus (Angus Council, 2004), East Lothian (East Lothian Council, 2001), and Fife (Fife Council, 2011).	Shoreline processes, coastal processes.	Tayside; Fife; East Lothian; and Angus.
Department of Trade and Industry (DTI) - Department for Business, Enterprise and Regulatory Reform (BERR)	SEA3 (Balson, *et al*., 2002), SEA 5 (Holmes *et al*., 2004) ; 2007/07 Atlas of Renewable Energy (BERR, 2008).	Regional geomarine assessment; and synoptic oceanographic parameters.	Regional.
UK Offshore Energy SEA (DECC, 2009)		Regional geomarine assessment.	Regional.
Scottish Marine Renewables SEA (Scottish Executive, 2007)		Regional geomarine assessment.	Regional.
Intertek METOC	The Forth and Tay Modelling System developed specifically for this assessment.	Coastal Processes (hydrodynamic, and spectral wave conditions, and the resulting sediment regime).	Regional and site-specific.

Table 9.1: Data sources used in the physical processes assessment

Site	Instrument	Parameter surveyed	Deployment date/time	Latitude (WGS84)	Longitude (WGS84)
Forth Array	Waverider	Wave height, wave period and wave direction.	08/12/09 13:30	56°03.433 N	001°54.964 W
Forth Array	ADCP	Water levels, current speed and direction.	08/12/09 12:25	56°03.421 N	001°55.081 W
Neart na Gaoithe	Metbuoy	Wind speed and wind direction.	10/12/09 15:22	56°15.718 N	002°14.043 W
Neart na Gaoithe	Waverider	Wave height, wave period, wave direction.	10/12/09 15:56	56°15.724 N	002°14.298 W
Neart na Gaoithe	ADCP	Water levels, current speed and direction.	10/12/09 15:31	56°15.723 N	002°14.330 W
Neart na Gaoithe	AWAC	Predominantly suspended sediment concentrations.	05/05/10 08:25	56º 15.656 N	002º 13.697 W
Inch Cape	Waverider	Wave height, wave period, wave direction.	10/12/09 13:30	56°27.539 N	002°11.422 W
Inch Cape	ADCP	Water levels, current speed and direction.	10/12/09 13:10	56°27.575 N	002°11.516 W
North Offshore	Waverider	Wave height, wave period, wave direction.	10/12/09 10:27	56°44.342 N	001°49.948 W
North Offshore	ADCP	Water levels, current speed and direction.	10/12/09 10:04	56°44.331 N	001°49.870 W

Table 9.2: Details of metocean survey locations and deployment times

Data Analysis Methodology

17 All of the metocean survey data have been quality controlled using procedures outlined in the UNESCO Intergovernmental Oceanographic Commission (IOC) Manual of Quality Control Procedures for Validation of Oceanographic Data (Commission of the European Community (CEC) *et al.,* 1993). Wave data have been quality controlled using Cefas WaveNet QA/QC procedures (Cefas, 2011) for data obtained from directional Waverider buoys via ARGOS and Orbcomm satellite telemetry. Directional data have been converted from degrees magnetic to degrees true by applying a magnetic variation correction of 3° 15’ W obtained from Admiralty Chart 1407 (Montrose to Berwick-upon-Tweed).

18 The data required for the purpose of the model construction, calibration and validation included those obtained from the commissioned surveys, together with other data from reliable third party sources. Prior to their application the data were reviewed to verify their suitability for the assessment. The review included assessments of the location and duration, the completeness, and the date and means of acquisition of the dataset. The review also included comparisons with other published information. Full details of the data review are provided in Appendix 9.3: Physical Processes Technical Report. The data applicable to the coastal processes assessment included:

- Oceanographic (water levels, current speed and direction, wave height, wave period and wave direction), bathymetric, geotechnical (particle size distributions) and geophysical (sediment layer thickness, bedforms) data of the development site from the commissioned surveys;
- Bathymetry data obtained under licence from C-MAP;
- Wind and wave hindcast data obtained under licence from the UK Meteorological Office (UKMO); and
- Tidal boundary conditions from Intertek METOC’s calibrated and validated tidal model of the North Sea.

19 The modelling assessment included the construction, calibration and validation of a hydrodynamic and spectral wave model (the FTMS) using the MIKE21 modelling software (DHI, 2011). This is detailed in full in Appendix 9.2: Hydrodynamic and Spectral Wave Model Calibration and Validation. The FTMS was used to determine any changes resulting from the developments to the oceanographic regime (meaning water levels, currents and waves but not winds), the sedimentary environment and the resulting coastal processes. In summary, the physical processes assessment included the following:

- Construction, calibration and validation of the modelling system by comparing modelled output with measured observations of water levels, current speeds and directions, wave heights, wave directions and wave periods;
- Determination of baseline (pre-development) conditions through analysis of field data, and subsequent modelling of baseline conditions using the FTMS;
- Assessment of the change to baseline conditions due to the Neart na Gaoithe development. This has been achieved by including structures in the FTMS to represent the effect of the turbines and their foundations on the hydrodynamic regime. The predicted change to conditions due to the development has been determined by subtracting the baseline scenario results from the ‘with-development’ scenario results;
- Assessment of the fate and behaviour of disturbed sediment due to any activities relating to the development, using the FTMS model;
- Assessment of the amount of scour that might result around the structures through the use of well-known empirical equations, combined with relevant sediment information obtained in the field surveys, and flow information provided by the FTMS;
- Assessment of cumulative effects from the Inch Cape and Firth of Forth developments together with the Neart na Gaoithe development by running the same scenarios but with additional structures included to represent turbines in these other development areas as well as the Neart na Gaoithe development; and
- Recommendation of appropriate mitigation measures to minimise any changes, and any suitable monitoring campaigns to ensure predicted changes are not exceeded.

9.3.2 Engagement and Commitments

9.3.2.1 Strategic and Site Level Requirements

20 There are a number of requirements and commitments made on behalf of the developer as well as recommendations provided in the form of advice through documents such as the Scoping Opinion (see Chapter 7: Engagement and Commitments). In addition to general requirements from statutory consultees and regulators, there are a number of issues more specific to coastal processes, which are detailed in Table 9.3 along with cross-references to discussion points within this chapter or wider Environmental Statement (ES).

Source	Comment	Relevance/reference
Blue Seas - Green Energy: A Sectoral Marine Plan for Offshore Wind Energy in Scottish Territorial Waters. Part A: The Plan (Marine Scotland, 2011	Assessment of the effects on water quality, including shellfish waters, hydrodynamic and water quality modelling is required at the project level.	Hydrodynamic modelling undertaken for metocean/physical processes assessment (refer to Section 9.4 and Appendix 9.3: Physical Processes Technical Report) but no water quality modelling has been undertaken. For the water quality assessment, please refer to Chapter 8: Geology and Water Quality.
	Specific impacts during construction, operation and decommissioning should be reduced through the selection and use of appropriate methods to reduce pollution risks, e.g., through the use of best practice marine construction procedures for prevention and control of spillages and discharges of harmful substances (such as antifouling agents, sacrificial anodes, biocides, grouts etc.) to the marine environment; for sediment mobilisation and associated turbidity and secondary impacts to avoid unacceptable impacts on marine and benthic fauna.	The procedures are considered within Chapter 5: Project Description. Best practice techniques will be employed to ensure sediment mobilisation is minimised.
	Assessment work is recommended to reduce current uncertainty regarding impacts on coastal processes. Sediment dynamic modelling will be required at the project level.	Assessment of sediment dynamics undertaken using the hydrodynamic and spectral wave modelling, together with an understanding of the sediment regime (refer to Section 9.4 and Appendix 9.3: Physical Processes Technical Report)
	Project design should seek to optimise the location and arrangement of structures and their arrangement to mitigate any issues of erosion or deposition and resulting impacts on sensitive receptors.	Please refer to Chapter 5: Project Description.
Scoping Opinion (SNH advice)	Advise that the scope of regional work proposed should also consider impacts of rock armouring for cable protection with regard to sediment mobility.	Potential impacts from rock armouring are likely to be low (refer to Section 9.6.1).
	An experienced coastal geomorphologist is used to assess cable route and landing site (the route of the cable through the 'wave base' needs careful consideration).	Please refer to Section 9.6.1.4 and Chapter 8: Geology and Water Quality.
Scoping Opinion (Scottish Environmental Protection Agency (SEPA) Advice)	Consultation with SEPA required for water quality issues (e.g., under Electricity Act 1989, Water Environment (Controlled Activities) (Scotland) Regulations 2005 (now the Water Environment (Controlled Activities) (Scotland) Regulations 2011)).	Please refer to Chapter 8: Geology and Water Quality.
	Baseline assessments should consider the natural variability in background parameters with regard to normal and extreme conditions, e.g., suspended solids.	Refer to Section 9.5.
	The ES should demonstrate Water Framework Directive objectives are not compromised: developments must be designed wherever possible to avoid engineering activities in the water environment (burns, rivers, lochs, reservoirs, wetlands and groundwater). A flood risk assessment is required if developments are likely to exacerbate flood risk (consult SEPA).	The water level is not predicted to change at the coast (see Section 9.6.2.3), and therefore the flood risk has not been investigated further.
	The ES should show areas of seabed affected by cabling/shore development including intertidal zone. Also consider existing coastal developments (e.g., use concept of system capacity to measure impacts to morphological conditions). Cumulative regional impacts need assessing.	The effects from the cable burial techniques have been modelled (refer to Section 9.6.1). Cumulative regional changes have also been modelled (refer to Section 9.6.2 - Impact Methodology and Appendix 9.3: Physical Processes Technical Report).
	Guidance documents to be consulted: 'A Review of the Sources and Scope of Data on Characteristics of Scottish Waters. An Assessment of the Adequacy of the Data and Identification of Gaps in Knowledge' (Robertson and Davies, 2009) and 'A Framework for Marine and Estuarine Model Specification in the UK' (Foundation for Water Research, 1993).	Foundation for Water Research (FWR) 1993 guidelines for marine model specification were used in the process of developing and calibrating/validating the FTMS.
Scoping Opinion (Royal Society for the Protection of Birds (RSPB) Advice)	Increased disturbance due to construction work and changes in the pattern of sediment transportation and deposition need to be addressed.	Modelling of changes due to the construction phase was undertaken (refer to Section 9.6.1 and Appendix 9.3: Physical Processes Technical Report).
Advice to Forth and Tay Offshore Wind Developer Group (SNH)	Advise that the scope of regional work proposed should also consider impacts of rock armouring for cable protection with regard to sediment mobility.	Potential impacts from rock armouring are likely to be low (refer to Section 9.6.1).

Table 9.3: Strategic and site level commitments and requirements – physical processes

9.3.2.2 Consultation

The proposed approach, as detailed in the Methodology Statement report (Appendix 9.4: Proposed Methodology for Metocean and Coastal Processes Assessments), was provided to Marine Scotland, the regulatory consultee and contact point for all interested stakeholders, for review. Marine Scotland collated comments from all relevant stakeholders, and provided a response to the proposed methodology, in a letter to SeaEnergy Renewables Limited (SERL – now REPSOL) and Mainstream. This letter is included in Appendix 9.5: Stakeholder Consultation. 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*."

21 However, a number of specific clarifications were requested, and these were addressed in a letter of response sent by REPSOL and Mainstream to Marine Scotland. This letter is also included in Appendix 9.5: Stakeholder Consultation. The main comments on the methodology raised by Marine Scotland and the other stakeholders have all been addressed, as summarised below:

- The identification of sensitive receptors was queried. This has been addressed since the sensitive receptors within and around the development area, and the potential impacts on these due to changes in the physical processes regimes, have been identified and considered as part of the broader Environmental Impact Assessment (EIA);
- The design and suitability of the survey campaigns was queried. This has been addressed since the targeted survey campaigns obtained sufficient information to enable construction, calibration and validation of the Forth and Tay Modelling System, and parameterisation of the baseline and inputs for the physical processes assessment. See Appendices D and E for full details;
- How the sediment regime was to be assessed was queried. This has been addressed since the study has fully considered the potential impact of the development on different aspects of the sediment regime. This includes changes to: sediment transport pathways, sources and sinks; bedforms and features (including sandbanks and sandbank stability); erosion; deposition; suspended load and suspended sediment concentrations; and bed load. See Appendix 9.3: Physical Processes Technical Report for full details; and
- A definition of "cumulative" and "in-combination" was requested. This has been addressed, and is clarified in Section 9.8.

9.4 Impact Assessment Methodology

22 Following Lambkin *et al.* (2009), the water levels, tides and waves are not considered as receptors. They are processes which may lead to a change in sediment transport, which in turn may cause an impact on sensitive bedforms or other sensitive receivers at the coast (the receptors). Consequently, a value of impact significance cannot be assigned to these parameters. However, a measure of the importance of the change to the physical process is discussed.

23 The study included the construction of a calibrated and validated hydrodynamic (HD) and spectral wave (SW) model of the area – the Forth and Tay Modelling System (FTMS). This was developed using MIKE21 (DHI, 2011) – an industry-standard modelling software package, which is identified in the COWRIE best practice guidance (Lambkin *et al*., 2009) as an appropriate modelling tool for physical processes assessments. The FTMS is described in full in Appendix 9.2: Hydrodynamic and Spectral Wave Model Calibration and Validation. The FTMS, together with field data and other relevant information, was used to assess the regional (far-field) and site-specific (near-field) characterisation of the metocean and physical geomarine environment. This allowed the baseline environmental conditions to be modelled, against which the effects and consequent changes due to each individual development, and also any cumulative effects of all developments, have been assessed.

24 The Impact Assessment Methodology follows the COWRIE best practice guidance (Lambkin *et al.,* 2009) and is in line with the approach agreed with Marine Scotland. The baseline hydrodynamic, wave and sediment regimes were modelled using the FTMS, and then changes to these regimes, in both the near and far-field due to the Neart na Gaoithe development, were quantified by modelling the same scenarios but with the development scheme included in the model. Any changes to the modelled physical processes or parameters (waves, currents and resulting sediment dynamics) were determined by subtracting the baseline (existing situation) modelled results from the 'with-development(s)' modelled results. This enabled the magnitude and spatial extent of any change due to the development(s) to be quantified. A positive difference therefore indicates an increase in the modelled parameter (for instance water level), and a negative difference indicates a reduction in that parameter. It should be noted that this technique of assessing the relative difference between two different modelled scenarios allows very small changes to be determined (i.e., at the scale of millimetres for the difference in water levels). However, this does not imply that the absolute values predicted by the model are of a similar accuracy, which is in fact in the order of 10 cm. Table 9.4 outlines all of the different potential effects that were assessed.

25 Any structures placed within the marine environment, such as the foundations for the turbines, will potentially lead to changes to the hydrodynamic regime, and the resulting sediment regime. The structures may have an effect on both near-field and far-field current and wave regimes, and consequently on the sediment dynamics, including suspended sediment and rates of scour. The FTMS uses the well-established technique of modelling these effects through the representation of structures and effects, and not explicit modelling of detailed effects. This representation within the modelling is termed parameterisation. The relevant parameters represent the effect of a particular process, such as turbulence around a structure. This approach is in line with the COWRIE best practice guidance (Lambkin *et al.,* 2009), and the parameterisation of the model for this assessment was based on the recommendations of the modelling software developers. The effect of flow around each turbine gravity base was modelled by calculating the current-induced drag force on each individual structure. The effect of the turbines and their bases on waves was taken into account by introducing a decay term to reduce the wave energy behind the structure. The details of how these effects have been parameterised, and how the proposed development was incorporated in the FTMS are provided in Appendix 9.3: Physical Processes Technical Report. All relevant potential effects on physical processes, in both the near and far-field, have been modelled at an appropriate scale for this assessment. The processes assessed, and the changes predicted are outlined in Table 9.4.

26 The parameterisation means that it avoids the need for very fine resolution Computational Fluid Dynamics (CFD). If individual processes were modelled, this would be required, and it is generally considered that such detailed analysis is not appropriate for an EIA. The COWRIE best practice guidance (Lambkin *et al.,* 2009) specifically advises against the use of CFD modelling for physical processes assessments as part of an EIA.

27 The study used different assessment techniques in order to account for all of the various temporal and spatial scales, and the different types of effect that were required to be investigated. These are summarised in Table 9.4.

Potential effect	Near-Field (NF)	Far-Field (FF)	Processes included	Changes modelled
Changes to hydrodynamics (water levels and current flows)	FTMS Hydrodynamic (HD) module (using the fine model resolution around the development site).	FTMS HD module (using the flexible resolution of the model mesh to assess over the entire model domain).	Bifurcation of flow around structures (NF); Localised acceleration of currents (NF); Change in general circulation (FF); Change in tidal symmetry, orientation (FF); and General change in energy of hydrodynamic regime (NF/FF).	Water level; and Current speeds and direction.
Changes to the wave climate	FTMS Spectral Wave (SW) module (using the fine model resolution around the development site).	FTMS SW module (using the flexible resolution of the model mesh to assess over the entire model domain).	Refraction; Shoaling; Bottom dissipation; Wave breaking; White capping; Wind-wave generation; Directional spreading; Frequency spreading; Wave-current interaction; and General change in energy of the wave regime.	Wave Height; Wave Direction; and Wave Period.
Changes to sediment regime	FTMS HD and SW modules. FTMS Particle Tracking (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 and sediment data).		Near-bed tidal currents; Near-bed wave orbital velocities; Seabed sediment size distributions; Bed shear stress; Critical shear stress for entrainment; and Sediment transport pathways.	Frequency of exceedance of critical shear stress; and Sediment transport pathways.
Fate of scoured material around foundations	Empirical scour equations plus sediment data.	FTMS PT module.	Scour around jacket legs due to acceleration of flow.	Equilibrium scour depth, scour pit dimensions, temporal evolution, volume of sediment displaced; Suspended sediment concentrations; and Deposited sediment thickness and extent.
Fate of dredged material from gravity base preparations	FTMS PT module plus sediment data.	FTMS PT module.	Dispersion and settling of discharged material due to dredging.	Suspended sediment concentrations; and Deposited sediment thickness and extent.
Fate of disturbed material during cable burying	FTMS PT module plus sediment data.	FTMS PT module.	Dispersion and settling of disturbed sediment due to cable burial.	Estimate of disturbed material volumes; Suspended sediment concentrations; and Deposited sediment thickness and extent.

Table 9.4: Summary of assessment topics and techniques applied

28 In addition, the cumulative impacts due to the other two proposed offshore wind farms in the region (Inch Cape and the Firth of Forth Round 3 Zone 2) were modelled. These developments were incorporated into the model in the same way as the Neart na Gaoithe development, by including individual gravity-base structures in an assumed array within each development site to represent a realistic high-impact scenario. The modelled turbine locations are shown in Figure 9.3.

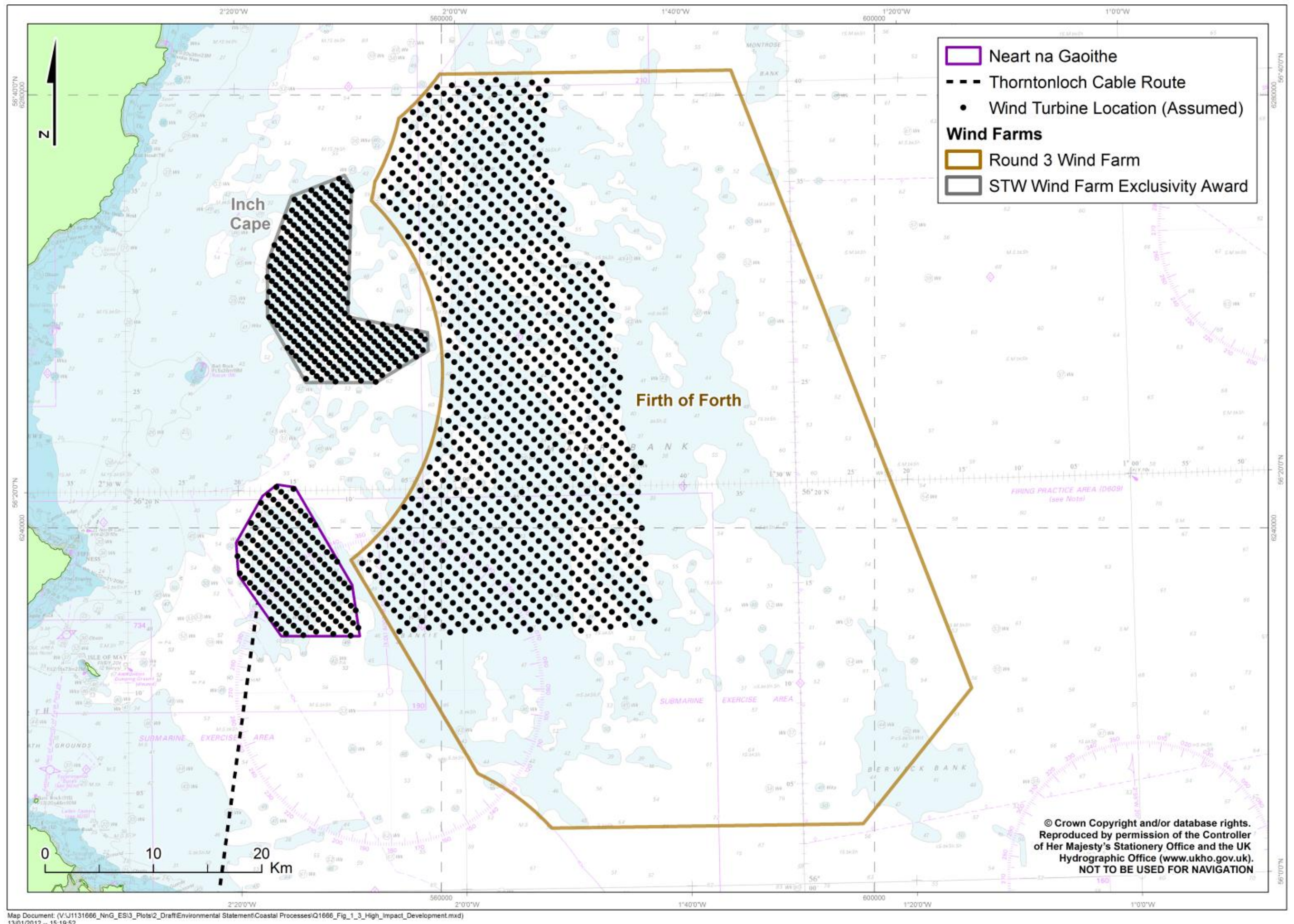

Figure 9.3: Modelled 'high-impact' development layout for the Neart na Gaoithe, Inch Cape and Firth of Forth offshore wind farm developments

29 No in-combination effects were considered, as no other industries or developments were identified as having the potential to contribute to impacts on physical processes in the region.

30 The magnitude, spatial extent and duration of the effects of the development(s) on the hydrodynamic conditions and subsequent sediment processes were quantified using the FTMS, as discussed above. The importance of the predicted changes on the parameter in question (for instance, the change to water level) was assessed on a case by case basis, based on expert judgement in placing the modelling outputs in context with the site-specific characteristics. For instance, a change in water level of 0.1 m in a water depth of 50 m might be of low or negligible importance, but a change of 0.1 m in 1 m of water depth would have a much greater importance. The magnitude of the predicted change, the spatial extent and the duration were taken into account, as well as the ambient conditions in the area of the predicted change.

9.4.1 The Rochdale Envelope

31 The detailed design of the Neart na Gaoithe development is currently not yet finalised. Therefore, in order to ensure a conservative approach to the assessment, a realistic 'high-impact' scenario was applied. This was based on the best available information at the time of the assessment (May 2011), and was aligned with the anticipated Rochdale Envelope for the design. Through discussion with project engineers, and based on previous experience, it was considered that the largest potential turbines using gravity bases would lead to the greatest impacts on the general metocean regime and subsequent sediment processes. The finalised Rochdale Envelope has since been refined for both Neart na Gaoithe and Inch Cape, and this differs to the design modelled in May 2011. The modelled parameters and the final Rochdale Envelope for the relevant parameters are provided in Table 9.5.

Parameter	Rochdale Envelope	Modelled		
	Neart na Gaoithe	Neart na Gaoithe	Inch Cape	Firth of Forth Round 3 Zone 2
Turbine capacity (MW)	7	6	7-10	6
Base diameter, DB (m)	25-45	35	50	50
Tower diameter, DT (m)	Not provided	8	8	8
Height of conical section	Not provided	34	45	45
Cross-sectional area per structure (m^2)	Not provided	859	1,345	1,345
Rotor diameter (m)	164	126	107‡	107‡
Spacing between turbines (along line) (m)	1,312	1,008	856‡	856‡
Spacing between turbine Lines (m)	820	630	535‡	535‡
Maximum spacing between turbines (m)	1,804	Not required		
Minimum spacing between turbines (m)	656	Not required		
Maximum number of turbines*	64	75*	167*	1,000*
Modelled number of turbines**	n/a	126†	328†	1,000*
Gravity base dredged material per turbine (m^3)	4,000	5,000	n/a	n/a
Export cable burial depth (m)	1 – 3	2	n/a	n/a
Inter-array cable burial depth (m)	1 – 1.5	2	n/a	n/a

*Based on awarded capacity of proposed development.
†Based on the complete coverage of the entire site.
‡Rotor diameter and spacings based on the smaller turbine, but note that gravity base dimensions are based on the larger turbine. This leads to greater overall impact.

Table 9.5: Summary of modelled parameters and finalised Rochdale Envelope

32 The modelled parameters are in line with the finalised Rochdale Envelope, and the predicted impacts reflect a reasonable 'high impact' scenario. In particular, the number of modelled turbines (126), which completely fill the development area, is nearly twice as many as the maximum number of 7 megawatt (MW) turbines that might be constructed (64), and therefore predicted impacts are generally conservative. However, it is noted that there are some differences between the modelled scenario and the finalised Rochdale Envelope, which could lead to different impacts, as follows:

- The modelled spacing between turbines is 1,008 x 630 m, whereas the Rochdale Envelope provides a minimum spacing of 656 m, which is less than one of the modelled dimensions. If the turbines with this smaller spacing had been modelled to fully cover the development area, there would be more turbines and thus a greater impedance to flow. However, this is countered by the fact that nearly twice as many turbines have been modelled as the likely maximum that would be built. If the maximum number of 64 turbines was modelled at the minimum spacing of 656 m (which would cover just part of the development area), the total impedance to flow would be less than that modelled, but it would be greater in the area of the turbines. So locally there might be slightly greater changes to the metocean climate (and thus to the sedimentological environment). There might also be greater interaction between turbines, e.g., in terms of sediment deposition footprints from scour – although the modelling undertaken suggests that such interaction will be limited even at the smaller (656 m) turbine spacing. However, as explained in Chapter 6: The Approach to Environmental Impact Assessment, the theoretical minimum of 656 m is solely to account for micrositing in specific locations and would not be applied to a block of turbines. Consequently, the model is representative of a worst case layout.
- The modelled gravity base dimension is 35 m, which is in the middle of the range provided in the Rochdale Envelope (25 m to 45 m), so this is representative but it is not the worst case. If the 45 m bases had been modelled, there would be a greater impedance to flow. However, as with the issue of the turbine spacing, the fact that 126 turbines have been modelled with 35 m bases means that the total impedance to flow is greater than if 64 turbines with 45 m bases were modelled.

9.4.1.1 Operational Impacts Scenario

33 As discussed above, it was considered by the project team that a gravity base foundation type, rather than a jacket structure, would lead to the greatest change in the hydrodynamic and sediment regime. This is due to the greater cross-sectional area which would lead to the greatest impedance to currents and waves within the water column, and therefore the greatest potential change in the sediment regime. Through calculation and discussion with Mainstream and REPSOL, it was agreed that the larger foundation (for a 6 MW turbine at the time) would lead to greater overall impact than the smaller foundation base required for a 3.6 MW turbine. Although the spacing between turbines would be slightly greater for the 6 MW turbines (1,008 m compared with 960 m), the significantly greater cross-sectional area of each of the larger bases would lead to potentially greater impacts overall.

34 In addition, owing to the fact that it is not yet confirmed which area of the proposed site will be developed, and to ensure the assessment was conservative, the layout used in the assessment assumed complete coverage of 6 MW turbines over the entire site. Using the assumed turbine spacing (1,008 m along the line and 630 m between lines), the number of modelled turbines was 126. This exceeds the maximum number of 6 MW turbines (75) based on the licensed capacity of the proposed development, and is therefore a conservative development layout. Figure 9.3 shows the layout of the modelled Neart na Gaoithe development, together with the modelled layouts for Inch Cape and the Firth of Forth Round 3 Zone 2.

9.4.1.2 *Construction Phase Impact Scenarios*

35 In preparation for gravity base foundations, the seabed will be levelled and some of the removed seabed sediment may be discharged back into the water column. 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 water depth. Additional information can be seen in Chapter 5: Project Description. At the time of the assessment, the finalised Rochdale Envelope was not available, and the dredging process, discharge volumes and discharge locations were not known. A realistic high-impact scenario was therefore undertaken to assess the fate of the dredged material. This was modelled using the FTMS Particle Tracking module, and was based on a number of assumptions and previous experience, as follows:

- A 50 m x 50 m (2,500 m^2) square area around each 35 m circular diameter gravity base would be dredged to a depth of 2 m. This provides a conservative tolerance of at least 7.5 m of prepared and levelled seabed around the edge of the gravity base. This gives a total dredged volume of 5,000 m^3 per turbine location;
- All of this material would be discharged to the water column, and this would be released at each turbine location;
- The dredging process would be on a continual basis, with the dredging of each foundation base taking 24 hours to complete, and the commencement of each new base starting immediately after the previous base. The discharge rate for the dredged material was also assumed to be on a continual basis;
- The dredged material might be discharged at any depth within the water column. Therefore two different scenarios were modelled, one with the discharge close to the sea surface, the other close to the seabed; and
- Since the spatial variation in conditions across the site was very small, in terms of the hydrodynamic regime and the sediment type and particle size distribution (as obtained from the benthic survey (EMU, 2011b)), this would not lead to any noticeable variation in the resulting impacts of suspended sediment concentration or deposition footprint.

36 Therefore, in order to determine the indicative worst case impacts that might occur at the site due to gravity base foundation preparation, two neighbouring lines of turbines (each with eight turbines) through the middle of the proposed development site were selected for the modelling. The resulting hydrodynamic changes from these two turbine rows were then translated across the whole site and any overlapping impacts were added together, to determine representative changes across the development site.

37 A representative particle size distribution (PSD) for the dredged sediment was applied. This was based on all of the sediment samples taken throughout the proposed development site during the benthic surveys (EMU, 2010a). The PSD for each sample was divided into 11 categories, or classes, based on grain size as per the Wentworth scale (i.e., very coarse gravel (largest) to mud (finest)). The classes were ranked in order of proportion for each sample, and the ranked samples were compared across the site. This established that the same or similar ranked pattern was observed at the majority of sample locations. The actual proportion in each of the 11 classes from the samples was then averaged to develop a representative PSD that was indicative of conditions across the site. A summary of the modelling inputs, including the PSD, is provided in Table 9.6 and Table 9.7. Full details are provided in Appendix 9.3: Physical Processes Technical Report.

Location	Discharge volume per gravity base (m^3)	Discharge rate (kg/s)	Discharge duration per gravity base
Mid development site	5,000	153.35	24 hours

Table 9.6: Summary of inputs for the gravity base preparation impact assessment

Sediment category	Mean grain size (mm)	Settling velocity (m/s)	%
Very Coarse Gravel	47.75	1.42	0
Coarse Gravel	24.00	1.06	0
Medium Gravel	11.94	0.80	0.08
Fine Gravel	5.93	0.55	0.22
Very Fine Gravel	3.00	0.35	0.35
Very Coarse Sand	1.50	0.20	0.54
Coarse Sand	0.75	0.10	1.97
Medium Sand	0.38	0.047	8.49
Fine Sand	0.19	0.018	48.76
Very Fine Sand	0.09	0.0054	29.50
Mud	0.03	0.0007	10.09

Table 9.7: Summary of particle size distribution information (EMU, 2010a) applied in the modelling of dredged material

38 Since the modelling was completed, the Rochdale Envelope has been finalised. Prior to confirming the disposal options, a best practicable environmental option (BPEO) will be undertaken to compare disposal on or off site. It should be noted that it has not been possible to model the potential impacts at the disposal site since the actual site has not yet been decided.

39 For the purposes of the realistic high impact scenario for the burial of the export and inter-array cables, a burial depth of 2 m and a trench width of 1 m were assumed. As described in Appendix 9.3: Physical Processes Technical Report, the trenching technique, as opposed to other cable burial methods including jetting or ploughing, is likely to lead to the greatest volume of disturbed seabed sediment. The rate of trenching depends on a number of factors, such as the vessel used, the water depth and the sediment type. A typical rate for trenching, based on practical experience of the assessment team in cable burial operations, is 400 m per hour, and a typical trench width is 1 m. For a trench depth of 2 m and width of 1 m, this equates to a maximum volume of displaced material of 800 m^3 per hour (conservatively assuming 100% liberation during trenching) (Pyrah, 2011).

40 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) along the export cable route. Three representative locations were modelled along the Torness export cable route (leading to Thorntonloch, which has been selected as the preferred cable landfall point). The modelled locations were: one close to the development site; one approximately mid-way along the route; and one close to landfall. These locations were selected based on the particle size distribution data from the site-specific environmental surveys. Since finer sediment will remain in suspension longer, it was assumed that areas with the greatest proportion of finer sediment would lead to larger plumes of suspended sediment and therefore potentially greater impacts. The specific PSD data collected during the benthic survey along the proposed cable route (EMU, 2010a) at the selected modelling locations were applied in the modelling. The chosen benthic sampling locations and the PSD applied at each location are provided in Table 9.8, and the modelling inputs are provided in Table 9.9.

Sediment Category	Mean grain size (mm)	Sample ID 99 (inshore) %	Sample ID 93 (midpoint) %	Sample ID 43 (offshore) %
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	0.19	0.00	0.00
Fine Gravel	5.93	0.10	0.00	0.00
Very Fine Gravel	3.00	0.20	0.00	0.10
Very Coarse Sand	1.50	0.28	0.01	0.07
Coarse Sand	0.75	1.77	0.02	0.70
Medium Sand	0.38	14.20	0.15	3.23
Fine Sand	0.19	47.02	0.64	43.69
Very Fine Sand	0.09	22.46	53.21	39.10
Mud	0.03	13.79	45.97	13.11

Table 9.8: Summary of particle size distribution information (EMU, 2010a) applied in the cable burial modelling

Release Location	Discharge volume per hour (m^3)	Discharge rate (kg/s)	Discharge duration	PSD sample ID
Inshore	480	353	12.5 hours (mean spring tide)	118
Midpoint	480	353	12.5 hours (mean spring tide)	122
Offshore	480	353	12.5 hours (mean spring tide)	78

Table 9.9: Summary of cable burial modelling inputs

9.4.1.3 Scour Assessment Scenario

41 For the purposes of the scour assessment, it was agreed that if gravity bases were employed as the foundation type, scour protection would definitely 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 gravity bases would 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 would be from jacket structures, and the scour assessment therefore assumed jacket structures would form the foundation type. The empirical assessment of scour around the jacket structures is detailed in full in Appendix 9.3: Physical Processes Technical Report.

42 This assessment determined that the maximum volume of scoured material from a single jacket structure (for the larger 6 MW turbine) would be 1,100 m^3, and that it would take approximately 86 days (several spring-neap tidal cycles) for the equilibrium depth scour pits to develop. The fate of the potential scoured material was modelled using the FTMS Particle Tracking module, driven by the modelled hydrodynamic regime. In order to be conservative, the maximum volume of scoured material (1,100 m^3) was released at a number of turbines in the middle of the proposed site over a 15-day period (i.e., approximately one spring-neap cycle). The same 16 turbine locations, and the same representative PSD, were used as in the gravity base foundation preparation scenario, and the material was discharged close to the seabed.

9.4.1.4 Far-Field Suspended Sediment Transport

43 In order to assess any changes to the general hydrodynamic regime, and consequently the net movement of suspended sediment from the development site, a continuous dummy discharge of a neutrally-buoyant plume of particles over a spring-neap cycle was modelled using the FTMS particle tracking module, driven by the baseline HD model. The same release was then modelled using the HD model configured with the three proposed developments in place. The outputs were compared with those from the baseline run in order to identify any changes. It should be noted that this scenario does not represent any specific discharge of sediment resulting from the development, but instead aims to identify any significant changes to the net far-field transport of suspended sediment.

9.4.1.5 Future (Changing) Climate Scenario

44 For the assessment of changes to physical processes under a different climate in the future, the UK Climate Impacts Project (UKCIP) projections of sea level rise and increased storminess (refer to Chapter 2: Climate Change and the Need for the Project) were applied to the baseline scenario. A period of 50 years from 2016 (the assumed year that construction will be completed) was used in order to determine the level of increases to sea level, extreme wave heights, and wind speeds. This is based on the expected time of completion of the development (2016), and the initial design life of the project (25 years), plus the expected extension of the life of the development through re-powering of the development (a further 25 years). The climate changes applied are summarised in Table 9.10.

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)	Present levels	+ 0.355 m
Wave height (m)	+5% (to 2055) +10% (2055-2115)	Present conditions	x 1.1
Wind speed (m/s)	+5% (to 2055) +10% (2055-2115)	Present conditions	x 1.1

Table 9.10: Projections applied in the future (changing) climate scenario

9.4.1.6 Intertidal Works

45 The nature of the intertidal works is not confirmed at this time. The preferred method is to directionally drill from the land immediately south of Thornton Burn, for a distance of approximately 1 km. This would avoid any surface ground breaking works within the intertidal area.

46 However, this procedure may not be considered feasible by the installation contractor, and therefore other methods are also being considered as described in Chapter 5: Project Description.

47 During construction, the worst case scenario is considered to be cutting through the rock in the intertidal area.

48 During operation, the worst case scenario is considered to be a surface lay of the cable, covered by rock armour.

9.4.2 The Approach to Impact Assessment

49 As stated previously, the significance of impacts on the hydrodynamic and sediment regime is not considered appropriate as this is not considered to be a vulnerable receptor (Lambkin *et al.*, 2009). However, the magnitude of the effect is assessed, as determined by the modelling in the context of the existing conditions. The importance of these changes has been determined by the expert judgement and experience of the assessment team. It is not practical to set defined threshold criteria on which the importance of a change can be categorised, since this will be dependent on the ambient conditions and the location of the predicted change.

50 The relevance of the predicted effects due to the construction, operation and maintenance, and decommissioning phases of the Neart na Gaoithe development has been determined in both the near and far-field. In addition, the cumulative effects from all three offshore wind farm developments have been assessed. To determine this, the magnitude of change has been predicted for the following parameters:

- Water level;
- Tidal currents;
- Wave heights;
- Suspended sediment concentrations;
- Seabed features (such as sandbanks); and
- Sediment regime.

51 The importance of the predicted effect has been assessed on the basis of the magnitude, spatial extent, duration and frequency of the effect, and the assessment has taken into consideration the relative scale of the predicted changes compared with the natural variability of the particular parameter in the area of change.

52 The only sensitive receptors considered in this assessment are bedforms, where the significance of impact can be determined. The impacts on coastal erosion and accretion, and water quality are discussed in Chapter 8: Geology and Water Quality.

9.4.3 Study Area

53 The regional extent for the purposes of the physical processes assessment is defined as the marine offshore region extending from St Abb's Head (Berwickshire) to Cairnbulg Point (northeast Scotland) and extending eastwards to the eastern boundary of the Firth of Forth Round 3 Zone 2. This area spatially embraces the two Scottish Territorial Waters (STW) Forth and Tay offshore wind farm sites on a scale which encompasses the potential for cumulative effects with the Firth of Forth Round 3 Zone 2. The northerly and southerly extents are defined by coastal sediment cell boundaries (Ramsay and Brampton, 2000a; 2000b). More specifically the study area is encompassed by latitudes 54.11°N to 57.72°N and longitudes 3.80°W to 0.34°E. The study area also encompasses the upper reaches of the Forth of Firth (to the Forth Road Bridge) and the Firth of Tay, and extends up to approximately 120 km offshore.

54 In order to ensure that the metocean and sediment regimes were adequately modelled, the model domain of the FTMS extends beyond the limits of the regional area – extending further up the Firth of Forth, further offshore, and further south along the English coast. This is shown in Figure 9.1.

9.4.4 Cumulative and In-Combination Impact Assessment Approach

55 For the cumulative impact assessment, the proposed Inch Cape STW and the Firth of Forth Round 3 Zone 2 offshore wind farms were also included in the model. This collaboration of the three Firth of Forth developers is known as the Firth of Forth and Tay Offshore Wind Developers' Group (FTOWDG). The same realistic 'high-impact' scenario approach was used for the layout of the Inch Cape development as for the Neart na Gaoithe development, with the assumed turbine array having complete coverage over the entire development site. This led to 328 x 6 MW turbines being included in the assessment, which is many more than the actual maximum number possible (167), based on the lease conditions. For the Firth of Forth Round 3 Zone 2 development, the larger gravity base (for the 6 MW turbine) was used, but the number of turbines was limited to the anticipated maximum number of 1,000 (based on 725 turbines for phases 2 and 3), as outlined in the Firth of Forth Round 3 Zone 2 offshore wind farm Scoping Report. Modelling complete coverage of the entire Firth of Forth zone at maximum capacity would have resulted in the inclusion of more than 3,000 turbines, which was considered too extreme and unrepresentative of worst case conditions. Since the actual location of the turbines is as yet unknown, the 1,000 modelled turbines were located as close as possible to the Neart na Gaoithe and Inch Cape sites, in order to ensure that modelled cumulative impacts are conservative. The modelled layout is therefore unlikely to be representative of the final design. The modelled 'high-impact' layout for the cumulative assessment is shown in Figure 9.3.

56 The FTOWDG has agreed to a number of commitments relating to the assessment of physical processes, and those that have been addressed as part of the physical processes are as follows:

- FTOWDG members committed to undertaking modelling of metocean conditions and coastal processes to inform project development, EIAs and to understand cumulative effects. The FTMS has been developed specifically for this purpose, and this has been applied in the physical processes assessment;
- A desk review to establish what data were available, and any gaps, was commissioned jointly by the STW and Round 3 developers. The STW developers also committed to commissioning a metocean survey and physical processes/regional modelling (Round 3 remained separate). The metocean campaign was undertaken and the physical processes/regional modelling has been completed;
- Each STW developer was assigned a copy of the regional metocean model to run a variety of scenarios, specific to each EIA; the Firth of Forth Round 3 Zone 2 project would cross-reference this in its study. The FTMS is available to Mainstream and REPSOL and any third party that they give permission to; and
- Potential cumulative effects were identified as: alteration of local hydrodynamic conditions (i.e., waves and tidal flows); changes to the sedimentary environment (e.g., suspended sediment concentrations, sediment transport pathways, patterns and rates, and sediment deposition); alteration of sedimentary seabed structures (e.g., sandbanks and other large scale bedforms); and indirect effects of the above changes on other environmental receptors (e.g., benthos, fisheries). The physical processes assessment using the FTMS has addressed the potential changes to the hydrodynamic regime and sedimentary environment, as identified, and the outputs from this assessment inform the assessment of the indirect impacts of these changes on other environmental receptors (e.g., Chapter 14: Benthic Ecology, Chapter 16: Commercial Fisheries, Chapter 19: Maritime Archaeology and Cultural Heritage).

9.5 Baseline Description

57 The existing physical environment, or baseline condition, has been described using a range of field data, existing literature and model outputs (as outlined in Table 9.1). The baseline hydrodynamic and sediment regimes on a regional basis are described in full in Appendix 9.6: Regional Baseline Description.

9.5.1 Site-Specific (Near-Field)

58 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 Neart na Gaoithe area, using the site-specific data obtained during the surveys. This analysis considered the bathymetry and sediment cover of the area, physical oceanographic processes (tides, waves and storm events), and the sediment transport regime, for both suspended sediment and bedload pathways. The full details of this analysis are provided in Appendix 9.3: Physical Processes Technical Report. The following provides a general summary of the physical processes regime for the Neart na Gaoithe site.

9.5.1.1 Water Levels and Currents

59 The seabed forms an expansive, largely level seabed plain with no dramatic changes in bathymetry or seabed slope. General water depths within the site boundary (encompassing about 105 km^2) range between 40 m and 58 m Chart Datum (CD), with a mean of 50.6 m CD (EMU, 2010b).

60 The hydrodynamic conditions do not vary much across the Neart na Gaoithe development site, with water levels and current flows being spatially uniform at each state of the tide. Relative to Mean Sea Level (MSL) water elevations range between about 2 m (High Water - HW) to -2.6 m (Low Water - LW) during mean spring tides (mean spring tidal range is thus ~4.6 m), and between about 1 m (HW) to -1.2 m (LW) during mean neap tides. Tidal elevation data have been obtained from the deployment of ADCPs (Partrac, 2010) as well as from the modelling of water levels across the study site (Appendix 9.2: Hydrodynamic and Spectral Wave Model Calibration and Validation). Water level and tidal current variation across the study site is illustrated in Figure 9.4.

61 Analysis of the field data collected during the metocean survey (Partrac, 2010) demonstrates that current speeds reach up to about 0.6 m/s on the flooding mean spring tide, and up to about 0.4 m/s on the flooding mean neap tide.

62 The field data also demonstrate that the tidal cycle has a slight asymmetry, with the flood tide dominating the ebb tide during both spring and neap tides. This asymmetry is more marked on the neap tide, when the ratio of flood to ebb current speeds is 1.3:1, compared with 1.1:1 on the spring tide. This tidal asymmetry influences the net sediment transport.

63 The semi-diurnal tide is the dominant cause of current flow throughout the Neart na Gaoithe development site. Non-tidal components of the total current are of 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 is similar in magnitude to the peak current on a mean spring tide (about 0.6 m/s) (and would be added to the tidal component). 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.

9.5.1.2 Wave Regime

64 The Neart na Gaoithe development site receives waves most frequently from a north-northeasterly direction (22.5 degrees); mean wave periods range between 2 and 9 seconds; and significant wave heights are up to about 6 m (Partrac, 2010). Waves also arrive from both the southeastern and southwestern quadrants but these form only a minor component of the wave direction spectrum.

65 The wave climate across the proposed development area is uniform, with little spatial variation in either significant wave height or mean/peak wave period. The typical range of wave conditions can be characterised by expressing the wave parameters as percentiles (%ile), where the 50%ile is that which is exceeded for 50% of the time, and the 90%ile is exceeded for 10% of the time. The significant wave height is shown to vary between 1.2 m and 1.4 m (50%ile) and 5.2 m and 5.4 m (99%ile), with the mean wave period varying between 4.5 s and 5.0 s (50%ile) and 8.5 s and 9.0 s (99%ile), and peak wave period varying between 9.5 s and 10.0 s (50%ile) and 14.0 s and 15.0 s (99%ile). Significant wave height variation across the study site is illustrated in Figure 9.5.

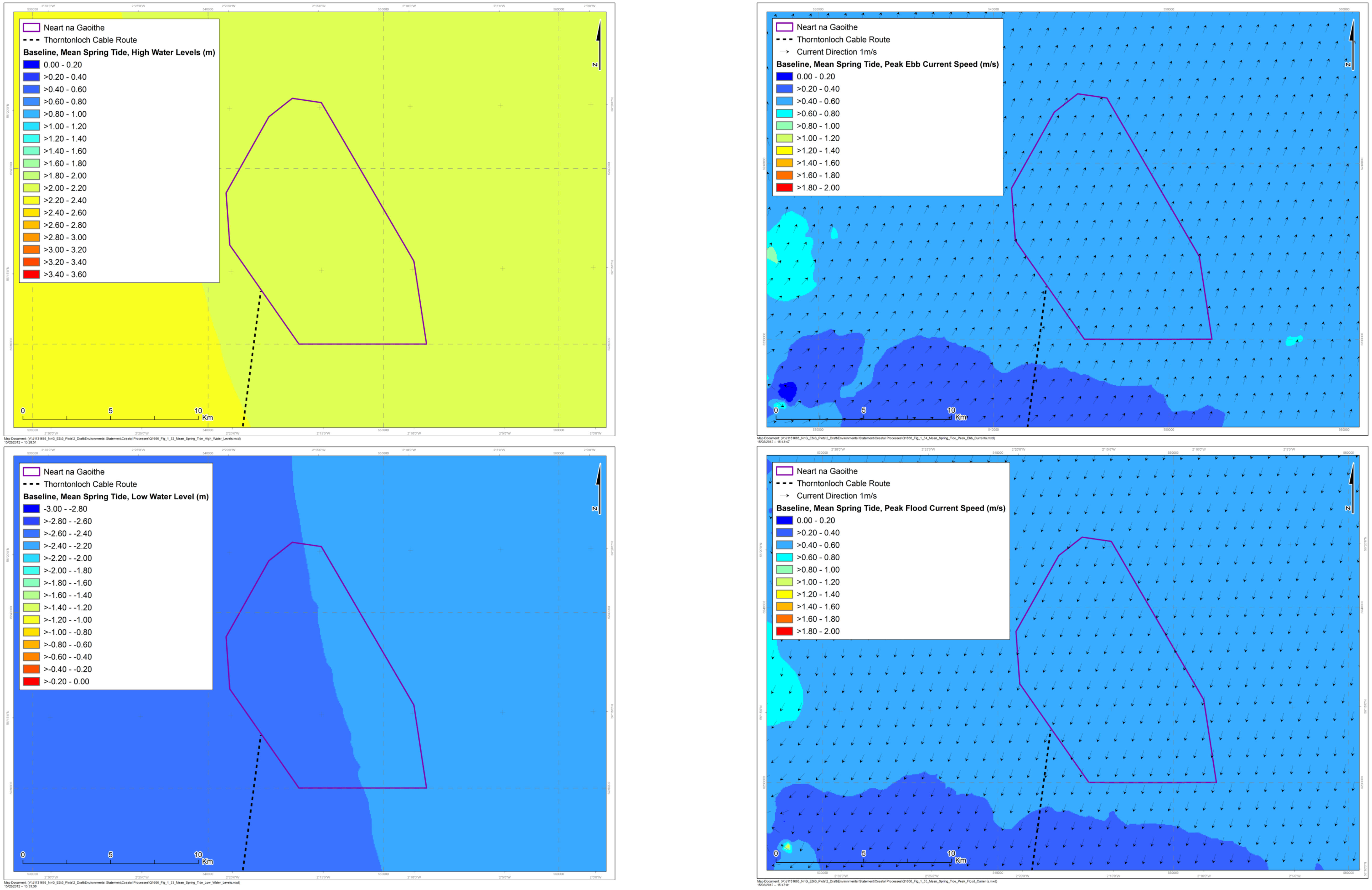

Figure 9.4: Water level (m) and current velocity field (m/s) for a mean spring tide across the Neart na Gaoithe offshore wind farm

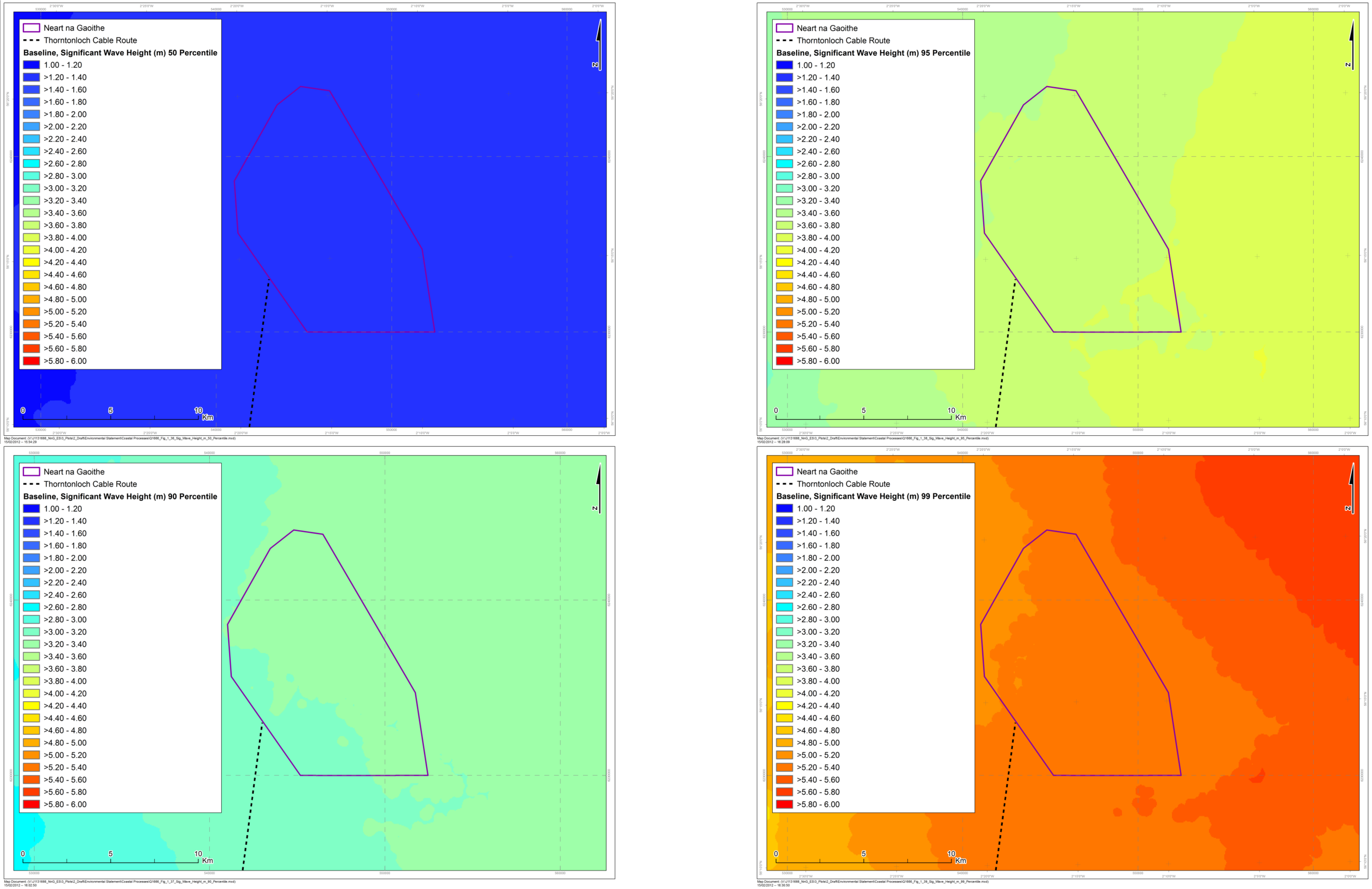

Figure 9.5: Significant wave height (m) across the Neart na Gaoithe offshore wind farm

9.5.1.3 Sediment Regime

66 The seabed across the Neart na Gaoithe development site is characterised by numerous low amplitude hummocks and mounds (over 25 mounds are present within the survey area – as shown in Figure 8.2, Chapter 8: Geology and Water Quality). The mounds are commonly up to 4-6 m shallower than the surrounding seabed at depths of 40 m to 48 m.

67 Bedforms, in a conventional sense (e.g., megaripples and sandwaves), are not found at the site, largely due to the generally weak currents. The hummock-mound features which characterise the central and southern areas of the offshore site are areas of exposed Quaternary features (post-glacial terrain) and therefore are unlikely to be dynamic sediment bedforms.

68 The sediments comprise gravelly muddy sand with boulders. Slightly gravelly muddy sand is most common across the western and southern parts of the development area where water depths are generally slightly greater. Towards the north of the offshore site the thickness of these sediments decreases and bedrock is close to the surface, where the seabed type has been classified as muddy sand with occasional rock. From the centre and to the east and southeast of the wind farm site the dominant sediment type is sand (Gardline, 2011; BGS, 1986).

69 Across the Neart na Gaoithe development site there is an almost complete absence of bedform features, except for scour features which are explicitly associated with localised flow accelerations around the seabed mound structures. Bedforms are an immediate indicator of sediment transport and therefore of a more dynamic sediment regime. Across most of the site, bedforms are not found, which suggests the site has a largely stable seabed.

70 Based on the analysis of the particle size distribution data collected at the site (EMU, 2010a), and the hydrodynamic and wave modelling, the ambient tidal current regime is not sufficiently powerful to generate significant sediment transport on either the spring or neap tidal phases. This is supported by other studies of the area (Ramsay and Brampton, 2000a; 2000b).

71 The site can be classified as 'slightly mobile' under the combined effects of waves and currents. The spatially-varying level of seabed mobility has been determined based on the amount of time that the spatially-varying total bed shear stress (as calculated from the modelled currents and waves, the measured particle size distribution (EMU, 2011b), and seabed sediment characterisation (BGS, 2012)) exceeds the spatially-varying critical shear stress (as calculated using the D50 – median particle size – of the seabed sediment; see Appendix 9.3: Physical Processes Technical Report). Since the D50 provides an indication of the typical seabed sediment size, what has been modelled is the level of general mobilisation of the seabed, and it should be noted that there will be individual particles that are smaller or larger than the D50 which will be mobilised more or less often.

72 Over the greater extent of the central and southern parts of the proposed Neart na Gaoithe development site, the exceedance of critical shear stress, is 5-10% (i.e., seabed sediment will generally be mobilised between 5 and 10% of the time). To the north of the site, down the eastern periphery, and at an area to the southwest of the site, sediments are mobilised for up to 10-15% of the time. Only storm conditions with waves in excess of 5.2-5.4 m significant wave height, and a mean wave period of 8-8.5 s are predicted to mobilise the fine sands and muddy sands sediments across the site, and such conditions have a return period of 1 in 10 years or more (meaning those conditions will typically only occur once every 10 years at most). Gravels are predicted to be mobilised under extreme, infrequent storm events. The baseline critical shear stress for the region is shown in Figure 9.6, and that for the Neart na Gaoithe area is shown in Figure 9.7. This is based on the sediment size as described in Section 9.4.1.2. Exceedance of the critical shear stress due to combined wave and current forces is shown in Figure 9.8 (which shows exceedance due to the mean combined wave and current bed shear stress over a wave cycle) and Figure 9.9 (which shows exceedance due to the maximum combined wave and current bed shear stress, resulting from the peak wave orbital velocities at the bed).

73 Based on analysis of the field data in the middle of the study site, at 56°15.656' N 002°13.697' W (EMU, 2010a; Partrac, 2010), and on the hydrodynamic and wave modelling, fair weather suspended sediment concentrations are very low (< 10 mg/l) and comprise predominantly silts. Concentrations are expected to rise generally across the study area only during storm conditions.

74 Based on analysis of the field data (EMU, 2010a; Partrac, 2010) and the hydrodynamic and wave modelling, under the existing conditions, large scale (vertical) changes to general seabed level due to seabed erosion or deposition, are not anticipated, except during storm surge conditions.

75 Based on analysis of the field data (EMU, 2010a; Partrac, 2010) and the hydrodynamic and wave modelling, a net directional (suspended) sediment transport in the direction of the flood tidal axis (south to south-southwest) exists, but residual tidal transport of suspended fine sediments is not judged to be significant on an annual basis.

76 Based on analysis of the field data (EMU, 2010a; Partrac, 2010) and the hydrodynamic and wave modelling, tidal bedload transport is not considered to occur, except in the vicinity of mound structures; wave-driven bedload transport may occur during storms but is not significant.

9.5.2 Cable Route

9.5.2.1 Water Levels and Currents

77 There is little spatial variation in hydrodynamic conditions throughout the region, and tidal range and tidal currents are fairly uniform along the selected Torness cable route. Similar hydrodynamic conditions (water levels and currents) as described for the proposed site will be experienced along the cable route., other than as the route approaches landfall, where the water depth will be reduced (see Figure 9.10).

9.5.2.2 Wave Climate

78 There is little spatial variation in the wave regime throughout the region, and significant wave heights, directions and periods are fairly uniform along most of the cable route. Wave heights do however diminish as the route approaches the coast (see Figure 9.11). The depth of the wave base (i.e., where wave motion is no longer detectable) along the cable route for mean annual wave conditions is ~ 6-8 m. The depth of the wave base (h) was determined using the criteria $h > 0.01T^2$ and $h < 10Hs$, where T = wave period and Hs = significant wave height, as given in Soulsby (1997).

9.5.2.3 Sediment Regime

79 The main sediment type along the Torness cable route is slightly gravelly muddy sand. Evidence of sediment mobility in the form of small dunes is apparent at locations along the route. The thickness of the soft-sediment cover ranges from 37 m-43 m but both rock and Wee Bankie Formation variously outcrop along the route.

9.5.2.4 Intertidal Region

80 The proposed cable transition pit is to the south of the Thorntonloch Burn. Therefore the cable would run offshore from this location to meet with the offshore cable. A potential area for this corridor is shown in Figure 9.12.

81 The shore area is sandy, but the depth of this sand has not been determined. A site visit (Engineering Technology Applications Ltd (ETA), 2011) identified a 1 m erosion feature below the high water mark, indicating that the sediment along the beach is mobile to some extent. However, the shoreline features do not indicate excessive along shore movement of sediment. The exact nature of the mobility of the sediment will need to be determined prior to construction works.

82 Within the intertidal area the sand is replaced by boulders and sand, and, then near low water, bedrock. This suggests that the sediment depth is not great, and that bedrock is relatively close to the surface. To the north is a rocky reef feature which protects the beach from northerly waves.

83 The geophysical and benthic surveys (EMU, 2010a; 2010b) identified bedrock in the nearshore area and approximately 1 km offshore. Measurements in between suggest the bedrock is present throughout this area, but this has not been confirmed with site data.

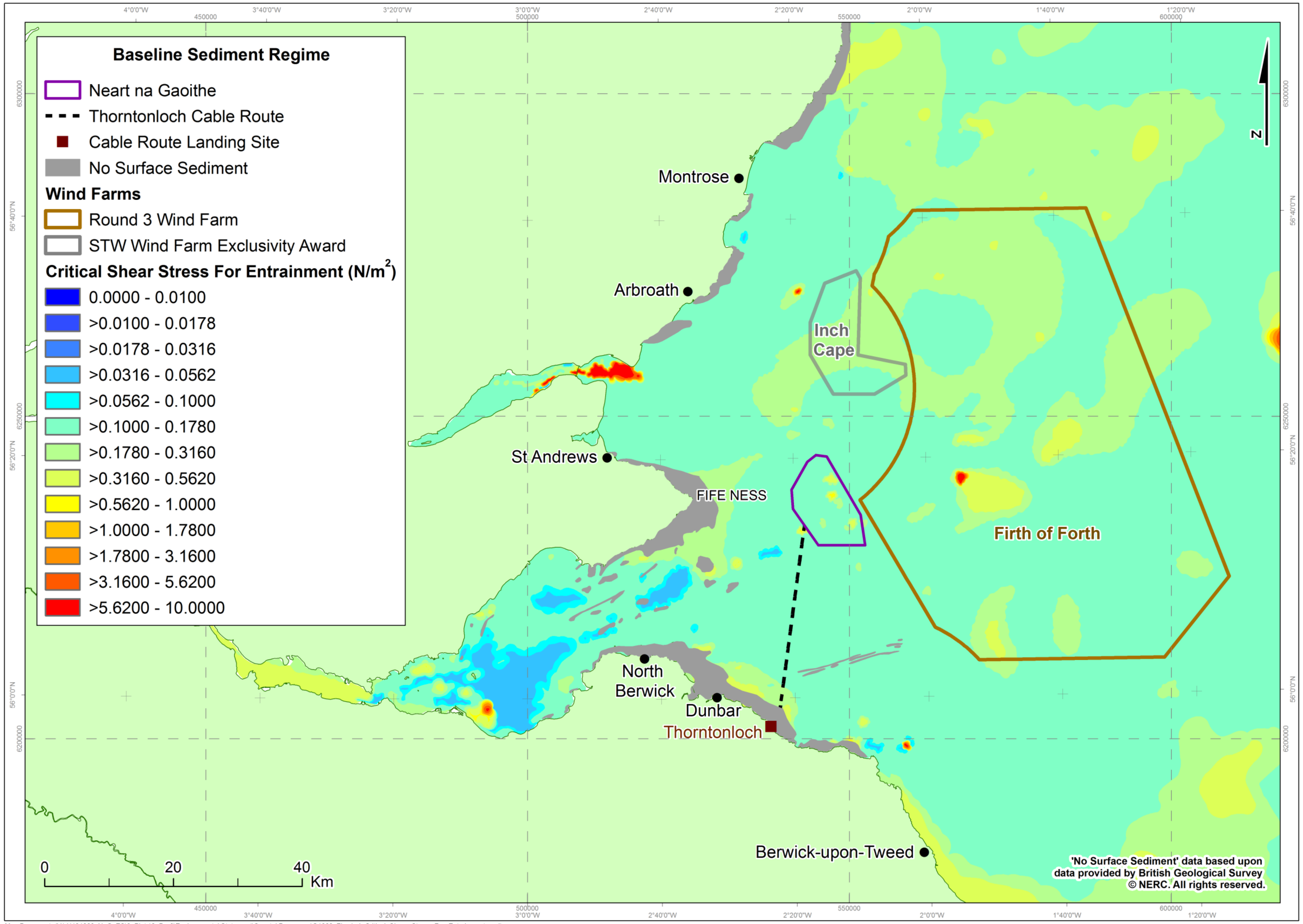

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Figure 9.6: Critical shear stress for entrainment (N/m^2) – regional (far-field) scale

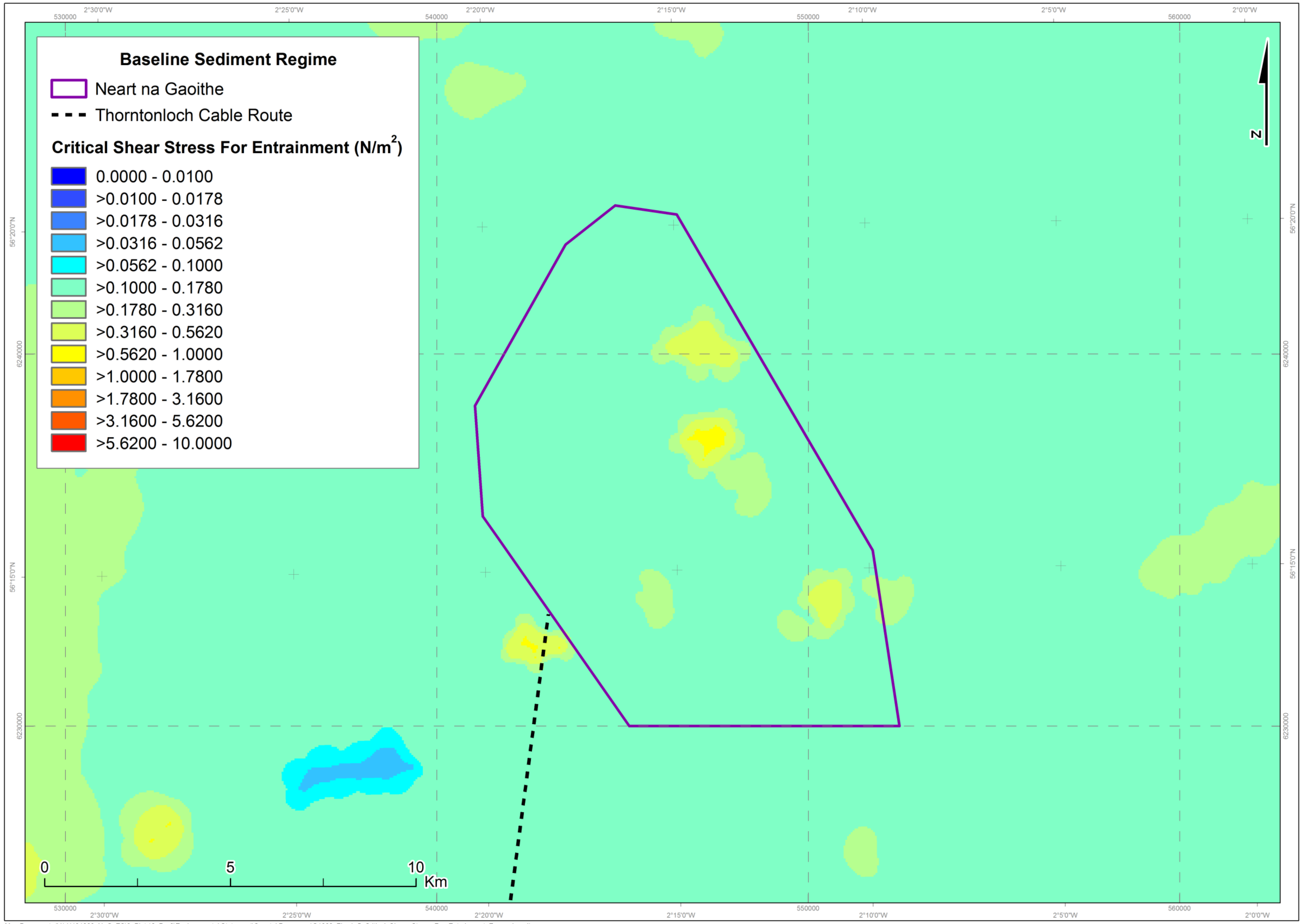

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Figure 9.7: Critical shear stress for entrainment (N/m^2) – Neart na Gaoithe offshore wind farm (near-field) scale

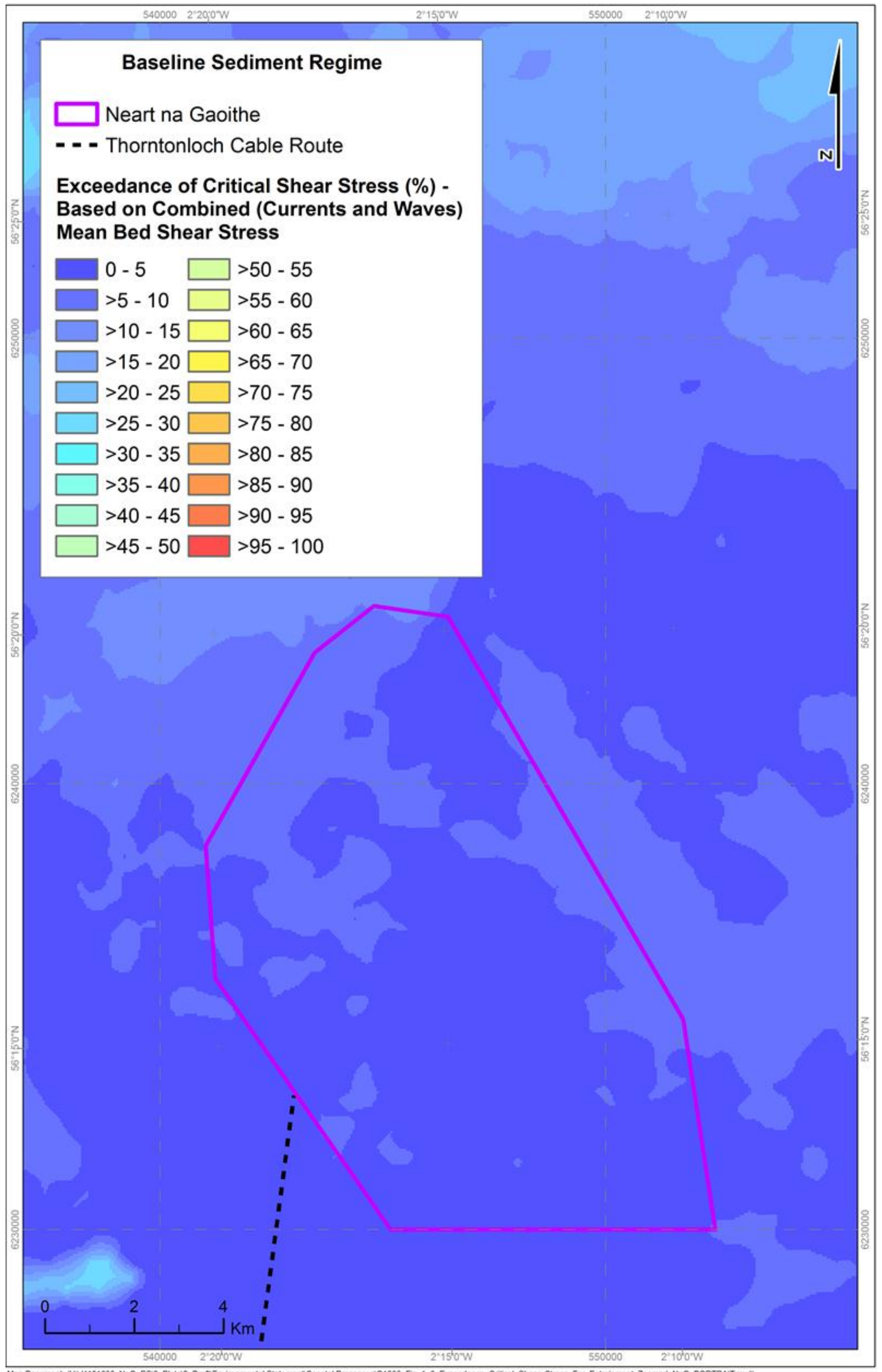

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Figure 9.8: Baseline exceedance of the critical shear stress for entrainment (%) due to mean combined bed shear stress at the Neart na Gaoithe site

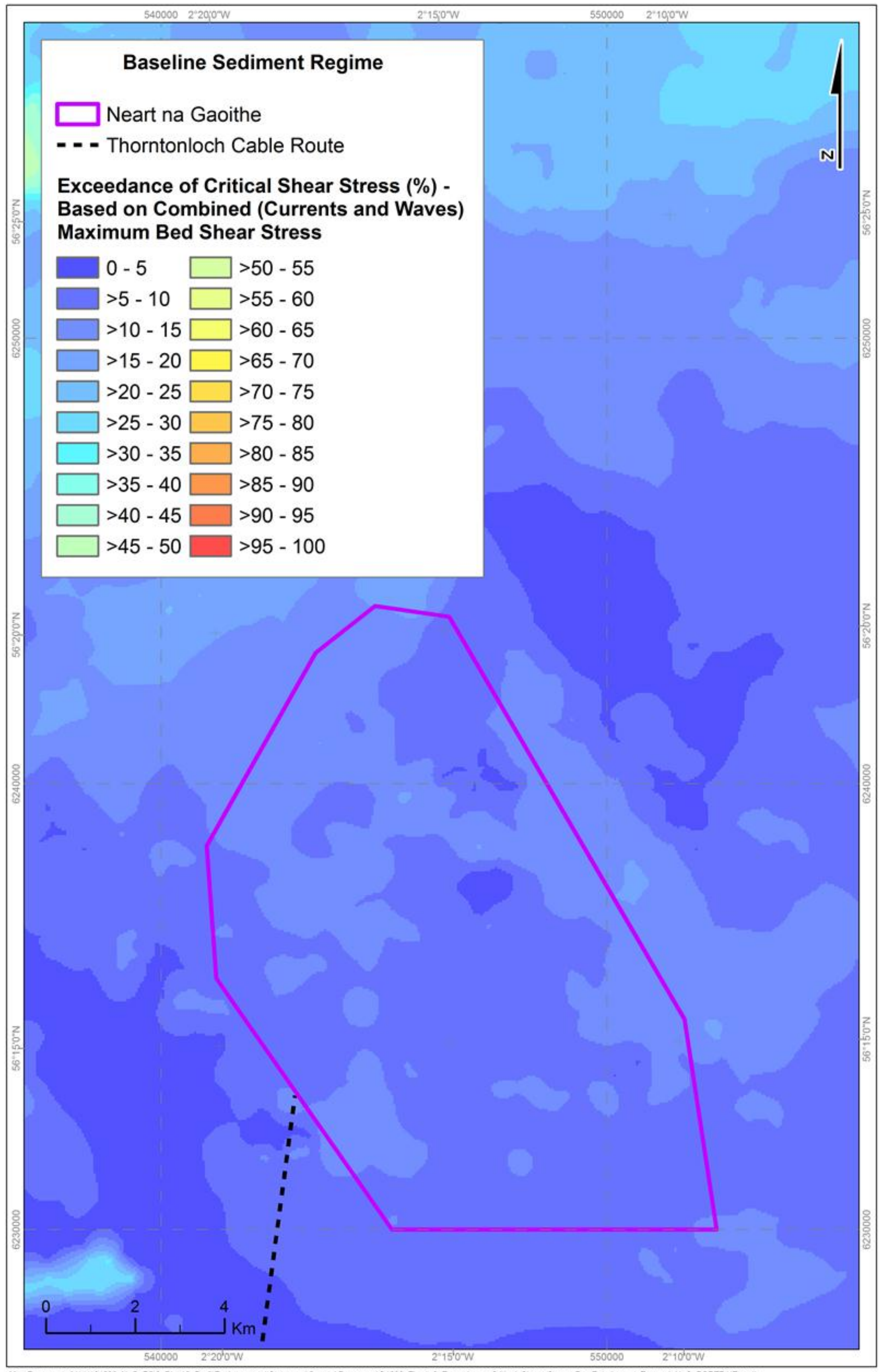

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Figure 9.9: Exceedance of the critical shear stress for entrainment (%) due to maximum combined bed shear stress at the Neart na Gaoithe site

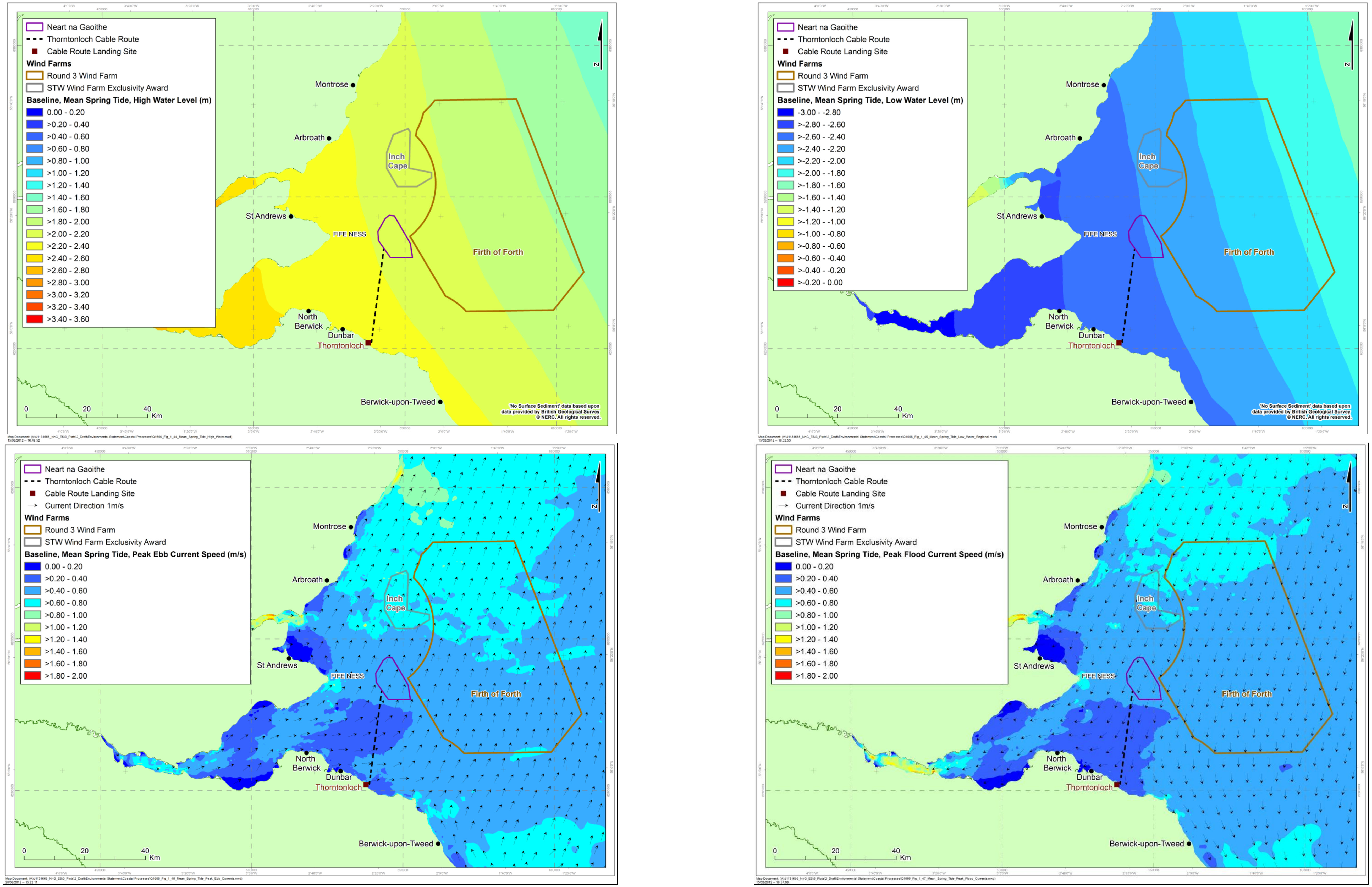

Figure 9.10: Regional water level (m) and current velocity field (m/s) for a mean spring tide across the Outer Firths area from the FTMS

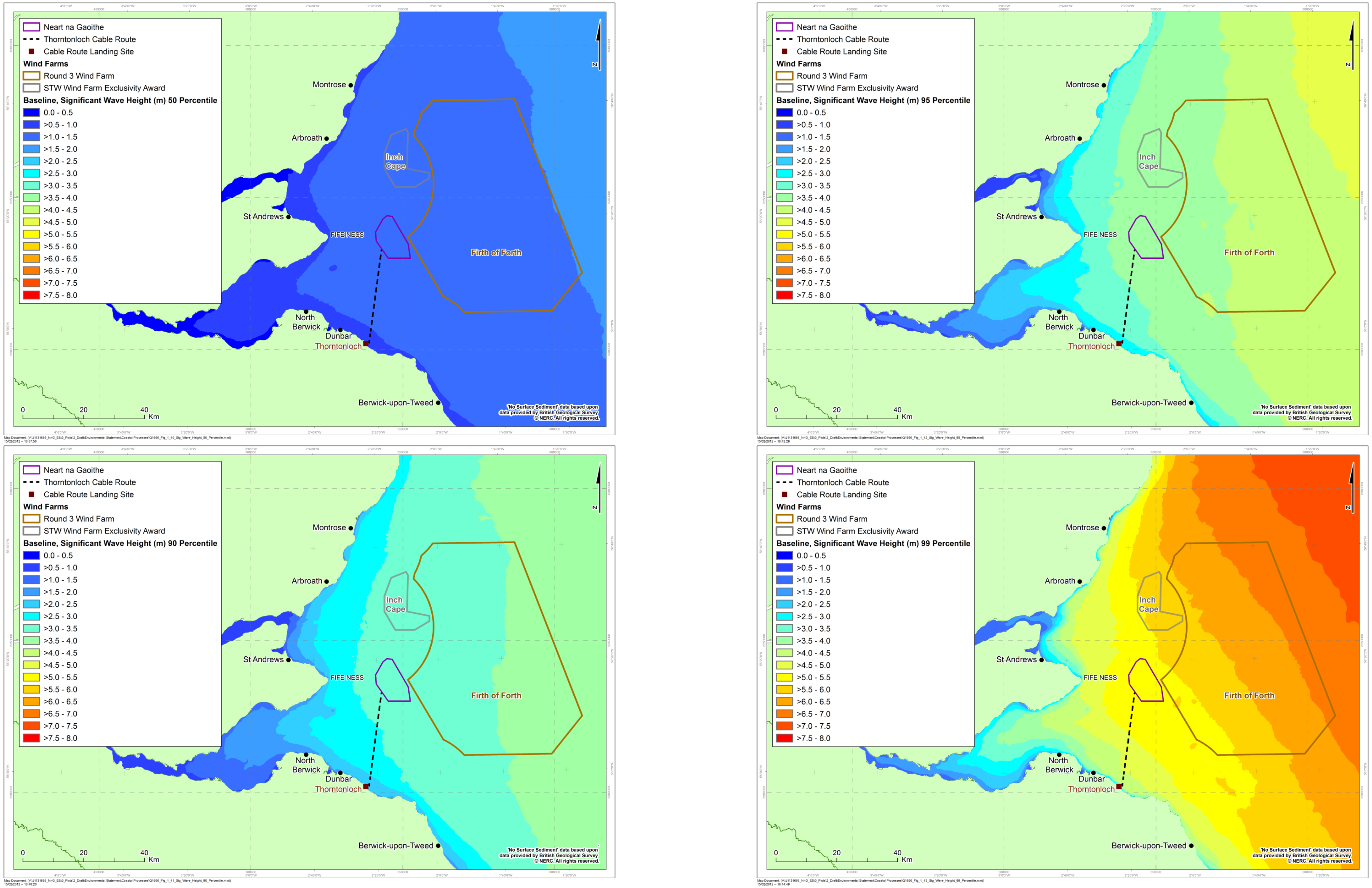

Figure 9.11: Regional significant wave height (m) across the Outer Firths area from the FTMS

84 Figure 9.12 shows the habitats within the intertidal area. From the land to offshore, the cable is likely to go through the following habitats:

- Mobile sand;
- Coarse sediment;
- Sand scoured rock; and
- Scattered boulders.

85 A nominal offshore cable point is shown on Figure 9.12, within the scattered boulder area, but this will be confirmed with a site survey prior to construction. If direction drilling is used, it is likely that the exit point will be further offshore (approximately 600 m from the shoreline).

86 Figure 9.12 also shows the bathymetry data that were collected during the geophysical survey (EMU, 2010a). Due to the shallow nature of this area, a full survey could not be completed. However, the tracks show that the depth gradually increases offshore, reaching approximately 5 m depth below CD at 700 m from the shoreline.

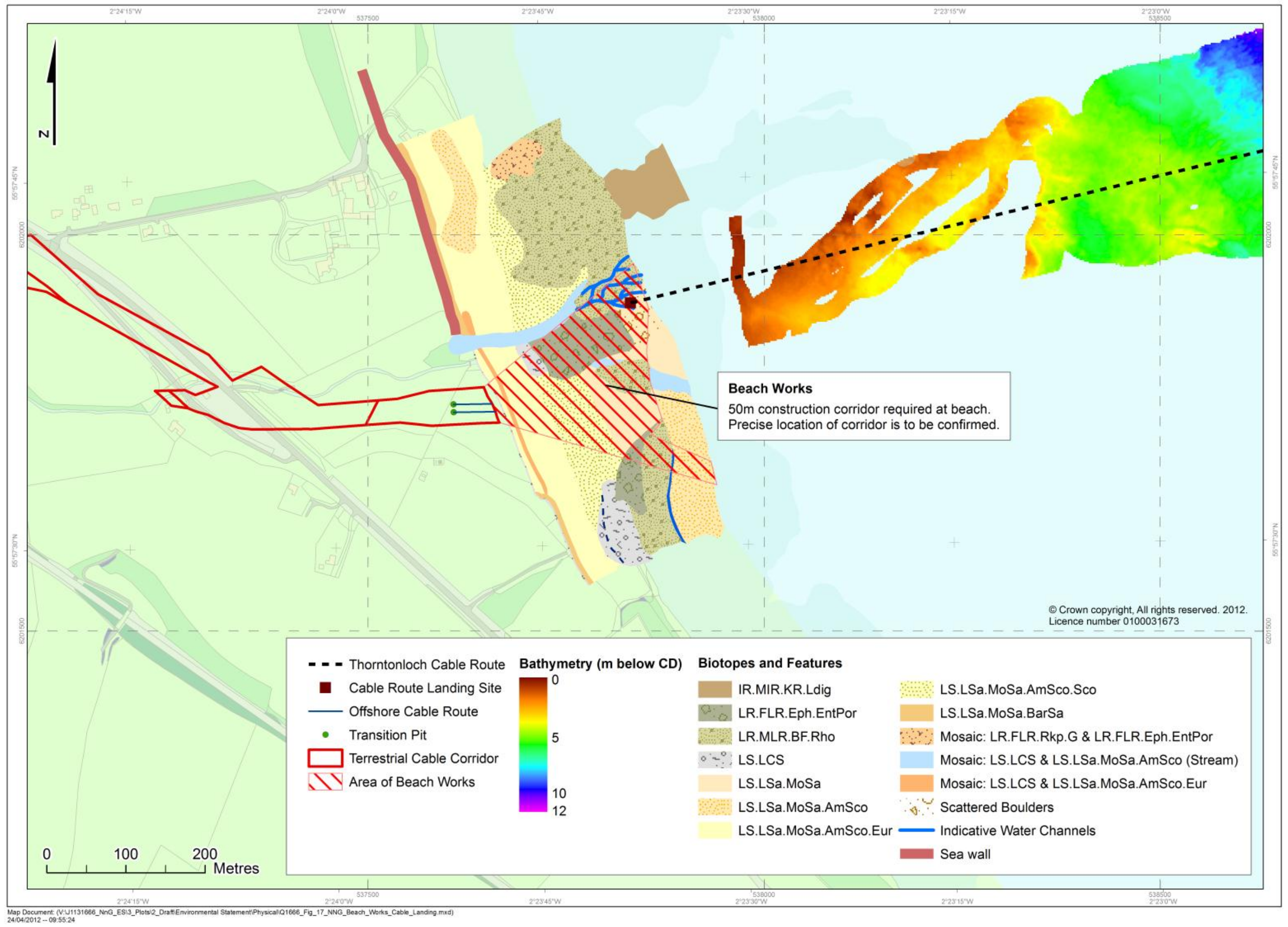

Figure 9.12: Intertidal area

Note: Please see Chapter 14: Benthic Ecology for an explanation of the biotope terms

9.6 Impact Assessment

87 Full details of the impact assessment, including all relevant plots showing the magnitude and spatial extent of predicted impacts, are provided in Appendix 9.3: Physical Processes Technical Report. However, representative plots are provided with this chapter.

88 The assessment is divided into the site-specific, or near-field assessment, and the regional, or far-field assessment. As per the COWRIE best practice guidance (Lambkin *et al.*, 2009), the near-field study considers the interaction between structures and the effect of the development within the site perimeter, whereas the far-field study considers the general effect of the development as a unit on the surrounding area. The far-field study also includes the assessment of cumulative effects from the Inch Cape and Firth of Forth Round 3 Zone 2 developments.

9.6.1 Impact Assessment – Construction

9.6.1.1 Water Levels and Currents

89 The effects on the hydrodynamic regime (water levels and currents) due to the construction phase at both the site and along the cable route 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 such equipment is assumed to be negligible, based on the fact that the equipment will be localised and temporary, and of a similar scale to any effects resulting from regular passing vessels. These effects will last for the duration of construction; but, at any one location, the vessel and equipment are only likely to be in place for 2-4 days, for instance while installing a pile. On this basis, and the fact that the modelled cumulative effects from the operational phase of the developments are also negligible, it is the considered opinion of the assessment team that no cumulative effects would result, even if several installation operations (i.e., cable burial and foundation preparation) were to occur simultaneously.

90 Based on the relevant field data, the modelling undertaken and the judgement of the assessment team, it is therefore considered that the overall effect of the construction phase on the water levels and currents, in both the near-field and far-field, will be ***negligible***.

9.6.1.2 Wave Climate

91 The effect of the construction phase on the wave climate at both the site and along the cable route 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 at one location at a time for short periods of time, and therefore any changes associated with the construction activities on the wave climate are assumed to be negligible, based on the fact that these will be localised and temporary, and of a similar scale to any effects resulting from regular passing vessels. These effects will last for the duration of construction; but, at any one location, the vessel and equipment are only likely to be in place for 2-4 days, for instance while installing a pile. In addition, it is very likely that the installation of the wind farm will need to take place during more quiescent wave conditions, as operations will not be possible when more extreme waves are present. Changes in the wave climate due to the presence of installation equipment are lower for smaller waves.

92 Based on the relevant field data, the modelling undertaken and the judgement of the assessment team, it is therefore considered that the overall change in the wave climate due to the construction phase, in both the near-field and far-field, will be ***negligible***.

9.6.1.3 Sediment Regime

93 The discharge of dredged sediments during the preparation of gravity base foundations will lead to elevated concentrations of suspended sediment (with very localised peaks up to 300 mg/l), but the resulting plumes will not be advected beyond the immediate vicinity of the development site, and they will settle out within 1 day of discharge. (This prediction is based on the original assumption that dredged sediments will be discharged at site.) The resulting deposition footprint is likely to cover the development area with varying thickness, generally between 1 mm and 10 mm, and with peaks between 30 mm and 300 mm. The predicted deposition footprints

from the sea surface and the near seabed discharges of dredged material at the site are shown in Figure 9.13 and Figure 9.14.

94 It is therefore considered that the effect of the construction phase on suspended sediments will be relatively high (significantly greater than ambient concentrations), but that this effect will only last for the duration of the dredging phase (between 2 and 4 days at each turbine location) with concentrations returning to ambient conditions very quickly. The resulting deposition of dredged material will remain within the local vicinity of the development site. The change in the near-field is therefore predicted to be ***low***, and the change in the far-field is predicted to be ***negligible***.

95 Bedforms are the only receptors considered within this chapter (see Chapter 8: Geology and Water Quality for coastal and water quality receptors). As the bedforms within the offshore site are not active, the vulnerability is assessed as ***low***. As the dredged sediment is very similar to the disturbed sub-surface sediment, and the deposition would form a relatively thin layer (if discharged at the site), the impact on the bedforms is considered to be of ***minor*** significance. Some resuspension may occur, but again the sediment is similar to the surface sediment, and it is also unlikely over such an area that changes in total suspended solid concentrations would be evident. Moreover, the timescales for foundation preparations are relatively short, and therefore no long term impacts would be seen.

96 There will therefore be ***no impact*** at the development site from the discharge of dredged material into the water column. It should be noted that it has not been possible to model the potential impacts at the disposal site since the actual site has not yet been decided.

9.6.1.4 Cable Route

Water Levels and Currents

97 As discussed in Section 9.6.1.1, the effects on the hydrodynamic regime (water levels and currents) due to the construction phase along the cable route are assumed to be negligible, based on the fact that these will be localised and temporary, and of a similar scale to any effects resulting from regular passing vessels. These effects will last for the duration of construction, but the cable laying barge will not remain in any one place for a sustained duration, since it will be moving at a rate of 400 m per hour (approximately 10 km per day). Based on the field data, the modelling undertaken and the judgement of the assessment team, it is therefore considered that the overall change to the hydrodynamic regime during the construction phase along the cable route, in both the near-field and the far-field, will be ***negligible***.

Wave Climate

98 As discussed in Section 9.6.1.2, the effects on the wave climate due to the construction phase along the cable route will be very small, localised and temporary. It is therefore considered that the overall change to the wave climate due to construction activities along the cable route, in both the near-field and the far-field, will be ***negligible***.

Sediment Regime

99 The process of cable burial might lead to very localised increases in suspended sediment concentrations (with peaks up to 30 mg/l above background concentrations, which are typically < 10 mg/l), but the resulting plumes will not be advected beyond the near-field vicinity of the cable (< 5 km), and will settle out within a few hours of disturbance. The resulting deposition footprint will be within 2 km either side of the cable route, and will be very thin (typically < 0.1 mm, with peaks up to 3 mm). The predicted deposition footprints at the three modelled locations along the route are shown in Figure 9.15, Figure 9.16, and Figure 9.17. The modelled deposited thickness is very thin and would be difficult to measure in the field. Such a negligible and localised impact will therefore not affect the ambient sediment regime, especially given the fact that the deposited material will be very similar to the surface sediment. The change in the sedimentary environment, in both the near-field and the far-field, is therefore considered to be ***negligible***.

100 The only sensitive receptors considered within this physical processes chapter are bedforms. However, as the geophysical survey (EMU, 2010b) did not identify any mobile bedforms along the cable route, these are not judged to be present. Consequently, there is no source-pathway-receptor chain, and therefore no impact to be assessed. It should be noted that no indirect effects on other environmental receptors have been assessed within this chapter. For impacts on the coast and water quality, please refer to Chapter 8: Geology and Water Quality, and for other potential receptors, Chapter 14: Benthic Ecology and Chapter 19: Maritime Archaeology and Cultural Heritage.

101 Although it is assumed that the export and inter-array cables will be buried for protection, there is the potential requirement to use rocks for protection where cable burial is not possible, although this has not been modelled at this stage. Rock protection is a common practice, and an assessment is generally undertaken to determine a stable rock size for the oceanographic conditions expected along the cable route (these may vary as wave exposure increases into shallower waters). Since the rocks would be substantially larger than the surrounding sediment along the export cable route, scour may occur around the periphery of the rock mound, a phenomenon termed 'secondary scour'. Rates of secondary scour are typically very low, highly localised, and in the form of a strip running adjacent to the rock mound. Greater secondary scour rates might be expected in the shallowest part of the cable route, where sediment resuspension by waves ordinarily occurs. This can be prevented either by placement of a fine gravel filter layer next to the rocks, or through use of an anti-scour apron. The former is more widely used. Where the cable cannot be buried, and rock armouring is required, scour may therefore occur. A detailed study will be undertaken to ensure the rock is graded to minimise scour once the final cable route and laying methods have been determined.

Intertidal Region

102 Due to the uncertainty of the exact nature of the seabed out to 1 km the installation techniques have not been determined. Consequently, several techniques are being considered:

- Horizontal directional drilling under the shore and intertidal area to approximately 1 km offshore;
- Open cut trenching in the sand as far as possible and then laying the cable on top of the bedrock and protecting it with rock armour or a split (articulated) pipe; and
- Open cut trenching in the sand as far as possible and then cutting into the bedrock to lay the cable, then infilling the cut trench afterwards to ensure the cable is protected.

103 The absence of known parameters has led this to be a qualitative assessment only, and therefore should be refined with further studies once the installation contractor has been determined and the preferred methods agreed, post-consent.

104 As explained in Chapter 5: Project Description, directional drilling would be undertaken from onshore, a duct would be drilled to approximately 600 m offshore and then the cable pulled through. The only structure offshore will be a jack-up rig to oversee the breakthrough of the seabed, and the pull through of the cable. This structure will be temporary. Consequently, the change to the hydrodynamics is considered negligible.

105 There is a slight chance that the drilling lubricant (bentonite, an inert substance) might be released at the end of the bore, when the drill breaks the surface. However, the bentonite will be within a closed system for the majority of the drilling process, with the arisings being stored in a suitable container onshore. The location of the drill bit will be monitored so that the operators are aware when it will break the surface, and will take precautions to minimise any loss. This is discussed further in Chapter 8: Geology and Water Quality.

106 Of the other two options for installation, cutting into the bedrock is considered to be the worst case. It may be necessary to cut into the bedrock for up to the 10 m contour, which is approximately 1 km offshore. This installation process could take up to 3 months. In this time, a safety zone of 50 m centred on the cable laying would be enforced. A jack-up vessel would be used to undertake the cutting and infill.

107 The jack-up may cause local interference to the currents and waves, but the temporary nature of the construction means that the change is predicted to be negligible.

108 Cutting of the bedrock may cause dispersion of the overlaying sand veneer and fine rock cuttings. The suspension of the sand will be short-lived and rapidly return to background levels, as this is a dynamic environment with sand as the natural seabed. The small amount of rock cuttings released is expected to disperse rapidly, and become part of the background sediment. The temporary nature of the change and rapid incorporation into the background suspended sediments means the change is predicted to be low.

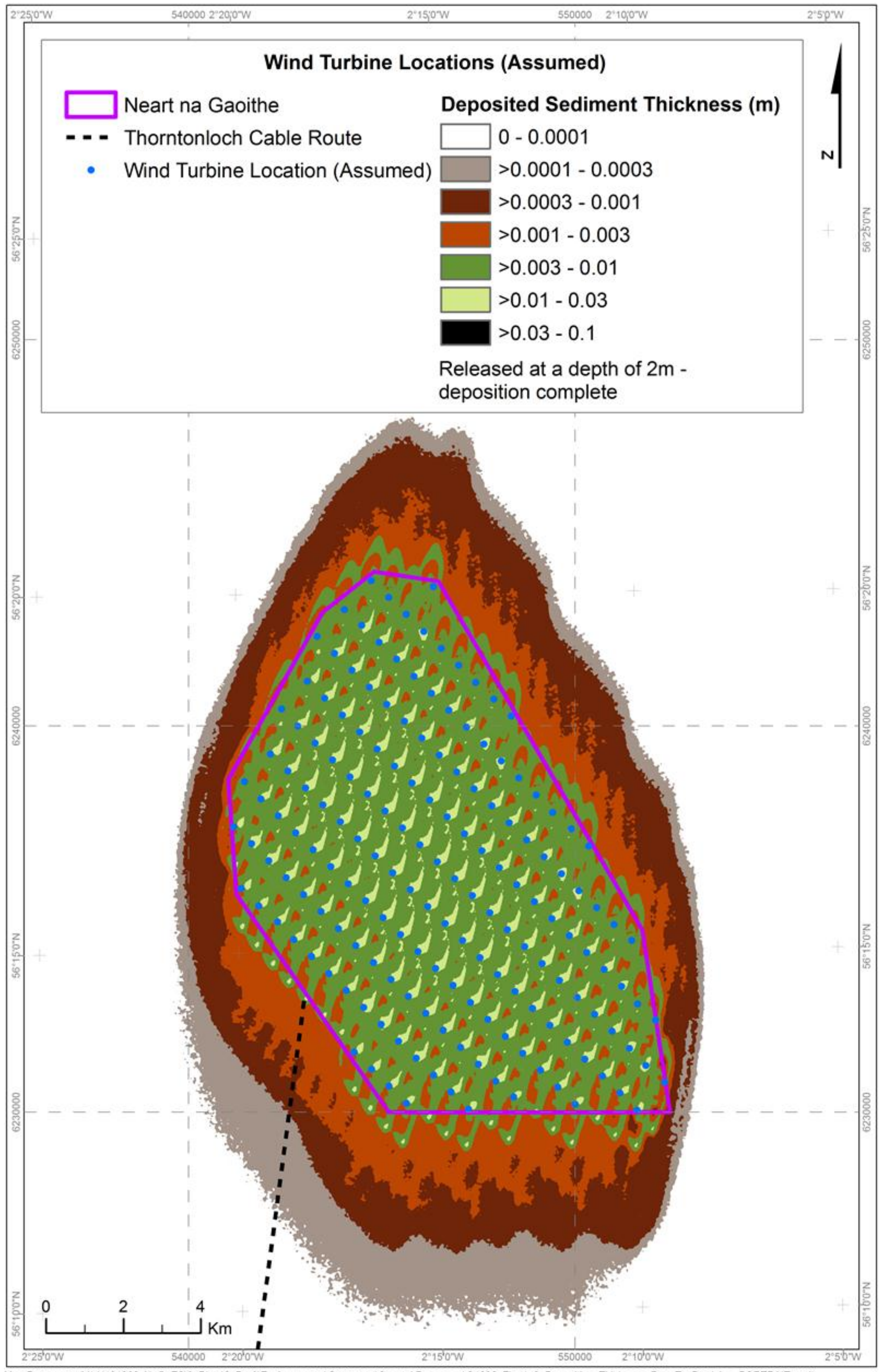

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Figure 9.13: Deposition thickness due to dredging (sea surface release) – after all material has settled

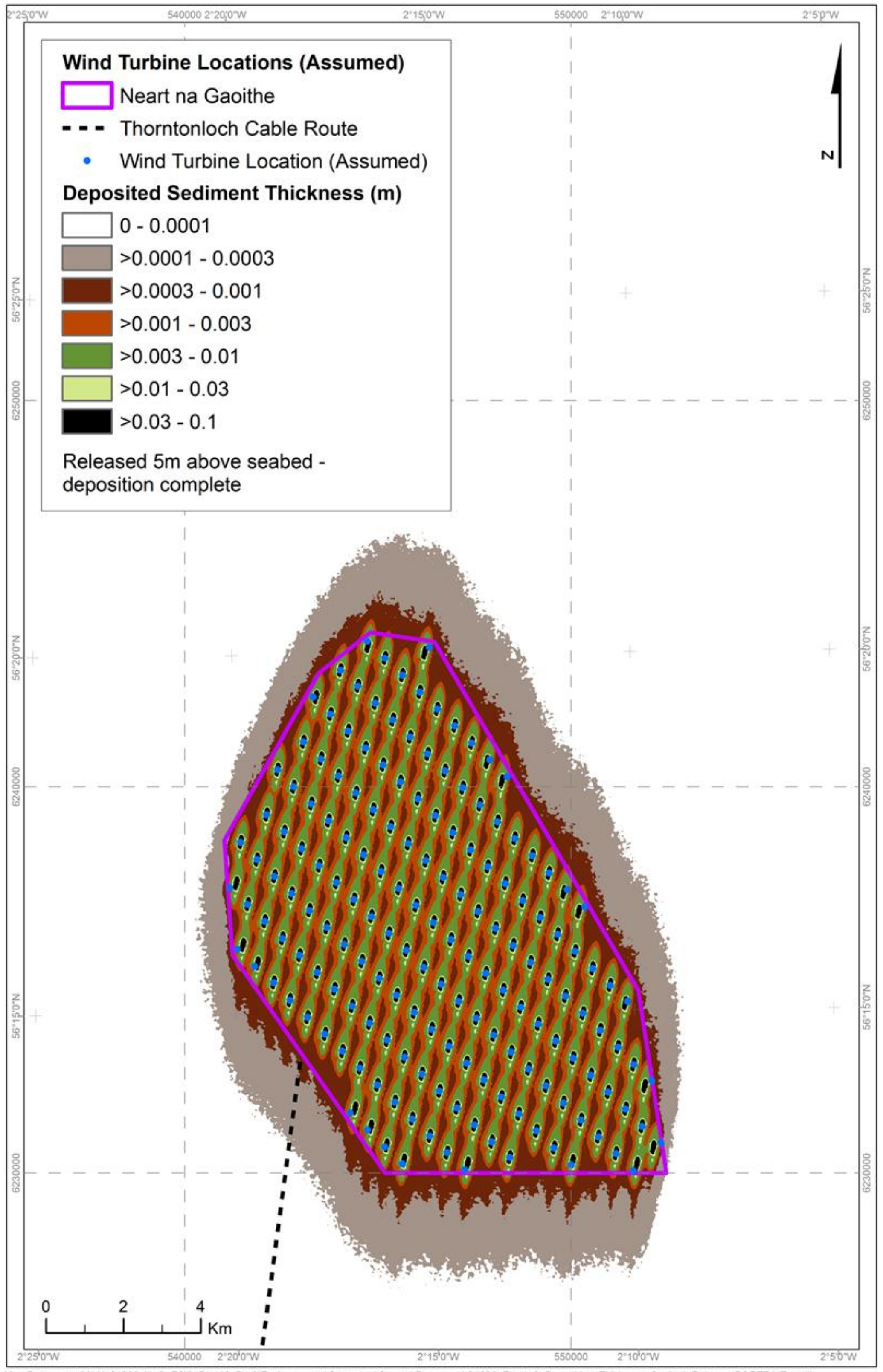

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Figure 9.14: Deposition thickness due to dredging (seabed release) – after all material has settled

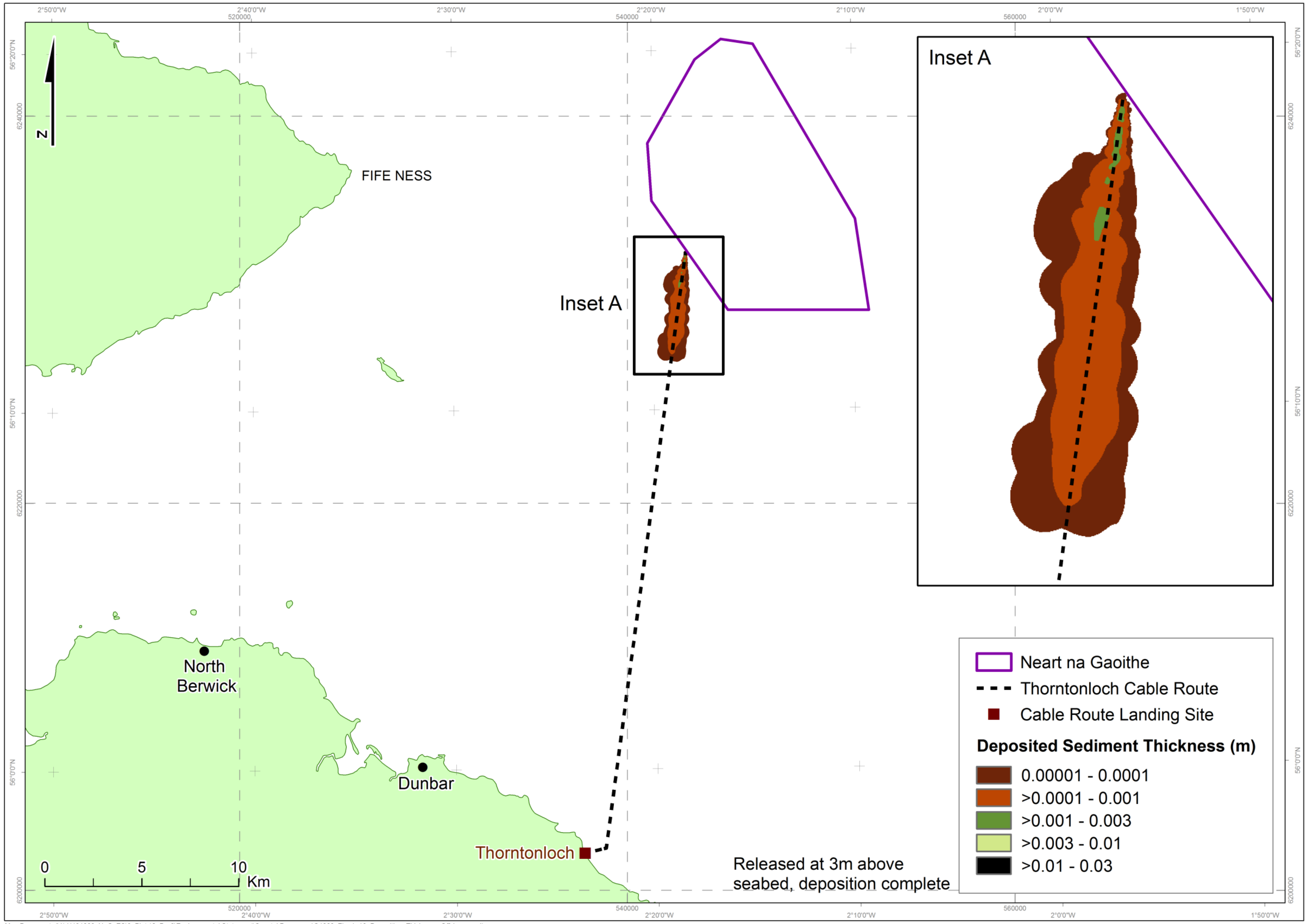

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Figure 9.15: Deposition thickness due to cable trenching – Thorntonloch route offshore area: after all disturbed material has settled

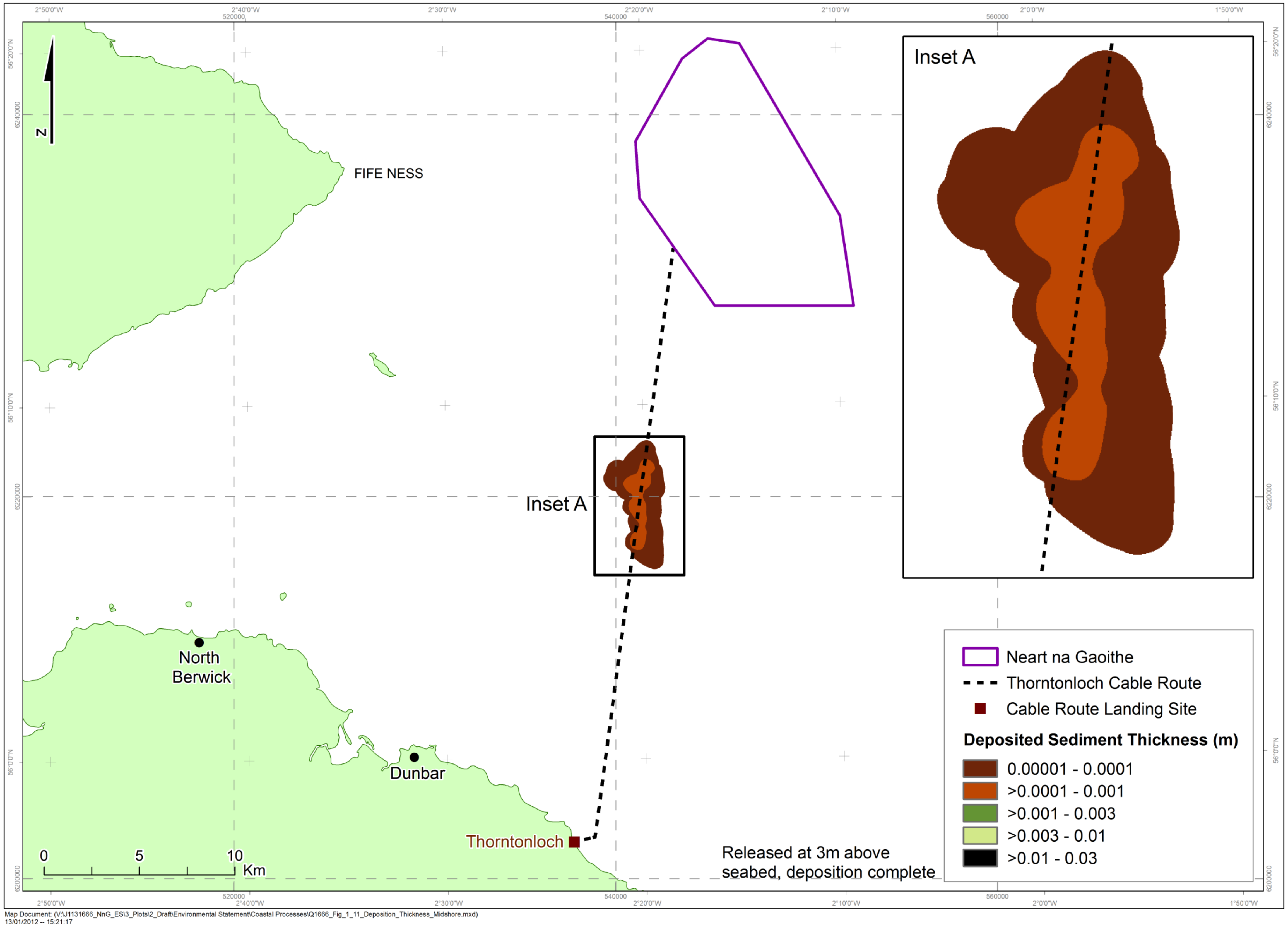

Figure 9.16: Deposition thickness due to cable trenching – Thorntonloch route midpoint area: after all disturbed material has settled

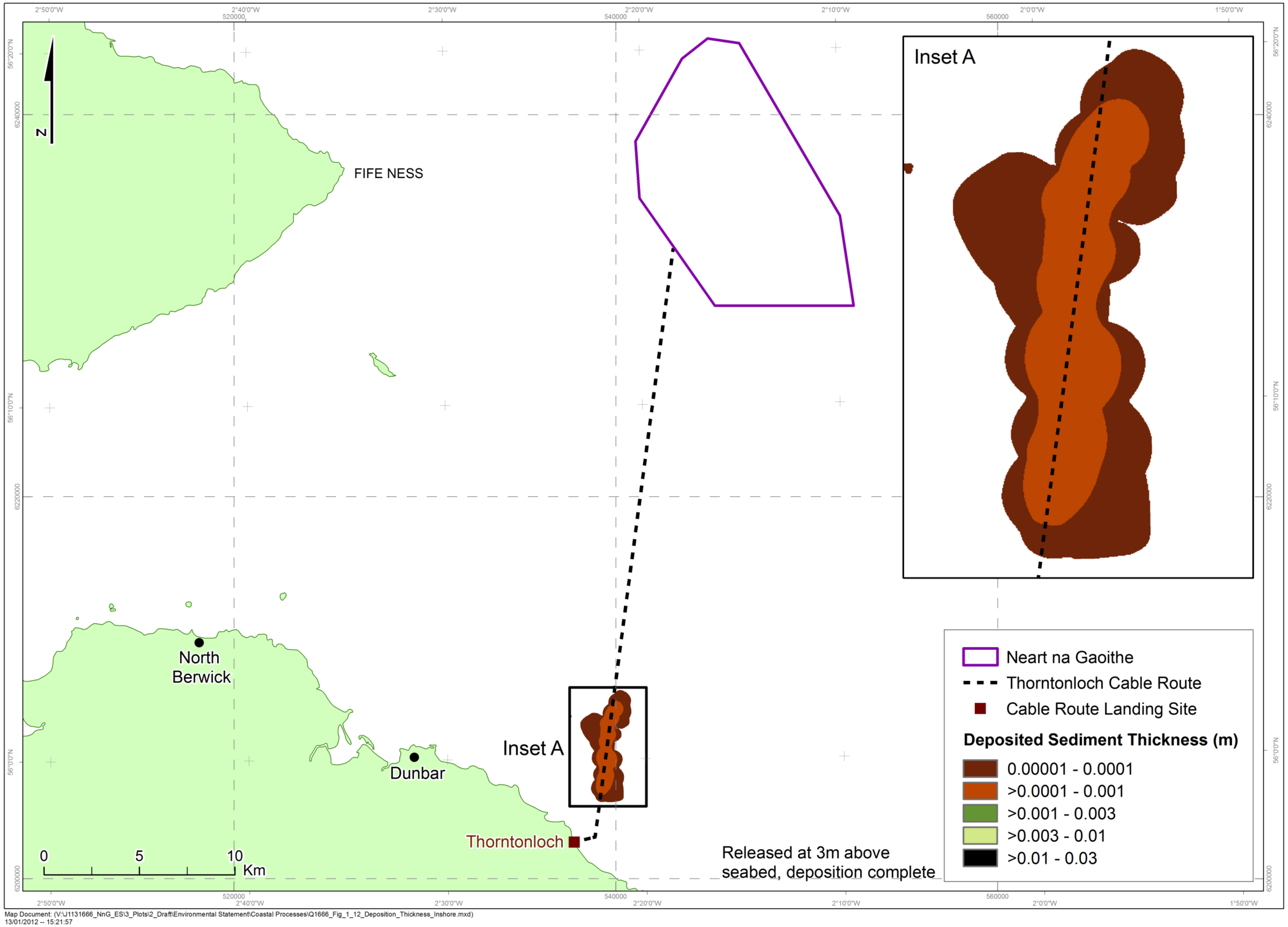

Figure 9.17: Deposition thickness due to cable trenching – Thorntonloch route inshore area: after all disturbed material has settled

9.6.2 Impact Assessment – Operation and Maintenance

9.6.2.1 Water Levels and Currents

109 The predicted change in water level due to the operation and maintenance of the Neart na Gaoithe development is negligible (up to ±1 mm or approximately 0.002% of the total water depth at the proposed site) and generally localised to the near-field (Figures 9.18 to 9.20). Given that such a predicted change would not be measurable, the magnitude is assessed as ***negligible***.

110 The predicted change in tidal currents due to the operation and maintenance of the Neart na Gaoithe development is minor (up to +0.02 m/s and -0.04 m/s, which is equivalent to between 3% and 6% of peak currents on a mean spring tide). Furthermore, these changes are restricted to the immediate vicinity of the development site (Figures 9.21 to 9.23). Although the frequency and duration of this effect is considered to be permanent during the lifetime of the development, given that the impacts are very local to the development site, and the predicted change is comparable with the natural variability that is likely to be experienced at the site, it is considered that the magnitude of this change to the general current regime is ***low***. It should be noted, however, that the localised change to flow could lead to scour around the structures. This is discussed further under Sediment Regime (Section 9.6.2.3).

111 Due to the operation and maintenance phase of the development, it is therefore considered that the overall change to water levels in both the near-field and the far-field will be ***negligible***, the change to currents in the near-field will be ***low***, and the change to currents in the far-field will be ***negligible***.

9.6.2.2 Wave Climate

112 The predicted effect on the wave climate due to the operation and maintenance of the Neart na Gaoithe development is considered to be low (up to 0.04 m or < 3% of average significant wave height), and restricted to offshore (up to a maximum 10 km from the site) (Figures 9.24 to 9.26). Although the frequency and duration of this effect is considered to be permanent during the lifetime of the development (when wave forcing exists), given that the predicted change is localised to the development site, and is comparable to the natural variability that is likely to be experienced at the site, the magnitude of change in the general wave climate is considered to be ***low***.

113 Due to the operation and maintenance phase of the development, it is therefore considered that the overall change to the wave climate in the near-field will be ***low***, and in the far-field will be ***negligible***.

9.6.2.3 Sediment Regime

Frequency of Seabed Sediment Mobilisation

114 The predicted effects on sediment transport processes due to the operation and maintenance of the Neart na Gaoithe development are considered to be low, with the predicted frequency exceedance of the critical shear stress changing typically by ±1-3%. This means that the percentage of time for which the spatially-varying typical seabed sediment across the development site is predicted to be generally mobilised by tidal and wave processes might change from up to 15% under existing conditions, to up to 18%, although some isolated areas might experience a greater change (up to a maximum of 21% of the time). These changes are restricted to the immediate vicinity of the offshore site. The frequency and duration of this effect is considered to be permanent during the lifetime of the development. The changes in the exceedance of the critical shear stress due to the development are shown in Figures 9.27 to 9.29. These show exceedance due to the combined current and wave shear stress, when taken as a mean across a wave cycle (i.e., the full wavelength from crest to crest or trough to trough), and when considering the maximum wave orbital velocity (i.e., the maximum speed of the water particles in their circular motion due to the passing of a wave).

115 The predicted changes in the bed stress due to waves and currents in combination indicate only low increases in the time (frequency) that the critical bed shear stress for sediment transport is exceeded. Based on analysis of the site-specific particle size distribution (EMU, 2010a) and the hydrodynamic and wave modelling, this may result in the formation of minor bedforms (e.g., ripples), but is not envisaged to produce dramatic changes in seabed morphology. The small absolute change in the stress exceedance will drive only small changes to seabed morphology processes that are within the range already found across the site. Although the site is not considered to be wave-dominated, it is the larger waves, rather than tidal currents, which lead to the excess bed shear stress required for the mobilisation of sediment. Therefore, any resulting bedforms will be stationary and ephemeral rather than translational (migratory – which form under tidal conditions), and thus will be limited to within the site boundary.

116 The geophysical survey data indicate some variations in bathymetry and ridge systems which are clearly associated with mound features, whereas in deeper areas there are no visible topographic features. These mound-associated features are found around the periphery of the Quaternary mound structures where baseline near-bed current flows are amplified. The predicted increases in excess stress may make these mound features more pronounced, but the changes will not be substantial, and would be within the range found across the site. The features will nevertheless remain 'attached' to the mound structures under increased flows, which might occur slightly more frequently.

117 The baseline classification for the site as 'slightly mobile' would remain unchanged post-development. Both the near-field and far-field effects due to the developments are therefore judged to be ***negligible***.

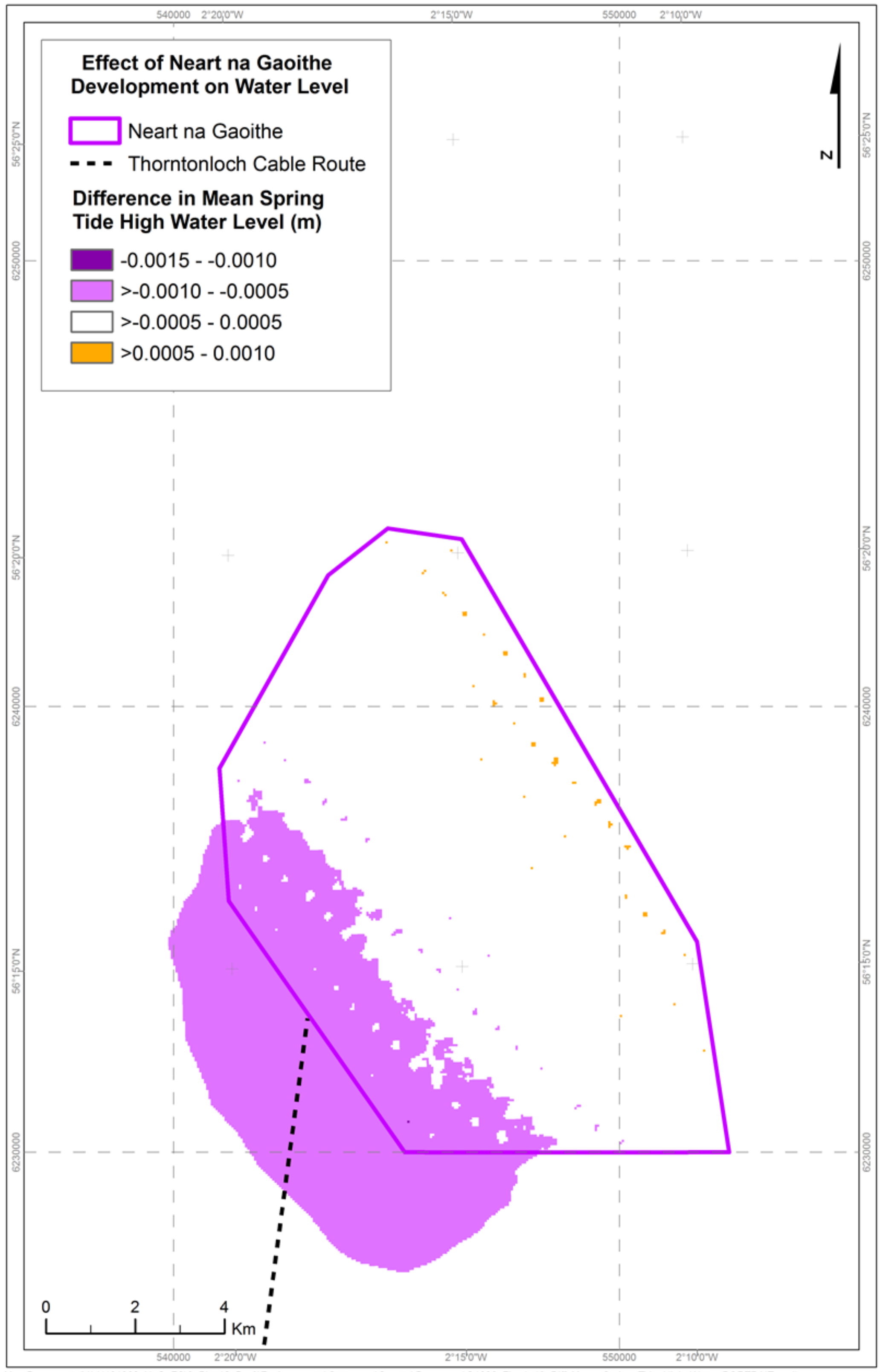

Figure 9.18: Difference in mean spring tide high water level (m) due to development – near-field

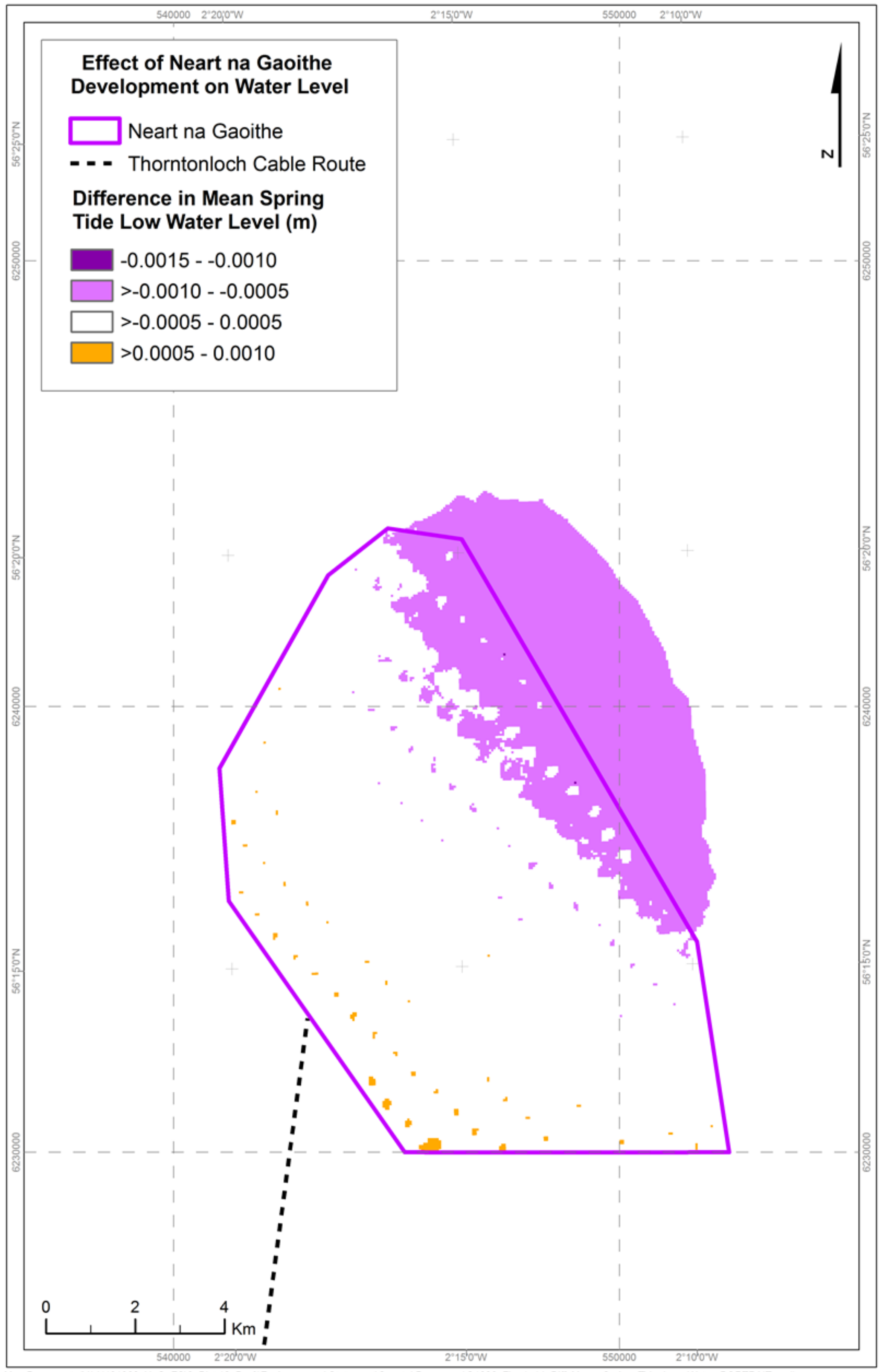

Figure 9.19: Difference in mean spring tide low water level (m) due to development – near-field

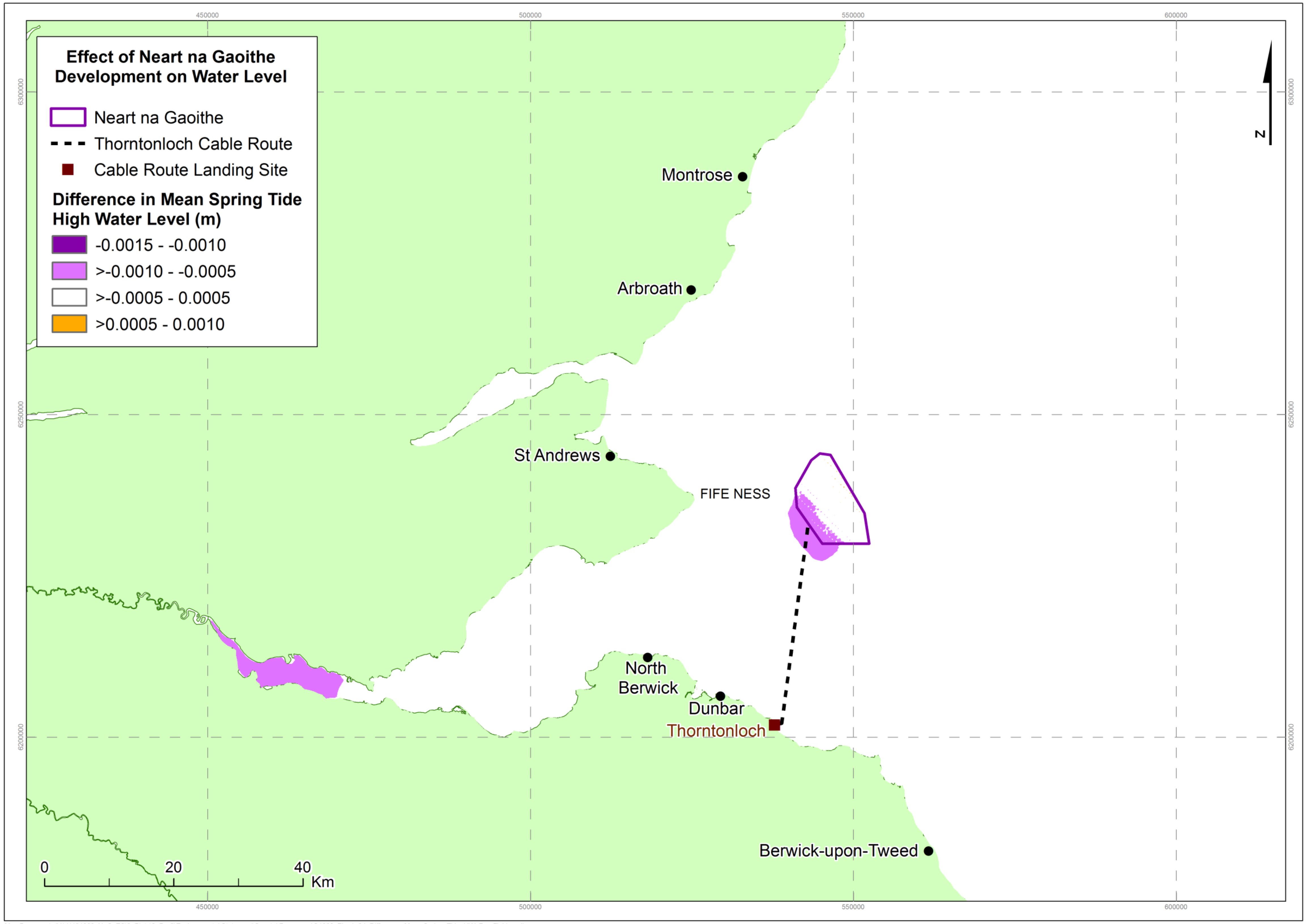

Figure 9.20: Difference in mean spring tide high water level (m) due to development – far-field

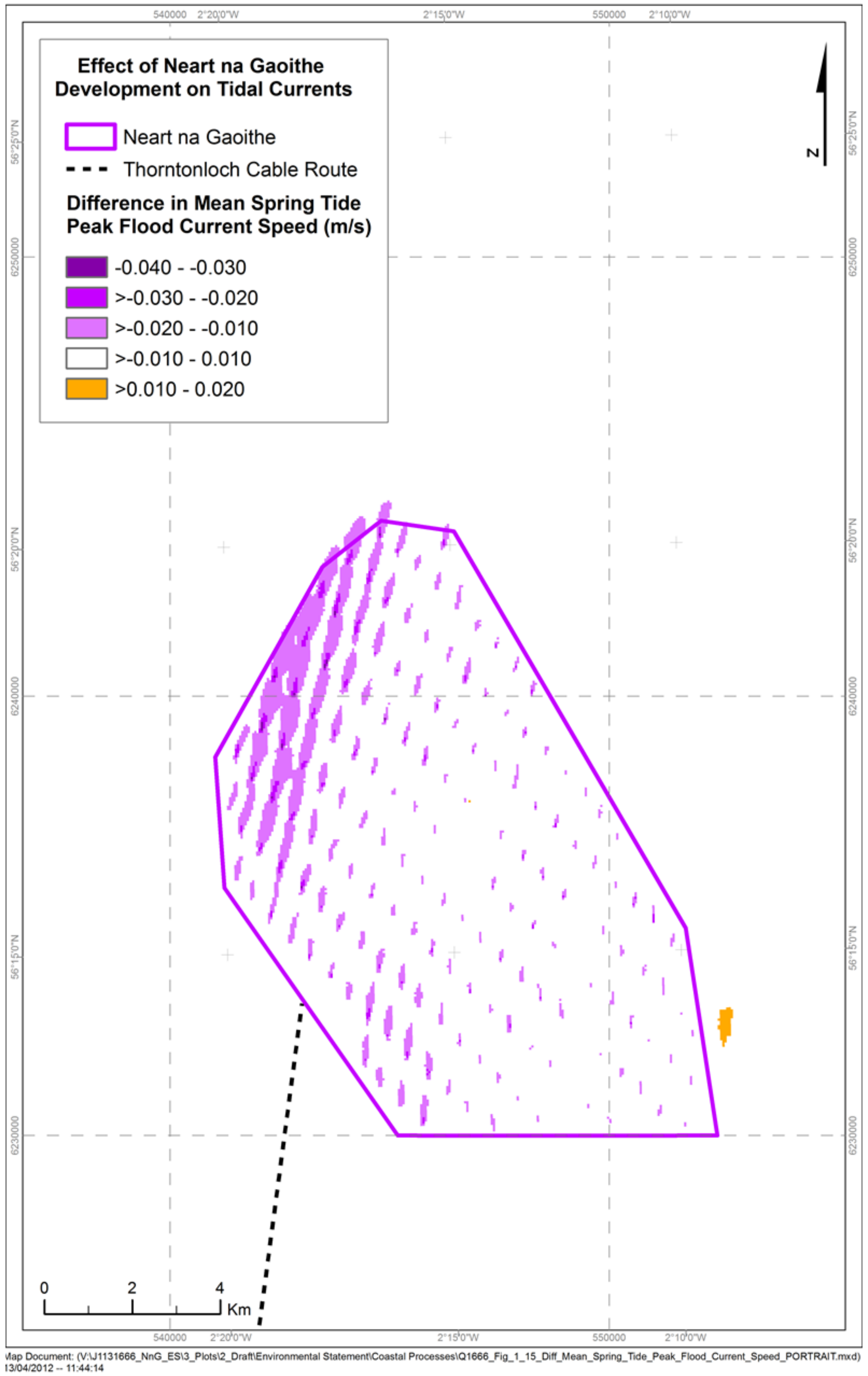

Figure 9.21: Difference in mean spring tide peak flood current speed (m/s) due to development – near-field

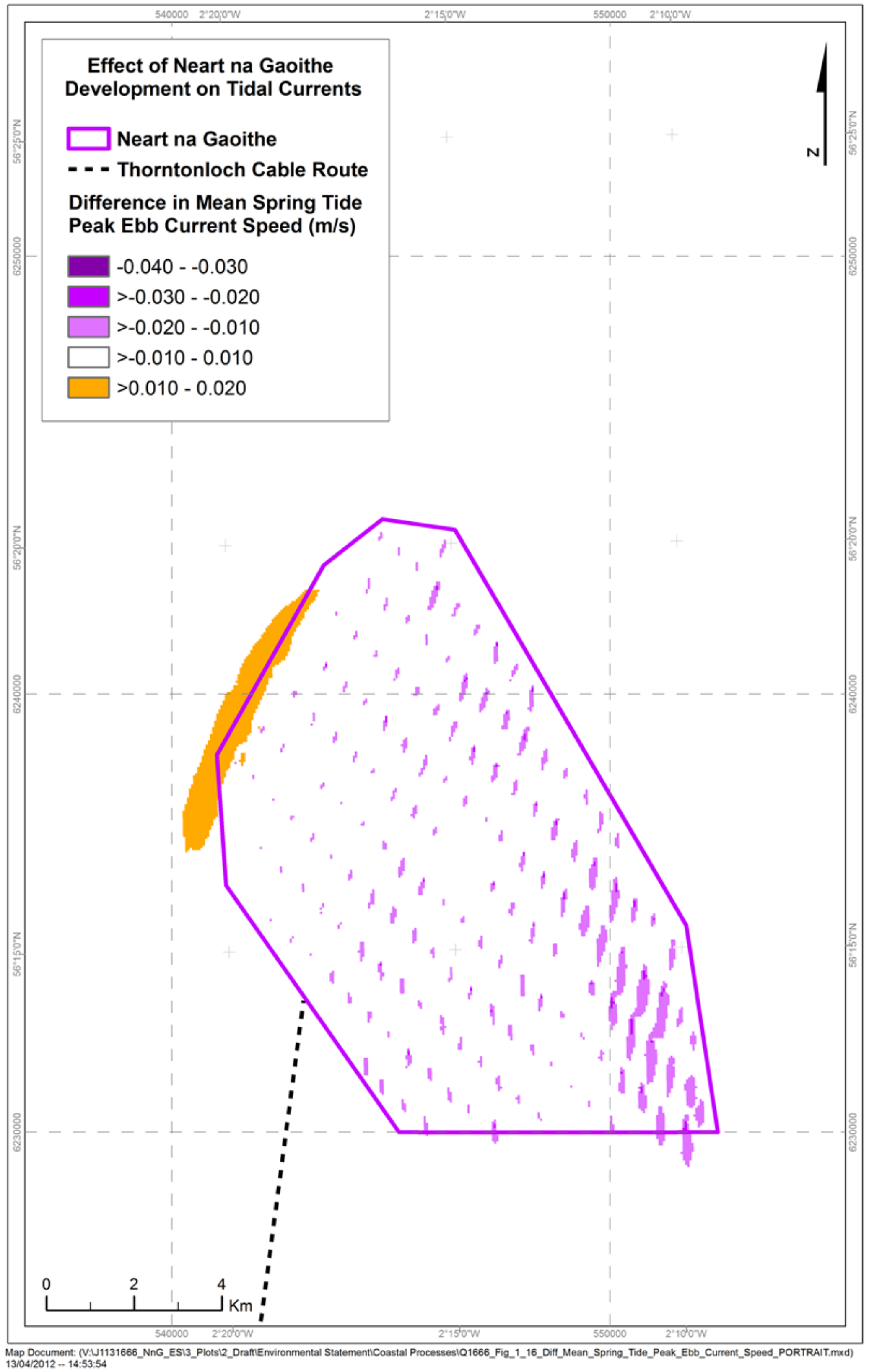

Figure 9.22: Difference in mean spring tide peak ebb current speed (m/s) due to development – near-field

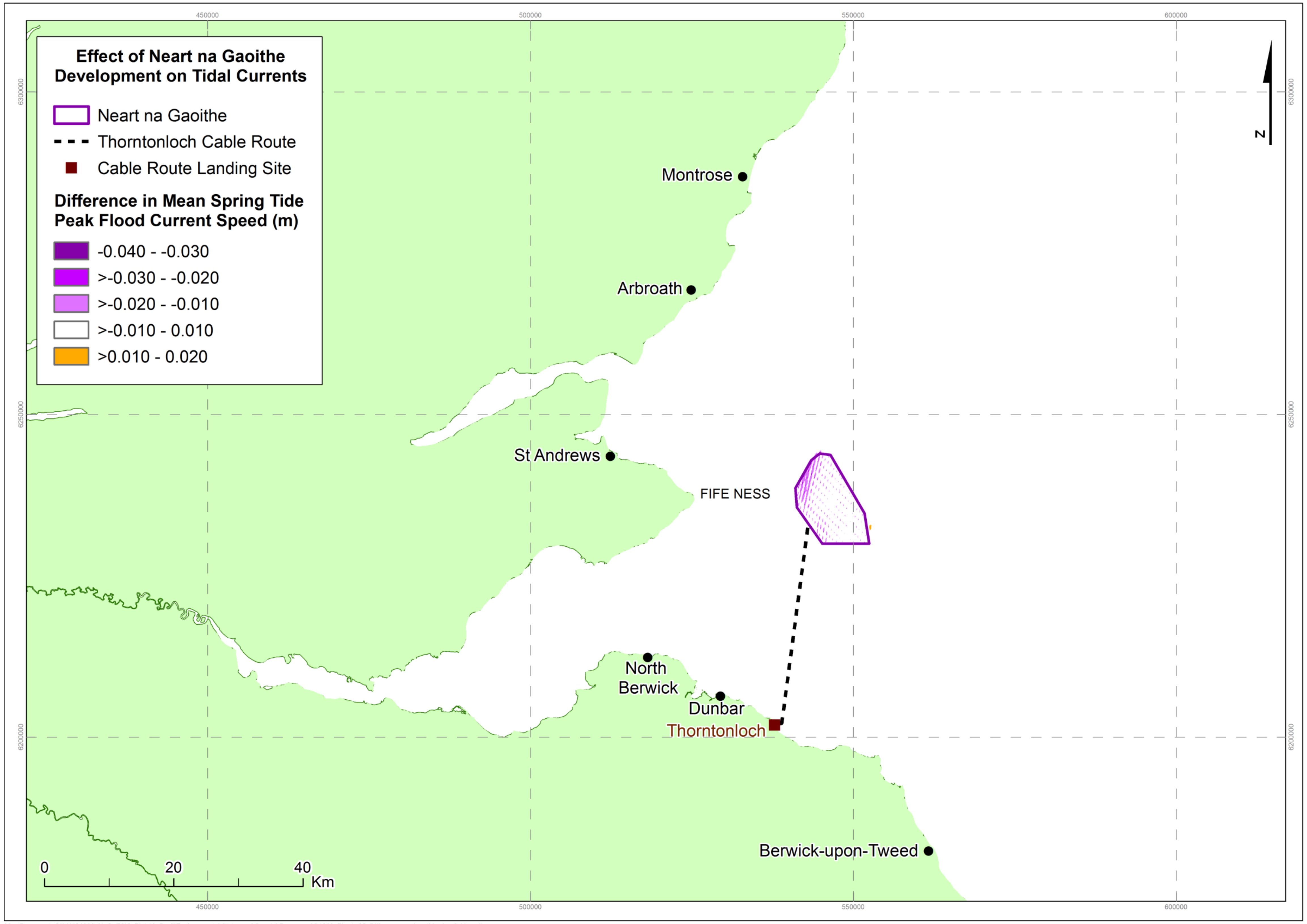

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Figure 9.23: Difference in mean spring tide peak flood current speed (m/s) due to development – far-field

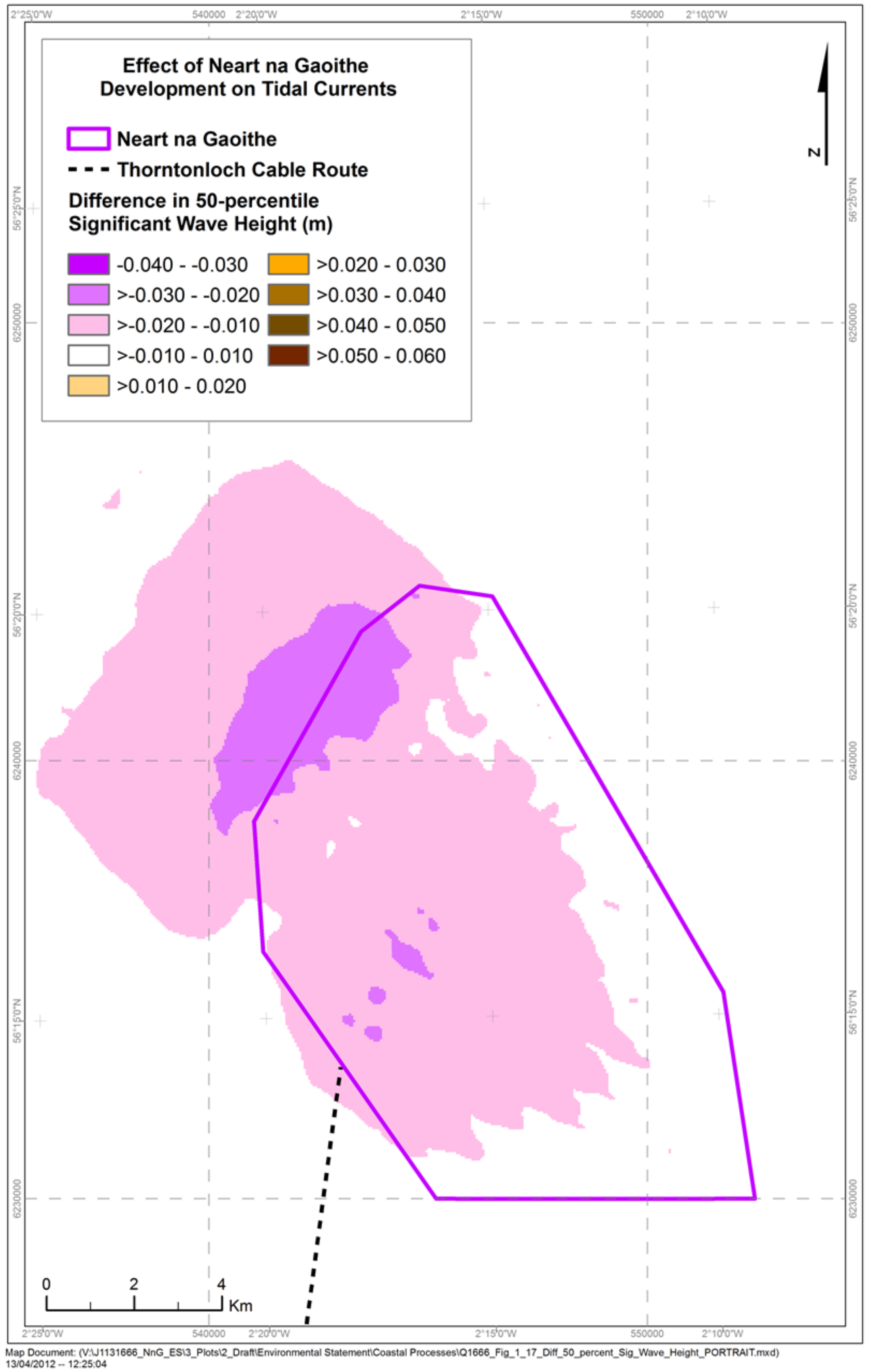

Figure 9.24: Difference in 50 %ile significant wave height (m) due to development – near-field

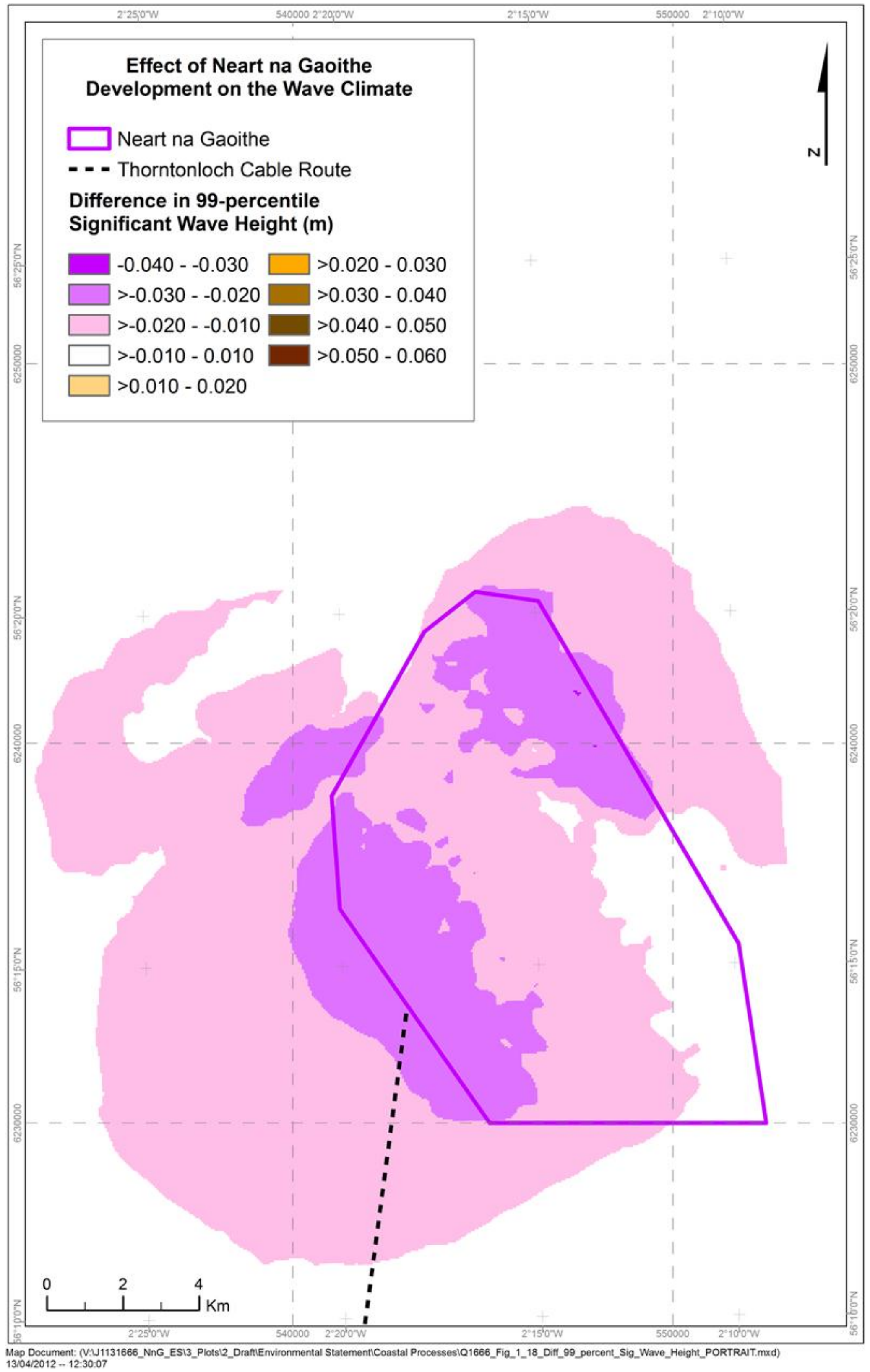

Figure 9.25: Difference in 99-%ile significant wave height (m) due to development – near-field

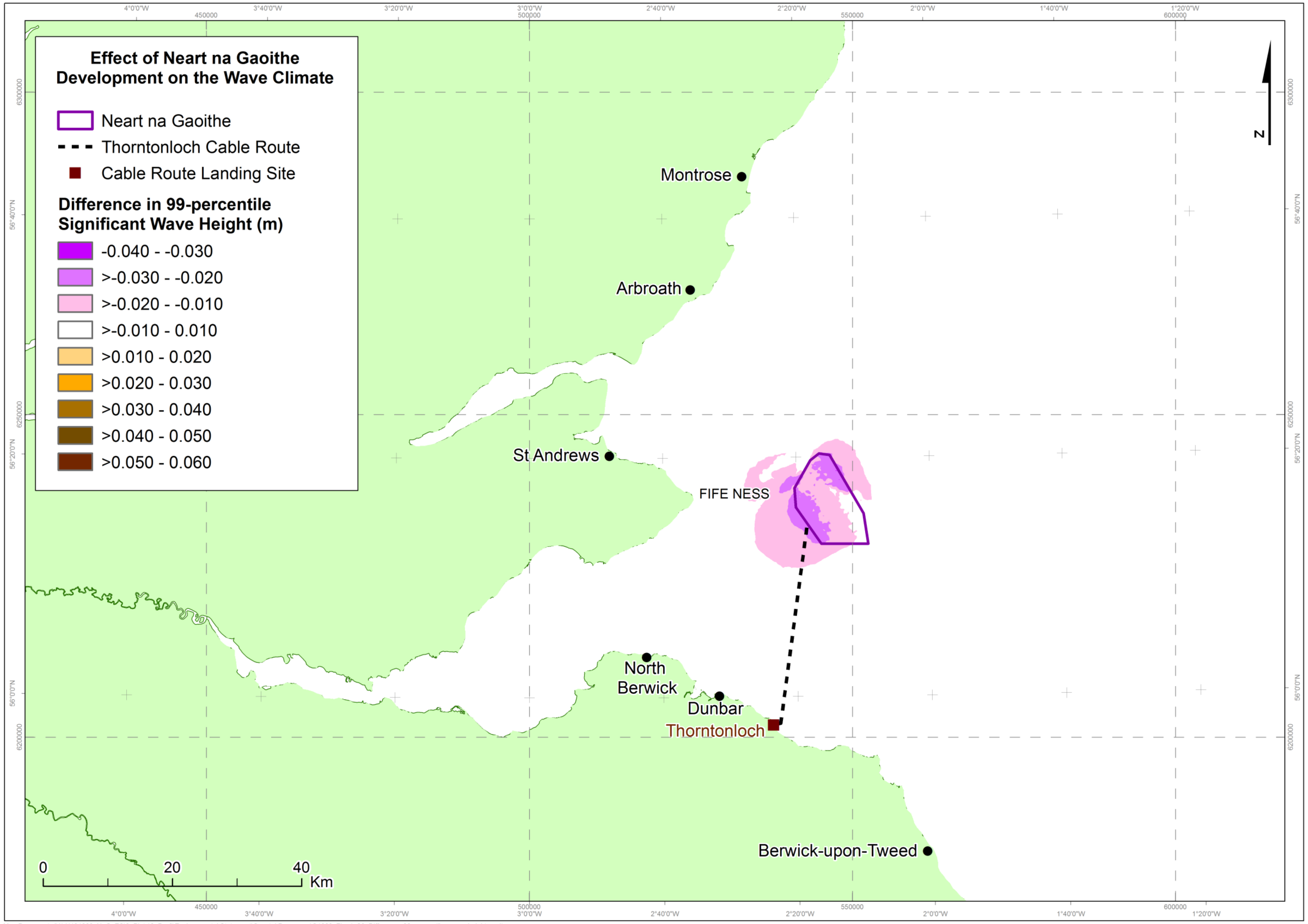

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Figure 9.26: Difference in 99-%ile significant wave height (m) due to development – far-field

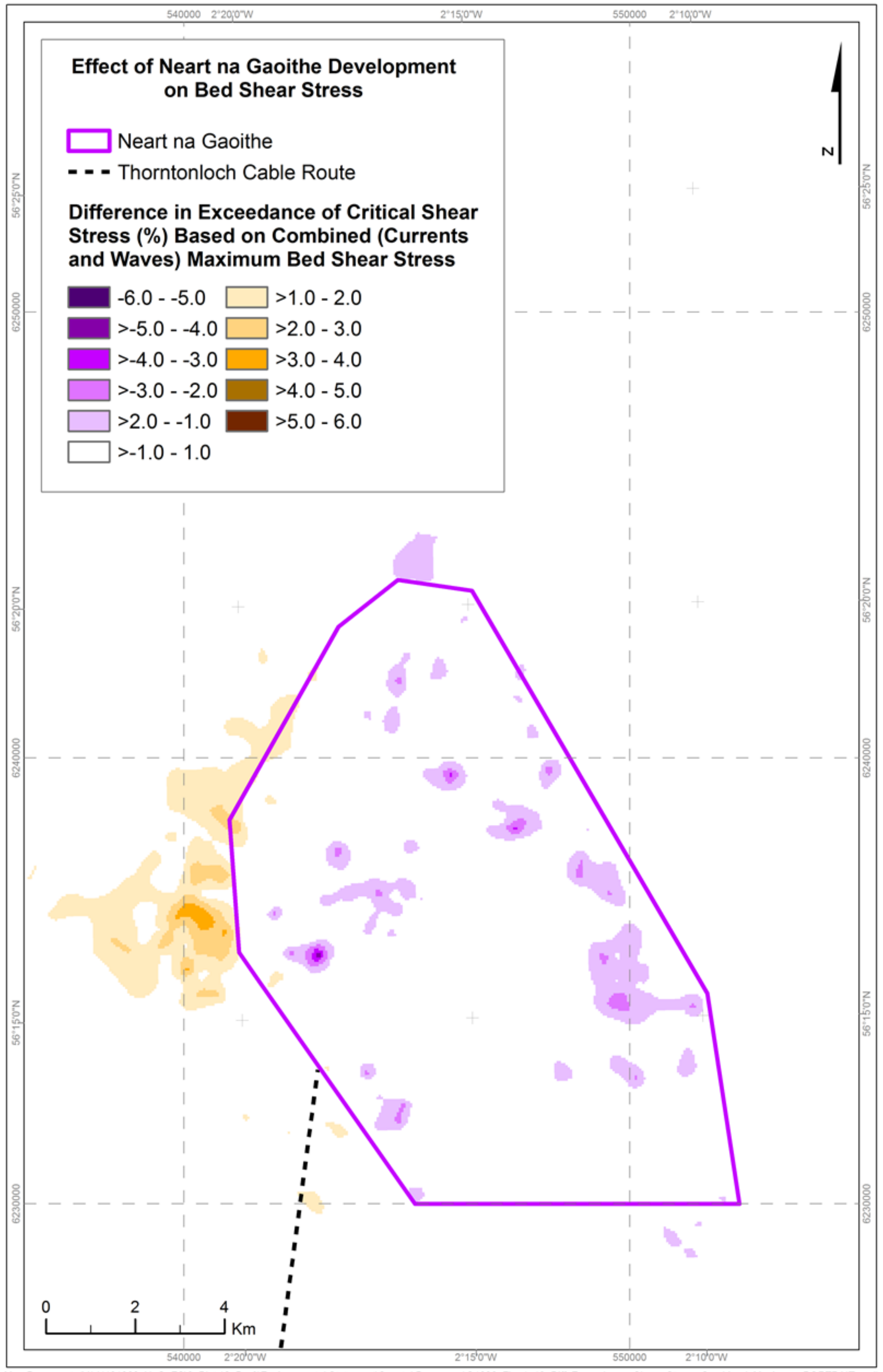

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Figure 9.27: Difference in the exceedance of critical shear stress (%) due to development – based on the combined (currents plus waves) maximum bed shear stress – near-field

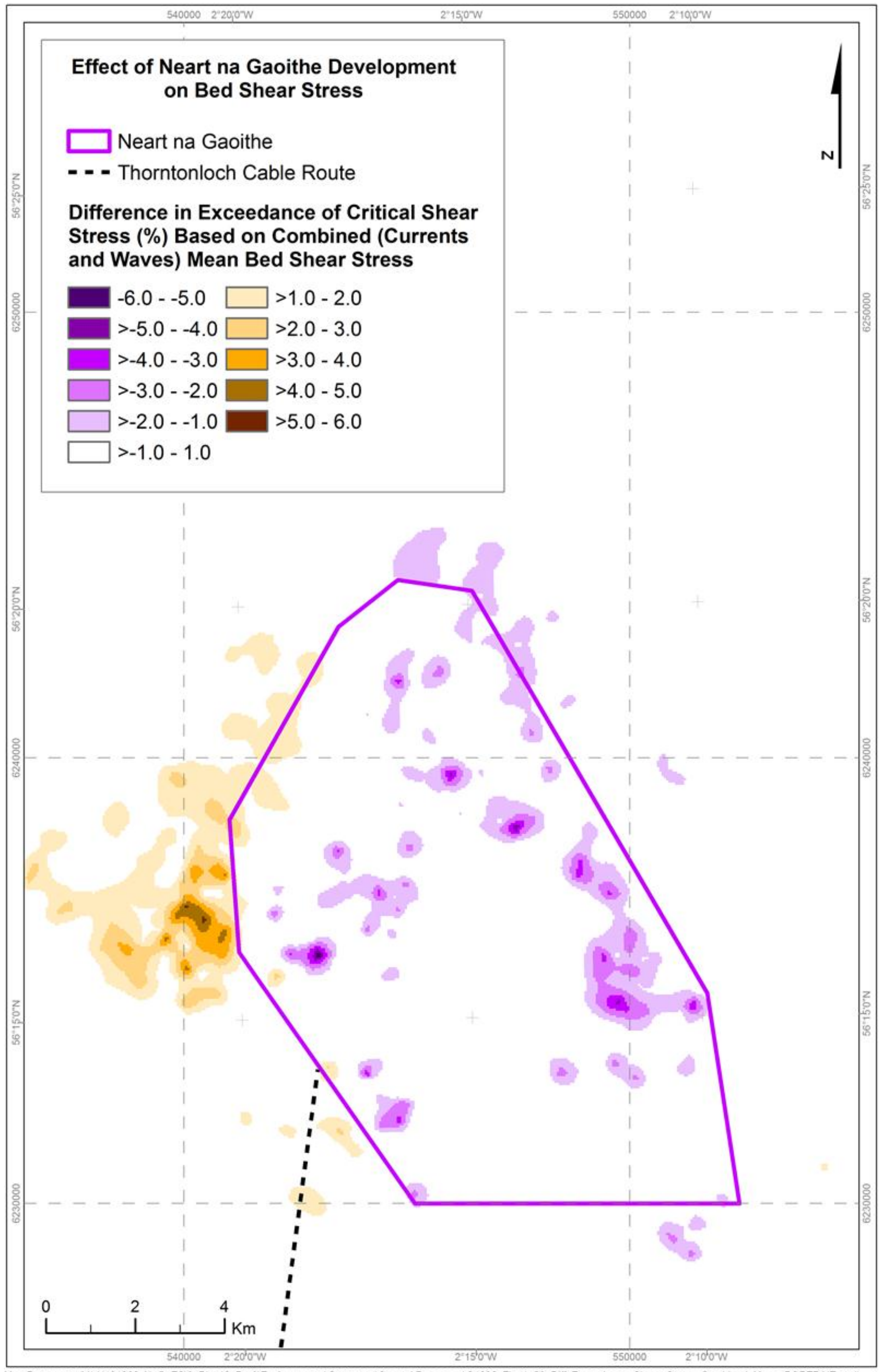

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Figure 9.28: Difference in the exceedance of critical shear stress (%) due to development – based on the combined (currents plus waves) mean bed shear stress – near-field

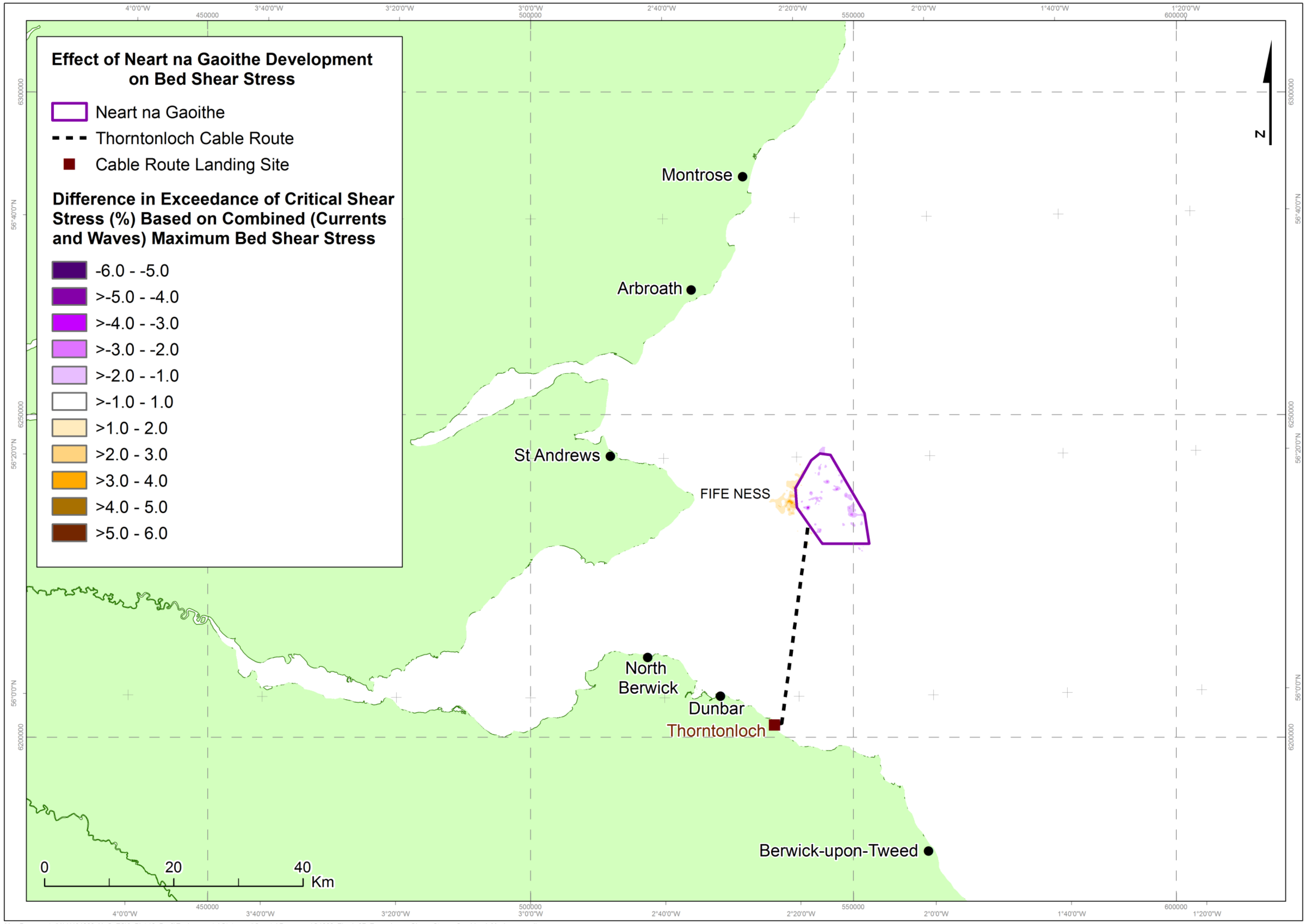

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Figure 9.29: Difference in the exceedance of critical shear stress (%) due to development – based on the combined (currents plus waves) maximum bed shear stress – far-field

Suspended Sediment Concentrations

118 The slightly greater frequency of mobilisation predicted (the typical seabed sediment is predicted to be mobilised slightly more often) in some parts of the site may give rise to more frequent and periodically higher concentrations of sediment in suspension through resuspension of surface sediment. However, the largely sandy nature of the site means that the majority of any resuspended sediments will return quickly to the bed. Both the near-field and the far-field effects are therefore considered to be ***negligible.***

119 The low increase in critical shear stress exceedance may have a greater impact on the resuspension of silts. These fractions of the sediment are resuspended more readily, and once in suspension are susceptible to transport by tidal and residual currents. An increase in the frequency may potentially lead to a medium-to-long term winnowing (removal) of the silts from the surface sediments across the site. This is of little importance as the silt forms only a minor fraction (0.1-14%) of the seabed sediments and removal has no direct consequence for the sediment stability.

Sediment Transport and Direction

120 Results from the modelling predict that there will be negligible change to the residual sediment transport direction, but the residual sediment flux may increase slightly. Based on analysis of the field data (EMU, 2010a) and the hydrodynamic and wave modelling, regular medium/large scale changes in the general bed level (bathymetry) are not expected to occur due to the proposed development.

121 As bedforms are not present within the footprint of change, there is no overlap between the effect and receptor, and therefore no impact to be assessed.

Scour

122 The scour assessment determined that, depending on the size of the jacket structures employed, the maximum scour depth would be 3.26 m; the maximum lateral scour extents would be 8 m; and the maximum volume of scoured material from a single jacket structure (for the larger 6 MW turbine) would be 1,100 m^3. The scour assessment, which used particle size data collected at the site (EMU, 2010a), together with the hydrodynamic and wave modelling, also determined that scour will only occur on spring tides, and that it is likely to take approximately 86 days (several spring-neap tidal cycles) for the maximum equilibrium-depth scour pits to develop (see Appendix 9.3: Physical Processes Technical Report). No overlap of scour pits will result, so combined impacts between individual legs or between turbine foundations will not occur, and scour will be local rather than global (which is when local scour pits from individual legs or structures overlap, and the whole seabed around the development are subject to scouring effects).

123 The impact of the scoured material from around the foundation structures in terms of elevated suspended sediment concentrations would be low and localised. Two representative plots of the suspended sediment plume resulting from the scour around foundations are shown in Figures 9.30 and 9.31. It should be noted that these plots show snapshots of the plume at two particular states of the tide (one ebbing and one flooding); different tidal states will give different plume shapes. Although peak concentrations very close to the scour pit are predicted to be between 100 and 300 mg/l (compared with ambient concentrations of less than 10 mg/l), these will occur very close to the structures, and beyond about 250 m of the structures concentrations will be less than 10 mg/l, reducing to less than 1 mg/l (above background) within 1 km. These impacts will be temporary and the suspended sediment will settle out relatively soon after release (on a timescale of hours). Once equilibrium scour depths are reached (within 2 to 3 months), no further scour is likely to result.

124 The resulting deposition footprints will be very localised around the turbine base, with a maximum thickness of 0.1 m; beyond 500 m from the turbine base, any deposition will be less than 1 mm thick. The predicted deposition footprint due to the scoured material across the site is shown in Figure 9.32. The magnitude of effect from the scoured material around the structures is therefore considered to be ***low*** and localised within the near-field.

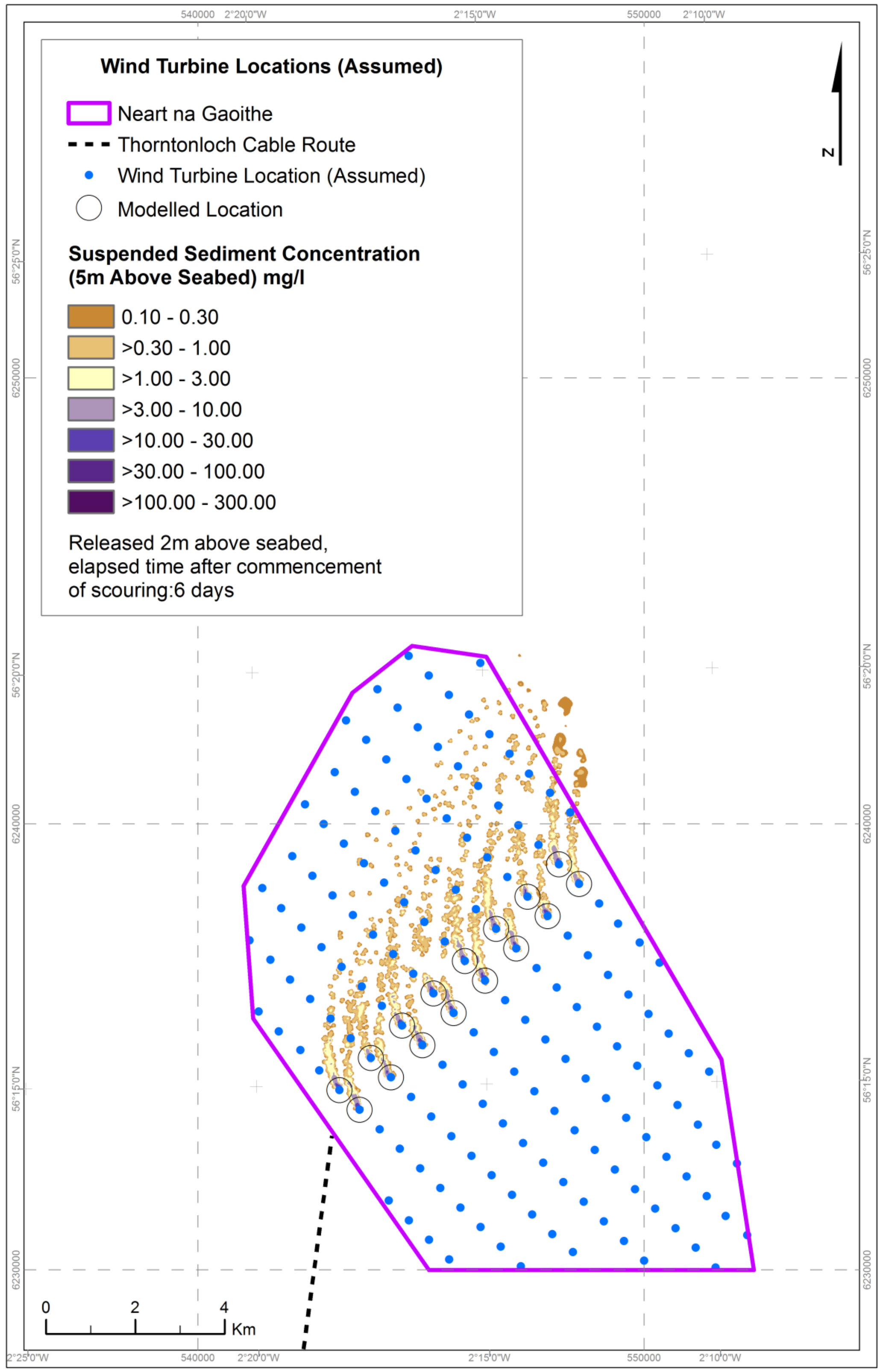

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Figure 9.30: Suspended sediment concentration due to scouring around gravity bases – 6 days after 'commencement'

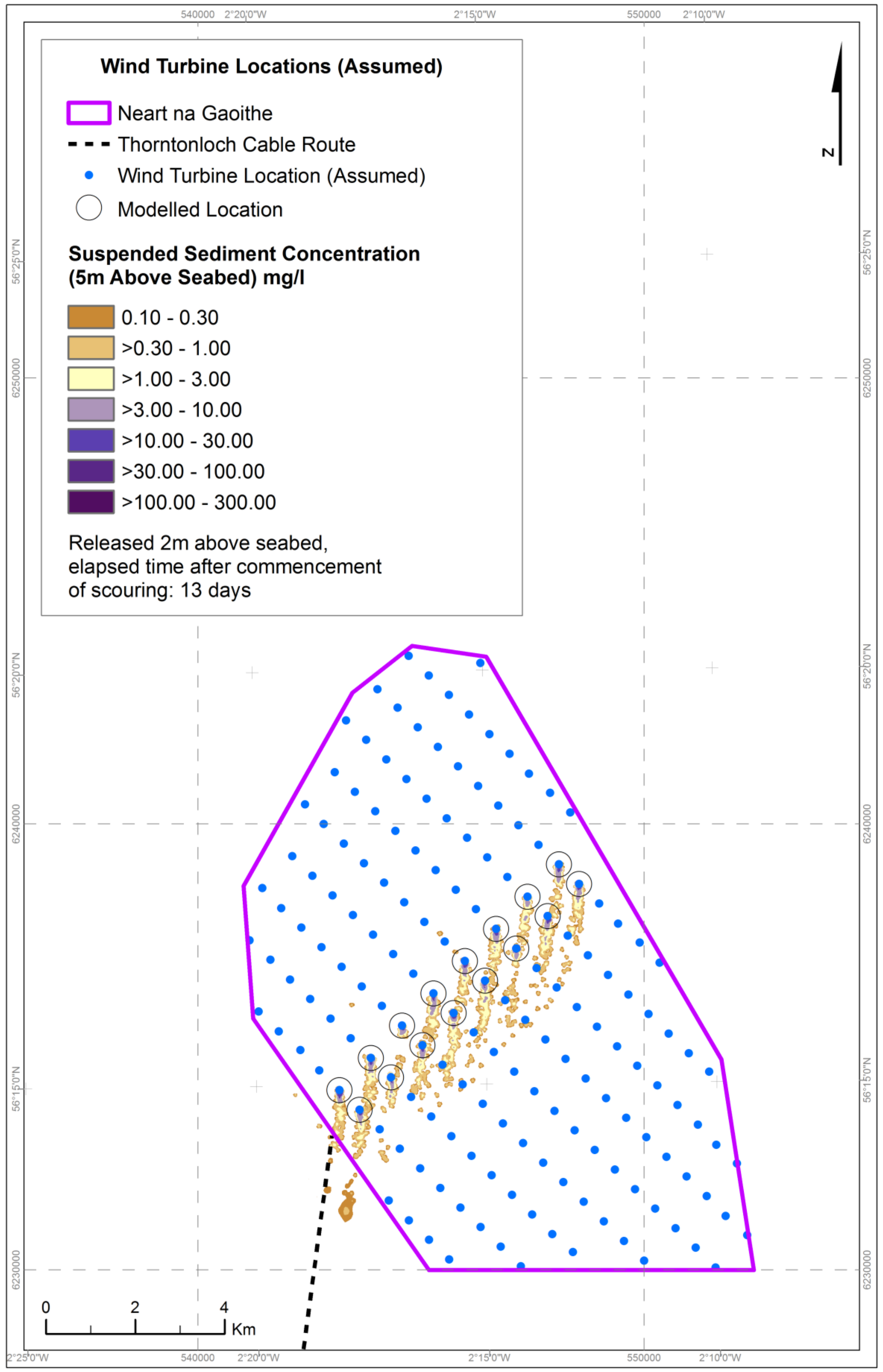

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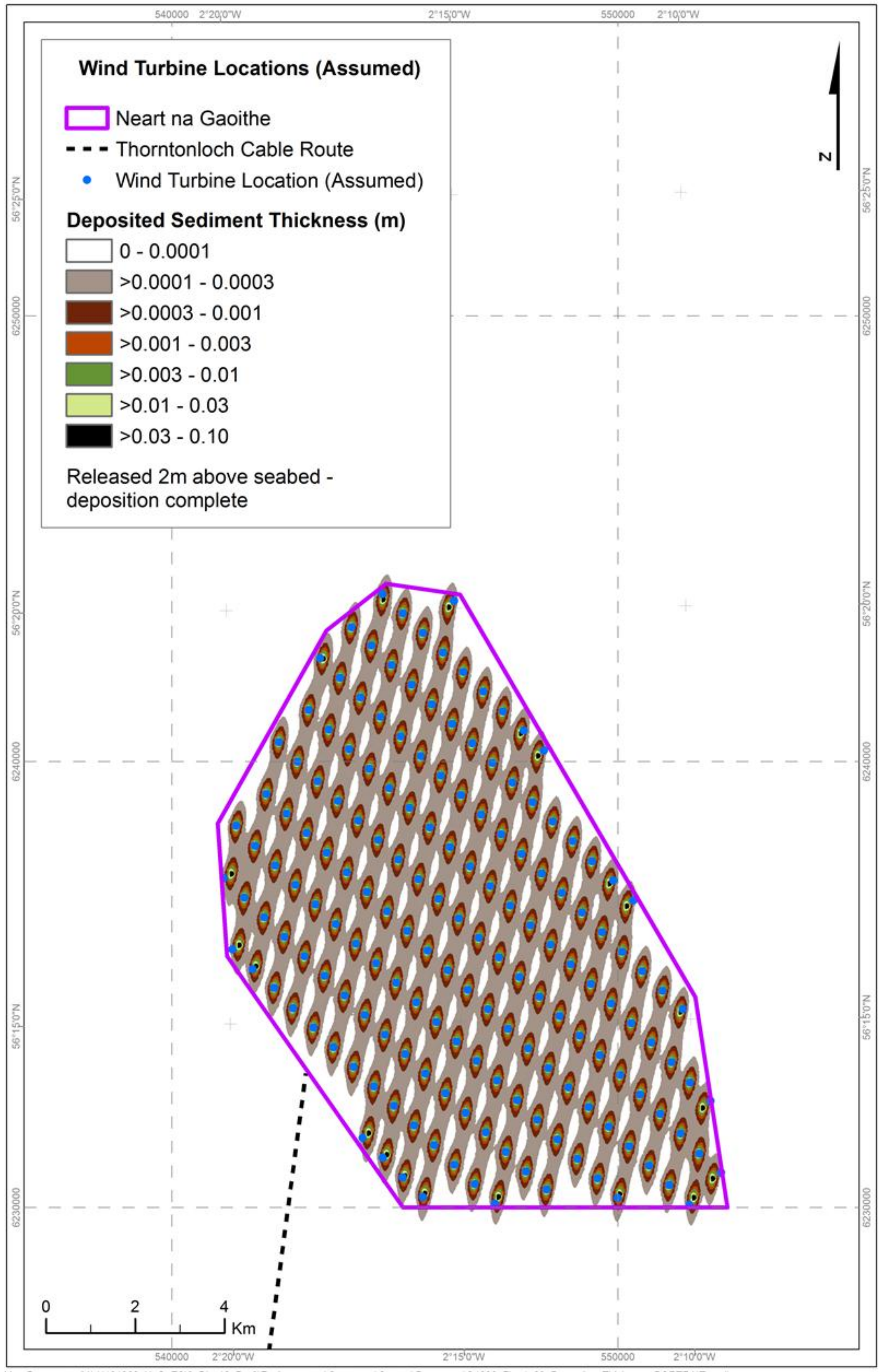
Figure 9.31: Suspended sediment concentration due to scouring around gravity bases – 13 days after 'commencement'



Map Document: (V:\J1131666_NnG_ES\3_Plots\2_Draft\Environmental Statement\Coastal Processes\Q1666_Fig_1_23_Depostion_Thickness_PORTRAIT.mxd)
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Figure 9.32: Deposition thickness due to scouring around gravity bases – after all scoured material has settled

9.6.2.4 Cable Route Assessment

Water Levels and Currents

125 Since the export cables will be buried, no change is predicted, and therefore the magnitude of effect on the water levels and currents along the cable route will be ***negligible***.

Wave Climate

126 Since the export cables will be buried, no change is predicted, and therefore the magnitude of effect of the wave climate along the cable route will be ***negligible***.

Sediment Regime

127 Since the export cables will be buried, no change is predicted, and therefore the magnitude of effect on the sediment regime is assessed as negligible. No scour around the buried cable will occur, unless the cable is exposed (e.g., due to severe storm conditions). In such an event, it is assumed that remedial action will be taken in order to re-bury the cable as a matter of urgency (to protect the cable), and therefore scour around the exposed cable would be minimised. Where the cable cannot be buried, and rock armouring is required, scour may occur. However, rock armouring is a standard form of protection, and a detailed study will be undertaken to ensure the rock is graded to minimise scour once the final cable route and laying methods have been determined.

Intertidal Region

128 If the cable is buried, there would be no changes to the nearshore environment during operation, unless maintenance of the cable was required. If that occurs, then the effects would be similar to the construction phase.

129 If the cable is laid on top of the seabed and protected by either rock armour or a split pipe, the worst case is considered to be the rock armour which would have a higher profile, and therefore affect the nearbed currents, and potentially waves. However, the rock armour would only extend up to 1 m above the seabed. From site visits (ETA, 2011), the boulders within the intertidal area are up to 1 m diameter, and therefore such features already exist within the natural environment. Consequently, it is unlikely that measurable changes to waves would occur as the seabed is already uneven and the waves are affected by a rough seabed surface. The change is therefore considered to be negligible.

130 However, the rock armouring may cause turbulence within the nearbed currents. Prior to installing the rock armour, a seabed survey should be undertaken to determine the exact nature of the seabed. This would then be used to design the rock armour composition and shape to minimise turbulence. While turbulence would usually result in scour, given the hard nature of the seabed and suitable design of the rock armouring, it is predicted that the scour would be a low magnitude change at most.

9.6.3 Impact Assessment - Decommissioning

131 It is assumed that the decommissioning phase will constitute activities that will be similar in nature to those during the construction phase. On this basis, any effects due to the decommissioning phase will be similar to, or potentially lower than, those resulting from the construction phase.

9.6.3.1 Water Levels and Currents

132 It is not known what decommissioning process will be employed at the end of the lifetime of the development. It is possible that all buried infrastructure (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 will be small, localised and transient, and of a similar magnitude to those that might occur during the construction of the development. It is therefore considered that the changes in the water levels and currents due to the decommissioning phase will be negligible.

9.6.3.2 Wave Climate

133 It is anticipated that any equipment required on site for the decommissioning of the development would have a negligible effect on the wave climate, since any effects will be very localised and temporary, and on a similar scale to effects resulting from regular passing vessels. Equipment (such as jack-ups and vessels) on site would be located at one place at a time, for a period of 2-4 days, while the particular infrastructure, such as the turbine foundation, is removed. Based on relevant field data (EMU, 2010a; BGS, 2012) and the modelling undertaken for other activities in this study, it is the judgement of the assessment team that any cumulative effects (resulting from simultaneous decommissioning activities within the Neart na Gaoithe development site, or from the simultaneous decommissioning of all three proposed offshore wind farm developments) would also be ***negligible.***

134 It is therefore considered that changes in the wave climate due to the decommissioning phase in both the near-field and the far-field will be ***negligible***.

9.6.3.3 Sediment Regime

135 It is anticipated that any equipment required on site for the decommissioning of the development would have only a very limited, localised and temporary effect on the sediment regime. Since no bed-levelling through dredging would be required, the changes to the sediment regime at the site due to decommissioning would be lower than those predicted for the construction phase. It is therefore predicted that magnitude of change on the sediment regime due to the decommissioning phase will be ***negligible***.

9.6.3.4 Cable Route Assessment

Water Levels and Currents

136 Based on the analysis of field data collected (EMU 2010a), the modelling undertaken in this assessment, and the conclusion that the construction phase will have only a negligible effect, it is it was considered that the overall changes to the water levels and currents due to the decommissioning phase along the cable route, in both the near-field and far-field, will be ***negligible***.

Wave Climate

137 Based on the analysis of field data collected (EMU 2010a), the modelling undertaken in this assessment, and the conclusion that the construction phase will have only a negligible effect, it was considered that the overall changes to the wave climate due to the decommissioning phase along the cable route, in both the near-field and far-field, will be ***negligible***.

Sediment Regime

138 The process of the removal of buried cables has not been modelled, as it is assumed that the potential effects from this activity would be very similar to those predicted for the cable burial process in the construction phase. On this basis, the effects from the decommissioning phase on the sediment regime will be localised and temporary, lasting for the duration of the work. Equipment and vessels are expected to be located in any one place for 2-4 days at a time. Elevated concentrations of suspended sediment (with peaks up to 30 mg/l above background levels) are predicted, but the resulting plumes will not be advected beyond the near-field vicinity of the cable (< 5 km), and will settle out within a few hours of disturbance. The resulting deposition footprint will be within 2 km either side of the cable route, and will be very thin (typically < 0.1 mm) with peaks up to 3 mm. Such a deposited layer would be barely measurable, and would be of a similar sediment type to the ambient surface sediment. Based on the temporary presence of the equipment, and the prediction that the deposition footprint will be negligible, it is considered that the effect on the sedimentary environment due to the removal of buried cables, in both the near-field and the far-field, will be ***negligible***. It should be noted that it is the effect on the physical environment – the seabed features and the sediment regime – that has been assessed as negligible, and this is not considered to be a sensitive receptor. Any potential indirect effects on other sensitive receptors, such as benthic communities living in the sediment, have not been assessed in this chapter.

Intertidal Region

139 As it is unknown whether the cable will remain *in situ* or be removed, a precautionary approach has been taken. The worst case would be the removal of the cable which would cause similar disturbance impacts to the construction phase, although rock cutting itself would not be required. Consequently, no significant impacts due to changes in the hydrodynamics and sediment regime within the intertidal region are predicted.

9.7 Mitigation and Residual Impacts

140 The physical processes assessment has adopted a conservative approach, and has assessed high-impact scenario impacts. The assessment has concluded that changes to the oceanographic regime and the subsequent sedimentary environment will be small and of a negligible to low significance (depending on the activity/process being assessed). It is therefore recommended that no mitigation is required in respect of physical processes effects. Consequently, the residual effects are as previously assessed.

141 All steps during the design and construction of the development that can reasonably be taken to minimise any impacts should be employed, for example minimising the sediment deposition in the development area by use of a licensed disposal site for dredged material. Similarly, a nearshore survey should be completed to inform the design of the intertidal and nearshore cable laying, and thus minimise impacts.

142 From an engineering perspective, the assessment has identified the potential for scour around the turbine foundations. A variety of techniques may be employed to reduce or eliminate this scour. These include: rock armouring, mattressing, and frond mats. Full details are provided in Appendix 9.3: Physical Processes Technical Report.

9.8 Cumulative and In-Combination Impacts

143 Cumulative impacts are considered to be those arising from interaction with similar developments, and in-combination impacts are those arising from interaction with unlike activities (refer to Chapter 6: The Approach to Environmental Impact Assessment). The cumulative impacts from the Inch Cape STW and the Firth of Forth Round 3 Zone 2 offshore wind farms, together with the Neart na Gaoithe development, have been assessed. For the operation and maintenance phase, all turbines for the three developments have been explicitly included in the model, and therefore cumulative effects have been explicitly modelled. For the construction and decommissioning phases, the other developments have not been modelled explicitly. However, although the Firth of Forth Round 3 Zone 2 development covers a larger area than that proposed for Neart na Gaoithe, the maximum size of the turbines is not expected to be greater. Therefore any effects from the construction or decommissioning phases of individual turbines will not be greater than those predicted for the Neart na Gaoithe development. Assessment of the cumulative effects during the construction and decommissioning phases has therefore been based on this principle.

144 As there are no other industries or developments identified in the region, there will be no in-combination impacts. All relevant details of the assessment, and plots showing predicted cumulative impacts, are provided in full in Appendix 9.3: Physical Processes Technical Report. However, indicative plots are included in this chapter.

9.8.1 Construction

9.8.1.1 Water Levels and Currents

145 The impact assessment for the Neart na Gaoithe development indicates that the effect of the construction phase on the hydrodynamic regime would be negligible, and that no cumulative effects due to construction phase activities for the Neart na Gaoithe development would occur. Similarly, any construction phase activities for the other two developments will also be of negligible importance on the water levels and currents, and no overlap of effect from different developments is predicted. It is therefore concluded that ***no*** cumulative effects will occur.

9.8.1.2 Wave Climate

146 The impact assessment for the Neart na Gaoithe development indicated that the effect of the construction phase on the wave climate would be negligible, and that no cumulative effects due to construction phase activities for Neart na Gaoithe would occur. Similarly, any construction phase activities for the other two developments will also be of negligible importance on the wave climate, and no overlap of effect from different developments is anticipated. It is therefore concluded that ***no*** cumulative effects will occur.

9.8.1.3 Sediment Regime

147 The impact assessment for the Neart na Gaoithe development indicated that the effect of the construction phase on the sediment regime might be relatively high, but that these effects would be very localised to the particular construction activity, and would be temporary. The overall importance of the effect was considered to be negligible to the sedimentary environment (although no indirect impacts on other environment receptors were assessed), and no overlap of effect from different developments is anticipated. It is therefore concluded that ***no*** cumulative effects will occur.

9.8.2 Operation and Maintenance

9.8.2.1 Water Levels and Currents

148 The predicted cumulative impacts to water level due to the Neart na Gaoithe development and other offshore wind farm developments are more widespread than those from the Neart na Gaoithe development on its own, with a change to water level predicted in the Forth and Tay estuaries, and as far south as Torness Head. Figure 9.33 presents the predicted cumulative changes to water level (mean spring tide). However, the predicted change is negligible in magnitude (< 0.07% of mean spring tidal range), and would not be measurable. Although some overlap of effects from different developments is predicted, the resulting change is still negligible. It is therefore concluded that only ***negligible*** cumulative effects will occur.

149 The predicted cumulative changes to tidal currents due to the Neart na Gaoithe development and other nearby offshore wind farm developments are low (up to a maximum of 6% increase or decrease, depending on the location and the state of the tide), and very localised to the near-field of each development. Figure 9.34 shows the predicted cumulative changes to tidal currents (on a mean spring tide). No overlap of changes from any of the developments under the modelled 'high-impact' scenario is predicted, and therefore ***no*** cumulative effects are predicted on the tidal current regime.

9.8.2.2 Wave Climate

150 The predicted cumulative changes to the wave climate due to the Neart na Gaoithe development and other developments are considered to be small (up to 0.04 m reduction or < 3% of average significant wave height), although the affected areas are considerably larger than those for impacts from the Neart na Gaoithe development on its own. Figure 9.35 shows the predicted cumulative changes to wave height (90%ile). A maximum reduction of 0.02 m in significant wave height (< 1.5% of average waves) is predicted along parts of the Angus coastline. Therefore a cumulative effect from the three offshore wind farm developments on the wave climate at the coast is predicted, but the magnitude of this effect is considered to be ***negligible***.

9.8.2.3 Sediment Regime

151 The predicted cumulative changes to sediment transport processes due to the Neart na Gaoithe development and other surrounding developments are considered to be low, with the predicted exceedance of the critical shear stress changing typically by 1-3% (with a maximum difference of 6%, meaning the percentage of time that typical sediment within the site might be mobilised is predicted to increase from (up to) 15% to (up to) 21%). Figure 9.36 shows the predicted cumulative changes to the exceedance of critical shear stress due to the combined wave and current bed shear stress (the maximum bed shear under peak wave orbital velocity is plotted). These changes are restricted to the immediate vicinity of the development sites, and therefore no cumulative effect on the far-field sediment regime is predicted. The magnitude of these cumulative changes to the sediment regime is therefore considered to be ***negligible***.

152 The proposed offshore wind farm developments 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. There will be no overlap of effects from different developments at the coast, and therefore ***no*** cumulative effects from all three developments are predicted.

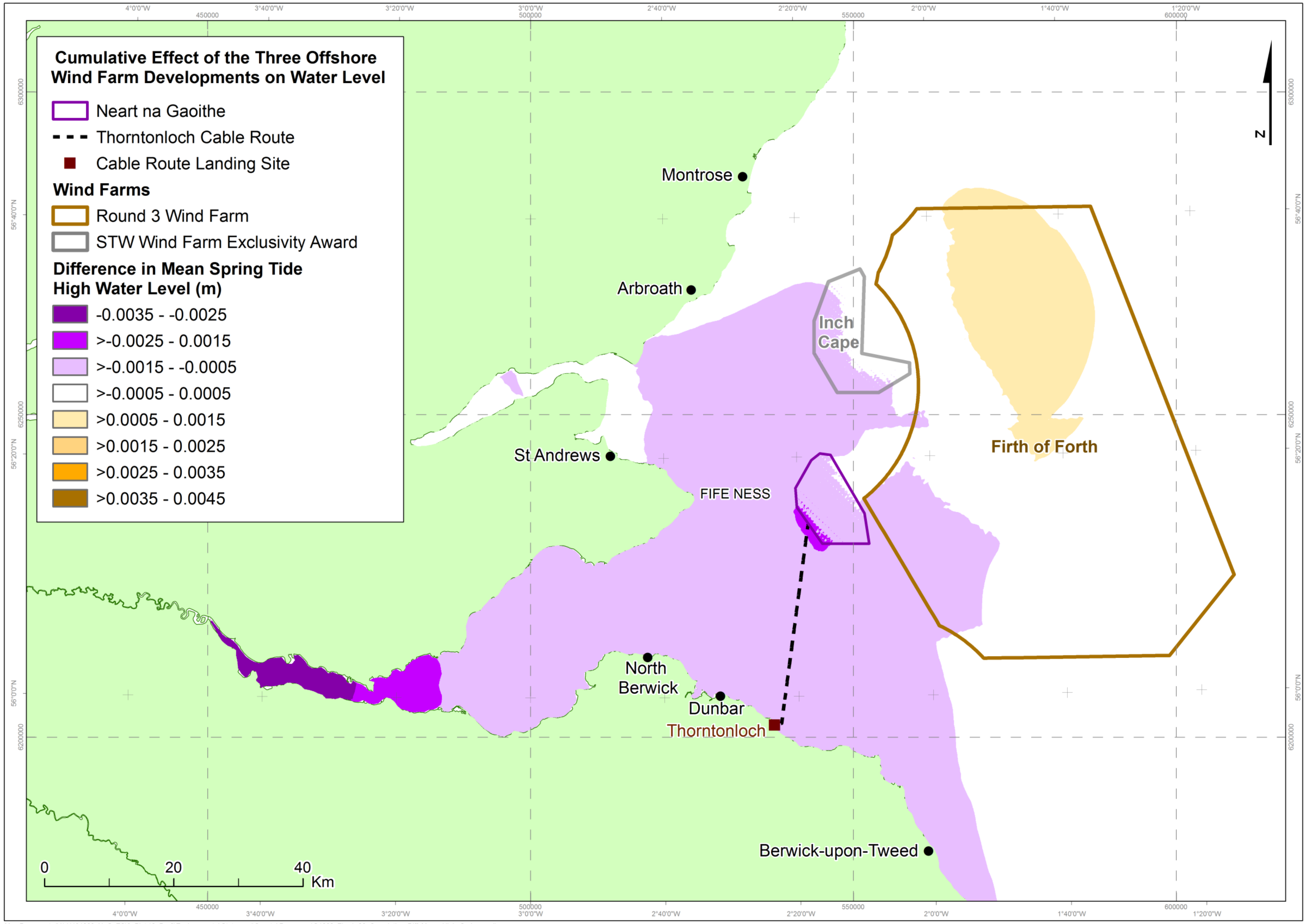

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Figure 9.33: Cumulative difference to mean spring tide high water level (m) due to the three developments

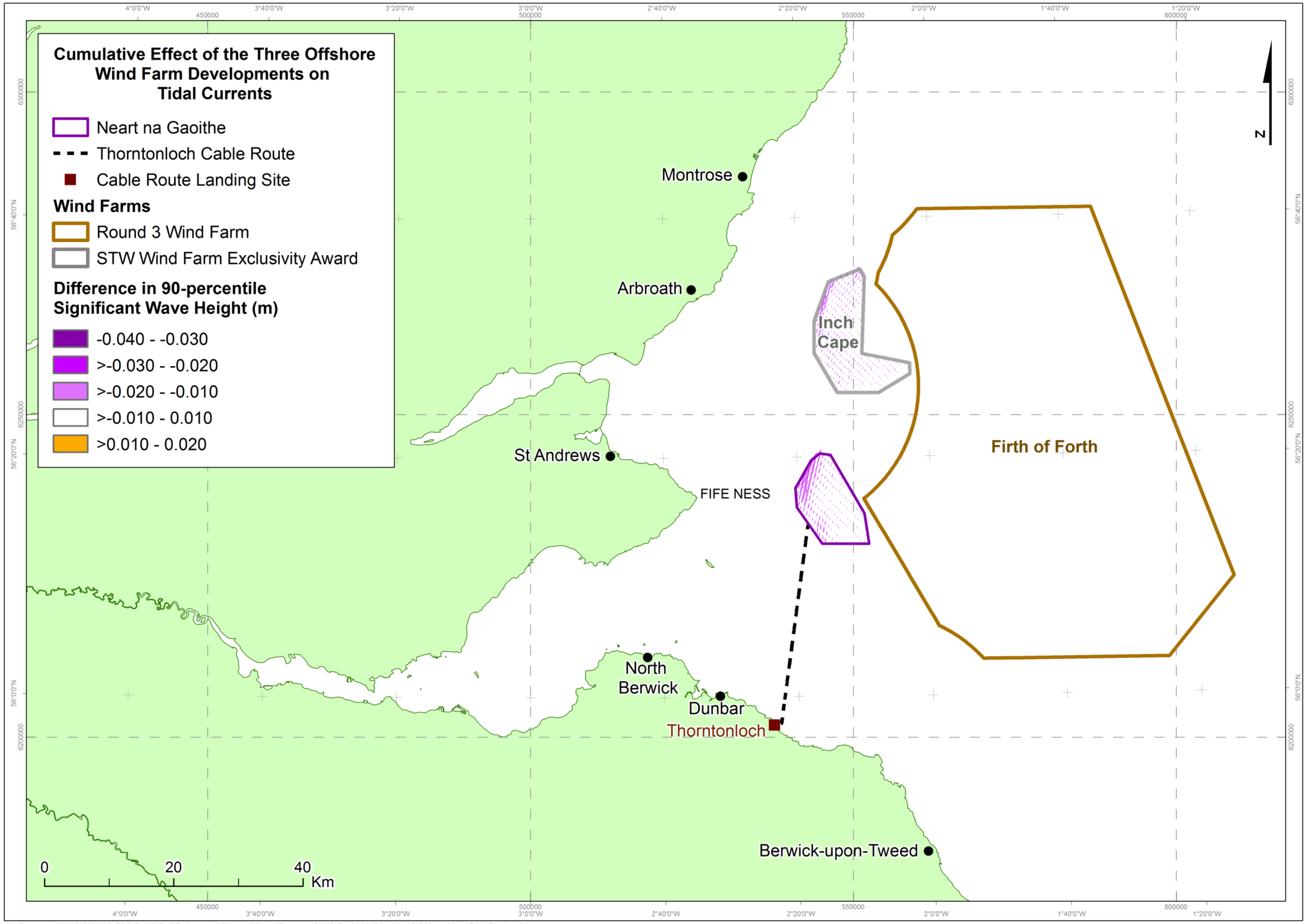

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Figure 9.34: Cumulative difference to mean spring tide peak flood current speed (m/s) due to the three developments

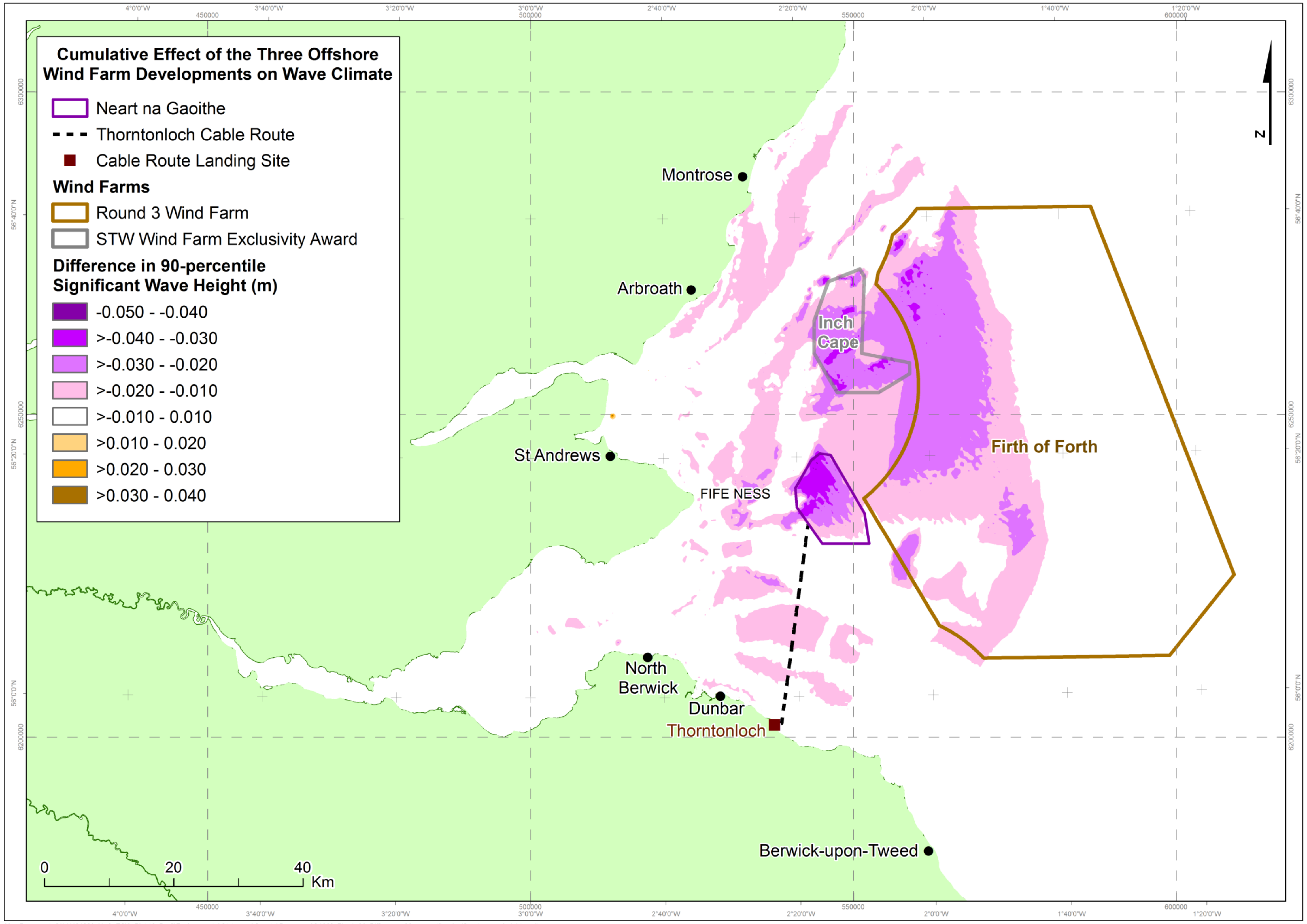

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Figure 9.35: Cumulative difference to 90-%ile significant wave height (m) due to the three developments

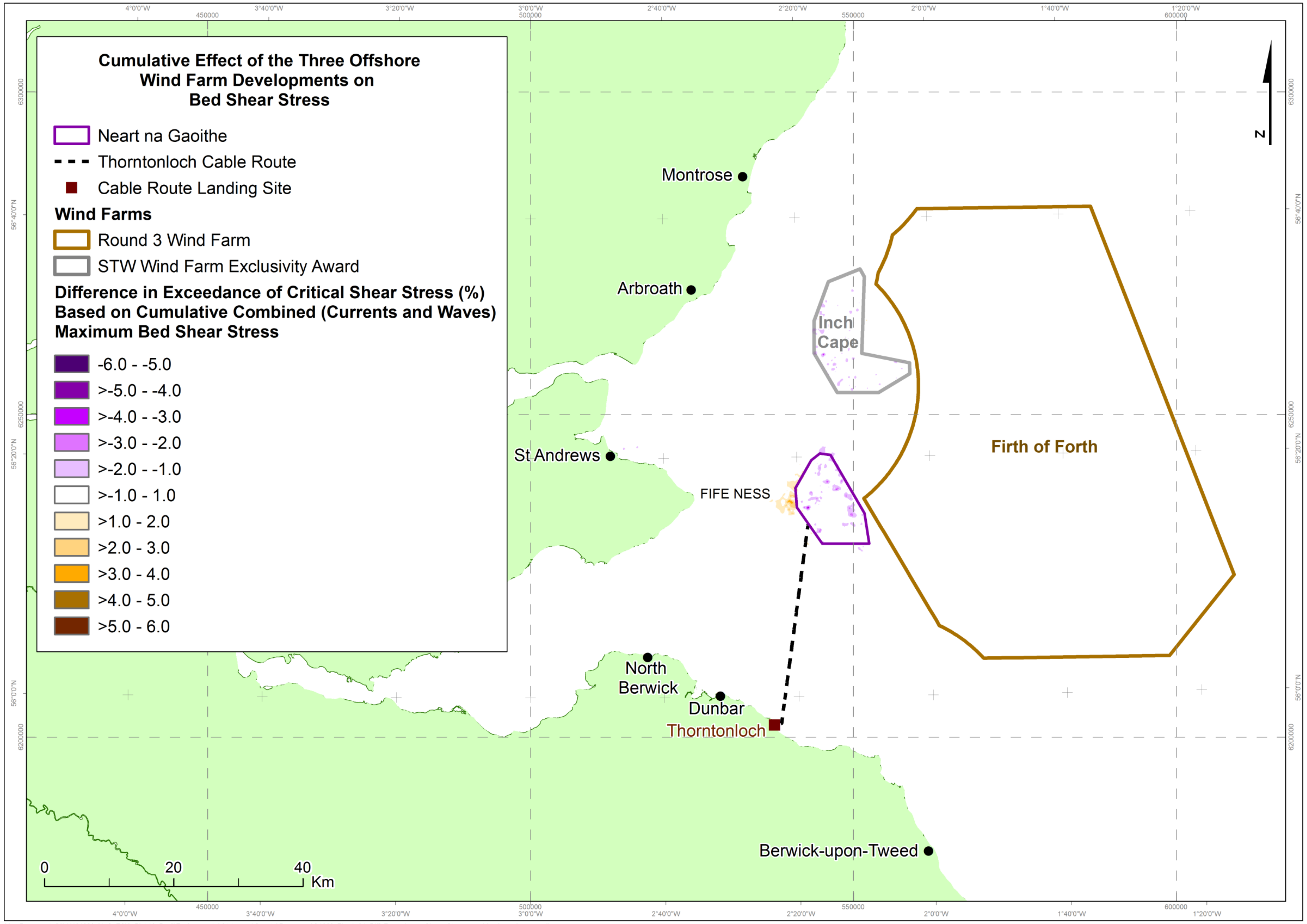

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Figure 9.36: Cumulative difference to exceedance of critical shear stress (%) due to the three developments – based on combined (currents plus waves) maximum bed shear stress

9.8.3 Decommissioning

9.8.3.1 Water Levels and Currents

153 The impact assessment for the Neart na Gaoithe development indicated that the effect of the decommissioning phase on the water levels and currents would be negligible. Similarly, any effects due to the decommissioning activities for the other two developments will also be of negligible magnitude, and there will be no overlap of effects from the different developments. Therefore, ***no*** overall cumulative effects are predicted.

9.8.3.2 Wave Climate

154 The impact assessment for the Neart na Gaoithe development indicated that the effect of the decommissioning phase on the wave climate would be negligible. Similarly, any effects due to the decommissioning activities for the other two developments will also be of negligible magnitude on the wave climate, and there will be no overlap of effects from the different developments. Therefore, ***no*** overall cumulative effects are predicted.

9.8.3.3 Sediment Regime

155 The impact assessment for the Neart na Gaoithe development indicated that the effect of the decommissioning phase on the sediment regime might be relatively high, but that these effects would be very localised to the particular activity, and would be temporary. The magnitude of the effects was considered to be negligible in terms of the sedimentary environment (although no indirect impacts on other environment receptors were assessed), and there will be no overlap of effects from the different developments. Therefore, ***no*** overall cumulative effects are predicted.

9.9 Monitoring

156 The physical processes assessment predicts the magnitude of effects due to the development of the offshore wind farm to be low or negligible. Therefore, there is no requirement for an extensive impact-monitoring campaign.

157 However, the potential for local and short term increases in suspended sediment concentrations is predicted during the foundation preparation and cable burial operations. It is recommended that limited sampling of in-water suspended sediment concentrations be undertaken during these operations, in order to confirm the predicted effect of construction activities. Further monitoring shortly after these operations are complete would demonstrate the predicted short term nature of these impacts.

158 It is also recommended that, from an engineering perspective, regular bathymetric surveys be undertaken around a limited number of turbines following installation in order to quantify scour pit depths and identify any possible need for further protection. Similar surveys are recommended along the cable route in order to identify any areas of cable exposure.

9.10 Summary and Conclusions

159 The Neart na Gaoithe offshore wind farm development may potentially affect the physical processes in and around the development area. The presence of the turbine structures 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 may also lead to a change in the bed shear stress, and an increase or reduction in the potential for sediment entrainment and mobility. In addition, localised acceleration of flows and turbulence around structure foundations might result in scour around the turbine foundations.

160 Generally, current flow will be reduced upstream and downstream of each structure, and increased around the sides, as the flow is first retarded in front of the structure, then bifurcates and accelerates around the structure, and finally slows and re-joins the ambient flow behind.

161 The interaction of the structures with the wave field will potentially cause scattering, refraction and shoaling of waves, leading to a general reduction of wave energy downstream of the development.

162 The near and far-field impacts to physical processes due to the Neart na Gaoithe development, together with any cumulative impacts associated with the neighbouring Inch Cape and Firth of Forth Round 3 Zone 2 offshore wind farms, have been assessed. The scale and significance of impacts on the hydrodynamic regime, the wave climate and the sedimentary environment from the Construction, Operation and Maintenance, and Decommissioning phases of the developments have been determined. These are summarised in Table 9.11, which shows that all changes are negligible or low.

Phase	Source	Receptor	Near-Field		Far-Field		Cumulative		Comments
			Magnitude of change	Duration of change	Magnitude of change	Duration of change	Magnitude of change	Duration of change	
Construction	Installation equipment	Water level	Negligible	Negligible	None	None	None	None	Only negligible changes are predicted in near-field. Scour rates around legs of installation vessels are negligible and temporary. No far-field or cumulative changes predicted.
		Tidal currents	Negligible	Negligible	None	None	None	None	
		Wave heights	Negligible	Negligible	None	None	None	None	
		Suspended Sediment Concentrations (SSC)	Negligible	Negligible	None	None	None	None	
		Seabed features (bedforms)	Negligible	Negligible	None	None	None	None	
		Sediment regime	Negligible	Negligible	None	None	None	None	
		Coastal processes	Negligible	Negligible	None	None	None	None	
	Bed preparation for gravity bases (dredging)	Water level	No impact	No impact	None	None	None	None	No effect predicted.
		Tidal currents	No impact	No impact	None	None	None	None	
		Wave heights	No impact	No impact	None	None	None	None	
		SSC	Up to 300 mg/l above background	During dredging period only.	None	None	None	None	Although changes to SSC are relatively high compared with background levels, this will be for short period during construction. Significance of this impact will be dependent on the vulnerability of the relevant receptors.
		Seabed features (bedforms)	Deposition up to 30 cm (typically < 10 mm)	Effectively permanent, but dependent on tidal conditions.	None	None	None	None	Resulting deposition will occur over the whole development area. Settled material will be the same as the ambient conditions, and will be subject to the natural processes of erosion/deposition experienced at the site. No material change to seabed features or bedforms are predicted.
		Sediment regime	No impact	No impact	None	None	None	None	No effect predicted.
		Coastal processes	No impact	No impact	None	None	None	None	
	Cable burial	Water level	No impact	No impact	None	None	None	None	No effect predicted.
		Tidal currents	No impact	No impact	None	None	None	None	
		Wave heights	No impact	No impact	None	None	None	None	
		SSC	Up to 30 mg/l (very localised)	High – during cable-burial period only.	None	None	None	None	Concentrations are relatively high compared with background levels, but will be very localised and temporary. Significance of impacts will be dependent on the vulnerability of the relevant receptors.
		Seabed features (bedforms)	Deposition up to 3 mm (typically < 0.1 mm)	Effectively permanent, but dependent on tidal conditions.	None	None	None	None	Resulting deposition will be very thin and localised. Settled material will be the same as ambient, and no material change to seabed features will result.
		Sediment regime	None	None	None	None	None	None	No effect predicted.
		Coastal processes	None	None	None	None	None	None	
Operation and Maintenance	Presence of gravity base and turbines	Water level	Up to 0.025% of water depth	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 spring tidal range	Effectively permanent, but dependent on tidal conditions.	Predicted changes are very small compared with natural variability, and would not be measurable. The importance of the change is therefore negligible in both near and far-field.
		Tidal currents	Up to 6% of spring velocities (typically < 3%)	Effectively permanent, but dependent on tidal conditions.	Negligible	Negligible	Negligible	Negligible	Near-field changes are small and within the range expected due to natural variability. Far-field changes will be negligible. The importance of the change to the tidal regime is therefore low.

Phase	Source	Receptor	Near-Field		Far-Field		Cumulative		Comments
			Magnitude of change	Duration of change	Magnitude of change	Duration of change	Magnitude of change	Duration of change	
		Wave heights	Reduced by up to 2.8% (dependent on wave conditions)	Effectively permanent, but dependent on wave conditions.	Negligible	Negligible	Reduced by up to 3% (dependent on wave conditions).	Effectively permanent, but dependent on wave conditions.	Near-field and cumulative far-field changes small compared with natural variability. The importance of the change to wave climate is therefore low.
		SSC	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible.
		Seabed features (bedforms)	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	
		Sediment regime	Up to 6% absolute increase in exceedance of critical shear stress (typically ± 1%)	Effectively permanent, but dependent on tidal and wave conditions.	Negligible	Negligible	Negligible	Negligible	Near-field changes are comparable with natural variability. No material change to seabed features is predicted. No far-field or cumulative changes are predicted. Importance of changes to sediment regime is therefore low.
		Coastal processes	Not applicable as site is more than 15 km offshore.	Not applicable as site is more than 15 km offshore.	Negligible	Negligible	Negligible	Negligible	No changes to coastal processes.
	Scour around jacket structures	Water level, tidal currents, wave heights	None	None	None	None	None	None	No effect predicted.
		SSC	Up to 300 mg/l locally (typically < 10 mg/l)	During formation of equilibrium scour pits – dependent on tidal but typically up to 3 months.	None	None	None	None	Scour occurs on spring tides only therefore excess sediments are introduced gradually and periodically.
		Seabed features (bedforms)	Scour pits formed around structures up to 3.26 m deep, with scoured area up to 1,063 m^2. Scoured material re-distributed within development area up to maximum of 0.1 m.	Effectively permanent, but dependent on tidal and wave conditions.	None	None	None	None	Scour pits are expected to remain as stable, permanent features around structures (highly limited infilling).
		Sediment regime Coastal processes	Negligible	Negligible	None	None	None	None	No effect predicted.
	Rock armour protection over nearshore cable	Tidal currents and waves	Negligible	Negligible	None	None	None	None	Changes are comparable with natural variability.
Decommissioning	Removal of gravity base and turbines	Water level	Negligible	Temporary	None	None	None	None	Negligible.
		Tidal currents	Negligible	Temporary	None	None	None	None	
		Wave heights	Negligible	Temporary	None	None	None	None	
		SSC	Up to 30 mg/l (very localised)	Temporary – during cable-removal period only	None	None	None	None	
		Seabed features (bedforms)	Deposition up to 3 mm (typically < 0.1 mm)	Settled material subject to the natural process of erosion/deposition experienced at site.	None	None	None	None	
		Sediment regime	Negligible	Temporary	None	None	None	None	
		Coastal processes	Negligible	Temporary	None	None	None	None	

Table 9.11: Summary of predicted near-field, far-field and cumulative changes due to the proposed development(s)

9.11 References

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Appendices

Appendix 9.1 – Data Gap Analysis and Data Review

Appendix 9.2 – Hydrodynamic and Spectral Wave Model Calibration and Validation

Appendix 9.3 – Physical Processes Technical Report

Appendix 9.4 – Proposed Methodology for Metocean and Coastal Processes Assessments

Appendix 9.5 – Stakeholder Consultation

Appendix 9.6 – Regional Baseline Description