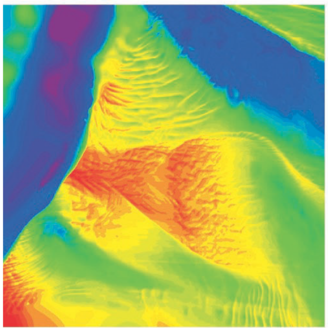
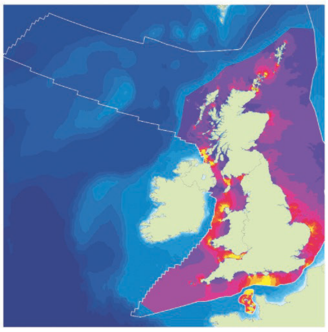
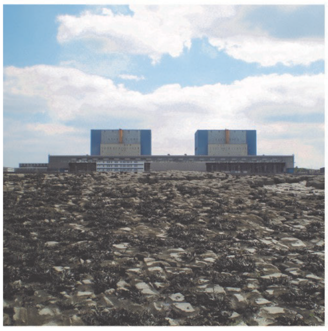
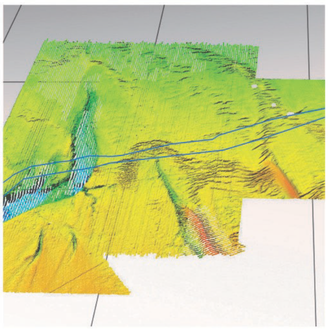
7.2 Documents provided to the EIA Evidence Plan

GoBe Consultants Ltd

Thanet Extension OWF Position Paper

Marine Geology, Oceanography and Physical Processes Method Statement

April 2017

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1 Introduction

At the Thanet Extension ('Thanet EXT') Offshore Evidence Plan meeting (held 28 February, 2017), it was agreed by all parties that it would be beneficial for a Position Paper to be circulated, setting out the proposed methodology for environmental impact assessment (EIA) of marine geology, oceanography and physical processes (hereafter collectively referred to as 'marine processes') as well as the justification for the proposed approach.

The assessment of marine processes for Thanet EXT is being undertaken by ABPmer. ABPmer has undertaken coastal processes assessments for over 30 Round 1, 2 and 3 projects and therefore has a very large body of knowledge to draw upon to inform the assessment. ABPmer also has considerable experience of working in the Greater Thames region, having previously supported numerous other offshore wind farm marine processes EIA studies including London Array, Gunfleet Sands, Greater Gabbard and Galloper.

From the outset, it is important to note that no new site specific wave, tide and sediment transport modelling is proposed for the Thanet EXT marine processes assessment. A range of analytical techniques are proposed to underpin the assessments, which are described in detail in this Position Paper. There are several project specific reasons why such an approach is justified and these are also set out.

Marine processes assessments have been carried out for a number of other UK offshore wind farm (OWF) developments, without project specific numerical modelling of waves, tides and sediment transport. These include:

- Seagreen Phase 1 (consented in 2014);
- Burbo Round 2 extension (consented in 2014);
- Walney Round 2 extension (consented in 2014); and
- Gunfleet Sands 2 and Demonstration sites (consented in 2008).

In addition to the above, the East Anglia THREE (Round 3) OWF EIA has been concluded without further project specific numerical modelling. The project is currently being considered by the Planning Inspectorate, with a decision anticipated in Q1-Q2 2017.

This Position Paper is structured as follows:

Section 2: offers a brief overview of the key characteristics of the Thanet EXT project;

Section 3: describes the assessment approach and key findings from Thanet OWF;

Section 4: sets out the proposed approaches to the Thanet EXT assessment; and

Section 5: summarises the key points of this position paper.

2 Thanet EXT Project

In order to identify the most appropriate impact assessment methodology, it is important to understand the likely design envelope of the project. This is summarised within this section.

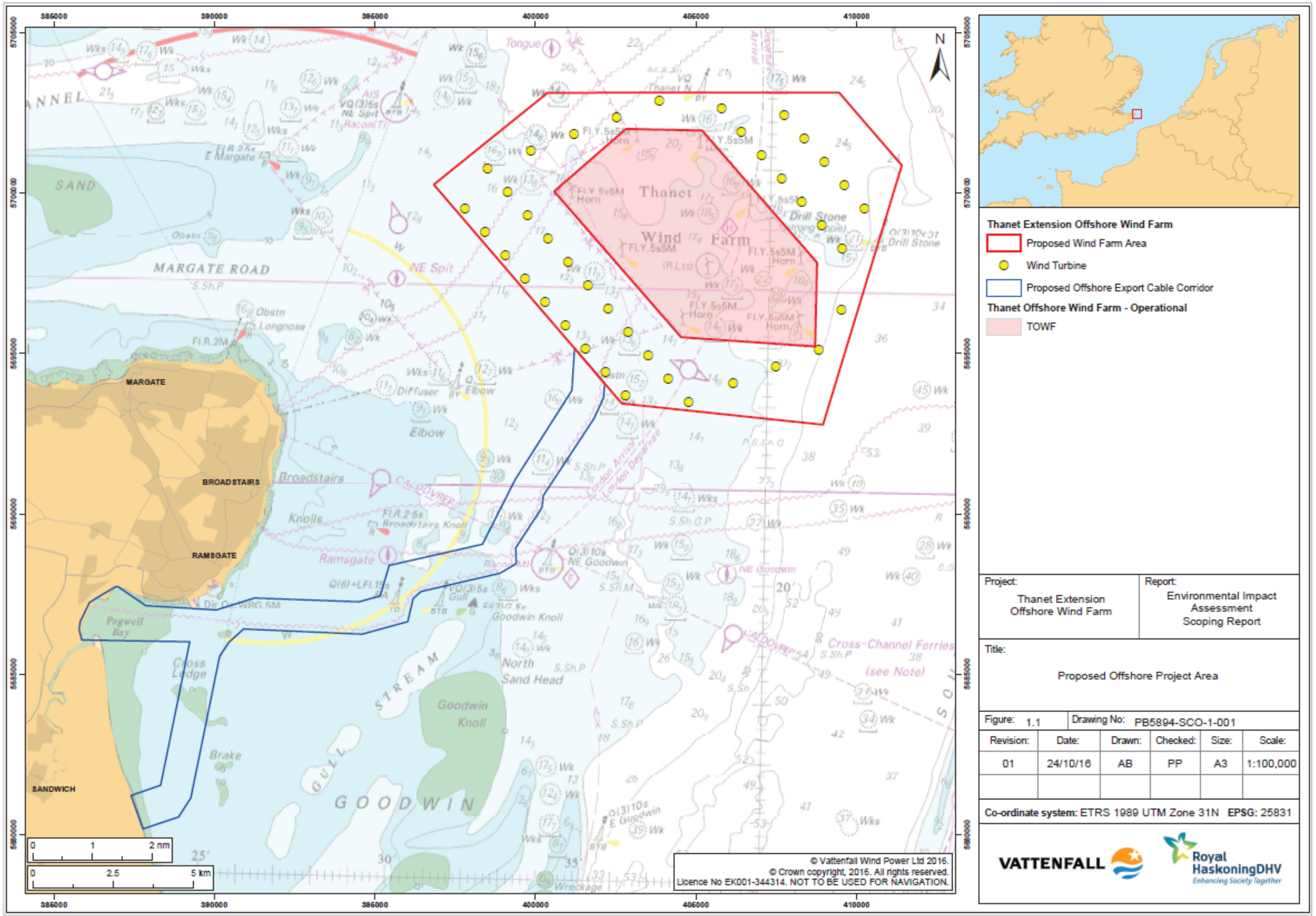
The proposed Thanet Extension Windfarm Area would be located approximately 8 km offshore (at the closest point), in proximity to the operational Thanet Offshore Wind Farm (Figure 1). Electricity generated in the windfarm area would be transported to the shore by offshore export cables installed within the proposed offshore export cable corridor. There are currently two options for landfall and Onshore Cable Route, Option 1 making landfall in Pegwell Bay (nearby to the operational Thanet OWF export cable landfall), and Option 2 making landfall at Sandwich Bay to the south.

A summary of the key project details relevant to the Thanet EXT marine processes assessment are set out in Table 1. For comparative purposes, equivalent details for the operational Thanet OWF are also included in this table.

Table 1. Summary of key metrics for the Thanet EXT and (operational) Thanet OWF projects

Metric	Thanet EXT	Thanet OWF
Array area	68.5 km^2	35 km^2
Water depth range	13 to 43 m	14 to 23 m
Max. no of turbines	34	100
Turbine capacity	8 to 10 MW	3 MW
Project capacity	340 MW	300 MW
Foundation options	Monopiles 3 or 4 legged jackets (pin piles) 3 or 4 legged jackets (suction caissons)	Monopiles
Turbine separation distance	960 m (each row) 1,350 m (between rows)	500 m (each row) 800 m (between rows)
Indicative turbine density	0.5 turbines/ km^2	2.9 turbines/ km^2

Up to 34 wind turbine foundations may be installed within the Thanet EXT site (Table 1). Wind turbines within the Thanet EXT site will be supported by monopile, jacket and/or suction caisson foundations (Table 1). Summary descriptions of the presently proposed dimensions of these foundation types are provided in Table 2. Based on experience during the construction of Thanet OWF, drilling is not expected to be required to assist with the installation of monopiles or jacket foundation pin piles (if used). Suction caisson foundations may require the seabed to be prepared by dredging prior to installation.



Source Vattenfall, 2016

Figure 1. Thanet EXT offshore project area

Table 2. Thanet EXT foundation descriptions

Foundation type	Description
Monopile	Cylindrical steel pile with conical transitions - up to 10 m diameter Penetration could be 30 to 60 m depth below seabed level
Three legged jackets on either pin piles or suction caisson anchoring	Typically single large diameter vertical column supported by three braces Steel pin piles - diameter approximately 3 m Seabed penetration of up to 60 m Spacing between legs is a maximum of approximately 60 m
Four legged jackets on pin piles or suction caisson anchoring	Steel pin pile - diameter approximately 3 m Numerous design variants available, typically, lattice structure comprising steel tubular sections Seabed penetration of up to 60 m Spacing between legs is approximately 40 m

The potential impacts being assessed for the Thanet EXT project are individually associated with certain phases of the wind farm life cycle, including:

- Construction phase;
- Operation phase; and
- Decommissioning phase.

The construction phase is defined as the period of construction activity up to the point that individual items of infrastructure are installed in the form they will remain for the operational lifetime of the project. Local construction activities may last in the order of hours to days and there may be several phases of construction activity at any given location. Construction of the whole wind farm will take place over months to years, with a gradual transition from a purely baseline condition at the start of construction, to a fully operational condition with all infrastructure in place at the end.

The operation phase will consider impacts occurring during the lifetime of the development due to the presence of the OWF infrastructure. This phase also includes any major maintenance activities that may potentially affect coastal processes, e.g. cable maintenance and repair.

The decommissioning phase will occur at the end of the operational lifetime of the offshore wind farm, which is expected to be around 25 years following construction. The operational lifetime is largely determined by the expected lifetime of the wind turbine generators. Repowering (replacement or refurbishment of wind turbine generators to extend the operational lifetime of the wind farm) will not be considered in this study. Potential coastal process impact types during decommissioning are generally similar to those considered in relation to construction, and are typically of a similar or lesser magnitude of effect.

3 Original Thanet OWF

This section summarises the data used, assessment methods and EIA results of the original Thanet OWF marine processes assessment. This is important in order to understand the applicability of findings to the Thanet EXT project.

For the original Thanet OWF marine processes assessment, a desktop review of existing studies (including academic literature, industry reports and regional scale numerical modelling investigations) was undertaken to provide hydraulic and sedimentary baseline information. This study was carried out in accordance with the best-practice guidance at that time for the assessment of offshore wind farms (Cefas, 2004). Project-specific geophysical and geotechnical information was also collected to augment the existing baseline evidence. Key datasets are summarised in Table 3.

Table 3. Summary of key datasets used for Thanet OWF

Parameter	Approach for Thanet OWF
Tides and water levels	(Publicly available information only) TELEMAC modelling output from the Southern North Sea Sediment Transport Study (HR Wallingford *et al*, 2002)
Waves	Project-specific wave measurements from Drill Stone Buoy (located in Thanet OWF site February to December 2004) Measured offshore wave data from Kentish Knock
Sediments	Project-specific geophysical survey of wind farm site and export cable corridor (EGS International, 2005)
Sediment transport	(Publicly available information only) Modelling output from the Southern North Sea Sediment Transport Study (HR Wallingford *et al*,2002)
Geology	Project-specific geophysical and geotechnical survey of wind farm site and export cable corridor (EGS International, 2005) BGS seabed sediment maps
Bathymetry	Project-specific geophysical survey of wind farm site and export cable corridor (EGS International, 2005) UKHO Admiralty Charts

With the agreement of Cefas at the time, no new regional scale project specific modelling was required to support the original Thanet OWF EIA. Instead, a range of quantitative and qualitative assessment approaches were used, as summarised in Table 4.

The assessment included the wind farm array area, with consideration given to wind turbine foundations, the inter array cables and the export cable route to the landfall. The assessment also considered potential cumulative impacts resulting from other consented and proposed offshore wind farm sites, seabed infrastructure and activities.

Table 4. Assessment approach for Thanet OWF

Issue	Assessment Approach for Thanet OWF
Potential changes to suspended sediment concentrations, bed levels and sediment type	A semi-quantitative desk based assessment, relying on expert judgment, taking into consideration the volume of displaced material and prevailing hydrodynamic and wave conditions.
Potential changes to landfall morphology	A qualitative desk based assessment of cable landfall in Pegwell Bay.
Potential changes to the tidal regime	A semi-quantitative desk based assessment, drawing upon existing evidence base and design guidance.
Potential changes to the wave regime	An array-scale quantitative assessment derived from modelling results presented in Ohl *et al.*, (2001). (Ohl *et al*, 2001 considered wave scattering and diffraction associated with obstruction from 6 m and 20 m diameter structures.)
Potential changes to the sediment transport regime	A qualitative desk based assessment, using expert judgement to link changes in the tidal and wave regime with potential changes in sediment transport.
Scour	A desk based assessment using empirical equations to enable determination of scour pit characteristics (horizontal extent and equilibrium scour depth) from foundation design.

Impacts were assigned a level of likely significance from **major** to **negligible** or **non-measurable**. In brief, although it was considered likely that Thanet OWF would have some localised impact on waves, currents and the corresponding sediment transport regime in the immediate vicinity of the Thanet OWF site, all potential far field impacts in relation to marine processes were assessed to be either negligible or non-measurable.

Thanet OWF has been operational since September 2010 (i.e. over 6 years at the time of writing). To date, no significant adverse morphological impacts have been observed that are attributed to the wind farm, which is consistent with the assessment and conclusions of the original EIA.

So called 'turbid wakes' are a coastal processes effect originating within the Thanet OWF array area that have been observed in satellite and other aerial imagery (e.g. NASA 2016, Vanhellemont *et al*, 2014) taken since the construction of the Thanet OWF. These features were not anticipated or assessed in the original Thanet OWF EIA. A separate position paper (ABPmer, 2017) has been produced to consider the likely causes of turbid wake features. In summary, turbid wake features are also associated with other wind farms in the Outer Thames Estuary, and are considered most likely to be a purely visual effect caused by upward mixing of naturally present sediment in suspension near to the seabed in the turbulent wake of individual turbine foundations. Turbid wake features are not likely to be associated with localised seabed erosion or associated morphological change.

A key finding from the original Thanet OWF marine processes EIA was that the combined effect of all the wind turbine foundations would be negligible (up to 100 x 20 m diameter monopiles was assessed). This conclusion was reached on the basis that the impacts of individual foundations in respect of the changes to waves and currents largely recover over distances less than the spacing between them. The joint conclusion was that the impact of individual foundations is of a limited magnitude and spatial extent, and that the array scale effects would not be greater than that for individual foundations. There is no evidence available which contradicts these conclusions.

4 Proposed Assessment Approach for Thanet EXT

4.1 Overview

This section provides a detailed description of the proposed assessment methodology and is informed by the current design envelope, existing data from Thanet OWF and from other OWFs. Each potential impact identified and scoped in for assessment in relation to marine processes has been defined and the assessment approach set out. The methods and approaches described here are informed by, and consistent with, the recommendations of ABPmer & HR Wallingford (2009), for OWF marine processes EIA.

The potential impacts to be assessed in relation to marine processes for Thanet EXT are specified in the scoping report (Vattenfall, 2016). The nature of the scoped in impacts are similar to that previously considered for the Thanet OWF project.

Having reviewed the Thanet OWF evidence as well as the Thanet EXT project design statement, it is considered that no new detailed site specific modelling is required. This is because it can be demonstrated that: (i) sufficient data is present to characterise the spatial and temporal ranges of natural baseline variability of the key parameters of interest; and (ii) the project under consideration remains of a sufficiently similar character (e.g. operation type, foundation type and number) to the existing operational Thanet OWF development. Further justification for this proposed approach is set out in Section 4.4.

4.2 Potential impacts

In most cases, marine processes are not in themselves receptors but are, instead, 'pathways' which have the potential to indirectly impact other environmental receptors. Accordingly, although assessment outputs from the Thanet EXT marine processes assessments will be reported in a stand-alone Environmental Statement chapter (and accompanying technical report), for the most part they will not be accompanied by statements of 'effect significance.' Instead, the information on changes to marine processes pathways will be used to inform other EIA topic assessments, namely:

- Marine Water and Sediment Quality;
- Benthic and Intertidal Ecology;
- Fish and Shellfish Ecology;
- Marine Mammal Ecology;
- Offshore Ornithology; and
- Commercial Fisheries.

Whilst marine processes can largely be considered as pathways, a small number of features have been identified as potentially sensitive marine processes receptors. These are:

- The shoreline; and
- Offshore sandbanks.

Where these receptors have the potential to be affected by changes to marine processes, a full impact assessment (i.e. assigning sensitivity, magnitude and significance) will be carried out.

The potential changes resulting from each phase of the wind farm life cycle are:

- Construction phase:
  - Potential changes to suspended sediment concentrations, bed levels and sediment type;
  - Potential changes to landfall morphology;
- Operation phase:
  - Potential changes to the tidal regime;
  - Potential changes to the wave regime;
  - Potential changes to the sediment transport regime;
  - Scour;
- Decommissioning phase:
  - Potential changes to suspended sediment concentrations, bed levels and sediment type; and
  - Potential changes to landfall morphology.

4.3 Assessment approach

The Thanet EXT marine processes EIA can be broadly divided into two parts:

- Baseline characterisation; and
- Impact assessment.

For the baseline characterisation, a large body of new project-specific data is available to inform understanding of the Thanet EXT and offshore cable corridor baseline environment, particularly in terms of seabed morphology and seabed/sub-seabed sediment characteristics. These project-specific datasets are being considered alongside existing publicly available information to enable robust characterisation of both the project boundary and surrounding area. Summary details of these surveys and datasets are provided in the Thanet EXT Scoping Report (Vattenfall, 2016).

Responses to scoping have confirmed that the project and non-project specific datasets are of sufficient spatial and temporal resolution to enable robust baseline characterisation. Accordingly, this aspect of the assessment is not discussed further.

For the impact assessment, the following combination of approaches is proposed:

- Use of the 'evidence base' of monitoring data collected during the construction, operation and maintenance of other sufficiently analogous offshore wind farms, in particular the adjacent Thanet OWF;
- Use of the 'evidence base' of results from pre-existing numerical modelling and desk based assessments undertaken to support EIA for other sufficiently analogous offshore wind farms (both in terms of project design and environmental setting);
- New analytical assessments of project-specific infrastructure design/s and activities, including the use of spreadsheet based tools; and
- Standard relationships describing (for example) hydrodynamic interactions with obstacles, sediment transport including settling and mobilisation, seabed scour, etc.

Detailed proposed methodologies for Thanet EXT marine processes assessment are set out for the construction phase in Table 5, for the operation phase in Table 6 and for the decommissioning phase in Table 7.

Table 5. Proposed approach for construction phase

Activity/ Potential Impact	Inputs/ Data	Method
Potential changes to suspended sediment concentrations, bed levels and sediment type	**Existing baseline** Satellite derived maps of suspended particulate matter (SPM) concentrations Thanet OWF geophysical, geotechnical and benthic survey data BGS seabed sediment maps Hydrodynamic data presented in Thanet Offshore Wind Ltd (2005) **Data acquisition** Thanet EXT geophysical, geotechnical and benthic survey data **Evidence base** Monitoring evidence (both from the Thanet OWF and other analogous developments) Previous plume modelling for EIA (including similar OWF foundation bed preparation activities and cable installation) in analogous environmental settings	In order to quantitatively inform the assessment of potential changes to suspended sediment concentrations and bed levels arising from bed preparation (dredging) or cable burial activities, a number of spreadsheet based numerical models will be developed, taking into consideration information on: ▪ Flow speed; ▪ Direction; ▪ Lateral dispersion (informed from plume modelling); ▪ Settling velocities; and ▪ Sediment properties (seabed and sub-seabed). Results will be provided for a range of hydrodynamic conditions and sediment types, capturing the realistic worst case (in terms of plume extent, concentration and sediment deposition). Similar models have been developed and successfully used to inform the environmental impact assessments for similar activities at Burbo Bank Extension, Walney Extension and Navitus Bay offshore wind farms (ABPmer, 2013a, b; 2014, respectively). The quantitative outputs from these spreadsheets will be qualitatively and semi-quantitatively validated for consistency with the existing evidence base from other offshore wind farm developments. This evidence base includes monitoring and modelling information for both seabed preparation activities (prior to foundation installation) and cable installation activities. The evidence base (which may be used to validate the spreadsheet based numerical model outputs) also includes information from other commercial activities taking place in the vicinity of the Thanet EXT site which involve bed disturbance, most notably aggregate extraction. Studies undertaken to support these activities (such as Marine Aggregate Regional Environmental Assessments- http://www.marine-aggregate-rea.info/) also offer useful supporting information.

Activity/ Potential Impact	Inputs/ Data	Method
		The magnitude of any increase in turbidity will be evaluated in the context of the expected natural range (e.g. that reported by Cefas (2016) and Dolphin *et al.* (2011)) and in relation to the location and nature of any identified sensitive receptors.
Potential changes to landfall morphology	**Existing baseline** Outputs from the Regional Coastal Monitoring Programme (e.g. beach topographic data, wave data, aerial photography etc.) Environment Agency LiDAR (pre- and post-construction of Thanet OWF) **Data acquisition** Thanet EXT geophysical and geotechnical landfall surveys (presently being undertaken) **Evidence base** BERR review of cabling methodologies (BERR, 2008) EIA and post-construction monitoring evidence base for Thanet OWF	Where the export cable makes landfall, it must transition through the intertidal and coastal zone. The variety of methods available for installing cables in such environments may physically disturb or disrupt the present coastal morphology to differing degrees. At the time of construction, any disturbance will be localised to the landfall site. The short-term physical impact of each potential cable installation method being considered at the landfall will be assessed as a desktop analysis, giving consideration to available relevant coastal processes data (e.g. LiDAR, inter-tidal topographic data, coastal monitoring reports etc.). The assessment will also draw upon observational evidence from other analogous projects, in particular any changes during and after installation of the Thanet OWF export cable in Pegwell Bay. The physical nature and extent of the likely disturbance will be characterised using the Project Design Statement and with reference to the wider evidence base. The potential impact on beach morphology, hydrodynamics and sediment transport will be assessed by an experienced coastal geomorphologist in the context of the baseline environment of the landfall site as well as observational evidence from other analogous projects. The significance of the likelihood, magnitude and nature of short-term localised impacts will be evaluated in the context of the expected naturally occurring variability in morphology at the landfall and in relation to the location and nature of identified sensitive receptors.

Table 6. Proposed approach for operation phase

Activity/ Potential Impact	Inputs/ Data	Method
Potential changes to the tidal regime Potential changes to the wave regime Potential changes to the sediment transport regime	**Existing baseline** BODC current records Cefas WaveNet wave data ABPmer SEASTATES hindcast wind/ wave data **Data acquisition** Thanet EXT metocean data **Evidence base** Previous OWF EIA modelling (hydrodynamics and waves)	Interaction between the naturally present metocean regime (waves and currents) and the foundations of the wind farm infrastructure will result in a reduction in current speed and wave energy, and also an increase in levels of turbulence, locally. The effect on sediment transport immediately adjacent to individual foundations is to cause scour (considered as a separate impact below). At greater distances but still within the extent of the wind farm site (i.e. in the near-field), the effect on tidal currents is evident as a series of discrete wake features extending downstream along the tidal axis from each foundation. The effect of a foundation on individual waves is typically not measurable in practice but the cumulative effect of many foundations is generally accepted to be a slight reduction in wave height (e.g. East Anglia Offshore Wind, 2012; Moray Offshore Renewables Ltd, 2012, Navitus Bay Development Ltd, 2014). Persistent changes to wave and currents may have a net effect over time on net patterns of sediment transport (rates and directions). The sensitivity of these patterns to change will depend upon the relative importance of currents and/or waves, the magnitude and extent of any effect, the nature of the seabed substrate and the degree to which the system is presently in balance (e.g. could a small change reverse the direction of net transport, or, is the present rate and direction of transport essential to the maintenance of a dynamic morphological feature). The importance of small changes to instantaneous wave and current parameters will be evaluated in the context of the wide range of natural temporal variability (and longer term trends, e.g. annual to decadal cycles) in these regimes on hourly to decadal timescales. Potential changes to the tidal (water levels and currents) and wave regimes caused by the presence of the wind farm foundations will be assessed initially by reference to the results of more detailed previous numerical modelling studies undertaken for sufficiently analogous wind farm developments and metocean conditions, with consideration of the environmental setting and the foundation type, number and layout.

Activity/ Potential Impact	Inputs/ Data	Method
		A quantitative assessment will then be made of the blockage density presented by the additional foundations in Thanet EXT through consideration of the cross sectional area of each foundation, turbine spacing, number and area of the Thanet EXT array area. The blockage density will be considered both in absolute terms, and in comparison to the Thanet OWF and other operational wind farms where no associated direct or indirect adverse impacts have (yet) been observed. Potential changes to the sediment transport regime will be primarily assessed on the basis of the nature and magnitude of any impacts on the tidal and wave regimes (which control the rates and patterns of sediment transport). Consideration will then be given to whether the nature or rate of sediment supply across the wider area (i.e. outside of the Thanet EXT array area) might be otherwise affected by the wind farm.
Scour	**Existing baseline** Thanet OWF geophysical, geotechnical and benthic survey data BGS seabed sediment maps **Data acquisition** Thanet EXT geophysical, geotechnical and benthic survey data **Evidence base** EIA and post-construction monitoring evidence base	Interaction between the naturally present waves and currents and the foundations of the wind farm infrastructure has the potential to cause localised scouring of seabed sediment, leaving a depression that will persist in some form until the structure is removed. The extent and depth of scour may vary over time and may be limited under certain physical conditions; however, a conservative approach will be applied to calculating the maximum expected dimensions independent of other factors. Scour protection measures are typically used to mitigate the engineering risk posed by scour and, where used, will largely prevent scour developing; however, the area occupied by the scour protection might also be similarly considered as a modification to habitat. Based on project design information, the likely dimensions of scour for given foundation types will be quantitatively estimated using empirical relationships available from the relevant literature (e.g. Whitehouse, 1998). The dimensions of site and foundation appropriate scour protection (if required) may be provided by the project design information or may be inferred from the estimated dimensions of scour. The area of seabed modified either by scour or scour protection will be calculated, as well as the volume of material that could be eroded. An estimate of the time required to develop the scour described will be made. The results will be presented as an estimated total area of effect and as a proportion of the site area.

Activity/ Potential Impact	Inputs/ Data	Method
		The results of the scour assessment will be validated against observed patterns of scour at the Thanet OWF site (Titan, 2012) Further comment will be offered as to any mitigating features of the physical environment according to the metocean baseline and survey data from the site that are expected to limit the dimensions of, or delay the development of scour.
Turbid wakes	**Existing baseline** Thanet OWF geophysical survey data Satellite imagery **Data acquisition** Thanet EXT geophysical, geotechnical and benthic survey data **Evidence base** EIA and post-construction monitoring evidence base Academic studies, in particular Vanhellemont *et al*, (2014)	Turbid wakes are visual features, likely to be caused by turbulence in the wake of turbine foundations elevating sediment which is already naturally in suspension near to the seabed into the upper water column. Turbid wake features are not likely to be caused by seabed scour around the foundations. The maximum typical spatial extent of turbid wake features will be determined initially with reference to the limited available observed information. The mean spring tidal excursion distance, the rate of turbulence recovery in the wake and the properties of the sediment in suspension will then be used to extend the range of estimates to account for other tidal and wave conditions if possible. (See ABPmer Report R.2785 (ABPmer, 2017) for further details).

Table 7. Proposed approach for decommissioning phase

Activity/ Potential Impact	Inputs/ Data	Method
Potential changes to suspended sediment concentrations, bed levels and sediment type	(Project design statement)	It is expected that decommissioning activities will result in a lesser rate of sediment disturbance than that already considered in relation to dredging or cable burial in the construction phase. No further quantitative assessment of the actual (similar or lower) resulting levels of suspended sediment concentration or the fate of locally re-suspended sediments will be undertaken.
Potential changes to landfall morphology	**Existing baseline** Outputs from the Regional Coastal Monitoring Programme (e.g. beach topographic data, wave data, aerial photography etc.) Environment Agency LiDAR **Data acquisition** Thanet EXT geophysical and geotechnical landfall surveys (forthcoming) **Evidence base** BERR review of cabling methodologies (BERR, 2008) EIA and post-construction monitoring evidence base	Where the export cable makes landfall, it must transition through the intertidal zone. The methods identified for removing or decommissioning the cable and/or cable protection measures may physically disturb or disrupt the intertidal morphology to differing degrees. If infrastructure previously affecting marine processes is removed, there will be a subsequent readjustment of marine processes back towards the (future) baseline conditions. This may include changes to the regional coastal morphology by local enhancement or interruption of a long-shore sediment transport pathways. The potential for impacts relating to the decommissioning of cables and/or cable protection measures at the landfall will be assessed as part of the cable landfall desktop analysis described in relation to the construction and operation phases. This will include the consideration of observational evidence from analogous cable decommissioning activities. The physical nature and extent of the likely disturbance will be characterised using the Project Design Statement and with reference to the metocean baseline understanding and the wider evidence base. The significance of the magnitude and nature of long-term and potentially more extensive impacts will be evaluated in the context of the expected naturally occurring variability in morphology of the coastline, the expected timescale for recovery of the system to an equilibrium state, and the location and nature of identified sensitive receptors.

4.4 Supporting justification

The assessment approach is considered to be suitable and robust for the reasons set out below.

4.4.1 Size of development and nature of the proposed foundation type

Up to 34 wind turbine foundations may be installed within the Thanet EXT site (Table 1). The overall scale of new infrastructure within the proposed development is therefore small, relative to both the existing Thanet OWF (100 turbines) and many other built and consented UK offshore wind farm projects.

Wind turbines within the Thanet EXT site will be supported by monopile, jacket and/or suction caisson foundations (Table 1). Summary descriptions of the presently proposed dimensions of these foundation types are provided in Table 2. Although individual foundations may potentially present greater blockage than the 4.1 and 4.9 m diameter monopile foundations installed in the operational Thanet OWF site, the relatively smaller number of foundations, wider spacing and similarly small cross sectional area of individual foundations mean the blockage effect on waves and currents through the Thanet EXT site will be limited, both in absolute terms and relative to the existing Thanet OWF.

Specifically, the project design statement for Thanet EXT does not include an option for gravity base or similar large volume foundations. Gravity base foundations typically present a much larger blockage effect than other foundation types (such as monopiles and jacket foundations) and, if included, usually represent the 'worst case' option in assessments of effect on waves, currents and sediment transport.

4.4.2 Proposed method of foundation installation

Owing to the nature of the sub soils, the monopile foundations within the Thanet OWF were successfully installed via piling and no drilling was required. It is anticipated that drilling will also not be required within the Thanet EXT site and as such, is not included within the project design statement. In comparison to drilling, piling will result in minimal sediment disturbance which might lead to sediment in suspension or subsequent resettlement to the seabed.

Bed preparation may be required if suction caisson structures are used. These activities would be carried out using standard dredging techniques for which a large body of information is already available from the aggregate dredging industry in the Greater Thames region.

4.4.3 Observational evidence from Thanet OWF

The operational Thanet OWF site provides a close, and in many respects a conservative analogue for the Thanet EXT project, both in terms of environmental setting, approximate size, and the type and dimensions of individual turbine foundations. No significant adverse change to coastal or seabed morphology has been observed as a consequence of the construction and/or operation of Thanet OWF, which is consistent with the assessments undertaken to support the Thanet OWF marine processes assessment (Thanet Offshore Wind Ltd, 2005). The turbid wakes are considered to be a visual effect with no adverse impacts on the local sediment transport processes. The likelihood and significance of these features for environmental receptors will be considered within the Thanet EXT Environmental Statement.

4.4.4 Availability of existing evidence

There is a large body of existing evidence available from analogous developments, especially the operational Thanet OWF, which can be directly used to inform an understanding of the likely magnitude of change. This includes:

- Monitoring evidence from the construction and operational phases of offshore wind farms (e.g. Cefas, 2006; ABPmer *et al*. 2010; BERR, 2008; Titan, 2012);
- Existing numerical modelling to inform EIA studies for offshore wind farm developments with analogous designs (in terms of foundation number and/or size) (e.g. ABPmer, 2002a, b; 2005, 2014); and
- Monitoring and modelling evidence from analogous activities and developments (e.g. aggregate extraction (e.g. TEDA, 2010).

4.4.5 Location of the development

As shown in Figure 1, the Thanet EXT site surrounds the operational Thanet Offshore Wind Farm. Accordingly, the baseline conditions and processes that prevail within the Thanet OWF site are anticipated to be similar in nature to that across the Thanet EXT site. This observation underlines the appropriateness and value of using the observational evidence from the Thanet OWF to directly inform the Thanet EXT assessment.

It should also be noted that, because the wind turbine foundations within the Thanet EXT site will be distributed relatively uniformly in a narrow area around the existing Thanet OWF site, the potential for further changes to waves and currents at locations outside of the Thanet OWF and Thanet EXT array areas will be low. This is because the additional blockage will be minimal and because the directional distribution of foundations (blockage density) in any given direction will not be greatly different from the present Thanet OWF alone condition.

5 Conclusions

This position paper sets out the proposed methodology for assessing potential changes to marine geology, oceanography and physical processes resulting from construction, operation and decommissioning of the Thanet EXT site. The proposed approach is summarised in Table 8, for each of the main impacts identified during scoping.

Table 8. Proposed assessment approach for Thanet EXT

Issue	Assessment Approach for Thanet EXT
Potential changes to suspended sediment concentrations, bed levels and sediment type	Spreadsheet based numerical model, validated using modelling outputs from analogous studies (e.g. aggregate dredging).
Potential changes to landfall morphology	Desk based assessment of historic variability to beach/ coastline, informed by quantitative analysis of available topographic beach data.
Potential changes to the tidal regime	Evidence based assessment, drawing upon the results of existing numerical modelling carried out for analogous projects.
Potential changes to the wave regime	Evidence based assessment, drawing upon the results of existing numerical modelling carried out for analogous projects.
Potential changes to the sediment transport regime	Wind turbine and substation foundations – desk based assessment supported by the analysis of potential changes to the tidal and wave regimes, in conjunction with wider understanding of baseline sediment transport. Cable protection measures – desk based assessment, supported by the existing evidence base and empirical equations considering, e.g. the volume of sediment that might be realistically blocked by the obstacle dimensions.
Potential for development of turbid wake features	Desk based assessment, discussing the observational evidence of the scale and nature of turbid wake features in the context of the prevailing local and regional metocean and sedimentary regimes.
Scour	Desk based assessment using standard empirical equations and geometry to estimate equilibrium scour pit characteristics (depth and horizontal extent) from the foundation design.

No new site specific wave, tide and sediment transport modelling is proposed for the Thanet EXT physical processes assessment. This approach is justified for reasons including:

- Wind turbines within the Thanet EXT site will be supported by relatively small cross section monopile, jacket and/or suction caisson foundations which will individually and collectively present limited blockage to currents and waves;
- There is a large body of existing evidence available from analogous developments, especially the operational Thanet OWF, which can be directly used to inform understanding of the likely magnitude of change;
- The scale of the proposed development is small, both in relation to the existing Thanet OWF site and many other built/ consented UK offshore wind farm projects; and
- No significant adverse changes to coastal or seabed morphology have been observed to date as a consequence of the operational Thanet OWF.

Quantitative assessments of potential change will be carried out for the proposed project specific activities for Thanet EXT. The methods used and results will be detailed within a technical report which will be appended to the PEIR.

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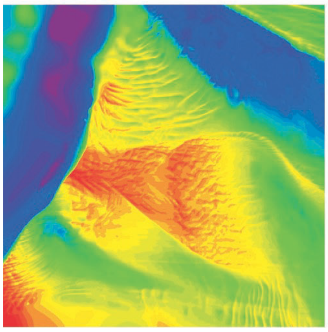
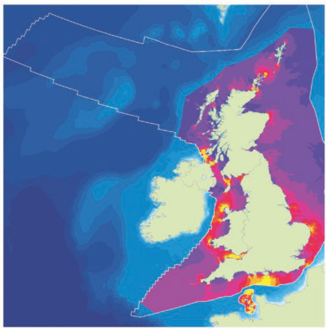
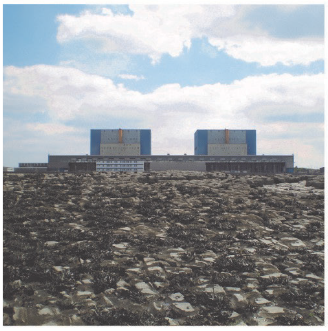
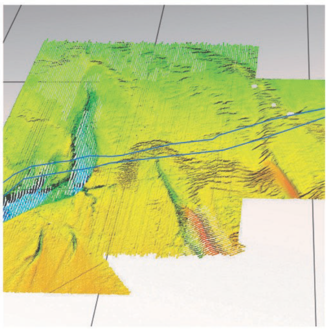
Thanet Extension OWF Position Paper

Turbid Wakes

April 2017

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Thanet Extension OWF Position Paper

Turbid Wakes

April 2017

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1 Introduction

Recent analysis of Landsat-8 satellite imagery (Vanhellemont and Ruddick, 2014; NASA, 2016) has noted an increase in suspended sediment concentrations (SSC) (turbidity[1]) in the wakes of individual turbine foundations associated with Offshore Wind Farms (OWFs) in the Outer Thames Estuary. Similar features are visible in aerial photographs of Thanet OWF. Because of the potential linkages between changes in SSC and impacts on marine ecology, Natural England has requested that due consideration is given to turbid wake features within the Thanet Extension OWF Environmental Statement:

> *We advise that the ES should address the issue of persistent sediment plumes seen in aerial photographs and satellite images at Thanet OWF. The cause and any associated impacts on the biological environment should be presented.*

At the Thanet Extension Offshore Evidence Plan meeting (held 28 February, 2017), it was agreed by all parties that it would be beneficial for a Position Paper to be circulated, detailing process understanding with regards to the formation of turbid wake features. Broad agreement regarding the likely processes behind the formation of turbid wakes is important because this information will be used within the Marine Geology, Oceanography and Physical Processes assessment to inform understanding of the likely extent, persistence and concentration of similar features at the Thanet Extension OWF site. This information will then be used to assess the potential for impacts to marine ecological receptors.

This Position Paper is structured as follows:

Section 2: Provides a brief summary of baseline conditions at the Thanet Extension OWF site, in terms of hydrodynamics, seabed sediments and turbidity;

Section 3: Summarises the key characteristics of the observed turbid wake features at Thanet OWF;

Section 4: Sets out an initial process understanding of the turbid wake features. This understanding will be included within the Marine Geology, Oceanography and Physical Processes Environmental Impact Assessment (EIA) reporting, under the heading of impact pathways;

Section 5: Describes the proposed assessment approach and also lists the EIA topics which contain receptor groups that may be sensitive to the presence of turbid wake features; and

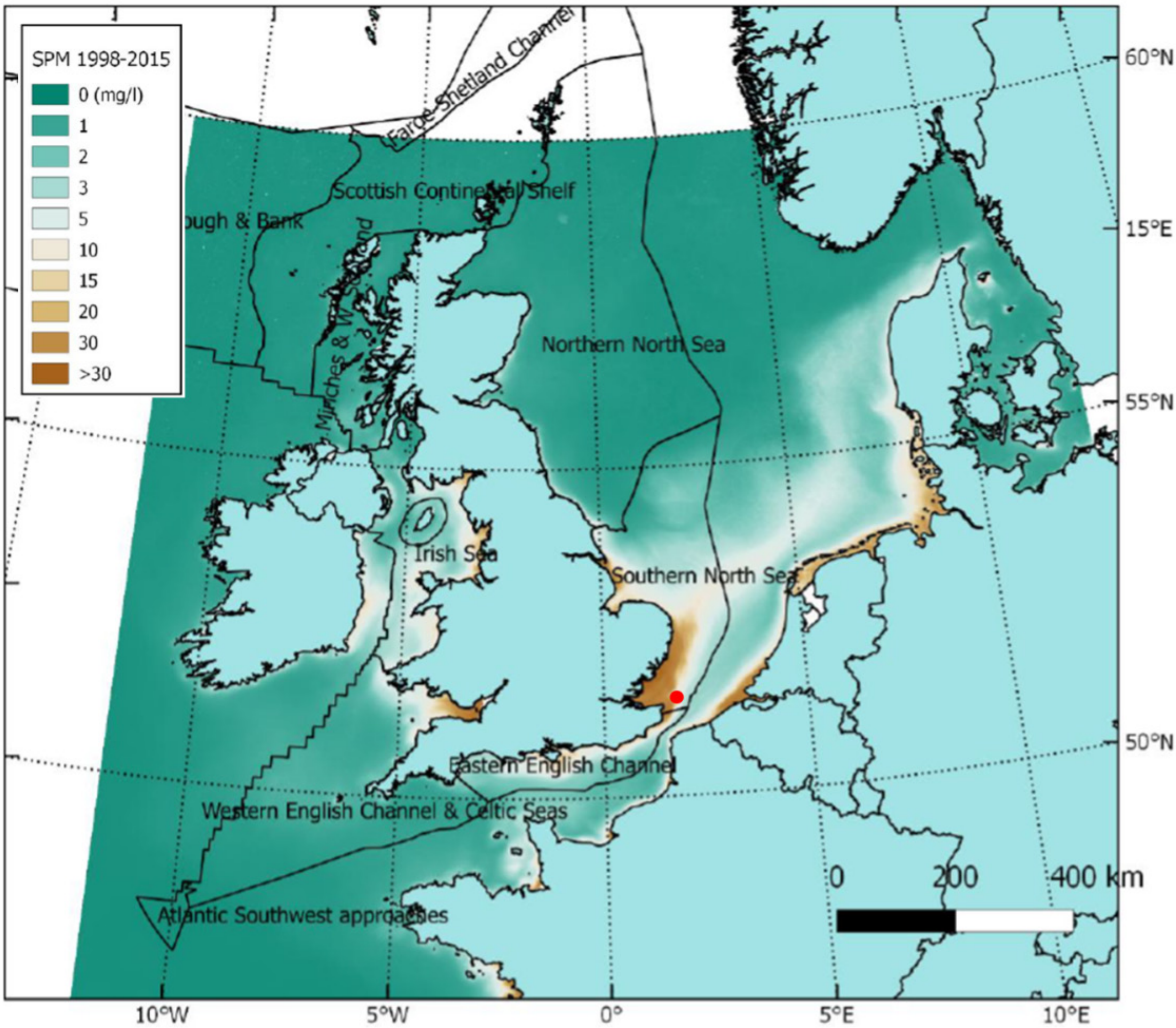
Section 6: Provides a summary of the findings.

Importantly, the potential significance of impacts to receptors arising from the presence of turbid wakes is not presented here. This will be described in detail within the Preliminary Environmental Information Report (PEIR) (due July 2017).

[1] Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particles. suspended sediment concentration (SSC) refers specifically to the in-organic (mineral) fraction of suspended solids whilst Suspended Particulate Matter (SPM) includes contributions from both in-organic and organic matter.

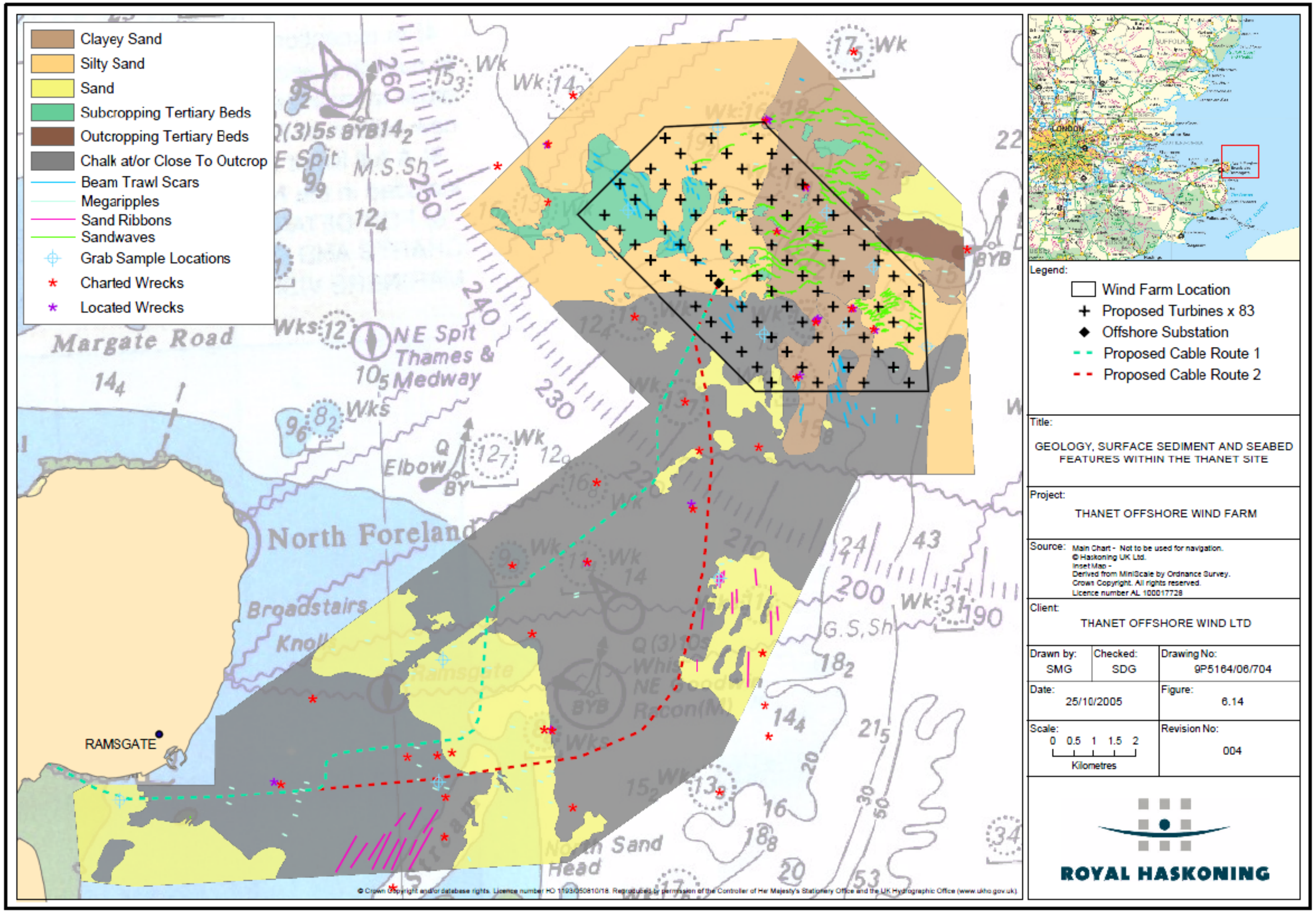
2 Background

The Thanet Offshore Wind Farm (OWF) and the proposed Thanet Extension Offshore Wind Farm sites are located in the Greater Thames region, approximately 8 km from the Kent coast. This region is characterised by naturally high levels of turbidity, primarily in response to the input of fine grained sediments from fluvial sources, erosion of soft cliff coasts and the frequent re-suspension of mobile material from shallow seabed settings (Figure 1) (Cefas, 2016). Seabed sediments within both the existing Thanet OWF site and the surrounding the Thanet Extension OWF array areas are typically characterised by the presence of muddy sand (Figure 2). These sediments will be regularly mobilised by the relatively strong tidal currents flowing across the site, which reach approximately 1.0 m/s during spring tides (Thanet Offshore Wind Ltd, 2005).



Source: Cefas, 2016

Figure 1. Average suspended particulate matter concentration for the period 1998-2015



Source: Thanet Offshore Wind Ltd, 2005

(The actually installed number and location of turbines is different from that shown here – see Figure 4)

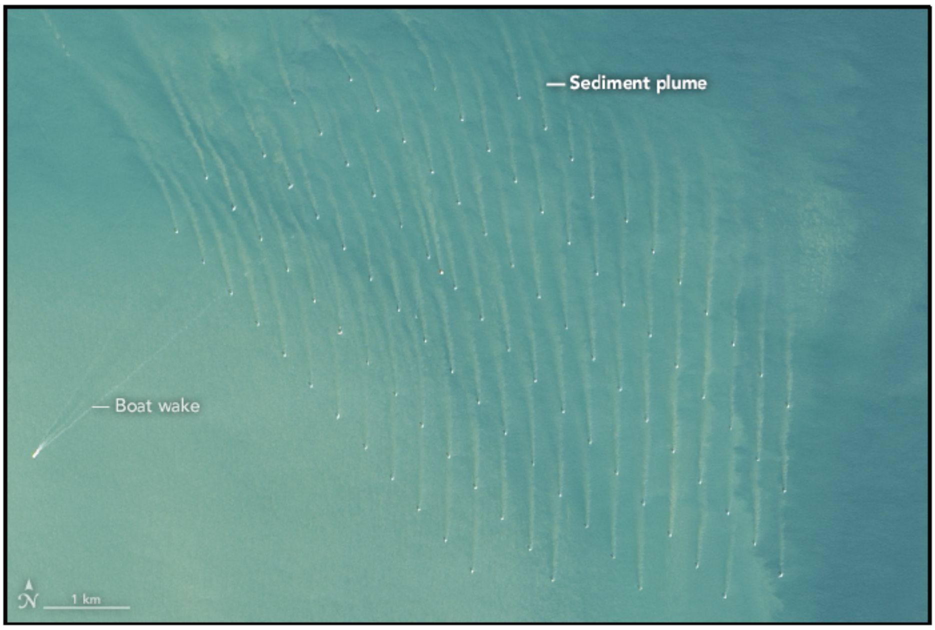
Figure 2. Geology, surface sediments and seabed features within the Thanet OWF

3 Turbid Wakes

Turbid wakes have been observed at the Thanet, London Array and Greater Gabbard OWFs in the outer Thames estuary in aerial (e.g. Vattenfall, 2017) and satellite imagery (e.g. Vanhellemont and Ruddick, 2014; NASA, 2016) (Figure 3, Figure 4 and Figure 5). The turbid wake features are aligned with the tidal stream locally, including a reversal of direction between flood and ebb tides. The features are reported by Vanhellemont and Ruddick (2014) as being typically 30 to 150 m wide and extending 'one or more' kilometres downstream from each turbine; in one case the plumes can be seen to extend for 'more than 10 km' at Thanet OWF. The overall plume length is suggested to be controlled by the time-integrated advection by currents (i.e. the tidal excursion distance) since the last flood/ebb flow reversal, and the rates at which the sediment is being laterally dispersed and settling out of suspension. Absolute SPM concentrations are reported as being 'probably dependent upon sea-floor sediment type and water depth' (Vanhellemont and Ruddick, 2014).

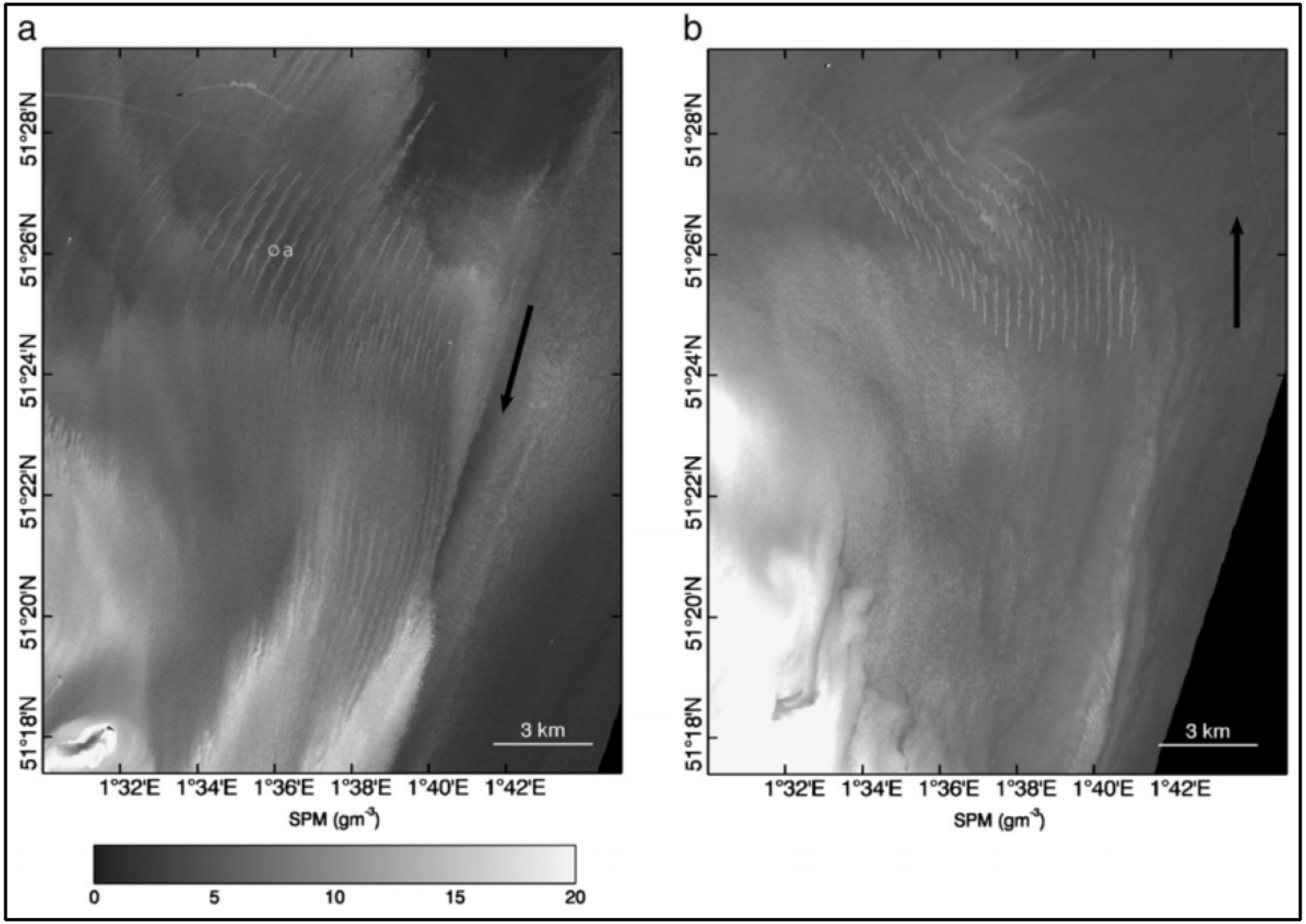
Source: Vattenfall, 2017

Figure 3. Aerial image of turbid wakes in Thanet OWF, unknown date



Source: NASA, 2016

Figure 4. Landsat 8 satellite imagery of Thanet OWF, acquired 30/06/2015.



Source: Vanhellemont and Ruddick, 2014

Figure 5. **Thanet OWF on (a) 28/04/2013 (10:54 UTC) and (b) 03/09/2013 (10:54 UTC)**

4 Process Understanding

The actual source of the sediment and the physical processes causing the turbid wakes observed in Thanet OWF are not addressed in detail by Vanhellemont and Ruddick (2014) although they do suggest that local scour around the turbine monopile foundations is a possible cause and they note that the foundations at Thanet OWF (monopiles, 4.1 to 4.9 m diameter) do not have scour protection. It is understood that the 3D structure of the turbid wake features is being studied by researchers at the University of Hull and at Cefas. If the outputs from this study are made available to the Environmental Impact Assessment (EIA) team then they will be used to inform the Thanet Extension Marine Geology, Oceanography and Physical Processes assessment. No further *in situ* observations or investigations of turbid wake features have apparently been reported to date for this or any other site.

As discussed in the following sections, there are considered to be several reasons why local scour is unlikely to be the source or cause of turbid wake features associated with operational OWF turbine foundations in the Thames Estuary, including:

- The majority of scour has already occurred;
- It is unrealistic that the volume of sediment required to cause the turbid wake is being eroded locally from around the foundations;
- Turbid wakes are also visible in areas where the local seabed is not susceptible to scour; and
- The level of turbidity in the wakes is not unusual in the context of the surrounding region.

Therefore, rather than being the result of enhanced erosion, it is considered more likely that the turbid wakes associated with the foundations in Thanet and London Array OWFs are the result of the upward turbulent mixing of naturally present suspended sediment from lower in the water column. A discussion of these mechanisms and processes is also provided in the following sections.

4.1 Reasons why local scour is unlikely to be the cause or source of turbid wake features

4.1.1 The majority of scour has already occurred

The satellite data used by Vanhellemont and Ruddick (2014) was collected in collected in April and September 2013 (Figure 5). All of the foundations at Thanet OWF were in place by June 2010, around 3 years before the satellite imagery in Figure 5 was acquired. Foundations were being installed in London Array OWF from 2011 (fully opened in 2014), so the foundations present in the 2013 satellite images will likely have been present for months or even years. Local scour is a time dependent process and will occur until an equilibrium depth is reached. The time taken for the equilibrium depth to be reached will vary depending upon the nature of the seabed geology but where erodible sandy sediments are present, may be achieved within a period of hours to a few days. Accordingly, the majority of scour should have already been achieved by the time the 2013 satellite imagery was acquired.

4.1.2 It is unrealistic that the volume of sediment required to cause the turbid wake is being eroded locally from around the foundations

The SSC in the surface waters of the turbid wakes (estimated from the satellite data images) is between 10 and 30 g/m^3 (10 and 30 mg/l). Using a representative water depth of 20 m for the sites, the volume of water in the wake from one foundation can be estimated as 1 million m^3

(20 m deep x 50 m wide x 1,000 m long). The total mass of sediment in suspension (assuming a representative concentration throughout the wake of 20 g/m^3) is 20,000 kg. Assuming a sediment density of 2,650 kg/m^3 and a porosity factor for seabed sediments of 0.6, this total mass equates to approximately 13 m^3 of seabed sediment. If 13 m^3 of seabed was being eroded from around each foundation every half tide (every 6 hours), this would cumulatively result in serious erosion in a short time scale (approximately 18,000 m^3 per year around each foundation). However, there are no such problems with local scour reported at these sites. Scour monitoring from Thanet OWF (Titan, 2012) shows that in 2012, scour pits typically had a diameter of approximately 20 m and a depth of 3.5 to 4.5 m, equating to a total locally scoured sediment volume in the approximate range 400 to 800 m^3 for individual foundations. Rather than assuming that a large volume of sediment is being eroded locally, the same mass of sediment in suspension per unit area (everywhere) can be more realistically achieved by resuspension of only 0.25 mm sediment thickness uniformly from the seabed (everywhere).

4.1.3 Turbid wakes are also visible in areas where the local seabed is not susceptible to scour

Comparing the interpreted seabed sediment type maps with the location of turbid wakes in the Thanet OWF shows that turbid wakes are also present in areas where the local seabed sediment type is not susceptible to scour (Figure 2). The southern margin of the array is characterised by the presence of chalk either at or very close to the seabed yet similar turbid wakes are also observed in this area (Figure 5). The chalk will be considerably more resistant to erosion than the unconsolidated surficial sediments found elsewhere in the site and it is therefore unlikely that active local scour is the cause of the turbid wakes observed in these areas.

4.1.4 The level of SSC in the turbid wakes is not unusual in the context of the surrounding region

In terms of instantaneous turbidity levels, the satellite data show large areas nearby but outside of the wind farm array areas that have higher (naturally present) surface SSC than that within the two wind farm arrays and as high as, or higher than, the associated turbid wakes. These areas appear to correlate with shallower parts of the Outer Thames Estuary where turbidity is naturally mixed through the water column to become more visible at the water surface.

In terms of annually averaged turbidity (Section 2 and Figure 1), it can be seen that background surface SPM concentrations in the range 20-30 mg/l are common within the outer Thames and therefore the absolute turbidity levels associated with the turbid wakes visible in the satellite data are actually within the range of naturally occurring variability (e.g. Eggleton *et al*. 2011; Cefas, 2016).

4.2 Likely causes of turbid wake features

Based on the reasons described in Section 4.1, turbid wakes are not considered to be an indication of ongoing local seabed erosion caused by the foundation.

It is considered more likely that the turbid wakes associated with the foundations in Thanet and London Array OWFs are the result of the upward turbulent mixing of naturally present suspended sediment from lower in the water column.

The sediment in the turbid wake likely originates in the naturally present near-bed layer of relatively higher SSC caused by sediment resuspension due to shear stresses between tidal currents and the seabed, potentially enhanced by wave action. Suspended sediment in this near-bed layer advecting through the array area will become entrained within the turbulent wake in the lee of individual foundation structures and mixed upwards by turbulent diffusion, becoming visible at the water surface. As the magnitude of turbulence in the wake decreases with time and distance from the foundation, the rate of downward settlement of the material will exceed the rate of upward dispersion by turbulence. At this point, the material in suspension will naturally tend to settle downwards and out of the surface waters, reducing the surface concentration towards ambient background values until the plume feature is no longer visible.

Outside of the relatively narrow and confined turbulent wake, the near-bed layer of higher suspended sediment concentration is also present, but is not mixed upwards to the same extent, and so does not result in the same increase in surface SSC. It is the contrast between the relatively higher surface SSC in the turbulent wake and the relatively lower surface SSC in the surrounding water that gives the visual appearance of the turbid wake. The absolute SSC of the turbid plume is within the range of naturally present ambient conditions.

The relative contrast between conditions inside and outside of the turbulent wake (and so the apparent visual strength of turbid wake features) is therefore expected to vary according to the general magnitude and timing of tidal currents (varying over time with flood/ebb and spring/neap cycles) and wave conditions (varying over time between calm, typical and storm conditions). These physical factors will jointly affect both the magnitude of SSC naturally present in the near-bed layer and the magnitude of turbulence both inside and outside of the wake of individual foundations. It is therefore probable that at some times the plumes may be less detectable, as a consequence of naturally higher background levels of SSC and/or a lower magnitude of turbulence in the wake.

5 Assessment Approach

5.1 Overview

It is reasonable to assume that the same naturally occurring near-bed layer of relatively higher SSC that is present across the Thanet OWF site will also be present across the Thanet Extension Site and as such, turbid wake features are also likely to develop in this area. These features can be expected to develop, regardless of whether turbines are supported by monopile or jacket foundations as both will realistically result in a turbulent wake.

The presence of turbid wake features could theoretically impact a range of environmental receptors via (for example):

- Adverse response by sensitive pelagic organisms;
- Reduced water column visibility, potentially reducing foraging success;
- Reduction in primary production; and
- Changes in water quality.

Benthic species are not likely to be affected by turbid wake features because SSC is only increased in the middle and upper water column while near-bed SSC might be slightly reduced (due to upwards dispersion of the sediment in suspension).

Significance of effect assessments associated with the presence of turbid wake features will be carried out and presented in the following EIA topic chapters:

- Marine Water and Sediment Quality;
- Benthic and Intertidal Ecology;
- Fish and Shellfish Ecology;
- Marine Mammal Ecology;
- Offshore Ornithology; and
- Commercial Fisheries.

To inform these assessments, it is necessary for key attributes of the turbid wake features to be described, in particular:

- The (horizontal and vertical) spatial extent of the features;
- The pattern and magnitude of changes in SSC (relative to naturally present background levels and ranges); and
- The duration and/or persistency of the features.

The approach proposed to determine these attributes is discussed in the following sections.

5.2 Spatial extent of turbid wakes

The (horizontal) spatial extent of the turbid wake features will be determined with reference to the (limited available) imagery evidence and on the wider basis of the range of ambient hydrodynamic conditions and the properties of the sediment likely to be in suspension. The maximum typical extent of the features can be estimated on the basis of spring tidal excursion ellipses (available from ABPmer *et al*. 2008). This information will then be collectively used to define a zone of potentially elevated turbidity within and around the Thanet Extension OWF site.

5.3 Magnitude of increase in turbidity

As a logical conclusion of the processes likely controlling turbid wakes (described in Section 4), depth averaged SSC within the Thanet Extension OWF will not be increased as a result of turbid wakes, as no additional sediment is being eroded or added to the water column.

On the basis of the analyses of satellite data presented in Vanhellemont and Ruddick (2014), SSC within the wake features was calculated to be approximately 20 mg/l at the time the satellite images were collected. SSC of this magnitude is within the range of naturally occurring annually averaged levels of surface SPM described by Eggleton *et al*. (2011) and Cefas (2016).

It is recognised that SSC within the turbid wake features, and the relative contrast in SSC inside and outside of the turbulent wakes, will likely vary in response to natural variability in the naturally present magnitude and vertical distribution of SSC. However, the absolute magnitude of SSC in the turbid wake will not be greater than that observed naturally within the region.

5.4 Persistence of features

The development and persistence of the turbid wake features will be dependent upon a range of factors including:

- The particle size distribution of material in suspension;
- The ambient flow conditions; and
- The extent to which material in suspension is mixed throughout water column, before entering the site.

In order to accurately quantify the anticipated frequency and duration of the turbid wake features, it would be necessary to have access to a relatively detailed record of satellite derived SPM maps from the Thanet OWF, covering a range of metocean conditions. Such interpreted satellite records are not available and therefore the worst case scenario will assume that turbid wake features are always present. Areas inside of the wind farm array area might be affected up to 100% of the time; areas outside of the wind farm array area might only be affected by turbid wake features for up to 50% of the time due to current direction reversal between flood and ebb tides.

6 Summary

The turbid wake features observed at the Thanet OWF site are likely to be caused by turbulence in the wake of turbine foundations, elevating sediment which is already naturally in suspension near to the seabed, up into the water column. The features are not likely to be caused by seabed scour around the foundations. As no additional sediment is being re-suspended, depth averaged SSC across the Thanet Extension OWF is not affected by the presence of turbid wakes.

The presence of turbid wake features could theoretically impact a range of environmental receptors and to inform these assessments, it will be necessary for key attributes of the turbid wake features to be described, in particular:

- The (horizontal and vertical) spatial extent of the features;
- The pattern and magnitude of changes in SSC (relative to naturally present background levels and ranges); and
- The duration and/or persistency of the features.

The maximum typical spatial extent of turbid wake features will be determined initially with reference to the limited available observed information. The mean spring tidal excursion distance, the rate of turbulence recovery in the wake and the properties of the sediment in suspension will then be used to extend the range of estimates to account for other tidal and wave conditions if possible. Turbid wake features can be assumed to be present most or all of the time, however, the relative difference between SSC inside and outside of the wake (i.e. the apparent strength of the turbid wake feature) may vary depending on recent patterns of tidal current and wave activity. In all circumstances, the absolute magnitude of SSC within the turbid wakes features will not exceed that which occurs naturally, under baseline conditions.

7 References

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Thanet Extension Offshore Wind Farm: Marine Mammal Noise Impact Assessment Draft Methodology

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		review (GoBe)				
		ter GoBe review				
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Thanet Extension Offshore Wind Farm: Marine Mammal Noise Impact Assessment Briefing note:

Reference populations, density estimates and metrics/criteria to be used in impact assessment

Authors:	Carol Sparling
Report Code:	SMRUC-GOB-2017-016
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Contents

1 Introduction

After the Thanet Extension Offshore Evidence Plan meeting on May 26th 2017, it was agreed by GoBe and SMRU Consulting that it would be beneficial for a briefing note to be circulated outlining key details of the assessment of the impacts of underwater noise on marine mammals. SMRU Consulting have previously supplied a briefing note: Thanet Extension Offshore Wind Farm: Marine Mammal Noise Impact Assessment Draft Methodology, 18th May 2017 which provides details on the methodology for the noise assessment. This note provides additional details that were discussed during the Evidence Plan meeting on May 26th but were either not included or not finalised in the previously circulated note. This information was agreed in principle with stakeholders in the meeting (Offshore Ecology Evidence Plan Meeting Minutes, 26th May 2017) and is presented here for final approval.

2 Reference populations

The predicted magnitude of impact (in terms of the numbers of animals predicted to be affected by each impact) will be expressed relative to the total population size for the relevent management unit. The following reference populations are proposed for use in the impact assessment.

2.1 Harbour porpoise

The current official estimate of the abundance of the North Sea harbour porpoise Management Unit (NS MU, Figure 1) is from the Inter-Agency Marine Mammal Working Group report published in 2015 (IAMMWG 2015). The abundance of the NS MU was 227,298 (95% CI 176,360-292,948) and were largely based on the results from the SCANS II surveys in 2005. However, since the 2015 report was published, the SCANS III surveys have taken place in summer 2016 and therefore a revised abundance estimate for the equivalent area is available. Hammond et al. (2017) presents design based estimates of abundance for harbour porpoise over an area equivalent to the IAMMWG NS MU (Figure 2) of 345,373 (95% CI 246,526-495,752). We propose using the later, updated abundance as the reference population for harbour porpoise in the Thanet Extension marine mammal impact assessment.

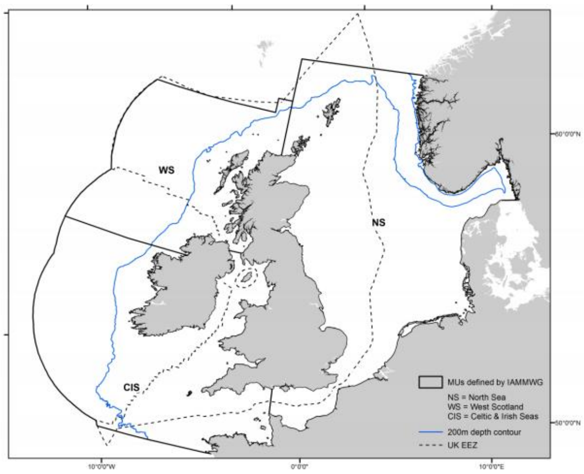

Figure 1. Harbour porpoise Management Units (MUs) as defined by IAMMWG (IAMMWG 2015).

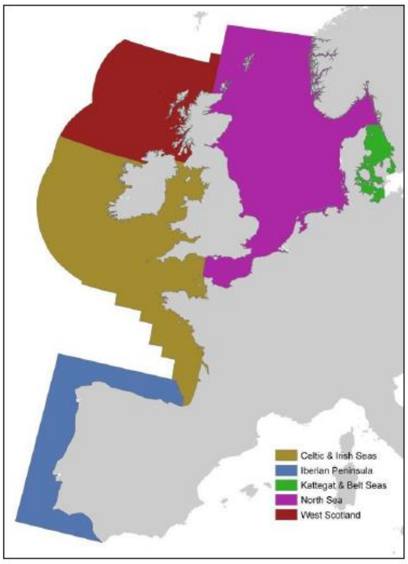

Figure 2. ICES assessment units for harbour porpoise, used for reporting design based abundance estimates for harbour porpoise from the SCANS III survey (Hammond et al. 2017).

2.2 Harbour and grey seals

Estimates of the abundance within UK seal management units were last published in draft form by the IAMMWG in 2013 (IAMMWG 2013). No updates have been available since then. Therefore we have used data presented in SCOS (2016) to calculate appropriate reference populations for seals. For harbour seals the appropriate UK reference population is that of the South East England management unit, encompassing the Wash and the Greater Thames area. The current estimate for that population is 6578. For additional context we will also present results including the Waddenzee harbour seal population for which some connectivity between south-east England has been demonstrated (IMARES 2015). This population numbers 39,100 (Galatius et al. 2014).

For grey seals the appropriate reference population is that of the combined English and Scottish North Sea colonies. Grey seal population size is estimated based on counts of annual pup production so taking the pup production estimate for this region of 12,487 and applying the UK wide ratio from the pup production models of 2.1 seals per pup, the total estimate of the reference population is 26,223. For additional context we will also present results including the Waddenzee harbour seal population for which considerable connectivity between UK North Sea colonies has been demonstrated (Brasseur et al. 2015). This population numbers 4276 (Brasseur et al. 2016).

3 Density estimates

Density estimates for each species will be used in combination with predictions of the spatial extent of underwater noise impact, to predict the numbers of animals that potentially will be impacted. Density estimates for each species will be taken from the following sources:

3.1 Harbour porpoise

Uniform absolute density estimates from SCANS III for the relevant blocks (Figure 3). The Thanet Extension site is located within block L which has a density estimate of 0.607 porpoise per km^2 (95% CI 0.221-2.092). If the impact contours extend into neighbouring blocks outside of block L, the density estimates for the appropriate blocks (e.g. Block N, O or C) will be used for that portion of the impact area.

For additional context, we will also present some impact assessment results using the corrected seasonal density estimates (that have been calculated by APEM from the analysis of Thanet Extension APEM aerial digital surveys (Voet et al. 2017). It is important to note that although these estimates have been corrected to take account of availability (proportion of porpoises underwater), they have not been corrected for variation in detectability as a result of survey conditions. The average density estimate for harbour porpoise (including unidentified porpoise/dolphin sightings) is 0.575 porpoise per km^2

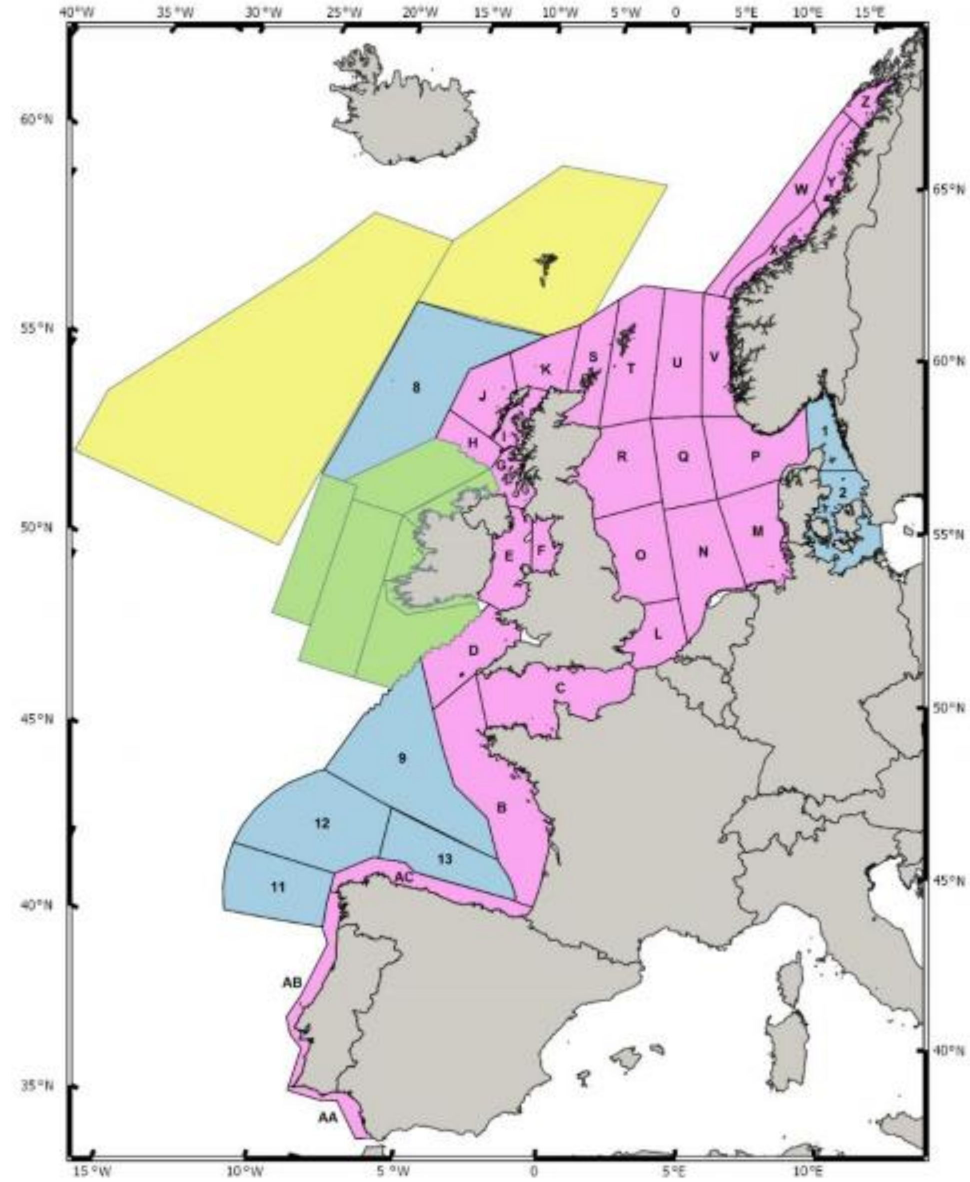

Figure 3. Survey blocks covered by SCANS III surveys. Pink lettered blocks were surveyed by air, blue numbered blocks were surveyed by ship. Blocks coloured green to the south, west and north of Ireland were surveyed by the Irish ObSERVE project. Blocks coloured yellow were surveyed by the Faroe Islands as part of the North Atlantic Sightings Survey in 2015. The Thanet Extension Offshore Windfarm site is located within Block 'L'.

Table 1. Density estimates for combined porpoise and dolphin/porpoise sightings from APEM aerial surveys of the Thanet Extension site before and after correcting for availability bias with the correction factor (calculated from data presented in Sweeney et al. (2017) and Voet et al. (2017).

	Density (#/km^2)	Correction Factor	Corrected Abundance	Corrected Density (#/km^2)	Sea State
Mar-16	0.25	0.571	**149**	**0.43**	**2**
Apr-16	0.39	0.571	**230**	**0.68**	**2**
May-16	0.00	0.571	**0**	**0.00**	**2**
Jun-16	0.08	0.547	**44**	**0.13**	**1-3**
Jul-16	0.14	0.547	**79**	**0.02**	**2**
Aug-16	0.1	0.547	**61**	**0.18**	**1-3**
Sep-16	0.03	0.455	**20**	**0.06**	**2-3**
Oct-16	0.02	0.455	**18**	**0.05**	**3**
Nov-16	0.19	0.455	**143**	**0.41**	**3-4**
Dec-16	0.18	0.472	**129**	**0.37**	**3**
Jan-17	0.13	0.472	**93**	**0.27**	**3**
Feb-17	2.03	0.472	**1466**	**4.30**	**1**

3.2 Harbour seal

Harbour seal density will be taken from a map of harbour seal density at a 5 km by 5 km grid scale generated for the whole of the UK based on seal telemetry data and annual haul out counts (described in Jones et al. (2015) and shown in Figure 4 New UK-wide density surfaces incorporating more recent telemetry data and updated count data are currently being generated at SMRU but the timeline for their release for external use is currently uncertain, they are expected to be submitted to Marine Scotland in July 2017.

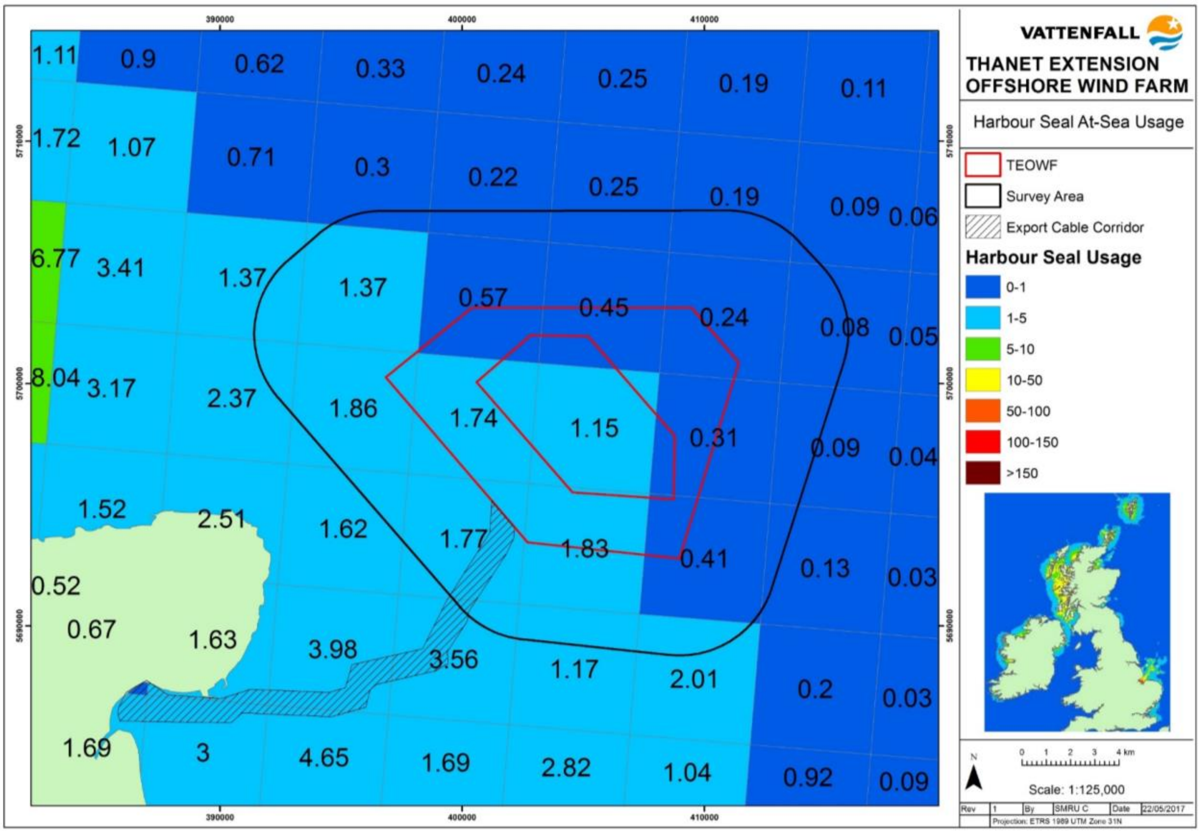

Figure 4. Predicted average numbers of harbour seals per 5 x 5 km grid cell across the Thanet Extension site from Jones et al. (2015)

3.3 Grey seal

Grey seal density will be taken from a map of at-sea density at a 5 km by 5 km grid scale generated for the whole of the UK based on seal telemetry data and annual haul out counts (Figure 5) described in (Jones et al. 2015). New density surfaces incorporating more recent telemetry data and updated count data are currently being generated at SMRU but the timeline for their release is currently uncertain, they are expected to be submitted to Marine Scotland in June 2017.

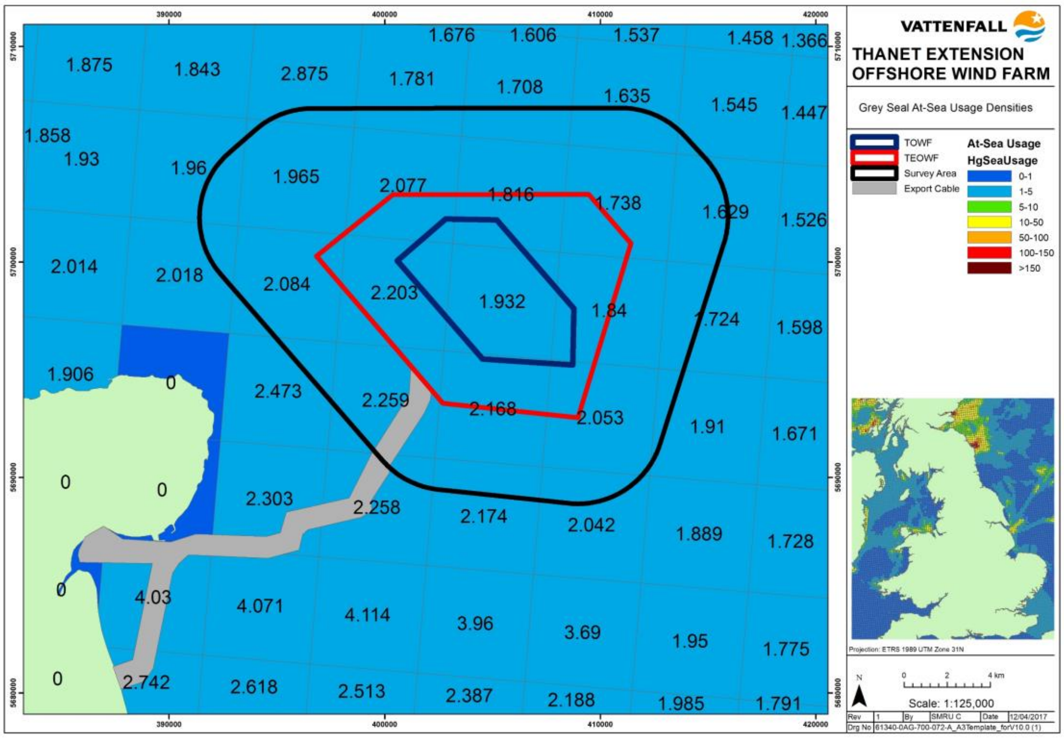

Figure 5. Predicted average numbers of grey seals per 5 x 5 km grid cell across the Thanet Extension site.

4 Noise thresholds

4.1 Lethal injury

Noise modelling will estimate of the range at which lethal injury may occur – the threshold adopted independent of the species will be peak-peak sound pressure level (SPL_{pp}) = 240 dB re 1 µPa (Parvin et al. 2007).

4.2 Physical injury

Noise modelling will estimate of the range at which non-auditory physical injury may occur – the threshold adopted independent of the species will be SPL_{pp} = 220 dB re 1 µPa (Parvin et al. 2007).

4.3 Auditory injury

Noise modelling will estimate of the range at which non-auditory physical injury (Permanent Threshold Shift, PTS) may occur – the thresholds adopted for each species are detailed in Table 2. For each PTS threshold, impact ranges from both SPL (peak) and SEL (cumulating total energy over a single pulse for 'instantaneous' PTS and cumulating energy over a whole piling event for 'cumulative exposure' PTS) metrics will be modelled.

Table 2. Noise thresholds and associated units to be used in the marine mammal noise impact assessment. All SPL thresholds are unweighted. Southall et al. (2007) SEL thresholds are M-weighted according to species hearing group, Lucke et al. (2009) SEL threshold is unweighted and NOAA SEL thresholds are weighted according to species hearing groups as detailed in National Marine Fisheries Service (2016).

	Southall et al (2007)		Lucke et al. (2009)		NMFS (2016)	
	$SPL_{z\text{-}p(flat)}$	$SEL_{(Mhg)}$	$SPL_{p\text{-}p(flat)}$	$SEL_{(flat)}$	$SPL_{z\text{-}p(flat)}$	$SEL_{(HG)}$
	(dB re 1 μPa)	(dB re 1 μPa²s)	(dB re 1 μPa)	(dB re 1 μPa²s)	(dB re 1 μPa)	(dB re 1 μPa²s)
Harbour porpoise	-	-	206	179	202	155
Harbour seal	218	186	-	-	218	185
Grey seal	218	186	-	-	218	185

4.4 Disturbance

Unlike for thresholds of auditory injury, there are currently no established regulatory guidance documents and few published scientific articles providing clear advice on the appropriate thresholds for behavioural response to pile driving noise. The options available for predicting the impact ranges for behavioural response from piling noise were presented and discussed in the previous briefing note (Thanet Extension Offshore Wind Farm: Marine Mammal Noise Impact Assessment Draft Methodology, 18th May 2017). SMRU Consulting will calculate the numbers of animals potentially impacted using a combination of fixed thresholds and a dose response approach (Table 3).

Table 3. Thresholds that will be used in the assessment of behavioural responses to piling noise in the Thanet Extension marine mammal noise impact assessment.

	Fixed threshold – 'possible avoidance'	Dose response curve
Harbour porpoise	Unweighted single strike SEL based on Lucke et al. (2009): 145 dB re $1\mu Pa^2s$	From Thompson et al. (2012) based on data from Brandt et al. (2011)
Harbour & grey seal	M-weighted SEL TTS[1] onset threshold from Southall et al. (2007): 171 dB re $1\mu Pa^2s$	From Russell et al. (2016)

5 Population modelling

We propose to use the interim PCoD framework (Harwood et al. 2013) to predict the population consequences of the predicted amount of disturbance and PTS resulting from the Thanet Extension construction as well as for the cumulative impact assessment including the construction of other offshore wind farms within the harbour porpoise North Sea Management Unit. We propose that the requirement for population modelling will be considered depending on the results of the first step in the assessment (determining the magnitude of impact in terms of the number of individuals affected) and suggest an impact affecting more than 5% of the reference population as a suitable threshold above which population level effects will be modelled.

[1] This threshold was proposed by Southall to determine the range at which Temporary Threshold Shift (a temporary form of auditory injury) would occur. This has been used in recent OWF impact assessments as a proxy for the sound level at which a 'fleeing' response might occur. Please see the briefing note: Thanet Extension Offshore Wind Farm: Marine Mammal Noise Impact Assessment Draft Methodology, 18th May 2017, for further discussion.

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Contents

1 Introduction

After the Thanet Extension Offshore Evidence Plan meeting on February 28th, 2017, it was agreed by GoBe and SMRU Consulting that it would be beneficial for a briefing note to be circulated outlining the proposed methodology for the assessment of the impacts of underwater noise on marine mammals. SMRU Consulting are responsible for carrying out the environmental impact assessment for marine mammals and are dependent on a number of outputs from the underwater noise modelling specialist subcontractors.

The production and review of this method statement will ensure a number of objectives are met:

- The Thanet Extension team and EIA technical team will get an understanding of the parameters important for the assessment;
- Statutory Consultees and stakeholders will get a chance to review, comment on, and input into the methodology;
- The Noise modelling subcontractor can review and input and in discussion with SMRU Consulting can ensure that outputs from the modelling are compatible with the methdology proposed.

This note outlines the proposed methodology for the impact assessment, along with details of the data sets that will be used in the assessment.

2 General Methodology

The approach to the impact assessment will consist of two stages, following the general approach detailed in Thompson et al. (2013b):

1) Quantitative prediction of the total number of individual animals likely to experience each potential impact. This will done by combining information on the spatial estimates of the likely propagation of noise for each specific impact pathway, with spatial estimates of animal density across this footprint. The output from this stage will be a total number of individuals which will also be expressed as a percentage of the appropriate reference population as a guide to potential magnitude.
2) Where the outcome of this prediction is deemed high enough to potentially have population level consequences a population modelling exercise will be carried out to predict the effect of the predicted level of impact on long term population health.

The overall significance of each impact will be determined using a standard matrix approach which combines the assessment of magnitude with an assessment of the sensitivity and 'value' of the receptor. Assessing the significance of each impact will also take into account the temporal nature of each impact – i.e. whether each impact is temporary or permanent and the duration of any temporary impact. More details on each of these stages are given in the sections below.

3 Species and data sets

The review of baseline data for the Thanet Extension impact assessment (Volume 3 Annex XX) provides a description of the available data characterising the marine mammal baseline of the site and surrounding area. The review suggests that harbour porpoise, harbour seal and grey seal should be considered in detail in the impact assessment and all other marine mammal species be scoped out. The datasets that will be used to predict the magnitude and significance of impacts from underwater noise are outlined below.

3.1 Harbour porpoise

Harbour porpoise density will be taken from one of the following sources (depending on the availability):

- Seasonal density surface maps from the JNCC commissioned Joint Cetacean Protocol analysis (JCP III; Figure 1) once they have been updated and rescaled based on the design based density estimates from the SCANS III surveys (timing of availability currently uncertain – Sonia Mendes (JNCC) has indicated that these are likely to be available in early June).
- Seasonal absolute density estimates from analysis of Thanet Extension APEM aerial digital surveys. SMRU Consulting understand that APEM are in the process of producing absolute density estimates for harbour porpoise from aerial digital photography surveys of the Thanet Extension site. Once available, SMRU Consulting will evaluate the methodology and consider the adoption of these density estimates in the assessment.
- Uniform absolute density estimate from SCANS III – in the absence of either of the above two data sources being available, we will adopt the uniform density estimate for the block from the SCANSS III survey (July 2016) in the assessment.

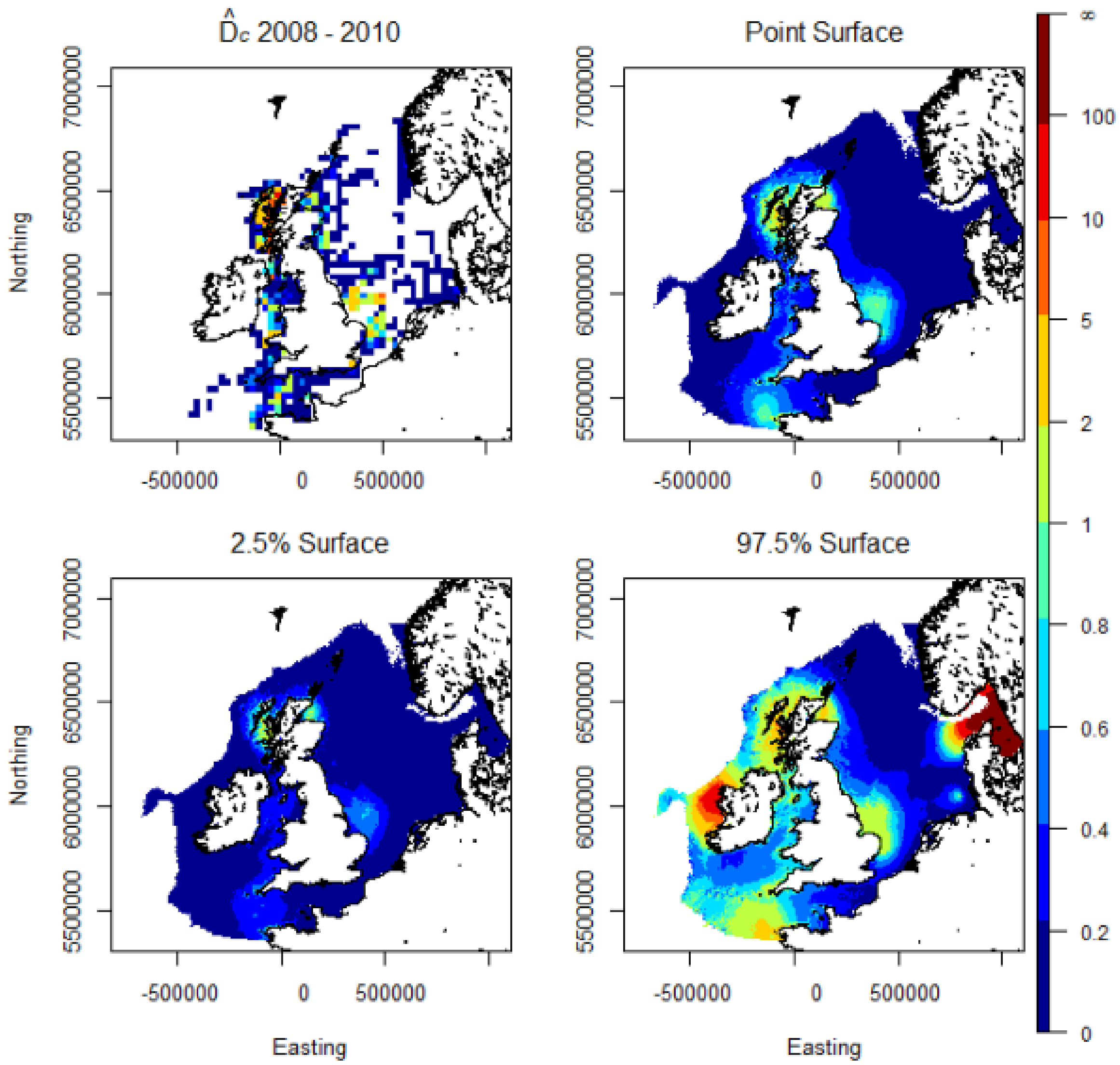

Figure 1. Joint Cetacean Protocol III predicted harbour porpoise densities (per km²) for summer 2010 (top right). Top left panel displays the survey effort over the period 2008-2010. Bottom panels display lower and upper confidence limits on predicted densities. JNCC are currently updating these maps based on SCANS III data.

3.2 Harbour seal

Harbour seal density will be taken from a map of harbour seal density at a 5 km by 5 km grid scale generated for the whole of the UK based on seal telemetry data and annual haul out counts (described in (Jones et al. 2013). New UK-wide density surfaces incorporating more recent telemetry data and updated count data are currently being generated at SMRU but the timeline for their release is currently uncertain, they are expected to be submitted to Marine Scotland in June 2017.

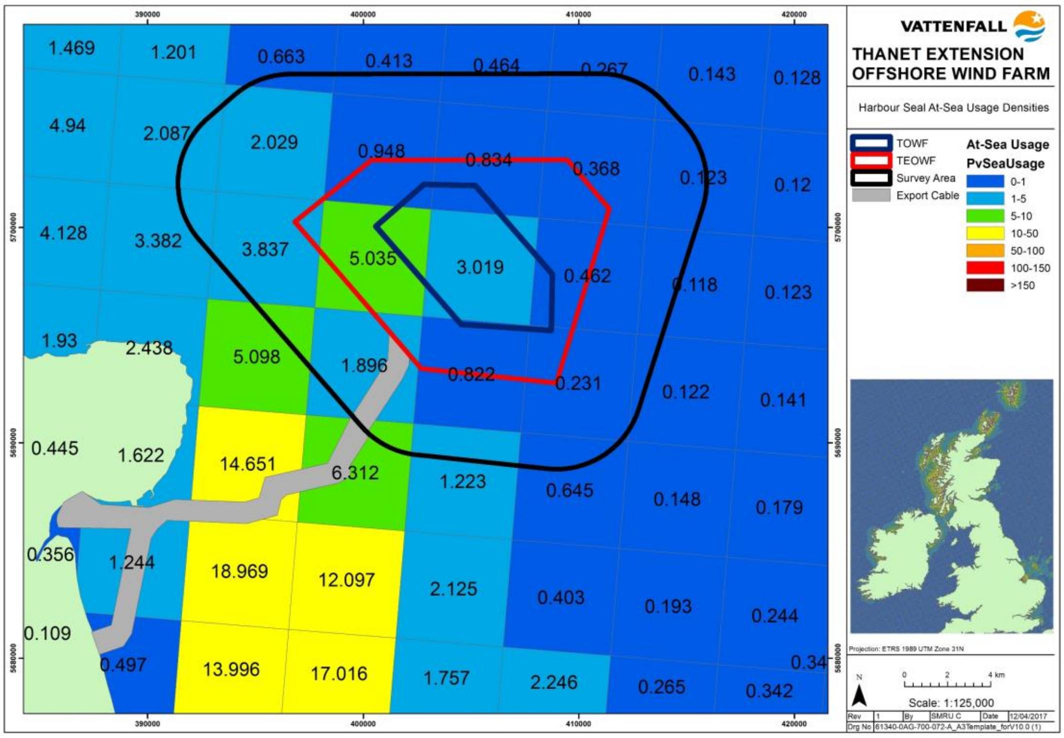

Figure 2. Predicted average numbers of harbour seals per 5 x 5 km grid cell across the Thanet Extension site.

3.3 Grey seal

Grey seal density will be taken from a map of at-sea density at a 5 km by 5 km grid scale generated for the whole of the UK based on seal telemetry data and annual haul out counts (Figure 3) described in Jones et al. (2013). New density surfaces incorporating more recent telemetry data and updated count data are currently being generated at SMRU but the timeline for their release is currently uncertain, they are expected to be submitted to Marine Scotland in June 2017.

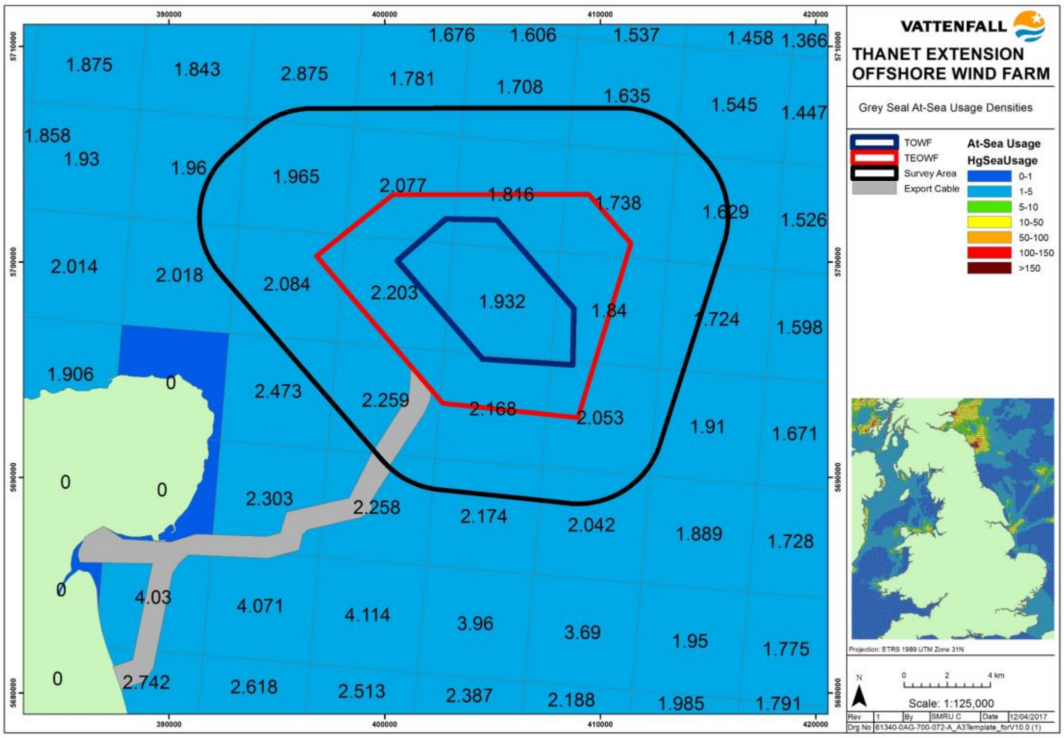

Figure 3. Predicted average numbers of grey seals per 5 x 5 km grid cell across the Thanet Extension site.

4 Specific noise impacts

4.1 Non piling construction noise

Potential non-pile driving sources of noise during construction include:

- Vessel activity
- Cable laying
- Dredging
- Seabed preparation

Potential noise sources during operational phase include:

- Vessel activity
- Noise from operating turbines

Note that in absence of a project description this is a general list of potential likely activities. For these noise sources it is not anticiated that a fully quantitative impact assessment will be required. For non-piling construction noise, it is expected that most of the noise produced by these activities will be within the bounds of background noise within very short ranges of the activities, in particular given the existing shipping traffic in this area. Given this, and the temporary and more limited nature of these activities, limited specific data for noise levels, and the lack of specific detail on the spatial and temporal distribution of these activities, the assessment for these impacts will be largely qualitative. For operational turbine noise, a review of existing empirical and modelled data will be used to determine whether any impacts are likely. Where activity-specific data is available it may be possible for noise modelling to estimate the range at which specific impacts may be encountered.

4.2 Piling Construction noise

Exposure to loud sounds can cause physical injury. Sound emitted during piling activity has the potential to cause damage to the auditory (hearing) system and can cause changes in the natural behaviour of animals exposed to sound.

Modelling locations have been chosen in conjunction with the noise modellers and project team to ensure that a range of 'realistic worst case' parameters are incorporated into the assessment. Locations were chosen based on sound propagation conditions and proximity to sensitive receptors.

Depending on the project design envelope, assessment may be carried out for single piling events or concurrent multiple piling events.. Two piling locations were selected based on physical propagation conditions and species sensitivities – one location in deeper water at the north east of the wind farm site (in the harbour porpoise cSAC) and the other in shallower water to the western boundary of the site (closest to seal haul outs) (Figure 4).

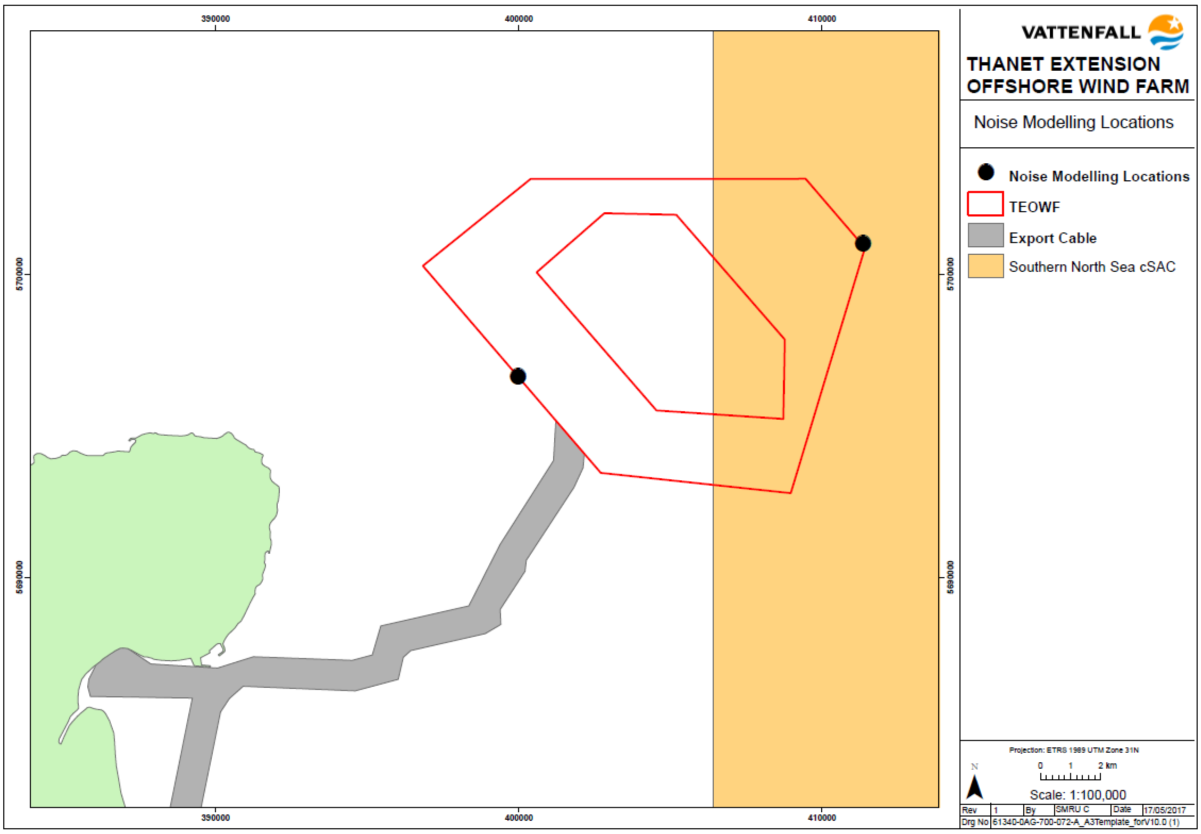

Figure 4 Proposed modelling locations for the noise modelling of piling events. Proposed is the modelling at two locations (black dots).

4.2.1 *Lethal injury*

It is assumed that noise modelling will estimate of the range at which lethal injury may occur – the threshold adopted independent of the species will be peak-peak sound pressure level (SPL_{pp}) = 240 dB re 1 µPa (Parvin et al. 2007).

4.2.2 *Physical injury*

It is assumed that noise modelling will estimate of the range at which non-auditory physical injury may occur – the threshold adopted independent of the species will be SPL_{pp} = 220 dB re 1 µPa (Parvin et al. 2007).

4.2.3 *Auditory injury*

Exposure to loud sounds can lead to a reduction in hearing sensitivity, which can be (and in general is) restricted to particular frequencies. This reduction (threshold shift) may be temporary or permanent.

For determining the number of animals that could potentially experience a permanent threshold shift (PTS), thresholds for PTS onset presented in Southall et al. (2007) have been adopted in most marine mammal piling noise impact assessments in recent years, following SNCB advice (with the adoption of more recently derived PTS thresholds for harbour porpoises from Lucke et al. (2009) – see Section 4.2.3.2 below). However, in July 2016, the US National Oceanic and Atmospheric Administration (NOAA) released updated guidance on noise assessment metrics for auditory injury (National Marine Fisheries Service 2016) with revised thresholds for PTS (henceforth referred to as NOAA thresholds). The UK Statutory Nature Conservation Agencies have not yet provided formal guidance on the adoption of the new NOAA thresholds although we are aware that other projects are presenting results based on NOAA thresholds alongside those based on Southall thresholds for PTS in their noise impact assessments. SMRU Consulting propose presenting PTS impact ranges using both approaches, the Southall et al. (2007) thresholds for seals along with the Lucke et al. (2009) thresholds for harbour porpoise, and the NOAA thresholds for all species for comparison.

4.2.3.1 Southall Thresholds

The sensitivity to different frequencies varies amongst different marine mammal species. Depending on a species audiogram (graph of hearing thresholds over the frequency range audible to the species) a species may be more or less vulnerable to the damaging effects of sound in a certain frequency range. Based on known or estimated auditory sensitivity, Southall et al. (2007) grouped marine mammals into five functional hearing groups (estimated auditory bandwidth given in brackets): High Frequency (HF) cetaceans such as harbour porpoise (200 Hz to 160 kHz), Mid Frequency (MF) cetaceans such as most dolphin species including bottlenose dolphins (150 Hz to 160 kHz), Low Frequency (LF) cetaceans such as baleen whales (7 Hz to 22 kHz), Pinnipeds in water (PW) (75 Hz to 75 kHz) and Pinnipeds in air (PA) (75 Hz to 30 kHz). Southall proposed the use of generalised frequency dependent weighting functions (M-weighting) for these functional hearing groups to filter sound according to the different hearing bandwidths of the various groups (Figure 5) before received sound levels are determined for comparison against PTS-threshold levels.

The M functions are flat across the range of audible frequencies, and are therefore considered precautionary. Outside the range of the audible frequencies, sensitivity 'rolls off' gradually, meaning that sounds outside the audible frequency range will be filtered out, and sound levels of frequencies near the roll off points will contribute less to the M-weighted sound level than those within the flat part of the M function.

Southall et al. (2009)'s proposed injury criteria incorporate a dual-criteria approach based on both peak sound pressure levels ($SPL_{z\text{-}p}$) and cumulative sound exposure levels (SEL_{cum}). For determining the

SEL_{cum} sound is M-weighted, while for the determination of $SPL_{z\text{-}p}$ unweighted values are used (flat). Whichever criterion is exceeded first (i.e., the more precautionary of the two measures) is used as the operative injury criterion for an exposed individual. The threshold values for PTS-onset proposed by Southall et al. (2007) are for different sound types: single pulses, multiple pulses and non-pulses. The values are based on the assumption that, for eliciting PTS, sound levels need to exceed the known or assumed levels that elicit TTS-onset to a certain amount. This is assumed to be 6 dB for $SPL_{z\text{-}p}$ and 15 dB for SEL_{cum}. Table 1 presents the proposed criteria for both $SPL_{z\text{-}p}$ and SEL_{cum} metrics for multiple pulses as relevant for pile-driving. For determining SEL_{cum}, the SEL should be cumulated over all pulses of a pile-driving event.

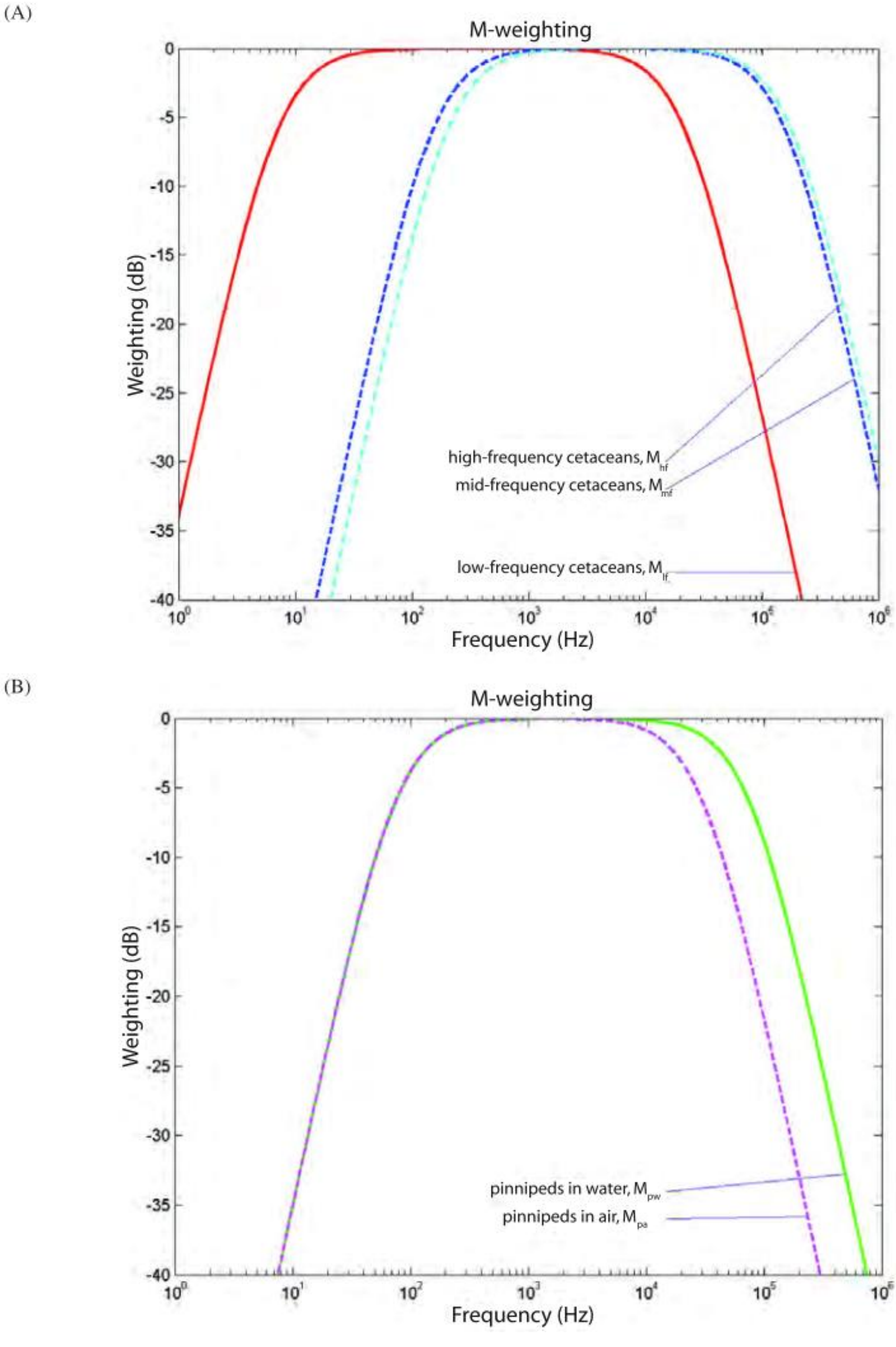

Figure 5. The M-weighting functions for (A) low-, mid-, and high-frequency cetaceans, as well as for (B) pinnipeds in water and air, taken from Southall et al. (2007).

Table 1. Proposed dual metric criteria for the onset of Permanent Threshold Shift from multiple pulse sounds, from Southall et al (2007).

Marine mammal group	SPL_{z-p} (dB re 1 µPa) (flat)	SEL_{cum} (dB re 1 µPa^2-s) (M_{wt})
HF cetaceans (e.g. harbour porpoise)	230	198
Pinnipeds (in water) **(e.g. harbour and grey seals)**	218	186

4.2.3.2 Lucke et al. (2009) threshold for harbour porpoises

Since the Southall Criteria were published, research carried out by Lucke et al. (2009) has led to the adoption of a different threshold for harbour porpoise. Lucke et al. (2009) showed that TTS was induced at a much lower level than previously thought. Based on their findings, Lucke et al. proposed TTS-onset levels for harbour porpoise at peak-peak sound pressure levels SPL_{pp} of 199.7 dB re 1 µPa and 164.3 dB re 1 µPa^2-s, with both values being unweighted. Applying the logic of PTS resulting from the noise level inducing TTS plus 6 dB for SPL-values and 15 dB for SEL values used in Southall et al. (2007) provides a predicted SPL_{pp} PTS-threshold value of 206 dB re 1 µPa and an SEL threshold injury level of 179 dB re 1 µPa^2-s. This dual-criteria threshold has therefore been adopted in the place of the Southall HF cetacean thresholds for assessments of the potential for PTS to occur in harbour porpoise in most recent assessments. We propose that PTS impact ranges for porpoises are calculated using this threshold.

4.2.3.3 US NOAA thresholds

Estimates of impact ranges using the latest NOAA thresholds for assessing the effects of anthropogenic sound on marine mammal hearing (National Marine Fisheries Service 2016) should also be calculated and presented. For determining the range of auditory injury, National Marine Fisheries Service (2016) provides different threshold values for a set of ‘functional hearing groups’ adapted from Southall et al. (2007). For impulsive sound such as those generated during pile driving, as in Southall et al. (2007), dual metric acoustic thresholds are provided for each hearing group: one $SPL_{z-p,\ flat}$ value for ‘instantaneous’ induced PTS, and one SEL_{cum} value for PTS induced by cumulative sound exposure. Noise modelling will calculate isopleths (contours) for both metrics.

National Marine Fisheries Service (2016) proposes the $SPL_{z-p,\ flat}$ being either unweighted or flat weighted across the entire frequency band of a hearing group). Hearing ranges are defined and generalised for the entire group as a composite as follows:

- PW: 50 Hz to 86 kHz
- LF: 7 Hz to 35 kHz
- MF: 150 Hz to 160 kHz
- HF: 275 Hz to 160 kHz

Cumulative sound exposure level (SEL_{cum}), will be weighted based on weighting curves given in Figure 6. The thresholds for PTS take into account the received level and the duration of exposure, accounting for the accumulated exposure over the duration of an activity within a 24-hour period. NOAA (2016) recommends the application of SEL_{cum} for the individual activity, i.e. not for multiple activities occurring within the same area or over the same time. National Marine Fisheries Service (2016) threshold values are given in Table 2.

Hearing Group	*a*	*b*	*f₁* (kHz)	*f₂* (kHz)	*C* (dB)	*K* (dB)
Low-frequency (LF) cetaceans	1.0	2	0.2	19	0.13	179
Mid-frequency (MF) cetaceans	1.6	2	8.8	110	1.20	177
High-frequency (HF) cetaceans	1.8	2	12	140	1.36	152
Phocid pinnipeds (PW) (underwater)	1.0	2	1.9	30	0.75	180
Otariid pinnipeds (OW) (underwater)	2.0	2	0.94	25	0.64	198

* Equations associated with Technical Guidance's weighting (*W(f)*) and exposure functions (*E(f)*):

$$W(f) = C + 10\log_{10}\left\{\frac{(f/f_1)^{2a}}{[1+(f/f_1)^2]^a[1+(f/f_2)^2]^b}\right\}$$

$$E(f) = K - 10\log_{10}\left\{\frac{(f/f_1)^{2a}}{\left[1+(f/f_1)^2\right]^a\left[1+(f/f_2)^2\right]^b}\right\}$$

Figure 6: Summary of weighting and exposure function parameters (taken from NOAA 2016).

Table 2. Proposed dual metric criteria for the onset of Permanent Threshold Shift from multiple pulse sounds, from NOAA (2016).

Marine mammal group	SPL_{z-p} (dB re 1 µPa) (flat)	SEL_{cum} (dB re 1 µPa^2-s) (M_{wt})
HF cetaceans (e.g. harbour porpoise)	202	155
Pinnipeds (in water) (e.g. harbour and grey seals)	218	185

4.2.3.4 Modelling cumulative sound exposure levels

In this impact assessment the sound modeller will calculate the SEL_{cum} over one piling event (i.e. the construction of one monopile foundation including a series of hammer strikes). If scenarios with more than one piling event are likely, these scenarios will also be modelled. The final decision on which scenarios will be modelled will require detailed information from the project design regarding piling parameters – in terms of hammer energies and strike rates including the consideration of ramp up (duration, energy and strike rate of each step), as well as the likelihood of concurrent piling activity and multiple activities in a 24h-period. Assumptions will be required in terms of the likely swimming speed of animals moving away from the piling – previous assessments have used a precautionary speed of 1.5 $m.s^{-1}$.

For calculating the number of animals that may be at risk of PTS due to accumulated sound exposure over piling events, SMRU Consulting propose that the "safe distance" methodology (NOAA 2016) is applied in the noise modelling, i.e., the isopleth of the SEL_{cum}-threshold will be at the distance from the sound source beyond which a threshold is not exceeded. This will provide an estimate of the closest distance to the piling that a receptor could be and either, depending on the location of the receptor with regard to the dose-response curve, stay stationary or escape a cumulative dose (over 24 hours) of noise exposure greater than cumulative PTS threshold.

4.2.4 Disturbance

Unlike for thresholds of auditory injury, there are currently no established regulatory guidance documents and few published scientific articles providing clear advice on the appropriate thresholds for behavioural response to pile driving noise. Southall et al. (2007) defined a severity score to categorize the effect of sound on marine mammals, with a score of 0 to 3 used to categorise relatively minor and/or brief behavioural reactions, scores 4 to 6 for behavioural changes that have a higher potential to affect foraging, reproduction or survival, and scores 7 to 9 for changes that are considered to likely affect vital rates. For the assessment of the behavioural impact of piling, responses with severity scores 4 to 6 are likely to require assessment as any responses affecting individual reproduction or survival have the potential to result in population level consequences.

A range of other thresholds to predict the impact ranges for predicted behavioural response from piling noise have been adopted in recent marine mammal noise impact assessments for offshore wind farms (see

Table 3).

Table 3. Thresholds and metrics used in the assessment of behavioural responses to piling noise in a selection of recent UK OWF impact assessments for harbour porpoise and seals.

Wind farm	Harbour porpoise	Seals (both species)
Dogger Creyke Beck A, B / Teeside A, B	Possible avoidance[1] SEL = 145 dB re 1µPa^{2}s Likely avoidance SEL = 164 SEL dB re 1µPa^{2}s	(Fleeing response (TTS onset) SEL = 171 dB re 1µPa^{2}s (M_{pw})
East Anglia 1	Possible avoidance SEL = 145 dB re 1µPa^{2}s	Fleeing response (TTS onset) SEL = 171 dB re 1µPa^{2}s (M_{pw})
East Anglia 3	Possible avoidance SEL = 145 dB re 1µPa^{2}s	Fleeing response (TTS onset) SEL = 171 dB re 1µPa^{2}s (M_{pw})
Hornsea 1	Possible avoidance SEL = 145 dB re 1µPa^{2}s Thompson et al. (2013b) dose response	Fleeing response (TTS onset) SEL = 171 dB re 1µPa^{2}s
Hornsea 2	Possible avoidance SEL = 145 dB re 1µPa^{2}s Also applied Thompson et al. (2013) dose response	Fleeing response (TTS onset) SEL = 171 dB re 1µPa^{2}s

4.2.4.1 Harbour porpoise

A threshold for harbour porpoise can be derived from the study conducted by Lucke et al. (2009). Studying TTS-thresholds of a harbour porpoise after the exposure to seismic airgun stimuli, the animal showed an aversive behavioural reaction to the stimuli at received peak-peak sound pressure levels (SPL_{pp}) above 174 dB re 1 µPa or an SEL of 145 dB re 1 µPa^{2}s, with the SEL being cumulated over one airgun impulse. Description of the behavioural response in Lucke et al. (2009) would appear to be consistent with classification on the Southall severity score of 4 to 6 (4 = moderate changes in response to trained behaviour, e.g., reluctance to return to station, long inter-trial intervals, 6 = refusal to initiate trained task), and would therefore be a suitable threshold to indicate a level at which a significant behavioural response would be expected. Although the Lucke et al. (2009) study is based on only one animal, field studies of the deterrence effect of pile driving during wind farm construction estimate the onset of a behavioural reaction at SEL values in the range of 140 – 152 dB re 1 µPa^{2}s (summarised in (Brandt et al. 2016). Thompson et al. (2013a) observed similar avoidance at levels of 145 – 151 dB re 1 µPa^2 s for a very similar acoustic signal (a seismic airgun).

For harbour porpoise, we propose to adopt a two-fold approach: The first is to use the fixed threshold of a single strike SEL of 145 dB re 1 µPa^2 s for assessing the behavioural impact range. The second approach is to use the dose-response curve. The use of a fixed threshold assumes that all animals

[1] From Lucke et al. (2009)

within the area of the threshold's isopleth display a behavioural reaction, while none of the animals outside this area will react. This is clearly biologically unrealistic. The proportion of animals responding will depend on the received sound level, which will decrease with increasing distance to the sound source. For this approach, a series of isopleths will be modelled and used to calculate the corresponding proportion of animals predicted to respond based on the dose-response curve. The dose-response curve that will be adopted in this assessment was generated from data from a study conducted by Brandt et al. (2011) on the response of harbour porpoises to pile driving activity at the Horns Rev II wind farm. It reflects the proportional decrease in occurrence of harbour porpoises with decreasing range from the piling site, as measured using static acoustic monitoring devices (CPODs). To enable the application of the dose-response curve in our study, the corresponding SEL levels for each point on the curve will need to be determined.

4.2.4.2 Seals

Until very recently there were no empirical data describing seal behavioural responses to pile driving noise. For calculating potential behavioural impact ranges around piling sites for seals, the TTS-onset threshold value provided in Southall et al. (2007) for seals in water is often adopted. Southall et al. (2007) acknowledges that this approach is used as a compromise for single pulses. Data on the reaction of pinnipeds in water exposed to multiple pulses was limited at the time of the Southall et al. (2007) review. The only data available at that time was from ringed seals, which suggested that these seals did not show behavioural reactions to sounds up to the TTS-onset levels for pinnipeds in water. A recent study by Russell et al. (2016) on the behaviour of 24 tagged harbour seals during pile driving at offshore wind farms in the Wash, south-east England provides the opportunity to incorporate recent, empirical data on behavioural responses in seals into piling noise assessments. In this study, seal abundance was reduced up to 25 km from the piling activity, with between a 20 to 80% decrease in usage compared to between breaks in piling (Figure 7). It is important to note that during this study displacement was limited to piling activity only and within 2 hours of piling ending, seals were distributed as per during non-piling. We will adopt the dose-response curve presented in Figure 7 in combination with spatially explicit estimates of seal density (see section 3) to estimate the number of seals potentially temporarily displaced during piling. For comparability with previous assessments we will also include assessment of the TTS-onset threshold value SEL = 171 dB re 1µPa^{2}s (M_{pw}) of Southall et al. (2007).

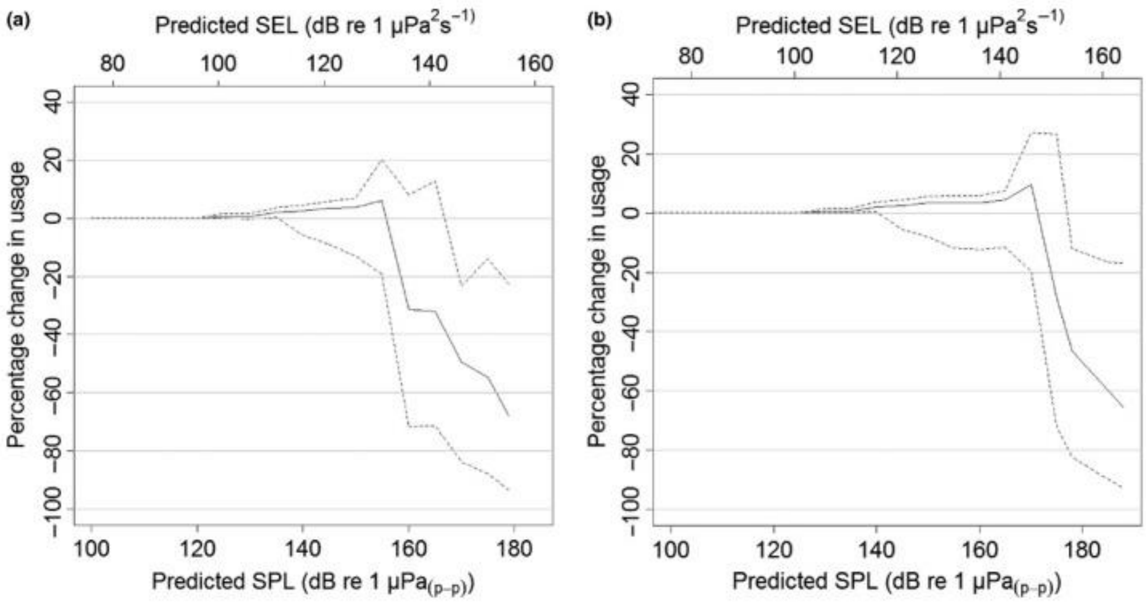

Figure 7. Percentage change in harbour seal usage in relation to sound levels from piling during construction of an offshore windfarm in the Wash (from Russell et al. 2016). (a) Presents values for the part of the water column with the lowest received SPL and SEL levels and (b) presents values for the parts of the water column with the highest received SPL and SEL levels. Dotted lines are 95% confidence intervals.

4.2.4.3 Weighting

Unweighted thresholds should be used for determining the impact radii for behavioural disturbances. (National Marine Fisheries Service 2016) points out that weighting functions do not reflect how an animal will perceive and behaviourally react to sound. They suggest that "*if a sound is on the edge of a hearing group's generalized hearing range and there is the potential for exposure to high sound pressure levels, then one should consider the potential for detection beyond normal auditory pathways.*" Sound outside the hearing range of an animal can be perceived via non-auditory mechanisms (e.g. Cunningham and Reichmuth 2016). Also Southall et al. (2007) argue that the application of a weighting function would not be appropriate for behavioural responses: *"because of the extreme degree of group, species, and individual variability in behavioural responses in various contexts and conditions, it is less appropriate to extrapolate behavioural effects as opposed to auditory responses*". Therefore we propose using unweighted values for the assessment of behavioural responses.

4.2.4.4 Outputs required from noise modelling for disturbance

Outputs from the noise modelling will be provided in the form of isopleths for each threshold discussed above. For dose-response calculations, isopleths of unweighted single strike SEL values at 5 dB increments will be provided.

5 Population modelling

We propose to use the interim PCoD framework (Harwood et al. 2013) to predict the population consequences of the predicted amount of disturbance and PTS resulting from the Thanet Extension construction as well as for the cumulative impact assessment including the construction of other offshore wind farms within the harbour porpoise North Sea Management Unit. iPCoD uses a stage structured model of population dynamics with 9 age classes (pups/calves, and individuals approaching their, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th and 9th birthdays) and 1 stage class (adults 10 years and older). The model is used to run a number of simulations of future population trajectory with and without the predicted level of impact to allow an understanding of the potential future population level consequences of predicted behavioural responses and auditory injury.

The iPCoD framework uses the results of an expert elicitation process conducted according to the protocol described in (Donovan et al. 2016) to predict the effects of disturbance and PTS on survival and reproductive rate. The process generates a set of statistical distributions for these effects and then population simulations are conducted using values randomly selected from these distributions that represent the opinions of a "virtual" expert. This process is repeated many 100s of times to capture the uncertainty among experts and predict a distribution of 'impact' population trajectories which can be compared to distributions of baseline populations (where only uncertainty in population parameters is included).

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Volume 3 Annex XX. Marine Mammal Baseline Review of the Thanet Extension Offshore Windfarm Region. SMRU Consulting report prepared for Thanet Extension.

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Europe • North America • Asia Pacific

Associating predictions of change in distribution with predicted received levels during piling

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December 2017

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Russell *et al.* (2016) generated predictions of at-sea distributions of harbour seals during piling and breaks in piling for construction of Lincs wind farm in The Wash (south east England) in 2012. These predictions were based on analyses of location data from 23 harbour seals equipped with GPS telemetry tags. The analyses were restricted to return trips from haul outs within The Wash and comprised a use-availability design within a generalised estimating equation (GEE) framework. Responses to piling, in terms of individual movements were not modelled directly. Rather, the population level at-sea distribution was modelled both during breaks in piling and during piling. The differences in these distributions on a 5 x 5 km resolution (867 cells) were then quantified. Such differences can result from both avoidance (seals not entering an area) and displacement (seals actively moving out of an area) from the vicinity of the windfarm. If displacement occurred, it would take time for harbour seals to redistribute after the onset of piling. The largest apparent change in distribution occurred when the two hours after an event (piling onset or piling cessation) were removed from the data. This suggests that, at least to some extent, the findings of Russell *et al.* (2016) were driven by active redistribution and thus displacement rather than simply avoidance. However, the behavioural mechanism underlying any displacement is currently unknown.

Russell *et al*. (2016) linked the results of the population level analyses, which considered piling as a binary metric, to predicted received levels. To do this, it was necessary to consider predicted received level averaged across piles, at a 5 x 5 km resolution. Acoustic source levels were derived using a combination of the blow energy values and acoustic recordings made using an autonomous underwater recorder (see Hastie *et al.* 2015 for more details). The predicted sound pressure level ($SPL_{(peak-peak)}$) at source, at the maximum blow energy was 235 dB re 1μ$Pa_{(p-p)}$-m and the predicted single pulse sound exposure level ($SEL_{(single\ pulse)}$) was 211 dB re 1 μPa^2 s. A series of range dependent acoustic propagation models were used to estimate transmission loss and received $SELs_{(single\ pulse)}$ at 5 m incremental water depths (Hastie *et al.* 2015). The predictions were made every 1,000 metres along 72 (every 5º) radii from each pile. For each pile, the predicted depth-delineated SELs closest geographically to the centre of each

5 x 5 km cell were assigned to that cell. Predicted minimum and maximum received SELs were then averaged for each cell across the installation of all piles, to generate a mean received SEL in the part of the water column with the lowest and highest predicted level.

For both the non-piling and piling scenario, the seal density (in terms of percentage of the at-sea population) was predicted for each cell (Russell *et al.* 2016). On a cell by cell basis, the predicted percentage change in density during piling was then related to zones of predicted received levels. For both minimum and maximum received levels, zones of increasing size were considered, from a zone encompassing all cells which had a predicted SEL of ≥ 160 dB re 1 μPa^2 s to a one encompassing all cells (SELs of ≥ 80 dB re 1 μPa^2 s). A parametric bootstrap of the GEE model was used to calculate 95% confidence intervals (CIs) for both the predicted usage (percentage of the at-sea population) and predicted change in usage (non-piling to piling) for each zone. As such, Figure 6 in Russell *et al.* (2016) represents the predicted change in usage in zones of received levels (i.e. approximately spherical areas from the wind farm location). For example, the zone represented by an $SEL_{(single\ pulse)}$ of 80 dB re 1 μPa^2s encompasses 100% of the population at-sea during piling and non-piling and thus the percentage change is 0. As the received level increases, the sample size decreases resulting in wider confidence intervals. This cumulative curve was used to contextualise the population level findings from the spatial study with the predicted sound fields from the pile driving and should not be interpreted as a dose-response curve.

For the current study, there was a requirement to link the results of Russell *et al*. (2016) to spatial variation in a single (depth-averaged) received level. To generate a depth averaged received level for the current study, the predicted received levels were converted to pressure (Pa) and averaged across the depths. For each pile, the predicted pressure closest geographically to the centre of each 5 x 5 km cell was assigned to that cell, resulting in a depth averaged pressure value (Pa) for each pile in each cell. The mean distance between the centre of the cell and the geographically closest pile-specific pressure was 2.15 km but was shortest (0.5 km) nearest the wind farm. To generate a single averaged received level for each cell, the pressures were averaged across the piles, and this value was then converted to $SEL_{(single\ pulse)}$ (10 x log (pressure)). Although the maximum estimated source level (211 dB re 1 μPa^2 s) used to predict received levels was assumed to be the same for each pile, the differing pile locations (and to a lesser extent the different distances between predicted pressure level and cell centroid) resulted in substantial variation in predicted received level across piles (mean range 30 dB). The mean range in received levels within a cell was 15 dB within 10 km of the windfarm and 25 dB between 10 and 50 km. This variation is not represented in the relationship between predicted received level and change in usage.
Usage and change in usage was predicted for all cells within 5 dB zones (i.e. annulus areas between predicted received levels). Following Russell et al. (2016), a parametric bootstrap of the GEE model was used to calculate 95% confidence intervals (CIs) for each zone (Figure 1, Table 1).

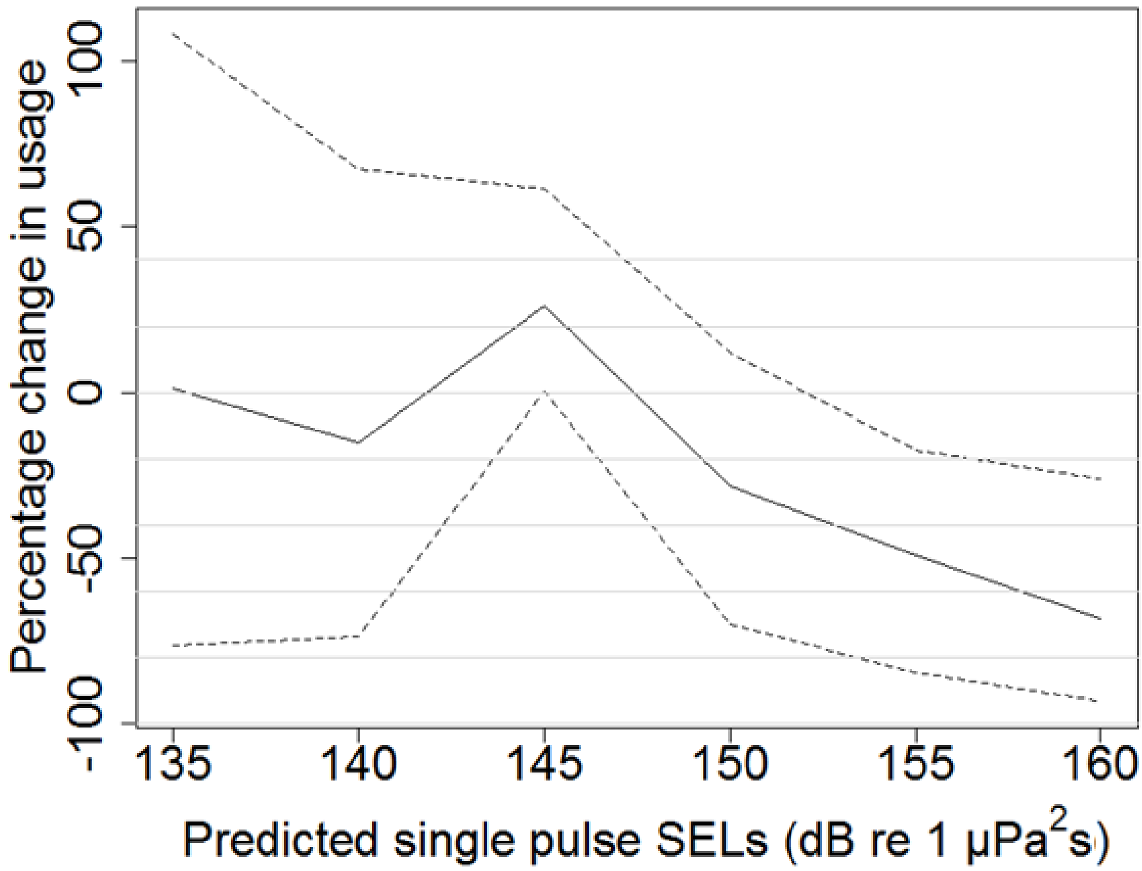

Figure 1. The predicted percentage change in usage at given SELs. Please note each point represents the following 5 dB. E.g. the predicted percentage change in usage value at 135 dB represents the mean for cells with an estimated SEL of 135dB ≤ 140dB.

Table 1. The predicted usage during piling and breaks in piling (and percentage change in usage) in zones of predicted received levels.

zone		Mean density (as percentage of at-sea population)			Percentage change			
SEL (dB)	number of cells	non-piling	piling	difference	mean	median	Lower 95% CI	Upper 95% CI
135 < 140	50	0.51	0.52	0.01	1.4	-7.1	-76.1	108.1
140 < 145	381	10.19	8.63	-1.56	-15.3	-15.9	-73.6	67.4
145 < 150	271	55.94	70.53	14.59	26.1	24.6	0.3	61.5
150 < 155	81	21.37	15.32	-6.05	-28.3	-28.7	-70.2	12.2
155 < 160	24	7.50	3.80	-3.70	-49.3	-54.0	-84.7	-17.5
160 < 165	7	0.88	0.28	-0.60	-68.1	-71.0	-93.0	-26.1

Applying this curve to impact assessments

SMRU Consulting propose to apply the percentage change values according to the 5 dB bands outlined in the above table at received levels above 150 (single pulse SEL dB), 100% displacement at received levels above 165 and a zero percentage change at received levels below 150.

highways england

Our ref: HE Ref AIP485
Your ref:
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AGREEMENT IN PRINCIPLE: - AIP 485
THANET EXTENSION OFFSHORE WIND FARM AIL STUDY

Further to your initial email dated 21 February 2018, requesting provision of an AIP for future abnormal load moves into Thanet Extension Offshore Wind Farm.

I can confirm that an AIP can be provided at this point specifically for a Wind Farm Super Grid Transformer Tank move from Ramsgate Port to Thanet Extension Offshore Wind Farm, the dimensions, weight and number of pieces as provisionally detailed below.

1nr. Super Grid Transformer Tank with an approximate gross weight of 360,000kg on a 20-Axle GFT.

Additional Wind farm components will be assessed individually upon movement application.

Delivery is expected to be around 2020.

This will of course be subject to formal application nearer the time at which Highways England will consult with all relevant parties and take into consideration their views and requirements. Consequently, any Special Order issued is likely to include specific requirements relating to the day(s) on which movements will be authorised. The Special Order may also prescribe specific times during the day or night when movement will be permitted (which may take into account seasonal variations in traffic) in order to minimise traffic congestion, and disruption to other road users.

highways england

The AIP is valid for a period of at least seven years but with the proviso that should a nearer, suitable access point such as the River Stour become apparent, or feasible in that time, Wood Plc. or its associated representatives would undertake to investigate and assess its potential for future use, with a view to that new facility becoming the agreed access.

It would be helpful if you could ask the designated haulier to quote the above AIP reference when applying for the Special Order permit.

I trust this information is sufficient for your purposes, but please do not hesitate to get in touch if you require anything further.

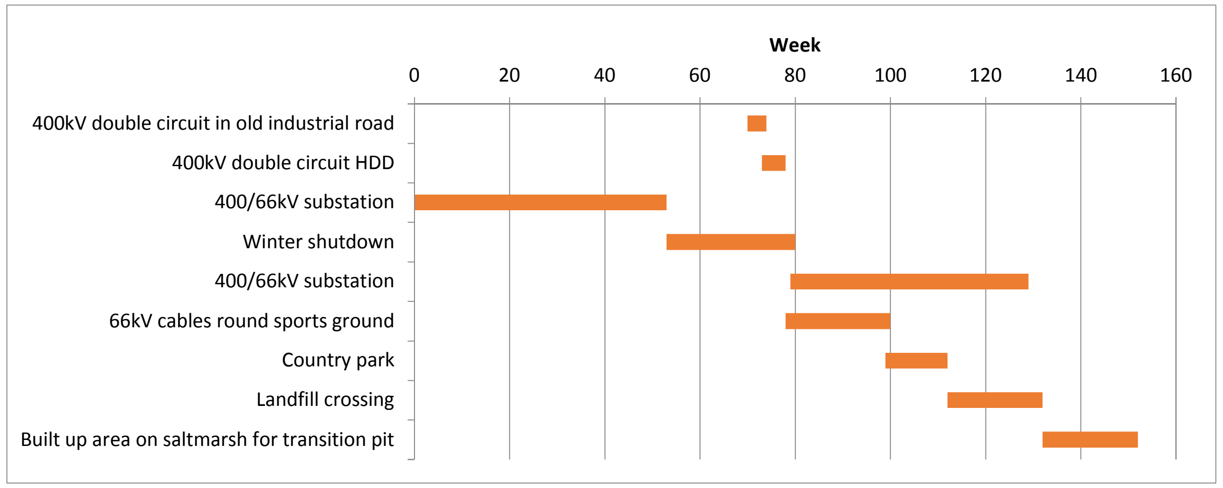
Yours sincerely

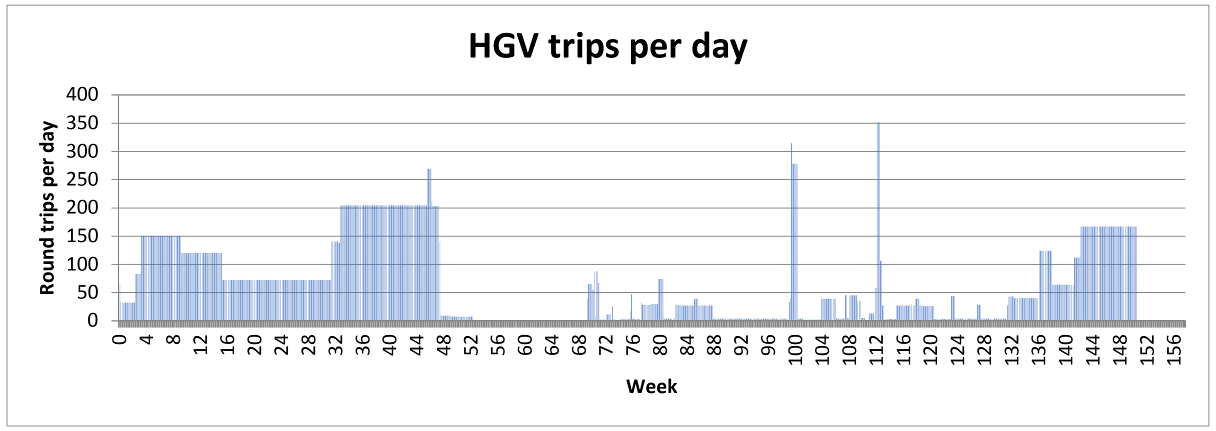
[redacted]

John Powell
Assistant Strategy & Customer Manager
Abnormal Loads
[redacted]

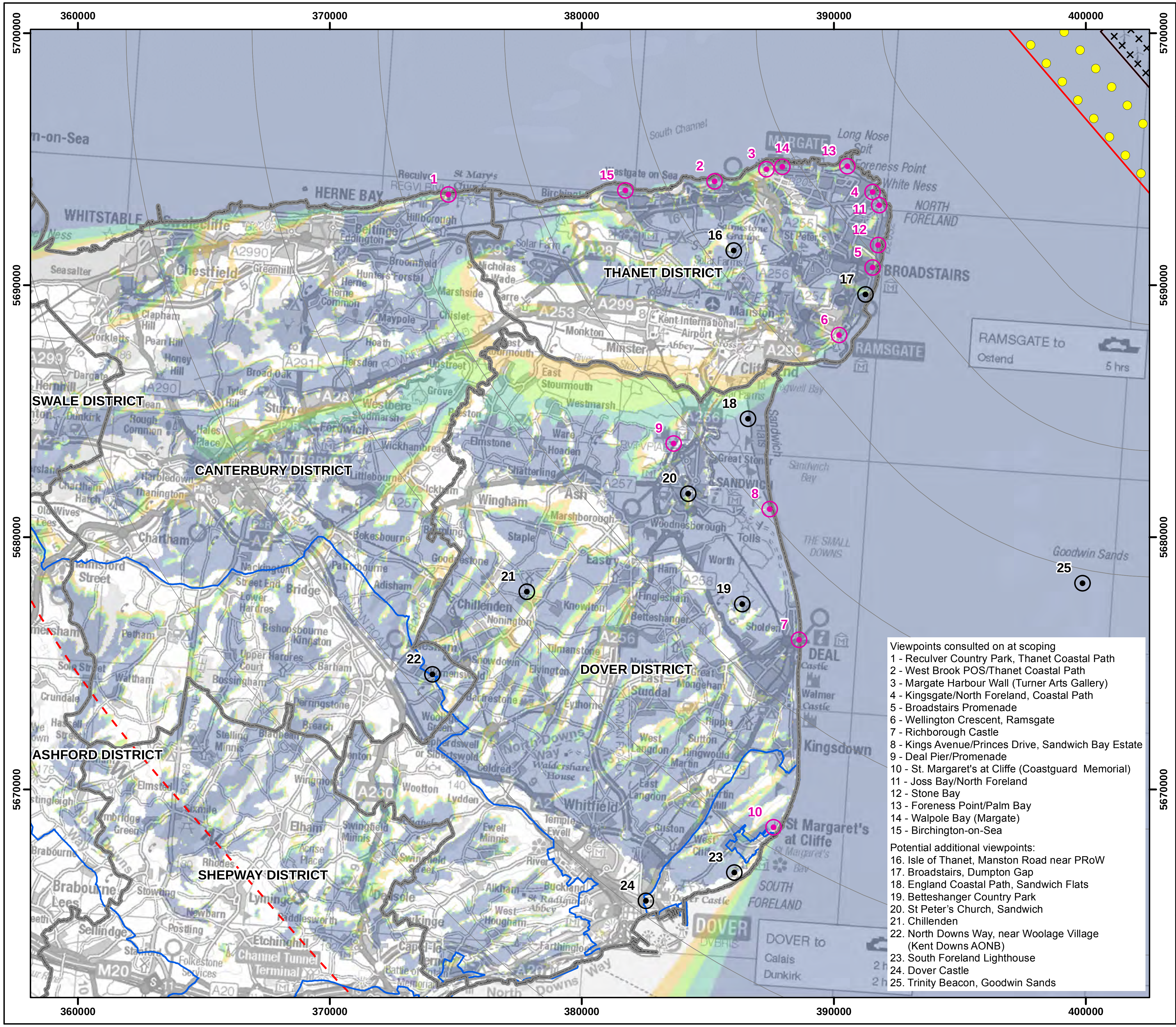
HGVs	2-way	No. days	Associated Activity	Accessed / Delivered via	Future HGV Baseline	Max % Impact
351	702	3	Landfill crossing	Sandwich Road	281	250%
314	628	1	Country park	Sandwich Road	281	223%
278	556	5	Country park	Sandwich Road	281	198%
269	538	4	400/66kV substation	A256	1298	41%
211	422	1	400/66kV substation	A256	1298	33%
204	408	77	400/66kV substation	A256	1298	31%
203	406	6	400/66kV substation	A256	1298	31%
167	334	50	Built up area on saltmarsh for transition pit	Sandwich Road	281	119%
150	300	36	400/66kV substation	A256	1298	23%
140	280	7	400/66kV substation	A256	1298	22%
138	276	2	400/66kV substation	A256	1298	21%
124	248	12	Built up area on saltmarsh for transition pit	Sandwich Road	281	88%
120	240	36	400/66kV substation	A256	1298	18%
112	224	6	Built up area on saltmarsh for transition pit	Sandwich Road	281	80%
106	212	2	400/66kV substation Landfill crossing	Sandwich Road	281	75%
88	176	1	400kV double circuit in old industrial road	A256	1298	14%
87	174	2	400kV double circuit in old industrial road	A256	1298	13%
83	166	5	400/66kV substation	A256	1298	13%
74	148	5	400/66kV substation 66kV cables round sports ground	A256	1298	11%
72	144	97	400/66kV substation	A256	1298	11%
67	134	1	400kV double circuit in old industrial road	A256	1298	10%
65	130	5	400/66kV substation	A256	1298	10%
64	128	19	Built up area on saltmarsh for transition pit	Sandwich Road	281	46%
58	116	1	400/66kV substation Landfill crossing	A256	1298	9%
55	110	1	400kV double circuit in old industrial road	A256	1298	8%
47	94	1	400kV double circuit HDD	A256	1298	7%
45	90	9	Country park	Sandwich Road	281	32%
44	88	4	Landfill crossing	Sandwich Road	281	31%
43	86	5	Built up area on saltmarsh for transition pit	Sandwich Road	281	31%
40	80	22	Country park	Sandwich Road	281	28%
39	78	22	400kV double circuit in old industrial road	A256	1298	6%
35	70	3	Country park	Sandwich Road	281	25%
33	66	1	Country park	Sandwich Road	281	23%
32	64	14	400/66kV substation	A256	1298	5%
30	60	6	400/66kV substation 66kV cables round sports ground	A256	1298	5%
28	56	16	66kV cables round sports ground	A256	1298	4%
27	54	48	400/66kV substation 66kV cables round sports ground	A256	1298	4%
26	52	11	Landfill crossing	Sandwich Road	281	19%
25	50	1	400kV double circuit HDD	A256	1298	4%
17	34	1	400kV double circuit HDD	A256	1298	3%
13	26	5	Country park	Sandwich Road	281	9%
11	22	4	400kV double circuit in old industrial road	A256	1298	2%
9	18	9	400/66kV substation	A256	1298	1%
7	14	21	400/66kV substation	A256	1298	1%
5	10	6	Country park	Sandwich Road	281	4%
4	8	133	400kV double circuit HDD	A256	1298	1%
3	6	38	400kV double circuit HDD	A256	1298	0%
2	4	23	400kV double circuit in old industrial road	A256	1298	0%
1	2	5	400/66kV substation	A256	1298	0%
0	**0**	**154**	**No activities occur for 154 days of 947 day programme**			

total days 947





Indicative construction programme



VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Blade Tip ZTV with Viewpoints

Legend

- Proposed Turbine Location
- Turbine Location
- Proposed Wind Farm Area
- Wind Farm Area
- 5km Radii
- 45km Study Area
- Local Authority Boundary
- Kent Downs AONB [1]

Blade Tip ZTV

No. of Blade Tips Visible

- 0
- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40

- Viewpoints consulted on at scoping
- Potential additional viewpoints

[1] Contains, or is based on, information supplied by Natural England, 2016

Blade Tip:	210m	Observer height:	2m
DTM:	OS T50	Surface features:	Excluded
DTM resolution:	50m	Earth curvature:	Included

Layout: LTHET2013

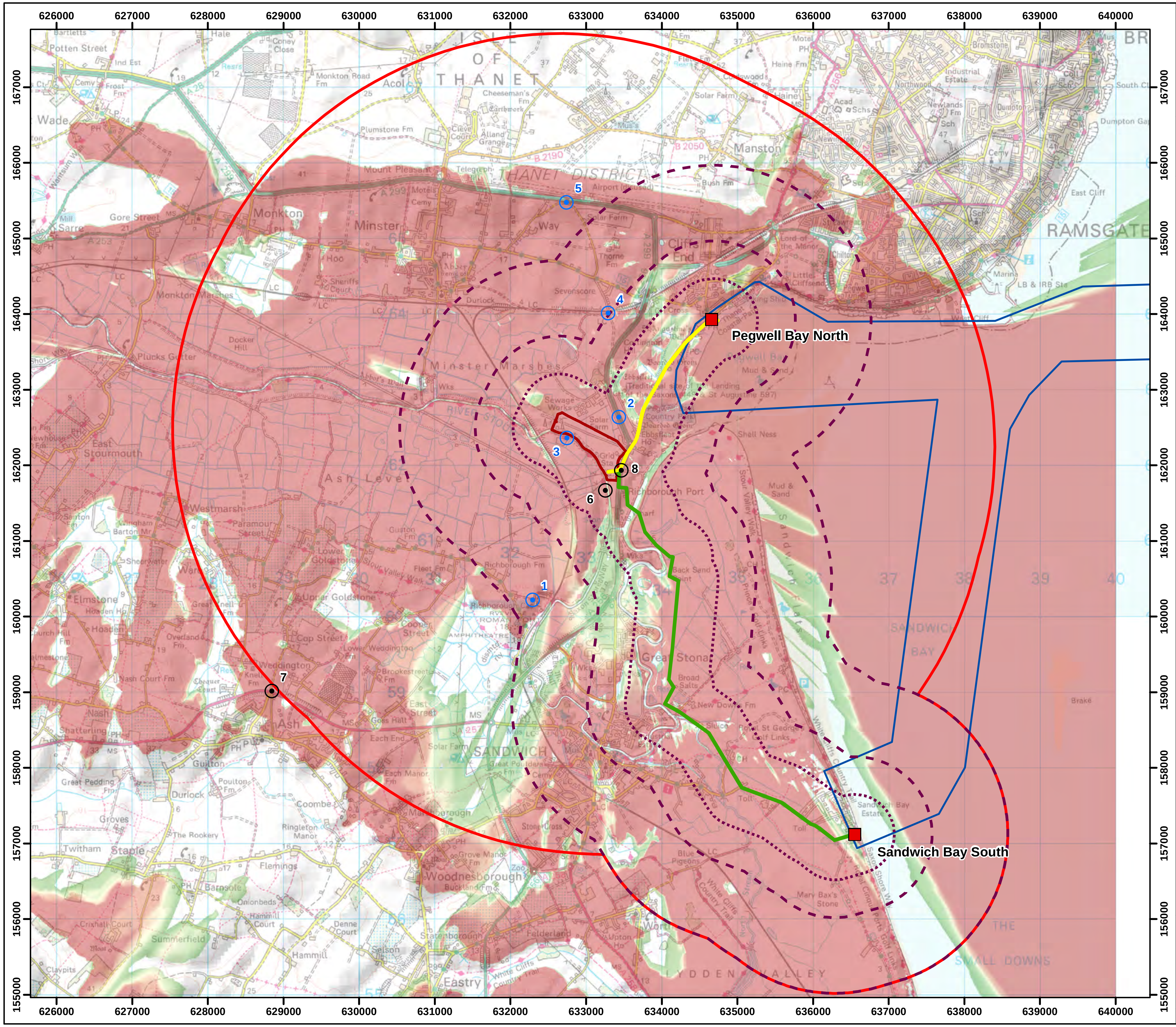
Projection: ETRS 1989 UTM Zone 31N

N

0 2.5 5 km

Scale: 1:150,000

Rev	0	By	TH	Date	06/04/2017
Drg No	160995_TEOWF_ZTV_BT_Kent_VP_PostScop_A3				



VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Indicative Substation Area ZTV with Viewpoints

Legend

- Cable Landfall Options
- Onshore Cable Route Option 1 with 25m Wide Corridor
- Onshore Cable Route Option 2 with 25m Wide Corridor
- Substation Area of Interest
- 500m Buffer Around 25m Corridor
- 1000m Radii Around 25m Corridor
- Proposed Offshore Export Cable Corridor
- Onshore LVIA Scoping Area

Indicative Substation Area ZTV

Level of Visibility

High

Low

Viewpoints

Viewpoints consulted on at scoping

1. Richborough Castle
2. A256, Richborough Way
3. Saxon Shore Way (north)
4. Sevenscore Crossing
5. A299, Thorne Hill

Potential additional viewpoints

6. Saxon Shore Way (south)
7. A257 near Ash
8. A256, Richborough Port

Max. Build Height	16m	Observer height:	2m
DTM:	OS T5	Surface features:	Excluded
DTM resolution:	5m	Earth curvature:	Included

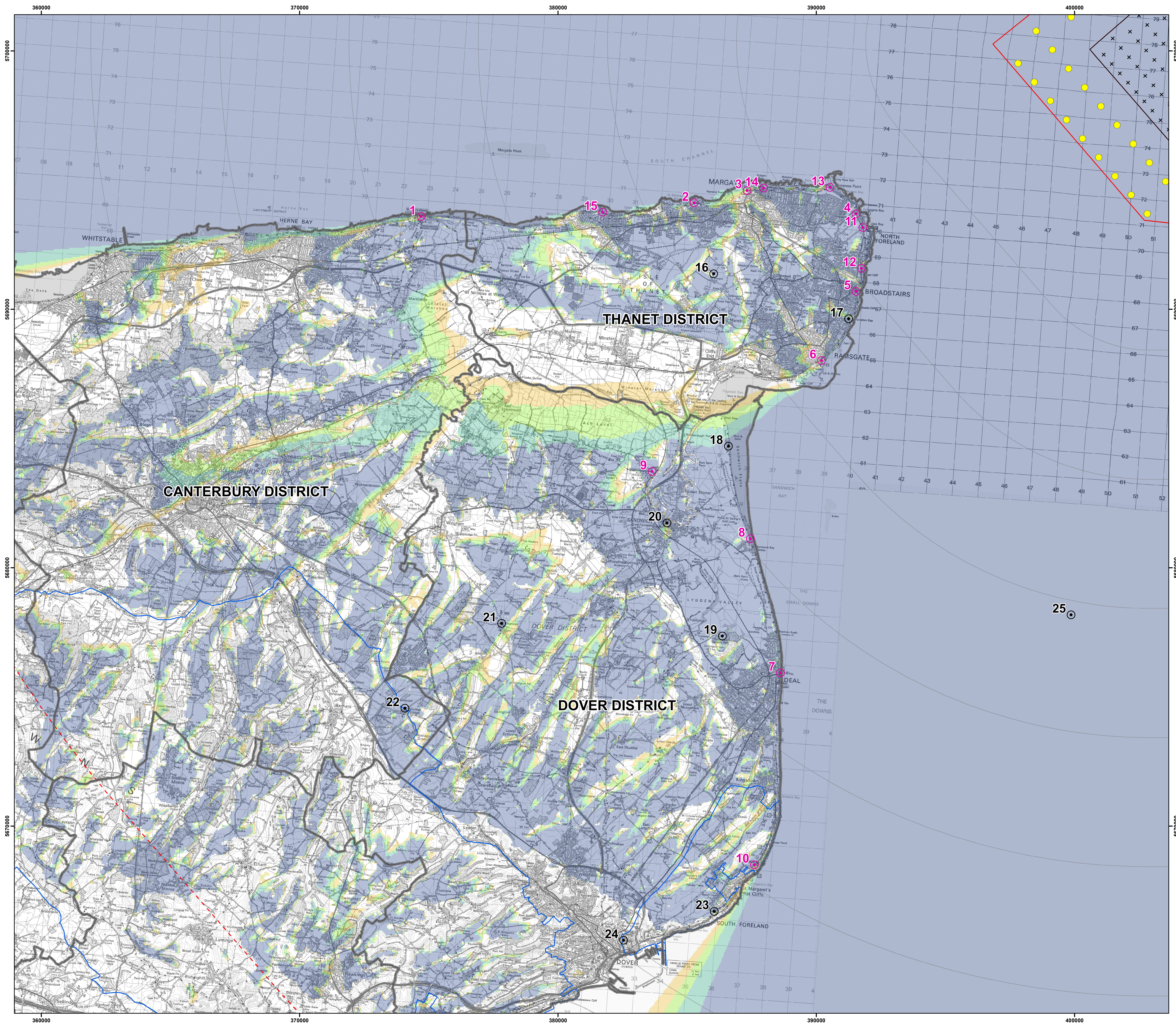
Layout: v02_170308nm_27700
Projection: British National Grid

N

0 1 2 km

Scale: 1:50,000

Rev	0	By	TH	Date	24/04/2017
Drg No	160995_TEOWF_ON_ZTV_DevtArea&VP_A3				



VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Blade Tip ZTV with Viewpoints

Legend

- Proposed Turbine Location
- Turbine Location
- Proposed Wind Farm Area
- Wind Farm Area
- 5km Radii
- 45km Study Area
- Local Authority Boundary
- Kent Downs AONB [1]

Blade Tip ZTV

No. of Blade Tips Visible

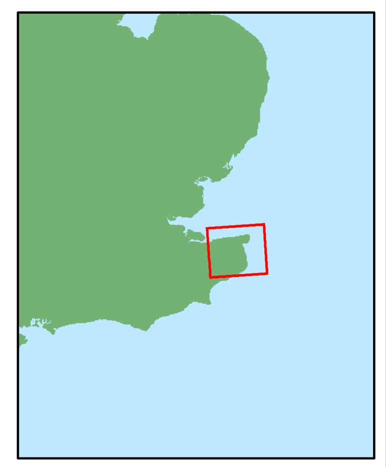
- 0
- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40

Viewpoints consulted on at scoping

1 - Reculver Country Park, Thanet Coastal Path
2 - West Brook POS/Thanet Coastal Path
3 - Margate Harbour Wall (Turner Arts Gallery)
4 - Kingsgate/North Foreland, Coastal Path
5 - Broadstairs Promenade
6 - Wellington Crescent, Ramsgate
7 - Richborough Castle
8 - Kings Avenue/Princes Drive, Sandwich Bay Estate
9 - Deal Pier/Promenade
10 - St. Margaret's at Cliffe (Coastguard Memorial)
11 - Joss Bay/North Foreland
12 - Stone Bay
13 - Foreness Point/Palm Bay
14 - Walpole Bay (Margate)
15 - Birchington-on-Sea

Potential additional viewpoints

16. Isle of Thanet, Manston Road near PRoW
17. Broadstairs, Dumpton Gap
18. England Coastal Path, Sandwich Flats
19. Betteshanger Country Park
20. St Peter's Church, Sandwich
21. Chillenden
22. North Downs Way, near Woolage Village (Kent Downs AONB)
23. South Foreland Lighthouse
24. Dover Castle
25. Trinity Beacon, Goodwin Sands



[1] Contains, or is based on, information supplied by Natural England, 2016

Blade Tip:	210m	Observer height:	2m
DTM:	OS T50	Surface features:	Excluded
DTM resolution:	50m	Earth curvature:	Included

Layout: LTHET2013
Projection: ETRS 1989 UTM Zone 31N

N

0 2.5 5 km

Scale: 1:75,000

Rev	0	By	TH	Date	06/04/2017
Drg No	160995_TEOWF_ZTV_BT_Kent_VP_PostScop_A1				

LVIA Worst Case: 28 x 12MW Layout
Blade tip height: 250m
Rotor diameter: 220m
Minimum spacing: 1540m x 1440m

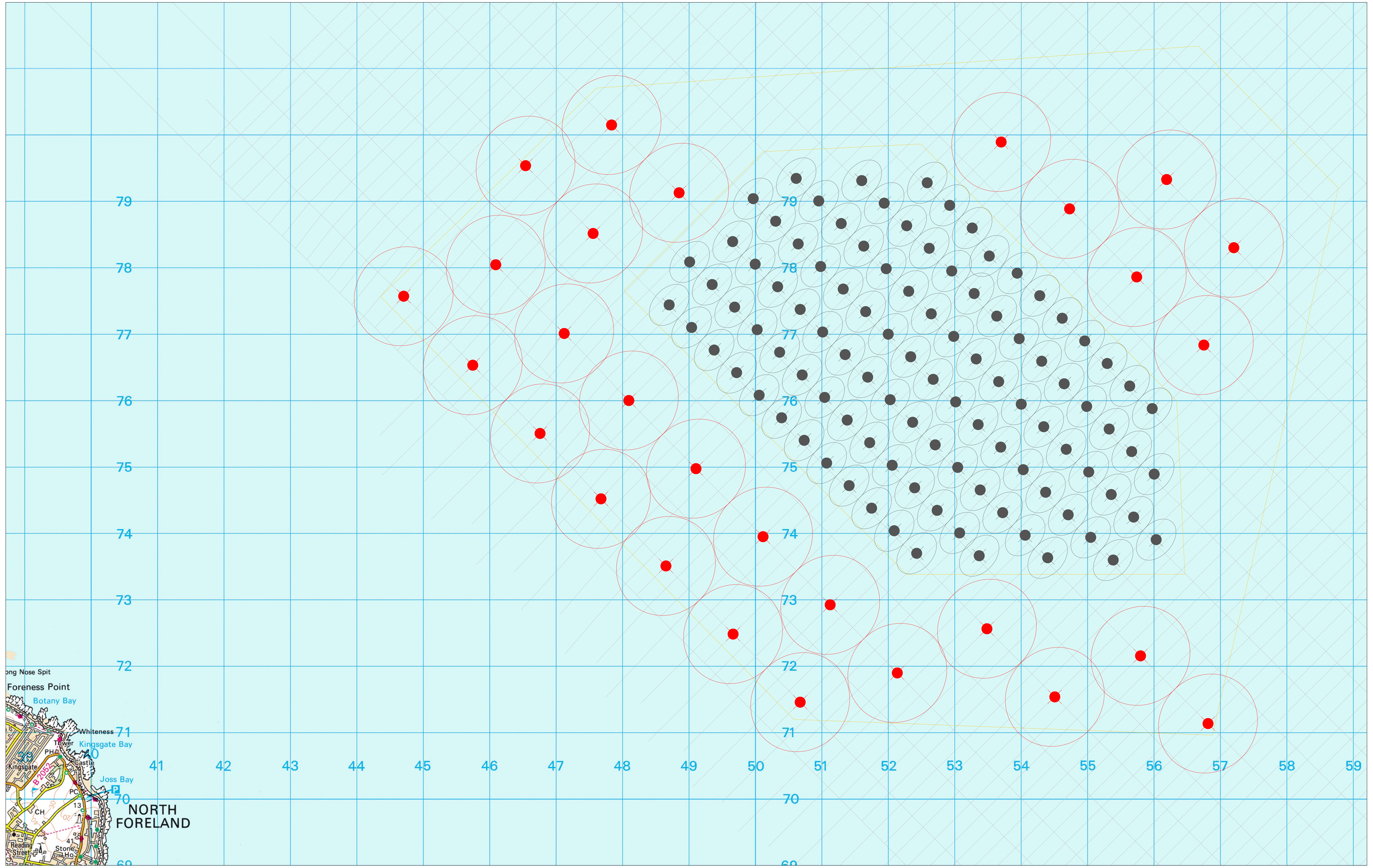
Figure 1 shows the worst case 28 turbine layout proposed for the LVIA. This layout has the highest turbine with largest rotor diameter, with a lower overall number of turbines and a less dense spacing (than the 34 x 10MW layout shown in Figure 2).

The worst case 28 x 12MW turbine layout is based on the following:

- turbine locations are sited entirely within the proposed wind farm area and based on spacing of 1540m x 1440m to represent densest possible turbine spacing for 12MW turbines.
- layout is weighted to have maximum number of turbines located in the areas within the site boundary that are closest to the coast. Turbines located in closer proximity to the coast will appear most prominent and largest in scale in views from land. Turbines located on the coastal side of Thanet Offshore Wind Farm (TOWF) will appear larger in scale and have a more marked scale difference, than turbines located 'behind' TOWF on the seaward side of the operational turbines.
- turbines are also located 'behind' TOWF, because this is realistic - the layout is likely to have turbines in the part of the site behind TOWF; but also because these turbines are likely to give rise to a scale effect, as a result of appearing larger in scale than TOWF, despite being more distant. Turbines located 'behind' TOWF also increase the density/massing of the central part of the array.
- turbines located towards the outer edges of site boundary to represent maximum lateral (horizontal) spread of turbines in views.
- turbine locations based on grid alignment (north-west to south-east) to represent realistic worst case.

Wirelines from three representative viewpoints are shown in Figures 3a, 4a and 5a illustrating the worst case 28 x 12MW layout.

The 28 x 12MW layout shown in Figure 1 is considered to be representative of the reaslistic worst case for the LVIA. The larger blade tip height of the 12MW turbine (250m blade tip) and larger rotor diameter (220m) will have the most apparent scale differences when viewed in combination with TOWF (115m blade tip). The 250m blade tip height turbines will also have a larger Zone of Theoretical Visibility (ZTV) and will be more visible in views from inland areas of Thanet above the intervening urban development around the coast. The 28 x 12MW layout will be illustrated in photomontage visualisations from all of the agreed viewpoint locations in the PEI.



LVIA Worst Case 28 x 12MW Layout

Layout based on: 28 x 12MW turbines
Blade tip height: 250m
Rotor diameter: 220m
Spacing: 1540m x 1440m

Figure: 1
LVIA Worst Case 28 x 12MW Layout

LVIA Worst Case 34 x 10MW Layout
Blade tip height: 210m
Rotor diameter: 180m
Minimum spacing: 1430m x 960m

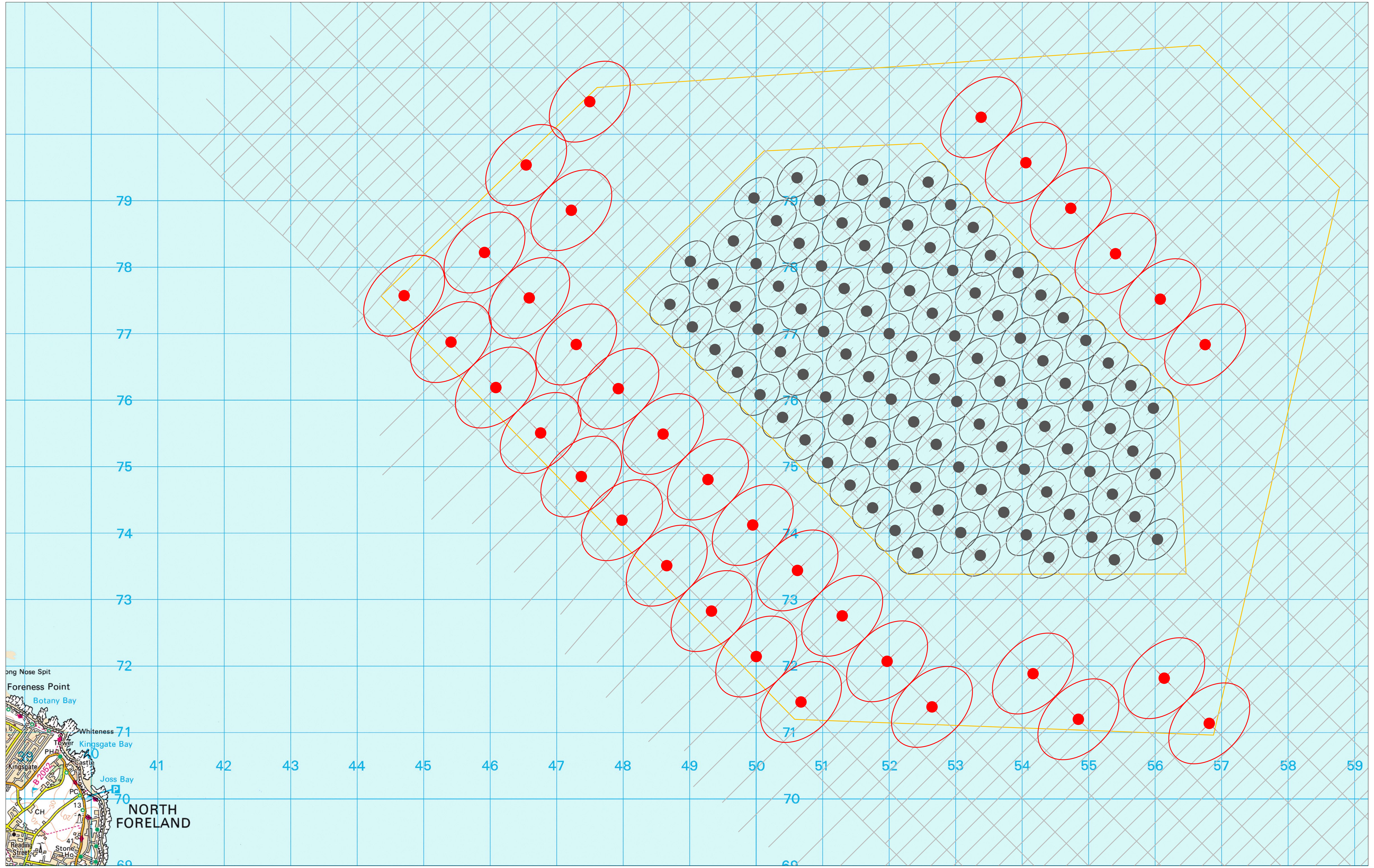
Figure 2 shows a realistic worst case 34 turbine layout proposed for the LVIA. This layout has the largest overall number of turbines at the densent turbine spacing.

The worst case 34 x 10MW turbine layout is based on the following:

- turbines are sited entirely within the proposed wind farm area and based on spacing of 1430m x 960m to represent densest possible turbine spacing.
- layout is weighted to have a higher number of turbines located in the areas within the site boundary that are closest to the coast. Turbines located in closer proximity to the coast will appear most prominent and largest in scale in views from land. Turbines located on the coastal side of TOWF will appear larger in scale and have a more marked scale difference, than turbines located ‘behind’ TOWF on the seaward side of the operational turbines.
- turbines are also located ‘behind’ TOWF, because this is realistic - the layout is likely to have turbines in the part of the site behind TOWF; but also because these turbines are likely to give rise to a scale effect, as a result of appearing larger in scale than TOWF, despite being more distant. Turbines located ‘behind’ TOWF also increase the density/massing of the central part of the array.
- turbines are sited at locations representing the outer edges of the site boundary to represent maximum lateral (horizontal) spread of turbines in views.
- turbine locations are based on grid alignment (north-west to south-east) to represent realistic worst case.

Wirelines from three representative viewpoints are shown in Figures 3b, 4b and 5b illustrating the 34 x 10MW layout.

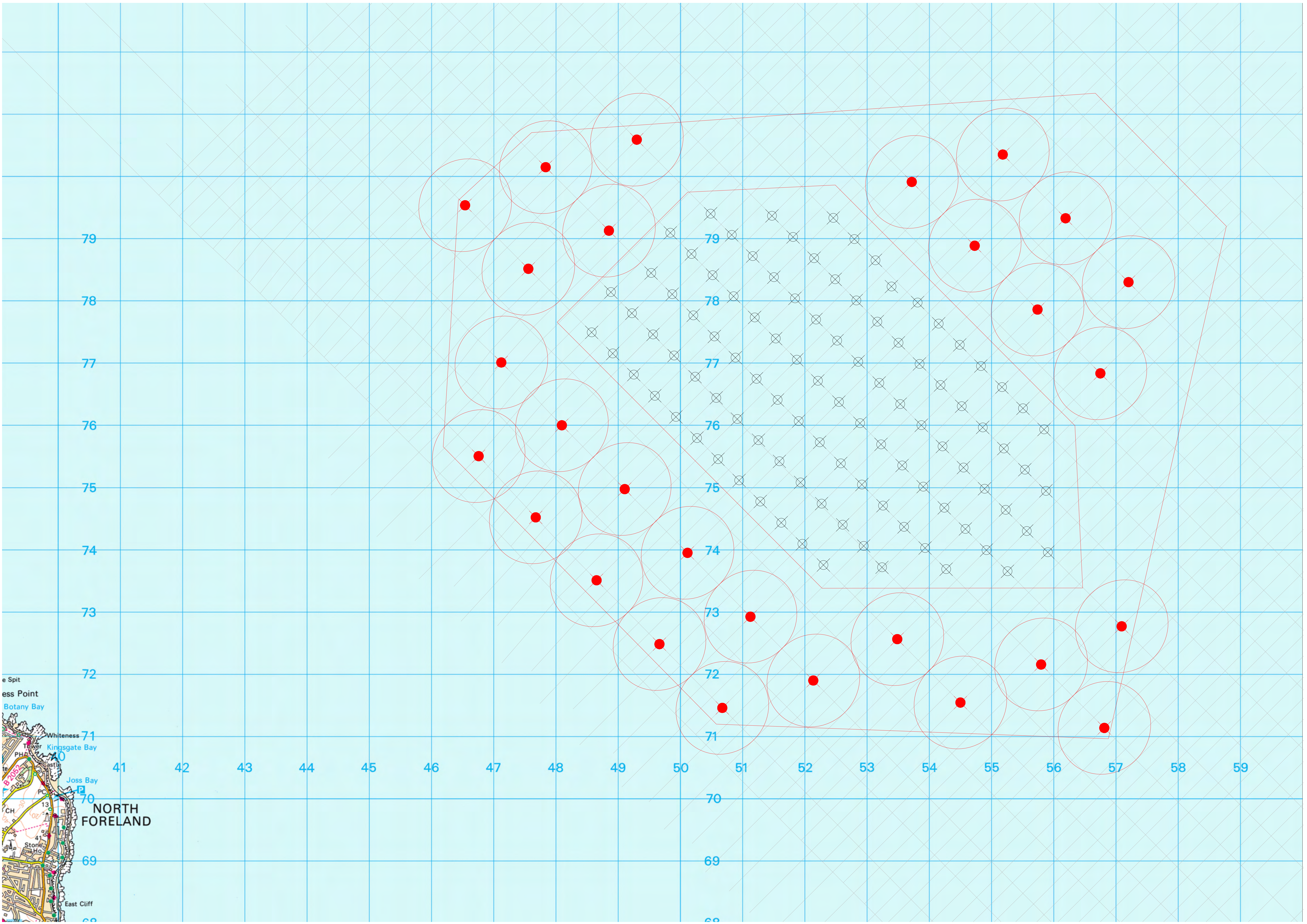
The 34 x 10MW layout (Figure 2) will be illustrated in wirelines from a selection key viewpoints in the PEI, to show the layout with the densest spacing and largest overall number of turbines, however the 28 x 12MW layout (Figure 1) is considered to be worst case for the LVIA.



LVIA Worst Case 34 x 10MW Layout

LVIA Worst Case: 34 x 10MW Layout
Blade tip height: 210m
Rotor diameter: 180m
Spacing: 960m x 1430m

Figure: 2
LVIA Worst Case 34 x 10MW Layout


NORTH
FORELAND
Botany Bay
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Whiteness
Kingsgate Bay
Joss Bay
East Cliff
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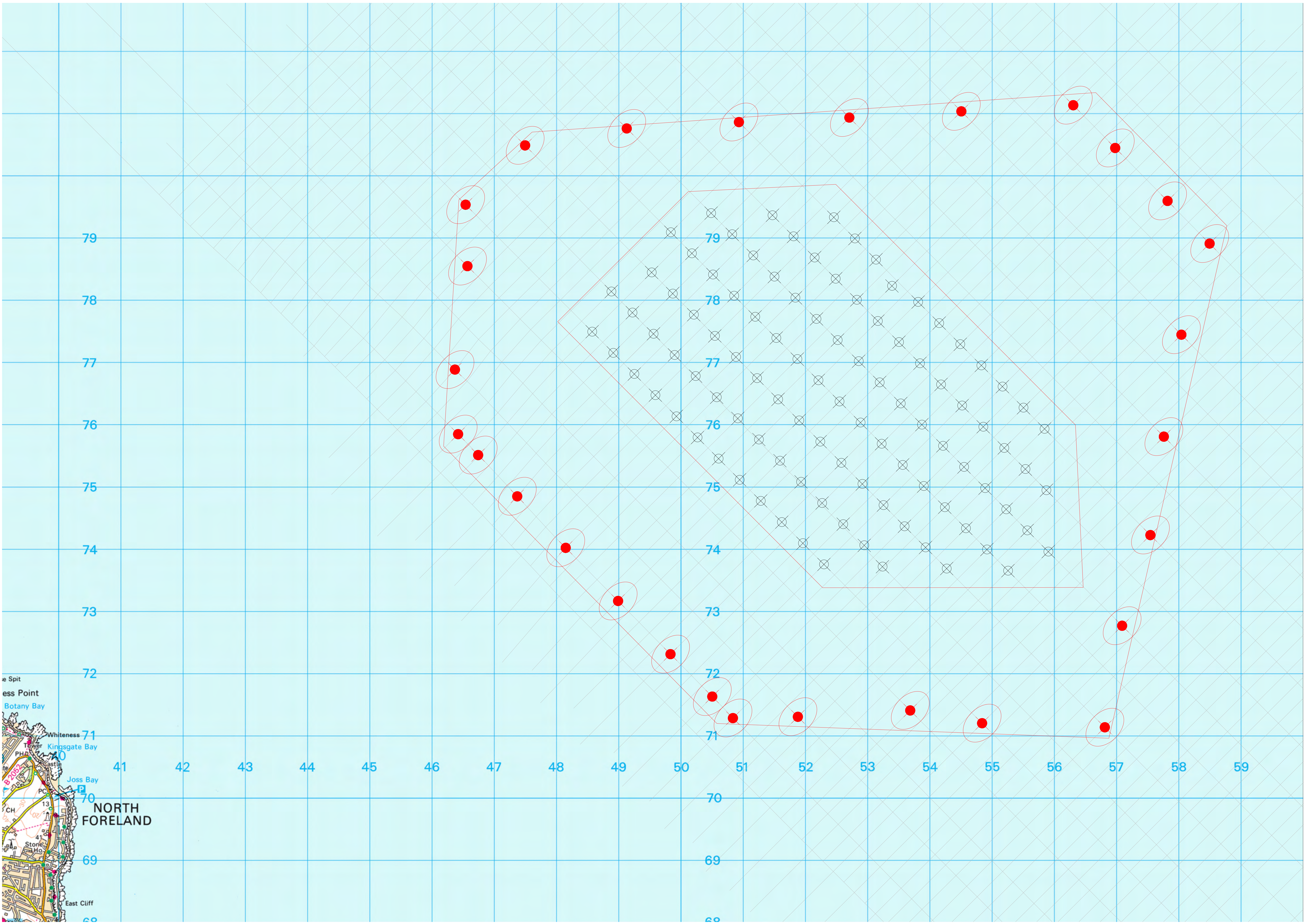

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Botany Bay
Whiteness
Kingsgate Bay
Joss Bay
NORTH
FORELAND
East Cliff

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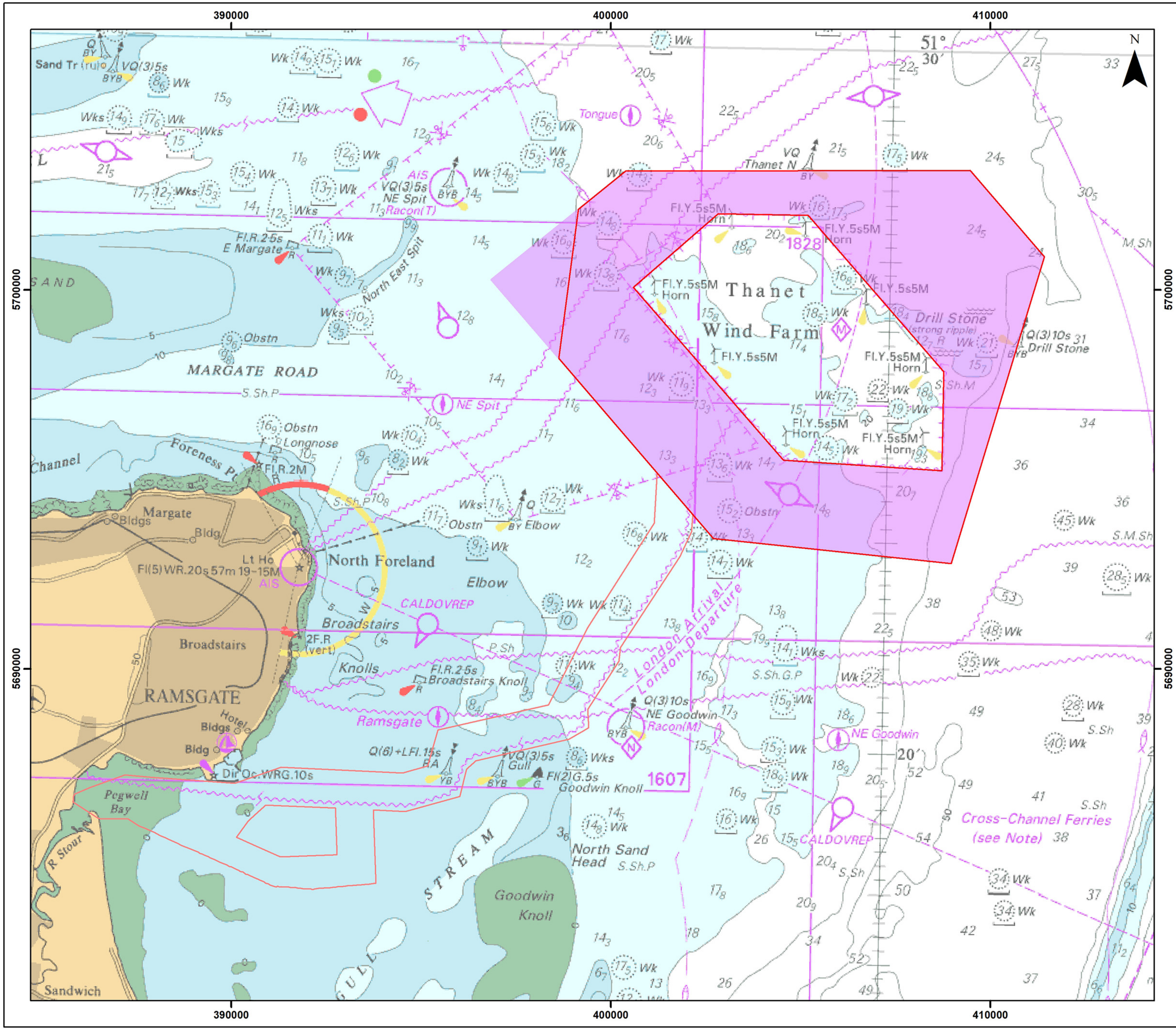
THANET EXTENSION OFFSHORE WIND FARM

Figure x

Thanet Extension Offshore Wind Farm Offshore RLB ES and PEI comparison.



Legend

- Offshore Red Line Boundary
- PEI Proposed Development Boundary

Datum: ETRS 1989
Projection: UTM31N

1:100,000 0 1 2 km 0 0.55 1.1 nm

Drg No	TEOW_ES_Off_RLB_changes_raster		
Rev	0.1	Date	16/04/2018
By	PN	Layout	N/A

Figure x

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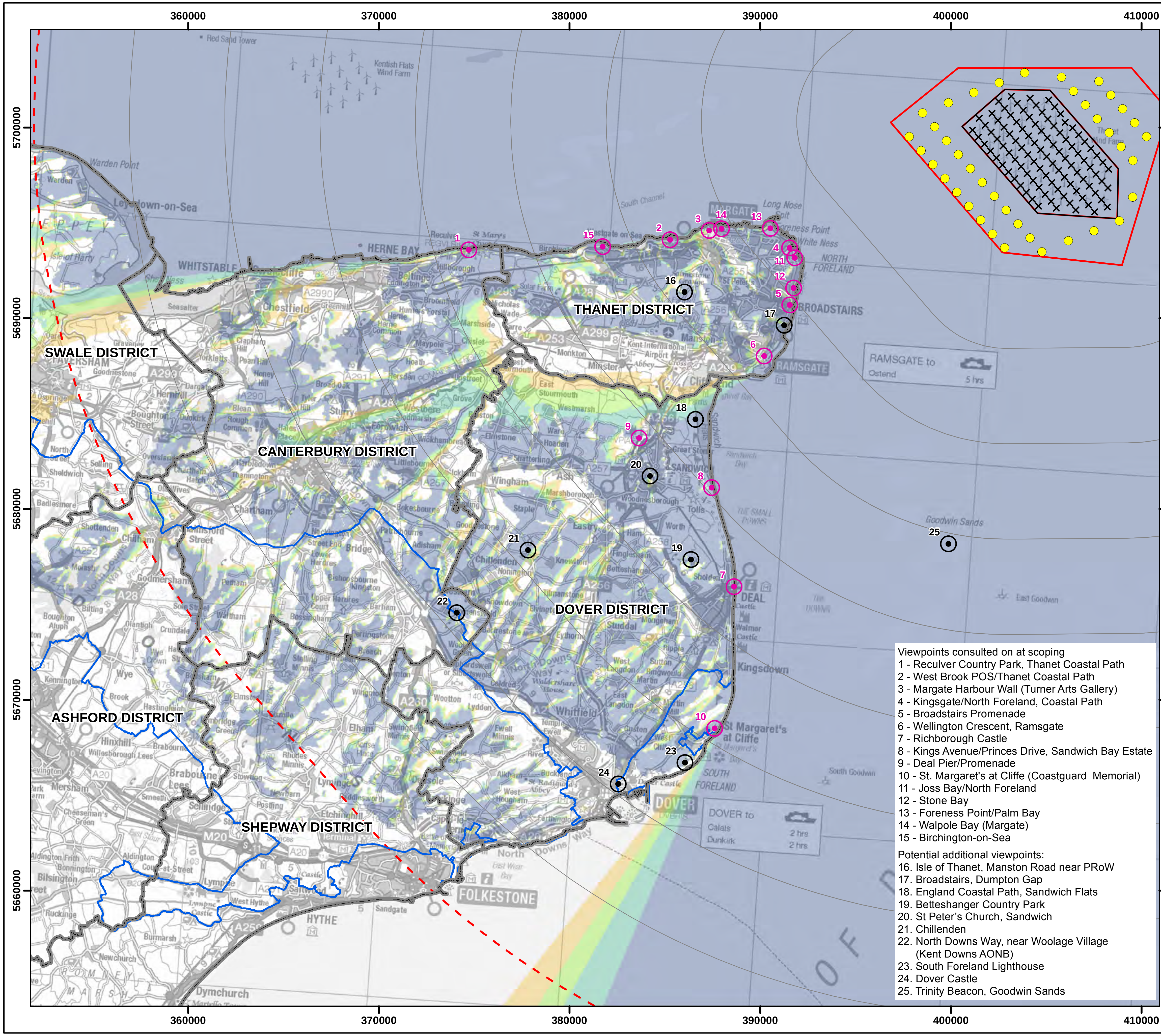
THANET EXTENSION OFFSHORE WIND FARM

Blade Tip ZTV with Viewpoints



Viewpoints consulted on at scoping
1 - Reculver Country Park, Thanet Coastal Path
2 - West Brook POS/Thanet Coastal Path
3 - Margate Harbour Wall (Turner Arts Gallery)
4 - Kingsgate/North Foreland, Coastal Path
5 - Broadstairs Promenade
6 - Wellington Crescent, Ramsgate
7 - Richborough Castle
8 - Kings Avenue/Princes Drive, Sandwich Bay Estate
9 - Deal Pier/Promenade
10 - St. Margaret's at Cliffe (Coastguard Memorial)
11 - Joss Bay/North Foreland
12 - Stone Bay
13 - Foreness Point/Palm Bay
14 - Walpole Bay (Margate)
15 - Birchington-on-Sea

Potential additional viewpoints:
16. Isle of Thanet, Manston Road near PRoW
17. Broadstairs, Dumpton Gap
18. England Coastal Path, Sandwich Flats
19. Betteshanger Country Park
20. St Peter's Church, Sandwich
21. Chillenden
22. North Downs Way, near Woolage Village (Kent Downs AONB)
23. South Foreland Lighthouse
24. Dover Castle
25. Trinity Beacon, Goodwin Sands

Legend

- TEOWF Scoping Layout
- Thanet Operational Turbine
- Proposed Wind Farm Area
- Wind Farm Area
- 5km Radii
- 45km Study Area
- Local Authority Boundary
- Kent Downs AONB [1]

Blade Tip ZTV

No. of Blade Tips Visible

- 0
- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- Viewpoints consulted on at scoping
- Potential additional viewpoints

[1] Contains, or is based on, information supplied by Natural England, 2016

Blade Tip:	210m	Observer height:	2m		
DTM:	OS T50	Surface features:	Excluded		
DTM resolution:	50m	Earth curvature:	Included		

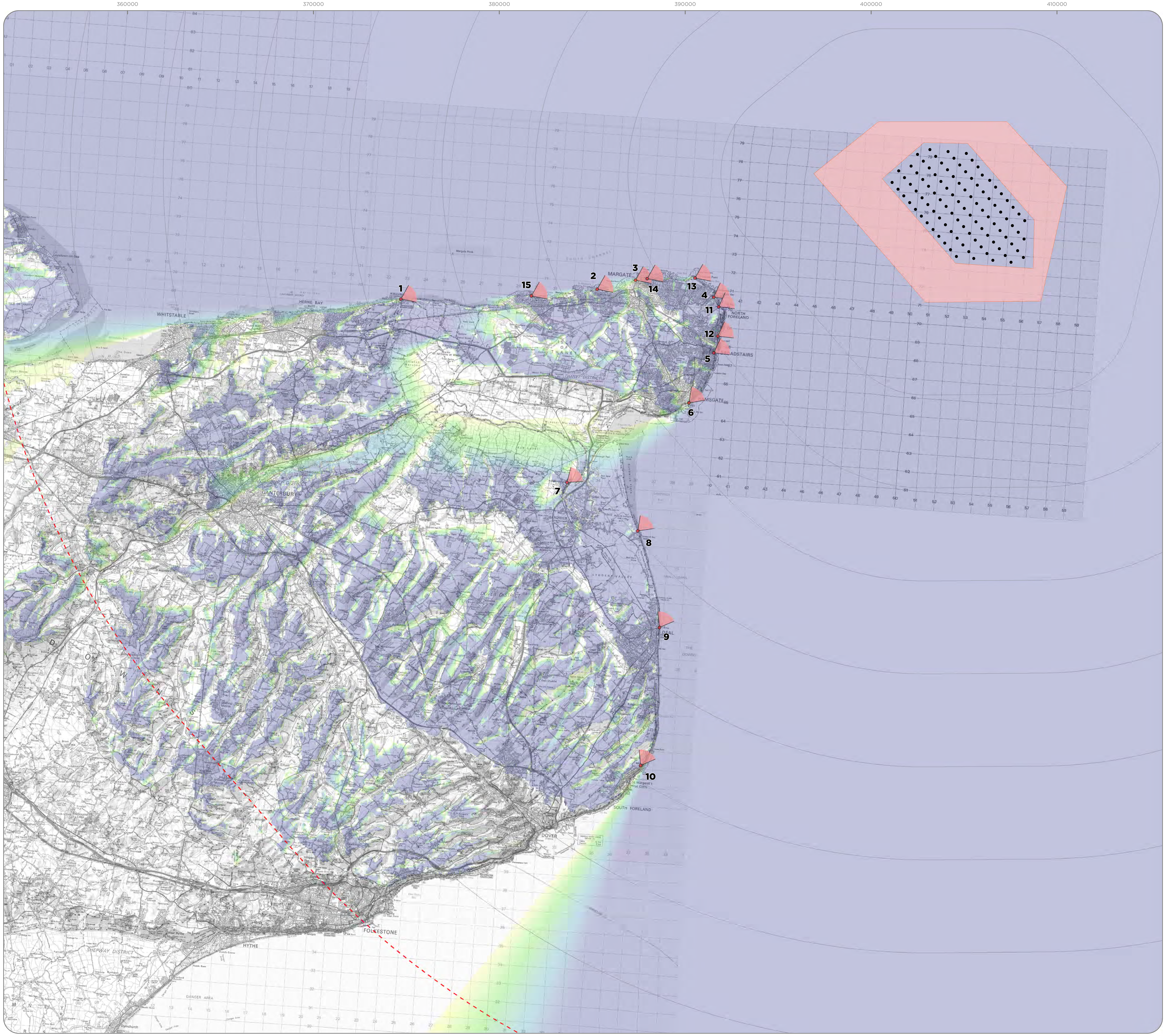
Layout: LTHET2013
Projection: ETRS 1989 UTM Zone 31N

N

0 2.5 5 km

Scale: 1:200,000

Rev	0	By	TH	Date	26/05/2017
Drg No	160995_TEOWF_ZTV_BT_Kent_VP_A3				



Legend

- Thanet Extension Area of Interest
- Thanet Wind Farm (Operational)
- 5km Radii
- 45km Study Area

Theoretical Blade Tip Visibility
- Higher Visibility
- Lower Visibility

Thanet ES Viewpoints:

1 - Reculver Country Park, Thanet Coastal Path
2 - West Brook POS/Thanet Coastal Path
3 - Margate Harbour Wall (Turner Arts Gallery)
4 - Kingsgate/North Foreland, Coastal Path
5 - Broadstairs Promenade
6 - Wellington Crescent, Ramsgate
7 - Richborough Castle
8 - Kings Avenue/Princes Drive, Sandwich Bay Estate
9 - Deal Pier/Promenade
10 - St. Margaret's at Cliffe (Coastguard Memorial)
11 - Joss Bay/North Foreland
12 - Stone Bay
13 - Foreness Point/Palm Bay
14 - Walpole Bay (Margate)
15 - Birchington-on-Sea

Blade Tip:	210m	Observer height:	2m
DTM:	OS T50	Surface features:	Excluded
DTM resolution:	50m	Earth curvature:	Included

0 2.5 5 10 km

THANET EXTENSION OFFSHORE WIND FARM

Blade Tip ZTV with Viewpoints Kent Coast

Ref No:	160995	Created By:	TH	Rev No:	0
Scale:	1:100,000	Drawing Size:	A1	Date:	28/09/2016

Coordinate System: WGS 1984 UTM Zone 31N

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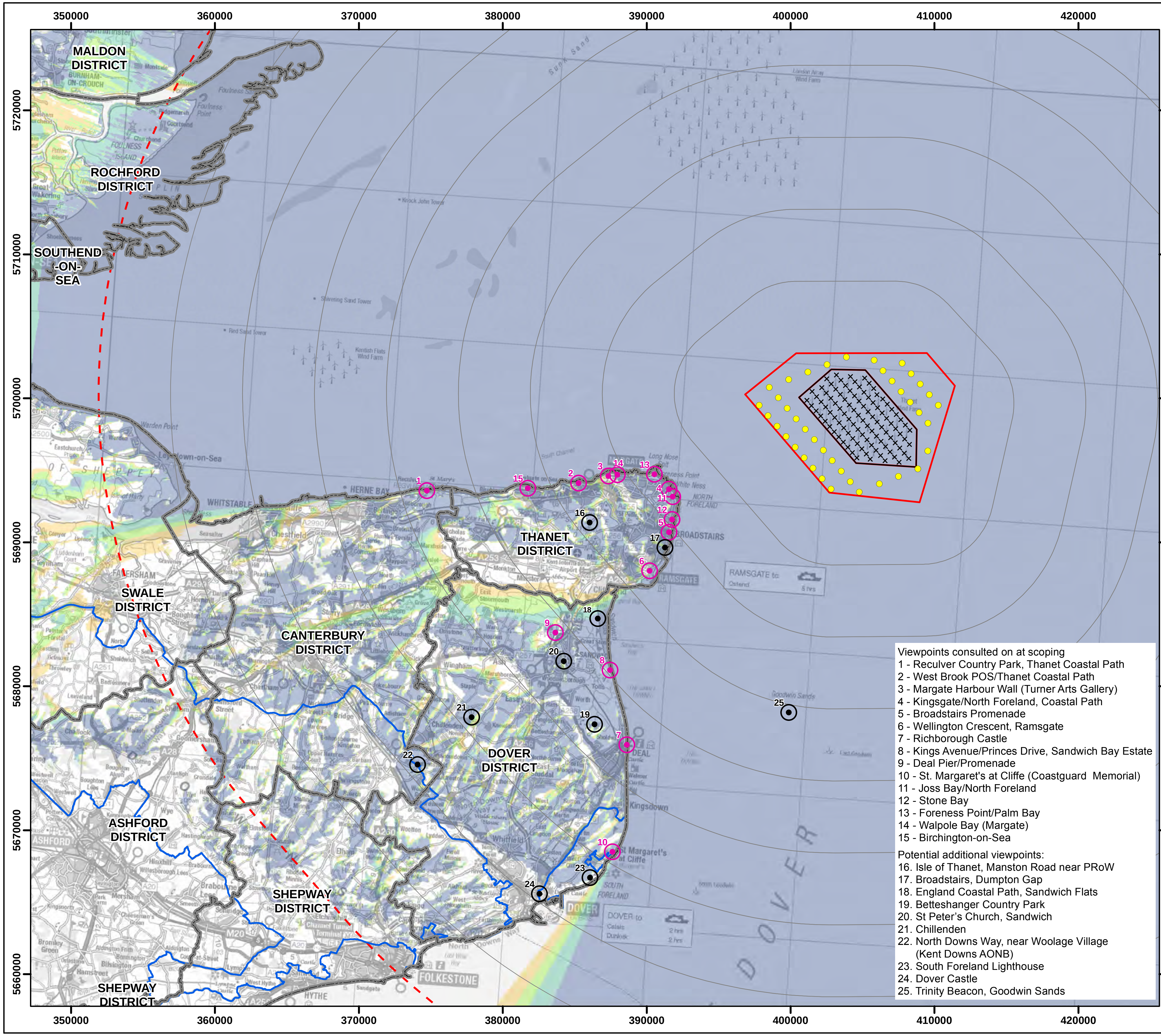
open optimised environments



Viewpoints consulted on at scoping

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2 - West Brook POS/Thanet Coastal Path
3 - Margate Harbour Wall (Turner Arts Gallery)
4 - Kingsgate/North Foreland, Coastal Path
5 - Broadstairs Promenade
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11 - Joss Bay/North Foreland
12 - Stone Bay
13 - Foreness Point/Palm Bay
14 - Walpole Bay (Margate)
15 - Birchington-on-Sea

Potential additional viewpoints:

16. Isle of Thanet, Manston Road near PRoW
17. Broadstairs, Dumpton Gap
18. England Coastal Path, Sandwich Flats
19. Betteshanger Country Park
20. St Peter's Church, Sandwich
21. Chillenden
22. North Downs Way, near Woolage Village (Kent Downs AONB)
23. South Foreland Lighthouse
24. Dover Castle
25. Trinity Beacon, Goodwin Sands

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THANET EXTENSION OFFSHORE WIND FARM

Blade Tip ZTV with Viewpoints

Legend

- TEOWF Scoping Layout
- Thanet Operational Turbine
- Proposed Wind Farm Area
- Wind Farm Area
- 5km Radii
- 45km Study Area
- Local Authority Boundary
- Kent Downs AONB [1]

Blade Tip ZTV

No. of Blade Tips Visible

- 0
- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40

- Viewpoints consulted on at scoping
- Potential additional viewpoints

[1] Contains, or is based on, information supplied by Natural England, 2016

Blade Tip:	210m	Observer height:	2m
DTM:	OS T50	Surface features:	Excluded
DTM resolution:	50m	Earth curvature:	Included

Layout: LTHET2013

Projection: ETRS 1989 UTM Zone 31N

N

0 2.5 5 km

Scale: 1:265,000

Rev	0	By	TH	Date	26/05/2017
Drg No	160995_TEOWF_ZTV_BT_Kent&Essex_VP_A3				

Wireline drawing

OS reference:	602737 E 171318 N	**Horizontal field of view:**	90° (cylindrical projection)
Eye level:	6.85 m AOD	**Principal distance**	522 mm
Direction of view:	60°		
Nearest turbine:	42.430 km		

Viewpoint: Leysdown-on-Sea / Warden, Isle of Sheppey