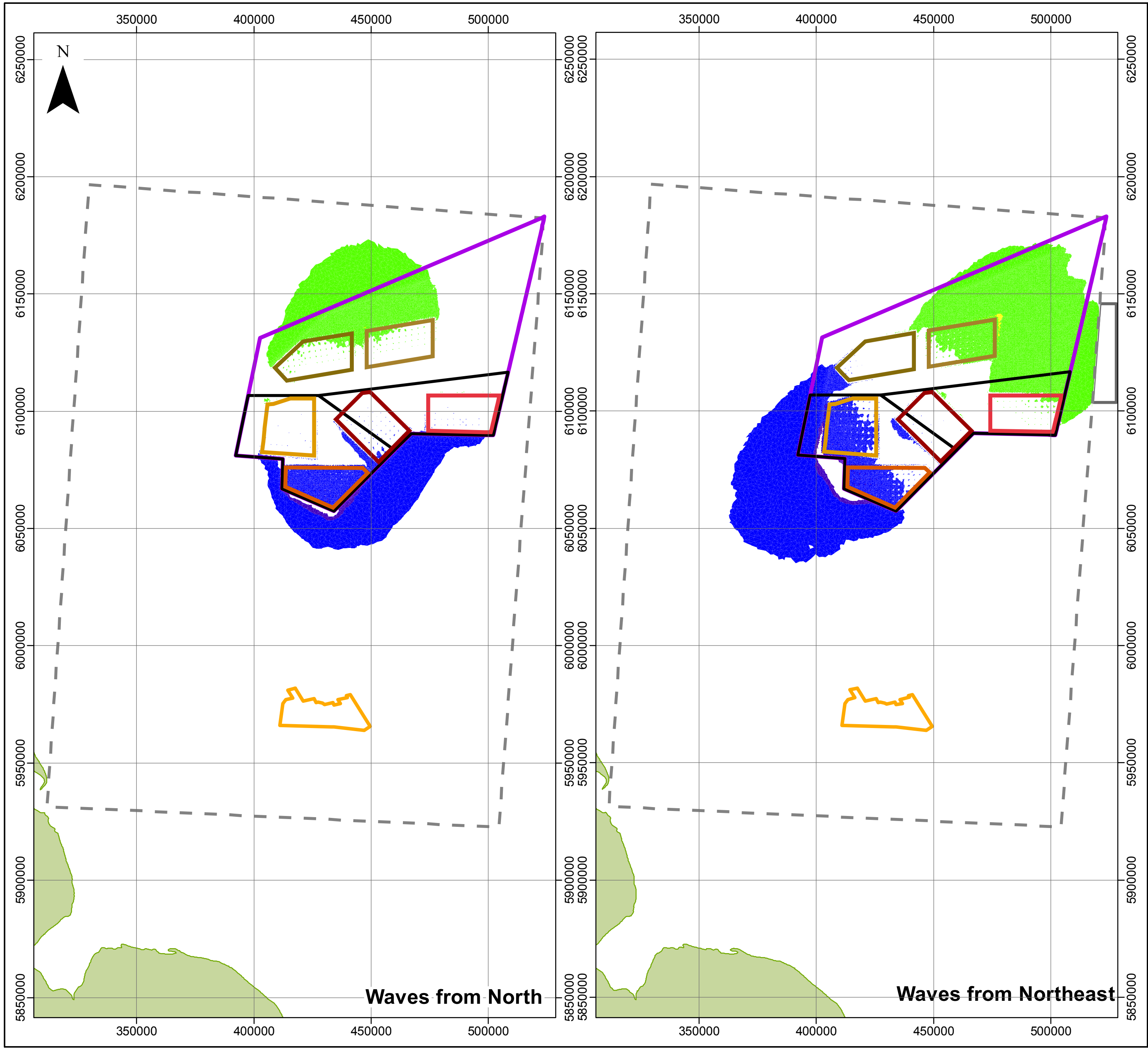
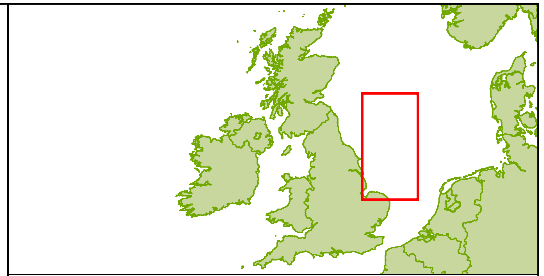




LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside C
- Dogger Bank Teesside D
- Hornsea Project One
- Model boundary

Wave height difference (%)

- 1.5 - 2
- 1 - 1.5
- 0.5 - 1
- 0 - 0.5
- -0.5 - 0
- -1.0 - -0.5
- -1.5 - -1.0
- Below - 1.5

0 30 60
Kilometres

Data Source:
Wave height © Royal HaskoningDHV, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

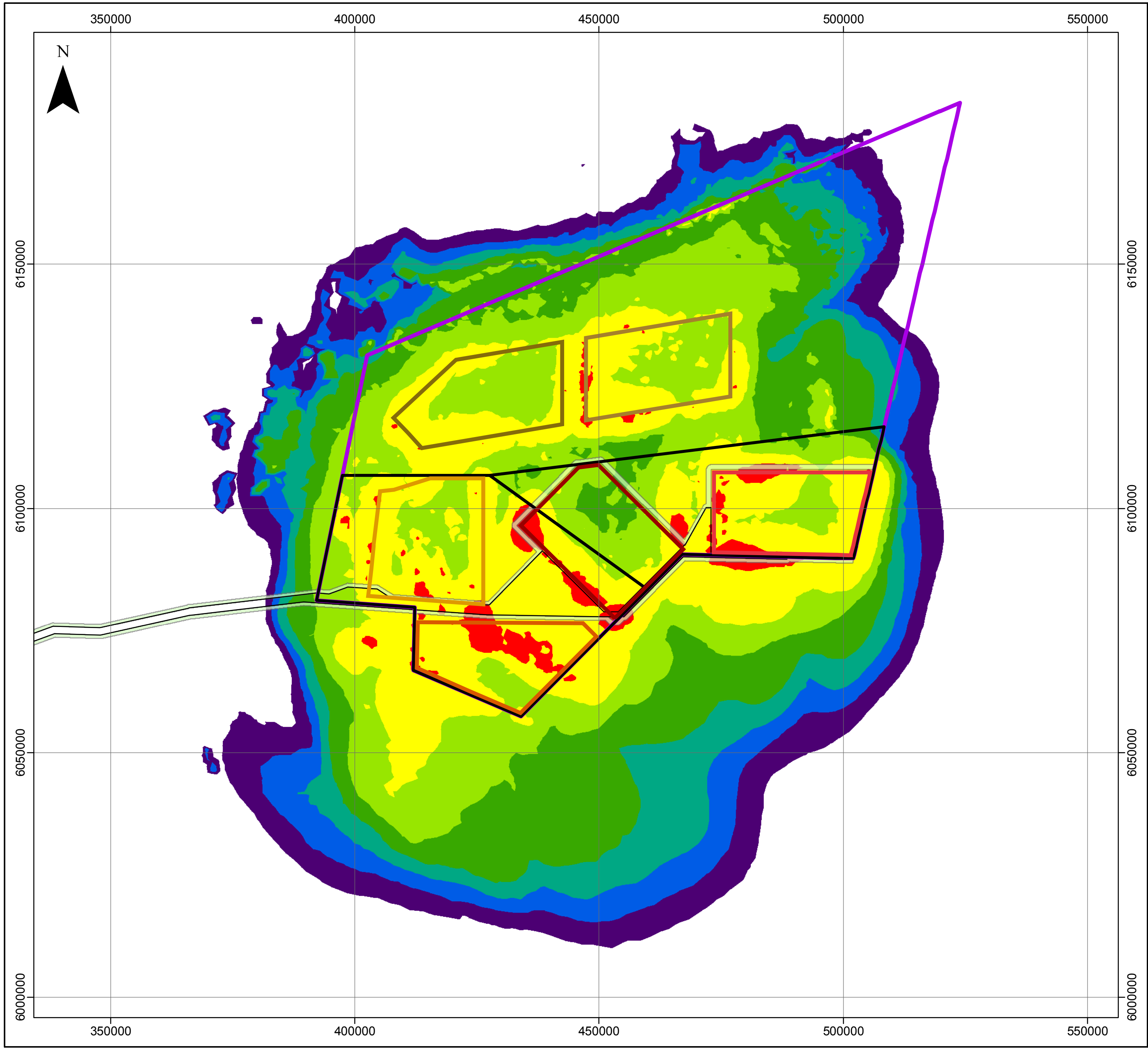
Figure 10.5 Cumulative percentage change to significant wave height for one-year waves from the north and northeast caused by 6MW conical GBS#1 foundations

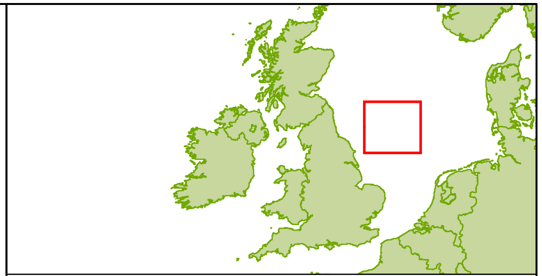
VER	DATE	REMARKS	Drawn	Checked
1	26/06/2013	Draft	FK	DB
2	07/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	GC	DB

DRAWING NUMBER: **F-OFL-MA-444**

SCALE	1:2,500,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Creyke Beck
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside C
- Dogger Bank Teesside D
- Dogger Bank Teesside A & B Export Cable Corridor
- Dogger Bank Teesside A & B temporary works area

Suspended sediment concentration kg/m³

- Above 0.200
- 0.100 - 0.200
- 0.050 - 0.100
- 0.020 - 0.050
- 0.010 - 0.020
- 0.005 - 0.010
- 0.002 - 0.005
- Below 0.002

0 10 20
Kilometres

Data Source:
Modelling © Danish Hydraulic Institute, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

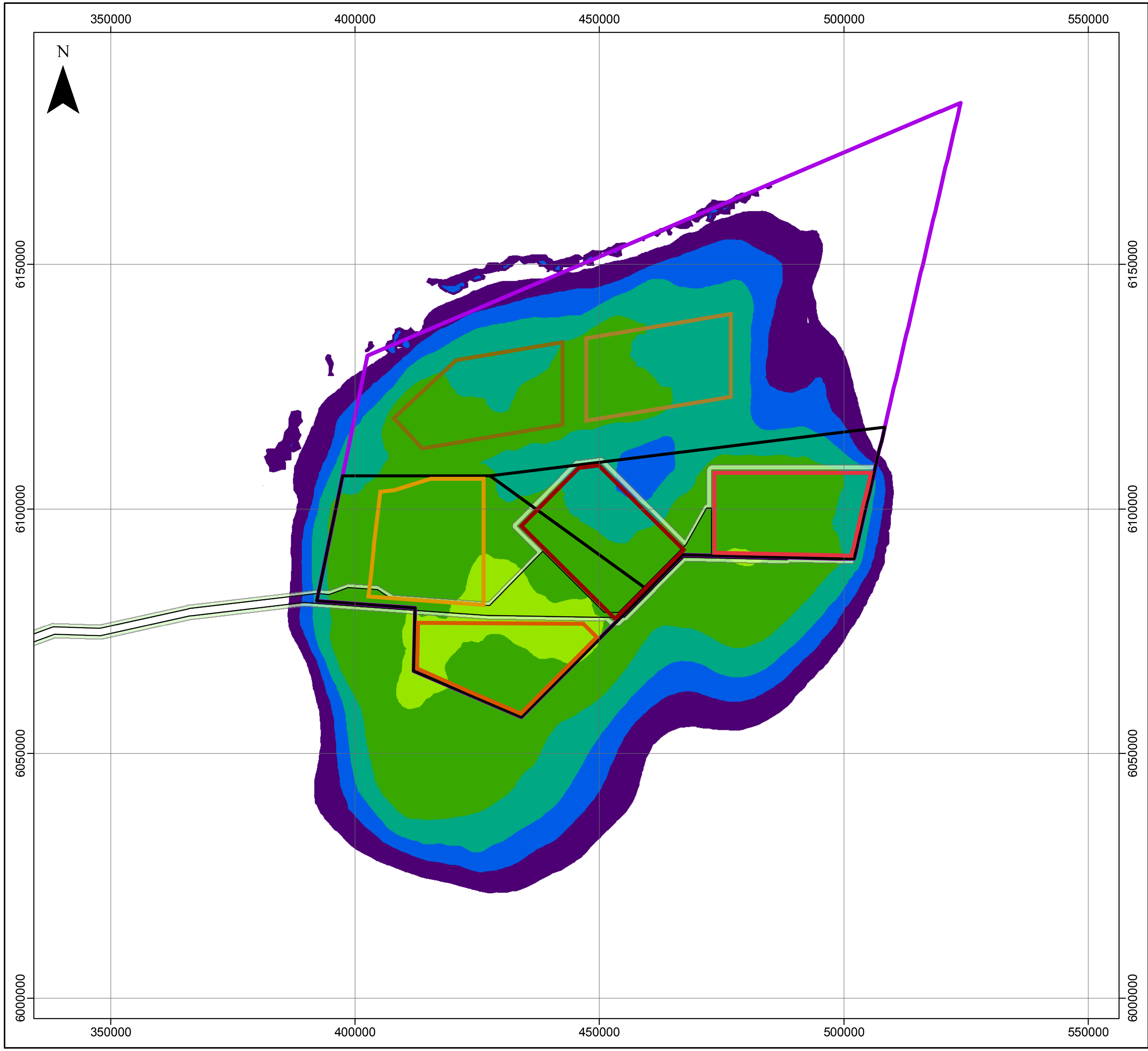
Figure 10.6 Maximum SSC in the bottom layer predicted over the simulation period after two years of operation using the re-suspension of fractions 1 and 2 method

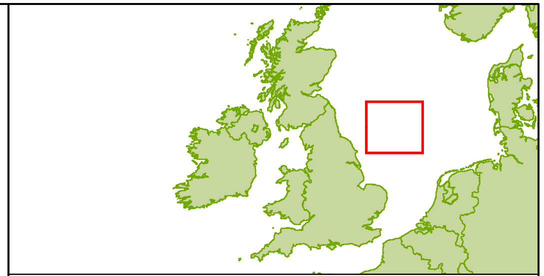
VER	DATE	REMARKS		Checked
1	08/04/2013	Draft	FK	DB
2	08/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	GC	DB

DRAWING NUMBER: **F-OFL-MA-445**

SCALE	1:1,200,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside C
- Dogger Bank Teesside D
- Dogger Bank Teesside A & B Export Cable Corridor
- Dogger Bank Teesside A & B temporary works area

Suspended sediment concentration kg/m³

- Above 0.200
- 0.100 - 0.200
- 0.050 - 0.100
- 0.020 - 0.050
- 0.010 - 0.020
- 0.005 - 0.010
- 0.002 - 0.005
- Below 0.002

0 10 20
Kilometres

Data Source:
Modelling © Danish Hydraulic Institute, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

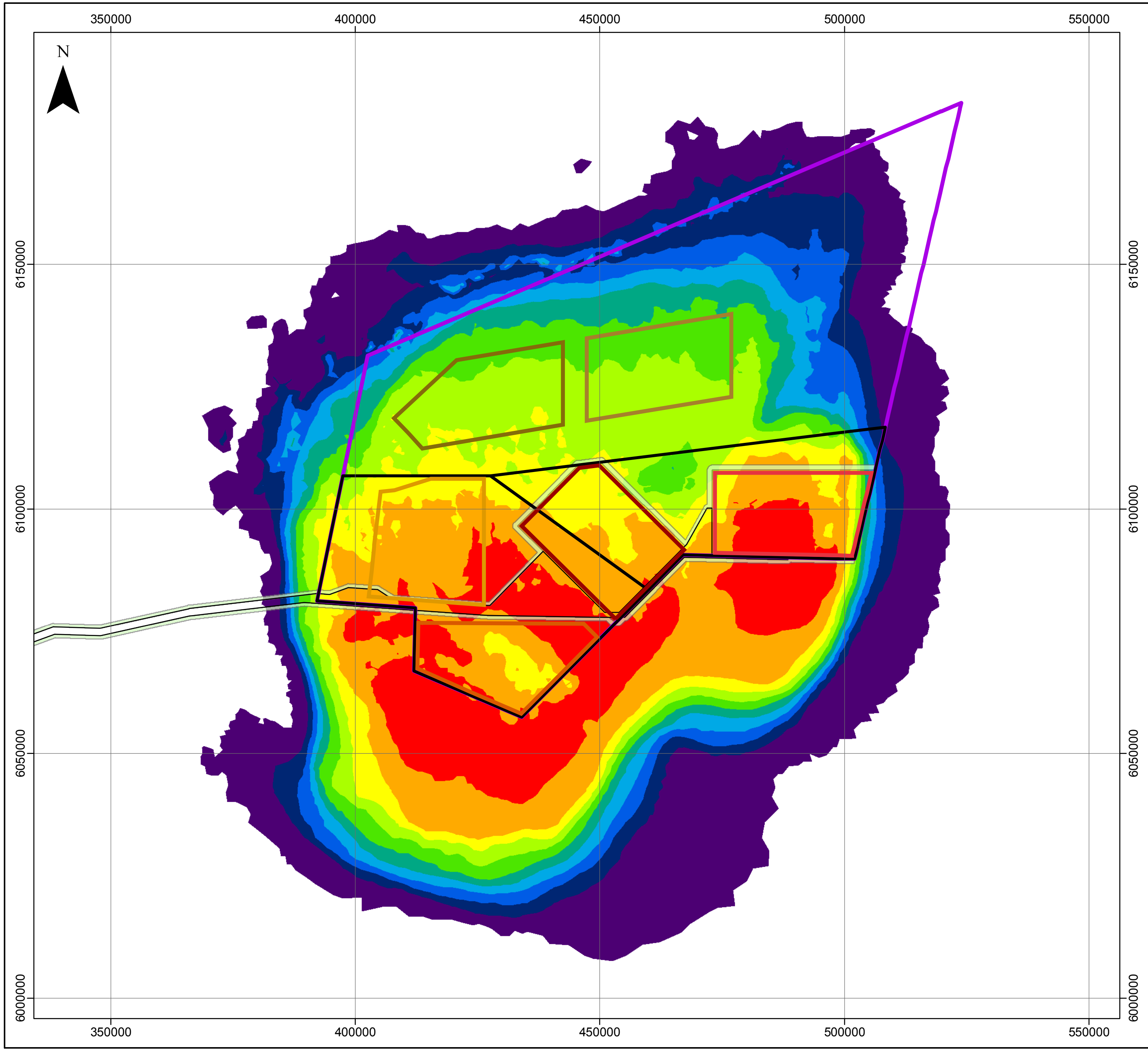
Figure 10.7 Average SSC in the bottom layer predicted over the simulation period after two years of operation using the re-suspension of fractions 1 and 2 method

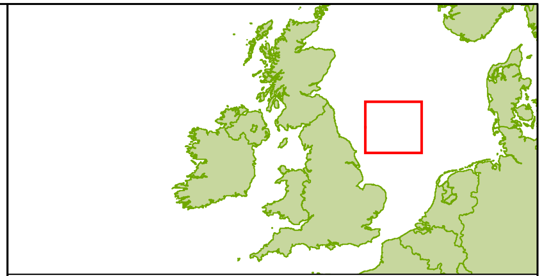
VER	DATE	REMARKS		Checked
1	08/04/2013	Draft	FK	DB
2	08/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	GC	DB

DRAWING NUMBER: **F-OFL-MA-446**

SCALE	1:1,200,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside C
- Dogger Bank Teesside D
- Dogger Bank Teesside A & B Export Cable Corridor
- Dogger Bank Teesside A & B temporary works area

Exceedance of 2 mg/l (%)

- Above 90
- 80 - 90
- 70 - 80
- 60 - 70
- 50 - 60
- 40 - 50
- 30- 40
- 20 - 30
- 10 - 20
- 0 - 10
- Below 0

0 10 20
Kilometres

Data Source:
Modelling © Danish Hydraulic Institute, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 10.8 Percentage of time predicted over the simulation period where SSC of 2mg/l is exceeded in the bottom layer after two years of operation using the re-suspension of fractions 1 and 2 method

VER	DATE	REMARKS		Checked
1	08/04/2013	Draft	FK	DB
2	08/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	GC	DB

DRAWING NUMBER: **F-OFL-MA-447**

SCALE	1:1,200,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND

Predicted cumulative deposition and re-suspension of dispersed sediment

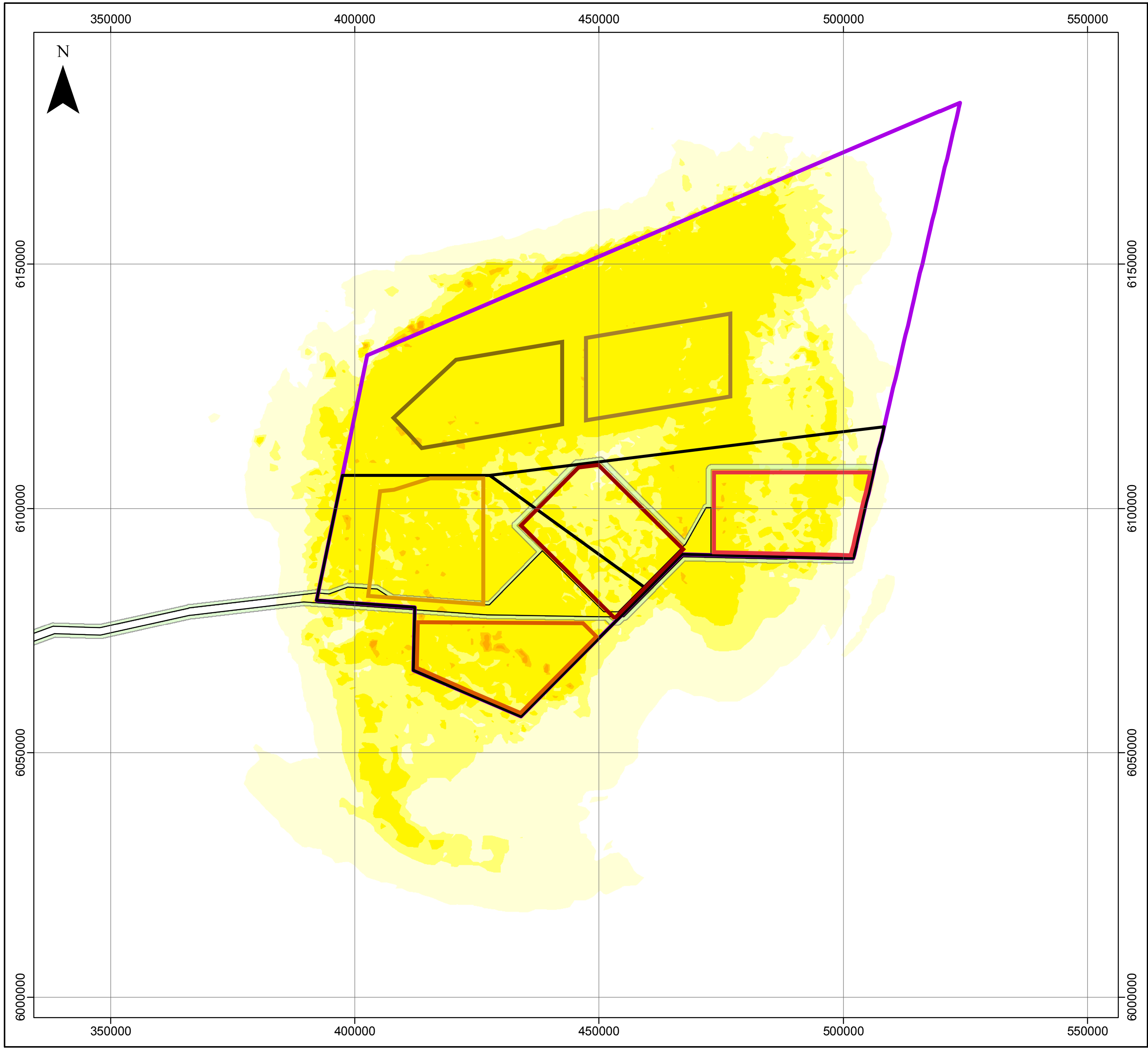
10.3.11 **Figure 10.9** shows the maximum change in deposition predicted at any time over the 30-day simulation period. The majority of the project areas are predicted to have maximum thickness of sediment over the simulation period of 5mm, reducing to 0.1mm about 31-43km from the southern boundaries of the projects and 23-33km from the northern boundaries.

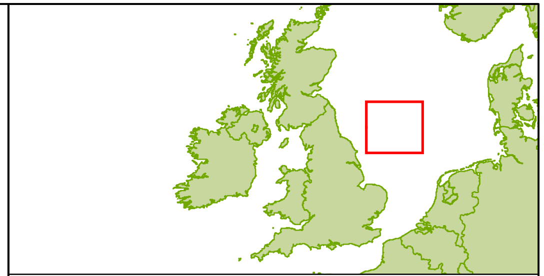
10.3.12 Average deposition is predicted to be 0.1-0.5mm in numerous patches across and outside most of the projects (**Figure 10.10**). The largest patch is up to 22km long and up to 12km wide. Average deposition is generally higher across Dogger Bank Teesside C & D than across the other projects. Average deposition is predicted to reduce to 0.1mm close to the southern boundaries and approximately 12-32km north of the northern boundaries.

10.3.13 Analysis of the time series of deposition from the plume over the 30-day simulation period at seven selected points (Points S1 to S7 in **Figure 10.11**) describes the persistency of sediment thickness on the seabed. **Table 10.3** demonstrates that maximum sediment thickness is 5.7mm at S1 and thicknesses greater than 3mm and 1mm persist for 244 hours (10.17 days) and 332 hours (13.83 days), respectively. At all other points, thicknesses never exceed 2.2mm and persist at greater than 1mm between 2 hours (0.08 days) (S4) and 80 hours (3.33 days) (S5).

Table 10.3 Maximum persistency of sediment thickness over the 30-day simulation period after two years of operation

Point	Maximum thickness (mm)	Maximum continuous time of sediment thickness (hours with days in brackets)				Thickness at end of simulation (mm)
		>10mm	>7mm	>3mm	>1mm	
S1	5.70	0	0	244 (10.17)	322 (13.83)	0.13
S2	1.22	0	0	0	52 (2.17)	<0.1
S3	1.18	0	0	0	50 (2.08)	<0.1
S4	1.03	0	0	0	2	<0.1
S5	1.41	0	0	0	38 (1.58)	<0.1
S6	1.63	0	0	0	6	<0.1
S7	2.17	0	0	0	80 (3.33)	<0.1





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside C
- Dogger Bank Teesside D
- Dogger Bank Teesside A & B Export Cable Corridor
- Dogger Bank Teesside A & B temporary works area

Sediment thickness (m)

- Above 0.1000
- 0.0500 - 0.1000
- 0.0100 - 0.0500
- 0.0050 - 0.0100
- 0.0010 - 0.0050
- 0.0005 - 0.0010
- 0.0001 - 0.0005
- Below 0.0001

0 10 20
Kilometres

Data Source:
Modelling © Danish Hydraulic Institute, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

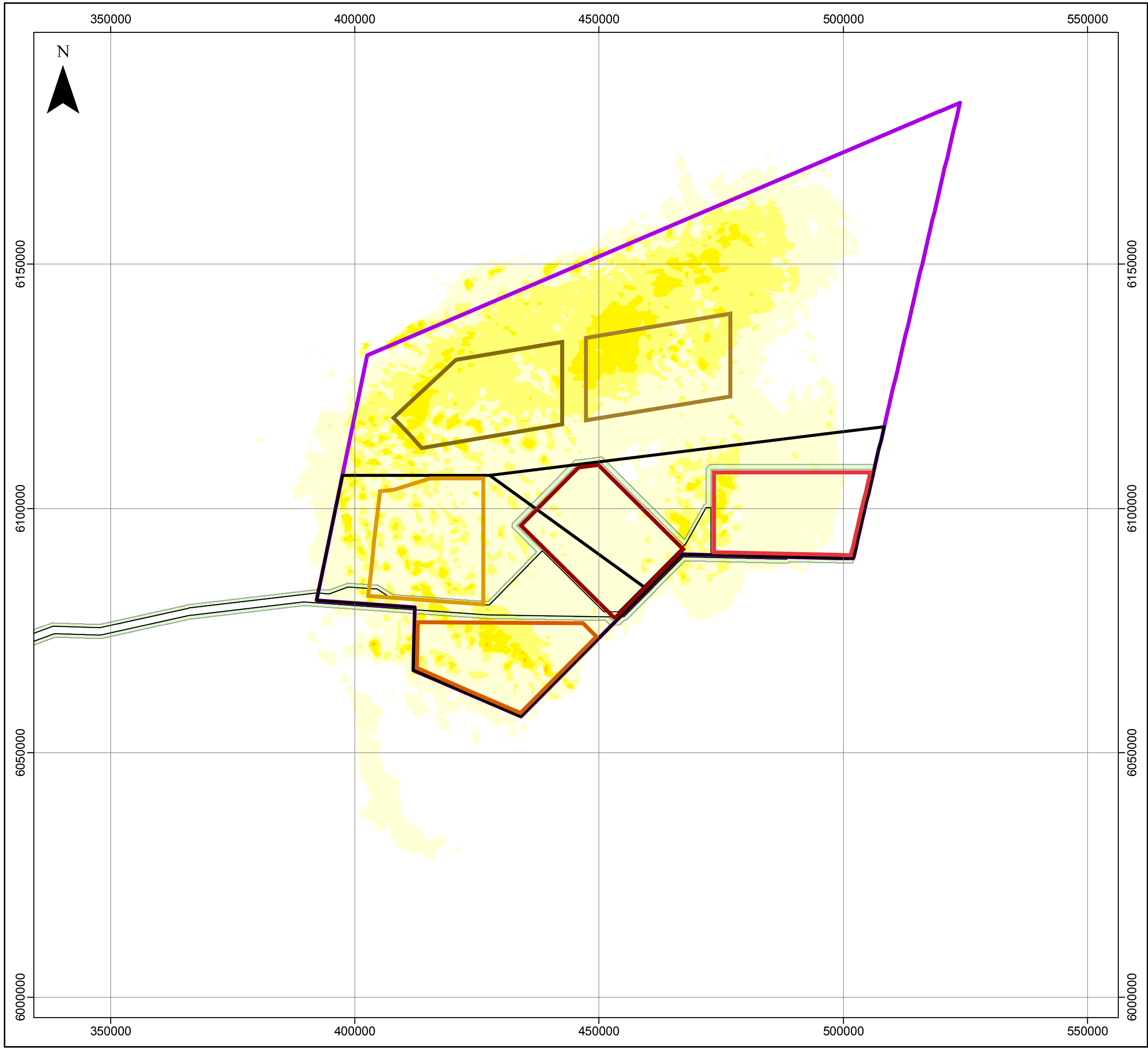
Figure 10.9 Maximum deposition predicted over the simulation period after two years of operation using the re-suspension of fractions 1 and 2 method

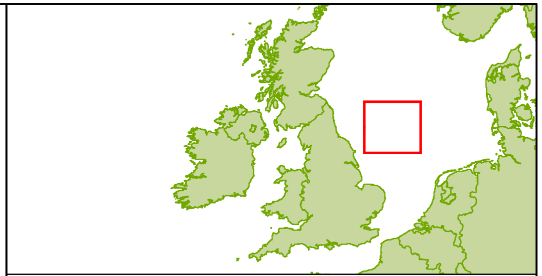
VER	DATE	REMARKS		Checked
1	08/04/2013	Draft	FK	DB
2	08/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	GC	DB

DRAWING NUMBER: **F-OFL-MA-448**

SCALE	1:1,200,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside C
- Dogger Bank Teesside D
- Dogger Bank Teesside A & B Export Cable Corridor
- Dogger Bank Teesside A & B temporary works area

Sediment thickness (m)

- Above 0.1000
- 0.0500 - 0.1000
- 0.0100 - 0.0500
- 0.0050 - 0.0100
- 0.0010 - 0.0050
- 0.0005 - 0.0010
- 0.0001 - 0.0005
- Below 0.0001

0 10 20
Kilometres

Data Source:
Modelling © Danish Hydraulic Institute, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

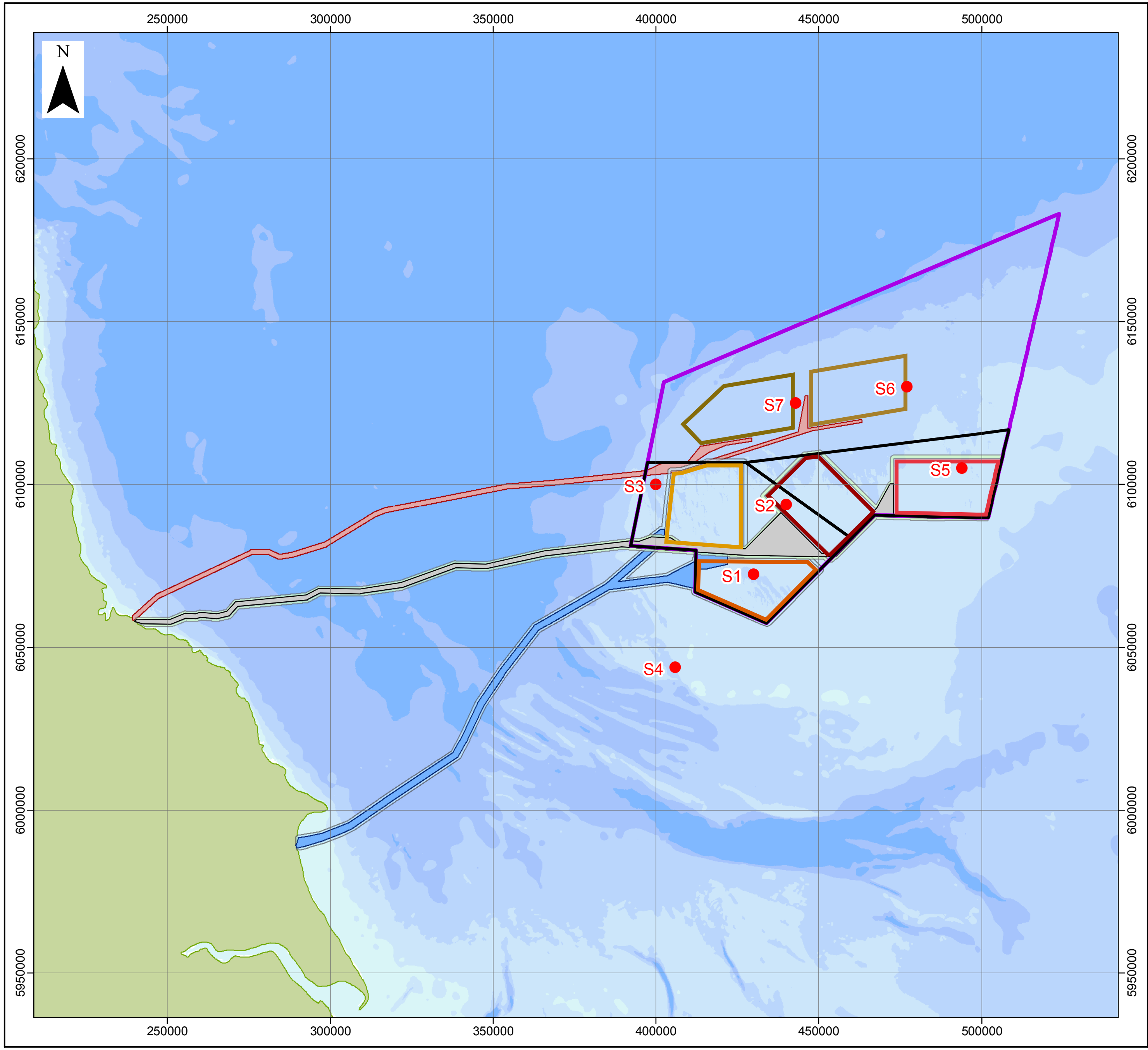
Figure 10.10 Average deposition predicted over the simulation period after two years of operation using the re-suspension of fractions 1 and 2 method

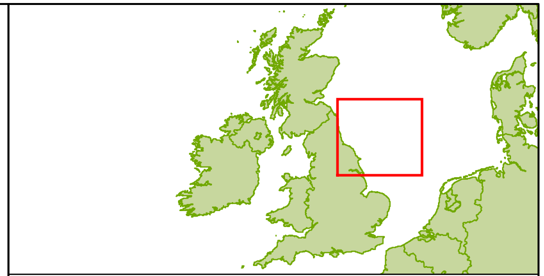
VER	DATE	REMARKS		Checked
1	08/04/2013	Draft	FK	DB
2	08/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	GC	DB

DRAWING NUMBER: **F-OFL-MA-449**

SCALE	1:1,200,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside C
- Dogger Bank Teesside D
- Dogger Bank Teesside A & B Export Cable Corridor
- Dogger Bank Teesside A & B temporary works area
- Dogger Bank Creyke Beck Export Cable Corridor
- Dogger Bank Creyke Beck temporary works area
- Dogger Bank Teesside C & D export cable corridor
- Sediment thickness time series analysis point

0 20 40
Kilometres

Data Source:
Sediment data from Danish Hydraulic Institute, 2012
Round 3 offshore wind farm boundary © Crown Copyright, 2013
Background bathymetry image derived in part from © TCarta data 2009.

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 10.11 Location of points for sediment thickness time series analysis for the cumulative operational phase

VER	DATE	REMARKS	Drawn	Checked
1	08/04/2013	Draft	FK	DB
2	07/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	GC	DB

DRAWING NUMBER: **F-OFL-MA-450**

SCALE	1:1,800,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND

10.4 Cumulative effects with Project One of Hornsea Offshore Wind Farm

10.4.1 The northern boundary of the Hornsea Round 3 Zone is located approximately 75km south of the southern boundary of the Dogger Bank Zone (**Figure 10.1**). The Hornsea Zone covers an area of 4,735km^2. With a maximum capacity of 1.2GW, Project One (407km^2), located towards the centre of the Hornsea Zone, is the first of a number of wind farm projects planned for the Hornsea Round 3 Zone to meet a target zone capacity of 4GW by the year 2020. Based on a capacity of up to 1.2GW, there will be between 150 and 332 wind turbines (depending on wind turbine type) within Project One, with wind turbine capacities ranging from 3.6MW up to 8MW.

10.4.2 Smart Wind has recently completed the Environmental Statement for Project One within the Hornsea Round 3 Zone (RPS Energy, 2013). The assessment of effects on marine physical processes at the wind farm site was carried out on the basis of the likeliest densest layout and the use of conical gravity base foundations presenting the greatest overall blockage effect. The worst case construction scenario was considered to be up to 332 foundations with a minimum spacing of 924m with up to 17,839m^3 of sediment excavated per foundation with disposal of the dredged sediment from the dredging vessel approximately 500m from the seabed preparation site.

10.4.3 The offshore cable route will extend from a proposed landfall at Horseshoe Point in Lincolnshire, offshore in a north east direction to the southern boundary of Project One. For construction of the export cable, a worst case scenario of cables up to 150km in length was considered with a burial depth below seabed of 3m, excavated using jetting.

10.4.4 For plume dispersion modelling, RPS Energy (2013) assumed that 5% of the sediment that would be excavated for seabed preparation (892 m^3) would be dispersed into the water column as fines (less than 63 microns). Four foundation locations were simulated to capture differences in tidal flows (and consequent potential differences in plume dispersion patterns) across Project One. The indicative worst case of increases in suspended sediment concentration above background levels extends for approximately 10km north of the northern boundary of the Project One area.

10.4.5 RPS Energy (2013) also concluded that the dispersion of fine sediment from seabed preparation and disposal operations will be relatively rapid (lasting for less than 24 hours) and widespread. Increases in suspended sediment concentration greater than 10mg/l above background levels were not observed outside Project One and concentrations return to background levels almost immediately after the construction is complete.

10.4.6 Scour protection is an integral part of the Hornsea project design, meaning that operational scour will effectively be zero and no plume will be available to interact with the Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck plume.

Interaction with combined Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D construction plume

10.4.7 It is considered unlikely that the construction plume of Hornsea (there will be no operational plume because of scour protection) would interact with the cumulative construction plume of Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D (foundations and cable laying) for several reasons:

- The shortest distance between the Dogger Bank and Hornsea developments is approximately 65km and construction plumes containing suspended sediment concentrations above the background are predicted to occur a maximum of 10km north of Project One; and
- There is a low probability that construction of Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck will overlap with construction of Project One of Hornsea.

Interaction with combined Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D operational plume

10.4.8 The worst case plume and deposited sediment from the plume for the combined operation of Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck are predicted to extend up to within 30km of the northern boundary of Hornsea Project One. It is unlikely that the Project One construction plume will interact with the Dogger Bank plume because the latter is created by a 50-year storm during which time it is unlikely that any construction at Project One will be possible.

10.5 Cumulative effects with Project Two of Hornsea Offshore Wind Farm

10.5.1 SMart Wind is currently undergoing the scoping phase of the Environmental Impact Assessment of Project Two within the Hornsea Round 3 Zone. To date a Scoping Report has been published (RPS Energy 2012a) which considers the potential effects of the wind farm and its associated offshore cable route and onshore infrastructure. The development is proposed with an estimated capacity of up to 1.8GW and covers an area of 400km^2 adjacent to the north and west of Project One.

10.5.2 No specific project details are currently available, but given the similar size and position relative to Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck, similar conclusions to those drawn for Hornsea Project One apply.

10.6 Cumulative effects with other UK offshore wind farms

10.6.1 Teesside Offshore Windfarm (EDF Energy) is currently being constructed with a predicted completion date of summer 2013. The wind farm is located 1.5km from the Redcar and Cleveland coast (at its closest point, **Figure 10.1**) and will comprise 27 turbines with the capacity to produce over 60MW of electricity. The turbines will be located in a 10km^2 area of seabed, within which they will be installed in three rows in water depths of up to 16m.

10.6.2 The construction of the Teesside Offshore Windfarm will be completed before construction/operation of the Dogger Bank projects. Hence, the only cumulative effects would arise from operation of the Teesside Offshore Windfarm. However, given that it is the intention to place scour protection around the turbine foundations (Entec UK Ltd. 2004), there will be no operational sediment plume from the wind farm and hence no cumulative effect with the Dogger Bank projects.

10.6.3 The National Renewable Energy Centre (Narec) proposes to develop infrastructure for a 100MW offshore wind demonstration project (Blyth Demonstration Project). The development is proposed to consist of three arrays offshore (**Figure 10.1**), each containing five turbines. The turbines would be 1km apart with over 5km spacing between each array.

10.6.4 Given the coastal location of the site, the only potential cumulative effects may be with the Dogger Bank Teesside A & B and Dogger Bank Teesside C & D export cable constructions. The Blyth Demonstration Project is 55km north of the Dogger Bank Teesside A & B Export Cable Corridor and the construction plume of the cable only extends for about 20km north (**Figure 4.1**). A similar plume can be expected from laying of the Dogger Bank Teesside C & D Export Cable which is a few kilometres closer to Teesside Offshore Windfarm, and hence it is unlikely that the construction plume of the Export Cable Corridors would overlap with either the construction or operation plumes of the limited number of turbines in the Blyth Demonstration Project, even if they were simultaneous.

10.7 Cumulative effects with German and Norwegian offshore wind farms

10.7.1 H2-20 and Nord-Ost Passat I, II and III offshore wind farms are in the German sector of the North Sea (**Figure 10.1**). The consent application for H2-20 has been submitted for a 400MW development containing 80 wind turbines. The proposed site has an area of 121km^2 and is approximately 90km east-north east of Dogger Bank Teesside A and Dogger Bank Teesside D. The Nord-Ost Passat I, II and III wind farms are adjacent to each other (**Figure 10.1**) and all are in the early planning and consent stages. The proposed Nord-Ost Passat I and II wind farms are currently planned to both have a capacity of 360MW whereas the proposed capacity of Nord-Ost Passat III wind farm is 480MW.

10.7.2 Idunn Energipark is in the Norwegian sector of the North Sea and is in the early planning stages. The proposed development is currently planned to contain 200 6MW turbines.

10.7.3 The worst case cumulative operation plume for Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck A & B is predicted to be mainly confined to UK waters (**Figure 10.6**). Given the distance of the German and Norwegian wind farms from the Dogger Bank Zone, the likelihood of interaction with the Dogger Bank projects is low.

10.8 Cumulative effects with Aggregates Area 466

10.8.1 Application Area 466 is located adjacent to the northern boundary of Dogger Bank Creyke Beck B and the western boundary of Dogger Bank Teesside C (**Figure 10.1**) and may become licensed during the lifetime of the Dogger Bank development. The aggregate area is located within the extent of the footprints of the Dogger Bank cumulative plumes generated from both construction and operation. Aggregate extraction activities at Area 466 have the potential to release further suspended sediment into the water column and to give rise to cumulative effects.

10.8.2 The Area 466 application is for the extraction of three million tonnes of aggregates over 15 years, with a maximum dredged volume of 600,000 tonnes in any one year (EMU Ltd. 2009). It is further proposed to limit the annual extraction for the first five years to a maximum of 200,000 tonnes.

10.8.3 The proposed extraction method is trailer dredging. During this operation, the drag head is trailed slowly over the seabed and a mixture of sediment and seawater is pumped up the dredge pipe and into the hold, with the excess water in the hold returned to the sea via spillways located along the sides of the dredger. The returned water would contain a proportion of suspended sediments. Screening may also be undertaken in order to increase the proportion of sand (or gravel) in the hold and results in a further return to the water column of a mix of sediment size fractions.

10.8.4 It is anticipated that, on average, one dredger will visit the site per week. The dredgers anticipated to work on Area 466 take approximately six hours to load a 7,000 tonne cargo. This equates to dredging taking place around 1% of any one year, if the estimated annual off-take of 200,000 tonnes is realised. When a maximum annual extraction of 600,000 tonnes is sought, the occupancy will potentially increase to 3% in any one year.

10.8.5 Some screening of the aggregate is expected in order to land a resource of 50% sand and 50% gravel. It is estimated that for every tonne of cargo loaded to a sand/gravel ratio of 50/50, about 0.43 tonnes of sand would be rejected as a result of screening. Therefore, for an average load of 7,000 tonnes, approximately 3,000 tonnes of predominantly fine grade sand will be returned to the seabed.

10.8.6 The Environmental Statement for aggregate Area 466 (EMU Ltd. 2009) concluded that increases in near-bed suspended sediment concentration during a spring tide are predominantly around 5mg/l (up to 2km east-south east of the dredging path and up to 1.5km to the west), rising to 15mg/l (confined to a corridor 100-250m either side of the dredge path), peaking at 30mg/l within the dredge area itself. EMU Ltd (2009) suggested that these suspended sediment concentrations are similar to those expected during storm activity and the conclusion was reached that there would be no significant changes in the suspended sediment concentration above background levels.

10.8.7 Modelled deposition rates are predicted to be in the order of 1-2mm per tide within 100m of the dredge track and 0.5mm per tide away from the dredge track during spring tides. Deposition during neap tides was predicted as 5mm per tide along the dredge path and <0.5 mm per tide away from the dredger.

Interaction of Area 466 with combined Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D construction plume

10.8.8 In terms of potential cumulative effects resulting from the interaction of the Area 466 plume with the construction plumes of Dogger Bank Teesside A & B, Dogger Bank Creyke Beck, and Dogger Bank Teesside C & D (foundations and cable laying), the greatest effect will occur when:

- Construction activities are taking place simultaneously along the north western part of Dogger Bank Teesside B, the northern part of Dogger Bank Creyke Beck B and the western part of Dogger Bank Teesside C, which are closest to Area 466; and
- The construction activities in these Dogger Bank projects and dredging in Area 466 are coincident.

10.8.9 The predicted worst case dispersion for a set of 24 foundations in the north west corner of Dogger Bank Teesside B and laying of the export cable shows that the plume and deposition of sediment from it, over a 30-day simulation period, have the potential to spread north west over Area 466 (**Figures 6.1** and **6.4**). A similar sized plume for Dogger Bank Teesside C & D foundations and cable would be expected. The predicted plume from the northern part of Dogger Bank Creyke Beck B would also migrate over Area 466 (Forewind 2013) (Dogger Bank Creyke Beck Environmental Statement). If the dredging activity in Area 466 is synchronous with the construction activity in the Dogger Bank projects (foundations and cable laying) there is a possibility there will be interactions.

10.8.10 EMU Ltd. (2009) showed that for Area 466, suspended sediment concentrations above 5mg/l are confined to the relatively small dredge path and dredge area. For the majority of the dispersed plume, the concentrations are less than 5mg/l. If interaction with the Dogger Bank cumulative construction plumes were to occur, the result will be:

- Short-term; given a dredger will only visit Area 466 once a week;
- Localised; given the limited extent of relatively high (greater than 5mg/l) suspended sediment concentration values for Area 466; and
- Small; given that the predominant suspended sediment concentration in the Area 466 plume is 5mg/l or less.

10.8.11 In addition, analysis of time series of sediment deposition from the Dogger Bank Teesside A & B worst case construction plumes in the vicinity of Area 466 shows that sediment thickness at any time is predominantly less than 1mm (**Table 6.1**). Occasionally, sediment is thicker than 1mm and can be continuously greater than 1mm for a maximum period of 6 hours (0.25 days). For Dogger Bank Creyke Beck construction sediment is continuously greater than 1mm for only 42 hours (1.75 days) (Forewind, 2013). Hence, deposition out of the Dogger Bank cumulative construction plume would have little persistent effect on the characteristics of the seabed sediment in Area 466.

Interaction of Area 466 with combined Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D operational plume

10.8.12 The plume from aggregate extraction in Area 466 would be very small in comparison to the cumulative operation plume from Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck A & B. Hence, inclusion of the short-lived Area 466 plume within the cumulative operational plume of Dogger Bank will have little effect on its overall size and it would be essentially unchanged in terms of suspended sediment concentration and distribution. Also, time series of deposition from the Dogger Bank operation plume immediately south of Area 466 shows that maximum sediment thickness at any time is less than 0.1mm for a 50-year storm after two years of operation (**Table 7.2**). This means that deposition out of the Dogger Bank cumulative operation plume would have little effect on the characteristics of the seabed sediment in Area 466.

10.9 Cumulative effects with Aggregates Area 485

10.9.1 There is also an application for a licence for Area 485 located approximately 30km to the south of Dogger Bank Teesside A & B Export Cable Corridor (about 20km south of the Dogger Bank Creyke Beck Export Cable Corridor). Area 485 covers approximately 14.5km^2 and is separated into two distinct sub areas (**Figure 10.1**) with a proposal to remove up to one million tonnes per year of aggregate over an (initial) licence period of 15 years, with the maximum total extraction over the licence period being 7.5 million tonnes. If Area 485 is licensed during the lifetime of Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck, the aggregate extraction activities have the potential to release further suspended sediment into the water column and to give rise to cumulative effects.

10.9.2 EMU Ltd (2007) indicated that the seabed sediment at Area 485 is heterogeneous with gravels interspersed with high quantities of sand. The gravel content within Area 485 has been estimated at 35%. The extraction process will remove a mixture of gravels and sand from the seabed together with a high volume of water (the solids content is approximately 25% by volume). As the hopper in the dredging vessel loads, the excess water (together with a proportion of the finer sediment) returns overboard via spillways creating a turbid plume of water. EMU Ltd (2007) presented the results of plume modelling studies that simulated the proposed dredging operations in both sub-areas of Area 485.

10.9.3 For dredging in the western sub-area, the increases in suspended sediment concentration above background were predicted to be less than 75mg/l and 100mg/l outside and inside the sub-area, respectively (EMU Ltd 2007). Close to and within the streamline of the dredger the increases may be higher as suspended sediment concentrations are not uniformly mixed through the water column. Suspended sediment concentration decreases with distance away from a dredger. The plume was predicted to disperse up to 5km north-north west and up to 3km south-south east of the sub-area. At these distances the predicted increases in suspended sediment concentration were approximately 10mg/l or less.

10.9.4 For dredging in the eastern sub-area, the depth-averaged increases in suspended sediment concentration were predicted to be less than 50mg/l both outside and inside the sub-area (EMU Ltd 2007). However, outside the immediate dredge track, increases in suspended sediment concentration are unlikely to exceed 25mg/l. Within the sub-area increases in suspended sediment concentration are up to 75mg/l above background. The plume was predicted to disperse up to 5km north-north west and up to 4.5km south-south east of the sub-area. At these distances the predicted increases in suspended sediment concentration are approximately 10mg/l or less. The footprint of deposition was predicted to extend up to 2km north of the eastern sub-area.

10.9.5 EMU Ltd (2007) concluded that increases above background suspended sediment concentration would be temporary, brief in duration and highly tide dependant. Predicted mean increases above background levels were 1-2mg/l and time series analysis showed that increases of more than 5mg/l occur for up to 10% of time outside the dredge area and up to 18% of time within the dredge area. The predicted mean increases in suspended sediment are within the natural range of conditions likely to be experienced at the proposed dredging area.

Interaction of Area 485 with combined Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D construction plume

10.9.6 The extent of the plume away from Area 485 towards Dogger Bank (up to 4km), and the distance of Area 485 from the Dogger Bank projects (25km) means that the cumulative construction plume of Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck could potentially overlap with the dredging plume of Area 485. The extent of overlap will depend on the relative timing of the respective activities and the extent and concentrations within the overlapping plumes.

10.9.7 EMU Ltd (2007) showed that for Area 485, suspended sediment concentrations above 5mg/l would only be present for up to 10% of the time outside the dredge area. If interaction with the Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck plume were to occur, the result will be short term, localised and small, given the limited extent and duration of high suspended sediment concentrations from aggregate dredging at Area 485.

Interaction of Area 485 with combined Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D operational plume

10.9.8 The suspended sediment concentration within and the extent of the cumulative operation plume from Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck would be large in comparison to the plume from aggregate extraction in Area 485. Hence, inclusion of the short-lived and localised plume from Area 485 within the Dogger Bank operational plume will have little effect on its overall size and will be essentially unchanged in terms of suspended sediment concentration and distribution.

10.10 Cumulative effects with Potash Mining Outfall Dredge Disposal

10.10.1 Cleveland Potash Ltd operates a potash mine and refining plant on the North Sea coast south of the Tees Estuary and has an effluent line which discharges clay, salt and brine into the nearshore area. The discharge point consists of two outfalls which are approximately 62m apart located about 1.5km offshore (**Figure 7.1**).

10.10.2 An Environmental Permit has been obtained to dredge sediment from close to the two outfall pipes and to dispose of the sediment nearby (**Figure 7.1**). The outfalls and dredge disposal area are located approximately 3.8km and 3km southeast of the Dogger Bank Teesside A & B Export Cable Corridor, respectively. Two dredging periods per year take place, one in spring and one in autumn. The license for dredge disposal runs from September 2012 to November 2015 and approximately 100,000 tonnes of silt per year is expected to be extracted.

10.10.3 Dredging takes place using a suction hopper dredging vessel with a volume of 1500m^3 and a load rate of 1200 m^3/hour. The sediment is discharged into the water column at the disposal site. Modelling of the disposal has shown that the plume would disperse naturally at the point of disposal and would not impact on the nearby coastal area.

10.10.4 Potential cumulative effects resulting from the interaction of the dredge disposal plume with the construction plume of the Dogger Bank Teesside A & B Export Cable would occur when the activities are coincident. The plume from dredge disposal would only interact with the plume created at the landward end of the Dogger Bank Teesside A & B Export Cable Corridor. Given that suspended sediment concentrations along the export cable are only elevated for a short period of time before dispersing to background levels, and the timings of the two operations are unlikely to overlap, the potential for interaction is very low.

10.10.5 Maximum suspended sediment concentrations as a result of the Dogger Bank Teesside A & B Export Cable construction could locally exceed 200mg/l close to the coast in the vicinity of the potash outfalls (**Figure 6.1**). However, this high concentration only translates into deposition on the seabed of less than 5mm (**Figure 6.4**). This is because the exceedance time for concentrations greater than 2mg/l in this area is less than 10% of the simulation period (i.e. less than three days) (**Figure 6.3**). So, the construction plume of the Dogger Bank Teesside A & B Export Cable Corridor will have no effect on the dredging requirements of the potash outfalls.

11 Transboundary Effects

11.1.1 This chapter has considered the potential for transboundary effects (effects across international boundaries) to occur on marine physical processes as a result of the construction, operation or decommissioning of Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D.

11.1.2 A summary of the likely transboundary effects of Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D is provided in **Chapter 32 Transboundary Effects**.

11.1.3 The eastern boundary of the Dogger Bank Zone is marked by the international boundary with Dutch and German waters. The eastern boundary of Dogger Bank Teesside A is located on the international boundary with the Netherlands.

11.1.4 Cumulative changes to wave and tidal current regimes were modelled using layouts of foundations across each of the six projects. The effects on tidal currents using these layouts do cross over the international boundary into Dutch waters (**Figures 10.2** and **10.3**). The effects on waves enter all adjacent international waters (**Figure 10.4**). However, the results show that predicted changes to waves would be of small magnitude in international waters (**Figure 10.5**) with limited secondary effects on sediment transport or seabed morphology.

11.1.5 Cumulative sediment plumes predicted for operation of Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck only disperse up to about 15km into Dutch waters and do not cross into German, Danish or Norwegian waters. Scour of the seabed is limited to the immediate vicinity of the Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck wind farm foundations.

12 Summary

12.1 Baseline physical processes

12.1.1 This chapter of the ES has provided a characterisation of the existing marine physical processes based on both existing and site specific survey data, which has established the following:

- Water depths range from approximately 20m to 78m below LAT within the Dogger Bank Zone, with 25-35m common in Tranche B. Water depths vary along the Dogger Bank Teesside A & B Export Cable Corridor from just above LAT near the coast to 80m at the deepest point. The predominant seabed sediment type across tranches A and B is sand with smaller patches of gravel and areas where the underlying geology is exposed at the seabed. The seabed along the Dogger Bank Teesside A & B Export Cable Corridor is covered mainly by sand;
- Only small proportions of mud in the surface sediments (less than 5%) indicate that the availability of sediment that can be suspended into the water column from the bed is limited. This is supported by regional data suggesting that suspended sediment concentrations across Dogger Bank and along the Dogger Bank Teesside A & B Export Cable Corridor are very low (less than 2mg/l);
- Tidal currents flowing across Dogger Bank are mainly directed north to south and south to north with mean velocities reaching a maximum of 0.40m/s. In places, these relatively weak currents have moulded the surface sediments into sand waves and megaripples. The geometry of these bedforms indicates that they have limited migration leading to the overall conclusion that sediment transport across tranches A and B is small. Measured waves in Tranche A have a mean significant wave height (the average of the highest one third of waves) of 1.7m with a maximum value of 6m; and
- Tidal currents flowing across the Dogger Bank Teesside A & B Export Cable Corridor vary from 0.4m/s at the offshore end to 0.20-0.60m/s off the coast at Redcar. There is limited development of sand waves and megaripples along the Dogger Bank Teesside A & B Export Cable Corridor. Where they are present, their crests are oriented north east-south west and their geometry indicates migration and hence sediment transport to the south east. Waves at the offshore end of the corridor have a mean significant wave height of 1.75-2.0m decreasing to less than 1.0m towards the landfall site.

12.2 Assessment of effects

12.2.1 In order to assess the potential effects of the wind farm (including all associated infrastructure), the export cables and the landfall site, relative to baseline (existing) conditions, a combination of detailed numerical modelling, expert geomorphological assessment and empirical evaluation has been used. These effects have been assessed using the worst case characteristics of the proposed development as provided by the project and presented, in part, in **Chapter 5**. Considerations of the proposed effects upon the wave, tidal current and sediment transport regimes have been made for the construction, operation and decommissioning phases of the development (**Table 12.1**).

12.2.2 Over the period of construction there is the likelihood for discrete short-term disturbances of the offshore seabed as the wind turbine foundations are installed and the export, inter-platform and inter-array cables are laid sequentially across the development site. Seabed sediments have the potential to be released into the water column resulting in the formation of sediment plumes. At the landfall site construction activities may result in short-term changes to the sediment budget as infrastructure causes temporary blockages to alongshore sediment transport. The decommissioning phase is generally considered to have a similar or lesser effect than the construction phase.

12.2.3 In this assessment, the effect on sediment transport of foundation and cable installation was modelled together over a 30-day installation period that included a one-year storm. A worst case total of 24 foundations were assumed to be installed sequentially at the same time as the laying of a single export cable and 20 inter-array cables. The foundations that were tested were located close to sensitive sandeel habitat.

12.2.4 For the worst case sediment plume (12m drilled monopoles), maximum suspended sediment concentration at any time throughout the 30-day simulation period was predicted to be elevated above natural background levels (2mg/l) by two orders of magnitude (greater than 200mg/l) within the 24-foundation layout and along the export cable route within the Dogger Bank Zone and between approximately 1km and 11km either side of the route. The maximum concentration reduces to background levels up to 40km to the north and up to 40km south of the export cable route within the Dogger Bank Zone. The highest average suspended sediment concentration is predicted to be 50-100mg/l within the confines of the 24 foundations and up to approximately 20km along the export cable route within the Dogger Bank Zone.

12.2.5 Maximum sediment deposition from the plume throughout the 30-day simulation period was predicted to be 10-50mm within a small part of the foundation layout reducing to less than 0.5mm up to a maximum of 35km away from the export cable route within the Dogger Bank Zone. Average deposition of 1-5mm occurs within and 10km to the north of the foundations, and in small patches along the Dogger Bank Teesside A & B Export Cable Corridor. Predicted average deposition decreases to less than 0.5mm along the remainder Dogger Bank Teesside A & B Export Cable Corridor, and is effectively zero in places.

12.2.6 Time series of deposition from the plume at several discrete points show that within the foundation layout, deposited sediment was predicted to persist at thicknesses greater than 1mm for a continuous period of up to 174 hours (7.25 days) at any time throughout the 30 days. Thicknesses of greater than 10mm could persist for a maximum continuous period of 32 hours (1.33 days). To the west of the layout (in the vicinity of the sand eel habitat), deposition at any one time throughout the 30-day simulation period rarely exceeds 1mm. The predicted deposition from the plume at the end of the 30-day simulation was less than 0.1mm across the whole of the footprint.

12.2.7 The excavation of the export cable could potentially create maximum suspended sediment concentrations of 100-200mg/l near the coast and about 50km offshore, although the predicted concentrations elsewhere along the cable are generally less than 100mg/l. Maximum concentrations reduce to the background of 2mg/l, up to 50km either side of the corridor. Maximum deposition from the plume along the export cable is predicted not to exceed 0.5mm.

12.2.8 At the coastal landfall site, physical processes have the potential to be affected by the temporary construction of infrastructure. The worst case scenario is considered to be construction, over a continuous period of 14 weeks, of two 15m-long cofferdams across the intertidal (beach) area. These structures offer partial barriers to alongshore sediment transport. The results of expert geomorphological assessment showed that potential alongshore sediment transport rates at Marske-by-the-Sea are low and directed to the south east. Although the coastline to the south east may be affected by cofferdam construction, the change is likely to be low magnitude and temporary. The presence of the cofferdams will not have an effect on natural coastal erosion rates given the short-term nature of the construction programme.

12.2.9 The greatest potential for changes to the wave and tidal current regimes occurs during the operational stage of the wind farm. In this assessment, the effect of operation on these processes was modelled using layouts of foundations across Dogger Bank Teesside A & B. The worst case scenario was determined to be arrays of foundations spaced 750m apart around their perimeters with a wider internal spacing including platforms, meteorological masts and vessel moorings. No potential effects are considered for the inter-array cables and most of the length of the export cables because, during operation, they will be buried. However, there is the possibility that in the nearshore subtidal zone the export cables will be on the surface and covered by remedial protection), which could potentially create a partial barrier to sediment transport.

12.2.10 The results show predicted changes to both waves and tidal currents would be relatively small. Predicted maximum changes (worst case) in significant wave height were for one-year waves from the north and north east. Significant wave heights change by up to +/-0.04m at the southern, south western, northern and north eastern boundaries of the projects. The predicted pattern is a maximum increase in wave height of 1% along the southern and south western boundaries of Dogger Bank Teesside B. The maximum change to depth-averaged current velocity is predicted to be +/-0.008m/s with the greatest effect occurring at the boundaries of the projects. The maximum change in current velocity is less than 2% along the boundaries of Dogger Bank Teesside A & B. The predicted changes in wave heights and tidal current velocities are so small that they would not translate into changes to regional sediment transport pathways and morphology.

12.2.11 Over the period of operation, there is the potential for creation of sediment plumes caused by seabed scour around non-scour protected wind turbine foundations after they have been installed. In this assessment, the effect of scour on sediment transport was modelled using the same layouts across Dogger Bank Teesside A & B that were used for wave and tidal current modelling. The worst case for plume dispersion would occur when all the foundations are operational and subject to a 30-day simulation including a larger 50-year storm.

12.2.12 The maximum concentration was predicted to increase to greater than 200mg/l in patches along the northern and southern boundaries of Dogger Bank Teesside A and the south western boundary of Dogger Bank Teesside B. Across the whole of both projects, maximum suspended sediment concentrations were greater than 20mg/l reducing to background levels up to approximately 54km from the projects southern boundaries. The highest average concentrations were 10-50mg/l within the projects and up to 19km to their south.

12.2.13 Maximum deposition of 5mm occurs, but more generally across each project, maximum deposition was 0.5-5mm. Thicknesses reduce to below 0.1mm up to a maximum of 35km from the project boundaries. Average deposition is predicted to be 0.5-5mm between the projects. Average deposition reduces to less than 0.1mm approximately 23km south west of Dogger Bank Teesside B and 19km north of Dogger Bank Teesside A.

12.2.14 Time series of deposition from the plume at several points show that the thickness may exceed 1mm continuously for up to 72 hours (3.00 days) and never exceeds 3mm. The predicted deposition from the plume at the end of the 30-day simulation period was less than 0.1mm across all of the depositional area.

12.2.15 A comparison of operational scour volumes with naturally occurring release of sediment during a 50-year storm shows that predicted scour volumes are about a sixth of the volume that would be suspended during a 50-year storm without the foundations in place.

12.2.16 In the nearshore, remedial protection is anticipated to be up to about 15m wide and stand 1.5m above the surrounding seabed and could potentially affect longshore sediment transport processes in the active transport zone (about 2km wide offshore from mean low water spring along the cable route). Longshore sediment transport rates are low and although some sediment would be trapped on the ‘updrift’ side of the remedial protection, it is anticipated to be a small volume. Therefore, the magnitude of changes ‘downdrift’ of the cable corridor due to the remedial protection is likely to be small.

12.2.17 The cumulative effect of operation of Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck on tidal currents, waves and/or sediment transport have been assessed. The worst case scenario was determined to be arrays of foundations spaced 750m apart around their perimeters with a wider internal spacing including platforms, meteorological masts and vessel moorings.

12.2.18 The results show predicted cumulative changes to both waves and tidal currents would be relatively small. Significant wave heights change by up to +/-0.06m at the southern, south western, northern and north eastern boundaries of the projects. The predicted pattern is a maximum increase in wave height of 1.5% along the southern and south western boundaries of Dogger Bank Creyke Beck A. Along the northern and north eastern boundaries, predicted changes are mainly up to 1%. The maximum change to depth-averaged current velocity is predicted to be +/-0.01m/s with the greatest effect along the western boundaries of Dogger Bank Creyke Beck B and Dogger Bank Teesside D. The maximum change in current velocity is approximately 3% along the western boundaries of Dogger Bank Creyke Beck B and Dogger Bank Teesside D. These percentage changes are within the natural variation of wave height and tidal current velocity across Dogger Bank and surrounding sea areas and are unlikely to affect the form of recent sediments over and above the natural processes.

12.2.19 The maximum cumulative suspended sediment concentration was predicted to be greater than 200mg/l along the boundaries of the projects (apart from the boundary of Dogger Bank Teesside C). Across all projects, maximum suspended sediment concentrations were greater than 50mg/l reducing to background levels up to approximately 55km from the projects southern boundaries. The highest average concentrations were 50-100mg/l across the boundaries of Dogger Bank Creyke Beck A & B.

12.2.20 Maximum deposition of 5mm occurs reducing to 0.1mm up to a maximum of 43km from the project boundaries. Average deposition is predicted to be 0.1-0.5mm and is generally higher across Dogger Bank Teesside C & D than across the other projects.

12.2.21 Time series of deposition from the plume at several points show that the thickness may exceed 3mm continuously for up to 244 hours (10.17 days) at isolated points. In general, thicknesses rarely exceed 2mm and persist at greater than 1mm between 2 hours (0.08 days) and 80 hours (3.33 days). The predicted deposition from the plume at the end of the 30-day simulation period was less than 0.1mm across most of the depositional area.

12.2.22 Cumulative effects with other offshore wind farms, aggregate license areas and potash mining dredge disposal have been considered with respect to sediment plume interaction. It is unlikely that the construction plumes of other wind farms will interact with the Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D plumes. Plumes from aggregate dredging areas and potash mining dredge disposal would be small and short-lived in comparison and no cumulative effects are anticipated.

Table 12.1 Summary of predicted effects of Dogger Bank Teesside A & B on marine physical processes

Effect	Metric	Value	Key distance
Construction			
Increased suspended sediment concentrations	Maximum suspended sediment concentration	>200mg/l	Up to 11km from source of sediment plume
		2mg/l (baseline)	Up to 40km from source of sediment plume
	Average suspended sediment concentration	50-100mg/l	Up to 9km from source of sediment plume
		2mg/l (baseline)	Up to 32km from source of sediment plume
Sediment deposition from plume	Maximum deposition	10-50mm	Within worst case foundation layout
		<0.5mm	Up to 35km from source of sediment plume
	Average deposition	1-5mm	Up to 10km from source of sediment plume
		0.5mm	Up to 30km from source of sediment plume
Operation			
Changes to waves	Wave Height	+/-0.04m	At the boundaries of the projects
Changes to tidal currents	Current Velocity	+/-0.008m/s	At the boundaries of the projects
Increased suspended sediment concentrations	Maximum suspended sediment concentration	>200mg/l	At the boundaries of the projects
		2mg/l (baseline)	Up to 54km from source of sediment plume (measured from project boundary)
	Average suspended sediment concentration	10-50mg/l	Up to 19km from source of sediment plume (measured from project boundary)
		2mg/l (baseline)	Up to 36km from source of sediment plume (measured from project boundary)
Sediment deposition from plume	Maximum deposition	0.5-5mm	Within the boundaries of the projects
		0.1mm	Up to 35km from source of sediment plume (measured from project boundary)
	Average deposition	0.5-5mm	Between the projects
		0.1mm	Up to 23km from source of sediment plume (measured from project boundary)

13 References

Babtie. 1997. *Redcar Beach Study*. Report to Redcar & Cleveland Borough Council, August 1997.

Babtie. 1999. *Seaham Harbour to Saltburn Shoreline Management Plan*. Report to Easington District Council, Hartlepool Borough Council and Redcar & Cleveland Borough Council, March 1999.

BERR (Department for Business, Enterprise and Regulatory Reform). 2008. *Atlas of UK Marine Renewable Energy Resources: Atlas Pages*. A Strategic Environmental Assessment Report, March 2008, 19pp.

British Geological Survey. 1998. *Guisborough. Sheet 34. Solid and Drift Geology*.

Cameron, T.D.J., Crosby, A., Balson, P.S., Jeffrey, D.H., Lott, G.K., Bulat, J. and Harrison, D.J. 1992. *United Kingdom offshore regional report: the geology of the southern North Sea*. HMSO, London, 152pp.

Cefas. 2004. *Guidance Note for Environmental Impact Assessment in Respect of FEPA and CPA Requirements*. Report to the Marine Consents and Environment Unit (MCEU), June 2004.

Cooper, N.J., Rowe, S., Parsons, A. and Cooper, T. 2009. *Cell 1 Regional Coastal Monitoring Programme*. Proceedings of the Flood and Erosion Risk Management Conference, Telford.

DECC (Department of Energy and Climate Change). 2011a. *Overarching National Policy Statement for Energy* (EN-1), July 2011.

DECC (Department of Energy and Climate Change). 2011b. *National Policy Statement for Renewable Energy Infrastructure* (EN-3), July 2011.

Eisma, D. 1981. Supply and deposition of suspended matter in the North Sea. In Holocene Marine Sedimentation in the North Sea Basin (ed. Nio, S.-D. *et al*). *Special Publication of the International Association of Sedimentologists*, 5, 415-428.

Eisma, D. and Kalf, J. 1987. Dispersal, concentration and deposition of suspended matter in the North Sea. *Journal of the Geological Society of London*, 144, 161-178.

EMU Ltd. 2007. *Area 485 Aggregate Extraction Licence Application Environmental Statement*. Report to CEMEX, March 2007.

EMU Ltd. 2009. *Area 466 Aggregate Extraction Licence Application Environmental Statement*. Report to CEMEX, June 2009.

EMU Ltd. 2010. *Dogger Bank Zonal Characterisation Interim Report*. Report to Forewind Ltd, October 2010.

Entec UK Ltd. 2004. *Teesside Offshore Wind Farm Environmental Statement*. Report to EDF Energy (Northern Offshore Wind) Ltd, March 2004.

Forewind. 2013. *Dogger Bank Creyke Beck Final Environmental Statement*. Chapter 9 Marine Physical Processes.

Fugro. 2011. *Geotechnical Report, Laboratory and In-situ Data: Dogger Bank Wind Farm Site Investigation UKCS, North Sea*. Report to Forewind.

Fugro. 2012. *Geotechnical Report, Site Investigation Data: Dogger Bank – Tranche B Borehole Sampling Campaign 2012 UKCS, North Sea*. Report to Forewind, September 2012.

Gardline 2011a. *Dogger Bank Zone Wide Acoustic and Geophysical Survey May to August 2010*. Survey Report to Forewind, January 2011.

Gardline, 2011b. *Dogger Bank Tranche A and Associated Export Route Benthic Survey, May-Aug 2011*. Environmental Field Report to Forewind, August 2011.

Gardline. 2011c. *Real-Time Wave and Current Monitoring, Dogger Bank, Southern North Sea*. 23rd September 2010 – On Going Project. Annual Report to Forewind, November 2011.

Gardline. 2012. *Dogger Bank Tranche B Benthic Survey 2012. UKCS 38/27*. Field Survey Report to Forewind, July 2012.

Gardline. 2013a. *Dogger Bank Geophysical Survey Tranche B Project Areas 1A, 1B, 2A and 2B*. June 2011 to May 2012. Results Report to Forewind, March 2013.

Gardline, 2013b. *Dogger Bank Geophysical Survey of Teesside Export Cable Corridor*, May-July 2012. Report to Forewind, February 2013.

GEMS. 2011. *Geophysics Results Report*. Volume 4 of 9. Dogger Bank Tranche A Acoustic and Geophysical Survey. Report (Revision: 01) to Forewind, September 2011, 73pp.

GEO (Danish Geotechnical Institute). 2012. Geotechnical Investigations: Field Report – Tranche B and A, Seabed CPTUs. Geo project no 35685 Report 1 to Forewind, July 2012, 556pp.

Houston, J. R. 1995. Beach-fill volume required to produce specified dry beach width. Coastal Engineering Technical Note 11-32, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

IPCC (Intergovernmental Panel on Climate Change). 2007. *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Core Writing Team, Pachauri, R. K., & Reisinger, A., (eds.)). IPCC, Geneva, Switzerland, 104pp.

Lambkin, D.O., Harris, J.M., Cooper, W.S. and Coates, T. 2009. *Coastal process modelling for offshore wind farm environmental impact assessment: best practice guide*. COWRIE COAST-07-08, September 2009.

Mathiesen, M. and Nygaard, E. 2010. *Dogger Bank Wind Power Sites Metocean Design Basis*. Statoil Report PTM MMG MGE RA 63, Rev no 1, June 2010, 129pp.

Mathiesen, M., Nygaard, E. and Andersen, O.J. 2011. *Dogger Bank Wind Power Sites Metocean Design Basis*. Statoil Report PTM MMG MGE RA 63, Rev no 3, October, 2011, 129pp.

OMM. 2013. *Teesside A & B Export Cable Corridors Route Assessment*. Technical Note to Forewind.

Royal Haskoning. 2007. *River Tyne to Flamborough Head Shoreline Management Plan 2*. Report to North East Coastal Authorities Group (NECAG), February 2007.

RPS Energy. 2012a. *Hornsea Project Two Environmental Impact Assessment scoping Report*. Report to SMart Wind, October 2012.

RPS Energy. 2012b. Dogger Bank Drilling Arisings Study – Teesside A and B. Technical Note to Forewind, November 2012.

RPS Energy. 2013. *Hornsea Offshore Wind Farm Project One Environmental Statement*. Draft Report to SMart Wind, 2013.

Stanev, E.V., Dobrynin, M., Pleskachevsky, A., Grayek, S. and Gunther, H. 2008. Bed shear stress in the southern North Sea as an important driver for suspended sediment dynamics. *Ocean Dynamics*, 59, 183-194.

Stoker, M.S., Balson, P.S., Long, D. and Tappin, D.R. 2011. *An overview of the lithostratigraphical framework for the Quaternary deposits on the United Kingdom continental shelf*. British Geological Survey Research Report RR/11/03, 40pp.

UKCIP (UK Climate Impacts Programme). 2009. *UK Climate Projections Science Report: Marine and Coastal Projections*. Met Office Hadley Centre, Exeter, UK.

Woodworth, P.L., Le Provost, C., Rickards, L.J., Mitchum, G.T. and Merrifield, M. 2002. *A review of sea-level research from tide gauges during the World Ocean Circulation Experiment*. In. Gibson, R.N., Barnes M. and Atkinson R.J.A. Eds. Oceanography and Marine Biology: an Annual Review. London: Taylor & Francis, 40pp.

