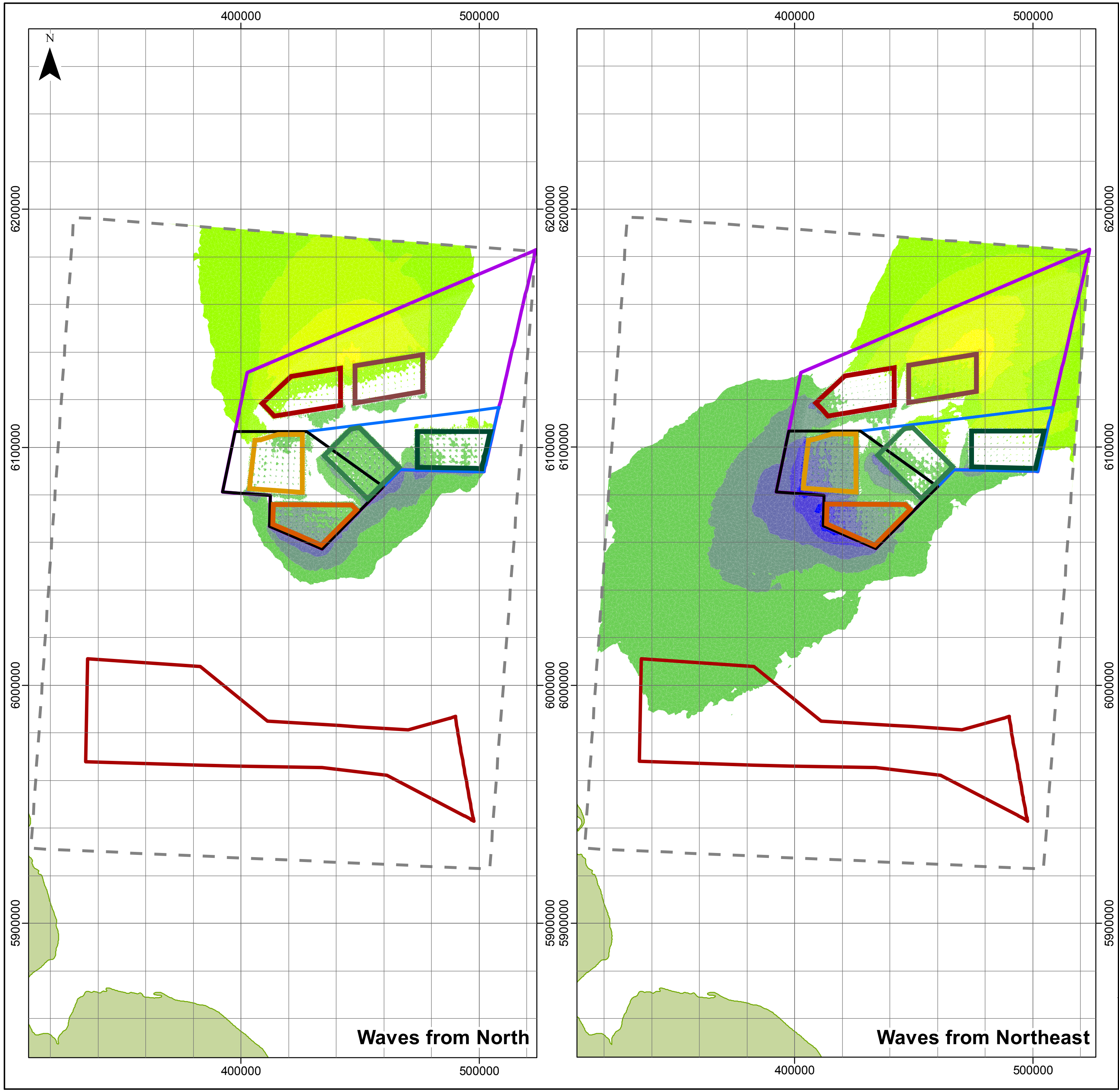
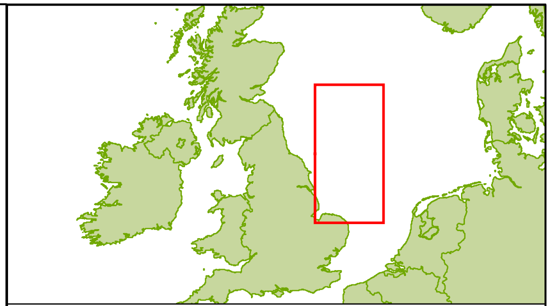




LEGEND

Change in Significant Wave Height (m)

- Above 0.09
- 0.08 - 0.09
- 0.07 - 0.08
- 0.06 - 0.07
- 0.05 - 0.06
- 0.04 - 0.05
- 0.03 - 0.04
- 0.02 - 0.03
- 0.01 - 0.02
- 0.00 - 0.01
- -0.01 - 0.00
- -0.02 - -0.01
- -0.03 - -0.02
- -0.04 - -0.03
- -0.05 - -0.04
- -0.06 - -0.05
- -0.07 - -0.06
- -0.08 - -0.07
- -0.09 - -0.08
- Below -0.09

- Dogger Bank Zone
- 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
- Tranche A Boundary
- Tranche B Boundary
- Hornsea Offshore Wind Farm
- Model Boundary

0 50
Kilometres

Data Source:
© UKDeal
Round 3 © TCE, 2013.

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

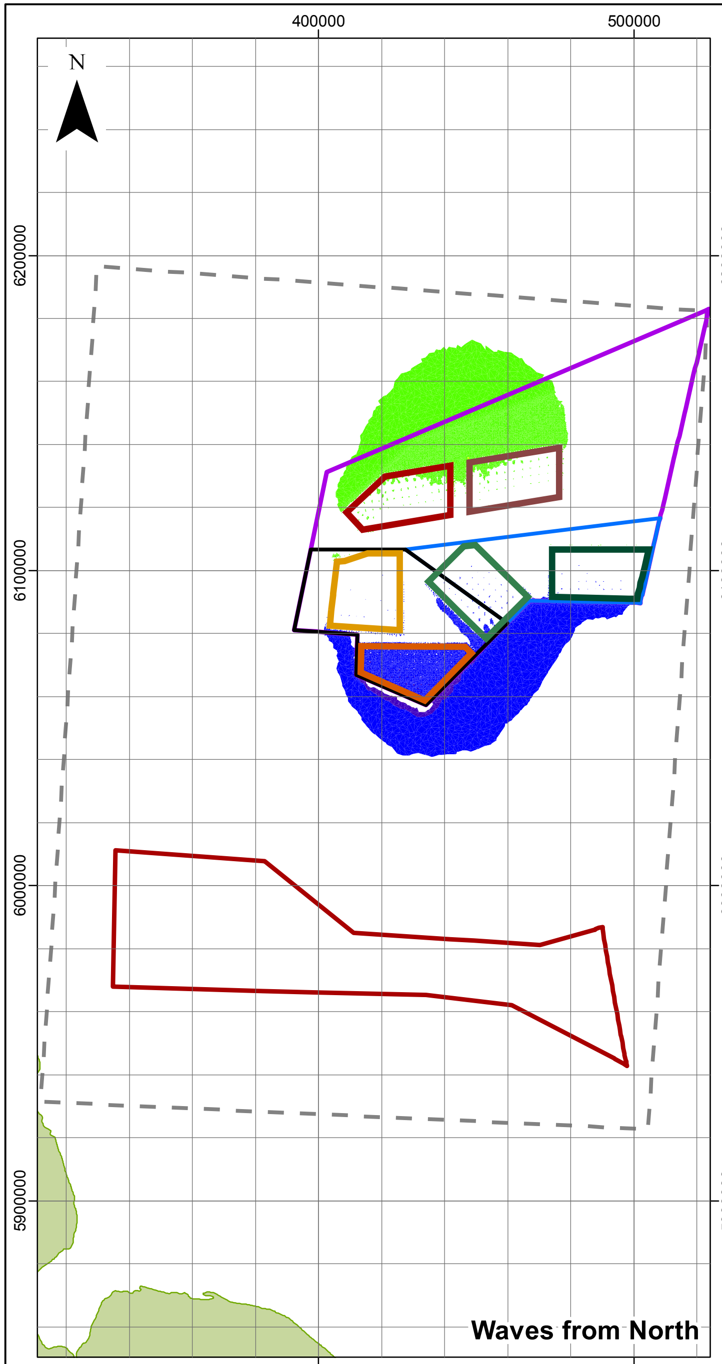
Figure 7.6 Cumulative Changes to Significant Wave Height for 50-year Waves from the North and Northeast Caused by 6MW Conical GBS#1 Foundations

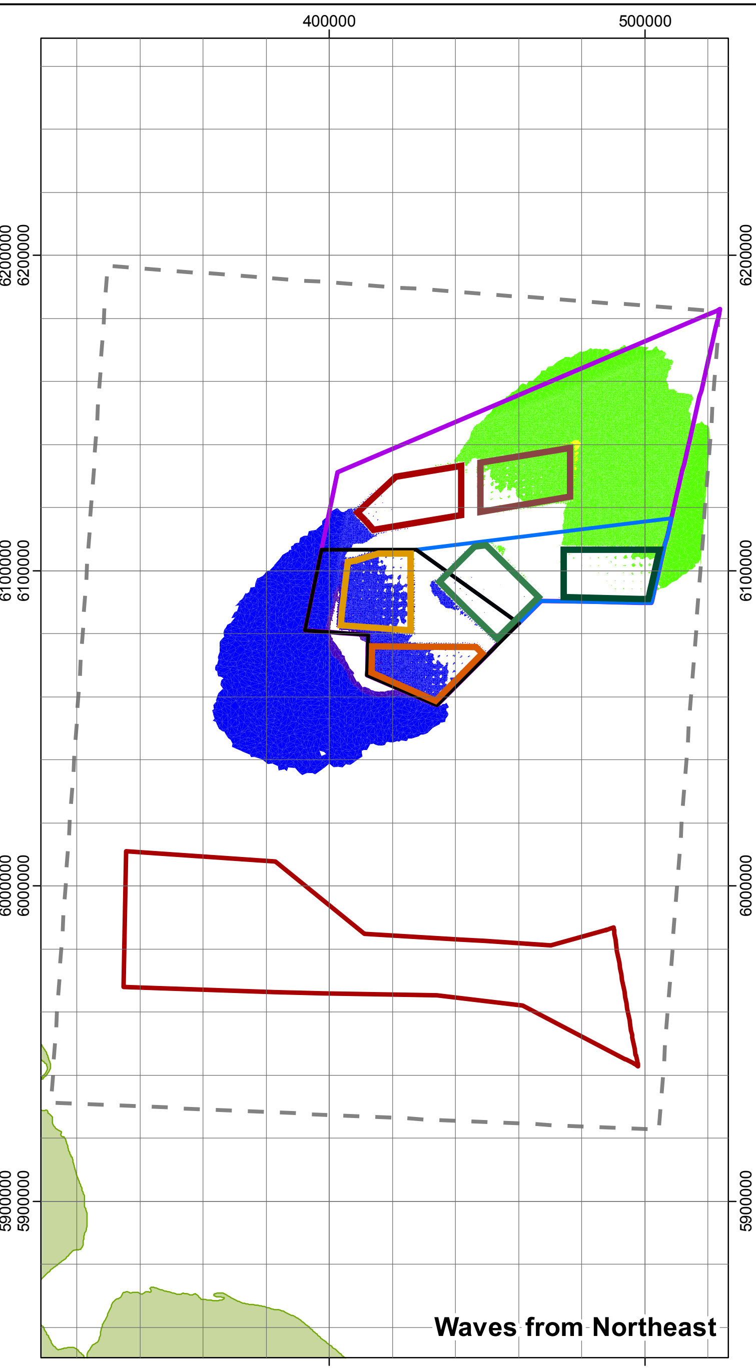
VER	DATE	REMARKS	Drawn	Checked
1	08/05/2013	Draft	FK	DB
2	01/10/2013	Final	LW	DB

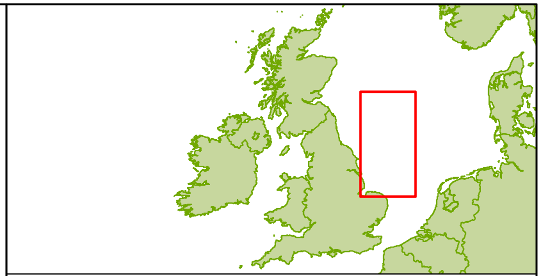
DRAWING NUMBER: **9X5889/04/113**

SCALE	1:2,400,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND







LEGEND

- Dogger Bank Zone
- 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
- Tranche A Boundary
- Tranche B Boundary
- Hornsea Offshore Wind Farm

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
- Model Boundary

0 50
Kilometres

Data Source:
Round 3 offshore wind farm boundary © Crown Copyright, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

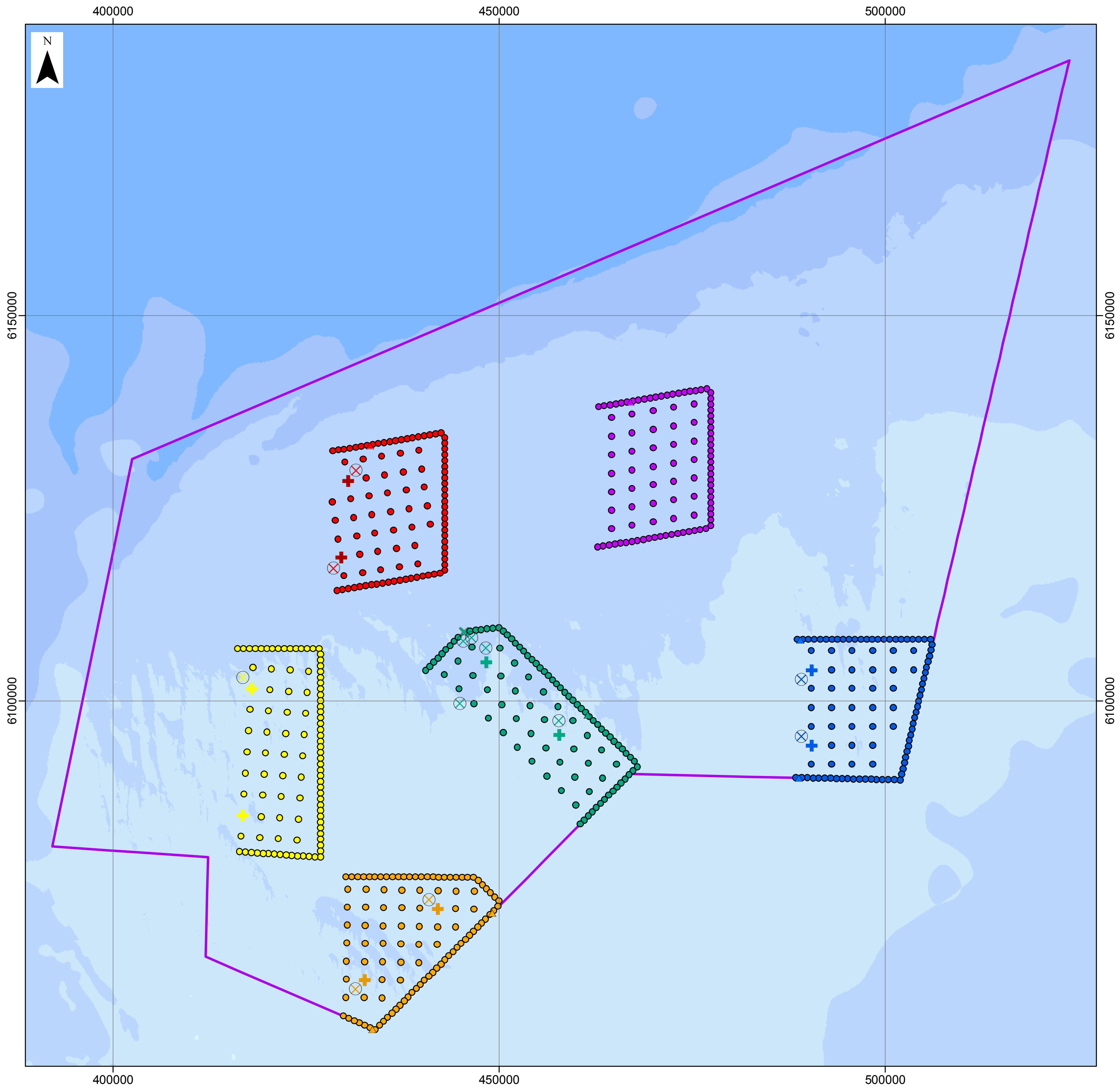
Figure 7.7 Cumulative Percentage Change to Significant Wave Height for One-year Waves from the North and Northeast Caused by 6MW Conical GBS#1 Foundations

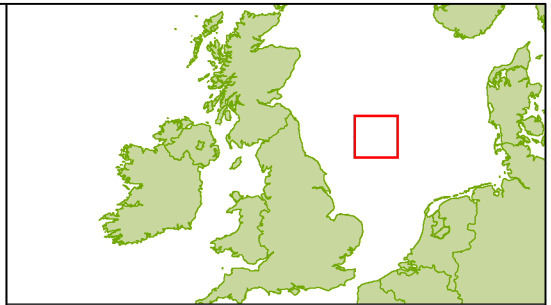
VER	DATE	REMARKS	Drawn	Checked
1	26/06/2013	Draft	FK	DB
2	01/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/114**

SCALE	1:2,400,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

Dogger Bank Zone

Dogger Bank Creyke Beck A Layout
- Collector Platform
- Met Mast
- Mooring
- Turbine

Dogger Bank Creyke Beck B Layout
- Collector Platform
- Mooring
- Turbine

Dogger Bank Teesside A Layout
- Accomodation Platform
- Collector Platform
- Converter Platform
- Met Mast
- Mooring
- Turbine

Dogger Bank Teesside B Layout
- Accomodation Platform
- Collector Platform
- Converter Platform
- Met Mast
- Mooring
- Turbine

Dogger Bank Teesside C Layout
- Collector Platform
- Met Mast
- Mooring
- Turbine

Dogger Bank Teesside D Layout
- Met Mast
- Turbine

0 25

Kilometres

Data Source:
© UKDeal
Round 3 © TCE, 2010.
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

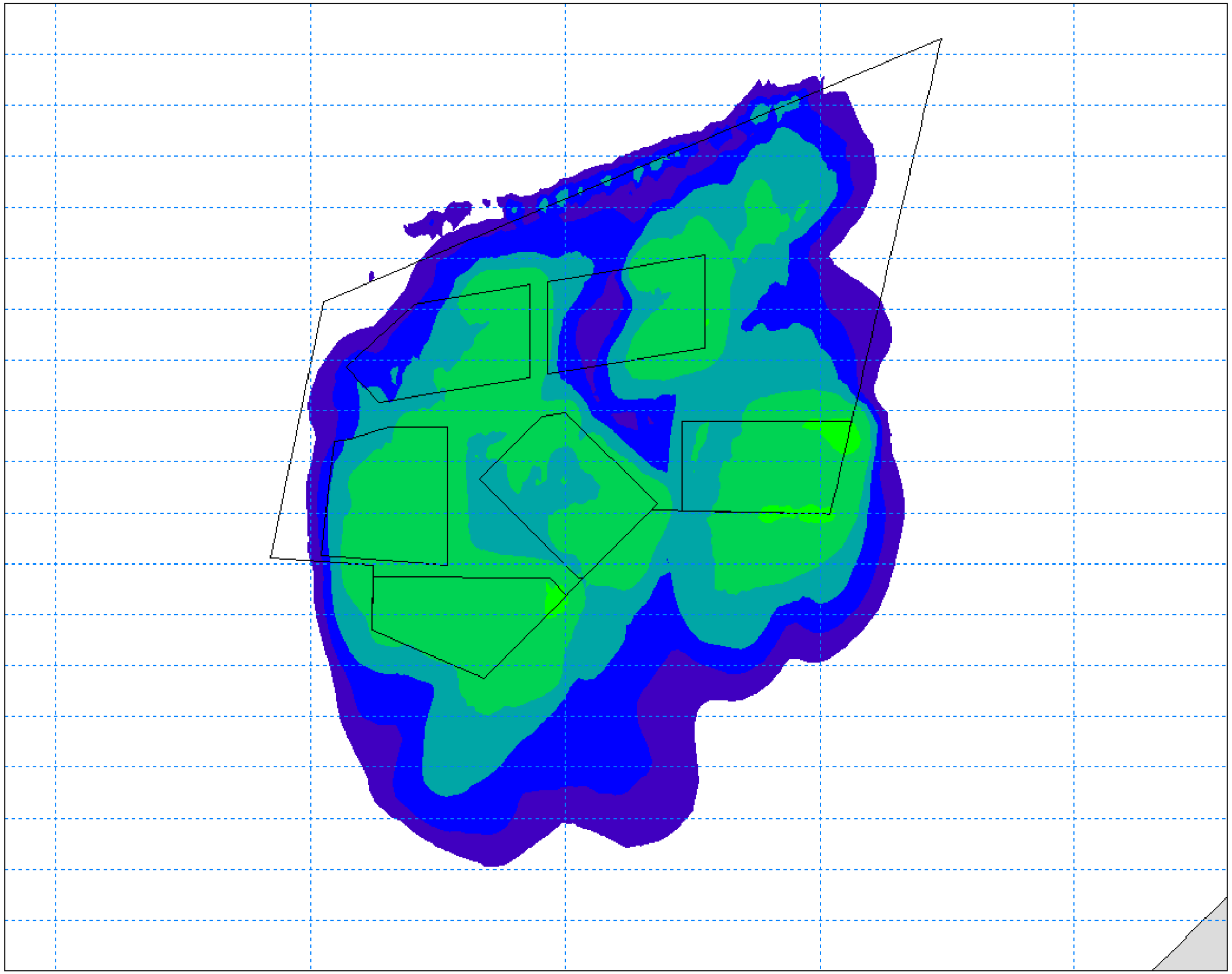
Figure 7.8 Cumulative 6MW Layouts for Dogger Bank Teesside A, B, C and D, and Dogger Bank Creyke Beck A and B after One Year of Operation

VER	DATE	REMARKS	Drawn	Checked
1	08/04/2013	Draft	FK	DB
2	15/10/2013	Final	LW	DB

DRAWING NUMBER: 9X5889/04/115

SCALE	PLOT SIZE	DATUM	PROJECTION
1:750,000	A4	WGS84	UTM31N

FOREWIND



LEGEND

Suspended Sediment Concentration (mg/l)

- Above 200
- 100 - 200
- 50 - 100
- 20 - 50
- 10 - 20
- 5 - 10
- 2 - 5
- Below 2

0 25 50

Kilometres

Data Source:
Image supplied by Danish Hydraulic Institute

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

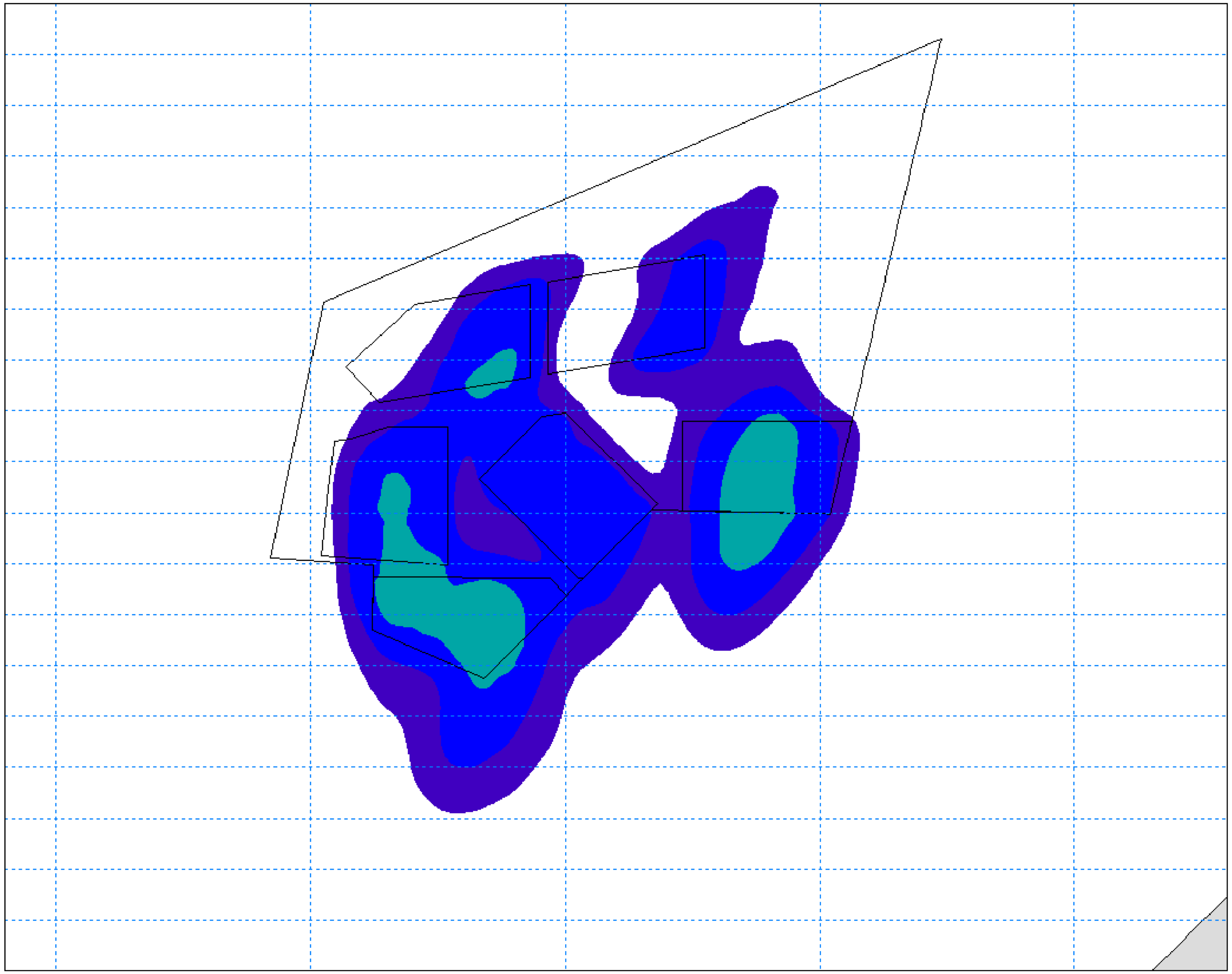
Figure 7.9 Maximum SSC in the Bottom Layer Predicted over the Simulation Period after One Year of Operation using the Re-suspension of Fractions 1 and 2 Method

VER	DATE	REMARKS	Drawn	Checked
1	15/04/2013	Draft	FK	DB
2	01/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/116**

SCALE	Taken from image	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND



LEGEND

Suspended Sediment Concentration (mg/l)

- Above 200
- 100 - 200
- 50 - 100
- 20 - 50
- 10 - 20
- 5 - 10
- 2 - 5
- Below 2

0 25 50
Kilometres

Data Source:
Image supplied by Danish Hydraulic Institute

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

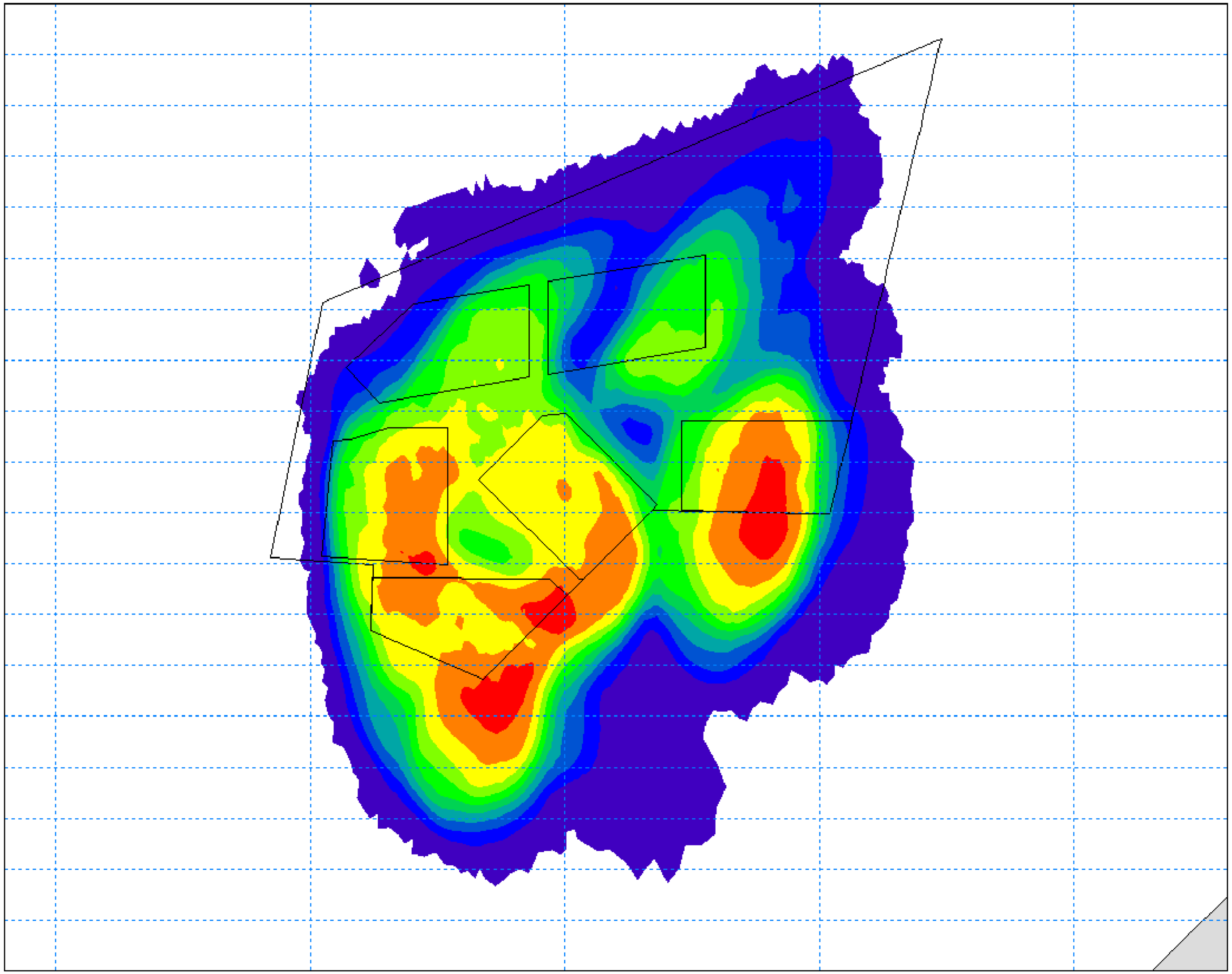
Figure 7.10 Average SSC in the Bottom Layer Predicted over the Simulation Period after One Year of Operation using the Re-suspension of Fractions 1 and 2 Method

VER	DATE	REMARKS	Drawn	Checked
1	15/04/2013	Draft	FK	DB
2	01/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/117**

SCALE	PLOT SIZE	DATUM	PROJECTION
Taken from image	A4	WGS84	UTM31N

FOREWIND



LEGEND

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 25 50
Kilometres

Data Source:
Image supplied by Danish Hydraulic Institute

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

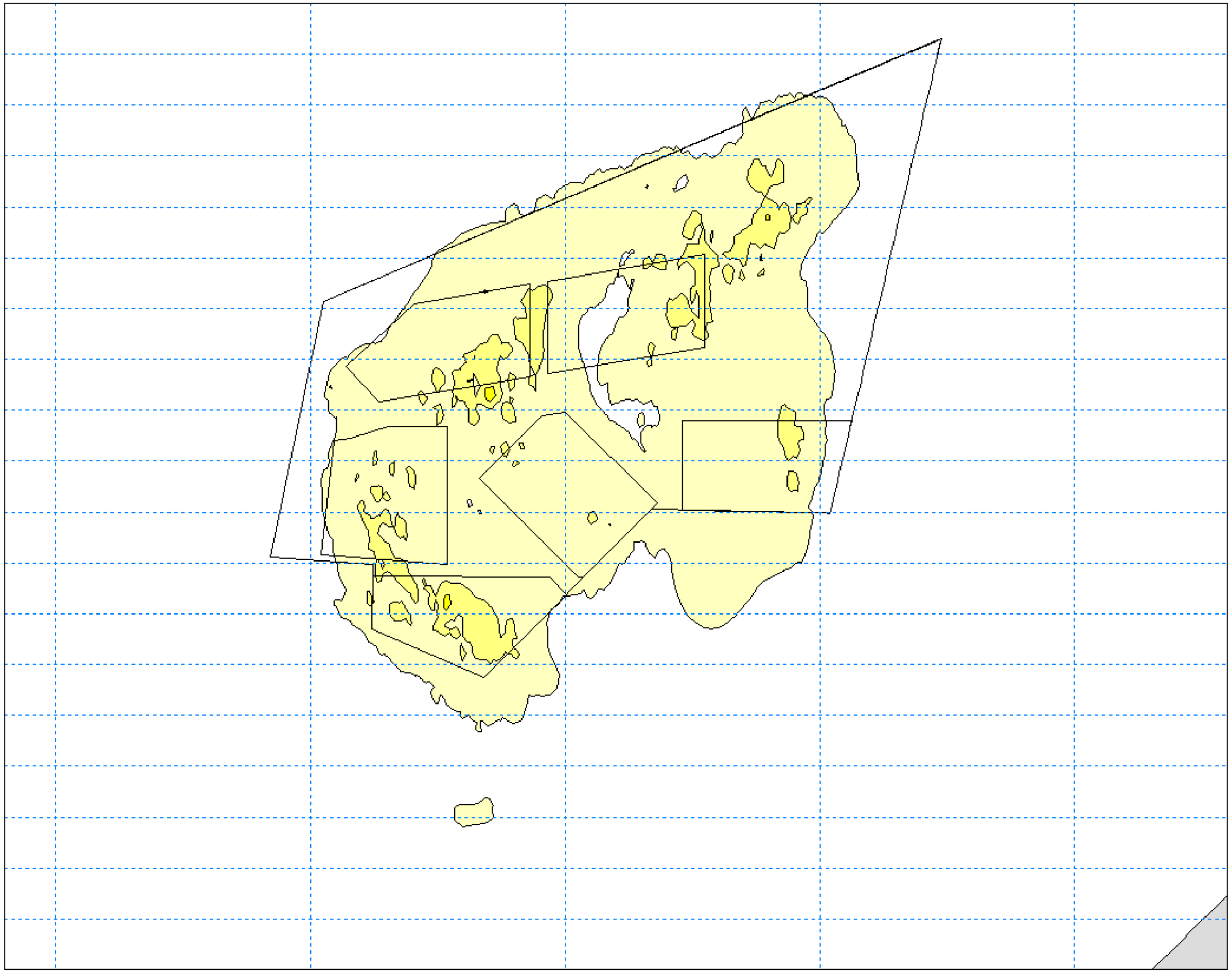
Figure 7.11 Percentage of Time Predicted over the Simulation Period where SSC of 2mg/l is exceeded in the Bottom Layer after One Year of Operation using the Re-suspension of Fractions 1 and 2 Method

VER	DATE	REMARKS	Drawn	Checked
1	15/04/2013	Draft	FK	DB
2	01/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/118**

SCALE	PLOT SIZE	DATUM	PROJECTION
Taken from image	A4	WGS84	UTM31N

FOREWIND



LEGEND

Sediment Thickness (mm)

- Above 100
- 50 - 100
- 10 - 50
- 5 - 10
- 1 - 5
- 0.5 - 1
- 0.1 - 0.5
- Below 0.1

0 25 50

Kilometres

Data Source:
Image supplied by Danish Hydraulic Institute

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

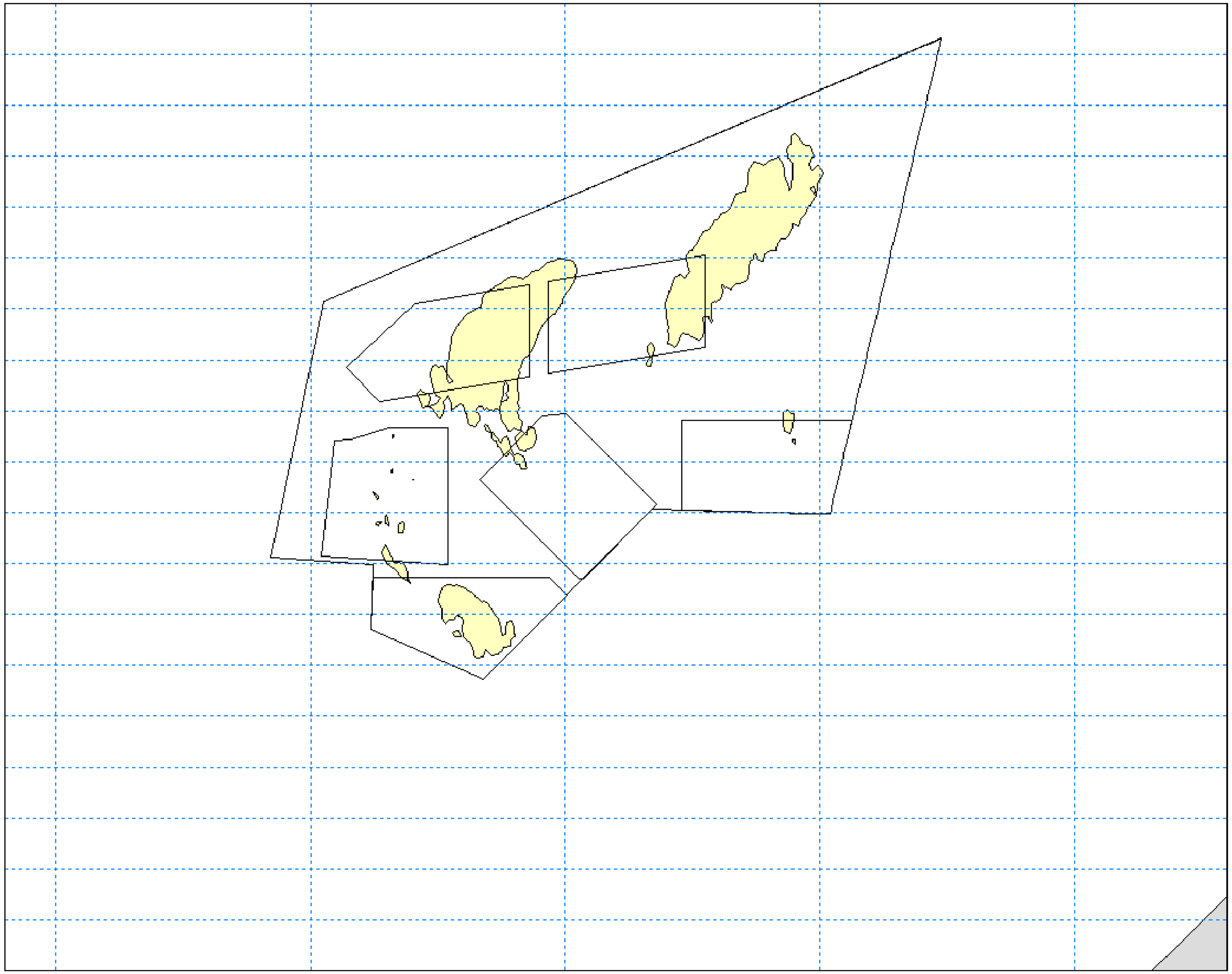
Figure 7.12 Maximum Deposition Predicted over the Simulation Period after One Year of Operation using the Re-suspension of Fractions 1 and 2 Method

VER	DATE	REMARKS	Drawn	Checked
1	15/04/2013	Draft	FK	DB
2	01/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/119**

SCALE	PLOT SIZE	DATUM	PROJECTION
Taken from image	A4	WGS84	UTM31N

FOREWIND



LEGEND

Sediment Thickness (mm)

- Above 100
- 50 - 100
- 10 - 50
- 5 - 10
- 1 - 5
- 0.5 - 1
- 0.1 - 0.5
- Below 0.1

0 25 50
Kilometres

Data Source:
Image supplied by Danish Hydraulic Institute

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

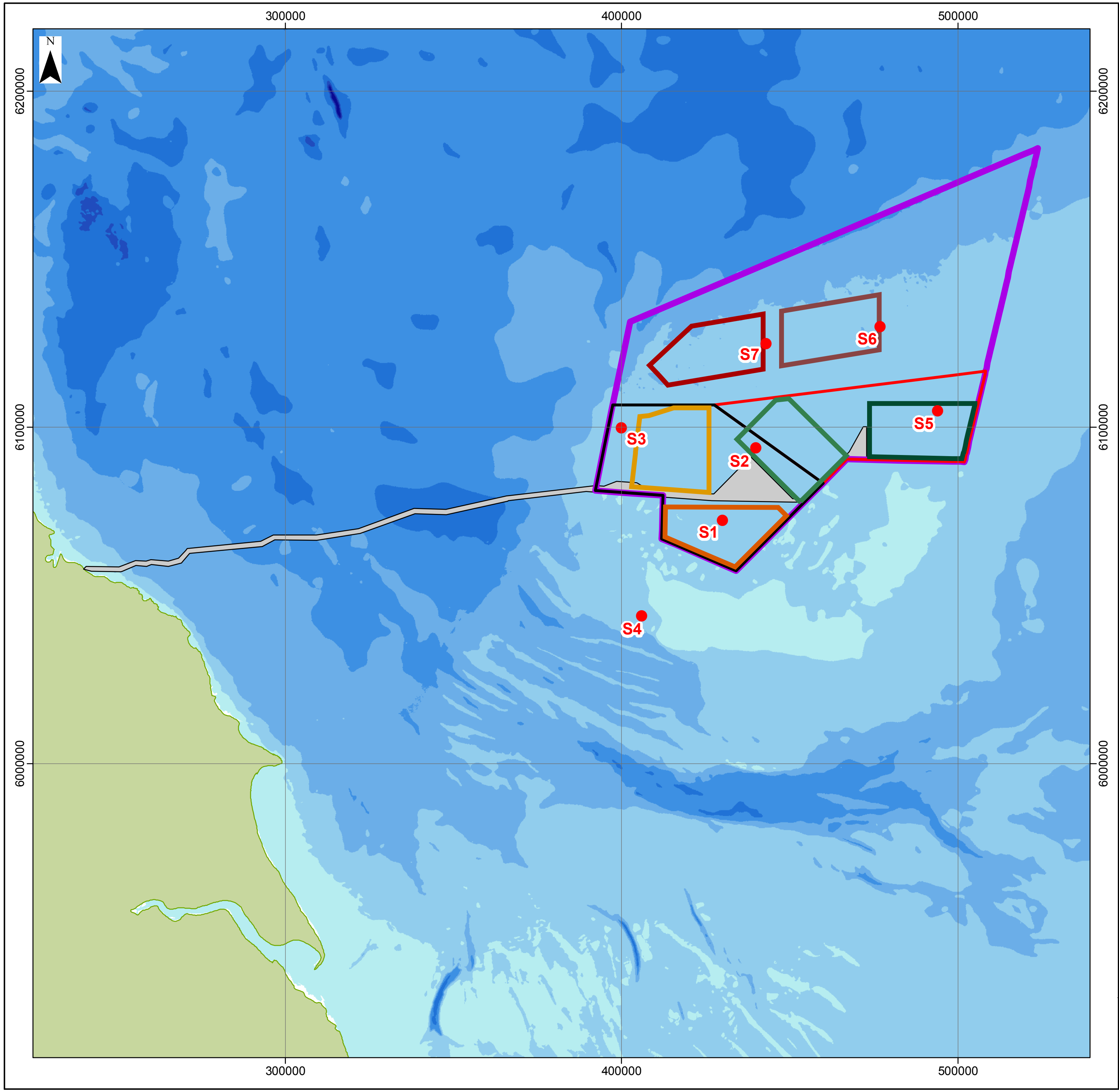
Figure 7.13 Average Deposition Predicted over the Simulation Period after One Year of Operation using the Re-suspension of Fractions 1 and 2 Method

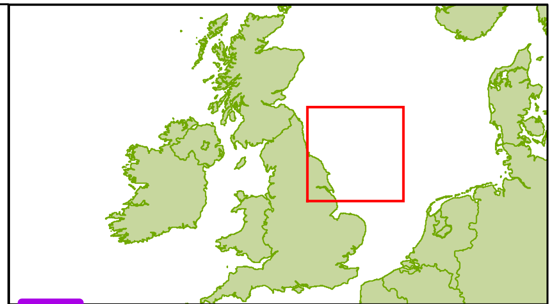
VER	DATE	REMARKS	Drawn	Checked
1	15/04/2013	Draft	FK	DB
2	01/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/120**

SCALE	Taken from image	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- 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
- Tranche A Boundary
- Tranche B Boundary
- Dogger Bank Teesside A & B Export Cable Corridor
- Sediment Thickness Time Series Analysis Point

Bathymetry (m below mean sea level)

- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- 100 - 120
- 120 - 140
- >140

0 20 40
Kilometres

Data Source:
© UKDeal
Sediment data © Danish Hydraulic Institute, 2012
Background bathymetry image derived in part from © TCarta data 2009.

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 7.14 Location of Points for Sediment Thickness Time Series Analysis for the Cumulative Operational Phase

VER	DATE	REMARKS	Drawn	Checked
1	15/04/2013	Draft	FK	DB
2	15/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/121**

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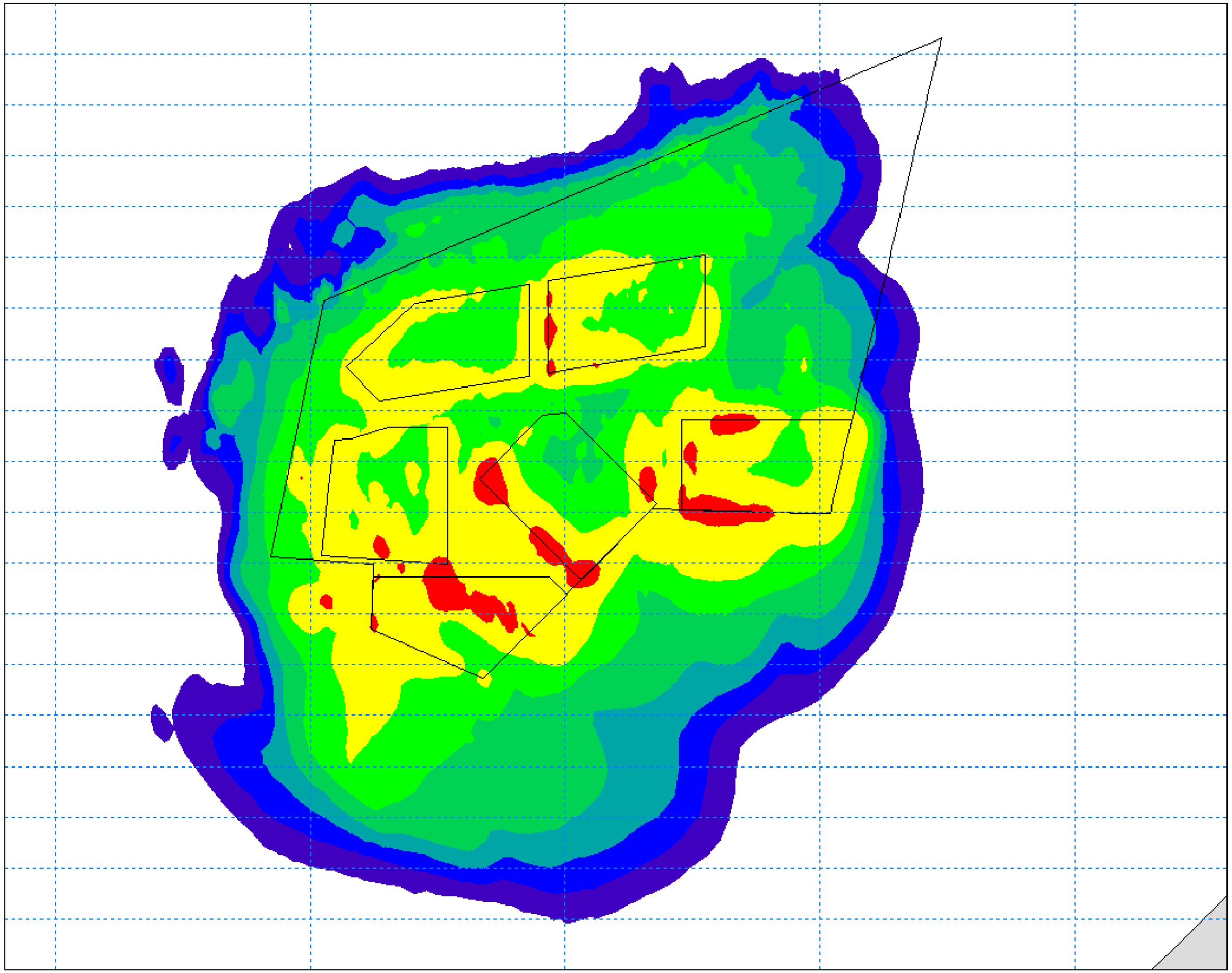
FOREWIND



LEGEND

Suspended Sediment Concentration (mg/l)

- Above 200
- 100 - 200
- 50 - 100
- 20 - 50
- 10 - 20
- 5 - 10
- 2 - 5
- Below 2

0 20
Kilometres

Data Source:
Image supplied by Danish Hydraulic Institute

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

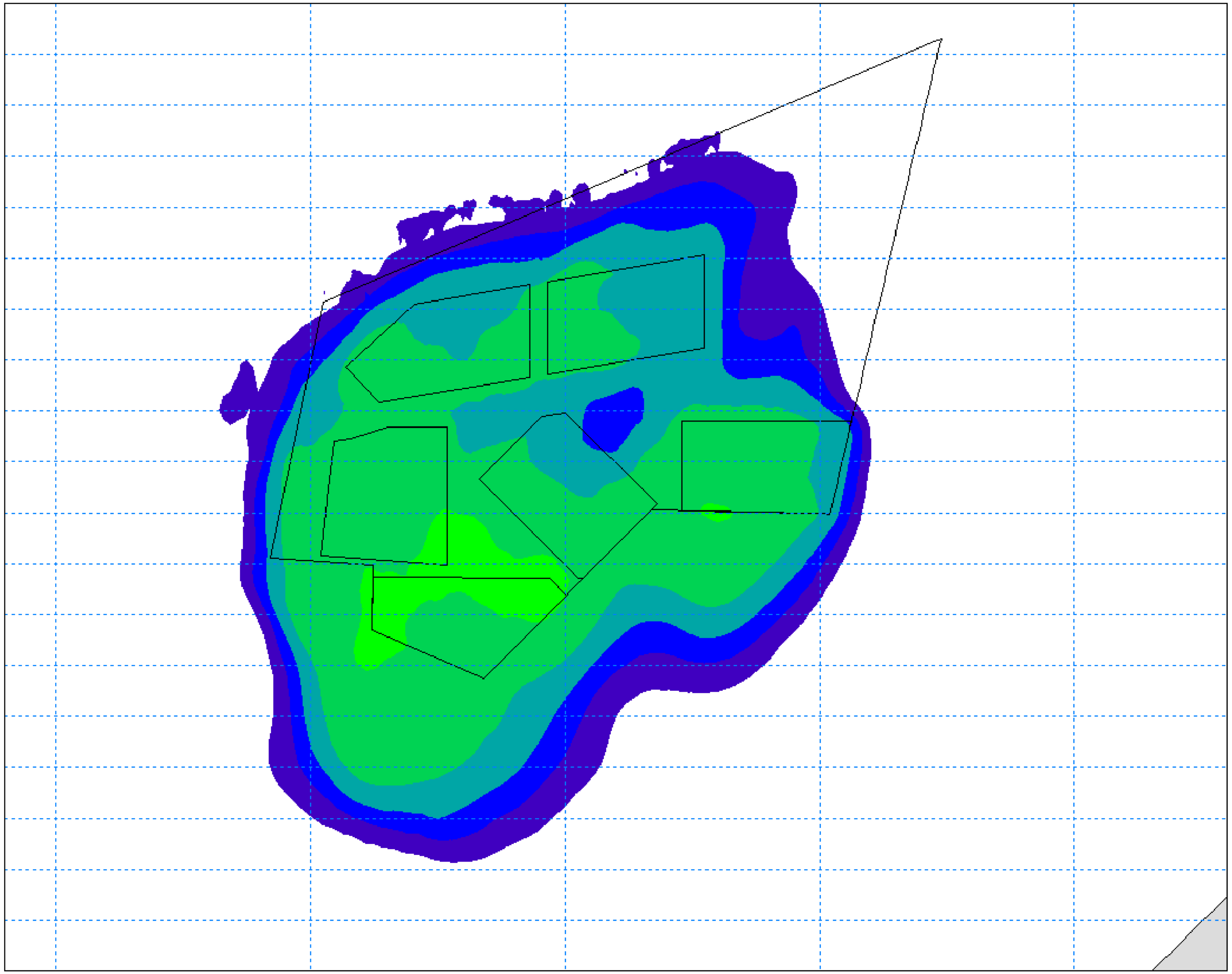
Figure 7.15 Maximum SSC in the Bottom Layer Predicted over the Simulation Period after Two Years of Operation using the Re-suspension of Fractions 1 and 2 Method

VER	DATE	REMARKS	Drawn	Checked
1	08/04/2013	Draft	FK	DB
2	01/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/122**

SCALE	Taken from image	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND



LEGEND

Suspended Sediment Concentration (mg/l)

- Above 200
- 100 - 200
- 50 - 100
- 20 - 50
- 10 - 20
- 5 - 10
- 2 - 5
- Below 2

0 20

Kilometres

Data Source:
Image supplied by Danish Hydraulic Institute

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

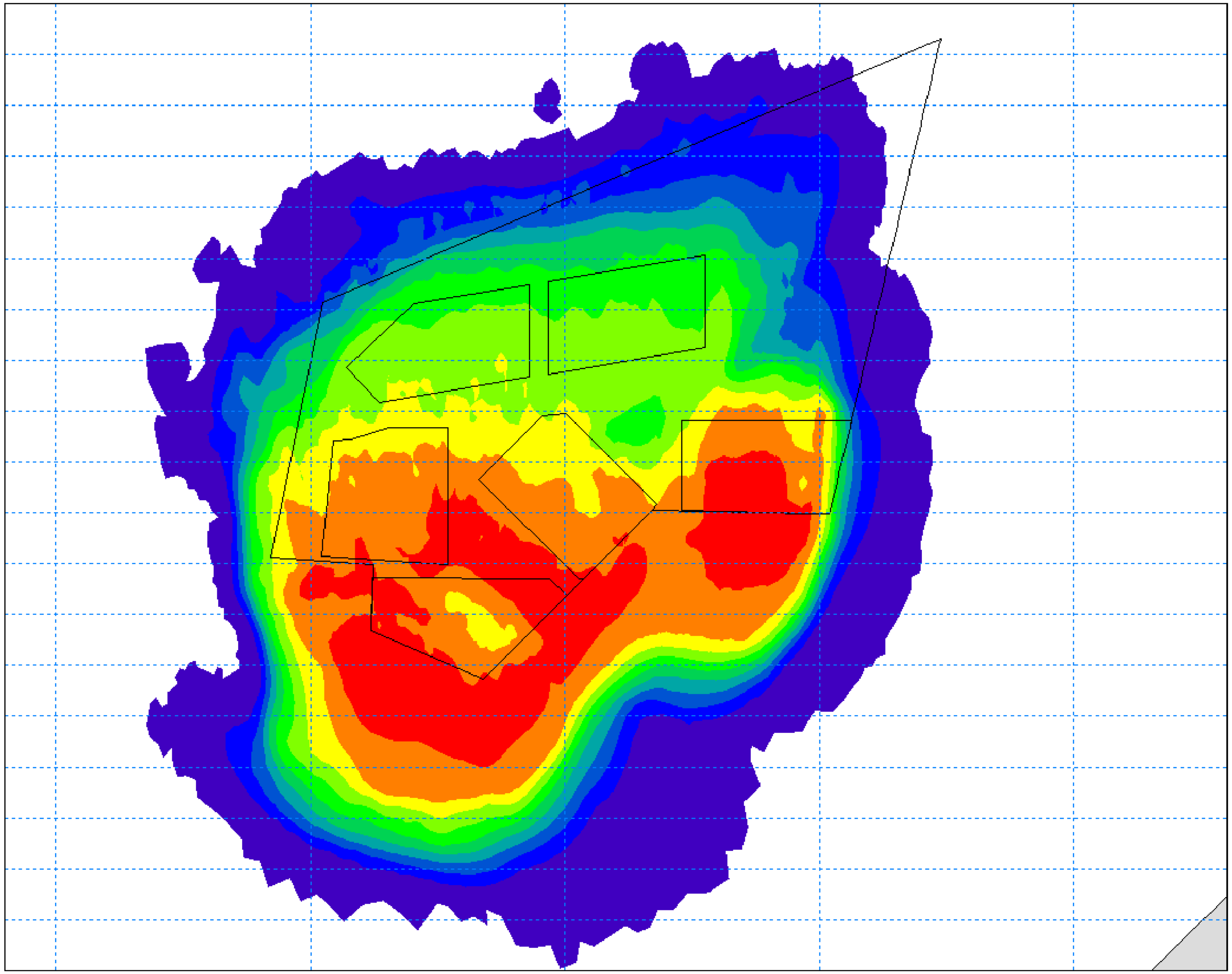
Figure 7.16 Average SSC in the Bottom Layer Predicted over the Simulation Period after Two Years of Operation using the Re-suspension of Fractions 1 and 2 Method

VER	DATE	REMARKS	Drawn	Checked
1	08/04/2013	Draft	FK	DB
2	01/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/123**

SCALE Taken from image | PLOT SIZE A4 | DATUM WGS84 | PROJECTION UTM31N

FOREWIND



LEGEND

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 20
Kilometres

Data Source:
Image supplied by Danish Hydraulic Institute

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

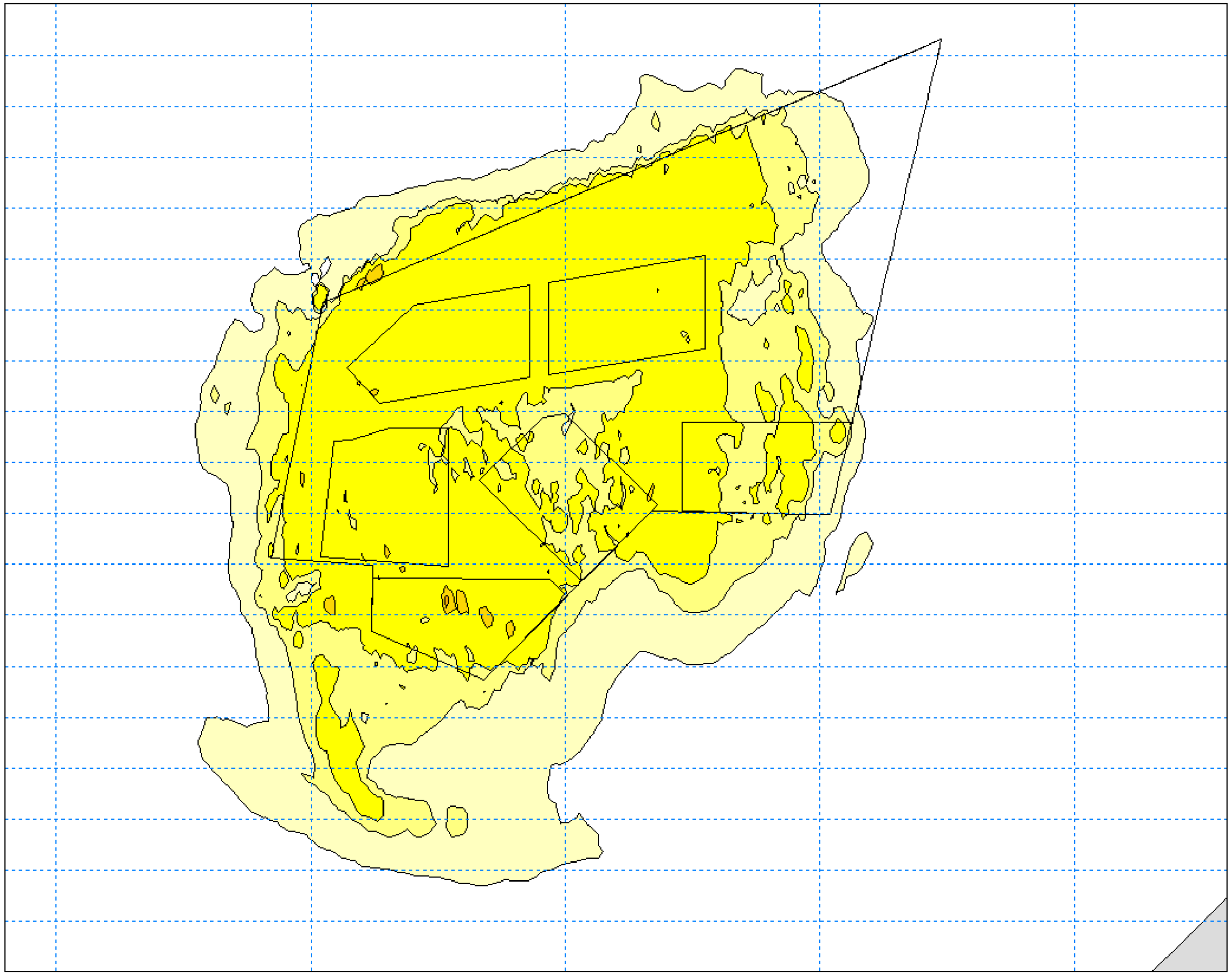
Figure 7.17 Percentage of Time Predicted over the Simulation Period where SSC of 2mg/l is exceeded in the Bottom Layer after Two Years of Operation using the Re-suspension of Fractions 1 and 2 Method

VER	DATE	REMARKS	Drawn	Checked
1	08/04/2013	Draft	FK	DB
2	01/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/124**

SCALE	PLOT SIZE	DATUM	PROJECTION
Taken from image	A4	WGS84	UTM31N

FOREWIND



LEGEND

Sediment Thickness (mm)

- Above 100
- 50 - 100
- 10 - 50
- 5 - 10
- 1 - 5
- 0.5 - 1
- 0.1 - 0.5
- Below 0.1

0 20
Kilometres

Data Source:
Image supplied by Danish Hydraulic Institute

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

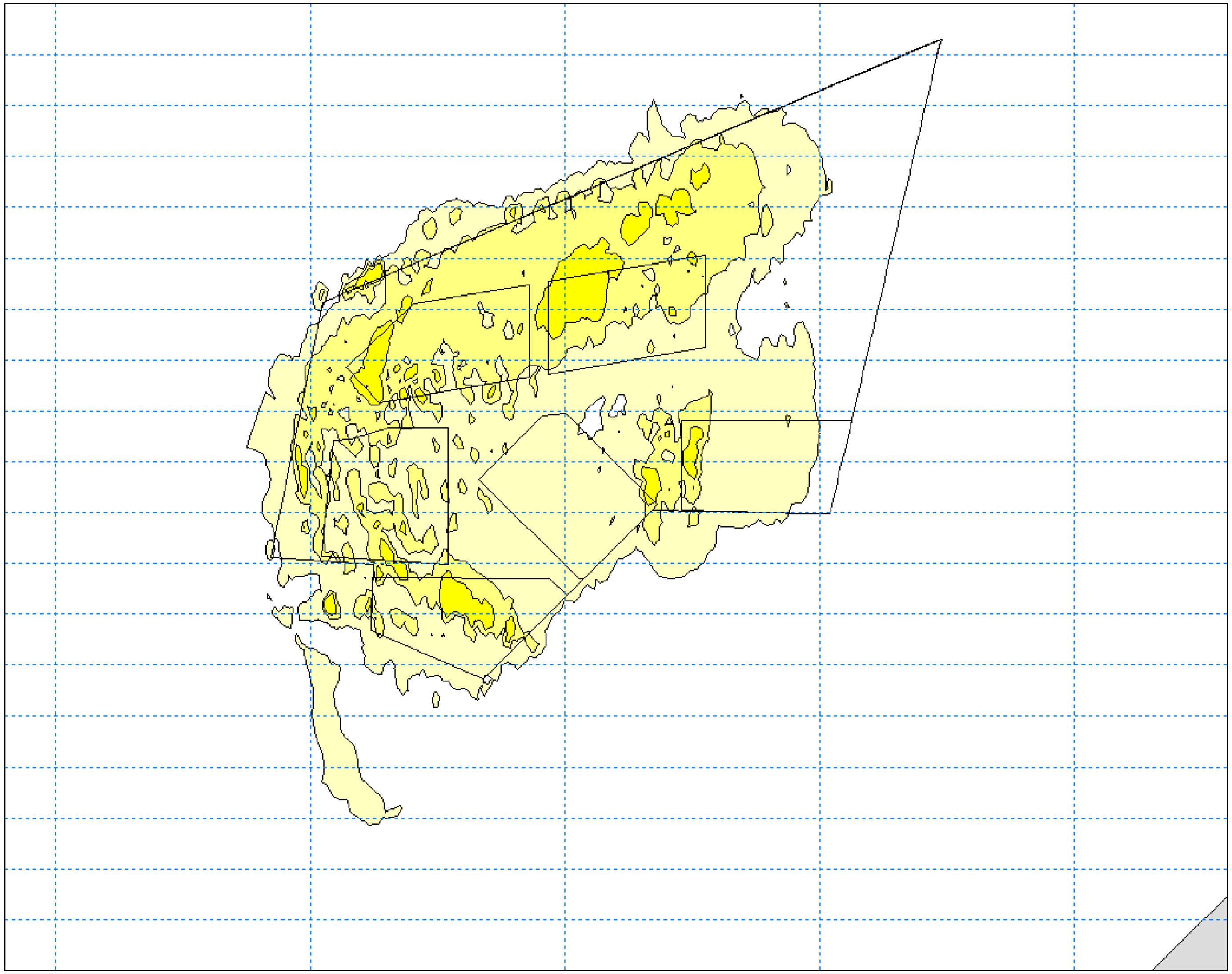
Figure 7.18 Maximum Deposition Predicted over the Simulation Period after Two Years of Operation using the Re-suspension of Fractions 1 and 2 Method

VER	DATE	REMARKS	Drawn	Checked
1	08/04/2013	Draft	FK	DB
2	01/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/125**

SCALE	PLOT SIZE	DATUM	PROJECTION
Taken from image	A4	WGS84	UTM31N

FOREWIND



LEGEND

Sediment Thickness (mm)

- Above 100
- 50 - 100
- 10 - 50
- 5 - 10
- 1 - 5
- 0.5 - 1
- 0.1 - 0.5
- Below 0.1

0 20
Kilometres

Data Source:
Image supplied by Danish Hydraulic Institute

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 7.19 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	Drawn	Checked
1	08/04/2013	Draft	FK	DB
2	01/10/2013	Final	LW	DB

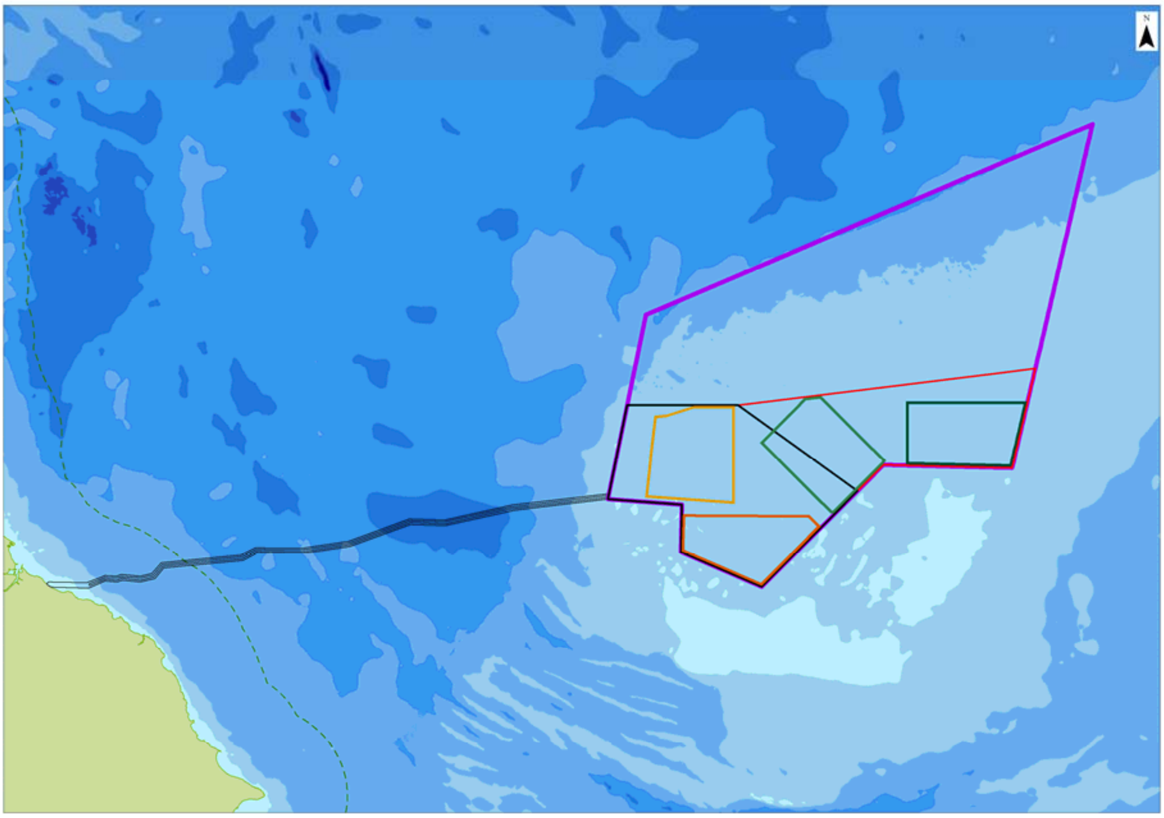
DRAWING NUMBER: **9X5889/04/126**

SCALE	PLOT SIZE	DATUM	PROJECTION
Taken from image	A4	WGS84	UTM31N

FOREWIND

APPENDICES

Appendix A: Dogger Bank Teesside A & B conceptual model



Conceptual Model – Wind Farm Area. Dogger Bank Teesside A & B

Forewind

20 January 2014

Final Report

9X5889

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Document title	Conceptual Model – Wind Farm Area. Dogger Bank Teesside A & B
Document short title	Conceptual Model – Teesside A & B
Status	Final Report
Date	20 January 2014
Project name	Dogger Bank Physical Processes
Project number	9X5889
Client	Forewind
Reference	9X5889/R03/303861/Lon

Drafted by	Jennifer Godwin and David Brew	
Checked by	Nick Cooper	N. J. Cooper
Date/initials check	20.01.2014	…………………
Approved by	David Brew	David S Brew
Date/initials approval	20.01.2014	…………………

NON TECHNICAL SUMMARY

Forewind Limited is in the process of developing Zone 3 Dogger Bank of Round 3 of the offshore wind farm programme. The development at Dogger Bank is anticipated to be taken forward in four tranches (A to D), with Tranche A across the southwest part of the Dogger Bank Zone being the first area to be developed. The first project areas identified were Dogger Bank Creyke Beck A & B in Tranche A. The second projects to be developed are primarily located within Tranche B comprising Dogger Bank Teesside A and Dogger Bank Teesside B projects.

This conceptual model describes the existing physical and sedimentary processes operating across Dogger Bank and the changes in seabed geometry driven by these processes to support the Environment Impact Assessment for Dogger Bank Teesside A & B. This baseline understanding is used to scope the potential changes to the processes caused by construction, operation and decommissioning of the Dogger Bank offshore wind farm.

The conceptual model is largely based on new data collected by Forewind specifically to understand Dogger Bank physical processes, alongside existing data and literature. The new data includes bathymetry, wave climate, tidal regime and seabed sediment characteristics. The focus of this new data collection was for tranches A & B.

Water depths range from approximately 20m to 78m within the Dogger Bank Zone, with 20-40m common in Tranche A and 25-35m common in Tranche B. The majority of the tranches A & B seabed is covered by sand with smaller patches of gravel and areas where the underlying geology is exposed at the seabed. These surface sediments contain less than 5% mud and less than 5% gravel. These small proportions 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 are very low (less than 2mgl^{-1}).

Tidal currents flowing across Tranche A are mainly directed north to south and south to north with mean velocities reaching a maximum of 0.30ms^{-1}. In Tranche B tidal currents mainly flow between north-northwest and south-southeast with mean velocities reaching a maximum of 0.21 ms^{-1}. In places, these relatively weak currents have molded 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 in tranches A & B the sediment transport regime is not dynamic. 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.

This conceptual model concludes by briefly outlining the baseline parameters that are most likely to be affected by construction and operation of the wind farm. These include changes to suspended sediment concentrations and seabed sediment distribution.

CONTENTS

Royal HaskoningDHV

FOREWIND

1 INTRODUCTION

1.1 Dogger Bank Offshore Wind Farm

1.1.1 Dogger Bank is a large and isolated positive bathymetric feature located in the central North Sea. The bathymetric high is approximately 300km long and is elongate in an east-northeast to west-southwest direction. It occupies approximately 17,600km^2 of UK, Dutch, German and Danish waters (Van Moorsel, 2011). In UK waters, Dogger Bank forms a plateau about 30m above the surrounding seabed. The shallowest areas are in less than 20m of water along its southern edge.

1.1.2 Forewind Limited has been awarded development partner status by The Crown Estate for Zone 3: Dogger Bank, as part of the third round of offshore wind licensing arrangements (Round 3). The Dogger Bank Zone outlined for development occupies an area of approximately 8,660km^2 across the UK part of Dogger Bank (Figures 1.1 and 1.2). It is bordered by deeper water to the northwest, by the shallowest part of Dogger Bank to the south and by the median line between UK and European waters to the east.

1.1.3 The development at Dogger Bank is anticipated to be taken forward in four tranches (A to D). The location of Tranche A was identified through the Zone Appraisal and Planning (ZAP) process undertaken in 2010. The zone-wide characterisation of the physical processes within the zone development envelope (RPS Energy, 2010) helped inform the identification of Tranche A covering approximately 2,000km^2 of seabed across the southwestern part of the Dogger Bank Zone (Figure 1.2). The first project areas identified were Dogger Bank Creyke Beck A & B located in Tranche A (Figure 1.2); these projects are collectively referred to as Dogger Bank Creyke Beck and have a proposed application for up to 2.4GW of installed capacity (up to 1.2GW in each).

1.1.4 The second projects to be developed are primarily located within Tranche B (approximately 1,520km^2). Dogger Bank Teesside will comprise projects referred to as Dogger Bank Teesside A (wholly in Tranche B) and Dogger Bank Teesside B (mainly in Tranche B and partially in Tranche A) (Figure 1.2), forming the second application by Forewind. Similarly to Dogger Bank Creyke Beck A & B, Dogger Bank Teesside A & B is anticipated to have an installed capacity of up to 2.4GW. Two further projects, namely Dogger Bank Teesside C & D are also planned. Collectively, Dogger Bank Teesside A, B, C and D are referred to as the Dogger Bank Teesside projects.

1.2 Objective of this Conceptual Model

1.2.1 This conceptual model uses existing data to describe the baseline physical and sedimentary processes operating across Dogger Bank and the changes in geomorphology driven by these processes. This conceptual understanding is used to:

- scope the potential changes to the processes caused by construction, operation and decommissioning of the Dogger Bank offshore wind farm. These are discussed in Section 5; and
- determine the set up and runs of numerical models that will predict the magnitude of the potential changes. These are discussed further in the Method Statement for the Dogger Bank Zone, and not presented in this report.

1.3 Data Collected for Dogger Bank Offshore Wind Farm

Geophysics

1.3.1 Geophysical data specifically for Dogger Bank Offshore Wind Farm has been collected during three main survey campaigns completed for different purposes at different stages of the project;

1. zonal characterisation of Dogger Bank at a wide transect spacing; and
2. detailed surveys of Tranche A and then Tranche B at narrow transect spacings.

1.3.2 Gardline (2011a) collected geophysical data across the Dogger Bank Zone to provide a broad characterisation of the potential development area. This survey was carried out between May 2010 and August 2010 and deployed single and multibeam echo sounder, side-scan sonar, and sub-bottom profilers (pinger, sparker and mini airgun). The survey was run in a square grid pattern with transect lines 2.5km apart (Figure 1.3), meaning that around 15% of the Zone's surface is covered by side scan and bathymetry (approximately 200m swathe along each transect).

1.3.3 GEMS (2012) carried out a geophysical survey of Tranche A to support development of projects within this area. The survey was carried out between July 2010 and December 2010 and included collection of side-scan sonar, sub-bottom profiling (pinger and sparker), bathymetry (single and multibeam echosounder), acoustic ground discrimination (AGDS) and magnetometer. The main geophysical lines were run 100m apart with 500m spaced cross lines (Figure 1.4), achieving 100% coverage of side scan and bathymetry.

1.3.4 Gardline (2013a) carried out a geophysical survey of Tranche B between June 2011 and October 2011, and between March 2012 and May 2012. The main geophysical lines were run at 100m apart with 500m or 1,000m spaced cross lines (Figure 1.5), achieving 100% coverage of side scan and bathymetry. The Tranche B data includes seabed characterisation (side-scan sonar, AGDS), sub-bottom profiling (pinger, sparker and mini airgun), and bathymetry (single and multibeam echosounder).

1.3.5 The geological results presented in this conceptual model are derived from Gardline (2011a, 2013a) and GEMS (2012).

Boreholes, Cone Penetration Tests and Grab Samples

1.3.6 Fugro (2011) collected 56 boreholes and wireline logs (45 in Tranche A) and 96 cone penetration tests (CPTs) across the Dogger Bank Zone. The distribution of these is shown in Figure 1.6, but note that at each location (114 locations), one or more of the different types of geotechnical data collection has been undertaken. Fugro (2012) collected 17 additional CPTs and 10 additional wireline logs across Tranche A. The boreholes were logged and various geotechnical tests were performed in situ and in the laboratory. Fugro (2013) carried out a geotechnical survey in Tranche B, collecting 17 borehole logs with combined CPTs. GEO (2013) collected 80 CPTs across Tranche B and eight CPTs in Tranche A.

1.3.7 Gardline (2011b) visited 106 sites for seabed sediment grab samples across Tranche A. At seven of these sites, no sediment was recovered. All of the 99 recovered samples (Figure 1.6) have been analysed for particle size distribution (EMU, 2013). Gardline (2012) investigated 55 sites in Tranche B at which seabed sediment grab samples were taken from 51 (Figure 1.6). The remaining four sites were not sampled as they were identified as areas of potential stony reef habitat. Particle size analysis and faunal analyses were carried out on all 51 samples (Gardline 2013b).

Meteorology and Oceanography (Metocean)

1.3.8 Currently, there are three locations where Forewind have deployed instruments to collect time series metocean data; the northern limit of the Dogger Bank Zone boundary, inside Tranche A and inside Tranche B (Figure 1.7). At all these locations, wave and tidal current data is being collected using waveriders and Acoustic Doppler Current Profilers (ADCP). The time series of data that has been collected is listed in Table 1.1.

Table 1.1. Metocean data available from the deployments in the Dogger Bank Zone.

Location (and type)	Coordinates (and water depth)	Currents		Waves	
		Start	End	Start	End
Tranche A Waverider	54° 51.72', 01° 59.83' (22m)	-	-	23/09/2010	31/03/2013
Tranche A ADCP	54° 51.61', 01° 59.64' (22m)	29/02/2012	31/03/2013	-	-
Tranche B Waverider	55° 05.90', 02° 42.04' (26m)	-	-	29/02/2012	31/03/2013
Tranche B ADCP	55° 05.90', 02° 42.04' (26m)	29/02/2012	31/03/2013	-	-
Northern Waverider	55° 29.54', 02° 09.71' (45m)	-	-	06/11/2011	31/03/2013
Northern ADCP (1)	55° 29.54', 02° 09.71' (52m)	07/11/2010	16/06/2012		
Northern ADCP (2)	55° 29.46', 02° 09.58' (52m)	09/05/2012	16/06/2012		

1.3.9 In addition to the new data collection, Mathiesen and Nygaard (2010) and Mathiesen et al. (2011) provided modelled metocean data for eight locations within the Dogger Bank Zone (Figure 1.7). The data is described fully in Chapter 3.

1.4 Environmental Designation

1.4.1 Dogger Bank is currently designated as a candidate Special Area of Conservation (cSAC) comprising an area of 12,331km^2 with Annex I sandbank qualifying habitat (Figure 1.8). The covering of sandy sediments in the shallower (<20m depth) areas to the southwest and their associated benthic fauna falls within the Annex I classification; sandbanks which are slightly covered by seawater all of the time (JNCC, 2011). In general, the biological communities on the Dogger Bank are typical of fine sand and muddy sand sub-littoral sediments. Species typical of these communities include the following:

- polychaetes: *Nephtys cirrosa* and *Magelona* sp;
- mobile amphipods: genus *Bathyporeia*;
- brittlestar: *Amphiura filiformis*; and
- bivalve molluscs: *Tellina fabula* (formerly *Fabulina fabula*) and *Mysella bidentata*.

1.4.2 Epifaunal species include:

- hermit crab: *Pagurus bernhardus*;
- sand eels: *Ammodytes* spp;
- plaice: *Pleuronectes platessa*; and
- starfish: *Asterias rubens*.

1.4.3 A detailed discussion of habitats and species across the entire Dogger Bank can be found in Van Moorsel (2011).

1.5 Structure of this Conceptual Model

1.5.1 This conceptual model comprises eight sections of which this introduction is Section 1. Section 2 provides an overview of the Quaternary geology. Section 3 outlines the physical processes which characterise the area and Section 4 presents an analysis of the sedimentary processes and geomorphology driven by the hydrodynamics. Section 5 scopes the potential effects and sensitivities of the sedimentary processes to changes in the system hydrodynamics caused by wind farm development. Sections 6, 7 and 8 present the conclusions, references and glossary, respectively.

2 QUATERNARY GEOLOGY

2.1 Current Status of Interpretation

2.1.1 The top 200m of the geology of Dogger Bank is dominated by sediments deposited during the Quaternary (Pleistocene followed by Holocene). The recent geological history of Dogger Bank is currently under review by the British Geological Survey (Carol Cotterill) based on the geophysical, geotechnical and geological data collected across the Dogger Bank Zone between 2010 and 2012 (Section 1.3). The information in Sections 2.2 to 2.5 below provides an update on the latest understanding of the geological history of Dogger Bank, particularly Tranche B.

2.2 Pleistocene Evolution of Dogger Bank

2.2.1 The evolution of the Dogger Bank is linked to a complex interplay between climate changes, ice sheet movement and sea-level change. Approximately 25,000 years ago, following the cooling that initiated an ice age approximately 110,000 years ago, massive ice sheets formed to their maximum extents across the North American continent and northern Europe. The effect of water entrainment into these ice sheets was to lower sea levels by approximately 120m across the North Sea Basin. This sea-level fall was enough to fully expose the southern, and majority of the central, North Sea Basin.

2.2.2 At this time, the Dogger Bank surface would have been a terrestrial tundra plain landscape, cut by braided river systems draining out of northern Europe. The ice sheets to the north, east and west of Dogger Bank provided glacial outwash which combined with the river system deposits.

2.2.3 It is proposed that there were up to eight pulses of advance and retreat of the ice masses. During each advance it is believed that the ice began to ‘ruck-up’ the underlying sediments, pushing them into a series of ridges ahead of the ice margin called terminal moraines. During periods of stillstand, where the ice limit did not fluctuate, additional, more laminar outwash sediments would have been piled up against these initial mounded sediments, forming the core of a push moraine complex; the topographic high of Dogger Bank. With addition of more glacially derived sediments to this complex, either through direct ice front emplacement or through outwash deposition, the complex began to form a topographic barrier against which later ice pulses would abut.

2.2.4 Where glacial obstructions are present, forming a barrier to outwash drainage coming off an ice front, there can be formation of significant pro-glacial lakes. Tranche B shows evidence for a large pro-glacial lake that formed due to damming by terminal moraines from older ice advance events. This suggests that the environment across Tranche B was significantly more pro-glacial in nature than the predominantly sub-glacial Tranche A.

2.3 Pleistocene Geological Units

2.3.1 The deeper Pleistocene formations preserved beneath tranches A & B of Dogger Bank comprise a variety of sedimentary units including marine and intertidal sediments, glacial (till) and terrestrial soils (Table 2.1). It is likely that all of the units listed in Table 2.1 approach within 50m of the seabed in tranches A and B.

Table 2.1. Stratigraphic summary of formations observed or believed to be present across Tranche B (source British Geological Survey, Norwegian Geotechnical Institute and RPS Energy).

Age	Formation Name	Composition / Sediment Type	Environment
Holocene	Bligh Bank	Medium to fine sand	Marine
	Indefatigable Grounds	Gravelly sand and sandy gravel	Marine
	Nieuw Zeeland Gronden – Terschellinger Bank Member	Fine sand with shell fragments	Marine
	Well Hole	Fine sand and sandy mud	Shallow Marine
	Elbow	Peat followed by clay followed by muddy fine sand	Fluvial to Intertidal
	Transitional	Various	Sub-glacial to Pro-glacial
	Botney Cut	Mud with cobble patches	Sub-glacial
Pleistocene	Dogger Bank	Clay diamicton	Sub-glacial and Pro-glacial
	Eem	Shelly sand and muddy sand	Marine
	Tea Kettle Hole	Fine sand with organics	Periglacial and Aeolian
	Cleaver Bank	Laminated clay and fine sand	Marine to Pro-glacial
	Egmond Ground	Gravelly sand with interbeds of clay and silt	Marine
	Swarte Bank	Diamicton followed by mud then clay	Sub-glacial to Pro-glacial
	Yarmouth Roads	Fine to medium sand	Fluvial to Intertidal to Shallow Marine

2.3.2 The shallower Pleistocene units are dominated by the Dogger Bank Formation, which rests unconformably on the underlying formations. It comprises two main units; Older Dogger Bank and Younger Dogger Bank, both of which are clay-rich formations with multiple sand-rich layers, of glacial origin (Table 2.1). The Dogger Bank Formation is present at or near the seabed, underlying Holocene sands, and in some areas underlying the channel infills of the Botney Cut Formation.

2.3.3 In Tranche B, the Older Dogger Bank unit comprises a series of pro-glacial morainic ridges in the west, oriented approximately northeast-southwest. The unit then thins across the central part of Tranche B before thickening again to the eastern side. The overlying Botney Cut Formation is composed of pro-glacial lake deposits that infill a basin in the Younger Dogger Bank unit. These sediments are thinly laminated clays with laminae of silts and fine sand.

2.3.4 To the south and west of Dogger Bank (and along the Dogger Bank Teesside A & B export cable corridor), the Dogger Bank Formation passes laterally into the Bolders Bank Formation (Cameron et al., 1992). The Bolders Bank Formation is a sub-glacial to pro-glacial diamicton laid down during the late Pleistocene glaciation (Cameron et al., 1992).

2.4 Post-glacial Processes

2.4.1 The peak of the last ice age, the Last Glacial Maximum occurred approximately 18,000 years ago. However, it wasn't until the start of the Holocene (11,700 years ago) that the glacial period ended and the northern hemisphere entered an interglacial period. At this time it is postulated that Dogger Bank was located towards the centre of a larger continental area, connected to mainland Europe, known as Doggerland (Coles, 2000; Gaffney et al., 2007, 2009).

2.4.2 During the Holocene, increased melting of the ice sheets released large volumes of water causing global sea levels to rise. As this rise occurred, the North Sea Basin was slowly inundated. Dogger Bank changed from being part of a land bridge connecting northwest Europe with mainland Britain to an island before finally flooding completely approximately 5,000–6,500 years ago (Shennan et al., 2000) (Figures 2.1 and 2.2). The nature of this transition from continental to fully marine conditions resulted in a number of different depositional environments acting across Dogger Bank over a short space of time, from terrestrial, fluvial or wind-blown, through lacustrine, estuarine and brackish to fully marine.

2.5 Holocene Geological Units

2.5.1 The Dogger Bank is formed mostly from a core of Pleistocene sediment, but is surrounded and covered by a veneer of Holocene sediments that reach 10m thickness around its margins and greater than 25m thickness in infilled channels on the Bank itself. The majority of these sediments are relict, being derived from reworking of the underlying coarser glacial sediments during the marine inundation of the early Holocene

2.5.2 Although there are a few localised depressions in Tranche B where the Holocene sediments are greater than 25m thick, there is also a large area where Holocene sediment appears absent (<5-10cm in thickness), with older glacial deposits near to the seabed (Figure 2.3).

2.5.3 The Bligh Bank and Indefatigable Grounds Formations, and the Terschellinger Bank Member of the Nieuw Zeeland Gronden Formation (Rijsdijk et al., 2005), form the marine sands component of the Holocene deposits. However, there are two older units (Well Hole and Elbow Formations) that were also deposited in the Holocene that encompass the early stages of the inundation following the decline of the ice sheets across the North Sea Basin. Therefore, the oldest Holocene deposits are not marine sands but terrestrial tundra through to estuarine and intertidal sediments.

3 HYDRODYNAMIC PROCESSES

3.1 Astronomic Water Levels

3.1.1 The tidal ranges across the Dogger Bank Zone are relatively small. Mean spring tidal ranges are approximately 1.0-2.5m and mean neap tidal ranges less than 1.5m (BERR, 2008) (Figures 3.1 and 3.2). Tidal range is higher in the western part of the Dogger Bank Zone and lower in the east. Mathiesen et al. (2011) estimated mean high water spring tide (MHWST), highest astronomical tide (HAT) and lowest astronomical tide (LAT) at eight locations (Figure 1.7) across Dogger Bank (Table 3.1). The data supports that of BERR (2008) and shows that the tidal range is greater across the western Dogger Bank Zone (locations 1, 2, 3 and 5) than across eastern areas.

Table 3.1. Elevation of highest astronomical tide (HAT) at eight locations across Dogger Bank (Mathiesen et al., 2011). Locations are shown in Figure 1.7.

	Elevation (m relative to mean sea level)			
Location	**MHWST**	**HAT**	**LAT**	**Range (LAT-HAT)**
1	1.15	1.50	-1.60	3.10
2	1.10	1.45	-1.55	3.00
3	0.95	1.30	-1.35	2.65
4	0.65	0.90	-0.95	1.85
5	0.95	1.30	-1.35	2.65
6	0.70	0.95	-0.95	1.90
7	0.60	0.80	-0.85	1.65
8	0.50	0.65	-0.65	1.30

3.2 Storm Surge and Extreme Water Levels

3.2.1 The effects of wind and pressure can influence astronomic water levels, either elevating levels above ('positive surge') or depressing levels below ('negative surge') the predicted astronomic values. Mathiesen et al. (2011) obtained information on storm surges from the NEXTRA hindcast database and showed a 50-year storm surge of 1.5m relative to mean sea level at all eight locations.

3.3 Tidal Currents

3.3.1 Dogger Bank is influenced by cool Atlantic water masses arriving from the north and warmer inflow from the English Channel to the south, resulting in the creation of a front (Flamborough Front) where these two masses meet. Therefore, Dogger Bank is subject to a relatively complex regime of low velocity tidal currents and eddies.

Admiralty Tidal Streams

3.3.2 Admiralty chart tidal streams show velocity maxima for the Dogger Bank Zone between 0.2ms^{-1} and 0.6ms^{-1}, with higher velocities in the west (Admiralty Charts 266, 268 and 1191). BERR (2008) modelled mid-depth peak flows for mean spring tides of between approximately 0.2 and 0.4ms^{-1} and mid-depth peak flows for mean neap tides between 0.1 and 0.2ms^{-1} (Figures 3.3 and 3.4).

Modelled Points

3.3.3 Mathiesen and Nygaard (2010) analysed depth-averaged current data at eight locations across the Dogger Bank Zone (Figure 1.7). The data were available from numerical computations performed by the Danish Hydraulic Institute (DHI). The currents cover the six-year period from 1st January 1989 to 31st December 1994 with a sampling interval of one hour. Current roses for each of the eight locations show variability in the predominant tidal flows (Figures 3.5 to 3.7). At locations 1, 2 and 3 (Tranche A, Figure 3.5), the predominant flow directions are north and south with subordinate currents flowing south-southeast and north-northwest. Mean current velocities are 0.14-0.30ms^{-1} with maximum velocities of 0.41-0.91ms^{-1} (Tables 3.2 and 3.3).

3.3.4 At location 4 (Tranche B, Figure 3.6), the predominant flow directions are north-northwest and south-southeast with subordinate east-southeast and west-northwest directions. Mean current velocities are 0.15-0.21ms^{-1} with maximum velocities of 0.46-0.88ms^{-1} (Tables 3.2 and 3.3).

Table 3.2. Mean depth-averaged tidal current velocities (ms^{-1}) at eight locations across Dogger Bank (Mathiesen and Nygaard, 2010). Locations are shown in Figure 1.7.

Location	Direction (Degrees north)											
	0	30	60	90	120	150	180	210	240	270	300	330
1	0.30	0.22	0.16	0.14	0.17	0.25	0.30	0.20	0.15	0.14	0.16	0.23
2	0.30	0.21	0.16	0.15	0.19	0.28	0.30	0.18	0.14	0.14	0.18	0.26
3	0.27	0.21	0.17	0.16	0.18	0.25	0.27	0.19	0.15	0.14	0.17	0.23
4	0.19	0.18	0.17	0.17	0.19	0.21	0.21	0.16	0.15	0.16	0.18	0.21
5	0.25	0.22	0.15	0.13	0.14	0.19	0.24	0.22	0.15	0.12	0.13	0.17
6	0.20	0.18	0.15	0.15	0.16	0.19	0.20	0.17	0.15	0.14	0.14	0.18
7	0.18	0.18	0.16	0.16	0.17	0.19	0.19	0.16	0.15	0.15	0.16	0.18
8	0.13	0.12	0.13	0.14	0.15	0.14	0.12	0.12	0.13	0.13	0.13	0.12

Table 3.3. Maximum depth averaged tidal current velocities (ms^{-1}) at eight locations across Dogger Bank (Mathiesen and Nygaard, 2010). Locations are shown in Figure 1.7.

Location	Direction (Degrees north)											
	0	30	60	90	120	150	180	210	240	270	300	330
1	0.66	0.66	0.48	0.45	0.60	0.81	0.82	0.63	0.42	0.39	0.41	0.59
2	0.67	0.69	0.54	0.52	0.73	0.91	0.88	0.68	0.41	0.41	0.44	0.63
3	0.61	0.66	0.63	0.53	0.68	0.84	0.82	0.64	0.41	0.42	0.42	0.59
4	0.58	0.65	0.68	0.64	0.76	0.88	0.77	0.59	0.48	0.46	0.48	0.54
5	0.54	0.52	0.40	0.38	0.43	0.62	0.67	0.57	0.36	0.28	0.30	0.43
6	0.55	0.62	0.55	0.51	0.62	0.72	0.71	0.54	0.44	0.39	0.44	0.50
7	0.58	0.66	0.59	0.55	0.67	0.77	0.72	0.51	0.51	0.46	0.47	0.48
8	0.44	0.43	0.38	0.49	0.55	0.56	0.51	0.35	0.41	0.41	0.40	0.40

3.3.5 Locations 5 to 8, to the north of tranches A & B (Figure 3.7), describe different current regimes to locations in tranches A & B. At location 5 the predominant flow directions are north and south with subordinate currents flowing north-northeast and south-southwest. Mean current velocities range from 0.13 to 0.25ms^{-1} and maximum current velocities from 0.28 to 0.67ms^{-1}. Location 6 is similar to the Tranche A locations, but mean current velocities are lower at less than 0.20ms^{-1}. Location 7 describes a current regime with no distinctive predominant direction. Mean current velocities are low (0.15-0.19ms^{-1}) and distributed across all directional sectors (Figure 3.7). At location 8, the predominant current directions are east, west, east-northeast and west-southwest. Mean current velocities are the lowest of all the locations, between 0.12 and 0.15ms^{-1} with maximum velocities up to 0.56ms^{-1} (Tables 3.2 and 3.3).

Forewind Operating Buoys

3.3.6 Gardline (2011c) provided statistics of the data series for the Forewind current profiler (Figure 1.7) between its deployment and the end of October 2011 (Table 1.1). Summaries were provided for the first (7th November 2010 to 21st January 2011) and third (31st July 2011 to 24th October 2011) periods of operation. The second period of only 19 days (5th July 2011 to 24th July 2011) cannot provide comparable statistics with any reliability. Gardline (2011c) provided surface current roses for the two periods which are shown in Figure 3.8.

3.3.7 Mathiesen et al. (2011), in an updated version of Mathiesen and Nygaard (2010), compared the modelled tidal current data to the current data recorded during the first period at the northern buoy (Figure 3.8). They argued that the directional information provided by the model was lower quality compared to the measured current data and did not present the modelled current roses in their updated report. It is difficult to reconcile this comparison given the following two factors:

- the water depth at the northern buoy is 55m, which is a deeper water and more northerly location than much of Dogger Bank; and
- the measured data do not overlap with the modelled point data.

Hence, the comparison of the two datasets and the rejection of the modelled data as low quality compared to the measured data by Mathiesen et al. (2011) would appear invalid.

3.4 Extreme Tidal Current Velocities

3.4.1 Mathiesen and Nygaard (2010) estimated extreme tidal current velocities at eight locations across Dogger Bank (Figure 1.7). The maximum extreme velocities for return periods of one, ten and 100 years were $0.88ms^{-1}$, $0.98ms^{-1}$ and $1.11ms^{-1}$, respectively (Appendix A).

3.5 Wind

3.5.1 The wind regime of the North Sea is characterised by frontal depressions and anti-cyclones (high pressure). Wind roses for the area directly south of Tranche A, show southwesterly prevailing winds between October and January (Metoc, 2004). These winds are typically classified on the Beaufort Scale as force 4-6 (moderate-strong breeze). However, a proportion of values exceed this, reaching force 9-12 (gale-hurricane). In April, there are a greater proportion of winds from the northeast, with generally calmer winds.

3.5.2 Mathiesen et al. (2011) compiled wind data for eight locations within the Dogger Bank Zone. Wind data was used from the Hirlam10 hindcast model operated by the Norwegian Meteorological Institute, covering the period 1958-2008 (51 years), with a sample interval of three hours. The Hirlam10 wind data was found to be good quality for wind speeds up to about $15ms^{-1}$. Wind speeds higher than this were underestimated. Consequently, wind speeds higher than $15ms^{-1}$ were adjusted (corrected) prior to analysis. The Hirlam10 wind data are one-hour averages 10m above sea level. The 10m wind speed was transformed into wind speed 100m above sea level using the wind profile formulae (Table 3.4).

Table 3.4. Mean and maximum one-hour average wind speed 100m above sea level at eight locations across Dogger Bank (Mathiesen et al., 2011).

Location	Mean wind speed (ms^{-1})	Maximum wind speed (ms^{-1})
1	10.11	34.2
2	10.11	33.6
3	10.13	33.7
4	10.15	34.3
5	10.15	33.9
6	10.17	34.6
7	10.16	34.3
8	10.20	35.5

3.6 Significant Wave Heights

3.6.1 Given its open sea location Dogger Bank is exposed to relatively high levels of wave energy. According to IACMST (2005), mean significant wave height (average height of the highest one third of waves - H_S) averaged across Dogger Bank varies seasonally from 1-1.5m in summer to 2-2.5m in winter. BERR (2008) described annual mean significant wave heights of 1.75-2.0m, which varied seasonally from 1.25-1.5m in summer to 2.25-2.75m in winter (Figures 3.9 and 3.10).

3.6.2 Mathiesen et al (2011) compiled wave data for eight locations within the Dogger Bank Zone (Figure 1.7). Data was available from the Wam10 hindcast model operated by the Norwegian Meteorological Institute, covering wave data from 1958 to 2008 with a sample interval of three hours. Their results show that most waves approach the site from the north and north-northwest sectors (Figures 3.11 to 3.13) with mean significant wave heights from 1.68-1.89m (Tables 3.5 and 3.6). The largest waves reach maximum significant wave heights between 10.2 and 11.9m (Table 3.6).

Table 3.5. Mean significant wave height (m) at eight locations across Dogger Bank (Mathiesen et al., 2011). Locations are shown in Figure 1.7.

Location	Direction (Degrees north)											
	0	30	60	90	120	150	180	210	240	270	300	330
1	1.6	1.2	1.4	1.5	1.5	1.5	1.7	1.9	1.9	2.0	1.9	2.0
2	1.5	1.2	1.4	1.5	1.5	1.5	1.6	1.9	1.9	2.0	1.9	2.0
3	1.6	1.2	1.4	1.5	1.5	1.5	1.7	1.9	2.0	2.0	1.9	2.0
4	1.5	1.2	1.4	1.5	1.6	1.5	1.7	1.9	2.0	2.0	1.9	2.0
5	1.7	1.2	1.5	1.6	1.6	1.5	1.7	2.0	2.0	2.1	2.0	2.1
6	1.6	1.2	1.5	1.6	1.6	1.5	1.7	2.0	2.0	2.1	2.0	2.1
7	1.5	1.2	1.5	1.6	1.6	1.5	1.7	1.9	2.0	2.1	2.0	2.0
8	1.6	1.3	1.6	1.7	1.8	1.6	1.8	2.0	2.1	2.3	2.1	2.2

Table 3.6. Maximum significant wave height (m) at eight locations across Dogger Bank (Mathiesen et al., 2011). Locations are shown in Figure 1.7.

Location	Direction (Degrees north)												Mean	Max
	0	30	60	90	120	150	180	210	240	270	300	330		
1	10.5	6.3	6.4	5.9	5.7	5.9	6.6	7.3	8.3	7.9	8.1	9.1	1.71	10.5
2	10.2	6.0	6.2	5.7	5.5	5.7	6.4	7.1	8.1	7.8	8.1	8.7	1.68	10.2
3	10.6	6.1	6.3	5.8	5.6	5.7	6.3	7.1	8.4	8.2	8.4	9.2	1.71	10.6
4	10.5	5.8	6.1	5.7	5.5	5.0	6.3	6.9	8.5	8.8	8.5	10.7	1.71	10.7
5	11.2	6.9	6.7	6.5	6.3	6.1	7.0	7.8	9.3	8.8	9.0	10.0	1.80	11.2
6	11.5	6.4	6.5	6.2	5.9	6.0	6.5	7.3	9.3	9.4	9.1	10.3	1.80	11.5
7	10.9	6.0	6.3	6.0	5.8	5.4	6.5	7.0	8.9	9.5	8.9	11.4	1.78	11.4
8	11.1	6.3	6.7	6.9	6.3	5.8	7.2	7.9	10.3	10.7	9.8	11.9	1.89	11.9

3.6.3 Mathiesen et al. (2011) noted that the wave conditions at Dogger Bank are affected by variations in bathymetry (changes in direction and height due to varying bathymetry and changes in height due to shoaling), which are not described by the Wam10 hindcast model. This means that 'actual' wave conditions are likely to differ from the wave conditions described by the Wam10 model. They indicated that wave heights at some locations may have uncertainties of 10-20%.

3.6.4 Mathiesen et al. (2011) compared the modelled data to measured data from 2010 at the two buoys operating at the time (northern buoy and Tranche A buoy) (Figure 1.7) and found good agreement. Gardline (2011c) presented wave roses for the Tranche A waverider buoy for time series between 23rd September 2010 and 19th May 2011 and for the northern buoy between 6th November 2010 and 31st October 2011 (Figure 3.14). For the Tranche A buoy, the mean significant wave height for the time series period was 1.71m and the maximum value was 6.04m. A comparison with the measured data from Tranche B has not been carried out.

3.7 Extreme Wave Heights and Periods

3.7.1 Mathiesen et al. (2011) estimated extreme wave conditions at eight locations across Dogger Bank (Figure 1.7). The maximum extreme significant wave heights for return periods of one, ten and 50 years were 8.0m, 10.2m and 11.7m, respectively (Appendix B). The longest one year wave period was

12.9 seconds increasing to 15.6 seconds for a 50 year event. In general, the highest waves have the longest periods.

3.7.2 Mathiesen et al. (2011) noted that due to refraction and shoaling, the extreme wave heights at some locations may differ from the values they provided, which are based solely on the Nora10 archive. They estimated the uncertainty in the extreme significant wave heights to be 10-15% with the greatest uncertainty in the western part of Dogger Bank (west of locations 3 and 5).

3.8 Sea-level Rise

3.8.1 Global sea level is primarily controlled by three factors; thermal expansion of the ocean, melting of glaciers and change in the volume of the ice caps of Antarctica and Greenland. Observed or projected changes in global sea level take into account the elevation of the water surface, caused by changes in the volume of the oceans, but do not take into account changes in land (seabed) level. At a local scale, the elevation of the sea surface relative to the land is known as relative sea level.

3.8.2 The Intergovernmental Panel on Climate Change (IPCC, 2007) estimated a global average sea-level rise over the 20th century of between 1.2 and 2.2mmyr^{-1} with an average value of 1.7mmyr^{-1}. Between 1961 and 2003, the rate was estimated at 1.8mmyr^{-1} (1.3-2.3mmyr^{-1}) rising to 3.1mmyr^{-1} (2.4-3.8mmyr^{-1}) between 1993 and 2003.

3.8.3 As climate change takes effect and the earth warms, sea level will continue to rise. Central estimates (50th percentile) of projected future relative sea-level rise for the northern Holderness coast (the nearest coastal location to tranches A & B) up to 2100 reported by the UK Climate Impacts Programme (UKCIP, 2009) ranged from 0.4m for the low emissions scenario to 0.6m for the high emissions scenario (relative to a 2009 baseline), with rates of change increasing during the second half of the 21st century (Table 3.7). Since these potential changes in sea level will occur over the expected life time of the proposed Dogger Bank wind farm, it is necessary to anticipate greater water depths.

Table 3.7. Summary statistics of 21st century relative sea-level rise at northern Holderness (relative to 2009 levels) (UKCIP, 2009).

Year	Relative Sea-Level Rise (m)		
	Low Emissions	Medium Emissions	High Emissions
2025	0.10	0.13	0.14
2050	0.19	0.20	0.26
2100	0.40	0.48	0.57

4 SEDIMENTARY PROCESSES AND GEOMORPHOLOGICAL CHANGE

4.1 Bathymetry

Dogger Bank Zone

4.1.1 Within the Dogger Bank Zone, water depths range from approximately 78m below LAT along the northern edge to just less than 20m below LAT in the southwest (Tranche A) and generally between 25-35m below LAT in the southeast (Tranche B) (Figure 4.1). Although the seabed deepens to 50m below LAT in the north, the slopes are generally less than 2%. Occasionally, local gradients in excess of 8% may occur over small bathymetric features.

Tranche A

4.1.2 GEMS (2012) mapped the bathymetry of Tranche A in more detail than the Dogger Bank Zone, dividing it into three main zones:

- Less than 20m below LAT; very small areas mainly occurring in the southwest of Tranche A at the summit of ridge forms or the crests of sand waves (Figure 4.2).
- Between 20 and 30m below LAT; these depths dominate Tranche A where the seabed is generally low relief compared to deeper areas.
- Between 30 and 40m below LAT; these depths occur at the base of valley forms in the north and southwest of Tranche A.

4.1.3 Slopes across Tranche A are all less than 10% with the predominant slopes being less than 2% (Gardline, 2011a). Steeper slopes may delineate the position of the valleys across the north and southwest of Tranche A. Low relief occurs across the east-central portion of the Tranche (Figure 4.2).

Tranche B

4.1.4 Gardline (2013a) mapped the bathymetry of Tranche B in more detail than the Dogger Bank Zone and divided it into three main zones:

- Less than 25m below LAT; predominantly in the form of a plateau in the southeast of Tranche B.
- Between 25 and 35m below LAT; these depths dominate most of Tranche B; the seabed here is generally low relief, with gradients of less than three degrees.
- Greater than 35m below LAT; these depths occur in the north of Tranche B in the form of northwest to southeast elongated gullies up to 6m deep with gradients up to six degrees along their sides.

4.2 Seabed Sediments

Sand

4.2.1 Diesing et al. (2009) showed that 80% of the seabed of Dogger Bank is fine sand (classified as sand, slightly gravelly sand and gravelly sand) with mud content less than 5% (Figure 4.3). This general distribution is supported by both the Dogger Bank Zone geophysical analysis (RPS Energy, 2010; Gardline, 2011a) and the geophysical analysis of both tranches A & B (GEMS, 2012; Gardline, 2012a).

4.2.2 In Tranche A, the majority of seabed sediments are slightly gravelly sand, sand and gravelly sand (GEMS, 2012) (Figure 4.4). Particle size analyses of seabed sand samples show that the medium particle diameter (d_{50}) falls predominantly between 0.15mm and 0.22mm (fine sand) with a few samples in the medium to coarse sand categories (Appendix C) (EMU, 2013). Most of the seabed sand samples contain less than 5% gravel and less than 5% mud, and can be categorised as slightly gravelly sand.

4.2.3 In Tranche B, the majority of seabed sediments are slightly gravelly sand with areas of gravelly sand and sand (Figure 4.4). Particle size analysis of seabed sand samples in Tranche B indicate that the medium particle diameter (d_{50}) is predominantly between 0.16mm and 0.19mm (fine sand) (Gardline, 2013b). There are also a few samples which fall into the coarse sand to medium gravel categories (Appendix D). The majority of seabed samples in Tranche B contain less than 5% gravel, and all but two contain less than 2% mud.

Gravel

4.2.4 Diesing et al. (2009) showed that 20% of the Dogger Bank seabed is gravelly sediment classified as gravel, sandy gravel and muddy sandy gravel (Figure 4.3). The gravel occurs as patches in slight topographic depressions across the shallowest southern and western parts of Dogger Bank usually in water depths of less than 40m. RPS Energy (2010) and Gardline (2011a) described occasional, small patches of gravelly sediments occurring throughout the sandy areas of the Dogger Bank Zone.

4.2.5 GEMS (2012) showed that gravel and sandy gravel occurs predominantly in north-south oriented 'strips' across the northwest and southwest of Tranche A (Figure 4.5), corresponding with deeper valleys in the bathymetry (Figure 4.2). Surface gravel covers approximately 7% or 135km^2 of Tranche A. Seabed sediment samples from the gravel areas of Tranche A show variable median particle diameters (d_{50}) ranging from 2.4mm to 50mm with gravel percentages ranging from 31% to 89% (Appendix C) (EMU, 2013). The mud content of the gravel areas is less than 5%.

4.2.6 In Tranche B, there are patches of gravel in the east and southeast (Figure 4.5). Seabed sediment samples from the gravel areas of Tranche B show median particle diameters (d_{50}) between 1.8mm and 10.5mm, with gravel percentages between 49% and 93% (Appendix D) (Gardline, 2013b). The mud content for the gravel areas in Tranche B is mainly less than 2%, however one sample of 7.2% mud content is also recorded (Appendix D).

Mixed Sediment

4.2.7 GEMS (2012) identified areas in Tranche A that they classified as 'mixed' sediment, composed of sand, gravel and diamicton, none of which dominates

(Figure 4.6). 'Mixed' sediment occurs mainly across the west and southwest of Tranche A and covers approximately 4% or 82km^2. There were no areas of 'mixed sediment' identified in Tranche B (Figure 4.6).

Outcrop of the Dogger Bank Formation

4.2.8 The bathymetry across the west and southwest of Tranche A and the central north and west of Tranche B describes a series of north-south, north-northwest to south-southeast and northwest to southeast oriented valleys (Figure 4.2) where seabed sediments are thin and the Dogger Bank Formation is exposed at the seabed (Figure 4.7). The outcrop of Dogger Bank Formation is closely associated with the gravel and mixed sediment substrates (Figures 4.5 and 4.6).

4.3 Bedforms

4.3.1 The Dogger Bank Zone seabed is largely benign and featureless because tidal current velocities are low (Section 3.3). However, sand waves (wavelengths greater than 25m) and megaripples (wavelengths between 0.5 and 25m) sculpted into both gravel and sand substrates are present in patches across Tranche A (Figure 4.8) (GEMS, 2012). In Tranche B, there is a field of megaripples formed in gravelly sand (Figure 4.8); there are no sand waves identified. Gardline (2013a) describe the presence of discrete elliptical and circular depressions within Tranche B.

Sand Waves in Tranche A

4.3.2 GEMS (2012) mapped patches of sand waves across Tranche A. They indicated that the bedforms were symmetrical (Figure 4.9) with wavelengths of 50-150m (average approximately 100m) and amplitudes up to 2m (average approximately 0.5m). Their crests are aligned in east-northeast to west-southwest directions, but their symmetrical nature suggests that they are not actively migrating in any one direction.

Megaripples

4.3.3 A large patch of megarippled sand (50km^2) populates the east-central part of Tranche A (GEMS, 2012) (Figure 4.8). Megaripples also populate the eastern margins of the gravel 'strips' (and some of the 'mixed' sediment areas) across the northwest and southwest of Tranche A. GEMS (2012) showed that the megaripples are asymmetrical with their steeper sides facing predominantly to the south-southeast. This indicates migration of the bedforms in a south-southeast direction. However, the crest orientation does vary locally to a more east-west direction.

4.3.4 Gardline (2013a) observed megaripples within the gravelly sand areas of Tranche B (Figure 4.8). The crests of the megaripples are aligned north-northwest to south-southeast and north to south, with amplitudes varying from 1.4m to 2.2m.

4.4 Bedload Sediment Transport

4.4.1 Connor et al. (2006) showed that parts of Dogger Bank are above the storm-wave base; hence, waves are able to disturb the seabed. According to Van der Molen (2002), sediment transport across Dogger Bank is driven mainly by waves (storms) with minor tidal influence; wave energy is more important than tidal currents in governing sediment mobilisation. Connor et al. (2006) showed the results of modelled maximum bed stress for tidal currents (a shearing force per unit area exerted on the seabed by water movements above the seabed) for the North Sea. Across Dogger Bank they categorised bed stress due to tidal currents as weak (0-1.8N/m^2). However, the presence of sand waves and megaripples shows that some sediment transport is driven by tidal currents.

4.4.2 Six wrecks have been identified across Tranche A (Wessex Archaeology, unpublished data). Four of these wrecks have no associated scour, whereas two have scour extending to the southeast (broad and shallow scour) and south-southeast (well defined for 80m). The lack of scour around four of the wrecks is consistent with limited sediment transport across Tranche A. Where scour has taken place, the location of the scour hollow is consistent with sediment transport to the south-southeast derived from bedform geometry.

4.4.3 Eight possible wrecks have been identified within Tranche B (Gardline, 2013). All identified wrecks show no real scour; however most sit within depressions of varying depths (Appendix E).

4.5 Suspended Sediment

4.5.1 Eisma (1981) mapped the general distribution of suspended sediment in the southern North Sea and found that Dogger Bank is characterised by values lower than 2mgl^{-1}. Eisma and Kalf (1987) carried out a water sampling programme in January 1980 and differentiated general surface concentrations from bottom concentrations. They showed that across Dogger Bank, the concentrations were similar at both elevations, ranging from 1mgl^{-1} across north Dogger Bank to 2mgl^{-1} across south Dogger Bank (Figure 4.10).

4.5.2 The main driving force for suspended sediment dynamics in the North Sea is turbulence induced by tidal currents and waves (Stanev et al., 2008). The fundamental mechanism controlling sediment re-suspension from the seabed is bed shear stress. Across Dogger Bank, Stanev et al. (2008) showed that during storm conditions, no clear correlation exists between Dogger Bank bed shear stress and suspended sediment concentrations. They conclude that the availability of re-suspendable sediment at the bed across Dogger Bank is limited.

5 POTENTIAL EFFECTS OF DEVELOPMENT

5.1 Introduction

5.1.1 This section briefly describes the key potential effects on physical and sediment transport processes. In the Environmental Impact Assessment scoping report for Dogger Bank Teesside A & B, Forewind (2012) outlined the potential effects on the physical environment from the wind farm.

5.2 Potential Effects during Construction

5.2.1 The construction phase of the wind farm has the potential to affect physical and sediment transport processes within and regional to tranches A & B. The activities in question are installation of the turbine foundations, laying of the inter-array cables and other construction activities (presence of plant and vessels), all of which may affect the wave climate, tidal current patterns and sediment transport processes. Over the construction period, there is the likelihood of discrete, short-term and potentially instantaneous disturbances of the seabed as a consequence of these localised construction activities. These disturbances have the potential to release seabed sediment into the water column which may result in the formation of sediment plumes. The level of disturbance will be a function of seabed type, the installation method and the hydrodynamic conditions that are able to disperse the suspended sediment.

5.2.2 The presence of construction infrastructure (such as jack-up barges, vessels and cable installation works) has the potential to result in temporary localised influences on the physical processes. These influences will not be expected to result in a significant impact on any related environmental parameter. Installation of foundations and inter-array cables will also cause disturbance to the seabed and generate additional suspended sediment into the water column. The mobilised sediment may then be transported away from the disturbance by waves and tidal currents. The seabed sediment distribution data and the bed shear stress to suspended sediment concentration relationship indicate that the quantities of sediment that can be suspended from Dogger Bank are small.

5.3 Potential Effects during Operation

5.3.1 The operation of the wind farm has the potential to affect physical and sediment transport processes. Foundations have the potential to change both wave climate and tidal current velocities and directions. Effects are most likely to manifest themselves in localised scour around the base of the turbine foundations, the scale of which will be dependent upon the foundation option deployed and the localised hydrodynamic conditions. Given the low current velocities across Dogger Bank compared to the relatively open wave conditions, it is likely that the main effect of the foundations will be on waves. Although, tidal current velocities across tranches A & B are low and not a driver of sediment transport in this area, it is possible that around each turbine foundation, velocities could accelerate, resulting in scour.

5.4 Potential Effects during Decommissioning

5.4.1 The effects during decommissioning will be similar to those described during the construction phase (unless the inter-array cables are left *in situ* in which case the effects will be less).

6 CONCLUSIONS

6.1.1 The conclusions regarding baseline conditions outlined below are selected based on how sensitive the particular parameter is to changes within tranches A & B of the Dogger Bank Zone. The baseline parameters that are most likely to be affected by construction and operation of the wind farm are suspended sediment and seabed sediment distribution, which are driven by tidal currents and waves. The geology of the near-seabed will be important in the design of the turbine foundations and cable installation.

6.1.2 **Suspended Sediment**: There is limited data on suspended sediment across Dogger Bank, suggesting that concentrations are very low (less than $2mgl^{-1}$). The low percentages of mud within the seabed sediments of Dogger Bank indicate that the availability of re-suspendable sediment at the bed is limited.

6.1.3 **Sediment Distribution and Transport**: The majority of the seabed sediments across tranches A & B are sand with smaller areas of gravel and exposed Dogger Bank Formation. The quantities of mud and gravel within these sediments are low (less than 5%). Some of this sediment has been sculpted into sand waves and megaripples in Tranche A and megaripples in Tranche B, but their geometry suggests that their migration across the seabed is limited. Overall, the sediment transport regime of tranches A & B is not dynamic.

6.1.4 **Tidal Currents**: Modelled and measured tidal currents flowing across the Dogger Bank Zone are relatively weak and spatially variable in direction. Across Tranche A, modelled directions are generally north to south and south to north with mean velocities of $0.14\text{-}0.30ms^{-1}$. Across Tranche B, modelled directions are generally north-northwest to south-southeast and south-southeast to north-northwest with mean velocities of $0.15\text{-}0.21ms^{-1}$.

6.1.5 **Waves**: The most frequent direction of wave approach is from the north. Waves have been modelled with mean significant wave heights of 1.7m to 1.9m, with the largest waves reaching maximum significant wave heights of 10m to 12m. The measured mean significant wave height (between September 2010 and May 2011) at tranches A & B is 1.7m with a maximum value of 6m.

6.1.6 **Geology**: The geology of the top 50m of the Dogger Bank Zone is dominated by the Dogger Bank Formation overlain by Holocene sand of varying thickness (up to 10m thick). The Dogger Bank Formation is a stiff to very stiff clay-rich diamicton forming the core of the Dogger Bank bathymetric high. Across tranches A & B, the Dogger Bank Formation outcrops at the seabed in numerous places.

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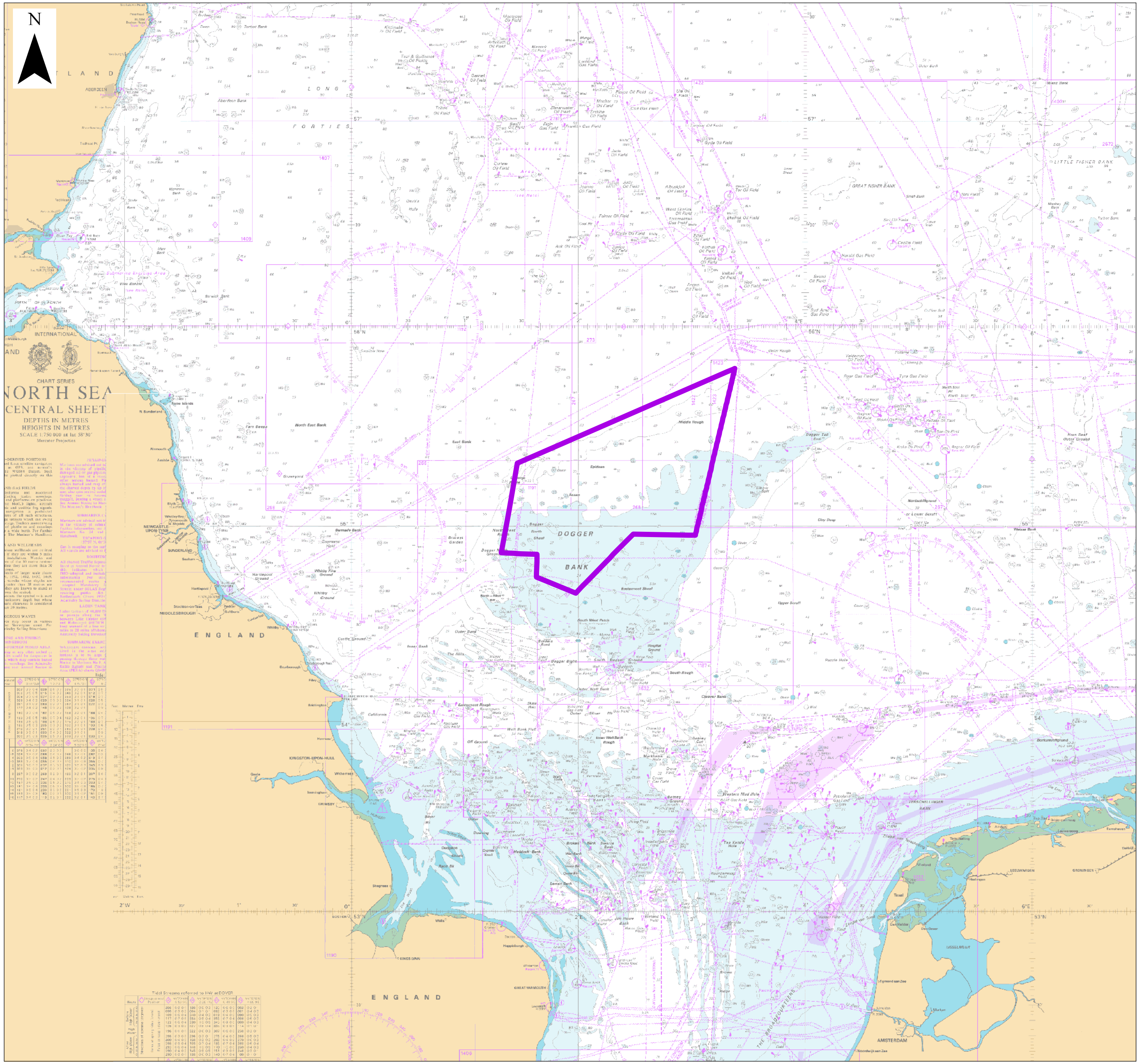
8 GLOSSARY

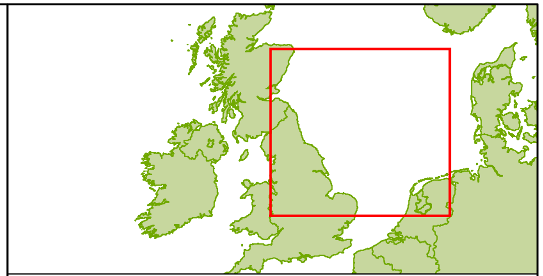
8.1.1 Table 8.1 provides a glossary of terms and abbreviations used in this conceptual model.

Table 8.1. Glossary of terms and abbreviations used in this conceptual model.

ADCP	Acoustic Doppler Current Profiler
AGDS	Acoustic Ground Discrimination
BERR	Department of Business, Enterprise and Regulatory Reform
cSAC	Candidate Special Area of Conservation
CPT	Cone Penetration Test
D_{50}	Median Particle Diameter
DHI	Danish Hydraulic Institute
IPCC	Intergovernmental Panel on Climate Change
JNCC	Joint Nature Conservation Committee
LAT	Lowest Astronomical Tide
UKCIP	UK Climate Impacts Programme
ZAP	Zone Appraisal and Planning

FIGURES





LEGEND

Dogger Bank Zone

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PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

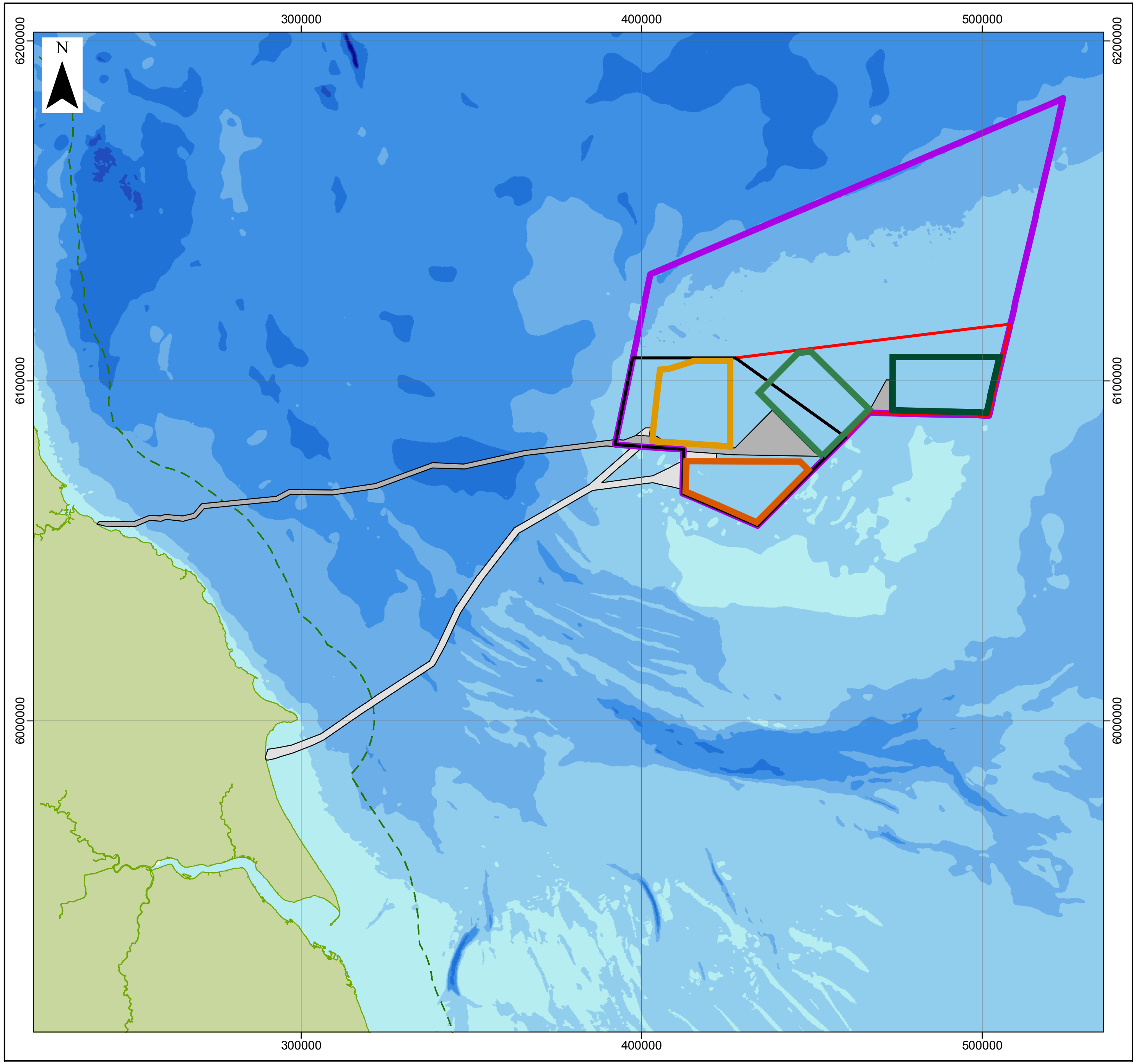
Figure 1.1 Location of Dogger Bank Zone

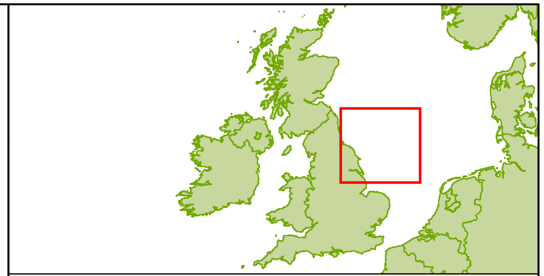
VER	DATE	REMARKS	Drawn	Checked
1	10/12/2012	Draft	FK	DB
2	12/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/001**

SCALE	Not To Scale	PLOT SIZE	A4	DATUM	OSGB36	PROJECTION	Mercator

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger BankTeesside A & B Export Cable Corridor
- Dogger Bank Creyke Beck A & B Export Cable Corridor
- 12nm Territorial Boundary

0 20 40
Kilometres

Data Source:
Round 3 © TCE, 2010,
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

Figure 1.2 Dogger Bank Zone Tranches A and B

VER	DATE	REMARKS	Drawn	Checked
1	10/12/2012	Draft	FK	DB
2	15/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/002**

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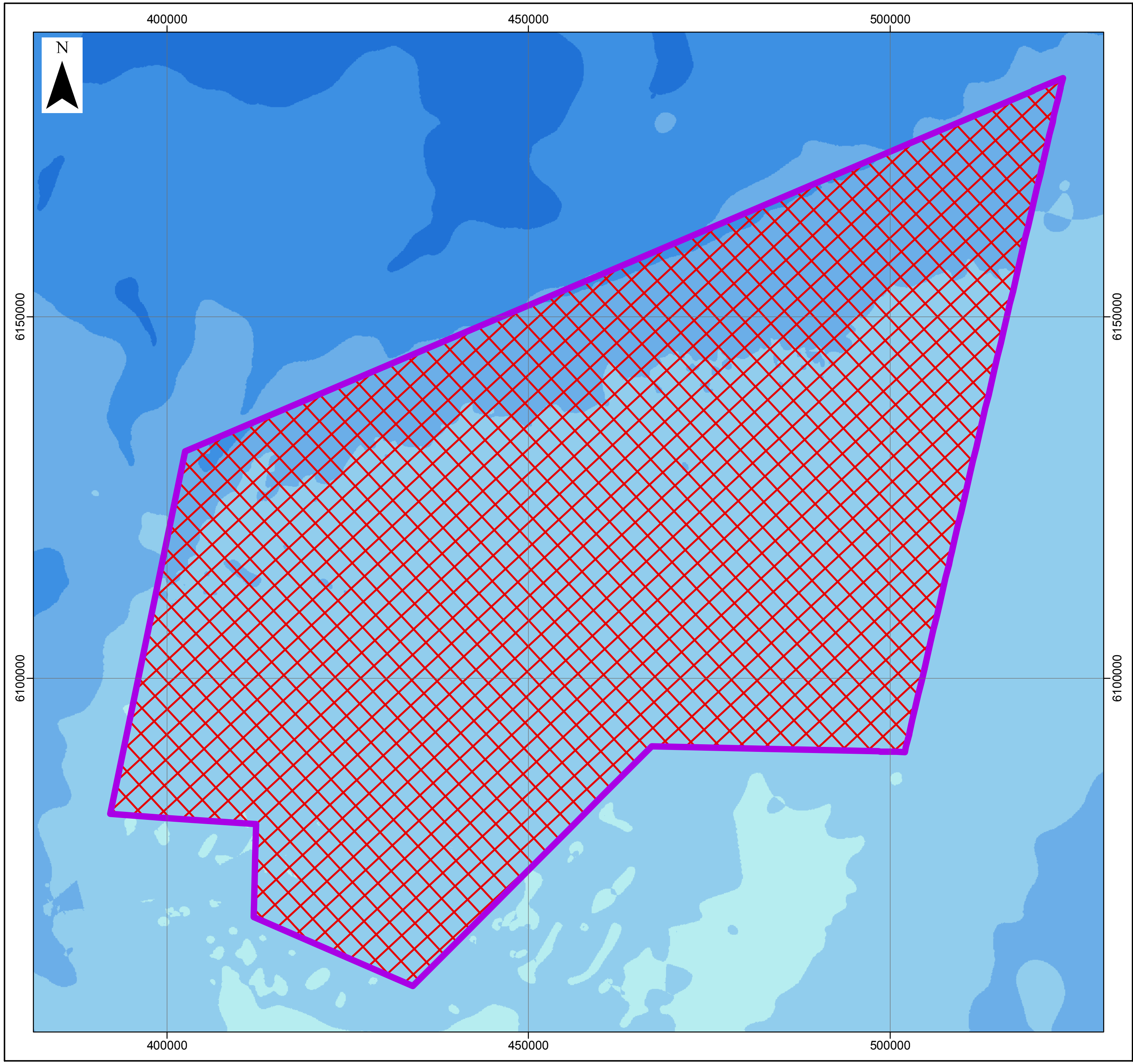
FOREWIND



LEGEND

Dogger Bank Zone

Survey Line

0 10 20
Kilometres

Data Source:
Round 3 © TCE, 2010,
Geophysical Survey Line from Gardline,
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

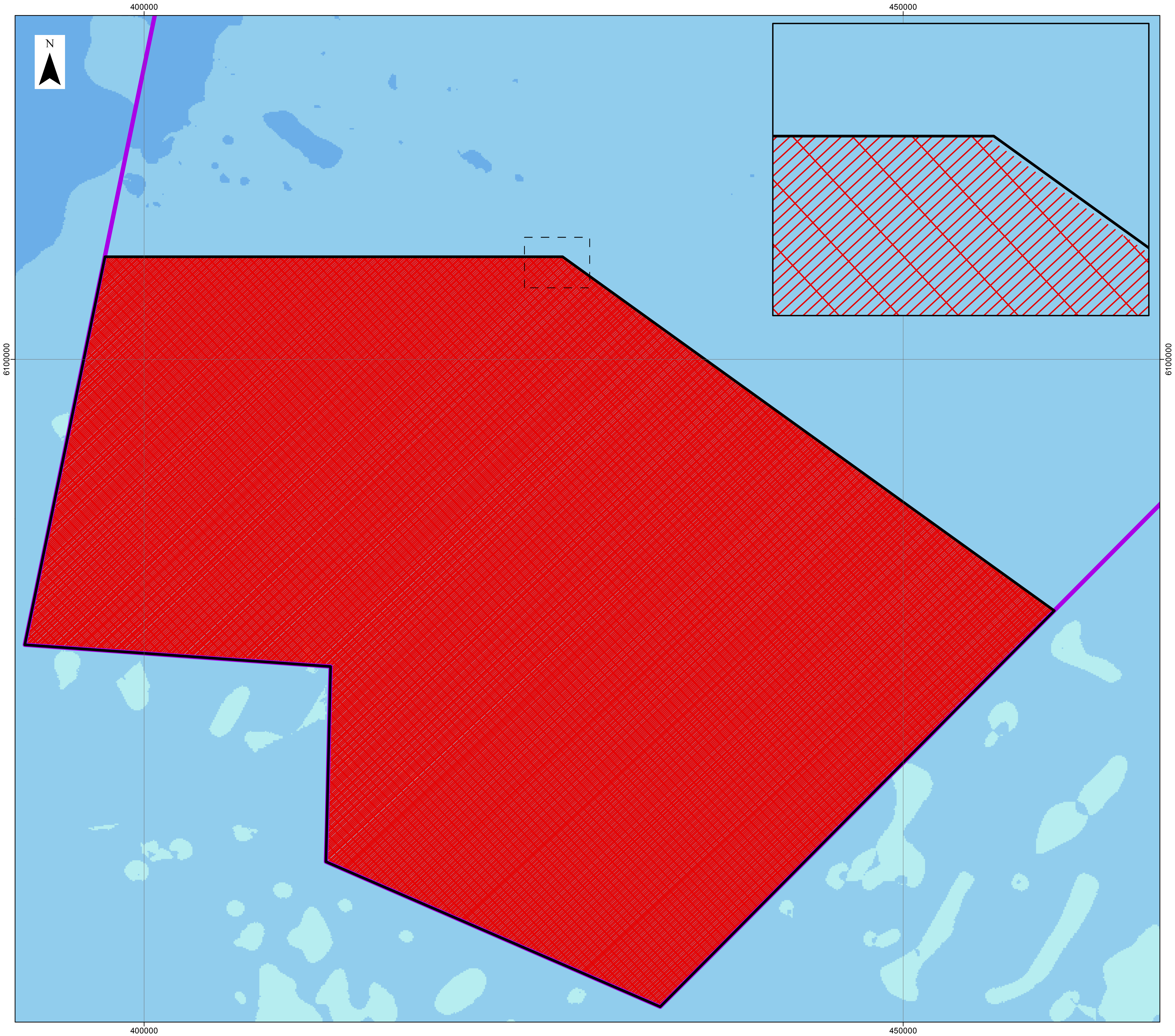
Figure 1.3 Dogger Bank Zone Geophysical Survey Lines

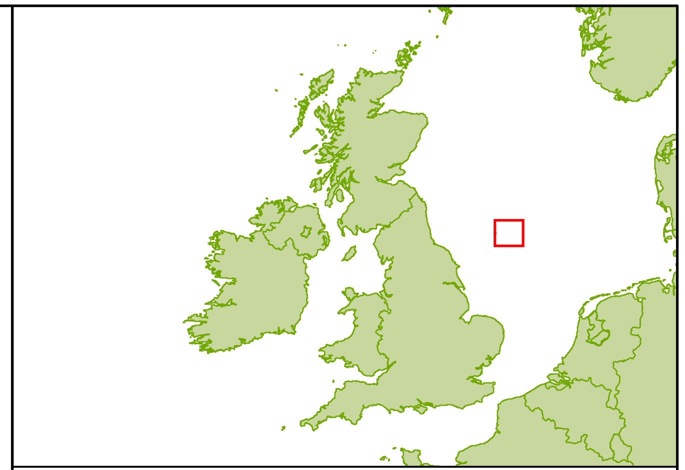
VER	DATE	REMARKS	Drawn	Checked
1	10/12/2012	Draft	FK	DB
2	12/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/003**

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

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Survey Line

0 5 10
Kilometres

Data Source:
Round 3 © TCE, 2010,
Geophysical Survey Line from GEMS,
Background bathymetry image derived in part from TCarta data © 2009

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DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

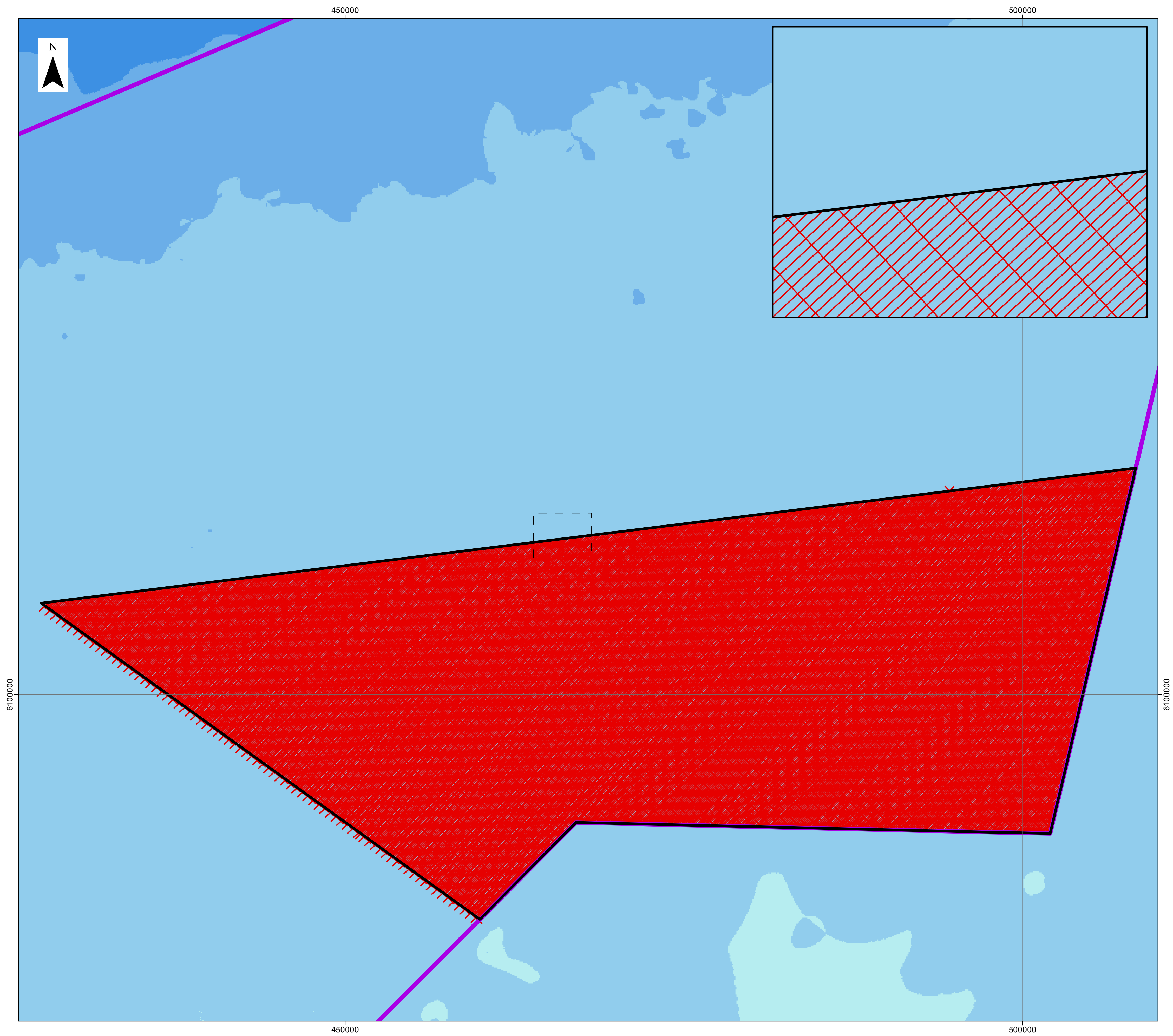
Figure 1.4 Tranche A Geophysical Survey Lines

VER	DATE	REMARKS	Drawn	Checked
1	10/12/2012	Draft	FK	DB
2	12/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/005**

SCALE	1:260,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND



Data Source:
Round 3 © TCE, 2010,
Geophysical Survey Line from Gardline,
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

Figure 1.5 Tranche B Geophysical Survey Lines

VER	DATE	REMARKS	Drawn	Checked
1	10/12/2012	Draft	FK	DB
2	12/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/004**

SCALE	1:290,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

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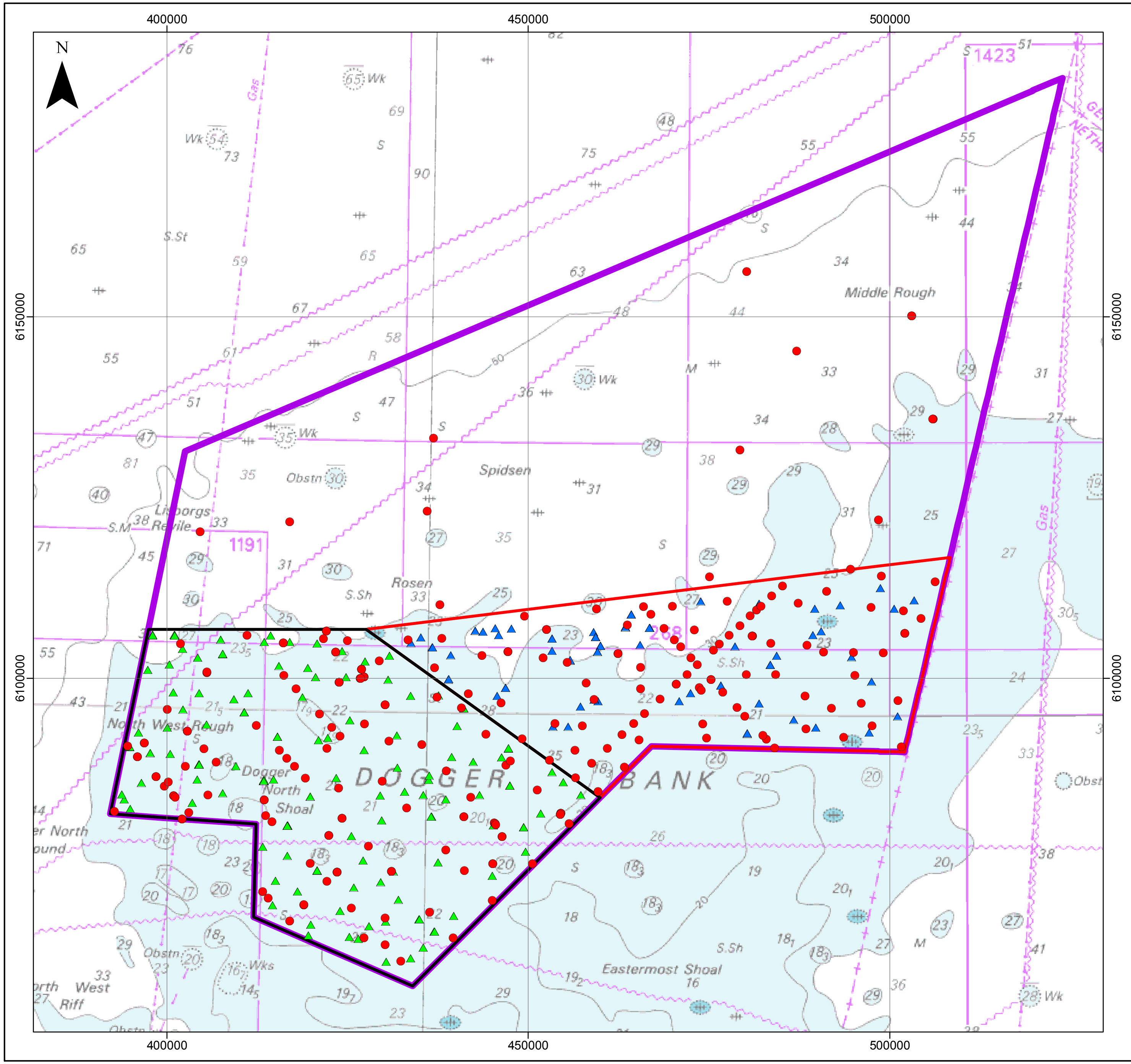

LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Geotechnical Sample Location
- Tranche A Seabed Sediment Sample Location
- Tranche B Seabed Sediment Sample Location

0 10 20
Kilometres

Data Source:
Round 3 © TCE, 2010,
Seabed Sediment Samples © Gardline, 2011,
Geotechnical Samples © Fugro, 2010, and GEO, 2012,
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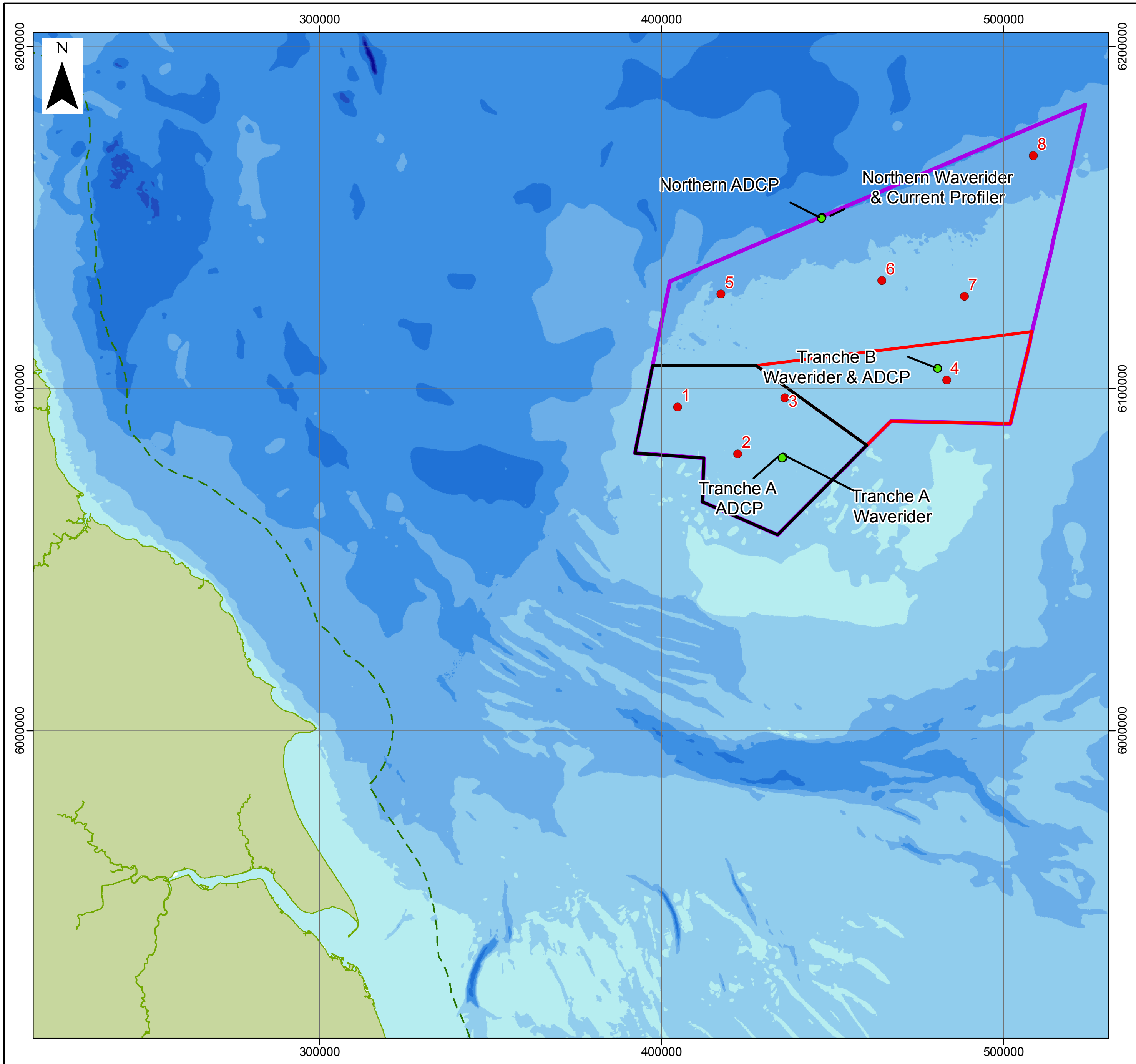
Figure 1.6 Sampling Locations

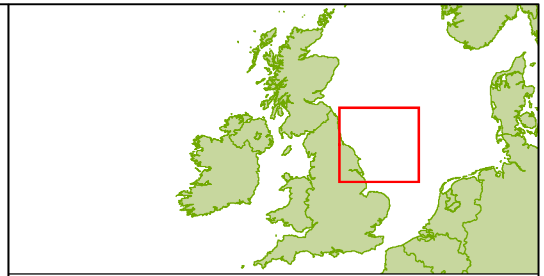
VER	DATE	REMARKS	Drawn	Checked
1	10/12/2012	Draft	FK	DB
2	12/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/006**

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

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- 12nm Territorial Boundary
- Modelled Metocean Location
- Forewind Metocean Deployments

0 20 40
Kilometres

Data Source:
Round 3 © TCE, 2010,
Forewind Operating Buoys © Gardline, 2012,
Background bathymetry image derived in part from TCarta data © 2009

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DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

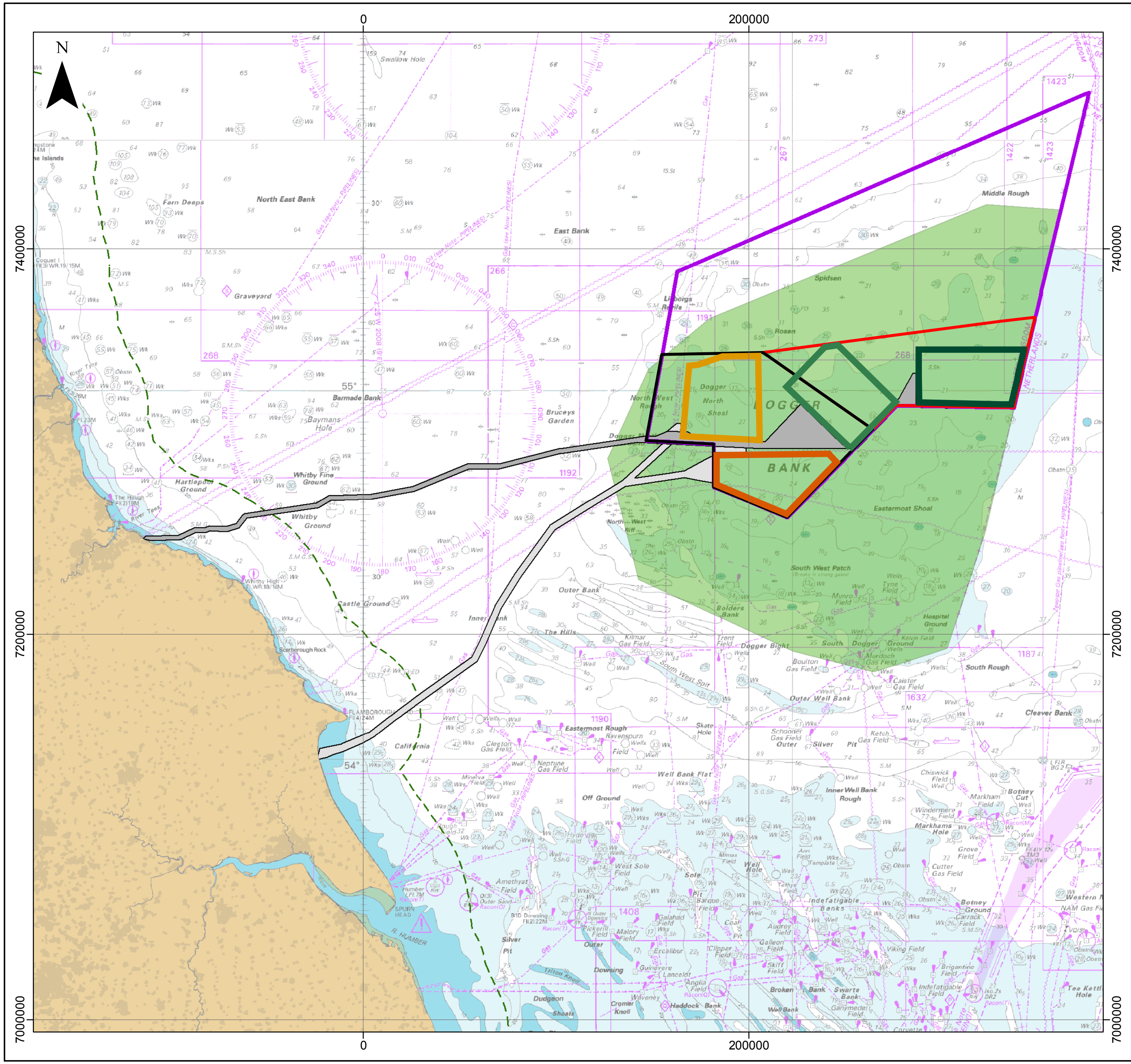
Figure 1.7 Metocean Data Points

VER	DATE	REMARKS	Drawn	Checked
1	10/12/2012	Draft	FK	DB
2	12/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/007**

SCALE	1:1,700,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND



LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- Dogger Bank Creyke Beck A & B Export Cable Corridor
- 12nm Territorial Boundary
- Dogger Bank Candidate Special Area of Conservation (cSAC)

0 50 100
Kilometres

Data Source:
Round 3 © TCE, 2010,
Environmental Designation © JNCC, 2012
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DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

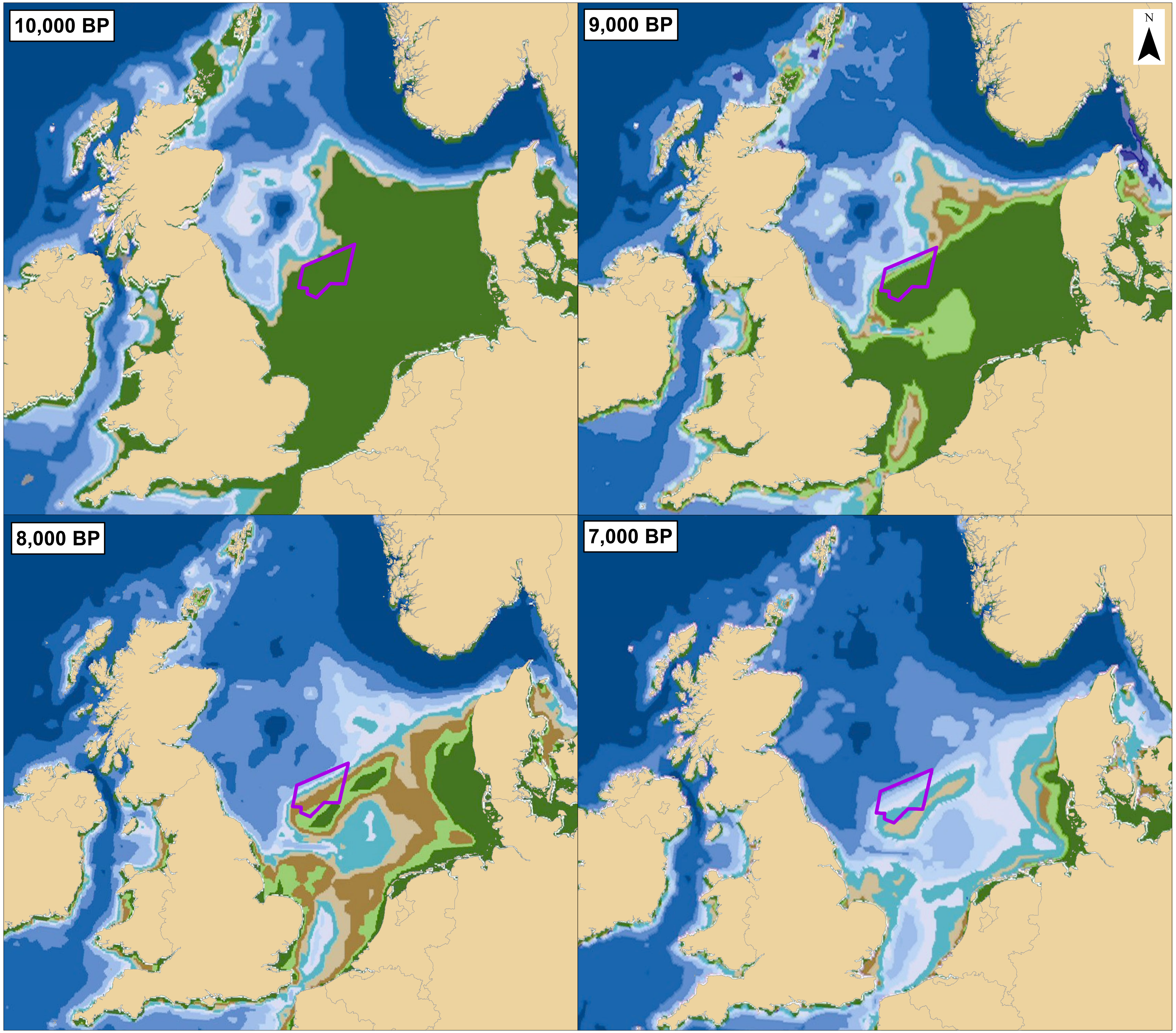
Figure 1.8 Dogger Bank Candidate Special Area of Conservation

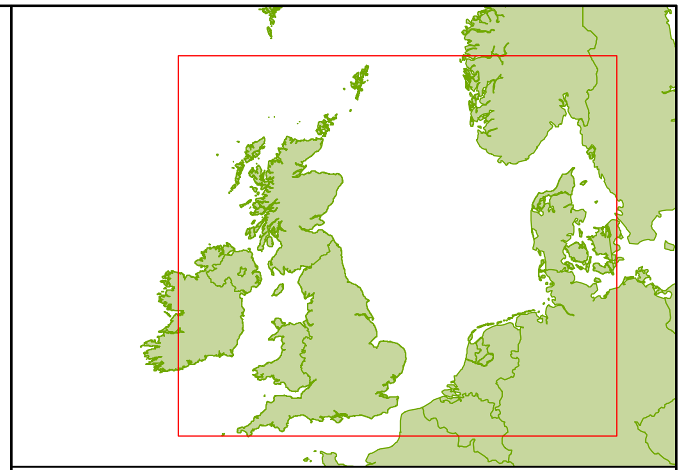
VER	DATE	REMARKS	Drawn	Checked
1	10/12/2012	Draft	FK	DB
2	15/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/008**

SCALE	Not To Scale	PLOT SIZE	A4	DATUM	OSGB36	PROJECTION	Mercator

FOREWIND





LEGEND

Dogger Bank Zone

m MSL

+10
+5
0
-5
-10
-15
-20
-30
-50
-100

0 250 500
Kilometres

Data Source:
Shennan et al. (2000)
Round 3 © TCE, 2010,

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

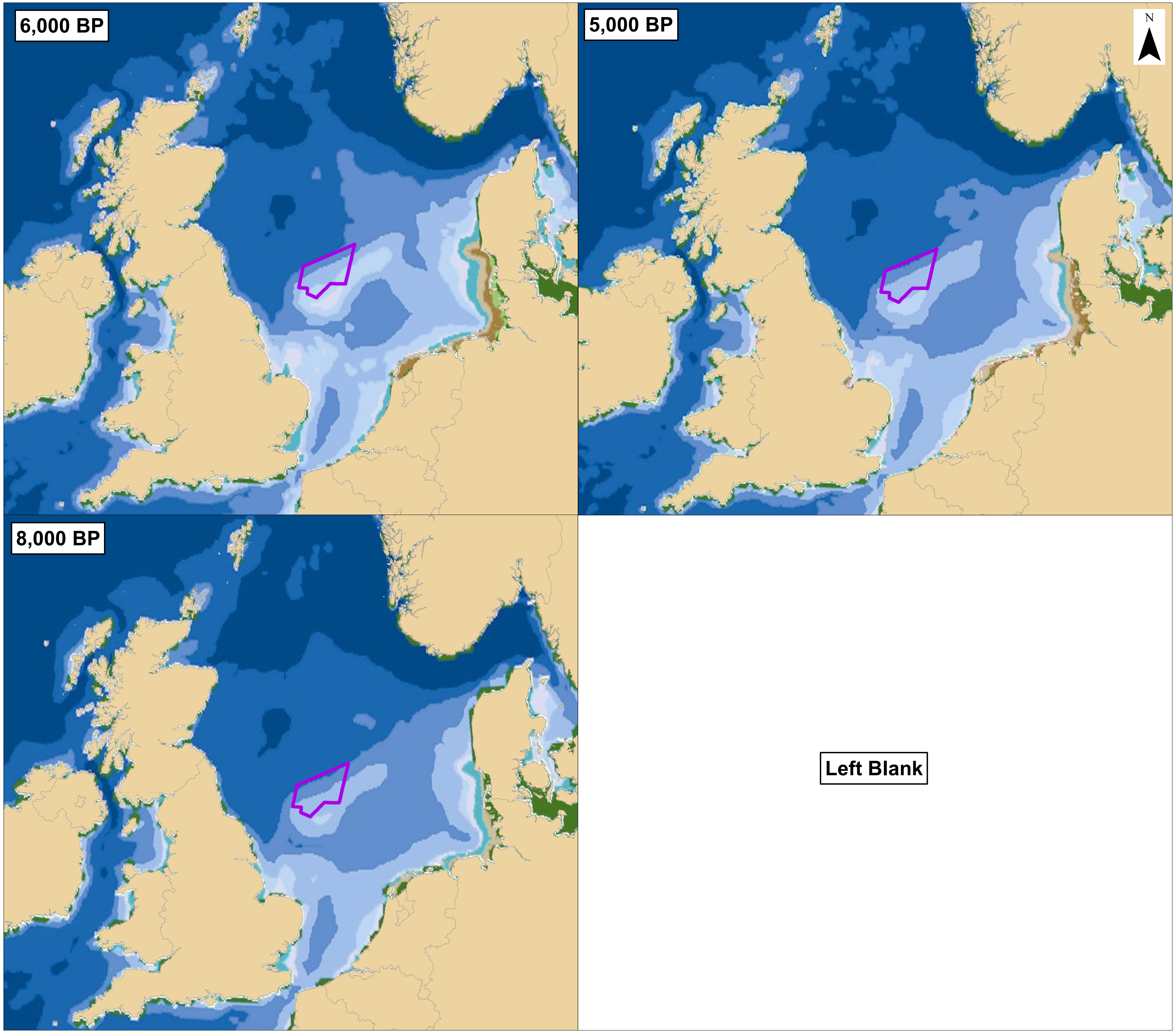
Figure 2.1 Holocene palaeogeography of the North Sea between 10,000 and 7,000 years ago

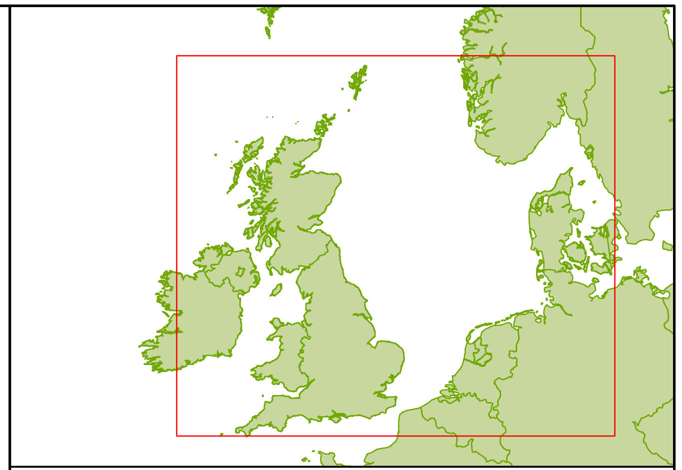
VER	DATE	REMARKS	Drawn	Checked
1	10/12/2012	Draft	FK	DB
2	12/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/035**

SCALE	1:9,500,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

Dogger Bank Zone

m MSL

+10
+5
0
-5
-10
-15
-20
-30
-50
-100

0 250 500
Kilometres

Data Source:
Shennan et al. (2000)
Round 3 © TCE, 2010,

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

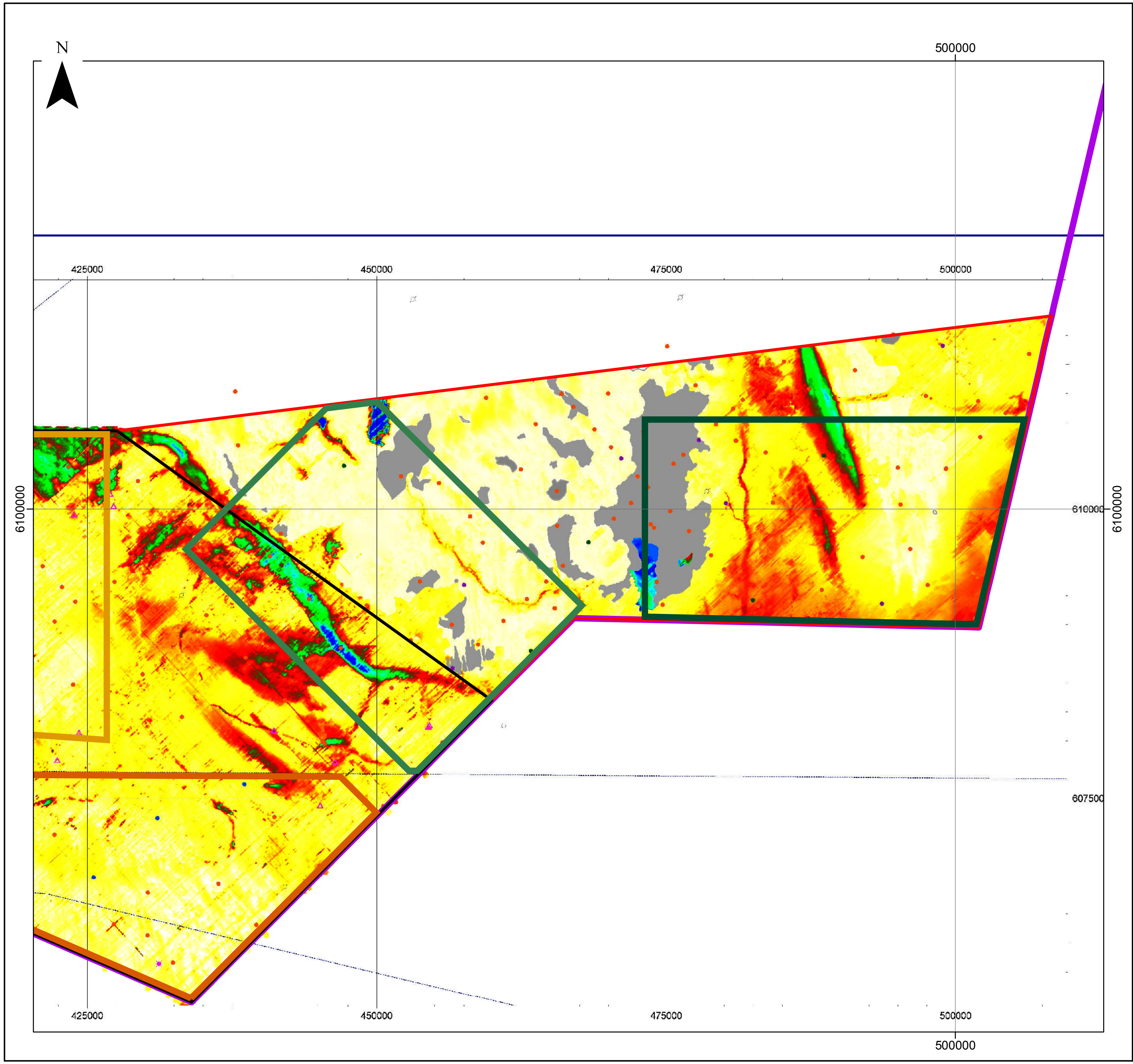
Figure 2.2 Holocene palaeogeography of the North Sea between 6,000 and 4,000 years ago

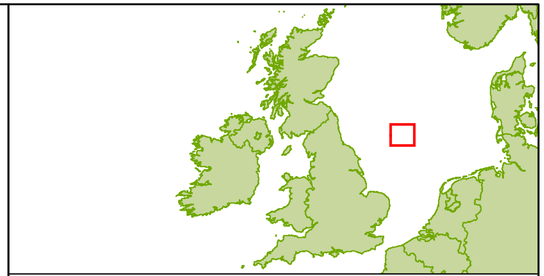
VER	DATE	REMARKS	Drawn	Checked
1	10/12/2012	Draft	FK	DB
2	12/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/023**

SCALE 1:9,500,000	PLOT SIZE A3	DATUM WGS84	PROJECTION UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A
- Tranche B Boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- 12nm Territorial Boundary

Sand Thickness (m)

0
0.875
1.750
2.625
3.500
4.375
5.250
6.125
7.000
7.875
8.750
9.625
10.500
11.375
12.250
13.125
14.000
14.875
15.750
16.625
17.500
18.375
19.250
20.125
21.000
21.875
22.750
23.625
24.500
25.375
26.250
27.125
28.000
28.875
29.750
30.625
31.500
32.375
33.250
34.125
35.000

0 10
Kilometres

Data Source:
Image dereived from RPS, 2013
Background bathymetry image derived in part from TCarta data © 2009

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DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

Figure 2.3 Holocene sand thickness across Tranche B

VER	DATE	REMARKS	Drawn	Checked
1	09/09/2013	Draft	LW	DB
2	12/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/033**

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

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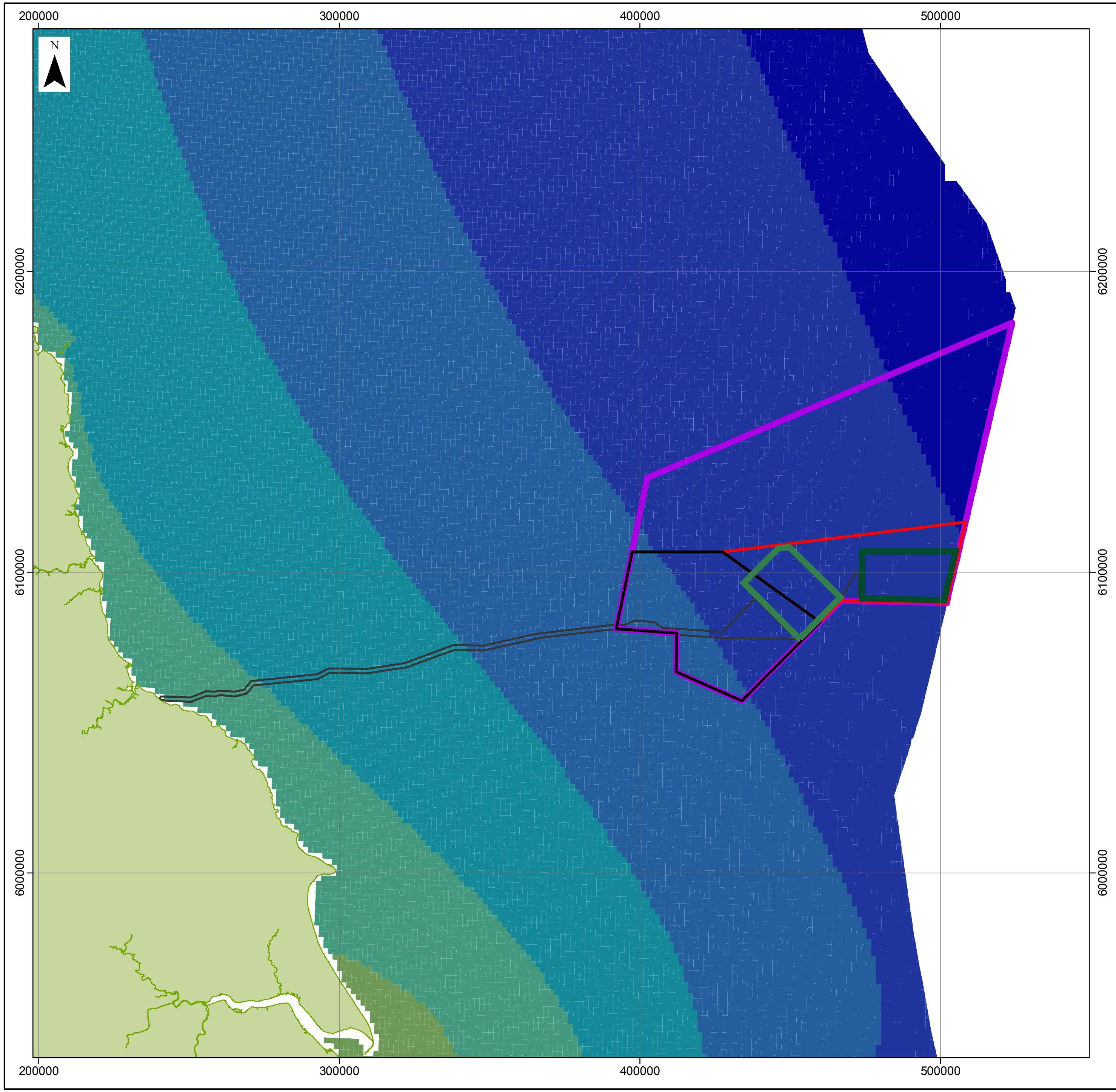

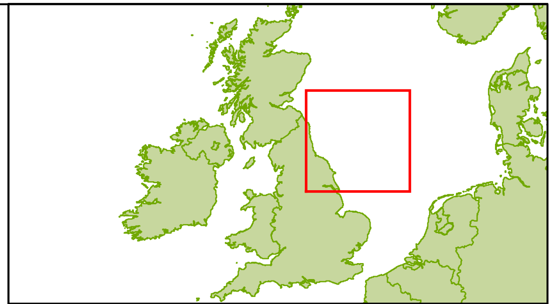

LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor

Mean Spring Tide Range (m)

- 0.10 - 1.00
- 1.01 - 2.00
- 2.01 - 3.00
- 3.01 - 4.00
- 4.01 - 5.00
- 5.01 - 6.00

0 25 50
Kilometres

Data Source:
Round 3 © TCE, 2010,
BERR (http://www.renewables-atlas.info/)

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DRAWING TITLE

Figure 3.1 Spring Tidal Range across the Dogger Bank Zone

VER	DATE	REMARKS	Drawn	Checked
1	10/12/2012	Draft	FK	DB
2	15/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/009**

SCALE	1:1,900,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

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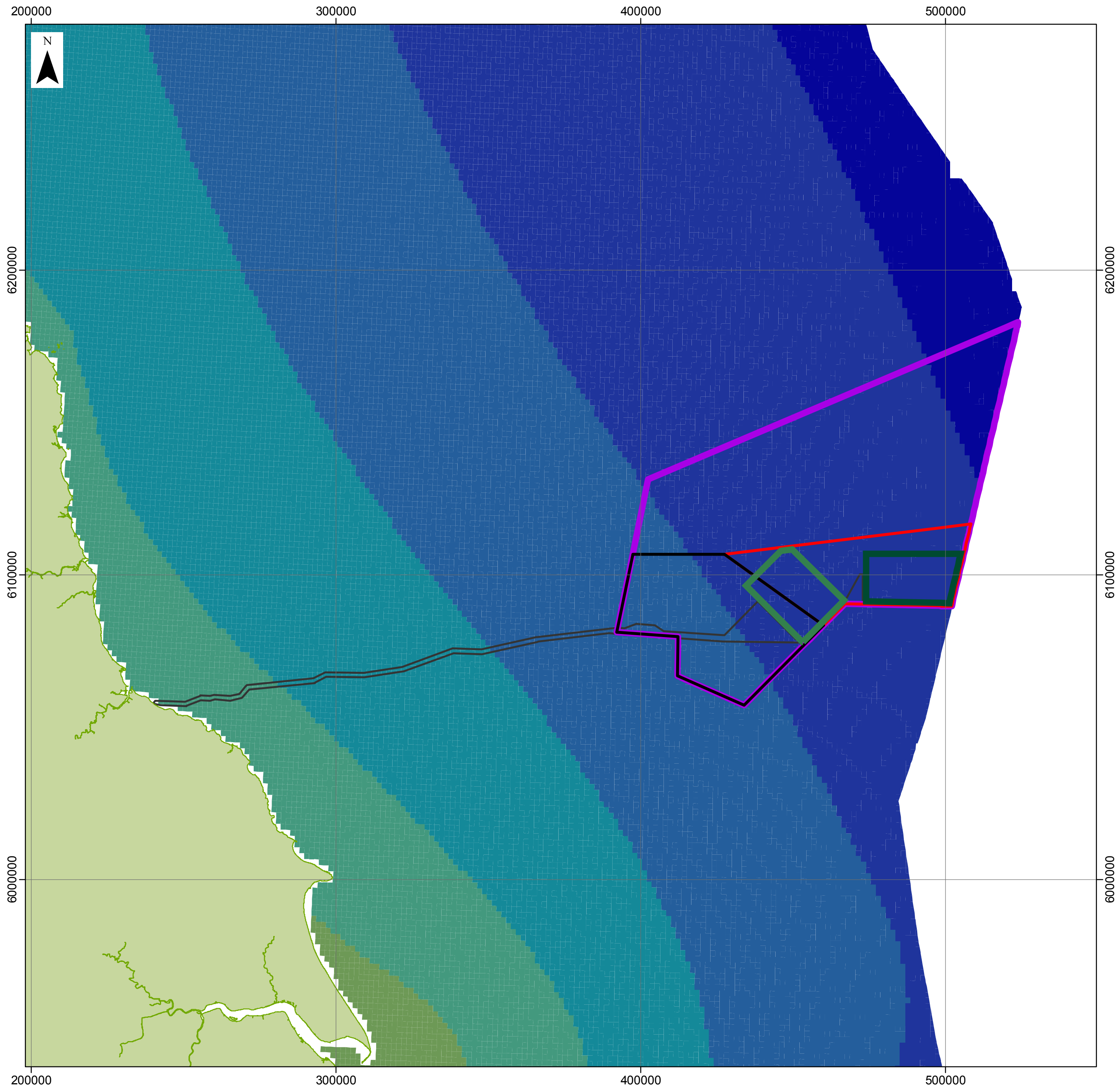

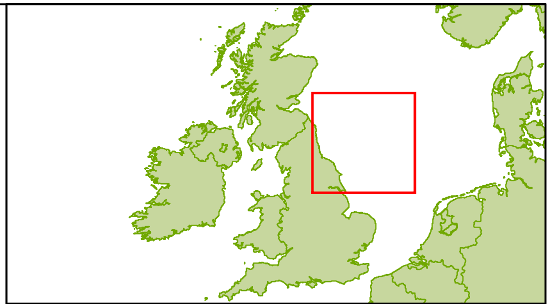

LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor

Mean Neap Tide Range (m)

- < 0.50
- 0.51 - 1.00
- 1.01 - 1.50
- 1.51 - 2.00
- 2.01 - 2.50
- 2.51 - 3.00

0 25 50
Kilometres

Data Source:
Round 3 © TCE, 2010,
BERR (http://www.renewables-atlas.info/)

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DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

Figure 3.2 Neap Tidal Range across the Dogger Bank Zone

VER	DATE	REMARKS	Drawn	Checked
1	10/12/2012	Draft	FK	DB
2	15/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/010**

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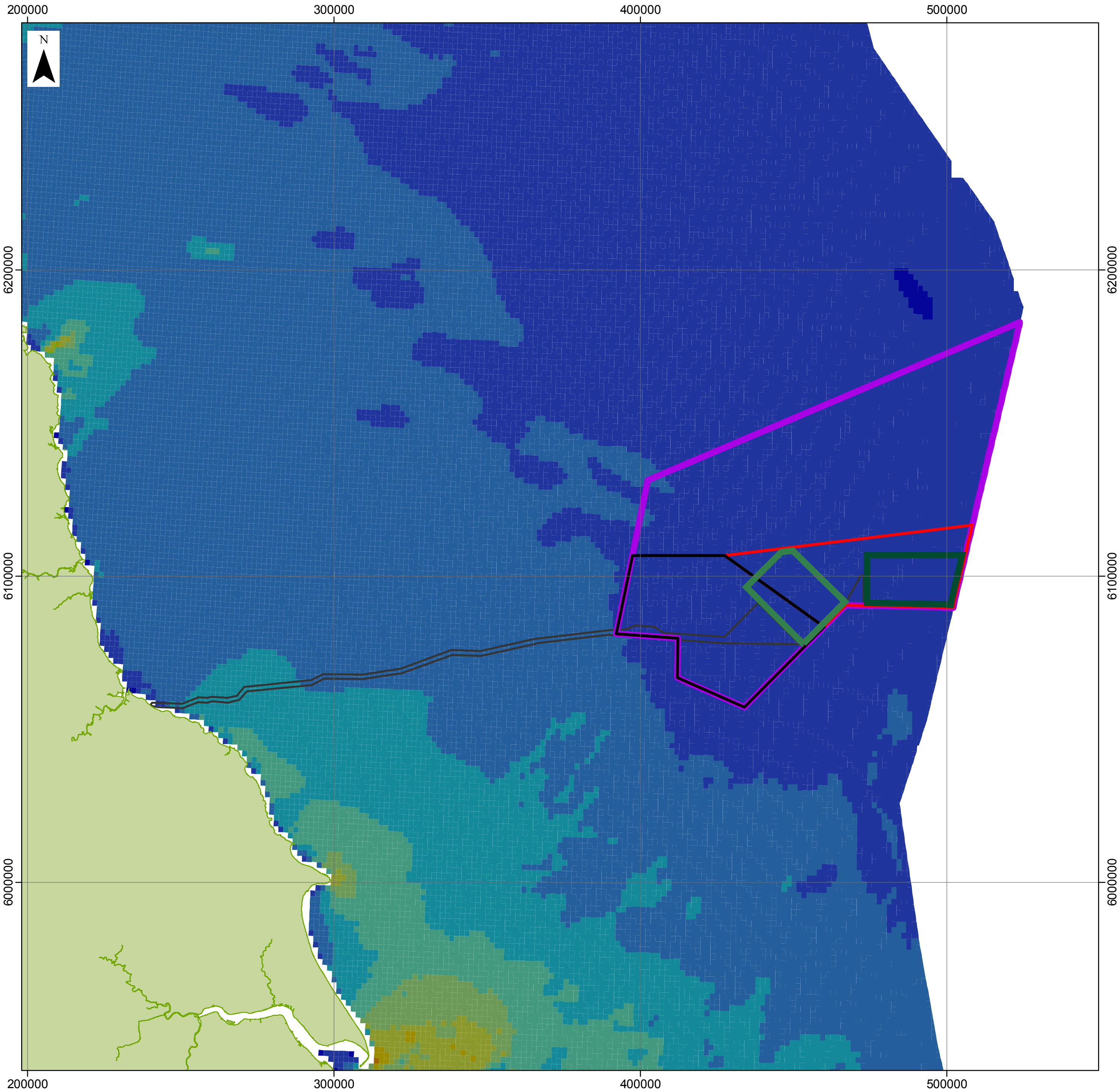
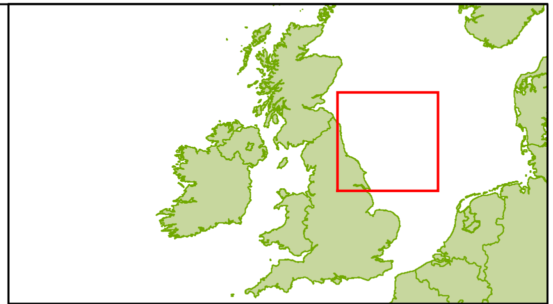
FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor

Peak Flow of Mean Spring Tide (m/s)

- < 0.20
- 0.21 - 0.40
- 0.41 - 0.60
- 0.61 - 0.80
- 0.81 - 1.00
- 1.01 - 1.20
- 1.21 - 1.40
- 1.41 - 1.60
- 1.61 - 1.80

0 25 50
Kilometres

Data Source:
Round 3 © TCE, 2010,
BERR (http://www.renewables-atlas.info/)

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

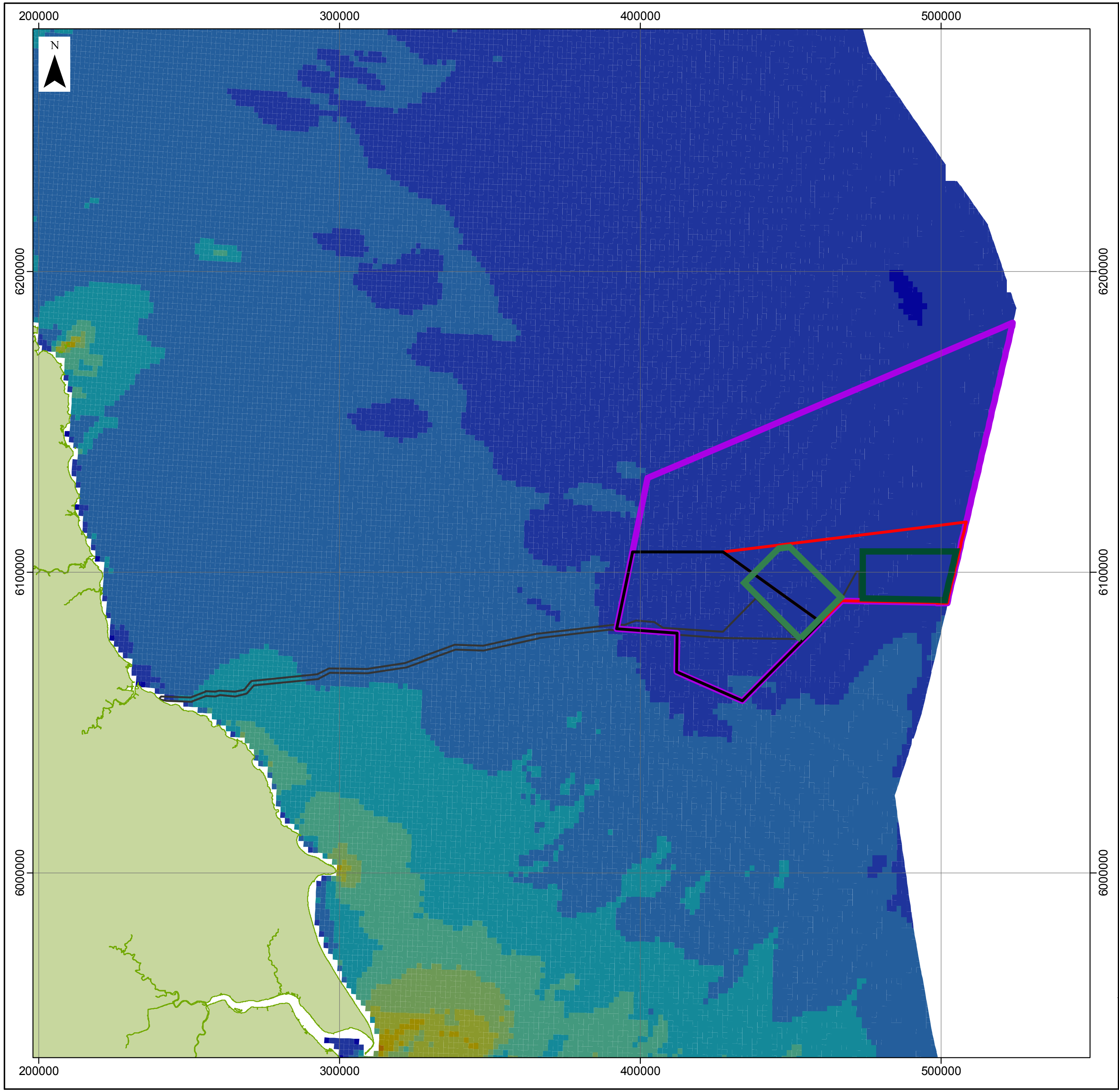
Figure 3.3 Peak Flow for a Mean Spring Tide across the Dogger Bank Zone

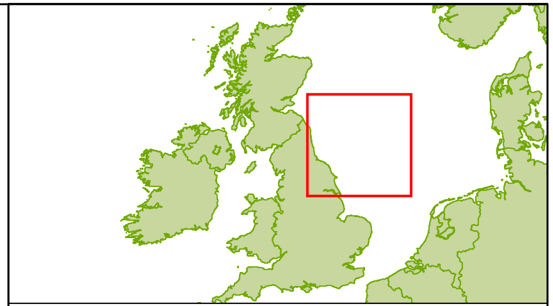
VER	DATE	REMARKS	Drawn	Checked
1	10/12/2012	Draft	FK	DB
2	15/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/011**

SCALE	1:1,900,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor

Peak Flow of Mean Neap Tide (m/s)

- < 0.10
- 0.11 - 0.20
- 0.21 - 0.30
- 0.31 - 0.40
- 0.41 - 0.50
- 0.51 - 0.60
- 0.61 - 0.70
- 0.71 - 0.80
- 0.81 - 0.90

0 25 50
Kilometres

Data Source:
Round 3 © TCE, 2010,
BERR (http://www.renewables-atlas.info/)

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DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

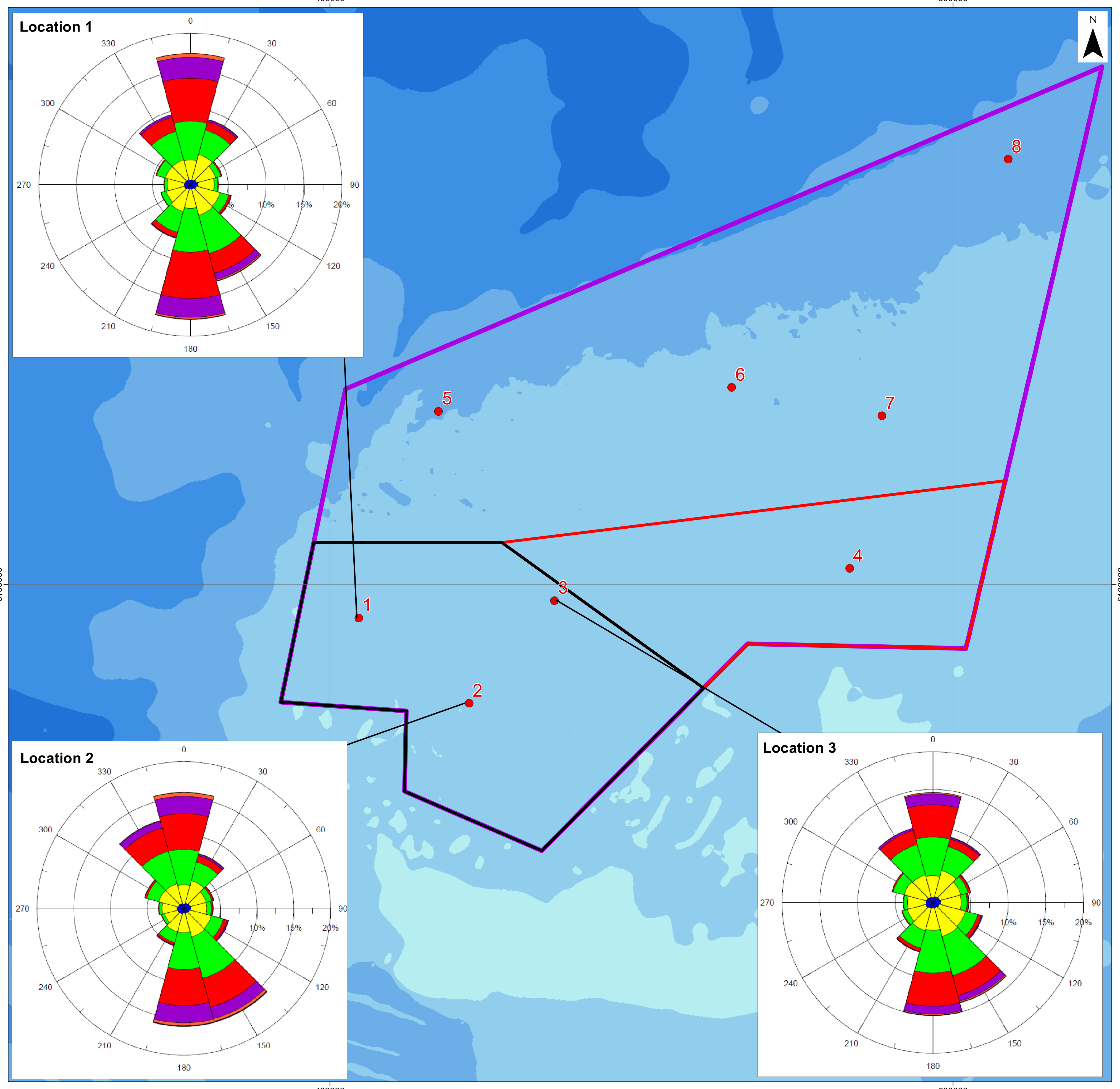
Figure 3.4 Peak Flow for a Mean Neap Tide across the Dogger Bank Zone

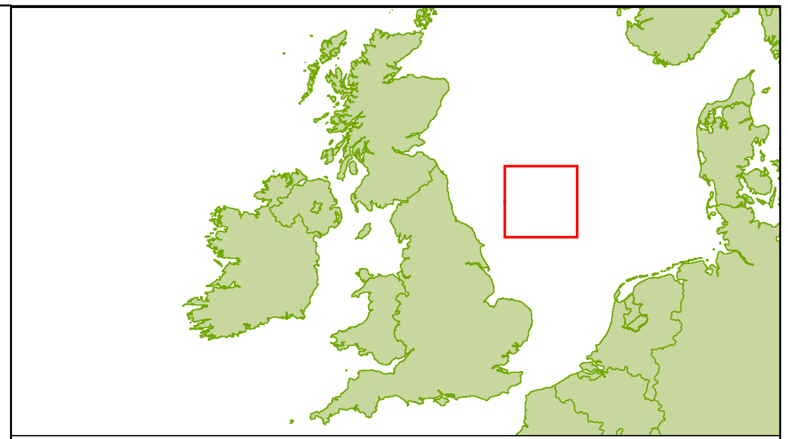
VER	DATE	REMARKS	Drawn	Checked
1	10/12/2012	Draft	FK	DB
2	15/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/012**

SCALE	1:1,900,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Modelled Metocean Location

Current Speed (m/s)

- 0-0.1
- 0.1-0.2
- 0.2-0.3
- 0.3-0.4
- 0.4-0.5
- 0.5-0.6
- 0.6-0.7
- 0.7-0.8
- above 0.8

0 25 50
Kilometres

Data Source:
Round 3 © TCE, 2010,
Current Roses © Gardline, 2011,
Modelled Metocean Location © Gardline, 2012,
Background bathymetry image derived in part from TCarta data © 2009

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DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

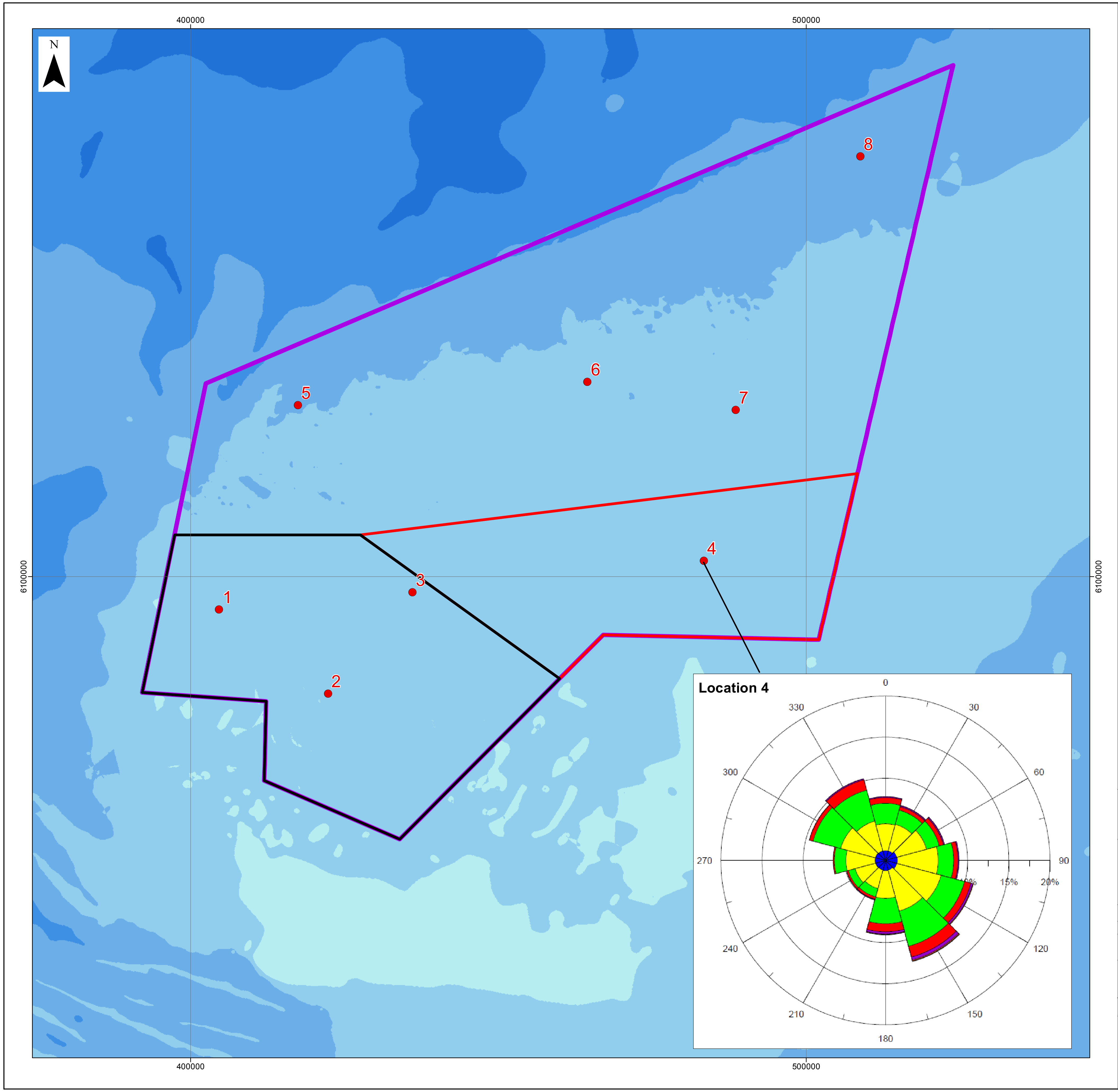
Figure 3.5 Current Roses: Within Tranche A

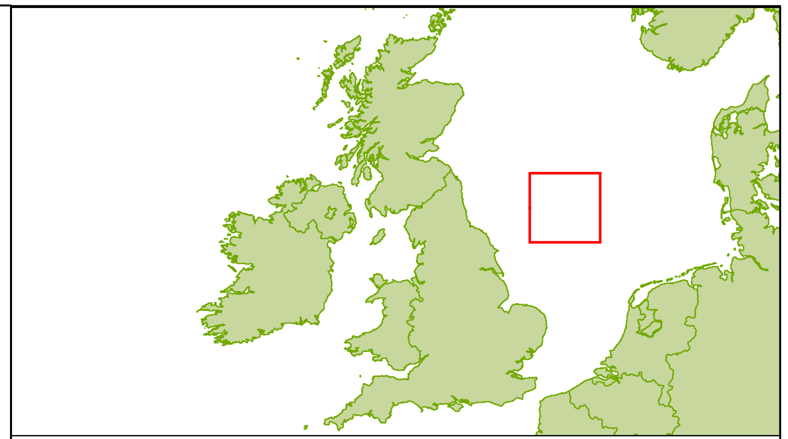
VER	DATE	REMARKS	Drawn	Checked
1	12/12/2012	Draft	FK	DB
2	16/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/013**

SCALE	1:670,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Modelled Metocean Location

Current Speed (m/s)

- 0-0.1
- 0.1-0.2
- 0.2-0.3
- 0.3-0.4
- 0.4-0.5
- 0.5-0.6
- 0.6-0.7
- 0.7-0.8
- above 0.8

0 25 50
Kilometres

Data Source:
Round 3 © TCE, 2010,
Current Roses © Gardline, 2011,
Modelled Metocean Location © Gardline, 2012,
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

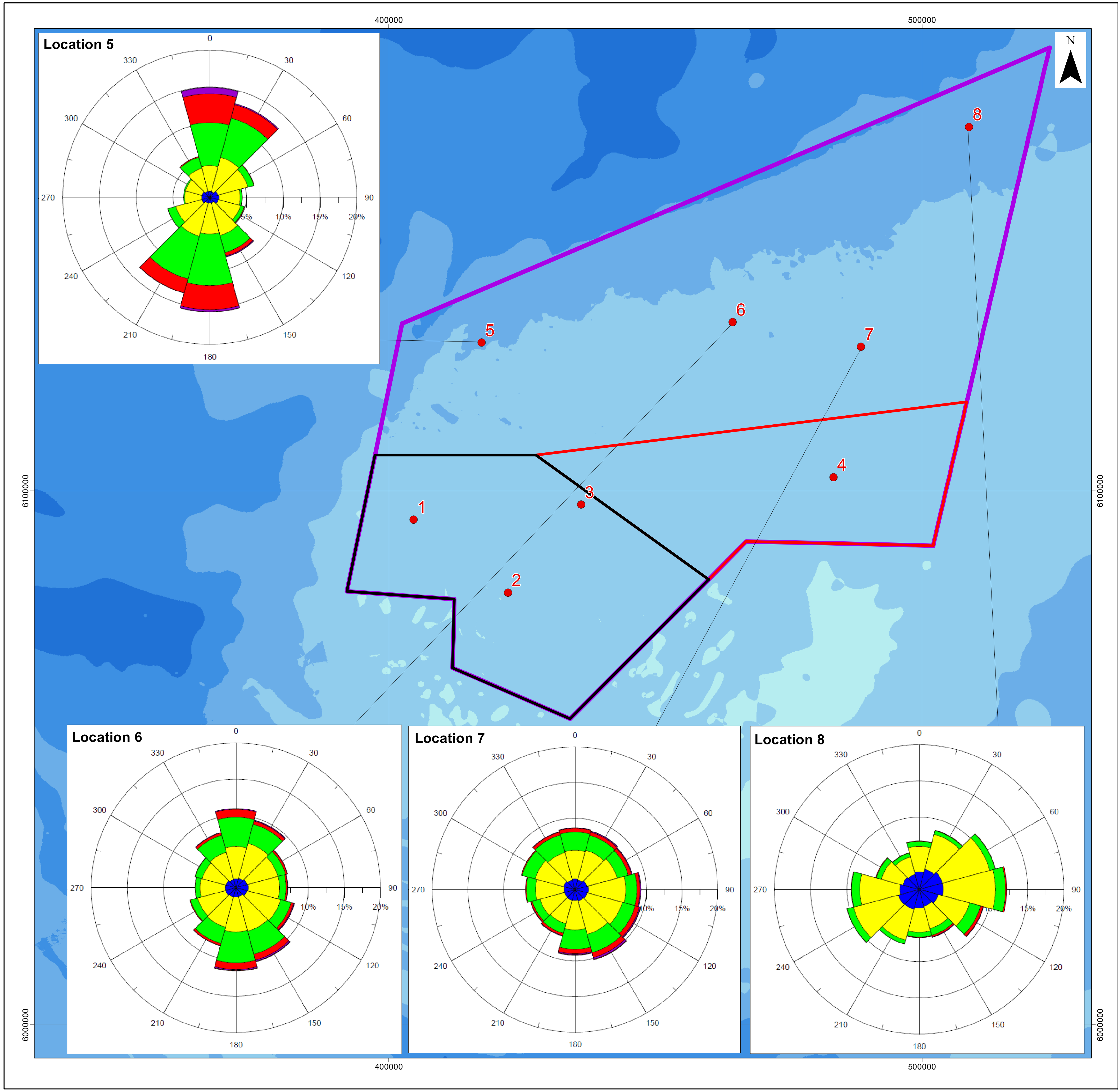
Figure 3.6 Current Rose: Within Tranche B

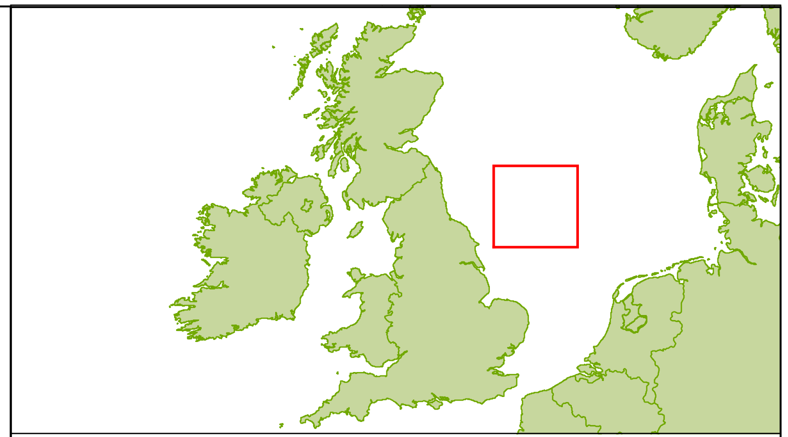
VER	DATE	REMARKS	Drawn	Checked
1	12/12/2012	Draft	FK	DB
2	16/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/014**

SCALE	1:650,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Modelled Metocean Location

Current Speed (m/s)

- 0-0.1
- 0.1-0.2
- 0.2-0.3
- 0.3-0.4
- 0.4-0.5
- 0.5-0.6
- 0.6-0.7
- 0.7-0.8
- above 0.8

0 25 50
Kilometres

Data Source:
Round 3 © TCE, 2010,
Current Roses © Gardline, 2011,
Modelled Metocean Location © Gardline, 2012,
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

Figure 3.7 Current Roses: Dogger Bank Zone Outside Tranches A and B

VER	DATE	REMARKS	Drawn	Checked
1	12/12/2012	Draft	FK	DB
2	16/09/2013	Final	LW	DB

DRAWING NUMBER: 9X5889/04/015

SCALE	1:750,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

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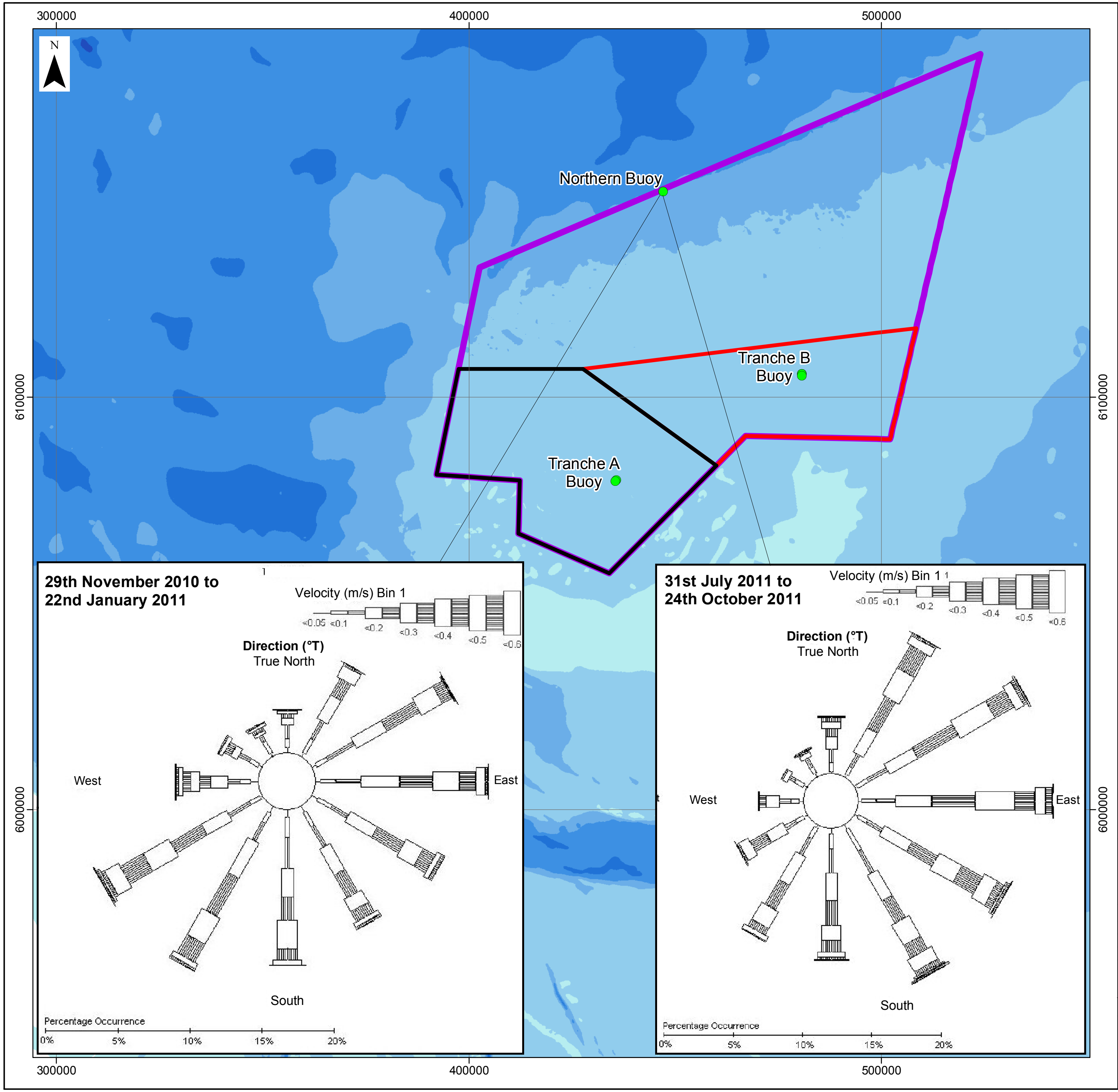
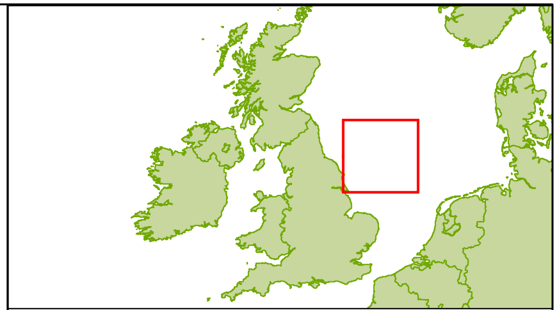




LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Forewind Operating Buoy

0 25 50
Kilometres

Data Source:
Round 3 © TCE, 2010,
Current Roses © Gardline, 2011,
Forewind Operating Buoys © Gardline, 2012,
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

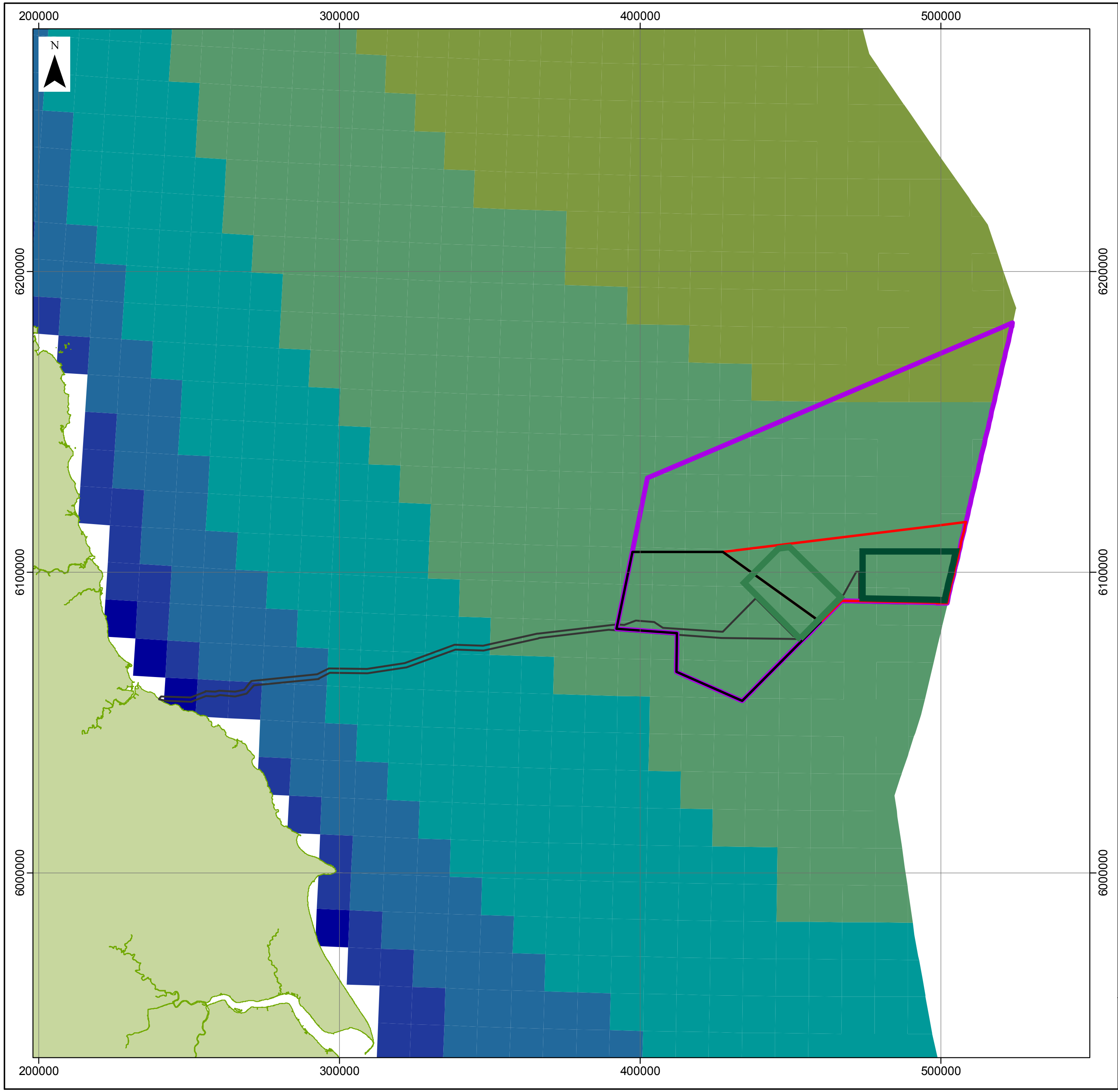
Figure 3.8 Surface Current Roses at the Northern Buoy

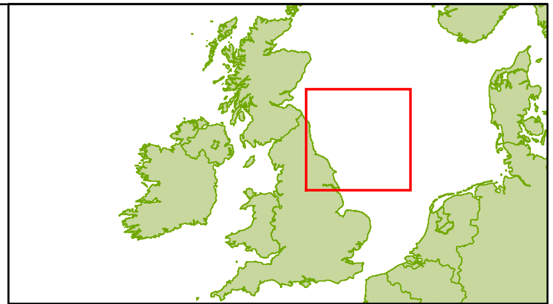
VER	DATE	REMARKS	Drawn	Checked
1	12/12/2012	Draft	FK	DB
2	16/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/016**

SCALE	1:1,370,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor

Annual Mean Significant Wave Height (m)

- < 1.00
- 1.01 - 1.25
- 1.26 - 1.50
- 1.51 - 1.75
- 1.76 - 2.00
- 2.01 - 2.25

0 25 50
Kilometres

Data Source:
Round 3 © TCE, 2010,
BERR (http://www.renewables-atlas.info/)

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

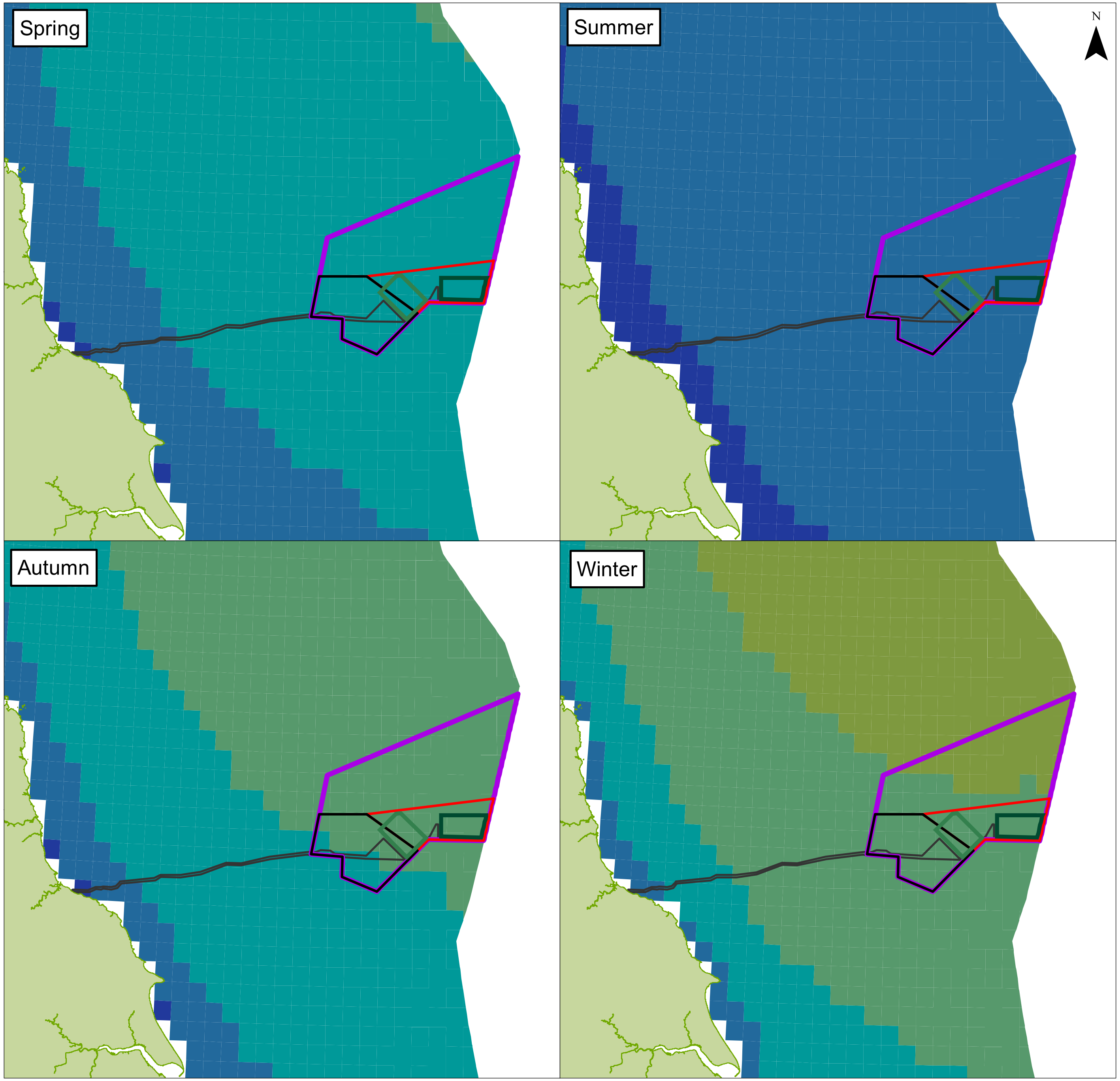
Figure 3.9 Annual Mean Significant Wave Height Across the Dogger Bank Zone

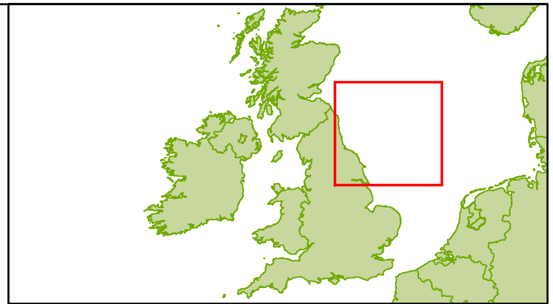
VER	DATE	REMARKS	Drawn	Checked
1	10/12/2012	Draft	FK	DB
2	15/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/017**

SCALE 1:1,900,000 | PLOT SIZE A4 | DATUM WGS84 | PROJECTION UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor

Seasonal Mean Significant Wave Height (m)

- 0.50 - 1.00
- 1.01 - 1.50
- 1.51 - 2.00
- 2.01 - 2.50
- 2.51 - 3.00

0 50 100
Kilometres

Data Source:
Round 3 © TCE, 2010,
BERR (http://www.renewables-atlas.info/)

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

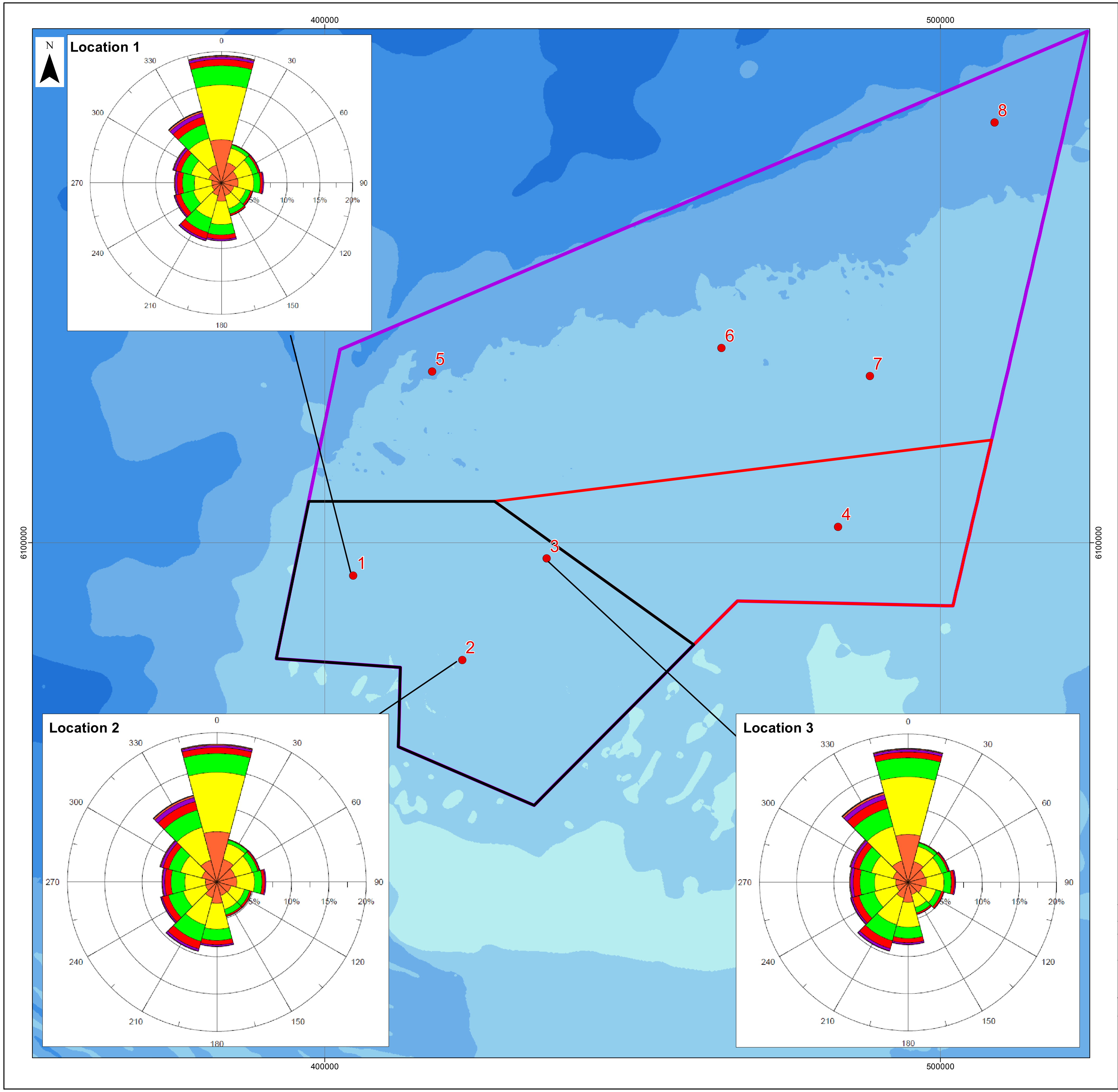
Figure 3.10 Seasonal Mean Significant Wave Height Across the Dogger Bank Zone

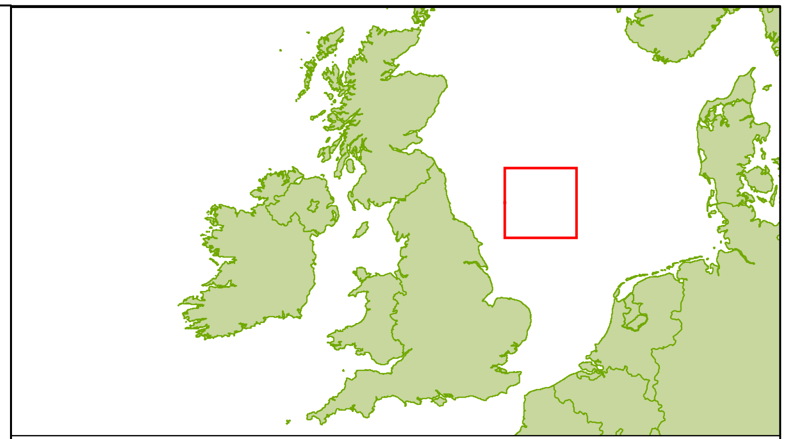
VER	DATE	REMARKS	Drawn	Checked
1	10/12/2012	Draft	FK	DB
2	15/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/018**

SCALE	1:3,800,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

Dogger Bank Zone
Tranche A Boundary
Tranche B Boundary
Modelled Metocean Location

Significant Wave Height (m)

- 0-1
- 1-2
- 2-3
- 3-4
- 4-5
- 5-6
- 6-7
- 7-8
- 8-9
- 9-10
- 10-11
- above 11

0 10 20
Kilometres

Data Source:
Round 3 © TCE, 2010,
Current Roses © Gardline, 2011,
Modelled Metocean Location © Gardline, 2012,
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

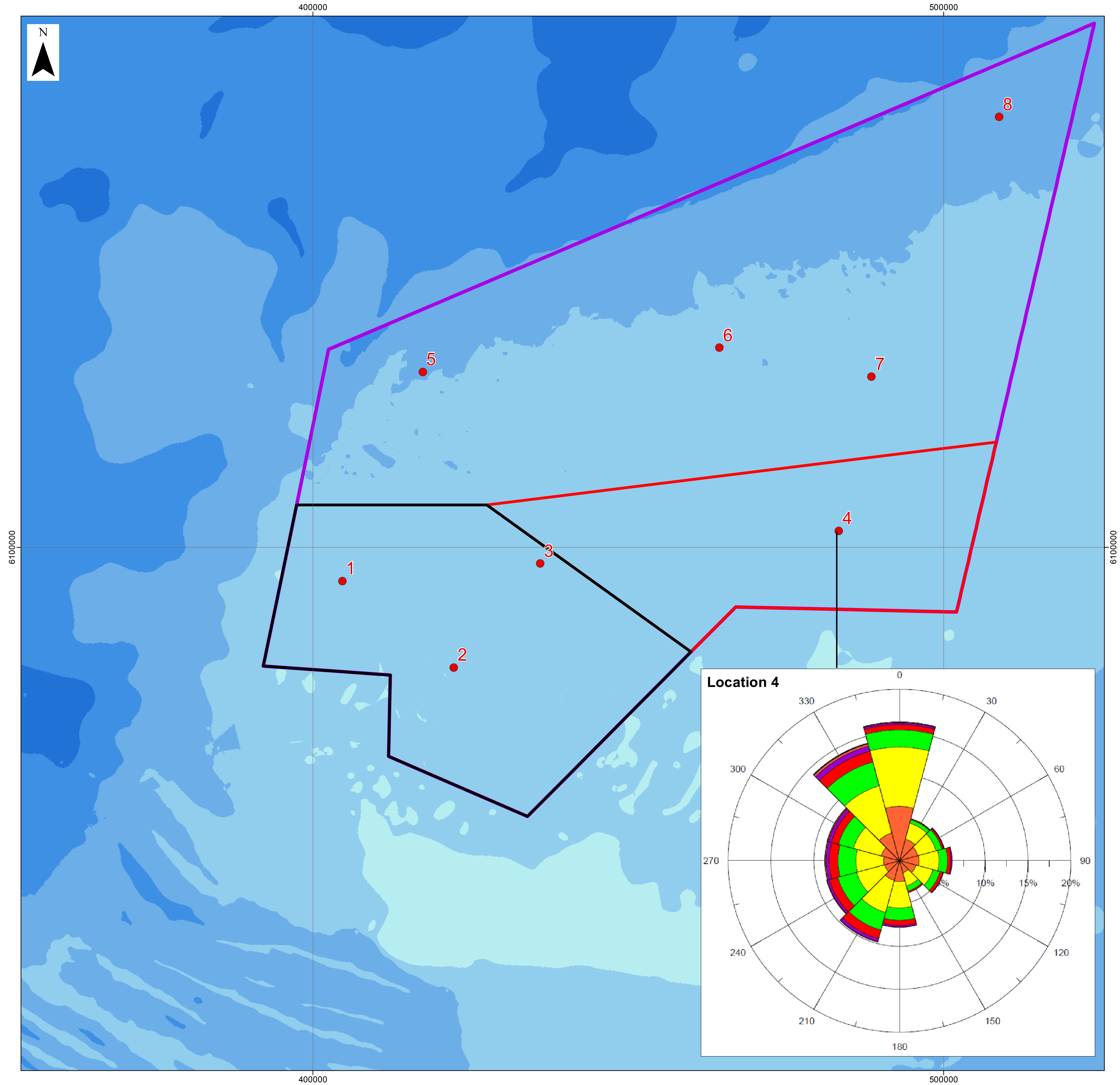
Figure 3.11 Wave Roses: Within Tranche A

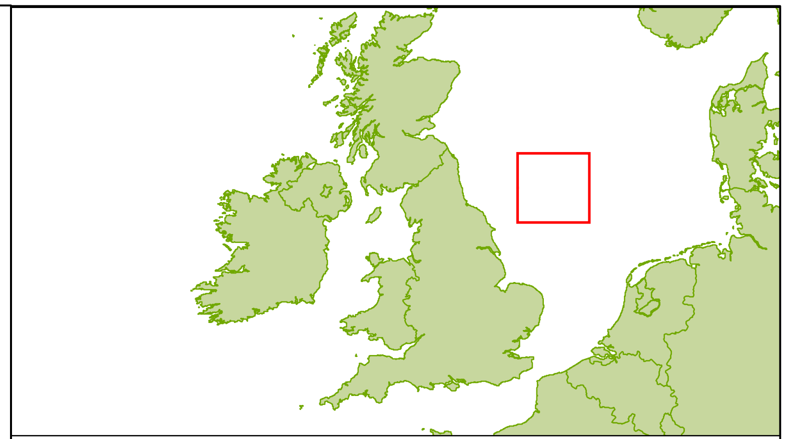
VER	DATE	REMARKS	Drawn	Checked
1	12/12/2012	Draft	FK	DB
2	16/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/019**

SCALE	1:650,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Modelled Metocean Location

Significant Wave Height (m)

- 0-1
- 1-2
- 2-3
- 3-4
- 4-5
- 5-6
- 6-7
- 7-8
- 8-9
- 9-10
- 10-11
- above 11

0 10 20
Kilometres

Data Source:
Round 3 © TCE, 2010,
Current Roses © Gardline, 2011,
Modelled Metocean Location © Gardline, 2012,
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

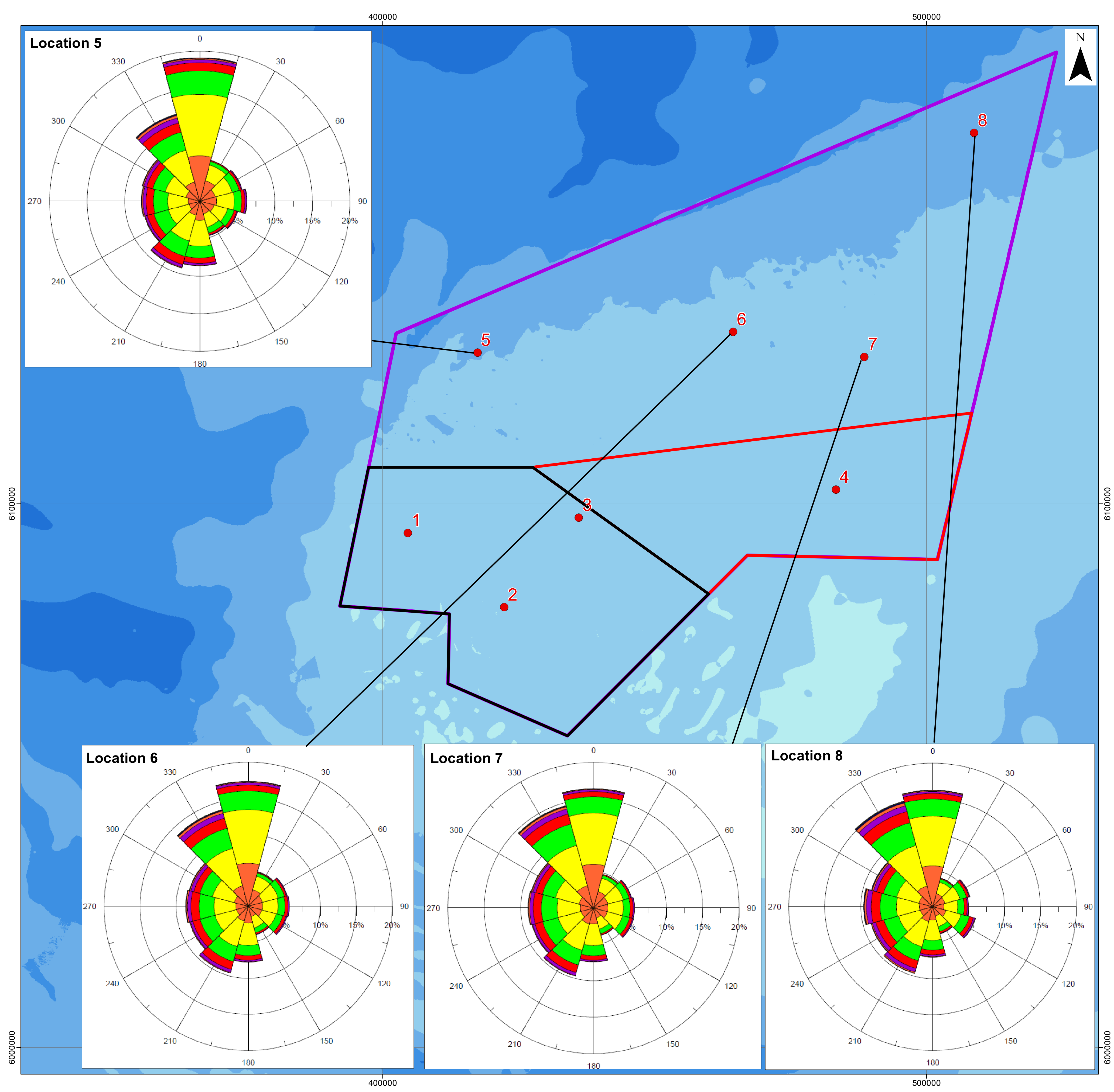
Figure 3.12 Wave Rose: Within Tranche B

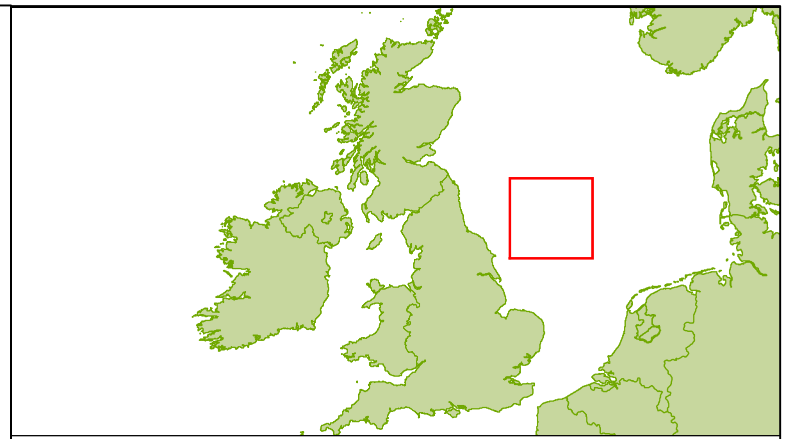
VER	DATE	REMARKS	Drawn	Checked
1	12/12/2012	Draft	FK	DB
2	16/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/020**

SCALE	1:650,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Modelled Metocean Location

Significant Wave Height (m)

- 0-1
- 1-2
- 2-3
- 3-4
- 4-5
- 5-6
- 6-7
- 7-8
- 8-9
- 9-10
- 10-11
- above 11

0 10 20
Kilometres

Data Source:
Round 3 © TCE, 2010,
Current Roses © Gardline, 2011,
Modelled Metocean Location © Gardline, 2012,
Background bathymetry image derived in part from TCarta data © 2009

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DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

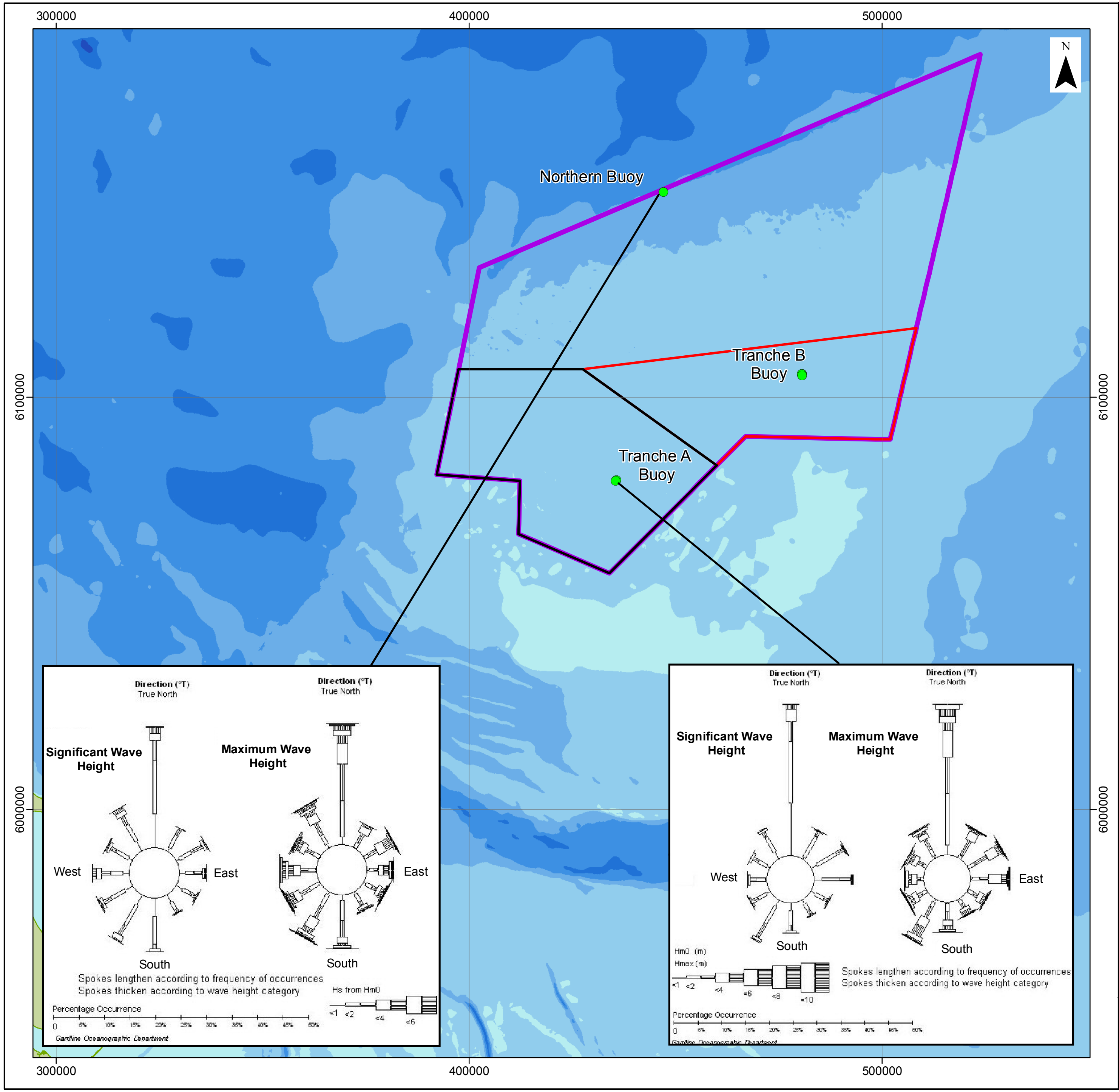
Figure 3.13 Wave Roses: Dogger Bank Zone Outside Tranches A and B

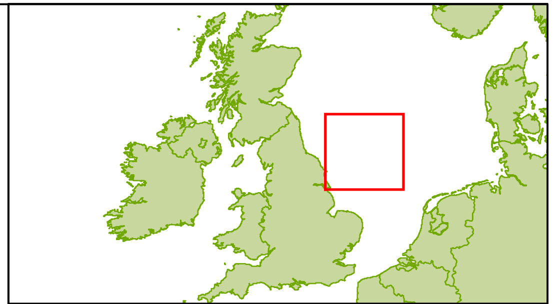
VER	DATE	REMARKS	Drawn	Checked
1	12/12/2012	Draft	FK	DB
2	16/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/021**

SCALE	1:750,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Forewind Operating Buoy

0 20 40
Kilometres

Data Source:
Round 3 © TCE, 2010,
Current Roses © Gardline, 2011,
Forewind Operating Buoys © Gardline, 2012,
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

Figure 3.14 Wave Roses at the Tranche A Buoy and the Northern Buoy

VER	DATE	REMARKS	Drawn	Checked
1	10/12/2012	Draft	FK	DB
2	16/09/2013	Draft	LW	DB

DRAWING NUMBER: **9X5889/04/022**

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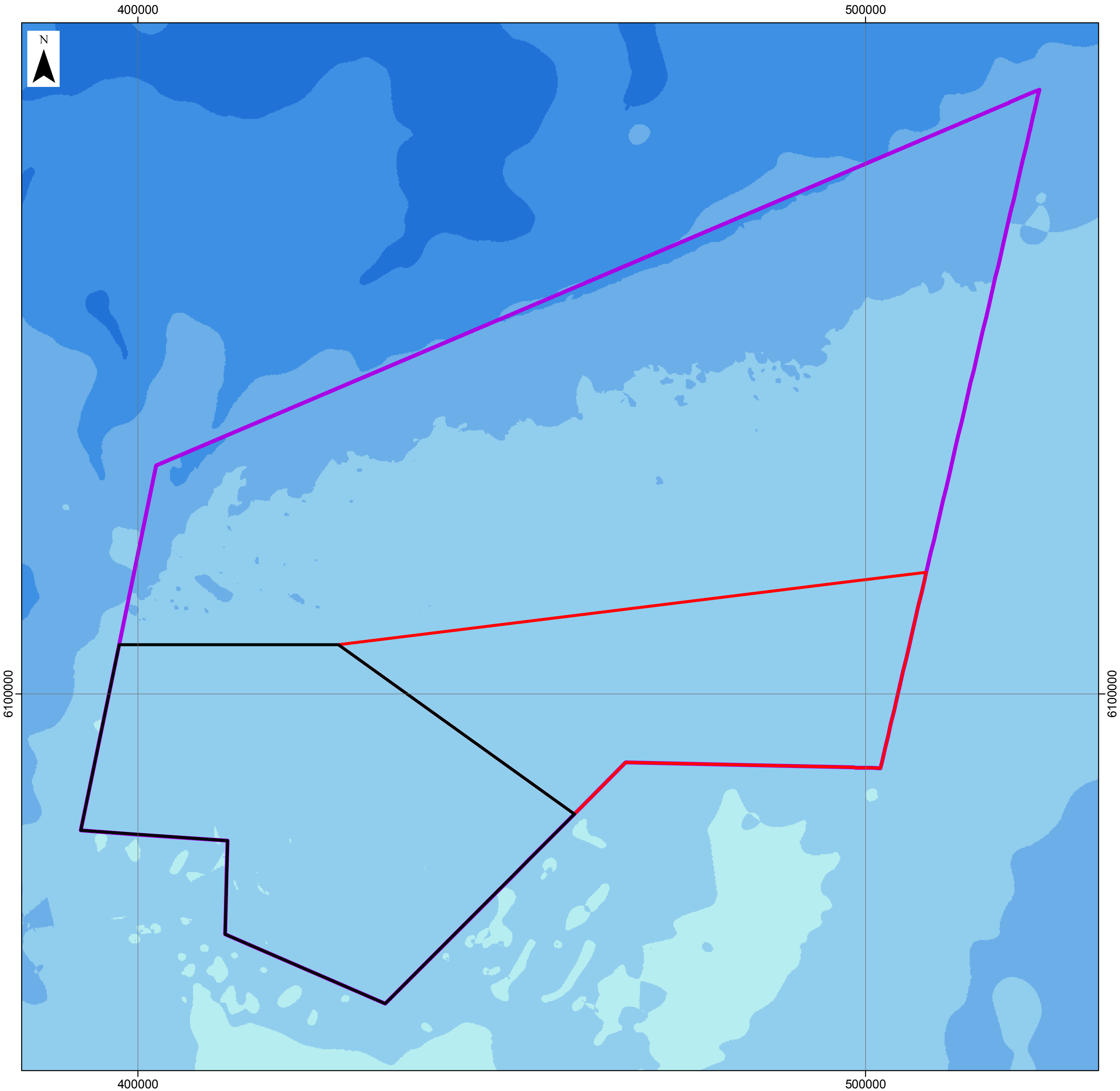
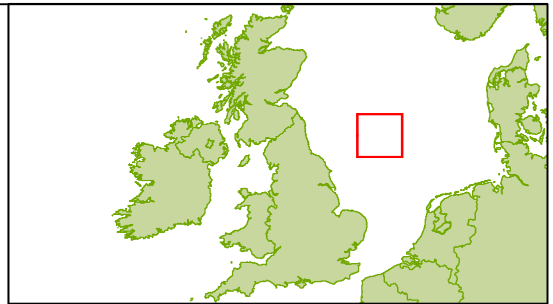
FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary

Bathymetry (m below mean sea level)

- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100

0 10 20
Kilometres

Data Source:
Round 3 © TCE, 2010,
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

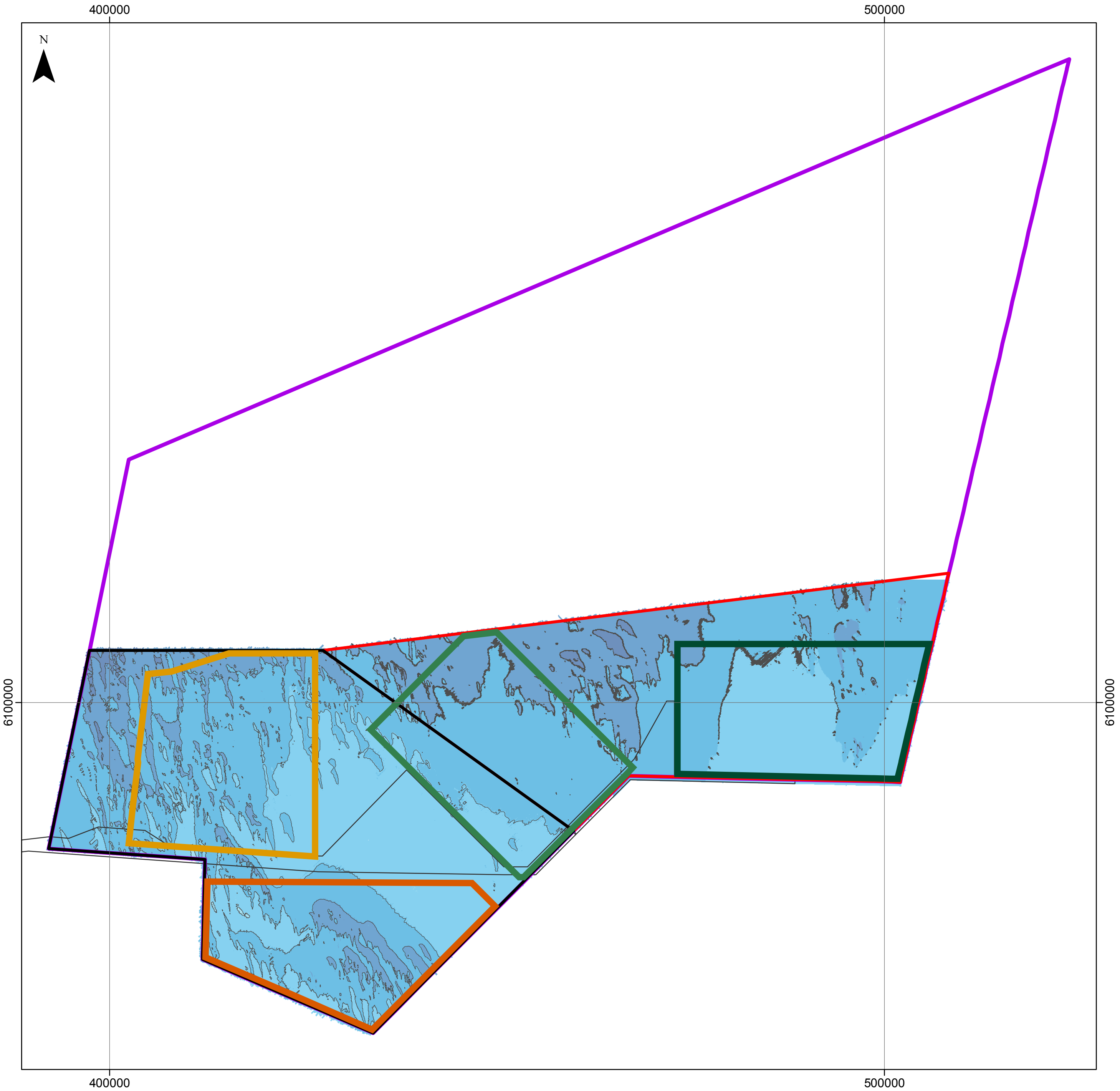
Figure 4.1 Bathymetry of the Dogger Bank Zone

VER	DATE	REMARKS	Drawn	Checked
1	12/12/2012	Draft	LW	DB
2	16/09/2013	Draft	LW	DB

DRAWING NUMBER: **9X5889/04/024**

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

FOREWIND



LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- Bathymetry Contours (m below LAT)

Bathymetry (m)

- -5 - -10
- -10 - -15
- -15 - -20
- -20 - -25
- -25 - -30
- -30 - -35
- -35 - -40
- -40 - -45

0 10 20
Kilometres

Data Source:
Round 3 © TCE, 2010,
Tranche A Bathymetry © GEMS 2010,
Tranche B Bathymetry © Gardline 2011

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

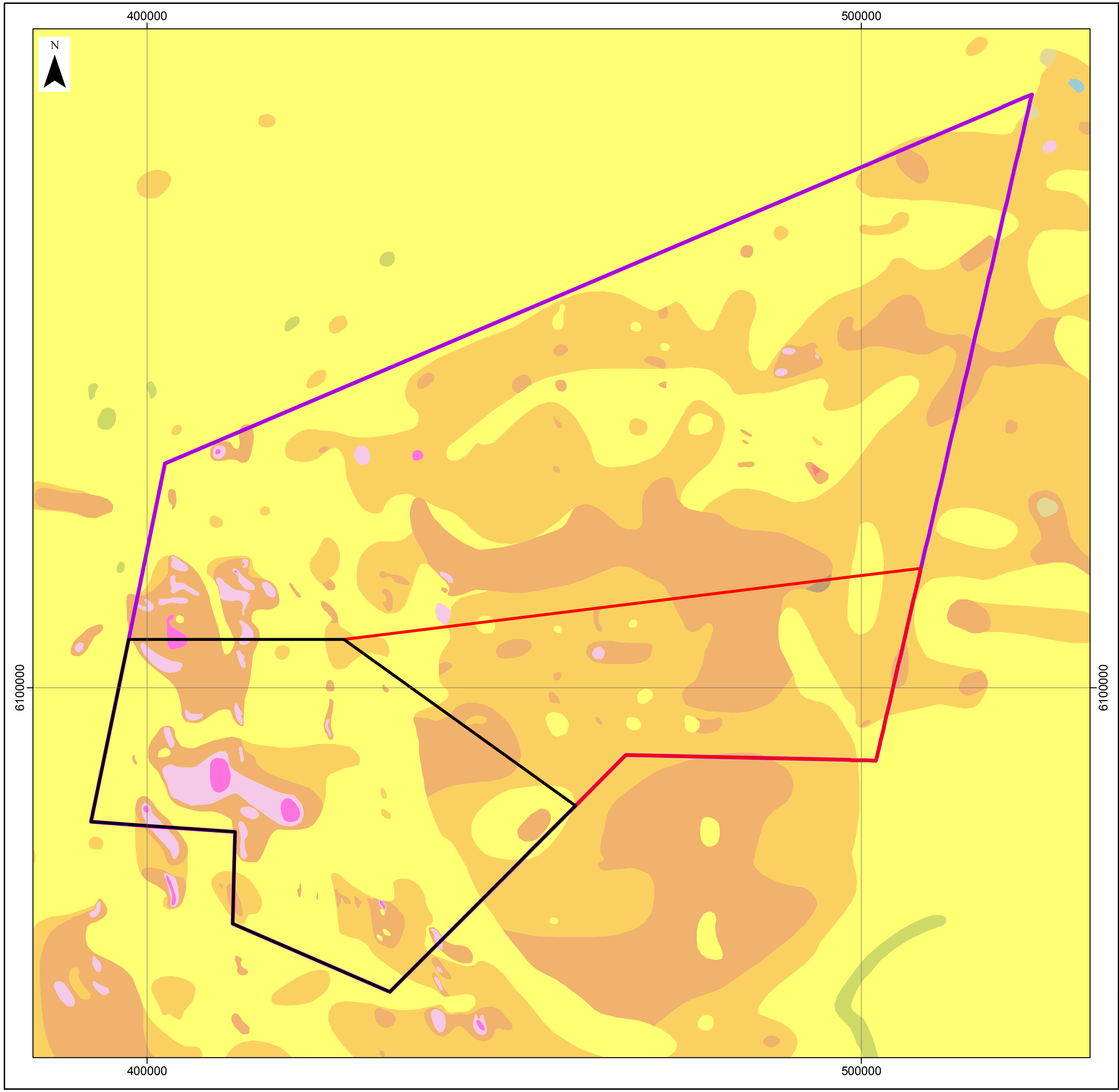
Figure 4.2 Bathymetry of Tranches A and B

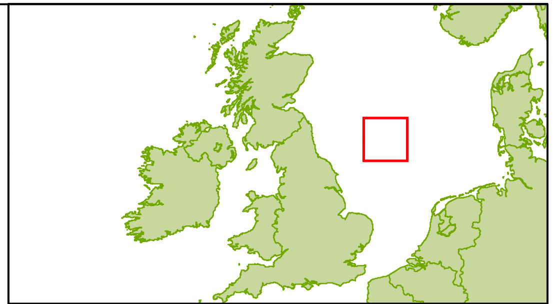
VER	DATE	REMARKS	Drawn	Checked
1	12/12/2012	Draft	LW	DB
2	15/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/025**

SCALE	1:750,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary

Seabed Sediments

- Gravel
- Gravelly Mud
- Gravelly Muddy Sand
- Gravelly Sand
- Muddy Sand
- Muddy Sandy Gravel
- Sand
- Sandy Gravel
- Slightly Gravelly Muddy Sand
- Slightly Gravelly Sand

0 10 20
Kilometres

Data Source:
Round 3 © TCE, 2010,

Products Licence No. 022010.005

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DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

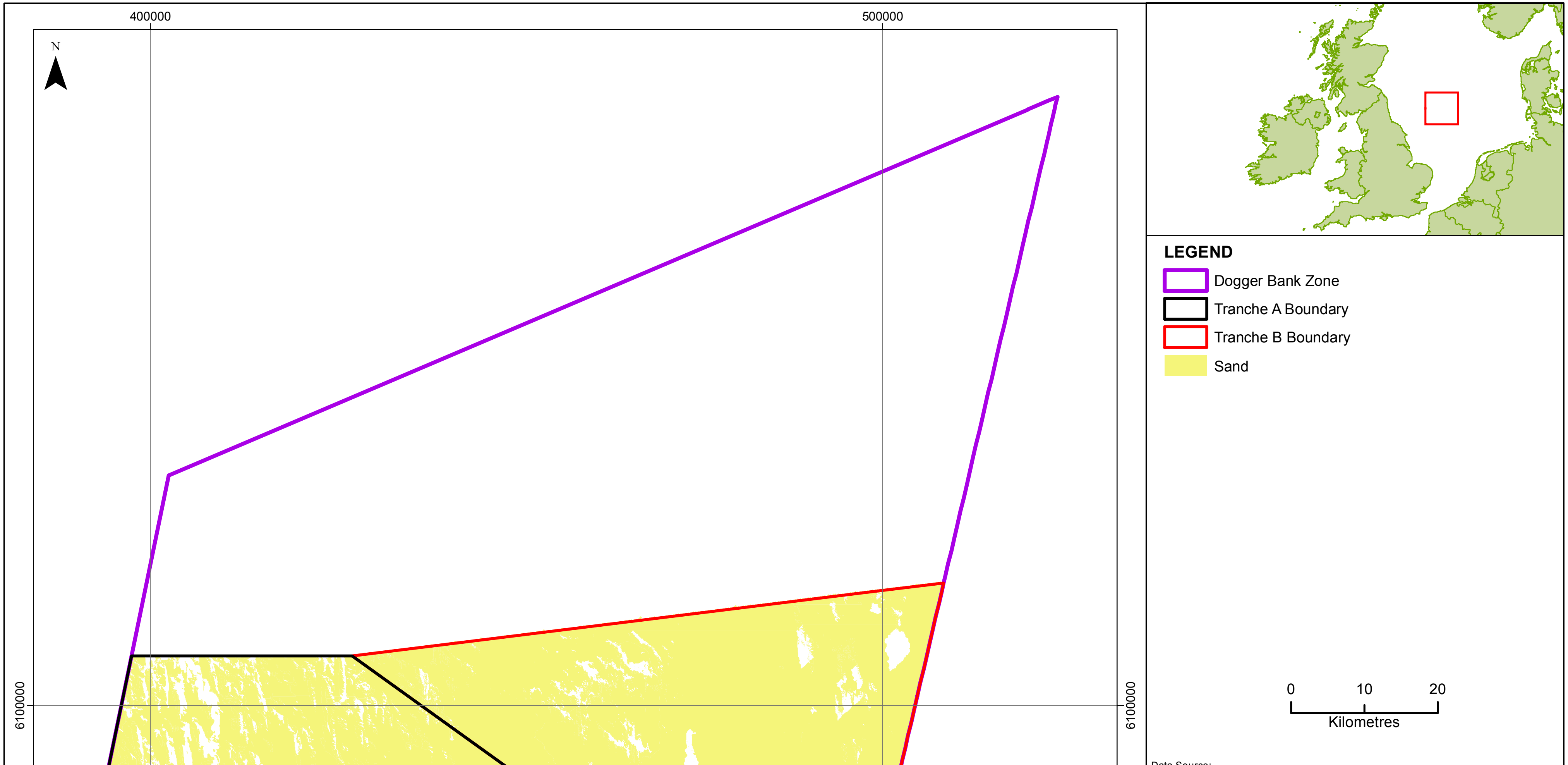
Figure 4.3 Seabed Sediment Distribution Across Dogger Bank

VER	DATE	REMARKS	Drawn	Checked
1	12/12/2012	Draft	LW	DB
2	16/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/026**

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

FOREWIND



Data Source:
Round 3 © TCE, 2010,
Tranche A Sediment © GEMS 2010,
Tranche B Sediment © Gardline 2011

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

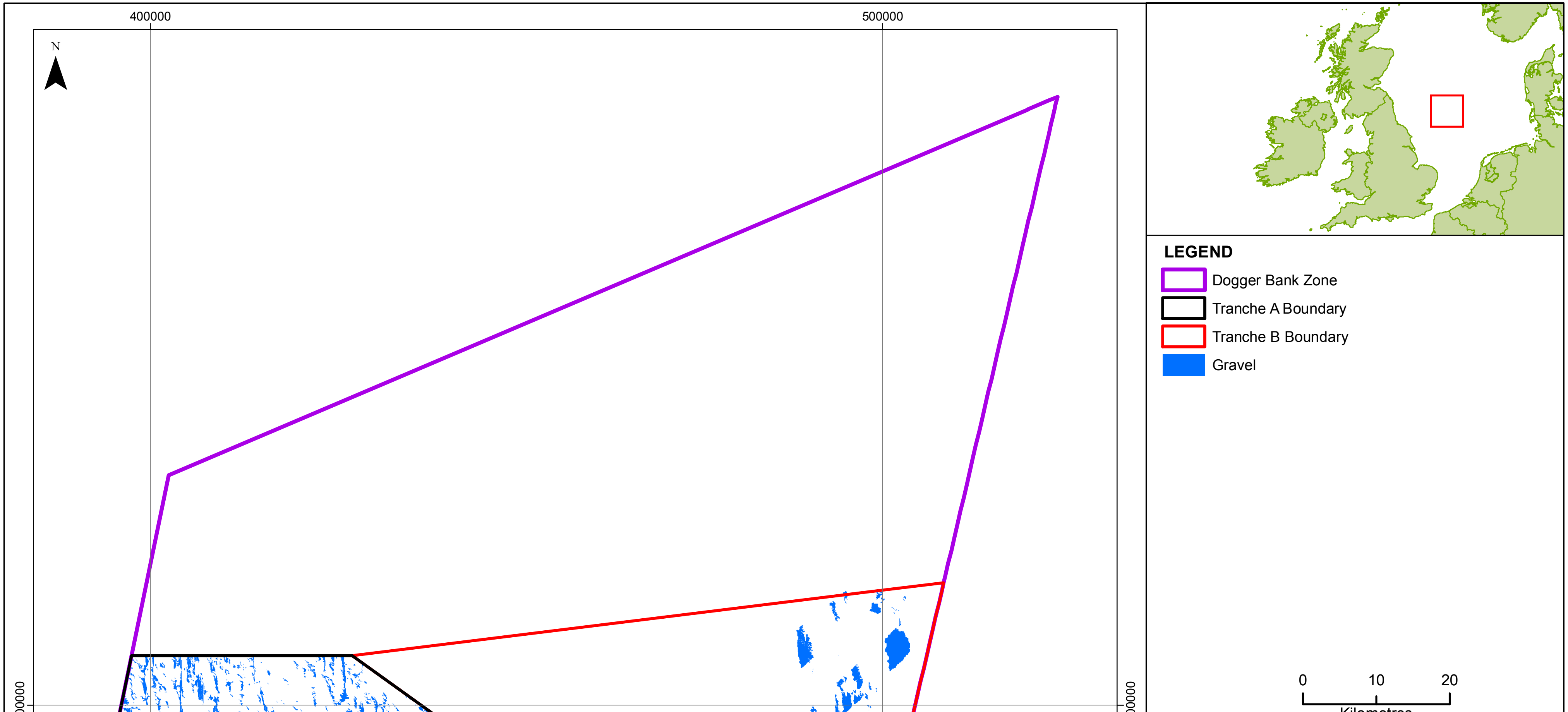
Figure 4.4 Distribution of Sand Across Tranches A and B

VER	DATE	REMARKS	Drawn	Checked
1	12/12/2012	Draft	FK	DB
2	16/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/027**

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

FOREWIND



Data Source:
Round 3 © TCE, 2010,
Tranche A Sediment © GEMS 2010,
Tranche B Sediment © Gardline 2011

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

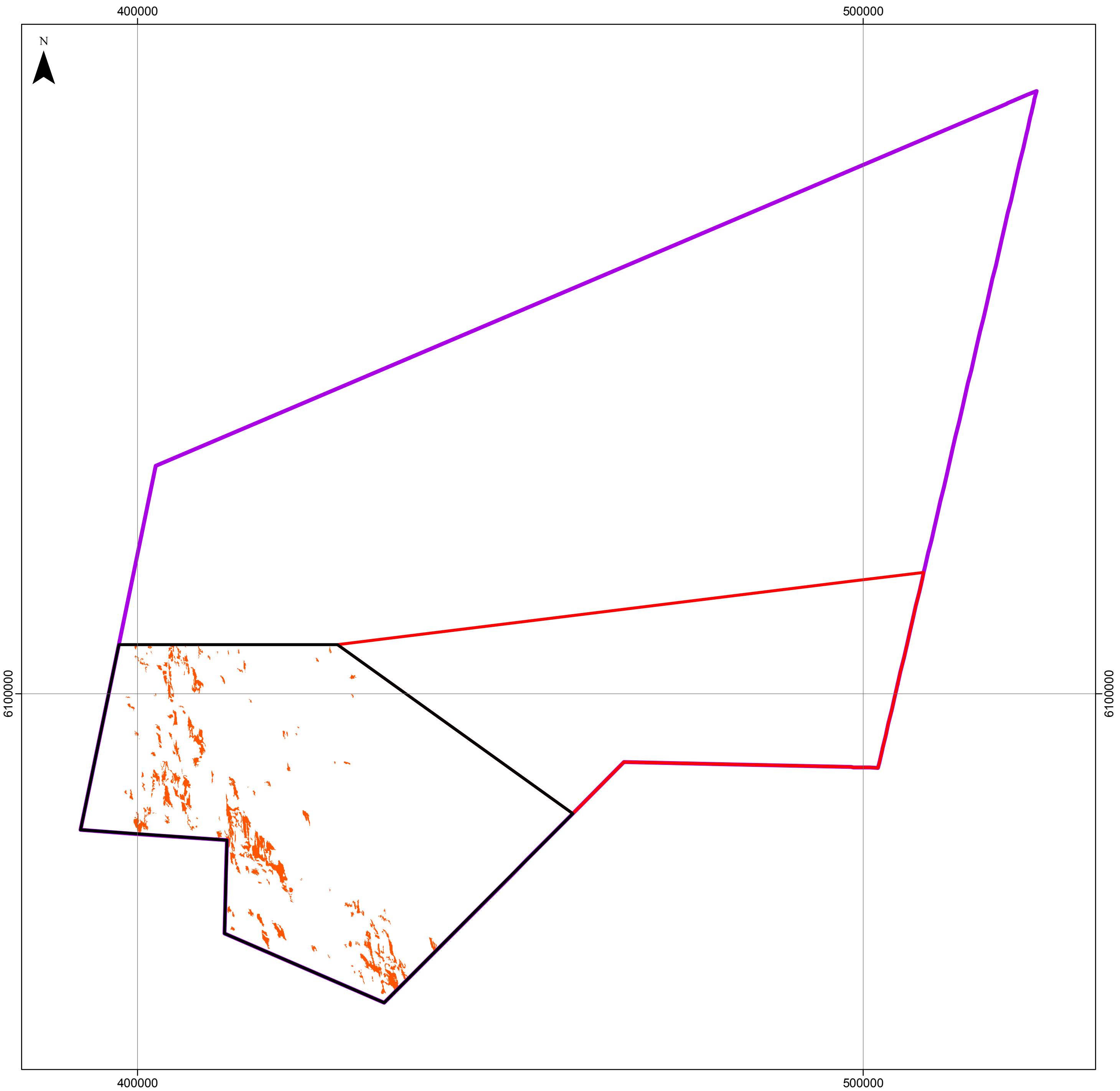
Figure 4.5 Distribution of Gravel Across Tranches A and B

VER	DATE	REMARKS	Drawn	Checked
1	12/12/2012	Draft	FK	DB
2	16/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/028**

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

FOREWIND



LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Mixed Sediments

0 10 20
Kilometres

Data Source:
Round 3 © TCE, 2010,
Tranche A Sediment © GEMS 2010,

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

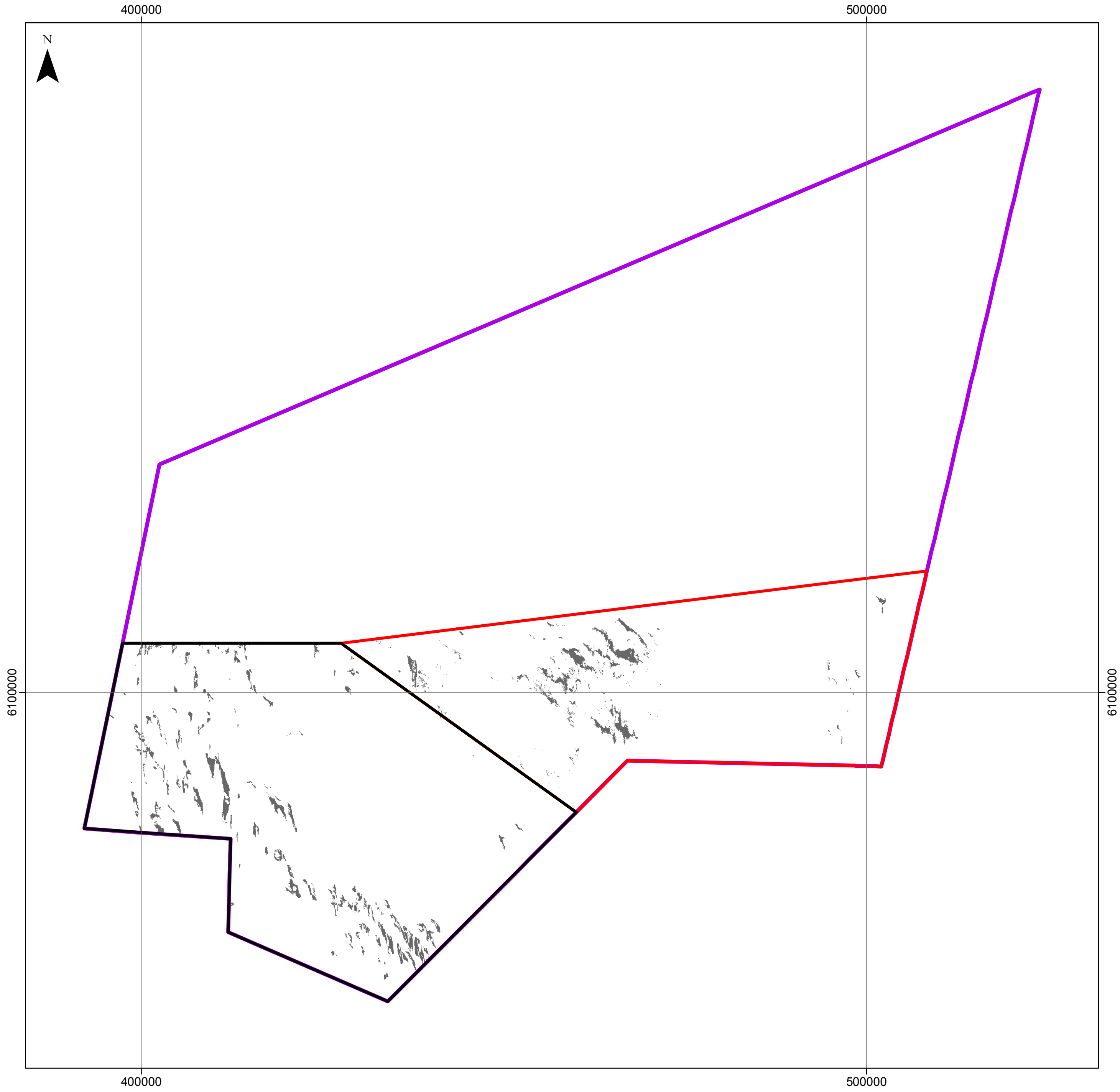
Figure 4.6 Distribution of Mixed Sediments Across Tranches A and B

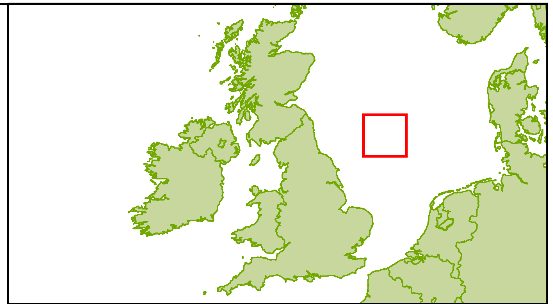
VER	DATE	REMARKS	Drawn	Checked
1	12/12/2012	Draft	LW	DB
2	16/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/029**

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

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Outcrop

0 10 20
Kilometres

Data Source:
Round 3 © TCE, 2010,
Tranche A Sediment © GEMS 2010,
Tranche B Sediment © Gardline 2011

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

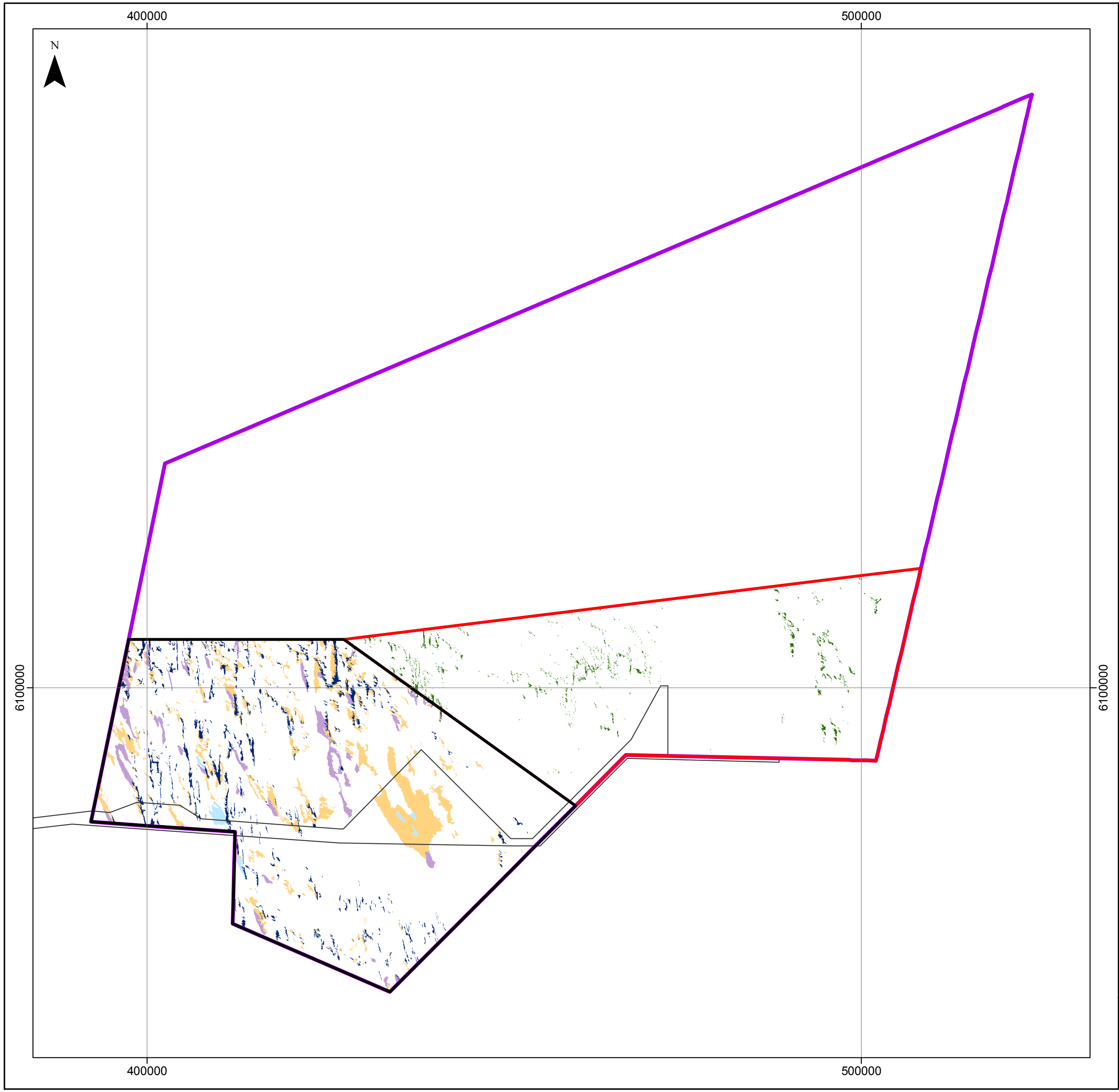
Figure 4.7 Distribution of Dogger Bank Formation Outcrop Across Tranches A and B

VER	DATE	REMARKS	Drawn	Checked
1	12/12/2012	Draft	LW	DB
2	16/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/030**

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

FOREWIND



LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Teesside A & B Cable Corridor
- Megarippled gravelly sand
- Megarippled gravel
- Megarippled sand
- Megarippled sand and sand waves
- Sand waves

0 10 20
Kilometres

Data Source:
Round 3 © TCE, 2010,
Tranche A Sediment © GEMS 2010,
Tranche B Sediment © Gardline 2011

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

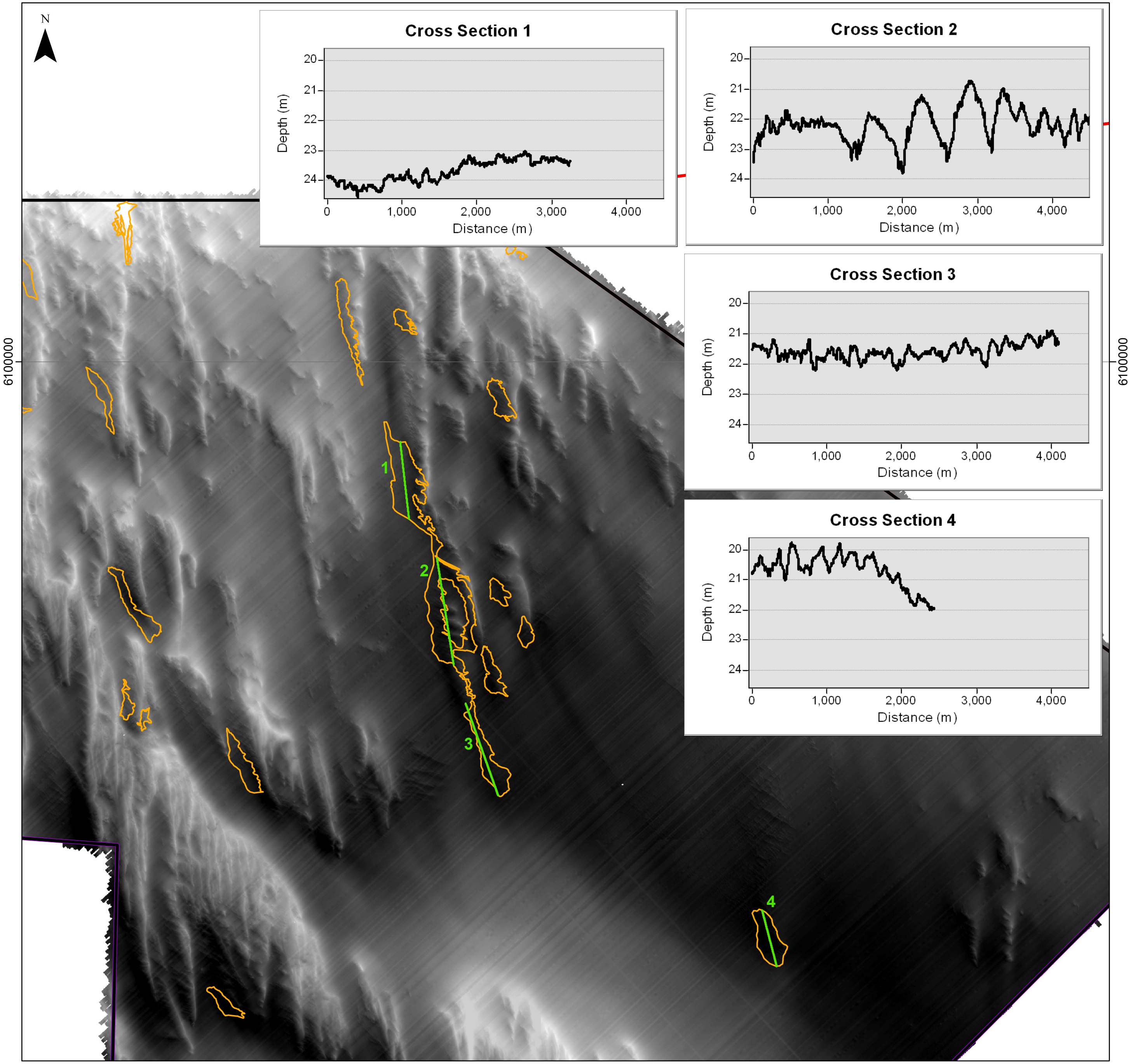
Figure 4.8 Distribution of Bedforms Across Tranches A and B

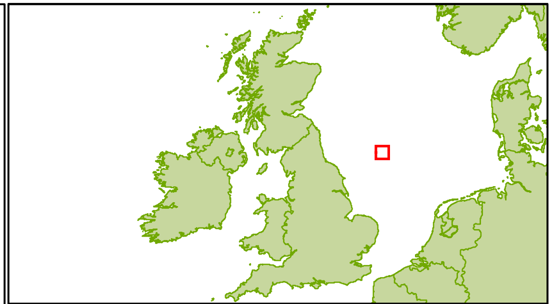
VER	DATE	REMARKS	Drawn	Checked
1	12/12/2012	Draft	LW	DB
2	12/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/031**

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

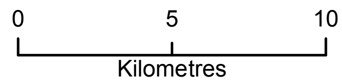
FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Areas of Sandwaves
- Sandwave Cross Sections



Data Source:
Round 3 © TCE, 2010,
Tranche A Bathymetry © GEMS 2010,

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

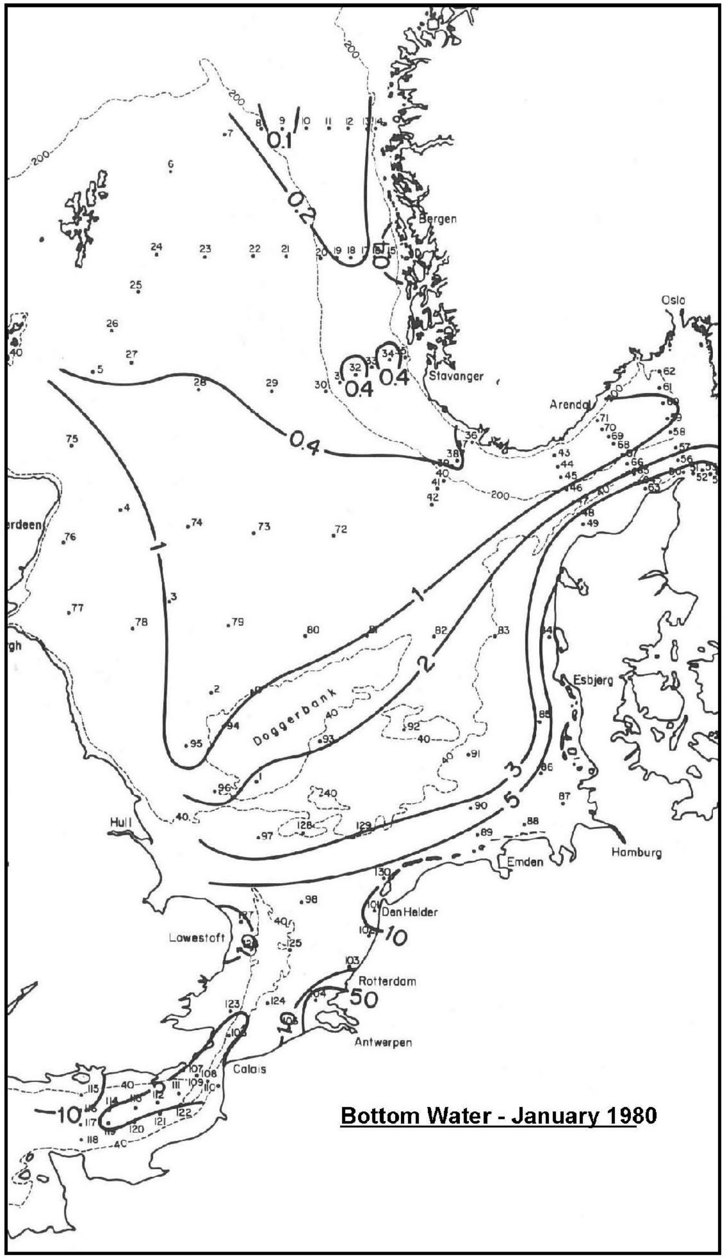
Figure 4.9 Example Sand Wave Cross Sections in Tranche A

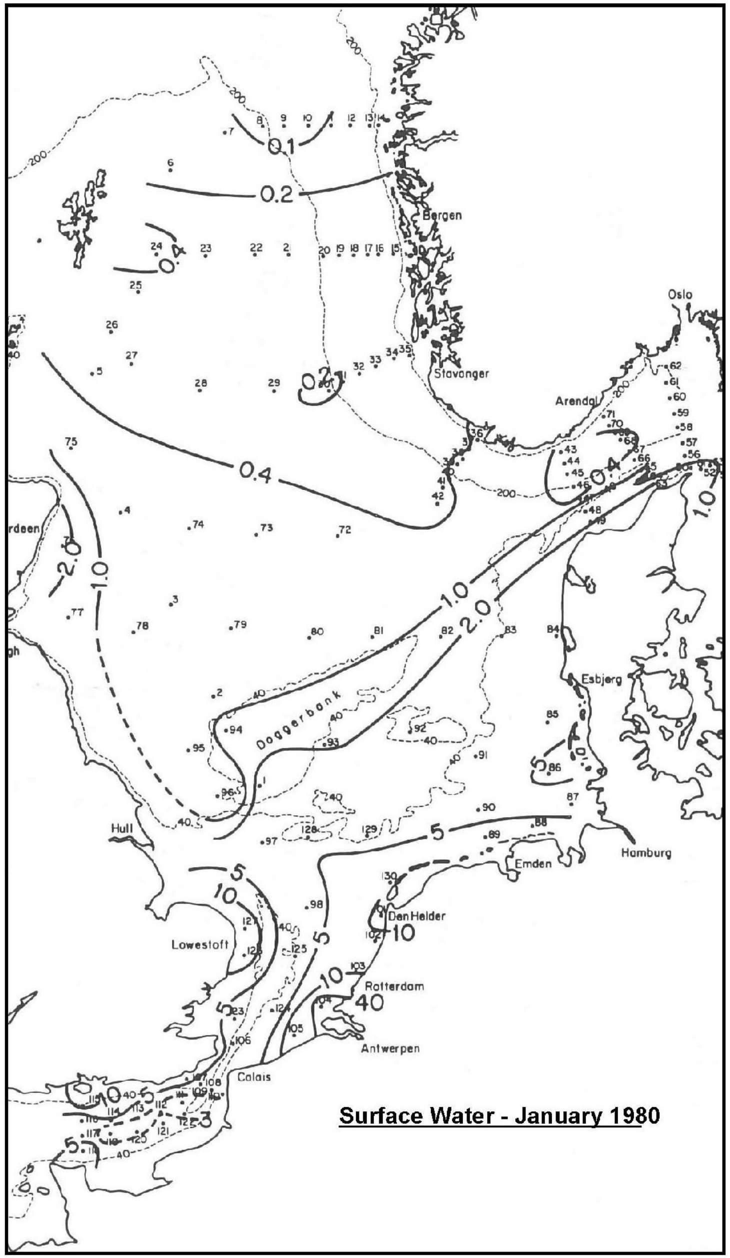
VER	DATE	REMARKS	Drawn	Checked
1	14/12/2012	Draft	LW	DB
2	12/09/2013	Final	LW	DB

DRAWING NUMBER: **9W8812/04/032**

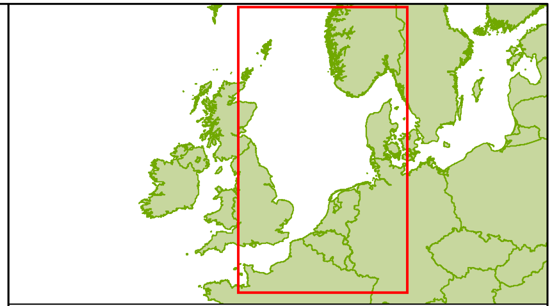
SCALE	1:246,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





N



LEGEND

Sediment contours (mg/l)

Sample point

Data Source:
Eisma and Kalf (1987)

PROJECT TITLE

DOGGER BANK CONCEPTUAL MODEL

DRAWING TITLE

Figure 4.10 Concentration of Suspended Sediment in the North Sea

VER	DATE	REMARKS	Drawn	Checked
1	04/01/2013	Draft	FK	DB
2	12/09/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/034**

SCALE	PLOT SIZE	DATUM	PROJECTION
Not to scale	A4		

FOREWIND

APPENDICES

Appendix A: Extreme Tidal Current Velocities

One-year return period depth-averaged extreme tidal current velocities (ms^{-1}) (Mathiesen and Nygaard, 2010). Locations are shown in Figure 1.6.

Direction (degrees north)	1	2	3	4	5	6	7	8
0	0.66	0.68	0.64	0.59	0.54	0.55	0.57	0.43
30	0.66	0.66	0.65	0.65	0.52	0.63	0.67	0.44
60	0.50	0.55	0.61	0.65	0.39	0.56	0.60	0.40
90	0.45	0.52	0.52	0.63	0.40	0.52	0.59	0.46
120	0.60	0.73	0.68	0.78	0.43	0.62	0.69	0.54
150	0.73	0.88	0.80	0.84	0.61	0.70	0.75	0.53
180	0.75	0.86	0.79	0.76	0.65	0.69	0.73	0.46
210	0.60	0.65	0.61	0.58	0.53	0.54	0.54	0.36
240	0.42	0.42	0.41	0.50	0.35	0.45	0.52	0.41
270	0.39	0.41	0.43	0.48	0.28	0.40	0.45	0.42
300	0.41	0.45	0.42	0.47	0.28	0.40	0.47	0.42
330	0.56	0.63	0.58	0.55	0.43	0.49	0.48	0.40

Ten-year return period depth-averaged extreme tidal current velocities (ms^{-1}) (Mathiesen and Nygaard, 2010). Locations are shown in Figure 1.6.

Direction (degrees north)	1	2	3	4	5	6	7	8
0	0.71	0.73	0.69	0.66	0.58	0.61	0.64	0.49
30	0.75	0.76	0.74	0.76	0.56	0.73	0.79	0.51
60	0.59	0.65	0.72	0.76	0.44	0.66	0.70	0.45
90	0.53	0.61	0.61	0.74	0.47	0.61	0.69	0.52
120	0.70	0.87	0.80	0.92	0.50	0.73	0.81	0.63
150	0.82	0.98	0.90	0.98	0.70	0.81	0.89	0.62
180	0.82	0.95	0.87	0.88	0.72	0.79	0.85	0.54
210	0.67	0.75	0.70	0.68	0.58	0.61	0.61	0.41
240	0.48	0.48	0.47	0.57	0.39	0.51	0.60	0.46
270	0.44	0.47	0.49	0.54	0.30	0.44	0.51	0.47
300	0.45	0.50	0.46	0.51	0.31	0.45	0.52	0.48
330	0.61	0.69	0.63	0.60	0.47	0.54	0.53	0.46

100-year return period depth-averaged extreme tidal current velocities (ms^{-1}) (Mathiesen and Nygaard, 2010). Locations are shown in Figure 1.6.

Direction (degrees north)	1	2	3	4	5	6	7	8
0	0.75	0.77	0.74	0.73	0.61	0.66	0.71	0.54
30	0.83	0.84	0.82	0.86	0.60	0.82	0.90	0.57
60	0.67	0.74	0.83	0.87	0.48	0.75	0.79	0.49
90	0.60	0.69	0.69	0.83	0.53	0.70	0.79	0.58
120	0.80	0.99	0.92	1.06	0.57	0.84	0.93	0.70
150	0.89	1.08	0.99	1.11	0.79	0.92	1.01	0.71
180	0.87	1.03	0.95	0.99	0.77	0.89	0.97	0.61
210	0.74	0.85	0.77	0.76	0.62	0.67	0.69	0.45
240	0.52	0.54	0.52	0.64	0.42	0.56	0.67	0.50
270	0.49	0.53	0.55	0.60	0.32	0.49	0.56	0.51
300	0.49	0.54	0.50	0.55	0.33	0.49	0.57	0.53
330	0.66	0.73	0.67	0.65	0.52	0.59	0.57	0.51

Appendix B: Extreme Significant Wave Heights

One-year return period extreme significant wave heights (m) and periods (seconds) (Mathiesen and Nygaard, 2010). Locations are shown in Figure 1.6.

Direction (Degrees north)	Location															
	1		2		3		4		5		6		7		8	
	H_s	T_p	H_s	T_p	H_s	T_p	H_s	T_p	H_s	T_p	H_s	T_p	H_s	T_p	H_s	T_p
0	6.6	12.0	6.5	12.1	6.5	12.0	6.5	12.2	7.1	12.1	7.0	12.1	6.9	12.3	7.3	12.1
30	4.2	9.9	4.0	9.8	4.0	9.8	3.8	9.7	4.4	10.0	4.0	9.7	3.8	9.6	4.0	9.6
60	4.6	10.3	4.4	10.2	4.5	10.2	4.4	10.2	4.8	10.3	4.6	10.2	4.7	10.4	5.0	10.4
90	4.8	10.4	4.6	10.4	4.8	10.5	4.6	10.4	5.1	10.5	4.9	10.4	4.8	10.5	5.2	10.5
120	4.4	10.1	4.4	10.2	4.6	10.3	4.5	10.3	5.0	10.5	4.9	10.4	4.8	10.5	5.3	10.6
150	4.1	9.9	4.2	10.0	4.2	9.9	3.9	9.7	4.5	10.0	4.2	9.9	4.0	9.8	4.3	9.8
180	5.0	10.6	4.8	10.6	4.9	10.6	4.9	10.7	5.2	10.6	5.2	10.7	5.1	10.8	5.3	10.7
210	5.6	11.1	5.4	11.1	5.5	11.1	5.4	11.2	5.8	11.2	5.9	11.3	5.5	11.1	6.0	11.2
240	5.8	11.4	5.7	11.4	5.8	11.4	6.0	11.7	6.4	11.6	6.5	11.8	6.1	11.7	7.2	12.0
270	5.9	11.4	5.7	11.5	6.1	11.6	6.3	12.0	6.3	11.6	6.7	12.0	6.7	12.2	7.6	12.3
300	6.2	11.6	6.1	11.8	6.1	11.6	6.2	11.9	6.6	11.8	6.7	11.9	6.6	12.1	7.2	12.0
330	6.7	12.1	6.5	12.1	6.7	12.1	7.1	12.7	7.2	12.3	7.3	12.4	7.6	12.9	8.0	12.6

Ten-year return period extreme significant wave heights (m) and periods (seconds) (Mathiesen and Nygaard, 2010). Locations are shown in Figure 1.6.

Direction (Degrees north)	Location															
	1		2		3		4		5		6		7		8	
	H_s	T_p	H_s	T_p	H_s	T_p	H_s	T_p	H_s	T_p	H_s	T_p	H_s	T_p	H_s	T_p
0	8.6	13.6	8.6	13.9	8.6	13.7	8.8	14.1	9.3	13.8	9.3	13.9	9.3	14.2	9.8	13.8
30	5.6	11.2	5.4	11.1	5.4	11.0	5.1	10.9	6.1	11.3	5.5	10.9	5.1	10.8	5.4	10.7
60	5.9	11.4	5.8	11.5	5.9	11.4	5.8	11.5	6.2	11.5	5.9	11.3	6.1	11.6	6.5	11.5
90	6.0	11.5	5.9	11.5	6.1	11.6	5.7	11.5	6.5	11.7	6.2	11.5	6.1	11.7	6.7	11.6
120	5.6	11.2	5.7	11.4	5.9	11.5	5.7	11.4	6.5	11.7	6.2	11.5	6.0	11.6	6.7	11.6
150	5.2	10.9	5.3	11.1	5.3	11.0	5.0	10.8	5.8	11.1	5.4	10.9	5.1	10.8	5.5	10.7
180	6.2	11.6	6.0	11.7	6.1	11.7	6.1	11.8	6.5	11.7	6.5	11.7	6.3	11.9	6.7	11.7
210	6.8	12.2	6.5	12.1	6.6	12.1	6.6	12.2	7.2	12.2	7.2	12.3	6.7	12.1	7.4	12.2
240	7.3	12.6	7.1	12.7	7.2	12.6	7.5	13.0	8.2	12.9	8.2	13.0	7.6	12.9	9.1	13.4
270	7.3	12.6	7.1	12.7	7.6	12.9	7.9	13.3	7.9	12.7	8.4	13.3	8.4	13.6	9.5	13.7
300	7.8	13.0	7.7	13.2	7.6	12.9	7.9	13.3	8.4	13.1	8.5	13.3	8.4	13.5	9.3	13.5
330	8.5	13.5	8.2	13.6	8.4	13.5	9.0	14.3	9.1	13.7	9.2	13.8	9.6	14.5	10.2	14.1

50-year return period extreme significant wave heights (m) and periods (seconds) (Mathiesen and Nygaard, 2010). Locations are shown in Figure 1.6.

Direction (Degrees north)	Location															
	1		2		3		4		5		6		7		8	
	H_s	T_p	H_s	T_p	H_s	T_p	H_s	T_p	H_s	T_p	H_s	T_p	H_s	T_p	H_s	T_p
0	10.0	14.7	10.0	15.1	10.0	14.8	10.3	15.3	10.8	14.8	10.9	15.0	10.9	15.5	11.5	15.0
30	6.6	12.0	6.4	12.0	6.3	11.8	6.0	11.7	7.2	12.2	6.4	11.7	6.0	11.6	6.4	11.4
60	6.8	12.2	6.6	12.2	6.8	12.2	6.6	12.3	7.2	12.2	6.8	12.0	7.0	12.4	7.5	12.2
90	6.9	12.2	6.6	12.2	6.9	12.3	6.5	12.1	7.4	12.4	7.0	12.1	6.9	12.3	7.6	12.3
120	6.4	11.8	6.5	12.1	6.7	12.2	6.4	12.0	7.4	12.4	7.0	12.2	6.7	12.2	7.5	12.3
150	5.9	11.5	6.1	11.7	6.1	11.6	5.6	11.4	6.6	11.8	6.2	11.5	5.8	11.4	6.2	11.3
180	6.9	12.3	6.8	12.3	6.9	12.3	6.9	12.5	7.3	12.3	7.3	12.4	7.1	12.5	7.6	12.3
210	7.5	12.8	7.2	12.7	7.4	12.7	7.3	12.8	8.0	12.8	8.0	12.9	7.4	12.8	8.3	12.8
240	8.3	13.4	8.0	13.4	8.1	13.3	8.4	13.7	9.3	13.8	9.2	13.8	8.5	13.6	10.4	14.2
270	8.2	13.3	8.0	13.4	8.5	13.6	8.9	14.2	8.9	13.5	9.5	14.1	9.5	14.4	10.8	14.5
300	8.9	13.8	8.8	14.1	8.6	13.7	9.0	14.2	9.6	14.0	9.7	14.2	9.5	14.4	10.6	14.4
330	9.6	14.4	9.2	14.4	9.5	14.4	10.3	15.3	10.4	14.5	10.4	14.7	11.0	15.6	11.7	15.1

Appendix C: Particle Size Analyses in Tranche A

Particle size distribution of seabed sand samples across Tranche A ordered by decreasing percentage of sand (EMU, 2013). Locations are shown in Figure 1.6.

Sample ID	% sand	% gravel	% mud	D_{50} (mm)	Classification
TA_GRAB_045	99.02	0.03	0.95	0.29	Slightly Gravelly Sand
TA_GRAB_046	99.01	0.01	0.97	0.22	Slightly Gravelly Sand
TA_GRAB_039	98.92	0.01	1.08	0.30	Slightly Gravelly Sand
TA_GRAB_044	98.88	0.01	1.11	0.18	Slightly Gravelly Sand
TA_GRAB_043	98.86	0.08	1.06	0.18	Slightly Gravelly Sand
TA_GRAB_076	98.85	0.11	1.03	0.20	Slightly Gravelly Sand
TA_GRAB_010	98.82	0.00	1.18	0.21	Sand
TA_GRAB_017	98.82	0.10	1.08	0.19	Slightly Gravelly Sand
TA_GRAB_015	98.82	0.03	1.15	0.18	Slightly Gravelly Sand
TA_GRAB_095	98.81	0.12	1.07	0.18	Slightly Gravelly Sand
TA_GRAB_049	98.80	0.08	1.12	0.17	Slightly Gravelly Sand
TA_GRAB_074	98.80	0.01	1.19	0.19	Slightly Gravelly Sand
TA_GRAB_047	98.78	0.07	1.14	0.17	Slightly Gravelly Sand
TA_GRAB_088	98.78	0.03	1.19	0.17	Slightly Gravelly Sand
TA_GRAB_101	98.77	0.10	1.13	0.18	Slightly Gravelly Sand
TA_GRAB_019	98.77	0.14	1.09	0.18	Slightly Gravelly Sand
TA_GRAB_094	98.74	0.12	1.14	0.20	Slightly Gravelly Sand
TA_GRAB_075	98.72	0.14	1.13	0.19	Slightly Gravelly Sand
TA_GRAB_096	98.71	0.05	1.25	0.17	Slightly Gravelly Sand
TA_GRAB_097	98.71	0.12	1.17	0.20	Slightly Gravelly Sand
TA_GRAB_061	98.68	0.14	1.18	0.19	Slightly Gravelly Sand
TA_GRAB_020	98.68	0.22	1.11	0.19	Slightly Gravelly Sand
TA_GRAB_093	98.67	0.24	1.09	0.17	Slightly Gravelly Sand
TA_GRAB_071	98.66	0.02	1.32	0.16	Slightly Gravelly Sand
TA_GRAB_068	98.64	0.01	1.35	0.25	Slightly Gravelly Sand
TA_GRAB_098	98.63	0.12	1.26	0.19	Slightly Gravelly Sand
TA_GRAB_053	98.60	0.13	1.27	0.17	Slightly Gravelly Sand
TA_GRAB_048	98.60	0.12	1.28	0.19	Slightly Gravelly Sand
TA_GRAB_042	98.59	0.02	1.39	0.18	Slightly Gravelly Sand
TA_GRAB_032	98.58	0.18	1.25	0.18	Slightly Gravelly Sand
TA_GRAB_084	98.56	0.07	1.37	0.16	Slightly Gravelly Sand
TA_GRAB_100	98.54	0.25	1.21	0.17	Slightly Gravelly Sand
TA_GRAB_016	98.53	0.08	1.39	0.19	Slightly Gravelly Sand
TA_GRAB_013	98.52	0.13	1.35	0.18	Slightly Gravelly Sand
TA_GRAB_090	98.49	0.25	1.26	0.17	Slightly Gravelly Sand
TA_GRAB_091	98.48	0.37	1.15	0.18	Slightly Gravelly Sand

Sample ID	% sand	% gravel	% mud	D_{50} (mm)	Classification
TA_GRAB_077	98.46	0.14	1.40	0.19	Slightly Gravelly Sand
TA_GRAB_080	98.45	0.39	1.16	0.18	Slightly Gravelly Sand
TA_GRAB_011	98.41	0.35	1.24	0.18	Slightly Gravelly Sand
TA_GRAB_063	98.36	0.41	1.23	0.20	Slightly Gravelly Sand
TA_GRAB_057	98.30	0.06	1.64	0.18	Slightly Gravelly Sand
TA_GRAB_060	98.28	0.37	1.35	0.17	Slightly Gravelly Sand
TA_GRAB_036	98.26	0.50	1.24	0.17	Slightly Gravelly Sand
TA_GRAB_079	98.26	0.24	1.50	0.17	Slightly Gravelly Sand
TA_GRAB_018	98.23	0.71	1.05	0.18	Slightly Gravelly Sand
TA_GRAB_051	98.23	0.59	1.18	0.16	Slightly Gravelly Sand
TA_GRAB_103	98.17	0.48	1.36	0.18	Slightly Gravelly Sand
TA_GRAB_008	97.94	0.31	1.74	0.15	Slightly Gravelly Sand
TA_GRAB_072	97.90	0.65	1.45	0.17	Slightly Gravelly Sand
TA_GRAB_003	97.87	0.31	1.82	0.17	Slightly Gravelly Sand
TA_GRAB_034	97.85	0.39	1.76	0.16	Slightly Gravelly Sand
TA_GRAB_021	97.85	1.16	0.99	0.17	Slightly Gravelly Sand
TA_GRAB_005	97.79	0.87	1.34	0.17	Slightly Gravelly Sand
TA_GRAB_083	97.65	0.08	2.27	0.16	Slightly Gravelly Sand
TA_GRAB_025	97.62	0.41	1.96	0.15	Slightly Gravelly Sand
TA_GRAB_037	97.42	1.45	1.13	0.20	Slightly Gravelly Sand
TA_GRAB_022	97.39	1.56	1.05	0.19	Slightly Gravelly Sand
TA_GRAB_029	97.11	1.02	1.87	0.15	Slightly Gravelly Sand
TA_GRAB_054	97.10	1.41	1.49	0.18	Slightly Gravelly Sand
TA_GRAB_012	96.92	1.43	1.65	0.17	Slightly Gravelly Sand
TA_GRAB_062	96.78	2.23	0.99	0.45	Slightly Gravelly Sand
TA_GRAB_041	96.78	0.36	2.86	0.17	Slightly Gravelly Sand
TA_GRAB_009	96.72	1.09	2.19	0.17	Slightly Gravelly Sand
TA_GRAB_052	96.71	1.82	1.47	0.17	Slightly Gravelly Sand
TA_GRAB_059	96.61	0.48	2.92	0.15	Slightly Gravelly Sand
TA_GRAB_085	96.57	1.62	1.82	0.16	Slightly Gravelly Sand
TA_GRAB_007	96.11	2.38	1.51	0.17	Slightly Gravelly Sand
TA_GRAB_087	95.81	3.13	1.05	0.28	Slightly Gravelly Sand
TA_GRAB_081	95.76	2.88	1.36	0.17	Slightly Gravelly Sand
TA_GRAB_004	95.75	2.95	1.30	0.17	Slightly Gravelly Sand
TA_GRAB_033	95.64	1.79	2.57	0.16	Slightly Gravelly Sand
TA_GRAB_070	95.53	2.75	1.72	0.18	Slightly Gravelly Sand
TA_GRAB_027	95.36	0.11	4.54	0.15	Slightly Gravelly Sand
TA_GRAB_056	95.26	3.52	1.23	0.17	Slightly Gravelly Sand
TA_GRAB_092	94.95	3.17	1.88	0.16	Slightly Gravelly Sand
TA_GRAB_001	94.84	3.70	1.46	0.18	Slightly Gravelly Sand
TA_GRAB_006	93.72	5.16	1.12	0.18	Gravelly Sand

Sample ID	% sand	% gravel	% mud	D_{50} (mm)	Classification
TA_GRAB_030	93.34	3.81	2.85	0.15	Slightly Gravelly Sand
TA_GRAB_014	93.19	5.79	1.01	0.18	Gravelly Sand
TA_GRAB_028	91.42	6.45	2.13	0.17	Gravelly Sand
TA_GRAB_089	88.00	11.08	0.92	0.62	Gravelly Sand

Particle size distribution of gravelly seabed sediment samples across Tranche A (EMU, 2013). Locations are shown in Figure 1.6.

Sample ID	% sand	% gravel	% mud	D_{50} (mm)	Classification
TA_GRAB_104	68.29	30.79	0.92	0.23	Sandy Gravel
TA_GRAB_078	42.27	53.12	4.61	2.40	Sandy Gravel
TA_GRAB_105	41.63	58.34	0.04	4.37	Sandy Gravel
TA_GRAB_066	38.38	60.52	1.10	2.38	Sandy Gravel
TA_GRAB_099	35.56	63.46	0.98	3.85	Sandy Gravel
TA_GRAB_040	35.14	60.59	4.27	3.75	Muddy Sandy Gravel
TA_GRAB_055	33.76	65.62	0.62	6.16	Sandy Gravel
TA_GRAB_024	29.89	69.18	0.93	9.35	Sandy Gravel
TA_GRAB_002	28.87	70.76	0.37	6.37	Sandy Gravel
TA_GRAB_026	27.37	71.07	1.56	4.18	Sandy Gravel
TA_GRAB_035	26.88	72.68	0.45	50.20	Sandy Gravel
TA_GRAB_106	25.45	72.90	1.65	5.34	Sandy Gravel
TA_GRAB_050	24.24	75.30	0.46	5.49	Sandy Gravel
TA_GRAB_038	22.65	75.88	1.47	7.71	Sandy Gravel
TA_GRAB_073	20.01	76.70	3.29	5.68	Muddy Sandy Gravel
TA_GRAB_065	18.06	81.76	0.18	46.94	Gravel
TA_GRAB_102	17.02	81.98	1.00	6.27	Gravel
TA_GRAB_064	10.21	89.42	0.36	6.10	Gravel

Appendix D: Particle Size Analyses in Tranche B

Particle size distribution of seabed sand samples across Tranche B ordered by decreasing percentage of sand (Gardline 2013b). Locations are shown in Figure 1.6.

Sample ID	% sand	% gravel	% mud	D_{50} (mm)	Classification
TB_GRAB_21	98.8	0.1	1.1	0.17	Slightly Gravelly Sand
TB_GRAB_41	98.8	0.2	1.0	0.17	Slightly Gravelly Sand
TB_GRAB_27	98.7	0.2	1.2	0.19	Slightly Gravelly Sand
TB_GRAB_39	98.7	0.1	1.2	0.17	Slightly Gravelly Sand
TB_GRAB_32	98.6	0.3	1.1	0.18	Slightly Gravelly Sand
TB_GRAB_22	98.6	0.3	1.2	0.17	Slightly Gravelly Sand
TB_GRAB_33	98.5	0.2	1.3	0.17	Slightly Gravelly Sand
TB_GRAB_44	98.4	0.3	1.3	0.17	Slightly Gravelly Sand
TB_GRAB_14	98.4	0.3	1.3	0.17	Slightly Gravelly Sand
TB_GRAB_08	98.3	0.7	1.0	0.17	Slightly Gravelly Sand
TB_GRAB_40	98.2	0.4	1.3	0.17	Slightly Gravelly Sand
TB_GRAB_23	98.2	0.5	1.2	0.17	Slightly Gravelly Sand
TB_GRAB_51	98.2	0.3	1.5	0.16	Slightly Gravelly Sand
TB_GRAB_11	98.2	0.4	1.4	0.17	Slightly Gravelly Sand
TB_GRAB_45	98.0	0.9	1.1	0.16	Slightly Gravelly Sand
TB_GRAB_46	97.9	0.9	1.2	0.17	Slightly Gravelly Sand
TB_GRAB_43	97.8	0.8	1.4	0.16	Slightly Gravelly Sand
TB_GRAB_34	97.8	0.6	1.6	0.16	Slightly Gravelly Sand
TB_GRAB_52	97.5	0.9	1.6	0.16	Slightly Gravelly Sand
TB_GRAB_26	97.4	0.8	1.8	0.17	Slightly Gravelly Sand
TB_GRAB_10	97.3	1.5	1.3	0.17	Slightly Gravelly Sand
TB_GRAB_42	97.1	1.3	1.6	0.17	Slightly Gravelly Sand
TB_GRAB_35	97.0	1.6	1.4	0.16	Slightly Gravelly Sand
TB_GRAB_38	96.7	1.7	1.6	0.17	Slightly Gravelly Sand
TB_GRAB_01	96.4	2.0	1.5	0.16	Slightly Gravelly Sand
TB_GRAB_18	96.2	2.7	1.1	0.16	Slightly Gravelly Sand
TB_GRAB_09	96.2	2.5	1.3	0.16	Slightly Gravelly Sand
TB_GRAB_28	96.2	2.5	1.3	0.17	Slightly Gravelly Sand
TB_GRAB_03	95.5	3.2	1.3	0.18	Slightly Gravelly Sand
TB_GRAB_13	95.5	3.2	1.3	0.17	Slightly Gravelly Sand
TB_GRAB_04	95.4	3.2	1.4	0.17	Slightly Gravelly Sand
TB_GRAB_07	95.4	3.4	1.1	0.16	Slightly Gravelly Sand
TB_GRAB_29	95.2	3.9	0.9	0.17	Slightly Gravelly Sand
TB_GRAB_25	95.2	3.6	1.3	0.17	Slightly Gravelly Sand
TB_GRAB_15	95.1	4.0	0.9	0.17	Slightly Gravelly Sand

Sample ID	% sand	% gravel	% mud	D_{50} (mm)	Classification
TB_GRAB_16	94.2	4.3	1.4	0.17	Slightly Gravelly Sand
TB_GRAB_02	92.6	5.7	1.7	0.16	Gravelly Sand
TB_GRAB_24	90.4	7.7	1.9	0.17	Gravelly Sand
TB_GRAB_36	89.2	9.3	1.5	0.17	Gravelly Sand
TB_GRAB_37	86.1	10.1	3.7	0.17	Gravelly Sand
TB_GRAB_19	85.0	13.8	1.2	0.18	Gravelly Sand
TB_GRAB_12	82.9	16.1	1.0	0.18	Gravelly Sand
TB_GRAB_05	82.6	16.1	1.4	0.17	Gravelly Sand
TB_GRAB_17	81.9	16.8	1.3	0.18	Gravelly Sand
TB_GRAB_20	80.2	18.8	0.9	0.19	Gravelly Sand
TB_GRAB_06	75.5	23.4	1.1	0.18	Gravelly Sand

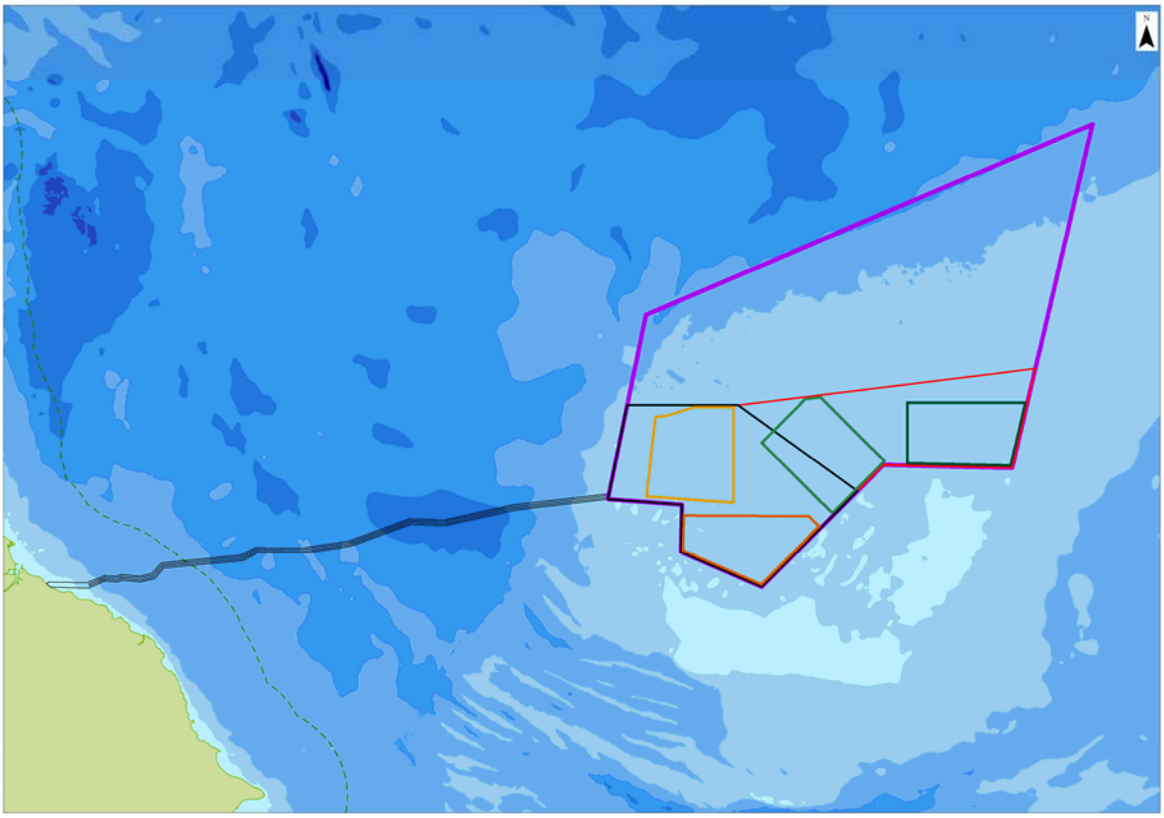
Particle size distribution of gravelly seabed sediment samples across Tranche B (Gardline 2013b). Locations are shown in Figure 1.6.

Sample ID	% sand	% gravel	% mud	D_{50} (mm)	Classification
TB_GRAB_49	49.3	49.0	1.7	1.78	Sandy Gravel
TB_GRAB_30	26.7	72.1	1.1	8.21	Sandy Gravel
TB_GRAB_53	20.4	72.4	7.2	5.52	Muddy Sandy Gravel
TB_GRAB_50	18.1	81.6	0.3	14.18	Gravel
TB_GRAB_48	6.4	93.3	0.3	10.49	Gravel

Appendix E: Wreck and scour data in Tranche B (source: Wessex Archaeology)

GL ID	Easting	Northing	Length	Width	Height	Description	Scour Description	Approx. Scour/ Depression Size	Approx. Scour/ Depression Volume
BW001	454569	6109318	30.0	10.0	0.8	Located outside of the development zone so not examined in detail. Wreck appears oriented approximately north-northwest-south-southeast.	No real scour, but located in a roughly circular depression.	45m x 48m x -0.7m	$324m^3$
BW002	459220	6084897	15.0	13.0	0.9	Distinct anomaly located within Teesside B, but appears as a mound rather than an obvious wreck site. No real scour, but located in a very shallow depression slightly elongated to the southeast.	Very shallow depression with no real scour, but depression is slightly elongated to the southeast.	29m x 25m x -0.2m	$33m^3$
BW003	466094	6090162	29.0	9.0	0.7	Distinct wreck site oriented north-northwest-south-southeast, located within Teesside B. No real scour, but wreck is located within a small depression elongated along the same orientation as the wreck.	Shallow depression with no scour, oriented north-northwest-south-southeast around the wreck.	39m x 28m x -0.5m	$94m^3$
BW004	471569	6107213	23.0	12.0	3.5	Located outside of the development zone so not examined in detail. Wreck appears orientated approximately north-northwest-south-southeast.	No real scour, located in a roughly circular depression.	38m x 37m x -0.8m	$323m^3$
BW007	470632	6103424	14.0	12.0	0.8	Located outside of the development zone so not examined in detail. Wreck appears oriented approximately north-northwest-south-southeast.	No real scour, located in a roughly circular depression.	27m x 22m x -0.4m	$34m^3$
BW008	476652	6109517	14.0	10.0	0.9	Located outside of the development zone so not examined in detail. Wreck appears oriented approximately north-northwest-south-southeast.	No real scour, located in a very small, irregular depression.	27m x 20m x -0.3	$17m^3$
BW005	484534	6107141	34.5	10.0	0.7	Distinct wreck site oriented northeast-southwest, located within Teesside A. Wreck itself is relatively small, but is located within a large depression. No real scour.	No real scour, located in a large, deep depression oriented northeast-southwest.	62m x 45m x -1.4m	$675m^3$
BW006	490302	6109170	48	11	3.5	Located outside of the development zone so not examined in detail. Wreck appears oriented approximately northwest-southeast.	No real scour, located in a shallow depression oriented northwest-southeast.	51m x 25m -0.6m	$127m^3$

Appendix B: Dogger Bank Teesside A & B export cable corridor conceptual model



Conceptual Model - Export Cable Corridor.
Dogger Bank Teesside A & B

Forewind

20 January 2014
Final Report
9X5889

Royal HaskoningDHV
Enhancing Society Together

FOREWIND

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Drafted by	Jennifer Godwin and David Brew	
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Date/initials approval	20.01.2014	…………………..

NON TECHNICAL SUMMARY

Forewind Limited is in the process of developing Zone 3 Dogger Bank of Round 3 of the offshore wind farm programme. The first area to be developed (Dogger Bank Creyke Beck A & B) is located in the southwest part of the Dogger Bank Zone. The second area to be developed, Dogger Bank Teesside A & B, lies to the east of Dogger Bank Creyke Beck A & B. Electricity from Dogger Bank Teesside A & B will be transferred to shore by export cables, which will be routed to a landfall point along the Teesside coast between Redcar and Marske-by-the-Sea.

This conceptual model describes the physical and sedimentary processes operating along the Dogger Bank Teesside A & B export cable corridor to support the Environment Impact Assessment for the Dogger Bank Teesside Projects. This baseline understanding is used to scope the potential changes to the processes caused by construction and decommissioning of the cable. The conceptual model is compiled predominantly from existing data supported by new bathymetry and seabed sediment data collected by Forewind.

Water depths vary along the export cable corridor from just above LAT close to the landfall site, deepening to about 80m below LAT mid-way. The seabed along the corridor is covered mainly by sand with some areas of gravel and exposed bedrock. Suspended sediment concentrations appear less than 2mg/l along most of the corridor.

Tidal currents flowing across the corridor vary from 0.40m/s at the offshore end to up to 0.60m/s off the coast at Redcar. Short stretches of the corridor seabed have been molded into sand waves and megaripples by these tidal currents. The crests of these bedforms are oriented northeast to southwest and their geometry indicates migration and hence sediment transport to the southeast. Waves at the offshore end of the corridor have a mean significant wave height (the average of the highest one third of waves) of above 1.75m decreasing to less than 1.0m towards the landfall site.

This conceptual model concludes by briefly outlining the baseline parameters that are most likely to be affected by construction and decommissioning of the export cables. The main effect will be changes to suspended sediment concentrations and dispersion of this sediment to other parts of the southern North Sea.

CONTENTS

1 INTRODUCTION

1.1 Dogger Bank Export Cable Corridor

1.1.1 Forewind Limited is proposing to develop an offshore wind farm on Dogger Bank. The first project areas identified were Dogger Bank Creyke Beck A & B located in Tranche A across the southwest part of the Dogger Bank Zone (Figure 1.1). The second projects to be developed, Dogger Bank Teesside A and Dogger Bank Teesside B, are primarily located within Tranche B, with a partial overlap into Tranche A.

1.1.2 Electricity from Dogger Bank Teesside A & B will be transferred to shore by export cables, which will be routed to a landfall point along the Teesside coast between Redcar and Marske-by-the-Sea before connecting to the National Grid just south of the Tees Estuary. The cables will likely be buried at shallow depths depending on localised seabed conditions. The Dogger Bank Teesside A & B export cable corridor is approximately 157km long from its connections at the Dogger Bank Zone to the beach at Redcar. The export cable corridor comprises two 500m wide sub-corridors separated by 500m of seabed (total cable corridor width of 1,500m).

1.1.3 This conceptual model uses existing data to describe the baseline physical, sedimentary and geomorphological processes operating along the Dogger Bank Teesside A & B export cable corridor. This conceptual understanding is used to scope the potential changes to the processes caused by construction and decommissioning of the cable.

1.2 Data Collected along the Export Cable Corridor

Geophysics

1.2.1 Gardline (2013) collected geophysical data along the two potential sub-corridors of the export cable corridor during a survey campaign between May 2012 and July 2012. Data collection included bathymetry (multi-beam echosounder and side-scan sonar) and sub-bottom profiling.

1.2.2 The main geophysical lines were run approximately 100m apart along the majority of the length of the export cable sub-corridors (Figure 1.2) achieving 100% coverage of side scan and bathymetry. For the cable corridor nearer to the coast, geophysical survey lines were approximately 25m apart up to 5km from the coast and then approximately 50m from 5km to 16km from the coast.

Grab Samples

1.2.3 Gardline (2013) collected 36 seabed sediment grab samples along the Dogger Bank Teesside A & B cable corridor (Figure 1.3). All of these samples have been analysed for particle size distribution. No boreholes or CPTs are planned to be taken in the cable corridor.

1.3 Environmental Designation

1.3.1 Dogger Bank is currently designated as a candidate Special Area of Conservation (cSAC) comprising an area of 12,331km^2 with Annex I sandbank qualifying habitat. The eastern extent (approximately 10km) of the Dogger Bank Teesside A & B export cable corridor falls within the cSAC boundary (Figure 1.4).

1.3.2 The cSAC's covering of sandy sediments in the shallower (<20m depth) areas to the southwest, and their associated benthic fauna fall within the Annex 1 classification; sandbanks which are slightly covered by seawater all of the time (JNCC, 2011). In general, the biological communities on the Dogger Bank are typical of fine sand and muddy sand sub-littoral sediments. Species typical of these communities include the following:

- polychaetes: *Nephtys cirrosa* and *Magelona* sp;
- mobile amphipods: genus *Bathyporeia*;
- brittlestar: *Amphiura filiformis*; and
- bivalve molluscs: *Tellina fabula* (formerly *Fabulina fabula*) and *Mysella bidentata*.

1.3.3 Epifaunal species include:

- hermit crab: *Pagurus bernhardus*;
- sand eels: *Ammodytes* spp;
- plaice: *Pleuronectes platessa*; and
- starfish: *Asterias rubens*.

1.3.4 A detailed discussion of habitats and species across the entire Dogger Bank can be found in Van Moorsel (2011).

1.3.5 Currently there are no other designations along the cable corridor route. However, the cable corridor passes to the north of two proposed Marine Conservation Zones (NG12 Compass Rose and NG 11 Runswick Bay) and one Recommended Reference Area (RA 10 Compass Rose) (Net Gain, 2011) (Figure 1.4).

1.4 Structure of this Conceptual Model

1.4.1 This conceptual model comprises five sections of which this introduction is Section 1. Section 2 provides an overview of the geology. Section 3 outlines the physical and sedimentary processes which characterise the area. Section 4 scopes the potential effects and sensitivities of the hydrodynamic and sedimentary processes to changes caused by export cable development. Section 5 presents the conclusions.

2 GEOLOGY

2.1 Introduction

2.1.1 Given the export cables are likely to be buried at shallow depths, the geological description is confined to those units that are within the top 3m of the geological column beneath the seabed. The nature of this shallow geology is mainly governed by the distribution and thickness of Holocene sand (Gardline, 2013). Where Holocene sands are thin or absent, the outcrop at the seabed and in the shallow sub-seabed is composed of Quaternary sediments (Cameron et al., 1992; Stoker et al., 2011). However, Jurassic/Triassic mudstone is exposed at the seabed along some stretches of the cable corridor.

2.2 Jurassic to Triassic

2.2.1 The bedrock geology along the Dogger Bank Teesside A & B export cable corridor is interpreted to be Jurassic to Triassic mudstone (Gardline, 2013). Along the export cable corridor route there are several places where the mudstone is within 2m of the seabed and in several places outcrops at the seabed (Figure 2.1). The bed rock was mapped using pinger data, which penetrates to a maximum depth of 10m. Between the Dogger Bank Zone and approximately 80km offshore the bedrock deepens to greater than 10m below seabed and is not resolved in the data (Figure 2.1).

2.3 Quaternary

Bolders Bank Formation

2.3.1 The significant geological sequence near seabed along the Dogger Bank Teesside A & B export cable corridor is the Upper Devensian (Weichselian) Bolders Bank Formation (Cameron et al., 1992; Stoker et al., 2011). The Bolders Bank Formation is a sheet of till typically composed of stiff clay with pebbles of chalk and other materials derived from the rocks of eastern England. The till along the cable corridor forms part of a larger (although generally less than 5m thick) sheet, spread over much of the southern North Sea. At approximately 77km offshore the till fills a channel extending up to 14m below the seabed (Gardline, 2013).

Dogger Bank Formation

2.3.2 At the eastern extremity of the export cable corridor, the Bolders Bank Formation passes laterally eastwards into the Dogger Bank Formation (Cameron et al., 1992; Stoker et al., 2011). It is a clay-rich formation of glacial origin, with transitional sand units present between clay layers.

Botney Cut Formation

2.3.3 The Botney Cut Formation, found up to 12m below the seabed, overlies the Bolders Bank Formation and comprises sandy clay with gravelly coarse sand at its base (Gardline, 2013). In the southern North Sea, this formation is a series of infilled sub-glacially formed palaeovalleys up to 100m deep and 8km wide (Cameron et al., 1992).

2.4 Holocene

Southern Bight Formation (Holocene Sands)

Following the inundation of the southern North Sea during the Holocene transgression, deposition of sand took place in the shallow marine environment. These Holocene sands are defined as the Southern Bight Formation (Stoker et al., 2011) and are widespread along the Dogger Bank Teesside A & B export cable corridor (Gardline, 2013). They generally range in thickness from absent, where the underlying till or bedrock are exposed at the seabed, to up to 5m, although thicknesses greater than 20m occur at the eastern extent of the cable (Figure 2.2).

3 HYDRODYNAMIC AND SEDIMENTARY PROCESSES

3.1 Bathymetry

3.1.1 Gardline (2013) mapped the bathymetry of the export cable corridor (Figure 3.1). Water depths range from just above LAT near the coast to approximately 80m below LAT with the deepest point about 90km offshore. The water depths decrease from 80m LAT to between 40m and 60m below LAT as the cable corridor approaches the 12 nautical mile territorial boundary.

3.2 Astronomic Water Levels

3.2.1 The tidal range along the Dogger Bank Teesside A & B export cable corridor increases from its eastern end to the landfall site. At the Dogger Bank Zone end of the cable corridor the mean spring tidal range is 2.0-3.0m whereas at the landfall site it is 4.0-5.0m (BERR, 2008). The corresponding mean neap tidal ranges are 1.0-1.5m at the Dogger Bank Zone end of the cable corridor and 2.0-2.5m at the landfall site (Figures 3.2 and 3.3).

3.3 Tidal Currents

3.3.1 BERR (2008) modelled mid-depth peak flows for mean spring tides of about 0.40m/s at the offshore end of the cable corridor to between 0.20m/s and 0.60m/s off the coast at Redcar. The corresponding mid-depth peak flows for mean neap tides are about 0.20m/s at the offshore end of the cable corridor to between 0.10m/s and 0.30m/s off the coast at Redcar (Figures 3.4 and 3.5).

3.4 Significant Wave Heights

3.4.1 At the offshore end of the cable, BERR (2008) described annual mean significant wave heights of 1.75-2.0m, which varied seasonally from 1.0m to 1.5m in summer to between 2.0m and 2.5m in winter. Close to the landfall site the annual mean significant wave height decreases to less than 1.0m, with seasonal variations of 0.5m-1.0m in summer and 1.0-1.5m in winter (Figures 3.6 and 3.7).

3.5 Sea-level Rise

3.5.1 Global sea level is primarily controlled by three factors; thermal expansion of the ocean, melting of glaciers and change in the volume of the ice caps of Antarctica and Greenland. Observed or projected changes in global sea level take into account the elevation of the water surface, caused by changes in the volume of the oceans, but do not take into account changes in land (seabed) level. At a local scale, the elevation of the sea surface relative to the land is known as relative sea level.

Historic Sea-level Rise

3.5.2 The Intergovernmental Panel on Climate Change (IPCC, 2007) estimated a global average sea-level rise over the 20th century of between 1.2 and 2.2mmyr^{-1} with an average value of 1.7mmyr^{-1}. Between 1961 and 2003, the rate was estimated at 1.8mmyr^{-1} (1.3-2.3mmyr^{-1}) rising to 3.1mmyr^{-1} (2.4-3.8mmyr^{-1}) between 1993 and 2003.

Future Sea-level Rise

3.5.3 As climate change takes effect and the earth warms, sea level will continue to rise. Central estimates (50th percentile) of projected future relative sea-level rise for the Redcar to Marske-by-the-Sea coast (the location where the export cable makes landfall) up to 2100 reported by the UK Climate Impacts Programme (UKCIP, 2009) ranged from about 0.2m for the low emissions scenario to about 0.9m for the high emissions scenario (relative to a 2009 baseline). Since these potential changes in sea level will occur over the expected life time of the proposed Dogger Bank Teesside wind farm, it is necessary to anticipate greater water depths.

3.6 Seabed Sediments

3.6.1 Gardline (2013) described the seabed sediment distribution along the export cable corridor (Figure 3.8). They showed that, in general, the seabed sediments are dominated by sand. However, patches of gravel occur between 60km and 110km offshore along the export cable corridor and where it connects to Tranche A. Between approximately 5km and 25km offshore, the cable corridor passes through mudstone with pockets of till at seabed (Gardline, 2013). Where bedrock or till are near the seabed, cobbles and boulders are present (Gardline, 2013).

3.6.2 Gardline (2013) collected seabed sediment samples along the cable corridor (Figure 1.3) (**Appendix A**). Particle size analyses of these samples show that the medium particle diameter (d_{50}) falls predominantly between 0.15mm and 0.30mm (mainly fine sand with some occasional medium sand). Most of the seabed samples contain less than 1.5% gravel and less than 5% mud, and can be categorised as slightly gravelly sand. Several samples contain between 7% and 21% gravel with three samples containing 32%, 62% and 65% gravel.

3.7 Bedforms and Sediment Transport

3.7.1 Although there is widespread occurrence of Holocene sands along the cable corridor that are mobile towards the seabed, there is only limited development of megaripples and sand waves (Figure 3.9). Sand waves are defined as bedforms with wavelengths greater than 25m whereas megaripples are smaller with wavelengths between 0.5m and 25m. Both are present along a short section of the export cable corridor, at approximately 25-35km offshore. The largest sand wave is up to 3m high and the bedform crests are generally aligned northeast to southwest (Figure 3.9). The megaripples and sand waves are predominantly asymmetric with their steeper sides facing to the southeast (Figure 3.9) indicating that they are migrating to the southeast.

3.8 Suspended Sediment

3.8.1 Eisma and Kalf (1987) provided a general distribution of suspended sediment in the southern North Sea. Data along the Dogger Bank Teesside A & B export cable corridor is limited, but appears to show concentrations less than 2mg/l until the coastline is approached.

3.8.2 Cooper (2004) measured suspended sediment concentrations at two sites along the nearshore zone approximately 1.5km offshore from the Tees Estuary mouth in October-December 2004. A clear response of suspended sediment concentrations to wave conditions was found. High concentrations (greater than 500mg/l) were recorded during storm events when stirring of the seabed sediments occurred, followed by advection (over short distances) by tidal currents. Lower concentrations (less than 100mg/l) were recorded during quieter periods.

4 POTENTIAL EFFECTS OF DEVELOPMENT

4.1 Introduction

4.1.1 This section briefly describes the key potential effects on physical and sediment transport processes and their predicted magnitude. In the Environmental Impact Assessment scoping report for Dogger Bank Teesside A & B, Forewind (2012) outlined the potential effects on the physical environment from the wind farm.

4.2 Potential Effects during Construction

4.2.1 The laying of the export cables has the potential to create discrete, short-term and potentially instantaneous disturbances of the seabed. These disturbances have the potential to release seabed sediment into the water column, which may result in the formation of sediment plumes. The magnitude of the plume will be a function of seabed type, the installation method and the hydrodynamic conditions that are able to disperse it away from the disturbance. The seabed sediment distribution data suggest that the quantities of sediment that can be suspended along the cable route are small.

4.3 Potential Effects during Operation

4.3.1 There are anticipated to be no effects during the operation of the export cable where it is buried beneath the seabed. However, potential effects to sediment transport may arise if mattressing is used at the seabed.

4.4 Potential Effects during Decommissioning

4.4.1 The effects during decommissioning are expected to be low as it is anticipated that the cable will be left *in situ*. However, if removal is required in any particular areas, the effects will be similar to those described during the construction phase.

5 CONCLUSIONS

5.1.1 The conclusions regarding baseline conditions outlined below are selected based on how sensitive the particular parameter is to changes along the Dogger Bank Teesside A & B export cable corridor. The baseline parameters that are most likely to be affected by construction and burial of the cable(s) are suspended sediment and seabed sediment distribution, which are driven by tidal currents and waves. The geology of the near-seabed of the cable corridor will be important in the design and burial of the cable(s).

5.1.2 **Suspended Sediment**: There is limited data on suspended sediment along the export cable corridor. Concentrations appear low along most of the route (less than 2mg/l).

5.1.3 **Sediment Distribution and Transport**: The export cable corridor is dominated by seabed sediments composed of sand. The quantities of mud within these sediments are low (less than 5%). In a relatively small area along the cable corridor, sediment has been sculpted into sand waves and megaripples with northeast to southwest crest alignments. The geometry of the sand waves indicates sediment movement and migration of the bedforms to the southeast.

5.1.4 **Tidal Currents**: Modelled (mid-depth) spring tide current velocities vary from 0.40m/s at the offshore end of the cable corridor to between 0.20m/s and 0.60m/s off the coast between Redcar and and Marske-by-the-Sea. Tidal currents have not been measured along the export cable corridor.

5.1.5 **Waves**: At the offshore end of the cable, annual mean significant wave heights of between 1.75m and 2.0m have been modelled, whilst close to the landfall site the modelled annual mean significant wave height decreases to below 1.0m. Waves have not been measured along the export cable corridor.

5.1.6 **Geology**: The geology of the top 3m of the export cable corridor is dominated by variable thicknesses of Holocene sand. Where it is thin or absent, Jurassic/Triassic mudstone or Bolders Bank Formation outcrop or sub-crop at the seabed.

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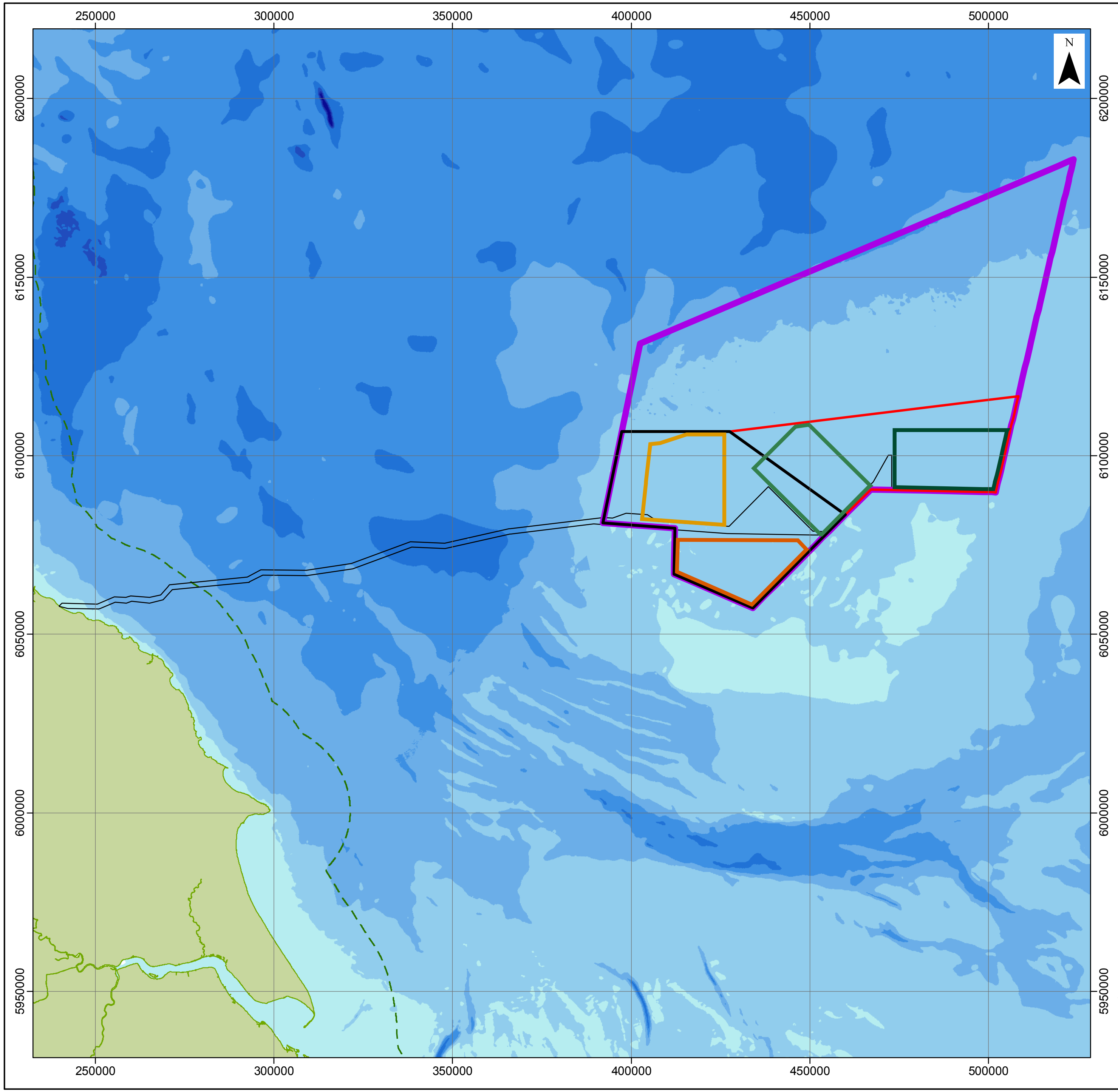
7 GLOSSARY

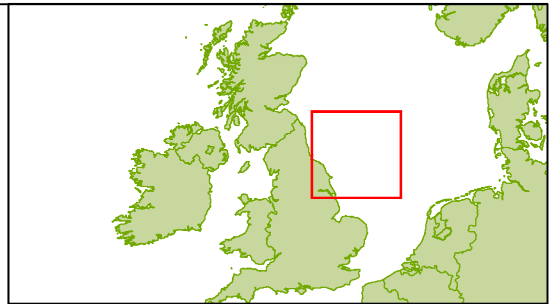
7.1.1 Table 7.1 provides a glossary of terms and abbreviations used in this conceptual model.

Table 7.1. Glossary of terms and abbreviations used in this conceptual model.

BERR	Department of Business, Enterprise and Regulatory Reform
cSAC	Candidate Special Area of Conservation
CPT	Cone Penetration Test
D_{50}	Median Particle Diameter
IPCC	Intergovernmental Panel on Climate Change
JNCC	Joint Nature Conservation Committee
LAT	Lowest Astronomical Tide
UKCIP	UK Climate Impacts Programme

FIGURES





LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Tranche B Boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- 12nm Territorial Boundary

0 50

Kilometres

Data Source:
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

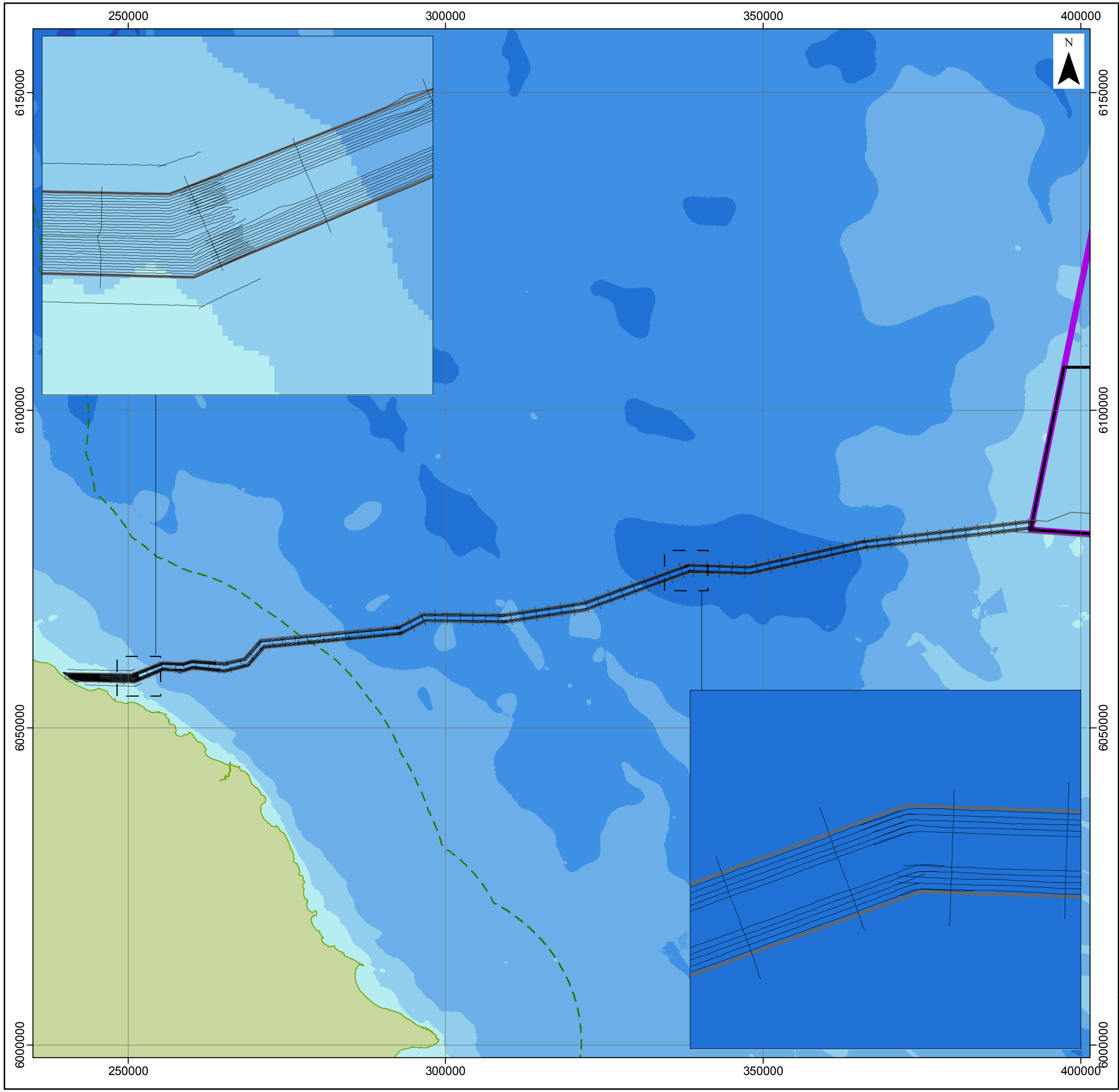
Figure 1.1 Export Cable Corridor, Dogger Bank Zone and Tranches A and B

VER	DATE	REMARKS	Drawn	Checked
1	08/03/2013	Draft	FK	DB
2	15/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/036**

SCALE	1:1,600,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM 31N

FOREWIND



LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Dogger Bank Teesside A & B Export Cable Corridor
- Geophysical Survey Lines
- 12nm Territorial Boundary

0 40
Kilometres

Data Source:
Geophysical Survey data © Gardline, 2012,
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

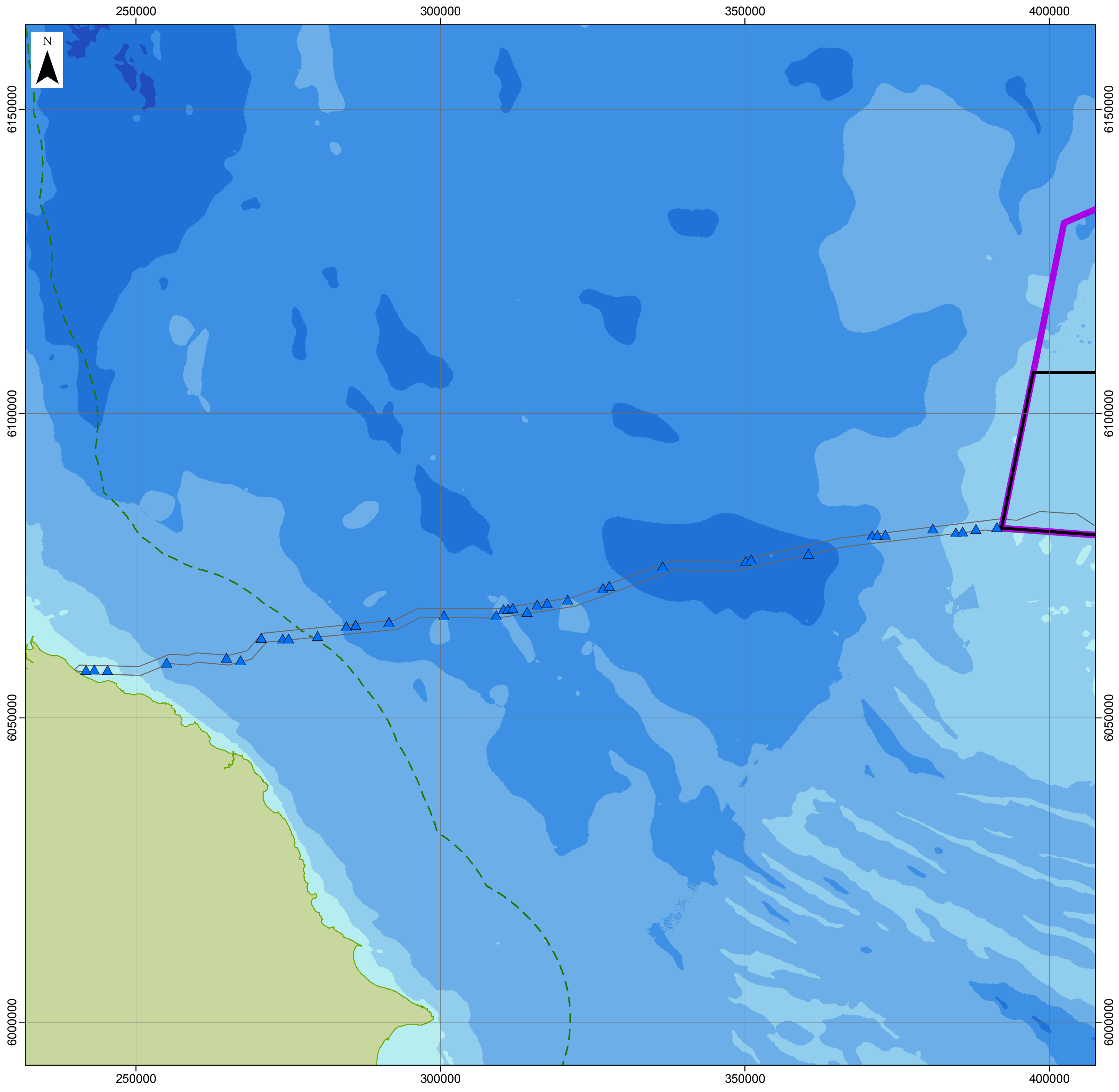
Figure 1.2 Export Cable Corridor Geophysical Survey Lines

VER	DATE	REMARKS	Drawn	Checked
1	08/03/2013	Draft	FK	DB
2	15/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/037**

SCALE	1:900,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM 31N

FOREWIND



LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Dogger Bank Teesside A & B Export Cable Corridor
- 12nm Territorial Boundary
- Grab Sample Locations

0 40
Kilometres

Data Source:
Grab Sample data © Gardline, 2012,
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

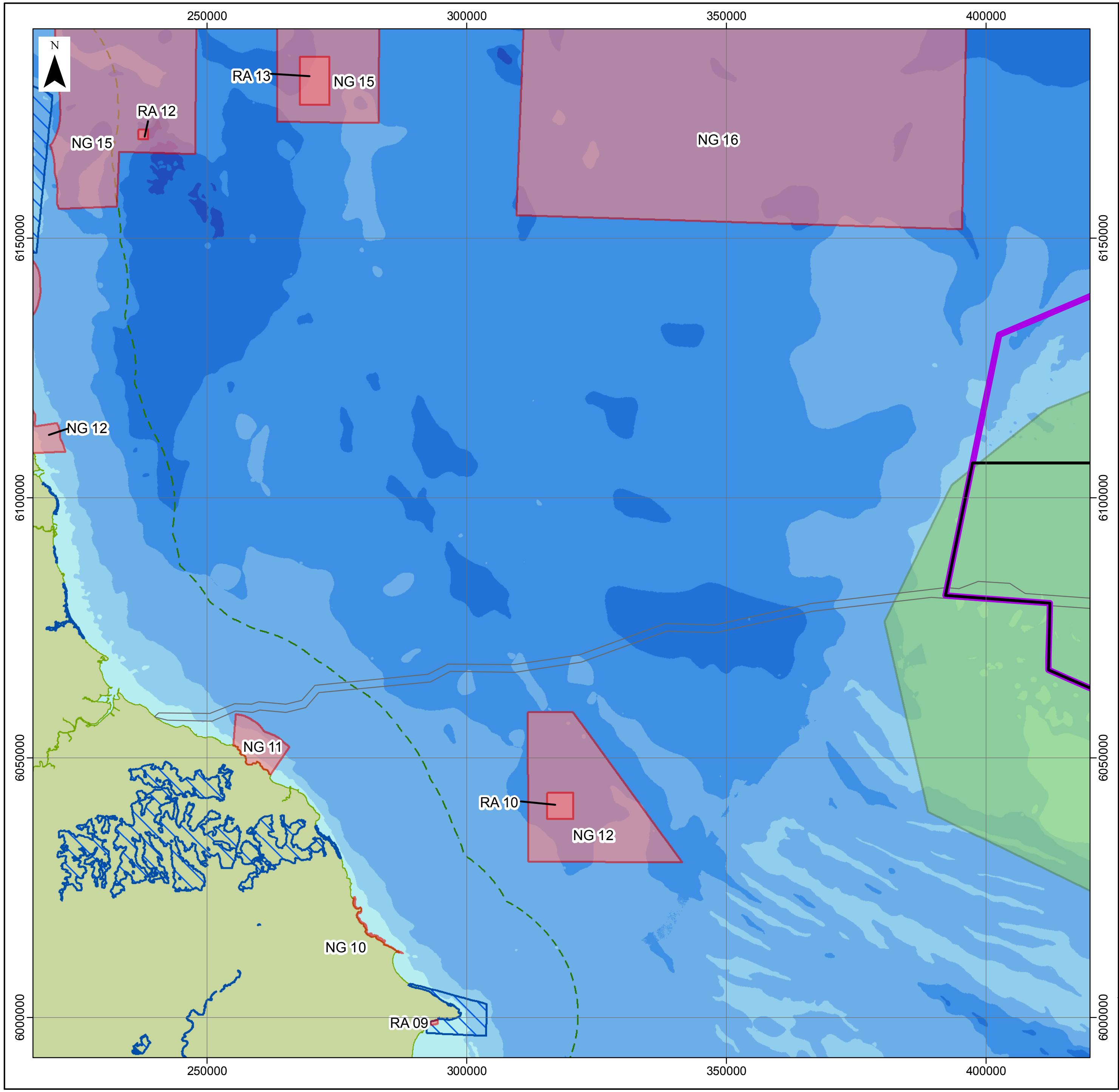
Figure 1.3 Export Cable Corridor Seabed Sediment Sample Locations

VER	DATE	REMARKS	Drawn	Checked
1	08/03/2013	Draft	FK	DB
2	15/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/038**

SCALE	1:950,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM 31N

FOREWIND



LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Dogger Bank Teesside A & B Export Cable Corridor
- 12nm Territorial Boundary
- Dogger Bank Candidate Special Area of Conservation (cSAC)
- Special Area of Conservation (SAC)
- Recommended Marine Conservation Zone (NG) & Recommended Reference Area (NG RA)

0 40
Kilometres

Data Source:
Environmental Designations © JNCC, 2012,
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

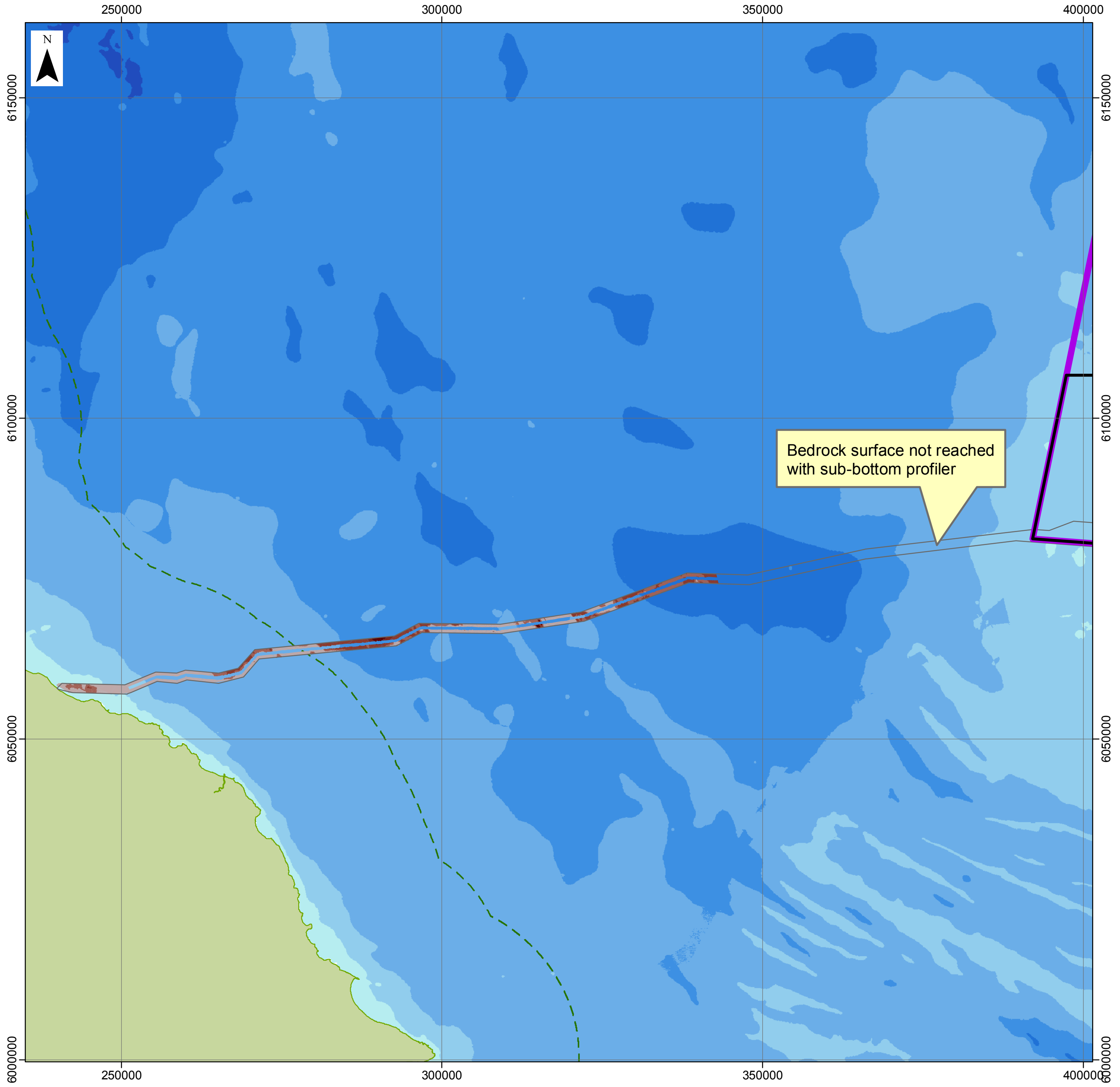
Figure 1.4 Dogger Bank Environmental Designations

VER	DATE	REMARKS	Drawn	Checked
1	19/12/2012	Draft	FK	DB
2	15/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/039**

SCALE	1:1,100,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM 31N

FOREWIND



LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Dogger Bank Teesside A & B Export Cable Corridor
- 12nm Territorial Boundary

Depth Below Seabed to Top of Bedrock (m)

- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10

0 40
Kilometres

Data Source:
Geophysical data © Gardline, 2012,
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

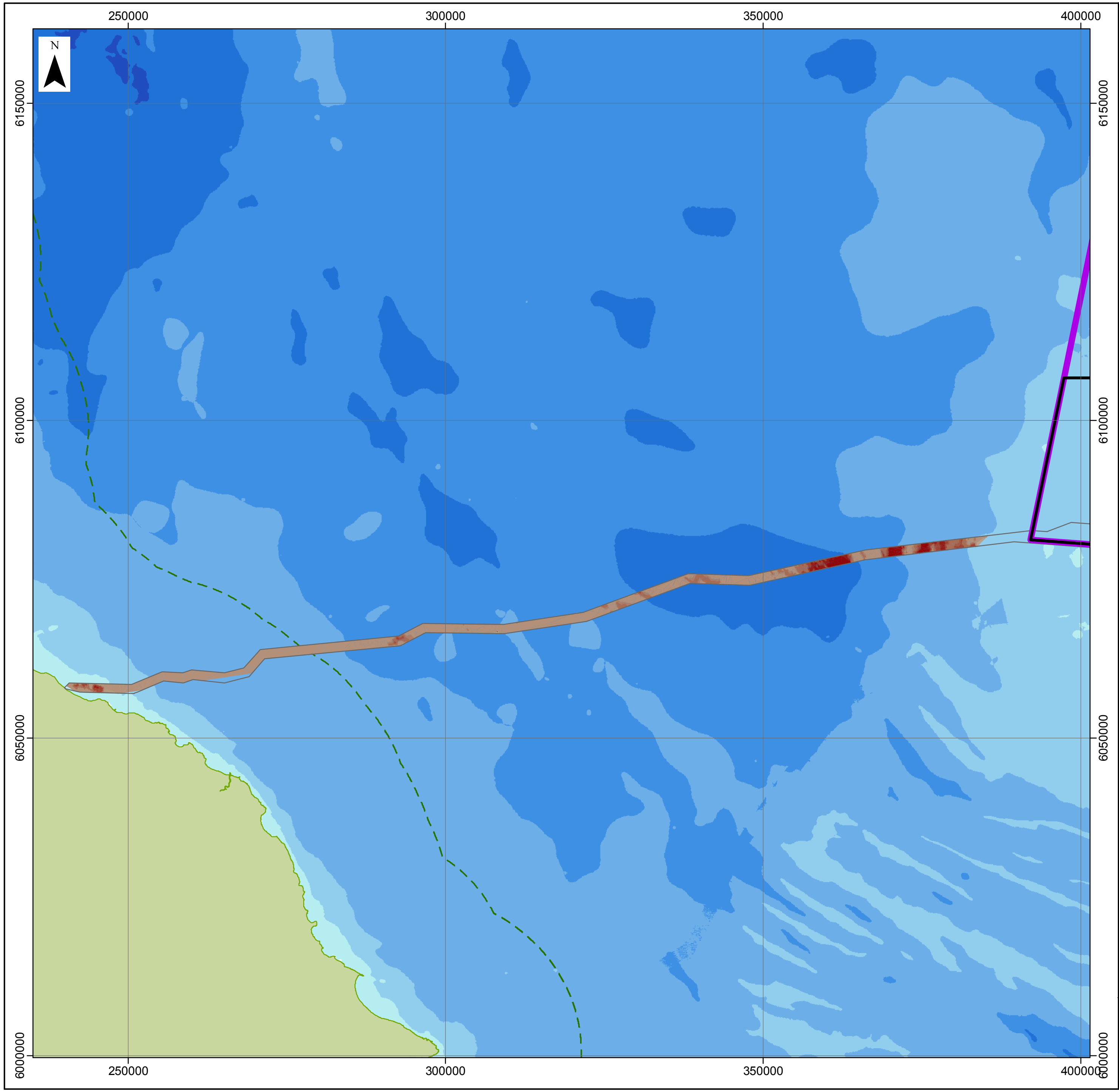
Figure 2.1 Export Cable Corridor Depth to Top of Bedrock

VER	DATE	REMARKS	Drawn	Checked
1	15/03/2013	Draft	FK	DB
2	15/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/040**

SCALE	1:900,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM 31N

FOREWIND



LEGEND

- Dogger Bank Zone
- Tranche A Boundary
- Dogger Bank Teesside A & B Export Cable Corridor
- 12nm Territorial Boundary

Depth Below Seabed to Base of Holocene Sand (m)

- 0 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 - 5

0 20
Kilometres

Data Source:
Geophysical data © Gardline, 2012,
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 2.2 Export Cable Corridor Depth to Base of Holocene Sand

VER	DATE	REMARKS	Drawn	Checked
1	15/03/2013	Draft	FK	DB
2	15/10/2013	Final	LW	DB

DRAWING NUMBER: **9X5889/04/041**

SCALE	PLOT SIZE	DATUM	PROJECTION
1:900,000	A4	WGS84	UTM 31N

FOREWIND