Dublin Array
Generation for generations

EIAR Volume 4: Offshore Infrastructure Technical Appendices Appendix 4.3.1-1 Technical Baseline Report Physical Processes

Kish Offshore Wind Ltd

RWE SLR GoBe APEM Group

www.dublinarray-marineplanning.ie

Dublin Array Offshore Wind Farm

Environmental Impact Assessment Report

Volume 4, Appendix 4.3.1-1: Technical Baseline Report - Physical Processes

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Glossary

Term	Definition
AA	Appropriate Assessment
ADCP	Acoustic Doppler Current Profiler
BODC	British Oceanographic Data Centre
BSB	Below Seabed
BSF	Below Sea Floor
CD / mCD	Chart Datum/ meters relative to Chart Datum
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CVI	Coastal Vulnerability Index
DAPPMS	Dublin Array Physical Process Modelling System
DCCAE	Department of Communications, Climate Action and Environment (now DECC)
DECC	Department of Environment, Climate and Communications (formerly DCCAE)
Dublin Array	Dublin Array Offshore Wind Farm
ECC	Export Cable Corridor
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
GDG	Gavin & Doherty Geosolutions
GSI	Geological Survey of Ireland
HWM	High Water Mark
ICPSS	Irish Coastal Protection Strategy Survey
INFOMAR	Integrated Mapping for the Sustainable Development of Ireland's Marine Resource
INSS	Irish National Seabed Survey
LAT/ mLAT	Lowest Astronomical Tide/ meters relative to Lowest Astronomical Tide
NAO	North Atlantic Oscillation
NTU	Nephelometric Turbidity Units
O&M	Operations and maintenance

PSA	Particle Size Analysis
PSD	Particle Size Distribution
SPM	Suspended Particulate Matter
SW	Spectral Wave
UK	United Kingdom
UKHO	UK Hydrographic Office
WWTP	Wastewater Treatment Plant
ZoI	Zone of Influence

Acronyms

Term	Definition
BERR	Department for Business, Enterprise and Regulatory Reform
BSF	Below Sea Floor
CD	Chart Datum
Cefas	Centre for Environment, Fisheries and Aquaculture
CHERISH	Climate, Heritage and Environment of Reefs, Islands, and Headlands
CGS	County Geological Sites
CREL	Centrica Renewable Energy Limited
DAPPMS	Dublin Array Physical Process Modelling System
DAS	Dumping at Sea
DECC	Department of Environment, Climate and Communications (formally DCCAE)
DCCAE	Department of Communications, Climate Action and Environment (now DECC)
DPSIR	Driver, pressure, states, impacts and responses
Dublin Array	Dublin Array Offshore Wind Farm
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EMODnet	European Marine Observation and Data Network
EPA	Environmental Protection Agency
FM	Flexible Mesh

Term	Definition
GSI	Geological Survey Ireland
GWFlood	Groundwater Flooding
HDD	Horizontal Directional Drilling
HVDC	High Voltage Direct Current
HWM	High Water Mark
HWS	High Water Springs
IAC	Inter-array cables
ICES	International Council for the Exploration of the Sea
IPCC	Intergovernmental Panel on Climate Change
INFOMAR	Integrated Mapping for the Sustainable Development of Ireland’s Marine Resource
LAT	Lowest Astronomical Tide
LWS	Low Water Springs
MAC	Maritime Area Consent
MDO	Maximum Design Option
MFE	Mass Flow Excavator
MSL	Mean Sea Level
MW	Megawatt
MW&SQ	Marine Water and Sediment Quality
NHA	National Heritage Area
NIS	Natura Impact Statement
NPWS	National Parks and Wildlife Service
NTU	Nephelometric Turbidity Units
O&M	Operations and Maintenance
offshore ECC	Offshore Export Cable Corridor
OPW	Office of Public Works
OSP	Offshore Substation Platform
OWF	Offshore Wind Farm
PINS	Planning Inspectorate
PSA	Particle Size Analysis

Term	Definition
PSD	Particle Size Distribution
SPM	Suspended Particulate Matter
SSC	Suspended Sediment Concentrations
STFATE	Short-Term Fate of Dredged Material Model
SW	Spectral Wave
TSHD	Trailer Suction Hopper Dredger
UKHO	United Kingdom Hydrographic Office
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USACE	United States Army Corps of Engineers
WTG	Wind Turbine Generator
ZoI	Zone of Influence

1 Introduction

1.1 Overview

1.1.1 This document has been prepared by GoBe Consultants Ltd on behalf of RWE to support the Environmental Impact Assessment (EIA) of the Dublin Array Offshore Wind Farm (Dublin Array).

1.1.2 This technical baseline should be read in conjunction with the following documents included within the EIAR:

- Volume 3, Chapter 1: Marine Geology, Oceanography and Physical Processes (hereafter referred to as the Physical Processes Chapter): *to be referenced for an overview on the surficial sediment properties, suspended sediments and seabed features, in addition to the metocean conditions. This chapter also provides an assessment of the potential impacts of the project upon the marine geology, oceanography and physical processes;*

- Volume 4, Appendix 4.3.1-2: Physical Process Modelling for Dublin Array Offshore Wind Farm (hereafter referred to as the Physical Processes Modelling Report)*: to be referred to for detail on the numerical modelling simulations undertaken to support the physical processes assessment;*

- Volume 4, Appendix 4.3.1-3: Hydrodynamic Calibration and Validation Report (hereafter referred to the Hydrodynamic Calibration and Validation Report)*: to be referenced for detail on the hydrodynamic model calibration and validation process and results against available tidal data (current speed; direction and water level);*

- Volume 4, Appendix 4.3.1-4: Spectral Wave Model Calibration and Validation Report (hereafter referred to as the Spectral Wave Model Calibration and Validation Report)*: to be referenced for detail on the wave model calibration and validation process and results against available wave (wave height; wave period; direction) data*;

- Volume 4, Appendix 4.3.3-2: Intertidal survey report (hereafter referred to as the Intertidal Survey Report): to be referred to for supporting information regarding the intertidal survey, including walk-over survey results and imagery, in addition to sediment sampling analysis and interpretation; and

- Volume 4, Appendix 4.3.3-3: Subtidal survey report (hereafter referred to as the Subtidal Survey Report): to be referred to for supporting information regarding the subtidal survey, including walk-over survey results and imagery, in addition to sediment sampling analysis and interpretation.

1.2 Purpose of this report

1.2.1 The purpose of the technical baseline report is to characterise the baseline environment for Marine Geology, Oceanography and Physical Processes, hereafter referred to collectively as 'physical processes', to inform the EIA and the Appropriate Assessment (AA). The potential impacts which may occur as a result of the construction, operation and maintenance (O&M) and decommissioning of the Dublin Array offshore infrastructure and the determination of sensitivity of the receiving environment, the magnitude of the effect, and the overall significance of each effect will be presented within the relevant chapter of the Environmental Impact Assessment Report (EIAR). Furthermore, the identification of the specific receptors, including any designations, to the potential impacts are identified in the EIA and the AA.

1.2.2 An indicative list of impacts which should be assessed in relation to physical processes is provided in Table 9 of the Department of Communications, Climate Action and Environment (DCCAE) Guidance (2017) and is as follows:

- "Coastal processes
  - Coastal erosion
  - Coastal protection
  - Estuarine and coastal flooding
- Sedimentation processes
- Seabed geology/morphology"

1.2.3 These potential impacts were considered in defining the scope of the EIA assessment and the definition of "physical processes" within the Dublin Array EIAR. Physical processes have been defined as the collective term for the following:

- Tides and tidal currents;
- Waves (and winds);
- Sediments and geology (including seabed sediment distribution and transport (including suspended sediments);
- Seabed geomorphology; and
- Coastal geomorphology.

1.2.4 The information collated in this technical report and Physical Processes Chapter have also informed the impact assessments for other EIA receptor groups which may be sensitive to changes in physical processes, such as, for example, benthic habitats and fish and shellfish species.

1.3 Report structure

1.3.1 This report is structured as follows:

- Section 1 introduces the report and outlines its aims;
- Section 2 presents the methodology and data sources applied to characterise the receiving environment;
- Section 3 presents the characterisation of the existing receiving environment for the physical processes assessment;
- Section 4 presents the characterisation of the future receiving environment;
- Section 5 presents any uncertainties or data gaps which were identified during the baseline characterisation; and
- Section 6 provides a high-level summary of the findings of this report.

2 Methodology

2.1 Approach

2.1.1 This section details the methodology applied to characterising the physical marine environment. It includes details on the data and information sources which have been collated, examined and analysed within the defined study area (see Section 2.2) and as a basis for the physical processes assessment in the EIAR.

2.2 Study area

2.2.1 The array area will be sited within the Irish Sea, approximately 10 km offshore from Dublin. The project is to be located upon, and adjacent to, two notable bathymetric features. These features, the Kish and Bray Banks, are approximately 2 to 3 m below the surface at their crest (see Section 3.5). Further detail regarding the characteristics of these features and their interactions with the metocean regime are presented in Section 3.

2.2.2 For the purposes of the EIAR for the physical marine environment, the study area for physical processes is determined by the Zone of Influence (ZoI) of the offshore infrastructure. The guidelines (DCCAE, 2017) recommend that the study area and ZoI are established at the scoping stage. It is acknowledged that these zones may differ between topics depending upon the pressure or ecosystem component under consideration. Data and identification of features of interest within the zones that might be impacted by an offshore renewable energy project are required so that a source – pathway – target risk assessment can be carried out and the subsequent evaluation of effects can be undertaken.

2.2.3 The ZoI for the physical marine environment has been defined by the maximum spring tidal excursion[1] within the array area (which is, approximately, 16 km[2] based on the project specific modelling undertaken[3] during a spring tide). The current speeds become faster with distance offshore in this region (see Section 3.2) and so the tidal excursions will be shorter within the Offshore Export Cable Corridor (ECC)[4]. Therefore, a study area of a 17 km buffer[5] around the proposed development is considered to be appropriately precautionary and to encapsulate all reasonably foreseeable effects on the physical marine environment. The study area is limited to the marine and coastal environment below the High Water Mark (HWM) mark. This has been defined as a natural boundary between the offshore and onshore water and terrestrial environments for the purposes of the EIA assessments. The study area for the marine physical environment EIA is presented in Figure 1.

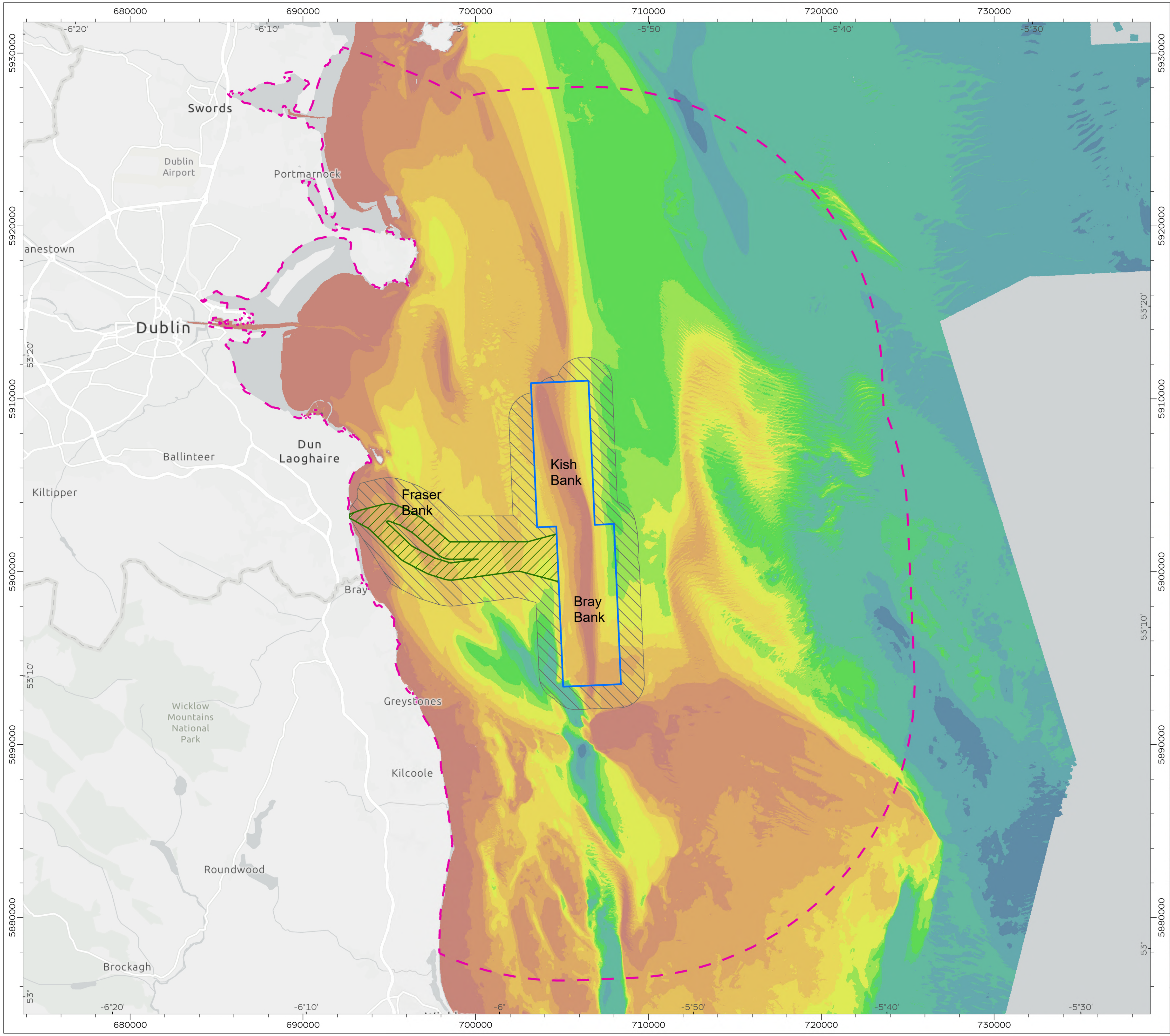
[1] Tidal excursion length is the net horizontal distance travelled by a water particle from Low Water Springs (LWS) to High Water Springs (HWS) or vice versa. It can be used to describe the movement of pollutants in estuaries during a tidal cycle (Zhen-Gang, 2008).

[2] All distances are taken from the outer boundary of all offshore works incorporating the offshore infrastructure, the buffer also incorporates the temporary occupation area and as such are inherently precautionary

[3] Based on the distance of sediment plume travelled which was released at low water until the flooding tide during a spring tide within the proposed array area.

[4] Activities undertaken within the temporary occupation area, namely the use of jack-up vessels and anchors during the construction, O&M, and decommissioning phases have been screened out within the physical processes chapter for suspended sediment and deposition with their use not resulting in notable changes in SSC and associated sediment deposition, however the use of a buffer ensures a precautionary approach is taken.

[5] Distances provided are straight line (geodesic) as calculated using GIS and taken from the outer edge of all offshore works and as such are precautionary in nature.



- Array Area
- Temporary Occupation Area
- Export Cable Corridor
- Physical Processes Study Area (17km Buffer)

Depth (m)

- >100
- 75 - 100
- 50 - 75
- 45 - 50
- 40 - 45
- 35 - 40
- 30 - 35
- 25 - 30
- 20 - 25
- 15 - 20
- 10 - 15
- 5 - 10
- 0 - 5

DRAWING STATUS

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Data Source: Bathymetry - INFORMAR 2023

PROJECT TITLE

Dublin Array

DRAWING TITLE

Geographical Overview of the Study Area for the Physical Marine Environment

DRAWING NUMBER: 1

PAGE NUMBER: 1 of 1

VER	DATE	REMARKS	DRAW	CHEK	APRD
01	2024-05-24	For Issue	GB	BB	SS

0 2 4 6 8 km
0 1 2 3 4 nm

SCALE 1:225,000 PLOT SIZE A3
DATUM WGS 1984 VERTICAL REF LAT
PRJ WGS 1984 UTM Zone 29N

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2.3 Data sources

2.3.1 The evidence used to characterise the baseline in Sections 3 to 4 of this report is informed by a data and literature search both within the broader region and specifically within the study area. A regional baseline (the wider Irish Sea) has been provided to contextualise the receiving environment within the study area. This section details the data sources identified through undertaking a review of:

- Primary, secondary and tertiary[6] datasets;
- Site specific survey datasets;
- Published and grey literature;
- The previous Dublin Array Environmental Impact Statement (EIS) (Saorgus Energy Ltd, 2012), EIS Addendum (MRG Consulting Engineers Ltd, 2013), supporting data; and
- Data archives/ online repositories.

2.3.2 A summary of the key data sources, utilised in the development of the characterisation of the receiving environment for physical processes, are presented in Table 1. Sections 3 to 4 presents the characterisation of the study area.

[6] Primary sources refer to original data collection, such as that from metocean buoys or survey reports; secondary sources refer to the sources that analyse or reorganise primary datasets, for example in textbooks or data compilations; and tertiary sources consist of primary and secondary source information that has been collected or distilled, for example within regional data overviews or atlases.

Table 1 Data sources considered in the development of the physical processes baseline

Data source	Type of data	Temporal and spatial coverage
Bathymetry		
Integrated Mapping for the Sustainable Development of Ireland's Marine Resource (INFOMAR)	Surveys covering the array area and offshore export cable corridor (ECC) completed in 2003, 2008, 2009, 2010, 2012 and 2016, as part of the ongoing INFOMAR project (formerly Irish National Seabed Survey or INSS). The INFOMAR project is a Department of the Environment, Climate and Communications (DECC) funded joint programme between the Geological Survey Ireland and the Marine Institute. Saorgus Energy Ltd. commissioned Hydrographic Surveys Ltd. to undertake a hydrographic and geophysical survey of the proposed development (2008). These surveys have been included in the INFOMAR project dataset.	The temporal and spatial coverage of the INFOMAR surveys relative to the proposed development are presented in Figure 2.
Tides and currents		
Modelled data	Data from the project specific constructed hydrodynamic model provides the primary source of tidal currents and levels data for the study area. Full details of the data	The study area for the marine physical environment is encapsulated within the modelling system domain.

	used to calibrate and validate this model is provided the Hydrodynamic Calibration and Validation Report.	The model represents tidal conditions over different tidal phases, i.e. both neap and spring tides.
Published literature	A literature review has been undertaken to provide regional context of the tides within the Irish Sea, the outputs of this literature review being used to inform the description of the baseline.	Various across Irish Sea
Metocean conditions		
Modelled data	Data from the project specific constructed wave model will provide the primary source of wave data for the study area. Full details of the data used to calibrate and validate this model is provided the Spectral Wave Model Calibration and Validation Report.	The study area for the marine physical environment is encapsulated within the modelling system domain. The model represents numerous design wave conditions which represent typical and more extreme wave conditions within the study area.
The Irish Marine Weather Buoy network	The Irish Marine Weather Buoy network[7] M2 buoy. These data have been used to calibrate the wave model.	M2 is located at 53.4800°N 05.4250°W (approximately 20 km east of Lambay Island) (Figure 3). An hourly time series data set from the buoy between August 2010 to June 2018 were provided.

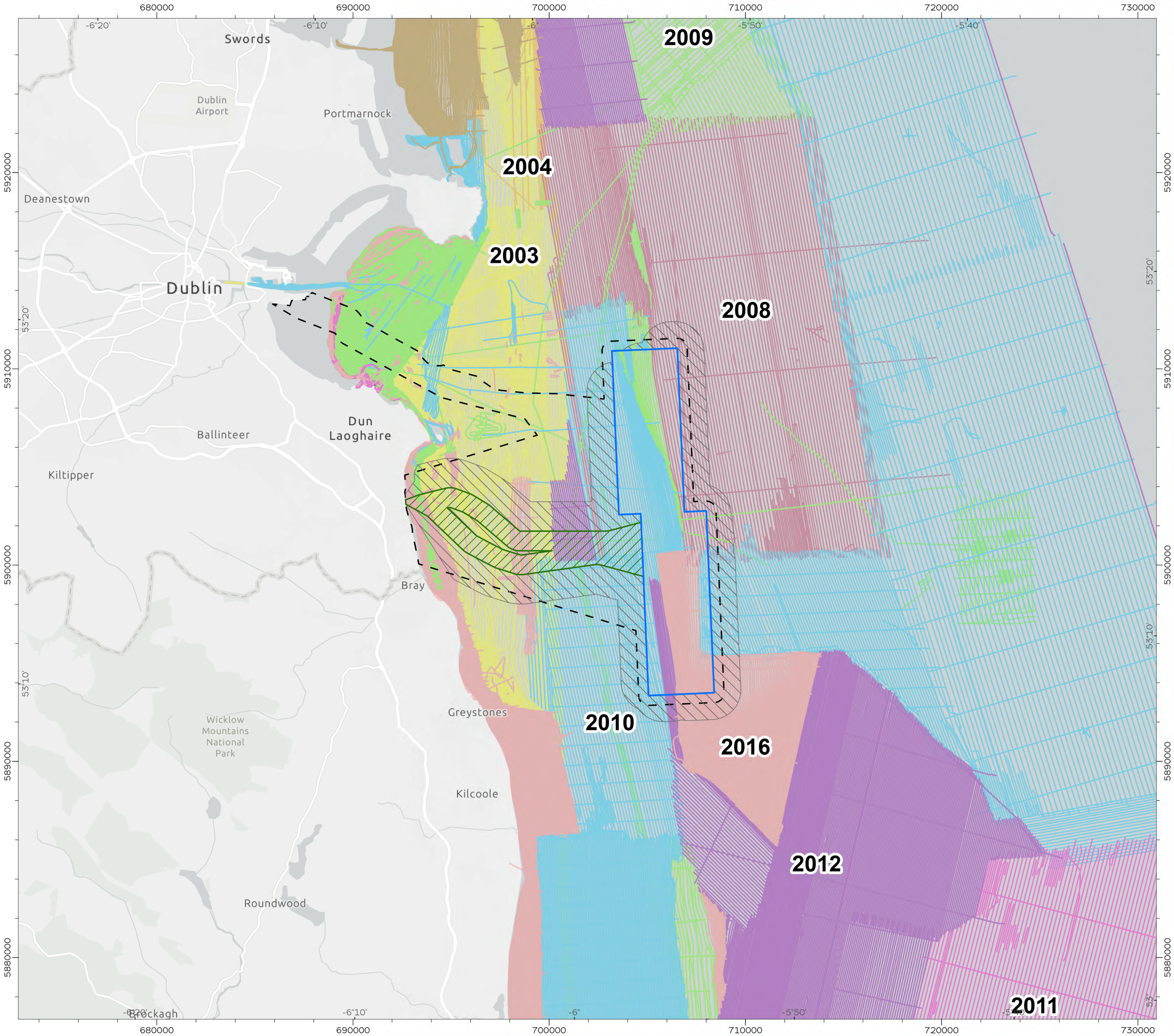
[7] http://www.marine.ie/Home/site-area/data-services/real-time-observations/irish-marine-data-buoy-observation-network

The Commissioners of Irish Lights – Dublin Bay buoy	The Commissioners of Irish Lights[8] is the Navigation and Maritime Service in Ireland. A selection of the nation's lighthouses and buoys are equipped with meteorological and oceanographic (MetOcean) sensors and transmit their data to Irish Lights HQ. They currently have several buoys and lighthouses collecting weather and sea state data; measurements include average wind speed, wind gust speed, average wind direction, gust direction, wave height, wave period and water temperature. Of interest to this baseline is the Dublin Bay Buoy which has been used to calibrate the wave model.	The Dublin Bay buoy is situated in Dublin Bay between Howth and Dún Laoghaire (Figure 3). A timeseries between February 2014 to May 2019 were provided.
Published literature	A literature review has been undertaken to provide regional context of the metocean conditions within the Irish Sea, the outputs of this literature review being used to inform the description of the baseline.	Irish Sea
Sediments and geology		
Published literature	A literature review has been undertaken to provide regional and local context of the	Irish Sea

[8] https://www.irishlights.ie/technology-data-services/metocean-charts.aspx

	underlying geology and sedimentary processes.	
INFOMAR	As shown, the INFOMAR programme covered most of the site and included multibeam bathymetry, backscatter, single beam echosounder, sub-bottom profiling, magnetometer data and seabed sampling data. These surveys provide 100% coverage of the array site and approximately 90% of the Offshore ECC. A composite of these surveys has been produced by INFOMAR and considered in this report. The information gathered has been used to inform bed mobility, sediment pathway and the physical processes assessment.	The array area and offshore ECC were surveyed in 2003, 2008, 2009, 2010, 2012 and 2016 as part of the ongoing INFOMAR project (formerly Irish National Seabed Survey or INSS), a joint seabed mapping project between the Geological Survey of Ireland (GSI) and the Marine Institute. Figure 2 depicts all the surveys performed at the sites of interest. These data were supplemented by EMODnet data to provide total coverage for the model domain, see the Hydrodynamic Calibration and Validation Report for more details.
EMODnet Geology (which have compiled Geological Survey Ireland's data)	Seabed substrate and seafloor geology maps have been utilised in the development of the characterisation of the surface and underlying geology.	The study area for the marine physical environment is encapsulated by these datasets.
Turbidity		
Centre for Environment, Fisheries and Aquaculture Science (CEFAS)	Annual average of non-algal Suspended Particulate Matter (SPM) data were available across the study area (Cefas, 2016). These data are based on the satellite derived Ifremer OC5 algorithm (Gohin *et al.*, 2011).	The data extends from 13°W to 12°E and 36°N to 60°N and so the study area for the marine physical environment is encapsulated by this dataset with the exception of the intertidal areas. These data are from peer-reviewed scientific literature and as such are considered

		robust and appropriate for use to inform this EIA. The daily images of non-algal SPM from 1/1/1998 to 31/12/2015 were averaged into 12 monthly means for the 18 years (216 fields). These were used to calculate a climatological average (Figure 7) as well as a climatological monthly average.
Dublin Port Company	Turbidity monitoring data from buoys within Dublin Bay were identified and have been used to supplement the monthly and annual SPM data to indicate natural variability within the region.	Three buoys within Dublin Bay (Figure 3).



Array Area
Temporary Occupation Area
Export Cable Corridor
Geophys Survey Boundary
Survey Year
2003
2004
2008
2009
2010
2011
2012
2013
2016

DRAWING STATUS
FINAL

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Survey Trackline Data - INFOMAR.ie

PROJECT TITLE
Dublin Array

DRAWING TITLE
Bathymetry 5m Grid
INFOMAR Merged Leg Data

DRAWING NUMBER: 2
PAGE NUMBER: 1 of 1

VER	DATE	REMARKS	DRAW	CHEK	APRD
01	2024-05-24	For Issue	GB	BB	SS

0 2 4 6 8 km
0 1 2 3 4 nm

N
GRID NORTH

SCALE	1:200,000	PLOT SIZE	A3
DATUM	WGS 1984	VERTICAL REF	LAT
PRJ	WGS 1984 UTM Zone 29N		

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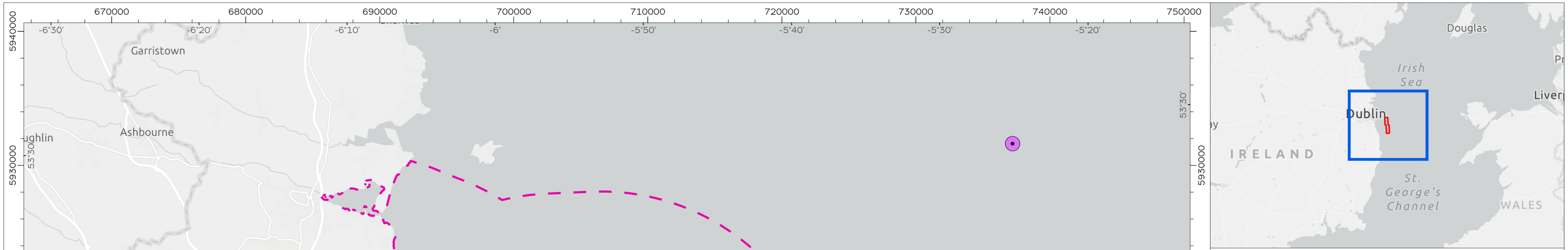

Array Area
Temporary Occupation Area
Export Cable Corridor
Physical Processes Study Area (17km Buffer)
Dublin Wave Buoy
JN1136 South Wave Buoy
M2 Offshore Wave Buoy
Turbidity Monitoring Location
Wave Buoy S1 Bray Bank
Wave Buoy S2 Kish Bank
Kish Lighthouse

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PROJECT TITLE

Dublin Array

DRAWING TITLE

Geographical Overview of Buoys used to Inform the Characterisation of the Receiving Environment

DRAWING NUMBER: **3**

PAGE NUMBER: **1 of 1**

VER	DATE	REMARKS	DRAW	CHEK	APRD
01	2024-05-24	For Issue	GB	BB	SS

0 2.5 5 7.5 10 km
0 1.25 2.5 3.75 5 nm

N
GRID NORTH

SCALE	1:300,000	PLOT SIZE	A3
DATUM	WGS 1984	VERTICAL REF	LAT
PRJ	WGS 1984 UTM Zone 29N		

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Project specific surveys

2.3.3 This Section provides a brief overview of the site-specific surveys undertaken to support the characterisation of the physical processes environment for the Dublin Array EIA. The site-specific surveys commissioned by RWE collected metocean, geophysical, geotechnical, benthic ecology, sedimentary and contaminants data to inform the characterisation of the receiving environment. The Subtidal Survey Report and the Intertidal Survey Report details the findings of the survey effort and the methodology applied. The findings of the surveys are summarised in Sections 3 of this report. Metocean data (including wave, current, and water levels) was collected for 12 months at two locations (shown in Figure 3) by Partrac (2022), and has been used to support the baseline characterisation in Section 3.

2.3.4 As part of the benthic ecology site investigation works, seabed sediments collected were processed for particle size analysis (PSA). Where necessary (e.g. for predominantly cobbly sediments) a larger PSA sample was taken from the separate grab sample to allow cobble content to be quantified during PSA. The samples were analysed in a laboratory and for each sampling station the results were expressed as cumulative percentage of each particle size passing through each sieve size. These data were used to validate the regional level data to ensure that it was representative of the sediment types.

2.3.5 A review of previous surveys and EIS was undertaken to inform this characterisation and has supplemented its development where still valid and appropriate. For example, the information from the boreholes collected by Glover Site Investigations in 2008 to inform the previous EIA for Dublin Array have been explicitly considered in this report.

3 Receiving Environment

3.1 Overview

3.1.1 The Irish Sea, off the eastern coast of Ireland, takes the form of a fairly shallow basin with water depths generally ranging from 20 m to 135 m. Wave energy in the Irish Sea is only approximately 20% of that on the more exposed Atlantic coasts due to sheltering effect afforded by the land mass of Ireland.

3.1.2 In general, the Irish Sea is exposed to strong tidal currents (up to 2 m/s), has a narrow annual temperature range (7°C to 14°C), and a seabed consisting predominantly of gravel and sand (Lee and Ramster, 1981). The Irish Sea is connected to the Atlantic Ocean via the North Channel in the north and to the Celtic Sea via the St George's Channel in the south. The water masses of the region have different origins and distinguishable temperature and salinity characteristics.

3.1.3 The surface water temperature of the Irish Sea is between 1 °C and 2°C cooler than other Irish coasts (such as the western coast) in winter and summer (Lee and Ramster, 1981). Whilst the bottom temperature in the Irish Sea is similarly cooler in winter, it is 1°C to 2°C warmer than bottom waters at other Irish coasts in summer. These contrasting temperature conditions are considered to reflect the absence of deeper waters and limited areas of stratified waters[9] to stabilise the summer water temperature on Ireland's eastern coast.

3.1.4 As presented in Figure 4, the wind direction typically experienced at the Kish Lighthouse (53.3108°N, 5.9257°W between July 2011 to June 2015; Figure 3), located immediately to the north of the array, predominantly originate from the south and westerly directions. Furthermore, the higher wind speeds are also associated with these directions (Figure 4).

[9] Stratification occurs when water with different properties such as salinity, density and temperature form layers, which act as barrier for water mixing.

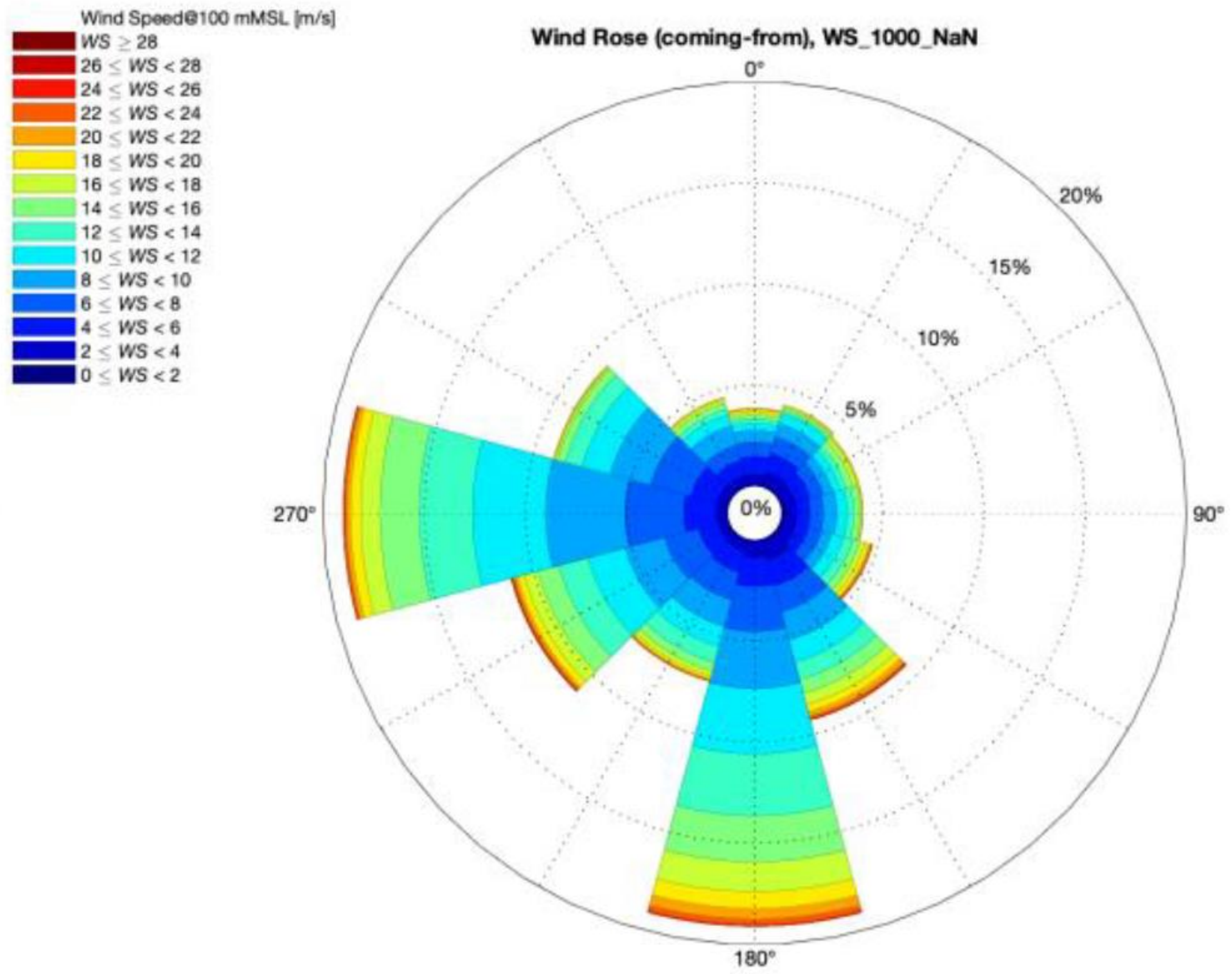


Figure 4 Wind rose derived from the Kish Lighthouse LiDAR measurements (C2wind, 2019)

Wave regime

3.1.5 Waves are directly driven by winds, modified by currents and shallow sea-floor topography. Surges are the apparent rise in sea level as a result of distant storms at sea. Waves and surges impact on a wide variety of human activities, including coastal infrastructure, shipping, settlement and coastal erosion (EPA, 2017).

3.1.6 The wave regime is defined as the combination of swell waves moving into, and propagating through, the study area in addition to more locally generated wind-waves. Swell waves are long-crested, uniformly symmetrical waves which are generated remotely from the study area, whilst wind-waves result from the transfer of wind energy to the water surface. The Irish Sea is constrained by two narrow channels (the Northern Channel and the St. George's Channel), and as such waves are predominantly locally generated, with short periods, and are often steep. Swell waves are present near the entrances and southern end of the St. George's Channel, and can propagate inwards (Howarth, 2005; Horrillo-Caraballo *et al.*, 2021).

3.1.7 Ireland is positioned on the path of major North Atlantic storms. This greatly influences wind directions and wave heights in Irish coastal waters which are exposed to strong wave energy and regular low-pressure systems. Consequently, storm surges in the Irish Sea are associated with major Atlantic depressions, usually from a westerly direction (Sweeney, 2000). Storms are experienced mostly during the winter months, with the most common directions of storms being southwest and northwest. During a storm event on the 6th of January 2014, a winter period noted for experiencing a particularly extreme wave climate (Met Éireann, no date), the M2 buoy (see Figure 3 and Section 2.3) recorded a maximum height of 7.4 m.

3.1.8 Data from the ABPmer SEASTATES interactive map indicates that along this area of the eastern Irish coast, the dominant wind direction is from the southwest (ABPmer, 2018). Data indicate a median wave height of, approximately, 1.6 m with an extreme (1 in 1,000) wave height of around 9 m (Orford, 1988). As presented in Figure 5, average significant wave heights[10] do not exceed 2 m in the Irish Sea coast in any season (Gallagher *et al.*, 2014), however, there is strong inter-annual variation.

[10] Traditionally defined as the mean wave height (trough to crest) of the highest third of the waves (H1/3). Nowadays it is usually defined as four times the standard deviation of the surface elevation.

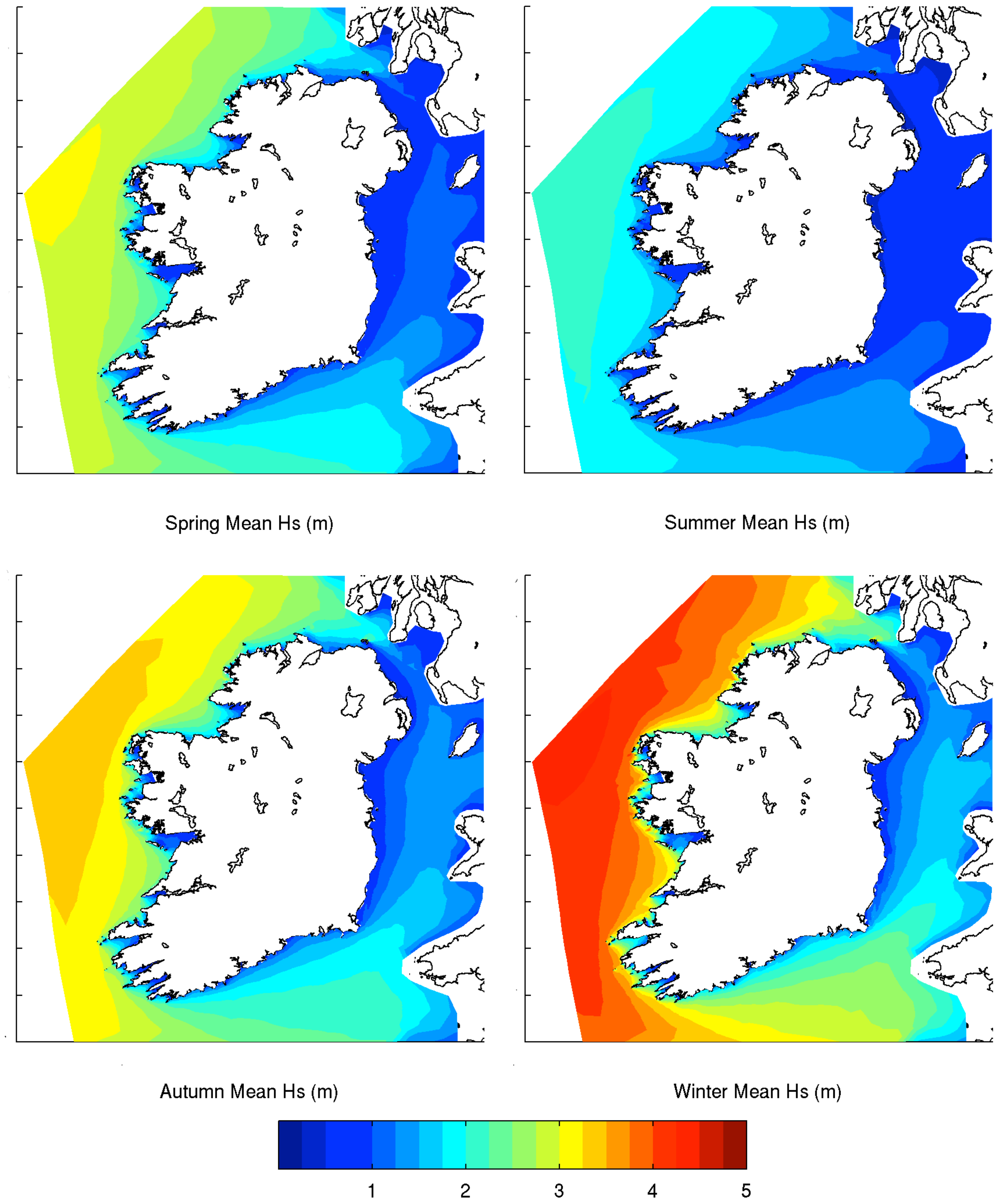


Figure 5 Average significant wave height (Hs) around the coast of Ireland (Met Éireann)

3.1.9 In general, there is a reduction in wave height as water depth decreases, although waves may become focused by refraction as they pass over the shallow areas of the Kish and Bray Banks. Wave heights are likely to be further reduced due to the influence of seabed friction and wave breaking as they pass over the very shallow areas of the banks. Data was collected for 12 months at two sites on the Kish and Bray Banks (the locations of which are shown on Figure 3) by Partrac (2022), a summary of which is provided in Table 2.

Table 2 Wave statistics based on 12 months of data collected along the Kish and Bray Banks (the location of which are shown on Figure 3) (Partrac, 2022)

Monitoring Station	Maximum Significant Wave Height (m)	Maximum Recorded Peak Period (s)	Dominant Wave Direction
June 2021 – November 20212			
Kish Bank	2.6	18.2	SSE (22.1% occurrence)
Bray Bank	2.0	18.0	S (16.3% occurrence)
November 2021 – March 2022			
Kish Bank	4.4	16.7	SSE (17.7% occurrence)
Bray Bank	3.8	18.2	SSE (17.4%)
March 2022 – June 2022			
Kish Bank	2.5	14.3	SSE (16.7% occurrence)
Bray Bank	2.3	16.7	S (17% occurrence)

3.1.10 A metocean hindcast study has been undertaken by the Danish Hydraulics Institute (DHI) for Dublin Array, with an analysis undertaken for data covering the period 1979 - 2018. Whilst noting the limitations of the use of the models used within the hindcast cases (DHI, 2019), the study corroborated that the largest wave heights within the proposed array come from the south and northeast[11]. The analysis also considered extreme sea-states which concluded that significant wave heights varied by, approximately, 0.3 m across the proposed array area with the peak heights in the south of the array. The extreme wave crest height varied by, approximately, 0.5 m across the array area with the highest values in the north.

[11] It should be noted that given the resolution of the model the effects of the Kish and Bray Banks on the wave climate was not resolved.

Site-specific Modelling

3.1.11 To inform the EIAR, a project specific spectral wave model (part of the Dublin Array Physical Process Modelling System (DAPPMS)) has been constructed to characterise and quantify the wave climate in the study area. Details of the model, calibration and validation and results are presented in the Spectral Wave Model Calibration and Validation Report.

3.1.12 The DAPPMS Spectral Wave (SW) model has been calibrated and validated against field measurements of wave data at three sites within the model domain (Figure 3). The calibration and validation data include:

- Wave measurements at the M2 Wave Buoy (offshore northeast of the proposed development);
- Wave measurements at the Dublin Bay Wave Buoy (in close proximity to the Offshore ECC transecting Dublin Bay); and
- Wave measurements at the JN1136 South Wave Buoy (within the south of the array area).

3.1.13 An analysis of the long-term wave measurements recorded at the M2 wave buoy, located in the Irish Sea (to the northeast of the study area) for an eight-year period, was undertaken as part of the wave model validation. Full details of this analysis are presented in the Spectral Wave Model Calibration and Validation Report. The analysis indicated a dominance in wave conditions from a southerly direction and a maximum significant wave height greater than 7 m. This is consistent with the concept that waves arriving from the south are a result of channelling from the Atlantic, whereas those from other directions are a result of the relatively short fetch of the Irish Sea. Significant wave heights with a 1 in 1-year return period are shown in Figure 6, with lower values over the bank crests indicating sheltering effects.

3.1.14 An analysis of the JN1163 South and Dublin Bay buoy were also undertaken to support the wave model calibration. JN1163 South is located in very shallow water at, approximately, 8 meters relative to Chart Datum (mCD), but also in the lee of the crest of Bray Bank, at around 3 mCD. Large waves originating from the east over the bank are likely to break before reaching JN1163 South and the bank crest is likely provide some sheltering. Full details of this analysis are presented in the Spectral Wave Model Calibration and Validation Report.

3.1.15 In summary, the wave climate at the Dublin Array site is dominated by waves approaching from a south to southeasterly direction, both in terms of magnitude and frequency. Southerly waves in particular may approach the site from the Atlantic and are therefore relatively large and exhibit a stronger swell influence. Waves also approach the site from the north, northeast and easterly directions; however, these waves have shorter fetch lengths and therefore tend to exhibit lower heights and shorter periods than Atlantic waves; they also occur less frequently than waves from south and southeasterly directions.

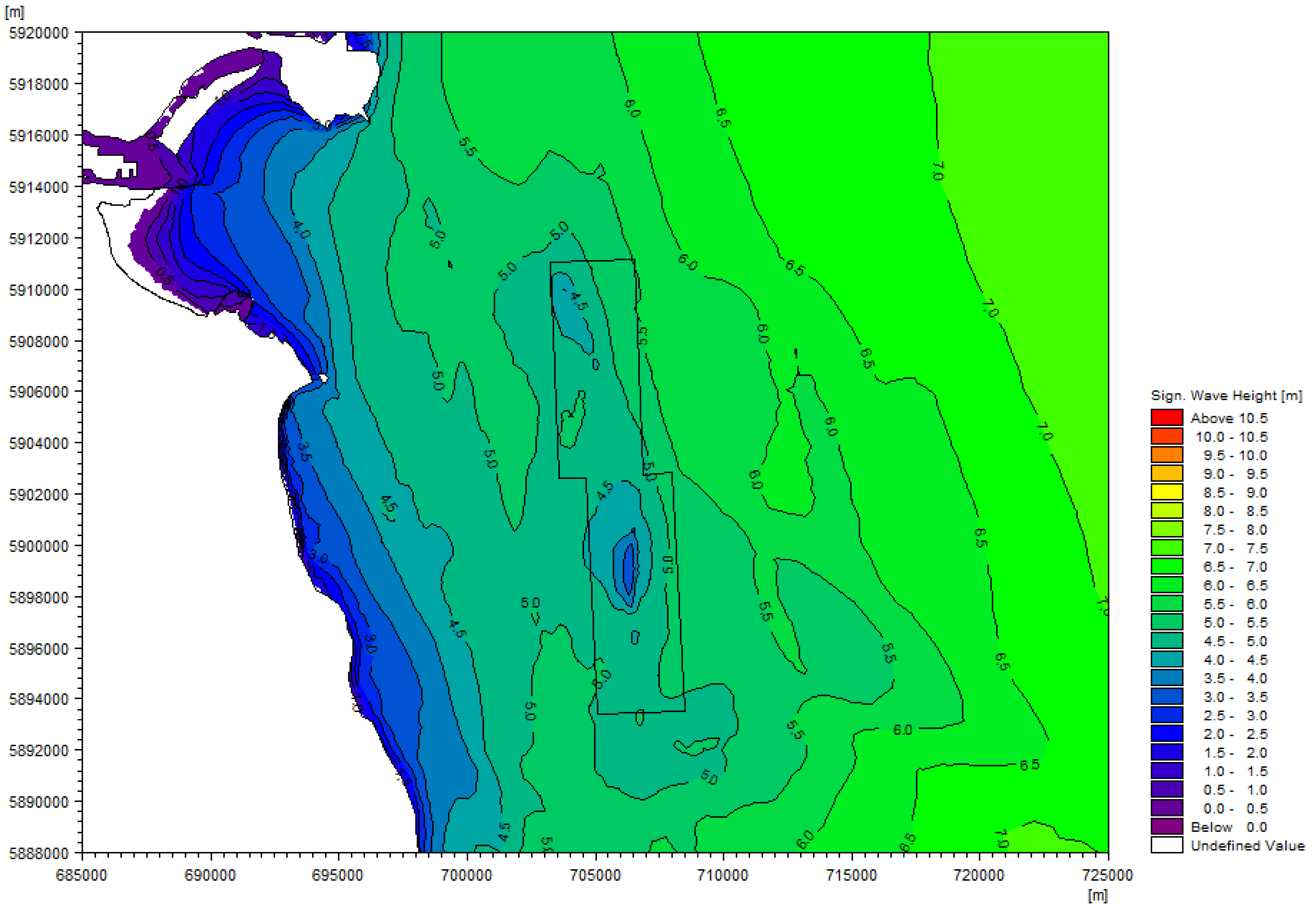


Figure 6 Significant wave heights from the south (a 1 in 1 year event) (DAPPMS)

3.2 Tides, currents and water levels

Overview

3.2.1 The tides in the Irish Sea are semi-diurnal. The tidal range varies in the Irish Sea with areas of very large tidal ranges[12] (such as in Liverpool Bay, UK) to areas of very small tidal range near the degenerate amphidromic point[13]) near Co. Wicklow and Co. Wexford (Howarth, 2005) (see Figure 7). The mean spring tidal range is 4 to 5 m near the median line between Ireland and the UK, decreasing to the Irish Coast to, approximately, 2 m.

3.2.2 Peak spring tidal currents can exceed 2 m/s at spring tides northwest of Anglesey. Areas of very weak tidal currents occur to the southwest of the Isle of Man, towards Dundrum and Dundalk Bays (less than 0.25 m/s at spring tides) and slightly less weak between the Isle of Man and the Cumbrian coast (approximately 0.5 m/s) both as a consequence of this being the region where the two tidal waves meet, referred to as a standing wave region (Howarth, 2005). The slack water[14] typically occurs at high and low water in Irish Sea as a consequence of the standing wave in the region.

[12] Co-tidal ranges are lined which link places having the same tidal range (amplitude) (see Figure 7). Co-phase links all points having the same phase. Numbers are hours of lag of high tide after the moon's transit over the Greenwich meridian (0°) or phase of the tide relative to Greenwich (e.g., a phase of 0° has high tide at the same time as the moon is passing over Greenwich, 180° has low tide at this time) (see Figure 7).

[13] An amphidromic point, also called a tidal node, is a geographical location which has zero tidal amplitude for one harmonic constituent of the tide. The tidal range (height difference between high tide and low tide) for that harmonic constituent increases with distance from this point. An amphidromic point is said to be degenerate when its centre appears to be located over land rather than water.

[14] A phase difference between currents and elevations of ±90°.

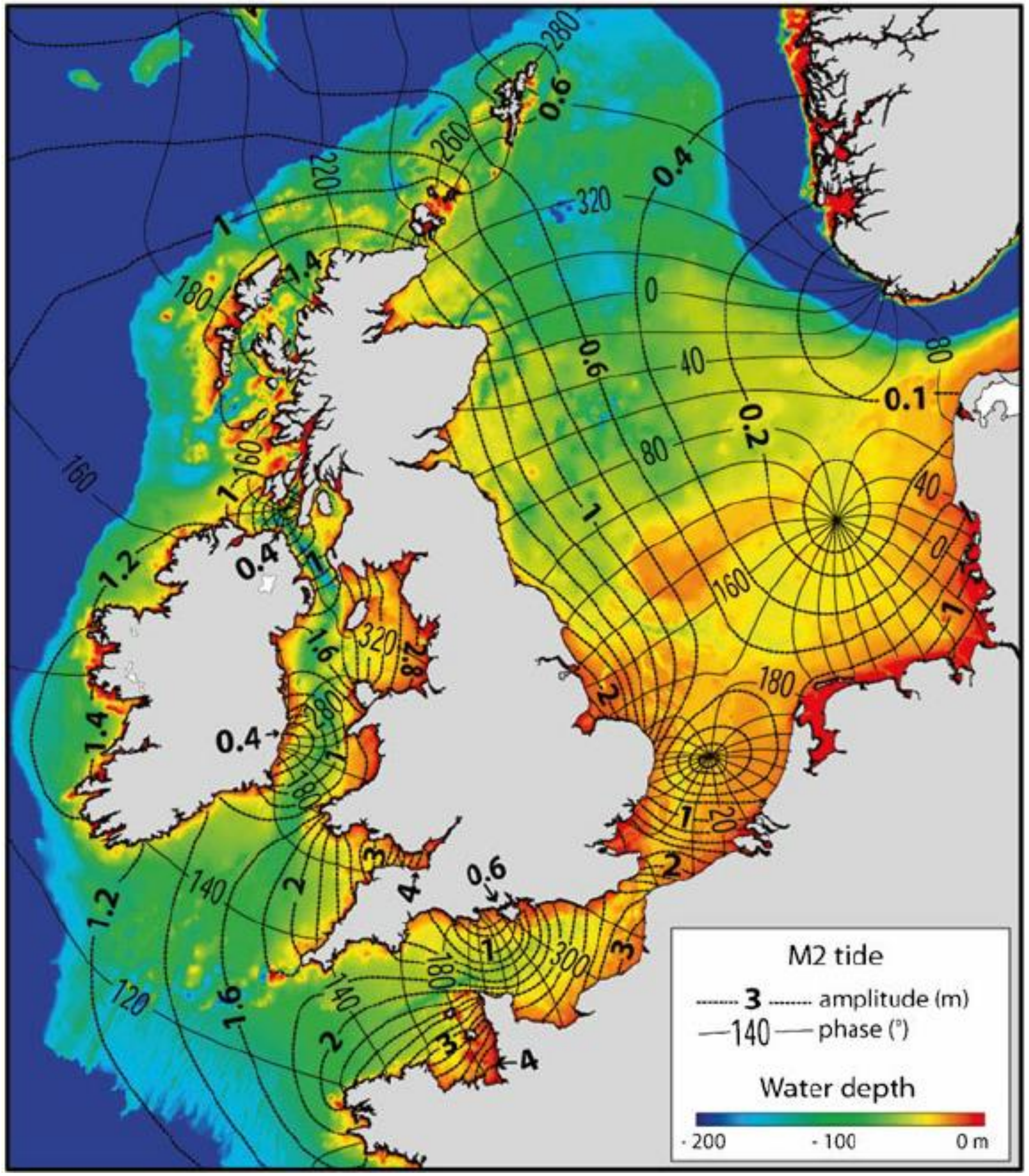


Figure 7 Amphidromic systems (M2 constituent only) (Reynaud & Dalrymple, 2012)

3.2.3 The strong currents result in the majority of the Irish Sea being vertically well mixed throughout the year (Howarth, 2005). Stratification occurs in the summer (May to October) in areas of weak tidal currents, such as in proximity of the Isle of Man and in Cardigan Bay, although it should be noted that stratification is not as well developed as in other areas such as the Celtic and North Seas (Howarth, 2005). In the western Irish Sea, between north Co. Dublin, Carlingford Lough, and the Isle of Man, a combination of deeper water and slower tidal currents allows the formation of stratification in spring and summer, with a maximum surface to bed temperature difference of around 5°C during stratification (Young and Holt, 2007; BEIS, 2022).

3.2.4 Atlantic swell will also enter the Irish Sea, in turn influencing the coastal form of the southeastern coast, producing northward opening crenulate bays[15]. The bays are cut into glacial drift deposits and are often separated by low rock projections. Constructional features also exist along the coast, these include sand spits, dunes, shingle and sandbars and intertidal flats to the east (Sinnott and Devoy, 1992).

3.2.5 Meteorological events, such as storm surges (when depressions move through an area and water levels are acted upon by wind to push water onshore; outlined previously in paragraph 3.1.7) can change the water levels along the east coast of Ireland. The implication of storm surge is typically in the order of 1 m increase in water levels. This can have ramifications such as coastal flooding and exacerbated coastal erosion. As presented in Figure 8, the depth averaged extreme surge current within the Irish Sea varies between, approximately, 40 cm/s and 50 cm/s (Flather, 1987).

[15] A scalloped shaped bay, varying in degrees of symmetry, which develop where the wave climate is asymmetrical.

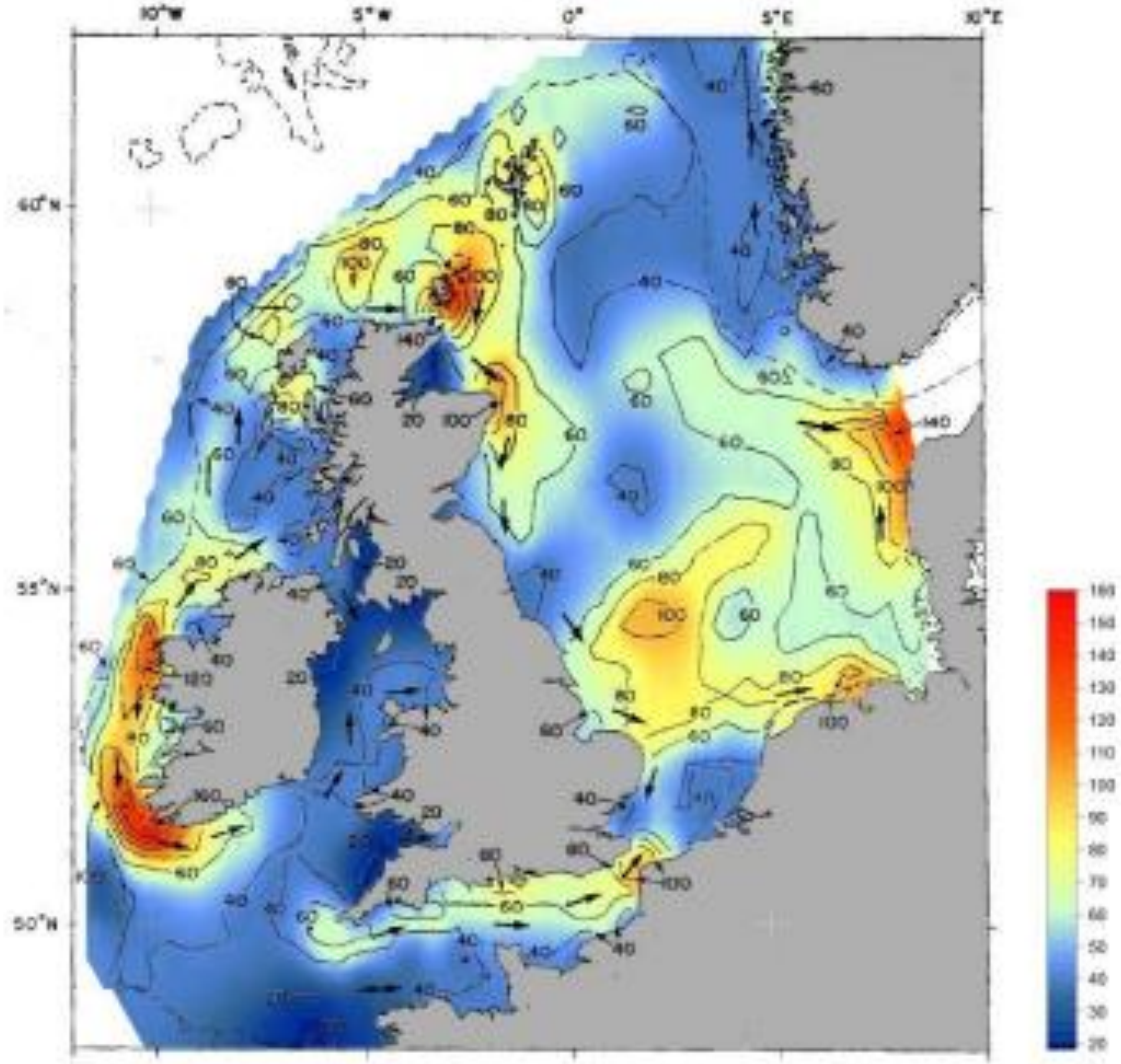


Figure 8 Depth averaged extreme surge current in cm/sec, with a return period of 50 years (Flather, 1987); (Kenyon and Cooper, 2005)

Site-specific Modelling

3.2.6 As part of the EIAR, a hydrodynamic model was developed (part of the DAPPMS) to characterise and quantify the tidal currents and water levels within the study area. The DAPPMS was calibrated against numerous sources of tidal data including:

- Four Acoustic Doppler Current Profiler (ADCP) deployments on the Kish and Bray Banks (undertaken by Aquafact International Services Ltd for Saorgus Energy Ltd in 2012);
- The Irish National Tide Gauge Network, operated by Foras na Mara/Marine Institute, provided water levels at the Kish Bank Lighthouse, Dublin Port and Howth Harbour;
- Information from the UK Hydrographic Office (UKHO) provided additional water level estimates at a number of ports along the coast; and
- British Oceanographic Data Centre (BODC) current meters and UKHO tidal diamonds were used to provide velocity data in the outer part of the model domain.

3.2.7 Details of the model, calibration and validation and results are presented in the Hydrodynamic Calibration and Validation Report. The data from this model are the primary source of information to inform effects and pathways associated within tidal currents within the EIAR, see the Physical Processes Chapter. Site-specific survey data has been included in order to support this data, including 12 months of wave, current, and water level data recorded on the Kish and Bray Banks (Partrac, 2022). A comparison between the data used to calibrate the model, and the data collected after the model setup, is provided in Annex A, which demonstrates that the data used within the EIAR numerical model(s) remains appropriate for both baseline characterisation and EIAR assessment.

Water Levels

3.2.8 The tidal regime in the area is semi-diurnal with a mean spring and neap tidal range of 3.4 m and 1.9 m, respectively, at Dublin Port (Admiralty, 2019). The DAPPMS shows that tidal range does not vary much over the proposed array area and its surrounding locations, with little spatial variation in water level at each tidal state (see Figure 9). Within the array, the predicted mean spring and mean neap tidal ranges are of the order of 3.3 m and 1.9 m, respectively.

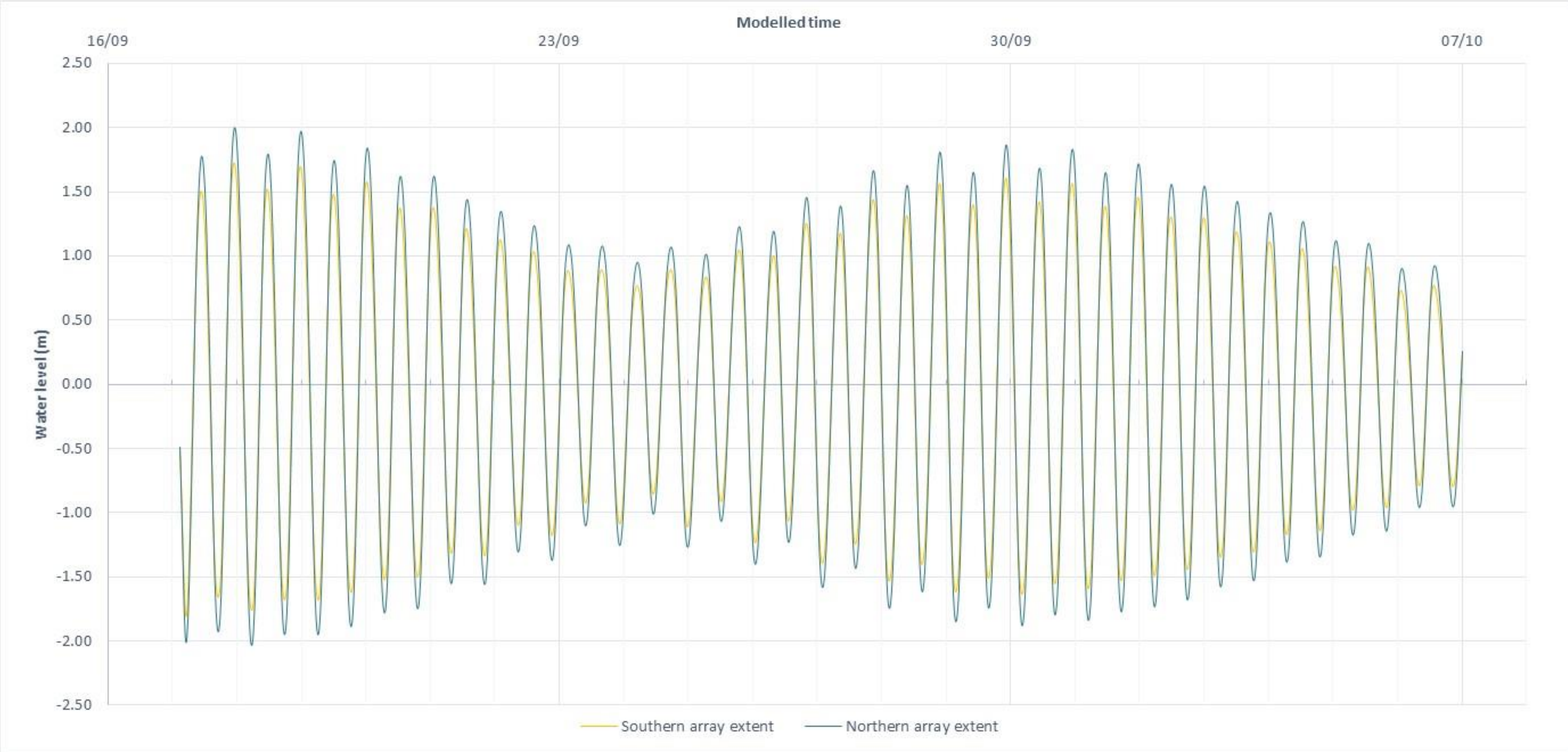


Figure 9 Modelled water levels within the array area (DAPPMS)

Currents

3.2.9 The calibrated DAPPMS model indicates that the area experiences flow to the south during the ebb tide and to the north during the flood tide, resulting in a clockwise circulation over a tidal cycle. These tidal patterns are evidenced by the sediment transport found on the banks, with bedform orientation providing further corroboration of clockwise transport, as outlined further in Paragraph 3.5.12 (Wheeler *et al.*, 2000; ABPmer, 2022). Data presented on the Admiralty Chart confirms this, with maximum tidal velocities of 2.2 knots (1.13 m/s) being experienced in the vicinity of the banks. The flood tide is identified as being slightly stronger than the ebb, leading to northward tidal residual (see Figure 10 and Figure 11). Further details are presented in Figures A9 to A16 in the Hydrodynamic Calibration and Validation Report.

3.2.10 Two TRIAXYS with current directional wavebuoys were deployed on the Kish and Bray Banks (to the northeast and southwest, respectively, with locations shown on Figure 3) between 2021 and 2022 (Partrac, 2022). At the Kish Bank location, spring current velocities are between 0.8 m/s and 1.0 m/s for near-surface currents, and approximately between 0.6 m/s and 0.8 m/s for near-bed currents. Currents are primarily directed towards the south (45% and 37% of the time for near-surface and near-bed, respectively) with a less frequent (as well as lower velocity) component towards the north (30% and 23% of the time, respectively).

3.2.11 At the Bray Bank location, spring current velocities reach between 1.2 m/s and 1.4 m/s for near-surface currents, and between 0.6 m/s and 1.0 m/s for near-bed currents. This is supported by the calibrated DAPPMS, which predicts higher speeds in the southern part of the array. In contrast to the Kish Bank location, near-surface currents are primarily directed towards the north (35% of the time), with a smaller component to the south (23% of the time). Near-bed currents, however, have a higher frequency towards the south (27% of the time as opposed to 18% of the time towards the north). This would add support to the interpretation of clockwise circulation around the banks, although it highlights localised complexity within the water column. At the Bray Bank site, currents directed towards the north have generally higher speeds, suggesting dominance of the flood tide (as identified by the DAPPMS model), which is not identified at the Kish Bank location.

3.2.12 The DAPPMS predicts strong currents and tidal flows around the Kish and Bray Banks (see Figure 10 to Figure 12). The tidal currents have peak speeds of 1.9 m/s during spring tides (see Figure 10) and 1.1 m/s during neap tides (see Figure 12) on Kish Bank. A short-term (spring-neap tidal cycle) deployment on the northern extent of Kish Bank indicates that spring current flows are of the order of 0.7 m/s to 1.4 m/s, for near-bed and sub-surface locations, respectively (Aquafact, 2012). The associated neap current flows are of the order of 0.5 m/s to 1.1 m/s, for near-bed and sub-surface locations, respectively (Aquafact, 2012). These are generally higher speeds than those recorded by the TRIAXYS wavebuoys (Partrac, 2022).

3.2.13 The greatest flow speeds occur on Bray Bank, at the southern end of the array area, occur during the peak flood and ebb phases of the mean spring tide, with peak flood and ebb speeds of 1.4 m/s and 1.2 m/s, respectively. During neap tides these reduce to speeds of 0.9 m/s during both the peak flood and peak ebb stages of the tide. Speeds are generally higher in the southern part of the array area. This pattern, as well as the identified speeds on the Bray Bank, corroborate the data recoded at the TRIAXYS wavebuoys (Partrac, 2022).

3.2.14 Detailed evidence of local flow conditions can be determined with reference to the geological bedforms observed within the site and as informed from the INFOMAR geophysical survey data, in addition to project-specific geophysical surveys (Fugro, 2021b; 2021c). For medium sands, sandwaves are observed to form under flow velocities of approximately 0.6 m/s (as identified close to the bed during spring conditions at both the Kish and Bray Bank locations by Partrac, 2022) and gradually change to high-energy planar bed features at velocities above 1 m/s (Leeder, 1999; Belderson *et al.*, 1982). Under flow velocities of less than 0.6 m/s, such sediments are observed to form ripples. As a result, the pattern of bedforms observed on the banks suggests that the strongest tidal flow conditions are found closest to the banks, due to the acceleration of tidal flows around the obstruction which the banks present.

3.2.15 As with current speeds, the DAPPMS identifies the highest instances of bed shear stress on a mean spring tide occur during the peak flood and ebb phases, which will lead to higher sediment mobilisation and therefore bedform migration. These reduce for the mean neap tide.

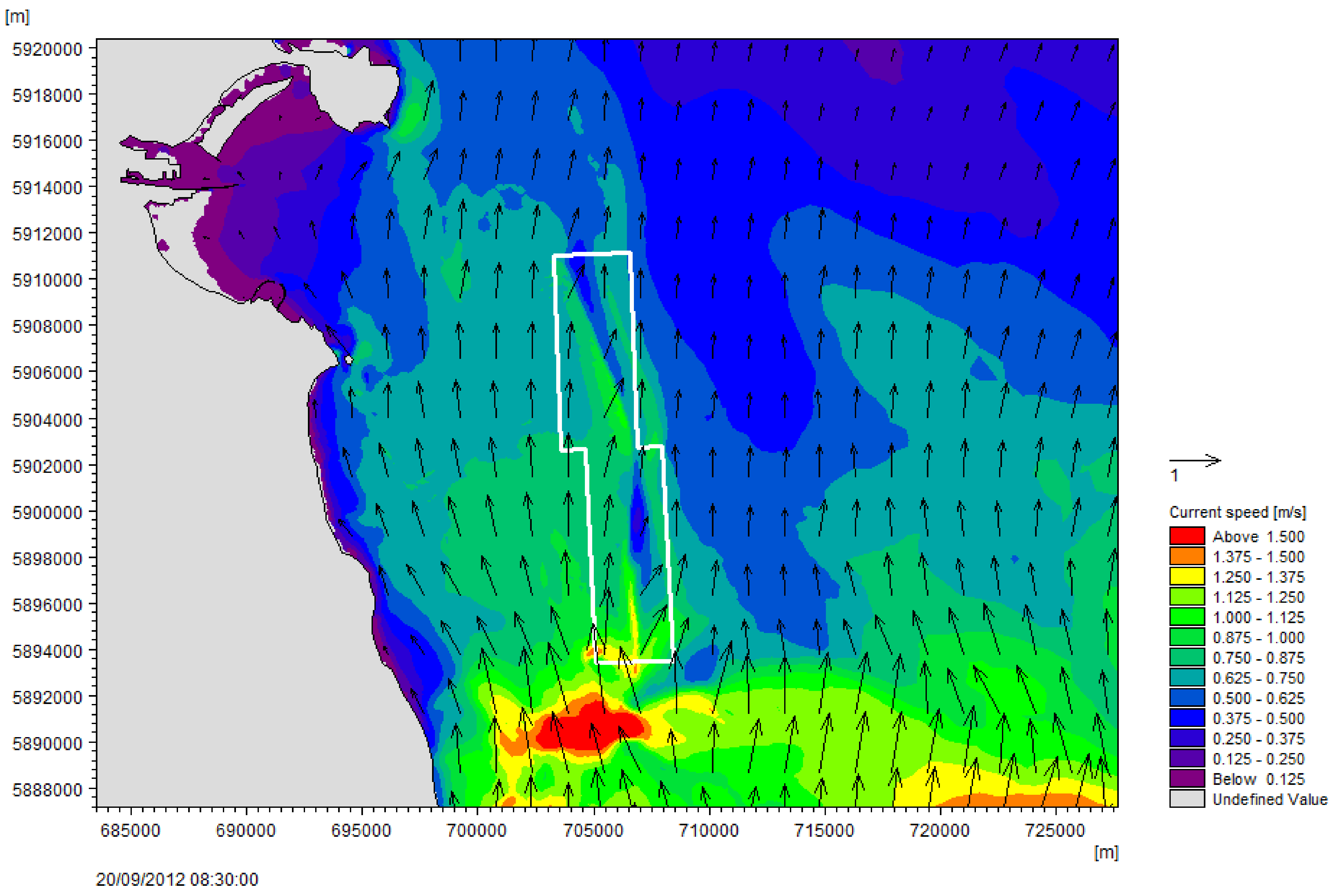


Figure 10 Mean spring tide current speeds at peak flood (DAPPMS)

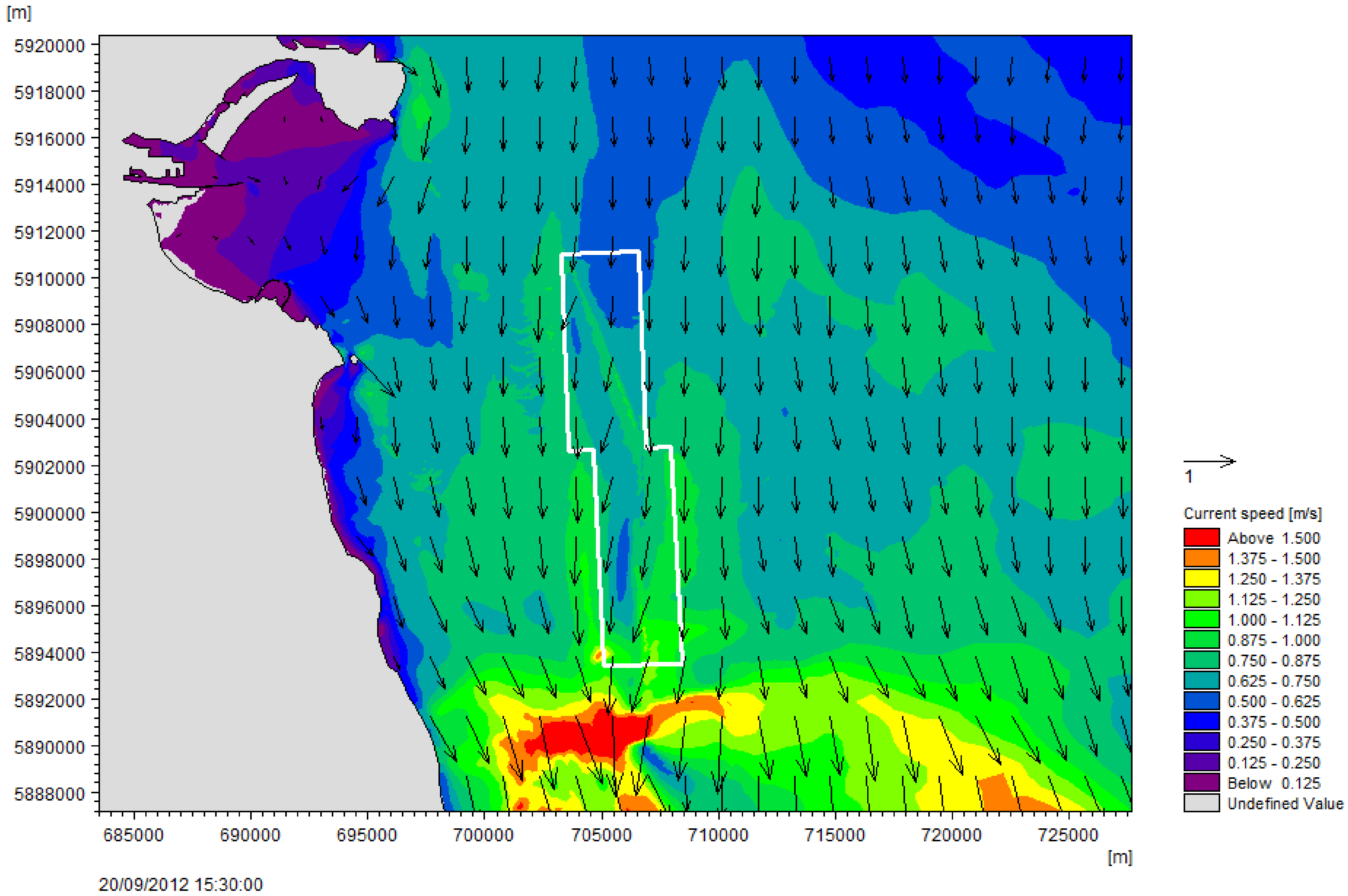


Figure 11 Mean spring tide current speeds at peak ebb (DAPPMS)

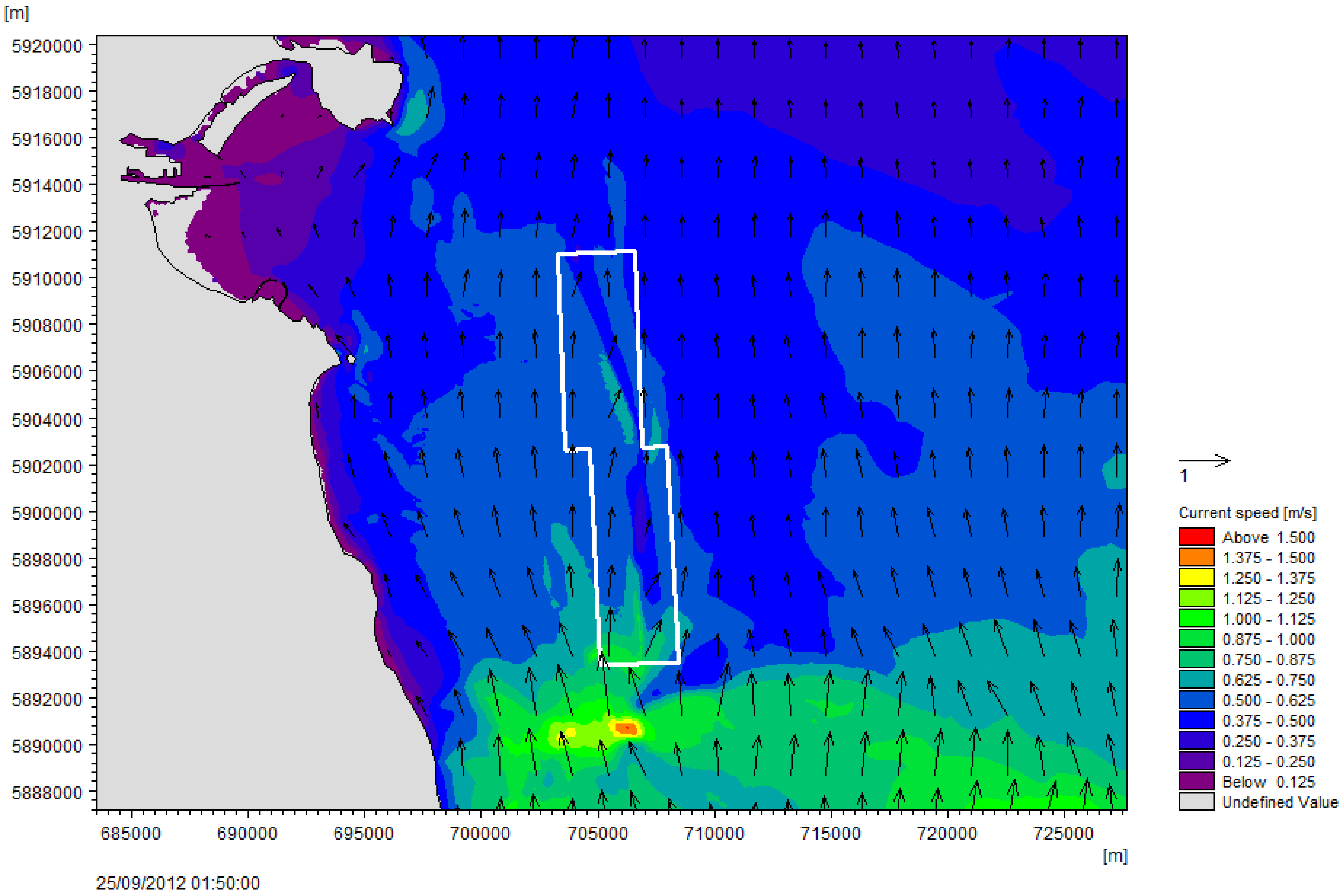


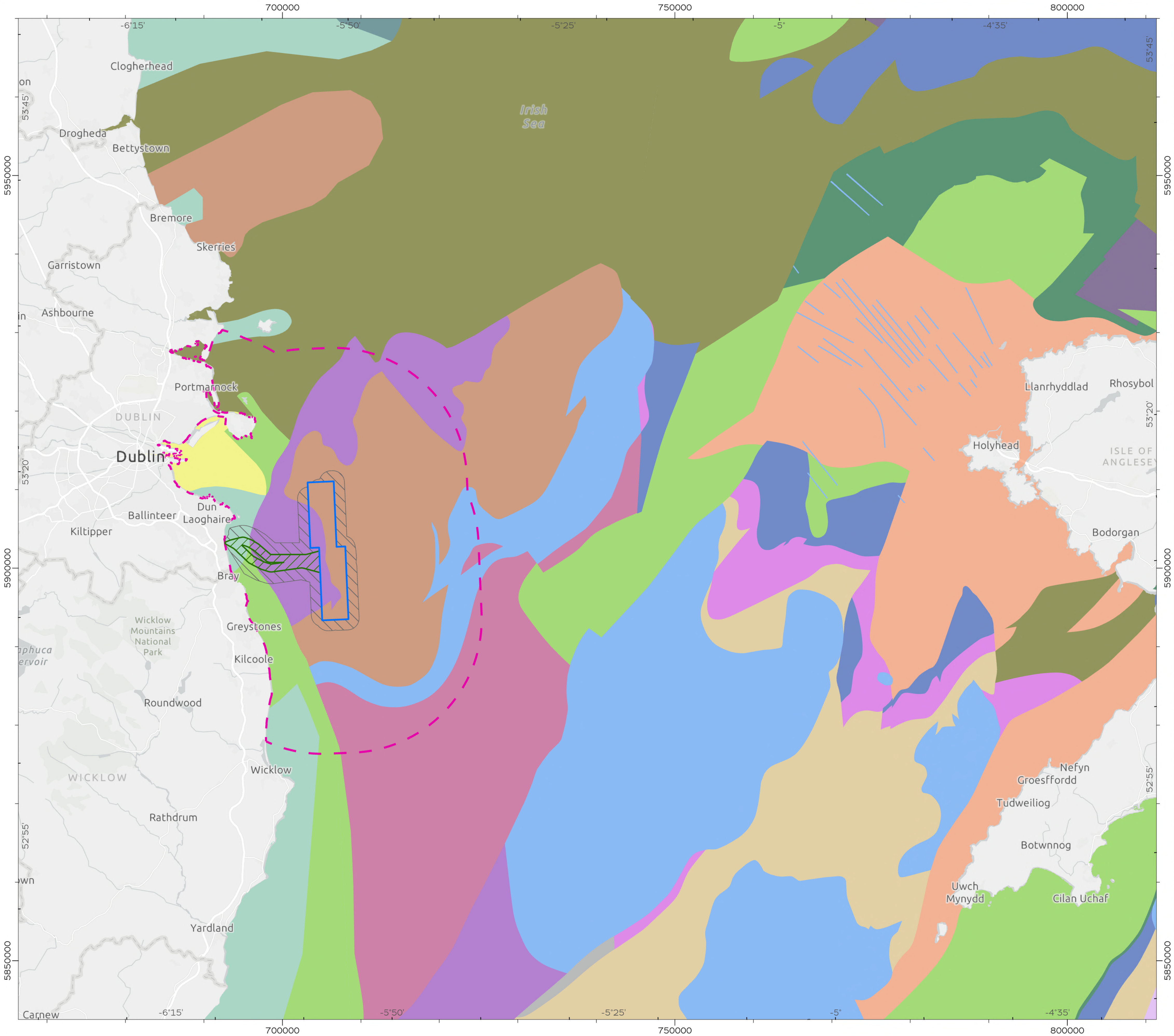
Figure 12 Mean neap tide current speeds at peak flood (DAPPMS)

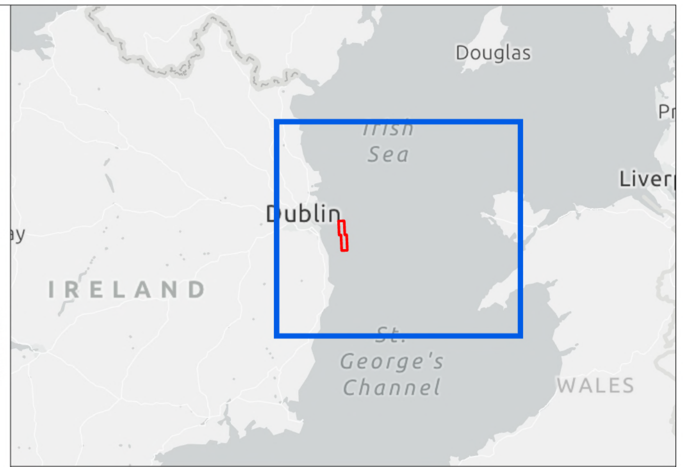
3.3 Geology

3.3.1 The current seabed landscape is a relic of the underlying bedrock geology and the actions of several glacial periods when large volumes of material were eroded and deposited on the seabed. The morphology and distribution of surficial sediments in the region has resulted largely from glacial deposition/scour processes combined with reworking and redeposition as a result of riverine input and tidal processes. The geological environment can generally be divided according to the main groupings of materials based on age and geological processes as follows:

- Bedrock geology – these are rocks older than 1.8 million years old formed before the last ice ages.
- Drift (Quaternary) geology – these are rocks and semi-consolidated material deposited since the start of the last ice age and are from 1.8 million to 10,000 years old.
- Seabed sediments – these represent the youngest materials and were formed from reworking of either the solid or quaternary material, river inputs of sediments or the creation of new materials such as biogenic shells.

3.3.2 The pre-quaternary age of the geology (bedrock) in the wider area of the proposed development is presented in Figure 13. The majority of the Irish Sea bedrock is Quaternary age (<2.6 million years) with limited areas of outcropping (typically north of Anglesey and in the North Channel). The Quaternary sediments (shown in Figure 14) typically exceed a thickness of 50 m in the western Irish Sea, known as the Western Irish Sea Formation, which are typically areas of soft muds. Carboniferous mudstone, sandstone and limestone are the second most common bedrock types occupying the central and western Irish Sea (Mellet *et al.*, 2015).





Array Area
Temporary Occupation Area
Export Cable Corridor
Physical Processes Study Area (17km Buffer)

Bashkirian	Neoproterozoic
Cambrian	Ordovician
Carboniferous	Paleogene
Llandovery	Pennsylvanian
Lopingian	Permian
Lower Jurassic	Rhaetian
Lower Triassic	Serpukhovian
Middle Triassic	Silurian
Mississippian	Tournaisian

DRAWING STATUS

FINAL

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PROJECT TITLE

Dublin Array

DRAWING TITLE

Pre-Quaternary Age of Bedrock in the Irish Sea

DRAWING NUMBER: 13

PAGE NUMBER: 1 of 1

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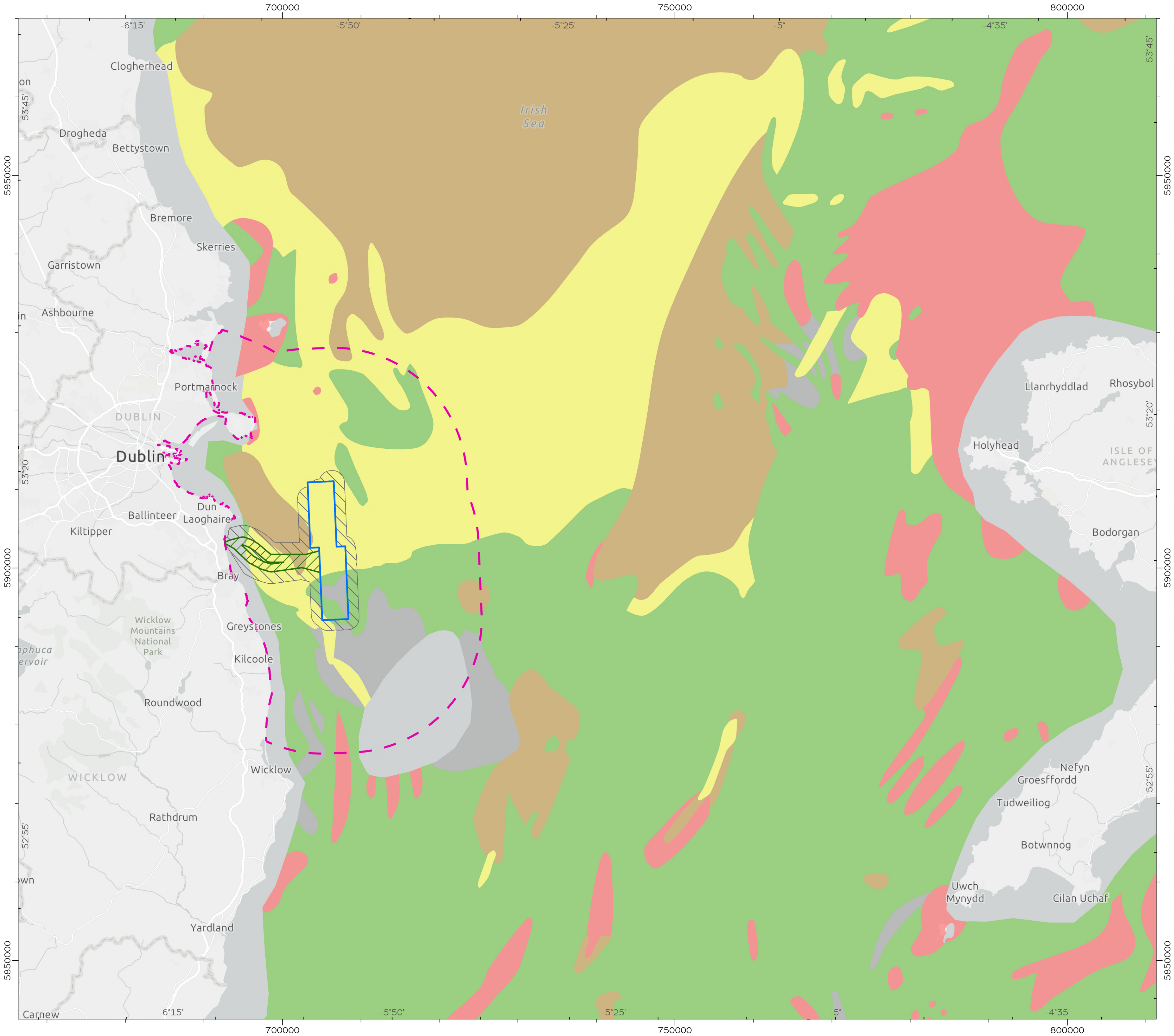
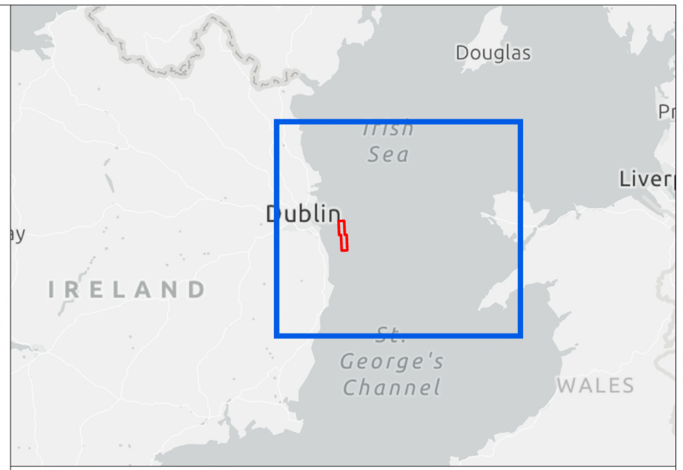
GoBe APEM Group

Dublin Array Generation for generations
Kish Offshore Wind Limited - Bray Offshore Wind Limited





Array Area
Temporary Occupation Area
Export Cable Corridor
Physical Processes Study Area (17km Buffer)
Diamicton
Gravel
Mud
Sand
Sediment

DRAWING STATUS
FINAL

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Data Source: EMODnet - Geology

PROJECT TITLE
Dublin Array

DRAWING TITLE
Quaternary Lithology in the Irish Sea

DRAWING NUMBER: 14
PAGE NUMBER: 1 of 1

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GRID NORTH

SCALE	1:500,000	PLOT SIZE	A3
DATUM	WGS 1984	VERTICAL REF	LAT
PRJ	WGS 1984 UTM Zone 29N		

APEM Group
Generation for generations
Kish Offshore Wind Limited - Bray Offshore Wind Limited

3.3.3 As presented in Figure 13 and Figure 14, the study area can be characterised as Palaeozoic and Mesozoic rocks overlain by Quaternary glacial deposits (principally from the Weichselian glaciation). The soils encountered in the three boreholes undertaken in the northern half of the array area by Glover Site Investigations (2008) (see Figure 15), to their maximum depth of 20 m, were marine sand deposits, loose/medium in the upper layers, soil of medium density down to 12 m and very dense soil 12 m and greater below the sea-bed. Of note is that these boreholes provide information on the sandbanks geology, rather than detail of bedrock underlying the features.

3.3.4 The project specific geophysical campaign within the array area and Offshore ECC has afforded detailed information on the underlying geology (Fugro, 2021b; 2021c). As presented in Table 3 there are five main horizons present within the array area and seven within the Offshore ECC.

Table 3 Geological horizons within the array area and Offshore ECC (Fugro, 2021b; 2021c)

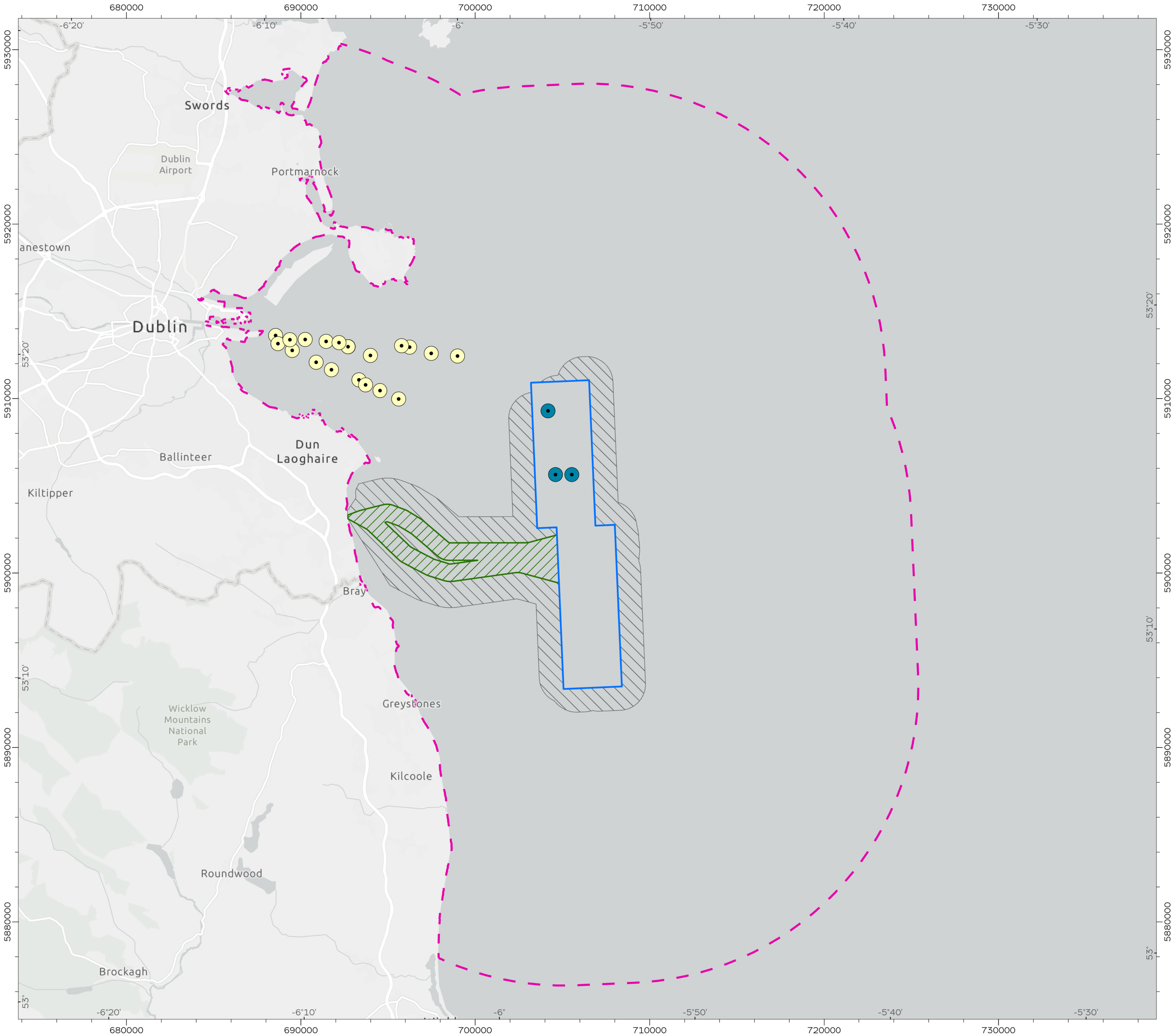
		Depth of horizon (m BSB*)	
Horizon	**Description**	**Array**	**Offshore ECC**
H10 Base Unit A	Mobile, unconsolidated sediments. Array area: Fine to medium sand, some shells, trace gravels. ECC: Mainly sand, with gravel, some fines.	0.0 – 6.8	0.2 – 6.7
H20 Base Unit B	Consolidated, recent sediments. Array area: Fine to medium sand, some shells and gravel. ECC: Silty sand, with fine to medium sand with shell fragments. More gravel with depth.	0.2 – 7.0	0.3 – 8.2
H25 Base Unit E	Sandy gravel. ECC: Gravel composed of limestone. Located in discrete part of northern ECC	n/a	2.0 – 18.9
H30 Base Unit C	Array area: Mainly sand, some gravel, clay, silt. ECC: Sandy clay in the east, to clayey sand in the west, occasional shells	0.2 – 20.3	0.3 – 19.4
H40 Base Unit D	Array area: Located in discrete part of southern array. ECC: Sandy clay. Located in discrete part of northern ECC.	0.7 – 13.6	8.9 – 23.3
H01 Top of Potential Shallow Gas	Array area: northeast and northwest of array area, small pocket on the southeast. ECC: absent from northern ECC.	4.2 – 19.2	3.0 – 18.4

		Depth of horizon (m BSB*)	
Horizon	**Description**	**Array**	**Offshore ECC**
H02 Top Bedrock	Outcrops at seabed towards the shore of the southern ECC.	n/a	0.2 – 22.0

*BSB – Below seabed

3.3.5 In October 2010, Dublin City Council commissioned a geotechnical campaign in the approaches to and within Dublin Bay to inform and facilitate the Ringsend Wastewater Treatment Plant (WWTP) works. This geotechnical campaign consisted of 21 boreholes and a bathymetric survey, located approximately 5 to 10 km north of the Offshore ECC (see Figure 15). On the western side of the profiles, in the majority of the boreholes, the surface layer is sand. The sediment changes to clay in the eastern part. Underneath there are bands of clay, gravel and sand in various combinations. Bedrock was encountered from 10 to 52 m Below Sea Floor (BSF) and is composed of limestone.

3.3.6 Areas interpreted as exposed bedrock were also identified within the Offshore ECC associated with the Shanganagh landfall and close to the shoreline (Figure 14). As such, areas of exposed hard surfaces are expected to be found in the western area of the Offshore ECC to Shanganagh. These areas are typically rough and undulatory northwesterly to southeasterly trending ridges.



Array Area

Temporary Occupation Area

Export Cable Corridor

Physical Processes Study Area (17km Buffer)

Borehole (Fugro, 2011)

Borehole (Glover, 2008)

DRAWING STATUS

FINAL

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PROJECT TITLE

Dublin Array

DRAWING TITLE

Borehole Locations Within the Study Area

DRAWING NUMBER: 15

PAGE NUMBER: 1 of 1

VER	DATE	REMARKS	DRAW	CHEK	APRD
01	2024-05-24	For Issue	GB	BB	SS

0 2 4 6 8 km

0 1 2 3 4 nm

N GRID NORTH

SCALE	1:225,000	PLOT SIZE	A3
DATUM	WGS 1984	VERTICAL REF	LAT
PRJ	WGS 1984 UTM Zone 29N		

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Dublin Array Generation for generations

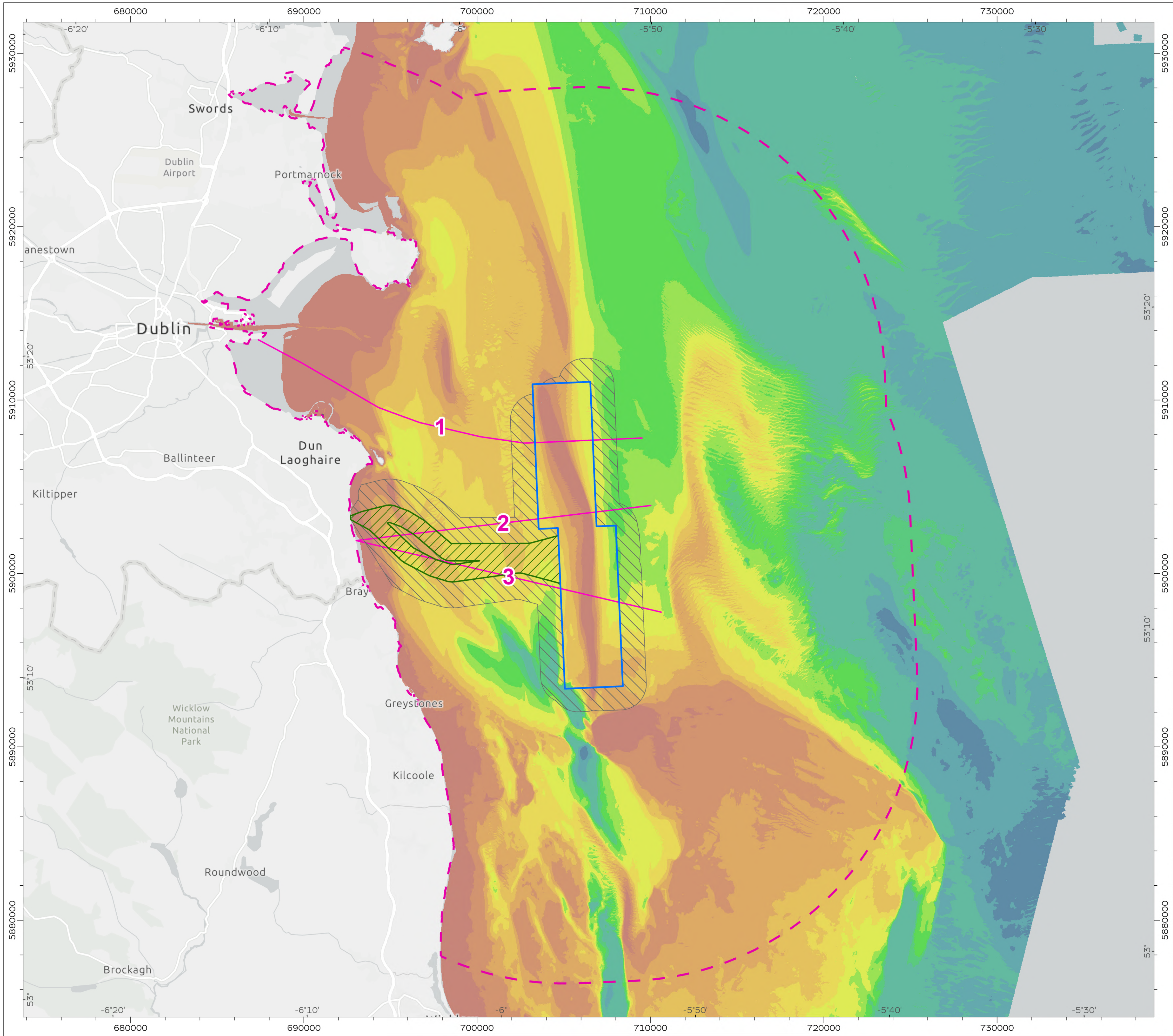
Kish Offshore Wind Limited - Bray Offshore Wind Limited

3.4 Bathymetry

3.4.1 The bathymetry of the wider study area, as derived from project specific surveys and INFOMAR data, is presented in Figure 16 and Figure 17 (Fugro, 2021b). These data are considered the most appropriate and robust for the characterisation of the bathymetry within the wider physical processes study area and are consistent with the bathymetric data collected for Wheeler *et al.* (2001) (Figure 16). Water depths of, approximately, 2 mCD to 26 mCD are identified within the region of the array area with shallower depths (approximately 1 m) being observed towards the northern end of the array area. This is supported by the project specific surveys, which indicate that water depths decrease along the offshore ECC and within the array area, to approximately 32 m (LAT) (Fugro, 2021a), with the exception of the Kish and Bray Banks.

3.4.2 The Kish and Bray Banks lie in 10 to 30 m of water and rise in places to, approximately, 3 m (relative to Lowest Astronomical Tide (LAT)) at the crest of the banks (Wheeler *et al.,* 2001; Fugro, 2021b). The area of the banks shallower than 20 m (LAT) covers an area of, approximately, 35 km^2, of which around a third (approximately 10 km^2) is shallower than 10 m (LAT). Bathymetry along transects (the location of which are shown in Figure 16) within the proposed development site are shown in Figure 19 to Figure 21, with the red dashed lines on the figures indicating the spatial location of the proposed array area. Further illustration of the profile of the offshore ECC is provided in Figure 21, along both potential routes.

3.4.3 A further distinctive feature within the array area is located towards its southwestern extent near Codling Deep, where depths increase from 25 m (LAT) to 60 m (LAT) within a horizontal distance of 750 m (Fugro, 2021b). Codling Deep has been interpreted as a tunnel valley, believed to have formed through erosional processes from glacial meltwater (Coughlan *et al.*, 2015).



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Bathymetry Data - INFOMAR 2023

PROJECT TITLE

Dublin Array

DRAWING TITLE

Geographical Overview of the Bathymetry in the Study Area

DRAWING NUMBER: 16

PAGE NUMBER: 1 of 1

VER	DATE	REMARKS	DRAW	CHEK	APRD
01	2024-05-24	For Issue	GB	BB	SS

0 2 4 6 8 km
0 1 2 3 4 nm

N GRID NORTH

SCALE	1:225,000	PLOT SIZE	A3
DATUM	WGS 1984	VERTICAL REF	LAT
PRJ	WGS 1984 UTM Zone 29N		

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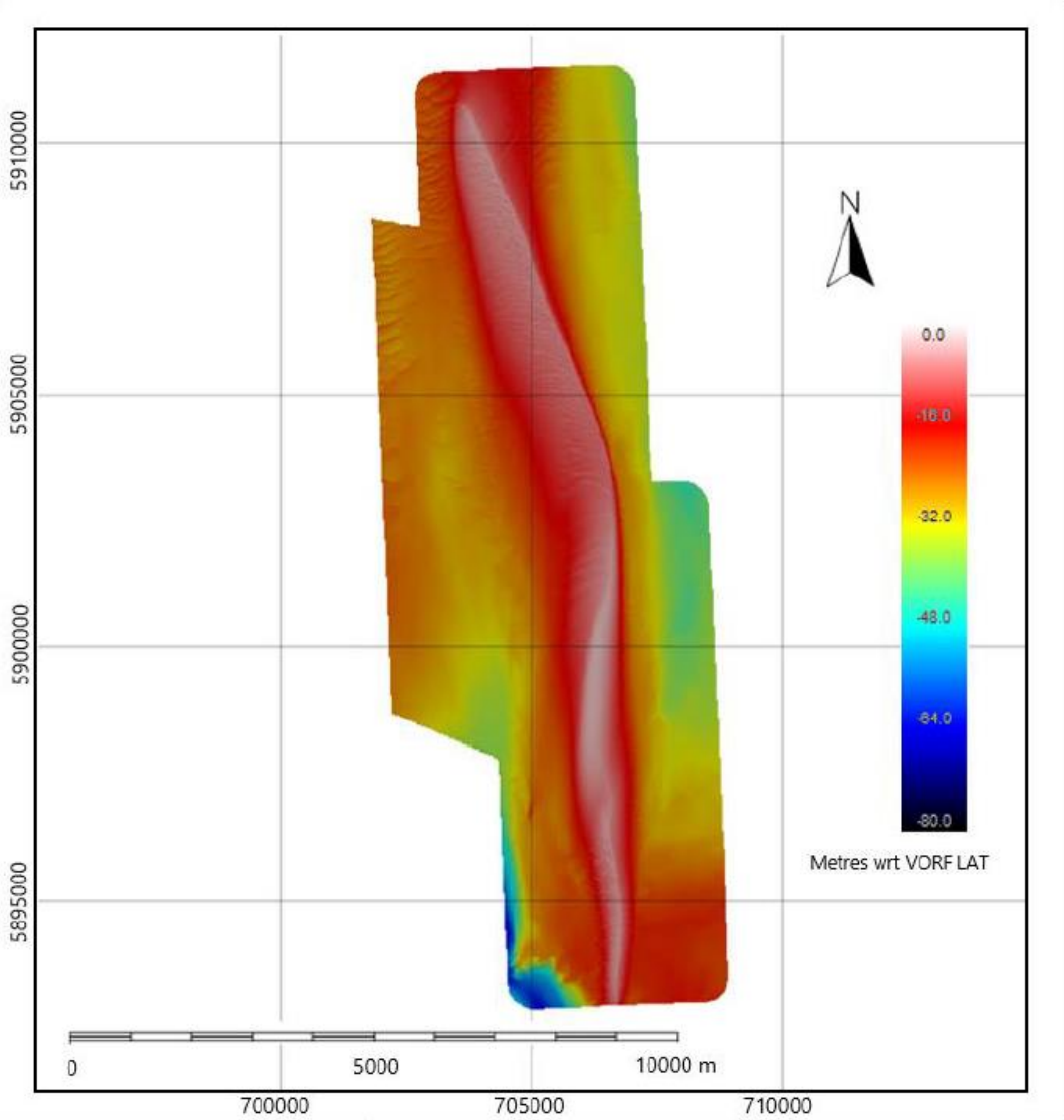


Figure 17 Detailed bathymetry within the array area (Fugro, 2021b)

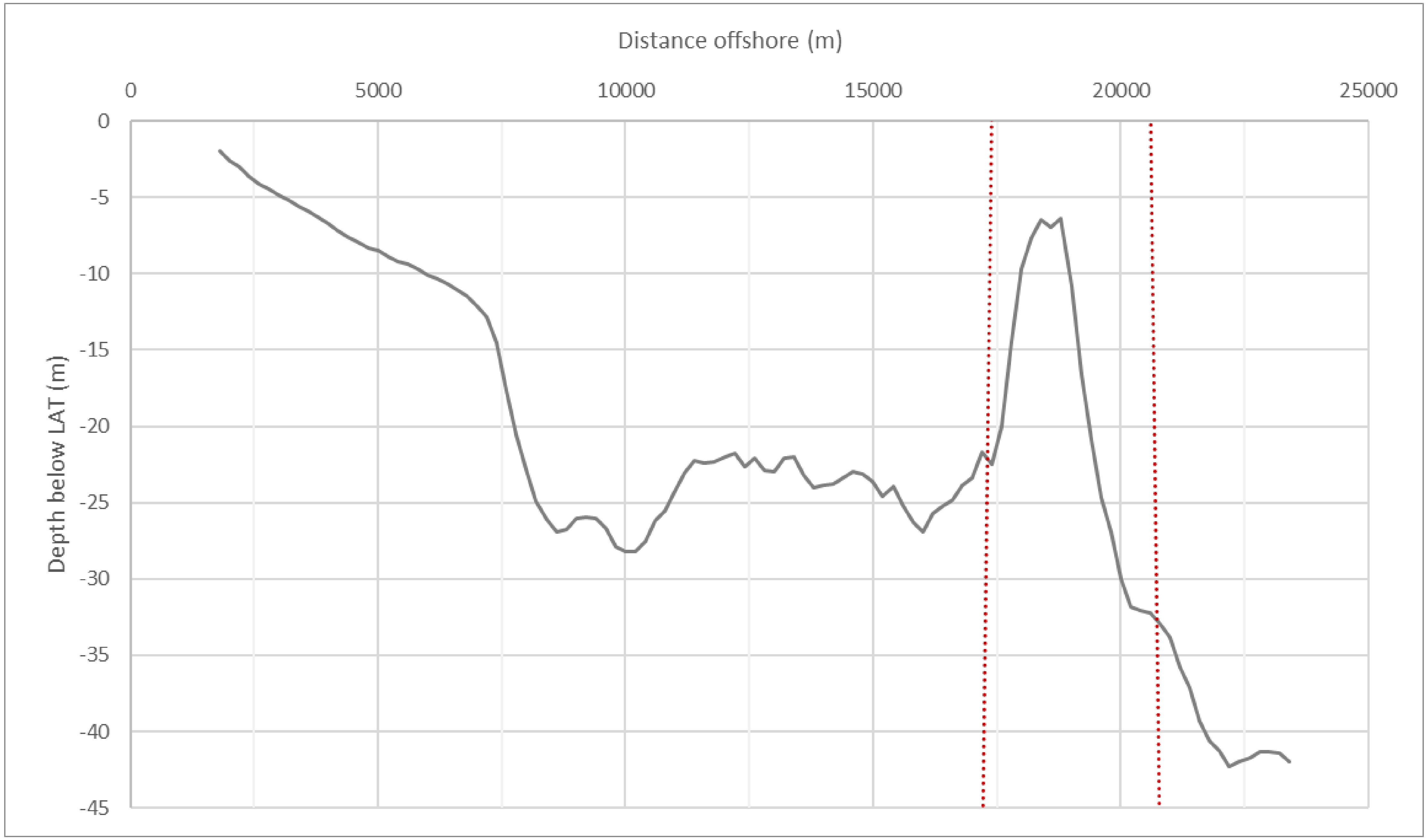


Figure 18 Transect of bathymetry within the proposed proposed site (Transect 1) (INFOMAR)

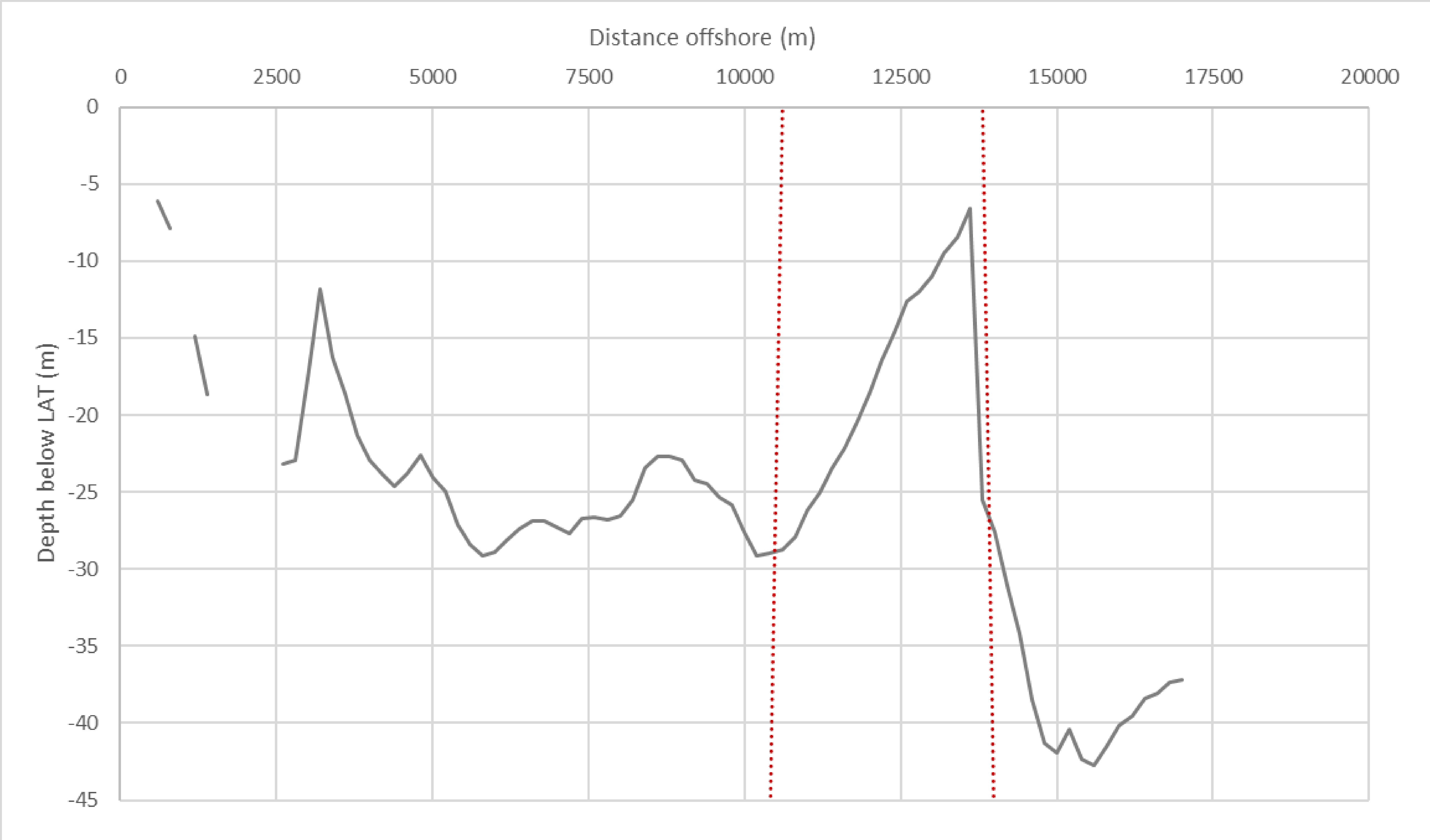


Figure 19 Transect of bathymetry within the proposed proposed site (Transect 2) (INFOMAR)

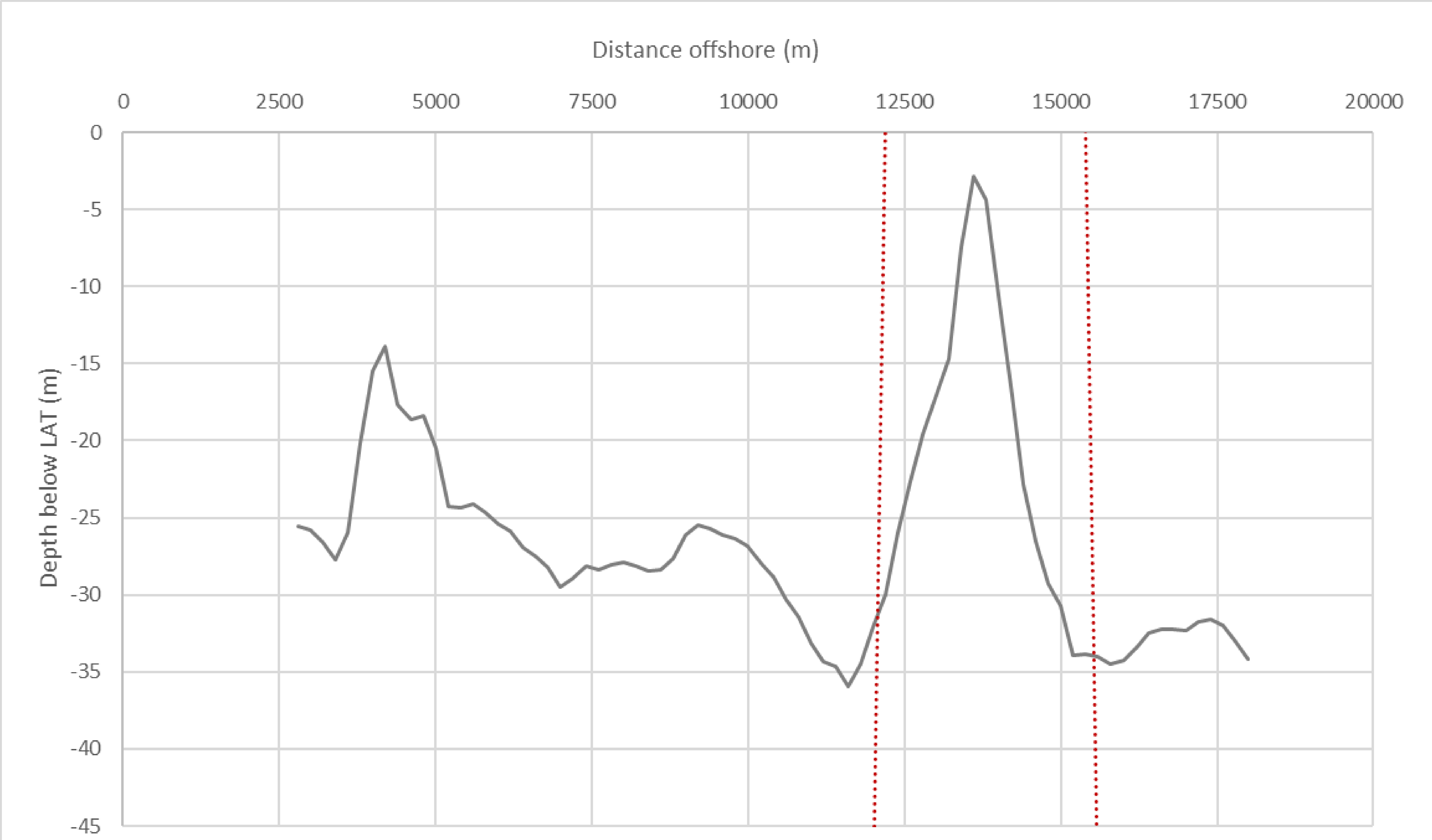


Figure 20 Transect of bathymetry within the proposed proposed site (bottom) (INFOMAR)

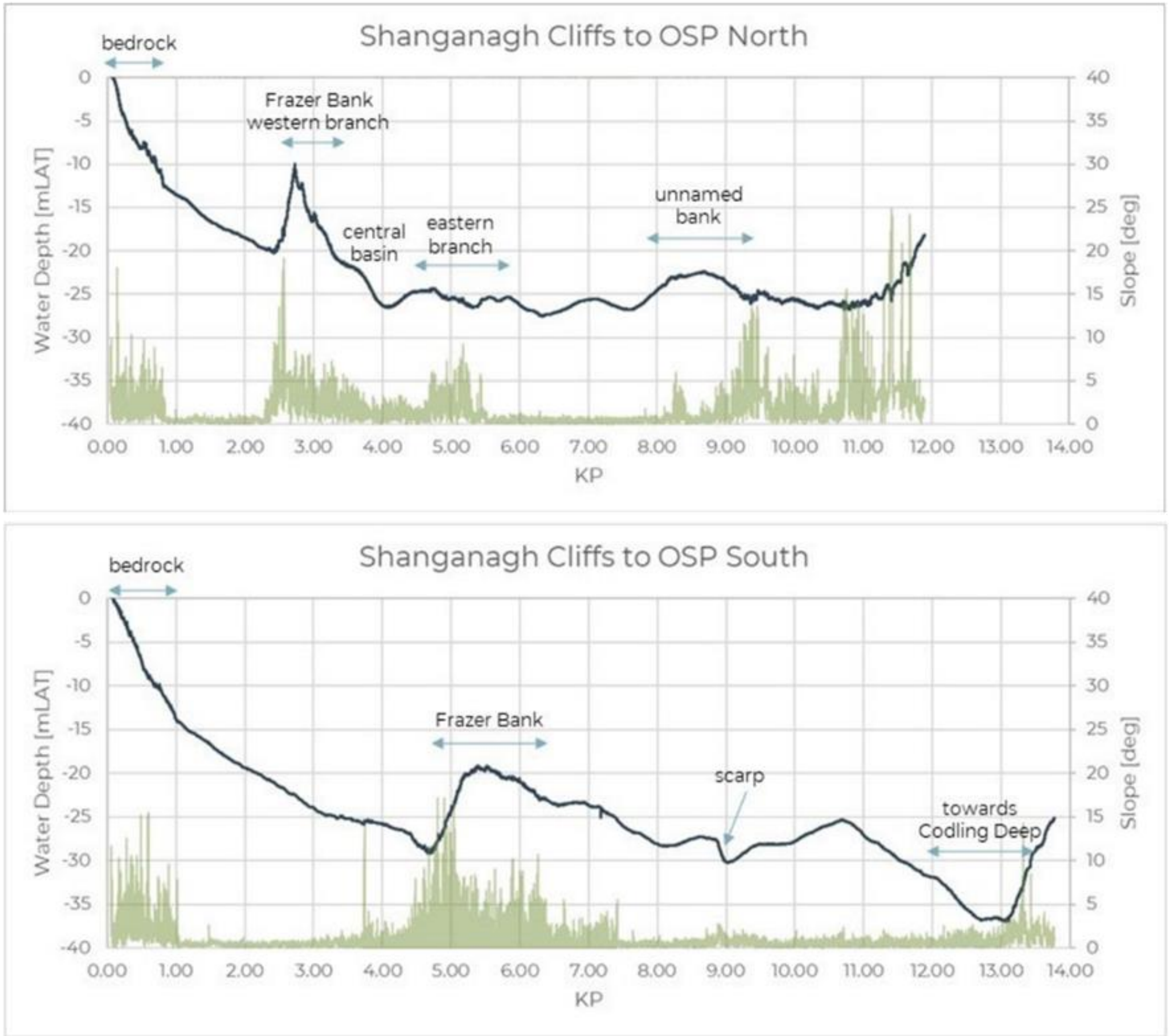


Figure 21 Transect of bathymetry along the offshore ECC routes (as shown on Figure 16, with KP referring to kilometre point along the respective routes)

3.5 Seabed geomorphology

3.5.1 The metocean regimes (as described in the preceding sections) control the sediment transport pathways and resultant seabed geomorphology. A net sand transport vector is induced in the direction of the residual tidal current (i.e. flood or ebb) where there is a sufficient difference in the current speed maxima (Harris *et al.*, 1995). The net directions and relative magnitudes of sand transport in the Irish Sea (Kenyon and Cooper, 2005) are presented in Figure 22 and have been computed from observations (analysis by M.J. Howarth in Johnson *et al.*, 1982).

3.5.2 The net sedimentary transport on the eastern coast of Ireland is presented in Figure 23, which is tidally dominated, with a divergence of direction near Wicklow county (south of Dublin) in St George's Channel (Kenyon and Cooper, 2005). The divergence in the net bedload transport vectors is referred to as a bed loading parting (see Figure 23) (Harris *et al.*, 1995). Bed load partings are centred around locations where both tidal current speed and bed shear stress[16] are a maximum. The area of maximum bed shear stress, for the bed load parting to the south of Wicklow County, is associated with the M2 tidal amphidromic point (see Figure 7). At the amphidromic point, the tidal elevation will be theoretically zero, but the horizontal tidal currents and bed shear stress will be at their maxima given its proximity to the coast.

3.5.3 Bed load partings are associated typically with a scour zone and a subsequent decrease of grain size with distance. Sediment is transported away from the zone of maximum bottom stress in a diffusive process over many tidal cycles and as such are winnowed[17] away and move down the transport gradient, eventually creating a scour zone.

3.5.4 Harris *et al.* (1995) defined the St Georges Channel bed load parting as an 'incipient' scour zone. An 'incipient' scour zone is defined as having eroded sediment occupying a significant proportion of the channel width. As the sand is winnowed away, and there is a reduction in bed shear stress along a transport pathway sand has the potential to accumulate (Dyer and Huntley, 1999); this accumulation is deposited in the form of a sand sheet and linear sandbank deposits (see Section 3.2) (Harris *et al.*, 1995) within the bedload convergence zones[18]. To maintain the stability of the sandbank) and become self-sustaining, localised processes of instabilities, such as waves and hydrodynamics, are then required to accumulate sediment (Dyer and Huntley, 1999).

[16] The sediment on the seabed is transported when it is exposed to large enough forces, or shear stresses, by the water movements. These movements can be caused by the current or by the wave orbital velocities or a combination of both.
[17] In sedimentology, winnowing is the natural removal of fine material from a coarser sediment by wind or flowing water.
[18] A bed load convergence is the opposite of a bed load parting in that they are zones of sediment accumulation rather than sediment being transported away.

3.5.5 In addition to sandbanks, sandwaves are present in areas where there is an abundance of sand in addition to sufficiently strong currents for its mobilisation (Belderson *et al*., 1982). Sandwaves migrate in the prevailing direction of the tidal currents. The speed at which they migrate seems to be inversely related to their size, with very small sandwaves migrating faster than larger sandwaves. Sandwaves are classified as highly mobile bedforms.

3.5.6 The array area lies in a region of the Irish Sea characterised by a series of coast-parallel north to south trending offshore sandbanks, approximately, 10 km offshore indicating an area of sedimentary accumulation. These sandbanks occur in a punctuated line along the east coast of Ireland, with breaks maintained by strong current activity and sediment movement. They are located in shallow water and in places rise to within a few metres of the sea surface. The sandbanks serve an important role in offering wave protection to the coast and controlling tidal flow in the region (Wheeler *et al.*, 2001). The overall bank structures are quasi-stable in nature, whereas surface sediments exist in dynamic equilibrium[19] with tidal and current conditions.

3.5.7 The array area is situated on two of these banks – the Kish and Bray Banks. (Wheeler *et al.* (2001) concluded that the Kish and Bray Banks are positioned as a result of an interaction between both wave and current regimes resulting in an equilibrium, although natural mobility may occur. This is supported by site-specific sediment mobility analysis, which indicated that the sandbanks are characterised by the presence of mobile bedforms in addition to lateral crest movement. The Kish and Bray Banks fit the classification of “Open Shelf linear banks” as defined by Kenyon and Cooper (2005). The Galloper and Greater Gabbard Offshore Wind Farms, within UK waters, are currently operational on sandbanks of the same classification, as well as the Arklow Bank Phase 1 Wind Park in Irish waters.

[19] A state of balance between continuing processes.

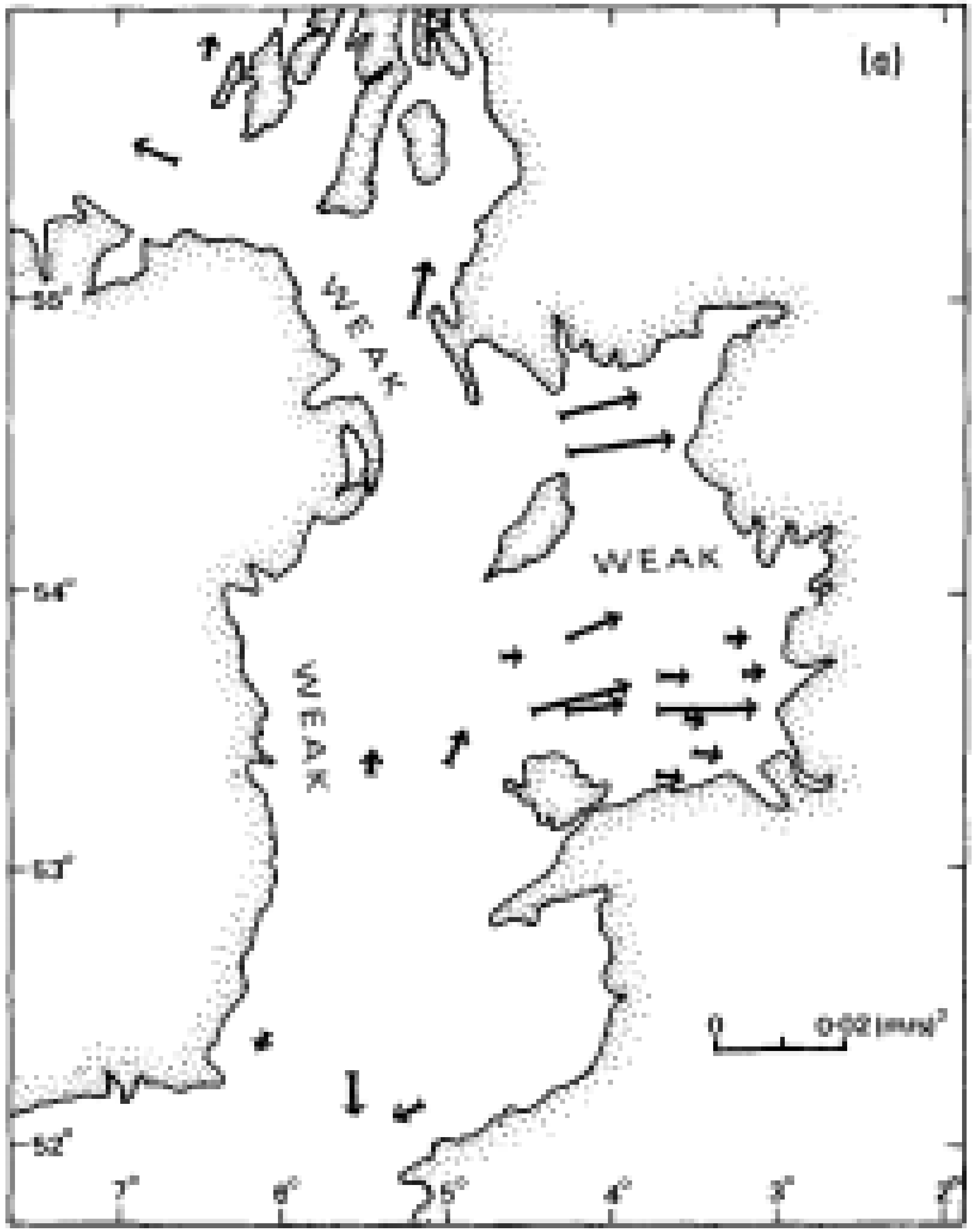


Figure 22 Net directions and relative magnitudes of sand transport in the Irish Sea (Kenyon and Cooper, 2005)

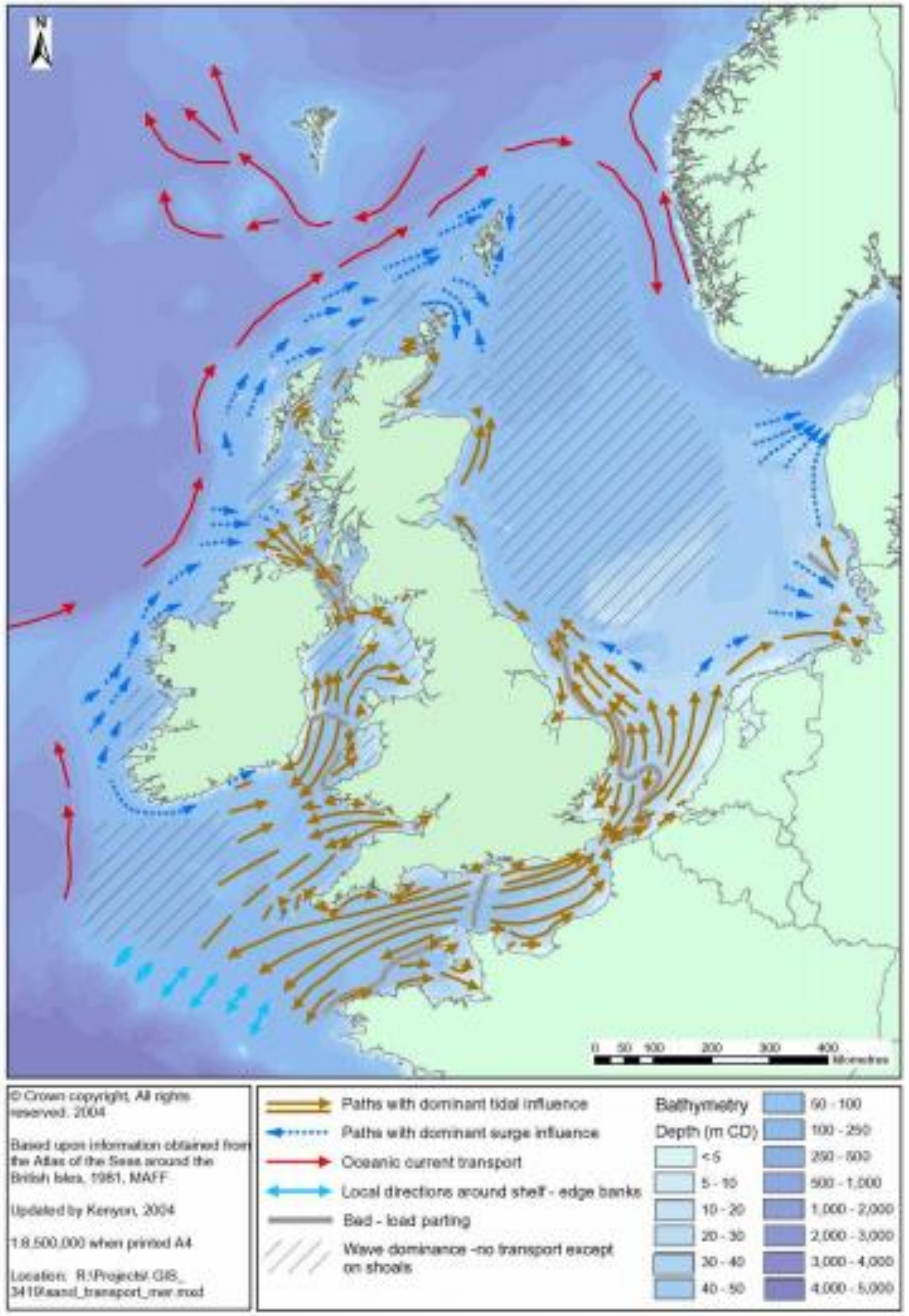


Figure 23 Sand transport paths around the British Isles, showing the dominance of different types of currents (Kenyon and Cooper, 2005)

Large scale bedforms

3.5.8 The Kish and Bray Banks form the central part of the proposed array area, with a lesser bank inshore known as Fraser Bank (see Figure 16 to Figure 20). The scientific literature indicates that near-shore Irish Sea sandbanks such as the Kish Bank and Bray Bank formed as moraines (immobile mounds of glacial debris) which are now overlain by mobile sand and gravel.

3.5.9 Historical evidence suggests that the banks have been present on charts since the 1500's, albeit with different names such as New Ground, South Ground(s), Middle Grounds(s) and North Ground(s). These early charts presented the banks as 'grounds' which are surrounded by 'shading' or 'broken water', this suggests that they were either sometimes, or always, above the water. Some of the 16th century charts depict these 'grounds' in the same way as islands, again suggesting that they were above the water. Sailing instructions from the 17th century indicate that the position of the Bray and Kish Banks were known (Stokes, 2019). A suite of historical charts are shown in Figure 22. Given their presence over such a long period of time, it is suggested that the Kish and Bray are long-term and quasi-stable features of the study area. Anecdotal evidence also suggests that the banks and areas of Dublin Bay dried out under extreme spring tides 'within living memory' (Stokes, 2019).

3.5.10 The banks are quasi-stable over time with their positions maintained due to the interaction between the local wave and current regimes (Wheeler *et al*., 2000). Their research defined five separate echo-facies[20] covering the area of the proposed development on the banks. These comprised of:

- Stippled Bank Crest Facies – This area occurs towards the north of the proposed development on the crest of the Kish Bank. It represents a transition from sandwave dominated sediments on the bank margins, to environments dominated by planar beds with scattered patches of more highly reflective sediments which were interpreted to represent more gravel rich deposits. The morphology of the sandwaves observed in this echo-facies was interpreted to indicate a northwardly transport direction of sediment over the bank;

- Bank-crest Facies – This echo facies occurs on the crest of the Bray Bank and is described as being similar in character to the previous unit but lacking the patches of increased reflectivity;

20 Sedimentary facies are bodies of sediment that are recognizably distinct from adjacent sediments that resulted from different depositional environments; facies being a distinct kind of sediment for that area or environment. Echo-facies are those sedimentary facies as detected by an echo-sounder or similar surveying device.

- Stippled Sandwave Facies – This unit occurs on the margins of the Kish Bank and represents areas dominated by sandwaves but also displaying areas of increased reflectivity interpreted to mean more gravel rich deposits;
- Sandwave Facies – This unit describes a highly mobile seafloor environment occurring on the margins of the bank complex. The facies are characterised by widespread sandwaves and other bedforms, with bedform development decreasing with distance from the bank complex. Again, bedform morphology implies a northerly net transport of sediment, with stronger tidal flows adjacent to the banks; and
- Stable Seabed Facies – The final facies are found at greater distances from the bank complex and represents regions where no bedforms were imaged. This unit is interpreted to represent a stable or non-mobile seafloor. Where no bedforms are imaged, small-scale ripples below the resolution of the sonar instrument may exist.

3.5.11 An analysis of the distribution of surface slopes over the proposed site indicated that slopes are steepest on the western face of the banks towards the north of the array area. Going south, the slope on the western face of the banks reduces while that on the eastern face becomes more prominent. Further south, the slope of the eastern face decreases while that of the western face increases, leading to a more symmetrical appearance. At the very south of the proposed site, the bank complex remains symmetrical, but the crest narrows substantially.

Figure 24 Historical charts of the Bray and Kish Banks (1595 (left), 1783, (middle) and 1805 (right)) (Journal of Research on Irish Maritime History)

3.5.12 Site-specific sediment mobility analysis has identified that the direction of net sediment transport and bedform migration on the open offshore seabed is predominantly and consistently towards the north. Bedforms on and around the Kish and Bray Banks are found to migrate in a clockwise direction due to tidal flow interaction with the body of the bank, with bedforms migrating to the north along the western flank, and to the south along the eastern flank. In addition, lateral migration rates of between 4 m/yr and 10 m/yr have been identified for the Kish and Bray Bank crests, with movement between 2010 and 2021 to the east along the northern section of Kish Bank and towards the west along the southern edge of Bray Bank (ABPmer, 2022). Fluctuations of the head and tail position have been observed in other similar sandbank systems, such as the Galloper and Greater Gabbard Banks, and it is considered likely that these crest migrations form part of fluctuations around a central quasi-equilibrium position, controlled by hydrodynamic-morphodynamic feedback loops as outlined in Creane *et al.* (2023).

3.5.13 The mobility of the surface sediments is likely to vary seasonally with greater mobility during the winter when storm events are more frequent. As indicated by Coughlan *et al.* (2021), although the tidal regime is the dominant process controlling sediment disturbance at these banks, wave action can have an important role in mobilising sediment. Sediment mobilisation frequency values based on τ_{cw}, the annual mean value for bed stress induced by both wave and current, exhibit moderate values of approximately 47% for the Kish and Bray Banks, indicating that the sediment thresholds for mobilisation by bed shear stress were exceeded for 47% of the modelled timeframe (Coughlan *et al.*, 2021). Further detail regarding the sandwaves present on the banks is provided in following sections.

3.5.14 As outlined in Creane *et al.* (2022), sandbank geometry can indicate regional-scale net tidal flow and net sediment transport pathways, while sediment waves associated with sandbanks indicated localised sediment transport regimes. The oblique alignment of a linear sandbank axis to the net tidal flow generates a flood and ebb dominance on either flank. On active sandbanks this is ultimately reflected in sediment wave asymmetry, where sediment lee slopes face in opposite directions on either side of the bank. Identification of symmetrical sediment waves at the end of sandbanks, in conjunction with progressive orientation change of sediment wave crests, led to the conclusion that circulation around and over the bank is what maintains the sandbank geometry (Kenyon and Cooper, 2005).

3.5.15 The presence of this circulatory flow pattern is supported by Horrillo-Caraballo *et al.* (2021), who identify residual gyre patterns around sandbanks in the Irish Sea by plotting the vorticity of the residual flow. Regions of positive vorticity (corresponding to anticlockwise, or cyclonic, circulation) coincide with the locations of sandbanks including the Kish and Bray Banks, while negative regions (corresponding to clockwise, anticyclonic circulations) coincide with the deeper channels either side (Horrillo-Caraballo *et al.*, 2021). This generally supports the interpretation of clockwise sediment transport around the banks (see Paragraph 3.5.12), although suggests that more localised transport processes along the bank may also occur.

3.5.16 These nearshore banks provide a degree of protection to the coastline, as they reduce the wave energy before the waves reach the shore. The Offshore ECC crosses through the Fraser Bank feature, a nearshore sandbank/ large sandwave (see Figure 16) approximately 10 to 20 mLAT, with superimposed sandwaves and megaripples (Fugro, 2021c). Peak spring current speeds around this feature generally range between 0.6 m/s to 0.8 m/s, with significant deposits of sandy mud and muddy sand identified within the sandbank feature and adjacent patches of associated sandwave bedforms. There is evidence of mobile bedform features over and around the sandbank, with typical bedform heights of around 3 m (although some reach up to 5 m). Sandwave asymmetry indicates migration generally towards the north, with average migration rates based on bathymetric comparison between 2010 and 2021 indicated as between 2 m/yr and 4 m/yr (ABPmer, 2022).

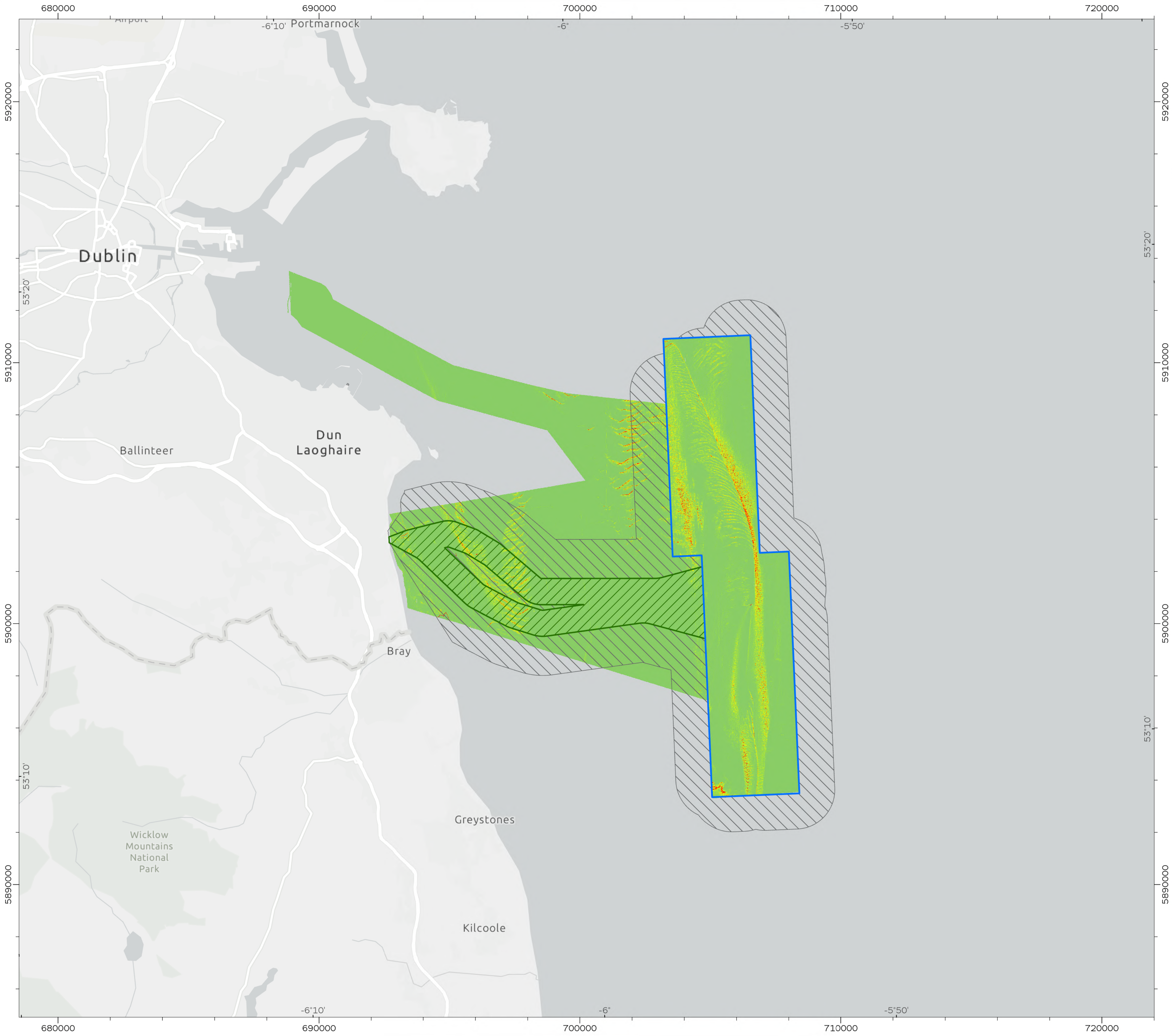
3.5.17 A detailed assessment of the seabed geomorphology and associated benthic habitats was undertaken as part of the project specific surveys (Fugro, 2020; Fugro, 2021b). Further detail on the benthic habitats is provided in Volume 3, Chapter 3: Benthic and Intertidal Ecology (hereafter referred to as the Benthic Ecology Chapter). These surveys provide evidence to show that the Kish and Bray Banks demonstrate features which are consistent with the Annex I habitat 'Sandbanks which are slightly covered by sea water all the time'. This is due to the following observed characteristics:

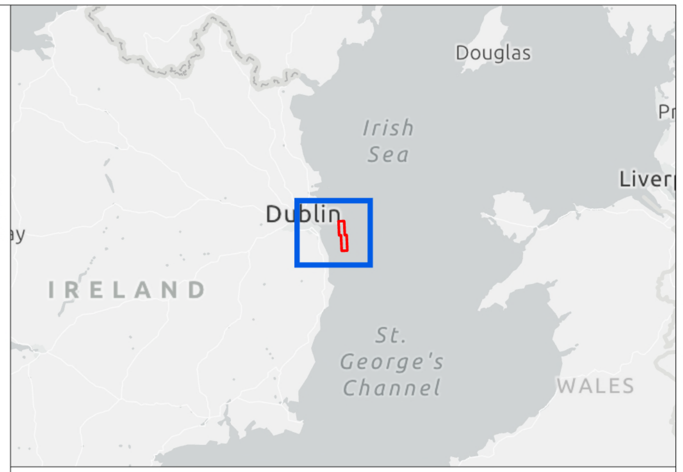
- The feature is permanently submerged;
- Water depths are seldom greater than 20 m; and
- Seabed sediments are predominately composed of sand.

Small scale bedforms

3.5.18 Within this section, small scale bedforms are used to refer to seabed features classified as megaripples and sandwaves. Sandwaves[21] (sometimes known as sediment waves) were identified visually and through the analysis of side-scan sonar data. This analysis indicated that surficial sediments on the banks are actively mobile and migrating northwards. Sediment mapping, based on both sampling and sonar techniques of the INFOMAR data, indicate that the banks are composed of an extensive thickness of sand to gravel sized material. Sandwaves were identified as areas of high slope (15 to 35° approximately) where they constitute the steep crests of the individual waves. The percentage slope rise is presented for the proposed development in Figure 25.

21 A large, ridgelike primary structure resembling a water wave on the upper surface of a sedimentary bed that is formed by water currents.





Array Area
Temporary Occupation Area
Export Cable Corridor
Slope (%)
High : 66
Low : 0

DRAWING STATUS

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Data Source: INFOMAR, analysis by GDG

PROJECT TITLE

Dublin Array

DRAWING TITLE

Percentage Rise of Slope in the Proposed Development Site

DRAWING NUMBER: **25**

PAGE NUMBER: **1 of 1**

VER	DATE	REMARKS	DRAW	CHEK	APRD
01	2024-05-24	For Issue	GB	BB	SS

0 1.5 3 4.5 6 km
0 0.8 1.5 2.3 3 nm

N GRID NORTH

SCALE	1:150,000	PLOT SIZE	A3
DATUM	WGS 1984	VERTICAL REF	LAT
PRJ	WGS 1984 UTM Zone 29N		

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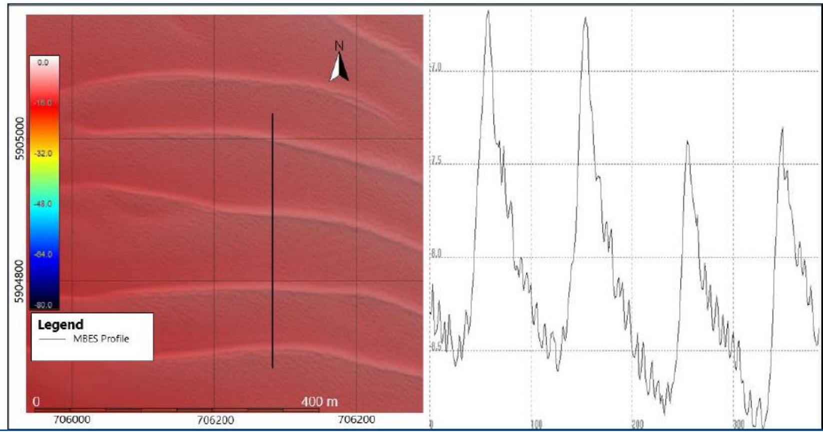
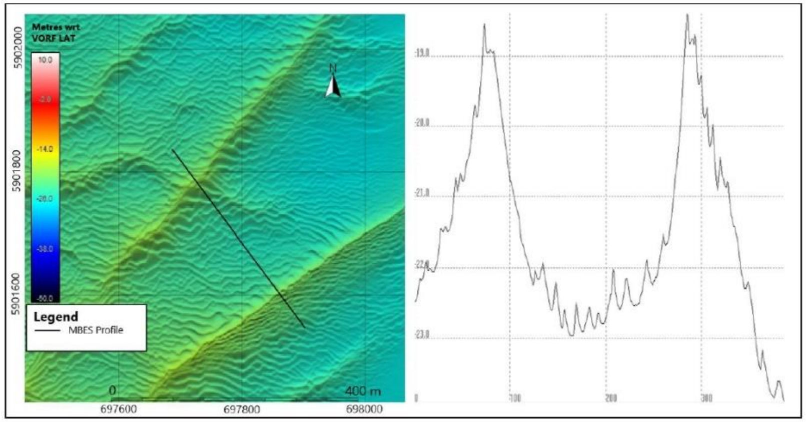
3.5.19 The identified sandwaves and megaripples, as presented in Figure 26, are present as both standalone features and as part of the bank structures within the proposed development site. The sandwaves vary in size and orientation, and given the hydrodynamics of the area, are considered likely to be highly mobile. The project specific survey provided further detail of the seabed features within the array area and Offshore ECC, as presented in Figure 26. The seabed mobility is also supported by evidence of scour around the wrecks identified in the geophysical survey (Fugro, 2021c). Further detail on the offshore archaeology is provided in Volume 3, Chapter 13: Marine Archaeology and Onshore Cultural Heritage (Archaeology and Monuments). More detailed evidence of local flow conditions can be interpreted through reference to the geological bedforms observed during the geophysical surveys in the study area, see paragraph 3.6.1 *et seq*.

3.5.20 In addition to these small scale features identified within the array area (Figure 26), sandwaves and megaripples have also been observed along the Offshore ECC, particularly over the northeast side and along the Fraser Bank (Figure 26; Fugro, 2021c).

Table 4 Details of seabed morphological features within the array area and Offshore ECC (Fugro, 2021b; 2021c)

Megaripple	Sandwave	Example
Array area		
▪ Height: 0.3 – 2 m ▪ Wavelength: 0.3 – 30 m	▪ Height: 2 – 6 m ▪ Wavelength: 15 – 300 m	
Offshore ECC		
▪ Height: 0.1 – 1.5 m ▪ Wavelength: 1 – 25 m	▪ Height: 1 – 7 m ▪ Wavelength: 50 – 250 m	

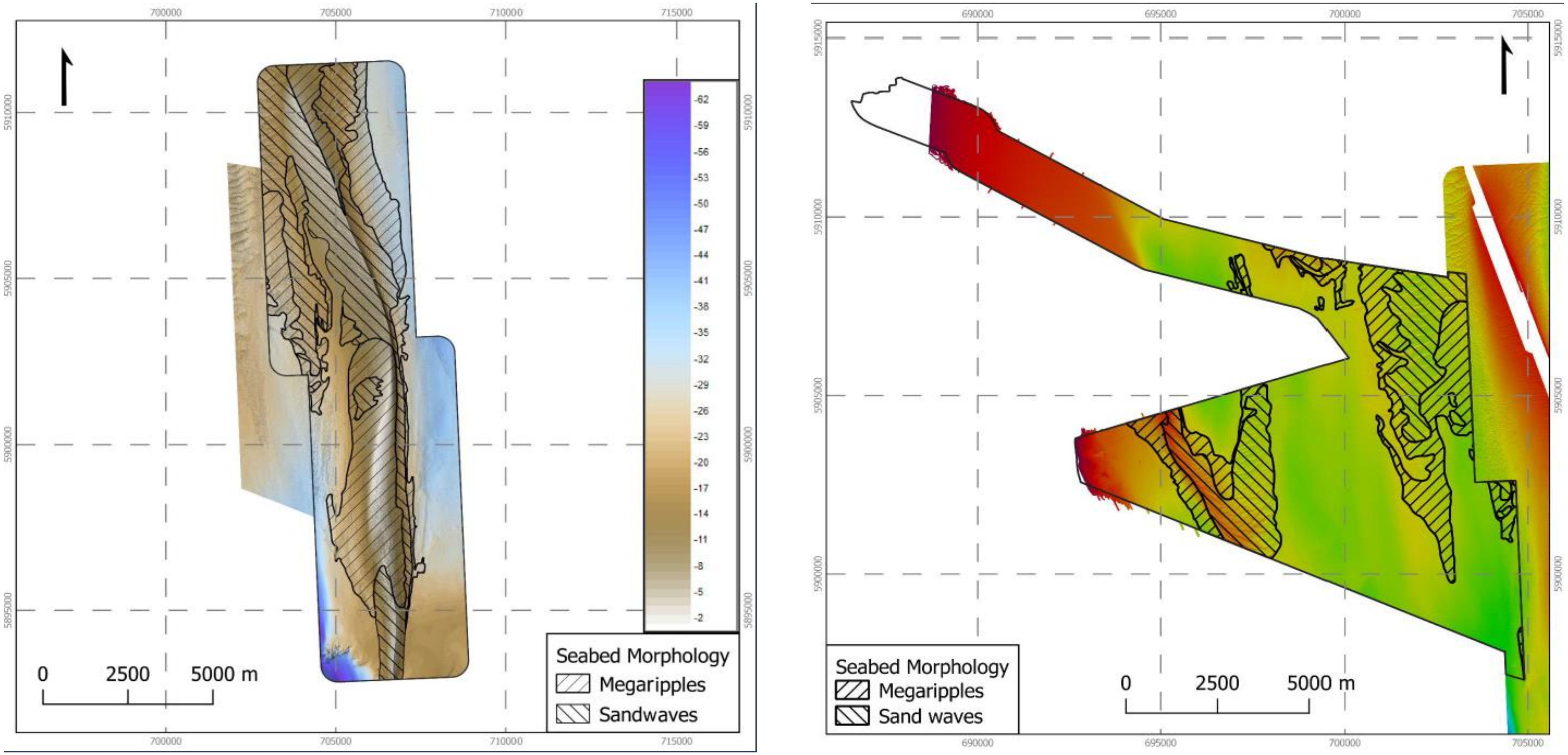


Figure 26 Seabed morphological features identified within the study area (Fugro, 2021c)).

3.6 Seabed sediments

Surface sediments

3.6.1 The regional seabed sediment map (British Geological Survey and Geological Survey of Ireland, 1990) depicts the survey area as covered by 'sand' with a tongue of 'slightly gravelly sand' extending up the western side of the Kish Bank. West of the Bray Bank, these facies form a continuous coverage towards the coast with sediments in a deep scour adjacent to the bank characterised by 'gravelly sand' and 'sandy gravel' (Wheeler *et al.*, 2000). This deep scour was formed due to Weichselian ice margin processes (Wingfield, 1990) or, more specifically, by glacial melt-water channel activity (Warren and Keary, 1989). A small area of gravelly sand was also identified southeast of the Fraser Bank (see Figure 27).

3.6.2 The proposed array area is dominated by sediment classed as sand (Figure 27). The backscatter data from INFOMAR suggests there are finer sand sediments on the crest of the bank and coarser sand on the flanks and to the south of the banks. Sediment mapping, based on both sampling and sonar techniques indicate that the upper parts of the banks are composed of extensive thicknesses of sand-to-gravel sized material, with coarser gravel material located towards the crest of the banks and evidence of sediment fining towards the north of the bank.

3.6.3 Project specific surveys have shown that the seabed sediments are homogeneous (Fugro, 2020), with Particle Size Distribution (PSD) analysis indicating a predominately sandy sediment (Fugro, 2021a; 2021b; 2021c). Specifically, the sediment samples are classified as gravelly sand, sand and muddy sand, representing 43%, 43% and 14% of the 28 samples collected (Fugro, 2021a). The finer sediments are observed along the, proposed, northern cable route and to the seaward extent of Fraser Bank. As shown in Figure 27, there is generally good agreement between the regional sediment data (INFOMAR), and site-specific grab samples collected. Therefore, the regional data is considered to be representative and appropriate for the purposes of EIA within the proposed development site.

3.6.4 The Offshore ECC has the potential for bedrock exposure close to the coast, progressing to sandy mud/ muddy sand and mixed sediments further offshore. The project specific geophysical survey identified the presence of bedrock at the seabed surface, which also had an exposed pipeline present (Fugro, 2021c). In 2017, grab samples from the offshore ECC were undertaken to characterise the sediment types within the landfall zone of the proposed development. These grab samples (in addition to the grab sample data available through INFOMAR) have been used to validate the nearshore regional sediment data (INFOMAR). As shown in Figure 28, there is reasonable agreement between the INFOMAR sediment type data and the grab samples (of all surveys in the study area).

3.6.5 Project specific intertidal surveys at the (Shanganagh) landfall location included PSA for six stations, ranging from the upper to lower shore extents (Aquafact, 2021). Sand was the predominant surficial sediment present, with samples classified as sand, sandy gravel or slightly gravelly sand. Fines represented less than 0.2% at all stations.

Sediment pathways

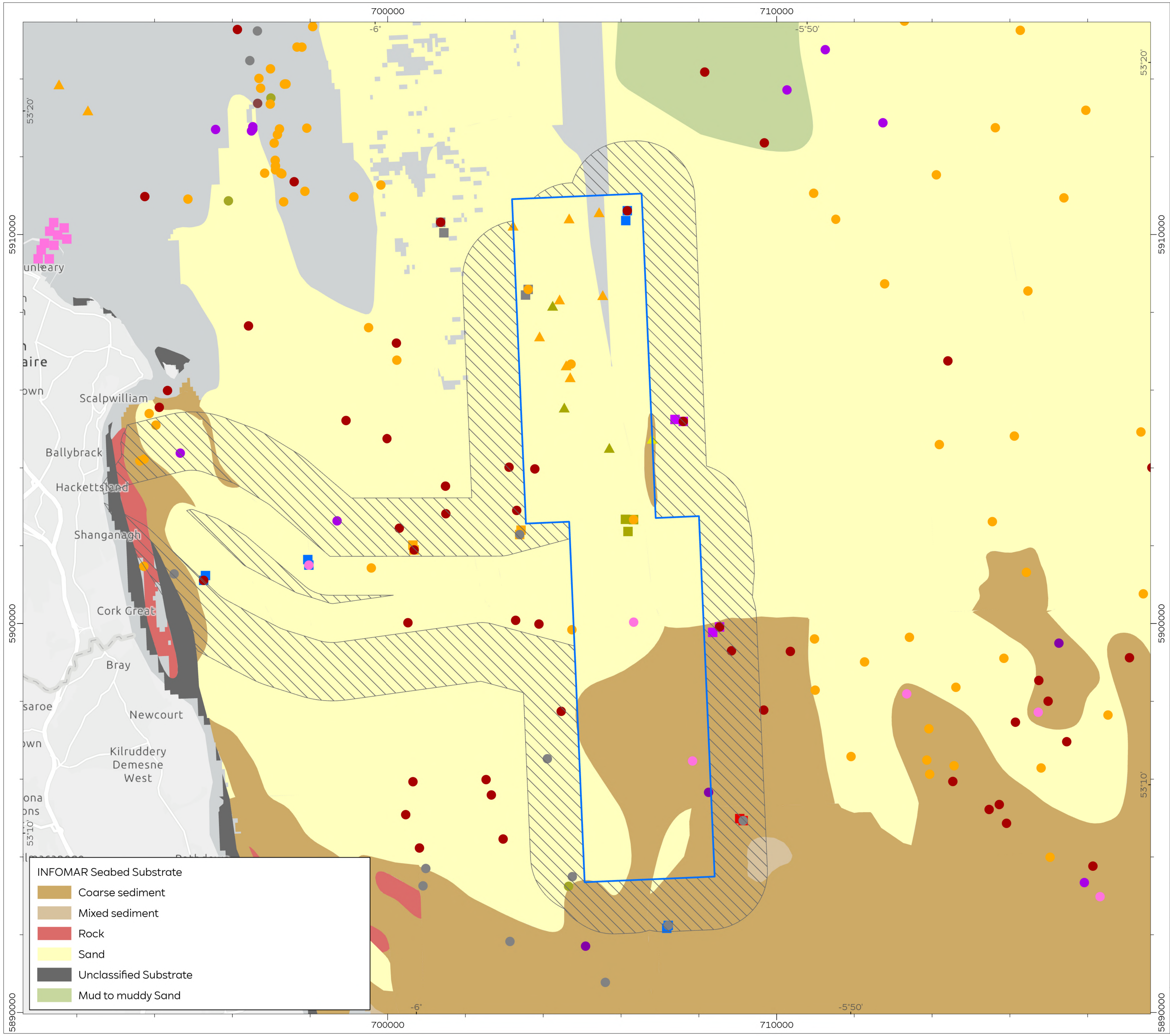
3.6.6 Tide-induced bed shear stress has been shown to be the dominant physical process driving seabed mobility in the south-western Irish Sea, with wave-action enhancing mobility in relatively shallow areas such as the southern banks (Coughlan *et al.*, 2021; Creane *et al.*, 2022). Net sedimentary transport is characterised by the presence of a bed load parting in St George's Channel, where tidal current speeds and bed shear stress are at a maximum, as outlined in Paragraph 3.5.2 and shown in Figure 23. In the study area, eroded sediments generally move alongshore following dynamic processes of erosion and deposition, controlled by sediment supply and waves (Caloca-Casado, 2018). Overall net sediment transport characteristics reveal a clockwise circulation along the Bray and Kish Banks with a northward trending residual flow on the west side and southwards trending residual flow on the east (ABPmer, 2022). Such residual flow patterns maintain the sandbanks integrity by retaining sediment within the circulation. Further details of sediment transport processes are provided in Paragraph 3.5.12 *et seq*.

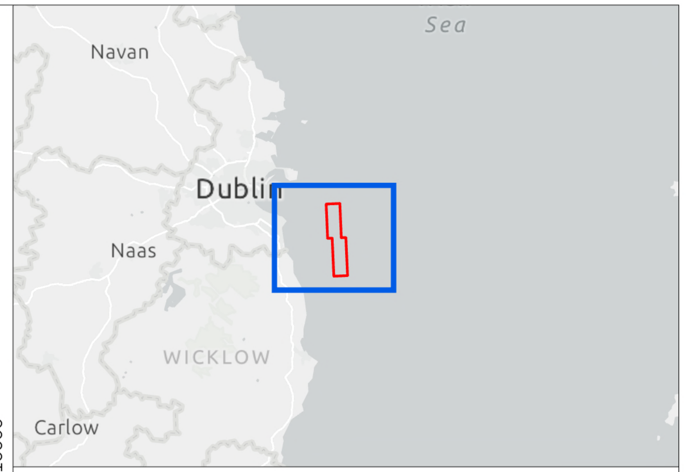
Suspended sediments

Suspended Particulate Matter

3.6.7 Spatially gridded, annual average of non-algal Suspended Particulate Matter (SPM) across the study area is presented in Figure 29 (Cefas, 2016). These data are based on information collected by satellite and the derived Ifremer OC5 algorithm (Gohin *et al.*, 2011). The annual average surface SPM across the array area is approximately 5 mg/l. There is a general trend of decreasing SPM concentrations with distance offshore, with the highest concentrations recorded in the study area observed in Dublin Port (see Figure 29 and Figure 32[22]). This data indicates that the highest monthly average concentrations, throughout the year, for the study area occur in December (see Figure 31 Monthly average Suspended Particulate Matter (SPM) in array area (Cefas, 2016) and Figure 30).

22 Note the transects presented in Figure 31 Monthly average Suspended Particulate Matter (SPM) in array area (Cefas, 2016) and Figure 30 are the same as those presented in Figure 16.





Array Area
Temporary Occupation Area
Gravelly muddy sand
Gravelly sand
Slightly gravelly sand
Muddy sand
Muddy sandy gravel
Sand
Sandy gravel
Sandy mud
Fine sand
Medium sand
Very fine sand
Fine Sands
Circalittoral muddy sand or slightly mixed sediment
Circalittoral fine sand
Circalittoral mixed sediment
Circalittoral muddy sand
Infralittoral coarse sediment
Infralittoral fine sand
Sublittoral mussel bed (on sublittoral sediment)

DRAWING STATUS

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Data Source: INFOMAR - Seabed Substrate

PROJECT TITLE

Dublin Array

DRAWING TITLE

Sediment Classification of the Array Area

DRAWING NUMBER: 27

PAGE NUMBER: 1 of 1

VER	DATE	REMARKS	DRAW	CHEK	APRD
01	2024-05-24	For Issue	GB	BB	SS

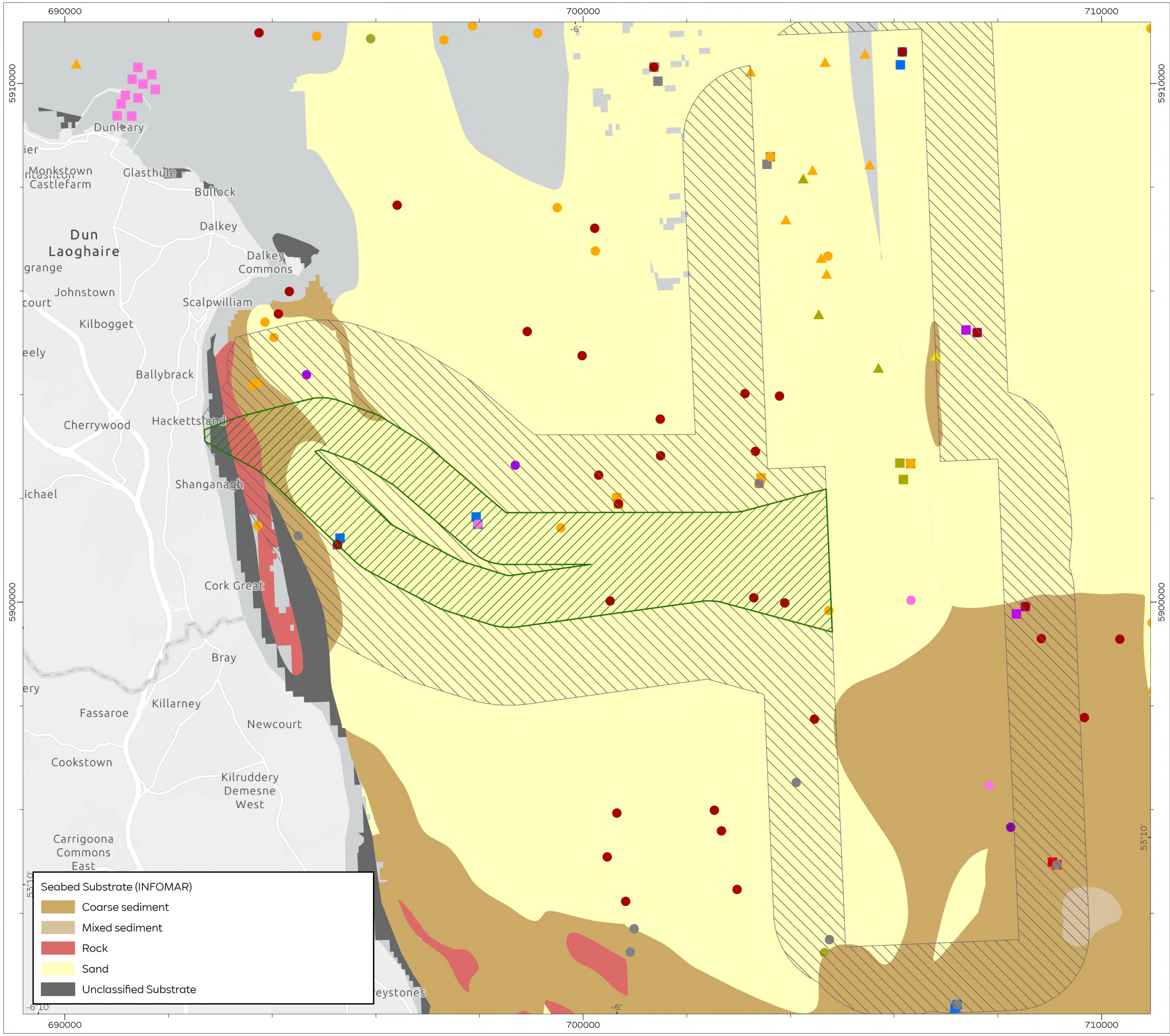
0 1 2 3 4 km
0 0.5 1 1.5 2 nm

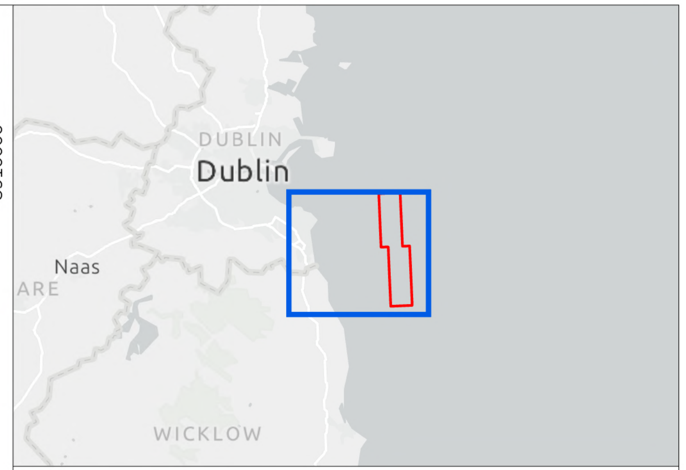
N
GRID NORTH

SCALE	1:100,000	PLOT SIZE	A3
DATUM	WGS 1984	VERTICAL REF	LAT
PRJ	WGS 1984 UTM Zone 29N		

GoBe APEM Group

Dublin Array Generation for generations
Kish Offshore Wind Limited - Bray Offshore Wind Limited





Temporary Occupation Area
Export Cable Corridor
Gravelly muddy sand
Gravelly sand
Slightly gravelly sand
Muddy sand
Muddy sandy gravel
Sand
Sandy gravel
Fine sand
Medium sand
Very fine sand
Fine Sands
Circalittoral muddy sand or slightly mixed sediment
Circalittoral fine sand
Circalittoral mixed sediment
Circalittoral muddy sand
Infralittoral coarse sediment
Infralittoral fine sand
Sublittoral mussel bed (on sublittoral sediment)

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Data Source: INFOMAR - Seabed Substrate

PROJECT TITLE

Dublin Array

DRAWING TITLE

Sediment Classification of the Offshore Export Cable Corridor

DRAWING NUMBER: 28

PAGE NUMBER: 1 of 1

VER	DATE	REMARKS	DRAW	CHEK	APRD
01	2024-05-24	For Issue	GB	BB	SS

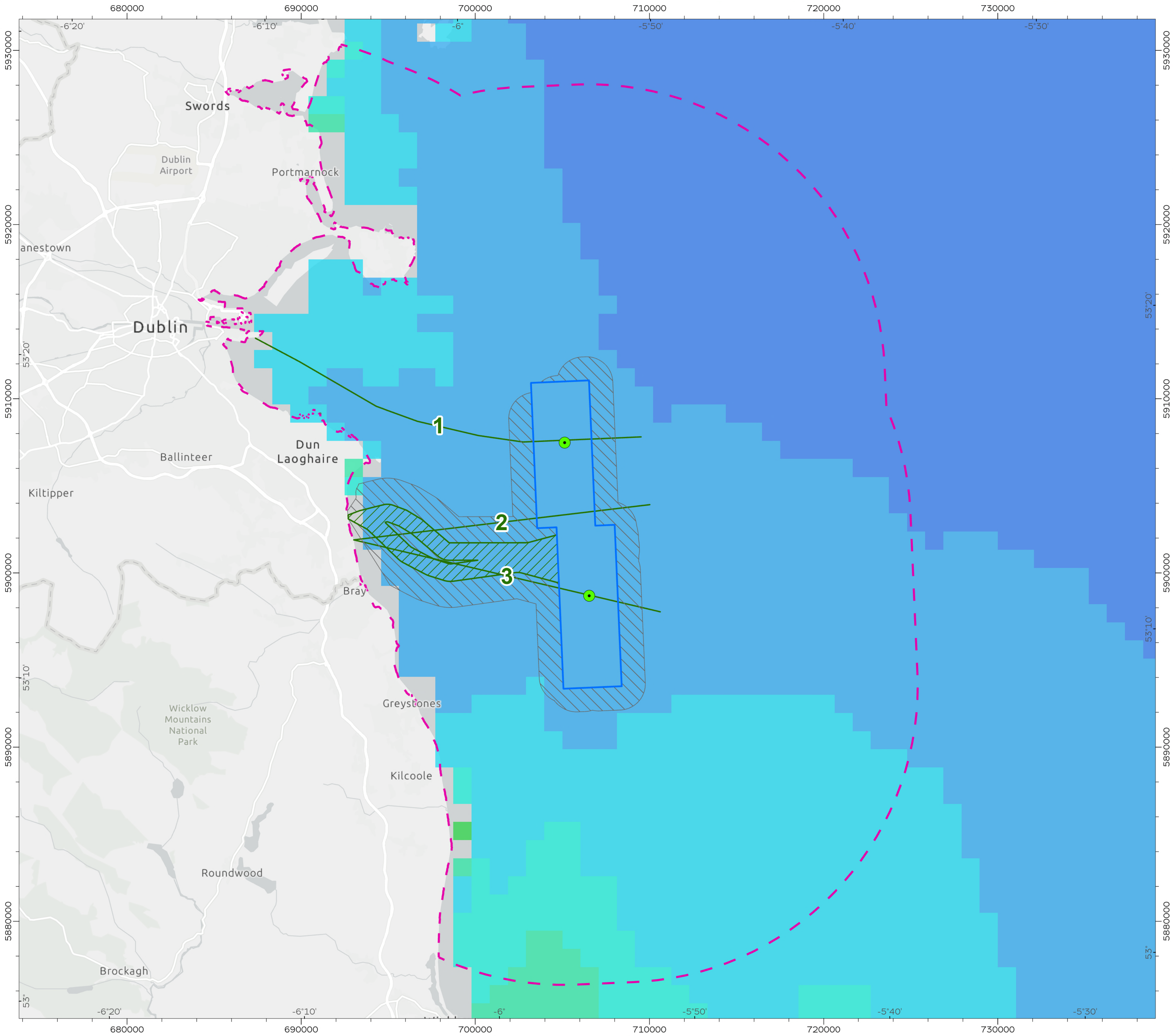
0 0.7 1.4 2.1 2.8 km
0 0.3 0.7 1 1.4 nm

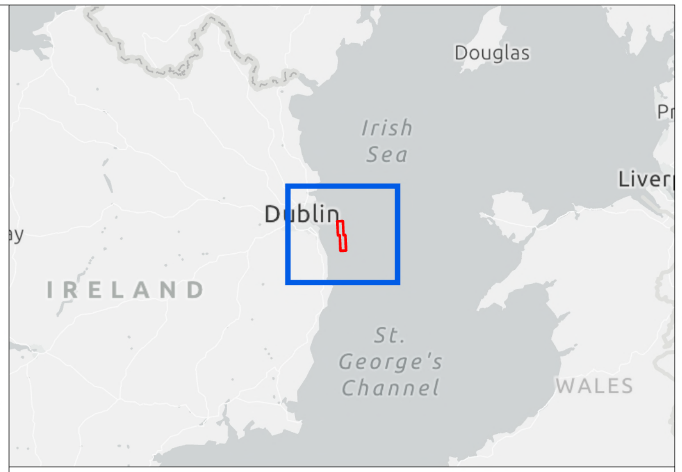
N
GRID NORTH

SCALE	1:75,000	PLOT SIZE	A3
DATUM	WGS 1984	VERTICAL REF	LAT
PRJ	WGS 1984 UTM Zone 29N		

GoBe
APEM Group

Dublin Array
Generation for generations
Kish Offshore Wind Limited - Bray Offshore Wind Limited





Array Area
Temporary Occupation Area
Export Cable Corridor
Physical Processes Study Area (17km Buffer)
Suspended Particular Matter Transects
Suspended Particular Matter Points

Suspended Particular Matter - Annual Mean (1998-2015) (CEFAS)

- 0.085 - 0.97
- 0.97 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- >16

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Data Source: Cefas; DOI: http://doi.org/10.14466/CefasDataHub.31

PROJECT TITLE

Dublin Array

DRAWING TITLE

Geographical Overview of Suspended Particulate Matter - Annual Mean (1998 - 2015)

DRAWING NUMBER: 29

PAGE NUMBER: 1 of 1

VER	DATE	REMARKS	DRAW	CHEK	APRD
01	2024-05-24	For Issue	GB	BB	SS

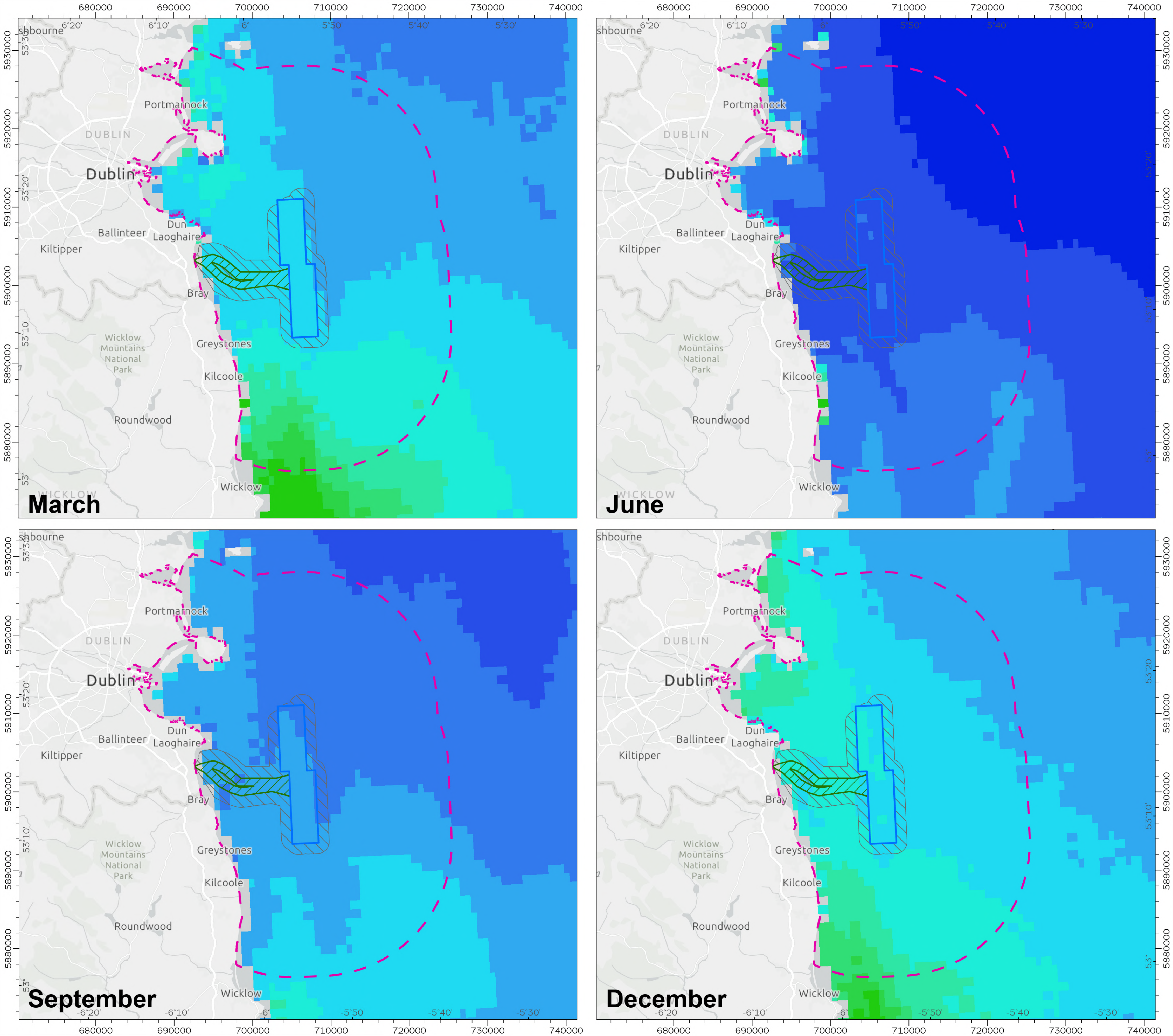
0 2 4 6 8 km
0 1 2 3 4 nm

N
GRID NORTH

SCALE	1:225,000	PLOT SIZE	A3
DATUM	WGS 1984	VERTICAL REF	LAT
PRJ	WGS 1984 UTM Zone 29N		

GoBe
APEM Group

Dublin Array
Generation for generations
Kish Offshore Wind Limited - Bray Offshore Wind Limited



Array Area
Temporary Occupation Area
Export Cable Corridor
Physical Processes Study Area (17km Buffer)

Suspended Particulate Matter - Monthly Mean (1998-2015) (CEFAS)

- 0.085 - 0.97
- 0.97 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- >16

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Data Source: Cefas; DOI: http://doi.org/10.14466/CefasDataHub.31

PROJECT TITLE

Dublin Array

DRAWING TITLE

Geographical Overview of Suspended Particulate Matter - Monthly Means (1998 - 2015)

DRAWING NUMBER: 30 | PAGE NUMBER: 1 of 1

VER	DATE	REMARKS	DRAW	CHEK	APRD
01	2024-05-24	For Issue	GB	BB	SS

0 5 10 15 20 km
0 2.5 5 7.5 10 nm

N GRID NORTH

SCALE	1:500,000	PLOT SIZE	A3
DATUM	WGS 1984	VERTICAL REF	LAT
PRJ	WGS 1984 UTM Zone 29N		

GoBe APEM Group

Dublin Array Generation for generations
Kish Offshore Wind Limited - Bray Offshore Wind Limited

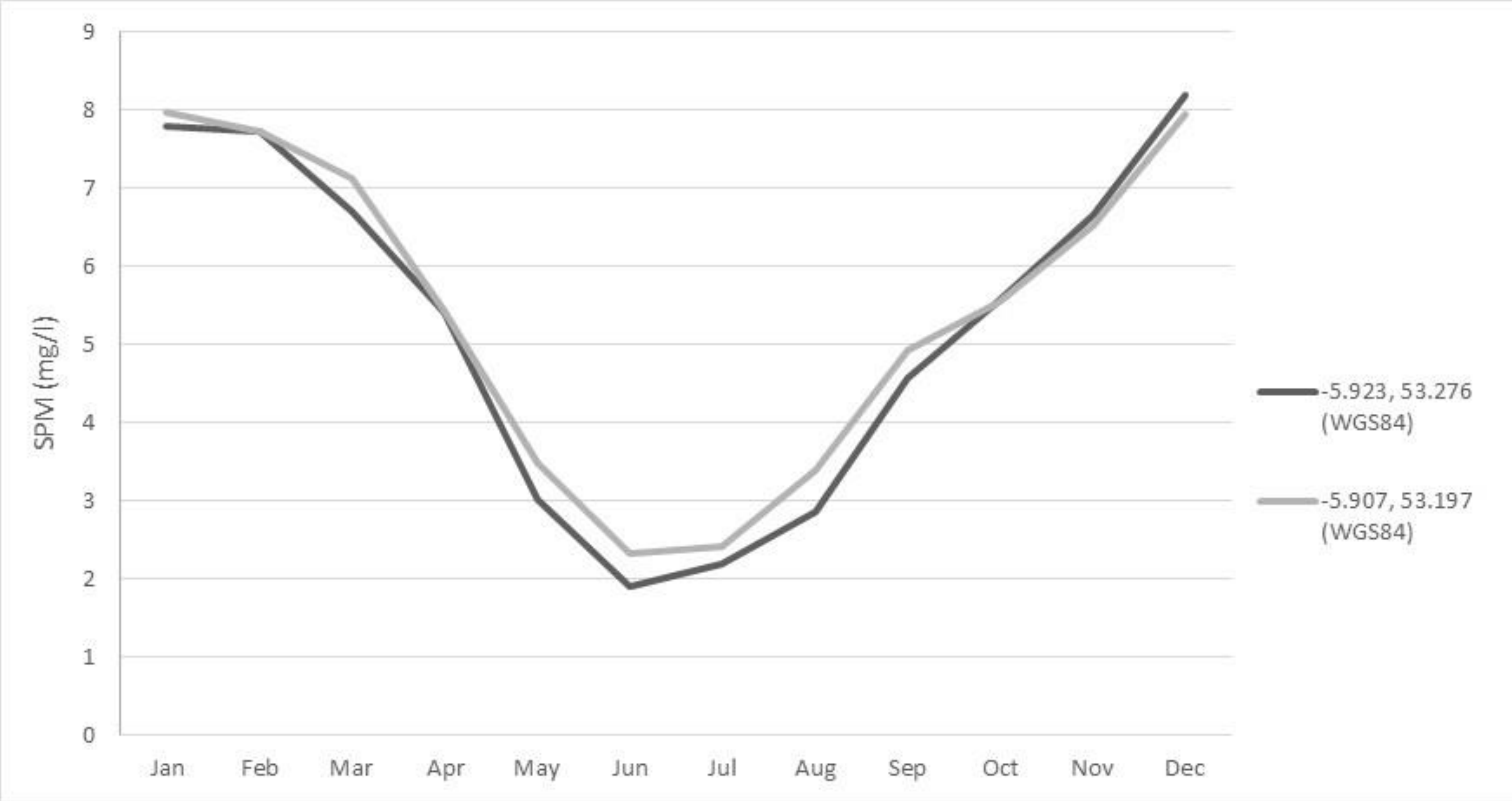


Figure 31 Monthly average Suspended Particulate Matter (SPM) in array area (Cefas, 2016)

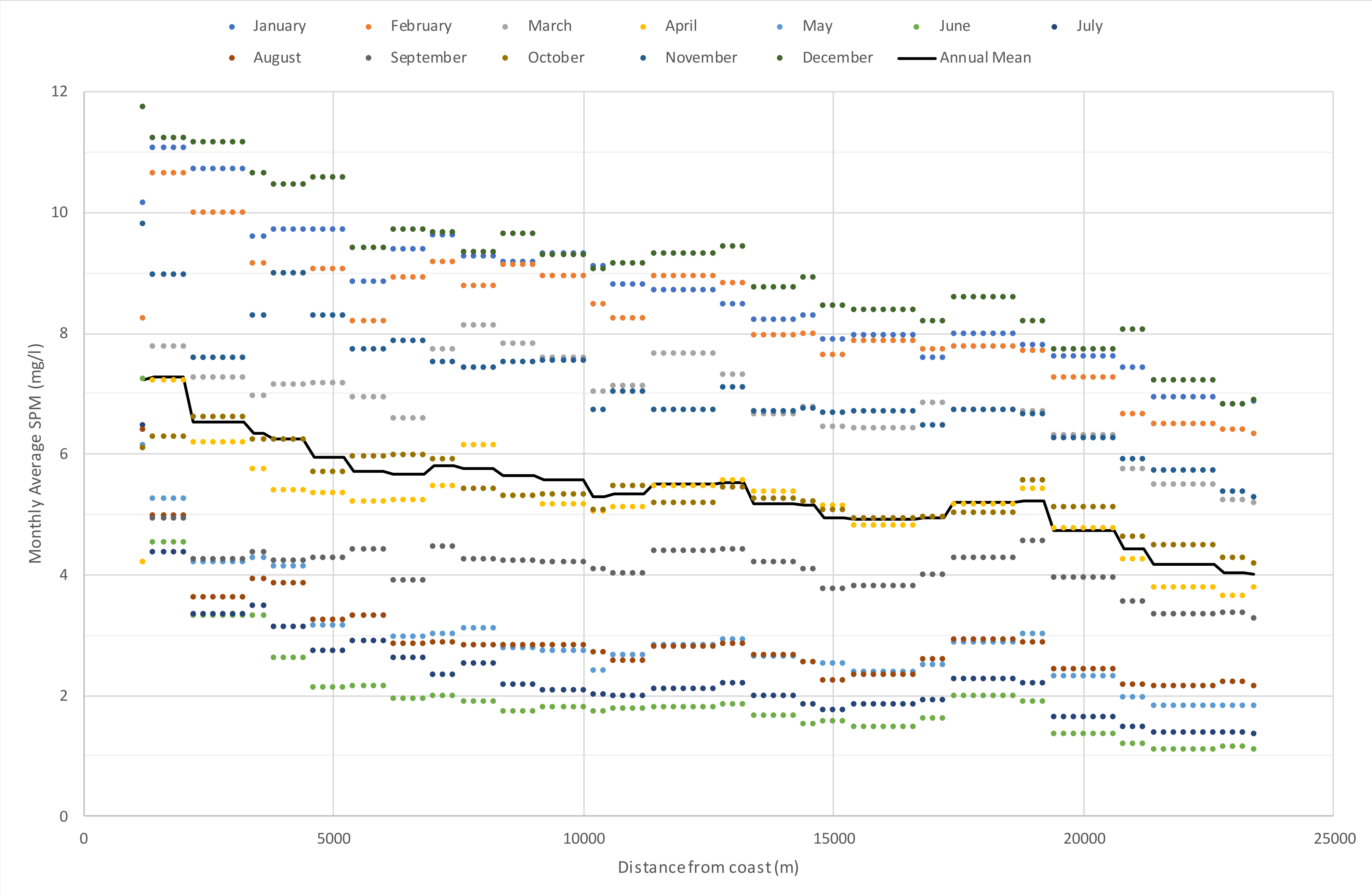


Figure 32 Average monthly SPM along northerly transect (Cefas, 2016)

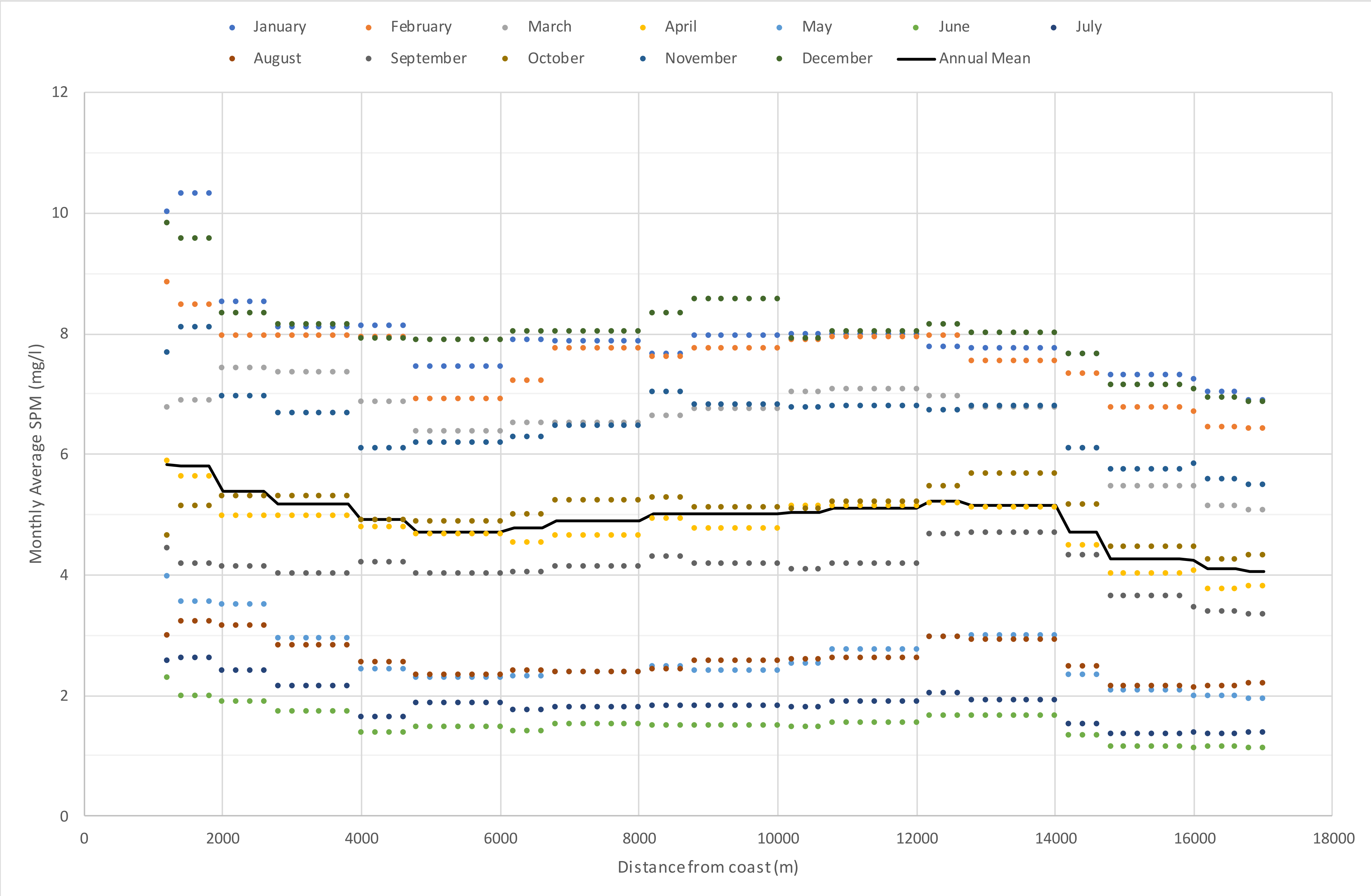


Figure 33 Average monthly SPM along middle transect (Cefas, 2016)

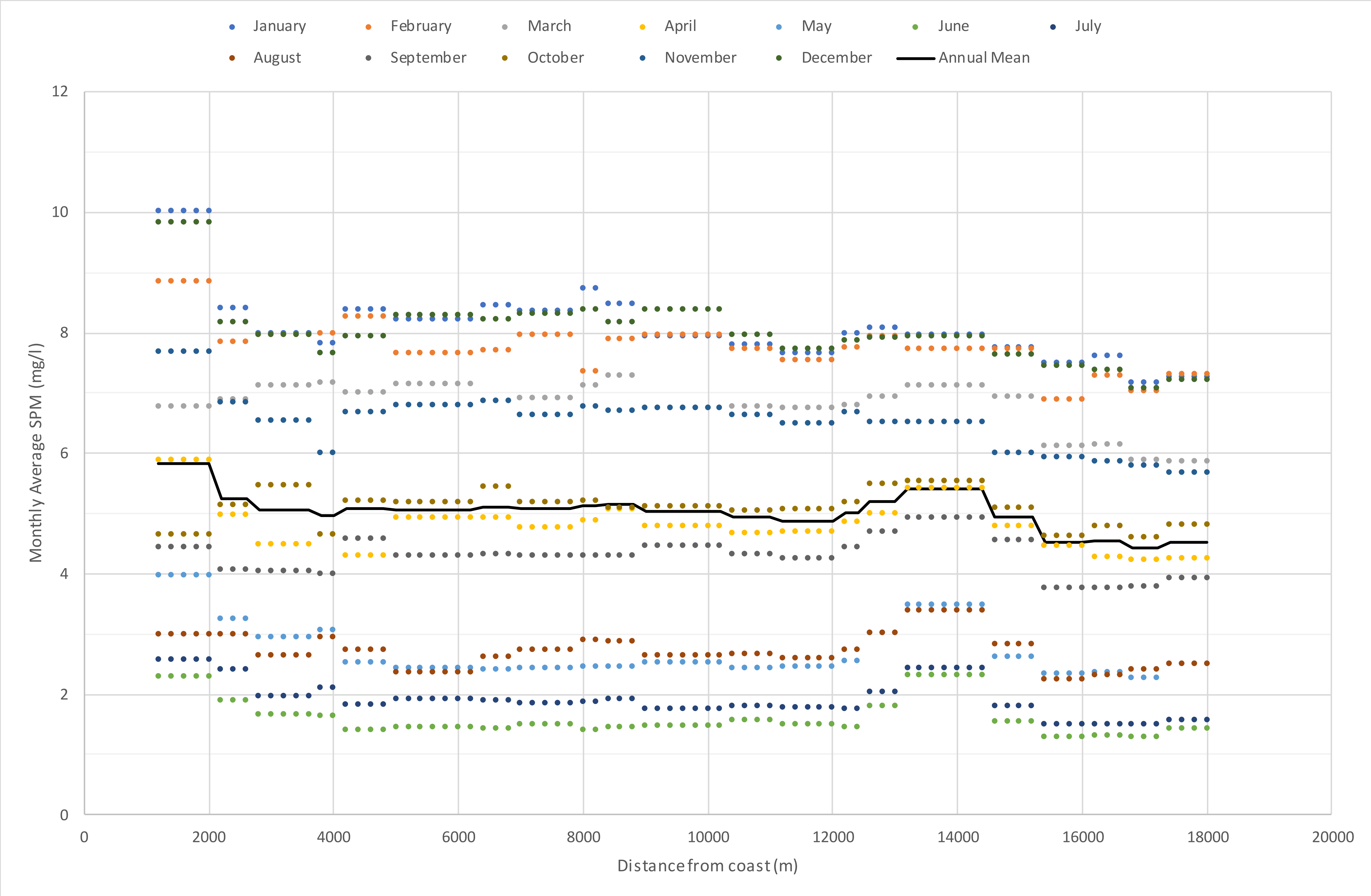


Figure 34 Average monthly SPM along southerly transect (Cefas, 2016)

Turbidity monitoring

3.6.8 Data are also available over the period 2017 and 2018 from four monitoring buoys positioned in Dublin Bay including one 2.5 km to the northeast of Dalkey Island. This buoy was used to quantify the background conditions in Dublin Bay away from dredging activities; the findings of the buoy between September 2017 to December 2018 are summarised in Table 5. The mean values generally agree with those identified in the northern transect of the Cefas data, although higher maximum values are identified from the monitoring buoy.

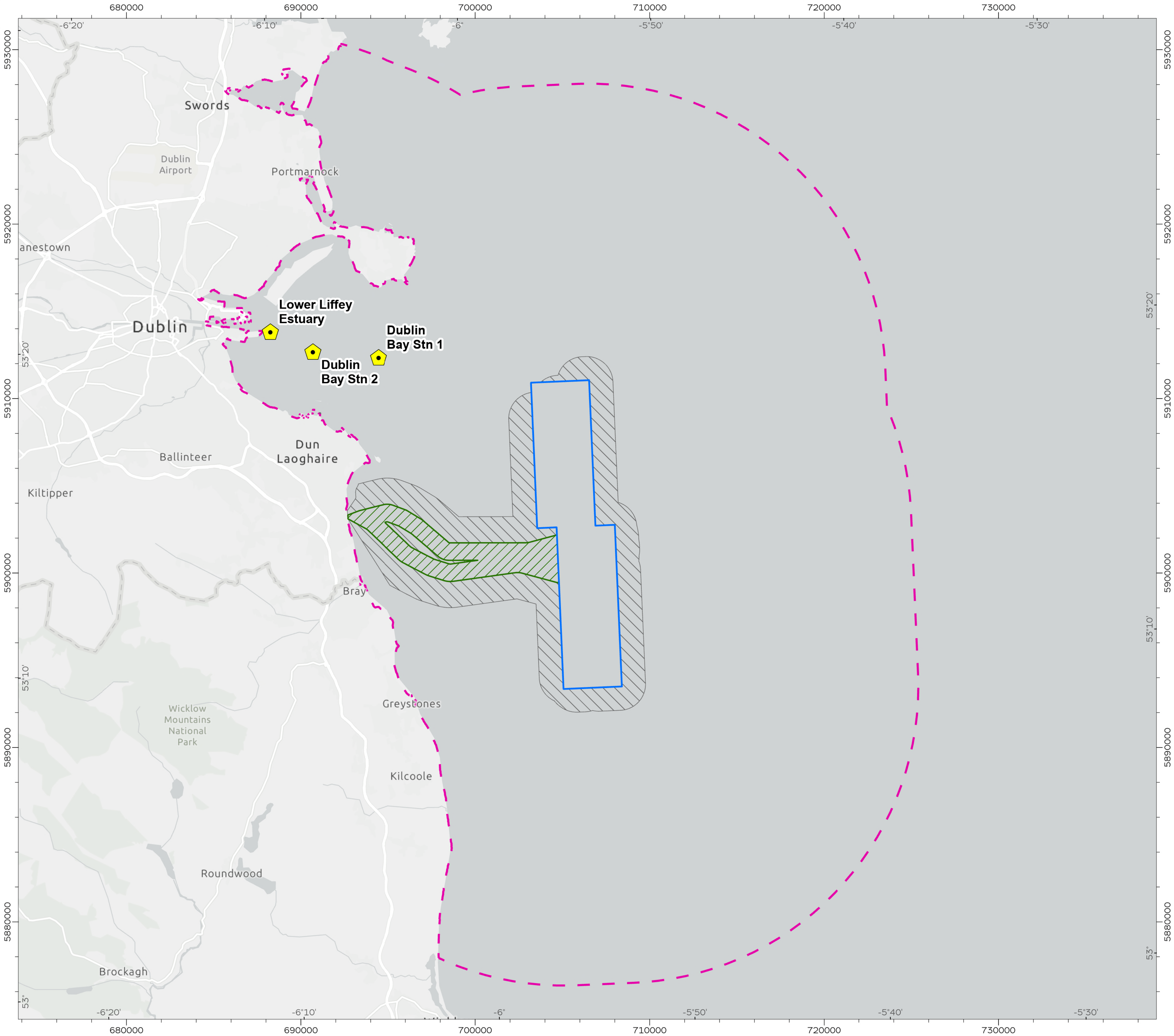
Table 5 Dublin Bay monitoring buoy (Dublin Port Company)

	Turbidity (Nephelometric Turbidity Units [NTU]) / Calculated TSS (mg/l)		
	Top of water column	Middle of water column	Bottom of water column
Mean	7.9 (12.7)	8.2 (13.2)	4.8 (7.7)
Maximum	37.4 (60.2)	53.5 (86.1)	20.6 (33.2)
95%ile	28.1 (45.2)	29.4(47.3)	11.7 (18.8)

3.6.9 The Marine Institute monitor water quality at two locations in Dublin Bay, one location in the Liffey Estuary and one location in Broadmeadow Water (see Figure 35). It should be noted that these data should be taken as indicative rather than an accurate quantitative record. The mean turbidity at the sites is typically low in Dublin Bay (less than 20 Nephelometric Turbidity Unites (NTU)[23]) and relatively high in Broadmeadow Water (83 NTU) (see Table 6, Marine Institute, 2020). The factors derived for the conversion of NTU to TSS have been applied to the Marine Institute data to enable a comparison between the baseline and the modelling results/ predicted impacts in the Dublin Array EIAR.

3.6.10 All four sites demonstrated episodic events of elevated turbidity (see Table 6 and Figure 36). This is demonstrated by the recordings of 3,000 NTU at various points in the records at three of the sites (see Table 6), it is likely that this is the upper limit of the instrument. However, there is typically good temporal agreement between all four sites when higher concentrations occur which suggests that they are correlated to storm events. presents some of The highest recorded peaks of turbidity (in the order of 100s to 1,000s of mg/l) in the datasets against measured wave heights (in Dublin Bay) are shown in Figure 37; this analysis shows that turbidity is elevated following larger wave heights, i.e. storm events.

[23] Turbidity refers to the clarity of water caused by the presence of suspended particles. Nephelometric Turbidity Units (NTU) provide a measure of turbidity utilising light scattering. Suspended Particulate Matter (SPM) refers to the relative concentration of particles suspended within water, with Suspended Sediment Concentrations (SSC) referring to inorganic particles in suspension. Both SPM and SSC provide an indication of turbidity and are measured in mg/l.



- Array Area
- Temporary Occupation Area
- Export Cable Corridor
- Physical Processes Study Area (17km Buffer)
- Turbidity Monitoring Location

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Data Source: Turbidity monitoring locations from Marine Institute

PROJECT TITLE

Dublin Array

DRAWING TITLE

Marine Institute Turbidity Monitoring Locations

DRAWING NUMBER: **35**

PAGE NUMBER: **1 of 1**

VER	DATE	REMARKS	DRAW	CHEK	APRD
01	2024-05-24	For Issue	GB	BB	SS

0 2 4 6 8 km
0 1 2 3 4 nm

N
GRID NORTH

SCALE	1:225,000	PLOT SIZE	A3
DATUM	WGS 1984	VERTICAL REF	LAT
PRJ	WGS 1984 UTM Zone 29N		

GoBe APEM Group

Dublin Array
Generation for generations
Kish Offshore Wind Limited - Bray Offshore Wind Limited

Table 6 Statistics derived from the Marine Institute monitoring stations (Marine Institute, 2020)

Station	Turbidity (NTU) / Calculated TSS (mg/l)				
	5%ile	50%ile	95%ile	Max	Mean
Lower Liffey Estuary	1 (2)	6 (15)	39 (98)	394 (985)	13 (33)
Dublin Bay Station 1	1 (2)	7 (12)	35 (57)	3,000 (4,830)	16 (26)
Dublin Bay Station 2	1 (1)	6 (9)	38 (62)	3,000 (4,830)	18 (29)
Broadmeadow Water	3 (5)	9 (15)	104 (167)	3,000 (4,830)	83 (134)

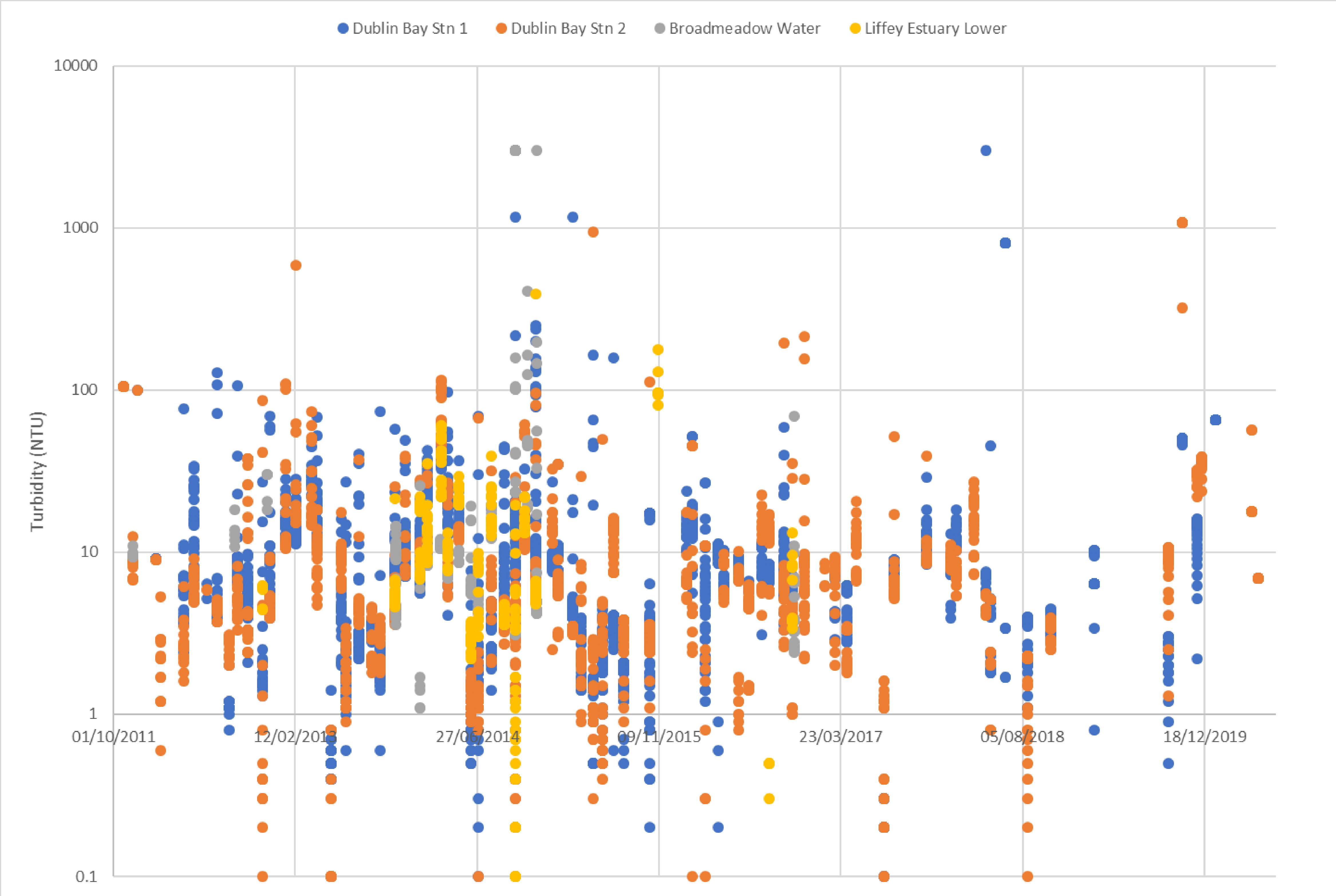

Figure 36 Marine Institute turbidity monitoring data (2011-2020)

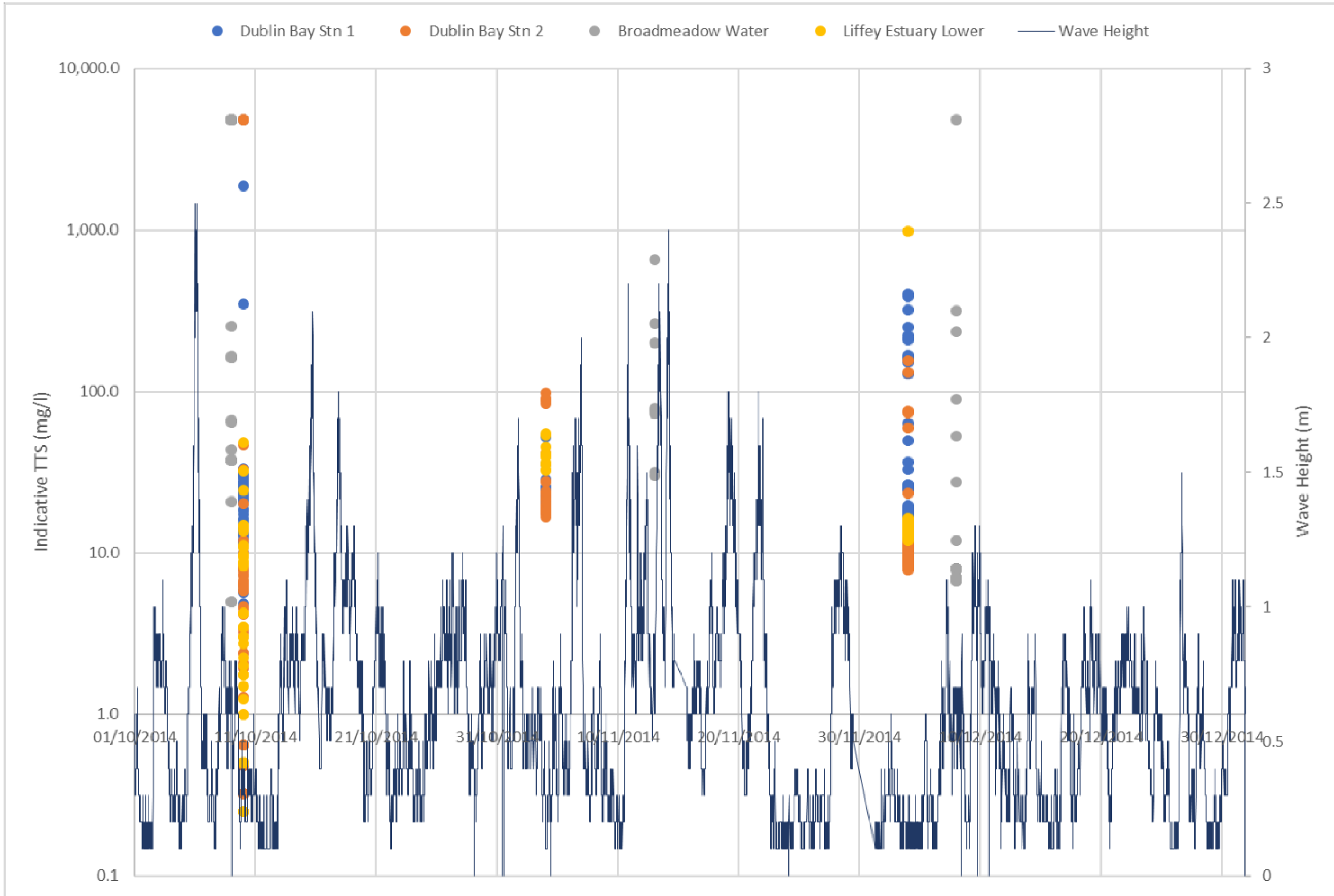

Figure 37 Marine Institute turbidity monitoring data and wave heights (The Commissioners of Irish Lights – Dublin Bay buoy) (Q4 2014)

Landfall

3.6.11 The current profile of the county Dublin and Wicklow coasts was mainly shaped during the last glaciation (circa 26,000 – 17,300 years before present) (Ballantyne et al., 2006). Three large ice sheets united: the Irish Sea Ice Sheet, the Northern Ice Dome and the Wicklow Mountains Ice Sheet (Hoare, 1975; Synge, 1977). When those ice sheets retreated, they left huge amounts of glacial/glaciofluvial sediments behind reaching thickness of 4.5 m to 30 m in areas such as Dublin Port and Killiney beach (Pellicer, 2008). As a consequence, the Dublin-Wicklow areas are largely covered by soft sediments with underlying bedrock, mainly outcropping in areas such as the Howth Peninsula and Wicklow coastal heads (McConnell et al., 1994).

Shanganagh

3.6.12 Further south within Dublin Bay, a series of outcrops such those at Bray, Greystones, or Wicklow alternate with low, soft and unconsolidated material from the Irish Sea Till. This material is derived from limestones, Cambrian sandstones, shale, gravels and sandy, gravelly alluvial and glaciofluvial sediments. Shingle and gravelly shores are present in South Dublin and also County Wicklow along with sandy beaches/sand-dune systems edged by low rocky cliffs (McConnell and Philcox, 1994).

3.6.13 A photograph (Aquafact, 2021) of the cliffs at Shanganagh is provided in Figure 38. The Shanganagh coastline is composed of generally heterogenous cliffs consisting of clay, gravel and diamict[24]. A site reconnaissance survey carried out on the beach of the Shanganagh Cliffs in 2020 identified the beach as being composed of coarse sand, cobbles and some boulders, with larger sizes more visible further away from the sea. The cliff face at this location is, approximately, 7 m high, composed of gravelly clay with cobbles and some boulders, and appears weathered and softened at the surface ().

3.6.14 The Shanganagh shoreline is highly susceptible to coastal erosion, with storm events often undercutting the cliff features Whilst rock armouring is present at the Shankill Beach access point, the erosion along the reminder of the coastline has resulted in exposed amenities, for example drainage pipes (Aquafact, 2021).

[24] Diamict is a terrigenous sediment (a sediment resulting from dry-land erosion) that is unsorted to poorly sorted and contains particles ranging in size from clay to boulders, suspended in a matrix of mud or sand.

Figure 38 Cliff features at the proposed Shanganagh landfall (Aquafact, 2021)

Coastal erosion and flooding

3.6.15 Waves are the most important erosive agent along most coasts, but their effect varies with wave energy and characteristics, and with the nature of the material exposed to wave attack (Summerfield, 1991). Coasts which are formed by steep cliffs which plunge straight into deep water are rarely subject to erosion owing to the waves not breaking prior to impact with the shore, therefore they are reflected with little energy loss. Where kinetic energy is displaced from breaking waves on a shoreline coastal erosion is likely to occur. Abrasion of the shoreline may also occur where materials (such as pebbles) are entrained within the breaking waves. Storm events, and the associated changes in the wave climate, will exacerbate coastal erosion.

3.6.16 Devoy (2008) describes the sediment deficit and coastal squeeze being noticeable on Ireland's coasts. The transfer of new sediment to most coasts from offshore–shelf sources has almost ceased. In the late Holocene, coastal barriers became stranded against the uplands and landwards-rising hard-rock surfaces. Consequently, beach-barrier sediments are being lost through reworking alongshore and diffused into other coastal environments. This leaves a regionally to locally varied distribution and often-limited capacity for the further onshore movement and adjustment of soft-sedimentary coasts to sea level rise impacts (Salman *et al.*, 2004).

3.6.17 The eastern coast of Ireland, including Dublin, is especially susceptible to coastal erosion owing to the presence of unconsolidated sediments (Dublin City Council, 2019). The eastern counties of County Dublin and Wicklow are susceptible to wave action, tidal and storm surges (Devoy, 2008) and so parts of these counties are predisposed to geomorphological changes from active erosion and deposition processes (Caloca-Casado, 2018) and flooding (OPW, 2010).

3.6.18 Coastal erosion rates upon sediment-dominated coasts (e.g. sandy systems and glacial sediments) reach average values of 0.2 m/year to 0.5 m/year, commonly rising to 1 m/year to 2 m/year on southern and eastern Irish coasts (Devoy, 2008). Total rates of land loss for Ireland from erosion and flooding have been estimated to be approximately 1.6 km^2/year, concentrated in about 300 sites (Devoy, 2008). Updated maps, published as part of the National Coastal Flood Hazard Mapping 2021 project, indicated that the coastline at the landfall area is vulnerable to flood events of 1 in 10-year return periods, resulting in depths of between 1 m to 2 m (OPW, 2021).

3.6.19 The east coastal zone has the highest rates of coastal erosion in Ireland, estimated to be between 0.2 m/year to 1.6 m/year (Devoy, 2008). Glacial sediments moderately erode at 0.2 to 0.5 m/year, normally intensifying to 1 m/year to 2 m/year, exceeding 3m/year in hotspots along southern and eastern coasts of Ireland (OPW, 2010). The maximum coastal erosion rate identified in the North East Coast Irish Coastal Protection Strategy Study (ICPSS) study was approximately 0.48 m/year at Portmarnock in County Dublin (RPS, 2010).

3.6.20 A more recent study undertaken by Caloca-Casado (2018) assessed aerial photography, satellite data and ground-truthed the vegetation lines between 1952 and 2017. This study estimated that the annual coastal retreat rates between Shanganagh and Bray were 0.65 m/year. The study also sought to identify areas of vulnerability of coastal erosion to future sea level rise (see Figure 39). Caloca-Casado (2018) produced a map with different segments which were assigned between low to high for their susceptibility to sea level rise, the study concluded a “moderate vulnerability” for the Shanganagh landfall zone (zone 3 – see Figure 39) and was concluded as a potential “hotspot” (i.e. particular sensitive areas to sea level rise and the associated implications of coastal erosion and flooding).

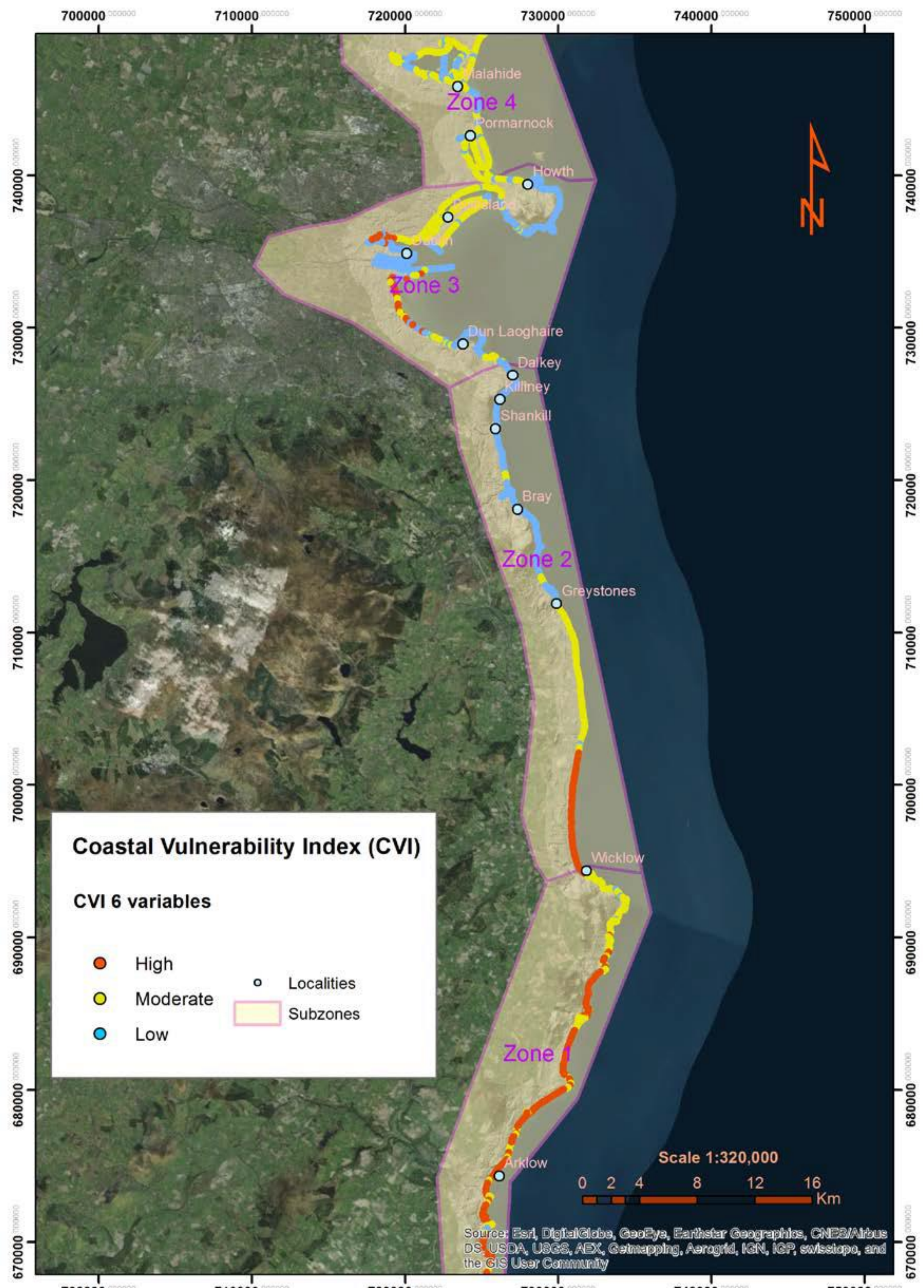

Figure 39 Coastal vulnerability map using six variables showing from high to low vulnerability ranking (Caloca-Casado, 2018)

4 Future receiving environment

4.1 Sea level rise

4.1.1 Satellite observations indicate sea level rise around Ireland in the order of, approximately, 2 to 3 mm/year since the early 1990s (Cámaro García *et al.*, 2021). Historically, tidal gauges, pre-1990, observed a slower rate of, approximately, 1 to 2 mm/year for Ireland's coastlines (EPA, 2017). An updated sea level dataset for Dublin Bay was presented by Shoari Nejad *et al.* (2022) which accounts for apparent biases arising from various instrument relocations and other changes. From this data, historic rates of sea level rise are estimated as 1.1 mm/year from 1953 to 2016, and 7 mm/year from 1997 to 2016. The higher rates of rise in recent years can be attributed to substantial multi-decadal variability, along with accelerating global sea level rise (Noone *et al.,* 2023).

4.1.2 The geological rebound following deglaciation after the last Ice Age (isostatic uplift), distorts the signal of sea level rise, but projections and the analysis of sea level rise around Ireland have sought to consider isostatic components. Furthermore, Dublin is located in a region of neutral glacial isostatic uplift, so these components should be minimised and greater consistency of local sea level rise rates with the global figure is to be expected (Bradley *et al.*, 2011; Shoari Nejad *et al*., 2022). A rise of 25 cm is projected for Dublin, and the east coast of Ireland, by 2080-2100 (Desmond *et al.*, 2017). Sea level rise is projected to continue beyond 2100 for thousands of years, but the stabilised level remains uncertain (Hansen *et al.*, 2015; Noone *et al*., 2023).

4.1.3 The increases in mean sea level will be a primary driver in magnifying the impacts of changing storm surge and wave patterns in coastal area (Desmond *et al.*, 2017; Noone *et al.*, 2023), including the east coast of Ireland.

4.1.4 To account for anticipated sea level rise over the life span of the Dublin Array development the hydrodynamic and SW models (DAPPMS) were configured to model a future baseline environment. This is based on advice / projections from the Environmental Protection Agency (EPA), which suggest a sea level rise of 0.55 to 0.60 m by 2100 (which encompasses the likely lifespan of the development) (EPA, 2017). For the purpose of the physical processes study the more conservative value of 0.60 m was adopted. This is comparable to estimates reported in Noone *et al*. (2023), with projected additional rises by 2100 ranging from 0.32 m to 0.6 m under Early action scenarios to 0.63 m to 1.01 m under Late action scenarios, with high uncertainty for the latter case due to highly uncertain ice sheet processes.

4.2 Waves and surge

4.2.1 Significant wave heights are projected to decrease around Ireland during the remainder of the next century, however, the future behaviour of extreme waves around Irish coasts is uncertain (Dabrowski *et al.,* 2023). This is principally related to changes in storminess in the North Atlantic sector, which remain highly uncertain (Seneviratne *et al.*, 2021; Noone *et al*., 2023).

4.2.2 Lowe *et al.* (2009) projects an increase by ≤ 9 mm/ year (for a 20 to 30 year return period) surge event, which is approximately equivalent of an up to 9 cm rise by 2100.

4.2.3 The predicted changes in North Atlantic storminess as part of climate warming are likely to cause Ireland's coastal wetlands and other soft-sedimentary systems to be among the first in Europe to respond to storm-led sea level rise[25].

4.2.4 Sea level rise combined with an increase in severity and frequency of coastal storms due to climate change is expected to exacerbate the problems in Irish Waters. In February 2002, a low-pressure system in the southern Irish Sea coincided with a spring tide, leading to an extreme water level of 2.9 m above mean sea level. This storm surge led to widespread flooding in Dublin and Belfast and marked coastal erosion between Cork and Belfast.

4.3 Coastal flooding

4.3.1 Coastal flooding occurs when high tides, surges and wave-overtopping combine to inundate coastal areas. Coastal erosion, which is intrinsically linked with coastal flooding, occurs when the sea progressively encroaches on to low lying coastal areas. As noted in the sections above sea level rise, storm surge and wave heights are projected to increase throughout this century and are likely to exacerbate coastal flooding in future climate scenarios. It has been projected that greater than 20% of Ireland's coastal wetlands could be lost under medium change scenarios (EPA, 2017).

[25] Devoy (2008) https://www.climatechangepost.com/ireland/coastal-erosion/

5 Data gaps or uncertainties

5.1.1 Some aspects of the baseline are well understood, such as the underlying geology and tides. However, some data sources or assumptions are less well studied and/or quantified for the study area. This section seeks to identify areas of uncertainty and potential data gaps.

5.1.2 Grab sampling and video surveys, while providing detailed information on the sediment types (and fauna) present, cannot cover wide swaths of the seabed and consequently represent point samples that must be interpreted in combination with the other appropriate datasets. As noted, several grab sampling surveys have been conducted in the area which show good validation against the regional data. Therefore, the regional data are considered sufficient to characterise the study (and wider) area.

5.1.3 Available geophysical survey data does not cover the full extent of the Offshore ECC as indicated in Figure 2. However, the existing geophysical data gives good agreement with the regional bathymetry data provided by INFOMAR, and the overlap between the two data sources has been considered sufficient to characterise the study area.

5.1.4 The literature notes uncertainties with regards to quantifying how much wave energy is lost due to the presence of the sandbanks and sandwaves within the study area. Therefore, the applicant has constructed a wave model of the study area to provide greater understanding and quantification of these local wave dynamics. The uncertainties with the model and its limitations are detailed in the Spectral Wave Model Calibration and Validation Report.

5.1.5 Uncertainty exists with regards to characterisation and climate projections of the future baseline. Key areas of uncertainty, within the published literature and scientific understanding, include the extent to which future changes in storminess may occur and the potential associated changes to the wave regime. There is also considerable uncertainty with regards to exactly how the coast may respond to a modified wave climate acting in combination with higher than present sea levels.

5.1.6 However, despite the above uncertainties, it should be noted that there is robust data available to characterise the marine physical environment within the study area. The seabed in the area is well studied and surveyed. As such, the available evidence base is considered to be sufficiently robust to underpin the assessment presented here and an overall high confidence is placed on the characterisation of the baseline.

6 Summary

6.1.1 The proposed array area is to be located on a bathymetric high of the seafloor, known as the Kish and Bray Banks. Strong currents and tidal flows are experienced around the Kish and Bray Banks. The area experiences an approximately southern flow during ebb tide and a northern flow during the flood tide. The data indicated that the larger waves in the area originate predominantly from the south and southeasterly directions with some input from the North East. This is consistent with the concept that waves arriving from the south are a result of channelling from the Atlantic, whereas those from other orientations are a result of the relatively short fetch of the Irish Sea.

6.1.2 The Dublin Array site is dominated by sediment classed as sand (Figure 27). The Offshore ECC is dominated by coarse sediments and the potential for rock exposure (Figure 28). There is a general decreasing trend of suspended particulate matter with distance offshore with the highest concentrations in the study area observed in Dublin Port.

6.1.3 The Kish and Bray Banks occur as part of a series of coast-parallel north to south trending offshore banks along the east coast of Ireland. The position of these banks are quasi-stable and in a natural equilibrium resulting from the metocean conditions. The Kish and Bray Banks and surrounding area are covered in highly mobile bedform features, such as sandwaves. Water depths on the Kish and Bray Banks vary between 2 to 26 m (see Figure 16). The Fraser Bank is a nearshore sandbank/ large sandwave feature within the proposed southerly Offshore ECC (see Figure 16). This also suggests sediment transport occurs within the study area although the extent of the mobility of this feature is unknown.

6.1.4 The current seabed landscape is dominated by glacial advance and retreat resulting in the deposition of glacial and post-glacial sediments on top of largely Palaeozoic sedimentary bed rock. The eastern coast of Ireland, including Dublin, is especially susceptible to coastal erosion owing to the presence of unconsolidated sediments.

6.1.5 Despite the above uncertainties outlined within this report, it should be noted that there is robust data available to characterise the physical environment within the study area. The seabed in the area is well studied and surveyed. As such, the available evidence base is considered to be sufficiently robust to underpin the assessment presented here and an overall high confidence is placed the characterisation of the baseline.

6.1.6 The characterisation of the region and the study area, as detailed in this report, is considered to be adequate for the purposes of undertaking an EIA.

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Dublin Array Offshore Wind Farm

Environmental Impact Assessment Report

Annex A: Physical Processes Data Comparison

Revision: 1.0

8 Introduction

8.1.1 The purpose of this technical report is to assure the quality and validity of the hydrodynamic models (wave and tide; hereafter referred to as the EIAR numerical model) developed by Intertek, which used data from 2012 to calibrate and validate it.

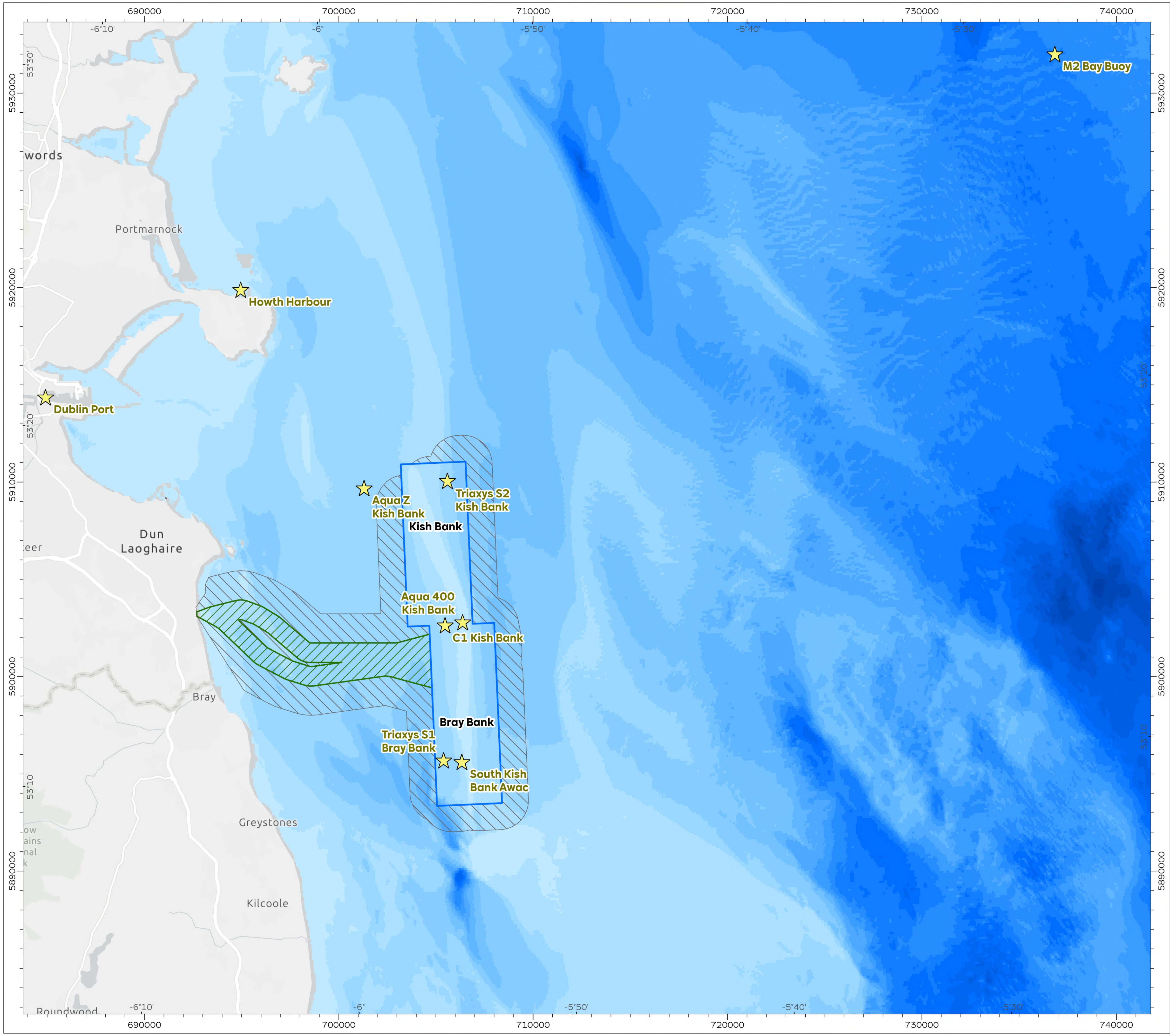
8.1.2 Data used by Intertek has been compared to recently collected data (post-2018) within the vicinity in order to demonstrate that the data used within the EIAR numerical model(s) remain applicable to the EIAR assessment presented in Volume 3, Chapter 1: Marine Geology, Oceanography and Physical Processes.

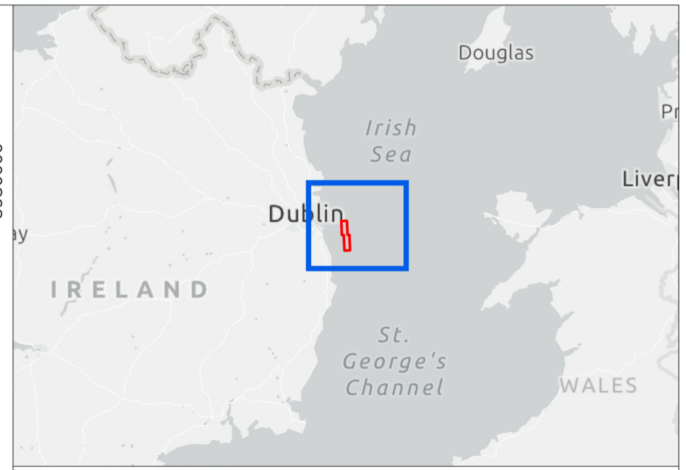
8.1.3 Collected oceanographic data (i.e., waves, tides and water level) are summarised in Table 7 and their locations is represented in Figure 40.

Table 7 Location of metocean instruments.

Location	Survey date	Latitude	Longitude	Data source	Parameters
Pre-hydrodynamic numerical model development (used in model calibration and validation) (pre-2018)					
South Kish Bank Awac	23/08/2012 to 20/09/2012	53° 10.187''N	5° 54.766''W	Innogy	Waves and water level
C1 Kish Bank	19/09/2012 to 20/09/2012	53° 13.992''N	5° 55.270''W	Innogy	Tidal currents
Aqua 400 Kish Bank	19/09/2012 to 20/09/2012	53° 14.056''N	5° 54.453''W	Innogy	Tidal currents
Aqua Z Kish Bank	23/08/2012 to 19/09/2012	53° 17.053''N	5° 56.165''W	Innogy	Tidal currents
Post-hydrodynamic numerical model development (post-2018)					
Triaxys S1 Bray Bank	12/06/2021 to 15/03/2022	53° 10.254''N	005° 55.604''W	Partrac	Waves and water level
Aquadrop S1 Bray Bank	12/06/2021 to 15/03/2022	53° 10.254''N	005° 55.604''W	Partrac	Tidal currents
TRIAXYS S2 Kish Bank	12/06/2021 to 15/03/2022	53° 17.696''N	005° 54.518''W	Partrac	Waves
Aquadrop S2 Kish Bank	12/06/2021 to 15/03/2022	53° 17.696''N	005° 54.518''W	Partrac	Tidal currents
Pre- and post-hydrodynamic numerical model development					
Dublin Port	13/02/2007 - still active	53° 20' 45.6''N	6° 13' 19.2''W	Foras na Mara, Marine Institute	Water level
Howth Harbour	24/10/2006 - still active	53° 23' 31.2''N	6° 4' 4.8''W	Foras na Mara, Marine Institute	Water level
M2 Dublin Bay buoy	09/08/2010 to 01/11/2023	53° 29' 0.96''N	5° 25' 48.72''W	Foras na Mara, Marine Institute	Waves

(Pre-2018 data collected at C1 Kish Bank and Aqua 400 Kish Bank have not been used in this data comparison as the measurement period is too short to allow meaningful statistical analysis).





Array Area
Temporary Occupation Area
Export Cable Corridor
Oceanographic Instruments

Depth (m)

- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 - 100
- 100 - 110
- 110 - 120
- 120 - 130
- 130 - 140
- 140 - 150
- 150 - 160
- 160 - 170

DRAWING STATUS

FINAL

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MAP NOTES / DATA SOURCES:

Esri UK, Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri UK, Esri, TomTom, Garmin, Foursquare, METI/NASA, USGS ©Ordnance Survey Ireland 2023 © Tailte Eireann. (CYSL50270365) Not to be used for Navigation.
Data Source: Bathymetry data from INFOMAR, Seabed features from GDG

PROJECT TITLE

Dublin Array

DRAWING TITLE

Oceanographic Data Collected for Dublin Array Offshore Windfarm

DRAWING NUMBER: **40**

PAGE NUMBER: **1 of 1**

VER	DATE	REMARKS	DRAW	CHEK	APRD
01	2024-05-20	For Issue	GB	BB	SS

0 2 4 6 8 km
0 1 2 3 4 nm

N
GRID NORTH

SCALE	1:200,000	PLOT SIZE	A3
DATUM	WGS 1984	VERTICAL REF	LAT
PRJ	WGS 1984 UTM Zone 29N		

GoBe
APEM Group

Dublin Array
Generation for generations
Kish Offshore Wind Limited - Bray Offshore Wind Limited

9 Data comparison

9.1 Data origin

9.1.1 Both data sources being compared have analysed the same features, albeit at different locations, meaning there will be subtle differences between the measured data. Both datasets have been analysed for varying durations and during different seasons and years. Due to the dynamic nature of ocean sciences, differences within the data are expected. Assessing the relevance of these differences will determine whether the numerical model used to assess the proposed development remains applicable.

Data sources pre-2018

9.1.2 The measured data sets used to calibrate and validate the EIAR numerical model, as shown on Figure 40 include:

- Water levels
  - Provided by Foras na Mara/Marine Institute at two sites (Dublin Port and Howth Harbour); and
  - Project specific water level data collected by the South Kish Bank AWAC during one month in 2012 was also used.
- Tidal currents were obtained by three ADCPs (Acoustic Doppler current Profiler), which are C1 Kish Bank; Aqua 400 Kish Bank and Aqua Z Kish Bank and which were deployed in 2012 for a maximum of one month; and
- Wave data (i.e., height, period and direction) used to validate the hydrodynamic model were collected at two sites, the M2 wave buoy and South Kish Bank AWAC during a period of seven years and one month, respectively.

9.1.3 All the data listed in this section have been used to calibrate and validate the EIAR numerical models as reported in :

- Volume 4, Appendix 4.3.1-2: Physical Process Modelling for Dublin Array Offshore Wind Farm (hereafter referred to as the Physical Processes Modelling Report);
- Volume 4, Appendix 4.3.1-3: Hydrodynamic Calibration and Validation Report (hereafter referred to the Hydrodynamic Calibration and Validation Report); and
- Volume 4, Appendix 4.3.1-4: Spectral Wave Model Calibration and Validation Report (hereafter referred to as the Spectral Wave Model Calibration and Validation Report).

Data sources post-2018

9.1.4 Metocean data has been collected using two TRIAXYS with currents directional wave buoys deployed for, approximately, nine months from June 2021 to March 2022. The wave buoys were located at the (i) north of the Kish Bank; and (ii) south of the Bray Bank (Figure 40). The full suite of details regarding the project specific metocean campaign is provided in Partrac (2022).

9.2 Water level

9.2.1 The maximum tidal range[26] calculated at the South Kish Bank AWAC in 2012 (3.6 m) is approximately 8% lower than that measured by TRIAXYS S1 Bray Bank between 2021 and 2022 (4 m), which shows good agreement between data. The difference can be explained by the distant between two locations of measurements (approximately 14 km) and the period of data acquisition. South Kish Bank AWAC is closer to the amphidromic point[27] located near Cahore (80 km south along the Irish coast from the oceanographic instrument), which explain the lower values of tidal range observed compared to TRIAXYS S1 located 90 km from the amphidromic point. In Europe, the biggest tides occur during the spring and autumn equinoxes (i.e., 20th of March and 22nd of September respectively). Data collected during 2012 did not measure the biggest tide of the year, whereas the measurement campaign post-2018 did capture the event due to the survey duration.

9.2.2 The tidal ranges during the neap and spring tide[28], 1.6 m and 3 m on average respectively, show the same results between data collected pre-2018 and post-2018 (Figure 41). The differences observed varies between 0.22m and -0.12m during neap tide and between 0.25m and -0.18m during spring tide (Figure 41). The good agreement for the maximum tidal range and similar average tidal range during neap and spring tides demonstrates that the EIAR numerical model remains valid for post-2018 assessments. Consequently, the model created can be used to describe the actual environment baseline concerning the variation of water level.

9.2.3 The tide gauge at Dublin Port (Figure 40) was used by Intertek to calibrate and validate the numerical model. The comparison of tidal range between pre-2018 and post-2018 for spring and neap tidal cycle show difference of 0.8% and 4.8%, respectively (Table 8). Consequently, it is considered that the EIAR numerical model remains a valid assessment tool for the proposed development's EIAR (Volume 3, Chapter 1: Marine Geology, Oceanography and Physical Processes).

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[26] Difference in height between high tide and low tide.

[28] Neap tide corresponds to the tide of minimal range, whereas spring tide corresponds to the tide of maximal range.

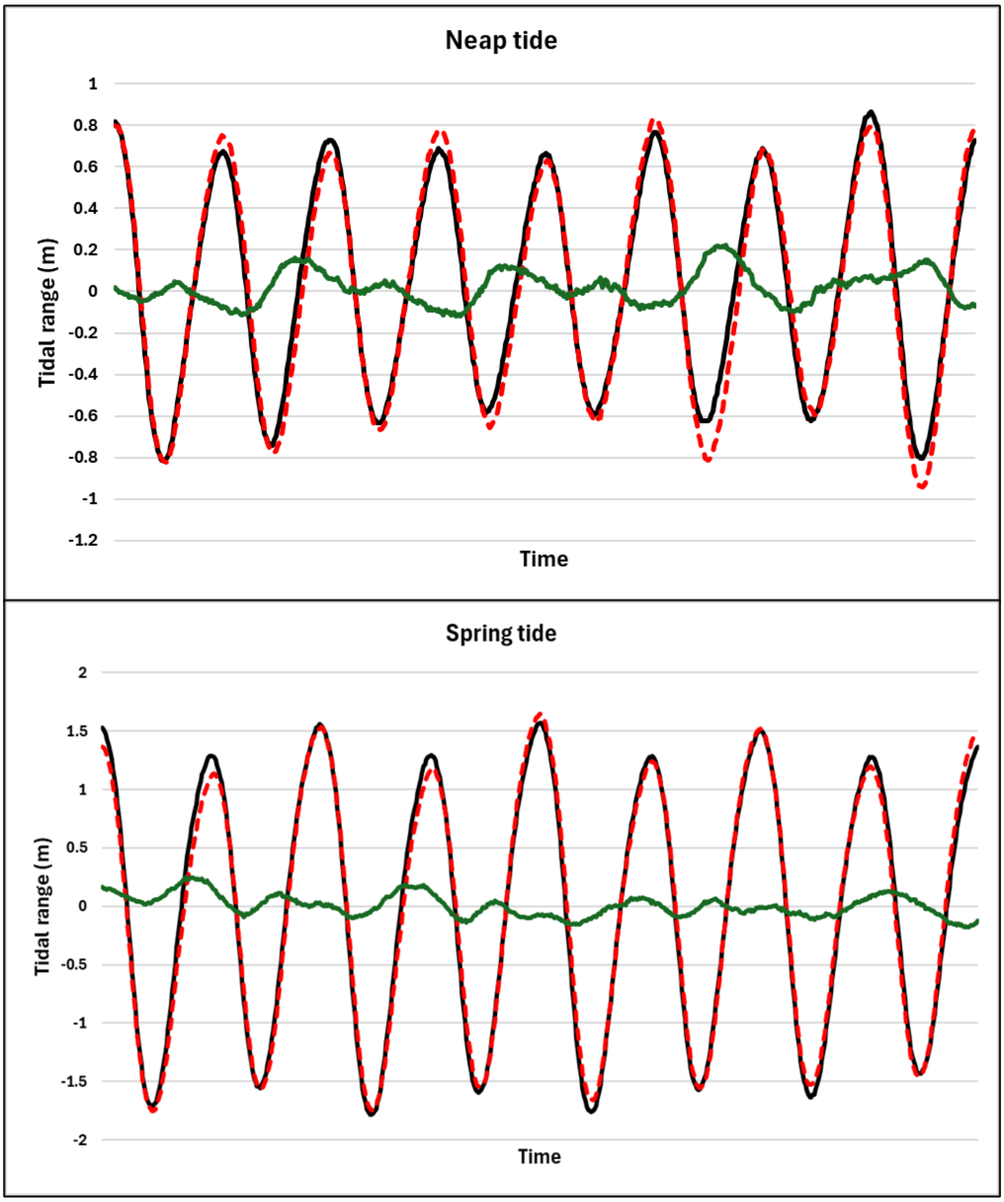

Figure 41 Tidal range during neap tide and spring tide at pre-2018 (in red) and post-2018 (in black) (with difference shown in green)

Table 8 Tidal range comparison at Dublin port tidal gauge (see Figure 40 for location).

Data	Tidal range (m)	Difference (m)	Difference (%)
Neap tide			
Pre-2018	1.53 ± 0.2	0.01	0.8
Post-2018	1.52 ± 0.3		
Spring tide			
Pre-2018	4.30 ± 1	0.21	4.8
Post-2018	4.51 ± 0.3		

9.3 Tidal data

9.3.1 Tidal currents data (i.e., velocity and direction at different depth) pre- and post-2018 have been collected in different locations and over different durations. Consequently, it is expected that there may be differences between the measurements. The variation may be due to a number of factors:

- Seabed morphology (influencing the near be local hydrodynamics; Easton *et al.*, 2011);
- Wind and wave influence (influencing surface flow direction and speed; Bowden, 1948);

9.3.2 The difference between measurement devices deployed post-2018 can't be explained by wind difference as data from ABPmer (2018) show the same wind speed and direction for the two devices deployed (Aquadropp S1 at Bray Bank and Aquadropp S2 at Kish Bank; Figure 42). Consequently, the main factor influencing the difference between the devices is the seabed morphology.

9.3.3 The measurement devices post-2018 located to the (i) south-west of Bray Bank and (ii) north-east of Kish Bank are, approximately, 15 km apart (Figure 40). The different device locations relative to the bank alignment results in differences in the tidal residual orientation such that it is oriented to the north at Bray Bank and towards the south at Kish Bank (Figure 43).

9.3.4 Deployment of measurement devices at differing locations relative to morphodynamic features but over comparable time periods inherently result in differences in the tidal data which do not reflect the quality, accuracy and viability of data.

9.3.6 Despite the comments above, similar trends are present between data pre-2018 (Aqua Z Kish bank) and post-2018 (Aquadrop S2 Kish Bank and Aquadrop S1 Bray Bank), as summarised below:

- The average current measured at 5 m depth below surface pre-2018 (0.51 m/s) is comparable to the values recorded post-2018 (0.45 m/s at Kish Bank and 0.55 m/s at Bray Bank);
- The same observation can be made for the average current at 11 m depth below surface, with value of 0.55 m/s pre-2018 and values of 0.5 m/s ± 0.05 m/s post-2018; and
- The main current direction (50% ± 2%) is observed towards the south for data pre-2018 and post-2018 (Aquadrop S2 Kish Bank).

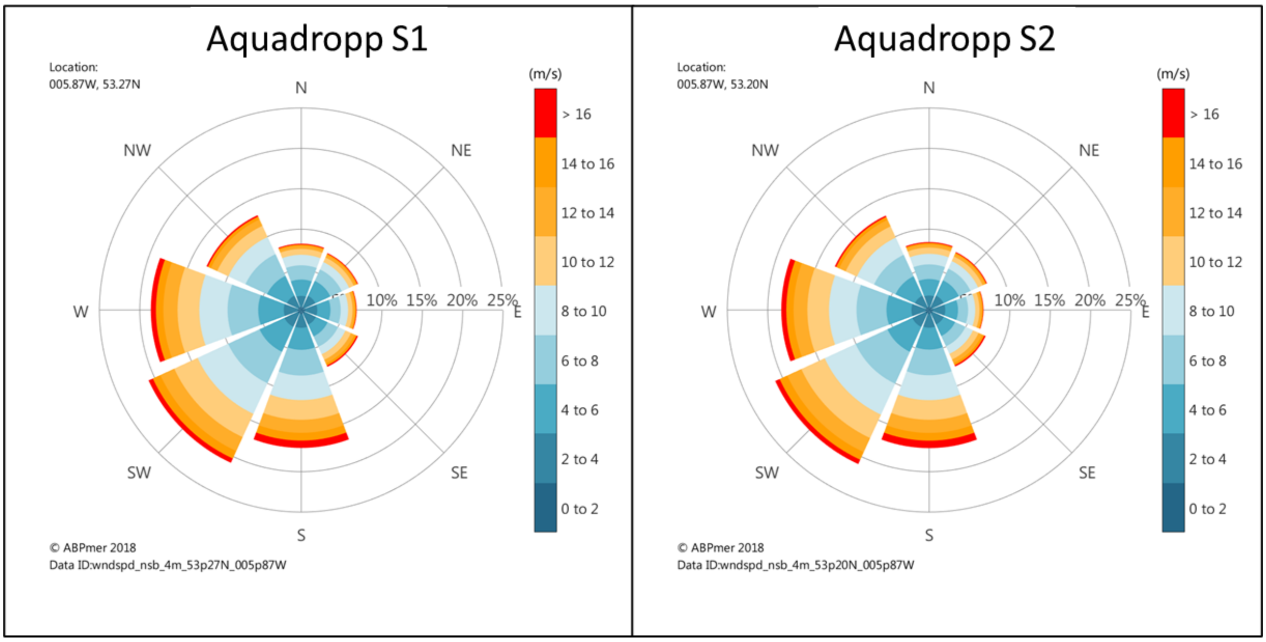

Figure 42 Wind speed and direction at the locations of devices deployment post-2018.

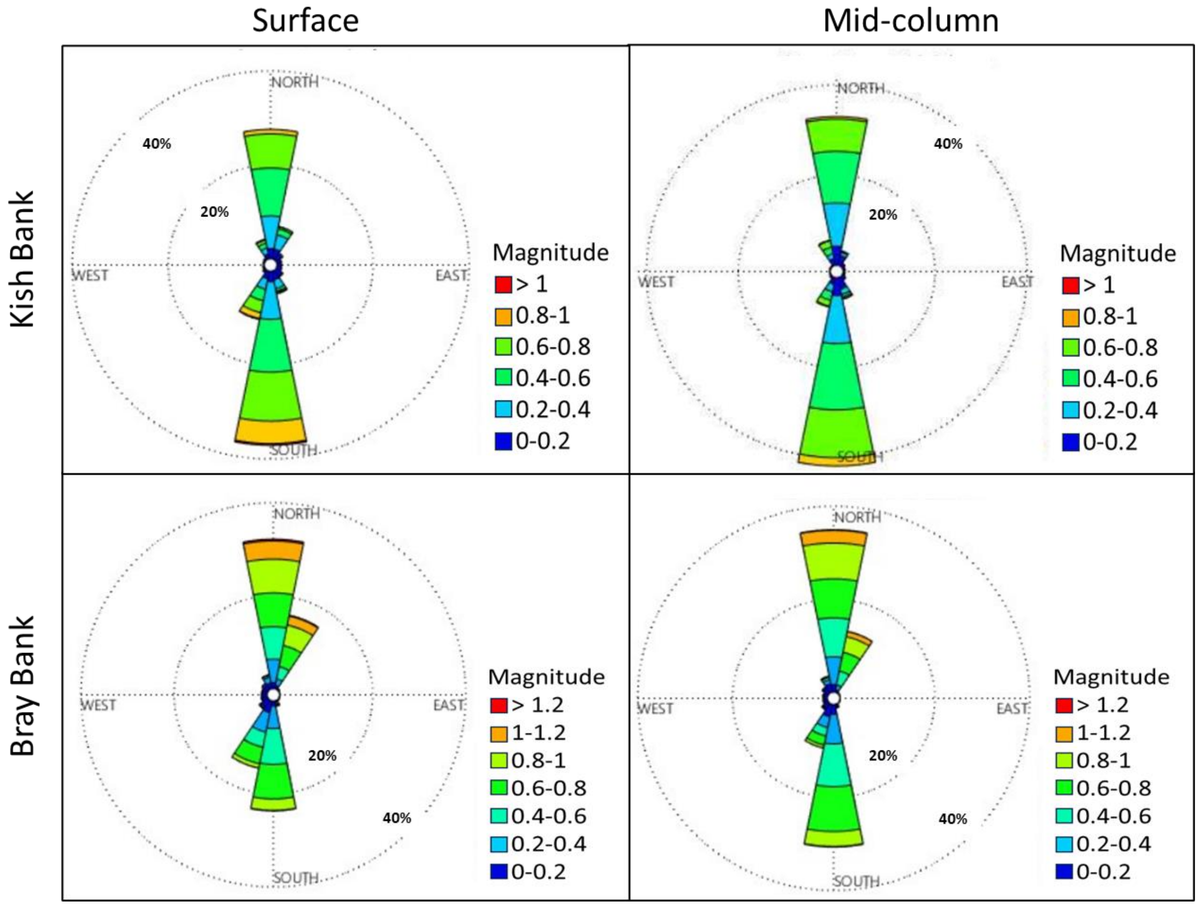

Figure 43 Rose plot showing the mean direction and magnitude of current (in m/s) at two locations for data collected post-2018.

9.4 Wave data

9.4.1 Wave generation depends on the transfer of energy from the wind to the surface water, which is a function of the fetch[29], water depth and duration of wind events (Fagherazzi and Wiberg, 2009). As presented in paragraph 9.3.1, the tide and wave data (i.e., height, period and direction) pre- and post-2018 have been collected at different locations, for different periods and over varying durations. Therefore, it is reasonable to assume that there will be differences between the parameters recorded by the different instruments. However, these variations do not mean that the data is of poor quality but is instead a consequence of an environment in constant motion.

[29] The unobstructed distance over which the wind can blow.

9.4.2 This can be demonstrated using data collected over the same period (post-2018) at two different locations (TRIAXYS S1 and TRIAXYS S2; Figure 40). The datasets show a small variation in wave height (0.1 m difference) and wave period (0.2 s), but a larger deviation in wave direction (Figure 44). At the same location but different period, the average wave height and wave period difference is higher (0.4 m and 1 s respectively), but the wave direction remains similar (Figure 45). In the Irish Sea wave climate is strongly seasonal with extreme waves heights occurring from November to March (Wolf *et al.*, 2010). The first deployment occurred mostly in summer (from mid-June 2021 to end of November 2021; Period 1 on Figure 45), whereas the second data collection happened mostly in winter (from end of November 2021 to mid-March 2022; Period 2 on Figure 45).

9.4.3 The data comparison pre-2018 and post-2018 from the wave buoy located at M2 Dublin Bay buoy can be summarised as follows (Table 9):

- The average wave height is 5% higher for data collected post-2018 (1.2 m against 1.1 m pre-2018), with a maximum observed around 6.5 m ± 0.1 m;
- The standard deviation for wave height remained the same at 0.74m pre- and post-2018, indicating stability in the wave height data;
- The average wave period is also slightly higher by 2.20% in data collected post-2018 (4.23 s) than pre-2018 (4.14 s), with a maximum measured at 8.6 s ± 0.05 s; and
- Results show that waves are coming from the south for 41.2% ± 0.1% for both data collected pre- and post-2018 (Table 10). Waves coming from other direction have been measured around 8.4% ± 3% (Table 10).

9.4.4 The maximum period measured pre-2018 reached 14 s against 8.7 s post-2018. This difference can be explained by the period of measurement. Data pre-2018 include 17 years of observations with ten notable storm events (Pasik, 2019), whereas between 2018 and 2022, only three storms were recorded (storm Eunice, Barra and Ellen). The hurricane Darwin in 2014, with wind speed exceeding 120 km/h, created long period waves coming from the south to reach Dublin Bay (Mc Grath, 2015).

9.4.5 There is a good correlation for waves coming from the south for both data sets (pre- and post-2018); waves coming from the south-west are more frequent pre-2018 (12.8%) than post-2018 (9.8%) at M2 Dublin Bay buoy (Table 10). These differences of, approximately 3%, are the results of the higher number of storms recorded for data pre-2018 compared post-2018, which also impacts the frequency of waves originating from the north-east (7.8% pre-2018 and 10.1% post-2018) (Table 10).

9.4.6 Inter-annual variation is expected in such a dynamic and changing environment. For example, Woolf *et al.* (2002a and 2002b) showed that wave data, using the same method of measurement at the same location during several years, varied at inter-annual and decadal scale in monthly mean wave heights with a strong linear dependence with the North Atlantic Oscillation (NAO). For example, the NAO index value pre-2018 is -0.20, whereas post-2018 value is 0.56 on average for all months (updated from Jones *et al.*, 1997), which means that wave data are expected to be different between the two periods compared. However, the low changes observed between data collected pre- and post-2018 at Dublin Bay strongly suggest that the measurements done before 2018 are accurate and remain valid. Therefore, the EIAR numerical model is considered applicable to the current EIAR.

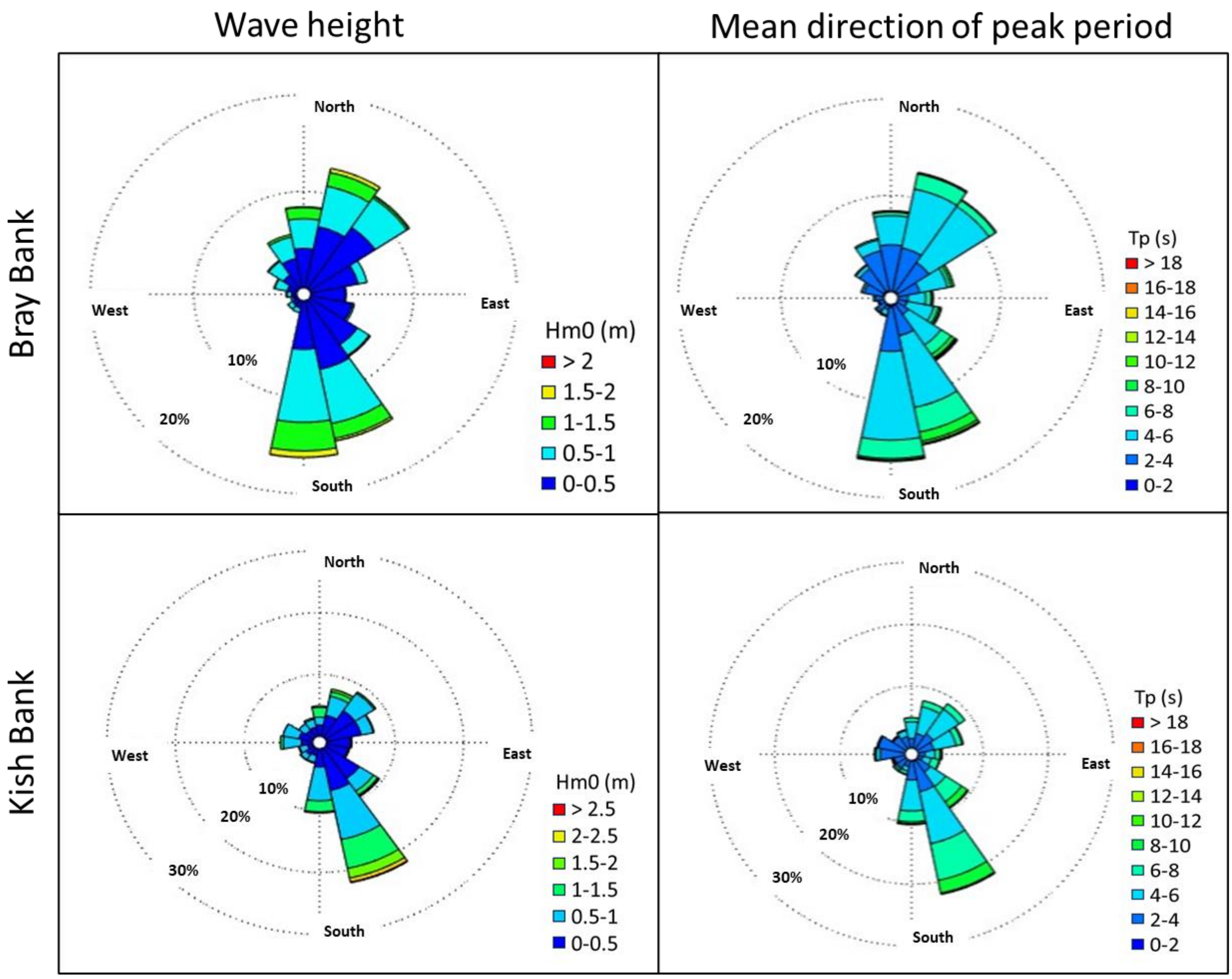

Figure 44 Rose plots showing the wave at two locations for data collected post-2018.

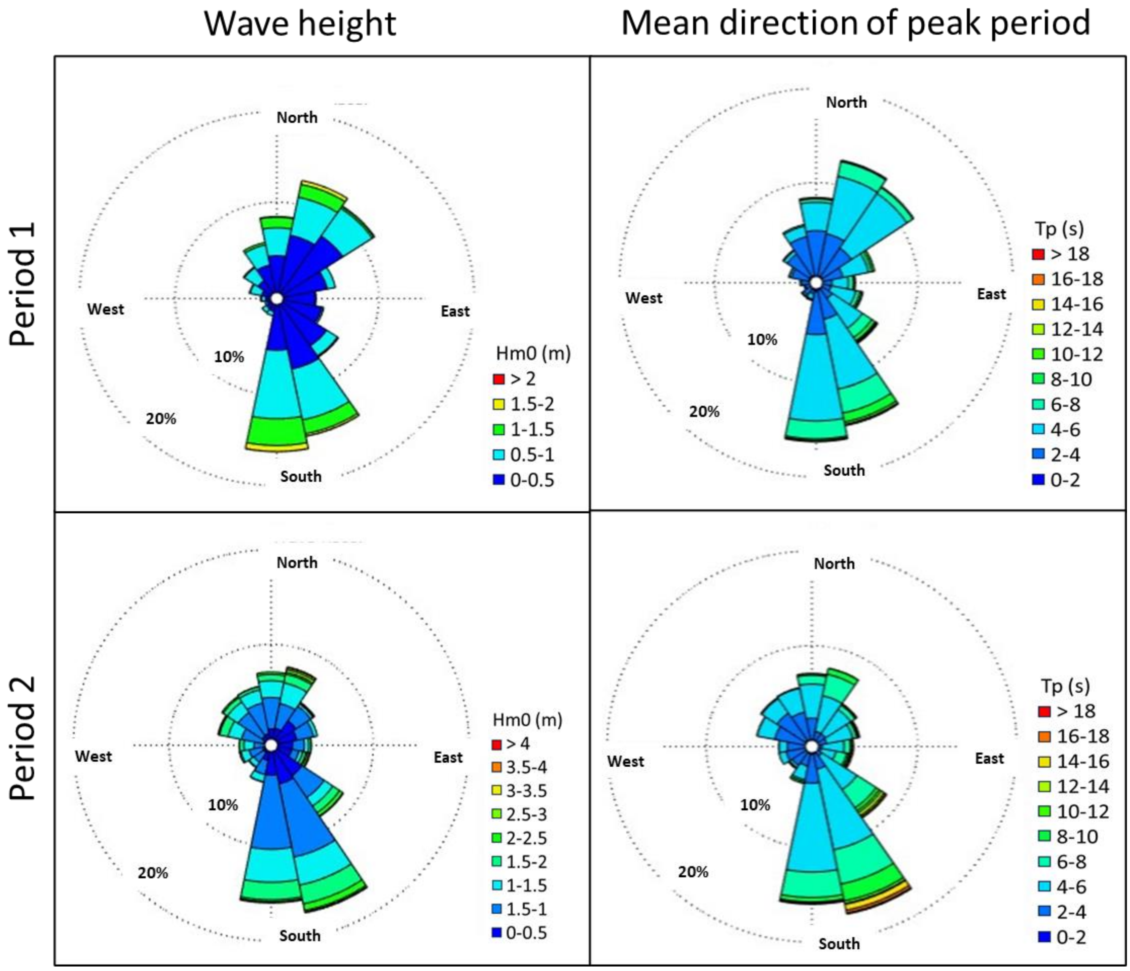

Figure 45 Rose plot showing wave characteristics at Bray Bank during two different periods post-2018.

Table 9 Wave height and wave period for M2 Dublin Bay buoy (see Figure 40 for location).

Wave parameter	Pre-2018	Post-2018	Difference (%)
Dublin Bay Buoy			
Maximum significant wave height (m)	6.64	6.41	3.5
Average significant wave height (m)	1.19	1.09	5
Maximum wave period (s)	14	8.67	38
Average wave period (s)	4.23	4.14	2.2

(Pre-2018 data represent the averaged values for seven years (2010 to 2017) and Post-2018 data represent the averaged values for five years (2019 to 2023) (Figure 40 and Table 7)).

Table 10 Wave direction for M2 Dublin Bay buoy (see Figure 40 for location).

Direction	Wave frequency (%) Pre-2018	Wave frequency (%) Post-2018	Difference (%)
Dublin Bay Buoy			
North	8.18	8.99	0.81
North-east	7.76	10.12	2.36
East	7.44	9.42	1.98
South-east	7.61	6.78	0.83
South	41.27	41.09	0.18
South-west	12.76	9.72	3.04
West	8.43	7.55	0.88
North-west	6.56	6.32	0.24

(The top three directions for each period are shaded in grey; Pre-2018 data represent the averaged values for seven years (2010 to 2017) and Post-2018 data represent the averaged values for five years (2019 to 2023) (Figure 40 and Table 7)).

10 Conclusion

10.1.1 A comparison of available metocean datasets has been undertaken in order to ascertain the viability of the EIAR numerical model(s) used to undertake an assessment of the potential impacts of the proposed Dublin OWF upon marine geology, oceanography and physical processes (as reported in Volume 3, Chapter 1: Marine Geology, Oceanography and Physical Processes). Specifically, the data used to calibrate and validate the EIAR numerical model(s), which dates pre-2018 has been compared against more recent (post-2018), project specific and publicly available, data. The full suite of datasets considered is detailed in Table 7. Details relating to the EIAR numerical model(s) are presented in:

- Volume 4, Appendix 4.3.1-2: Physical Process Modelling for Dublin Array Offshore Wind Farm (hereafter referred to as the Physical Processes Modelling Report);
- Volume 4, Appendix 4.3.1-3: Hydrodynamic Calibration and Validation Report (hereafter referred to the Hydrodynamic Calibration and Validation Report); and
- Volume 4, Appendix 4.3.1-4: Spectral Wave Model Calibration and Validation Report (hereafter referred to as the Spectral Wave Model Calibration and Validation Report).

10.1.2 The comparison shows the following:

- Water level data comparison between pre-2018 and post-2018 show good agreement with only negligible variations resulting from differences in the duration of measurements.
- Comparison of tidal currents and wave data show differences between data collected pre-2018 and post-2018. These variations, as demonstrated in paragraphs 9.3.2 and 9.4.2, were expected as the ocean is a complex and dynamic environment in constant motion influenced by numerous parameters (i.e., sea bed morphology; North Atlantic Oscillation; fetch of the wind etc).

10.1.3 The comparison shows that, despite the observed differences amongst the data collected for the numerical models validation pre-2018 and more recent measurements post-2018, the EIAR numerical model(s) remain applicable to the EIAR assessment presented in Volume 3, Chapter 1: Marine Geology, Oceanography and Physical Processes.

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