Environmental Impact Assessment Report

NISA

North Irish Sea Array

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Appendix 18.1

Palaeogeographical Investigation

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Report Information

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Summary

Wessex Archaeology was commissioned by GoBe Consultants Ltd and Arup on behalf of North Irish Sea Array Limited (NISA Ltd) to undertake a palaeogeographic assessment of sub-bottom profiler data acquired at the proposed North Irish Sea Array Offshore Wind Farm. This involved the review of sub-bottom profiler data provided by contractor Gavin and Doherty Geosolutions in the form of Kingdom projects containing parametric sonar and sparker data, acquired by Fugro in 2022, N-Sea in 2023, and interpreted by Gavin and Doherty Geosolutions.

The assessment of the geophysical data within the Geophysical Study Area (GSA) resulted in a total of 4 major features of palaeogeographic interest comprising three channel complexes and one channel feature. The stratigraphy suggests these features formed during the late Pleistocene and developed during early Holocene. As coastal-terrestrial features interpreted as being formed during periods of known human occupation of the British Isles and Ireland, those features given a P1 archaeological rating (defined as a feature of probable archaeological interest, either because of its palaeogeography or likelihood for producing palaeoenvironmental material).

Further geoarchaeological assessment of existing geotechnical datasets (e.g. vibrocore, and borehole logs) by a suitably qualified and experienced geoarchaeologist is recommended, and would aid in refining the interpretation and archaeological potential of these features and potentially provide further valuable information on early Holocene sea level context.

Should further marine geotechnical survey be undertaken within the GSA, it is recommended that a geoarchaeologist be consulted to advise on obtaining/retaining potential samples from these campaigns or to acquire dedicated vibrocores/boreholes for geoarchaeological purposes, particularly from channel **70003**, and other identified features of archaeological interest identified.

Acknowledgements

The assessment of geophysical data was commissioned Arup and GoBe Consultants Limited (GoBe) on behalf of North Irish Sea Array Limited (NISA Ltd). The data over the proposed array area was acquired by Fugro with additional processing performed by GeoSurveys Ltd. The Export Cable Route dataset was acquired by N-Sea. These data were then interpreted by Gavin and Doherty Geosolutions who produced a ground model and fully interpreted Kingdom project datasets. Wessex Archaeology would like to acknowledge the above organisations for their input to this project in these regards.

North Irish Sea Array Offshore Wind Farm – Palaeogeographic Investigation

Archaeological assessment of geophysical data

1 INTRODUCTION

1.1 Project background

1.1.1 Wessex Archaeology was commissioned by GoBe Consultants Limited (GoBe) and Arup on behalf of North Irish Sea Array Limited (NISA Ltd) to undertake a palaeogeographic assessment of the proposed North Irish Sea Array (NISA) Offshore Wind Farm (OWF) and associated export cable corridor (ECC). This was to be undertaken as part of assessments associated with the proposed development scheme.

1.1.2 The GSA is defined by the geophysical dataset received and relates to the initial array area and ECC survey areas (for this report this is called the Geophysical Study Area- GSA), located within the Irish Sea off the coast of County Dublin, to landfall around the County Dublin/County Meath boundary (Fig. 1). The array area and ECC areas are also presented on this figure.

1.1.3 The report consists of an assessment of geophysical survey data comprising sub-bottom profiler (SBP) data only.

1.2 Aims and objectives

1.2.1 The aims and objectives of this assessment are:

- identify any buried palaeolandscape features of possible archaeological potential; and
- provide recommendations for archaeological mitigation.

1.3 Co-ordinate system

1.3.1 The survey data was acquired in WGS84 UTM30N, and all results are reported in the same coordinate system.

2 METHODOLOGY

2.1 Data sources

2.1.1 The GSA geophysical datasets were initially collected by Fugro and then transferred to GeoSurveys Ltd for initial processing. ECC data was acquired by N-Sea. The processed dataset was then provided to Gavin & Doherty Geosolutions Ltd. (GDG) who further processed and interpreted the data, producing two fully geologically interpreted Kingdom project datasets, and two associated Ground Model reports.

2.1.2 The main datasets consulted during this assessment were as follows:

- Client supplied survey and interpretation reports (GDG 2023, Fugro 2023); and,
- Kingdom projects containing data acquired by Fugro and N-Sea and interpreted by GDG.

2.2 Geophysical data – technical specifications

2.2.1 The geophysical data for the array were acquired by Fugro between February-March 2022 onboard the *Fugro Mercator*, and the ECC data were acquired in September 2022 by Fugro, with data collection performed on the N-Sea vessel *Geo Focus* offshore, and the sub-contracted Hydromaster vessel, *Ros Aine.* Further details on the equipment used is in **Table 1**.

Table 1 Summary of survey equipment

Survey Company	Survey Vessel	Data Type	Equipment	Data Format
Fugro	*Fugro Mercator*	SBP	Innomar standard parametric Sonar	*.sgy*
		SBP	Geo Marine Survey Systems Geo-Source 400 Sparker Geo-Sense reference hydrophone – single element	*.sgy*
N-Sea	*Ros Aine*	SBP	Innomar SES-2000	*.sgy*
	Geo Focus	SBP	Innomar SES-2000	*.sgy*
		SBP	GSO-360	*.sgy*

2.3 Geophysical data – Interpretation

2.3.1 The geophysical data were interpreted using the following software (**Table 2**).

Table 2 Software used for geophysical assessment

Dataset	Interpretation Software	Interpretation and rationalisation
Seismic	S&P Kingdom	S&P Kingdom, ArcMap 10.8.1

2.3.2 The geophysical data, in the form of processed and interpreted Kingdom datasets, were used as the primary datasets for the palaeographic assessment. Kingdom is a software suite for the interpretation of seismic data sets, allowing for the processing, visualisation and interpretation of seismic surveys and the identification of features and horizons of interest by applying colour bars and adjusting settings to adapt the method of visualisation to suit the dataset on a line-by-line basis. Interpreted horizons in individual lines can be extrapolated into grids to form fully visualised surfaces, which can then be visualised in 3D to form a recreation of the sub-surface environment, all aiding in the identification and interpretation of shallow geological features that may be of archaeological interest.

2.3.3 The geophysical data were interpreted with a two-way travel time (TWTT) along the z-axis. In order to convert from TWTT to depth, the velocity of the seismic waves was estimated to be 1,600 ms^{-1}. This is a standard estimate for shallow, unconsolidated sediments.

2.3.4 The Kingdom datasets were received with stratigraphic horizons interpreted, as well as the identification of acoustic hyperbole and shallow gas accumulations. Alongside these datasets were ground model reports, detailing the interpreted geology. This was reviewed alongside previous Wessex project reports from around the area and reviewed as part of an initial analysis.

2.3.5 Using both the previously interpreted dataset and associated report literature, stratigraphic units were reviewed and identified. Once units had been identified, the seismic data were analysed to interpret the potential depositional environments, with a view to identify those environments that were most likely to be of high archaeological potential.

2.3.6 For the geophysical assessment, the initial analysis focussed on the identification of features mentioned in previous reports (GDG 2023). From here, additional channels were interpreted, and a priority was made to ascertain the extent of identified channel complexes present.

2.4 Geophysical data – data quality

2.4.1 The geophysical data sets were individually assessed for quality and their suitability for archaeological purposes and rated using the following criteria (**Table 3**).

Table 3 Criteria for assigning data quality rating

Data quality	Description
Good	Data which are clear and unaffected or only slightly affected by weather conditions, sea state, background noise or data artefacts. Seabed datasets are suitable for the interpretation of upstanding and partially buried wrecks, debris fields, and small individual anomalies. The structure of wrecks is clear, allowing assessments on wreck condition to be made. Subtle reflectors are clear within SBP data. These data provide the highest probability that anomalies of archaeological potential will be identified.
Average	Data which are moderately affected by weather conditions, sea state and noise. Seabed datasets are suitable for the identification of upstanding and partially buried wrecks, the larger elements of debris fields and dispersed sites, and larger individual anomalies. Dispersed and/or partially buried wrecks may be difficult to identify. Interpretation of continuous reflectors in SBP data is problematic. These data are not considered to be detrimentally affected to a significant degree.
Below Average	Data which are affected by weather conditions, sea state and noise to a significant degree. Seabed datasets are suitable for the identification of relatively intact, upstanding wrecks and large individual anomalies. Dispersed and/or partially buried wrecks, or small isolated anomalies may not be clearly resolved. Small palaeogeographic features, or internal structure may not be resolved in SBP data.
Variable	This category contains datasets where the individual lines range in quality. Confidence of interpretation is subsequently likely to vary within the GSA.

2.4.2 The quality of the Parametric Sonar and Sparker data in the array area has been rated as "Good" using the above criteria and allows for detailed analysis of the palaeogeography. The data quality for the Parametric Sonar and Sparker data in the ECC area were judged as "Below average", as noted in GDG (2023), due to poor conditions at sea and chosen acquisition parameters. As such, palaeogeographical analysis was difficult in this location, with units of interest obscured by low-quality data. However, alongside interpretation and processing undertaken by the project originator (GDG 2023), it was possible to identify major features within the data, and, as such, was deemed acceptable for the purpose of this assessment.

2.5 Geophysical data – feature discrimination

2.5.1 The previous section describes the initial interpretation of the SBP data, which results in the identification of numerous palaeogeographic features which may be of different origins, ages, and types. Following this initial process, archaeological potential discriminations are applied to features to help identify those of high archaeological potential. Each feature is also assigned an individual ID number at this stage. The archaeological discriminations used for palaeolandscape features are as follows (**Table 4**).

Table 4 Criteria discriminating relevance of identified features to proposed scheme

Overview classification	Discrimination	Criteria	Data type
Archaeological	P1	Feature of probable archaeological interest, either because of its palaeogeography or likelihood for producing palaeoenvironmental material	SBP
Archaeological	P2	Feature of possible archaeological interest	SBP

2.5.2 The grouping and discrimination of information at this stage is based on all available information and is not definitive. It allows for all features of potential archaeological interest to be highlighted, while retaining all the information produced during the course of the geophysical interpretation and desk-based assessment for further evaluation should more information become available.

2.5.3 Any features located outside of the defined GSA, are deemed beyond the scope of the current assessment and are subsequently not included in this report.

3 PALAEOGEOGRAPHIC ASSESSMENT

3.1 Geological baseline and archaeological potential

3.1.1 The following is an overview of the geological and archaeological history of the wider region from the Pleistocene to the Holocene marine transgression. This is based on a range of secondary sources, including academic papers, monographs, geological information (e.g. BGS mapping), and previous work undertaken by Wessex Archaeology within the Irish Sea area and the wider region. This serves as a baseline for the palaeogeographic assessment, and aids in producing a stratigraphy for the GSA, assigning archaeological potential to identified units, and informing future sampling strategies. The basement geology of this area of the Irish Sea comprises sandstones and mudstones dating from the Cambrian through to the Triassic, with Carboniferous mudstone, sandstone and limestone being expected in the central and western Irish Sea, as well as some localised igneous intrusions (Jackson *et al.* 1995, Mellett *et al.* 2015, MMT 2021).

3.1.2 The upper surface of the bedrock represents a significant unconformity, and the bedrock units are directly overlain by Quaternary sediments within the GSA (Jackson *et al.* 1995, Mellett *et al.* 2015). The Quaternary history of the Irish Sea, as with most of the British Isles and Ireland, is complex and has been dominated by recent glacial/interglacial cycles, which have been recorded within the regional geology.

Pre-Elsterian to Eemian (>478 ka – 115 ka; >MIS 12 – 5e)

3.1.3 The western Irish Sea has experienced at least three glacial advances and retreats since the Elsterian period. These advances and retreats are recorded as repeated phases of major incisions, lodgement/ablation tills, and associated interglacial deposits and landforms identified at different levels within the Irish and Celtic Sea stratigraphic records of the Britian and Ireland ice sheet (Jackson *et al.* 1995, Mellett *et al.* 2015, Giglio et al., 2022).

3.1.4 The periodic formation and ablation of ice sheets affected local (and global) relative sea levels, fluctuations in which likely resulted in the western Irish Sea being periodically sub-aerially exposed. Although the region was directly covered by ice during multiple glacial advances, periods of time may have existed between marine regression and glacial advance (and *vice versa*) where the landscape was free of both water and ice.

3.1.5 From an archaeological perspective, evidence for human occupation, from populations expanding westwards during phases of favourable climatic conditions, prior to 700,000 years, has previously been recorded at sites around the North Sea basin, particularly in the East Anglia region (Parfitt *et al.* 2005, Parfitt *et al.* 2010). Periods of sub-aerial exposure of the shallow shelf areas around the British Isles has permitted the movement of Pleistocene animals and facilitated occupation and exploitation of this landscape by early hominins. Direct evidence of hominin occupation of the shallow shelf areas of south east England has previously been identified off the coast of Suffolk, when numerous lithic artefacts dating from the Early Middle Palaeolithic (c. 350 ka – 180 ka BP) were recovered from the seabed during aggregate dredging (Wessex Archaeology 2011d, Tizzard *et al.* 2014).

3.1.6 At present, there is limited archaeological evidence of earlier Palaeolithic archaeology in Ireland, with four isolated lithic finds of Lower to Middle Palaeolithic appearance having been identified: two hand axes of uncertain provenance and two flakes from re-worked contexts (Westley and Woodman 2020). However, the presence of Palaeolithic cave sites along the North Wales coast indicates that occupation of the Irish Sea coastal hinterland during times of low relative sea level was possible. In particular, early Neanderthal remains discovered in Pontnewydd Cave near St Asaph, Denbighshire, dating from c. 225 ka before present (BP), indicate hominin presence in the area during the Early Middle Palaeolithic, prior to the late glacial maximum (LGM) (Lynch *et al*. 2000, Flemming 2005). However, the area will have been uninhabitable during the heights of the Elsterian and Saalian glaciations and so will have been abandoned during these periods. As such, any habitation in the area was potentially sporadic and punctuated by extended periods of absence.

Weichselian to Late Glacial Maximum (c. 115 ka – 18 ka; MIS 5d – 2)

3.1.7 The Devensian glaciation was the last, although not the most extensive, glacial advance experienced by Britain and Ireland, during which the Irish Sea was again likely to have been entirely covered by ice. Relict terrestrial features still visible on the seabed, such as drumlins, moraines, eskers, and periglacial patterned ground, are all evidence of the advance and retreat of the Devensian ice sheet and its effect on the underlying landscape (Jackson *et al.* 1995, Van Landeghem *et al.* 2009, Van Landeghem and Chiverrell 2011, Mellett. *Et al.* 2015).

3.1.8 Several bathymetric deeps within the area are interpreted as being tunnel valleys which were proglacial or sub-glacially formed by the Irish Sea Ice Stream during the Last Glacial Maximum when it was the main ice stream draining the former British-Irish Ice Sheet (Coughlan *et al.* 2020).

3.1.9 As noted in section 3.1.6, there is rare evidence of earlier, Palaeolithic human activity in Ireland; however, more recently, development-led investigations around Loughshinny have resulted in the discovery of two lithics within a bulk soil deposit. Initial analysis of the lithics was based on the assumption that these were Neolithic or Bronze Age samples, but later radiocarbon dating of the bulk soils places the deposit at 47,000 years old (Kyle, 2023). Should this discovery be further validated, it suggests Upper Palaeolithic human activity during the pre-LGM Pleistocene, which would significantly expand the archaeological record of Ireland.

3.1.10 The reasons for relatively scarce of Palaeolithic evidence are unclear; however, it may be explained in part by the removal of material by subsequent glaciation (Westley and Woodman 2020). Within the Irish Sea, palaeoenvironmental analysis of borehole samples acquired for the Walney OWF in the eastern Irish Sea recovered pollen sequences relating to the Upper Palaeolithic (ca. 34 ka BP), suggesting isolated pockets of material from the earlier, pre-glacial advance of the Devensian period may have survived further offshore (Wessex Archaeology 2010a). Although, as with the previous glacial advances, the area would again have been uninhabitable and abandoned by the Last Glacial Maximum. It is also hypothesised that a lack of faunal resources, particularly large game animals, may have made Ireland a less viable location for subsisting (Westley and Woodman 2020).

3.1.11 Across the Irish Sea in Wales, there is evidence of occupation at least during the earlier Devensian, with Neanderthal finds dating from 50 ka BP identified from Coygan Cave near Tenby, and modern human remains dating from 26 ka BP discovered in Paviland Cave on the Gower Peninsular, both in South Wales (Lynch *et al.* 2000, Flemming 2005).

Post-Late Glacial Maximum and early Holocene (18,000 – 6000 BP; MIS 2 – 1)

3.1.12 The history of the Irish Sea since the LGM is unclear, and relative sea level (RSL) content for the region is complicated due to complex interactions between global sea level rise and isostatic readjustment (Flemming 2005, Shennan *et al.* 2011, Westley and Woodman 2020). There is a general lack of robust RSL data points beyond relatively shallow water and the Holocene (Plets et al., 2015) making inferences on palaeolandscape development and archaeological potential currently difficult from academic and available datasets alone. The long-standing view suggests that, as climate conditions warmed and the ice front retreated northwards, relative sea level remained low throughout the whole Irish Sea, exposing the area as a terrestrial environment for a significant period of time (Jackson *et al.* 1995, Coles 1998). The opening of the North Channel between 16 and 15 ka BP allowed a gradual inundation, with approximate modern day sea levels reached by around 6,000 ka BP (Coughlan *et al.* 2020).

3.1.13 This is also supported by work undertaken as part of the West Coast Palaeolandscapes Survey (WCPS), where potential Holocene features such as coastlines, fluvial channels (e.g. the offshore extension of the river Mersey across Liverpool Bay) and deltaic features were identified and mapped from geophysical data sets (Fitch *et al.* 2011). Potential Holocene terrestrial features were also identified during the assessments of the Irish Sea Round 3 Zone, Rhiannon OWF and Awel y Môr which supported this (Wessex Archaeology 2011d, 2014, 2021).

3.1.14 However, more recent studies undertaken in the area suggest a marine termination of the retreating ice sheet with no, or a very limited, period of sub-aerial exposure between LGM and marine transgression (Van Landeghem *et al.* 2009, Van Landeghem and Chiverrell 2011, Mellett. *Et al.* 2015). This is based in part due to the presence of interpreted iceberg plough marks cut into the now submerged relict glacial landforms on the seabed of the Irish Sea, suggesting direct iceberg calving into water from the foot of the retreating ice sheet (Van Landeghem *et al.* 2009, Van Landeghem and Chiverrell 2011).

3.1.15 Flemming (2005, p. 16-17) proposes a third model for glacial retreat – one with an extensive proglacial lake which initially partially covered the present-day Irish Sea area, before retreating northwards with the ice front to expose a terrestrial landscape, followed by final inundation sometime after 7,000 BP. This model would explain iceberg calving into a large lake, whilst still providing a terrestrial environment within which features such as those identified by Fitch *et al.* (2011) could develop.

3.1.16 The correct model of glacial retreat has significant consequences for the post-LGM archaeological potential of the Irish Sea; a fully inundated landscape has low potential for the deposition of artefacts, and *vice versa*. However, the majority of models and field evidence agree that the Late Glacial/Early Holocene low stand, which occurred across the Irish shelf, is concurrent with the earliest occupation of Ireland (Westley and Woodman 2020). As models suggest that Ireland was not connected to Britain from at least 15,000 years ago, it is hypothesised that Mesolithic settlement in Ireland was accomplished by people who were able to make seafaring journeys (Westley and Woodman 2020).

3.1.17 Post-LGM archaeological evidence includes four isolated lithics, as well as a cut-marked bear patella (radiocarbon dated to 12,810 – 12,590 cal BP) and cut marked bear vertebrae (dated to 11,080–10,400 cal BP), both found in Alice and Gwendoline Cave (County Clare). This material suggests human activity during the Later Upper Palaeolithic, if not full-time occupation (Dowd and Carden 2016, Westley and Woodman 2020).

3.1.18 Assuming a terrestrial followed by transgression model, gradual sea level rise would have probably placed much of the Irish Sea either on the coastline or just offshore by the Mesolithic period (c. 10 ka – 6 ka BP) (Shennan and Horton 2002). Past identification of submerged peat deposits and drowned forests around the Irish and Welsh coastlines of the Irish Sea suggests coastlines in the area were stable for periods of time during marine transgression (Steers 1948, Flemming 2005, Wessex Archaeology 2009, Westley and Woodman 2020).

3.1.19 The earliest, irrefutable evidence of occupation in Ireland is an Early Mesolithic hunter-gatherer camp at Mount Sandel in County Derry, dated to c.9800 cal BP (Dowd and Carden, 2016, Westley and Woodman 2020), which appears to have a single, continuous phase of archaeological activity. Although the make-up of the flint assemblages discovered at Mount Sandel suggest that there may have been earlier traces of Mesolithic settlement which have not yet been discovered in Ireland (Bayliss & Woodman 2009).

3.1.20 It is thought that during the Mesolithic, populations were mobile hunter gatherers (Westley and Woodman 2020). The Mesolithic record of Britain and Ireland suggests a strong relationship between human activity and coasts, wetlands, rivers and streams. These areas provide rich sources of food and resources for these hunter/gatherer groups, as well as important transport routes inland or between islands. Any surviving sedimentary deposits from this period could potentially contain both *in-situ* and derived artefacts from a time when these coastal and littoral landscapes, now submerged by the sea, were utilised intensively by human populations.

3.1.21 In addition to these submerged coastal landscapes, the Mesolithic archaeological record potentially contains examples of coastal or sea going craft made from dugout logs or hide covered wooden frames as well as worked flint and chert artefacts.

3.1.22 A number of archaeological sites have been identified around the coast of Ireland although, at present, none of the sites which are completely submerged are *in situ* sites (Westley and Woodman 2020). However, it should be noted that two worked flint nodules were recovered during dredging works on the Arklow Bank in 2003 ahead of work for the Arklow Bank Wind Park, just to the south of the GSA (Campbell 2003, SPLASHCOS, Westley and Woodman 2020).

3.1.23 By the end of the Mesolithic, the Irish Sea would have been completely submerged, with coastlines approximately close to their present-day positions, and archaeological evidence from the Neolithic onwards will be of an increasingly maritime nature. However, continued use of the intertidal zone surrounding the Irish Sea has been found in the form of lithic and organic artefacts, including a log boat, dated to 5500–5000 cal BP which was found in intertidal mud in Strangford Lough, Northern Ireland (Westley and Woodman 2020). Further offshore, any artefacts from this period not related to maritime activity are likely to be derived and re-deposited after introduction to the area by fluvial processes or coastal erosion.

3.2 Palaeogeographic assessment results

Overview

3.2.1 A number of palaeogeographic features of archaeological potential have been identified within the GSA. These features are discussed below, individually described in gazetteer format in Appendix 1.

3.2.2 The identified geology within the GSA has been divided into 4 phases and 7 units, as described in **Table 5**.

Stratigraphy

Table 5 Shallow stratigraphy of the GSA

Formation	Unit	Unit name	Geophysical Characteristics (1)	Interpreted Sediment Type (2)	Archaeological Potential
Surface Sand Formation	4b	Holocene Sediments SL1– Post-transgression (Holocene, MIS 1)	Acoustically quite with occasional, rare, bedded reflectors, dependant on location.	Unstructured marine muds and silts.	Considered of low potential, but possibly contains reworked artefacts and can cover wreck sites and other cultural heritage.
	4a	Holocene Sediments SL2 – Pre-transgression / transgression (Early Holocene, MIS 2 – 1)	Broad blanket deposit characterised by numerous horizontal reflectors. Basal reflector obscured by gas in places.	Possible intertidal to marine sediments of sands, silts and clays. Shallow gas within base of unit, and possible channels extant.	Potential to contain *in situ* and derived archaeological material, and palaeoenvironmental material.
Western Irish Sea Formation	3c	Mud facies (late Devensian, MIS 2-1)	Generally, acoustically quiet with some dipping internal reflectors, although occasionally seen as chaotic	Glaciomarine to marine Muds.	Likely a glacial deposit, and so low potential for *in situ* archaeological material, but may contain derived material depending on age.
	3b	Prograded facies (Late Devensian, MIS 2 – 1)	Variable geophysical characteristics, ranging from chaotic to internal dipping reflectors. Generally, a strong basal reflector.	Potential delta front deposit comprising muddy sands, infilling channels in preceding glacial deposits.	Likely a glacial/ glacial proximal deposit, and so low potential for *in situ* archaeological material, but may contain derived material depending on age.
	3a	Chaotic facies (Late Devensian, MIS 2 – 1)	Weakly defined characteristics. Acoustically chaotic with occasional dipping horizons.	Potentially glaciolacustrine/glaciomarine gravels and cobbles displaying poor cohesion.	Likely a glacial proximal deposit, and so low potential for archaeological material.
Cardigan Bay Formation	2	Upper Till (Devensian, MIS 5d – 2)	Chaotic, with frequent hyperbole and occasional dipping reflectors.	Stiff to hard glacial melt-out till.	Glacial till – low potential for in situ archaeological material.

Formation	Unit	Unit name	Geophysical Characteristics (1)	Interpreted Sediment Type (2)	Archaeological Potential
Caernarfon Bay Formation	1	Incision infill member (Elsterian, MIS 12-5)	Acoustically variable according to overlaying sediment. Faint bedding structures visible.	Spatially limited, roughly bedded diamictonic glacial infill. Variable sedimentation rates due to successive glacial melting phases lead to the formation of rough bedding planes.	Unlikely to contain archaeological material.
	(1) Based on geophysical data (2) Based on geophysical characteristics, Jackson *et al.* (1995), and Mellett *et al*. (2015)				

3.2.3 The potential sediment types described in **Table 5** are based on previous research in the wider region (e.g. Jackson *et al.*1995, Mellett et al., 2015) and the geophysical characteristics of the units. No ground truthing data (e.g. core logs) have been supplied to Wessex Archaeology from within the GSA at this time, and such sampling would be required in order to confirm (or otherwise) the sedimentary interpretation provided in this report.

3.2.4 Sediment thickness across the GSAs is variable, with two distinct zones of increased quaternary sediment package thickness. Sediment thickness is greatest in the north-east of the array area and in the western ECC area, with locations displaying the greatest thickness appearing to conform to a north-west/south-east orientation. When comparing the extrapolated orientations to the trend of glacial features onshore Ireland, these areas of increased quaternary basal depth can be inferred to align with general onshore glacial trends, suggesting that these areas were cut by glacial action. As both features appear to extend beyond the boundaries of the survey area, however, further study with additional datasets would be required to confirm this.

3.2.5 Unit 1 represents the oldest quaternary sediment present within the surveyed area. This unit is composed of dimictic glacial infill and belongs to the Incision Infill member of the Caernarfon Bay formation. Spatially discontinuous throughout the area of interest, Unit 1 is present within glacial channels and in limited thickness overlying the region's Palaeozoic bedrock. In those areas where the unit is thick enough, rough bedding structures are visible. These structures are likely to have been generated by successive glacial melting phases supplying the region with temporally limited increased sediment supply.

3.2.6 The acoustic signature of this unit is variable in strength across the area of interest, with the level of visibility relying on the acoustic characteristics of the overlying material, though the upper boundary is represented by a strong acoustic return throughout. When at its thinnest, the internal structure can appear chaotic. Within thicker units, the bedding planes of the Incision Infill Member are clearly visible, though with rough laminations that have been deformed. Occasionally shallow gas presence in the upper layers of the column can heavily occlude identification of the sedimentary structures by causing acoustic "blanking" of the underlying data (Fig. 2). Unit 1 formed within the Elsterian, and, as such, predates human inhabitation of the region, so it is not judged archaeologically significant.

3.2.7 Unit 2 is a deposit of over consolidated glacial till (Fugro 2022), deposited during the Midlandian glaciation and is, to a lesser extent to Unit 1, spatially discontinuous, with a greater concentration present in the north-western reaches of the GSA. In the data, Unit 2 is seen to be generally acoustically unstructured and chaotic, with occasional sloping reflectors and frequent acoustic hyperbole which may represent gravel accumulations or glacial dropstones.

3.2.8 Unit 2's archaeological potential relies upon the outcome of future investigation in the region and characterising the origin of reworked sediments. 10 km to the south of the ECC at Loughshinny Beach, deposits containing anthropogenic material (worked flints within bulk soils) potentially from as early as 47,000 years ago have been encountered (Kyle, 2023), but no definitive conclusion regarding the potential for this unit is currently possible.

3.2.9 Shallow gas in the region has been interpreted in both the wider GSA around the array and ECC locations. Previous studies (Fugro 2022, GDG 2023) identify the potential for biological material to be included within the strata of Unit 4a, either reworked or *in situ*. While this may be a source for some shallow gas, in many locations the upper boundary of shallow gas migration is within lower units (Fig. 2)

3.2.10 Shallow gas identification has been linked to two locations specifically, one in the ECC and the other in the wider GSA around the array area (Fig.3). Both instances occur only in locations where the quaternary sediment is at its thickest. Units 1 and 2 have been identified as containing pockets of organic matter (GDG 2023). It is therefore hypothesised that shallow gas may have originated from either of these units. Due to the limited size of the GSA, it is difficult to fully constrain the shape and orientation of sediment supply these units, though initial analysis suggests that they are oriented towards onshore glacial features, and future surveys may allow a greater constraint of the scale and orientation of glacial deposition.

3.2.11 All three units of the Western Irish Sea formation (Units 3a, b and c) are present in both areas, and are seen to be acoustically chaotic, with occasional dipping reflectors and frequent hyperbole which may represent gravel accumulations and/or dropstones. While there is the potential that the prograded and later glaciolacustrine units may contain reworked archaeological materials, this is unlikely as the units themselves predate the earliest archaeological evidence of *Homo* migration into Ireland. As such this unit has been judged as being of low archaeological interest.

3.2.12 Units 4a and 4b represent members of the Surface Sands Formation, recording the final transgressive phases of the region from the beginning of the Holocene. Unit 4a is visible as a broad bed with well defined, numerous horizontal reflectors, and comprises interbedded laminae of mud and silt, reflecting the changing energy of sediment flow into the region. Unit 4b is acoustically quiet, from the strong basal reflector to the seabed. This is likely due to the unconsolidated nature of the sediments due to their relatively recent deposition as well as the depositional environment.

3.2.13 Unit 4a is visible across the GSA in all locations. Formed of muds and silts in well-defined beds, the unit is frequently cut by channels within the wider GSA around the array area. The channels are likely to have formed cyclically, possibly with sea-level change being the key controlling factor in the changing deposition. Channelised strata may represent a period of low sea-level and exposure. Channels were potentially cut by fluvial systems supplied from inland and were arrayed as part of an interpreted lower delta plain. Sea level would then rise, and the channels would be infilled by marine muds and silts.

3.2.14 Identified within Unit 4a are four features recording fluvial environments. Features **70001** and **70002** (Fig. 4), are interpreted as two major channel complexes that may have been deposited at the same time. While these features may be part of the same channel system, there is no evidence within the GSA, so no conclusions can be drawn. With regards to the orientation of channels, a north-west to south-east trend has been tentatively viewed, though study limitations prevented full analysis of palaeochannel orientation and spatial distribution. Within palaeochannel features **70001** and **70002,** channels are distributed vertically, suggesting closely spaced intertidal cycles (Fig. 5).

Palaeogeographic context

3.2.15 Features **70001** and **70002** (Fig. 4, 5) are observed around -58 to -60 m LAT. Within the context of existing relative sea level models, and the noted lack of sea level reference points in deeper water (see section 3.1.12), these palaeochannel complexes suggest a notably lower relative sea level context (e.g. examples summarised in Westley & Woodman 2020) at the time of their formation. The unit stratigraphy (Table 5) suggests an early Holocene / Late Pleistocene age.

3.2.16 Features **70003** and **70004** (Fig. 6, 7) are observed around -46 to -4 9m LAT. These features are interpreted as being a channel and channel complex associated with the same intertidal system as **70001** and **70002**, recording a final intertidal deltaic environment prior to transgression. These features are at a slightly higher elevation than 70001 and 70002, and located landwards, perhaps indicating the transgressive formation of the palaeo-deltaic system as post-LGM sea levels rose in the region. Continuous data coverage from these features is not available to the current coast (the ECC is located to the SW), but these features may reflect major relict coastal systems of the “palaeo-Boyne” valley.

3.2.17 **70003** is a broad (>1000 m) channel visible on multiple lines (Fig. 5), trending north-west to south-east before becoming no longer visible. The basal reflector of channel **70003** is not always clear in the SBP data, making the exact extents of the feature difficult to discern. It is possible that **70003** may represent a continuation or segment of the channel complex **70004**, although this is not certain.

3.2.18 Infill of features **70003** and **70004** is interpreted as being largely Unit 4a, though some do have a component of post-transgressional infill. As with **70001 and 70002,** these features are thought to represent former coastal geomorphology, and, as such, the sediments associated with these features are deemed to be of high archaeological potential, as they could contain *in situ* or derived anthropogenic artefacts, preserved palaeoenvironmental archives which may also record sea level reference information (e.g. organic and minerogenic sediments, microfossil and other proxy records that can inform and potentially date horizons in the stratigraphy relative to sea level of the time).

3.2.19 Unit 4b is the most recent deposit, and is acoustically quiet, with only occasional laminations rarely visible. Assessed to be a marine deposit, it is unlikely to be of palaeogeographic and prehistoric archaeological interest in itself. Reworked and out of context ecofact and artefact material may be encountered. The more mobile upper reaches of this sediment may obscure more recent features of maritime archaeological interest, though this is outside of the remit of this current study.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Palaeogeographic features of archaeological interest

4.1.1 The wider GSA around the array and ECC areas contain sedimentary stratigraphy indicating a well-preserved post-LGM glacial-marine transgressional record, reflecting the development of a terrestrial glacial environment through to marine transgression throughout the Holocene. The unit with the greatest archaeological interest was observed to be Unit 4a; SL2 of the Surface Sands formation.

4.1.2 The assessment of the geophysical data within the GSA resulted in the identification of four features of palaeogeographic interest and prehistoric archaeological potential. These comprised three channel complexes, **70001, 70002** and **70004** and one individual channel feature, **70003** all of which were assigned a P1 archaeological rating.

4.1.3 As terrestrial and coastal features interpreted as being deposited during periods of known human activity of the British Isles and Ireland, those features given a P1 archaeological rating are considered of high archaeological potential.

4.1.4 Furthermore, Relative Sea Level data from deeper water locations and corresponding understanding of the archaeological potential of these palaeolandscapes, offshore Ireland, are rare, very poorly constrained and identified as a national priority for study (e.g. Plets et al., 2015, Westley and Woodman 2020).

4.2 Recommendations

4.2.1 Preliminary geoarchaeological assessment, such as review of geotechnical logs, core logging and sub-sampling, would aid in refining the interpretation of these features, and therefore help determine the archaeological potential of the area. This would include any regional marine and terrestrial context, where available, for these extensive and complex palaeochannels and palaeo-deltaic system identified within this report.

4.2.2 It is recommended that any future geotechnical logs from within the GSA are made available for geoarchaeological assessment by a suitably qualified and experienced geoarchaeologist in order to more fully characterise the palaeogeographic baseline.

4.2.3 It is recommended that a geoarchaeologist be consulted in advance to advise on obtaining/retaining potential high-potential samples from these campaigns or to acquire dedicated vibrocores/boreholes for geoarchaeological purposes within the identified features of archaeological interest, particularly from palaeochannel 70003, and other identified features of archaeological interest identified.

4.2.4 If warranted, based on the results of preliminary geoarchaeological assessment of existing logs, more detailed and targeted paleoenvironmental analysis and dating of high-potential geotechnical samples may be recommended and reported on, in discussion and agreement with relevant Stakeholders and their archaeological advisors.

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APPENDICES

Appendix 1: Palaeogeographic features of archaeological potential.

ID	Classification	Depth (mBSB)		Archaeological discrimination	Description	Area
		From	To			
70001	Palaeochannel Complex	18.0	21.2	P1	Palaeochannel complex **70001** is a wide palaeochannel complex within the central array area. Largely restricted to mid-depth zone of Unit 4a, the fluvial processes forming this complex appear to have been active for a stretch of time, with channels appearing within the complex vertically across a thickness of approx. 2.4m, occurring from -58 to -60.4 mLAT or 11.2 mBSB. The area in which has been identified is approx. ~110 Sq.km	Array
70002	Palaeochannel Complex	5.2	12.0	P1	Palaeochannel complex **70002** is a wide palaeochannel complex in the northernmost reaches of the wider GSA around the array area. Largely restricted to mid-depth zone of Unit 4a, the fluvial processes forming this complex appear to have been active for a stretch of time, with channels appearing within the complex vertically across a thickness of approx. 2.4m, occurring from -58 to -60.4 mLAT or 11.2 mBSB. This complex is approx. ~11 Sq.km, though likely extends out of the survey area.	GSA outside array area
70003	Palaeochannel	6.4	12.8	P1	Palaeochannel **70003** is a broad (~1000m at widest) feature appearing on multiple lines in the West-central region representing a single large palaeochannel. The length of the recorded channel is ~4000m. This feature is visible on 9 SBP seismic lines and is ~6.4mBSB, from -46.4 to -48.8 mLAT.	Array
70004	Palaeochannel Complex	6.4	12.8	P1	Palaeochannel complex **70004** is a complex limited to the western array area vertically associated with Channel **70003**. Identified as covering ~25 Sq. Km, the channel complex is tentatively identified as preserving the channels from a lower delta plain. This complex is visible on multiple seismic lines, and is approximately 6.4 mBSB, from -46.4 to -48.8 mLAT.	Array