Unpath'd Waters: Lands Beneath the Sea

Work Package 3.3 Data Package Documentation

Background - Doggerland

At the height of the last glacial period, around 20 ka (20,000 years ago), when global sea levels were 130 metres lower than present, 20 million km² of new territory was exposed along the world's continental margins. The European continent expanded by as much as 40%, exposing over 3 million km² of new land. Once deglaciated, this vast territory persisted for thousands of years.

In northwest Europe, the largest of these areas was in the southern North Sea and is often referred to as Doggerland. With an area approaching that of Great Britain, its coastal plains, low hills, lakes, river valleys, marshes, estuaries, shorelines, and offshore islands would have provided some of the most productive territories and resources for human settlement and dispersal anywhere in Europe. From 16 ka onwards, progressive global warming and sea-level rise transformed and inundated this landscape. By 6 ka, these unique territories had almost entirely disappeared.

Essentially *terra incognita* for millennia, investigations in Europe have generally focused on the discovery and excavation of late Mesolithic and early Neolithic settlements and cultural deposits (circa 7–5 ka) in shallow waters close to the modern shoreline, accessible for diver investigation. However, these findings represent only the final stages of sea-level rise. Even today, we know very little about the deeper, previously habitable areas of Doggerland and the communities that likely lived there.

An alternative approach has been to model landscapes in the North Sea using seismic data collected by the hydrocarbon industry and higher-resolution geophysical remote-sensing and sediment coring from research vessels. This approach has enabled the mapping and dating of much older (>8 ka) and more deeply submerged landscape features, including major river valleys, coastlines, marshes, and lakes. Over the past decades, researchers in the UK and Europe have pioneered such methods, resulting in significant knowledge of the area's topography and environment. However, this remains a largely depopulated landscape in our understanding, with little evidence of its former inhabitants.

Even with these advances, we have only tantalising glimpses of this underwater world. Moreover, ongoing climate change and the rapid expansion of offshore wind farms and other marine industries are set to intensify in the coming years. This creates an imperative for the research community to develop better and more engaging methods to:

- Inform the public about the significance of archaeological landscapes they may never see or visit.

- Provide researchers with innovative ways to interact with this data.

- Guide public policy on the location and management of the unique underwater cultural heritage of the North Sea.

Data Package

The data package has been developed to facilitate access to a broad range of datasets covering the Late Pleistocene to Holocene submerged landscapes of the southern North Sea. Users are strongly encouraged to access the original datasets whenever possible.

Palaeolandscape Shapefile Data Sources

The palaeolandscape shapefile data was compiled from multiple sources and serves as the foundation for the palaeolandscape features represented in the simulation model for this work package. The simulation can be viewed at https://zwack.itch.io/unpathd-home.

North Sea Palaeolandscapes Project (NSPP)

- Created in 2005–2006 using 3D seismic data from the PGS Southern North Sea MegaSurvey and the Central North Sea MegaSurvey (now TGS).

- Features were digitized from these datasets and revised during the *Unpath'd Waters* project as new data became available.

Submerged Landscapes Research Centre, University of Bradford

- Data from the ERC-funded *Europe's Lost Frontiers* project (2015–2021), including data acquired by the University of Bradford in collaboration with the Flanders Marine Institute (VLIZ).

- Southern North Sea MegaSurvey (2015 version).

Dutch Open Access Data

- Open-access 3D seismic data from the DEFAB dataset and the A15 license block, interpreted for palaeolandscape features during the *Unpath'd Waters* project to improve spatial coverage in the Dutch sector.

- Available via the Dutch Oil and Gas Portal (https://www.nlog.nl/en).

Additional Sources

- UK Sector: Features were digitized from open-access windfarm reports and academic literature. Detailed references are included in the shapefile's attribute table and in the *UK and Dutch Windfarm Document Sources* spreadsheet.

- Dutch Sector: Features were compiled from open-access sources provided by the Netherlands Enterprise Agency (RVO).

Key Reports and Literature

These are the full references cited within the attribute table of the features shapefile that are not given elsewhere.

1. Thames REC (2009) Outer Thames Estuary Regional Environmental Characterisation by EMU Ltd and the University of Southampton for MALSF. Accessible at https://eprints.soton.ac.uk/153173/.

2. Wessex Archaeology (2013) Wessex Palaeo-Yare Catchment Assessment.* Available via the Archaeology Data Service (ADS).

3. Dove et al. (2017) Phased occupation and retreat of the last British–Irish Ice Sheet in the southern North Sea; geomorphic and seismostratigraphic evidence of a dynamic ice lobe. Quaternary Science Reviews, 163, 114–134.

4. Brown et al. (2018) Late glacial/early Holocene palaeoenvironments in the southern North Sea Basin: new data from the Dudgeon offshore wind farm. Journal of Quaternary Science, 33(6), 597–610.

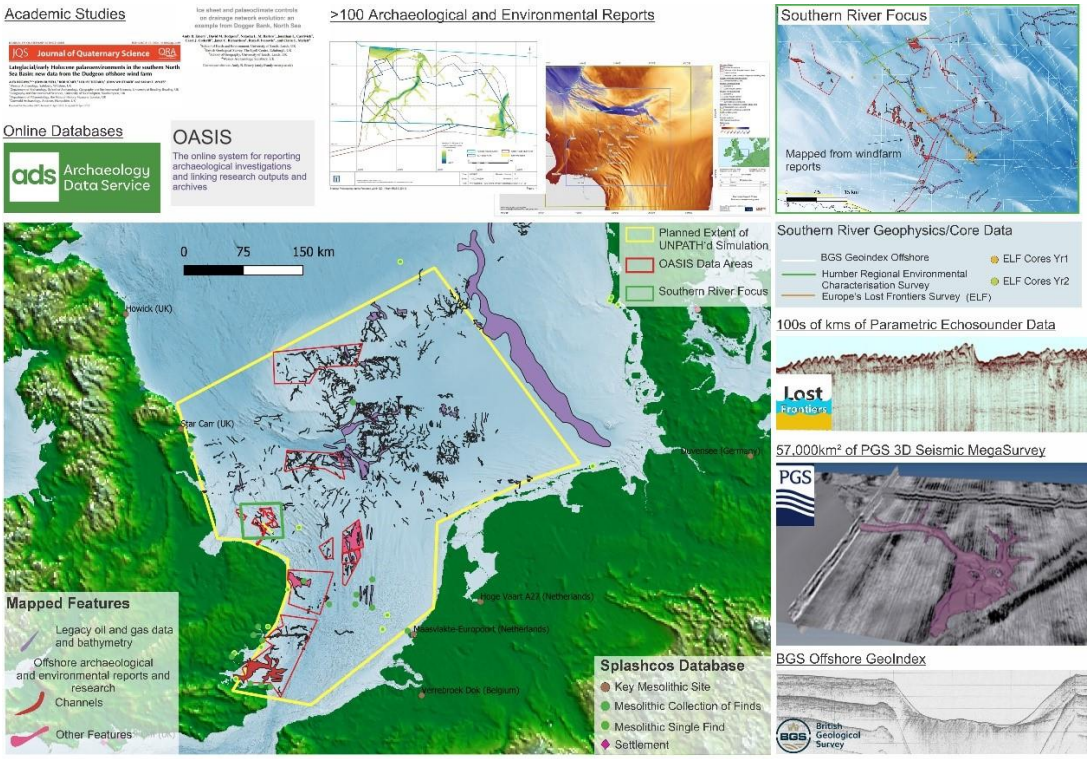


Figure 1 Data types utilised to map key features

Shapefile Construction

The shapefiles were created in QGIS v3.34.13 using the WGS84UTM31 coordinate reference system. Each feature layer includes attributes such as type, relative age, source, and metadata.

<u>Features</u>

- Most features are "negative," such as palaeochannels, representing depressions in the landscape and are within the shapefile *Unpath'd Waters Palaeolandscape Features.*

- Positive features (e.g., high ground) are separated into a distinct shapefile (*Unpath'd Waters Positive Palaeolandscape Features*).

<u>Compilation and Interpretation</u>

- Features not derived from seismic data were digitized from maps in open-access reports or academic publications.

- Where original files were unavailable, data was georeferenced and digitized.

- The collection of external data and digitization of raw geophysical information was completed in stages as new data became available.

- Features were merged into a single layer with a standardized attribute table, including type, relative age, source, and access date.

Notes on Use and Future Development

This data package is a prototype and will continue to be developed at the University of Bradford. It is not intended for direct targeting of features; users should refer to original data sources.

The package amalgamates palaeogeographic features from the Late Pleistocene to the early Holocene, representing a composite view of landscapes rather than a single moment in time.

Future external projects may refine interpretations and mapping, particularly for windfarm areas where original data was unavailable during this work.

Geophysical Data Interpretation and Workflow

Software and Data Sources:

Industry-standard geophysical software, including S&P Global's Kingdom and Schlumberger's Petrel, was employed to interpret subsurface features.

3D seismic reflection datasets:

High-resolution datasets (~meter-scale) covered extensive areas, enabling the identification of large-scale features such as drainage systems.

These datasets were crucial for visualizing channel systems and tunnel valleys, allowing for analysis of their form, structure, and potential reuse by Holocene channels.

Ultra-high-resolution sparker and parametric echosounder data:

Derived from the Europe's Lost Frontiers project, these data provided centimeter- to decimeter-scale resolution for finer subsurface imaging.

The limited lateral coverage of these datasets, dictated by budget constraints, restricted their application to targeted areas.

Data Processing and Interpretation Techniques:

Enhancing visibility through attributes:

Algorithms (attributes) were applied to 3D seismic volumes to highlight geomorphological features, such as channels, incised valleys, and drainage patterns.

Mapping geomorphological features in flat and complex areas:

In areas with flat strata, time slices were generated to create a bird's-eye view of channel systems. External edges of key features were digitized and categorized.

In areas where strata were more complex, seismic layers were manually "picked" and converted into grids. Attributes were then applied to extract additional feature details, such as sediment infill and cross-cutting relationships.

Exporting data to GIS:

Polygons representing interpreted features were exported as shapefiles, integrated into QGIS, and added to feature layers for visualization and analysis.

Interpretation Depth and Key Findings:

Features were interpreted down to a depth of approximately 70ms (milliseconds two-way travel time).

Tunnel valleys, incised features, and Holocene channels were mapped. Many of these features likely had surface expression during the period of interest, particularly before they filled with sediment during early Holocene sea-level rise.

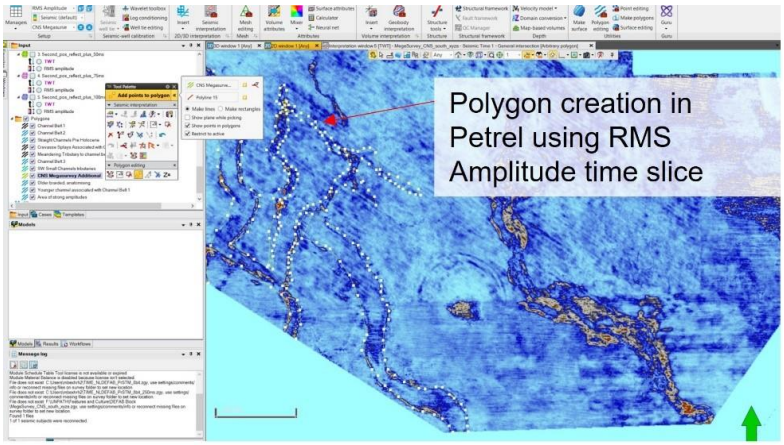
Earlier features, formed during lower sea levels, were observed to have been modified into broader, shallower features due to sediment deposition during transgression events.

Contribution to Simulation Development:

Geological layers developed for the simulation combined features into a single layer with an arbitrary depth of -5m, based on the average channel depth from the Lost Frontiers project.

This generalized approach was necessitated by the lack of precise dating and depth control for many features.

Future work aims to refine the depth and chronology of these features to enhance their accuracy in simulations.



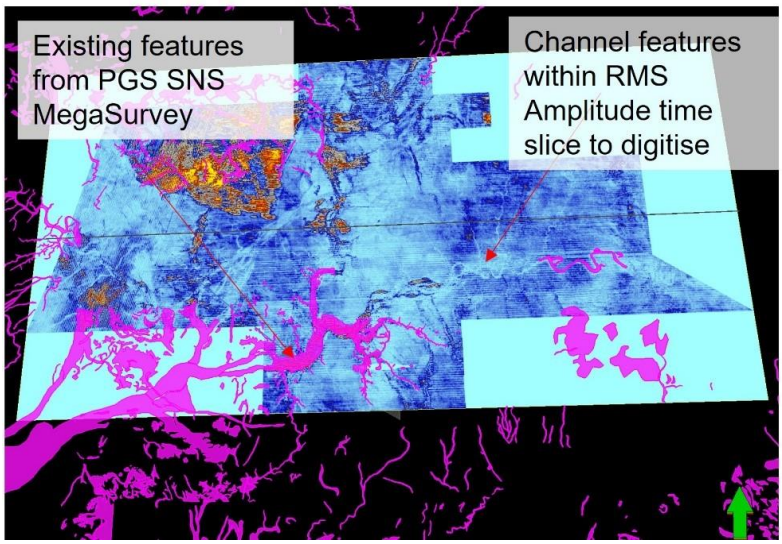


Figure 2 Example of the digitisation process using 3D geophysical data within Schlumberger's Petrel software, generously donated to the University of Bradford. The data shown is from the DEFAB block, open-access legacy oil industry data originally acquired by Fugro and available via the Dutch Oil and Gas Portal (https://www.nlog.nl/en).

Palaeogeography and Comparisons with Academic Models

Incorporation of Academic Contributions:

The dataset includes digitized interpretations of palaeochannels and drainage patterns across the southern North Sea, drawn from key academic studies (Amkreutz et al., 2022; Garcia Moreno, 2017; Hijma and Cohen, 2011).

These reconstructions represent hypotheses about drainage patterns during the period of interest, offering valuable insights into the evolution of the submerged landscape.

Raw vs. Extrapolated Data in Current Work:

The current simulation deliberately uses raw, unextrapolated data to maintain accuracy and avoid introducing biases.

Academic reconstructions were included in the data package for reference but were not directly applied to this version of the simulation.

Future Applications:

Future iterations of this work will integrate these palaeogeographic reconstructions with the raw data to produce updated drainage pattern models.

These updates will inform outreach materials, including refined palaeogeographic maps of Doggerland for both academic and public audiences.

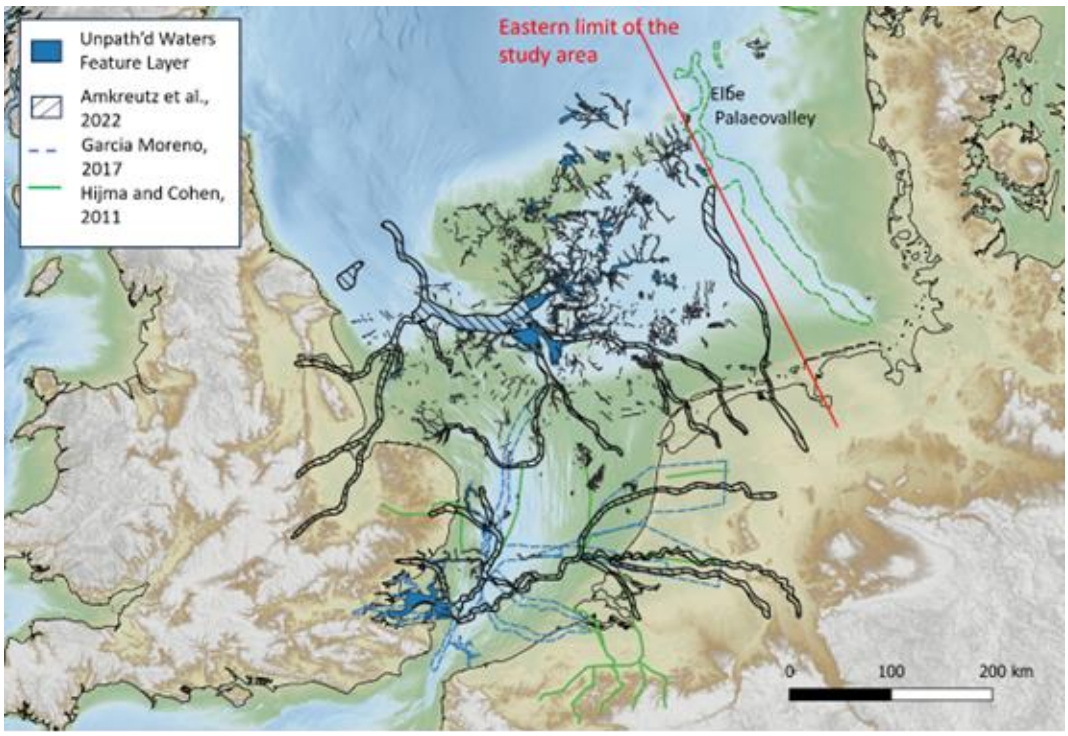


Figure 3 Comparison of academic sourced palaeogeophraphic reconstruction with the Unpath'd Waters feature layer. Background is GEBCO bathymetry utilising the WIKI 2.0 colour ramp to highlight areas which would have been land during the early Mesolithic at about 10,000 years ago (green) and which would be marine (blue).

Palaeoenvironmental and Peat Data

Direct Sampling Efforts:

Since 2016, over 80 sediment cores and ~3m² of dredged material have been collected from sites spanning the Doggerbank to the Brown Banks.

Sampling was conducted by the Submerged Landscapes Research Centre and includes:

-Pollen analysis for vegetation reconstruction.

-SedaDNA and diatom studies to understand palaeoecological conditions.

-Geochemical analyses to characterize sediment composition and provenance.

-Radiocarbon (C14) and optically stimulated luminescence (OSL) dating to establish chronological frameworks.

Core data, including photographs and dating results, are set to be published soon. These will be incorporated into the data package post-publication. The methods used are covered in the 2022 book Europe's Lost Frontiers Volume 1, which is open access. Inquiries about specific boreholes can be directed to submergedlandscapes@bradford.ac.uk.

Peat Feature Layers:

Peat data is represented in two formats: polygons and points shapefiles, reflecting the original data sources' nature.

Key sources include:

NSPP datasets and windfarm reports (UK and Dutch sectors).

EMODnet's Organic Rich Deposits and Environments which includes data from the Historic England Offshore and intertidal peat deposit database: Hazell (2008): Offshore and intertidal peat deposits database, providing essential context for historical peat layer mapping.

Peat data is restricted to samples within 10m of the seabed where there is no dating of the sections available to ensure compatibility with post-Last Glacial Maximum and marine inundation timescales.

The *Coastal Landforms-Wetlands-PG Layer*, which is part of the EMODnet Organic Rich Deposits and Environments layer is not included in the data package but is recommended for download directly from EMODnet, as it contains higher-resolution data. Compiled by TNO, the layer is available via EMODnet (https://emodnet.ec.europa.eu/en). For best results, this layer should be displayed alongside the peat layers provided in this data package to enhance the understanding of peatland distribution and characteristics.

Archaeological Data

Primary Source:

The SPLASHCOS Viewer Database (http://splashcos.maris2.nl/) consolidates information on submerged prehistoric archaeology and landscapes across Europe.

This dataset is not included in the Unpath'd Waters Data Package, as it is already publicly available online. Users are encouraged to download it directly from the SPLASHCOS website and incorporate it into their GIS projects to complement the features provided in this package.

Supplementary Data:

Archaeological finds from the Submerged Landscapes Research Centre surveys (post-2016) are included as a polygon shapefile. This represents the broad areas where archaeological material has been recovered.

Additional **References used (Windfarm Reports denoted in Spreadsheet)**

Amkreutz, L., Cohen, K., Hijma, M., Odé, O (2022) Mapping a drowning land, in: Doggerland. Lost World under the North Sea. Edited by Luc Amkreutz & Sasja van der Vaart-Verschoof. Sidestone Press, Leiden.

Bradley, S.L., Ely, J.C., Clark, C.D., Edwards, R.J. and Shennan, I. (2023), Reconstruction of the palaeo-sea level of Britain and Ireland arising from empirical constraints of ice extent: implications for regional sea level forecasts and North American ice sheet volume. J. Quaternary Sci, 38: 791-805. https://doi.org/10.1002/jqs.3523

Brown, A., Russell, J., Scaife, R., Tizzard, L., Whittaker, J., & Wyles, S. F. (2018). Lateglacial/early Holocene palaeoenvironments in the southern North Sea Basin: new data from the Dudgeon offshore wind farm. *Journal of Quaternary Science*, *33*(6), 597-610.

Clark, C.D., Ely, J.C., Hindmarsh, R.C.A., Bradley, S., Ignéczi, A., Fabel, D., Ó Cofaigh, C., Chiverrell, R.C., Scourse, J., Benetti, S., Bradwell, T., Evans, D.J.A., Roberts, D.H., Burke, M., Callard, S.L., Medialdea, A., Saher, M., Small, D., Smedley, R.K., Gasson, E., Gregoire, L., Gandy, N., Hughes, A.L.C., Ballantyne, C., Bateman, M.D., Bigg, G.R., Doole, J., Dove, D., Duller, G.A.T., Jenkins, G.T.H., Livingstone, S.L., McCarron, S., Moreton, S., Pollard, D., Praeg, D., Sejrup, H.P., Van Landeghem, K.J.J. and Wilson, P. (2022), Growth and retreat of the last British–Irish Ice Sheet, 31 000 to 15 000 years ago: the BRITICE-CHRONO reconstruction. Boreas, 51: 699-758. https://doi.org/10.1111/bor.12594

Clark, C.D., Ely, J.C., Fabel, D., Bradley, S.L. (2022): BRITICE-CHRONO maps and GIS data of the last British-Irish Ice Sheet 31 to 15 ka, including model reconstruction, geochronometric age spreadsheet, palaeotopographies and coastline positions [dataset]. PANGAEA, https://doi.org/10.1594/PANGAEA.945729

Dove et al., 2017 academic artcle full reference:, Dove, D., Evans, D. J., Lee, J. R., Roberts, D. H., Tappin, D. R., Mellett, C. L., ... & Callard, S. L. (2017). Phased occupation and retreat of the last British–Irish Ice Sheet in the southern North Sea; geomorphic and seismostratigraphic evidence of a dynamic ice lobe. *Quaternary Science Reviews*, *163*, 114-134.

Garcia Moreno, D (2017) Origin and geomorphology of the Dover Strait and southern North Sea palaeovalleys and palaeo-depressions. PhD Thesis. University of Ghent. http://hdl.handle.net/1854/LU-8536549

Hazell, Z. J. (2008). Offshore and intertidal peat deposits, England — a resource assessment and development of a database. *Environmental Archaeology*, *13*(2), 101–110. https://doi.org/10.1179/174963108X343227

Hijma, M.P. and Cohen, K.M. (2011), Holocene transgression of the Rhine river mouth area, The Netherlands/Southern North Sea: palaeogeography and sequence stratigraphy. Sedimentology, 58: 1453-1485. https://doi.org/10.1111/j.1365-3091.2010.01222.x

Missiaen, T., Fitch, S., Harding, R et al. (2022) Targeting the Mesolithic: Interdisciplinary approaches to archaeological prospection in the Brown Bank area, southern North Sea, Quaternary International, 584: 141-151. https://doi.org/10.1016/j.quaint.2020.05.004

Thames REC Outer Thames Estuary Regional Environmental Characterisation written by Emu Ltd & University of Southampton for the Marine Aggregate Levy Sustainability Fund (MALSF), July 2009 https://eprints.soton.ac.uk/153173/

Wessex Palaeo-Yare Catchment Assessment, Wessex Archaeology, January 2013 available from the ADS