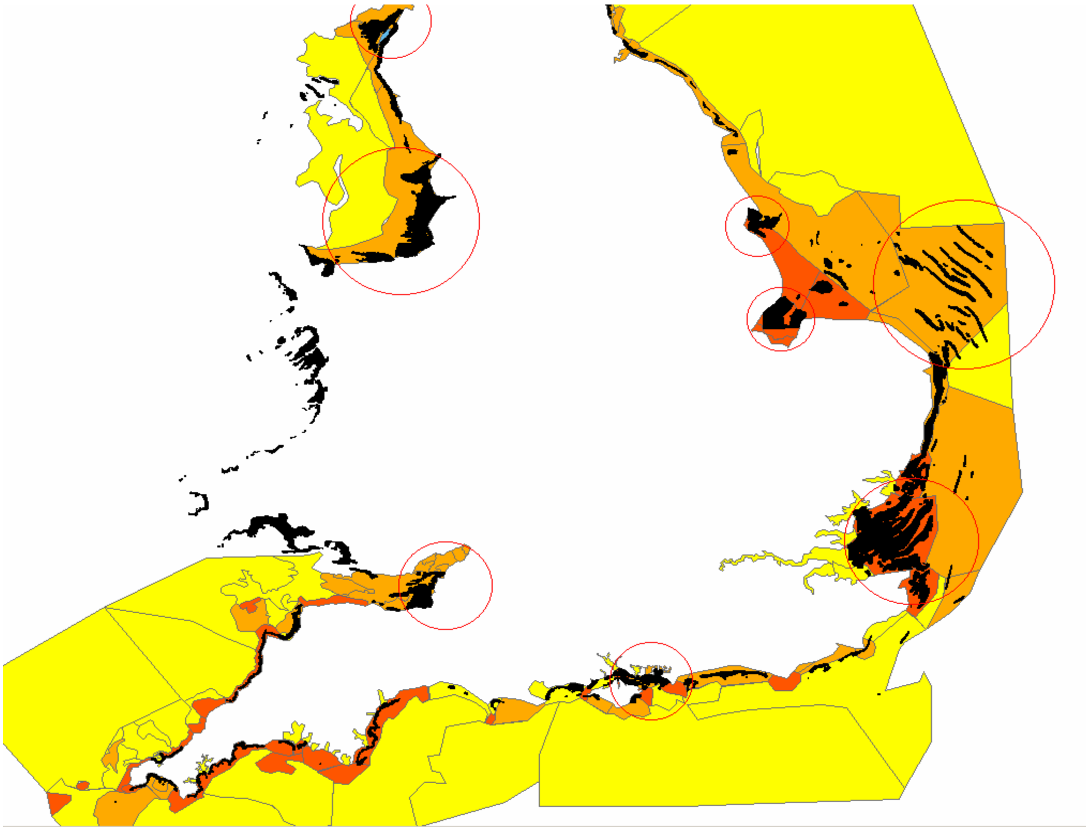
Bournemouth University

ENHANCING OUR UNDERSTANDING OF THE MARINE HISTORIC ENVIRONMENT:
NAVIGATIONAL HAZARDS PROJECT

FINAL REPORT



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for

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ENHANCING OUR UNDERSTANDING OF THE MARINE HISTORIC ENVIRONMENT

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1. INTRODUCTION

1.1. Bournemouth University has been commissioned by English Heritage to undertake a project entitled *Mapping Navigational Hazards as Areas of Maritime Archaeological Potential*, which is being funded by the Aggregate Levy Sustainability Fund.

1.2. The project uses historical records of navigational hazards to interpret and characterise the hazardous nature of the marine environment. The trends identified from historical records have been combined with a model of the preservation potential of marine sediments in order to identify areas where a high potential for ship losses coincides with a high potential for preservation of archaeological materials. These areas, known as Areas of Maritime Archaeological Potential (AMAPs) and the characterisation on which the interpretation was based has been supplied as a series of GIS layers, linked to an associated geodatabase.

1.3. The core objective of the English heritage ALSF scheme is to reduce the impact of aggregate extraction on the marine historic environment. Under Objective 2 of the ALSF, the Navigational Hazards project has provided a firm basis for the characterisation of the potential for the presence of archaeological materials in different marine environments, in order to assist industry, regulators and curators in giving guidance on the possible impact of different types of aggregate extraction on the marine historic environment.

1.4. This document reports on the methodological developments following the pilot study produced in February 2006 and outlines the final conclusions of the project. The report reflects Milestone 3 of the project.

2. BACKGROUND

2.1. The development of a method for characterising the potential for the maritime archaeological resource to exist and survive in different seabed environments is vital to improving the assessment of potential impacts of aggregate extraction on the historic environment and developing a long-term strategic approach to the management of marine historical assets. The results of the Navigational Hazards project represent the foundations for the development of a quantative system for assessing the archaeological potential for shipwreck material in the marine environment.

2.2. A proposal has been put forward to continue to develop and refine the method for assessing archaeological potential through the identification of AMAPs. The AMAP1 project will build on the conclusions of the Navigational Hazards project, integrating the results with available data on the preservation potential of marine environments and with a quantative analysis of the potential significance of shipwrecks scatters.

2.3. The results of the data will be produced for the National Monument Record. The system has already been put to use for characterising and informing the English heritage Maritime team on the potential for loss and preservation of archaeological materials for areas surrounding designated wrecksites. It is also being proposed that the system be independently trialled for development-led impact assessments by the *Hampshire and Wight Trust for Maritime Archaeology,* in order to provide feedback which can be used to enhance the ALSF-funded *AMAP1 project* methodology.

2.4. A Source Appraisal (Milestone 1) was undertaken in September 2005 to assess the quality, accessibility and availability of primary and secondary source data drawn from historical charts and other primary sources. The results of the source appraisal highlighted the wide contrasts in accuracy and detail of charts from different periods. The review also suggested that there was a great deal of duplication of information between sources as a result of which a phasing of source data was proposed for the project.

2.5. The method proposed in the Project Design was reviewed during the Pilot Study produced in February 2006. The primary sources were gathered, georeferenced and applied following the requirements of the Project Design as far as possible in order to extract and map historical evidence on the recording of navigational hazards. The results of the Pilot Study were outlined in a report (Milestone 2) produced in February 2006.

2.6. During the development of a pilot method, the need for the information on navigational hazards to be brought together in the form of a characterisation was highlighted. This was due to the inherent spatial inaccuracies affecting many of the primary sources such as charts and maps, and the inability to accurately map written sources such as pilot books and sailing directions. A Variation Request was submitted to English Heritage to request changes to original method proposed.

2.7. A database, derived from the ArcGIS geodatabase was developed during the Pilot Study to display the relationships between data gathered including the historical records which, due to their spatial inaccuracies, cannot be included directly within the GIS but must be linked to their mapped modern equivalent hazards in order to support the project results. This includes data relating to the historical sources, the descriptions of the hazard data extracted from these sources and additional tables such as the sediment preservation potential model. The character polygons and modern hazards have been incoropr ated within the database format as well as being accessible within the GIS.

3. AIMS & OBJECTIVES

3.1. Project Aim

3.1.1. The aim of the project is to use the UK's extensive hydrographic archives, including charts, sailing directions and pilotage notes, and modern seabed geology mapping to identify and map Areas of Maritime Archaeological

Potential (AMAP) , areas where high potential for shipwreck losses coincide with areas of high preservation potential.

3.1.2. The output of the project aims to produce a GIS system which can be put to immediate use in informing industry, regulators and curators on the potential impact of aggregate extraction and other intrusive industrial activities on the unrecorded archaeological resource on the seabed. A system which could be put to immediate use as well as being further developed through later projects would provide the marine industry with the foundations for a quantative assessment of the potential for unrecorded shipwreck material to exist within seabed sediments.

3.1.3. The project has advanced the key aims of the ALSF priorities by:

1. Improving our understanding and ability to ***assess the potential impact and the significance of aggregate extraction*** on maritime heritage assets by promoting a better understanding of the processes which affect historical assests within aggregate licensed areas.

2. Enabling stakeholders to make more informed decisions on how to manage the marine environment and ***improve efficiency during the planning process*** by providing end-users with interpreted marine data through the accessible and flexible spatial medium of GIS and the ***development of a national dataset***

3. Enabling the potential for shipwreck remains to be better quantified by integrating grading systems for the data displayed within the system and ***enabling areas of increased archaeological potential to be identified*** and increasingly accurately characterised.

4. Providing a firm foundation for ***developing an effective management tool*** for predicting archaeological potential which can be used to better evaluate the historical asset and develop best practice mitigation strategies and long-term management plans

3.1.4. The project aim addresses the following priorities listed in Taking to the Water (Roberts & Trow, 2002):

(a) Projects designed to enhance and validate the Maritime Record through desk based survey (para12.5 point 1)

(b) National evaluation studies to characterize poorly recorded or little understood elements of the seamless maritime cultural landscape (para 12.5.point 7)

(c) Studies designed to develop methodologies that can help seabed developers meet their obligation under the Environmental Impact Regulations to identify underwater cultural heritage and mitigate damage incurred in the course of their activities (para 12.5 point 9)

3.2. Project Objectives

3.2.1. The objective of the project is to design a staged methodological approach to drawing data from sources which informs us on the nature, recording and historical importance of navigational hazards in English waters and creating a format which allows the data to be combined with a sediment stability model in order to produce AMAPs. The data needs to be presented in a format which is compatible with modern marine spatial planning datasets so that it can be integrated with them for the process of marine spatial planning.

3.2.2. The following objectives need to be achieved in order to meet the project aim:

- Identify and map all known navigational hazards within the project area
- create character polygons to reflect the interpretation of navigational hazards to characterise the hazardous nature of different marine environments
- Develop a model to reflect the preservation potential of the various geological forms shown on the BGS offshore seabed mapping
- Identify areas of seabed where high potential for shipwreck losses coincide with high potential for preservation of archaeological materials.
- Meet the relevant requirements of The ALSF and English Heritage research priorities

4. METHODOLOGY

4.1. Introduction

4.1.1. The project was conducted by the Primary Researcher responsible for the day-to-day running of the project, under the supervision of the principal investigators. Input was also received from the consultant employed on the project to advise on navigational issues.

4.1.2. The development of the methodology continued following the initially production of a system based around a pilot area in the Solent. The application of the pilot method to the wider study area highlighted the need for some adjustments to be made to the data structure in order to optimise the user's ability to query the contents of the GIS and database.

4.2. Background

4.2.1. The methodology used to create the GIS layer needs to be as uniform as possible across the study area chosen to produce a consistent approach to data gathering. The application during the Pilot Study (Merritt et Al., 2006) of the method proposed in the Project Design (Parham et Al., 2005) showed that fewer sources than anticipated could be used as a basis for digitising data in the GIS. This led to a reappraisal of the methodology described both in the Project Design and in the Source Appraisal (Merritt et Al., 2005).

4.2.2. The Variation Proposal suggested that the hazard data be gathered as points rather than polygons to avoid misrepresentation of historical features through the digitisation of polygons from inaccurate sources. The points would then provide the basis for the creation of a series of character polygons to which the historical data could be attached. These polygons could then be used in combination with the sediment stability model to create AMAPs.

4.2.3. On this basis, the GIS has been developed to provide a characterisation of areas containing different combinations of navigational hazard on two levels. In addition to providing a description of the hazards, the relationships between them and their recording in historical sources, the trends arising from the data encouraged the creation of a typology for hazardous environments based on the historical data gathered. Recurring trends in environmental hazards such as water depth and exposure to prevailing winds were incorporated with the hazard data to enable the identification of areas where these hazards coincide. These variables have been typologised as far as possible and given a simple grading system to enable the data to be easily queried in order to identify AMAPs. The concept of a typology was identified during the Pilot phase of the project and has been extensively developed during the core phase of the research project

4.3. Data Collection

4.3.1. As with the Pilot Area, data was gathered from a series of repositories to gain an even coverage of charts from the earliest Portulan to recent Admiralty charts. Sailing directions and name places were also reviewed for further information on the hazardous features identified from the charts in the Solent pilot area.

4.3.2. The libraries visited for the purpose of the project included:

- the archives of the UK Hydrographic Office (UKHO),
- the Caird Library at the National Maritime Museum (NMM),
- the Maritime Collection and Archive Office at the Southampton City Library (SCL),
- Southampton University Libraries,
- Bournemouth University Libraries,
- Personal Libraries.

4.3.3. Historical charts were used as core datasets to provide a basis for mapping navigational hazards. Descriptive information provided in written documents such as sailing directions, place names and piloting notes were used to support data contained in charts.

4.3.4. The reoccurrence of navigational hazards in historical sources suggests either that they are well known features, either because they are easily identifiable or because they present a substantial and reputable hazard to boats and ships. Therefore, the project sought to identify and characterise the reoccurance of key individual hazards or types of hazard.

4.3.5. Following the results of the Pilot Study, the collation of data was phased to ensure an even coverage of data for the whole study area. The Pilot Study showed a great deal of repetition in the data displayed between sources. This suggested that a phasing of data sources would produce clearer results than entering large quantities of data from charts which may have been reproductions from other sources. The data gathering was phased to target periods where large scale surveys were undertaken of the British Isles. This ensured that the repetition in data gathered would be minimised. The key phases in survey were identified from research undertaken during the Source Appraisal.

4.3.6. Therefore, the key phases of data gathered were as follows:

- Portulan charts (1200 - 1800s)
- Waggoners (1584)
- Collins Great Britain's Coasting Pilot (1630)
- Privately commissioned Admiralty charts (1630s - 1795)
- Early Hydrographic Office Admiralty Survey (1795 – 1850)
- Pilotage descriptions
- Place Names

4.3.7. From the early 20th century, the detail on Admiralty charts had increased to such a degree that their recording in the GIS blurred the trends identified from earlier charts, making it difficult to prioritise features by their importance. It was therefore proposed in the conclusions of the Pilot Report that a date limit be set for the project to the completion of the Beaufort surveys at around 1850. The charts produced during the Beaufort surveys provided the basis for modern Admiralty charts and were regularly updated but saw a sudden increase in detail around the turn of the century with the addition of military practice areas, dumping grounds and wrecks and obstructions. The project therefore focussed on gathering information on environmental navigational hazards to avoid blurring the earlier data gathered with extensive records of hazards produced by human action.

4.3.8. Additional digital data was obtained during the Pilot Study to provide a basis for developing character area polygons. *Seazone* bathymetric data and *BGS* sediment data was used as a guide for drawing the navigational hazard polygons used to describe the hazard data gathered from historical sources and for producing a layer of derived polygons. BGS sediment data was obtained for the development of the preservation potential model. The method for the production of character polygons was reviewed during the core phase of the project. The manipulation and typologising of sediments and bathymetry formed the basis for creating polygons which reflected the nature of the marine environment.

Georeferencing

4.3.9. Georeferencing was done using the tools provided in ArcGIS which enabled charts to be stretched to fit over modern charting using multiple reference points. As the errors in charting were a product of their time, due to inaccurate survey methods rather than contrasting chart projections, it was in most cases not possible to georeference to a standard which allowed features to be extracted from the chart as polygons. As survey methods evolved, the accuracy of charts gradually improved so that by the 19th century, there remained little difference between historical Admiralty charts and modern Admiralty charts.

4.3.10. It was found that accurate georeferencing of the trial charts was not achievable for most charts produced before 19th century standardised Admiralty charts. A method was therefore developed during the Pilot Study to gather data from even the most inaccurately georeferenced sources. This removed the need for accurate georeferencing of source data.

4.3.11. These conclusions provided the basis for a Variation Proposal to be put forward to make changes to the Project Design which would allow a GIS processing method to be developed which removes the requirement for accurate charting of features from historical sources. This method requires the features to be gathered as points rather than polygons and translated into character areas which summarise the data.

4.3.12. The accuracy of each chart used during the project has been recorded within the database as part of the source metadata.

Digitising

4.3.13. The limitations identified for the georeferencing of historical charts led to a reassessment of the methodology outlined in the Project Design and the Source Appraisal. An alternative approach was sought during the Pilot Study which required minimal variations in the original method proposed and met the aims and objectives of the project but tackled to issues arising from the pilot study.

4.3.14. In order to avoid the misrepresentation of data through the digitisation of inaccurate polygons, a Variation Request was submitted proposing that navigational features be digitised in the GIS as point data rather than polygons.

4.3.15. Each point recorded from historical sources has been linked to its equivalent modern key feature point plotted from modern charts via the modern feature name. This method allows data to be mapped from both charts and written historical sources irrespective of their spatial accuracy. All data digitised was recorded at a scale of 1:500 000. The scale of each chart has been recorded within the source forms in the database.

4.3.16. The hazards recorded include sandbanks, intertidal areas, rocks, cliffs and currents. In most cases features were drawn, but some feature where also annotated with names or descriptive notes. Other features relating to navigational safety such as buoys and beacons were also recorded where present as their presence suggests that the feature is important enough or dangerous enough to warrant marking to warn seafarers away from the risk.

4.3.17. The recording of anchorages on historical charts was documented as the data provides a useful insight into areas perceived as being less hazardous or “safer”, even in dangerous sea conditions. This suggests that even if hazardous features such as banks and rocks are present, the area may be sheltered enough, have the right seabed makeup and deep enough to provide a safe-haven. The anchorage data was later used to support the development of a grading system for hazard polygons in terms of potential risk from natural hazards.

4.3.18. The point data was gathered irrespective of the accuracy of the chart. The attributes contain a list of keywords based on the names of the features reflected in modern charts. These keywords allow the historically charted features to be linked to their modern equivalent to enable them to be accurately displayed and queried through the attributes. This removes the importance of spatial accuracy from the methodology as the focus is on enabling the charting of feature to be traced through the GIS by their name rather than their location.

4.3.19. This approach allows the data to be analysed and summarised into character areas, even if the feature’s name has varied between charts or their location does not fit within the correct polygon due to inaccurate charting. The polygons, discussed in further detail below were hand-drawn on the basis of bathymetry and seabed sediment types as these are the two variables, at this stage in the project, which most affect risk to navigation and potential for preservation.

4.3.20. Digitised features have been divided into five groups as follows (Map 1):

- Banks and spits
- Rocks, cliff and ledges
- Navigational marks
- Anchorages
- Sea state

Historical Data Attributes

4.3.21. The attribute list for the point data has been structured so that all the historical data is recorded in the same way. Although the data has been divided into sub-groups, each file has the same set of attributes. No changes were made to the attribute data for the points during the main phase of the project, following the Pilot Study.

4.3.22. The attributes are as follows:

Attribute	**Data Type**	**Description**
OBJECTID	AutoNumber	Auto ID
Shape	OLE Object	Auto object description
Source	Text	Source reference combining surveyor name and the date of chart publication to produce unique reference
feature_ty	Text	One word description of feature type. eg. spit, bank, cliff, beacon

Source_ty	Text	Description of the nature of the source eg. Port Book, Chart, Place Name
Feature_na	Text	In cases where the feature is annotated with a name, it is entered as spelt in the chart
feature_2	Text	Differentiation between whether the feature is a hazard, a safe haven or a hazard marker
Source_na	Text	Name of source. This has been reduced for long sources. The full name is then recorded in the database
Source_da	Number	Date of publication
Depiction	Text	Differentiated between features which are drawn but not annotated, those annotated but not drawn and those which are both
Notes	Text	Additional information on the feature including approximate location, nearby features, depth.
Nav_mark	Text	Whether there is a navigational marker present, entered as Yes or No
key_word	Text	based on modern feature name where referring to a bank or rock. For unamed features, nearest locality/town is entered

Table 1: Attributes collated for historical records for navigational hazards

4.3.23. The attributes are designed to deal with the variations in the name and location of features between charts. The language in which the chart is published may also vary. A record of the original description of the feature is therefore recorded in the attributes alongside its modern name to link it to its modern equivalent, enabling it to be traced through GIS and database queries.

4.3.24. A notes field has been added to the attributes to enable details to be added describing the location of the feature in relation to it's surrounding as this could prove invaluable in identifying misplaced features of feature only charted on a small number of charts.

4.3.25. The way in which features recorded are depicted in different sources is recorded as this may reflect on the perceived importance of a hazard. Some features are simply drawn onto charts while others are annotated with a name or even a note on the nature of the hazard. The mention of a feature in sailing directions, place names or other written sources could also imply a greater perceived importance of risk. Navigational markers have been recorded in association with their features as their presence suggests the perceived importance of a hazard to navigation.

4.3.26. Although the data was gathered using a GIS, the data is designed to be spatially displayed only through the modern feature data in the GIS. The historical data can be accessed using the database. The data has therefore been supplied in this format as records linked to a modern points layer as the provision of the spatial datasets could be misinterpreted if used in their original format.

Modern Data Attributes

4.3.27. The major features which figured repeatedly from the earliest charts onwards and were mentioned in sailing directions were recorded from modern bathymetry as key features (Map 2).

4.3.28. The modern features have been recorded to provide a basis for translating the historical features into a modern context by joining the historical data to their equivalent modern feature via a feature name. The distribution and feature type for these points also played a part in designing a set of character types and their environmental attributes.

4.3.29. In most cases, features were recorded using the names recorded on modern charts. A small number of natural features, such as some banks and most hazards relating to sea state, were recorded with no name if they recurred in historical charts but were not named on modern charts. In these cases a name referring to the location of the feature was created as a name is required in order to join the historical data to the feature. Navigational markers also tend to be drawn as symbols on charts rather than named.

4.3.30. The attributes structure used for modern feature points was different to that of historical data as is set out as follows:

Attribute	Data type	Example
OBJECTID	autoID	1029
HAZ_NA 1	Text drawn from modern charts	Bramble Bank
HAZ_TY	Text relating to historical character type	Sandbank
AREA	Text relating to Character area name	Brambles
SOURCE	Text	Seazone + UKHO 1192

Table 2: Attributes collated for modern records for navigational hazards

Hazard Point Data Analysis

4.3.31. The approach to data analysis has developed substantially from the method developed during the Pilot Study. The same method was used to interpret the relationships between point data in order to produce character areas. The data was therefore initially analysed by separating the hazard types into four groups and looking at the relationships between point types to identify areas with concentrations in navigational features.

4.3.32. The trends in feature types were compared with modern BGS sediment data, showing clear correlations between feature types and seabed sediments.

4.3.33. The trends identified from the analysis were combined with modern bathymetry, BGS sediment data and the predominance of a prevailing south westerly wind to provide the basis for the delineation of a set of manually defined character polygons. These polygons were attributed with broad environmental character descriptions which could then be attached to a final, higher resolution character polygon layer which had been derived from baseline marine datasets.

4.4. Character Area Development

Introduction

4.4.1. The aim of the Navigational Hazards project is to produce a final set of polygons which are derived from recognised and relevant baseline datasets, which reflect a high level of hazards in an area in the context of its environmental character, along with a high potential for preservation.

4.4.2. The relationships between the nature of the hazards, the marine environment and their recording within charts and other documents were highlighted during the development of the GIS during the Pilot Study. The reoccurance of these relationships suggested the potential for typologising character types as a basis for producing AMAPs.

4.4.3. .During the Pilot Study, the polygons for the character areas were drawn based on a combination of modern bathymetry, trends in the recording of navigational hazards and the standard concept of prevailing winds. The historical point data has been collated into a character description of each polygon which allows the user to access a summary of the navigational hazards taking effect and allows further information to be accessed on data sources, data accuracy and point data recorded via the database.

4.4.4. Following the Pilot Study, it was recognised that the use of manually produced character polygons, although free of copyright restrictions, did not meet data standards as outlined by the *Digital National Framework (DNF).* As the areas had been drawn using parameters drawn from bathymetry and seabed sediment types, a set of derived polygons were produced using the same datasets.

4.4.5. The character polygons for the Hazards project were therefore produced in four phases as follows:

- Production of hand-drawn broad “feeder” character areas, containing descriptions of trends in hazards and environmental character, which enable the characterisation to be fed via a union into derived polygon layer
- Production of higher resolution simple derived character polygons drawn from the manipulation of bathymetry and seabed sediments polygons containing graded depth and sediment preservation groups
- Integration of attributes from the “feeder” layer with the derived character polygons
- Identification of areas where high level of hazard coincides with high potential for preservation

“Feeder” Character Areas

4.4.6. The “feeder” character areas were developed from the method used during the Pilot Study. The term "feeder" was allocated in-house to indicate their primary purpose as broad scale container for producing the characterisation, later used for transferring the characterisation attributes to a higher resolution derived dataset from which the AMAPs have been extracted.

4.4.7. Each polygon had been given a character type which summarises the trends in hazards for each area. The potential for the definition of recurring environment types has been identified as a result of the pilot study. The use of a singular description however became more complicated as the study area was extended to the whole of English waters.

4.4.8. During the Pilot Study, the character descriptions were defined with the aim of identifying potentially reoccurring types of hazardous environment. The descriptions produced for the Solent Pilot area were as follows:

• Exposed rocky coastline with rocky outcrops and shingle banks offshore and onshore prevailing winds
• Exposed rocky coastline with ledges, no offshore hazards and onshore prevailing winds
• Partially sheltered deep channel with numerous anchorages, no offshore hazards
• Partially sheltered rocky coastline, with ledges, some offshore hazards and some anchorages
• Partially sheltered rocky coastline characterised by extensive rock ledges and offshore shoals
• Sheltered narrow channel with extensive sandy foreshore banks
• Sheltered natural harbour, very shallow muddy foreshore, limiting access to large vessels, sanbanks on approaches
• Sheltered Estuary approach with narrow channel, substantial mobile sandbanks and numerous coastal anchorages
• Sheltered Estuary with narrow channel, extensive foreshore banks and numerous anchorages
• Exposed rocky coastal area characterised by foreshore rocks and small offshore ledges
• Exposed offshore area on approaches to channel, no offshore hazards
• Exposed offshore area, deep water, no charted hazards

Table 3: Character descriptions produced during the Pilot Study, forming the foundations for the typologies produced for the main study

4.4.9. Following the Pilot Study, it was decided that to increase the potential for querying out trends in character, it would be beneficial to sub divide the character descriptions into four sub-groups: coastal character, hazard character, seabed character and conditions character. This enables more specific information on the marine environment to be drawn out of the GIS. It also provided a basis for a methodology to be produced for identifying areas where a combination of environmental characteristics suggest them to be more hazardous to shipping.

4.4.10. Character area descriptions are designed to reflect the trends in feature types recorded in historical sources and how they work together to reflect the hazardous level of the environment.

- *Coastal character* describes the character of sea areas, taking into account depth, distribution of prevailing hazards and location with respect to the coastline. The character types developed during the project are as follows:

- *Hazard character* describes the morphology of the seabed areas and trends in hazards natural hazards. The character types developed are as follows:

- *Conditions character* refers primarily to trends in sea conditions, sea state hazards and exposure of the sea areas to prevailing winds. The character types developed are as follows:

- *Seabed character* describes the prevalence of sediment types in each area, grouped to reflect their potential for preserving archaeological materials. The character types developed are as follows:

4.4.11. In order to apply best practice in the production of new digital datasets, character areas need to be derived from baseline datasets, as defined by the Marine Data Information Partnership (MDIP), which include seabed sediment data drawn from **BGS DigMapGB – Offshore250 Seabed Sediments theme (SBS)** and bathymetric data including **Seazone Hydrospatial Depth_areas**. The "feeder" polygons are therefore being used initially to identify trends in the character polygons produced, but for the final deliverables of the project, also enable the attributes gathered for the characterisation to be transferred to a derived set of polygons which represents the main GIS output of the project.

Derived Character Polygons

4.4.12. In order to produce a set of character polygons which meet standards of interoperability as outlined by the *Digital National Framework (DNF)*, a derived layer has been produced by manipulating bathymetry and seabed sediment types to produce a layer which reflects the datasets which most determine the nature of natural hazards in the marine environment. It is however recognised that in order to maintain, that interpretative character polygons should be derived from relevant baseline datasets.

4.4.13. The methodology employed was designed to meet copyright licensing requirements outlined by *Seazone Solutions Ltd.* and the *British Geological Survey (BGS)*. Both organisations have been approached for feedback on the acceptability of the methodology. The manipulation applied was the same for both datasets.

4.4.14. The polygons needed to be drawn from bathymetry and seabed sediment types as water depth and seabed sediments are the two variables, within the scope of this project, which most affect risk to navigation and potential for preservation. These were also the datasets used to guide the delineation of the "feeder" polygons.

4.4.15. An alternative set of character polygons has therefore been derived from bathymetry and sediments to more accurately reflect the project results. The potential for copyright issues surrounding the manipulation of these datasets has however been recognised.

4.4.16. To produce the character polygons, sediment types derived from Folk's Triangle Classification for seabed sediments (1954) by the BGS were grouped based on five categories of grain size:

- *Coarse grained sediments*
- *High % of coarse grain sediments*
- *High % of fine grain sediments*
- *Fine gained sediments*
- *Solid Bedrock Deposits*

4.4.17. Each group was selected out from **BGS DigMapGB – Offshore250 Seabed Sediments theme (SBS)** and saved as a separate layer.

4.4.18. Each layer was then buffered using a 500m buffer to reduce the number of islands, smooth the polygons and further generalise the BGS data, to avoid reproduction of BGS polygons.

4.4.19. Overlaps created by the buffers were then removed by using archaeologically significant data groups with a higher potential for preservation (based on grain size) to erase the coarser grain layers. This approach prioritises areas with a predominance of fine grain sediments whilst making it impossible to reproduce original BGS data from the resulting polygon layer.

4.4.20. The resulting layer showed broad trends in grain size based on BGS sediments, highlighting areas based on the five categories ranging from fine grained sediments to solid bedrock deposits (**Map 7**), based on the sediment preservation model reported on in Appendix 1.

4.4.21. The bathymetric data was then processed in the same way, using **Seazone Depth_Areas,** by re-categorising the polygons, clipping them using the shallowest seabed groups and unioning them to produce the following categories within a single layer (**Map 8**):

- *under 10m*
- *10-20m*
- *over 20m*

4.4.22. The derived sediment groups and depth groups were then unioned to produce a single layer of polygons with attributes reflecting the categories listed above.

4.4.23. The attributes of the unioned layer have then been populated via a spatial join using a hand-drawn polygon layer which reflects the original results of the environmental characterisation of navigational hazards. The output layer provides the basis for extracting the AMAP polygons which reflect a high potential for loss, based primarily on depth of water and a high potential for preservation based on the ratio of fine grained sediment to coarse grained sediments.

Copyright Issues

4.4.24. The copyright issues surrounding the manipulation, reproduction and transfer of digital data to English Heritage are currently not clearly defined. Consultation has therefore been sought with *Seazone Solutions Ltd.* and the *British Geological Survey* to ensure that no copyright regulations are infringed upon during the project development. As a response has not yet been received and the management of these copyright issues lies outside of the remit of the project, The Project Officer and the Corporate GIS Co-ordinator at English Heritage will both be kept up-to-date during discussions and will be advised in writing of the conclusions when the issues have been resolved.

4.4.25. It is therefore recommended that the derived polygons be made available for internal use only in the meantime, until an agreement has been made. The “feeder” polygons on the other hand are under English Heritage copyright and, although do not reflect best practice in terms of interoperability, contain the core of the data used. If an agreement is not met between Bournemouth, English heritage, Seazone and the BGS, the attributes for the derived polygons can be directly attached to **BGS DigMapGB – Offshore250 Seabed Sediments theme (SBS)** and **Seazone Depth_Areas** by license holder, using an attribute join. Tables enabling these joins have been incorporated into the database, along with an instruction note on how to do this.

Sediment Stability Model

4.4.26. A sediment stability model has been developed during the later stages of the project to categorise sediment types in terms of their potential for preservation. A geological statement has been produced by Dr. David Gregory (Appendix 1) outlining the theoretical background to the classification applied to BGS seabed sediments during the main phase of the project. The results of the model have been integrated within the structure of the GIS in order to identify Areas of Maritime Archaeological Potential.

4.4.27. The model has been based on the percentage of coarse grained sediments within each of the BGS DigMapGB – Offshore250 Seabed Sediments theme (SBS). The report produce (Gregory 2006) states that the key variable which determines the potential for wreck remains to be buried is the bearing capacity of each sediment type which is dependant on the percentage of coarse grained material within each sediment type.

4.4.28. It is recognised that the preservation of archaeological materials depends on a wide range of environmental variables including seabed stability, sediment types, salinity, temperature and presence of micro and macro-fauna. The Project Design proposed a geological statement to be made based on BGS sediment types.

4.4.29. The results of the geological statement identified grain size as the key factor affecting the potential for preservation or archaeological materials when looking at sediment type alone. In his report Dr Gregory states that, "When a shipwreck, or other maritime structure, is deposited or submerged in the marine environment, its' physical survival is primarily dependent upon whether it comes to lie on or within the seabed. Should it lie exposed to seawater, it may be attacked by wood boring organisms. Even in the absence of these organisms' saprotrophic organisms, that is to say bacteria, fungi and protozoa, which utilise non-living organic material, will still cause deterioration. In the event of the wreck sinking into the seabed or being covered due to sediment transport, deterioration will still occur, albeit it at a slow rate, due to the activity of saprotrophic organisms. The rate of deterioration in sediments will be generally much slower due to the absence of dissolved oxygen, which is rapidly depleted by microbial activity. However even in the absence of oxygen other chemical species in the marine environment, such as sulphate and methane, will be utilised by saprotrophic micro-organisms." The report therefore considers the fate of archaeological material when it is deposited in the marine environment in terms of the likelihood of settling on or within the seabed, effects of sediment transport and biological processes of deterioration in open seawater and buried environments. The grading of sediments is undertaken based on this assessment.

4.4.30. The Theoretical grading of preservation produced as a result of the assessment is outlined in table 4.

Lithology Description	Folk Classification (Modified)	Gravel (%)	Theoretical Grade of preservation
Mud	M	1	1
Undifferentiated Mud			1
Sandy Mud	sM	1	2
Muddy sand	mS	1	3
Clay and sand			3
Sand	S	1	4
Sand			4
Slightly Gravelly mud	(g)M	5	5
Slightly gravelly sandy mud	(g)sM	5	6
Gravel, sand and silt			6
Slightly gravelly muddy sand	(g)mS	5	7
Slightly gravelly sand	(g)S	5	8
Gravelly mud	gM	5-30	9
Gravelly muddy sand	gmS	5-30	10
Gravelly sand	gS	5-30	11
Gravelly sand			11
Muddy gravel	mG	30-80	12
Muddy sandy gravel	msG	30-80	13
Sandy gravel	sG	30-80	14
Sandy gravel			14
Gravel	G	80	15
Gravel			15
Mussell deposit			16
Diamicton			17
Rock and sediment			18
Rock or Diamicton			19

Table 4: Theoretical classifications for BGS sediment types as outlined in the geological statement (Gregory 2006) in *Appendix 1*

4.4.31. Copyright restrictions will apply to the sediment classification as it is based on the BGS sediment types defined within the **BGS DigMapGB – Offshore250 Seabed Sediments theme (SBS)**. Therefore the classification can be used on two levels. The results have been generalised to some degree and integrated within the characterisation although sediment types have been grouped so the preservation potential is reflected via scale ranges. The model can also be linked directly to the BGS layer (for license-holders) using the above table which will be integrated within the project database, along with instructions on how to link the two datasets.

4.5. Identification of Areas of Marine Archaeological Potential

4.5.1. A detailed assessment and record of the hazards in each area was undertaken in order to identify and classify areas by their hazard to navigation. In addition to assessing the hazards, based on the data drawn from historical records, other variables drawn from modern datasets have been taken into account.

4.5.2. In order to enable queries to be run to identify areas where a high potential for shipwreck losses coincided with a high potential for preservation of archaeological materials, the data gathered needed to be converted into a queriable graded format. Consultation was sought from the project specialists regarding the grading of individual polygons and reviewed where necessary.

4.5.3. In order to identify areas with a high potential for shipwreck loss, the following variables have been interpreted in order to grade them in terms of their significance as hazards:

- Depth of water
- Hazard types and density
- Exposure to prevailing winds

4.5.4. In order to identify areas with a high potential for preservation, based on the assessment made during the project, the graded sediment types were divided into groups and reclassified. The processing of each dataset to produce a grading is outlined below.

Depth

4.5.5. The derived polygons were built using **Seazone Depth_Areas** divided into three categories: *under 10m, 10-20m, over 20m.* These categories were chosen to reflect the maximum draft of vernacular vessels and pre-1850 merchant and naval vessels in stormy sea conditions. The assumption is that at depths under 10m the area will be hazardous, with a high risk of grounding, to all vessel types in bad sea conditions , at depths of between 10-20m the area will still remain hazardous to larger vessels in bad conditions but not necessarily to smaller vessels. At depths of over 20m, the risk of grounding is low for all vessels produced before 1850.

4.5.6. Therefore, the derived polygons have been reclassified based on Table 5. In the GIS, the results were equivalent to those shown in **Map 8**.

DEPTH	**HAZ_GRADE**
Under 10m	HIGH
10-20m	MEDIUM
Over 20m	LOW

Table 5: Grading of re-categorised water depth data derived from Seazone Depth_Areas

Hazards

4.5.7. The grading of the hazards gathered as point data from historical charts was undertaken by looking at trends in the data. Each of the "feeder" polygons was given a grade of high, medium and low. The parameters used are outlined in table 6.

4.5.8. Once the feeder polygons have been graded by the level of hazard for each area, the derived polygons will be populated with a grade which reflects the hazards in the area rather than for each individual polygon.

HAZ_AREA	Parameters
HIGH	Shallow coastal areas with: Presence of shallow offshore hazards (banks, rocks) Presence of seastate hazards (eddies, overfalls) High density of coastal hazards
MEDIUM	Medium depth with some notable hazards
LOW	No notable hazards Presence of anchorages

Table 6: Grading of hazard character areas

4.5.9. As the process of deciding on the level of hazard for an area is inevitably to some degree subjective, and requires the interpretation of risk over a wider area, the assessment of hazards feeds through to the smaller derived polygons to reflect the area rather than each of the smaller polygons. In order to ensure that derived polygons reflecting individual hazards are graded as HIGH, the polygons in a depth of under 10m have been queried out and automatically converted where necessary. Therefore, where isolated shallow areas exist in an area which has been graded as medium, the polygon representing the hazard has been regarded to reflect its potential risk. The results are illustrated in **Map 9**.

Exposure

4.5.10. The assessment of exposure of sea areas to prevailing winds has been kept very general and is based primarily on the assessment made of how sheltered each area was from South-Westerly prevailing winds on the west and south coasts and North- Easterly winds on the east coast.

4.5.11. The grading was kept very simple using a HIGH, MEDIUM, LOW system due to the extreme variability of sea and weather conditions. Although it was felt necessary to take weather conditions into account, it was felt that the system produced could only act as a general guide. The results are illustrated in **Map 10**.

4.5.12. The categorisation was based on the written descriptions produced for *Condition Character* and grouped as follows:

EXP_HAZ	Condition character types
HIGH	Open coastlines which are predominantly exposed to prevailing winds
MEDIUM	Partially sheltered areas with open coastlines which are partial exposed to prevailing winds
LOW	Predominantly sheltered areas, enclosed sea areas, rivers and estuaries, offshore areas which are not in proximity of the shore

Table 7: Grading of sea condition character descriptions

Preservation

4.5.13. The model produced during the project provides each BGS sediment type with a theoretical grade of preservation. The grade remains theoretical because the model does not currently take into account the other variables in the marine environment which contribute to the preservation of archaeological materials underwater. The complexity of site formation processes is recognised and discussed in the report produced by the consultant (Appendix 1). The integration of other variables in order to refine the assessment of preservation potential is outside the remit of the Hazards project, representing a project in itself. Further development of the model will be proposed in future project proposals.

4.5.14. During the production of derived character polygons, the BGS sediment types were grouped to produce five categories of grain size:

- *Coarse grained sediments*
- *High % of coarse grain sediments*
- *High % of fine grain sediments*
- *Fine gained sediments*
- *Solid Bedrock Deposits*

:

4.5.15. The tables below list the sediment types grouped within each category.

Lithology Description	Gravel (%)	Theoretical Grade of preservation	Preservation group
Mud	1	1	V HIGH (1-4)
Undifferentiated Mud		1	V HIGH (1-4)
Sandy Mud	1	2	V HIGH (1-4)
Muddy sand	1	3	V HIGH (1-4)
Clay and sand		3	V HIGH (1-4)
Sand	1	4	V HIGH (1-4)
Sand		4	V HIGH (1-4)

Table 8: Grouping of fine grained sediments into a preservation groups for integration with GIS polygons

Lithology Description	Gravel (%)	Theoretical Grade of preservation	Preservation group
Slightly Gravelly mud	5	5	HIGH (5-8)
Slightly gravelly sandy mud	5	6	HIGH (5-8)
Gravel, sand and silt		6	HIGH (5-8)
Slightly gravelly muddy sand	5	7	HIGH (5-8)
Slightly gravelly sand	5	8	HIGH (5-8)

Table 9: Grouping of sediments with a high percentage of fine grained sediments into a preservation group for integration with GIS polygons

Lithology Description	Gravel (%)	Theoretical Grade of preservation	Preservation group
Gravelly mud	5-30	9	MEDIUM (9-11)
Gravelly muddy sand	5-30	10	MEDIUM (9-11)
Gravelly sand	5-30	11	MEDIUM (9-11)
Gravelly sand		11	MEDIUM (9-11)

Table 10: Grouping of sediments with a high percentage of coarse grained sediments into a preservation group for integration with GIS polygons

Lithology Description	Gravel (%)	Theoretical Grade of preservation	Preservation group
Muddy gravel	30-80	12	LOW (12-15)
Muddy sandy gravel	30-80	13	LOW (12-15)
Sandy gravel	30-80	14	LOW (12-15)
Sandy gravel		14	LOW (12-15)
Gravel	80	15	LOW (12-15)
Gravel		15	LOW (12-15)

Table 11: Grouping of coarse grained sediments into a preservation group for integration with GIS polygons

Lithology Description	Gravel (%)	Theoretical Grade of preservation	Preservation group
Mussell deposit		16	V LOW (16-19)
Diamicton		17	V LOW (16-19)
Rock and sediment		18	V LOW (16-19)
Rock or Diamicton		19	V LOW (16-19)

Table 12: Grouping of solid bedrock deposits into a preservation group for integration with GIS polygons

4.6. Final Character polygon Attributes

4.6.1. The attributes fed into the derived character polygons which form the final results of the project represent an amalgamation of the attributes created for both the "feeder" polygons and the derived polygons.

4.6.2. The attributes contain both the character descriptions and grading as described above and are outlined in the table below. The attributes from the derived polygons are marked in blue:

Attribute	**Data Type**	**Description**
FID		Auto ID
Shape	OLE Object	Auto object description
OBJECTID	AutoNumber	Auto ID
FID_COAST_CHAR	AutoNumber	Unique auto ID drawn from "feeder" polygons
AREA_NAME	Text	Unique name based on NMR named location names where possible. Otherwise general descriptions of an area was used. Used to join the data in the database to the "feeder" GIS polygons
DEPTH	Text	Based on the categorisation *Under10m, 10-20m, 0ver 20m*
DEPTH_HAZ		Based on a categorisation of *HIGH, MEDIUM, LOW*
COAST_CHAR	Text	Describes the character of sea areas, taking into account depth, distribution of prevailing hazards and location with respect to the coastline
HAZ_CHAR	Text	describes the morphology of the seabed areas and trends in hazards natural hazards
HAZ_GRADE	Text	Based on a categorisation of *HIGH, MEDIUM, LOW*
ANCHORAGES	Text	Based on a categorisation of *HIGH, MEDIUM, LOW*
COND_CHAR	Text	Refers primarily to trends in sea conditions seastate hazards and exposure of the sea areas to prevailing winds
COND_GRADE		Based on a categorisation of *HIGH, MEDIUM, LOW*
SEABED_CHAR	Text	describes the prevailence of sediment type in each area as this reflects significantly on the potential for preservation of archaeological materials
GRAIN_SZ	Number	*Based on the following categories:* • *Coarse grained sediments* • *High % of coarse grain sediments* • *High % of fine grain sediments* • *Fine gained sediments* • *Solid Bedrock Deposits*
PRES_POT	Text	Based on a categorisation of *V HIGH, HIGH, MEDIUM, LOW, V LOW*

Table 13: Character polygon attributes for derived polygons (blue) and drawn polygons (black)

4.6.3. The feeder polygons form part of the final product although the results will be integrated within the derived polygons. The analysis of the data demonstrated that the polygons provided a useful interface for comparing the data between the more general character descriptions in the drawn polygons and the more specifically derived data from the derived polygons. Therefore, the polygons will still be transferred as part of the archive, even if the copyright issues surrounding the derived polygons are resolved.

4.6.4. The AMAP polygons were extracted from the derived data layer by selecting out polygons where a HIGH or VERY HIGH potential for preservation coincides with a HIGH or MEDIUM potential risk from depth to both small and large ships built before 1850 (**Map 11**).

4.7. Database

Introduction

4.7.1. The database for the project has been developed using the GIS geodatabase as a platform for developing the structure. The data has been reviewed to ensure that it is MIDAS and INSCIPTION compliant. Where terms are not present in INSCRIPTION lists, a definition will be supplied by the Navigational consultant for the project and discussed with the NMR. The data in the database has been divided into five areas.

4.7.2. The data fields relating to the spatial data, including the modern and historical point data and the character polygons are exactly the same in the GIS attributes as in the database. Data that cannot be directly accessed via the GIS include the historical point data, the source data and the Preservation Potential table which allows the classification to be joined to BGS sediment data.

4.7.3. Therefore, in addition to the tables produced from the GIS, which are automatically integrated within the geodatabase structure, the database is also designed to allow information to be collated on the following:

- Source records
- Historical hazard point data
- Preservation potential conversion table
- Conversion tables for grading of Seazone depth-areas

Source Records

4.7.4. A form has been created in the database to enable information to be compiled on the nature, age, availability and accuracy of the sources. This is designed to provide a structure for referencing the sources on which the characterisation of each area is based. It provides a paper trail to support the management of the sources, and the hazards and polygons each one is associated with.

4.7.5. The source fields recorded in the database are as follows:

FIELD	DESCRIPTION
OBJECTID	AutoID
Shape	AutoShape
Id	AutoID
Source_ty	Port book, chart, secondary source
Source_na	Name of publication or chart
publ_year	date of publication
last_corr	year of last corrections
Commissioned_by	name of person who commissioned the survey
Surveyor	surveyor name
Survey_year	year of original survey
Georeferenced	Yes/No
Mapability	High/Medium/Low
Description	Text description of chart and its features
Location	location source drawn from for the project
Format	scanned/digital

4.7.6. Many of the charts were updated with corrections and republished repeatedly over several decades until a new survey was undertaken. The Sheringham charts of the Solent produced in the mid 19th century were last republished in 1935. Earlier charts and surveys undertaken by independent surveyors were often sold to multiple parties, producing variations of the same chart. It is therefore very important to record the source information in great detail to accurately keep track of the documents used.

4.7.7. The source data contains information on the surveyor as well as the commissioner of the survey or chart. The survey year, publication year and the year of the last corrections made to the chart all need to be recorded to ensure that the exact version of the chart can be traced.

Historical Hazard Point Data

4.7.8. The navigational hazards identified from each source were represented in the GIS using points. The characteristics of these points were recorded as GIS attributes during the digitisation process. No changes have been made to the attribute structure of the point data since the pilot study.

4.7.9. Once a GIS methodology had been developed, the shapefiles were compiled into a geodatabase to form the basis from which to develop a database. The fields for the point data therefore exist both in the project database and in the GIS.

4.7.10. The fields used to describe the historical point data are as follows:

FIELD	DESCRIPTION
OBJECTID	AutoID
Shape	AutoShape
Id	AutoID
feature_ty	Inscription word list for maritime features e.g. cliff, sandbank, ledge
Source_ty	Port book, chart, secondary source

Feature_na	e.g. Bramble Bank, Swan Cliff – as referred to in the source
feature_2	differentiates between hazard of haven (anchorages, annotated safe areas)
Source_na	Name of publication or chart
Source_da	date of publication
Depiction	differentiates between references to features, depiction or annotations
Notes	summary of feature location, annotation and points of interest
Nav_mark	Yes or No
key_word	Name of key feature point data layer recorded from modern charts – provides means for translating and joining the historical data to "feeder" polygons and derived polygons

4.7.11. In order to represent the historical point data gathered within a modern spatial context, the key hazards recorded in historical charts were identified and digitised from modern charts and recorded as a separate layer. The data can be accessed via the GIS and via the database. The linking of the point data has been done by relating the **key_word** in the historical point data attributes to the **HAZ_NAME** in the modern feature attributes using a one-to-many relationship. The historical features recorded from charts are therefore drawn together, irrespective of name changes or inaccurate charting, and translated into a modern context by linking them to the same key features in modern bathymetry.

4.7.12. The fields used to describe the modern point data are as follows:

FIELD	DESCRIPTION
OBJECTID	AutoID
Shape	AutoShape
Id	AutoID
HAZ_NA	Brambe Bank, East Knoll, Needles... - key_word
HAZ_TY	sandbank/bank/rocks/ledge
AREA	character polygon it falls within – unique area name

Sediment Modelling

4.7.13. A simple table has been integrated within the database to contain the results of the sedimentary model. This has allowed the database structure to be developed with the relationships between the sediment model and the character polygons in place to provide a basis for its integration and the creation of AMAPs during the next stage of the project.

4.7.14. It is anticipated that the model for the preservation potential of BGS sediments will require a simple table containing the preservation definition of each sediment type. On this basis the table incorporated into the database is as follows:

FIELD	DESCRIPTION
AutoID	AutoID
Lithography description	BGS sediment type
Folk Classification	Original sediment classification modified for the project

Gravel %	BGS data
Theoretical grade of preservation	Preservation grade produced by Dr. Gregory

5. RESULTS

5.1. Introduction

5.1.1. Following the gathering and interpretation of the hazard data from historical sources, a series of trends were identified by querying the data using the grading categories assigned to different variables which affect both the potential for ship losses and comparing the with the results of the preservation potential model.

5.1.2. The types of hazards were recorded and the way that they interact between themselves was assessed before the “ feeder” polygons were assigned a hazard level. The grading for sea conditions was also assigned to the “feeder” polygons. The derived polygons were graded by the potential for preservation and a hazard grade based on the categorisation of water depth.

5.1.3. The results of the analysis showed clear relationships between the hazards recorded, the bathymetry within the pilot area and the seabed sediments recorded within each area.

5.1.4. The data was queried so that the derived polygons were separated between areas with a high potential for preservation coincided with a high potential for loss. In addition, areas with a high potential for preservation coincided with a low potential for loss, and vice versa. Finally, areas with a low potential for preservation and low potential for loss were also queried out. These were then compared with the results of the drawn polygons graded by sea conditions and hazard level.

5.1.5. In areas where the banks recorded vary from one chart to the next tend to coincide with areas where the charts indicate that the seabed is made up of sand. Similarly, areas where overfalls have been recorded in charts tend to coincide with a sudden change in bathymetry still in evidence in modern charting. These relationships provided the basis for the development of a character typology.

5.1.6. It was felt that in addition to describing the features recorded in each area, the project would benefit from being classified within a set of generic character types which draws relationships between seabed areas presenting similar characteristics. These character types are heavily based on the trends drawn from historical sources but at the same time, reflect the hazards still present in the marine environment today. In addition to this, to provide an accurate record of sources on which the characterisation is based, it was necessary to provide a brief individual description of each area which outlines the recording of the key features in historical sources.

5.1.7. Key features tend to be natural hazards as these were those most prone to reflecting trends during the data gathering phase. Although the presence of wrecks and obstructions are in many cases deemed to be major hazards, it was felt that features recurring from the earliest charts onwards would provide a more accurate reflection of the long term hazardous character of each area.

5.1.8. The areas identified in this project as AMAPs have been discussed below in the context of their individual characters and the features identified which define them.

5.2. AMAPS (Areas of Maritime Archaeological Potential)

5.2.1. Areas of maritime archaeological potential were defined in the Project Design as "*areas where a high potential for ship losses coincide with a high potential for preservation of archaeological materials*" (Parham et Al, 2005). In order to identify these areas, parameters for the grades within the derived polygons had to be decided upon.

5.2.2. Areas were queried out where a high or medium grade for depth hazard coincided with a high potential for preservation, based on a reclassification of grain size. These polygons were then compared with areas with high risk from natural navigational hazards and a high risk from sea conditions based primarily on exposure to prevailing winds.

5.2.3. As anticipated, the results suggested that the highest potential for risk would be predominantly inshore, and therefore the query results focused on inshore areas with a high percentage of fine grained sediments. The results of these queries showed a general higher potential for loss and preservation on approaches to estuaries inshore and shallow fine-grained sandbanks offshore.

5.2.4. The results showed that the largest areas where these trends coincided are as follows (**Map 12**):

- *Estuaries:*

- The approaches to the Thames
- The approaches to the Wash
- The Humber Estuary
- Morecambe Bay and approaches
- Approaches to the Severn
- Eastern Solent and approaches to Portsmouth, Langstone and Chichester Harbours

- *Offshore banks:*

- The Southern North Sea sandbanks
- The Goodwin Sands

Approaches to the Thames

5.2.5. The expansive area on the approaches to the Thames is characterised by an extensive area of long narrow sandbanks running parallel to each other in a NE-SW direction. The larges of these banks include Long Sand and the Shingles, Kentish Knock at the eastern extremity of the estuary, East and West

Barrow to the north of Long Sand, and Gunfleet Sand at the north of the estuary, leading onto Foulness sand. The charting of the Thames estuary tend to be detailed although the location and shape of banks vary, suggesting the mobile nature of the seabed around this area.

5.2.6. The coastal character of the area is that of an exposed coastal area with offshore sandbanks The seabed is characterised predominantly by sand with layers of gravel in between the banks suggesting a gravel substrate. There are areas of mud and silt deposits at the entrances to Foulness in the Crouch Estuary and around the entrance to the Swale, stretching out towards Margate.

5.2.7. Although there are no records of difficult sea conditions such as eddies or overfalls, the area is exposed to prevailing winds from the north east during the winter, increasing the risk to shipping of being blown on to the shallow mobile banks.

5.2.8. Despite the expansive banks, few navigational markers are drawn onto the early admiralty charts, besides a black buoy marking the east of Margate Sand. This may be due to the level of mobility of the area.

Approaches to the Wash

5.2.9. The Wash is characterised by very shallow banks within the estuary itself, with a considerable number of small shallow banks and shoals on the approaches from the north-east, including Dungeon Shoal, Northern Ridge, Race Bank and Docking Shoal. The approaches along the coast from the north are characterised by numerous overfalls caused by a series of small banks within the channel and the Dowsing Banks on the eastern side of the channel. The approaches from the east require considerable circumnavigation of Sheringham Shoal and its overfalls followed by substantial foreshore banks known as the Woolpack and the east. The estuary itself has a large partially sheltered channel running into it known as Lynn’s Deep.

5.2.10. The estuary itself has a predominantly sandy seabed, with fine grained silts and mud along the foreshore surrounding the river entrances. The approaches are characterised primarily by a gravel seabed although the areas where the banks have formed tend to be sand or gravely sand. The whole area remains exposed to the north eastwith little opportunity for shelter on the approaches.

The Humber Estuary

5.2.11. The Humber Estuary has been recorded as an AMAP, primarily because of the high potential for preservation in an area of shallow water rather than because of a high number of hazards on the approaches. The approaches remain fairly clear although very exposed to prevailing winds and onshore winds. The approaches from the south suffer the same presence of numerous overfalls as the northerly approaches to the Wash. There are substantial foreshore banks on the entrance to the estuary including notably Spurn Head, a large sand spit on the north shore, and the Outer Binks. Spurn Head is marked by a beacon along with a couple of banks on the south bank inside the estuary, outside East Grimsby. The river channel is deep with some large banks along the shores.

5.2.12. The seabed character outside of the estuary is predominantly coarse grained gravels, whereas the inside of the estuary is characterised by extensive estuarine muds and silts, encouraging the preservation of archaeological material.

Liverpool Bay and Morecambe Bay

5.2.13. Liverpool Bay is characterised by several major estuaries including the River Dee, River Mersey, the River Ribble and Morecambe Bay. All of these areas are characterised by a sandy seabed offshore, with finer grained sediments at the entrance to and within the rivers themselves.

5.2.14. The foreshore along the whole of Liverpool Bay is very shallow (0-10m) with numerous inshore sandbanks. The entrance to the Mersey is banked by Great Burbo Bank to the west and Taylors Bank to the east. The Mersey is an area of extensive maritime activity, and has catered for large scale shipping since the Medieval period. Therefore the risk to shipping is far greater on the approaches to Liverpool where the seabed is shallow, highly mobile and has attracted larger ships for a long time.

5.2.15. The Ribble Estuary is characterised by extensive foreshore banks leading out from the estuary. This area and indeed Morecambe Bay have far less contact with larger ships as the trade around these areas focused more on local fisheries.

5.2.16. The presence of Morecambe Bay and the Ribble estuary in the query results is therefore an interesting illustration of the need for further work to develop the assessment of archaeological potential in English waters. The area meets the criteria in that it is an area which is hazardous to shipping although having data on the size and age of ports and harbours in use in these areas would improve the resolution of results for the project.

Approaches to the Severn

5.2.17. The results show that the approaches to Bridgewater are the key area of potential for the Severn Estuary. Although the mouth of the Severn River is characterised by fine grained sediments and has been a popular and busy port for over 600 years, the lack of **Seazone depth_area** data for such inshore means that the river itself has not been flagged up as a high potential AMAP.

5.2.18. The approaches to the estuary, although wide and exposed, has a seabed which is characterised by solid bedrock deposits which are not condusive to burial and in situ preservation. There are few hazards in the estuary between Lundy and the entrance to Minehead after which the estuary becomes much more shallow with extensive insore banks such as Flat Holme and Steep Holme between Weston-super-Mare and Cardiff. The foreshore is extensively shallow with extensive flats outside Bridgewater.

Eastern Solent and approaches to Portsmouth, Langstone and Chichester Harbours

5.2.19. The areas on the eastern approaches to the Solent tend to be characterised by the presence of fine grained sands and silts in the channel, known to be highly mobile. Although fairly well sheltered, the risk lies in the shallowness of the area, its mobility and the extensive foreshore banks lying on either side of the approaches to several major harbours and ports including Southampton, Portsmouth and Chichester. The area encompasses several of the areas assessed during the Pilot Study including the Brambles and the north-east Coast of the Isle of Wight.

5.2.20. The area between the entrance to Cowes and the entrance to Southampton Water is focussed around an extensive area of sandbanks the larges of which is known as Brambles Bank. Brambles Bank is known to dry out at low water and figures on all of the charts studied apart from a Portulan chart which covers Britain on a very small scale. The sandbanks recorded around Brambles Bank vary both in their location and name from one chart to the next. It is likely that this is due to the mobile nature of the seabed around this area.

5.2.21. The seabed is characterised as sandy for this area which supports the idea of constant mobility in the already shallow bathymetry of the area. Other key banks recorded include Ryde Middle Bank which lies in the middle of the channel to the south east of Brambles Bank and East Knoll which is a slightly deeper but equally hazardous extension of Brambles Bank to the south west.

5.2.22. The area is sheltered from south westerly prevailing winds and has extensive sandy and muddy intertidal areas along the north eastern foreshore of the Isle of Wight, including Mother Bank, and the mainland coast.

5.2.23. By the time of the Beaufort survey in the mid 19th century, a beacon had been put on the western edge of the bank to mark the channel into Southampton water and the bank edge.

5.2.24. To the west of the eastern channel leading into the Solent, the channel between Spit sand and the approaches to Chichester Harbour has been defined as a separate area to Bramble Bank. Although the environment is similar to the Brambles Bank area, the water is less shallow and features no mid-channel banks.

5.2.25. The area is very sheltered although the channel remains narrow and provides access to a series of natural inland harbours including Portsmouth Harbour, Langstone Harbour and Chichester Harbour. A small number of anchorages are recorded outside the harbour entrances. These increased in number on later charts with the development of Portsmouth’s naval importance.

5.2.26. The main hazardous features of this area are the extensive intertidal areas on either side of the channel including Horse Sand to the north and Mother Bank to the south. To the eastern extremity of the north east coast of the Isle of Wight, there is a sheltered area known as St Helen’s Road where there is a further safe anchorage area which is depicted on several charts.

The Southern North Sea sandbanks

5.2.27. This is an extensive offshore area in the southern extremity of the North Sea stretching out to the north of Great Yarmouth and to the east of the approaches to the Wash. It's characterised by a series of shallow long narrow gravely sandbanks running in a NW-SE direction across the offshore approaches to the coast. They mostly lie at a moderate depth of between 10-20m, causing little risk to smaller vessels, but representing a considerable risk to larger vessels, particularly in bad weather.

The Goodwin Sands

5.2.28. The Goodwin Sands lie off the east Kent coast between Ramsgate and Dover. The area is characterised by a large area of very shallow mobile sandbanks and are a well know hazard to shipping of all types. The coastline is also characterised, particulary around the Brake outside Ramsgate. To the south of the Brake and to the west of the Goodwin Sands there is a large sheltered area, known as the Downs, which has been recorded in numerous historical charts as a safe anchorage area. Although the Goodwin Sands are exposed to the north-east, the Downs area is sheltered both towards the south-west and north-east.

5.2.29. The seabed in the Goodwins area is characterised mainly by sand and gravely sand, with muddy gravely sand across the Brake. The predominance of fine grained sediments suggests this area to have a high potential for preservation although the mobility of the banks in this area may counteract this to some degree. The seabed becomes increasingly gravely inshore to the south of the Brake where the coastline is characterised by chalk cliffs.

5.2.30. This remains one of the sea areas in English waters with the greatest reputation for ship losses. The route into Ramsgate from the north and the top end of many of the northern ends of the sandbanks are marked by buoys and beacons on early admiralty charts.

5.3. Application of the Navigational Hazards project to Industry

5.3.1. The results of the data will be produced for the National Monument Record, the public archive of English Heritage.

5.3.2. The system has already been put to use for characterising and informing the English heritage Maritime team on the potential for loss and preservation of archaeological materials for areas surrounding designated wreck sites. It is also being proposed that the system be independently trialled for development-led impact assessments by the *Hampshire and Wight Trust for Maritime Archaeology*, in order to provide feedback which can be used to enhance the ALSF-funded *AMAP1 project* methodology. The feedback received will be used in the development of the AMAP1 project.

5.3.3. To demonstrate the applicability of the system to the marine industry in its current state, the results for two areas for which information was requested by the English heritage Maritime Team have been outlined below. The areas are (1) Hurst Spit (**Map13a,b**) and (2) The Lizard (**Map14a,b**).

- *Lizards Point*
  - The Lizard is a headland highly exposed to sea conditions. It is characterised by a rocky foreshore with a rapidly dropping bathymetry, creating overfalls off the tip of the Lizard. Lizard Point is therefore characterised as having a high potential for ship losses based on the combination of rocky foreshore, potentially dangerous sea conditions, and overfalls.
  - The seabed around the headland is bedrock, producing a very low potential for preservation of archaeological material due to the rocky nature of the surrounding seabed, which encourages scattered preservation within gullies rather than the presence of large segments of wreck.
  - Therefore, although the coastal areas adjacent to the Lizard, (where the seabed is characterised by fine grained sediments)are categorised as areas of maritime archaeological potential (AMAPs),as a result of the Navigational Hazards Project, Lizard Point is not classified as an AMAP due to very low potential for preservation.
- Hurst Spit
  - Hurst Spit is a gravel spit running out into the western channel into the Solent. The area is exposed to prevailing winds on the western shore of the spit and the seabed is characterised by gravel. The eastern shore is sheltered although bordered by overfalls and strong currents at the mouth of the channel.
  - The potential for preservation of archaeological materials is low on the western side of the spit where there is a high density of gravel. The eastern side is however characterised by fine grained estuarine silts running out from the Lymington River and is therefore characterised by a high potential for preservation.
  - The potential for loss is therefore high on either sides of Hurst Spit due to the currents and sea conditions in the area, whereas the potenial for preservation is high only on the eastern side of the spit which has been classified as an area of maritime archaeological potential (AMAP) as a result of the Navigational Hazards Project.

6. CONCLUSIONS

6.1. In conclusion, this assessment provides a detailed overview of the methodological development of the GIS undertaken for the Navigational Hazards Project.

6.2. The project deliverables have been met through the production of a GIS and associated geodatabase which contains a layer of data reflecting AMAPs where a high potential for preservation coincides with a high potential for ship losses. In addition, the characterisation polygons which led to the creation of this layer have been provided for use alongside the AMAPs layer to put the interpretation within the overall context of the trends in navigational hazards and preservation potential that define them. The historical data gathered is contained within the structure of the geodatabase.

6.3. The output of the project has provided English Heritage with a GIS system which can be put to immediate use in informing industry, regulators and curators on the potential impact of aggregate extraction and other intrusive industrial activities on the unrecorded archaeological resource on the seabed. A system which could be put to immediate use as well as being further developed through later projects would provide the marine industry with the foundations for a quantative assessment of the potential for unrecorded shipwreck material to exist within seabed sediments.

6.4. Following the completion of a Source Appraisal and a pilot study focusing on the Solent area, a method has been developed which identifies areas with a high potential for ship losses based on historical data. This model has been combined with a sediment stability model produced for the project in order to highlight Areas of Maritime Archaeological Potential (AMAPs).

6.5. The inaccuracies identified in historical data sources led to a Variation Proposal being made to amend the Project Design so that the hazard data could be recorded as points rather than polygons which could then be summarised within hazard character areas. many of the chart sources impossible to accurately georeference.

6.6. The accuracy issues have been removed through the characterisation of the hazards in each seabed area and their display via the digitisation of the same features from modern charts. The key features identified during the data analysis are linked to modern features through the feature name.

6.7. The character areas have been analysed to produce a summary of the navigational hazards recorded in historical sources, the identification of the most important features for each area, and the recognition of trends in the coincidence of different types of environmental hazard. The identification of trends has enabled a typology of hazard areas to be developed to complement the area descriptions and to provide a basis for the development of AMAPs.

6.8. The areas identified as AMAPs, within the scope of the project, have highlighted recurring environmental characteristics which tend to characterise an increased potential for loss and preservation. These areas include approaches to estuaries, offshore mobile sandbank areas and some coastal areas where a high density of navigational hazards coincides with the presence of fine grained sediments.

6.9. It is however important to note that there are limitations to such a model. The areas reflected in the results highlight areas with particular potential for loss and preservation, and the project takes into account the hazardous character of different sea areas. The model cannot however quantify the potential for loss in deeper areas where the risks to navigation are more likely to be due to large storm events and, with the advent of steam driven vessels from the 19th century onwards, collisions. The model also does not take into account the potential for losses through human action such as warfare. The potential both for ships losses and for preservation of materials also depend on other variables than sediment type and the nature of hazards in a sea area.

6.10. From the perspective of risk to shipping, it is also vital to take into account the potential for shipping to be travelling within an area of seabed. Although there are inevitably isolated occurrences of vessels making unscheduled stops in ports and harbours due to human error or for emergency purposes, the potential for shipping in an area is primarily dependent on the presence of ports and harbours, the scale of activity and the size of vessels frequenting them. This was clearly illustrated in the presence of the Ribble estuary and southern bank of Morecambe Bay in the AMAP results. The incorporation of additional datasets such as an enhanced England's Shipping database (ALSF round 1) and a reclassified wrecks and obstructions dataset which takes into account potential biases in data gathering can only enhance a dataset which has proven to highlight recurring trends in environmental parameters which do affect the potential for AMAPs.

6.11. From the perspective of potential for preservation, key variable which need to be taken into account include seabed mobility and the depth of sediments mapped by the BGS. The results may prove different if a shallow layer of sand has been recorded (using shallow grab samples) over a deeper gravel substrate.

6.12. Both of these areas of study are being tackled via proposals being put forward for round 3 of ASLF funding.

6.13. A proposal has been put forward to continue to develop and refine the method for assessing archaeological potential through the identification of AMAPs. The AMAP1 project will build on the conclusions of the Navigational Hazards project, integrating the results with available data on the preservation potential of marine environments and with a quantitative analysis of the potential significance of shipwrecks scatters.

6.14. This will make best use of results of Hazards project to further refine the assessment and characterisation of the potential for shipwreck remains within different types of marine environment. In addition, the results will be integrated with those of the ALSF project "*Development of a Regional Sediment-Erosion Model for submerged Archaeological Sites*" undertaken by Southampton University (Dix et Al, 2007), in order to highlight further research.

6.15. Finally it is also important to note that the digital data which is vital for these types of GIS project do have their shortfalls. Some areas in both the Seazone and BGS datasets have not yet been covered as part of their datasets. There may also be ongoing issues surrounding copyright for which a long-term agreement needs to be sought between English heritage and the data provider, which can be incorporated within research standards and project designs to avoid any recurring disagreements.

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